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ATTACHMENT 1

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Hydrodynamics of a ship/whale collision

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ABSTRACT

All endangered large whale species are vulnerable to collisions with large ships; and "ship strikes" are the greatest known threat to one of the world's rarest whales, the North Atlantic right whale (*Eubalaena glacialis*). The magnitude of this threat is likely to increase as maritime commerce expands. Factors influencing the incidence and severity of ship strikes are not well understood, although vessel speed appears to be a strong contributor. The purpose of this study was to characterize the hydrodynamic effects near a moving hull that may cause a whale to be drawn to or repelled from the hull, and to assess the accelerations exerted on a whale at the time of impact. Using scale models of a container ship and a right whale in experimental flow tanks, we assessed hydrodynamic effects and measured accelerations experienced by the whale model in the presence of a moving vessel. Accelerations at impact were measured while the whale was at the surface, for various vessel speeds, orientations of the whale relative to the vessel path, and distances off the direct path of the vessel. Accelerations experienced by the whale model in a collision: increased in magnitude with increasing ship speed; were not dependent on whale orientation to the vessel path; and decreased exponentially with increasing separation distances from the ship track. Subsequent experiments with the whale model submerged at one to two times the ship's draft indicated a pronounced propeller suction effect, a drawing of the whale toward the hull, and increased probability of propeller strikes resulting from this class of encounter. Measured accelerations are a proxy for impact severity, but do not constitute a detailed study of injury mechanism in a living animal, though they may help inform future work. We present a heuristic map of the hydrodynamic field around a transiting hull likely involved in close whale/vessel encounters. These results may have bearing on policy decisions, particularly those involving vessel speed, aimed at protecting large whales from ship strikes worldwide.

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1. Introduction

Collisions with vessels (or "ship strikes") can result in injury and death in a number of marine vertebrate taxa, including large whales (Laist et al., 2001; Jensen and Silber, 2003; Glass et al., 2009), sirenians (*i.e.*, manatees and dugongs) (U.S. Fish and Wildlife Service, 2001; Greenland and Limpus, 2006; Lightsey et al., 2006), and turtles (Hazel and Gyuris, 2006; Hazel et al., 2007). All endangered large whale species are vulnerable to collisions with ships. Several reports provided summations of records of ship strikes involving large whales worldwide, accounting for nearly 300 incidents through 2002 (Laist et al., 2001; Jensen and Silber, 2003) and over 750 incidents through 2007 (Van Waerebeek and Leaper, 2008). These numbers are certainly minima as many other strikes likely go undetected or unreported, some collisions do not leave external evidence of collision, and in the case of some recovered carcasses, the cause of death could not be determined (Glass et al., 2009) due, for example, to advanced decomposition.

Observed injuries resulting from whale/ship collisions can include, for example, broken bones, hemorrhaging, other evidence of blunt trauma, and severe propeller cuts (Knowlton and Kraus, 2001; Moore et al., 2005; Campbell-Malone, 2007); and on occasion a vessel may arrive in port with a whale carcass pinned to its bow or riding atop the bulbous bow.

One critically endangered species, the North Atlantic right whale (*Eubalaena glacialis*), appears to be more prone, on a per-capita basis, to vessel collisions than other large whale species (Vanderlaan and Taggart, 2007) and ship strikes are considered a significant threat to recovery of the species (National Marine Fisheries Service, 2005). In a

Abbreviations: λ, Linear scale ratio (non-dimensional); ρ, Mass density of salt water taken as 1025.9 kg/m^3; *a*, Acceleration; A_I, Impact severity; *AX*, Magnitude of acceleration in the *X* direction; *AY*, Magnitude of acceleration in the *Y* direction; *AZ*, Magnitude of acceleration in the *Z* direction; *Fn*, Froude number; *g*, gravities 9.81 m/s^2 (32.2 ft/s^2); Hz, hertz; kJ, Kilojoule; *L*, Generic unit of length for dimensional analysis or characteristic length of a ship; *M*, Generic unit of mass for dimensional analysis; m, meters (3.2808 ft); *p*, Pressure (N/m^2); s, Seconds; *T*, Generic unit of time for dimensional analysis; T_{Peak}, Time of peak measured acceleration in an encounter; *V*, Velocity (given in meters per second or knots 1 knot = 0.5144 m/s).

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population estimated to contain only 300–400 individuals, there were 50 confirmed right whale deaths between 1986 and 2005, 38% of which have been attributed to ship collisions (Kraus et al., 2005). An average of 2.2 known North Atlantic right whale deaths and serious injuries from ship strikes occurred annually between 2003 and 2007 (Glass et al., 2009).

Ocean-going and coastal vessels are increasing in number, size, and speed to keep pace with waterborne commercial, industrial, and recreational activities. The number of commercial vessels engaged in maritime commerce has tripled in the last 50 years with most of the growth occurring in the 1970s (Vanderlaan et al., 2007), and continued growth of global freight transport is projected at a rate of 4% or more at least thorough 2020 (Corbett and Winebrake, 2007). Thus, the threat of ship strikes to whales may also increase.

A number of steps have been taken in North American waters and elsewhere to reduce the occurrence of ship strikes of whales and other marine mammal species. The depleted status of the North Atlantic right whale and its vulnerability to ship strikes has prompted the U.S. National Oceanic and Atmospheric Administration (NOAA) to establish recommended shipping routes in key right whale aggregation areas and modify a vessel Traffic Separation Scheme servicing Boston (Bettridge and Silber, 2008). NOAA also issued vessel speed restrictions in certain locations along the U.S. eastern seaboard to reduce the threat of ship strikes to North Atlantic right whales (National Marine Fisheries Service, 2008), and established a seasonal Area to be Avoided in the Great South Channel. The U.S. National Park Service limits the number of entries and speed of cruise ships in Glacier Bay National Park, Alaska, to reduce the likelihood of fatal strikes of humpback whales (U.S. National Park Service, 2003). In Canadian waters, Bay of Fundy shipping lanes were recently moved (International Maritime Organization, 2003; Vanderlaan et al., 2008) to reduce the co-occurrence of vessels and right whales. Spain issued a notice in 2007 to mariners requesting that vessels in the Strait of Gibraltar restrict their speed, and has repositioned a Traffic Separation Scheme off Cabo de Gata, to reduce the incidence of whale strikes (International Whaling Commission Ship Strikes Working Group, 2006). In an analogous effort, vessel speed restrictions have also been established in Florida to reduce small craft collisions with manatees (*Trichechus manatus*) (Laist and Shaw, 2006).

Uncertainties exist regarding factors contributing to ship strikes, particularly in the seconds prior to a collision, including possible ship detection and avoidance by the whale and the role of the flow field about the vessel at various vessel speeds. In assessing records of ship strikes of whales, several studies concluded that vessel speed is an important factor in contributing to the severity or lethality of the strike (Laist et al., 2001; Pace and Silber, 2005; Vanderlaan and Taggart, 2007). Vanderlaan and Taggart (2007) also suggested, based on elementary momentum theory considerations, that the fate of the whale in a ship strike is a function of both vessel speed and whale mass. With regard to detection and avoidance, Nowacek et al. (2004) found that right whales showed little overall reaction to the playback of sounds of an approaching ship, and Laist et al. (2001) suggested some collisions may involve only a last second flight response by the whale. However, the role of hydrodynamic effects associated with a moving vessel and the impact accelerations potentially experienced by a whale during a collision have received little consideration, except by way of computer simulation (Knowlton et al., 1995; Knowlton et al., 1998; Raymond, 2007).

The goals of this study were to characterize the flow field near a moving hull, assess accelerations experienced by a whale in a collision or close encounter, and determine the influence of vessel speed on both. Using a scaled ship model proportional to the specifications of a commercial container ship and a proportionally-scaled right whale model, we quantified impact accelerations at various (appropriately scaled) hull speeds in an experimental setting to provide a better understanding of the hydrodynamic conditions affecting a whale when struck or in close proximity to a moving vessel. The results have implications for efforts to lessen the threat of ship strikes to endangered whales, particularly as they pertain to vessel speed and other aspects of vessel operations.

2. Materials and methods

2.1. Study location and facilities

We conducted two series of trials at the experimental flow tank facilities at the Carderock Division of the Naval Surface Warfare Center, Bethesda, Maryland (David Taylor Model Basin). The first set of trials, to determine interaction effects around the hull while the whale model was stationary at the surface, were conducted in a towing basin measuring 15 × 383 × 3 m with an electro-hydraulically driven carriage capable of towing a ship or submarine model at speeds of up to 12 knots (Stahl 1995) (Fig. 1a). The second set of trials, to determine effects on a submerged whale model, were conducted in a circulating water channel with a test section measuring 18.3 × 6.7 × 2.7 m (Fig. 1b) in which the same vessel model was held stationary and water and whale model were forced past it. The two basins and the types of techniques used in this study have been employed for over 60 years to study vessel flow dynamics and to model the types of relationships described in this paper.

2.2. Hydrodynamic scaling

We used scaled models of both whale and ship to approximate real world relationships between the two. Well established scaling rules for hydrodynamic model testing have been developed over the past century and a half, allowing for the prediction of full scale responses based on model scale experiments (Lewis 1988). The physical basis of modern ship model experimentation was developed in the mid-19th century by William Froude (Froude 1888). Froude's experiments determined that the similarity criterion for the wave patterns involving a ship and a model varied with the square root of the linear scale ratio λ. Equivalent speeds are commonly described by the nondimensional Froude Number, $Fn = \frac{V}{\sqrt{gL}}$ where V is ship speed, g is the gravitational constant, and L is a characteristic length, typically taken as length between perpendiculars for displacement hull vessels. From this relation, it follows that time also scales as $\lambda^{1/2}$. Mass is related to volume by Archimedes law, and scales as λ^3 for equivalent fluid densities. Because atmospheric pressure and fluid characteristics such as viscosity and surface tension are difficult or impossible to vary in a model experiment, phenomena that depend on these characteristics will not scale directly. Most notably, Reynolds Number, describing the relationship between viscous and inertial forces in a flow, will not be equivalent between model and ship scale in a typical Froude scaled experiment. In the case of a collision between a ship and a whale, it can be safely assumed that the viscous aspects of the encounter are less significant than the kinematic or inertial, allowing us to neglect the difference between model and full scale Reynolds Number. Dynamic pressure, defined as $\frac{p}{\rho V^2}$, is the same at ship and model scale when taken relative to a local reference pressure to remove the effects of atmospheric pressure. Acceleration is also equivalent, as shown by the following simple analysis: acceleration has units of length per time squared, as in $a = \frac{L}{T^2}$. From the Froude scaling criteria given above, $L_{Ship} = \lambda L_{Model}$ and $T_{Ship} = \lambda^{1/2} T_{Model}$ so $a_{Ship} = \frac{L_{Ship}}{T_{Ship}^2} = \frac{\lambda L_{Model}}{(\lambda^{1/2} T_{Model})^2} = a_{Model}$. Note that the scale factors cancel, so accelerations are equivalent at ship and model scales. Similarly, momentum has units of mass times velocity, so $mv_{Ship} = \frac{M_{Ship} L_{Ship}}{T_{Ship}}$ and $MV_{Ship} = \frac{M_{Ship} L_{Ship}}{T_{Ship}} = \frac{\lambda^3 M_{Model} \lambda L_{Model}}{\lambda^{1/2} T_{Model}} = \lambda^{7/2} MV_{Model}$, leading to a momentum scaling factor of $\lambda^{7/2}$. Therefore, water flow velocities scale

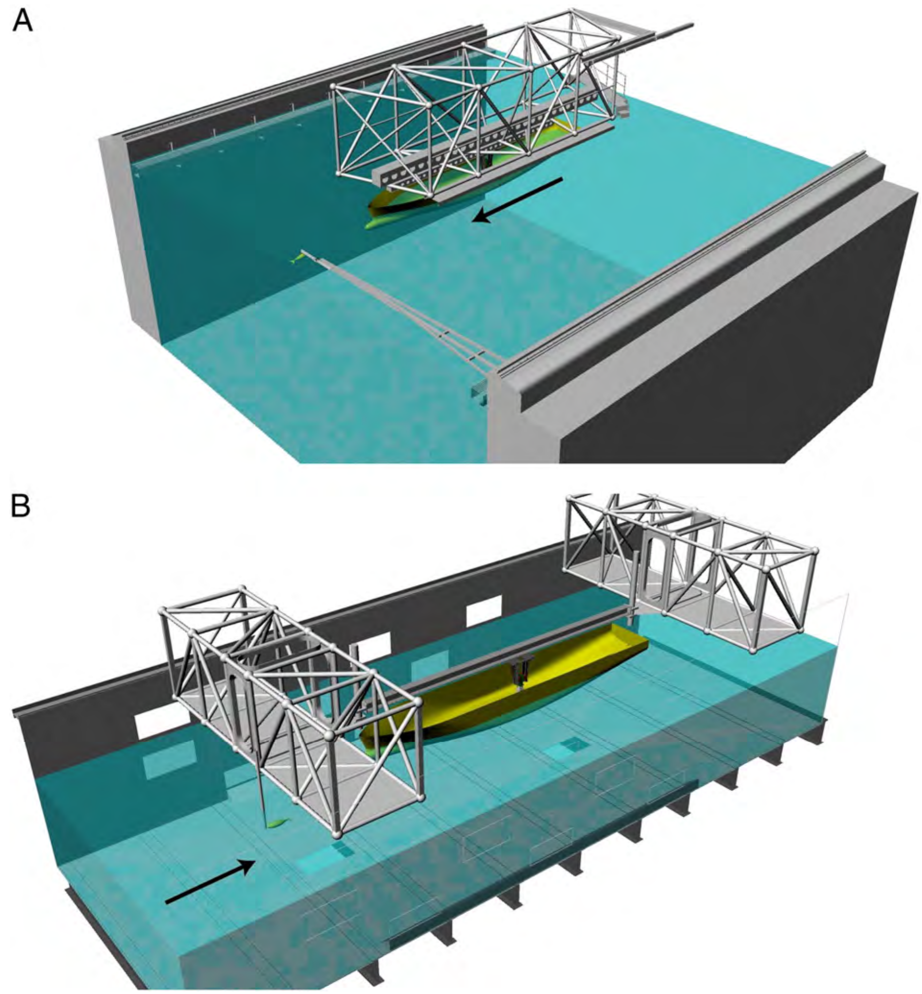

Fig. 1. (A) Rendering of test basin, center carriage structure, and whale release mechanism used in the initial (surface) test series. Direction of carriage motion is indicated by an arrow. (B) Rendering of circulating water channel, gantry structures, and whale release mechanism used in the second (submerged) test series. Direction of water flow is indicated by an arrow.

to real world scenarios at a ratio of 1:4.97. Physical properties such as viscosity and surface tension are sufficiently small relative to inertial and other forces that they may be discounted. Based on these well established similarity criteria, the scale model experiment is assumed to capture the major physical phenomena of a full scale encounter.

2.3. Ship and whale models

The ship model was selected from the inventory of existing hydrodynamic test models. The model was selected for its resemblance to a “Panamax” type vessel (210 m length, 32 m breadth, 8 m draft, 34,000 long tons displacement), representing a broad range of modern commercial container ship types with an elliptical bow bulb,[3] fine entrance lines with pronounced flare, a full midships section, and a dry transom stern. The scale ratio of the selected model was $\lambda = 24.67$, setting the general characteristics of the full scale ship (Table 1). A single skeg-supported propeller (using a stock propeller design) and a spade type rudder were fitted to the model. During testing, the propeller was powered by an electric motor run at the ship self-propulsion point in order to simulate the pressure and velocity fields due to an operating propeller. The ship model was instrumented for towing force and trim, and the drive train was fitted with a dynamometer to measure thrust and shaft torque and a magnetic pickup to measure shaft rotation rate.

A model right whale was designed using morphology derived from Moore et al. (2005) (Table 2, Fig. 2). Relative proportions and gross morphology were set for an adult whale, and a three-dimensional computer model of the whale was prepared using a commercial software package (Rhinoceros 4.0, Robert McNeel & Associates). To facilitate model construction, it was necessary to simplify the shape of the jaw and cross-sectional profile of the body. The whale's tail flukes and pectoral fins were designed as separate pieces to facilitate replacement during the testing process. The model was constructed to approximate a posture an adult whale might adopt while at rest at the surface (Fig. 3).

The size of the whale model was set at 54.91 cm length overall, corresponding to the typical length of an adult right whale (13.7–

Table 1
Particulars of ship model.

	Model	Full scale
Length overall (cm/m)	851.2	210.0
Waterline length (cm/m)	778.3	192.0
Beam (cm/m)	130.5	32.2
Draft (cm/m)	32.4	8.0
Displacement (kg/tonne)	2240.3	3455.0

[3] The bulbous bow is a structural feature situated just below the water line and is a characteristic of many cargo, naval, and passenger vessels. First developed in the early 1900s and further developed after WWII, it improves vessel fuel efficiency by modifying water flow around the hull to reduce drag.

Table 2
Particulars of whale model.

	Model	Full scale
Length overall (cm)	54.91	1354.6
Length to base of tail (cm)	44.78	1104.7
Maximum width (cm)	12.37	305.2
Flipper length (cm)	13.69	337.7
Fluke width (cm)	19.69	485.8
Maximum girth (cm)	39.51	974.7
Surfaced mass (kg)	2.788	41,850.0
Neutral buoyant mass (kg)	3.097	46,500.0

16.7 m) and to scale correctly with the ship model, *i.e.*, the physical dimensions of both the vessel and whale models scaled to real world dimensions at a ratio of 1:24.67. The physical model was constructed directly from the computer model from a thermoplastic resin using a stereolithography machine. The model surface was hand sanded and finished.

The resin was rigid in comparison to a living whale. This affected the collision dynamics after impact, most notably because little or none of the impact energy was expended in deforming or otherwise damaging the structure of the whale model. This would obviously not be true of a collision involving a living animal because the tissue of a living organism would absorb some of the energy of the impact; but it was a necessary experimental compromise. Our focus was on appropriate physical scaling of the whale–vessel size relationship. However, proper scaling of structural and tissue rigidity and resiliency of living right whales is not known and therefore was beyond the technology of small model construction in the context of our experiments. Nonetheless, the rigid model was considered to adequately represent a living whale in the moments leading up to the collision and the accelerations experienced by the model were regarded as establishing an upper bound for an impact with a living animal.

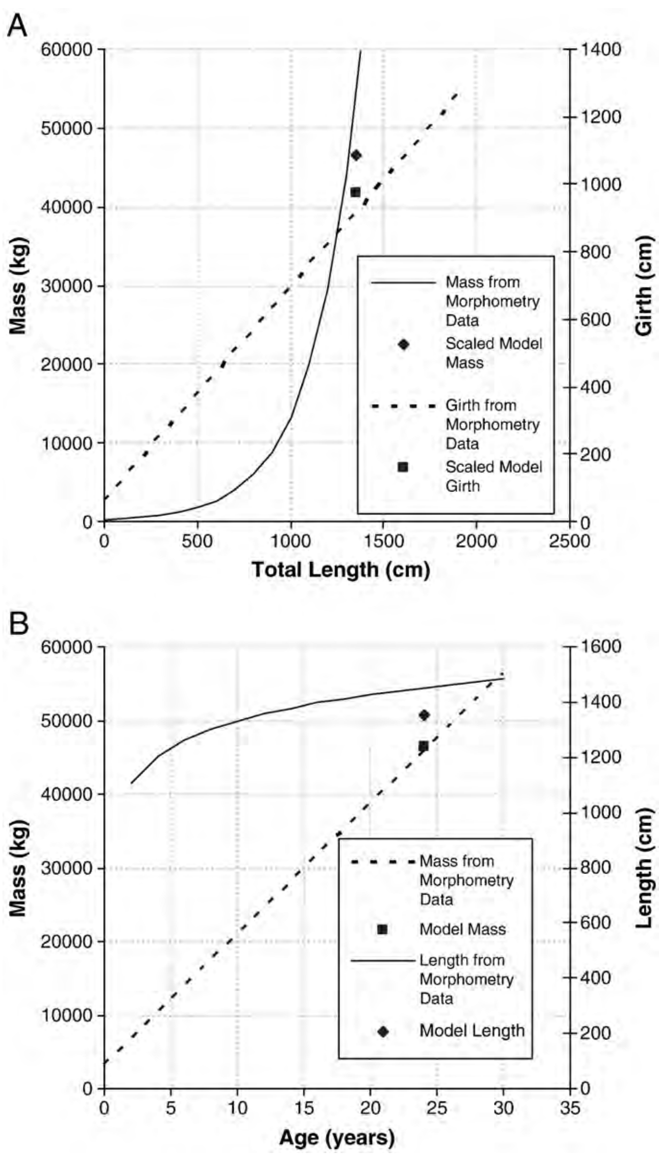

Fig. 2. Whale model dimensions as compared to trend lines derived from whale necropsy morphological data including (A) length versus mass and length versus girth; (B), age versus length and age versus mass (Moore et al., 2005).

Right whales are known to be slightly positively buoyant (Nowacek et al., 2001), but we know of no specific mass properties data from living animals. The reserve buoyancy of the whale model for the surface trials was set at 10% of the total mass as a reasonably accurate approximation (based on field observations) of a living whale while at rest at the surface. For the submerged trials, the whale model was ballasted as nearly as possible to neutral buoyancy.

The instrument package selected for the whale model was a single triaxial accelerometer with an internal data collection capability (Fig. 4). The axes of the accelerometer were aligned with the principal axes of the whale model, such that the y direction was longitudinal (positive from tail to head), x was to starboard, and z was upward. Accelerations were thus measured in a whale-fixed coordinate system, rather than a world- or ship-fixed system that possessed an external position reference point. For the purposes of measuring the magnitude of impacts, this system was suitable for characterizing some impact features to the whale model only, but did not provide a quantitative measure of the whale model's movements during the encounter. The latter information was reconstructed from video data.

The accelerometer was set to activate when the whale model's acceleration in any direction exceeded 0.1 gravities (gravity (g) = 9.81 m/s^2) or its velocity at model scale exceeded 0.3048 m/s. Upon activation, the instrument recorded acceleration as a function of time for 1.5 s (at a rate of 1200 Hz) or until a subsequent event again triggered the accelerometer.

For the surface trials, video was recorded from three angles: looking directly down at the bow of the ship model, a wide shot of the bow and area ahead of the model from the side, and looking directly forward from behind the model. For the submerged trials, video was recorded from above the waterline looking at the bow quarter of the model, below the waterline looking at the bow and stern from beside the model, and from directly below the propeller. In both cases, accelerometer data were time-stamped via an internal clock, which was synchronized with the time codes of video recording equipment and ship model instrumentation system.

2.4. Vessel speeds, offsets, and depths during trials

Two experimental series were conducted: Series One involved the whale model at the free surface; Series Two involved the whale model submerged.

2.4.1. Series One: surface lateral offsets

In the first series, the hull was connected to a towing carriage that pulled it toward the stationary, free floating whale model. In this case, the goal was to assess hydrodynamic responses of the whale model at a variety of lateral offset distances and orientations relative to the ship track (Fig. 1a).

A release mechanism was designed such that the whale model could be held stationary in the tank at a desired offset distance and orientation. The mechanism was released and retracted by a remotely

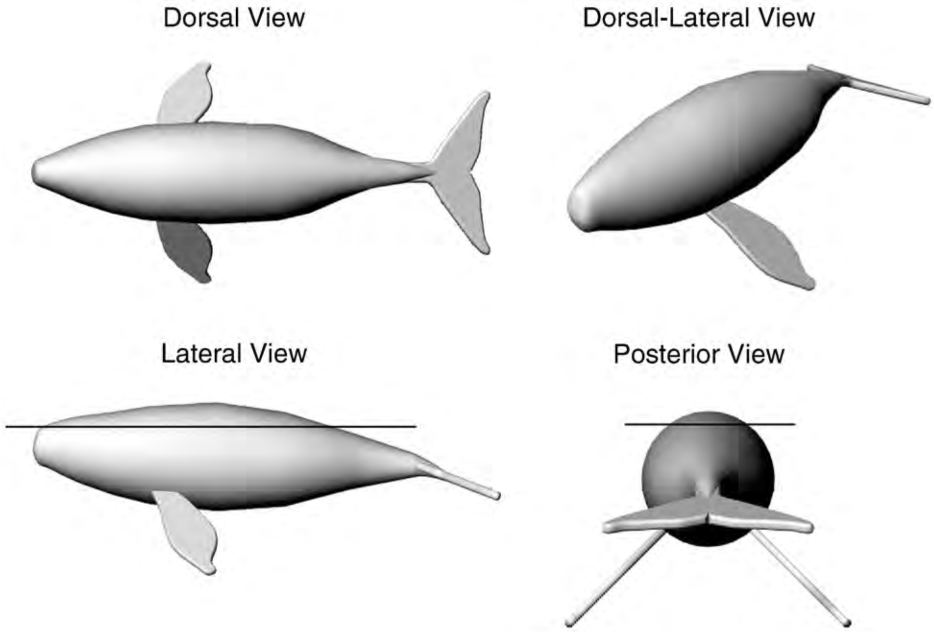

Fig. 3. Computer rendering of whale geometry used in the experiment. This computer model was used to generate the physical model using a stereolithography machine. The approximate waterline for the surface experiments is shown in the lateral and longitudinal views.

actuated solenoid as the ship model approached the release point, leaving the whale model free floating at the time of collision. In each trial, the whale model was released immediately prior to approach of the ship model and the model was run past the position of the whale. Ship data and video were obtained throughout the encounter, from before contact to well after the whale model was clear of the ship.

Ship speeds were set at equivalents of 5–25 full scale knots in 5 knot increments, which covers the operating speed range of almost all commercial cargo vessels. Tests were performed at arbitrarily set distances off the ship track line that were scaled such that they corresponded to distances of 0, 20, 40, and 60 ft (0, 6.1, 12.2, and 18.3 m, respectively) if models were full-sized (Fig. 5). Trials were

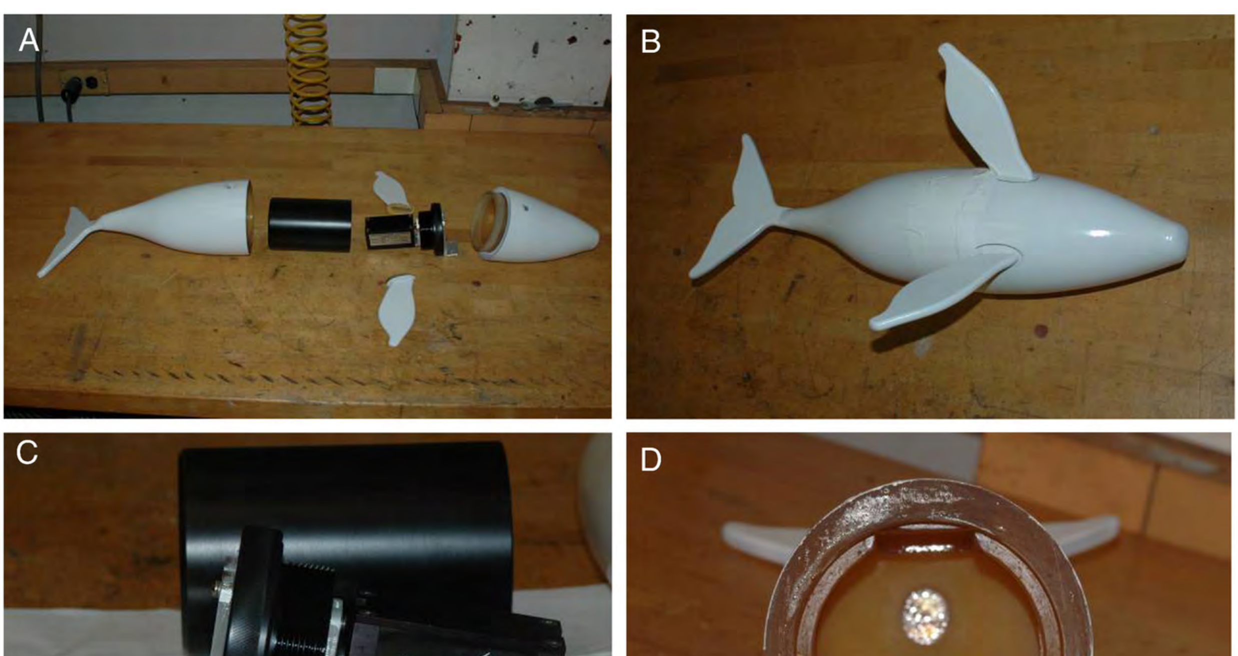

Fig. 4. Whale model: (A) exploded overview of whale model components, (B) assembled whale model, (C) accelerometer and instrument casing, (D) interior view of whale afterbody showing alignment tab for instrument casing.

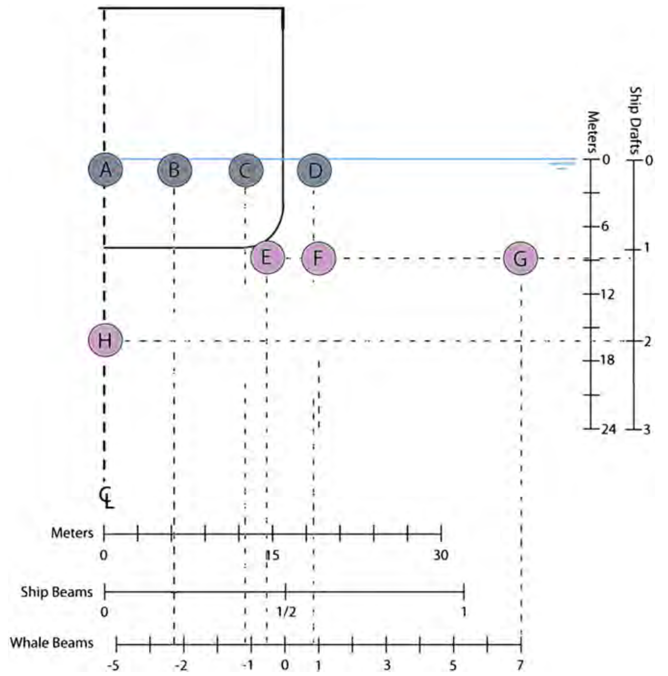

Fig. 5. Release positions of the whale model relative to the ship track for the surfaced and submerged series of experiments. Positions A through D relate to the surface trials of Series One; positions E through H relate to the submerged trials of Series Two.

also run using whale orientation angles ranging from 0 to 315° in 45° increments such that 0° indicates an overtaking encounter and 180° indicates a head-on collision. Approximately three trials were made at each test condition.

2.4.2. Series Two: submerged whale tests

In the second experimental series the hull was held stationary and the submerged whale was released into the flow that was moving toward the vessel at various water speeds. This is comparable to the use of wind tunnel testing in aerodynamics, using a model-fixed frame of reference in which the flow moves past the body, and is hydrodynamically equivalent to the towing tank approach used in the surface experiments. The goal was to determine if the hull, effectively traveling at various speeds, acted to attract the submerged whale model. New requirements for enhanced underwater camera coverage to collect video data and the need for a mechanism to release the model at depth led to the decision to use a circulating water channel for the second series of experiments (Fig. 1b). The tank is equipped with numerous viewing ports and fixed photo lighting.

In this case, the whale model was submerged at 1.2 and 2.0 times the ship's draft at lateral offsets of 0.0, 4.5, 6.0 and 12.0 whale beams (0.0, 14.5, 19.2, 38.0 m, respectively) from centerline and released into the flow toward the fixed hull at full scale ship speeds of 5, 10, and 15 knots (Fig. 5). Safety issues with the test facility precluded testing at the 20 and 25 knot ship speeds in this configuration.

The same whale model and instrumentation design was used in the submerged experimental series (dimensions provided in Table 2), with the exception of a slight shortening of the pectoral fins to better represent the morphology of actual animals. The weight of the whale model was increased by the addition of ballast to set the whale model at approximately neutral buoyancy.

2.5. Acceleration measurements

Impacts were identified by cross-referencing video of the encounter with activations recorded by the whale's onboard accelerometer. Severity (A_I) was measured in terms of the root mean square value of the directional components (in the *x*, *y*, or *z* directions) at the instant of the peak measured acceleration (T_{Peak}) such that:

$$A_I = \sqrt{AX^2_{TPeak} + AY^2_{TPeak} + AZ^2_{TPeak}}.$$

For cases where the encounter was not sufficient to activate the accelerometer (*i.e.*, if acceleration was <0.1 g and speed <0.3048 m/s), A_I was arbitrarily set to zero.

This system gave a reasonable measure of the relative magnitude of impact in cases where actual contact between the whale model and ship's hull or propeller were observed, though it did not take into account the length of the encounter or successive peaks in the acceleration record. The duration and rise time of accelerations experienced by a living whale are important parameters for understanding the biomechanics of ship strike induced injuries; however, any resulting traumas are also heavily influenced by the structural properties of a living animal and other factors and are therefore beyond the scope of the present rigid-body experiment. Therefore, these results may help establish some parameters for such detailed collision analysis, but are not substitutes for it.

2.6. Statistical analyses

A Pearson Product-Moment Correlation Coefficient was used to test the relationship between ship speed and acceleration impact A_I.

3. Results

3.1. Series One: accelerations experienced in the centerline position

Collisions were observed in all cases when the whale model was directly in the ship's path (0 m offset) and at full scale offset distances of 6.1 m from the centerline. Numerous collisions produced accelerations measured at over 5 g at vessel speeds of 5 knots, over 10 g at vessel speeds of 10 knots, and over 15 g at vessel speeds of 15, 20, and 25 knots (Fig. 6). Accelerations were closely related to, and varied linearly with ship speed. We found statistically significant correlations between vessel speed and acceleration impact at the centerline ($n=47$, $r=0.740$, $P<<0.0001$) and at 6.1 m offset distances ($n=30$, $r=0.418$, $P=0.0218$).

For centerline conditions (0 m offset) below 15 knots, the whale model tended to roll up and over the bow bulb, with the most severe impact coming when the stem above the bulb subsequently hit the whale. After the initial impact, the whale model was either carried along on the stem or slid off the bow and passed closely down the side of the ship.

At ship speeds of 15 knots and above, there was a marked increase in the apparent intensity of centerline impacts. In approximately one-third of high speed centerline trials, the initial impact pinned the whale model to the ship's bow bulb, followed by the ship riding over the whale, forcing it below the surface. In some instances, the whale model resurfaced along the waterline and passed along the side of the ship, but in others it remained below the hull for a considerable portion of the ship's length. One 25-knot trial with the whale at the centerline of the ship track in which the whale was forced under and traveled beneath the hull produced the only propeller strike observed during the surfaced test series.

3.2. Series One: accelerations experienced in offset positions

As the whale model's position was moved laterally away from the centerline of the ship track, the point of contact moved back along the ship's waterline, and glancing blows were more common than direct impacts. Acceleration at impact declined exponentially with increasing offset distance, to the point that very few encounters registered on the accelerometer in the 12.2 m and 18.3 m offset distances (*i.e.*, at or near

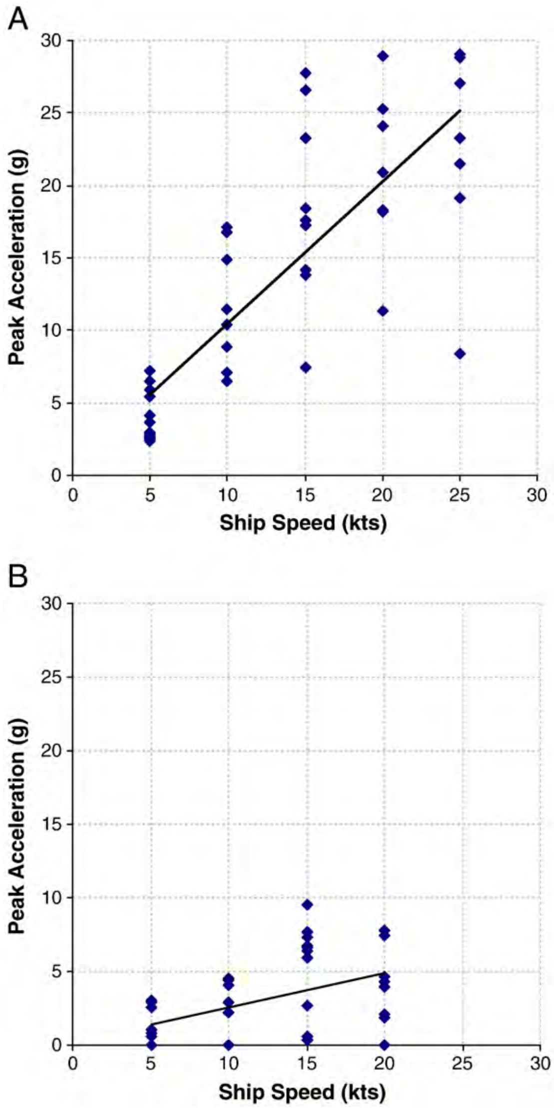

Fig. 6. Impact acceleration versus nondimensional ship speed for the centerline (A) and 6.1 m (B) offset conditions at all orientations.

the maximum beam of the ship) (Fig. 7). At these distances, the effects on the whale were too light to reliably activate the accelerometer and too few to make a good determination of speed dependency.

At the 20- and 25-knot speeds, the ship generated a significant bow wave, but the whale model responded only with one cycle of vertical movement, but no lateral deflection away from the ship. This movement was also observed at 12.2 m and 18.3 m full scale offset distances — cases in which the whale model encountered the first crest of the divergent wave system before the hull itself.

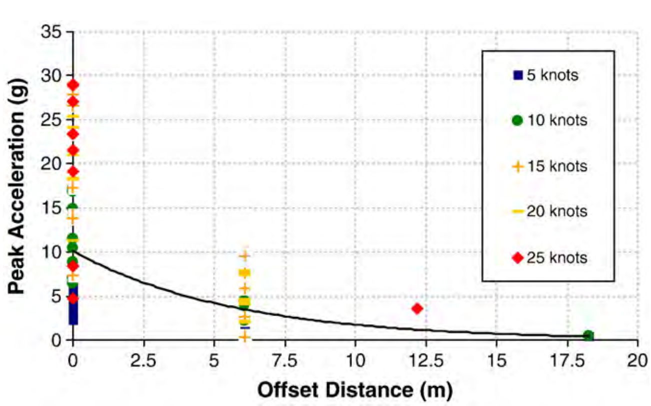

Fig. 7. Impact acceleration versus offset distance for all ship speeds and orientations.

In all trial conditions, as the whale model passed along the stern of the ship it entered the influence zone of the propeller. Propeller suction was sufficient to cause the whale model to orient toward the propeller, but not sufficient to draw it into the blades. This behavior appeared to be somewhat speed dependent, with a greater heading change observed at higher ship speeds. Arbitrarily increasing propeller speed beyond the self-propulsion level also increased the rate and magnitude of the observed response, although the primary effect was still orientation rather than inward movement. The whale model frequently passed within 1–2 propeller diameters of the blades.

In all cases, the orientation of the whale model did not appear to affect accelerations it experienced, except in cases where the orientation effectively changed the offset by placing an extremity of the model in the path of ship's stem.

For both the 0 m and 6.1 m offset conditions, we observed significant scatter in the measured accelerations (Fig. 6A), although visually, test conditions appeared to be extremely repeatable. Because the whale model data were measured in a whale-fixed coordinate system (*i.e.*, relative to the whale, only), it is difficult to relate the measured accelerations to the model's movements in an earth- or ship-fixed system. It is possible that the accelerometer mounting was susceptible to impact induced high frequency vibration at certain angles, which would account for some of the variation.

3.3. Series Two: responses of the submerged whale model

The behavior of the submerged whale model in the presence of the ship model at 5–10 knots was characterized by inboard motion toward the stern of the ship. This movement was accompanied by a change in orientation of the whale model such that the head of the whale rotated inboard toward the ship. This motion was consistent with the orientation behavior during the surface trials, and likely resulted from suction from the acceleration of flow along the ship's afterbody and the working of the propeller. This behavior appeared to depend at least partially on depth, with a greater orienting effect being observed when the whale model was at or near the depth of the propeller. The inboard suction was sufficient to draw the whale model to within one body length of the propeller from the outboard-most position (G) (Fig. 5) in low speed trials. Lateral motion was substantially more apparent than vertical.

At the outboard position (F), the lateral motion toward the centerline and orientation of the whale model toward the propeller were also observed, which was consistent with the propeller as the origin of the lateral force. Vertical motion, however, was more pronounced, with the whale model tending to be driven downward starting at approximately one quarter of the ship length from the bow. In approximately half the trials undertaken at the inboard spacings the whale model finished a run laterally in line with the propeller but below it vertically.

At the inboard position (E), the whale model was also observed to be driven down in approximately half of the observed trials. Conversely, in cases where significant vertical deflection did not occur, the whale model was drawn rapidly onto the centerline and passed down the hull just below the skin of the ship. In some cases, the whale model was observed to bump and scrape down the ship rather than pass just below it. When moving past the after part of the hull, the whale model tended to pass along either the bottom or side of the skeg, and approach the propeller very closely.

A limited number of trials were conducted with the whale model submerged at two ship drafts directly on the ship centerline (H). These trials resulted in the whale model passing closely down the centerline of the ship and approaching or striking the propeller. In general, the behavior was not notably different from the inboard position (E). In those cases, vertical deflection was moderate, and exclusively in the downward direction, and there was significant danger of propeller strike.

At positions (E) and (H), over 50% of the trials were judged to have resulted in a propeller strike. At the outboard positions (F) and (G), no propeller strikes were observed, although a number of close encounters were observed. Based on these results, we predict that under the experimental conditions, the critical lateral offset distance to avoid contact with the propeller lies approximately at one-half beam of the ship, between positions (E) and (F).

In one 10 knot trial at position (E), the whale model rode up over the bow bulb, sustaining a heavy impact with the bulb and stem. This result was very similar to the response observed at positions (A) or (B) in the surface testing series, and illustrates a continuity of results between the two experimental sequences.

4. Discussion

4.1. Factors likely involved in whale/vessel collisions

Large whales are relatively agile, acoustically aware, and at times can be easily disturbed by noise and other stimuli (see, for example, Richardson et al., 1995). It therefore seems reasonable that a whale could detect and avoid an oncoming vessel; nonetheless, ship strikes are rather common. Except in the very near-field, whales may not regard an approaching ship as a threat, or may be engaged in a vital activity (*e.g.*, feeding and mating) on which they are intently focused, and thus fail to engage in an avoidance response. Right whale vulnerability to ship strikes is probably related, at least in part, to slow swimming speeds, positive buoyancy, and a largely coastal distribution that exposes them to various activities near human population centers (National Marine Fisheries, 2008).

Terhune and Verboom (1999) postulated that right whales either have difficulty detecting ships that are relatively near or choose not to avoid them. Using a multi-sensor acoustic recording tag to measure the responses of right whales to passing ships Nowacek et al. (2004) observed little or no response by right whales to playback sounds of approaching vessels or actual vessels, regardless of vessel speed or acoustic characteristics. Ships and ship noise are fairly ubiquitous in most seas, particularly in areas of high human activity therefore, whales may habituate to the presence of ships. For whatever reason, a whale may suddenly and unexpectedly find itself directly in front of a ship or, in the case of highly buoyant right whales (Nowacek et al., 2001), emerging from a dive with little maneuverability.

Given that field trials involving full scale vessels and living whales are not possible (or at least highly ill advised), we endeavored to address some uncertainties (heretofore only studied using computer simulations) in whale/vessel interactions in an experimental setting using an inanimate object. Our study incorporates neither a whale's behavioral response nor the absorptive aspects of an actual living (or simulated, *e.g.*, Raymond, 2007) organism. The use of a rigid-body whale model, while a necessary experimental compromise, will tend to overstate acceleration experienced by the whale because no energy is lost in deforming the model as would be the case with a living animal. Therefore, whereas this study provides some insight into the physical forces at play in a collision or close encounter, it is not a substitute for detailed biomechanical analysis of a ship strike using more intensive modeling of the structural properties of a whale (*e.g.*, Tsukrov et al., 2009).

4.2. Impact characterization of a ship-whale collision

To our knowledge, no study directly links the physical and operational characteristics of a vessel to the nature and consequences of an impact experienced by a whale involved in a collision or close encounter. Generally, the extent of a trauma suffered in a collision is dependent on angle of incidence, the size of the area of impact, contact duration, integrity of the tissue contacted, and vessel mass (Campbell-Malone, 2007; Raymond, 2007), or a combination of these. Our trials do not account for most of these variables nor certain additional factors (*e.g.*, a whale's possible behavioral reaction or movements), and therefore our findings cannot be used to completely characterize the nature of an impact or resulting injury in a collision. However, to the extent both a diminished duration of impact onset (Raymond, 2007) and increased acceleration experienced by a whale may be important determinants in the nature and severity of a collision, we conclude that the role of these two variables is enhanced by increasing vessel speeds. In a related study, Clifton (2005) concluded that typical speeds of small watercraft were capable of generating sufficient kinetic energy (ca. 18–20 kJ; occurring at vessel velocities of 13–15 mph) to result in fatal bone fractures in manatees, although caution should be used when making comparisons to whales as manatee bones are denser, but perhaps more fragile than those of whales, and the vessels studied were smaller than those observed here.

Our findings regarding the relationship between vessel speed and accelerations experienced by the whale model are consistent with other studies that concluded vessel speed is an important factor in the fate of a whale in a vessel/whale collision (Pace and Silber, 2005; Vanderlaan and Taggart, 2007). Vanderlaan and Taggart's (2007) elementary momentum theory analysis in a perfectly inelastic collision assumed that the mass of the ship was orders of magnitude greater than the mass of the whale (a reasonable assumption for oceangoing cargo vessels, if not for coastal fishing and pleasure craft) and that for those conditions, vessel speed and whale mass were the primary variables affecting momentum transfer to the whale. Therefore, numerical results involving the role of vessel speed from the method proposed by Vanderlaan and Taggart are consistent with the results of the model experiment to within an order of magnitude.

4.3. Hydrodynamic zone of influence

Our results conform to the basic hydrodynamics of a moving vessel in that the upstream disturbance is extremely localized. This means that the whale model ahead of the ship experienced no forces induced by the vessel until contact was imminent. Thus in the absence of action on the part of the whale, the probability of a collision is largely dependent on the position of the whale relative to the ship's track.

We provide a heuristic map of the hydrodynamic field around a hull that likely is at play in a close whale/ship encounter (Fig. 8). As such, our qualitative results prompt us to classify the space about the ship track into three categories: a high danger (lethal) zone in which any encounter, absent a behavioral response by the whale, appears likely to lead to either a propeller or bow strike; a moderate danger (conditional) zone in which the whale model passes within less than two body lengths of the stem or propeller disk; and a low danger (safe) zone giving at least two body lengths of clearance.

These delimiters are qualitative, and necessarily somewhat imprecise, but provide approximations of the hydrodynamic environment experienced by a whale in proximity to a ship. The conditional zone in a hydrodynamic context indicates the importance of buoyancy and ship-speed effects in comparing the results of the two experimental series, but also encompasses much of the uncertainty associated with whale behavior.

Response of the whale model to the ship's bow wave was less than expected. Potential flow simulations (Knowlton et al., 1995; Knowlton et al., 1998) predicted a significant sway response from the bow wave, sufficient to move the whale out of the way of the ship when it was positioned just inside the maximum beam of the ship. In contrast to the computer simulations, the observed response to the bow wave in both experimental series was vertical rather than lateral.

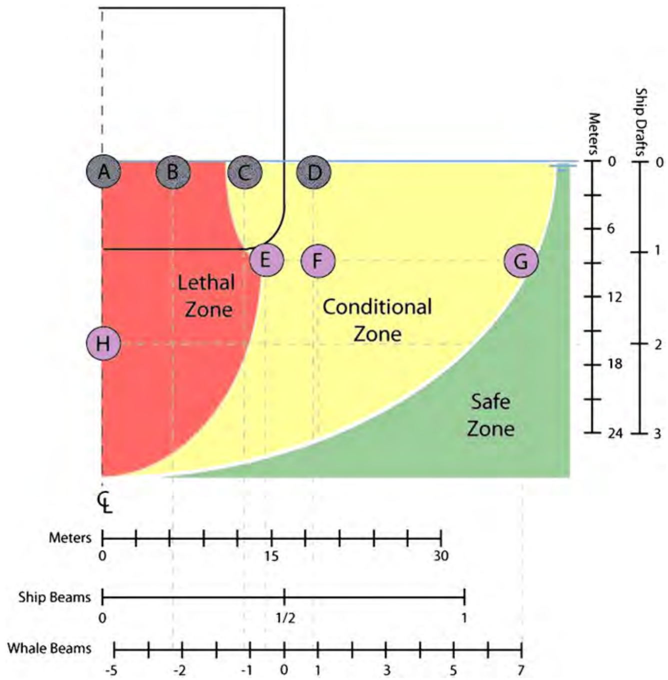

Fig. 8. Approximate delineation of critical zones about the ship track. Within the lethal zone, the whale model is judged likely to experience either a violent impact with the hull or a propeller strike. The conditional zone indicates the area in which for one or more conditions the whale model passed within one body length of the propeller or a near-miss from the bow. While these zones are defined by observation of the hydrodynamic response of the inert whale model, much of the uncertainty associated with whale behavior is believed to be critical in roughly this same area.

In the surface experiments (Series One) at position (D) the whale model encountered the first crest of the diverging wave system before the hull itself. In this case the model response was a single cycle of vertical motion. In the submerged experiments (Series Two), the tendency of the whale model to be driven down at the inboard lateral positions is due to the high pressure region at the ship's bow. The selected ship model includes a modern bulbous bow design that tends to reduce the magnitude of the wave system about the ship. It is possible that an encounter with a vessel with a traditional stem bow design (as used in the Knowlton et al. simulations) might yield a larger deflection due to effects of the bow wave.

4.4. Bow versus propeller strikes

Databases of ship strikes involving all whale species (Jensen and Silber, 2003; Van Waerebeek et al., 2007) contain a number of records (ca. 10–20% of all records) of dead whales pinned to, or having ridden up onto, the bow of a large vessel. Therefore, if our trials are analogous to real-world scenarios, this consequence could have occurred at any vessel speed when the whale was on the centerline of ship's path. In offset conditions, accelerations measured when the whale was within one-half beam width (*i.e.*, 15.6 m in this experiment) were still substantial and possibly sufficient to deliver a fatal or near fatal blow. We believe that in a real-world collision, these strikes may still result in potentially substantial tissue damage, and may be represented in actual ship strike records as generalized blunt trauma.

Likewise, observations of propeller strikes comprise approximately 20% of the recorded real-world ship strikes (Jensen and Silber, 2003; Glass et al., 2009). Whereas, these records may not be a faithful representation of all ship strikes, as many others likely go undetected, we regard the numbers reflected in the databases as reasonable approximations of actual proportions. In the model experiments, propeller strikes were observed in two situations. At ship speeds of 15 knots and greater, the whale model could be sucked under the ship model after being struck by the bow. This behavior resulted in one actual propeller strike of our model and several near-misses in Series One trials.

During the submerged test series, propeller strikes were observed in approximately half of the inboard trials (positions E and H). These results suggest that a majority of propeller strikes occur in cases where the whale is below the surface at the time of the encounter in which it is drawn laterally toward the hull, and may correspond to real-life scenarios. It should be noted as well that some propeller strike records involve small craft — a vessel class not addressed in our study.

The frequency of propeller strikes observed during testing may also be affected by one of the fundamental compromises of the experimental design — the whale model is not only a rigid body, but is guaranteed to remain perfectly still during the encounter with the ship. In most of the conditions considered in testing, a significant number of trials resulted in the whale model passing within one body length of the ship's propeller. For the inert whale model, these conditions are near-misses with no significant accelerations measured, but it is easy to envision the behavioral response of a living animal leading to propeller strikes in a number of these conditions, whereby a "startle" response may actually move a whale toward the propeller. This also is a probable scenario if a whale was attempting to dive — a typical flight reaction in response to a strong stimulus (see, for example, Richardson et al., 1995) — but was still under the influence of the vessel's drawing forces.

Whale buoyancy (set at 10% in the Series One and neutrally buoyant in the Series Two trials) may also be an important determinant of collision dynamics in bow-on encounters. Notably, there are taxonomic differences in relative buoyancy among whale species and right whales are particularly buoyant in this regard (Nowacek et al., 2004). The tendency of the whale to be driven under versus struck by the bow bulb may be affected at least in part by this factor and may vary with the species involved.

4.5. Relevance to policy decisions

Steps have been taken by governments and wildlife management entities to reduce the incidence of whale/ship collisions that include limits on vessel speed. Our findings on the role of vessel speed in such incidents, both in regard to the dimensions of the zone of influence created by a ship and the magnitude of an impact, have application to the study of physiological injury from collisions (*e.g.*, Campbell-Malone, 2007; Tsukrov et al., 2009) and policy-driven management actions regarding vessel speed restrictions. In addition to having a role in reducing the severity of impact lowered vessel speeds may have the added advantage of providing greater opportunity for either whale or (in some rare instances) mariner avoidance reactions. Therefore, our results add to a growing body of literature indicating that vessel speed restrictions are a meaningful management tool (where other alternatives such as vessel routing to avoid whale aggregation areas are not feasible) in reducing the threat of ship strikes to all large whale species.

5. Conclusion

When the whale model was hit by the ship's stem, measured accelerations were dependent on ship speed in an approximately linear relationship. Observed severity of collisions was such that direct impact with the ship's stem or propeller appears likely to result in serious injury to the whale. For cases with the whale model at the surface, the primary collision type was a strike by the bow of the ship model; and when directly on the ship's track, this would likely manifest itself in a real-life scenario with the pinning of the whale atop the bulbous bow. With the whale model submerged, the primary collision type was a propeller strike, with significant lateral drawing action due to the propeller.

The overall danger zone about a moving ship appears to be on the order of one ship beam about the centerline of the ship track in the horizontal plane and one to two times the draft vertically if the whale is considered to act as a rigid body incapable of independent action. Accelerations experienced by the whale diminished as distance from the vessel increased; and whale orientation had little effect on the nature and severity of the encounter. Nonetheless, we conclude that, to the extent that increasing vessel speed significantly increases accelerations experienced by a whale, limits on vessel speed will reduce the magnitude of the acceleration; may increase response time for a whale attempting to maneuver away from a vessel; and appear to be reasonable actions to consider in policy decisions aimed at reducing the overall threat of ship strikes.

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ATTACHMENT 2

biology letters
Conservation biology

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Dangerous dining: surface foraging of North Atlantic right whales increases risk of vessel collisions

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North Atlantic right whales are critically endangered and, despite international protection from whaling, significant numbers die from collisions with ships. Large groups of right whales migrate to the coastal waters of New England during the late winter and early spring to feed in an area with large numbers of vessels. North Atlantic right whales have the largest *per capita* record of vessel strikes of any large whale population in the world. Right whale feeding behaviour in Cape Cod Bay (CCB) probably contributes to risk of collisions with ships. In this study, feeding right whales tagged with archival suction cup tags spent the majority of their time just below the water's surface where they cannot be seen but are shallow enough to be vulnerable to ship strike. Habitat surveys show that large patches of right whale prey are common in the upper 5 m of the water column in CCB during spring. These results indicate that the typical spring-time foraging ecology of right whales may contribute to their high level of mortality from vessel collisions. The results of this study suggest that remote acoustic detection of prey aggregations may be a useful supplement to the management and conservation of right whales.

Keywords: foraging ecology; endangered species; vessel collision; right whale

1. INTRODUCTION

North Atlantic right whales (*Eubalaena glacialis*) are critically endangered and, despite international protection from whaling, significant numbers die from collisions with ships [1]. During the winter and spring, a majority of the remaining population of right whales migrates to New England waters to feed, residing for months in a region also intensively used by coastal and international shipping [2]. North Atlantic right whales have the largest *per capita* record of vessel strikes of any large whale population in the world [3].

Almost half (45%) of the right whale population was present in Cape Cod Bay (CCB) in the late winter and early spring of 2010 [4]. In the spring, these whales are commonly observed feeding at or just below the water's surface on dense patches of copepods, their preferred zooplankton prey [5]. Right whale feeding behaviour in CCB is probably a contributing factor to collisions with ships. There have been five confirmed right whale deaths owing to ship strike in and around CCB in spring months over the past 30 years [6]. Previous tagging studies of right whales on their summer feeding grounds demonstrated that right whale dive depth closely tracks the peak concentration of their prey [7]. In this study, we combine data on the diving behaviour of feeding right whales with data on the distribution of their prey in the water column in CCB, to assess whether the foraging ecology of right whales leads to increased risk of vessel collisions.

2. MATERIAL AND METHODS

This study was conducted in April of 2009 and 2010, using a combination of a suction cup archival recording tag to document the subsurface behaviour of individual right whales, and direct (net and pump sampling) as well as indirect (acoustic backscatter) sampling methods to quantify and track the distribution of the right whale prey in the bay. Our goal was to measure the time right whales spend at a depth where they are most vulnerable to being struck by a ship.

(a) *Tagging*

An archival recording tag with suction cups (Dtag) [8] was attached to 13 individual North Atlantic right whales in CCB, MA, USA (41°–42° N latitude, 70°–70.5° W longitude) in April 2009 and 2010, for periods of 0.5–4.8 h (mean = 2.2 h, s.d. = 1.47 h). The depth (pressure) sensor of the tags has an accuracy of ±0.5 m. Dive profiles were derived from the pressure sensor data from tagged whales (figure 1).

(b) *Active acoustic prey sampling*

In 2010, a towfish with multiple frequency acoustic echosounders (SIMRAD ES 60 (38, 120 and 200 kHz) and EK 60 (710 kHz)) measured volume backscattering strength in the water column around the tagged whale (electronic supplementary material, figure S1). The system was towed off the starboard beam of the large vessel at a speed of approximately 5 knots at a depth of 0.25 m. Owing to near-field effects of the acoustic echosounders, volume backscatter data were collected from depths of 2.0 m (38 kHz), 1.0 m (120 and 200 kHz) and 0.5 m (710 kHz) to the sea floor. Single beam (38, 200 and 710 kHz) and split beam (120 kHz) systems were used. The ping rate was 0.5 Hz with the system defaults for all other parameters for all systems. CCB has a mean depth of 30 m, so data were averaged into depth bins of 0.25 m for 38, 120 and 200 kHz and 0.05 m for 710 kHz. All echosounders were calibrated in CCB using a 38.1 mm diameter Tungsten carbide sphere.

Scatterers were acoustically identified as being small crustaceans (copepods) when the volume backscatter strength at 710 kHz was more than 10 dB greater than at 38, 120 or 200 kHz, thus eliminating fish and large crustaceans from inclusion in the volume backscatter used to estimate copepod abundance. Such data filtering does not exclude non-biological sources of scattering; however, we do not believe those contributions to be large because the acoustic estimates of copepod distribution and abundance agree strongly with those from the net and pump sampling. A distorted wave born approximation scattering model [9] calculated the target strength (TS) at 710 kHz of a 1.5 mm-long copepod (mean length of copepods sampled in this study) to be −114.6 dB. Volume backscattering strengths (S_v) were converted to numerical density (N) estimates by $S_v = 10 \log_{10}(N) + TS$.

(c) *Net sampling*

Vertical net casts to depths of 1, 5 or 20 m depth were conducted at 10 sites in CCB, using a 0.5 m diameter ring net with 150 μm mesh.

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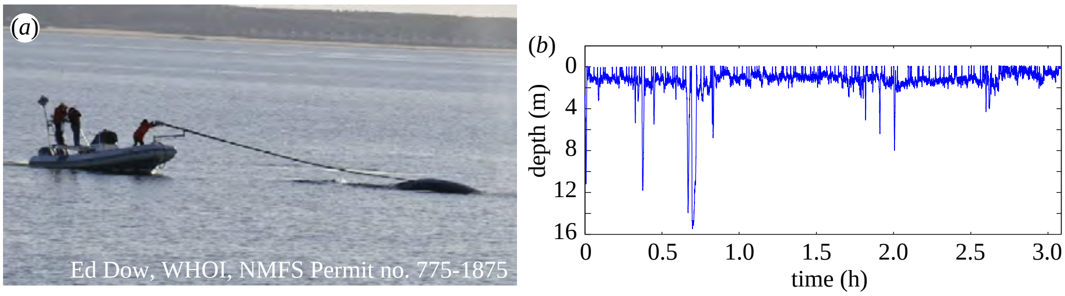

Figure 1. (*a*) Attachment of the suction cup Dtag to the back of a North Atlantic right whale and (*b*) the resulting dive depth profile for this individual whale.

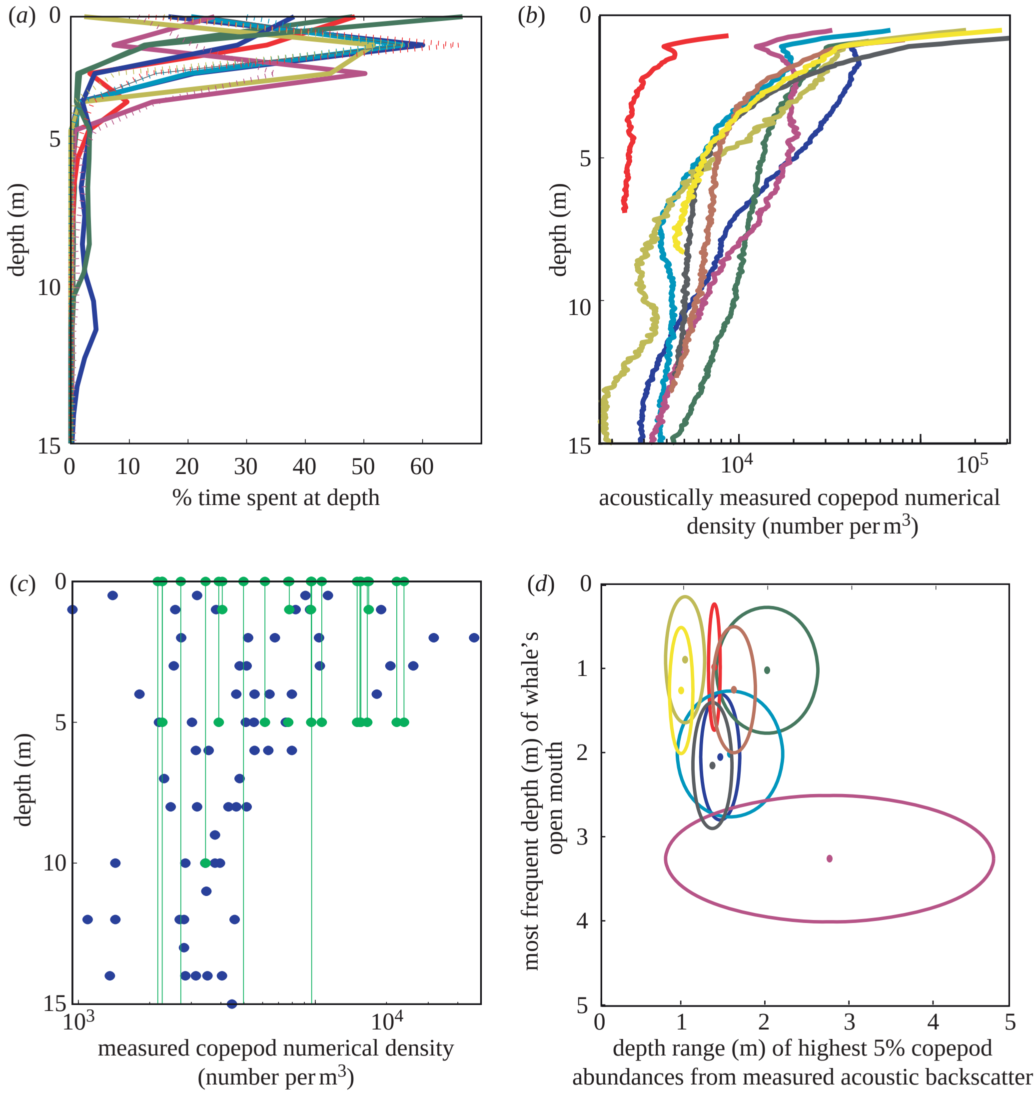

Figure 2. (*a*) Percentage of the total time each tagged whale spent in 1 m depth bins. Dashed lines, 2009 data; solid lines, 2010 data, (*b*) Acoustic backscatter estimates of copepod numerical density by depth from 2010 measured near tagged right whales ($n = 9$), (*c*) net tow (green) and pump sample (blue) measurements of copepod numerical density from 2009 and 2010 measured near tagged or feeding right whales, and (*d*) peak (most frequent) depth of a feeding right whale's open mouth (top of ellipse shows measured tag depth, central point estimates centre of the whale's open mouth, with the estimated 1.5 m mouth gape for a feeding whale) and the depth range of the greatest 5% of copepod abundance in the water column based on acoustic backscatter measurements for whales from 2010. Dive profile and acoustic backscatter measurements are colour-coded to indicate measurements from individual whales.

Sampling sites were within 500 m of tagged right whales. Samples were preserved in 10 per cent buffered formalin solution, with subsamples being identified (to species when possible) and enumerated using compound and dissecting microscopes.

(d) ***Pump sampling***

Vertical profiles of zooplankton abundance were sampled within approximately 500 m of the tagged whales. A discrete depth vertical pump [10] was used to filter a known volume of sea water through a

333 μm mesh [11]; all samples were rinsed off the mesh with sea water and preserved with 6–8% buffered formalin. Date, time, location, depth of sample and depth of water column were recorded in a data-logging program for each sample collected. Each vertical profile was therefore made up of discrete depth samples, for which metadata were uniformly collected.

3. RESULTS

The dive data from 13 tagged right whales indicate that the whales spent the majority (mean = 84%, range 62–98%) of their time with their dorsal surface between 0.5 and 2.5 m of the water's surface, making them difficult to see and vulnerable to collisions with vessels of a range of sizes (figure 2*a*). The most abundant zooplankton in the net samples were *Calanus finmarchicus* (C-IV, C-V and adult). *Psuedocalanus newmani* and *Oithona similus* were also present. The daytime distribution of copepods documented by acoustic backscatter data, pump and net sampling identified high concentrations of zooplankton only in the upper 5 m of the water column (figure 2*b,c*). Prey sampling around tagged whales found that these surface patches often covered an area greater than several square kilometres and persisted for several hours. Acoustic estimates and pump sampling of the prey field in the surface layers near feeding whales found numerical densities of 10^3–10^5 m^{-3} copepods (and in some regions greater than 10^5 m^{-3}). Previous studies [5] established a feeding threshold of approximately 10^3 m^{-3} copepods for right whales in this habitat. There was a strong relationship between the depth of the centre of a feeding whale's mouth and the mean depth of the top 5 per cent concentration of their prey in the water column (figure 2*d*; $r^2 = 0.44$).

4. DISCUSSION

The diving behaviour of foraging whales observed during this study was markedly different from dive profiles described in other deeper water habitats, and in CCB during times of year when prey aggregate at depth [7]. The stereotyped deep 'flat-bottom' dives described for right whales feeding on deeper prey aggregations [7] were not observed during this study. Instead, most whales stayed at or just below the surface while actively feeding, at a depth that corresponded to the peak concentration of their zooplankton prey.

While in-the-field monitoring and research remain important components of right whale conservation, remote monitoring for right whales can be used to alert managers, and in turn boat operators, of whale presence. Currently, a real-time passive acoustic monitoring (PAM) network of buoys is in place to monitor for right whale vocalizations in Massachusetts waters [12]. However, our data indicate that tagged right whales did not vocalize while actively feeding, leaving whales exposed to the risk of ship strike while they are particularly vulnerable because of their shallow dive pattern. The development of autonomous active acoustic echosounders for remote detection of zooplankton to be moored in feeding habitats may provide an additional way to remotely monitor the influential right whale prey patches, and therefore, may be a key way of predicting the location of right whales [13], their diving behaviour and the risk of ship collision.

This study highlights the importance of documenting endangered species' ecology to the management of anthropogenic risks that hinder population recovery. In this example, the seasonal behaviour of right whale prey makes right whales in CCB particularly vulnerable to collisions with vessels during April. CCB has been dynamically managed for 13 years using aerial right whale surveys, boat-based zooplankton surveys [4] and more recently PAM [14] to alert managers to the presence of right whales in the bay. When feeding right whales aggregate around a surface or subsurface zooplankton resource, dynamic management areas with voluntary speed restrictions are implemented to warn mariners of increased ship strike risk [4]. The results of this study support the management strategy used in CCB, and suggest that remote acoustic detection of prey aggregations may be a useful supplement to the study and management of right whales. More broadly, understanding the typical foraging ecology of threatened or endangered species can lead to better predictions of their distribution, and identify locations and periods of particular vulnerability for negative anthropogenic interactions.

Tag data, photographs, and nearby zooplankton samples were collected under NOAA NMFS Scientific Permit nos. 655-1652-01, 775-1875 and 633-1763 and were approved by the Penn State Institutional Animal Care and Use Committee.

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ATTACHMENT 3

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Implementing conservation measures for the North Atlantic right whale: considering the behavioral ontogeny of mother-calf pairs

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Keywords
behavioral ontogeny; activity budget; call rate; passive acoustic monitoring; North Atlantic right whale; vessel collision; marine mammal.

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Abstract

Understanding the behavioral ecology of a species is fundamental to effective conservation and management efforts. This study quantifies the behavioral ontogeny of North Atlantic right whale mother-calf pairs from birth to weaning spanning three critical habitat areas off the eastern coast of the United States and Canada. Data from 55 focal follows of 34 mother-calf pairs were collected from 2011 to 2015. Resting behaviors dominated the activity budgets for both mother and calf during the first 5 months, putting them at increased risk of vessel collisions. There was an increase in the proportion of active behaviors (travel, foraging, social activity) in both mother and calf as the calf matured. Importantly, the type of active behaviors, in particular surface skim feeding and surface active social behavior, meant that the risk of vessel collision to the pair did not decrease as the calf matured. Mother-calf right whale pairs showed very low calling rates on the calving grounds, suggesting that passive acoustic monitoring may not be an effective mitigation tool during the early months. However, calling rates increase once the pair leave the calving areas with both calf age and activity levels increasing, at which point passive acoustic monitoring becomes valuable. Protective measures need to take these rapid developmental changes throughout calf growth into account to improve the efficacy of protection measures for the endangered North Atlantic right whale and other species where behavioral ecology changes rapidly during maturation.

Introduction

Whaling has had a major impact on our oceans, removing at least 2/3 of all great whales from marine ecosystems (Roman *et al.*, 2014). As a result, the role that whales serve as key ecosystem engineers has been lost: as consumers, as prey, as vectors for nutrients and as detrital sources of energy and habitat in the deep sea (Roman *et al.*, 2014; Willis, 2014; Smith *et al.*, 2015). Since the ban on whaling, many species have shown a steady recovery in their population numbers, with some species even reproducing at unprecedented rates (e.g. 10–11% increase per year in humpback whales *Megaptera novaeangliae* off eastern Australia (Noad *et al.*, 2016)). However some species, such as the North Atlantic right whale (NARW) *Eubalaena glacialis*, are not recovering and the future of these species remains uncertain. Recognizing the driving factors that impede recovery and using science to inform conservation measures is essential in giving these populations a chance of survival.

NARWs are an endangered baleen whale species, hunted almost to extinction by the early 20th century. Despite a ban on whaling for this species imposed in 1935 (Tønnessen & Johnsen, 1982), the recovery rate of this population has been slow, around 2.8% per year between 1990 to 2010, with the population increasing from 295 to roughly 500 individuals (e.g. Knowlton, Kraus & Kenney, 1994; Waring *et al.*, 2016). However their population trajectory has been in decline since 2010, decreasing to an estimated 458 individuals (Pace, Corkeron & Kraus, 2017), leaving the NARW at a crisis point. The combination of a lower than expected birth rate and unsustainable levels of accidental mortality from anthropogenic sources, such as vessel collisions and entanglements, are driving this crisis (e.g. Kraus *et al.*, 2016; Brilliant *et al.*, 2017; Van der Hoop, Corkeron & Moore, 2017). Of concern is the disproportionate representation of calf and

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juvenile mortality from ship-strikes in this species (e.g. Moore *et al.*, 2004).

Over the past 30 years, NARWs have routinely calved in the waters off the southeastern United States during the winter months. Mother-calf pairs migrate north and are regularly observed feeding in the Great South Channel, Cape Cod Bay and Massachusetts Bay during the spring (Kraus & Rolland, 2007). During the summer months, when the calves reach about 8 months of age, NARWs are commonly found further north in Canadian waters, including the Bay of Fundy and Roseway Basin (Kraus & Rolland, 2007). However, recent changes in movement patterns of right whales within their known range (Davis *et al.*, 2017; Meyer-Gutbrod & Greene, 2018) are making their seasonal and spatial occurrence more unpredictable. This in turn makes it difficult to maintain an understanding of the anthropogenic risks they face. For species that show such large-scale movements, mothers and their dependent young are challenged by changing habitats during migration, exposing their calves to a wide range of ecological and anthropogenic threats along the way. It is thought that fewer than 100 reproductive females remain in the species (P. Corkeron, pers. comm.). Therefore, the need to conserve mother-calf pairs is paramount if this species stands any chance of survival.

Currently, passive acoustic monitoring (PAM) is used in a number of ways, including long-term monitoring of NARW occurrence throughout their range using fixed archival recordings (Davis *et al.*, 2017), as well as real-time fixed buoys and mobile platforms (Van Parijs *et al.*, 2009; Baumgartner *et al.*, 2013). This information is actively used to direct research efforts, understand changes in distribution, and mitigate vessel collisions (Van Parijs *et al.*, 2009; Davis *et al.*, 2017). The level of acoustic activity can vary depending on a species' behavior, habitat, age, sex and group composition. Understanding the behavioral and acoustic activity of mother-calf pairs is paramount to understanding when specific conservation measures directed at reducing anthropogenic impacts can be successful. In this study we quantify the surface and acoustic behaviors of NARW mother-calf pairs, tracking changes from birth onwards across their known habitat areas during the first year of the calf's life, with the goal of better understanding and mitigating vessel collision risk.

Materials and methods

Combined behavioral and acoustic data were collected from North Atlantic right whale (NARW) mother-calf pairs over five consecutive years, from 2011 to 2015. Field work was conducted in three separate right whale critical habitats. Efforts were focused during time periods when NARWs have previously been documented in these areas (Kraus & Kenney, 1991; NOAA, 2016): the southeastern United States (SEUS) NARW calving grounds between the months of January and March; and two subsequent foraging habitats, Cape Cod Bay (CCB), in the northeastern United States in April, and the Bay of Fundy (BOF), Canada between August and September (Fig. 1). Mother-calf pairs were present in the SEUS in all 5 years, CCB in 4 years and the BOF in 2 years (Table S1).

All behavioral observations and acoustic recordings were made using small boats (<8 m length) launched on fair--weather days (wind speed ≤10 knots and Beaufort sea state ≤3). In both the SEUS and CCB, visual sightings from concurrent aerial surveys directed at collecting photo identification information on NARWs aided in locating mother-calf pairs (Brown *et al.*, 2007; Gowan & Ortega-Ortiz, 2014). When no aerial survey information was available, mother-calf pairs were located opportunistically or via line transect surveys.

Photographs were taken to identify the mother based on individually distinct callosity patterns and other markings (Kraus *et al.*, 1986). Photographic identification (EGNO, individual NARW identification number) was confirmed at the end of each season by the New England Aquarium, which manages the NARW photo-identification catalog (Hamilton & Martin, 1999; http://rwcatalog.neaq.org).

Behavioral data collection

Continuous focal animal sampling was carried out by a dedicated observer for each mother-calf pair. This has been shown to be a reliable method for analyzing cetacean activity budgets and/or behavioral states (e.g. Mann, 1999; Karniski *et al.*, 2014). An ethogram was constructed to represent the complete activity budget of mother-calf pairs and behavioral states were considered mutually exclusive to one another (Table 1). The five behavioral states used are similar to those used for a previous study on the behavior of NARW mother-calf pairs (Hain *et al.*, 2013), as well as for other cetaceans including grey whales *Eschrichtius robustus* (Stelle, Megill & Kinzel, 2008), southern right whales *Eubalaena australis* (Taber & Thomas, 1982; Thomas & Taber, 1984), humpback whales (Cartwright & Sullivan, 2009; Zoidis *et al.*, 2014), and killer whales *Orcinus orca* (Ford, 1989). The duration of time spent in these key behavioral states was calculated for each focal follow to determine the overall activity budget.

Focal follows were conducted while attempting to maintain a distance of 50–200 m between the observation platform and the whales to minimize any impact on their behavior while remaining within range to record behavior with confidence. When conditions allowed, or a whale approached to <50 m, the engine was put into neutral or shut down completely. Behavioral data collection was suspended if the whales were >400 m from the vessel or if the Beaufort sea state was >4. As the behavioral development of the calf was the priority in this study, if the mother and calf separated, the calf became the focus of the follow and sampling for the mother was terminated until she returned within the sighting range.

Acoustic data collection

Acoustic recordings were made of the mother-calf pairs during each focal follow to determine call rates in each habitat. Two different methods were used for obtaining recordings depending on the behavior of the mother-calf pair (e.g. travelling or resting) and the habitat (shallow or

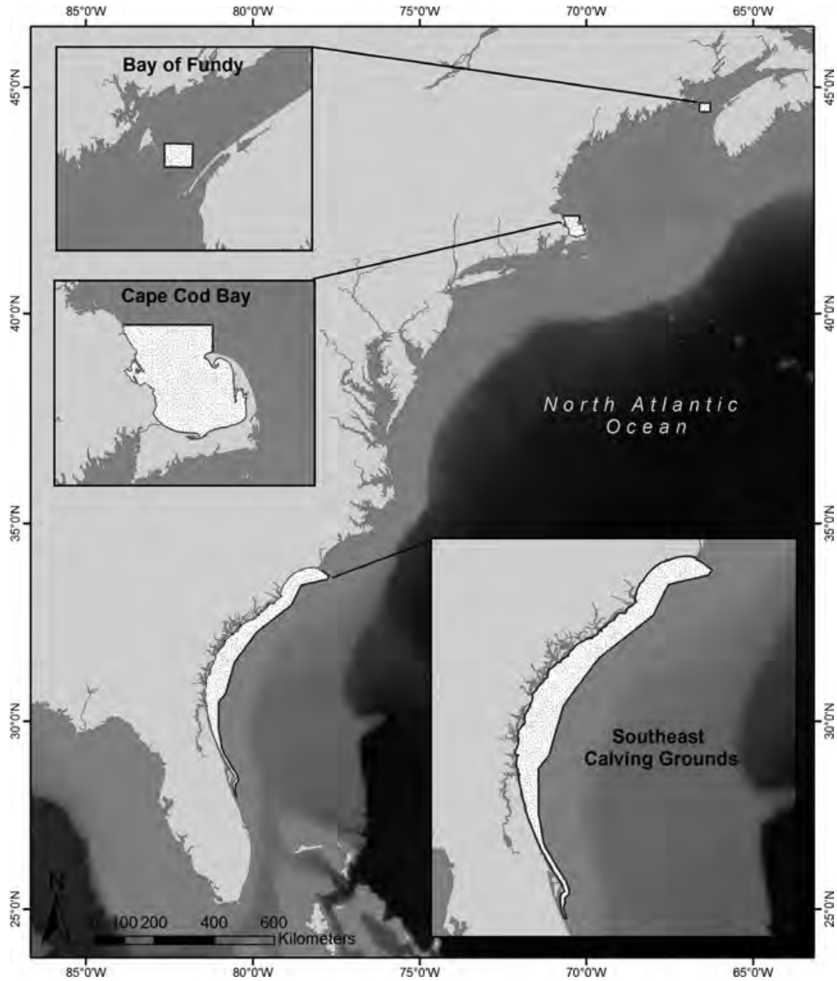

Figure 1 Location of the three critical habitat areas in which data collection occurred.

Table 1 The ethogram for North Atlantic right whale mother-calf pairs, consisting of five behavioral states recorded during focal follows

State	Definition	References
Rest	Resting motionless at the surface or just subsurface, and 'slow travel', with no change in heading or significant increase in speed.	Mann & Smuts, 1999; Stelle *et al.*, 2008; Hain *et al.*, 2013; Zoidis *et al.*, 2014
Nurse	Determined based on the calf's position relative to the mother's mammary slit while she is logging at the surface, and a common pattern of descending on one side and resurfacing on the opposite side of the mother.	Thomas & Taber, 1984; Hain *et al.*, 2013
Feed	High or low skim feeding evidenced by an open mouth, or subsurface feeding evidenced by long dives (up to 16 minutes) and a surfacing location in close proximity to the location of the initial dive.	Mayo & Marx, 1990; Baumgartner & Mate, 2003; Baumgartner, Mayo & Kenney, 2007
Travel	Directed forward active movement at a steady speed.	Thomas & Taber, 1984; Stelle *et al.*, 2008; Cartwright & Sullivan, 2009; Videsen *et al.*, 2017;.
Surface active/ play (SAP)	Increased activity at the surface, including participation in social activities such as surface active groups (SAGs), flipper and tail slapping, rolling, breaching, and interacting with other species or objects (*e.g.* the boat).	Würsig *et al.*, 1985; Ford, 1989; Baird *et al.*, 2002; Parks *et al.*, 2007; Stelle *et al.*, 2008; Hain *et al.*, 2013; Zoidis *et al.*, 2014

deep water). Depending on the hydrophone set-up, recordings were made using either an Edirol R-4 Pro 4-channel portable recorder (44.1 kHz sampling rate, 16-bit, frequency response 20 Hz–40 kHz (±3 dB)), or a Marantz PMD-661 hand-held solid-state recorder (44.1 kHz sampling rate, 16 bit, flat (±1 dB) frequency response 20 Hz–22 kHz).

For travelling behavior or in deeper water, recordings were made with either a three-element array or a single element hydrophone attached to a pole extended from the stern of the boat (HTI-96-MIN, High-Tech, Inc., flat (±1 dB) 2 Hz–30 kHz sensitivity, nominal −164 dB re: 1V/μPa). The three-element array was 90 m in length and the hydrophones were spaced 10 m apart at the tail end of the cable. The single element towed hydrophone was 20 m in length. Surgical tubing was used for stress relief at the attachment point to the pole in order to minimize self-noise when drag was applied to the cable. Towed recordings were only made when the vessel was travelling at speeds of 4–10 knots (most recordings at ~5 knots) to minimize the amount of flow noise in the recording. The 3-element hydrophone towed array was of sufficient weight that, when fully extended, the elements maintained a depth of at least 3 m while towing, and greater than 5 m when stationary. The single element towed hydrophone was weighted with 0.4–0.9 kg weights in order to maintain a similar depth as the array when towed and stationary. Observers on the vessel monitored the towing hydrophone visually to confirm that the hydrophone remained submerged during towing and aurally to assess the quality of the acoustic recording to make sure that cable strumming and/or flow noise levels were of an acceptable level.

During stationary behaviors, or in shallow habitats in the SEUS where water depth was often <10 m, dip hydrophones (HTI-96-MIN, High-Tech, Inc., flat (±1 dB) 2 Hz–30 kHz sensitivity, nominal −164 dB re: 1V/μPa) were deployed from spar buoys tethered to both sides of the boat. The drop hydrophones were weighted with 0.25 kg weights in order to keep the hydrophone vertical when attached to the spar buoy, and were deployed between 5 and 10 meters. For both the towed hydrophones and stationary hydrophones, the objective of the recordings was to detect tonal calls utilized for passive acoustic monitoring (Van Parijs *et al.*, 2009). Given that the source levels of these calls is estimated to exceed 147 dB_{rms} re 1 μPa (Parks & Tyack, 2005), and our recordings occurred <200 m from the whales, there was a low probability of missing a detection of any calls produced by the focal whale(s).

In 2014 and 2015, suction cup attached acoustic recording tags (Acousonde 3B, Greeneridge Sciences, Inc.) were used to collect data in CCB. These tags were equipped with sensors that record acoustic signals, pressure (depth), temperature, acceleration and magnetic field along three axes. Tags were programmed to sample audio at 25 kHz, with an anti-alias low pass filter setting to provide a flat (±3 dB) recording frequency range of 22 Hz–9.2 kHz. Additional sensors were sampled at 10 Hz.

All acoustic recordings were reviewed visually and aurally by an experienced acoustic technician using Raven Pro 1.5 (Cornell Bioacoustics Research Program, 2014 http://www.birds.cornell.edu/raven) software for the presence of NARW vocalizations (Parks *et al.*, 2011). The occurrence, timing, call type and number of calls produced were noted during each focal follow. The primary aim of the recordings was to assess the number of vocalizations detected in the presence of mother-calf pairs to inform passive acoustic monitoring, therefore no attempt was made to identify the caller (i.e. mother or calf). The behavioral sequencing was synced with the acoustic recordings; therefore each call could be assigned to an associated behavioral state. Only calls for which a behavioral state could be assigned were retained in subsequent analysis. Similar to the behavioral focal follows, if the mother and calf were in different behavioral states, the state of the calf was used to assign a behavioral state to the detected call.

Behavioral and acoustic analyses

Only focal follows >10 min duration were used in these analyses. Mother and calf were evaluated separately in order to obtain activity budgets for both individuals. To remain conservative, in a situation where a state was unclear to the observer, states were "turned off" and the animal(s) were not assigned to a state for that period of time. The cumulative time that an animal was unable to be assigned to a state was removed from the overall follow time to account for this. We then obtained percentages by dividing the time spent in the state by the adjusted focal follow time to determine relative time spent in each behavioral state.

For statistical comparisons of time spent in states, hours were used rather than proportions. This was done to reduce bias in the results as the observation times for focal follows were highly variable. To account for pseudoreplication (repeated measurements on the same mother-calf pair), non-normality and unbalanced sample sizes (unequal number and duration of follows in each habitat), linear mixed-effects models (LMMs) (Cnaan, Laird & Slasor, 1997) were used. Habitat was considered the fixed effect and whale ID and year were added as random effects. Models were run using restricted maximum likelihood estimates (REML) in order to provide unbiased estimates of the variance components. All analyses were conducted in R (R core team 2016) using the package lme4 (Bates *et al.*, 2015). Initial model results using Akaike information criterion (AIC) scores indicated that year was not an important variable, and it was subsequently removed from the analyses. Post hoc analyses on the LMMs were done using the package lsmeans (Lenth, 2016) and contrasts were done between all habitats using the Tukey method. The function lsmeans produces least squares means for contrasts based off of the model rather than raw data. This incorporates the other covariates of the model and is more appropriate for unbalanced designs (Lenth, 2016).

Call rates (calls per hour) were obtained by dividing the number of calls detected within a state or within a habitat by the total time of the behavioral follow or cumulative follow time for the season respectively. Mixed models were then used to analyze the calling rates between habitats and to assess the activity state in which vocalizations were predominantly detected. Habitat was set as the fixed effect, and whale ID and year were included as random effects. Year was removed from the model based on AIC scores during model development. Post hoc analyses using lsmeans were again used with contrasts between habitats and between states.

Results

A total of 64 focal follows were conducted between 2011 and 2015. Follows of less than 10 minutes in duration were discarded from further analysis, with 55 focal follows from 34 different mother-calf pairs, comprising 122.2 h of behavioral data used for analyses (Table S1). Thirteen pairs were followed on more than one occasion, with five repeat follows on one pair (catalog #3390). One mother (catalog #2040) was followed in two different years with subsequent calves (twice in 2011 and once in 2014). Seven pairs were followed in two habitats during the same year, although no pair was followed in all three habitats during a single year.

SEUS: 32 focal follows were conducted in the SEUS over the course of 5 years (average duration 2.2 ± 1.3 h), with 75.2 h of concurrent acoustic data collected. A total of 51 calls were recorded over the 5 years.

CCB: No data were obtained in CCB during 2012, but a total of 17 focal follows were conducted (average duration 2.0 ± 1.5 h) across the other 4 years, with 35.7 h of acoustic recordings. A total of 1175 calls were recorded over the 4 years.

BOF: NARW sightings declined precipitously between 2012 and 2015 in the BOF (Pettis & Hamilton, 2015). As a result, no data were collected on mother-calf pairs from 2013 to 2015 in this area. Six focal follows were conducted between 2011 and 2012 (average duration 3.1 ± 1.7 h), however one follow had to be dropped for a mother due to the short duration of the follow, leaving a total of five follows for mothers in the BOF and six for calves. A total of 20.3 h of acoustic data were collected in this habitat during the 2 years, with 1069 calls detected.

Behavioral activity budgets

The difference in time spent in specific behavioral states was compared for NARW mothers and their calves, however due to the very unbalanced sample sizes among habitats, especially in the BOF habitat, caution must be used in directly comparing percentages (Table 2). The activity budgets for mothers and calves were similar, with time spent in nurse and travel virtually identical across all habitats. Mixed models identified a statistically significant difference in the amount of time spent in *rest* and *feed* between mothers and calves in CCB only (Table S2). This was due to the increased amount of observed time feeding by mothers in this habitat and the lack of observations of feeding by the calves. No other statistically significant differences were observed in the time spent in each behavioral state when mothers were compared with calves.

For NARW mothers, *rest* dominated the activity budget in the SEUS, followed by *travel* and *nurse* (Fig. 2a, Table 2). No time was spent in *feed* on the calving grounds. The occurrences of *surface active/play* (*SAP*) in the SEUS were brief and infrequently observed, therefore they didn't constitute a measurable part of the activity budget. *Feed* was the principal state in CCB, followed by *rest*, *travel*, *SAP* and lastly *nurse*. In the BOF, *rest* was again the dominant activity for mothers, followed by the highest incidence of *travel* observed, and almost equal amounts of time spent in *feed* and *SAP*. *Nurse* again comprised a small percentage of the activity budget. Analysis from the mixed models showed a significant difference between the amount of time spent in *rest, nurse* and *feed* between the SEUS and CCB, and the amount of time spent in *travel* between the SEUS and both of the other habitats (Table S3).

As with mothers, the predominant activity for NARW calves in the SEUS was *rest*, followed by *travel* (Fig. 2b, Table 2). An almost equal amount of time was spent in *nurse* as in *SAP* for the calves in this habitat. No time was spent in *feed* in the SEUS. In CCB, *rest* was still the principal activity, and a similar amount of time was devoted to this state in this habitat as in the southeast. *Nurse* occurred at a low rate. *Feed* was observed once in CCB for calves, but the behavior was observed for <1 min, and so was not a measurable part of the overall activity budget. In CCB, *travel* and *SAP* made up a similar portion of the budget. *Rest* again made up the dominant activity in the BOF and *nurse* again comprised a small portion of the activity budget. No time was spent in *feed*. Time spent in *travel* was similar to time spent in *SAP*. When comparisons between habitats were made with the mixed models, the only significant difference was observed in the amount of time spent in *nurse* between the SEUS and CCB, and time spent in *travel* between the SEUS and the BOF (Table S4).

Calling behavior

A total of 2295 calls were detected across the entire the study period from 131.2 h of recordings, 75.2 h of which were in the SEUS, 35.7 h in CCB and 20.3 h in the BOF. Of the 2295 calls, 2059 were paired with behavioral sequencing data and subsequently used to assess calling rates/number of calls detected (Table 3). Both the calling rate (calls per hour) and production of calls increased as the calf aged, with the lowest

Table 2 Activity budgets of North Atlantic right whale mothers and calves in all three critical habitat areas showing percentage of total time spent in each behavioral state

State	SEUS (%)	CCB (%)	BOF (%)
Mom			
Rest	81	24	45
Nurse	9	3	4
Feed	0	54	11
Travel	10	13	30
SAP	0	6	10
Calf			
Rest	74	70	50
Nurse	8	3	3
Feed	0	0	0
Travel	10	13	27
SAP	8	14	20

SAP, surface active/play; SEUS, southeastern United States; CCB, Cape Cod Bay, Massachusetts, USA; BOF, Bay of Fundy, Canada.

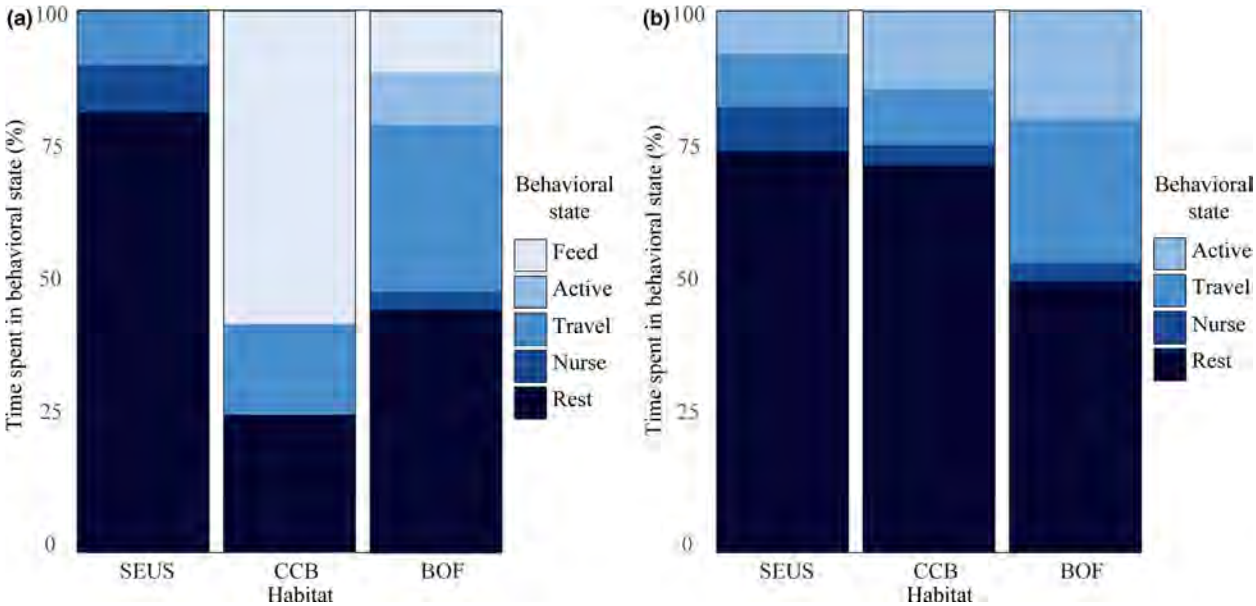

Figure 2 The activity budget of right whale mothers (a) and calves (b) in three habitat areas. SEUS, southeastern United States; CCB, Cape Cod Bay, Massachusetts, USA; BOF, Bay of Fundy, Canada. [Colour figure can be viewed at zslpublications.onlinelibrary.wiley.com]

call rates recorded in the SEUS (total calls = 51; call rate lsmean = 1.1 ± 5.0), followed by CCB (total calls = 1175; call rate lsmean = 33.0 ± 7.5) and the BOF (total calls = 1069; call rate lsmean = 55.1 ± 11.0). There was a significant difference in the call rate between the SEUS and CCB, and the SEUS and the BOF (Table 3, Table S5).

When broken down by behavioral state, the lowest number of calls detected and the lowest call rates occurred during *nurse* (total calls = 25; call rate lsmean = 4.11 ± 7.0), followed by *travel* (total calls = 159; call rate lsmean = 6.5 ± 8.1) and *rest* (total calls = 548; call rate lsmean = 7.4 ± 6.5) (Table 3, Table S6). The highest number of vocalizations occurred during *SAP* (total calls = 1327; call rate lsmean = 65.6 ± 8.9), or times when the mother and calf were separated (Fig. 3). The call rate increased as the calf aged for all activity states with the exception of *SAP* between CCB and the BOF, however the only significant differences occurred in *rest* between the SEUS and the BOF, *rest* between CCB and the BOF, *nurse* between the SEUS and the BOF, *nurse* between CCB and the BOF, *SAP* between the SEUS and CCB, and *SAP* between the SEUS and the BOF (Table 3, Table S6). It should be noted that while it is possible that some calls were missed due to masking from flow noise, especially during times of travel, any calls that were missed would have been of such low amplitude that they would also likely be missed from any passive acoustic monitoring device due to the relatively close proximity of the whales to the hydrophone.

Discussion

This study demonstrates how the behavioral states of NARW mother-calf pairs alter over the course of their migration across the first 9 months of a calf's life. Similar to other marine mammals, the time calves spent resting decreased as they matured and they became more active, while mothers spent more time foraging (e.g. Kovacs, 1987; Cortez *et al.*, 2016). Of interest is that the extensive time periods spent in resting and nursing states reflect times that the whales are at the surface or just subsurface. These behaviors place the pair at an increased risk of ship strike, which may explain a high proportion of calves suffering from ship strike mortality in this species (e.g. Moore *et al.*, 2004). In addition, all of the behavioral observations were taken from the surface, so

Table 3 The total number of calls detected and the call rates (average calls per hour) of North Atlantic right whale mother-calf pairs in each behavioral state in the three habitat areas. As the behavioral state of the calf was used for the analysis on calling behavior, *feed* was not included

Habitat	Hours of acoustic recordings	Calls in *rest*	Calls in *nurse*	Calls in *travel*	Calls in *SAP*	Calls/hour (lsmean ± SE) in *rest*	Calls/hour (lsmean ± SE) in *nurse*	Calls/hour (lsmean ± SE) in *travel*	Calls/hour (lsmean ± SE) in *SAP*
SEUS	75.2	14	2	0	32	0.4 ± 3.5	0.2 ± 3.0	0 ± 6.2	5.1 ± 20.5
CCB	35.7	389	7	19	699	11.2 ± 4.7	3.3 ± 5.1	3.0 ± 11.2	142.6 ± 27.2
BOF	20.3	145	16	140	596	37.0 ± 9.0	25.3 ± 7.2	33.1 ± 12.6	135.2 ± 39.9

SAP, surface active/play; SEUS, southeastern United States; CCB, Cape Cod Bay, Massachusetts, USA; BOF, Bay of Fundy, Canada.

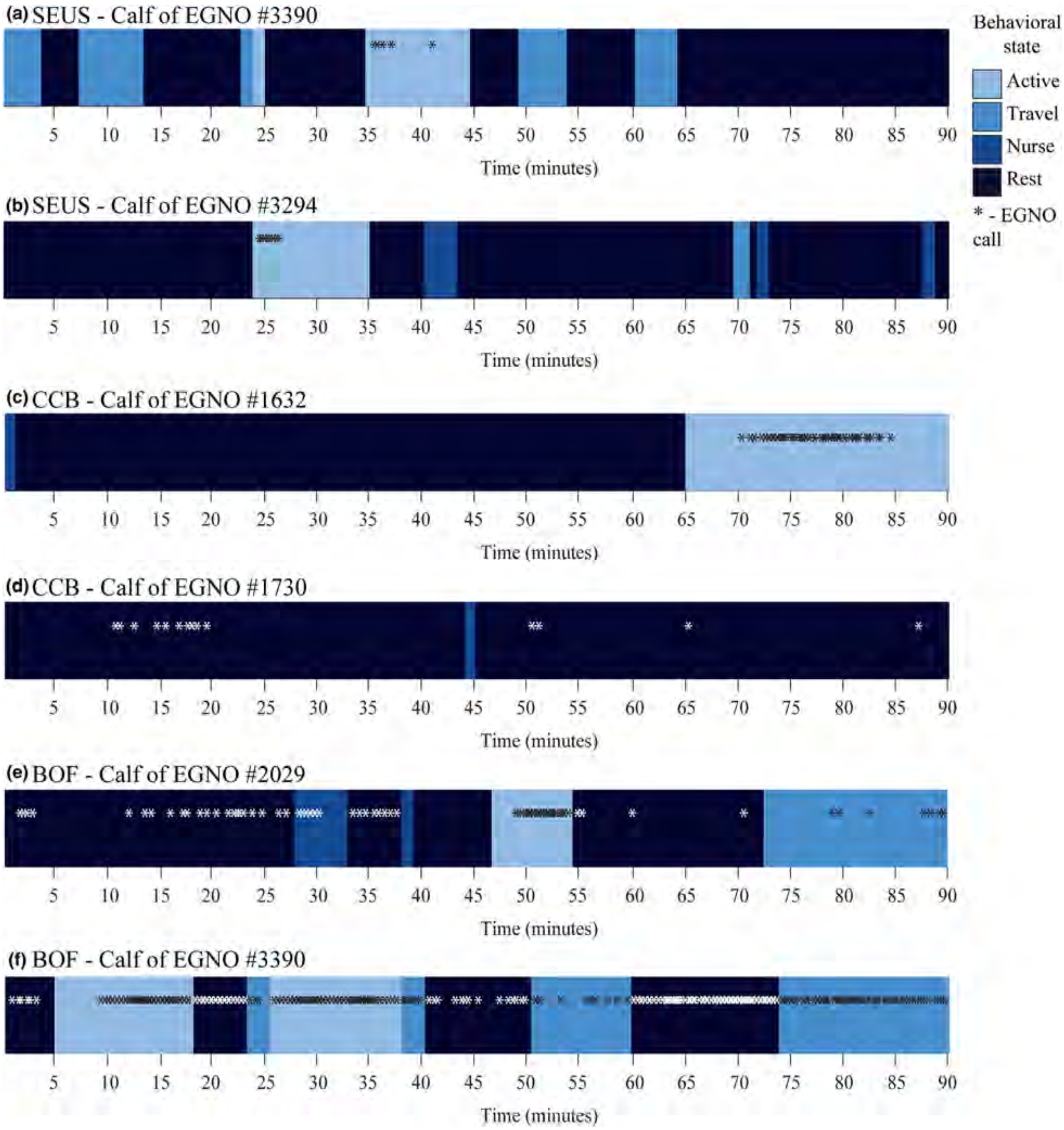

Figure 3 Example focal follows from calves in three study habitat areas, highlighting both the frequent state transitions and the changes in the time spent in certain behavioral states with age. Times of detected right whale vocalizations are marked with an * within the timeline. (a) calf of EGNO #3390, 5 February 2012 in the SEUS (b) calf of EGNO #3294, 21 January 2013 in the SEUS (c) calf of EGNO #1632, 17 April 2013 in CCB (d) calf of EGNO #1703, 30 April 2015 in CCB (e) calf of EGNO #2029, 17 August 2011 in the BOF (note that the mother and calf were separated from each other by hundreds of meters throughout most of this focal follow), and (f) calf of EGNO #3390, 3 September 2012 in the BOF. SEUS, southeastern United States; CCB, Cape Cod Bay, Massachusetts, USA; BOF, Bay of Fundy, Canada; EGNO, individual NARW identification number. [Colour figure can be viewed at zslpublications.onlinelibrary.wiley.com]

particularly cryptic behaviors such as nursing are likely minimum estimates. However, as the same behavioral sequencing protocols were used in all habitats, there is not likely to be a directional bias between habitats for this state.

Ship strike risk differed for the mother and the calf depending on the habitat and the age of the calf. For example, mothers (81%) and calves (74%) were equally at risk when resting in the SEUS calving region. Calves remain vulnerable throughout the spring (CCB = 70%) while time spent near the surface decreased with age and independence from its mother (BOF = 50%). Once mothers enter CCB, their focus switches to foraging (54%) to replace the energetic expenditure of producing and rearing a calf (Lockyer, 1981; Kraus, Pace & Frasier, 2007). Although mothers make a switch to this more active behavior, NARWs in CCB tend to feed on near-surface prey patches, which keeps them at the surface and at risk of vessel collision (Mayo & Marx, 1990; Parks *et al.*, 2012). While on the summer foraging grounds (BOF), mothers switched back to spending the majority of their time resting (45%), however they increased their time spent in surface active groups (SAGs) (Kraus & Hatch, 2001; Parks *et al.*, 2007) (10%). In addition, they increased the amount of time spent traveling (30%), which is typically characterized by shallow dives in this area (Parks *et al.*, 2011). These behavior changes kept mothers near the surface where they remained at risk for vessel collisions.

The number of NARW calls detected and call rates were found to be highly variable and dependent on activity state. Very few calls were recorded from mother-calf pairs in the SEUS, however calling activity increased as the pair entered CCB and the BOF. Overall, the highest call rates were detected during *SAP*, despite the fact that mother-calf pairs spent a relatively small amount of time in this behavioral state. This pattern of calling behavior is consistent with call rates described from juvenile and adult NARWs from the BOF (Parks *et al.*, 2011). As the activity levels of calves increased over time, so did the number of calls emitted and the call rates. This is consistent with studies on the calling behavior of humpback whale mother-calf pairs showing increasing call rates over the course of the seasonal migration period (e.g. Dunlop, Cato & Noad, 2008; Videsen *et al.*, 2017).

Low calling rates in mother-calf pairs in the first months after birth likely serve as a method of limiting detectability by predators, while the close proximity of right whale mother-calf pairs during this period on the calving grounds allows for contact (visual or tactile) without the need for high amplitude vocalizations (Taber & Thomas, 1982; Hain *et al.*, 2013). Given the very low call rates in the SEUS, and the limited propagation of these calls in the shallow waters of this calving ground (Parks, Urazghildiiev & Clark, 2009; Soldevilla *et al.*, 2014), it is clear that relying solely upon acoustic cues as a method for detecting NARW mother-calf pairs to mitigate ship strike in the SEUS is insufficient. However, once they leave the calving grounds, PAM does become viable as a detection and mitigation strategy.

This study demonstrates that data on calling rates and behavioral activity states provide a valuable method for understanding NARW mother-calf detectability and risk exposure. As each individual moves between habitats, their risk levels and detectability using PAM change depending upon the behavior in which the whale is engaged. However, this risk does not necessarily decrease linearly as expected based on an increase in activity and remained high even outside of their calving habitat. As NARW distribution changes it will be important to understand how their behavioral states and communication changes as a result of the habitats that they utilize. Each one of these habitats may raise new vulnerabilities and concerns depending on the timing, age class, sex and behaviors for NARWs in the area.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. The focal follows of mother-calf North Atlantic right whale pairs during which behavioral data and acoustic recordings were collected across three different habitats.

Table S2. Results of lsmeans comparing time spent in each state per habitat between North Atlantic right whale calves and mothers, with a negative mean estimate and t-value indicating the mother spent less time in that state than the calf

Table S3. Results of lsmeans of hours spent in each behavioral state by habitat for North Atlantic right whale mothers with a negative mean estimate and t-value indicating the mother spent less time in that state in the first habitat of the two being compared

Table S4. Results of lsmeans comparing hours spent in each behavioral state per habitat for calves with a negative mean estimate and t-value indicating the calf spent less time in that state in the first habitat of the two being compared

Table S5. Results of lsmeans comparing call rates in each habitat, with a negative mean estimate and t-value indicating lower call rates were detected in the first habitat of the two being compared

Table S6. Results of lsmeans comparing call rates in each behavioral state per habitat, with a negative lsmean estimate and t-value indicating lower call rates were detected in the first habitat of the two being compared

ATTACHMENT 4

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VESSEL COLLISIONS WITH WHALES: THE PROBABILITY OF LETHAL INJURY BASED ON VESSEL SPEED

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ABSTRACT

Historical records demonstrate that the most numerous, per capita, ocean-going-vessel strikes recorded among large-whale species accrue to the North Atlantic right whale (*Eubalaena glacialis*). As vessel speed restrictions are being considered to reduce the likelihood and severity of vessel collisions with right whales, we present an analysis of the published historical records of vessels striking large whales. We examine the influence of vessel speed in contributing to either a lethal injury (defined as killed or severely injured) or a nonlethal injury (defined as minor or no apparent injury) to a large whale when struck. A logistic regression model fitted to the observations, and consistent with a bootstrap model, demonstrates that the greatest rate of change in the probability of a lethal injury (P_{lethal}) to a large whale occurs between vessel speeds of 8.6 and 15 knots where P_{lethal} increases from 0.21 to 0.79. The probability of a lethal injury drops below 0.5 at 11.8 knots. Above 15 knots, P_{lethal} asymptotically approaches 1. The uncertainties in the logistic regression estimates are relatively large at relatively low speeds (*e.g.*, at 8 knots the probability is 0.17 with a 95% CI of 0.03–0.6). The results we provide can be used to assess the utility of vessel speed limits that are being considered to reduce the lethality of vessels striking the critically endangered North Atlantic right whale and other large whales that are frequent victims of vessel strikes.

Key words: vessel strike, vessel speed, lethal injury, whales, right whale, probability, logistic regression, bootstrap.

Recently compiled historical (1885 through 2002) records of vessels striking large whales worldwide ($n = 294$; Laist *et al.* 2001, Jensen and Silber 2003) reveal the most frequently reported victims of vessel strikes to be fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), North Atlantic (NA) right (*Eubalaena glacialis*), gray (*Eschrichtius robustus*), and several other large whales (Fig. 1). On a per-capita basis using contemporary worldwide population-size estimates (Aguilar 2002, Clapham 2002, Ford 2002, Horwood 2002, Jones and Swartz 2002, Kato 2002, Kenney 2002,

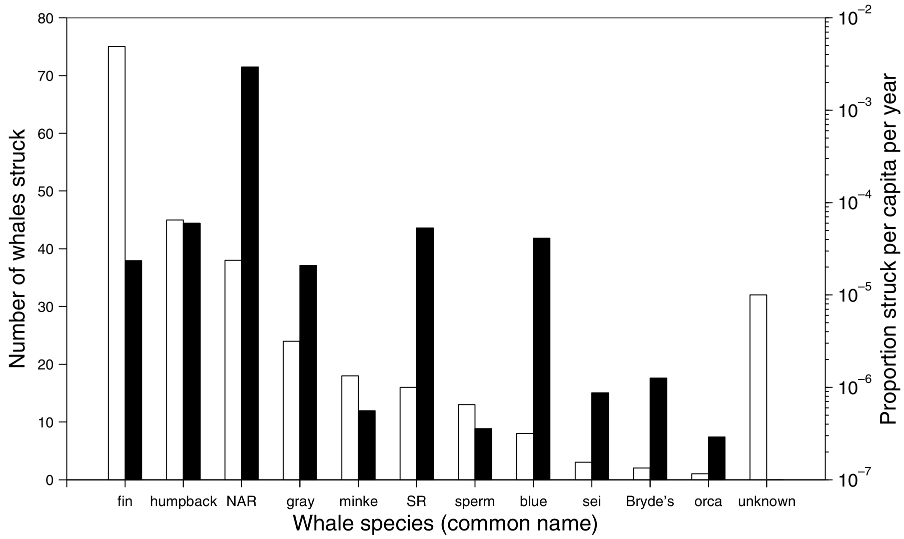

Figure 1. Frequency histograms of worldwide documented (Laist *et al.* 2001, Jensen and Silber 2003) numbers of large whales, including North Atlantic (NAR) and southern (SR) right whales, reported struck by vessels for the period 1960 though 2002 only (open bars), and the same data presented as a temporally adjusted per capita rate (solid bars; $\log_{10}$ scale) using contemporary population size estimates for each species (Aguilar 2002, Clapham 2002, Ford 2002, Horwood 2002, Jones and Swartz 2002, Kato 2002, Kenney 2002, Perrin and Brownell 2002, Sears 2002, Whitehead 2002) where the proportion struck per capita per year = (number of species-specific whales struck/contemporary species-specific population size)/43 years. Where a range in population size was provided, we use the midpoint of the range.

Perrin and Brownell 2002, Sears 2002, Whitehead 2002), and relative to all other large whales reported struck over the period 1960–2002 inclusive ($n = 275$), the NA right whale is two orders of magnitude more prevalent as victim (Fig. 1). These statistics suggest that relative to other large whales, NA right whales are more prone to being struck by vessels.

Following the U.S. National Oceanic and Atmospheric Administration (NOAA) advance notice of proposed rulemaking (Federal Register (USA) 2004) for right whale ship-strike reduction, Kraus *et al.* (2005) called for emergency measures to reduce ocean-going vessel speeds in east-coast regions of the United States and thereby to reduce vessel-related NA right whale mortality. The call for emergency measures rested on arguments that (1) the NA right whale is the most endangered species of baleen whale (Kraus *et al.* 2001); (2) the population size is diminishing (Fujiwara and Caswell 2001); (3) species extinction is expected within ~200 years unless human-induced kills are reduced (Caswell *et al.* 1999); (4) of all documented kills, most are attributable to vessel-strike (Knowlton and Kraus 2001); and (5) contemporary vessel-kill rates remain high (Kraus *et al.* 2005). Subsequently, and in an attempt to reduce mortalities due to vessel strikes, the NOAA proposed rule (Federal Register (USA) 2006) aims to "impose vessel speed restrictions of 10 knots or less" in "certain areas and at certain times of the year, or under certain conditions," and "also invites comments on vessel speed restrictions of 12 knots or less, and 14 knots or less."

The above observations, arguments, and proposals led us to estimate the probability of a lethal injury (*i.e.*, killed or severely injured) to a large whale as a function of vessel speed at the time of the vessel–whale collision. We report statistically determined estimates of the probability of a lethal injury and their associated 95% confidence intervals (CIs) based on vessel speed and offer the estimates as a first step toward assessing the utility of vessel speed restrictions in areas where vessels are likely to encounter whales.

Methods

We use the only published sources detailing the historical record of vessels striking large whales ($n = 294$; Laist *et al*. 2001, Jensen and Silber 2003) where the records ($n = 47$) jointly provide the vessel speed estimate and the severity of injury to the stricken whale. Laist *et al*. (2001) describe four injury classes: killed (carcass observed); severe (bleeding wounds and/or blood in the water); minor (visible nonbleeding wound, signs of distress, no report of blood); none apparent (resighted, no visible wound or distress, animal resumed prestrike activity); and a 5th unknown-injury class (animal not observed again and no report of blood). Jensen and Silber (2003) assess injury differently, though their descriptions allowed us to classify according to the four injury classes of Laist *et al*. (2001). Those data where speed was known and injury was unknown are excluded. "Unknown" species are included where speed was known. Apart from the unknown species, all but one record (*Orcinus orca*, retained) involved large whale species (Fig. 1). We use knots as the unit of speed as it is the nautical convention. Vessel speed is classified in two-knot intervals for all analyses except in the chi-square tests described below. If vessel speed was reported as a range, the midpoint is used. One case reported <10 knots for a vessel accelerating at the time of strike and a speed of 10 knots is assumed for the analyses.

The few data detailing vessel collisions with right whales require us to assume that the other large whales, primarily baleen whale species (Fig. 1), serve as suitable proxies, at least from a body-mass perspective. This assumption is justified by the average mass at maximum length relation provided by Trites and Pauly (1998) that shows one relation applies to all mysticetes and sperm whales (*Physeter macrocephalus*) with a mid point mass of 42.5×10^3 kg. Additionally, the average mass across all species, excluding *Eubalaena sp*. and *O. orca,* based on data provided by Lockyer (1976), is 39×10^3 kg ($n = 219$, CV = 84%), and the mean of the species-specific means is 31×10^3 kg. These estimates above are broadly consistent with the 39×10^3 kg estimate for a 20 year-old right whale (Moore *et al*. 2004).

Chi-square tests are used to assess the independence of vessel speed and the severity of injury according to the four injury-classes of Laist *et al*. (2001) above. We employ the simple logistic regression model, $P_{\text{lethal}} = \frac{1}{1+\exp^{-(\beta_0+\beta_1 \text{speed})}}$, (*e.g.*, Myers *et al*. 2002) using mid point speeds among the two-knot speed classes, the proportion of whales suffering either "nonlethal" or "lethal" injury, and maximum likelihood estimation to determine the parameters and the CIs around model estimates. We define nonlethal as the sum of the minor and none-apparent injury classes above, and lethal as the sum of the killed and severe injury classes above. In the latter case, we explicitly assume a severely injured whale ultimately succumbs to the injury. This assumption has some merit for a number of reasons (1) other evidence of vessel strikes, such as scars from propeller wounds on live animals, has a low incidence of reporting (7%) and is interpreted as indicating such strikes are deadly to NA right whales (Kraus 1990);

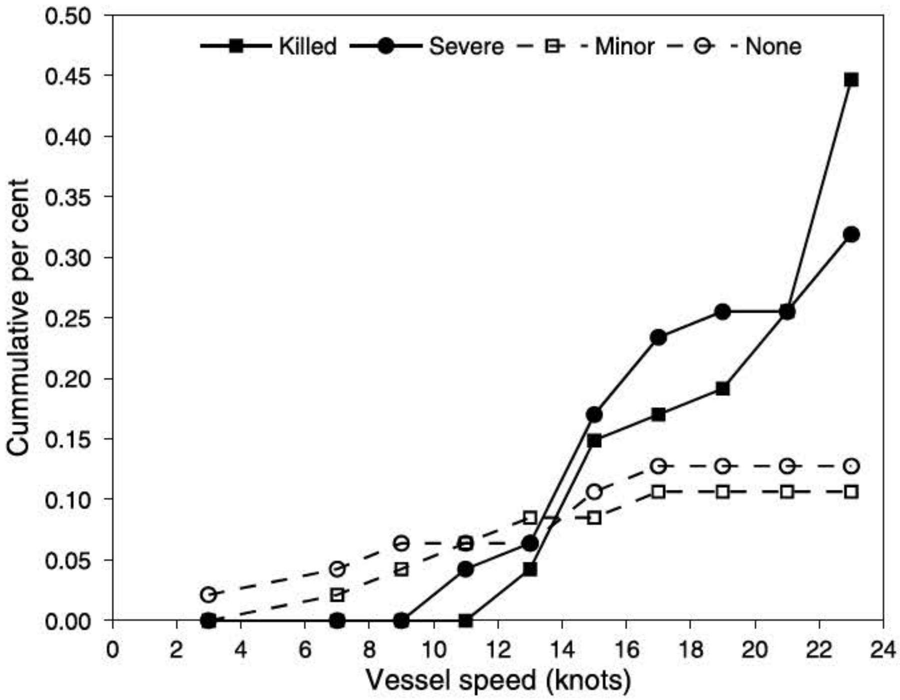

Figure 2. Cumulative per cent increase in each of four whale-injury classes as a function of the midpoint of the two-knot vessel-speed classes illustrating how the killed and severe injury classes increase similarly and in parallel, as do the minor and none apparent injury classes.

(2) of the documented vessel strikes in the NA right whale population, 1/2 of known propeller injuries proved fatal (Knowlton and Kraus 2001); (3) blunt trauma that is consistent with vessel strike is not externally obvious and frequently results in death (Wiley *et al.* 1995, Best *et al.* 2001, Moore *et al.* 2004); and (4) the cumulative percent of the killed and severe-injury classes in the data we examine increase similarly and in parallel with speed as do the cumulative percent minor and none-apparent injury classes, though the latter at a lower level (Fig. 2). The results of the logistic regression are used to draw inferences based on its inflection as well as on the two inflections of the first derivative of the functional relation.

The reliability of the data and the simple logistic regression model are examined using a bootstrap technique computed using "R" (R Development Core Team 2005) by resampling the data, with replacement, 1,000 times and by fitting the logistic to the resultant predicted probability distributions (based on nonlinear least squares estimation) across speed classes.

RESULTS

Speed and injury are not independent (6 df, $P = 0.014$) when vessel speed is categorized across three 8-knot speed intervals: low ($0 \leq$ knots ≤ 8), moderate ($8 <$ knots ≤ 16), and high (>16 knots); that is, as speed increases the severity of injury

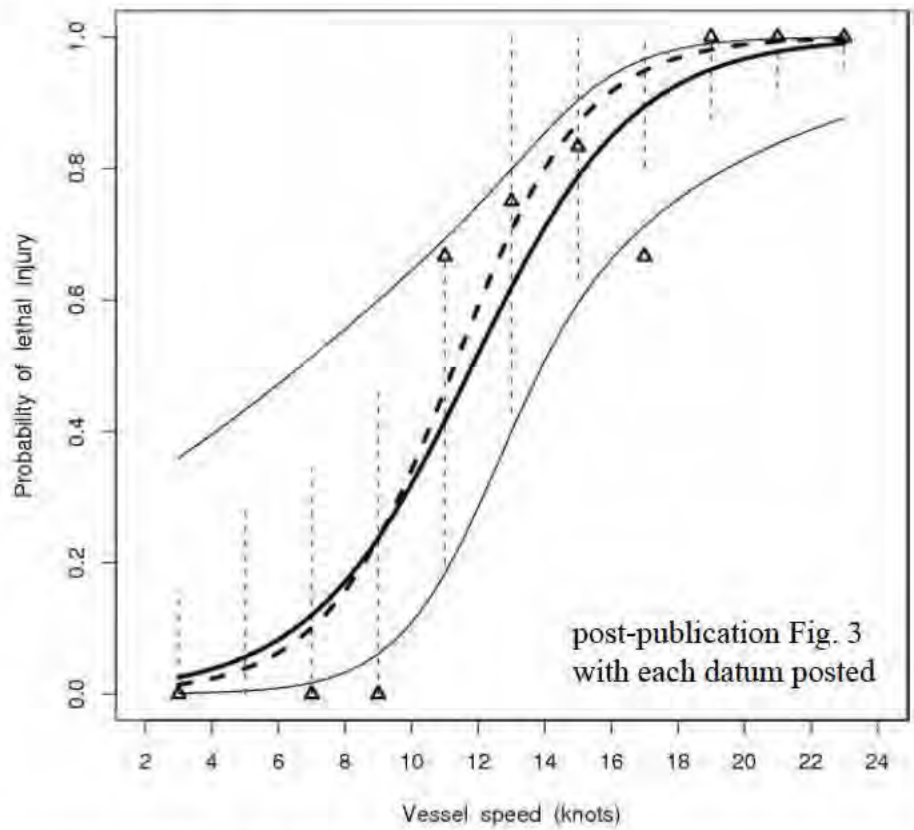

Figure 3. Probability of a lethal injury resulting from a vessel strike to a large whale as a function of vessel speed based on the simple logistic regression (solid heavy line) and 95% CI (solid thin lines) and the logistic fitted to the bootstrapped predicted probability distributions (heavy dashed line) and 95% CI for each distribution (vertical dashed line) where each datum (Δ) is the proportion of whales killed or severely injured (*i.e.*, lethal injury) when struck by a vessel navigating within a given two-knot speed class. There are no data in the 4–6 knot speed class.

increases. The same test based on four-speed classes incrementing at six knots and three-speed classes incrementing at 10 knots, and assessed against the four severities-of-injury, leads to the same conclusion (9 df, $P = 0.0007$ and 6 df, $P = 0.0001$, respectively).

The probability of a lethal injury (Fig. 3) as a function of vessel speed (knots) is determined as: $P_{\text{lethal}} = \frac{1}{1+\exp^{-(-4.89+0.41\text{speed})}}$. Wald's chi-square shows both β_0 and β_1 as different from zero ($P = 0.013$ and 0.003, respectively), and the overall model is significant ($P < 0.001$) according to a likelihood ratio test. The logistic fitted to the bootstrapped probability distributions has similar parameter estimates: $\beta_0 = -5.76$ and $\beta_1 = 0.51$.

The simple logistic regression model (Fig. 3) shows that the greatest rate of change in the probability of a lethal injury to a large whale occurs between 8.6 knots

Table 1. The odds ratio and associated lower and upper 95% confidence limit of a lethal injury to a large whale occurring at a given vessel-speed increment.

Speed increment (knots)	Odds ratio	Lower 95% limit	Upper 95% limit
1	1.51	1.15	1.99
2	2.29	1.32	3.94
3	3.45	1.52	7.83
4	5.22	1.75	15.5
5	7.89	2.02	30.9

($P_{\text{lethal}} = 0.21$) as defined by the first inflection of the first derivative of the logistic and 15 knots ($P_{\text{lethal}} = 0.79$) as defined by the second inflection of the first derivative. Only at speeds below 11.8 knots (inflection of the logistic) does the probability of a lethal injury drop below 0.5, though the uncertainties around the estimates are large. Above 15 knots P_{lethal} asymptotically approaches 1. The odds ratio, that is the ratio of the odds, $\frac{P_{\text{lethal}}}{1-P_{\text{lethal}}}$, of a lethal injury occurring at a given initial speed relative to the odds at some incremented speed, increases with the magnitude of the speed increment (Table 1). For example, an increase in vessel speed by 1 knot increases the odds of a lethal injury 1.5-fold (95% CI 1.2 2.0) regardless of initial speed. A two-knot increase in speed increases the odds by 2.3-fold (95% CI 1.3 3.9) and a five-knot increase leads to a 7.9-fold (95% CI 2.0 31) increase in the odds of a lethal injury.

The logistic fitted to the bootstrapped (with resampling) predicted probability distributions provides statistically similar results (Fig. 3), and there is no difference in the predicted values derived from the logistic fitted to the bootstrapped probability distributions and those provided by the simple logistic regression model (bootstrapped parameters are well within $\pm$ 1 SE of the simple logistic parameter estimates). For this reason the inferences below rely on estimates derived from the simple logistic regression model and the associated 95% CI.

Discussion

The logistic regression model estimates demonstrate that the greatest rate of change in the probability of a lethal injury to a large whale, as a function of vessel speed, occurs between the inflections of the first derivative of the logistic model; that is, between vessel speeds of 8.6 and 15 knots. Across this speed range, the chances of a lethal injury decline from approximately 80% at 15 knots to approximately 20% at 8.6 knots. Notably, it is only at speeds below 11.8 knots that the chances of lethal injury drop below 50% and above 15 knots the chances asymptotically increase toward 100%.

The data used in our analyses are limited and do not incorporate all variables (*e.g.*, species of whale, age, size or mass, and behavior; and vessel type, size or mass, and angle of attack) relevant to vessel–whale collisions. They are, however, the only published data that include vessel-speed observations. Consequently, the CIs are large, particularly at low vessel speeds (<10 knots) where there are few observations. Assuming that the mass of the vessels represented in the data are much greater than the mass of the whales struck, we conclude that vessel speed is sufficient to predict the probability of a lethal injury if a whale is struck, where lethality includes killed or severely injured. This conclusion is not unreasonable, at least within the limits of the two extremes of elastic or perfectly inelastic collisions in one dimension and by assuming that both the mass and speed of the colliding vessel are much greater than the mass and speed of the colliding whale. In such a simplification, it can be shown that it is only the mass of the whale and the speed of the vessel that contribute to the impact forces (see Appendix) and presumably the severity of injury to the whale. Although this simplification ignores the time over which the collision occurs (Δt in Appendix) and how the energy is dissipated during the collision (neither easily determined), it does demonstrate that vessel speed is expected to be a reasonable predictor of lethality—at least as a first approximation. It is notable that the functional forms of the ascending limbs of the logistic models illustrated in Figure 3 are proportional to the square of the vessel speed and thus consistent with expected collision-related kinetic-energy dissipation in the whale.

This study provides insights into the role vessel speed plays in determining the fate of a right whale, or other large whale, if struck. The probability estimates and their associated 95% CIs provide insight into how effective vessel-speed restrictions might be in reducing the severity of vessel-strike injuries. Such restrictions may complement other efforts designed to reduce vessel strikes (Kraus *et al*. 2005). Despite increased awareness of the vessel-strike problem and changes to vessel routing, such as the modified traffic separation scheme in the Bay of Fundy right whale habitat (International Maritime Organisation 2003), there has not been a reduction in the reporting of lethal vessel-strike injuries. There were at least three and possibly four right whale deaths attributed to vessel strikes in the 16 months prior to Kraus *et al*. (2005). It is possible that increased awareness may be responsible for increased reporting. However, if contemporary average vessel speeds of 14–16 knots through two critical right whale habitats (Ward-Geiger *et al*. 2005) are maintained, it is reasonable to expect the probability of lethal vessel-strike injuries to remain in the 0.70–0.85 range based on the simple logistic model (Fig. 3).

One factor our analysis cannot address is the consequence of increased whale exposure to vessels navigating at low speed. Therefore, we briefly explore average vessel–whale encounter probability (P_m) and how it may change as vessel speed decreases. We do this by employing a model, in two dimensions, of a random walk (whale), in the presence of traps (vessels), provided by Gallos and Argyrakis (2001). The probabilities are explored within a specified areal domain, using a vessel frame of reference and a randomly moving whale with a speed that is the sum of the vessel (v_v) and the whale (v_w). In this example, and for simplicity, we assume a square domain of dimension (a) and length (l_v) and beam (b_v) of the vessel and the whale (l_w and b_w). To determine the number of steps in the random walk, we require the time (t_v) for the vessel to transit the domain and the area (c_v) occupied by the transiting vessel within the domain. We approximate that, on average, a vessel transit parallels the edges of the domain; thus, $t_v = \frac{a}{v_v}$. Vessel area within the domain is defined by the number of vessels (N) and their dimensions: $c_v = \frac{N \cdot l_v \cdot b_v}{a^2}$. During the time the vessel transits the domain, the whale will move through an area specified as $A_w = b_w(v_w + v_v)t_v$. The above equations are used to determine the number of steps (S_n) taken by the whale during its random walk: $S_n = \frac{A_w}{l_w b_w} = \frac{a}{l_w}(\frac{v_w}{v_v} + 1)$. There are other means of deriving S_n and in this derivation the whale becomes one-dimensional (l_w). Gallos and Argyrakis (2001) define the average "survival" probability (*i.e.*, no encounter) as $P_s = e^{-\lambda S_n}$, where $\lambda = -log_e(1 - c_v)$. Thus, the average probability that the vessel will encounter the whale is, $P_m = 1 - P_s$. We use an example vessel ($l_v = 125$ m, $b_v = 20$ m) and example length ($l_w = 16.5$ m) and swimming speed ($v_w = 1.5$ ms^{-1})

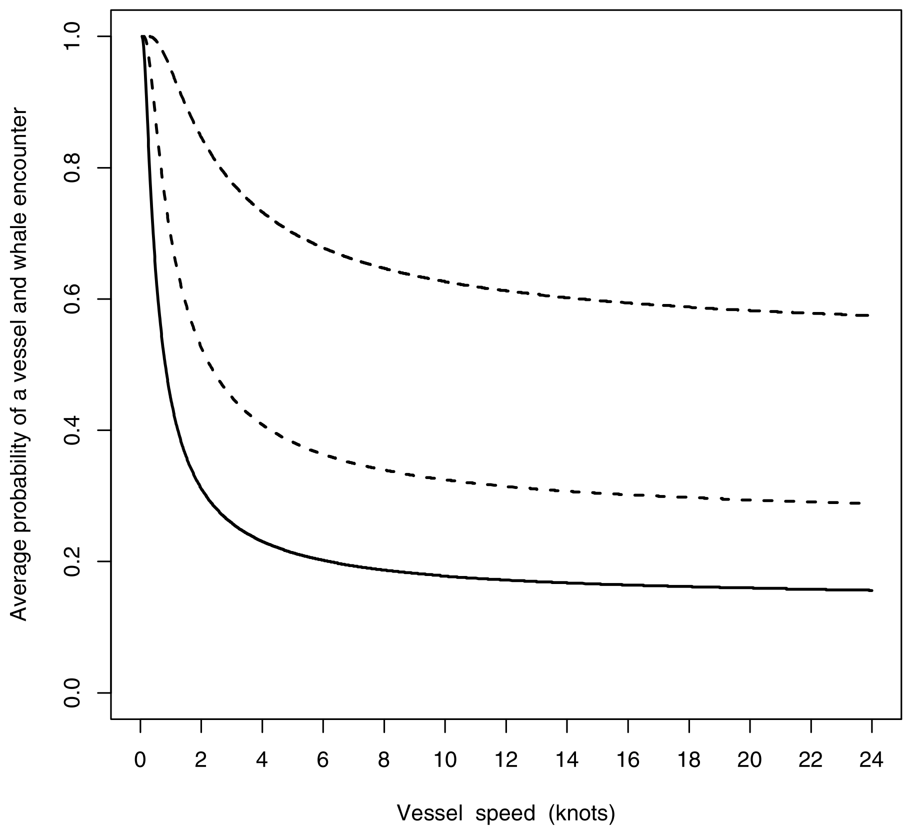

Figure 4. The probability of a vessel and whale encounter, as a function of vessel speed, within a 1 km^2 domain estimated using a random walk model in two dimensions of a 16.5 m whale swimming at 1.5 ms^{-1} in the presence of an example vessel (125 m length and 20 m beam). The lines represent the domain with one whale and one vessel (solid), two vessels (dash), and five vessels (dash dot).

of a whale within a 1 × 1 km domain. Vessel number and vessel speed (in this example vessels have identical dimensions and speed) are varied in the presence of one whale in the domain. Although slow-moving vessels spend more time within the domain than fast-moving vessels, this simple model (Fig. 4) demonstrates that the encounter probability increases slowly as speed decreases from 24 knots or greater and then begins to increase more rapidly as vessel speed continues to decrease toward zero. This model represents an approximation of average encounter probabilities as a function of vessel speed, yet it serves to illustrate that the encounter probability does not increase with decreasing speed as simply as one might expect. Determining such probabilities will be much more complex as the size and shape of the domain (habitat) changes, as the number, sizes, and speeds of vessels and how they transit the domain changes, as well as how the number, sizes, and speeds of whales and how they move in the habitat changes.

Slow-moving vessels may provide opportunity for whales to avoid a collision or for vessel operators to avoid the whales. However, we are unaware of any compelling evidence for either. According to Nowacek *et al*. (2004), NA right whales show neither a behavioral response to the sounds of an approaching vessel nor to actual vessels and suggest that NA right whales may be habituated to vessels noise and ignore it. Southern right whales do not elicit "strong boat-avoidance" behavior (Best *et al*. 2001). Terhune and Verboom (1999) report an adult NA right whale turning into the path of a small motor-vessel and cite Mayo and Marx (1990; though we cannot verify) that on 64 of 138 occasions, NA right whales turned toward a parallel-running small motorized vessel. For a vessel operator to avoid a collision with a whale, the whale must first be detected and the operator must then maneuver to avoid the collision. Large vessels navigating at low speed may not be able to maneuver successfully where success is partially dependent on the operator's ability to predict the movement of the whale once detected. Whale detection is dependent on the surface profile of the whale (right whales have no dorsal fin and thus minimum profile), unpredictable whale behavior, lighting, meteorological conditions (day or night, fog, sea-state, *etc*.), and observer bias (Hain 1997). Laist and Shaw (2006) report that small vessel operators are unable to consistently detect and avoid manatees, and Best *et al*. (2001) report a vessel collision with two or more whales where no avoidance action was taken because the vessel operator anticipated the whales would dive to avoid the vessel.

We cannot dismiss vessel or whale avoidance of a pending collision as explaining the few low-speed collision reports in the data we analyzed. We can suggest that the paucity of low-speed collision reports is related to a paucity of vessels operating at low speed. Our analysis of at-sea vessel speeds, associated with 1989–2002 mandatory (>500 gross registered tons) and voluntary vessel reporting in the NW Atlantic, shows 11.5% of the vessels navigating at ≤9 knots and 6.2% at ≤7 knots (n = 98,562; Eastern Canada Traffic Regulating System, ECAREG, unpublished data). It is also possible that the few reports of vessel collisions with whales prior to 1960 (19 of the 294 records) may be related to (1) lower vessel speeds in earlier decades and associated whale or vessel avoidance, and/or (2) collisions not being reported because of an absence of interest in reporting and/or concern regarding vessel strikes. In the first case, we have little quantitative evidence with which to reject the possibility, although we note that of the nineteen pre-1960 collision reports, only six include a vessel speed at the time of collision, and all six were ≥13 knots. Thirteen knots is the contemporary mean vessel speed for the ECAREG data analysis noted earlier, and it is consistent with the 14–16 knot contemporary average speed estimates of Ward-Geiger *et al*. (2005). In the second case, we simply have no evidence to reject, or not, the possibility.

In summary and acknowledging the uncertainties, our analyses provide compelling evidence that as vessel speed falls below 15 knots, there is a substantial decrease in the probability that a vessel strike to a large whale will prove lethal. The estimates we provide can be used to consider the efficacy of vessel speed limits that have been proposed in the United States (Federal Register (USA) 2006a) and are being proposed elsewhere (United Nations Environmental Programme 2005, International Whaling Commission 2006, Panigada *et al*. 2006).

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APPENDIX: ONE-DIMENSIONAL COLLISIONS WITHIN THE LIMITS OF THE ELASTIC AND INELASTIC EXTREMES (SEE ONLINE SUPPLEMENTARY MATERIAL FOR GREATER DETAIL)

Nomenclature

In all equations below, subscript 1 refers the vessel and subscript 2 refers to the whale. The prime indicates the respective postcollision momenta and velocities. The delta (Δ) indicates the change in either momentum ($\Delta \boldsymbol{p}$) or time (Δt), and boldface indicates vector quantities.

Newton's Second Law is

$$\boldsymbol{F} = \frac{d\boldsymbol{p}}{dt}, \tag{1}$$

where $\boldsymbol{F}$ is force, $\boldsymbol{p} = m\boldsymbol{v}$ is the momentum; the product of mass (m) and velocity ($\boldsymbol{v}$).

Conservation of Linear Momentum: When no net external force acts on a system, the total linear momentum of the system cannot change, thus,

$$m_1\boldsymbol{v}_1' + m_2\boldsymbol{v}_2' = m_1\boldsymbol{v}_1 + m_2\boldsymbol{v}_2. \tag{2}$$

One-dimensional elastic collision:

An elastic collision is one where the postcollision kinetic energy of the system is equal to the precollision kinetic energy of the system

$$\frac{1}{2}m_1 v_1'^2 + \frac{1}{2}m_2 v_2'^2 = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2, \tag{3}$$

which with Eq. 2, yields

$$v'_2 - v'_1 = -(v_2 - v_1). \tag{4}$$

Hence, for elastic collisions the relative speed of recession postcollision equals the relative speed of approach precollision.

Using Eq. 2 and Eq. 4, the postcollision velocity of the whale is solved as:

$$v'_2 = \frac{2m_1 v_1 + m_2 v_2 - m_1 v_2}{m_1 + m_2}. \tag{5}$$

Substituting Eq. 5 into the momentum term of Eq. 1 yields

$$F = \frac{dp}{dt} \doteq \frac{\Delta p}{\Delta t} \doteq \frac{p'_2 - p_2}{\Delta t} \doteq \frac{m_2\left(\frac{2m_1 v_1 + m_2 v_2 - m_1 v_2}{m_1 + m_2}\right) - m_2 v_2}{\Delta t}. \quad (6)$$

One-dimensional inelastic collision: A perfectly inelastic collision is one where only the momentum of the system is conserved and the postcollision velocities of the two colliding bodies are equal and move as one body at velocity v'(*i.e.*, $v' = v'_1 = v'_2$). By using Eq. 2, the postcollision velocity is defined as:

$$v' = \frac{m_1 v_1 + m_2 v_2}{(m_1 + m_2)}. \quad (7)$$

Substituting Eq. 7 into the momentum term in Eq. 1 yields

$$F = \frac{dp}{dt} \doteq \frac{\Delta p}{\Delta t} \doteq \frac{p'_2 - p_2}{\Delta t} \doteq \frac{m_2\left(\frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}\right) - m_2 v_2}{\Delta t}. \quad (8)$$

Assumptions for the one-dimensional limiting cases first approximations: For both types of collisions above, elastic and perfectly inelastic, we can reasonably assume that both the mass and velocity of a large whale are much less than for a vessel; that is, $m_1 \gg m_2$ and $v_1 \gg v_2$. With these assumptions, the force equations (Eq. 6 and Eq. 8) above simplify to
the elastic extreme

$$F \approx \frac{2m_2}{\Delta t} v_1 if \frac{v_2}{v_1} \ll 1 \quad \text{and} \quad \frac{m_2}{m_1} \ll 1, \quad (9)$$

and the perfectly inelastic extreme

$$F \approx \frac{m_2}{\Delta t} v_1 if \frac{v_2}{v_1} \ll 1 \quad \text{and} \quad \frac{m_2}{m_1} \ll 1. \quad (10)$$

Thus, in either case, the forces involved in the collision are the product of the mass of the whale and the speed of the vessel.

Supplementary Material

The following supplementary material is available for this article online:
One-dimensional collisions within the limits of the elastic and inelastic extremes.

ATTACHMENT 5

esa ECOSPHERE

Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales

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Abstract. Collisions with vessels are a serious threat to a number of endangered large whale species, the North Atlantic right whale (*Eubalaena glacialis*) in particular. In late 2008, the U.S. National Oceanic and Atmospheric Administration issued mandatory time-area vessel speed restrictions along the U.S. eastern seaboard in an effort to mediate collision-related mortality of right whales. All vessels 65 feet and greater in length are restricted to speeds of 10 knots or less during seasonally implemented regulatory periods. We modeled mortality risk of North Atlantic right whale when the vessel restrictions were and were not in effect, including (1) estimation of the probability of lethal injury given a ship strike as a function of vessel speed, (2) estimation of the effect of transit speed on the instantaneous rate of ship strikes, and (3) a consideration of total risk reduction. Logistic regression and Bayesian probit analyses indicated a significant positive relationship between ship speed and the probability of a lethal injury. We found that speeds of vessels that struck whales were consistently greater than typical vessel speeds for each vessel type and regulatory period studied; a use-availability model fit to these data provided strong evidence for a linear effect of transit speed on strike rates. Overall, we estimated that vessel speed restrictions reduced total ship strike mortality risk levels by 80–90% with levels that were closer to 90% in the latter two of the four active vessel speed restriction periods studied. To our knowledge, this is the most comprehensive assessment to date of the utility of vessel speed restrictions in reducing the threat of vessel collisions to large whales. Our findings indicate that vessel speed limits are a powerful tool for reducing anthropogenic mortality risk for North Atlantic right whales.

Key words: Bayesian risk analysis; endangered whales; *Eubalaena glacialis*; right whale; ship strike; speed restrictions; use-availability; whale-vessel collisions.

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INTRODUCTION

Violent collisions involving vessels and whales are a growing concern for marine resource managers. The outcome for the whale is often death or serious injury, including fractured bones, hemorrhaging, or propeller lacerations (Moore et al. 2004, Campbell-Malone et al. 2008). The occurrence of vessel strikes is a threat to a number of endangered large whale species (Clapham et al. 1999, Waring et al. 2011). In U.S. waters alone, tens of large whale deaths per year are ascribed to vessel strikes (Henry et al. 2012, van der Hoop et al. 2012), and globally the number may be in the hundreds of deaths each year (Laist et al. 2001, Jensen and Silber 2003, Van Waerebeek et al. 2007). Not all dead whales are detected (particularly in offshore waters), and the cause of death for carcasses that are recovered cannot always be determined due to decomposition (Henry et al. 2012). Thus, the actual number of whales that succumb to vessel collisions is likely far higher than reported.

The North Atlantic right whale (*Eubalaena glacialis*) is particularly vulnerable to vessel strikes. In a population that contains fewer than 500 individuals, an average of about two known deaths have been documented each year for at least the last decade (Waring et al. 2011, Henry et al. 2012). This anthropogenic threat has slowed the recovery of this highly depleted species (Knowlton and Kraus 2001, Kraus et al. 2005, NMFS 2005).

A number of approaches have been taken to reduce the threat of vessel strikes to right whales. These actions include mariner awareness-raising programs and modifications of customary vessel operation practices that include vessel speed reductions and changes in vessel routing patterns (Vanderlaan and Taggart 2009, Silber et al. 2012).

Vessel speed has been identified as a contributing factor in the occurrence and severity of vessel collisions with various marine vertebrates (Laist and Shaw 2006, Hazel et al. 2007), large whale species in particular (Laist et al. 2001, Jensen and Silber 2003, Pace and Silber 2005, Vanderlaan and Taggart 2007). Impact forces involved in a collision increase with increasing vessel speed (Wang et al. 2007, Campbell-Malone et al. 2008, Silber et al. 2010) and the probability of death or serious injury of a whale involved in a collision increases as vessel speed increases (Pace and Silber 2005, Vanderlaan and Taggart 2007, Wiley et al. 2011). Gende et al. (2011) found that the encounter distance between whale and vessel is also influenced by vessel speed such that higher vessel speeds may increase the probability of a strike occurring. These various findings have prompted the use of vessel speed restrictions as a means of diminishing the threat of vessel strikes to endangered marine mammal species in various locations (NPS 2003, Laist and Shaw 2006, Tejedor et al. 2007).

To address the threat of vessel strikes to North Atlantic right whales, the U.S. National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) issued regulations that limit vessel speeds in certain locations along the U.S eastern seaboard (NOAA 2008). The speed limits are in effect seasonally in prescribed areas (''seasonal management areas'', or "SMAs"). The SMAs were designed to correspond with the timing and locations of right whale migration, feeding, and nursery activities where they co-occur with high vessel traffic densities (typically near sizable port entrances and vessel traffic bottlenecks), while also minimizing economic impact to the maritime transport industry (Fig. 1). While in a management zone, all vessels 65 feet and greater in length are required to travel at 10 knots or less (speed over ground). Sovereign (e.g., U.S. military) vessels are exempted from the regulations.

It can be difficult to determine with certainty if vessel speed limits and related management actions are achieving their intended objective of reducing whale strikes, particularly in the relatively short period since their enactment (Pace 2011, Silber and Bettridge 2012). Studies have used risk reduction models to assess the relative effectiveness of various vessel routing measures (Vanderlaan and Taggart 2009, Vanderlaan et al. 2009, van der Hoop et al. 2012). Others have provided estimates of vessel strike risk reduction resulting specifically from NOAA's vessel speed restrictions (Lagueux et al. 2011, Wiley et al. 2011). However, estimates arising from the latter studies were obtained by examining only limited aspects of the restrictions both temporally and geographically. Further, most assessments of risk to date have been made by simulating whale and vessel movement to quantify strike rates. Although this approach is useful for determining how likely a whale is to come in close proximity to a vessel, it cannot be used to account for whale avoidance behavior that can prevent vessel collisions.

In this paper, we attempt to model the effect of mandatory vessel speed restrictions along the U.S. east coast on comprehensive North Atlantic right whale mortality risk. This includes an assessment of risk associated with different years and management regimes (i.e., vessel speed restrictions in/not in effect). Our analysis includes three components: (1) estimation of the probability of lethal injury given a ship strike at different

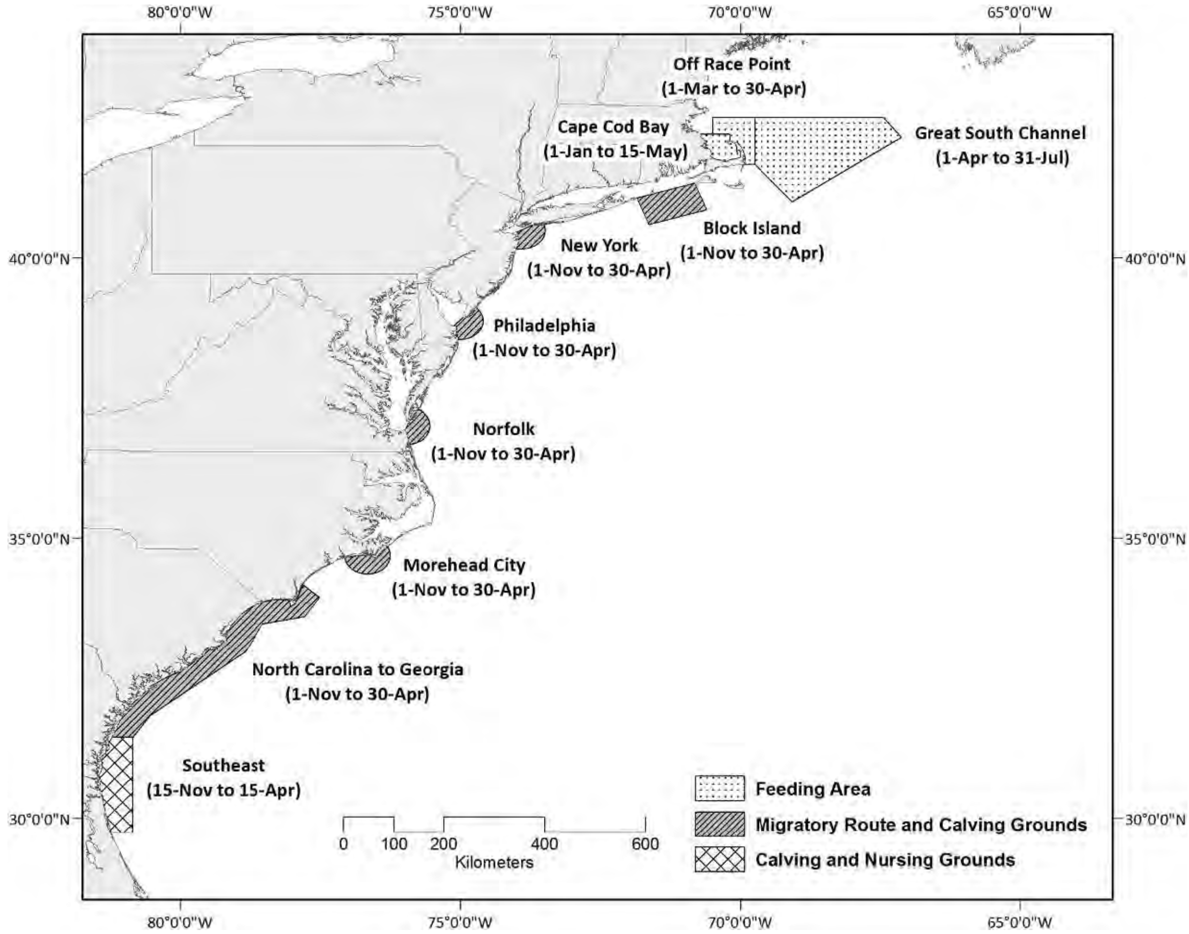

Fig. 1. Times and locations of vessel speed restriction seasonal management areas (SMAs) for North Atlantic right whales along the U.S. east coast.

vessel speeds; (2) estimation of the effect of transit speed on the instantaneous, per capita rate of ship strikes; and (3) a consideration of total risk reduction. The first component involves analyzing a dataset of ship strikes roughly twice the size as in previous work (e.g., Vanderlaan and Taggart 2007), while the second involves fitting a Bayesian model to describe the differences in observed ship speeds for vessels that struck whales from those which may or may not have struck whales. This latter approach differs conceptually from previous approaches to quantifying strike rates in that the effect of vessel speed on instantaneous strike rate is explicitly estimated via a statistical model. Finally, we jointly analyze all of these data sources to produce an estimate of mortality risk that simultaneously accounts for all sources of uncertainty.

Methods

Lethality of whale strikes

To explore the relationship between vessel speed and the lethality of vessel strikes, we examined records of known vessel strikes of whales in which sufficient information was provided to indicate with certainty both the speed of the vessel at the time of the strike and the severity of injury or fate (e.g., death resulted) of the whale involved in the collision. Records included all large whale species and all geographic areas worldwide.

In compiling vessel strike data for our analysis, we relied on the same data used in related studies by Pace and Silber (2005) and Vanderlaan and Taggart (2007). The latter study used published sources (Laist et al. 2001, Jensen and Silber 2003) that detailed the historical record of vessels striking large whales ($n = 47$). Pace and Silber (2005) used these same data in addition to unpublished records of vessel/whale strikes ($n = 5$) not used by Vanderlaan and Taggart (2007). We began our compilation with the data set ($n = 52$) used by Pace and Silber.

By reviewing scientific literature and canvassing information from various stranding programs and data sources, we then compiled additional vessel strike records that occurred after the Pace and Silber (2005) study had concluded in May 2005, or were not previously documented in the Pace and Silber analysis. We included only those cases in which both the vessel speed and the fate of the whale were known with certainty. This yielded a total of 38 records not analyzed in previous studies. Unique records that met criteria for evaluation were derived from Neilson et al. (2012) for Alaskan waters ($n = 7$); NMFS' National Marine Mammal Stranding databases for the U.S. northeast ($n = 10$), northwest ($n = 2$), and southwest ($n = 7$) regions, national program ($n = 5$), and the Hawaiian Islands Humpback Whale National Marine Sanctuary ($n = 7$). A total of 90 records meeting the criteria identified above were used in our analysis. These data included records through September 2012.

For each record we recorded a binary response variable for whether injuries were lethal/not lethal, using the same criteria as in previous studies (e.g., Vanderlaan and Taggart 2007, Andersen et al. 2008). Records in which the whale was known to have died (e.g., carcass observed) or a severe injury was described (e.g., blood in the water, open or bleeding wounds observed) were classified as "lethal" (Vanderlaan and Taggart 2007). Individuals that were known to have survived (for example, where there were subsequent sightings of the living whale), who exhibited no apparent injury, or only minor injuries (e.g., visible non-bleeding wound, or no report of blood) were recorded as non-lethal "0" responses (i.e., we assumed these whales did not die as a result of the encounter). In making these determinations, we adopted the same classification of records utilized by Pace and Silber (2005), Vanderlaan and Taggart (2007), and Neilson et al. (2012). This left $n = 30$ records for which we made new injury determinations.

In total, our data set consisted of roughly double the number of observations previously used to estimate the relationship between vessel speed and the lethality of ship strikes (see, e.g., Vanderlaan and Taggart 2007), so we hoped to substantially increase precision of parameters describing the strike speed-mortality relationship. Two different analyses were performed. First, we analyzed the data using a simple logistic regression model where severity of injury ($Y_\text{i} = 1$, lethal injury; $Y_\text{i} = 0$, non-lethal injury) is modeled as a Bernoulli response variable with success probability M_i, where

$$\text{logit}(M_i) = \beta_0 + \beta_1 x_i.$$

Here, M_i gives the probability of a lethal injury for strike i, and x_i gives the speed (in knots) of the vessel involved in the collision. We provide estimates from this approach for historical consistency; several authors have used this formulation when addressing mortality associated with ship strikes (Pace and Silber 2005, Vanderlaan and Taggart 2007, Lagueux et al. 2011). For this approach, we conducted analysis with the 'glm' function in the R statistical language (R Development Core Team 2012).

Second, to integrate the relationship between ship speed and mortality into our comprehensive mortality risk analysis, we conducted a Bayesian probit regression analysis, which is similar to a logistic regression but uses the probit link function in place of the logit. In particular, we considered the model

$$\text{probit}(M_i) = \beta_0 + \beta_1 x_i. \quad (1)$$

The probit link function leads to some computational advantages when conducting Bayesian analysis; in particular, one can construct a collapsed Gibbs sampler as suggested by Albert and Chib (1993) to sample regression parameters. Defining $\mathbf{X}$ to be the design matrix where

$$\mathbf{X}' = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ x_1 & x_2 & \cdots & x_N \end{bmatrix}$$

and augmenting the parameter space with $\tilde{Y}_i$ values for each observation, the algorithm proceeds as follows:

(1) Update $\tilde{Y}_i$ values according to a truncated normal distribution. If $Y_i = 1$, sample $\tilde{Y}_i \sim$ Normal ($[\mathbf{X}\beta]_i$, 1) with the constraint that $\tilde{Y}_i > 0$; if $Y_i = 0$, sample $\tilde{Y}_i \sim$ Normal ($[\mathbf{X}\beta]_i$, 1) with the constraint that $\tilde{Y}_i < 0$.
(2) Update the vector of regression parameters (in this case $\boldsymbol{\beta}' = [\beta_0\ \beta_1]$) according to $\boldsymbol{\beta} \sim$ MVN $((\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\tilde{\mathbf{Y}},\ (\mathbf{X}'\mathbf{X})^{-1})$, where MVN denotes the multivariate normal distribution. This formulation implies a flat, improper prior distribution for the regression coefficients.

Posterior predictions of mortality probability at pre-specified vessel speeds can then be produced by sampling from

$$M_k = \Phi(\mathbf{X}_k\beta) \tag{2}$$

where $\Phi(Z)$ denotes the cumulative distribution function of the standard normal distribution evaluated at Z, and $\mathbf{X}_k$ gives the design vector associated with predictions (e.g., $\mathbf{X}_k = [1\ x_k]$). We used this algorithm to sample the posterior distribution of model parameters and make posterior predictions; 11,000 such values were simulated, and we discarded the first 1,000 as a burn-in. We provide R code to conduct this analysis as an online supplement.

Strike rate analysis

In an analysis of vessel encounter rates with humpback whales, Gende et al. (2011) provided evidence that the likelihood of vessel-whale encounters increases with vessel speed. Others have used simulation to model the likelihood of whale-vessel intersections given assumptions about whale and vessel movement (e.g., Vanderlaan and Taggart 2007, van der Hoop et al. 2012). However, the degree to which whales are likely or able to move to avoid vessels of varying speeds has heretofore been a subject of uncertainty.

To investigate the relationship between whale strike rates and vessel speeds, we compared the speeds of vessels that struck whales to a larger population of vessel speeds. From a statistical perspective, these data sources are similar to use-availability data as commonly modeled in animal resource selection studies (see, e.g., Manly et al. 2002), where speeds that resulted in whale strikes can be viewed as "use" and random vessel speeds can be viewed as "availability."

For this analysis, we obtained randomly selected vessel speeds in SMAs along the U.S. east coast summarized for analysis by speed and vessel type (i.e., cargo, passenger, sovereign vessel types). Vessel operations in SMAs were monitored using the Automatic Identification System (AIS), a safety-at-sea navigation tool that transmits very high frequency (VHF) radio signals. All vessels 300 gross tons or greater making international voyages are required by the International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea to maintain functioning and operational AIS capabilities. The same requirement applies to nearly all vessels 65 feet or greater sailing in U.S. waters. An AIS signal is transmitted several times per minute and contains both static (e.g., ship name, call sign, and hull specifications) and dynamic information that is unique to that particular voyage. Dynamic information includes vessel location, heading, and speed, and is automatically incorporated into the AIS signal by a global positioning system (GPS). Due to its signal transmission rate, AIS provides a detailed, continuously sampled, and precise record of vessel operations for a nearly complete census of vessels subject to the speed limits. Additional information about the function and characteristics of the AIS can be found in Aarsæther and Moan (2009) and Tetreault (2005); a description of methods used to acquire and parse AIS data for this study can be found in Silber and Bettridge (2010 and 2012).

Using the U.S. Coast Guard (USCG) network of AIS receivers, we obtained vessel operations data from 9 December 2008 to 31 July 2012. We randomly selected one speed value per SMA vessel transit. This sample was restricted to speeds that were >2 knots because AIS transmitters may continue to operate while vessels are at anchor or while in port. To generate a random population of such vessel speeds, we resampled these speeds with replacement, weighting each observation by the number of AIS records available per transit.

For analysis of instantaneous per capita strike rates, we limited strike records to the U.S. east coast and to vessel types that were comparable to the categories available in the AIS data. Strike records were derived from published large whale ship strike databases (Jensen and Silber 2003) and those maintained by NMFS stranding personnel. We restricted analysis to cargo vessels ($n = 1$ strike), passenger vessels ($n = 1$ strike), and to sovereign vessels (e.g., USCG operated vessels ($n = 10$ strikes)). Strike records were obtained over a wider time frame than AIS data; $n = 6$ were from 2000–2009, $n = 4$ were from 1990–1999, and $n = 2$ records came from 1950–1980. There is little indication that the speeds of vessels changed appreciably even over this relatively long horizon. We did not include strikes with small private vessels or whale watching vessels as these types of vessels were seldom identifiable in the AIS database. Although it may have been possible to isolate random transit speeds associated with particular whale watching vessels, we anticipated that these would not adequately represent the activities being conducted when whale strikes occurred (since whale watching vessels are actively searching for whales during portions of their transits). Since the fate of whales was not necessary for analysis of strike rates, we included records where the fate of the animal was unknown. A simple comparison of strike speeds from our vessel strike database to transit speeds randomly sampled from our AIS database in different regulatory periods suggested that strikes occurred when vessels, in each vessel category studied, were traveling faster than average vessel speeds (Fig. 2).

To formalize the relationship between vessel speed and strike rates, we start by defining the per capita, instantaneous rate at which whales are struck, λ_i. In particular, we express it as a function of vessel speed, x_i, with a log link. We considered both linear and quadratic functional forms for the effect of vessel speed on strike rate:

$$\text{Model 1: } \log(\lambda_i) = \alpha_0 + \alpha_1 x_i \qquad (3)$$

$$\text{Model 2: } \log(\lambda_i) = \alpha_0 + \alpha_1 x_i + \alpha_2 x_i^2.$$

Letting $[X|Y]$ denote the conditional distribution of X given Y, we can describe the likelihood of observing strike speeds $\mathbf{x}$ for a particular combination of vessel type and regulatory period as

$$[\mathbf{x}|\mathbf{y}=1,\alpha] = \frac{[\mathbf{y}=1|\mathbf{x},\alpha][\mathbf{x}]}{\int[\mathbf{y}=1|\mathbf{x},\alpha][\mathbf{x}]d\mathbf{x}}$$

where $y = 1$ if a particular vessel speed resulted in a strike. Here, $[\mathbf{y} = 1 \,|\, \mathbf{x}, \boldsymbol{\alpha}]$ is the joint probability that the observed vessel strike speeds resulted in strikes, and can be given as

$$[\mathbf{y}=1|\mathbf{x},\boldsymbol{\alpha}] = \prod_{i=1}^{S} 1 - \exp(-\lambda_i).$$

The component $[\mathbf{x}]$ denotes the probability density function for vessel speeds independent of whether or not those vessels struck whales. We follow Lele and Keim (2006) in approximating the denominator as

$$\int[\mathbf{y}=1|\mathbf{x},\alpha][\mathbf{x}]d\mathbf{x} \approx \frac{1}{B}\sum_{j=1}^{B}[\mathbf{y}=1|\mathbf{x}_j^*,\alpha]$$

where $\mathbf{x}_j^*$, $j \in 1, 2, \ldots, B$ denotes a randomly sampled vessel speed from our transit database. This formulation has the advantage that we can use the empirical distribution of transit speeds as opposed to a fitted model, a desirable property since observed vessel speeds often were multimodal and/or bore little resemblance to parametric distributions. We set $B = 10{,}000$ in subsequent analysis.

The parameter α_0 controls the proportion of vessel speed observations that result in reported whale strikes. This parameter is not identifiable using the previous setup; however, inference can still be drawn regarding α_1, the effect of vessel speed on strike rates (Lele and Keim 2006). We used maximum likelihood to estimate parameters for the linear and quadratic models for strike rates, employing AIC (Burnham and Anderson 2002) for model selection. We then used the model with highest support in a Bayesian analysis of strike rates, imposing diffuse Normal(0,100) prior distributions on regression parameters (i.e., the α values). For this purpose, we used Markov chain Monte Carlo (Gelman et al. 2004) to sample from the joint posterior. When implementing this approach, we used separate data models for $[\mathbf{x}]$ for each combination of vessel type (cargo, passenger, sovereign) SMA speed restriction active/inactive period. An R script to conduct this analysis is provided in the Supplement.

Joint risk analysis

To estimate a total risk reduction value, we again sampled AIS data transmitted between 9 December 2008 and 31 July 2012 by cargo, tanker,

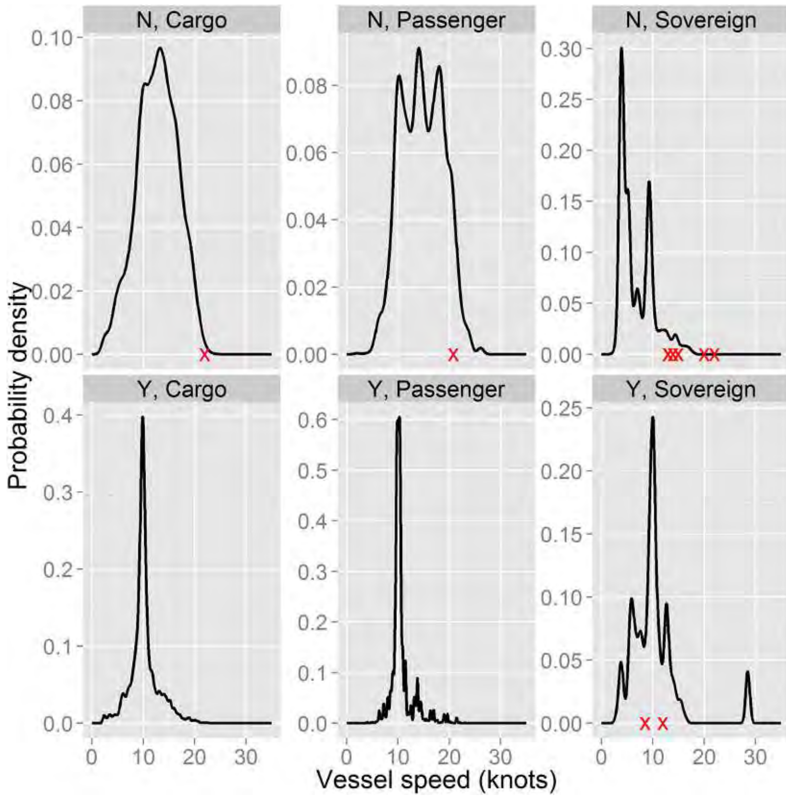

Fig. 2. A comparison of randomly sampled ship speeds from our Automatic Identification System (AIS) database (black kernel densities) to speeds at which vessels struck whales (represented by X's). Data are partitioned by vessel type ("Cargo", "Passenger", or "Sovereign") and by whether the data point occurred during periods when Seasonal Management Area (SMA) speed restrictions were ("Y") or were not ("N") in effect. Each panel represents a distribution of 10,000 randomly sampled ship speeds which are used to define separate availability datasets in the strike rate analysis (strike rate itself is only modeled as a function of ship speed).

and passenger vessels with lengths of 65 feet or greater (a total of tens of millions of individual speed records). We analyzed vessel speed information for 73,319 trips in SMAs at times in which speed restrictions were in effect and for 68,099 trips in the same geographic areas defined by SMAs when restrictions were not in effect. A single mean speed was computed for each trip. Vessel speed analyses were limited to transits that were at least one nautical mile in length, had at least five AIS records, and an average transit speed of >2 knots.

We formulated alternative expressions for relative mortality risk associated with R time periods with different management regulations. Assuming that the risk of mortality is temporally and spatially homogeneous within time period r, the probability that a single whale, chosen at random, is lethally injured can be given as

$$p_r = 1 - \exp(-T_r h_r)$$

where T_r gives the time interval and h_r gives a constant hazard rate associated with period r. The hazard rate h_r is fundamental to survival analysis (cf. Cox and Oakes 1984) and measures instantaneous mortality risk. In practice, we expect variability in h_r over time and space, but little information exists to quantify changes in spatial distributions of whales over the entire east coast. Assuming that this distribution remains relatively constant, comparisons of constant h_r over different management regimes may still prove illuminating. In particular, the relative risk of morality in management period r relative to some reference period 0 may be written as

$$R = h_r/h_0 \tag{4}$$

with values of $R > 1$ indicative of increased risk associated with a management action, and $R < 1$ indicative of reduced risk. In practice, there is considerable uncertainty in the hazards associated with each period because of uncertainty about mortality and strike rates, so that R is best viewed as a probability density function. Further, managers may be interested in different functional forms of h_r since these may provide different interpretations of the effect of management actions.

Ultimately, the mortality hazard throughout the management area (i.e., over all SMAs) in a given time interval is the sum of independent hazards associated with different transits (which are at different speeds and of different lengths). If we wish to directly compare the realized mortality risk in different management periods (i.e., speed regulation in effect/not in effect), we can approximate the mortality over each management period using a single, constant hazard during regulation period r:

$$h_r = \sum_{t=1}^{N_r} \lambda_{tr} D_{tr} M_{tr} / T_r.$$

Here, λ_{tr} is the instantaneous striking hazard for transit t in regulation period r (assumed here to be constant for the entire transit), D_{tr} is the duration of the transit, and M_{tr} gives the probability that a whale is lethally injured given that it is struck during transit t in period r. This formulation describes actualized change in mortality risk, but is dependent upon N_r, the number of transits in regulation period r, as well as the duration of such trips. Thus, changes in the total number of transits over time (or the duration of such transits) will affect interpretation of R. This formulation is also problematic for right whales because vessel speed regulations were temporally staggered based on location (Fig. 1) so T_r is not well defined.

Although absolute increases and decreases in risk can be of interest, managers may also be interested in standardized risk, or changes in risk associated with a management action while controlling for variables not under control of management. For instance, if the number and durations of transits varied markedly between regulation periods due to extrinsic factors, realized risk may give an unclear picture of the effects of regulations. In this case, managers may still be interested in changes in mortality risk that would have resulted had the number of transits remained constant. To make this estimate, we suggest calculating relative risk using

$$h_r^* \propto \sum_{t=1}^{N} \lambda_{tr}^* \Delta_{tr}^* M_{tr}^*$$

where λ_{tr}^*, Δ_{tr}^*, and M_{tr}^* are random draws for strike rate, vessel transit duration, and mortality probability (see below). We refer to risk computed using this approach as standardized risk.

Since we have empirical data on the length and speed of transits by management period and models for how whale mortality (M) and strike rate (λ) change as a function of transit speed (Eqs. 1 and 3) it is a relatively simple matter to calculate comprehensive risk reduction associated with speed restrictions. To properly account for uncertainty in these relationships, we computed a posterior distribution for the standardized risk ratio R (Eq. 4) by incorporating uncertainty in the estimated lethality-vessel speed relationship and the estimated strike rate-speed relationship. Again letting [X | Y] denote the conditional probability distribution of X given Y, and bold symbols denote vectors of parameters, we start by symbolically writing the joint posterior distribution of R and transit speed and mortality parameters given the data as

$$\begin{aligned}&[R, \mathbf{M}, \Delta, \beta, \theta, \alpha_1 | \mathbf{S}, \mathbf{Y}, \mathbf{Z}, \mathbf{x}]\\ &\quad = [R|\mathbf{M}, \Delta, \alpha_1][\mathbf{M}|\theta, \beta][\beta|\mathbf{Y}][\Delta|\mathbf{Z}, \theta][\theta|\mathbf{S}][\alpha_1|\mathbf{x}].\end{aligned}$$

Here, **S** denotes vessel speed data for different management periods, **Z** denotes transit length data, and **Y** denotes strike/mortality data as analyzed in our Bayesian probit analysis. The posterior distribution depends on simulated vessel speed values θ, which are assumed to be distributed according to $[\boldsymbol{\theta} | \mathbf{S}]$, and simulated transit durations, Δ. The latter depend upon both the empirical distribution of transit length values **Z** and upon vessel speed (given a particular transit length Z_i, and speed θ_i, duration can be calculated as Z_i/θ_i). Posterior predictions of lethality at different vessel speeds associated with the component $[\mathbf{M} | \boldsymbol{\theta}, \boldsymbol{\beta}][\boldsymbol{\beta} | \mathbf{Y}]$ may be generated via Eq. 2, while posterior values of α_1 can be sampled from the strike rate analysis.

Given these values, we express the standardized risk ratio as

$$[R|\mathbf{M}, \Delta, \lambda] = \frac{\sum_{t=1}^{19,345} \lambda_{tr}^{*} \Delta_{t}^{*} M_{tr}^{*}}{\sum_{t=1}^{19,345} \lambda_{t0}^{*} \Delta_{t}^{*} M_{t0}^{*}} = \frac{\sum_{t=1}^{19,345} \exp(\alpha_1^{*} \theta_{tr}^{*}) \Delta_t^{*} \Phi(\beta_0^{*} + \beta_1^{*} \theta_{tr}^{*})}{\sum_{t=1}^{19,345} \exp(\alpha_1^{*} \theta_{t0}^{*}) \Delta_t^{*} \Phi(\beta_0^{*} + \beta_1^{*} \theta_{t0}^{*})}. \quad (5)$$

Note that the non-identifiable strike rate parameter α_0 cancels out of the above expression. As correlation between transit lengths and vessel speeds was low (Pearson correlation coefficient $\rho = -0.03$), we used independent probability density functions for both quantities. In particular, we drew vessel speed values $\boldsymbol{\theta}$ from the AIS-generated empirical distribution of vessel speeds within sampling regime r, and simulated Δ_t^{*} based on draws from the empirical distribution of observed transit lengths $\mathbf{Z}$ over the whole study period. We selected the limits of summation, 19,345, because it was the average number of transits occurring within a six month period. As results were somewhat sensitive to high speeds outside the range of strike rate and/or mortality analyses, we replaced any randomly selected transit speed above the 99th percentile of transit speeds (22.5 knots) with a value of 22.5 knots.

To summarize comprehensive risk ratios, we generated 10,000 posterior predictions using Eq. 5. Separate predictions were made for each year (1–4) of the study and for control and treatment periods for each strike rate scenario. We also analyzed pooled control and treatment data (pooling over years).

Results

Using logistic regression analysis, we detected a significant positive relationship between ship speed and the probability of a lethal injury ($\hat{\beta}_1 = 0.217$; SE 0.058; $p < 0.001$); the intercept was estimated as $\hat{\beta}_0 = 1.905$ (SE 0.821). The Bayesian probit analysis produced an almost identical

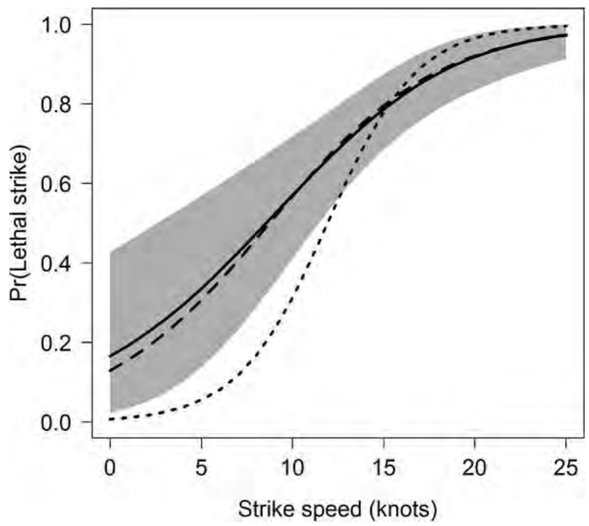

Fig. 3. Probability of a lethal whale strike given strike speed. The dashed line gives predictions from a logistic regression, the solid line gives posterior mean estimates from a Bayesian implementation of probit regression, and the dotted line gives logistic regression estimates reported by Vanderlaan and Taggart (2007). The gray area represents a 95% credible interval from the Bayesian analysis.

relationship to the logistic regression analysis (Fig. 3), with posterior means of $\beta_0 = -1.067$ (SE 0.452) and $\beta_1 = 0.124$ (SE 0.030). As with logistic regression, there was substantial evidence for a positive effect of vessel speed on strike lethality (the posterior sample for β_1 was greater than zero for all realizations). Owing to several new observations of serious injury vessel strikes at lower vessel speeds (e.g., one each at 2 and 5.5 knots), the relationship between lethality and strike speed was less extreme than the one produced by Vanderlaan and Taggart (2007) and used in previously published risk analyses (Fig. 3).

The speeds of vessels that struck whales were consistently greater than typical vessel speeds for each vessel type and regulatory period (Fig. 2). Accordingly, maximum likelihood fits of the use-availability model for strike speeds provided strong evidence for a linear effect of transit speed on strike rates ($\hat{\alpha}_1 = 0.49$, SE $= 0.09$); however, there was insufficient evidence to support a quadratic effect (ΔAIC $= 1.1$). We therefore used a linear formulation for the effect of transit speed

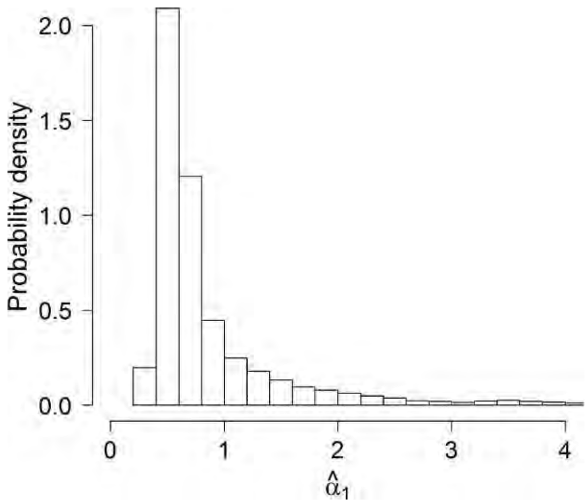

Fig. 4. Estimated posterior density function for α_1, the effect of vessel speed on the log of the instantaneous rate at which vessels strike whales. A value greater than zero indicates that instantaneous strike rate increases with vessel speed.

on strike rates in our Bayesian analysis. The posterior distribution for $\hat{\alpha}_1$ was substantially greater than zero (Fig. 4), providing further evidence that strike rates increase as a function of vessel speed.

Estimates of comprehensive risk reduction suggest a large decrease in standardized mortality risk associated with vessel speed restrictions (Fig. 5). In particular, control periods (i.e., when SMAs were not in effect) all had similar risk levels, while treatment periods (i.e., when SMAs were in effect) resulted in a risk reduction of 80–90%. Examining individual years separately (Fig. 5), it appeared that risk reduction was on the order of 80% for the first 2 years of vessel speed restrictions, and closer to 90% for the final 2 years of regulation. Pooling over years and simply comparing risk between treatment periods when speed regulations were in effect versus control periods when regulations were not in effect, the posterior mean mortality risk level in treatment periods was 14% of that in control periods (95% credible interval 5.6–29.0%), representing an 86% reduction.

Discussion

Various measures, focused primarily on changes in vessel routing patterns and reductions of vessel speed, have been employed to reduce the threat of vessel collisions with North Atlantic right whales. Routing changes that result in lowered co-occurrence of vessels and whales is the most desirable approach in most settings (Silber et al. 2012, van der Hoop et al. 2012), and several studies have provided estimates of vessel strike risk reduction afforded by established routing modifications (Firestone 2009, Vanderlaan and Taggart 2009, Vanderlaan et al. 2009, Lagueux et al. 2011). However, changing vessel routes is not always feasible due to navigational safety constraints, particularly in coastal waters.

Arguments for lowering vessel speed to limit the threat of fatal vessel collisions with both large whales (Laist et al. 2001) and manatees (*Trichechus manatus*) (Laist and Shaw 2006) first appeared in the early- and mid-2000s. These assertions were bolstered by risk reduction analyses (Pace and Silber 2005, Vanderlaan and Taggart 2007) and helped prompt use of speed restrictions in a number of locations (NPS 2003, Tejedor et al. 2007), the most extensive of which occur along the U.S. eastern seaboard. NOAA's vessel speed limits have been the subject of legal (Norris 2008, Firestone 2009), economic (Silber and Bettridge 2012), and risk reduction analyses (Lagueux et al. 2011, Wiley et al. 2011). Estimates of risk reduction to date have been applied to limited areas and times and relied on previously published logistic regression curves. Risk reduction values provided here include the full geographic scope of the vessel speed restrictions over a multi-year period using quantified vessel speeds, new whale strike data, and novel analyses. We believe this to be the most comprehensive assessment to date of the utility of vessel speed restrictions in reducing the threat of vessel collisions with large whales.

Our analysis highlights the importance of accounting for the combined effects of ship speed on (1) the rate at which vessels strike whales, and (2) the probability of mortality given that a whale is struck. In particular, we have shown that vessel speed is positively related to both components. To our knowledge, this is the first time that a use-availability model has been used to analyze the effect of vessel speed on the rate of whale strikes. Although simulation analyses (e.g., by modeling whale and vessel movement) can

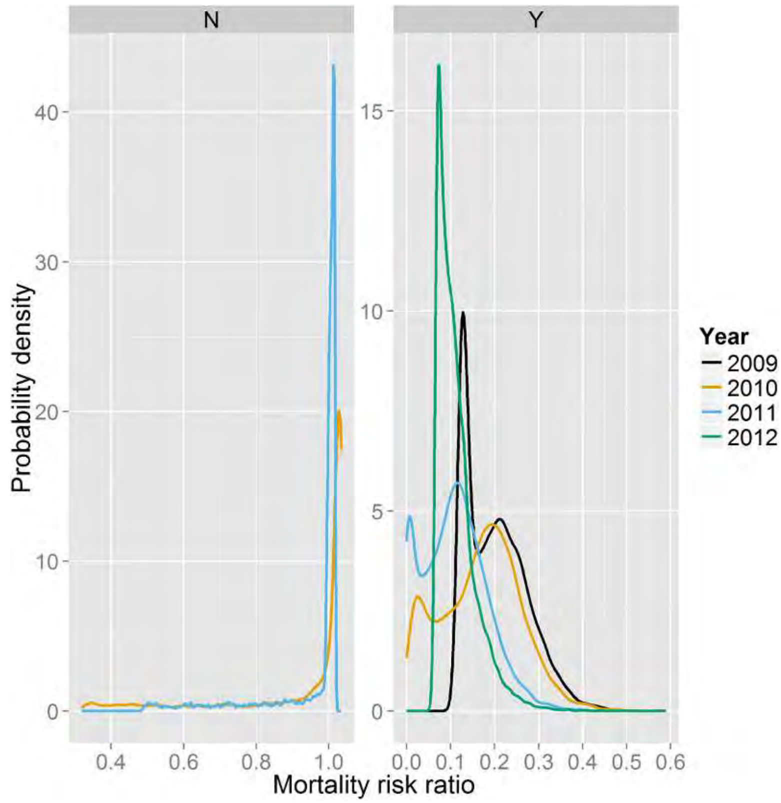

Fig. 5. Posterior predictive densities for comprehensive mortality risk ratio associated with transit speed restrictions in different years and management regimes. The left panel gives results for control periods ('N') while the right panel shows risk ratios when speed restrictions were in effect ('Y'). A ratio less than one indicates reduced risk relative to the control period in 2009.

provide some guidance as to likely functional forms for the relationship between vessel speed and the likelihood of a whale coming into close proximity with a vessel, it is difficult to use these analyses to reliably predict the probability of a collision because of uncertainty about fine scale nature of whale avoidance behavior. For instance, little is known about whale reaction, if any, to approaching vessels, particularly in the near-field. We view our analysis as an improvement in this regard, in that it allows one to explicitly estimate the effect of vessel speed on instantaneous strike rate. The obvious limitation of this approach is the small sample size associated with whale strike speeds, particularly when limited to vessels for which we had reliable control (availability) data. Nevertheless, with just 12 data points there appeared to be ample indication that strike rates increased with vessel speed. By contrast, if one fixes strike rates to be constant and simply uses the mortality curve to account for changes in mortality risk, it is actually possible to arrive at an (erroneous) increase in mortality risk, simply because slower vessel speeds increase transit times (and thus exposure of whales to vessels). This emphasizes the importance of simultaneously accounting for the effects of vessel speed on whale mortality and on strike rates.

The present analysis does not account for potential reductions in whale mortality attributable to changes in vessel routing regimes. For instance, previous analysis of vessel routing measures designed to lessen vessel occurrence in or near right whale aggregation areas (Lagueux et al. 2011, van der Hoop et al. 2012) suggested that there were substantial decreases in strike rates in at least portions of the range of North Atlantic right whales. In fact, Areas To Be Avoided and modifications to Traffic Separation

Schemes and other routing changes were made in the range of this species during the same period as vessel speed restrictions were introduced (Silber et al. 2012), albeit in targeted localized areas such as the Bay of Fundy, and waters off Georgia, Florida, and New England. We do not currently have data sufficient to account for the effects of management actions based on vessel routing across the entire east coast; however, we note that proportional changes to strike hazards result in an equivalent change to our risk ratio (Eq. 5). For instance, if vessel routing restrictions decreased the strike rate hazard by half, then the risk ratio in Eq. 5 would also be reduced by half. This suggests that our standardized risk ratio likely underestimates the true level of risk reduction accompanying the full suite of implemented management actions. However, we believe the risk ratios we provided here are valuable because it allows us to isolate the effects of a particular management action (in this case, transit speed regulations).

Our finding that vessel strike risk was lowest in the latter two of the four active periods studied is consistent with a measurable increase in vessel trips that comported with the required speed limits in years three and four, particularly as citations and fines were issued at the outset of year three (G. K. Silber, J. D. Adams, S. Bettridge, and B. Sousa, *unpublished manuscript*). This substantial shift in behavior observed across the entire regulated community helps explain, and contributes to, increased risk reduction in the latter two periods of our study.

We note the disparity of records of known vessel strikes by vessel type. Although cargo vessels represent the vast majority of vessels utilizing U.S. east coast ports and are the type most strongly represented in our AIS database, we were only able to obtain a single cargo vessel whale strike record for which strike speed was recorded. In contrast, sovereign vessels account, proportionally, for much higher numbers of recorded vessel strikes than other vessel types (Fig. 2). However, we wish to strongly emphasize that sovereign vessels are much more likely than other vessel types to report a struck whale because they are required to do so by internal protocol, and are obliged by conditions of U.S. Endangered Species Act Section 7 consultations to endeavor to reduce vessel strikes of whales by posting dedicated lookouts, traveling at reduced speeds when traversing active SMAs when and where feasible and when not jeopardizing vital or national security missions, and reporting when a whale strike has occurred. In addition, due to the sheer size of most commercial cargo and passenger vessels (which may be substantially larger than many sovereign vessel classes), these types of vessel operators are rarely aware that a collision with a whale has occurred. Nevertheless, it is important to note that our overall inference about the effect of ship speed on vessel strike rates could be biased if there were a statistical interaction between ship speed and ship type on vessel strike rates (that is, if whales respond to increasing ship speed differently among vessel types). Unfortunately, we do not have data sufficient to test this assumption, but believe it is the safest (and statistically parsimonious) to proceed with the assumption that transit speed affects strike rates similarly regardless of vessel type. A large number of additional reports of transit speed for non-sovereign vessel whale strikes would likely be necessary to relax this assumption.

Indications are that expansion will occur in the commercial maritime transport industry (Corbett 2004, Dalsøren et al. 2007), the cruise industry, offshore energy development, and other maritime sectors, thereby increasing risk of vessel strikes to whales. Conversely, factors such as restrictions on air-borne emissions from large vessels and the recent economic downturn may result in reduced vessel speeds (Khan et al. 2012) or fewer vessel trips (McKenna et al. 2012), which could reduce the likelihood of whale strikes. Nonetheless, the threat is likely to remain a concern as maritime transport and other activities increase and as whale populations grow in some locations. Our analysis suggests that vessel speed restrictions will likely remain a key tool for reducing anthropogenic mortality risk and promoting recovery of endangered large whale species.

Acknowledgments

We thank NMFS's regional stranding network coordinators Brent Norberg, Kate Savage, Jamison Smith, Sarah Wilkin, and Kate Wilkinson, and Ed Lyman of the National Ocean Service Hawaiian Islands Humpback Whale National Marine Sanctuary for graciously providing records of vessel strikes of whales. We are grateful to Kam Chin and David Phinney of the John A. Volpe National Transportation Systems Center for their assistance and guidance in the acquisition and analysis of vessel AIS data, and to Jeff Adams for his hard work in analyzing AIS data. The USCG National AIS program has been invaluable to this and other vessel operation analyses. Thanks to Devin Johnson for noting the link between strike and transit speed data and use-availability data, and for comments by B. Sousa, M. Ferguson, J. Ver Hoef, and two anonymous reviewers on a previous version of this manuscript. The findings and conclusions in the paper are those of the authors and do not necessarily represent the views of the National Marine Fisheries Service, NOAA. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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Supplemental Material

Supplement

R code to implement mortality risk analysis for North Atlantic right whales as a function of vessel speed (*Ecological Archives* C004-006-S1).

esa ECOSPHERE

ERRATUM

In the first paragraph of the *Results* section in the paper by Conn and Silber ("Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales"; *Ecosphere* 4:43), there was a typographical error in the intercept of the logistic regression model, $\hat{\beta}_0$. The value should have been -1.905, not 1.905. The remaining statistics (including standard error) are correct.

ATTACHMENT 6

Methods in Ecology and Evolution

Methods in Ecology and Evolution 2016, **7**, 42–50 doi: 10.1111/2041-210X.12447

A quantitative framework for investigating risk of deadly collisions between marine wildlife and boats

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Summary

1. Speed regulations of watercraft in protected areas are designed to reduce lethal collisions with wildlife but can have economic consequences. We present a quantitative framework for investigating the risk of deadly collisions between boats and wildlife.

2. We apply encounter rate theory to demonstrate how marine mammal–boat encounter rate can be used to predict the expected number of deaths associated with management scenarios. We illustrate our approach with management scenarios for two endangered species: the Florida manatee *Trichechus manatus latirostris* and the North Atlantic right whale *Eubalaena glacialis*. We used a Monte Carlo simulation approach to demonstrate the uncertainty that is associated with our estimate of relative mortality.

3. We show that encounter rate increased with vessel speed but that the expected number of encounters varies depending on the boating activities considered. For instance, in a scenario involving manatees and boating activities such as water skiing, the expected number of encounters in a given area (in a fixed time interval) increased with vessel speed. In another scenario in which a vessel made a transit of fixed length, the expected number of encounters decreases slightly with boat speed. In both cases, the expected number of encounters increased with distanced travelled by the boat. For whales, we found a slight reduction (~0·1%) in the number of encounters under a scenario where speed is unregulated; this reduction, however, is negligible, and overall expected relative mortality was ~30% lower under the scenario with speed regulation. The probability of avoidance by the animal or vessel was set to 0 because of lack of data, but we explored the importance of this parameter on the model predictions. In fact, expected relative mortality under speed regulations decreases even further when the probability of avoidance is a decreasing function of vessel speed.

4. By applying encounter rate theory to the case of boat collisions with marine mammals, we gained new insights about encounter processes between wildlife and watercraft. Our work emphasizes the importance of considering uncertainty when estimating wildlife mortality. Finally, our findings are relevant to other systems and ecological processes involving the encounter between moving agents.

Key-words: animal movement, effectiveness of speed zones, encounter rate, Florida manatee, marine mammals, North Atlantic right whale, protection zones, speed zones, wildlife collision

Introduction

The creation of protection zones and the regulation of the speed of watercraft are viewed as primary management actions taken to protect some species of marine wildlife from lethal collisions (Calleson & Frohlich 2007; Hazel *et al*. 2007; Vanderlaan & Taggart 2007; Van Der Hoop, Vanderlaan & Taggart 2012; Bauduin *et al*. 2013). Regulating speed or rerouting vessel traffic can have economic consequences, so it is important to quantify potential effects of watercraft on animal populations. This knowledge, in turn, can help identify cost-effective solutions for balancing multiple objectives, such as

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maintaining sustainable populations of marine mammals while minimizing cost of regulations.

Ultimately, managers are interested in linking regulations to a projected reduction in mortality or injury events. Several co-occurring processes leading to death or injury of marine wildlife from boat strikes are clearly related to boat speed. For example, the probability of avoidance between boats and marine animals may be reduced as boat speed increases (Calleson & Frohlich 2007; Hazel *et al.* 2007), and the severity of injuries caused by an impact is likely to increase with vessel speed (Calleson & Frohlich 2007). These processes can be synthesized into a simplified conceptual framework that links boat speed and other factors to marine mammal deaths and their effects on the overall population (Fig. 1).

The influence of one of these processes in particular can be difficult to grasp intuitively: the rate at which trajectories of animals and boats intersect in space and time. We define the encounter rate as the rate at which an animal and a boat will be close enough in space and time to potentially collide (Hutchinson & Waser 2007; Gurarie & Ovaskainen 2013a). Encounters should not be confused with collisions. Collisions imply that an animal was actually struck by a boat (which may depend on other parameters, for instance the probability of avoidance by the animal or boat). Some authors have indicated that there is a negative relationship between boat speed and the probability of encounter (Vanderlaan & Taggart 2007). To date, the encounter process in the context of watercraft strikes has been approached primarily through simulations (Van Der Hoop, Vanderlaan & Taggart 2012). Although encounter rate theory (Gurarie & Ovaskainen 2013a) is relevant to understanding the process of collision between boats and marine mammals, there have been few detailed examinations of these concepts for this important application. Encounter rate theory has been developed for other applications, including naval operations research (Koopman 1956), encounter rate in the context of community structure of zooplankton and animal movement (Gerritsen & Strickler 1977; Evans 1989; Hutchinson & Waser 2007; Gurarie & Ovaskainen 2013a), and collisions between marine wildlife and renewable energy devices (Wilson *et al.* 2007). Here, we apply encounter rate theory to marine mam-

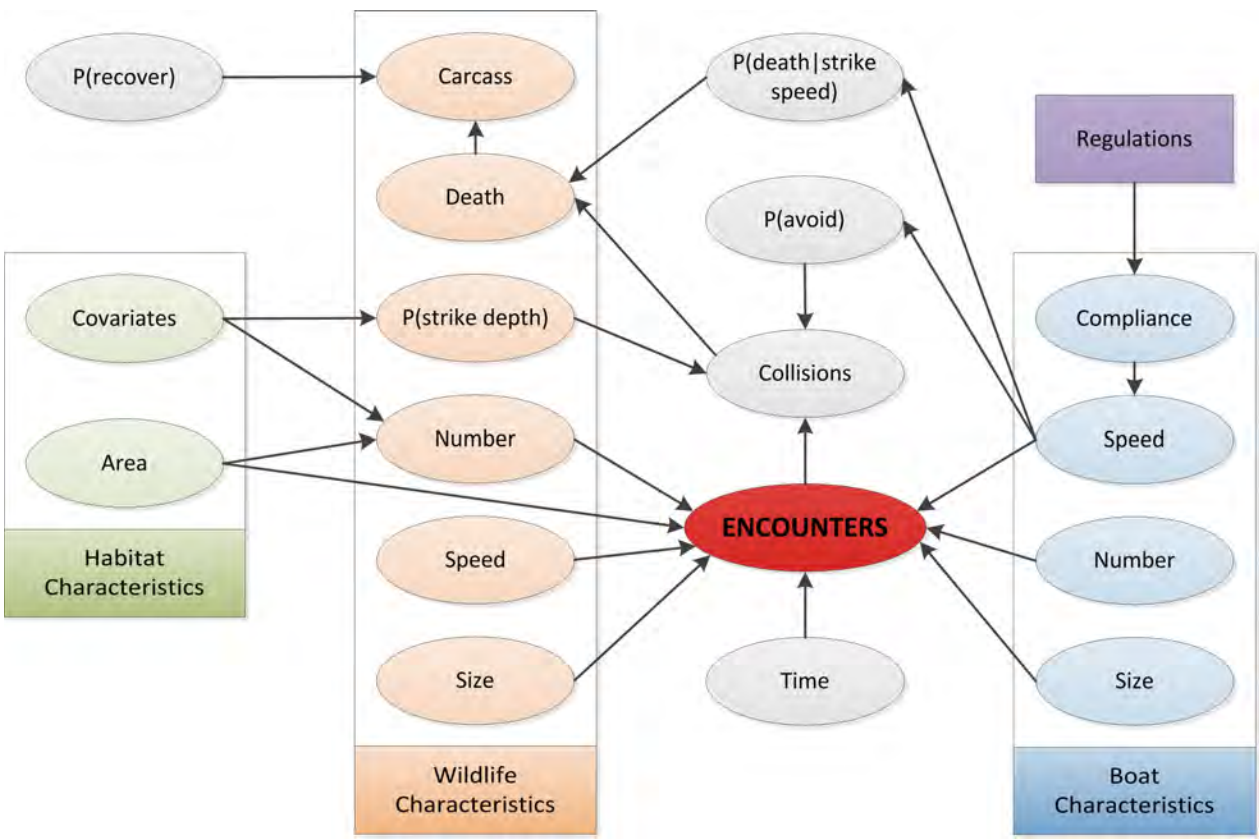

Fig. 1. Conceptual diagram describing the relationship between key components involved in the collision process between boats and marine mammals. Number of marine mammal deaths: *Death*; number of marine mammals and boats: *Number*; habitat characteristics (e.g. waterway configuration, bathymetry, presence of seagrass, sea surface temperature) are included in *Covariates*; the number of encounters (as a function of animal/vessel densities and vessel speed): *Encounters*; the probability of the animal's being within striking depth during an encounter: *P(*strike depth); the number of potential collisions: *Collisions*; the probabilities of avoidance by boaters and/or marine mammals combined: *P*(avoid) which may be affected by speed of the boat; the probability of lethal injury given strike speed: *P*(death|strike speed); boat and marine mammal *Speed* and *Size*; compliance of boaters with regulations: *Compliance* and *Regulations*. Only a fraction of the total number of deaths are reported: *Carcass*, which is determined by a probability of recovery: *P*(recover).

mal–boat collisions and present our own analytical presentation of the solution in two dimensions, the most relevant case in many ecological applications. In our model, the encounters correspond to first encounters (i.e. an animal can encounter a given boat only once per boat transit, which is applicable in most situations where the vessel moves faster than the animal). Our solution relates the number of encounters to time, area, the number of boats and marine mammals, and the speed of boats and marine mammals (Fig. 1). We used a Monte Carlo simulation approach (MCS) to incorporate uncertainty, which has seldom been accounted for in estimates of mortality rates due to watercraft collisions (see Conn & Silber (2013) for an alternative approach).

We illustrate our approach with two endangered mammals, the Florida manatee *Trichechus manatus latirostris* and the North Atlantic right whale *Eubalaena glacialis*. Although we used the best available parameter values based on the scientific literature or empirical data, we caution against the use of specific values from our results for management purposes. Instead, the primary goals of our study were to gain general insights about processes involved in risk of deadly collisions and to provide an analytical framework for conducting more detailed analyses for evaluating potential management actions aimed at reducing risk of collisions. Although this framework can help improve the design of protection zones and evaluate the effectiveness of speed zones for marine wildlife, it is also applicable to other systems (e.g. road traffic in protected areas).

Materials and methods

ANALYTICAL APPROACH FOR ESTIMATING ENCOUNTER RATE

We consider a boat of size r_b and an animal of size r_m moving in an area with surface S between start time t_I and final time t_F. We assume that the boat moves at constant velocity v_b. The number of mammals in the area is assumed to be distributed as a Poisson random variable with parameter λ_m. The distribution of the speed v_m of the moving animals is assumed to be independent of time, the location of the animal and its orientation. Here, we define an encounter at time t if the distance between an animal and a boat is $>r_m + r_b$ at time t, and $\leq r_m + r_b$ at some time during the interval $[t, t + \varepsilon]$. We refer to the critical distance of encounter as $r_c = r_m + r_b$. Some of the concepts described below are based on concepts discussed by Koopman (1956) in the context of naval operation research and Gerritsen & Strickler (1977) in the context of plankton movement. Wilson *et al.* (2007) applied equations developed by Gerritsen & Strickler (1977) to the problem of marine mammal collision with rotating turbines. We used a two-dimensional case of the problem (see Koopman (1956) for naval operations applications), which is more appropriate for vessel strikes. We derived an equation for the mean encounter rate λ_e for one boat and one animal (see Appendix S1, Supporting information for derivations):

$$\lambda_e = \frac{2\,r_c}{S}\int_{v_m} I(v_m, v_b) f_v(v_m)\,\mathrm{d}v_m \qquad \text{eqn 1}$$

where S is the surface area of the study region; r_c is the critical distance of encounter; function I is a monotonically increasing function of the velocities (described in Appendix S1); and $f_v(v_m)$ is the probability distribution of the animal velocity.

We now consider two limit scenarios that are relevant to our study. In the *fixed time scenario*, a boat will spend a fixed amount of time in an area, travelling without a specific destination; therefore, the faster the boat travels, the greater the distance it covers. This scenario is relevant to manatees because it is characteristic of some recreational boating activities (e.g. water skiing). The number of encounters during the boat's time in the area can be described by a Poisson distribution with parameter λ_{FT}. The Poisson parameter λ_{FT} is the encounter rate λ_e multiplied by the time interval t_d (Gerritsen & Strickler 1977); specifically, t_d is the fixed duration of time travelled by the boat within the study area:

$$\lambda_{FT} = t_d \times \lambda_e \qquad \text{eqn 2}$$

In the *fixed distance* scenario, a boat travels to a specific destination, and the travel distance is independent of the boat's speed. This is the more relevant scenario for whales, as commercial vessels tend to go from origin to destination in the shortest distance possible. It also applies to manatees and other marine mammals whose habitat includes navigable channels. The number of encounters can be described by a Poisson distribution with parameter λ_{FD}:

$$\lambda_{FD} = \frac{d}{v_b} \times \lambda_e \qquad \text{eqn 3}$$

where d is the fixed distance travelled by the boat as it crosses the study area.

We estimated encounter rates for the *fixed time* and *fixed distance* scenarios for manatees. For whales, we focused exclusively on the *fixed distance* scenario. Programming scripts written in R (R Core Team 2015) to estimate encounter rates are available on Dryad (see Data accessibility).

APPLICATIONS TO WHALES AND MANATEES

Manatee data and analysis

For our manatee example, we considered encounter rate with boats in a 2·82 km^2 section of Lemon Bay in south-west Florida (Fig. S2). For simplicity, we considered that on average, one manatee and one boat were present at all times in the study area. The abundance process for manatees was assumed to follow a Poisson distribution with parameter λ_m set to one. We assumed that the manatee's swimming speed followed a Weibull distribution (shape: 0·72, scale: 0·16; mean: 0·20 m/s, SD = 0·28), estimated from manatees equipped with a DTAG (a multisensor digital acoustic tag; Johnson & Tyack 2003) and an Argos-linked GPS tag attached via a tether (for details, see Appendix S2 and Rycyk (2013)). The radius of encounter for this example was based on boat width (2·34 m) and an average manatee width (0·63 m, SD = 0·046, n = 6, FWC data).

Whale data and analysis

We also provide an illustrative application of our model for estimating encounter rates between right whales and vessels in the south-eastern USA. For this example, we summarized vessel traffic collected through the Automatic Identification System (AIS) (Silber & Bettridge 2010) in the recommended shipping route off Jacksonville, FL (Fig. S3), over a 2-week period (January 16–31, 2010). We considered the bounded shipping route as our study area (S = 754·1 km^2). As with the manatee example, we set the expected number of whales to one. We considered a whale with a length of 14 m, width of 3·5 m and a swimming speed that followed a Weibull distribution (shape: 1·48, scale: 0·43; mean: 0·39 m/s, SD: 0·27) (Fortune *et al.* 2012; Miller *et al.* 2012; Hain *et al.* 2013). A total of 421 vessel transits within the shipping route were recorded through AIS during the study, and we used the mean vessel length (146 m) and vessel width (22 m) for all vessels in this example.

We conceptualized the radius of encounter, r_c, in three ways to determine the sensitivity of the model to this parameter. (i) The areas of the whale and vessel were estimated based on their length (L) and width (W); these areas were considered as circles whose radii were calculated as $r = \sqrt{\frac{LW}{\pi}}$. The radius of encounter was estimated as the sum of the circles' radii (r_{c_disk} = 31·98 + 3·95 = 35·93 m). The radius of encounter was also estimated as the sum of vessel width and (ii) whale width, for the scenario in which the whale's body is parallel to the vessel (r_{c_width} = 22 + 3·5 = 25·5 m), or (iii) whale length, where the whale is perpendicular to vessel (r_{c_length} = 22 + 14 = 36 m).

We calculated encounter rate for values of vessel speed ranging from 1 knot (1·85 km/h) to 33 knots (61·12 km/h). For each vessel speed value, we estimated the duration of a single transit in the area by dividing the mean transit length (27·8 km) by the vessel speed. To estimate the total number of encounters over a day, we calculated the product of the encounter rate, duration of a transit and the number of transits per day (421/15 = 28). We then extrapolated to a duration of 15 or 600 days. Furthermore, we compared the expected number of encounters under the current management case (vessel speed = 10 knots (18·52 km/h) (Silber & Bettridge 2010)) with that of the previous conditions (vessel speed = 15·7 knots (29·08 km/h) (Ward-Geiger *et al.* 2005)); for reference, the weighted mean vessel speed from AIS data during this study period was 9·6 knots (17·78 km/h).

Encounters, collisions and expected mortality of North Atlantic right whales

As shown in Appendix S3, the expected number of encounters over a period of time t_d is $\lambda_e\, t_d$.

It is important to understand that the number of encounters is different from the number of collisions; indeed, the collision rate is as follows:

$$\lambda_c = \lambda_e P(\text{Strike depth})\,(1 - P(\text{Avoidance}_m))\,(1 - P(\text{Avoidance}_b)) \qquad \text{eqn 4a}$$

where *P*(Strike depth) is the probability that the whale is within the striking depth during an encounter (Fig. 1). *P*(Avoidance) is the probability of avoidance by the mammal *m* or the boat driver *b* and may depend on v_b. Eqn 4a implies that there is no covariation between the avoidance probabilities and would require these probabilities to be estimated separately. An alternative parameterization would be as follows:

$$\lambda_c = \lambda_e P(\text{Strike depth})\,(1 - P(\text{Avoidance}_{mb})) \qquad \text{eqn 4b}$$

where $P(\text{Avoidance}_{mb})$ is the probability of avoidance by the animal and boater combined, which may be easier to estimate. We fixed $P(\text{Avoidance}_{mb})$ to 0 because of lack of information, but we explored the importance of this parameter on model predictions (see Appendix S4, Fig. S1). We used a probability of being within striking depth of 0·6 (SD = 0·22) based on Hain *et al.* (1999). This is probably an underestimate because that study focused on the probability that whales were at the surface rather than within striking depth. The death rate is as follows:

$$\lambda_\varepsilon = \lambda_c\, P(\text{Death}|\text{Strike speed}) \qquad \text{eqn 5}$$

where *P*(Death|Strike speed) corresponds to the probability of death of a whale at a given striking speed. This probability was obtained from Conn & Silber (2013). The expected number of deaths follows a Poisson distribution (Appendix S3 for justification):

$$\text{Pois}(\lambda_\varepsilon\, t_d\, \lambda_m\, N_b) \qquad \text{eqn 6}$$

where t_d is the time on the appropriate scale, N_b is the number of boats, and λ_m is the parameter of the Poisson random variable for the number of mammals, with, $\lambda_m = \gamma_m\ S$, where γ_m is animal density. The expected number of deaths is therefore:

$$E[\text{Pois}(\lambda_\varepsilon\, t\, \lambda_m\, N_b)] = \lambda_\varepsilon\, t\, \lambda_m\, N_b \qquad \text{eqn 7}$$

We used a MCS approach to account for uncertainty when estimating the relative number of deaths as a function of the parameters noted in eqns 4–7. In order to make inference about new data (e.g. carcass counts), it is straightforward to convert this MCS model to a Bayesian belief network (BBN, e.g. Smid *et al.* 2009). In our case, we used a MCS approach to implement the BBN because we did not try to fit models to the data. Each component of the model followed a probability distribution; details about the structure of the MCS model and the distributions are provided in Appendix S5. Because we fixed the probability of avoidance (in eqn 4b) to 0 and animal abundance (λ_m) to one, the expected number collisions is in fact a measure of the relative number of collisions. Similarly, the number of expected deaths (or expected mortality) should be viewed as a measure of expected relative mortality. An estimate of absolute mortality would require estimating the probability of avoidance which is currently not available and may be a function of vessel speed (see Appendix S4). R scripts for this analysis are available on Dryad (see Data accessibility).

Simulations

For validation purposes, we compared the results from our analytical framework to simulation results using the right whale example. For the simulations, we considered a circular study area (S = 754·1 km^2) with a single vessel transiting the area in a straight line at constant speed (either 10 knots (18·52 km/h) for a relevant management speed, or 1·18 knots (2·18 km/h) for an unrealistically low vessel speed) for 27·8 km. Vessel location was recorded every 1-s time-step for the duration of the transit. The locations of a single whale moving within the area were simulated using either a random walk, representing an area-restricted search behaviour, or a correlated random walk, representing nearly linear directed movement behaviour. The initial location of the whale was randomly selected within the study area, and subsequent locations at 30-s intervals were simulated based on draws for step length from a Weibull distribution (shape: 1·48, scale: 0·43*30; equivalent to a mean 0·39 m/s) and draws for turning angle from a wrapped Cauchy distribution (μ = 0, ρ = 0·001 for the random walk; μ = 0, ρ = 0·999 for the nearly linear directed movement). If the whale travelled outside the bounds of the area, its location was replaced with a new randomly generated point within the area to approximately replicate λ_m = 1. Simulated whale locations were interpolated to a 1-s time-step resolution to match the boat's resolution and avoid one agent's 'jumping over' the other (Van Der Hoop, Vanderlaan & Taggart 2012) by assuming a straight path and constant speed between 30-s time-step locations.

At each 1-s time-step, the distance between the boat and whale was calculated; an encounter was recorded if this distance was less than r_c = 35·93 m. We counted the number of encounters per simulation in two ways: (i) allowing a maximum of 1 encounter per simulation (i.e. a whale can encounter the single vessel only once, this is the case that is best approximated by the analytical approach) and

(ii) allowing a maximum of 1 encounter for each 30-s segment of the whale's path (to maintain independence among intersections; otherwise, the number of recorded encounters would approach infinity for a low vessel speed or small time-step). At the end of the vessel's transit (d = 27·8 km), the simulation was terminated. The simulation (1 whale and 1 boat) was repeated 1000 times for each vessel speed and whale behaviour scenario, and the average number of encounters per vessel transit was calculated. The average number of encounters per transit was then multiplied by 28*15 to estimate the number of encounters from all vessel transits over the 15-day period. We repeated this process 500 times to compute mean and 95% CI using a bootstrap approach. R scripts for this analysis are available on Dryad (see Data accessibility).

Results

ANALYTICAL APPROACH

The manatee model shows a positive relationship between boat speed and encounter rate; note that the effect of uncertainty of manatee speed on encounter rate was small (Fig. 2a). For the *fixed time* scenario (time spent in the area independent of boat speed; in this case, the boat is assumed to spend 30 min in the study area), boats at faster speeds travel a greater distance in the area of interest, resulting in a correspondingly greater number of expected encounters (Fig. 2b). Because the relationship is nearly linear, an 80% decrease in speed (e.g. from 21·5 knots (39·82 km/h) to 4·3 knots (7·96 km/h) leads to an 80% decrease in distance travelled and in the expected number of encounters. Conversely, there is a declining relationship between boat speed and expected number of encounters for the *fixed distance* scenario, but this decrease is negligible for the manatee case – less than 0·2% for the same speed range (Fig. 2c). Although the encounter rate is low when boat speed is slow (Fig. 2a), the expected number of encounters is greatest when boat speed tends towards zero in the fixed distance scenario (Fig. 2c), because time spent in the area tends to infinity. The relationship quickly reaches an asymptote when speed increases. To show the contribution of animal speed on these relationships, we also plotted the curves for the case where animal speed was increased to 3·1 m/s, which represents the case for the speed of bottlenose dolphins, *Tursiops truncatus* (Fig. 2a–c, grey lines).

The whale model likewise shows a positive linear relationship between encounter rate and vessel speed (Fig. 3a). The decline in the expected number of encounters is most noticeable at very slow speed (e.g. <2 knots (7 km/h) for r_{c_disk}, Fig. 3b). The reduction in the expected number of encounters for the speed considered for management purposes was miniscule (Fig. 3b). Under case A (whale abundance in the area of interest was 1 for a short time frame (15 days) with 28 vessels per day, and vessel speed was 10 knots), there were an expected 1·114 encounters, whereas under case B (same as A, but vessel speed was 15·7 knots), the expected number of encounters was 1·113. Assuming no collision avoidance behaviour by the whale or the ship, the expected relative number of collisions was 0·669 for case A and 0·668 for case B. The expected relative number of deaths was 0·378 for case A and 0·546 for the higher

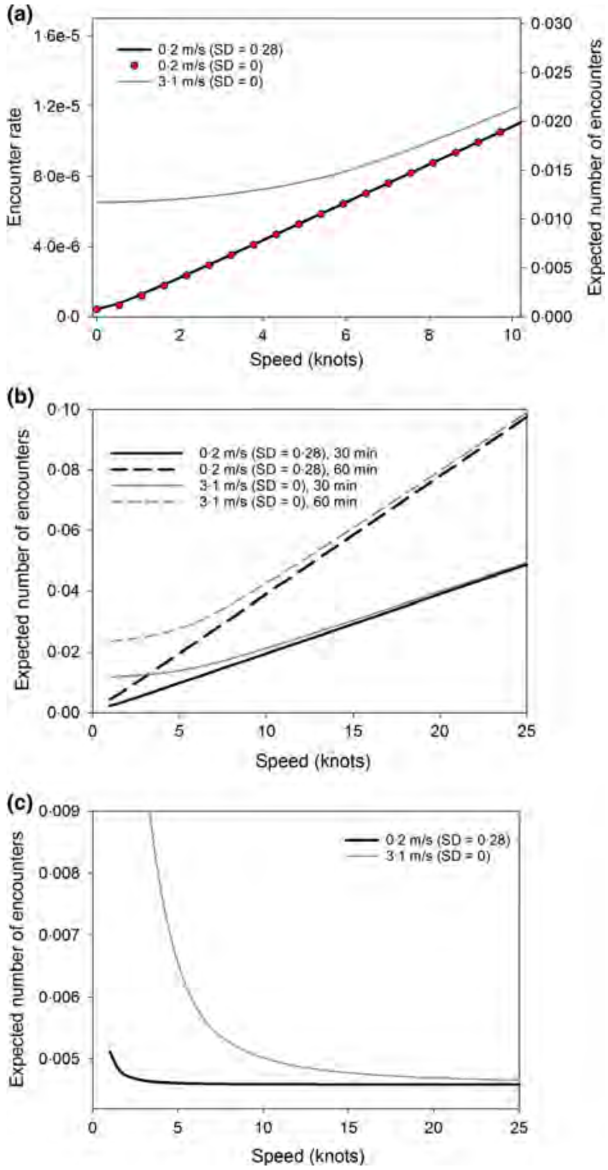

Fig. 2. Relationship between boat speed and the encounter rate (a), and expected number of encounters for the fixed time (a–b) and fixed distance scenario (c). The thick black solid lines correspond to the case of manatees with a mean speed of 0·2 m/s (SD = 0·28), the red dots correspond to a fixed mean speed of 0·2 m/s (SD = 0), and the thin grey lines correspond to a speed of 3·1 m/s (SD = 0) (based on bottlenose dolphins *Tursiops truncatus* mean sustainable speed, reviewed in Noren, Biedenbach & Edwards (2006)). The dashed lines in (b) correspond to the case where a boat is in the study area for 60 min instead of 30 min [solid lines; and red dots in (a)].

speed case B (see also Appendix S4). We also computed these expected numbers of encounters over a longer time frame (600 days, considering 2 months of high whale density in the south-eastern USA per year for 10 years). The expected number of encounters for the long time frame was 44·57 for case A and 44·53 for case B. The expected relative number of collisions for the long time frame was 26·74 for case A and 26·72 for case B. The expected relative number of deaths was 15·13 for case A and 21·85 for case B. Our results illustrate that the expected mortality process is largely driven by the probability

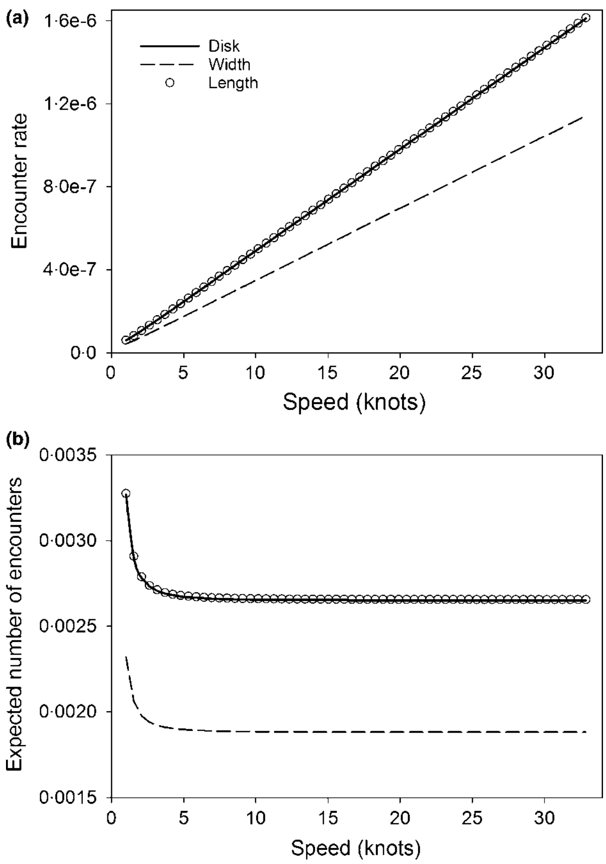

Fig. 3. Relationship between boat speed and the encounter rate (a), and expected number of encounters (b) between one boat and one whale. The symbols and lines indicate the cases in which the encounter radius was based on a disc with area approximately equal to that of a whale (black line), the width of the whale (dashed line) or the length of the whale (white circles).

of death given striking speed. The percentage reduction in the expected number of encounters based on our analyses was <0·1% when comparing management cases A and B. However, the slower speed case (A) resulted in a 31% reduction in the expected relative number of whale deaths relative to case B. Figure 3 shows the effect of varying values of the encounter radius, r_c. Not surprisingly, using whale length led to the highest encounter rates, and width to the lowest; these represent the two extremes.

When accounting for uncertainty using a MCS approach, the mean difference in expected relative mortality between cases A and B over 15 days was 0·14; 95% CI (−2 to 2), which represents a 27% reduction in expected relative mortality. This result illustrates that despite a greater expected relative mortality at higher speeds, there is a large uncertainty associated with the projected relative numbers of mortality events and that detailed analyses of the impact of watercraft on wildlife should incorporate relevant sources of uncertainty.

SIMULATIONS

Under case A, the analytical framework resulted in an expected 1·114 encounters for a time frame of 15 days with 28 vessel transits per day. For the same case and allowing a maximum of one encounter per vessel transit, the simulations resulted in an expected [mean (95% bootstrap CI)] 1·18 (0–2·94) encounters if the whale's movement followed a correlated random (nearly linear) walk and 1·16 (0–2·52) encounters if the whale's movement followed a random walk. Under the same case but allowing for multiple encounters per simulation, the simulations resulted in an expected 1·56 (0–3·78) encounters if the whale's movement followed a correlated random walk and 1·55 (0–3·78) encounters if the whale's movement followed a random walk.

Under the case with an extremely slow speed (1·18 knots), the analytical approach resulted in an expected 1·213 encounters. For the same case and allowing a maximum of one encounter per vessel transit, the simulations resulted in an expected 1·56 (0·42–3·36) encounters if the whale's movement followed a correlated random (nearly linear) walk and 1·27 (0–2·74) encounters if the whale's movement followed a random walk. Under the same case but allowing for multiple encounters per transit, the simulations resulted in an expected 5·90 (0·84–13·66) encounters if the whale's movement followed a correlated random walk and 4·81 (0–10·92) encounters if the whale's movement followed a random walk.

Discussion

By applying encounter rate theory to the problem of boat collisions with marine mammals, we were able to gain valuable insights that may not have been as apparent using a simulation approach. We examined two limit case scenarios. Many recreational boating activities are consistent with the *fixed time* scenario. In the example that we considered, we found that a reduction from 21·5 knots (39·8 km/h) to nearly idle speed (~4·2 knots [7·8 km/h]) reduced the number of encounters by 80%. This is due to the nearly linear relationship between speed and encounter rate (Fig. 2a). In this scenario, a boat with greater speed will cover a greater distance for a given amount of time, resulting in more expected encounters.

We also considered the case of the *fixed distance* scenario, where vessels go to a specific destination and the distance travelled is not affected by speed. For instance, we described the case of vessels travelling distances within shipping lanes where encounters with whales may occur. The fixed distance scenario has been discussed by Vanderlaan & Taggart (2007), who described a theoretical scenario for whales, but acknowledged that their initial analysis warranted a more detailed investigation to better elucidate the encounter process. Their analyses used a different approach (Galos, Argyrakis & Kehr 2001). Results from our new analytical solutions also showed a slight decrease in the number of encounters as boat speed increases (Figs 2c, 3b). Our mathematical framework [which builds on concepts developed and discussed by Koopman (1956) and Gerritsen & Strickler (1977)], however, is more comprehensive than that of Vanderlaan & Taggart (2007), provides more accurate estimates, and provides a mathematical rationale for extrapolation in space and time and over heterogeneous habitats. Wilson *et al.* (2007) applied equations developed by

Gerritsen & Strickler (1977) (who considered the problem of encounter of plankton to be 3-dimensional) to the problem of marine mammal collision with rotating turbines. In contrast, we used a 2-dimensional case of the problem (Koopman (1956) for naval operations applications), which we view as more appropriate for vessel strikes because it better approximates movement of boats. The analytical approach is more easily employed and allows for a more rapid assessment of parameter uncertainties on model output than does a simulation approach, which requires extensive computer run time and the selection of an appropriate time-step resolution (Clyde & Kennedy 2001; Van Der Hoop, Vanderlaan & Taggart 2012). Finally, our framework explicitly incorporates uncertainty, which has seldom been accounted for in estimates of mortality rates due to watercraft collisions (but see Conn & Silber (2013) for an alternative approach that also accounts for uncertainty).

Although Vanderlaan & Taggart (2007) used a different approach from ours, we found a similar general pattern: the expected number of encounters was negatively related to boat speed, with a probability of encounter that approaches one when boat speed approaches zero (Fig. 3b). This finding, however, should be interpreted cautiously. Indeed, by decomposing the expected number of encounters (Fig. 3b) into the encounter rate and its time component, we can see that the encounter rate remains low at idle speed (Fig. 3a). The expected number of encounters is greater at extremely low boat speeds because as boat speed tends towards zero, time spent in the area tends to infinity and the animal thus has longer exposure to the boat. In the extreme case where the boat is stationary, if the moving animal is not actively avoiding the boat and is confined to an area that includes the boat, the animal will eventually cross paths with the boat. This is a theoretical result with little relevance for practical situations. As illustrated with the whale case, the ratios of the boat speed to animal speed are such that the decrease in risk of encounter due to an increase in speed is negligible. For instance, the expected number of encounters for a projected time frame of 600 days was 44·57 and 44·53 under cases A and B, respectively. In contrast, the expected relative mortality due to collision was 15·13 under case A and 21·85 under case B. This shows that the slight reduction in the number of encounters (~0·1%) is overwhelmed (and in fact negligible) by the increased probability of mortality due to increased vessel strike speed, resulting in a reduction of approximately 31% for the deterministic model and 27% when accounting for uncertainty with the MCS approach under the scenario with regulated vessel speed. This reduction jumps to 62% when using estimates [of probability of death given striking speed, with no uncertainty] from Vanderlaan & Taggart (2007) instead of Conn & Silber (2013). This finding emphasizes the importance of obtaining accurate estimates of the probability of death given boat striking speed, which remains a challenging task. For instance, estimation of this parameter is complicated by the fact that animals may be hit yet never seen or reported.

Limitations of our analytical approach relate primarily to the estimation of parameters necessary for realistic models. In particular, the probability that marine mammals will avoid boats or that boaters will avoid animals may also be affected by speed (Vanderlaan & Taggart 2007; Gende *et al.* 2011; Van Der Hoop, Vanderlaan & Taggart 2012; Conn & Silber 2013). Very little is known about the avoidance process, and in our estimates of expected relative mortality, we set the avoidance probability to 0 (in fact it is because of this constraint that we report expected relative mortality instead of expected 'absolute' mortality). In Appendix S4, we examined this issue with exploratory analyses. These results show that avoidance probabilities could have an important impact on estimates of expected mortality and that future research should focus on estimating these probabilities. Furthermore, the management scenarios that we explored were conceptual; for instance, we considered the case for one whale or one manatee. Nevertheless, the mechanistic framework that we have outlined (Fig. 1) is well-suited for incorporating new information (e.g. detailed information about animal density; Martin *et al.* (2015)). The MCS analyses confirmed that the expected whale mortality was greater at faster vessel speeds but indicated that large uncertainty was associated with these estimates. The model that we used for the analytical approach is based on a number of assumptions. Our approach assumes that the animals are spatially distributed according to an equilibrium distribution and that the orientation of the animal is part of the information contained in the equilibrium distribution. In addition, it assumes that the distribution of the speed of the animal is stationary, independent of time, of the animal's position and of its orientation. This analytical solution ignores the effect of boundaries of the area, which can affect the spatial distribution of the animals there. To address this specific concern, a simulation approach can be used to check the consistency of the results. The model also assumes no interactions among boats or animals (e.g. no aggregations). As explained earlier, the model estimates the rate of first encounters. Considering only first encounters can be justified because if an animal is killed, future encounters will be irrelevant; if the animal survived, it may alter its behaviour, increasing its probability of avoidance; and in most situations, the boat will be travelling in a nearly linear transit at a much greater speed than the animal, making multiple encounters unlikely.

Interestingly, the selection of the radius of encounter may have an important effect on estimates of encounter rates (Fig. 3). When boats move much faster than the animal, it makes sense to consider the width of the boat and the orientation of the animal with respect to the boat's trajectory as key parameters. The relative orientation of the boat and animal (including orientation in the vertical dimension, because the animal may be diving) at the time of encounter can also influence the probability of collision and death; if known, these effects could be incorporated into the overall conceptual framework. We recommend further investigation to derive alternative metrics for encounter radius that better approximate the encounter process, which would likely lead to intermediate values between the extremes (width and length) and would account for the shape of the moving agents.

When considering the encounter process, the ratio of speeds between the two moving agents should also be considered instead of just absolute speeds for each moving agent independently. As shown in eqn 1 and Fig. 2b–c, with everything else being equal (e.g. animal and boat density in the area) at a given boat speed, the encounter rate will be higher for faster-moving animals than for slowly moving animals (Koopman 1956; Evans 1989; Anderson, Gurarie & Zabel 2005; Gurarie & Ovaskainen 2013a,b in the contexts of zooplankton interactions and animal movement).

An appealing property of our approach is that it is scalable and can be applied to heterogeneous landscapes or can be extrapolated in time (see Appendix S3 for mathematical justification). For instance, North Atlantic right whales in the south-eastern USA tend to occur at higher densities in cooler, nearshore waters (Keller *et al.* 2006). Observed data or predictive models can be incorporated into this analytical framework to estimate the number of collisions in habitats with different animal or vessel densities. Thus, our framework should facilitate the creation of risk maps through straightforward integration in GIS which would be more cumbersome with a simulation approach.

The simulations of animal–boat collisions led to encounter rates that were reasonably consistent with the analytical results for the speeds that we considered, particularly for speeds relevant to regulations. But we found substantial discrepancies at very slow vessel speeds when allowing multiple encounters per whale; this is due to the fact that the analytical approach that we used assumes a maximum of one encounter between an animal and a boat during a transit. As expected based on the assumptions of the analytical approach, if we allowed only one encounter per whale, the encounter rates from the simulated and analytical approaches did not differ substantially.

Here, we set most parameters to fixed values because the primary purpose of this paper was to provide general insights based on our solutions rather than to focus on detailed applications. Although we used empirically based values for our parameters when possible to make the analyses more meaningful, we intend to extend this framework to account for additional details and sources of uncertainties. In fact, the framework we have presented can be modelled with a MCS model or BBN to describe these sources of variation. As a case in point, we computed estimates of mortality events for whales that accounted for uncertainty, mostly as a way to illustrate the approach. Such a network would also be appropriate for incorporating some of the processes we have not included, such as mammals' ability to avoid vessels, vessel operators' ability to avoid collisions and compliance with regulations. The benefit of such an approach is that it is well-suited for combining the estimation and statistical methods advocated by Conn & Silber (2013) with more mechanistic approaches described by Gerritsen & Strickler (1977) and Van Der Hoop, Vanderlaan & Taggart (2012). In fact, carcass recovery data could be incorporated into the analyses to assess and inform predictions. Finally, our analytical approach could be coupled with a population projection model (e.g. Runge *et al.* 2015), allowing us to infer impacts of regulations on the population of interest.

To conclude, our work constitutes a significant advance in understanding the process of encounter rates and risk of collisions between marine mammals and vessels. It provides an interesting case where theoretical work can be used to help improve management decisions and policies. The generality of our framework makes it applicable to other marine animals (e.g. sea turtles) and other animal groups and systems, including wildlife collisions involving motor vehicles on roads, snowmobiles and wind turbines. Finally, because many ecological processes involve the encounter between moving agents (e.g. predator-prey interactions) our findings are also relevant to these ecological topics (e.g. Gerritsen & Strickler 1977; Hutchinson & Waser 2007; Gurarie & Ovaskainen 2013a).

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Data accessibility

Data and programming scripts are available on Dryad at: http://dx.doi.org/10.5061/dryad.vv150.

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Appendix S1. Derivation of the analytical formula.

Appendix S2. Details about estimation of manatee speed from multi-sensor digital acoustic tag.

Appendix S3. Scalability justification of Poisson process.

Appendix S4. Probability of avoidance (includes Fig. S1).

Appendix S5. Monte Carlo simulation model.

Figure S1. Probability of avoidance and expected mortality as a function of vessel speed.

Figure S2. Study area for the manatee model.

Figure S3. Study area for the North Atlantic right whale model.

ATTACHMENT 7

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A Bayesian approach for understanding the role of ship speed in whale–ship encounters

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Abstract. Mandatory or voluntary reductions in ship speed are a common management strategy for reducing deleterious encounters between large ships and large whales. This has produced strong resistance from shipping and marine transportation entities, in part because very few studies have empirically demonstrated whether or to what degree ship speed influences ship–whale encounters. Here we present the results of four years of humpback whale sightings made by observers aboard cruise ships in Alaska, representing 380 cruises and 891 ship–whale encounters. Encounters occurred at distances from 21 m to 1000 m ($\bar{x} = 567$ m) with 61 encounters (7%) occurring between 200 m and 100 m, and 19 encounters (2%) within 100 m. Encounters were spatially aggregated and highly variable across all ship speeds. Nevertheless a Bayesian change-point model found that the relationship between whale distance and ship speed changed at 11.8 knots (6.1 m/s) with whales encountering ships, on average, 114 m closer when ship speeds were above 11.8 knots. Binning encounter distances by 1-knot speed increments revealed a clear decrease in encounter distance with increasing ship speed over the range of 7–17 knots (3.6–8.7 m/s). Our results are the first to demonstrate that speed influences the encounter distance between large ships and large whales. Assuming that the closer ships come to whales the more likely they are to be struck, our results suggest that reduced ship speed may be an effective management action in reducing the probability of a collision.

Key words: Alaska; Bayesian; change-point model; cruise ship; Glacier Bay National Park and Preserve, Alaska, USA; humpback whale; ship speed; ship strike; ship–whale encounters.

Introduction

Understanding the interactions between large ships and large whales has become a global conservation issue owing to the dramatic increase in commercial shipping traffic in recent decades (Andrew et al. 2002, Ross 2005) and an emerging awareness of the deleterious impacts that large vessels may have on individuals and populations of large whales. For example, shipping produces underwater sound that may disrupt vital activities for whales, such as feeding or reproduction, or hinder communication (NRC 2005, Parks et al. 2011). Whale–ship encounters may also result in lethal or sublethal collisions (Laist et al. 2001, Kraus et al. 2005). Consequently, a number of U.S. and international management entities have initiated efforts aimed at reducing these impacts, focusing primarily on reducing spatial overlap between ships and whales (e.g., Fonnesbeck et al. 2008, Vanderlaan et al. 2008). In some cases, this management approach is both feasible and effective; in the Bay of Fundy, for example, slight changes in routing of vessels can reduce the relative risk of collision by up to 62% (Vandelaan et al. 2008). In other cases, however, this management action may not be effective or appropriate, either because whale distribution may shift over time, or because ships may not be able to reroute around high-use whale habitat when approaching ports of call, or in narrow passages. In these instances, the primary management action has been to implement regulations for, or request voluntary compliance with, reductions in ship speed (National Park Service 2006, NMFS 2008, Carrillo and Ritter 2009).

Although relatively common, there is considerable uncertainty in the effectiveness of regulating ship speed in meeting whale-conservation objectives due, in part, to a paucity of data (e.g., Vanderlaan and Taggart 2007, NMFS 2008). The difficulty of applying an experimental framework, and the legal and logistical issues associated with putting observers aboard large, ocean-ranging

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vessels, have resulted in few field-based efforts and a corresponding lack of data on the role of ship speed during ship–whale encounters. Not surprisingly, the shipping industry has legitimately raised concern about the focus on ship speed in the absence of studies confirming its effectiveness (World Shipping Council 2006).

For four years (2006–2009) we used shipboard observers to record encounters between cruise ships and humpback whales in Alaska, including Glacier Bay National Park. Cruise ships make multiple ports of call in coastal Alaska, providing a logistically feasible means by which to place observers on board to record ship–whale encounters. In addition, cruise ships are one of the most rapidly expanding forms of leisure travel (Dowling 2006), overlap spatially with whale hotspots in the Caribbean, Hawaii, South Pacific Islands, Mediterranean, Alaska, and Baja California (Hoyt 2005), and consequently cruise ships have been involved in a number of collisions with whales both in Alaska and globally (Jensen and Silber 2003, Gabriele et al. 2008). Thus cruise ship–whale interactions are global in scope, likely to increase, and an emerging conservation issue.

Our objective was to better understand the nature of ship–whale encounters by recording the frequency and severity (closeness) of encounters between ships and whales. Our study included the area in and near Glacier Bay National Park, one of the largest marine mammal protected areas in the world. Given that cruise ships are essential for allowing visitor access into Glacier Bay and thus rerouting around the park is not a viable management alternative, we focused specifically on the relationship between encounter distance and ship speed. To our knowledge, this is the first large-scale study to use observers on ships for the purpose of better understanding large ship–large whale encounters, and assessing the effectiveness of ship speed in meeting conservation and management objectives.

Methods

Our study was located in southeastern Alaska and included Glacier Bay National Park and Preserve (hereafter "Glacier Bay" or "the park") and adjacent waters (approximately 58°41.127' N, 136°11.740' W; Fig. 1). Cruise ships are the primary mode of transport by which visitors access Glacier Bay: in 2009 more than 400 000 cruise ship passengers, constituting over 95% of all visitors to the area, came to Glacier Bay during 224 ship entries into the park. The U.S. National Park Service (NPS) regulates the number of all commercial and private ships in Glacier Bay, and is currently considering a >20% increase in the seasonal quota of allowable cruise ship entries (NPS 2006).

The NPS also regulates ship speed within Glacier Bay using two types of speed restrictions. *Seasonal whale waters* occur near the entrance of Glacier Bay extending from the mouth of the bay to an imaginary line between northern Strawberry Island and Lars Island (Fig. 1). All motorized vessels over 5.5 m (18 feet) must maintain speeds of 20 knots (10.3 m/s) or less while in this area from 15 May through 31 August although the time may be extended later in the season or the maximum speed may be reduced to 13 knots (6.7 m/s) depending upon management recommendations. *Temporary whale waters* may be designated in any area of Glacier Bay and this limits ship speeds to 13 knots or less when >3 whales occur for three or more days based on weekly monitoring efforts. During our study the cruise ships were subject to speed restrictions in the lower part of Glacier Bay, but not in the waters immediately adjacent to the park boundary, providing a fortuitous natural experiment to examine how speed influences encounter distances with whales.

A total of 18 different cruise ships representing four different cruise companies participated in the study. All ships were large, averaging 256 m in length (range, 181–294 m), 32 m in beam (26–37 m), and 8 m in draught (5.9–8.2 m). Most carry 1500–3000 passengers and 500–1500 crew. Most (14 of 18) of the ships used during this study had similar "diesel-electric" propulsion systems. Beginning in 2006 an observer based in Bartlett Cove (location of the headquarters for Glacier Bay) was transported to the ships as they entered the park ($n = 45$ cruises; July–September) and in 2007 two separate observers (one per ship) were transported to ships ($n = 138$ cruises, May–September). However, concurrent, independent humpback whale monitoring efforts conducted by Glacier Bay staff indicated that many ship–whale encounters (see Plate 1) were occurring just prior to, or soon after, the Bartlett Cove-based observer embarked/disembarked the ship. Thus, in 2008 and 2009, in addition to the continued effort of the Bartlett Cove-based observer ($n = 83$ cruises conducted May–September 2008; $n = 74$ cruises conducted May–September 2009), a Juneau-based observer boarded the ships at the port of call prior to Glacier Bay (either Skagway or Juneau), and recorded encounters throughout Icy Strait, Glacier Bay, and in some cases Cross Sound (Fig. 1). The Juneau-based observer then disembarked at the next port of call (Ketchikan or Sitka, Alaska), and traveled back to Juneau or Skagway to board another ship. The total number of cruises for the Juneau-based observer was 49 ($n = 20$ cruises in 2008 and $n = 29$ cruises in 2009; cruises conducted May–September).

Once aboard the ship, the protocol was the same regardless of embarkation port. The observer was positioned on the forward-most bow of the ship (generally the seventh or eighth deck on most ships) in the early morning. For the Juneau-based observer, survey effort started around daybreak (04:06–06:47 hours) somewhere in Icy Strait and ended around dusk either in Cross Sound or Chatham Strait (Fig. 1) depending upon itinerary and day length (effort ending 17:21–22:10 hours). For the Bartlett Cove-based observer effort started just after embarkation generally between 07:00 and 10:30 hours (range, 05:53–12:08

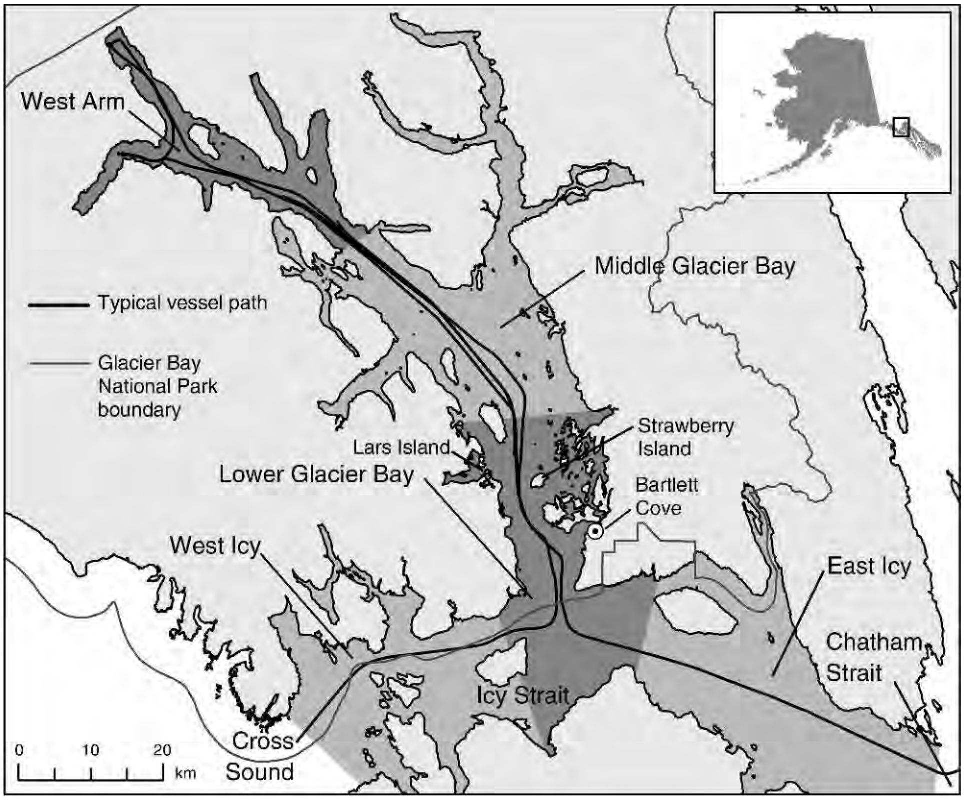

FIG. 1. Study area in southeastern Alaska, USA, showing the boundary of Glacier Bay National Park and Preserve and the five subareas designated a priori based on long-term average oceanographic conditions (Etherington et al. 2007) and historical and contemporary sighting frequency of humpback whales (Neilsen and Gabriele 2005). The five subareas are West Arm, Middle Glacier Bay, Lower Glacier Bay, West Icy, and East Icy. The heavy lines indicate typical cruise ship tracks through Icy Strait and into Glacier Bay.

hours) and ended when they disembarked with the NPS Interpretive Rangers as the ship exited the park (14:20–20:50 hours). Thus, all cruises occurred during the daylight. Only in middle to late September at the end of the cruise season are there cruise ships in Glacier Bay after dusk.

All of the large cruise ships are configured similarly, with the forward most bow of the ship ahead of the bulbous bow by an average of 13.5 m (range, 5.8–27.5 m). On average, the observer was 15.5 m above the water (range, 12–19.3 m), providing a clear 180° view of the waters surrounding the ship. Nevertheless, due to both the height of the deck railing and the overhang of the observation deck past the bulbous bow, there was a small "blind area" where observers could not see if whales surfaced within an average of 32 m of the bulbous bow.

Once at the bow, observers used Leica Viper II Rangefinder binoculars (accuracy, ±1 m at 1 km) (Leica, Charlottesville, Virginia, USA) and a Garmin 76Cx handheld GPS unit (Garmin, Olathe, Kansas, USA) to record the distance and location of encounters between ships and whales. The GPS units were set to record the location of the ship every 5 s, from which the track and speed (over ground) of the ship could be reconstructed. Observers continuously scanned the waters with naked eye or Swarovski 10 × 42 binoculars in a 180° arc around the bow of the ship. When a whale was sighted, the rangefinder binoculars were used to record the distance and bearing between observer and the whale. Sightings on the whale or group of whales continued until they were no longer seen and/or passed directly abeam of the observer, i.e., 90° from the ship's course.

In some cases, however, the whale dove before the rangefinder binoculars could be used. For these encounters (31% of total) the distances were estimated. To determine if estimating the distance biased our results, on 10 different occasions during each cruise, the observers estimated the distance to inanimate objects in the water (e.g., logs, ice bergs) and then immediately used the rangefinder binoculars to record the actual distances. This "estimation error" (difference between actual and estimated) was relatively small (average is ±12% of the actual encounter distance across all distances) and unbiased (percentage error did not change appreciably across encounter distances). Thus, no corrections were made for estimated vs. observed distances.

Following each cruise, all encounter data were entered into a Microsoft Access database, and all spatial data were downloaded from the GPS units (Garmin, Olathe, Kansas, USA) using DNR Garmin (free software from the Minnesota Department of Natural Resources, *available online*).[8] The cruise-ship track data (locations automatically logged every 5 s) and whale-sighting data (waypoints taken during whale observations) were merged in ArcGIS using a Visual Basic script. Ship speed at the time of whale sighting was calculated by extracting 10 points from the track data—five ship location points immediately preceding and immediately following a whale-encounter waypoint—and summing the distance over which the ship traveled during that time and dividing by the time it took to cover that distance.

Our analytic approach was to calculate the management-relevant metric of distance of the whale to the bulbous bow (where most whale–ship collisions are likely to occur) based on the distance of the observer to the whale and the bearing of the whale to the ship. This equates to calculating the length of the line segment AC based on the triangle ΔABC with vertices of whale location (A), location of observer (B), and the bulbous bow (C). To do so, we first calculated the distance of the observer to the bulbous bow (BC), which is $\sqrt{h^2 + q^2}$ where h is the height of the observer above water and q is the distance of the bow (observer) to the bulbous bow at the water level (both of these ship dimensions were provided by the cruise companies). We then calculated the distance of the whale to the observer at water level $p = \sqrt{\mathrm{AB}^2 - h^2}$. The encounter distance (AC) $= \sqrt{p^2 + q^2 - 2pq\cos\alpha}$ where α is the bearing of the whale relative to ship direction (180° when the whale is directly in front of the ship).

If several locations were taken on the same whale, only one encounter (the minimum distance) was used for analysis to ensure independence and because minimum encounter distance was the management-relevant metric. The maximum encounter distance was limited to <1 km for three reasons. First, it was unclear at what maximum distance whale–ship interactions can still be considered biologically meaningful. Second, we felt confident that using only encounters within 1 km would ensure a near 100% detection probability, similar to what was found by Zerbini et al. (2009) using distance sampling during ship-based abundance estimates for humpback whales in the Gulf of Alaska. Nevertheless, to test this assumption on nine separate cruises we placed two independent observers (double sampling) aboard the same cruise ship, one each on the port and starboard sides of the bow, and found 100% concurrence of sighting frequency. Finally, ships are almost always at least 2 km from shore in all directions while in our study area, although in a few areas they travel to near 1 km of shore (Fig. 1). Thus, by truncating encounters to 1 km, we assumed an unbiased probability of detecting whales around the ship independent of geographic location.

We also divided the study area a priori into five separate subareas (Fig. 1) corresponding to differences in oceanographic conditions (Etherington et al. 2007). These subareas also reflected differences in whale habitat use, based on long-term monitoring efforts conducted by NPS personnel (Neilson and Gabriele 2005). No oceanographic monitoring has occurred in the West Icy subarea.

To test whether there was a change in the mean encounter distance as a function of ship speed (given the management application, the knot is the speed metric used in this analysis), we used a change-point model. Change-point models have the flexibility to identify changes in a relationship while incorporating uncertainty (Thomson et al. 2010). Our change-point model can be described as

$$Y_i \sim \log\mathcal{N}(\beta_k, \sigma^2) \quad (1)$$

$$k = 1 + \mathrm{step}(X_i - X_{\mathrm{CP}})$$

where the Y_i are the individual encounters (each with a distance and speed) $i = 1, \ldots N$, which are modeled by the mean values β_k and variance σ^2, and X_i is the speed during encounters $i = 1, \ldots N$. Assuming a single change point (CP) is identified, the mean encounter distance can have two levels above and below X_{CP}, thus $k = 1,2$. The mean level is determined by whether the speed of the vessel is above or below the threshold with mean distance β_1 and β_2, respectively. The function step() = 1 if the value inside the parenthesis is positive and equates to 0 if negative. There are four coefficients to be estimated in the change-point model: β_1, β_2, σ^2, and X_{CP}. Of particular interest is how the speed threshold X_{CP} affects parameter estimates of β_1 and β_2. We used a log-normal distribution in the change-point analysis because all encounter distances were positive.

The change-point model was conducted in a Bayesian estimation framework that allowed us to calculate probability densities representing the uncertainty for each of the four model parameters. We used noninformative prior probabilities for all model coefficients with the goal of allowing the data to support identification of the speed threshold (change point) at which there was a difference in mean distance from ship to whale. This noninformative approach corresponded to the change-point coefficient having a uniform prior distribution between 9 and 17 knots (4.6 and 8.7 m/s) [$X_{\mathrm{CP}} \sim \mathrm{Unif}(9,17)$]. Although encounters with whales occurred at speeds faster and slower than this range, these speeds corresponded to the range where we had at least 20 observations in each 1-knot speed increment (1 knot = 0.5144 m/s). The mean distances above and below the change point were specified with a lognormal distribution with large variance [$\beta_1 \sim \log\mathcal{N}(0,1000)$, $\beta_2 \sim \log\mathcal{N}(0,1000)$] and the standard deviation of the lognor-

[8] ⟨http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html⟩

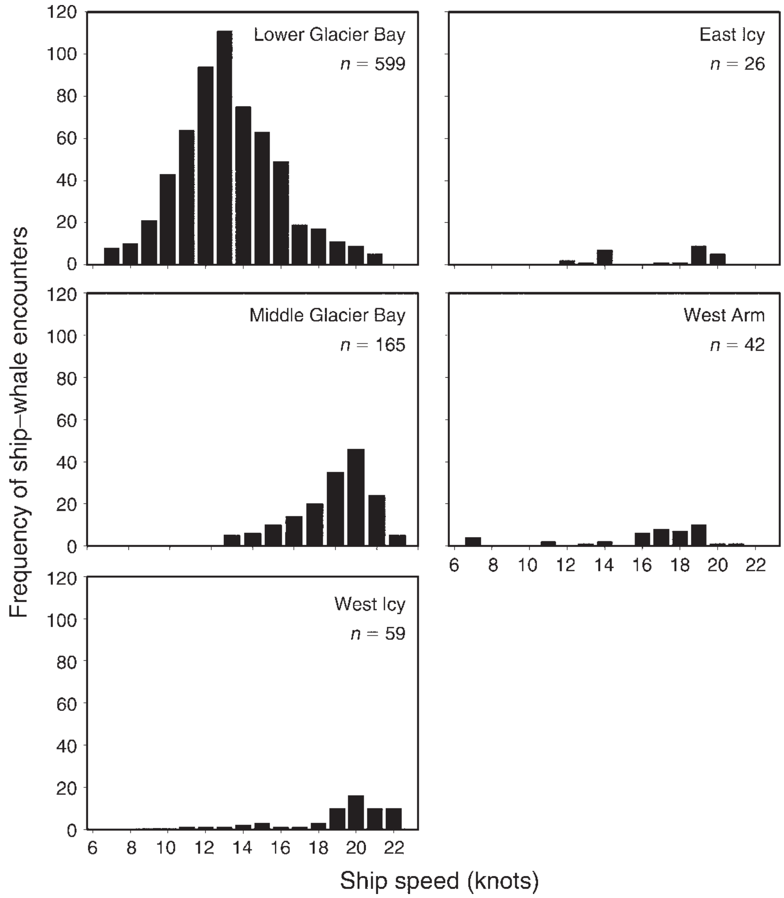

FIG. 2. Frequency of encounters between cruise ships and humpback whales, 2006–2009, by subarea and binned by 1-knot (0.5144 m/s) ship-speed increments ($n = 891$ unique ship–whale encounters).

mal observations was specified with a diffuse uniform distribution [$\sigma \sim$ Unif(0, 20)]. The coefficients were estimated through use of the Gibbs sampler, a Markov chain Monte Carlo (MCMC) algorithm implemented in WinBUGS (Spiegelhalter et al. 2003). Multiple chains were run using dispersed initial values for each model to ensure the MCMC chain converged to a stationary target distribution. Monitored parameters in all models had scale reduction factor (SRF) values that indicated samples were being drawn from the target distribution (i.e., SRF $\sim$ 1). The initial 30% of the samples were used to reach the stationary target distribution and were discarded with the subsequent samples thinned to produce approximately 1000 draws from the stationary target distributions. The 1000 draws were used to compute the posterior mean and 95% central probability intervals (credible intervals; 95% CrI). The diagnostics were implemented using the R2WinBUGS package in R (R Development Core Team 2007).

RESULTS

From 2006 through 2009 observers logged more than 2760 hours recording ship–whale encounters during 380 unique ship entries into Glacier Bay, Alaska, USA. Observations occurred aboard 18 different cruise ships and constituted ~49% of all ship entries into the park during that period. A total of 891 unique ship–whale encounters were recorded at distances ranging from 21 m to 1000 m ($\bar{x} = 567$ m, median = 576 m). Most (811) of the encounters (91%) occurred between 300 m and 1000 m although there were 61 encounters (7%) at 200–100 m, and 19 encounters (2%) within 100 m. No collisions were detected. Nearly all (754) of the encounters were with a single whale (85%) or with a group of two whales ($n = 96$ encounters; 11%); the remaining 4% of encounters occurred with group sizes of $\geq$3 whales. Encounter distances did not differ when comparing group sizes of 1 vs. >1 (group size 1 whale, $\bar{x} = 565 \pm 10$ m; group size $\geq$ 2 whales, $\bar{x} = 572 \pm 29$ m; $t = 1.96$, $P = 0.81$) and thus all analyses were considered independent of group size.

The average and range of ship speed (over ground) during encounters, as well as the frequency of encounters varied dramatically among subareas (Fig. 2). For example, in Middle Glacier Bay there was a large number of encounters recorded (165 encounters) but mostly (>76%) between 17 and 20 knots (8.7 and 10.3 m/s). In contrast, there was high variation in the speed when whales were encountered in the West Arm subarea

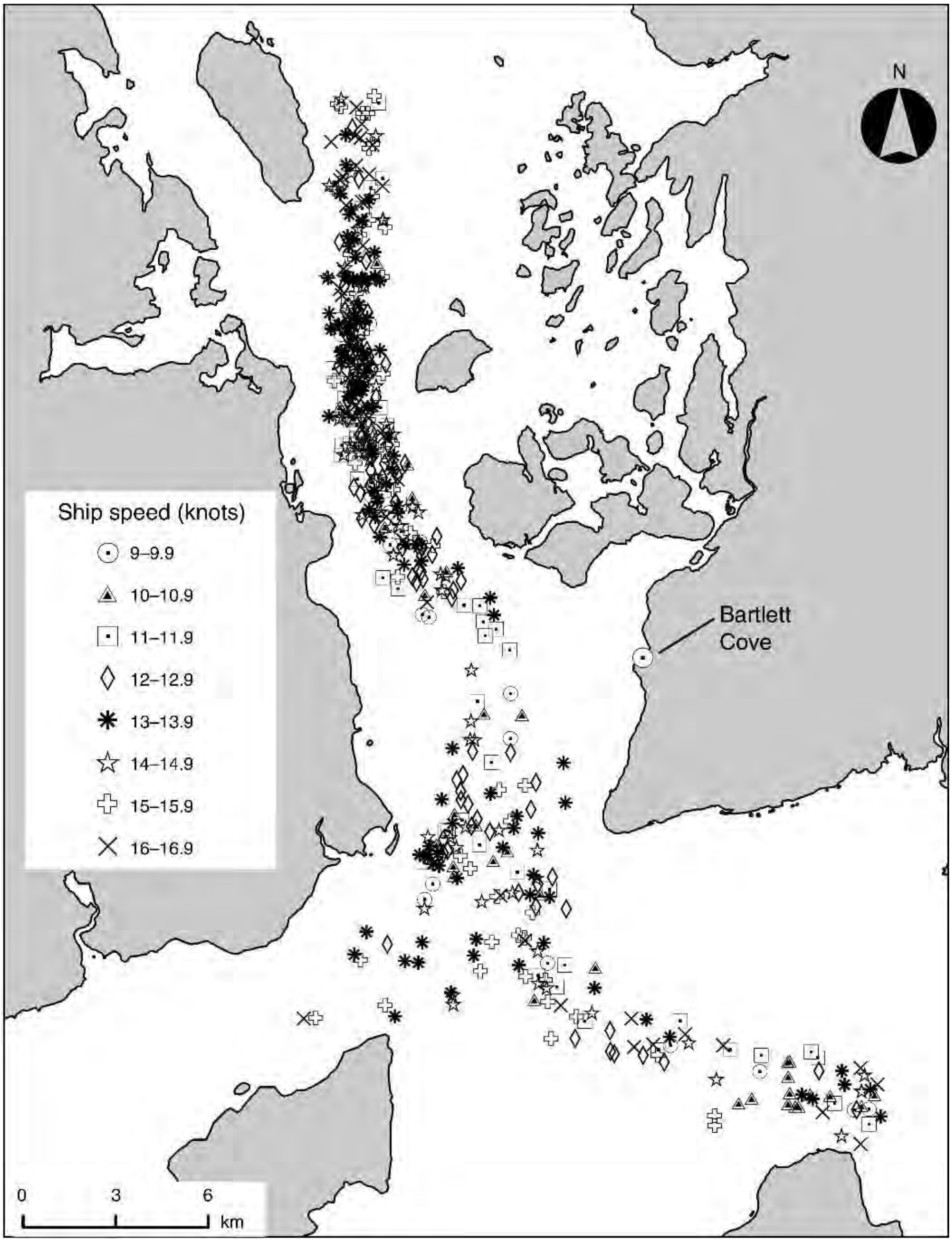

FIG. 3. Locations of humpback whales ($n = 599$) during encounters with cruise ships at different ship speeds in the Lower Glacier Bay subarea, 2006–2009. For ship speeds, note that 1 knot = 0.5144 m/s.

but very low sample size (<10 encounters) for any given speed. In contrast there were at least 20 encounters at speeds from 9 to 17 knots (4.6 and 8.7 m/s) in the Lower Glacier Bay subarea. This was due to ships slowing during transfer of NPS interpretive rangers from Bartlett Cove, speed regulations (with variable compliance), and a consistent presence of whales.

Thus, to reduce the possibility of spatial autocorrelation between speed and probability of encounter, we used only the data from the Lower Glacier Bay subarea in our Bayesian change-point model. Doing so reduced our sample size only marginally because this subarea accounted for almost 70% of all encounters recorded during the study. Within the Lower Glacier Bay subarea, there was no evidence that whale encounters were spatially aggregated at higher ship speeds (Fig. 3).

The Bayesian change-point model identified a high probability of a change in the relationship between ship speed and encounter distance around 11.8 knots (6.1 m/s) (Fig. 4A). The maximum probability of a change

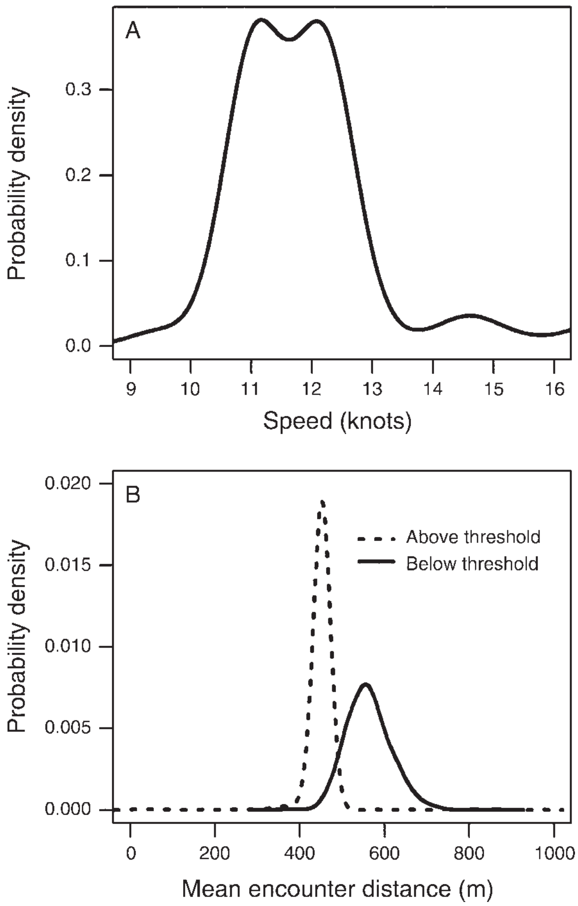

FIG. 4. Posterior probability distribution of (A) the speed threshold coefficient in the Bayesian change-point model (1 knot = 0.5144 m/s) and (B) the mean encounter distances to whales above (solid line) and below (dashed line) the speed threshold.

point occurred at 11.8 knots although there was only a slightly lower probability the change point occurred at 12.2 knots (6.3 m/s) (Fig. 4A). The probability that the change point occurred over the interval between 10 to 13 knots (5.1–6.9 m/s) was 0.88, i.e., P(10 knots $< X_{CP} <$ 13 knots) = 0.88). As a result, the highest probability for β_1 and β_2, the average encounter distances above and below the 11.8 knot change point were 448 m (95% credible interval, 398, 485) and 562 m (95%CrI, 468, 676; Fig. 4B). Binning the speeds by 1-knot (0.5144 m/s) increments clearly demonstrates that, on average, when ships were traveling faster, whales were encountered more closely (Fig. 5).

DISCUSSION

Reducing the probability of severe injury or death as a result of a collision—a primary management objective in regulating ship speed—can occur by reducing the probability of any of the series of constituent events during a collision including the probability of (1) an encounter given a ship's presence in an area, (2) a close (severe) encounter given an encounter, (3) a collision given a severe encounter, and (4) severe injury or death given a collision. Recently Silber et al. (2010), using scale models of ships and whales in experimental flow tanks, demonstrated that under certain conditions reduced ship speed may reduce the probability of a collision given a severe encounter, and Vanderlaan and Taggart (2007) demonstrated that in the event of a collision, reduced ship speed may reduce the probability of severe injury or death. Our study is the first to demonstrate that the average distance between ships and whales decreases with increasing ship speed, confirming that speed reduction is an effective means for reducing the probability of severe encounters. If we assume that the closer that whales encounter ships the more likely they are to be struck, then, by extension, reducing ship speed may be an effective management action in reducing the probability of a collision.

It is beyond the scope of our study to identify the mechanism underlying the speed–distance relationship, although we feel the results are not likely a function of ship avoidance behavior of the whales. Cruise ships in our study area have no designated marine mammal observer on the bridge, which can influence the probability of detecting whales (Weinrich et al. 2010) needed prior to initiating avoidance measures. In addition, we regularly communicated with the ship captains/pilots and many have stated that when a whale is detected they generally retain course and speed, noting that the confined space within Glacier Bay hinders large course alterations. What is more, despite nearly 900 encounters with whales over four years we know of only two instances when ships altered course or speed in order to avoid whales (in both cases it was a group of >2 whales), and one instance when the ship captain knew of an approaching whale but took no evasive measures. In this instance, the observer radioed the ship bridge to inform them that a whale, which appeared to

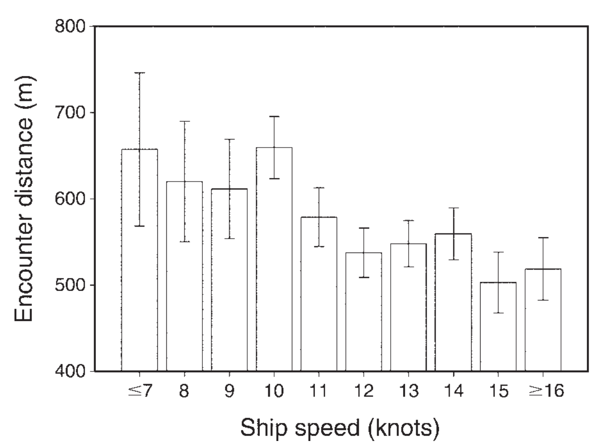

FIG. 5. Average encounter distances (mean ± SE) between cruise ships and humpback whales, binned for 1-knot speed increments in the Lower Glacier Bay subarea, 2006–2009. 1 knot = 0.5144 m/s.

PLATE 1. A humpback whale encounters a cruise ship in Glacier Bay National Park and Preserve. Photo credit: Janet Neilson, National Parks Service.

be resting at the surface, was directly in the path of the ship ~4 km away. Over the next nine minutes the observer repeatedly radioed the bridge as the ship–whale encounter distance decreased, and despite acknowledging the location of the whale, the ship captain/pilot maintained course and speed. As the ship approached to less than 70 m, the whale initiated a deep dive and a collision was narrowly avoided.

If in fact the speed–distance relationship is a function of whale avoidance behavior of the ships (as opposed to ship avoidance behavior of the whales), one scenario by which faster ships result in closer encounters could occur if whales are initiating avoidance behavior once an acoustical threshold is exceeded, and acoustic signals from ships are somewhat independent of speed. There is currently no information available regarding detection and response by large whales (cetaceans) to variation in received acoustic signals under different ship speeds (NRC 2005). Nevertheless, recent acoustic measurements of four cruise ships with diesel-electric propulsion systems recorded at the U.S. Navy's Southeast Alaska Acoustic Measurement Facility, including several ships used in our study, demonstrated that the overall sound levels emanating from these ships was similar at speeds differing by up to 8 knots (4.1 m/s) (Kipple 2002). If the acoustic signals are somewhat independent of speed, the distance between ship and whale at any acoustic threshold will thus be the same. Yet the whale will have less time to process the signal and initiate avoidance measures for the faster ships. Using the data from Kipple (2002) as an example, if a whale initiated avoidance measures at 130dB (an arbitrarily defined threshold) it would have only 8 s before collision for a ship traveling 20 knots (10.3 m/s) vs. 16 s for ships traveling 10 knots (5.1 m/s).

Regardless of mechanism, our results add to the sparse yet growing evidence that reducing ship speed may serve as an effective measure in meeting whale conservation objectives. Ultimately however, application of our results will need confirmation in other areas with different oceanographic conditions, vessel types, and whale species. Nevertheless, we highlight the effectiveness of using shipboard observers for understanding the relationship between whales and ships, and testing the effectiveness of applied management actions.

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ATTACHMENT 8

esa ECOSPHERE

Quantifying risk of whale–vessel collisions across space, time, and management policies

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Abstract. Transportation industries can negatively impact wildlife populations, including through increased risk of mortality. To mitigate this risk successfully, managers and conservationists must estimate risk across space, time, and alternative management policies. Evaluating this risk at fine spatial and temporal scales can be challenging, especially in systems where wildlife–vehicle collisions are rare or imperfectly detected. The sizes and behaviors of wildlife and vehicles influence collision risk, as well as how much they co-occur in space and time. We applied a modeling framework based on encounter theory to quantify the risk of lethal collisions between endangered North Atlantic right whales and vessels. Using Automatic Identification System vessel traffic data and spatially explicit estimates of right whale abundance that account for imperfect detection, we modeled risk at fine spatiotemporal scales before and after implementation of a vessel speed rule in the southeastern United States. The expected seasonal mortality rates of right whales decreased by 22% on average after the speed rule was implemented, indicating that the rule is effective at reducing lethal collisions. The rule's effect on risk was greatest where right whales were abundant and vessel traffic was heavy, and its effect varied considerably across time and space. Our framework is spatiotemporally flexible, process-oriented, computationally efficient and accounts for uncertainty, making it an ideal approach for evaluating many wildlife management policies, including those regarding collisions between wildlife and vehicles and cases in which wildlife may encounter other dangerous features such as wind farms, seismic surveys, or fishing gear.

Key words: encounter theory; *Eubalaena glacialis;* North Atlantic right whale; spatial modeling; speed restrictions; speed zones; whale–vessel collision; wildlife–vehicle collision.

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Introduction

The transportation industry creates many problems for wildlife, including altered movement patterns and home ranges, decreased reproductive success and gene flow, and increased mortality through wildlife–vehicle collisions (Trombulak and Frissel 2000). Traffic from human transportation has the most negative population-level impacts on wildlife species that move long distances, have low reproductive rates, and do not avoid transportation networks or vehicles (Fahrig and Rytwinski 2009). These problems have been studied extensively across many taxa in terrestrial systems (e.g., road ecology; Forman and Alexander 1998, Trombulak and Frissel 2000). In marine systems, they have received less attention, mostly related to collisions between vessels and cetaceans (Laist et al. 2001, Van Waerbeek et al. 2007), sirenians (Calleson and Frohlich 2007, Hodgson and Marsh 2007), and sea turtles (Hazel et al. 2007).

Estimating the risk of wildlife–vehicle collisions across space and time is necessary to develop effective conservation policies.

Studies that examined the risk of whale–vessel collisions have taken many approaches to quantify the problem. These include estimating the co-occurrence of whales and vessels (Fonnesbeck et al. 2008, Vanderlaan et al. 2008, 2009, Nichol et al. 2017), simulating whale and vessel movements and collisions (van der Hoop et al. 2012*b*), comparing the number of detected whale mortalities due to vessel collisions at a regional scale before and after management activities (Laist et al. 2014, van der Hoop et al. 2015), and analyzing the relationship between vessel speed and the probability of lethal injury to whales from reported collisions (Vanderlaan and Taggart 2007, Conn and Silber 2013). Each of these approaches has limitations that prevent researchers from fully accounting for processes that affect the risk of whale–vessel collisions. For instance, metrics of whale–vessel co-occurrence do not account for the influence of vessel size and speed and whale behavior on the risk of a collision occurring. Simulating the movements of individual vessels and whales is computationally expensive, making it cumbersome to run enough simulations to account for uncertainty in model parameters and processes. Estimates of risk based on the number of detected whale mortalities that are determined to be due to a vessel collision may be confounded by temporal or spatial variation in the probability of detecting a whale carcass or the probability of assigning its cause of death to a collision. Finally, evaluating the risk of collisions at a regional scale over time ignores any changes in whale abundance and vessel traffic at fine spatial scales, which could dramatically alter risk.

We extend a modeling framework based on encounter rate theory for estimating the risk of vessel collisions that addresses the aforementioned limitations (Martin et al. 2016). The framework is process-based, decomposing collision risk into its underlying elements, and estimates the encounter rate between whales and vessels (i.e., the rate at which their paths intersect in two-dimensional space and time, where space can be restricted to two dimensions because vessels only travel along the water's surface). This encounter rate is determined by the area that vessels and whales share; the abundance, speed, and size of vessels and whales in the area; and the distance traveled by vessels (Martin et al. 2016). We extend this framework to estimate whether an encounter results in a collision and whether a collision results in a death by accounting for the probability that a whale is at the water's surface during an encounter, the probability that a vessel and a whale avoid each other during an encounter, and the probability that a whale dies when a collision occurs. We demonstrate the utility of this framework by quantifying the risk of lethal collisions between endangered North Atlantic right whales (*Eubalaena glacialis*, referred to henceforth as right whales) and vessels in the southeastern United States before and after the implementation of a vessel speed restriction rule. Our analyses are based on an extensive data set of Automatic Identification System (AIS) vessel traffic data and spatially explicit estimates of right whale abundance, which account for imperfect detection of right whales.

Collisions with vessels are a leading cause of mortality for right whales (Moore et al. 2004, van der Hoop et al. 2012*a*, Henry et al. 2017). Right whales die from collisions with vessels more often, per capita, than any other large whale species (Vanderlaan and Taggart 2007). Moreover, right whales are among the most endangered species of large whales (Kraus et al. 2005), with a recent estimated population size of 458 and a declining population trajectory (Pace et al. 2017).

The distribution and life history of right whales expose them to anthropogenic threats (Moore et al. 2004, Campbell-Malone et al. 2008, Knowlton et al. 2012). Right whales are migratory, with individuals summering in feeding grounds in coastal waters off the northeastern United States and eastern Canada, and some individuals, including calving females, wintering in the coastal waters of the southeastern United States, their only known calving grounds (Firestone et al. 2008, Brillant et al. 2015). Throughout these regions, right whales co-occur with busy shipping and fishing industries. These industries expose right whales to vessel collisions and entanglement in fishing gear, the causes of most recorded right whale deaths (Moore et al. 2004, Campbell-Malone et al. 2008, Knowlton et al. 2012).

The National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service has taken steps to address the threat of vessel collisions to right whales. In the southeastern United States, NOAA implemented voluntary speed restrictions of 12 and 10 kt (22.2 and 18.5 km/h) in 2004 and 2005, respectively, and established recommended shipping lanes in 2006 to reroute vessel traffic and minimize co-occurrence with right whales (Fonnesbeck et al. 2008, Lagueux et al. 2011). Compliance with the voluntary speed restrictions was low, 9–24% during years the voluntary restriction was implemented, and NOAA implemented a mandatory vessel speed restriction rule of 10 kt (18.5 km/h) starting in December 2008 (NOAA 2008; Lagueux et al. 2011). The speed restriction rule established seasonal management areas (SMAs) along the U.S. Eastern Seaboard. Under the rule, at times of the year when SMAs are active, vessels ≥65 ft (19.8 m) long, excluding military and other government vessels, are required to travel at ≤10 kt (18.5 km/h). These slower vessel speeds are thought to increase the ability of whales and vessel operators to avoid each other and to reduce the severity of injury and the likelihood of death when a collision does occur (Calleson and Frohlich 2007, Vanderlaan and Taggart 2007, Conn and Silber 2013, Calleson 2014, Rycyk et al. 2018).

Using our modeling framework, we estimate the expected number of deaths and mortality rates of right whales due to vessel collisions in the southeastern U.S. (SEUS) SMA during the winters from 2006–2007 through 2010–2011 while accounting for uncertainty in the framework's parameters. Additionally, we evaluated the effectiveness of the SEUS SMA in reducing the risk of lethal vessel collisions by comparing the expected number of right whale deaths and mortality rates in and adjacent to the SEUS SMA under two hypothetical scenarios, in which vessels traveled at speeds typical of the winters either before or after the implementation of the speed restriction rule in December 2008.

Methods

Study area

We examined the risk to right whales from vessel traffic within and just east of NOAA's SEUS SMA (Fig 1). The SEUS SMA covers ~9100 km^2, extending from 29.75° N to 31.45° N and from the Atlantic coastlines of Florida and Georgia to 80.86° W (NOAA 2008). The SEUS SMA is active between 15 November and 15 April each year. Our study area extended 12 nm east of the SEUS SMA to 80.60°W, covering an additional ~4700 km^2 (Fig. 1). The SEUS SMA is adjacent to three shipping ports: Brunswick, Georgia; Fernandina Beach, Florida; and Jacksonville, Florida.

Model framework

We evaluated the risk posed to right whales by vessels subject to the NOAA speed restriction rule. We overlaid our study area with a grid of 30.87 km^2 (5.556 × 5.556 km) grid cells and evaluated risk across this grid for each semimonth (days 1–15 and 16–end) of the winter months (December–March) from 2006–2007 to 2010–2011. We did not evaluate risk during the last semimonth of November, the first semimonth of April, or any winter since 2010–2011, though the speed restriction rule was in effect, because estimates of right whale abundance in the study area during those times were not available. We evaluated risk using the framework described by Martin et al. (2016), which estimates the encounter rate, $\lambda_{i,t}$, at grid cell i, during semimonth t, between whales and vessels in two-dimensional space as:

$$\lambda_{i,t} = \frac{2r_{c,i,t}d_{i,t}\mathrm{N}_{i,t}}{Sv_{b,i,t}} \int_{v_m} I(v_m, v_{b,i,t}) f_v(v_m) dv_m \quad (1)$$

here, the encounter rate is directly proportional to the critical distance of encounter, r_c, which is based on the size of right whales and vessels; the distance transited by vessels, d; and the abundance of right whales, N, in a grid cell during a semimonth. The encounter rate is inversely proportional to the surface area, S, of the study region (grid cell in this case) and to vessel speed, v_b. The encounter rate is also influenced by the relative velocity of a right whale with respect to a vessel, $I(v_m, v_b)$, and the distribution of right whale speed, $f_v(v_m)$. See Martin et al. (2016) for a thorough explanation of this framework. We then estimated the expected number of collisions and deaths in each grid cell by incorporating the probability that a right whale is at the water's

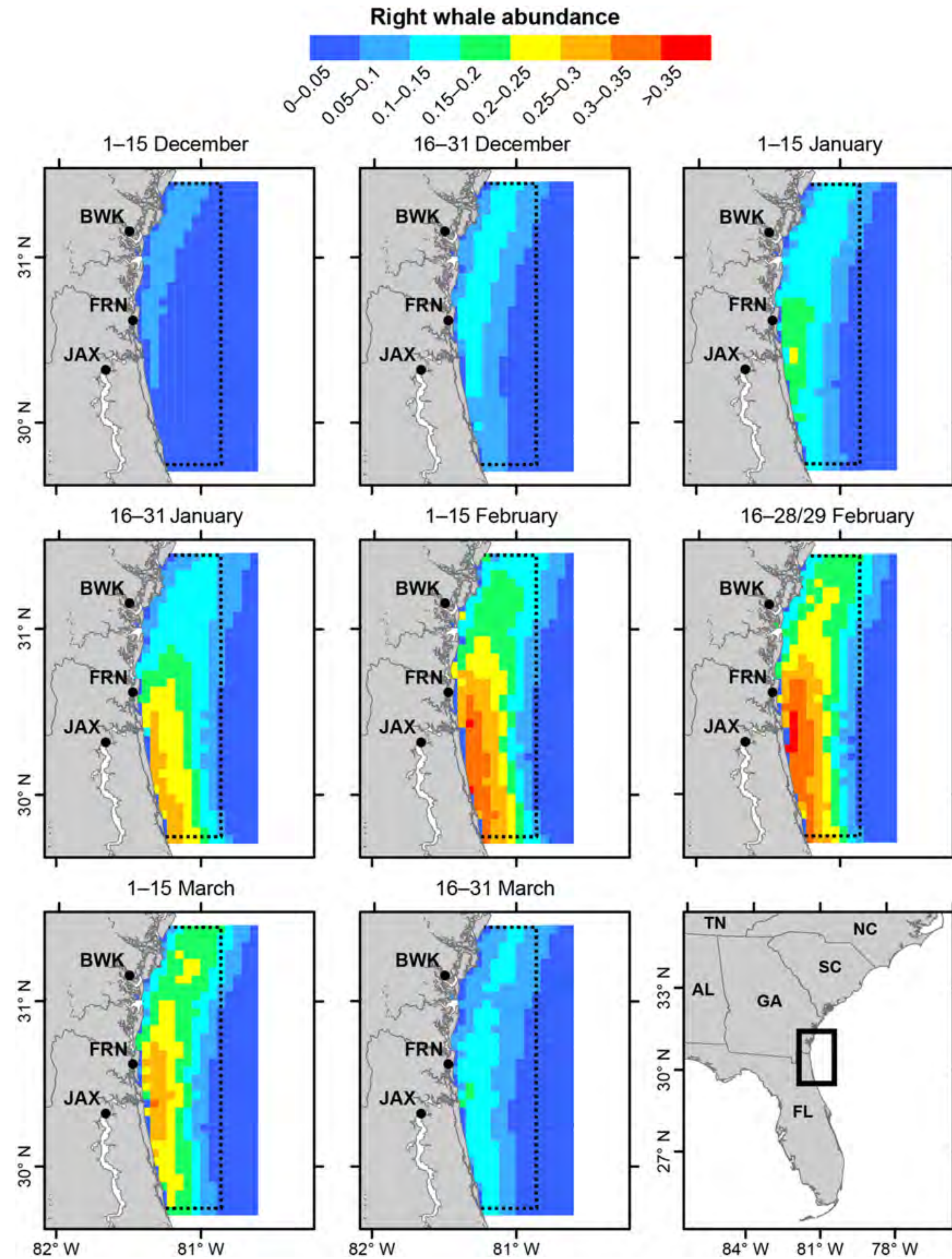

Fig. 1. Mean abundance of North Atlantic right whales in the southeastern United States during the winters from December 2006 through March 2011. The southeastern U.S. right whale seasonal management area is outlined by a black dashed line. The ports Brunswick, Georgia (BWK), Fernandina Beach, Florida (FRN), and Jacksonville, Florida (JAX), are indicated by black circles.

surface during an encounter, $p_{surfacing}$, and the probability of death given vessel speed during a collision, $p_{death|vb}$. These parameters were informed by available data and relevant literature, described below.

Whale abundance

We used results from Gowan and Ortega-Ortiz (2014) and Krzystan et al. (2018) to estimate right whale abundance, N, across our study area during each semimonth, the temporal scale we adopted. Both studies analyzed right whale sightings from aerial surveys and were conducted across a similar spatial extent in the southeastern United States and at a semimonthly temporal scale. Gowan and Ortega-Ortiz (2014) estimated spatial patterns of relative abundance (i.e., the expected number of sightings per grid cell) of right whales in relation to environmental covariates using a hurdle model (Dorazio et al. 2013), which derives relative abundance from estimates of occurrence probability, o, and expected count, c. They estimated relative abundance at a resolution of 30.87 km^2, which we adopted as the spatial resolution of our risk analyses. Krzystan et al. (2018) estimated the detection probabilities of five demographic groups (male, calving female, non-calving female, juvenile, and unknown) of right whales in the southeastern United States from December of 2004 to March of 2011 using mark–recapture data. We estimated regional abundance of right whales across the southeastern United States in each semimonth by summing the number of right whales observed in each demographic group during each semimonth corrected for their respective detection probability from Krzystan et al. (2018). Then, we derived our estimates of abundance by scaling the spatially explicit estimates of relative abundance from Gowan and Ortega-Ortiz (2014) so that they summed to the regional abundance estimates for each semimonth (Fig. 1).

Vessel traffic

We collected data regarding transit distance, d, and speed, v_b, of vessels ≥65 ft long using the AIS, which tracks vessels' movements through VHF radio transmissions, starting in 2006. The International Maritime Organization requires that ships of ≥300 gross tons traveling internationally, cargo ships of ≥500 gross tons, and all passenger ships carry AIS transceivers. We used data collected by AIS receivers stationed in Brunswick, Georgia (operated by the Florida Fish and Wildlife Conservation Commission), and Jacksonville, Florida (operated by Jacksonville Marine Transportation Exchange). Dynamic data, including a vessel's location and timestamp, were recorded from AIS transmissions at 1-min intervals. Static ship data, which vessel operators report and which include a vessel's identity, ship type, length, and width, were recorded every 6 min. We reconstructed a vessel's path by connecting consecutive locations, and we calculated its speed from the time and distance between consecutive locations. If consecutive transmissions from a vessel were over one hour apart, a new path was started for that vessel. Transmissions were omitted if consecutive transmissions indicated that a vessel traveled at greater than 35 kt (65 km/h) or traveled over 65 km. Military and other government vessels and vessels <65 ft long were excluded because they were not subject to the speed restriction rule. Because we were not interested in the risk posed by individual vessels, we aggregated vessel transit distance within each grid cell and semimonth by ship type. This allowed us to assess the risk due to different ship types over time and space.

Right whale and vessel sizes

We calculated the critical distance of encounter, r_c, using the disk method (r_c = radius$_{whale}$ + radius$_{vessel}$), which represents whales and vessels as circles with radii of $\sqrt{(\text{length*width})/\pi}$ (Martin et al. 2016). We assumed that right whales had a length of 14 m and a width of 3.5 m (Fortune et al. 2012, Miller et al. 2012). Because we were only interested in risk posed by different ship types, we averaged vessel length and width for each ship type, in each grid cell, during each semimonth, weighted by each vessel's distance traveled. Vessels with unreported length or width data, which constituted 1.6% of vessels included, were assigned average values of length and width from other vessels of the same ship type during the same winter for the purpose of these calculations.

Right whale and vessel speeds

We assumed that the swimming speed of right whales, v_m, was 0.39 m/s, the average swimming speed of right whales observed in the southeastern United States (Hain et al. 2013). We evaluated three hypothetical scenarios related to vessel speed, v_b. In each scenario, vessel speed varied by grid cell and ship type. The speed of vessels of a given ship type in a grid cell was the average speed of vessels, weighted by distance traveled, of the same ship type in the same grid cell. Scenarios differed by the period of time from which average vessel speeds were calculated. Scenario 1 was used to estimate the true risk of lethal vessel collisions. Therefore, we averaged vessel speeds for each semimonth, meaning that our model accounted for variation in vessel speed across time, space, and ship types. Scenarios 2 and 3 estimated what risk would have been if the entire study area was not or was subject to the speed restriction rule for all five winters of our study, respectively. We evaluated the effectiveness of the speed restriction rule within the current SEUS SMA and of extending the eastern boundary of the SEUS SMA 12 nm east based on the differences between scenarios 2 and 3. In scenario 2, we used vessel speed averaged from the two winters before the speed restriction rule was implemented (December 2006–March 2008). In scenario 3, we used vessel speed averaged from the three winters after the speed restriction rule was implemented (December 2008–March 2011). Additionally, in scenario 3, vessel speeds east of the SEUS SMA were assigned the average vessel speed from the three eastern-most columns of grid cells within the SEUS SMA. Therefore, vessel speed was constant across time for each ship type and grid cell combination in scenarios 2 and 3, reflecting the average vessel speed before and after the speed restriction rule was implemented, respectively. By estimating risk using AIS data, we accounted for vessel operator compliance with the speed restriction rule without having to make assumptions regarding compliance rate.

Simulation analysis

We accounted for uncertainty in our estimates of whale abundance and in the collision process using Monte Carlo simulation. We used 10,000 Monte Carlo simulations to estimate the expected number of encounters, collisions, and deaths in each grid cell during each semimonth for each ship type. First, we simulated abundance, N, of right whales across the study area to account for the uncertainty in Gowan and Ortega-Ortiz's (2014) estimates of relative abundance. We simulated abundance from normal distributions based on the mean and standard error of the estimated probability of occurrence, o, and expected count, c, on the link scale (logit and natural log, respectively) for each grid cell, i, during each semimonth, t. Simulated values, o and c, were back-transformed and multiplied together to obtain estimates of relative abundance. We rescaled the simulated relative abundance estimates to sum to estimates of regional right whale abundance for each semimonth in the southeastern United States based on Krzystan et al. (2018); cells within our study area were retained for subsequent analysis.

$$o_{i,t} \sim \text{Normal}\left(\mu_{\text{occurence},i,t}, \sigma_{\text{occurence},i,t}\right)$$

$$c_{i,t} \sim \text{Normal}\left(\mu_{\text{count},i,t}, \sigma_{\text{count},i,t}\right)$$

$$\text{N}_{\text{relative abundance},i,t} = \frac{1}{1+e^{-o_{i,t}}} * e^{c_{i,t}}$$

$$\text{N}_{\text{abundance},i,t} = \frac{\text{N}_{\text{relative abundance},i,t} * \text{N}_{\text{regional abundance},t}}{\sum_{i=1}^{I} \text{N}_{\text{relative abundance},i,t}} \quad (2)$$

Using Eq. 1, we calculated encounter rates between right whales and vessels under each of the three speed scenarios during each semimonth for each of the simulated grids. We then simulated the expected number of encounters in each grid cell during each semimonth using a Poisson distribution with a mean equal to the encounter rate.

$$\text{N}_{\text{encounters},i,t} \sim \text{Poisson}\left(\lambda_{i,t}\right) \quad (3)$$

Next, we simulated the expected number of collisions based on the simulated number of encounters. We assumed that if a right whale was at the surface during an encounter, it would be struck by the vessel. We used a beta distribution based on data obtained by Hain et al. (1999) to simulate the probability that a right whale is at the surface during an encounter. Then, we simulated the number of collisions under each speed scenario for each grid cell during each semimonth using a binomial distribution with the number of draws equal to the number of encounters and with the probability that a collision occurs equal to the simulated probability that a right whale is at the surface.

$$p_{\text{surfacing}} \sim \text{Beta}(\alpha = 2.38, \beta = 1.58)$$

$$N_{\text{collisions},i,t} \sim \text{Binomial}\left(N_{\text{encounters},i,t}, p_{\text{surfacing}}\right) \quad (4)$$

This approach could be extended by incorporating the probability that a right whale and vessel avoid each other and the probability that a right whale collides with a vessel's draft below the water's surface during an encounter. Due to a lack of data to inform these parameters, we omitted these extensions from our approach (but see Appendix S2). Therefore, our model's expectations should be considered a relative metric of collision risk.

Finally, we simulated the expected number of right whale deaths based on the simulated number of collisions. Conn and Silber (2013) and Vanderlaan and Taggart (2007) used a logistic regression to estimate the relationship between vessel speed and the probability of death given a collision for large whales. We simulated the slope and intercept of this relationship on the logit scale from normal distributions using estimates from Conn and Silber (2013). Simulated values were back-transformed to obtain probabilities of death given vessel speed. We then simulated the number of deaths under each speed scenario for each grid cell during each semimonth using a binomial distribution with the number of draws equal to the simulated number of collisions and the probability of a death equal to the simulated probability of death given vessel speed.

$$a \sim \text{Normal}(\mu = 0.217, \sigma = 0.058);$$
$$b \sim \text{Normal}(\mu = -1.905, \sigma = 0.821)$$

$$p_{\text{death}|v_b} = \frac{1}{1 + e^{-(a(v_b)+b)}}$$

$$N_{\text{deaths},i,t} \sim \text{Binomial}\left(N_{\text{collisions},i,t}, p_{\text{death}|v_b}\right) \quad (5)$$

Because whale abundance differed between years, we calculated per capita mortality rates (number of deaths divided by abundance; hereafter referred to as mortality rates) to assess the speed restriction rule's effectiveness.

We summarized the mean mortality rate and the number of encounters, collisions, and deaths and their 95% confidence intervals across all simulations over the entire study area, for each semimonth and year of our study period. Additionally, we summarized the mortality rate and the number of encounters, collisions, and deaths across all simulations within each grid cell for each semimonth and year of our study period.

Results

Mean abundance of right whales within the SEUS SMA peaked during the last semimonth of February in each winter except 2009–2010, when abundance peaked in the first semimonth of March. Peak semimonthly abundance ranged from 39.8 right whales (2006–2007) to 94.8 right whales (2008–2009). Abundance was lowest in the first semimonth of December of each year except 2010–2011, when abundance was lowest in the last semimonth of March. Minimum semimonthly abundance ranged from 1.7 right whales (2010–2011) to 16.9 right whales (2008–2009). The majority of right whale abundance (94–96.5%) during the study occurred in grid cells within or overlapping the SEUS SMA (Fig. 1).

Most of the vessel traffic (77–91% of transit distance each winter) recorded by AIS receivers within our study area was of vessels subject to the speed restriction rule. The total distance that these vessels transited within a grid cell during a semimonth varied across the study area, ranging from 0 to 3024.2 km. Vessel transit distance was greatest in grid cells adjacent to Jacksonville and was relatively high in cells adjacent to Brunswick and in Jacksonville's shipping lanes (Appendix S1: Fig. S1). Transit distance was greater in grid cells within and overlapping the SEUS SMA (yearly mean = 127,016.8 km, standard deviation [SD] = 7,981.5 km) than in grid cells east of the SEUS SMA (yearly mean = 14,337.1 km, SD = 3391.2 km). We recorded no traffic of vessels subject to the speed restriction rule in an average of 39% of grid cells during each semimonth. In the two winters before the speed restriction rule was implemented, 27.7% (2006–2007) and 39.3% (2007–2008) of the distance transited by vessels that would be subject to the rule were under 10 kt (18.5 km/h), respectively. In the three winters following implementation of the speed restriction rule, 59.5% (2008–2009), 66.8% (2009–2010), and 71.3% (2010–2011) of the distance transited by vessels subject to the rule was under 10 kt (18.5 km/h). In grid cells within and overlapping the SEUS

SMA, vessels traveled at an average of 11.89 kt (22.02 km/h; SD = 3.55 kt [6.57 km/h]) before and 9.27 kt (17.17 km/h; SD = 2.07 kt [3.83 km/h]) after implementation of the rule. In grid cells east of the SEUS SMA, vessels traveled at an average of 15.20 kt (28.15 km/h; SD = 2.92 kt [5.41 km/h]) before and 15.01 kt (27.80 km/h; SD = 3.03 kt [5.61 km/h]) after implementation of the rule (Appendix S1: Fig. S2).

In scenario 1, in which we approximated the actual risk of lethal vessel collisions, we estimated the greatest number of right whale deaths from vessel collisions occurred in the winter of 2008–2009 and the highest right whale mortality rate in the winter of 2006–2007. The smallest number of right whale deaths occurred in the winter of 2010–2011 and the lowest mortality rate in the winter of 2008–2009 (Table 1). Risk of lethal vessel collisions was highest in the shipping lanes east of Jacksonville, Florida, and to a lesser extent in the shipping lanes east of Brunswick, Georgia, where vessel traffic was heaviest (Fig. 2). Less than one encounter, collision, and death per winter occurred in our study area east of the SEUS SMA.

Cargo ships, which comprised 62% of the transit distance recorded by our AIS receivers, accounted for 69–78% of expected right whale deaths each year, while tanker ships (8% of total transit distance) accounted for 8–11%. Tugs (14% of total transit distance), dredges (8% of total transit distance), and passenger ships (5% of total transit distance) each accounted for 2–10% of expected right whale deaths each year. Expected mortality rates of right whales due to collisions with cargo and tanker ships were 14–32% lower in winters following implementation of the speed restriction rule. Expected mortality rates of right whales due to collisions with other common ship types were not consistently lower following implementation of the speed restriction rule (Appendix S1: Figs. S3–S7). Expected mortality rates of right whales due to collisions with all vessels decreased by an average of 22% in the winters following implementation of the speed restriction rule (Table 1).

An average of 2.05 fewer right whale deaths, a 17% decrease, caused by vessel collisions occurred each winter when vessels within the SEUS SMA traveled at speeds as if they were subject to the speed restriction rule, scenario 3, in comparison with scenario 2, in which vessels traveled at speeds as if they were not subject to the speed restriction rule. Differences in risk of lethal vessel collisions between scenarios 2 and 3 were greatest in the shipping lanes east of Jacksonville, Florida, and to a lesser extent the shipping lanes east of Brunswick, Georgia (Fig. 3). These scenarios were similar in risk of lethal vessel collisions east of the SEUS SMA, with 0.04 fewer right whale deaths occurring in this area each winter when vessels traveled at speeds as if they were subject to the speed restriction rule. Fewer deaths of right whales occurred in each semimonth, especially from late January through early March, when vessels traveled at speeds as if they were, rather than were not, subject to the speed restriction rule (Fig. 4).

Discussion

Our model framework allowed us to quantify the relative risk of lethal vessel collisions to right whales before and after implementation of NOAA's speed restriction rule. The rule was effective in reducing risk; according to our

Table 1. Expected number of encounters and collisions between vessels and right whales and deaths and mortality rates of right whales (95% confidence intervals in parentheses) due to vessel collisions in and adjacent to the southeastern U.S. seasonal management area under scenario 1, our closest approximation to reality.

Year	Encounters	Collisions	Deaths	Mortality rate
2006–2007	23.37 (14–34)	14.05 (7–23)	9.02 (2–18)	0.044 (0.010–0.089)
2007–2008	36.20 (25–50)	21.72 (13–32)	13.12 (3–25)	0.043 (0.010–0.081)
2008–2009	42.55 (30–58)	25.51 (16–37)	13.59 (3–28)	0.033 (0.007–0.067)
2009–2010	40.26 (28–55)	24.13 (15–36)	12.80 (2–26)	0.035 (0.005–0.071)
2010–2011	24.99 (16–37)	15.00 (8–24)	7.77 (1–18)	0.034 (0.004–0.079)

Notes: A speed restriction rule that required vessels ≥65 ft long to travel at <10 kt (18.5 km/h) was implemented during the winters of 2008–2009 through 2010–2011.

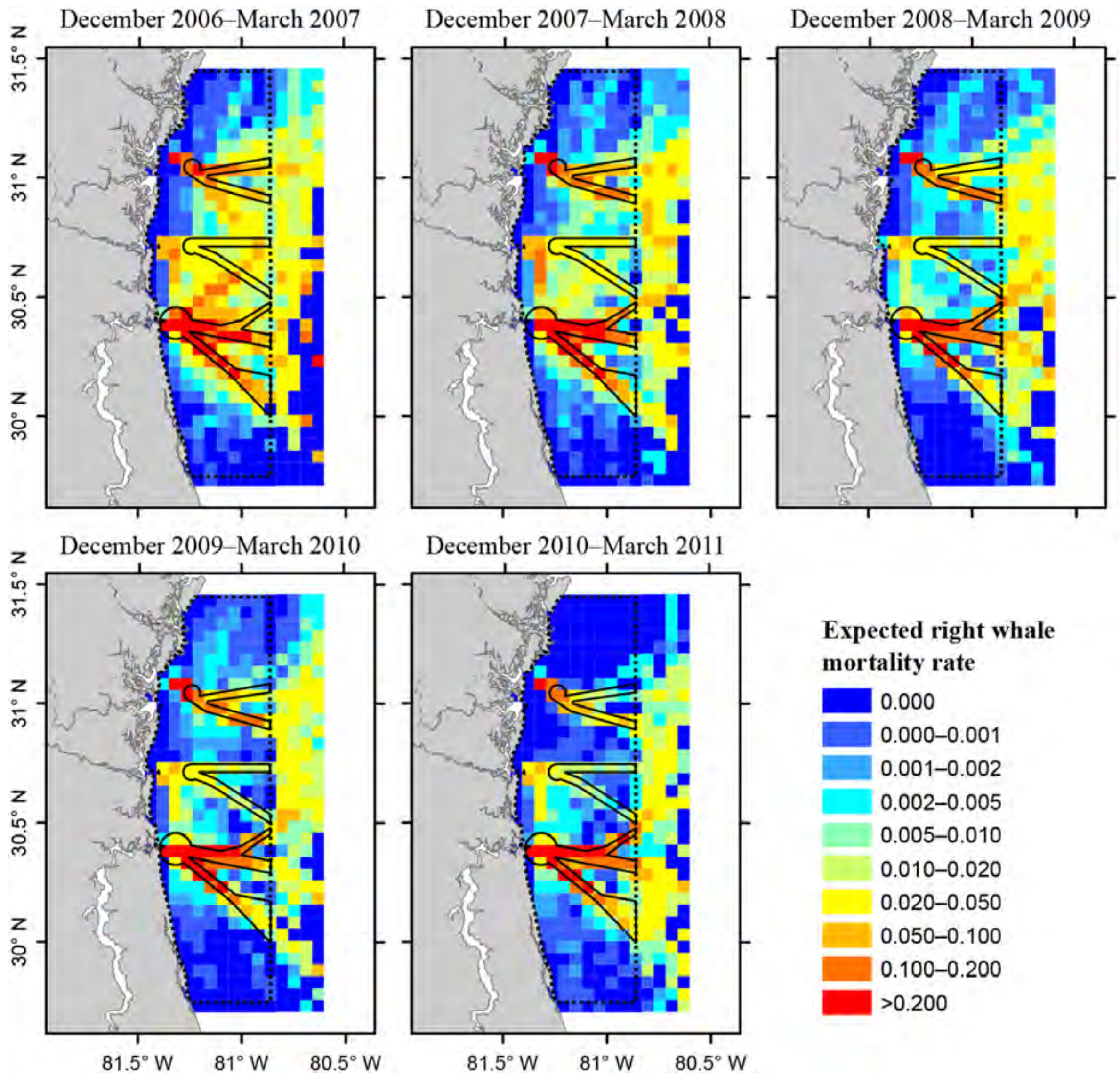

Fig. 2. Mean expected right whale mortality rates due to vessel collisions during each winter from 2006–2007 through 2010–2011 within the southeastern U.S. right whale seasonal management area (black dashed outline) according to scenario 1. Vessel speed restrictions were in effect in the seasonal management area during the 2008–2009 through 2010–2011 winters. Recommended shipping lanes are outlined in black.

model, right whale mortality rates declined 22% on average in the three winters following implementation, and 17% fewer right whale deaths occurred in scenario 3, where vessels traveled at speeds as if they were subject to the speed restriction rule, in comparison with scenario 2, where they were not subject to the rule. However, this reduction in relative risk varied across space and time.

The speed restriction rule was most effective at reducing risk of lethal vessel collisions at times when and in areas where right whales were abundant and vessel traffic was heavy and fast. These times and locations showed the greatest differences in the number of lethal collisions between scenarios 2 and 3 (Figs. 3, 4). The difference in risk between scenarios 2 and 3 (17%), which had identical input parameters except for

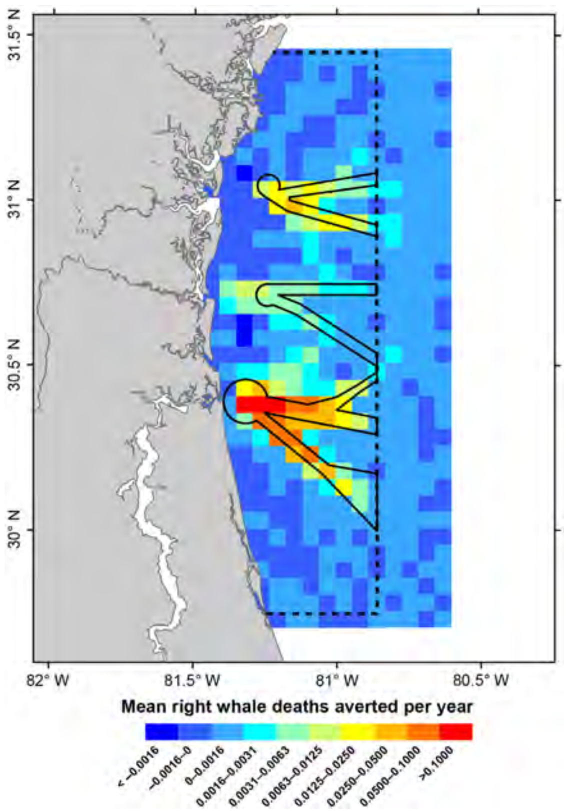

Fig. 3. Expected number of North Atlantic right whale deaths caused by vessel collisions averted under the speed restriction rule. The southeastern U.S. right whale seasonal management area (SEUS SMA) has a dashed black outline, and recommended shipping lanes are outlined in solid black. We calculated the number of deaths averted as the difference between two scenarios, (1) vessels traveled at the average speed from when the speed restriction rule was not in effect (scenario 2) and (2) vessels traveled at the average speed from when the speed rule was in effect, unless they were outside of the SEUS SMA, in which case they traveled at the average vessel speed from the three eastern-most columns of cells within the SEUS SMA when the speed rule was in effect (scenario 3).

vessel speed, estimated a smaller reduction in risk than the difference between the two years before and three years after the speed restriction rule was implemented according to scenario 1 (22%). This suggests that the reduction in risk following the implementation of the speed restriction rule may not be entirely attributable to slower vessel speeds. Total vessel transit distances each winter were similar before and after the rule was implemented (Appendix S1: Table S1), but increased compliance with recommended shipping lanes may have contributed to the reduction in risk (Fig. 2; Fonnesbeck et al. 2008). Additionally, the rule primarily reduced the risk of lethal collisions from cargo ships and tankers. These two ship types accounted for the majority of AIS vessel traffic in the SEUS SMA each winter (Appendix S1: Table S1), traveled faster than other ship types, such as tugs and dredges, before the speed restriction rule was implemented (Appendix S1: Table S2), and commonly used the recommended shipping lanes after they were established (Appendix S1: Figs. S3–S7).

Our model expected low risk of lethal vessel collisions east of the SEUS SMA and nearly no difference in risk between scenarios with and without the speed restriction rule in place (Fig. 3). Risk of lethal vessel collisions was very low east of the SEUS SMA because there was less vessel traffic and relatively low predicted abundance of right whales. With low initial risk, reducing vessel speeds hardly altered the expected number of lethal collisions. Conversely, our model expected the highest risk and greatest reduction of risk in and around shipping lanes inside the SEUS SMA, where vessel traffic is heaviest. Similarly, risk and the effectiveness of the speed restriction rule were greatest between late December and late February, when predicted right whale abundance was highest, compared to early December and late March. Because the risk of lethal collisions is sensitive to abundance, changes in right whale abundance and distribution could alter the number of right whale deaths that the speed restriction rule averts, that is, the difference in the number of right whale deaths expected if the rule were or were not implemented. For instance, since 2012 the number of observed right whales in the SEUS SMA has been lower than during our study period, which ended in 2011 (Gowan et al. 2019), likely leading to fewer lethal collisions being averted due to the speed restriction rule. However, even during years of low abundance in the SEUS, the speed restriction rule remains important, because the survival of pregnant and nursing females and their calves is key to the species' recovery (Fujiwara and Caswell 2001). Additionally, decreased

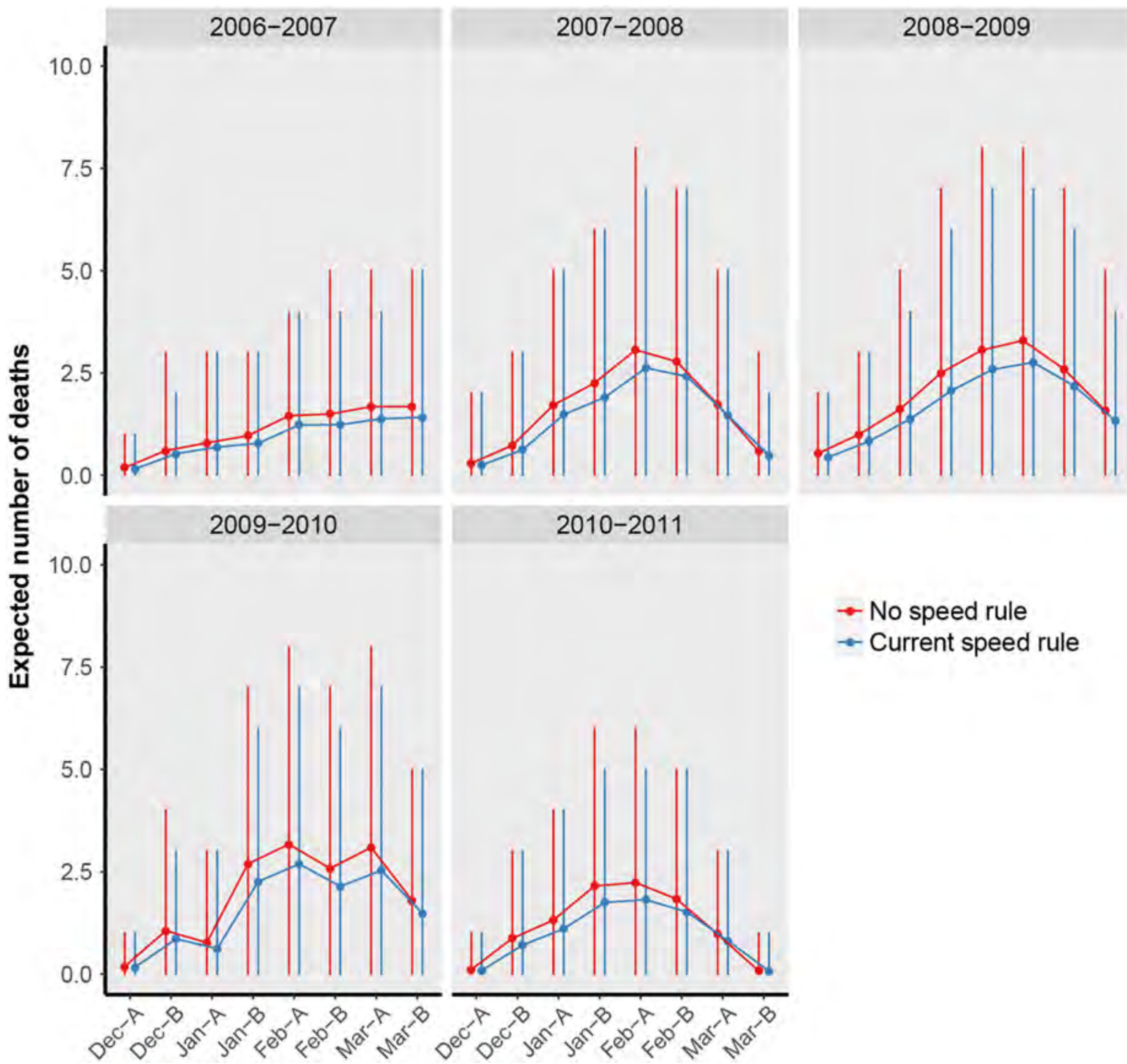

Fig. 4. Expected number of deaths, and associated 95% confidence intervals, of North Atlantic right whales due to collisions with vessels either subject to (scenario 3, in blue) or not subject to (scenario 2, in red) the speed restriction rule inside the southeastern U.S. right whale seasonal management area during each semimonth of the winters from 2006–2007 through 2010–2011.

observations of right whales in the SEUS SMA in recent years suggest that many right whales may be wintering elsewhere (Gowan et al. 2019). If this trend continues, it may be worth investigating where these right whales are wintering and how speed restriction rules would alter risk at those locations.

According to our model, 11 right whales on average were expected to have been struck and killed by vessels each winter in our study area between December 2006 and March 2011. In contrast, only one right whale death attributable to a vessel collision was documented within our study area during that time (Laist et al. 2014). Many factors can help explain this discrepancy, including that not every right whale death is detected, and the cause, location, and time of detected deaths cannot always be determined (Epperly et al. 1996, Williams et al. 2011). Therefore, the number of observed right whale deaths due to vessel collisions typically underestimates the actual number of deaths. Nevertheless, our model likely overestimated the risk of lethal vessel collisions due to our modeling choices. We did not account for avoidance of collisions by either right whales or vessel operators, which may have positively biased our expectations of risk (Appendix S2). Although there is a lack of evidence suggesting right whales avoid oncoming vessels (Nowacek et al. 2004), limited avoidance behavior has been documented in other large whale species (McKenna et al. 2015). Additionally, our approximation of the critical distance of encounter may have been too large. By using the disk method to represent vessels, we accounted for their length and width in the critical distance of encounter. However, since a vessel travels in the direction perpendicular to the axis of its width, it might be more reasonable to use only a vessel's width in calculating the critical distance of encounter. Martin et al. (2016) found that this method reduced risk estimates as much as 30% compared to the disk method. Our model also considered the process of lethal vessel collisions as sampling with replacement, meaning that a simulation could result in more deaths than there were whales. This was an infrequent occurrence (happening in fewer than 1% of simulations within an average grid cell during a semimonth) but may have contributed to an overestimation of risk, particularly in areas of high traffic. This issue could be addressed by modeling the process of lethal vessel collisions as sampling without replacement or using an individual-based simulation approach that removes a right whale from the population following a lethal vessel collision as van der Hoop et al. (2012*b*) did. Finally, when estimating risk of lethal vessel collisions inside of the SEUS SMA, we included all grid cells that overlapped the SEUS SMA. A small subset of these grid cells did not fall entirely within the SEUS SMA, and therefore, our estimates of risk inside the SEUS SMA included risk that, in reality, would be outside of the SEUS SMA.

Conversely, we modeled risk only from vessels that were subject to the speed rule and were recorded by our AIS receivers and risk to right whales that were at the water's surface. So, there was unmodeled risk from vessels <65 ft long and military and other government vessels, which are not subject to the speed restriction rule, and from vessels whose AIS transmissions were not received because their signal was too weak, or they were out of range of our receivers, for example. Additionally, our model underestimates risk for whales that are not at the surface but still no deeper than a vessel's draft or hydrodynamic effects (Silber et al. 2010). This could be incorporated into our model if information was available regarding vessels' drafts (often reported through AIS), the region's bathymetry, and the diving profiles of right whales in the southeastern United States.

Although we found that the speed restriction rule reduced the risk of lethal vessel collisions, we did not find as large of an effect as have other evaluations of the rule, such as Conn and Silber (2013). They estimated a reduction in the mortality rate of right whales due to vessel collisions of 80–90%. They measured the effect of vessel speed on a process that combined the encounter rate and avoidance rate, whereas our model considered these as separate processes. Our model would expect the rule to be as effective as Conn and Silber (2013) did if right whales were four to eight times more likely to avoid collisions with encountered vessels traveling at post-rule speeds than at pre-rule speeds (Appendix S2: Figure S2). McKenna et al. (2015) predicted that blue whales exhibiting avoidance behavior are more susceptible to collisions with faster vessels. If right whales exhibit similar avoidance behavior, then, depending on when they react to oncoming vessels and how this varies with vessel speed, the speed restriction rule would be more effective than our model expects currently. Additionally, compliance with the speed restriction rule increased throughout and after our study period (Silber et al. 2014). With all other factors equal, this would indicate that the rule may be more effective now than during the three years over which we evaluated it, highlighting the importance of considering compliance during policy development (Silber et al. 2014).

Our framework is a step forward from other metrics of right whale–vessel collision risk. We accounted for several factors that had not been collectively considered by other studies, namely the effects of vessel size, speed, and transit distance and right whale abundance and behavior on encounter and collision rates. Additionally, the framework's computational efficiency and our use of Monte Carlo simulations allowed us to account for parametric uncertainty and the stochastic nature of processes leading to a lethal vessel collision for which other studies have not fully accounted (van der Hoop et al. 2012*b*, Conn and Silber 2013, Rockwood et al. 2017). Still, our study only provides a relative metric of risk, as have other studies, because we did not fully account for potentially important processes, including avoidance, or parameters, including traffic from vessels excluded from the speed restriction rule. Moreover, this framework could be advanced in multiple ways, including developing an integrated population model that incorporates carcass recovery data to improve understanding of mortality and carcass recovery processes; optimizing the timing and location of management activities based on managers' valuations of risk and the cost of such activities to shipping and boating communities (Udell et al. 2018); and producing coastwide estimates of risk (Rockwood et al. 2017).

Our modeling framework facilitated a thorough evaluation of how NOAA's speed restriction rule affects the risk of vessels colliding with and killing right whales in the SEUS SMA. This framework accounts for factors that are key to the collision process and were generally overlooked by earlier evaluations of the speed restriction rule and whale–vessel collisions; is spatiotemporally flexible, accommodating any spatial or temporal scales for which abundance and traffic data are available; and is computationally efficient, expediting sensitivity analyses, model updates, and the ability to account for parametric and process uncertainty. With such attributes, this framework can be used to help managers evaluate risk associated with shipping industry trends and prospective policies. Additionally, the framework can be useful to managers in other fields, including those who must evaluate policies related to the timing and locations of fishing activities that pose entanglement risk to marine wildlife; military activities, such as sonar testing, and seismic surveys that may impact marine mammals; transportation planning that may affect wildlife–vehicle collision risk; and the location of wind farms, which present collision risk to wildlife (Martin et al. 2016, Udell et al. 2018). Using this framework, we provided a better understanding of where and when right whales are at risk of being killed by vessel collisions in the SEUS SMA. Future work can build upon this understanding and make practical use of the framework by using methods of systematic conservation planning to optimize the location and timing of SMAs.

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ATTACHMENT 9

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LETTER

Vessel Strikes to Large Whales Before and After the 2008 Ship Strike Rule

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Abstract

To determine effectiveness of Seasonal Management Areas (SMAs), introduced in 2008 on the U.S. East Coast to reduce lethal vessel strikes to North Atlantic right whales, we analyzed observed large whale mortality events from 1990–2012 in the geographic region of the "Ship Strike Rule" to identify changes in frequency, spatial distribution, and spatiotemporal interaction since implementation. Though not directly coincident with SMA implementation, right whale vessel-strike mortalities significantly declined from 2.0 (2000–2006) to 0.33 per year (2007–2012). Large whale vessel-strike mortalities have decreased inside active SMAs, and increased outside inactive SMAs. We detected no significant spatiotemporal interaction in the 4-year pre- or post-Rule periods, although a longer time series is needed to detect these changes. As designed, SMAs encompass only 36% of historical right whale vessel-strike mortalities, and 32% are outside managed space but within managed timeframes. We suggest increasing spatial coverage to improve the Rule's effectiveness.

Introduction

Vessel strikes contribute significant mortality to large whale stocks in the Northwest Atlantic despite mitigation efforts (van der Hoop *et al.* 2013). In 2008, the United States regulated to reduce vessel-strike mortalities in U.S. waters to North Atlantic right (*Eubalaena glacialis*; hereafter right) whales, mandating speeds <10 knots (18.5 km/hour) for commercial vessels ≥65 ft (20 m) long in 10 spatially and temporally defined Seasonal Management Areas (SMAs; Figure 1; Table 1; NOAA 2008).

This "Ship Strike Rule" also established Dynamic Management Areas (DMAs), recognizing interannual variability in whale distribution and habitat use (Winn *et al.* 1986; Patrician *et al.* 2009). DMAs provide 15-day voluntary speed limits for right whale aggregations ($n \geq 3$) detected outside active SMAs. In addition, mariners are requested to avoid DMAs (NOAA 2008). SMA sites and seasons consider (1) right whale movement, distribution, and aggregation patterns from sightings and telemetry data; (2) vessel-strike distribution and occurrence; and (3) regions with predictable vessel traffic (Merrick 2005; NOAA 2006). Although its design was right-whale specific, it was expected that the Ship Strike Rule should benefit other large whales (NOAA 2006; NMFS 2008), as the effect of speed on the lethality of a vessel collision is not species specific (Vanderlaan & Taggart 2007).

The 2008 Ship Strike Rule included a 5-year sunset clause to relieve any affected entities, and enable the National Marine Fisheries Service (NMFS) to assess and report on its efficacy (NOAA 2008). Although this clause has been eliminated (NOAA 2013), Rule assessment remains critical to determine whether amendments are required to meet its goals.

We evaluate the Rule's effectiveness with a series of indicators against specific objectives (Hockings *et al.* 2006). Here, indicators are observed vessel-strike mortalities, and the objective is reduced likelihood of death to right whales from vessel collisions (NOAA 2008). We test the null hypothesis that SMAs introduced by the Ship Strike Rule were not effective in reducing observed vessel-strike mortalities to right whales specifically, and other large whale species generally. If effective, we expect the Rule to have yielded significant changes in the spatial distribution and a decrease in the rate of observed vessel-strike mortalities. We expect significant spatiotemporal interaction, whereby observed vessel-strike mortality rates are reduced in managed areas during managed times. By including additional large whale species other than right whales, we assess whether SMAs provide mutual benefit to other species (as expected; NMFS 2008), and calculate the degree of protection SMAs offer these populations.

Table 1 Location and active time periods of Seasonal Management Areas implemented annually, since December 9, 2008

Seasonal Management Area (SMA)		Active time period
Southeast United States:	Coastal Florida and Georgia	November 15 to April 15
Mid-Atlantic United States:	Brunswick, GA to Wilmington, NC	November 1 to April 30
	Ports of Morehead City and Beaufort, NC	November 1 to April 30
	Entrance to Chesapeake Bay: Ports of Hampton Roads, VA, and Baltimore, MD	November 1 to April 30
	Delaware Bay: Ports of Philadelphia, PA, and Wilmington, DE	November 1 to April 30
	Ports of New York/New Jersey	November 1 to April 30
	Block Island Sound	November 1 to April 30
Northeast United States:	Cape Cod Bay	January 1 to May 15
	Off Race Point	March 1 to April 30
	Great South Channel	April 1 to July 31

Methods

We obtained information on 1,198 mortality events (hereafter, mortalities) from 1990 to 2012 to blue (*Balaenoptera musculus*), Bryde's (*B. edeni*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*), minke (*B. acutorostrata*), right, sei (*B. borealis*), sperm (*Physeter macrocephalus*), and unidentified large whales in the Northwest Atlantic between the southern tip of Florida (25.4083° N, 80.3° W) and Cape Sable, Nova Scotia, Canada (43.5087° N, 65.69° W), from the coast to continental shelf. This geographic range encompasses numerous vessel-strike related management schemes introduced since 1997 in Canada and the United States (see e.g., Mullen *et al.* 2013 for a review) and envelops the Gulf of Maine allowing for carcass drift and coastline geography.

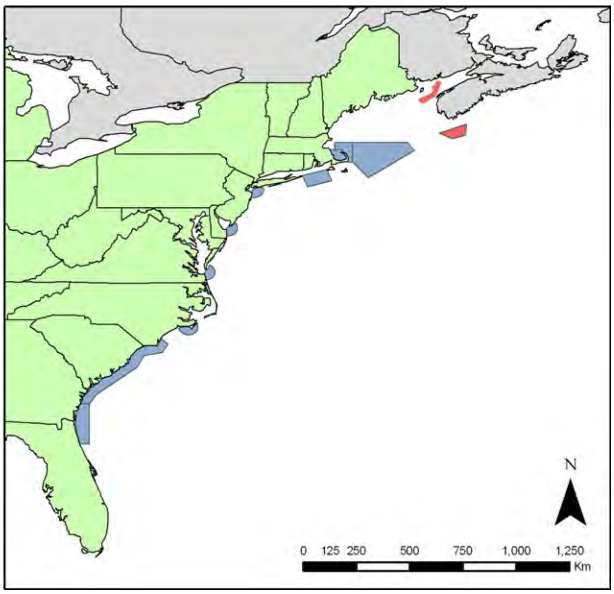

Figure 1 Map of Seasonal Management Areas (SMAs; blue) implemented on December 9, 2008 as part of the United States' vessel-strike reduction strategy (the "Ship Strike Rule") and existing vessel-strike reduction measures in Canada in the Bay of Fundy (2003) and Roseway Basin (2007) (red).

We obtained records (on shore and floating at sea) collected by stranding responders in the Canadian Maritime provinces from the Maritime Marine Animal Response Network, and American records from (1) National Oceanic and Atmospheric Administration (NOAA) Southeast and Northeast U.S. Marine Mammal Stranding Network Databases, and local response programs therein, and (2) NOAA's Northeast Fisheries Science Center (NEFSC).

The presumed cause of death, provided by the stranding responders or agency, was categorized as entanglement, vessel strike, other human cause (e.g., marine debris), nonhuman cause (e.g., perinatal), and undetermined (due to decomposition or where no cause of death was provided). Data were qualified through the mortality determinations of NOAA's NEFSC (e.g., Henry *et al.* 2013).

We included records of dead animals only, though previous studies include "serious injuries" that would likely result in death (Vanderlaan & Taggart 2007; NOAA 2011; Cole & Henry 2013). Estimates herein are therefore lower than in van der Hoop *et al.* (2013) and are a greater underestimation of the true number of mortalities.

We examined opportunistic and survey (aerial and vessel) sightings of all large whales, maintained within the North Atlantic Right Whale Consortium database (NARWC 2008) from 1990 to 2008 to assess their percent occurrence within SMAs.

Temporal analyses

To determine whether SMA implementation affected observed mortality rates, we used Webster's method (Webster 1973) with $y_i + y_i$ window sizes of $y = 3$ and 4 years to detect discontinuities in the time series of vessel-strike mortalities per year to right whales and, separately, to all other (including unidentified large whale) species. Discontinuities separate periods over which mortality rates are consistent, or stationary. We calculated Student's t-statistic for Webster's method with the standard deviation of the entire data series as window sizes are small (Legendre & Legendre 2012), and considered discontinuities significant at $\alpha = 0.1$.

We calculated Poisson cumulative distribution functions (CDFs) with bootstrap estimated 95% confidence intervals (CIs) based on the average number of observed vessel-strike mortalities per year (μ) as in Vanderlaan *et al.* (2009) for the stationary time periods detected with Webster's method.

Spatial analyses

Spatial coordinates reflect the location where a mortality was first detected or reported. We estimated location for 33 cases where coordinates were not provided but location information was descriptive (e.g., an address). We created a 1-D spatial coordinate system, selecting all mortalities observed within 20 nmi (37 km, i.e., the distance to which most SMAs extend) of the coastline ($n = 934$) and assigning them a coordinate for the closest location along the coastline. We then calculated the distance from the southern tip of Florida (our spatial origin), to each coastline location. We calculated smoothed (200 km bandwidth) normal kernel density distributions of these locations in two pre-Rule (19 year, January 1, 1990 to December 8, 2008; 4 year, December 8, 2004 to December 8, 2008) and one post-Rule (4 year, December 9, 2008 to December 31, 2012) period, all inclusive. To determine whether these distributions for all causes of death or attributed to vessel strike ($n = 140$) differed between each pre-Rule period and the post-Rule period, we used a two-sample Kolmogorov-Smirnov test (H_0 = no difference).

Spatiotemporal interaction

We assigned two binomial indicators (space, S; time, T) to all observed vessel-strike mortalities: $S = 1$ if the mortality was observed inside and 0 if outside SMAs, and $T = 1$ if the mortality was observed when the closest SMA was active and 0 if not active (Table 1). For example, for a vessel-strike mortality observed inside an SMA during the inactive period (e.g., Delaware Bay; September): $S = 1$, $T = 0$. For a vessel-strike mortality observed outside an SMA when nearby SMAs were active (e.g., Cape Hatteras, NC; March): $S = 0$, $T = 1$. Active times were applied to pre-Rule and post-Rule periods to test for interaction before Rule implementation. Because of SMA geometry, Great South Channel and Off Race Point SMAs were combined, yielding an active period of March 1 through July 31.

To examine whether SMAs were designated in appropriate areas, we calculated the percentage of (1) observed vessel-strike mortalities and (2) opportunistic and survey sightings for each species in the four different binomial combinations ($S = 0$, $T = 0$; $S = 1$, $T = 0$; $S = 0$, $T = 1$; and $S = 1$, $T = 1$) before implementation, 1990–2008.

To test for an interaction between space and time on the observed number of vessel-strike mortalities we performed an approximate permutation test for an analysis of variance (Anderson 2001). To remove the effects of each factor, space and time, we subtracted the appropriate mean from each observation (the number of vessel-strike mortalities within a year either pre- or postimplementation of the Ship Strike Rule) to obtain corresponding residuals that were used in the approximate permutation test (10,000 replications).

Results

From 1990 to 2012, 1,198 mortalities were observed. We identified 975 cases to one of eight large whale species; 223 cases involved unidentified large whales. Consistent with previous findings over the last 40 years (van der Hoop *et al.* 2013), the leading diagnosed causes of death (determined in 458 cases, 38%) were entanglement ($n = 169$), nonhuman causes ($n = 147$), and vessel strike ($n = 135$). Since Rule implementation (cause of death determined in 67/204 cases, 33%), entanglement has remained the leading diagnosed cause of death ($n = 29$) for all large whales over this geographic range, followed by vessel-strike ($n = 25$), and nonhuman-caused mortalities ($n = 10$).

Table 2 Percentage of opportunistic and survey sightings per species, 1990–2008 (pre-Rule implementation), located inside and outside (bold text) what would become 10 active Seasonal Management Areas (SMAs) following implementation of the Ship Strike Rule (NOAA 2008)

Species (*n* total sightings)	Blue (5)	Fin (6,717)	Humpback (9,503)	Minke (1,806)	Sei (3,006)	Sperm (570)	Right (21,749)
Area							
Southeast United States	–	–	0.31	0.0046	–	–	26
South Carolina Area	–	0.0046	0.083	–	–	–	2.9
Morehead City	–	–	0.023	–	–	–	0.10
Chesapeake Bay	–	–	–	–	–	–	0.092
Delaware Bay	–	–	–	–	–	–	0.014
New York, New Jersey	–	0.0092	–	–	–	–	0.0046
Block Island Sound	–	0.060	0.0046	0.028	–	–	0.11
Cape Cod Bay	–	5.3	2.5	0.65	0.0046	–	26
Off Race Point	–	1.5	1.2	0.38	–	–	3.2
Great South Channel	–	12	21	2.8	11	0.028	25
Outside	**100**	**81**	**75**	**96**	**89**	**100**	**17**

Table 3 Total number (*n*) and percentage of observed vessel-strike mortalities per species, 1990–2008, during combinations of active (= 1) and inactive (= 0) space (*S*) and time (*T*) of Seasonal Management Areas before being implemented by the Ship Strike Rule (NOAA 2008)

Species (total *n* svessel-strike mortalities)	Blue (1)	Fin (34)	Humpback (28)	Minke (11)	Sei (5)	Sperm (3)	Right (22)
$S = 0, T = 0$ (inactive space, inactive time)	–	15	21	9.1	40	100	27
$S = 0, T = 1$ (inactive space, active time)	100	8.8	32	–	–	–	32
$S = 1, T = 0$ (active space, inactive time)	–	23	21	64	20	–	4.6
$S = 1, T = 1$ (active space, active time)	–	53	25	27	40	–	36

Based on sightings data, 17% of right whale sightings, 1990–2008, were outside of what would become active SMAs following implementation (Table 2). In contrast, 27% of pre-Rule right whale mortalities occurred outside, and only 36% occurred fully inside, these spatiotemporal boundaries (Table 3). Comparable proportions of pre-Rule mortalities are observed inside future active SMA boundaries for right (36%), humpback (25%), minke (27%) and sei (40%) whales, and higher proportions for fin (53%) whales (Table 3).

Temporal

We detected three discontinuities with Webster's method, where right whale vessel-strike mortality rates were consistent from 1990 to 2000, 2001 to 2006, and 2007 to 2012 (inclusive; Figure 2). Bootstrapped 95% CIs around Poisson-aggregated CDFs indicate no difference in the right whale vessel-strike mortality rate between 1990–2001 (0.91 per year) and 2001–2006 (2.0 per year), followed by a significant decrease to 0.33 per year during 2007–2012. We detected no significant discontinuities for all other species of large whale over the entire data series. No significant discontinuities were detected for either right whales or all other large whale species between 2008 and 2009, immediately following Rule implementation.

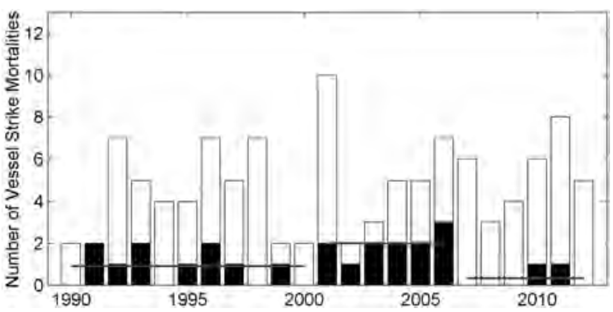

Figure 2 Total number of observed vessel-strike mortalities per year to North Atlantic right whales (black bars), and eight other, including unidentified, large whale species (white bars). Horizontal lines represent the average number of vessel-strike mortalities per year for right whales (grey) over periods separated based on discontinuities detected using Webster's method (see text).

Spatial

The smoothed kernel density distribution of vessel-strike mortalities for all species post-Rule differed significantly from the 19-year ($P = 0.013$, Kolmogorov-Smirnov Test Statistic [KS] = 0.22) and 4-year pre-Rule ($P = 0.0018$; KS = 0.26) periods. Postimplementation, increases in mortality occurred from Delaware to New York, and decreases from the Great South Channel, northward (Figure 3). In contrast, no significant differences were

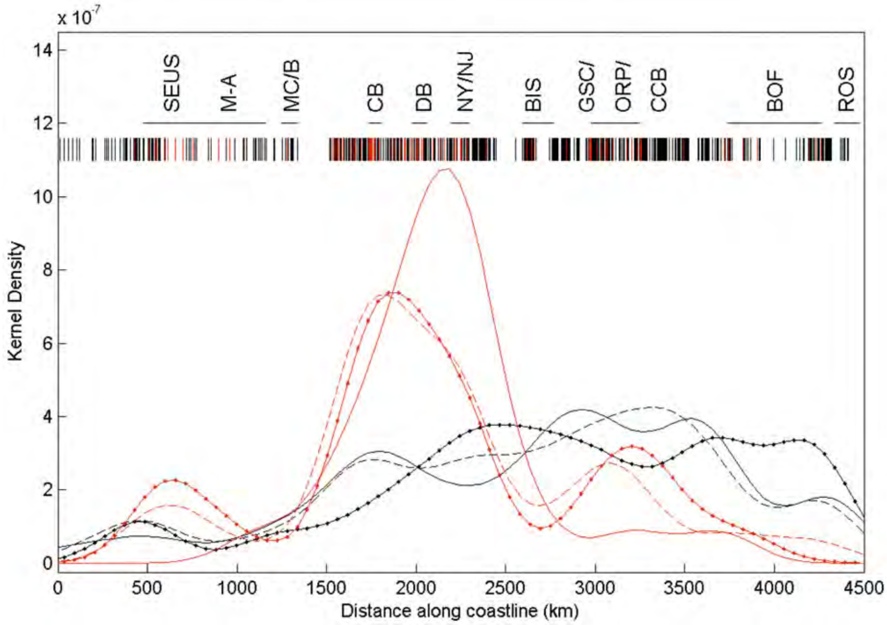

Figure 3 Smoothed kernel density estimates of all (black) and vessel-strike related (red) mortalities to large whales, including unidentified to species, before (1990 to December 8, 2008, dash; December 8, 2004–December 8, 2008, dot-dash) and after (December 9, 2008 to December 31, 2012, solid line) enactment of the "Ship Strike Rule" along the coastline from the southern tip of the Florida Peninsula, USA, to Cape Sable, Nova Scotia, Canada. Vertical lines indicate the location of all (black) and vessel strike (red) mortalities. Horizontal lines indicate the spatial extent of mandated Seasonal Management Areas (SMAs; SEUS, Southeast United States; M-A, Mid-Atlantic; MC/B, Morehead City/Beaufort, NC; CB, Chesapeake Bay; DB, Delaware Bay; NY/NJ, New York/New Jersey; BIS, Block Island Sound; GSC, Great South Channel; ORP, Off Race Point, MA; CCB, Cape Cod Bay, MA) in U.S. waters and voluntary regulations in Canadian waters (BOF, Bay of Fundy; ROS, Roseway Basin).

observed in the density distributions of mortalities for all other causes of death between either pre-Rule or the post-Rule periods (1990–2008: $P = 0.89$, KS $= 0.080$; 2004–2008: $P = 0.34$, KS $= 0.13$).

Spatiotemporal

We detected no significant interaction between space and time on the observed number of vessel-strike mortalities for all species in the 4-year pre- ($P = 0.82$) and post-Rule implementation periods ($P = 0.48$; Figure 4). There was a significant interaction in the 19-year pre-Rule period ($P = 0.040$), indicating that sample size or short time series may preclude the determination of significant interactions in 4-year periods. Observations suggest that following Rule implementation, fewer vessel-strike mortalities have occurred inside active SMAs, whereas their prevalence has increased outside inactive SMAs (Figures 4 and 5).

Discussion

Given the continued interest in implementing speed restrictions around the world (Silber *et al.* 2012b), it is essential that existing measures be assessed for their ability to achieve their objectives, and to determine what factors may contribute to their success or failure (Hockings *et al.* 2006). The significant reduction in right whale vessel-strike mortality between 2001–2006 and 2007–2012 observed here is not directly coincident with the implementation of the Ship Strike Rule alone (which would be 2008–2012), but likely reflects the combined effect of numerous measures introduced since 2006 (see e.g., Mullen *et al.* 2013 for a review). Voluntary and mandatory routing changes in the Bay of Fundy (since 2003), and in the Southeast United States and Cape Cod Bay (since 2006); and an Area to be Avoided (ATBA) in Roseway Basin (since 2008) have provided significant decreases in relative (Fonnesbeck *et al.* 2008; Vanderlaan *et al.* 2008; Vanderlaan & Taggart 2009) and absolute (van der Hoop *et al.* 2012) vessel-strike risk to right whales.

Though spatial and temporal trends are often analyzed separately, their interaction must be considered when testing the effectiveness of a regulation with specific extents in space and time. The lack of significant interaction following Rule implementation suggests that SMAs have been ineffective in reducing vessel-strike mortality in managed areas during managed times. We attribute

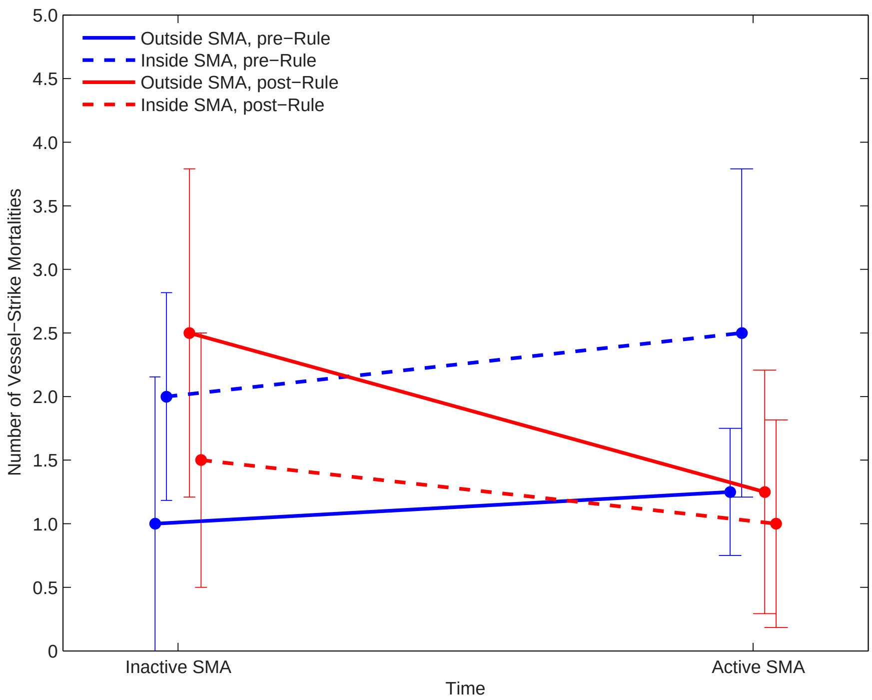

Figure 4 The number of vessel-strike mortalities per year to large whales (including unidentified to species) observed inside (dashed lines) and outside (solid lines) inactive and active Seasonal Management Areas (SMAs) before (blue) and after (red) their implementation on December 9, 2008.

our inability to detect many of the intended effects of the Ship Strike Rule to three issues of rule design and implementation: (1) low vessel compliance with the SMAs; (2) insufficient time and/or monitoring to examine effectiveness; and (3) SMAs may be inappropriately located, or may be too short in duration and/or too small (Schick *et al*. 2009).

The rule's perceived ineffectiveness could be due to compliance, which has been low (20.7%–32.8%, 2009–2011; Silber & Bettridge 2012) and is in many areas unknown. Although automatic identification system data have been used to determine changes in relative vessel-strike probabilities since Rule implementation (Wiley *et al*. 2011; Conn & Silber 2013), these studies do not report on compliance or vessel traffic distributions. Rule awareness by mariners likely increased following implementation, as outreach (e.g., through compliance guides, Mandatory Ship Reporting Systems) and enforcement programs (e.g., through violation notices, at-sea hailings) developed and particularly strengthened in 2010 (Silber & Bettridge 2012). How these efforts have influenced operator compliance, and how the Rule has influenced vessel distribution remains unknown.

The detection of a significant spatiotemporal interaction in the 19-year pre-Rule period, but not the 4-year pre-Rule period suggests the second issue, that the Rule likely imposed an insufficient time frame for monitoring to detect an effect. Indicators available to assess the Ship Strike Rule (i.e., observed mortalities) occur with relatively low frequency, and require long periods to accumulate adequate sample sizes (Pace 2011). If the rule does not include sufficient monitoring provisions or support to test its own efficacy, then that is a failure in its design and implementation.

Finally, SMAs may not be appropriately located or timed. The SMAs only protect 23% of our study area and the active boundaries of SMAs encompass only 36% of historical right whale vessel-strike mortalities (Table 3). Although they overlap critical habitat and calving areas, SMAs do not provide protection in the mid-Atlantic migratory corridor where mortality density and incidence is greatest (Figures 3 and 5). Further, SMAs may be too short in duration and/or too small (Schick *et al*. 2009). A large proportion (32%) of pre-Rule right whale vessel-strike mortalities occurred outside SMAs during their active times, suggesting that the spatial extent is insufficient in certain seasons.

From Delaware to New York, SMAs are small and protect only port entrances (Figures 1 and 5). Here, visual survey data are sparse (Russell *et al*. 2001), and acoustic survey data are available but have not been used to design regulations. Increasing the size of SMAs

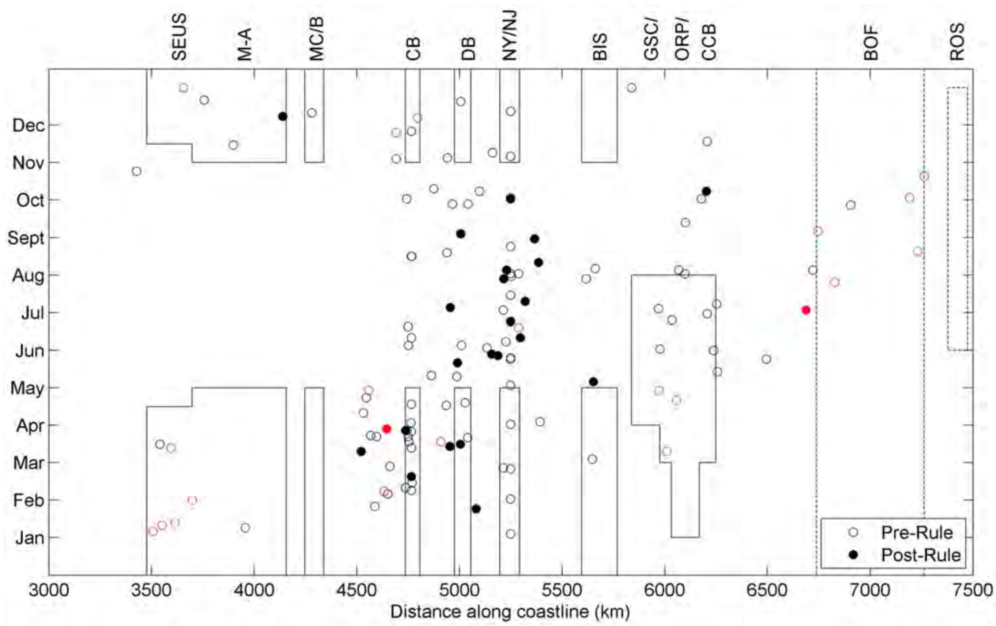

Figure 5 Spatial and temporal distribution of vessel-strike mortalities to North Atlantic right (red) and other (including unidentified) species of large whale (black) before (open circle) and after (closed circle) the enactment of the "Ship Strike Rule" on December 9, 2008. Boxes illustrate the spatial and temporal extents of mandated Seasonal Management Areas (SMAs; solid line; SEUS, Southeast United States; M-A, Mid-Atlantic; MC/B, Morehead City/Beaufort, NC; CB, Chesapeake Bay; DB, Delaware Bay; NY/NJ, New York/New Jersey; BIS, Block Island Sound; GSC, Great South Channel; ORP, Off Race Point, MA; CCB, Cape Cod Bay, MA) and concurrent regulations in Canadian waters (dashed lines) active since 2003 (BOF, Bay of Fundy) and 2007 (ROS, Roseway Basin).

could mitigate this high-risk area (overlapping high vessel and whale densities), maximizing conservation gain, while minimizing industry cost. Similar strategies (e.g., the shipping lanes in the Bay of Fundy or ATBA in Roseway Basin) have been extremely successful in reducing vessel-strike risk and incidence to right whales (Vanderlaan *et al*. 2008; Vanderlaan & Taggart 2009; van der Hoop *et al*. 2012), though effectiveness still relies on compliance.

Laist *et al*. (2014) conclude SMAs are properly located, as 87% of right whale vessel-strike mortalities in U.S. waters were found in or near SMAs during what would become effective dates. This large difference (87% vs. 36% reported here) is likely due to a 45 nmi (74 km) buffer zone around SMAs in their analysis. This increases SMA size by a relatively arbitrary amount, especially given that the authors recommend a 10-nmi extension of SMAs, which would fall within the managed area, under their definition.

Although low sample size and limited power precluded the determination of some significant effects of the Rule (see also Pace 2011; Silber & Bettridge 2012), it appears that vessel-strike mortality to large whales has decreased inside active SMAs (Figure 4). Otherwise, vessel-strike mortalities have increased outside of active SMA (Figures 4 and 5), contrary to expectation. If effective, DMAs should have contributed to decreased vessel-strikes outside of SMA time periods and regions, which does not appear to be the case. Unfortunately, DMAs have not been found to result in any changes in vessel speeds or routing (Silber *et al*. 2012a), which would explain these observations.

It was expected that SMAs should benefit other whales (NMFS 2008). Pre-Rule sightings and mortalities (Tables 2 and 3) suggest SMAs provide little-to-no benefit to blue and sperm whales, but offer similar (though low) protection to humpback, minke, sei, and fin whales as they do for right whales.

The number of observed vessel-strike mortalities is affected by many variables that change through time (van der Hoop *et al*. 2013). The exact detection location is not necessarily where death, or the vessel strike, occurred; however, there is a limited amount of drift data available for vessel-struck animals, drift will differ with location, and thus designating a limit of potential drift would remain subjective. Whale distribution may have changed throughout the study period, though we believe that it has remained fairly constant because the distribution of whale mortalities for other causes of death has not changed. The factors that then likely affected vessel-strike mortality distributions are related to vessels (abundance, distribution, and speed).

Conclusions

Lethal vessel-strikes to right whales appear to be less common than before SMAs and other mitigation strategies were implemented, and the spatial density of vessel-strike mortality to all large whales has changed. However, measures of spatiotemporal interaction are required to directly assess whether SMAs have been effective in reducing mortality inside managed areas during managed times. It would be optimistic to expect that changes in rare events could be detected in the short time period imposed by a sunset clause; rules should include adequate time periods to evaluate their own efficacy with sufficient statistical power. The Ship Strike Rule has been extended indefinitely (NOAA 2013). These and other methods should be applied as part of NMFS's agreement to periodically review the Rule as implementation continues. Suggested improvements to the Rule, specifically, increasing the spatial and temporal extent of SMAs in the mid-Atlantic, should be considered.

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ATTACHMENT 10

RAPID COMMUNICATION / COMMUNICATION RAPIDE

Striking the *right* balance in right whale conservation

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Abstract: Despite many years of study and protection, the North Atlantic right whale (*Eubalaena glacialis*) remains on the brink of extinction. There is a crucial gap in our understanding of their habitat use in the migratory corridor along the eastern seaboard of the United States. Here, we characterize habitat suitability in migrating right whales in relation to depth, distance to shore, and the recently enacted ship speed regulations near major ports. We find that the range of suitable habitat exceeds previous estimates and that, as compared with the enacted 20 nautical mile buffer, the originally proposed 30 nautical mile buffer would protect more habitat for this critically endangered species.

Résumé : Malgré de nombreuses années d'étude et de protection, la baleine franche du nord (*Eubalaena glacialis*) de l'Atlantique Nord demeure au bord de l'extinction. Il y a une faille essentielle dans notre compréhension de leur utilisation de l'habitat dans le corridor de migration le long de la côte est des États-Unis. Nous caractérisons ici la convenance des habitats pour les baleines franches en migration en relation avec la profondeur, la distance de la rive et la réglementation récemment en vigueur sur la vitesse des navires près des ports principaux. Nous trouvons que la gamme d'habitats adéquats dépasse les estimations précédentes et que, par comparaison à la zone tampon de 20 milles marins présentement en vigueur, la zone tampon de 30 milles marins proposée à l'origine protégerait plus d'habitats pour cette espèce sérieusement menacée de disparition.

[Traduit par la Rédaction]

Introduction

Despite many years of study and protection, the North Atlantic right whale (*Eubalaena glacialis*) remains on the brink of extinction (Fujiwara and Caswell 2001; Kraus et al. 2005). Although a more complete understanding of right whale movement, feeding, and distribution patterns on their northern foraging and southern calving grounds has emerged (Kraus and Rolland 2007), the space used by right whales along their migratory corridor remains almost entirely unknown. This lack of knowledge impedes management of the segment of this critically endangered species, namely pregnant females and nursing mothers, whose death most impacts population survival (Fujiwara and Caswell 2001). As right whales migrate, they pass several of the largest ports on the eastern seaboard (Knowlton et al. 2002) (Fig. 1). Ship strikes are one of the primary factors limiting recovery of this species; more than a quarter of known ship strike mortalities for right whales occur in this region (Knowlton

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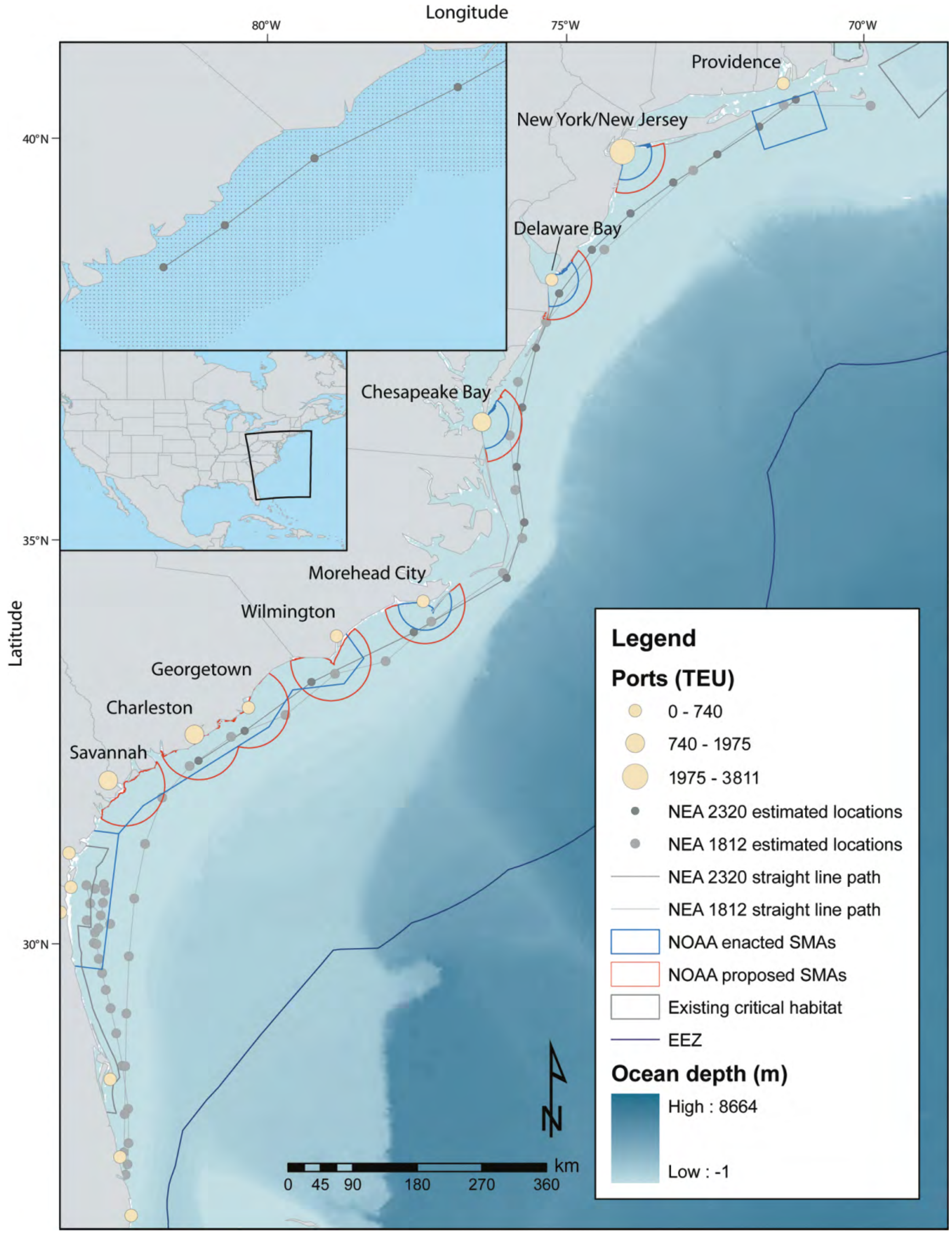
Fig. 1. The portions of two movement paths that cross the migratory corridor are depicted in relation to the proposed (red) and enacted (blue) seasonal management areas (SMA). Light grey and dark grey circles are estimated locations of NEA 1812 and NEA 2320. Major ports are in beige. The upper inset map shows the last four locations of NEA 2320's track in grey with the buffered track shown in light grey. The lower inset map highlights the study area. TEU, twenty foot equivalent units; EEZ, exclusive economic zone.



et al. 2002). Knowledge of how right whales perceive and move through this area will help inform the risk of ship strikes near these ports. Accordingly, we fit a new movement model to the migratory paths of two female right whales to estimate habitat suitability along the Mid-Atlantic corridor. In fitting this model, we emphasize (*i*) the general suitability of this important migratory corridor and (*ii*) the spatial relationship between habitat suitability and recently enacted vessel speed restrictions near shipping ports along the east coast (NOAA 2008).

Data

The data used here come from portions of movement paths from two female right whales: NEA 1812, tagged in 1996 (C.K. Slay and S.D. Kraus, unpublished data), and NEA 2320, tagged in 2000 (Baumgartner and Mate 2005). Both animals were tagged with ARGOS satellite-monitored radio tags. NEA 1812 is a reproductively active female at least 20 years old. She was first identified in Roseway Basin on the Nova Scotian Shelf in September 1988 and was last seen in August 2008 in the Bay of Fundy. NEA 1812 was accompanied by a newborn calf at the time of tagging. NEA 2320 is a reproductively active female first identified in January 1993 off Florida and last seen in March 2008 in Cape Cod Bay. Information about age, sighting history, and reproductive status comes from The North Atlantic Right Whale Catalog (http://rwcatalog.neaq.org/Default.aspx, last accessed 12 December 2008). The track of NEA 1812 originated off Fernandina Beach, Florida, on 21 February 1996 and ended in the Gulf of Maine on 2 June 1996 (Fig. 1). (Note that the ports are symbol coded according to TEU (twenty foot equivalent units), where 1 TEU approximately represents the capacity of a standard shipping container, or 1360 ft^3, information taken from the United States Army Corps of Engineers, Navigation Data Center (http://www.iwr.usace.army.mil/ndc/wcsc/by_portname06.htm, last accessed 19 February 2009).) The track of NEA 2320 originated in the Bay of Fundy on 11 August 2000 and ended just north of the calving grounds in Florida and Georgia on 15 December 2000 (Fig. 1). In both cases, we ignored the Gulf of Maine portion of the tracks because this comprised a demonstrably different behavioral state and locations were no longer in the migratory corridor. For NEA 1812, 24 locations spanned the calving ground and migratory corridor; for NEA 2320, 16 locations spanned the migratory corridor. NEA 1812 transmitted for 103 days and covered 2676 km (average of 26.0 $km \cdot day^{-1}$). NEA 2320 transmitted for 127 days and covered 5612 km (average of 44.2 $km \cdot day^{-1}$).

Methods

Because the model from Schick et al. (2008) assumes equal time intervals between locations, we fit the model from Jonsen et al. (2005) to the data as a first-stage filter to obtain an estimate of the true path. The model from Jonsen et al. (2005) is a state-space model that uses a directed correlated random walk as the process model and that returns daily estimates of the animal's true position and, where appropriate, estimates of a behavioral state. We then buffered positions along this estimated path to compare actual location visited at time t versus a range of possible locations. We chose a 100 km spatial buffer around each location at time t because this distance slightly exceeded the maximum daily distance covered by the individual whales (97 km). Using GIS, we sampled two environmental covariates, water depth (metres) and distance to shore (kilometres), at each of these possible locations along the path of the individual as well as at the centroid of each 4 km grid cell within the buffered track (Fig. 1, inset). Because there is no literature describing the response of migrating right whales to dynamic covariates such as sea surface temperate, we did not include them in our model. In certain cases where shorter movements by the animal resulted in overlap of the spatial buffers, a separate time index was derived for each of the points. In other words, at time $t = 3$, the possible locations were, for example, 100. At $t = 4$, the locations were also 100, but since the animal only moved 5 km, 90 of these 100 possible locations were the same as the previous time step. In this case, we calculated and kept the space and time index of each patch in relation to when it could have been visited by the moving animal (Fig. 1, inset). We built upon these two covariates by separately calculating quadratic terms for both water depth and distance to shore. We used quadratic terms to see if there was an optimal range for each of these covariates and because without them, the assumption would be that right whales prefer the smallest possible values for each covariate, i.e., the closer right whales are to shore, the higher the suitability. In addition, we calculated the distance from the animal's position at time $t - 1$ to the current location of possible patches at time t. This allowed us to make inference on how distance from the animal affects suitability.

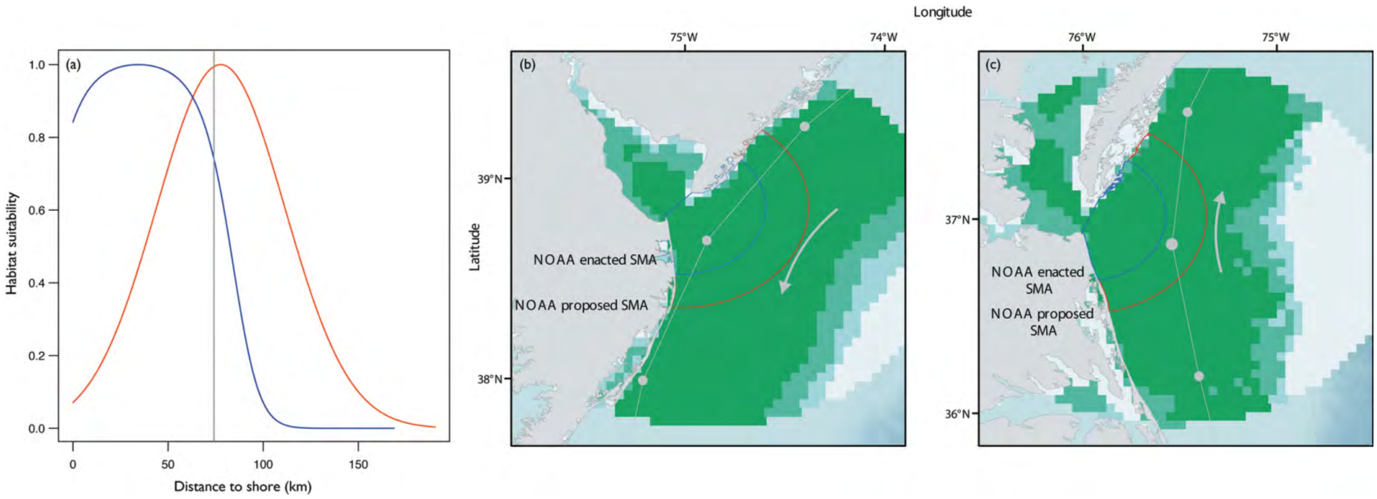
To these data, we applied the Bayesian movement model from Schick et al. (2008) that embeds a resource selection function (Manly and McDonald 2002) inside a movement model in an effort to infer the parameters governing relative habitat suitability h, where h is a function of environmental covariates. That is, how does the suitability of the patch chosen differ from those the animal could have chosen to visit? We modeled suitability as a function of the two environmental covariates, including both linear and quadratic terms for both. The model from Schick et al. (2008) exploits observed movement relative to the options available as the basis for inference on habitat preference.

We used these covariates and regression parameters to model the suitability h of areas along the track. At each point along the movement track, the animal chooses one location of many possible locations. We used a multinomial for the likelihood based on the assumption that the animal chooses the location with probability θ. Probability θ was mechanistically derived from the relative suitability h of the visited patch. Suitability h was normalized by dividing by the sum of h for all other patches. Suitability h had a functional form $\mathbf{X}\beta$. We constructed $\mathbf{X}$, and in a Gibbs sampling framework, we drew βs from a truncated multivariate normal distribution with mean values based on the current values of $\beta^{(g)}$, where the g superscript represents the current step in the Gibbs loop. The density a of the proposed value is determined in relation to the current value, and if $a > 1$, the proposed values were accepted. We derived and used an empirical covariance matrix $\mathbf{V}$ for this multivariate distribution. A default covariance matrix was used at the start of the Gibbs sampler, and we then twice calculated and employed the empirical covariance matrix after 1000 and 100 000 steps through the Gibbs sampler. We used uninformative flat priors centered on 0 with large variance. We ran the Gibbs sampler for 250 000 steps, saving the last thinned 150 000 values. Summary statistics were calculated for each of the posterior estimates of the parameters. To display habitat suitability, we used median estimates of the regression parameters and plotted estimates of suitability around each point. For the global suitability, we fixed distance and depth at their mean values while calculating suitability as a function of distance to shore.

Results

Results from the two migratory tracks analyzed here (whales NEA 1812 and NEA 2320) indicate that the estimate of habitat suitability should be revised farther offshore (Fig. 2*a*). Peak suitability values for distance to shore are slightly farther offshore for NEA 1812 than for NEA 2320 (Fig. 2*a*). In particular, NEA 1812, a migrating female with a newborn calf, occurred relatively far offshore during some

Fig. 2. (*a*) Posterior estimates of habitat suitability as a function of distance to shore across the entire migration for NEA 2320 (blue line) and NEA 1812 (red line). The vertical grey line corresponds to 75 km (40 nautical miles) offshore. Posterior estimates of habitat suitability are shown for (*b*) NEA 2320 near the mouth of Delaware Bay, and (*c*) NEA 1812 near the mouth of Chesapeake Bay. Suitable habitat is colored from high (dark green colors) to low (light blue colors). Shown are the southbound (Fig. 2*b*) and northbound (Fig. 2*c*) paths of the animal (grey dots and lines) as well as the 37 km (20 nautical miles) and the originally proposed 55.6 km (30 nautical miles) buffer around these two ports (blue line and red line, respectively). SMA, seasonal management area.



points in her migration (Figs. 1 and 2*a*). Because the analysis was Bayesian, uncertainty the parameters indicate a range of peak suitability as a function of distance to shore from 32 to 200 km for NEA 1812 and from 14 to 75 km for NEA 2320. Results thus indicate that the migratory corridor may be broader than originally thought (Fig. 2) (Knowlton et al. 2002).

Discussion

We estimated habitat suitability around all seasonal management areas (NOAA 2008) in relation to the new 37 km (20 nautical miles) speed restriction buffers and earlier proposed 55.6 km (30 nautical miles) buffers (NOAA 2006). Our analysis indicates that the enacted seasonal management area boundary covers only a small portion of suitable habitat. Enacting the original proposed zones over the Mid-Atlantic would protect an additional 15 453 km^2 of suitable habitat as follows: (*i*) 3849 km^2 around the southeastern United States, a 22% increase, (*ii*) 3042 km^2 around Morehead City, a 135% increase, (*iii*) 2052 km^2 around Chesapeake Bay, a 123% increase, (*iv*) 2188 km^2 around Delaware Bay, a 119% increase, and (*v*) a 1761 km^2 around New York/New Jersey, a 107% increase (see detailed views for Chesapeake Bay and Delaware Bay presented herein). We prefer the contiguous border for the seasonal management areas from Savannah to Wilmington but feel it would be improved by extending the boundary the full 30 nautical miles from shore, as it is clear that peak suitability for both whales ranges farther than 20 nautical miles.

While we do not undertake a full model selection analysis herein, the fact that there is a Pearson r correlation value of 0.45 between the covariates bears some discussion. To determine the effect this has on the analysis, we reran the model using one environmental covariate at a time, e.g., distance to future patch and depth, distance to future patch and distance to shore. For example, the estimate for the β governing depth for NEA 1812 is 0.12 (Bayesian credible interval 0.02, 0.27) with just depth in the model and 0.069 (Bayesian credible interval 0.005, 0.21) with depth and distance to shore. Results are similar for distance to shore: 0.47 (Bayesian credible interval 0.05, 1.14) with just distance to shore and 0.68 (Bayesian credible interval 0.1, 1.56) with both covariates. In both cases, the credible intervals for the single-covariate model contain the parameters estimated in the two-covariate model, thereby giving us confidence in the model formulation.

By taking a new approach to inference, we find that habitat suitability for migrating right whales extends farther offshore than previously thought (Knowlton et al. 2002). In addition, we show that the original proposed boundary of 30 nautical miles would protect more suitable habitat near ports. Future management and conservation activities should take these two findings into account. While we cannot draw too much inference from analysis of two tracks, we note the following. First, the entire population is extremely small, comprised of approximately 300–400 individuals, so two tagged reproductively active females represent a significant portion (2%) of the most valuable segment of the population (current estimate is 97 breeding females, Philip Hamilton, Edgerton Research Laboratory, New England Aquarium, Central Wharf, Boston, Massachusetts, personal communication). Previous estimates of population viability have stressed that if two females per year can be saved, the population growth will become positive (Fujiwara and Caswell 2001). Second, the migratory section of the species' range is the least understood but critical for pregnant females migrating southward from the Gulf of Maine to calving grounds and for mothers with newborn calves migrating northward to feeding grounds. Because these north- and southbound migration routes pass close to several of the largest shipping ports on the eastern seaboard, and because a substantial number of ship strike mortalities occur in this area (Knowlton et al. 2002), we argue that the speed restriction boundaries be revisited. While we are not estimating risk of ship strike, previous work has documented the successful reduction in risk of ship strike to right whales with a combination of traffic separation schemes and speed restrictions (Fonnesbeck et al. 2008; Vanderlaan et al. 2008). Incorporating the results presented here in conservation and management schemes would protect a larger portion of right whale habitat in this critical yet understudied area of their range.

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Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales

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ABSTRACT: To reduce right whale *Eubalaena glacialis* deaths caused by ship collisions along the US East Coast, a rule was implemented on 8 December 2008 requiring all vessels ≥65 feet (19.8 m) to travel 10 knots (18.5 km h^{-1}) or less in 10 seasonal management areas (SMAs). To evaluate the effectiveness of this rule, we plotted the locations of all right whale and humpback whale *Megaptera novaeangliae* carcasses attributed to ship-strikes since December 1990 in US waters to determine their proximity to SMAs. In the 18 yr pre-rule period, 13 of 15 (87 %) right whales and 12 of 26 (46 %) humpback whales killed by ships were found inside later SMA boundaries or within 45 nmi (83 km) of their perimeters during later active dates. In the first 5 yr after the rule became effective, no ship-struck right whales were found inside or within 45 nmi of any active SMA. This was nearly twice as long as the longest pre-rule period without discovery of a ship-struck carcass in those areas during effective time periods. Based on the 18 yr pre-rule period, bootstrap resampling analyses revealed that the probability of finding no ship-struck whales in or near SMAs during the first 5 yr post-rule period would be a statistically significant reduction in such deaths (p = 0.031). The results suggest the rule has been effective at reducing right whale deaths. We suggest enlarging SMAs to include additional parts of the right whale migratory corridor.

KEY WORDS: North Atlantic right whales · Humpback whales · Ship strikes · Conservation · Vessel speed limits

INTRODUCTION

The North Atlantic right whale *Eubalaena glacialis* was hunted nearly to extinction by 1000 yr of whaling that ended in the early 1900s (Reeves et al. 2007). Now one of the world's most endangered large whales (Marine Mammal Commission 2008), the species currently occurs almost exclusively over the continental shelf off the eastern USA and Canada. As of late 2013, it was estimated to number about 500 whales (www.narwc.org/papers.php?mc=3). The principal threats to its survival — vessel collisions and entanglement in fishing gear (Knowlton & Kraus 2001, Moore et al. 2004, Knowlton et al. 2012, van der Hoop et al. 2013) — are the main constraints to its recovery (Kraus et al. 2005, National Marine Fisheries Service 2005). From 1990 through 2012, more than half of all dead right whales found stranded or floating at sea (39 of 73) were attributable to ship collisions (n = 23) or entanglement (n = 16) (Knowlton & Kraus 2001, Moore et al. 2004, Marine Mammal Commission 2013). With no apparent progress in reducing entanglement deaths (Knowlton et al. 2012, van der Hoop et al. 2013), reducing vessel collisions has become even more important.

Several early studies indicated that reducing ship speed in key right whale habitats could reduce vessel-related whale deaths. Knowlton et al. (1995) modeled hydrodynamic forces around ships traveling at different speeds and concluded that objects the size and density of a whale can be pulled towards hulls and propellers of large ships with a force that increases as

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speeds increase above 10 knots. Clyne (1999) also simulated risks of collisions with vessels traveling at various speeds and found that collisions with the bow were more likely when speeds increased above 10 knots. Laist et al. (2001) examined accounts of accidental collisions with whales by vessels travelling at known speeds and concluded that lethal collisions increase sharply between speeds of 10 to 14 knots (18.5 to 15.9 km h^{-1}) and were rare at speeds below 10 knots. Based on those findings the seasonal distribution of right whales, the location of ship-struck carcasses, and input from the shipping industry, Russell et al. (2001) recommended seasonal management areas with 10 knot speed limits off major ports and in key habitats along the eastern US coast. Assuming whale deaths due to ships are strictly a function of impact force and vessel hydrodynamics, Vanderlaan & Taggart (2007) concluded that the greatest rate of change in the probability of lethal collisions was between vessel speeds of 8.6 to 15 knots (15.9 to 27.8 km h^{-1}) and that the probability of death declined by 50% at speeds of <11.8 knots (21.9 km h^{-1}).

Based largely on those findings and their own analyses, the National Marine Fisheries Service (NMFS) adopted a rule to limit vessel speeds in key US right whale habitats as part of its 'right whale ship-strike reduction strategy' (NMFS 2008a). The rule became effective on 8 December 2008 for a 5 yr period (i.e. until 8 December 2013). Although intended to protect right whales, the measure was also expected to provide some protection to humpback whales *Megaptera novaeangliae* and other large whales whose ranges overlap with those of right whales (NMFS 2008b). The rule requires all vessels 65 feet (19.8 m) or longer (also herein referred to as 'ships') to use speeds of 10 knots or less when transiting 10 Seasonal Management Areas (SMAs) along the US East Coast during periods of peak right whale occurrence (Fig. 1). The 10 SMAs comprise 6 that extend 20 nautical miles (nmi; 37 km) from shore, off major ports along the species' coastal migratory corridor between southern New England and Georgia (effective 1 November to 30 April); 3 in feeding areas off Massachusetts (i.e. Cape Cod Bay, effective 1 January to 15 May; the Great South Channel, effective 1 April to 31 July; and an area immediately east and north of Cape Cod, effective 1 March to 30 April); and 1 in the core of the species' calving grounds off the southeastern US coast of Georgia and Florida (effective 15 November to 15 April).

In addition to SMAs, the NMFS ship-strike reduction strategy included new vessel routing measures for the port of Boston in Massachusetts and 3 ports in the southeastern US right whale calving grounds, and established 2 other types of management areas: Dynamic Management Areas (DMAs) and a seasonal 'Area To Be Avoided' (ATBA). DMAs are temporary 15 d management areas established on short notice to protect aggregations of 3 or more right whales found at unpredictable locations outside of active SMAs. When DMA boundaries are announced through customary maritime communication media (e.g. voice radio and local notices to mariners) ships are asked, but not required, to limit speeds to 10 knots or to steer clear of those areas. ATBAs, established under the authority of coastal nations after approval of the International Maritime Organization, are areas where ship operators are asked, but not required, to avoid transits. Such an area off Nova Scotia, Canada, has been shown to be effective at reducing the risk of lethal vessel strikes in right whale habitats (Vanderlaan et al. 2008). The ATBA for right whale protection lies principally within the boundary of the Great South Channel SMA, east of the shipping lanes that run along that SMA's western edge (Fig. 1). The new routing measures: (1) narrowed and shifted the

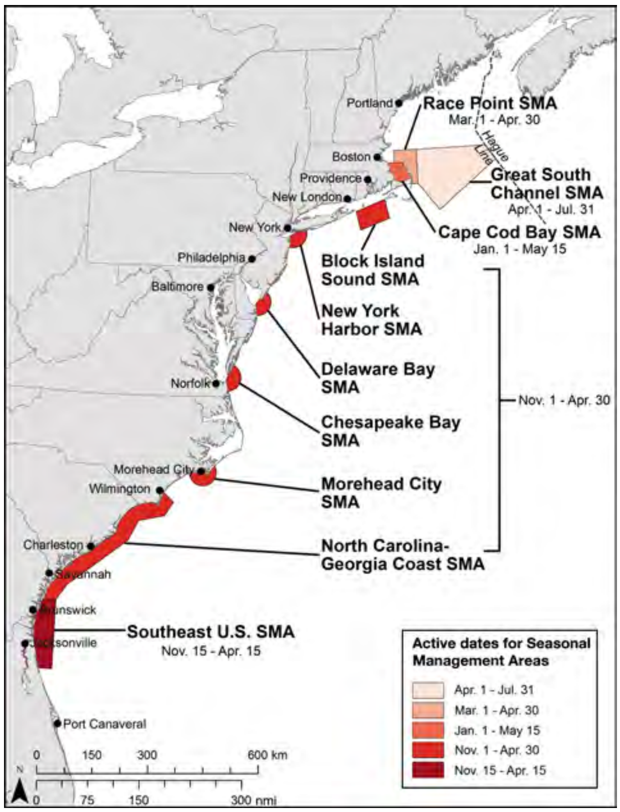

Fig. 1. *Eubalaena glacialis*. Locations and effective dates of Seasonal Management Areas (SMAs) requiring 10 knot ship speed limits after 8 December 2008 to protect North Atlantic right whales

east–west leg of track of vessel traffic separation lanes leading into Boston Harbor to reduce overlap with right whale habitat in Cape Cod Bay (Silber et al. 2012a) and (2) recommended routes through Cape Cod Bay and off the ports of Jacksonville, Fernandina, and Brunswick to minimize transit distances through areas used least intensively by right whales (Lagueux et al. 2011).

Initially proposed in June 2006 (NMFS 2006), the rule finally adopted in 2008 was subject to a protracted review by high-level officials in the US government. Concerned about its economic impacts and skeptical of the measure's effectiveness, several changes were imposed on the action preferred by the NMFS. In part, the width of SMAs along the species' migratory corridor was reduced from 30 to 20 nmi (55 to 37 km), and a sunset provision was added requiring the rule to expire 5 yr after its effective date (i.e. 8 December 2013). During the 5 yr period the NMFS was to evaluate effectiveness of the speed requirement for reducing whale deaths and decide whether to extend, modify, or allow it to lapse. Another required change was making the 10 knot speed limit in DMAs voluntary instead of mandatory. On 9 December 2013, the rule was extended indefinitely subject to further review to determine if dredged channels through SMAs should be exempted from its provisions as requested by petition (NMFS 2013).

After the 2008 rule was adopted, the NMFS developed a plan to evaluate its effectiveness (Silber & Bettridge 2009). Based on the first 3 yr of post-rule experience, the NMFS examined vessel compliance rates and economic impacts using data from an Automatic Identification System for ships (Silber & Bettridge 2012) and evaluated its biological effectiveness based on intervals between all documented collisions with large whales along the east coast 2 yr before the rules went into effect versus 2 yr afterwards (Pace 2011). From those analyses, the NMFS concluded that biological data were not yet sufficient to reach statistically meaningful conclusions, but that „…there may be 'a meager amount of evidence in support of a reduction in ship-strike deaths and serious injuries of large whales'" (Silber & Bettridge 2012, p. iv).

Several other studies have investigated compliance with the new speed restrictions in both SMAs (Silber & Bettridge 2010, Lagueux et al. 2011, Mueller et al. 2011, Wiley et al. 2011) and DMAs (Asaro 2012, Silber et al. 2012b). Initial compliance in SMAs was poor, but improved after warnings began to be issued in late 2009 and improved further after notices of violations with speed limits were issued in late 2010 (Silber & Bettridge 2012). Most ships, however, reduced their speed to varying degrees, although not necessarily to 10 knots. Compliance in DMAs was very poor. This result was similar to a voluntary request asking vessels to travel at 10 knots off Southern California to protect blue whales, which resulted in almost no change in vessel speeds (McKenna et al. 2012). Still other studies have recently provided further evidence that collision risks increase as vessel speeds increase above 10 knots due to hydrodynamic effects (Silber et al. 2010), and whale deaths are correlated with vessels traveling at increasing speeds (Conn & Silber 2013).

The reason why slow speeds are thought to reduce lethal collisions is subject to debate. Some suggest it is due solely to reduced impact and hydrodynamic forces (Vanderlaan & Taggart 2007, Vanderlaan et al. 2009, Silber et al. 2010); others suggest it provides added time for whales to avoid oncoming ships (Laist et al. 2001, Gende et al. 2011). Regardless of the mechanism and its intuitive rationale for reducing speed to reduce collision risks, the effectiveness of speed requirements remains poorly documented and is still subject to doubt by some. To further explore whether speed restrictions have been effective at reducing lethal whale collisions, we examined information on known and possible ship-strike deaths of right and humpback whales found in and near SMAs before and after the NMFS implemented its rules limiting ship speeds along the US East Coast.

Specifically, we examined the locations and discovery dates of all right whale and humpback whale carcasses attributed to ship strikes or unknown causes to determine their proximity to SMA boundaries and their occurrence relative to SMA effective dates before and after the rule went into effect on 8 December 2008. We did not include fin whales because, unlike right whales and humpback whales, they can be carried 1000s of kilometers into ports on the bows of ships making it unclear where they were struck (Laist et al. 2001). We also did not consider other large whales (i.e. sperm, blue, sei, or minke whales), because they occur infrequently in areas where SMAs have been designated and because lethal collisions with those species along the US East Coast have been rare over the past 25 yr (Laist et al. 2001). We hypothesized that the average annual tally of right whale carcasses, and possibly also humpback whale carcasses, attributable or possibly attributable to ships discovered in or near SMA boundaries during SMA time frames would be lower after the ship-strike reduction rule went into effect.

MATERIALS AND METHODS

We searched the National Marine Mammal Stranding Database maintained by the NMFS for records of all known right whale and humpback whale deaths attributed to ship strikes along the eastern US and Canadian coasts after 8 December 1990. For right whales, we also examined the Right Whale Photo-identification Catalogue maintained by the New England Aquarium for such deaths. Because the NMFS ship-strike reduction strategy is focused on US waters, our analyses of SMA effectiveness used only records of dead whales found within the US Exclusive Economic Zone. We sought records from Canada (i.e. waters north and east of the Hague Line that serves as the boundary between the US and Canadian Exclusive Economic Zones; Fig. 1), the only other area where North Atlantic right whales are known to have been killed by ships, to indicate what proportion of the ship-collision problem occurs in US waters. For right whales, our study period extended through 8 December 2013, the latest date for which records were available from the Right Whale Photo-identification Catalogue. Because of delays in entering stranding data into the national database, analyses of humpback whales extended only through 8 July 2011.

We also searched for records of all right whale deaths after 8 December 1990 that were attributed to unknown causes, because some of those whales may have been killed by ship strikes (e.g. some whales were documented floating offshore, but were not examined closely). We selected 8 December 1990 as the start of our study period because: (1) that date generally corresponds with the time when East Coast carcass recovery efforts for right whales were expanded and necropsy teams began flensing carcasses to the bone to look for internal ship-collision injuries not always apparent externally, and (2) it was statistically convenient to use the same day and month as the 8 December 2008 effective date for the NMFS rule. Data recorded for each dead whale in the national stranding database include the date, latitude and longitude, and general description of where the carcass was first seen; the cause of death, if it can be determined; the whale's decomposition state; and a summary of necropsy results (if conducted) or other findings explaining the assigned cause of death. When those data for right whales were missing, supplemental information was obtained when available from the Right Whale Photo-identification Catalogue.

Carcass locations were mapped using ArcGIS Version 10.0. SMA boundaries were added using coordinates available from the NMFS. Separate maps showing carcass discovery locations before and after the rule went into effect on 8 December 2008 were prepared for right whales killed by ships and for right whales that died of unknown causes that might have involved ship collisions. To identify carcasses of whales possibly killed by ships, we narrowed the list of carcasses attributed to unknown causes by eliminating those that were thoroughly necropsied and had no signs of ship-collision injuries. We also prepared a map for humpback whales, but only for deaths attributed to ship strikes; 275 humpback whale carcasses attributed to unknown causes were not plotted. Much less effort is made to retrieve and necropsy dead humpback whales than right whales; thus, unlike the situation for right whales, almost no records of humpback whales could be ruled out as possibly being collision related. Because of the large number of humpback whale carcasses attributed to unknown causes and the inability to exclude any that were clearly not caused by ship collisions, we concluded that for this species it would not be possible to distinguish meaningful trends relative to ship collisions and implementation of SMAs from such carcasses.

From plotted locations we identified all right whale carcasses attributed to ship strikes and to unknown causes potentially involving ship strikes found inside SMA boundaries during effective time frames before and after the ship-strike reduction rule went into effect. For all other right whale carcasses in US waters, we calculated their distance to the nearest SMA boundary. To account for carcasses that may have drifted outside SMA boundaries after whales were struck and before they were found dead, we considered any carcasses inside SMAs or within 45 nmi (74 km) of SMA boundaries during their active time frames (hereafter referred to as 'in or near active SMAs') to be potential victims of collisions inside SMA boundaries. We did the same for humpback whale carcasses, but only for those attributed to ship strikes. We then calculated the average annual number of ship-struck carcasses found in or near active SMAs for each species during the 18 yr pre-rule period and for post-rule periods of 5.0 yr (1826 d) for right whales and 2.5 yr (942 d) for humpback whales (i.e. the latest dates for which data were available).

The drift distance of 45 nmi was based on estimates of carcass degradation and drift rates. Almost all right whale deaths attributed to ship collisions in this study were found moderately decomposed (Code 3) or fresher according to the 5 category ranking system (with Code 5 representing the most degraded) used to describe carcass degradation states (Geraci & Lounsbury 2005). We estimated it would take a maximum of 6 d for a right whale carcass to become moderately decomposed. This was based on a right whale named Staccato (Catalogue No. 1014) that was photographed alive and uninjured on 15 April 1999 and next seen 5 d later floating dead off Cape Cod, Massachusetts, after being struck by a ship. Its carcass was towed ashore the day it was sighted and it was necropsied the following day (i.e. 21 April), at which time it was recorded as being moderately decomposed (i.e. Code 3). Although carcass degradation can proceed at different rates depending on temperature, because right whales along the US East Coast almost always occur in cool water similar to temperatures in Cape Cod Bay in April, we considered the April 1999 case to be the best available estimate of the time needed for a right whale to degrade to a Code 3 condition.

Average carcass drift rate was estimated from the distances of movements reported for 5 right whale carcasses seen drifting in US waters and later resighted at another location. These carcasses were first seen floating on the following dates: 3 September 2002, 6 September 2002, 7 February 2004, 27 June 2010, and 2 March 2012. Coordinates for initial and resighting locations documented drift distances of at least 77 nmi (143 km) in 22 d, 112 nmi (204 km) in 8 d, 54 nmi (100 km) in 2 d, 21 nmi (39 km) in 3 d, and 27 nmi (50 km) in 5 d, respectively, giving an average drift distance of 7.3 nmi (13.5 km) per day or 43.8 nmi (81.1 km) in 6 d, which we rounded off to 45 nmi (83.3 km) for mapping convenience. Although these records do not reflect all possible conditions that could influence carcass drift rates, they reflect at least some range of conditions in different seasons and areas and are the best available data at this time.

We conducted a bootstrap resampling analysis (Efron & Tibshirani 1993) to test the hypothesis that the average annual number of ship-struck whale carcasses found after the speed rule went into effect would be less than the average number during the 18 yr before the speed rule went into effect. This hypothesis was tested separately for right whale carcasses found in or near active SMAs and for right whale carcasses found >45 nmi from SMAs (Table 1). We did the same for ship-struck humpback whale carcasses. For right whales, annual carcass totals from the 18 yr pre-rule period were resampled one million times, with each sample consisting of a random selection of 5 annual carcass totals to match the number of years in the post-rule period. After each annual total was selected, it was returned to the pool of eligible years so that each draw in a 5 yr sample had 18 annual totals from which to select (i.e. random selection with replacement). We followed the same procedure for humpback whales, but had only 2.5 yr of post-rule data. Therefore, each bootstrap sample for humpback whales consisted of a random selection of 3 annual pre-rule carcass totals. The mean of each bootstrap sample was calculated, and those values were sorted in ascending order. The limits of the upper 95% of values were used as the confidence interval. The percentage of mean values less than the lower bound constituted the p-value.

To investigate the hypothetical probability of discovering ship-struck right whale carcasses in or near SMAs in the sixth post-rule year, we did an additional bootstrap resampling as described above, but drew 6 values instead of 5 from the pool of 18 pre-rule annual ship-strike carcass totals in or near SMAs. From those samples we calculated the probability of discovering zero whales in the first 5 yr, followed by discovering ≤1 and ≤2 carcasses in the sixth year. We considered only 0, 1, or 2 carcass discoveries because these were the only values observed in any given year during the pre-rule period and, thus, were the only values possible in the bootstrap samples.

We also compared maximum waiting times between discovery of ship-struck right whale and humpback whale carcasses found in or near active SMAs during pre- and post-rule periods to determine the extent to which intervals between recorded ship-collision deaths differed.

RESULTS

Over the entire study period, 23 of 72 confirmed right whale deaths (31.9%) were attributed to ship collisions. Three-fourths of those deaths were in US waters (17 deaths including 15 pre-rule and 2 post-rule) and one-fourth (6 deaths) were in Canadian waters (Table 1, Fig. 2). During the 18 yr pre-rule period, 10 of the 15 carcasses in US waters were inside SMAs, and 3 others were within 45 nmi of SMA boundaries (including 2 within just 6 nmi) during later SMA active dates. Together, those 13 carcasses comprised 87% of all known ship-strike deaths (Table 2) in US waters during the pre-rule period for an average carcass discovery rate of 0.72 right whales yr^{-1} in or near active SMAs.

The decomposition state of all ship-struck right whale carcasses found in or near later SMA boundaries in the pre-rule period was moderate or fresher,

Table 1. *Eubalaena glacialis*. Date and distance from Seasonal Management Areas (SMAs) of all North Atlantic right whale carcasses attributed to ship collisions along the US East Coast: 1 January 1990 to 8 December 2013, before (pre-rule) and after (post-rule) the SMA implementation on 8 December 2008. Decomposition (Decomp.) codes — 1: alive; 2: fresh; 3: moderate decomposition; 4: advanced decomposition; Unk: unknown condition; nmi: nautical mile

Date (mm/dd/yy)	Nearest SMA	Inside SMA dates?	Inside SMA boundary?	Distance from SMA (nmi/km)	Decomp. code
Pre-rule					
03/12/91[a]	Calving grounds SMA	Yes	Yes	0	3
01/05/93[a]	Calving grounds SMA	Yes	Yes	0	1
12/06/93[a]	Chesapeake Bay SMA	Yes	No	2.6/4.8	Unk
01/30/96[a]	Calving grounds SMA	Yes	Yes	0	3
03/09/96[a]	Cape Cod Bay SMA	Yes	Yes	0	Unk
04/20/99[a]	Cape Cod Bay SMA	Yes	Yes	0	3
03/17/01[a]	Delaware Bay SMA	Yes	No	36/66.7	3
06/18/01	New York Harbor SMA	No	Yes	0	3
08/22/02	Delaware Bay SMA	No	No	15.4/28.5	4
02/07/04[a]	Chesapeake Bay SMA	Yes	Yes	0	3
11/17/04[a]	Chesapeake Bay SMA	Yes	Yes	0	3
01/12/05[a]	Calving grounds SMA	Yes	Yes	0	2
04/28/05[a]	Outer Cape Cod SMA	Yes	No	5.9/10.9	3
01/10/06[a]	Calving grounds SMA	Yes	Yes	0	2
12/30/06[a]	Calving grounds SMA	Yes	Yes	0	3
Post-rule					
07/02/10	Great South Channel SMA	Yes	No	112/207	3
03/27/11	Chesapeake Bay SMA	Yes	No	47/86	4

[a]Carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames

suggesting they may have drifted up to 45 nmi between the time of death and carcass discovery. The 3 longest waiting times between finding such carcasses in the pre-rule period were 2.8 yr (i.e. 1057 d between 17 March 2001 and 7 February 2004), 2.2 yr (i.e. 785 d between 6 December 1993 and 30 January 1996), and 1.9 yr (i.e. 709 d between 30 December 2006 and 8 December 2008). Only 2 pre-rule ship strikes were found outside the potential reach of eventual SMA protection provisions; both were inside or within 45 nmi of SMA boundaries, but were discovered 7 wk or more outside later SMA active dates. During the first 5.0 post-rule years, no ship-struck right whales were found in or near any active SMAs, giving a carcass discovery rate of 0 yr^{-1}. During that period, 2 ship-struck right whales were found in US waters; both were found within the active dates of the nearest SMA, but were >45 nmi away from the nearest SMA boundary (one 47 nmi away in Code 4 condition, the other 112 nmi away in Code 3 condition).

Thirty-three right whale deaths were attributed to unknown causes over the entire study period; 29 in US waters and 4 in Canadian. Eight of the 29 in US waters were recovered in moderate to fresh condition (mostly neonates) and were ruled out as possible ship-collision victims based on necropsy results that found no evidence of collision injuries. Therefore, 25 of all mortalities attributed to unknown cause might have been due to ship strikes; 21 in US waters (14 pre-rule and 7 post-rule) and 4 in Canadian waters (Table 3, Fig. 3). During the 18 yr pre-rule period, 8 of the 14 possible ship-strike carcasses in US waters (57.1%) were found either inside (n = 5) or within 45 nmi (n = 3) of SMA boundaries during their later effective dates for an annual pre-rule discovery rate of 0.44 right whale carcasses yr^{-1} in or near active SMAs. During the first 5.0 yr after the rule's effective date, 4 of 7 carcasses (57.1%) found in US waters attributed to unknown causes that may have included ship strikes were inside (n = 1) or within 45 nmi (n = 3) of active SMAs for an average discovery rate of 0.80 carcasses yr^{-1} (Table 2).

Over the entire study period, 32 humpback whale ship-strike deaths were discovered. They were all in US waters (Table 4, Fig. 4) and included 26 during pre-rule years and 6 during the first 2.5 post-rule years. During the pre-rule period 12 of 26 ship-struck humpback whales (46%) were found inside (n = 6) or within 45 nmi (n = 6) of SMA boundaries during later SMA effective dates, giving a discovery rate of 0.66 carcasses yr^{-1} (Table 4). The longest waiting time between finding at least one such carcass in pre-rule years was 5.6 yr (i.e. 2064 d between 14 April 1992

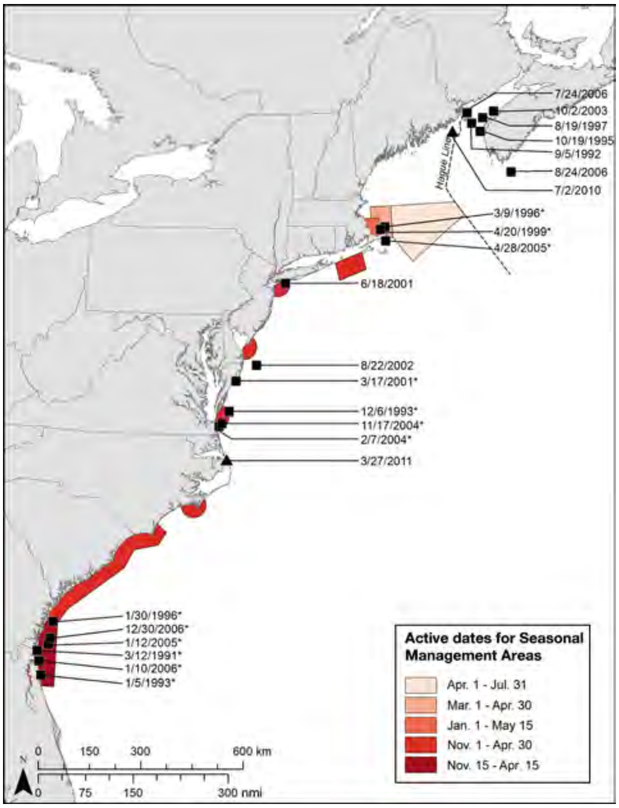

Fig. 2. *Eubalaena glacialis*. Locations and dates where all North Atlantic right whales killed by ships were found before and after Seasonal Management Areas (SMAs) were established on 8 December 2008. *: carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames; ■: carcass locations during pre-rule years, 1990 to 2008; ▲: carcass locations during post-rule years, 9 December 2008 through 8 December 2013

and 10 December 1997), 2.9 yr (i.e. 1090 d between 10 December 1997 and 4 December 2000), and 2.8 yr (i.e. 1045 d between 8 February 2002 and 19 December 2004). During the 2.5 yr (912 d) post-rule period, no ship-struck humpback whales were found inside active SMAs, but 2 were within 45 nmi of active SMAs, giving a post-rule discovery rate of 0.80 humpback whale carcasses yr^{-1}.

From our bootstrap resampling analysis, the upper 95% confidence interval around the annual pre-rule mean number of right whale ship-strike deaths in or near SMAs (0.72 carcasses yr^{-1}) was 0.2 to 2.0 (Fig. 5). As of 5.0 yr after the rule's adoption, the post-rule annual mean number of ship-strike deaths in or near SMAs was 0. The probability of a 5 yr post-rule carcass discovery rate of 0 is significantly lower ($p = 0.031$) than the pre-rule mean. An additional bootstrap resampling analysis was conducted to estimate the probabilities of finding 0, ≤1, or ≤2 carcasses in the sixth post-year rule after 5 consecutive years of no deaths. Those probabilities were estimated to be $p = 0.012$, $p = 0.024$, and $p = 0.031$, respectively.

Table 2. *Eubalaena glacialis*, *Megaptera novaeangliae*. Number of known right whale and humpback whale deaths along the US East Coast attributed to ship strikes and unknown causes, possibly including ship strikes, inside or within 45 nmi of active Seasonal Management Area (SMA) boundaries or beyond 45 nmi of SMA boundaries, before and after the SMA implementation on 8 December 2008 (i.e. 8 December 1990 through 8 December 2013 for right whales and through 8 June 2011 for humpback whales)

	Pre-rule	Post-rule
Right whales — ship strikes		
Inside or within 45 nmi of SMA boundaries	13	0
Beyond 45 nmi of nearest SMA	2	2
Right whales — unknown cause		
Inside or within 45 nmi of SMA boundaries	8	4
Beyond 45 nmi of nearest SMA	6	3
Humpback whales — ship strikes		
Inside or within 45 nmi of SMA boundaries	12	2
Beyond 45 nmi of nearest SMA	14	4

We found no other significant or borderline significant differences between pre- and post-rule carcass discovery rates. For right whales, there were no apparent differences for (1) ship-struck carcasses found >45 nmi from active SMAs ($p = 0.99$) or (2) carcasses attributed to unknown causes that might have included ship strikes either in or near active SMAs ($p = 0.92$) or beyond 45 nmi of the nearest active SMA ($p = 0.87$). For humpback whales, there was no significant difference in discovery rates for ship-struck carcasses either within or near active SMAs ($p = 0.68$) or beyond 45 nmi of the nearest active SMAs ($p = 0.85$).

DISCUSSION

Right whales

Results of this study indicate that the locations and time frames of SMAs were well-chosen to protect North Atlantic right whales from ship strikes. During the 18 yr before SMAs were implemented, 87% (13 of 15) of all right whales known to have been killed by ships in US waters were found inside or within 45 nmi of SMAs during later SMA effective dates. Indeed, most of those carcasses (i.e. 12 of 15 or 80%) were inside or within 6 nmi of SMA boundaries. It therefore appears that most right whales killed by ships before December 2008 were found in or near

Table 3. *Eubalaena glacialis*. Date and distance from Seasonal Management Areas (SMAs) of all North Atlantic right whale carcasses attributed to unknown causes, possibly including ship strikes, along the US East Coast: 1 January 1990 to 8 December 2013, before (pre-rule) and after (post-rule) the SMA implementation on 8 December 2008. Decomposition (Decomp.) codes — 1: alive; 2: fresh; 3: moderate decomposition; 4: advanced decomposition; Unk: unknown condition; NC: North Carolina; GA: Georgia

Date (mm/dd/yy)	Nearest SMA	Inside SMA dates?	Inside SMA boundary?	Distance from SMA (nmi/km)	Decomp. code
Pre-rule					
01/15/93	Calving grounds SMA	Yes	No	62/115	Unk
12/06/93[a]	Chesapeake Bay SMA	Yes	No	1.2/2.2	Unk
02/08/96[a]	Calving grounds SMA	Yes	Yes	0	4
02/19/96[a]	Calving grounds SMA	Yes	Yes	0	3
10/07/98	Chesapeake Bay SMA	No	No	8.5/15.7	4
01/19/00[a]	Block Island Sound SMA	Yes	Yes	0	Unk
01/27/01[a]	Calving grounds SMA	Yes	No	15/28	Unk
03/17/01[a]	NC-GA Coast SMA	Yes	No	3/5.6	4
06/10/02[a]	Great South Channel SMA	Yes	Yes	0	4
09/03/02	Chesapeake Bay SMA	No	No	38/70.3	3
09/06/02	Chesapeake Bay SMA	No	No	65/120.3	4
12/09/04	Great South Channel SMA	No	No	38/70.3	Unk
01/09/05	Great South Channel SMA	No	No	21/38.9	4
02/14/08[a]	Calving grounds SMA	Yes	Yes	0	4
Post-rule					
02/17/09[a]	Calving grounds SMA	Yes	Yes	0	3
02/25/09	Great South Channel SMA	No	Yes	0	3
08/18/09	New York Harbor SMA	No	No	44/81.5	4
12/19/09	Great South Channel SMA	No	No	6.1/11.3	2
02/19/11[a]	NC-GA SMA	Yes	No	34/63.0	4
03/17/11[a]	Delaware Bay SMA	Yes	No	40/74.1	3
03/02/12[a]	Race Point SMA	Yes	No	24/44.5	3

[a]Carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames

areas where SMAs were later established and also during their eventual effective dates.

The results also suggest that SMAs have effectively reduced the number of whale deaths due to ships. Average annual discovery rates of ship-struck right whale carcasses in or near active SMAs declined significantly from 0.72 to 0 carcasses yr^{-1} for at least the first 5.0 yr after the rule went into effect. This measure of reduction is likely to be conservative given that estimates of the size of the North Atlantic right whale population increased over the study period from about 295 whales in 1992 (Knowlton et al. 1994) to about 500 whales in 2013, with the addition of about 80 whales from 2008 through 2013 (New England Aquarium unpubl. data). Thus, the number of whales available to be struck has increased in post-rule years. In addition, the 5.0 yr post-rule period during which no ship-struck right whales carcass were discovered in or near any acitve SMAs is almost twice as long as the longest gap (i.e. 2.8 yr) between such discoveries during the pre-rule period.

These results are encouraging, but require a longer time period to confirm if the apparent effectiveness holds up over time. The recommended routing changes off Boston, the new recommended routes in Cape Cod Bay and the southeastern US calving grounds, and new ATBA also may have contributed to the apparent reduction in right whale ship-strike deaths by directing traffic through habitats used somewhat less frequently by whales. For example, a 58% reduction in collision risks was predicted by shifting a segment of the Boston shipping lanes (www.scimaps.org/maps/map/realigning_the_bosto_88/), and Fonnesbeck et al. (2008) predicted as much as a 44% reduction with new shipping lanes through the calving grounds. However, the new routes must still cross key right whale habitats, and no useful routing alternatives exist for mid-Atlantic ports along the right whale's coastal migratory corridor, where nearly half of all vessel-related right whale deaths have been discovered. Thus, although there should be some uncertain amount of risk reduction from new routes now in place, we believe speed restrictions are likely to be a more important factor in reducing collision risks along the US East Coast.

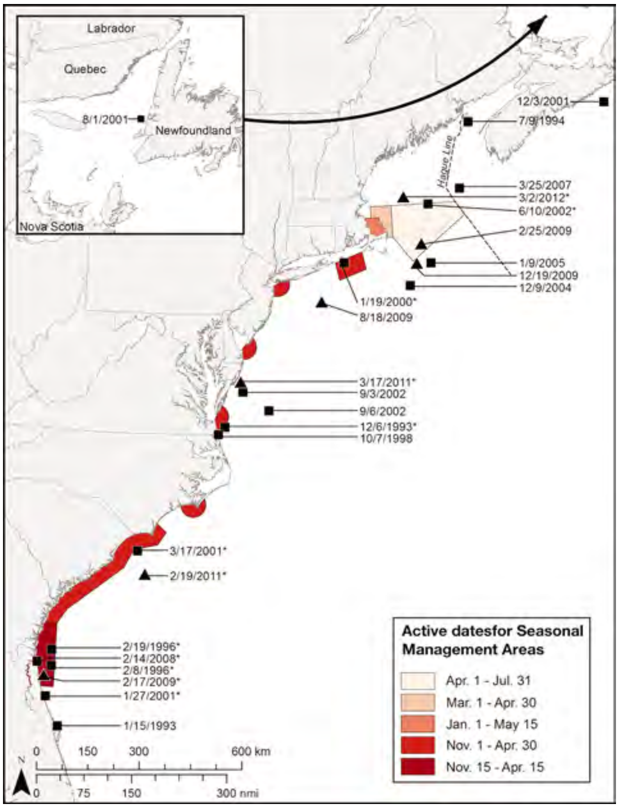

Fig. 3. *Eubalaena glacialis*. Locations and dates where all North Atlantic right whales killed by unknown causes, possibly including ship strikes, were found before and after Seasonal Management Areas (SMAs) were established on 8 December 2008. *: carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames; ■: carcass locations during pre-rule years, 1990 to 2008; ▲: carcass locations during post-rule years, 9 December 2008 through 8 December 2013

We found no indication that SMAs have reduced the number of right whale deaths attributed to unknown causes. The percentages of such deaths in or near active SMAs in the pre-rule (57.1%, 8 of 14) and post-rule (57.1%, 4 of 7) periods were identical, and the average annual carcass recovery rate actually increased from 0.44 to 0.80 carcasses yr^{-1} during the post-rule period. The most parsimonious interpretations for the increase in deaths due to unknown causes are that (1) all or most right whale deaths that may have been attributed to unknown causes but were actually due to ship strikes occurred >45 nmi from the nearest active SMA, (2) most right whale deaths attributed to unknown causes were not caused by ship collisions, and the increase reflects stochastic variability. As indicated below, an example of the first possibility may be the cluster of 4 carcasses attributed to unknown causes found in the southern Great South Channel area in winter. This is an area with high ship traffic and limited winter survey effort. The second possibility has some support from past experience. During a 4 yr period between 1993 and 1996, the annual discovery rate for right whale carcasses attributed to unknown causes in or near later active SMAs was 0.75 carcasses yr^{-1} (3 of 4 carcasses), which approaches the post-rule rate of 0.80 (Table 3).

Other studies have found little or no evidence that recent management measures have reduced vessel-related right whale deaths along the US East Coast. Analyses to date, however, have been too broad in scope, or involved time frames ill-suited for assessing effectiveness of the SMA network. For example, van der Hoop et al. (2013) found no noticeable reduction in large whale vessel- and entanglement-related deaths from 2003 through 2009 (when a number of management actions were implemented, including outreach efforts to advise mariners of collision risks), compared to earlier years. That study, however, was not designed to assess the effectiveness of site-specific measures or specifically of SMA vessel-speed restrictions. In particular, it included only 1 yr of data after SMAs were established.

Similarly, Pace (2011) found no significant reduction in ship-collision deaths after the rule went into effect. However, his analysis was based on only 2 yr of post-rule data, measured intervals between collisions involving all species of large whales (i.e. humpback, right, fin, and sei whales), considered all types of vessels (including those <65 ft in length that are not subject to regulation), and included all US and Canadian waters (including those not near SMAs). Furthermore, it did not distinguish between collisions inside versus outside SMA time frames. In contrast, our analysis focuses on those collisions most likely to have occurred within SMA boundaries, during effective dates, on the species of greatest concern (i.e. right whales), and on the vessels most likely to have been subject to management (i.e. all carcasses considered in this analysis had large wounds or contusions indicative of collisions with vessels that likely were >65 feet long). Therefore, we believe this analysis provides a more direct and useful measure of the rule's effectiveness for right whales.

Humpback whales

Our results suggest that SMAs have not provided a significant benefit for humpback whales. Whereas 87% of all ship-struck right whales were found in or near SMAs during effective dates in the pre-rule period, less than half (46%) of all such humpback

Table 4. *Megaptera novaeangliae*. Date and distance from Seasonal Management Areas (SMAs) of all humpback whale carcasses attributed to ship strikes along the US East Coast: 1 January 1990 to 8 June 2011, before (pre-rule) and after (post-rule) the SMA implementation on 8 December 2008. Decomposition (Decomp.) codes — 1: alive; 2: fresh; 3: moderate decomposition; 4: advanced decomposition; Unk: unknown condition; NC: North Carolina; GA: Georgia

Date (mm/dd/yy)	Nearest SMA	Inside SMA dates?	Inside SMA boundary?	Distance from SMA (nmi/km)	Decomp. code
Pre-rule					
11/08/91[a]	New York Harbor SMA	Yes	No	22.6/41.9	Unk
02/14/92[a]	Chesapeake Bay SMA	Yes	Yes	0	3
04/16/92[a]	Delaware Bay SMA	Yes	No	22.7/42.0	4
06/04/95	Chesapeake Bay SMA	No	No	0.1/0.2	3
05/09/96	Delaware Bay SMA	No	No	0.5/0.9	3
11/03/96[a]	Chesapeake Bay SMA	Yes	No	42.9/79.5	3
12/10/97[a]	Morehead City SMA	Yes	Yes	0	3
12/04/00[a]	Morehead City SMA	Yes	Yes	0	
01/25/01	Chesapeake Bay SMA	Yes	No	51.6/95.6	2
04/08/01[a]	NC-GA Coast SMA	Yes	Yes	0	2
07/29/01	New York Harbor SMA	No	No	6.8/12.6	3
08/18/01	Delaware Bay SMA	No	No	22.5/41.7	2
10/01/01	Cape Cod Bay SMA	No	Yes	0	3
02/08/02[a]	Chesapeake Bay SMA	Yes	No	4.8/8.9	Unk
05/30/02	Race Point SMA	No	No	51.7/95.7	3
08/01/02	New York Harbor SMA	No	No	0	4
06/06/03	Chesapeake Bay SMA	No	No	4.6/8.5	2-3
12/19/04[a]	Delaware Bay SMA	Yes	Yes	0	3
01/09/06[a]	NC-GA Coast SMA	Yes	Yes	0	3
03/17/06[a]	Chesapeake Bay SMA	Yes	No	1.5/2.8	3
09/27/06	Delaware Bay SMA	No	Yes	0	4
10/15/06	Delaware Bay SMA	No	No	6.2/11.5	4
05/10/07	Chesapeake Bay SMA	No	No	21.6/40.0	4
05/13/07	Race Point SMA	No	No	9.2/17.0	4
06/24/07	Race Point SMA	No	Yes	0	3
11/04/08[a]	Delaware Bay SMA	Yes	No	20.1/37.2	2
Post-rule					
07/27/09	New York Harbor SMA	No	Yes	0	3
03/13/10[a]	Delaware Bay SMA	Yes	No	12.8/23.7	3
06/10/10	New York Harbor SMA	No	No	0.1/0.2	3
07/04/10	Delaware Bay SMA	No	No	12.0/22.2	4
03/07/11[a]	Morehead City SMA	Yes	No	15/27.8	1
05/28/11	New York Harbor	No	No	23.9/44.3	4

[a]Carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames

whales were in or near those areas during active dates. However, it is notable that 12 of the other 15 pre-rule humpback whales killed by ships were found in or near SMA boundaries, but were outside of SMA active dates (Table 5). This pattern persisted in post-rule years when all 6 of the ship-struck humpback whale carcasses were found in or near SMA boundaries, but only 2 were within their active dates. Thus, it would seem that SMAs could be beneficial for humpback whales if their effective dates were expanded to better reflect the timing of their seasonal occurrence in SMA boundaries. The occurrence of humpback whale collisions outside of active dates is understandable given that SMA time frames were developed specifically for right whale protection.

Uncertainties in the time and location of collisions

In addition to constraints due to the small sample size of ship-struck carcasses on the statistical power of our analyses, 2 other limitations led to uncertainties: (1) the precise dates of collisions and (2) the precise locations of collisions relative to SMA dates and boundaries. Because the length of time between a collision and the discovery of collision-related carcasses is unknown and variable, there is some uncertainty about whether those whales were struck during SMA active dates. In most cases, we believe carcass discovery dates can be related with reasonable accuracy to active SMA dates. All ship-struck right whale carcasses found in or near SMAs during

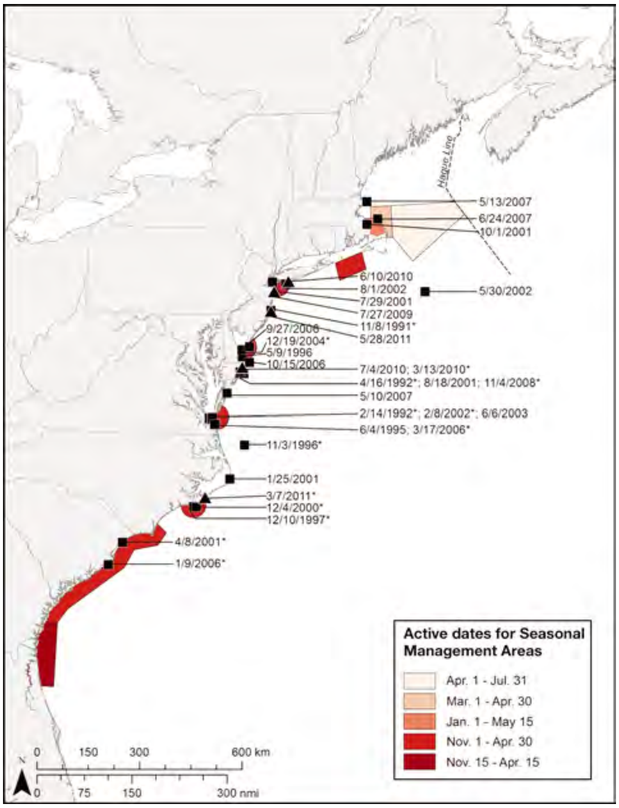

Fig. 4. *Megaptera novaeangliae*. Locations and dates where all humpback whales killed by ships were found before and after Seasonal Management Areas (SMAs) were established on 8 December 2008. *: carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames; ■: carcass locations during pre-rule years, 1990 to 2008; ▲: carcass locations during post-rule years, 9 December 2008 through 8 June 2013

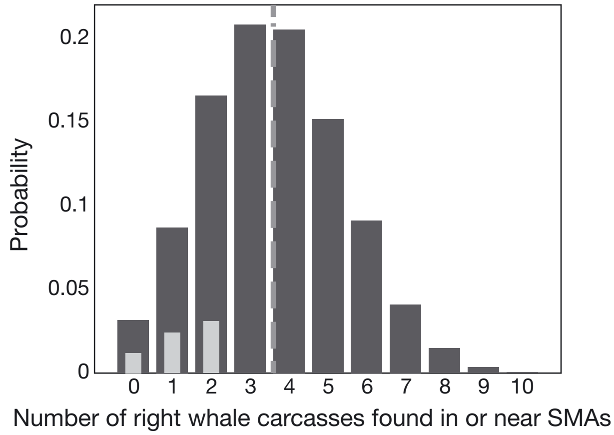

Fig. 5. *Eubalaena glacialis*. Probabilities of finding 0 to 10 right whale carcasses in or near Seasonal Management Areas (SMAs) over the 5 yr post-rule period (8 December 2008 to 8 December 2013) based on bootstrap resampling of discovery records during the 18 yr pre-rule period (8 December 1990 to 7 December 2008). Dark gray bars show probabilities of 5 yr totals assuming whales could be found in any year during the 5 yr period; light gray bars show probabilities assuming no whales were found in years 1 to 5 and 0, ≤1, or ≤2 whales were found in Year 6; gray dashed line shows the annual mean pre-rule discovery rate of 0.72 (equivalent to 3.6 carcasses over 5 yr)

pre-rule years with information on their decomposition state (i.e. 11 of 13) were moderately decomposed (Code 3) or fresher. Similarly, all but 1 ship-struck humpback whale found in or near SMAs with information on decomposition condition (7 of 8) were Code 3 or fresher. As noted above, right whale carcasses can degrade to a Code 3 condition within a week or less. Because most right whale carcasses attributed to ship strikes along the US East Coast have involved massive injuries, such as fractured skulls or vertebrae, severed tail stocks, and long, deep propeller wounds (Moore et al. 2004), it seems reasonable to assume that most victims die within a day or 2, if not hours, of being hit. By adding those pre- and post-mortem times together, it seems likely that most ship-collision deaths reported in this study occurred no more than about 7 to 8 d before the discovery dates. Only 1 ship-struck whale found in or near an SMA was found <9 d after the beginning or end dates of the nearest active SMA (i.e. a humpback whale with no information on its decomposition state was found 8 d after the start of the nearest SMA 22.6 nmi away). Thus, it seems reasonable to believe that most, if not all, carcasses considered to have been struck in or near SMAs during active SMA dates were in fact struck during those periods.

Far less clear is whether ship-strike victims found in or near SMA boundaries were in fact struck within SMA boundaries. Complicating factors include the possibility of whales swimming some distance after being struck and before they die and drift an additional distance from collision locations. Because of those possibilities, some dead whales discovered outside SMA boundaries may have been struck inside SMA boundaries and vice versa. In general, it seems unlikely that lethally struck whales would swim long distances after being hit. Even if whales do not die instantly or within a few hours, massive injuries typical of collision deaths are likely to leave them moribund or highly immobile. Transport of moribund or dead whales by wind and currents is more difficult to gauge. As noted above, resighted right whale carcasses drifted an average of 7 nmi d^{-1}, and 1 drifted 112 nmi (204 km) in 8 d, for an average of 14 nmi (26 km) d^{-1}. Thus, it is possible that some ship-struck carcasses could have drifted into SMAs from adjacent areas. Indeed, given that 5 of 8 right whale carcasses found inside SMA boundaries during pre-rule years were moderately decomposed, it would seem likely that at least some drifted 45 nmi before being found, which could have put them outside but near SMA boundaries.

A detailed analysis of carcass drift for ship-strike victims found in the past was beyond the scope of this study. To improve understanding of where ship-strike victims are actually struck relative to SMA boundaries in the future, we recommend conducting a retrospective drift analysis as a routine part of investigations for future ship-struck right whale carcasses. Where possible, estimates should be made during necropsies of the time between death and the discovery of all carcasses attributed to ship strikes. That time span should then be used to trace the possible drift path back to a predicted location at the time of death based on prevailing winds and currents over that period.

Despite uncertainty about precisely where past ship-strike victims were struck, the pattern of carcass recovery shown in Fig. 2 strongly suggests that nearly 90% of all right whale deaths attributed to ship strikes in US waters since 8 December 1990 and before the rule became effective were struck in or near SMAs during the periods in which these were in effect. The possibility that some of those whales were struck in waters adjacent to SMA boundaries underscores the importance of expanding SMA boundaries along the species' migratory corridor (i.e. from Georgia to New York) to the 30 nmi limit originally proposed by the NMFS based on its past assessment of the width of the right whale migratory corridor and relevant new information. In addition, we recommend that further studies be undertaken to better define the distances from shore that most right whales travel during their migrations in spring and fall between Georgia and New York.

SMA boundaries

With half of all known right whale deaths in US waters since 1990 due to ship strikes found along the species' migratory corridor — which is thought to extend to approximately 30 nmi from shore (Schick 2009, Keller et al. 2012) — failure to include waters between 20 and 30 nmi in SMA boundaries leaves a potentially significant gap in protection of right whales from ship collisions. Its lack of inclusion also complicates evaluations of SMA effectiveness. With current SMA boundaries along the migratory corridor set as 20 nmi arcs around port entrances, it is possible that vessels entering or leaving port may hit whales in the offshore third of the species' presumed migratory corridor (i.e. 20 to 30 nmi from shore), where speed limits do not apply. Those carcasses may drift into SMAs and be assumed incorrectly to have been struck by ships complying with speed restrictions inside an SMA. Also, because carcass detection and retrieval becomes more difficult as distance from shore increases, whales struck and killed in this offshore zone that do not drift towards shore may be underestimated.

To more rigorously protect right whales and reduce uncertainty about whether ship-strike victims are struck just beyond SMA boundaries where speed restrictions do not apply, we recommend that (1) the boundaries of the SMAs along the species' migratory corridor be extended to 30 nmi from shore, as initially proposed by the NMFS; (2) the configuration of SMAs be modified from an arc to a rectangle, with boundaries extending perpendicular from the points where current SMA perimeters intersect with land out to 30 nmi offshore, to cover a greater portion of vessel tracks across core migratory areas; and (3) SMAs be made effective indefinitely, with a view towards retaining them unless further analyses demonstrate they are ineffective or should be modified. Changing SMA boundaries along the migratory corridor from arcs to rectangles that extend 20 (or 30) nmi from shore would increase their size by about 25%. This change would increase the probability that ships entering or leaving port along routes that are not perpendicular to the coast would travel at speeds safe for whales when transiting areas where migrating whales are most likely to be encountered.

It is also interesting that several right whale deaths due to unknown causes, possibly including ship strikes, were found offshore at distances and/or at times of the year when retrieval was more difficult. In this regard, 4 of 15 right whale deaths of unknown cause were clustered in or near the southern tip of the Great South Channel SMA from December through February, when that SMA was not in effect (Fig. 2). Those deaths, which occurred at a time of year with poor weather conditions and where carcass retrieval is very difficult, lie near an area where several heavily used vessel traffic corridors intersect (Ward-Geiger et al. 2005). That area may, therefore, be an additional site where ship collision risks are high and where the designation of an SMA should be considered. In general, carcasses are less likely to be found farther offshore, because of reduced survey effort. We do not, however, believe this bias would alter our conclusions, because, with the exception of waters in the Gulf of Maine, right whale occurrence is believed to decrease in waters beyond 30 nmi from shore. In addition, those areas were not subject to regulation either before or after the rules went into effect, and thus right whale occurrence in or near SMAs should not differ in either period. The whales' distance from shore may also make it less likely they would drift into SMAs.

CONCLUSIONS

Analyses of the locations where ship-struck whale carcasses are found provide useful methods for evaluating the biological effectiveness of SMAs established to protect North Atlantic right whales. The overall pattern of carcass discovery locations shown in Fig. 2 strongly suggests that a large majority of ship-collision victims found in pre-rule years were struck by ships entering and leaving ports where the 10 SMAs were later designated and also on dates that coincided with periods in which the later SMAs were in effect. The increased waiting time between discovery of ship collisions in or near active SMAs after the December 2008 implementation (i.e. 5.0 yr as of the date of this analysis) also suggests that the seasonal 10 knot speed limit has been effective, although additional time is needed to confirm long-term trends. When the rule was adopted, it was thought it would also benefit humpback whales, but there is no evidence from this analysis that this has been true. Numerous collisions involving humpback whales were found within or near SMA boundaries, but most were not during active SMA dates.

Based on these results, speed restrictions and the existing SMAs are tools that should be kept in place indefinitely. Dredged channels passing through SMAs should not be exempted from restrictions, as requested by petition, because whales must travel across those channels and are at no less risk of being struck in those channels. The rules appear to have been effective and remain necessary to prevent ship-related right whale deaths. However, to better cover areas where right whales are at greatest risk, SMA boundaries along the right whale migratory corridor should be extended from 20 to 30 nmi from shore, as originally proposed by the NMFS. In addition, consideration should be given to: (1) changing the configuration of SMA boundaries off ports in mid-Atlantic states from arcs to rectangles, to better protect whales migrating farther offshore; (2) establishing a new winter SMA along a segment of designated shipping lanes south of the Great South Channel SMA, where 4 unretrieved right whale carcasses possibly struck by ships were found in the months of December through February; and (3) extending the dates of SMAs, to better cover times when humpback whales are likely to occur in SMA boundaries. Given the apparent effectiveness of reduced speed limits and experience indicating a lack of compliance with voluntary requests to use reduced speeds (McKenna et al. 2012, Silber et al. 2012b), we also recommend that speed limits in short-term DMA zones be made mandatory, rather than voluntary, to protect periodic right whale aggregations found outside of active SMAs. Our study provides encouraging evidence that 10 knot speed restrictions are effective for reducing vessel-related right whale deaths. Such restrictions should be considered as an option for mitigating vessel strikes of large whales in other parts of the world where this problem is considered significant.

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ATTACHMENT 12

• Whale and Dolphin Conservation • Center for Biological Diversity •
• Conservation Law Foundation • Defenders of Wildlife •
• Humane Society of the United States • Humane Society Legislative Fund •

August 6, 2020

Wilbur Ross
Secretary of Commerce
United States Department of Commerce
14th and Constitution Avenue, NW
Washington, DC 20230

Chris Oliver
Assistant Administrator for NOAA Fisheries
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910

RE: Petition for Rulemaking to Prevent Deaths and Injuries of Critically Endangered North Atlantic Right Whales from Vessel Strikes

"Preventing any additional deaths of North Atlantic right whales is our highest priority." -Chris Oliver, July 3, 2019[1]

Dear Secretary Ross and Mr. Oliver,

Despite nearly 50 years of federal protections, the North Atlantic right whale (*Eubalaena glacialis*) has not recovered. Indeed, it is considered to be one of the most endangered large whales in the world, with only around 400 individuals in the population. While the species faces a plethora of threats, collisions with marine vessels remains one of the two primary threats inhibiting the species' recovery and threatening its continued existence. Since 2017, just over half of the known or suspected causes of mortality for the species have been attributed to vessel strikes, closely followed by incidental entanglements in fishing gear.[2] Without dramatically reducing these threats, the species faces a very real prospect of extinction.

Only 10 calves were born to the population this season, and of those, two have already been killed as a result of vessel strikes. On January 8, 2020, the newborn calf of right whale #2360

[1] *Immediate Action Needed to Save North Atlantic Right Whales*, NMFS (July 3, 2019), https://www.fisheries.noaa.gov/leadership-message/immediate-action-needed-save-north-atlantic-right-whales.
[2] *2017–2020 North Atlantic Right Whale Unusual Mortality Event*, NMFS, https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2020-north-atlantic-right-whale-unusual-mortality-event (updated July 28, 2020).

was seriously injured by a passing vessel off the coast of Georgia.[3] The prognosis for survival was determined to be poor, and the calf has not been seen since January 16.[4] A second calf born this season was found dead on June 25, 2020 off the coast of New Jersey.[5] The examination of the carcass indicated that this calf had been struck twice; a non-fatal strike occurred several weeks before the collision killing the whale.[6] Given the close association between mothers and calves, adverse impacts to the mothers from these vessel strike events cannot be ruled out. This population cannot sustain further anthropogenic mortalities of reproductive females or their calves.

Regulations implementing vessel speed restrictions in specific areas and seasons along the U.S. East Coast were first promulgated in 2008 and subsequently made permanent in 2013. The initial data suggested that these measures reduced the risk of vessel strikes to the species by nearly 90 percent.[7] However, NMFS also specifically noted at the time of promulgation that it would consider: (1) "means, including through future rulemaking, to address vessel classes below 65 ft;"[8] (2) making Dynamic Management Areas mandatory if adherence to the voluntary measures were not satisfactory;[9] and (3) "modify[ing] [the size of Seasonal Management Areas], as appropriate, if changes are warranted based on shifts in right whale occurrence or additional analysis."[10] Furthermore, these data were based on the historic distribution of right whales, which has significantly changed since 2010, likely due to a changing climate impacting the location and quality of prey for the species.[11]

The unprecedented number of recent deaths and serious injuries warrants the agency acting quickly to ensure that this endangered species receives the protections necessary to reduce the risk of vessel strikes and ensure its continued existence throughout its range. The time has come for NMFS to follow through on the promises it made in 2008 to expand the ship speed rule based on the best available scientific data to address the urgent crisis the right whale faces.

Accordingly, pursuant to 5 U.S.C. § 553(e), Whale and Dolphin Conservation, the Center for Biological Diversity, Conservation Law Foundation, Defenders of Wildlife, the Humane Society of the United States, and Humane Society Legislative Fund, hereby petition the Secretary of

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[3] *North Atlantic Right Whale Calf Injured by Vessel Strike*, NMFS (Jan. 13, 2020), https://www.fisheries.noaa.gov/feature-story/north-atlantic-right-whale-calf-injured-vessel-strike.
[4] *Id*.
[5] *Dead North Atlantic Right Whale Sighted off New Jersey*, NMFS (June 29, 2020), https://www.fisheries.noaa.gov/feature-story/dead-north-atlantic-right-whale-sighted-new-jersey.
[6] *Id*.
[7] P.B. Conn et al., *Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales*, 4 ECOSPHERE 43 (2013).
[8] 73 Fed. Reg. 60,173, 60,180 (Oct. 10, 2008).
[9] *Id*.
[10] *Id.* at 60,179.
[11] *See, e.g.*, S.A. Hayes et al., *North Atlantic Right Whales - Evaluating Their Recovery Challenges in 2018*, NOAA Technical Memorandum NMFS-NE-247 (Sept. 2018) at 4 ("NMFS Right Whale Tech Memo").

Commerce, acting through NMFS, to take the additional steps necessary to protect this critically endangered species. Specifically, we request that NMFS utilize its authorities under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA) to amend the ship speed rule as follows:

- extend vessel speed restrictions to vessels under 65 feet (19.8 meters);
- require mandatory vessel speed restrictions in all Dynamic Management Areas, and strengthen the trigger for Dynamic Management Areas to include any sighting of a cow/calf pair;
- expand the Seasonal Management Area outside the ports of New York and New Jersey to 40 nautical miles, effective year-round, with dynamic vessel speed restrictions in areas of designated Traffic Separation Schemes;
- expand the Block Island Seasonal Management Area to the east, and make the Seasonal Management Area effective year-round;
- expand the Seasonal Management Area off Virginia out to 45 nautical miles;
- expand all other Mid-Atlantic and Southeast Seasonal Management Areas out to 30 nautical miles;
- combine the Off Race Point and Cape Cod Bay Seasonal Management Areas into a single management area effective January 1 through April 30; and
- maintain all other vessel speed restrictions not specifically revised as requested here[12] to prevent further mortality and injury resulting from incidental vessel strikes.

Expanding the ship speed rule as requested in this petition would provide meaningful long-term protection from one of the most significant threats to right whales, thus helping fulfill the agency's statutory obligations under the ESA and MMPA to ensure the species' survival and recovery.

Background

A. The Critically Endangered North Atlantic Right Whale

Although the North Atlantic right whale has been protected under the ESA since 1973,[13] the species has never recovered to a sustainable population level.[14] As NMFS itself has recognized, the North Atlantic right whale is "one of the world's most endangered large whale species" and

[12] *See Reducing Ship Strikes to North Atlantic right whales*, NMFS, https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales (updated June 23, 2020).
[13] Right whales were first listed as "endangered" under the Endangered Species Conservation Act in June 1970, *see* 35 Fed. Reg. 8,491, 8,495 (June 2, 1970), and subsequently, in 1973, under the ESA. *See* 50 C.F.R. § 17.11. Right whales have been listed as a "depleted" species under the MMPA since 1973, 38 Fed. Reg. 20,564, 20,570 (Aug. 1, 1973), and are also considered a "strategic" species under this statute. *See* 16 U.S.C. § 1362(19) (defining "strategic").
[14] NMFS, *Recovery Plan for the North Atlantic Right Whale* (*Eubalaena glacialis*) (Aug. 2004) ("Recovery Plan").

"has been steadily declining for nearly the past decade."[15] There are currently estimated to be fewer than 95 breeding females left in the population, and calving rates have significantly decreased in recent years.[16] A recent analysis of mortalities in the species indicates that anthropogenic trauma remains the leading, if not the only, cause of death facing North Atlantic right whales who survive their first year.[17]

Research led by NMFS scientists concluded that "anthropogenic mortality has limited the recovery" of the right whale.[18] For the last two decades, anthropogenic-linked right whale mortalities have consistently exceeded the potential biological removal (PBR) level[19] for the species. NMFS has stated there is "a 99.99% chance that abundance declined from 2011 to 2017 when the final estimate was 428 individuals."[20] Accordingly, the PBR for the North Atlantic right whale is 0.8,[21] indicating that *any* mortality or serious injury is significant for the species. Since 2017, 31 right whale deaths have been documented; another 10 right whales are likely to die or have died of serious injuries.[22] As a result of this unprecedented number of confirmed mortalities, NMFS declared an "Unusual Mortality Event" for the species, stating that "given there are only approximately 400 individual . . . whales remaining, these 41 individuals . . . represent approximately 10% of the population, which is a significant impact on such a critically endangered species."[23] Further, NMFS has determined that at least 28 percent of mortalities are not observed.[24] Thus, the actual number of dead whales since 2017 is likely to be much higher.

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[15] *10 Things You Should Know About North Atlantic Right Whales*, NMFS (Oct. 17, 2019), https://www.fisheries.noaa.gov/feature-story/10-things-you-should-know-about-north-atlantic-right-whales.

[16] *Immediate Action Needed to Save North Atlantic Right whales*, *supra* note 1; *see also Species Directory: North Atlantic Right Whale*, NMFS, https://www.fisheries.noaa.gov/species/north-atlantic-right-whale (accessed Aug. 4, 2020).

[17] S. Sharp et al., *Gross and histopathologic diagnoses from North Atlantic right whale Eubalaena glacialis mortalities between 2003 and 2018*. 135 DIS. AQUAT. ORG. 1–31 (2019).

[18] P. Corkeron et al., *The recovery of North Atlantic right whales, Eubalaena glacialis, has been constrained by human-caused mortality*, 5(11) ROYAL SOC'Y OPEN SCI. 180892 (2018).

[19] PBR "means the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population [(OSP)]." 16 U.S.C. § 1362(20). OSP "means, with respect to any population stock, the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element." *Id*. § 1362(9).

[20] NMFS, *US Atlantic and Gulf of Mexico Draft Marine Mammal Stock Assessments – 2019: North Atlantic Right Whale* (June 2020) at 20 ("2019 SAR").

[21] *Id.* at 22.

[22] *2017–2020 North Atlantic Right Whale Unusual Mortality Event*, *supra* note 2.

[23] *Id.*

[24] *See* 2019 SAR at 23 ("For North Atlantic right whales, estimates of the total mortality exceed or equal the number of detected serious injury injuries and mortalities (Figure 5) and currently 72% of mortalities since 2000 are estimated to have been observed").

In 2018, NMFS published a technical memorandum concluding that "[s]hip strikes are still a real threat to the population. At the current rate of decline, all recovery achieved in the population over the past three decades will be lost by 2029."[25] In recognition of the need for additional actions to prevent extinction, NMFS reconvened its North Atlantic Right Whale Recovery Plan Northeast U.S. Implementation Team in 2018.[26]

In 2019, NMFS declared North Atlantic right whales the ninth "Species in the Spotlight"—a dubious distinction reserved for those species "whose extinction is almost certain in the immediate future because of rapid population decline or habitat destruction, and its survival conflicts with construction, development, or economic activity."[27] In July 2019, Chris Oliver, Assistant Administrator for NOAA Fisheries, stated that "[p]reventing any additional deaths of North Atlantic right whales is our highest priority."[28]

Most recently, on July 9, 2020, the International Union for Conservation of Nature revised the status of North Atlantic right whales from endangered to critically endangered in recognition of the dire status of the species.[29] It is the only large whale species to be classified as critically endangered.

B. Vessel Strikes and the Ship Speed Rule

NMFS lists ship strikes and entanglement in commercial fishing gear as the two primary threats impeding right whale recovery.[30] Right whales are particularly vulnerable to vessel strikes because their habitat requirements and coastal migration necessitate their use of waters heavily traversed by vessels and because their feeding, resting, and socializing behavior bring them to the surface often.[31]

On October 10, 2008, NMFS promulgated a final rule implementing ship speed restrictions to reduce the threat of collisions with North Atlantic right whales.[32] The rule was initially

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[25] NMFS Right Whale Tech Memo at 1.
[26] *North Atlantic Right Whale Recovery Plan Northeast U.S. Implementation Team*, NMFS, https://www.fisheries.noaa.gov/new-england-mid-atlantic/endangered-species-conservation/north-atlantic-right-whale-recovery-plan-northeast-us-implementation-team (updated May 27, 2020).
[27] *Species in the Spotlight*, NMFS, https://www.fisheries.noaa.gov/topic/endangered-species-conservation#species-in-the-spotlight (accessed Aug. 4, 2020); *North Atlantic Right Whale: In the Spotlight*, NMFS, https://www.fisheries.noaa.gov/species/north-atlantic-right-whale#spotlight (accessed Aug. 4, 2020).
[28] *Immediate Action Needed to Save North Atlantic Right Whales*, *supra* note 1.
[29] *Almost a Third of Lemurs and North Atlantic Right Whale Now Critically Endangered – IUCN Red List*, IUCN (Jul. 9, 2020), https://www.iucn.org/news/species/202007/almost-a-third-lemurs-and-north-atlantic-right-whale-now-critically-endangered-iucn-red-list.
[30] *See, e.g.*, NMFS Right Whale Tech Memo at 1, 7.
[31] Susan Parks, *Dangerous Dining: Surface Foraging of North Atlantic Right Whales Increases Risk of Vessel Collisions*, 8:1 BIOL. LETT. 57–60 (2012).
[32] 73 Fed. Reg. at 60, 173.

promulgated with a five-year sunset clause and then made permanent in 2013.[33] The rule establishes a speed limit of 10 nautical miles per hour in certain areas at certain times of year along the U.S. eastern seaboard for all non-sovereign vessels 65 feet or greater in overall length.[34]

The current rule establishes three separate areas known as Seasonal Management Areas (SMAs) in which speed restriction apply: the Northeast, the Mid-Atlantic, and the Southeast.

- In the Northeast, the rule applies in Cape Cod Bay from January 1 through May 15; in an area identified as "Off Race Point" from March 1 through April 30; and in the Great South Channel from April 1 to July 31 to help reduce risk in the late winter and spring when right whales can be found feeding in the Northeast.[35]

- In the Mid-Atlantic, the rule applies from November 1 through April 30 in parts of Block Island Sound; within a 20-nautical-mile radius of the Ports of New York/New Jersey, Entrance to the Delaware Bay, Entrance to the Chesapeake Bay, and Ports of Morehead City and Beaufort, North Carolina; and out to 20 nautical miles along a contiguous strip between Wilmington, North Carolina and Brunswick, Georgia to help reduce risk in the migratory corridor.[36]

- In the Southeast, the rule applies in the core right whale calving area from November 15 through April 15 to reduce risk in this area.[37]

In addition, NMFS established a program of voluntary slow speed in designated Dynamic Management Areas (DMAs).[38] Under this program, DMAs of at least a three nautical mile radius are established upon the sighting of aggregations of three or more right whales in areas not already included in seasonal management zones.[39] The DMAs are temporary, lasting for 15 days with a possible 15-day extension if whales are resighted in the same area. Mariners are asked, but

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[33] 78 Fed. Reg. 73,726, 73,726 (Dec. 9, 2013).
[34] As NMFS noted in the Federal Register notice announcing promulgation of the final rule, the exemption for sovereign vessels from the mandatory speed restrictions does "not relieve Federal agencies of their obligations to consult, under section 7 of the ESA, on how their activities may affect listed species." 73 Fed. Reg. at 60,180–81; *see also* 16 U.S.C. § 1536(a)(2) ("[e]ach federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency. . . is not likely to jeopardize the continued existence of any endangered species. . . or result in the destruction or adverse modification of [critical] habitat. "). In addition to exempting any sovereign vessel, the rule also contains an exemption for situations in which traveling more than 10 nautical miles per hour is necessary due to "oceanographic, hydrographic and/or meteorological conditions." *See* 50 C.F.R. § 224.105(c).
[35] *See* 50 C.F.R. § 224.105(a)(3).
[36] *See id*. § 224.105(a)(2).
[37] *See id*. § 224.105(a)(1).
[38] 73 Fed. Reg. at 60,180.
[39] *Id*.

not required, to avoid these areas altogether or to travel through them at no more than 10 nautical miles per hour.[40]

While a reduction in serious injuries and mortalities from vessel strikes has been documented since the implementation of the ship speed rule in U.S. waters, subsequent analysis and deaths demonstrate the necessity of expanding the rule. Indeed, NMFS itself has concluded that "[r]ight whales continue to face the risk of being struck by vessels throughout their range."[41]

Even though the risk of ship strikes has declined within SMAs, it has increased outside active SMAs.[42] Numerous studies evaluating the rule recommend that the boundaries of current SMAs be expanded,[43] noting that voluntary DMAs are ineffective in reducing vessel strikes as compliance with voluntary vessel speed restrictions is poor.[44]

In fact, since 2013, when the current rule was made permanent, at least 12 right whale collisions have been documented in U.S. waters, four of which NMFS has determined are serious injuries or mortalities (Table 1). In the majority of these cases, vessels under 65 feet (19.8 meters) in length were either known to have been involved or cannot be ruled out as the source of the collision. These are in addition to the eight confirmed mortalities resulting from vessel strikes in Canadian waters since 2017.[45] Given that nearly one-third of right whale mortalities are not observed, possibly more than these 12 right whales have been seriously injured and/or killed by vessel collisions since 2013. Reported collisions alone exceed PBR for this species on a five-year average, and this threat continues to impede the recovery of right whales.[46]

It is important to note that Knowlton and Costidis (2013)[47] found that juveniles (i.e., calves to eight-years old) and females were disproportionately impacted by vessel strikes. Additionally, of the 39 cases for which the scientists could determine vessel size, 56 percent (22) involved vessels

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[40] *Id.*
[41] NMFS, *Status Report North Atlantic Right Whale (Eubalaena glacialis) 5-Year Review* (Oct. 2017) at 17 ("Five-Year Status Review").
[42] J.M. van der Hoop et al., *Vessel strikes to large whales before and after the 2008 Ship Strike Rule*, 8 CONSERV. Lett. 24−32 (2014).
[43] D.W. Laist et al., *Effectiveness of mandatory vessel speed limitations for protecting North Atlantic right whales*, 23 ENDANG. SPECIES RES. 133−47 (2014); *see also* van der Hoop et al. 2014; Sharp et al. 2019.
[44] M.J. Asaro, *Geospatial analysis of management areas implemented for protection of the North Atlantic right whale along the northern Atlantic coast of the United States*, 36 MAR. POLICY 915−921 (2012); G.K. Silber et al., *Vessel operator response to a voluntary measure for reducing collisions with whales*, ENDANG. SPECIES RES. 17: 245−254 (2012); *Vessel Speed Report in Voluntary DMA – United States*, Oceana (Mar. 6, 2020), https://usa.oceana.org/sites/default/files/13222/dma_ais_data_final.pdf.
[45] *2017–2020 North Atlantic Right Whale Unusual Mortality Event*, *supra* note 2.
[46] *Id.*
[47] A. Knowlton and A. Costidis, *A review of vessel strike wounding in North Atlantic right whales to assess frequency, wound and vessel dimensions, and lethal and sub-lethal impacts*, Final report to the Volgenau Foundation, June 28, 2013.

under 65 feet (19.8 meters) in length.

Table 1: Confirmed vessel collisions in U.S. waters since the 2013 permanent implementation of the ship speed rule.[48]

Date	ID/Name	Age Class	Location	Narrative	Vessel size	Condition
29-Jan-13	2013 Calf of 1612	C	FL	"skeg & small propeller wounds on its back"	<65'	Alive
07-Mar-13	3692	A	SC	"moderate propeller cuts"	Possible <65'	Alive
08-Apr-13	3705/Check mark	S	CCB	"Missing trailing edge of right fluke lobe"	Unknown	Alive
09-Apr-14	U	A	CCB	"Struck by 39ft vessel @ 9 kts"	39'	Prorated SI
06-May-15	3999/Braid	S	CCB	"Sighted with fresh lacerations bisecting blowholes . . . On May 3rd a 33' recreational boater reported striking a whale"*	33'	Alive
11-May-15	4545	C	CCB	"Shallow wound on back from either prop or keel"	Possible <65'	Alive
02-Sep-15	BK01MB15	C	CCB	"superficial propeller & skeg marks"**	<65'	Alive
03-May-16	4681	C	MA	"9 large/deep ventral lacerations"	>65'	Mortality
13-Apr-17	4694	S	CCB	"Deep hemorrhage and muscle tearing"	Unknown	Mortality

48 https://archive.fisheries.noaa.gov/garfo/protected/whaletrp/trt/meetings/April%202019/2000-2018_right_whale_incident_data_3_19_19v.xlsx; *Dead North Atlantic Right Whale Sighted off New Jersey*, *supra* note 5; *North Atlantic Right Whale Calf Injured by Vessel Strike*, *supra* note 3.
*H. Pettis, *Monitoring injured North Atlantic right whales*, New England Aquarium, Dec. 2015.
**WDC images and sightings indicate injuries are consistent with vessel under 65' in length. WDC unpublished data. WDC, 7 Nelson Street, Plymouth, MA 02360.
^ *North Atlantic Right Whale Calf Injured by Vessel Strike*, *supra* note 3.
^^ *Dead North Atlantic Right Whale Sighted off New Jersey*, *supra* note 5.

01-Mar-18	4145	S	CCB	"minor lacerations. . . Scar from skeg on left dorsal fluke"	Possible <65'	Alive
09-Jan-20	2020 calf of 2360	C	GA	"two roughly parallel and S-shaped injuries that experts say were consistent with the propeller of a vessel"^	Possible <65'	SI
25-Jun-20	2020 calf of 3560	C	NJ	(struck twice) "skeg and rudder"^^	Possible <65'	Mortality

Right whales are at risk of being struck by a wide range of vessels employed along the eastern seaboard, including those used in the commercial shipping industry, surveying and construction of numerous offshore wind projects, and military activities, as well as fishing boats and recreational vessels. The cumulative impact of vessel strikes poses a daunting obstacle to the species' survival and recovery. Indeed, the best available science now demonstrates that more protective regulations are necessary to ensure the survival and recovery of this imperiled species.

NMFS Must Expand the Ship Speed Rule to Comply with the ESA and MMPA

Both the ESA and MMPA mandate that NMFS protect and recover right whales. To meet these statutory mandates, NMFS must ensure that North Atlantic right whales are protected from one of the primary threats to their continued existence—vessel strikes—by expanding the areas and times in which the speed limit applies and by including vessels smaller than 65 feet in length to reduce this threat and allow the species to recover.

A. The Endangered Species Act

Enacted in 1973, the ESA is a broad statutory scheme designed to protect endangered and threatened species and conserve the habitats upon which they depend.[49] Considered "the most comprehensive legislation for the preservation of endangered species ever enacted by any nation," the ESA embodies the "plain intent of Congress . . . to halt and reverse the trend toward species extinction, whatever the cost."[50]

To that end, Section 2(c) establishes that it is the "policy of Congress that all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes [of the ESA]."[51] Similarly, Section 7(a)(1) mandates that all federal agencies, "utilize their authorities in furtherance of the purposes of [the ESA] by carrying out programs for the conservation of endangered species and threatened species."[52] The ESA defines "conserve" as "the use of all methods and procedures which are

[49] 16 U.S.C. § 1531(b).
[50] *Tenn. Valley Auth. v. Hill*, 437 U.S. 153, 180, 184 (1978).
[51] 16 U.S.C. § 1531(c)(1).
[52] *Id*. § 1536(a)(1).

necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to th[e] Act are no longer necessary."[53] "Section 7 substantially amplifies the obligation of federal agencies to take steps within their power to carry out the purposes of" the ESA.[54]

In addition, Section 4(f) specifically requires that NMFS "develop *and implement* plans (. . . referred to as 'recovery plans') for the conservation and survival of endangered species."[55] Consistent with the intent that recovery plans actually be implemented, Congress required that recovery plans "incorporate . . . a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species."[56] The Recovery Plan for the North Atlantic right whale explicitly requires NMFS "to reduce or eliminate" mortality and injuries from vessel strikes, and concludes that "rigorous and urgent action is needed to reduce these threats."[57] Thus, for NMFS to meet its mandates under Sections 2, 4, and 7 of the ESA, the agency must take additional action aimed at reducing the continuing threat of right whale injury and death from vessel strikes.

Collisions with vessels are not only impeding the recovery of the North Atlantic right whale, but the mortalities and injuries that result from such collisions are also themselves unlawful. The ESA prohibits the unauthorized "take" of an endangered species.[58] The ESA defines take to include engaging in or attempting to engage in conduct that will "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" an individual of a listed species.[59] Vessel strikes resulting in the injury or death of a right whale "take" whales in violation of Section 9 of the ESA. The ownership, operation, and authorization of vessels that take right whales have occurred, and continue to occur, without any permit from NMFS authorizing such takes. NMFS must therefore further regulate the operations of vessels within right whale habitat to eliminate these illegal takes.[60]

B. The Marine Mammal Protection Act

Similar to the ESA, the MMPA requires NMFS to "prescribe such regulations as are necessary and appropriate to carry out the purposes of [the statute]."[61] In enacting the MMPA, Congress

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53 *Id*. § 1532(3).
54 *Tenn. Valley Auth.*, 437 U.S. at 183 (citing 119 Cong. Rec. 42913 (1973)) (alterations removed).
55 16 U.S.C. § 1533(f)(1) (emphasis added).
56 *Id*. § 1533(f)(1)(B)(i).
57 Recovery Plan at II.
58 16 U.S.C. § 1538(a)(1)(B), (C).
59 *Id*. § 1532(19). NMFS defines "harm" to include "an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering." 50 C.F.R. § 222.102.
60 *See* 16 U.S.C. § 1540(f) (authorizing NMFS to "promulgate such regulations as may be appropriate to enforce" the mandates of the ESA).
61 *Id*. § 1382(a).

declared that "marine mammals have proven themselves to be resources of great international significance, esthetic and recreational as well as economic" and "that they should be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management and that the primary objective of their management should be to maintain the health and stability of the marine ecosystem."[62] The MMPA seeks to maintain stable, functioning marine ecosystems, to secure and restore healthy marine mammal populations,[63] and to protect individual animals from harm.[64]

To achieve these goals, the MMPA establishes a "moratorium on the taking" of marine mammals,[65] and specifically forbids "any person . . . or any vessel or other conveyance subject to the jurisdiction of the United States to take any marine mammal on the high seas;" "any person or vessel or other conveyance to take any marine mammal in waters or on lands under the jurisdiction of the United States;" and any person from "us[ing] any port, harbor, or other place under the jurisdiction of the United States to take or import marine mammals or marine mammal products."[66] The statute broadly defines take to mean "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal."[67]

Vessel strikes resulting in the injury, death, or harassment of a right whale are clearly "taking" whales in violation of the MMPA. Moreover, the take via mortality or serious injury of even one right whale by a vessel collision exceeds PBR and will, by definition, impede recovery and preclude the species from reaching OSP. Therefore, the MMPA clearly provides the mandate for NMFS to establish additional regulatory measures designed to reduce the threat of vessel strikes within right whale habitat and thereby effectuate the purpose of the statute.[68]

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[62] *Id.* § 1361(6).
[63] *Id*. § 1361(2).
[64] *See e.g.*, *id*. § 1362(18)(A) (defining "harassment" to include acts that affect "*a* marine mammal or marine mammal stock in the wild") (emphasis added); *id.* § 1372(b) (requiring that authorized take of a marine mammal be humane); *Animal Welfare Institute v. Kreps*, 561 F.2d 1002, 1007 (D.C. Cir. 1977) ("the MMPA is an unusual statute . . . motivated by considerations of humaneness toward animals, who are uniquely incapable of defending their own interests").
[65] 16 U.S.C. § 1371(a).
[66] *Id*. § 1372(a).
[67] *Id*. § 1362(13) (emphasis added); *see also id*. § 1362(18)(A) (definition of "harassment").
[68] Indeed, in enacting the MMPA, Congress specifically recognized that the statute would provide the much-needed means for regulating vessels that harm marine mammals. *See* 1972 H.R. Rep. No. 92-707 (1972), reprinted in 1972 U.S.C.C.A.N. 4144, 4147–4150 (stating that "the operation of powerboats in areas where the manatees are found" posed a threat to manatees and, without the MMPA, "the Federal government is essentially powerless to force these boats to slow down or curtail their operations." The MMPA "would provide the Secretary of the Interior with adequate authority to regulate or even forbid the use of powerboats in waters where manatees are found.").

The Petitioned Action is Necessary for the Conservation and Recovery of North Atlantic Right Whales as Required by the ESA and MMPA

NMFS promulgated the ship speed rule to "reduce the occurrence and severity of vessel collisions with North Atlantic right whales," thereby contributing to the preservation and recovery of the species "while minimizing adverse impacts on ship operations."[69] NMFS stated that it intended to conduct periodic reviews of the rule and consider modifications based on its assessments.[70] As noted above, NMFS stated in 2008 that it would reconsider the provisions of its ship strike rule should it become clear that smaller vessels warranted regulation, DMAs needed to be mandatory, or SMAs required revision. These conditions have been met. Indeed, myriad recent data and studies clearly demonstrate that NMFS must maintain the 10 nautical mile per hour speed limit and expand the rule's reach.

Based upon all of the above, we hereby petition NMFS to:

- extend vessel speed restrictions to vessels under 65 feet (19.8 meters);
- require mandatory vessel speed restrictions in all DMAs and strengthen the trigger for DMAs to include any sighting of a cow/calf pair;
- expand the SMAs outside the ports of New York and New Jersey to 40 nautical miles, effective year-round, with dynamic vessel speed restrictions in areas of designated Traffic Separation Schemes;
- expand the Block Island SMA to the east and make the SMA effective year-round;
- expand the SMA off Virginia out to 45 nautical miles;
- expand all other Mid-Atlantic and Southeast SMAs out to 30 nautical miles;
- combine the Off Race Point and Cape Cod Bay SMAs into a single management area effective January 1 through April 30; and
- maintain all other vessel speed restrictions not specifically revised as requested here[71] to prevent further mortality and injury resulting from incidental vessel strikes.

These measures are necessary to reduce the risk of vessel strikes to North Atlantic right whales and promote the conservation and recovery of this critically endangered species, as required by the ESA and MMPA. Consistent with the letter and purpose of the ESA and MMPA, any new vessel speed restrictions should not contain a sunset provision.[72]

A. Extend the Vessel Speed Restrictions to Vessels Under 65 Feet (19.8 Meters) in Length

NMFS has acknowledged "that vessels less than 65 ft (19.8 m) may pose a threat to right

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[69] 73 Fed. Reg. at 60,174; *see also id*. at 60,182 ("[t]he goal [of the ship speed rule] is to reduce or eliminate the threat of ship strikes . . . in the endangered population").
[70] 78 Fed. Reg. 73,726, 73,732 (Dec. 9, 2013).
[71] *See Reducing Ship Strikes to North Atlantic right whales*, *supra* note 12.
[72] Nor should the rule include any exemptions for federally maintained dredged channels or any other areas. An exemption would pose an increased and unnecessary risk to critically endangered North Atlantic right whales and would not provide any additional safety benefit to pilots, who are already allowed to deviate from the rule based on legitimate safety concerns.

whales."[73] In fact, NMFS's Large Whale Ship Strike Database reveals that blood was seen in the water in at least half of the cases where a vessel known to be less than 65 feet in length struck a whale.[74] This is likely an underestimate of the magnitude of the threat, as small vessel collisions with whales are underreported.[75] Indeed, since 2013 there have been at least eight right whales struck and injured by vessels confirmed or suspected to be under 65 feet in length in U.S. waters (Table 1).

Small vessels striking right whales also pose a significant risk to human safety. Small vessels involved in whale strikes have suffered cracked hulls, damage to propellers and rudders, and blown engines.[76] Passengers have been knocked off their feet or thrown from the boat upon impact with a whale. In one example, a 30-foot vessel that struck a right whale on March 31, 2009 resulted in a passenger being thrown into the air and landing in the cockpit.[77] The damage to the vessel itself was significant and resulted in a response by the U.S. Coast Guard to rescue the passengers.[78]

Given the risk to whales, NMFS must extend the current speed restrictions to vessels under 65 feet (19.8 meters) in length. As NMFS considers exactly what length is appropriate below 65 feet, we urge the agency to examine documented strikes as well as the makeup of the fleet that operates in established and emerging right whale habitats.

B. Make Compliance with Dynamic Management Areas Mandatory

NMFS should make compliance with DMAs mandatory. The agency's 2012 analysis of the ship speed rule found "that DMAs, as measured by mariner response to the voluntary measure, likely had only modest, if any, consequence in lowering the risk of vessel collisions with right whales."[79] The analysis noted "that the lack of adherence to the DMAs was due more to their voluntary nature than to a lack of awareness of the management zones."[80] Moreover, the analysis also concluded that studies of the location, number, and timing of DMAs demonstrate that "a relatively large number of DMAs have occurred regularly in certain locations in waters off New England" and "that to include a large number of right whale observations that have occurred incidentally outside SMAs" NMFS should consider "*either expanding the sizes of the SMAs to*

[73] 73 Fed. Reg. at 60,180.
[74] A.S. Jensen and G.K. Silber, *Large Whale Ship Strike Database*, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-OPR-25 (Jan. 2004) at 12–37.
[75] A.N. Hill et al., *Vessel collision injuries on live humpback whales, Megaptera novaeangliae, in the southern Gulf of Maine*, 33 MARINE MAMMAL SCI. 558–573 (2017).
[76] *See, e.g.*, *Large Whale Ship Strike Database*, *supra* note 71 at 4–5.
[77] Bigfish123, Comment to *Collision at Sea*, The Hull Truth (May 1, 2009, 5:44 am), http://www.thehulltruth.com/boating-forum/222026-collision-sea.html.
[78] *Id.*
[79] G. K. Silber and S. Bettridge, *An Assessment of the Final Rule to Implement Vessel Speed Restrictions to Reduce the Threat of Vessel Collisions with North Atlantic Right Whales*, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-OPR-48 (Feb. 2012) at 36 ("2012 Ship Speed Rule Analysis").
[80] *Id.* at 38.

encompass a large portion, if not all, of the recurring DMAs, or to establishing new SMAs."[81]

More recent information corroborates these findings. For example, NMFS's 2017 Right Whale Status Report notes "that compliance with the voluntary speed restrictions within DMAs was poor, with vessels showing a very modest reduction in speed that was unlikely to reduce ship strike risk significantly."[82] A 2019 case study conducted by NMFS scientists of DMAs in place from November 2018 through April 2019 off New York found a "lack of detectable change in ships' speed despite direct communication to operators," leading the scientists to conclude "that conservation measures without consequence were not effective."[83] In addition, a 2020 analysis found that more than 41 percent of vessels transiting a DMA south of Nantucket traveled in speeds in excess of 10 knots, with ship speeds exceeding 22 knots reported.[84]

The time has come to promulgate an updated ship speed rule that will address the lack of compliance identified in NMFS's 2012 review as well as more recent studies demonstrating that compliance with voluntary measures remains poor. To address the risk of vessel strikes in areas where right whales are present outside of SMAs, we request that NMFS make compliance with DMAs mandatory.[85]

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[81] *Id*. at 42 (emphasis in original). NMFS currently establishes the location of DMAs by surveying right whale habitat primarily through aerial surveys. 73 Fed. Reg. at 60,180; 2012 Ship Speed Rule Analysis at 33. However, NMFS's ability to conduct such surveys is dependent on adequate funding and good weather, which can substantially frustrate NMFS's ability to establish DMAs. Thus, the need to establish SMAs in areas of recurring DMAs is even more apparent.

[82] Five-Year Status Review at 18.

[83] T. Cole et al., *Ships do not comply with voluntary whale protection measures in Northeast USA waters*, Presentation at the 2019 World Marine Mammal Conference, Barcelona, Dec. 2019, available at https://www.wmmconference.org/wp-content/uploads/2020/02/WMMC-Book-of-Abstracts-3.pdf.

[84] *E.g.*, *Oceana Exposes Ships Ignoring Voluntary Speed Zone Designed to Protect Endangered Right Whales*, Oceana (Mar. 20, 2020), https://usa.oceana.org/press-releases/oceana-exposes-ships-ignoring-voluntary-speed-zone-designed-protect-endangered-right.

[85] While NMFS's analysis of the ship speed rule found low compliance with the voluntary measures suggested in designated DMAs, voluntary DMAs did serve an ancillary purpose of raising industry awareness in specific areas where North Atlantic right whales have been sighted. Indeed, NMFS's 2012 Ship Speed Rule Analysis noted that "the DMA program may have had some tacit benefit in raising the awareness of mariners to the problem of right whale vulnerability to ship strikes." 2012 Ship Speed Rule Analysis at 35. Moreover, a survey of mariners in the southeast found that 91 percent plotted whale sighting information on charts for voyage planning purposes and 89 percent said they alerted bridge teams to be on the lookout. NMFS SEIT, Unpublished Data, Mariner Survey. Though many indicated that data more than 24 hours old was less useful, 62 percent still indicated that they would plot the information and 58 percent would alert bridge teams and lookouts. *Id.* Thus, should NMFS choose to deny our request that compliance with DMAs be made mandatory, we request that it maintain the voluntary DMA program.

Additionally, we note that the two most recent vessel strike mortalities involved dependent calves and that no voluntary vessel speed reduction areas were triggered under current DMA regulations. These tragic events demonstrate that a sighting of three or more North Atlantic right whales is too high of a bar to trigger a DMA. Accordingly, we request that NMFS include any sightings of a cow-calf pair as a trigger for a DMA. NMFS should otherwise retain the current regulatory structure for how DMAs are triggered.

C. Extend the Seasonal Management Area Outside of the Ports of New York/New Jersey Spatially and Temporally and Create Dynamic Vessel Speed Restrictions in the Designated Traffic Separation Schemes

It is well documented that right whales have shifted their geographic range due to climate change.[86] Prior to the shift, the species migrated seasonally to forage in the western Gulf of Maine in the winter and spring and in the eastern Gulf of Maine and Scotian Shelf in the summer and autumn. However, since 2010, the species has increasingly used the waters south of Cape Cod and east of the New York port entrance year-round.

Multiple lines of evidence—including sighting information, acoustic detections, stranding data, and a series of DMAs declared by NMFS in response to whale sightings pursuant to the ship speed rule—demonstrate that right whales rely heavily on this area. Between 2016 and 2019, right whales were detected in the area in all months of the year; NMFS declared multiple DMAs in this area during most months of the year, confirming that current seasonal measures do not adequately address the risk of vessel strikes in this area (Figure 1).

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[86] *See, e.g.*, N. Record et al., *Rapid Climate-Driven Circulation Changes Threaten Conservation of Endangered North Atlantic Right Whales*, 32:2 OCEANOGRAPHY 162–69 (2019).

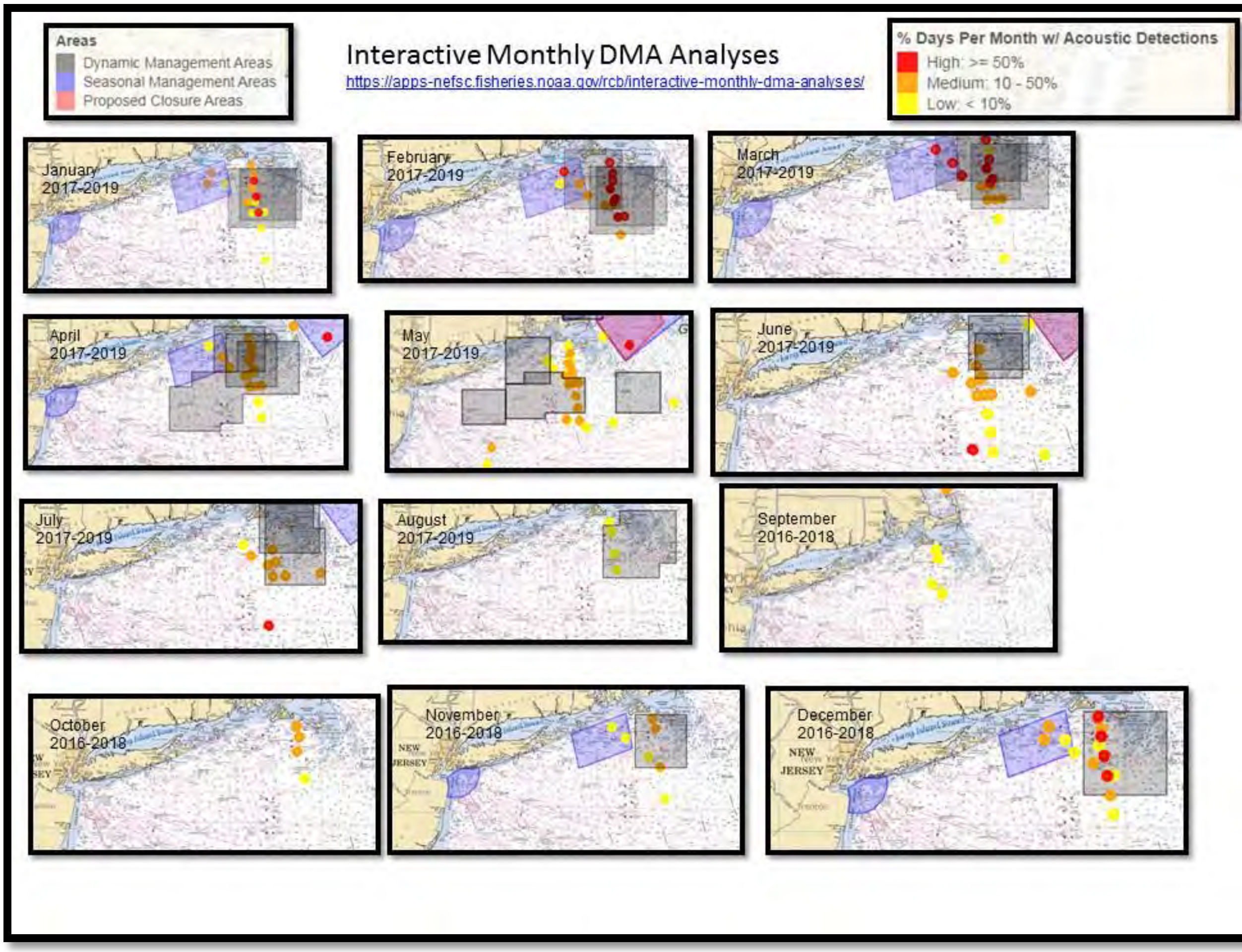

Figure 1. (*Interactive Monthly DMA Analysis*, NMFS, https://apps-nefsc.fisheries.noaa.gov/psb/surveys/interactive-monthly-dma-analyses/)

In our view, the current SMAs in the region are inadequate (Figure 2) and we propose that NMFS expand the SMA off New York spatially and temporally as well as establishing dynamic speed zones in the Traffic Separation Scheme from New York to the region east of Cape Cod (Figure 3). This proposal is corroborated by sightings data indicating that right whales are increasingly found in, or in close proximity to, the New York Traffic Separation Scheme and are therefore at a high risk of vessel strike in this region (Figures 3–6).

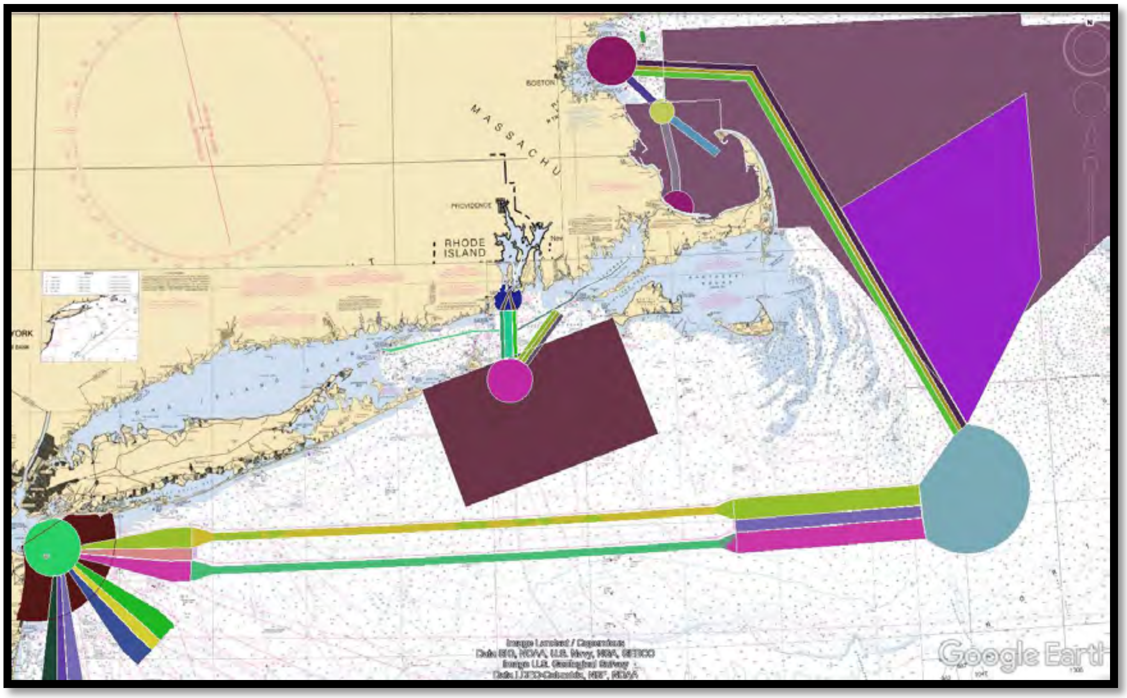

Figure 2. Current SMAs in New York, Block Island, Off Race Point, and GSC

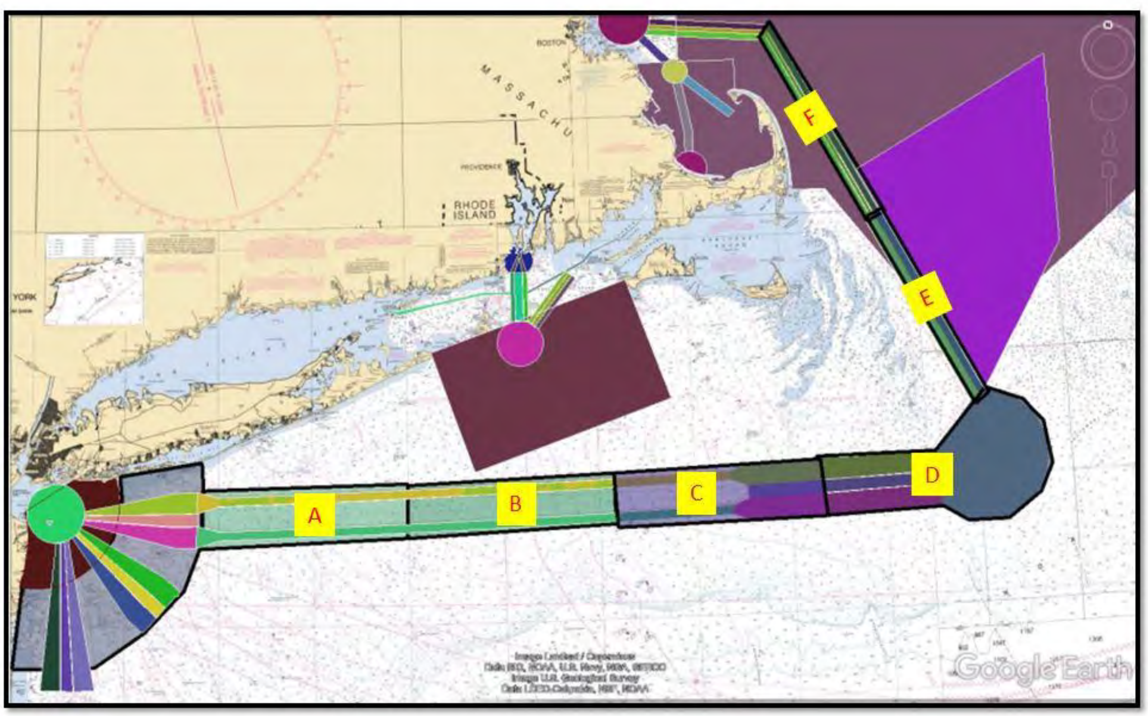

Figure 3. Representation of Petitioners' Requests

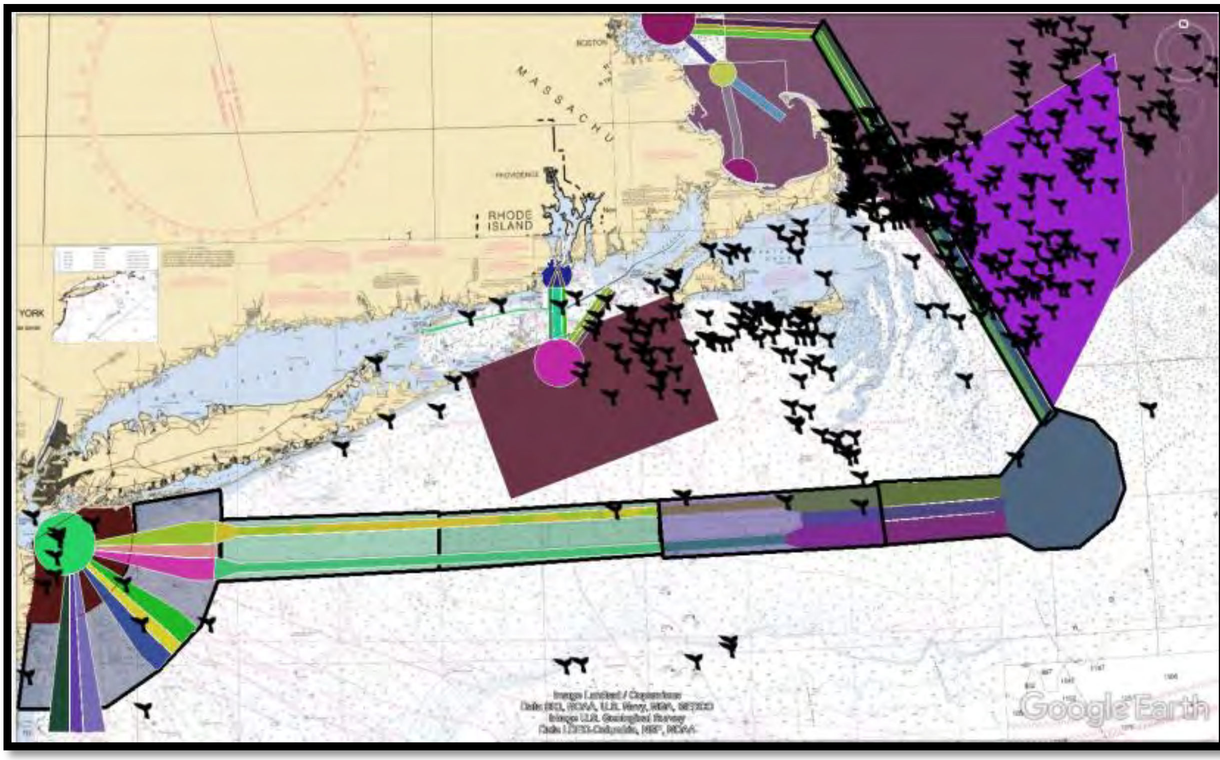

Figure 4. Right whale sightings 2010–2014 (NOAA SAS Data) imposed over Petitioners' Requests

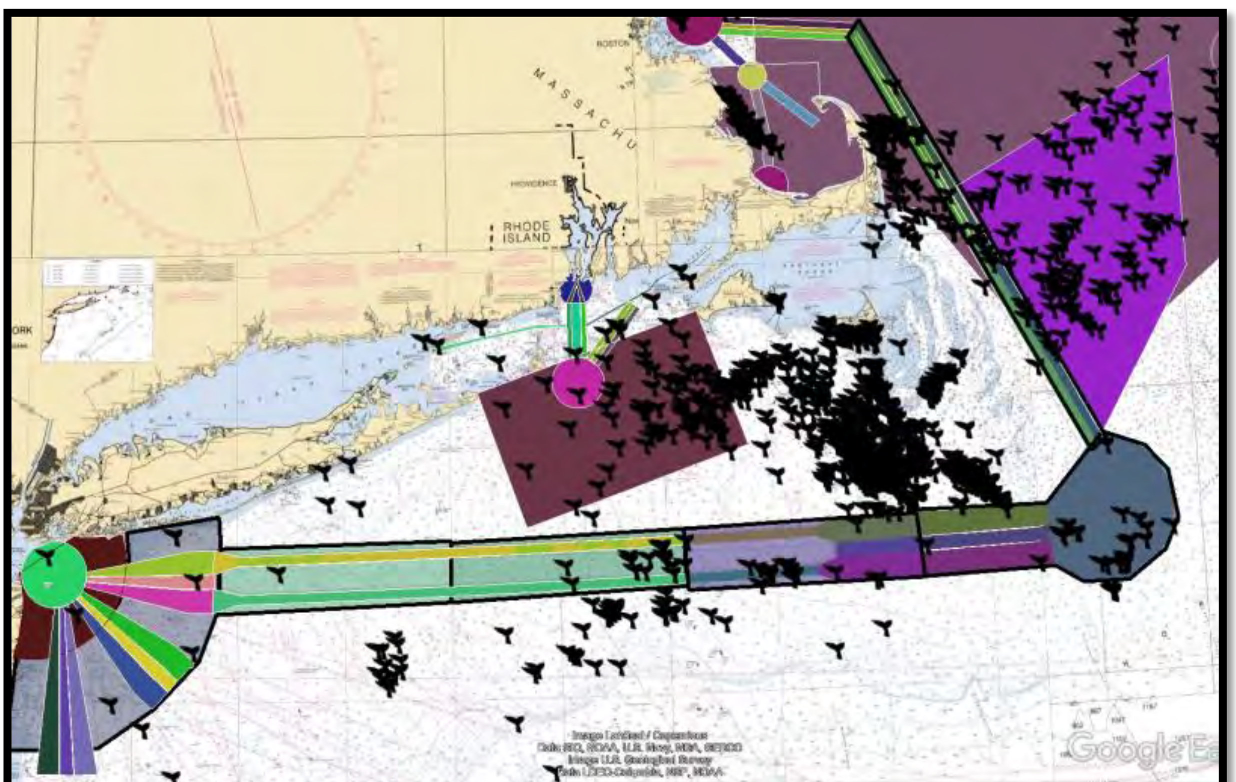

Figure 5. Right whale sightings 2015–2020 (NOAA SAS Data)

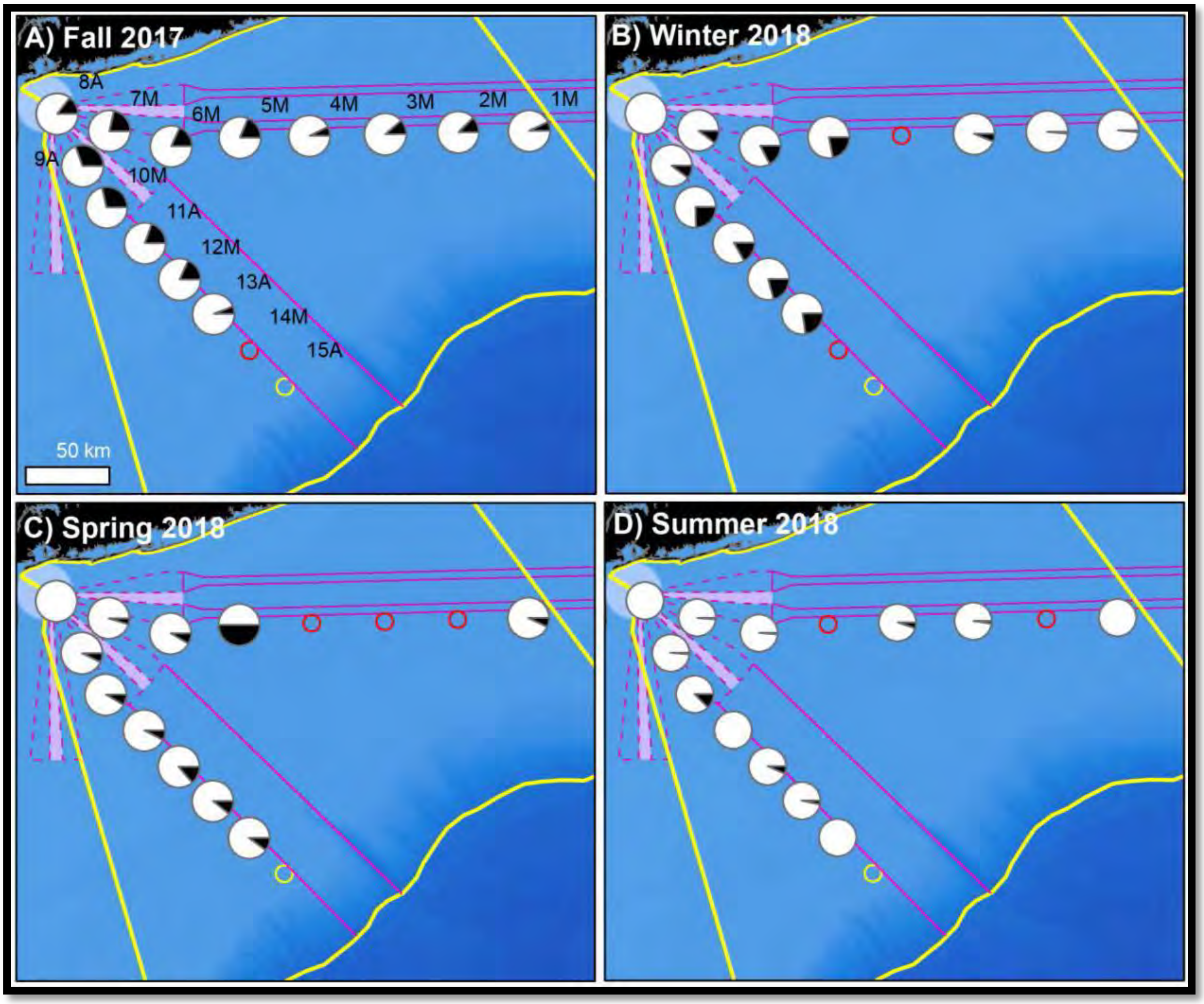

Figure 6. Spatial patterns of seasonal acoustic presence of North Atlantic right whale upcalls in New York Bight, shown as percentage of days per season on each recording unit. Black indicates the proportion of presence; white indicates no detections. A) Fall (October – December), B) Winter (January – March), C) Spring (April – June), and D) Summer (July – September). Hollow circles denote AMAR (in yellow) and MARU (in red) site locations in which there are no data for that season. (NY Department of Environmental Conservation, *Year-1 Annual Survey Report for New York Bight Whale Monitoring Passive Acoustic Surveys: October 2017 – October 2018* (2019), *available at* https://www.dec.ny.gov/docs/fish_marine_pdf/dmrnybacousticone(1).pdf)

Accordingly, we request that NMFS extend the vessel speed restrictions outside the New York SMA to 40 nautical miles, rather than the current distance of 20 nautical miles, and make the SMA effective year-round. We also request that mandatory speed restriction zones of approximately 50 nautical miles in length be established in the shipping lanes requiring vessels to slow to 10 knots or less when triggered by either acoustic or visual detections within the Traffic Separation Scheme, including the buffer between lanes, of one right whale (see Figure 3). The speed restrictions should be in place for at least 15 days after a detection is documented.

D. Expand the Block Island Seasonal Management Area to the East and Make the Seasonal Management Area Effective Year-Round

As noted in Figures 1 and 5, right whale visual and acoustical detections are increasingly documented in the area south of Martha's Vineyard and Nantucket. A significant portion of these detections are east of the current Block Island SMA (depicted in green in Figure 7). Also, as previously noted, right whales are increasingly using this region as a year-round habitat.

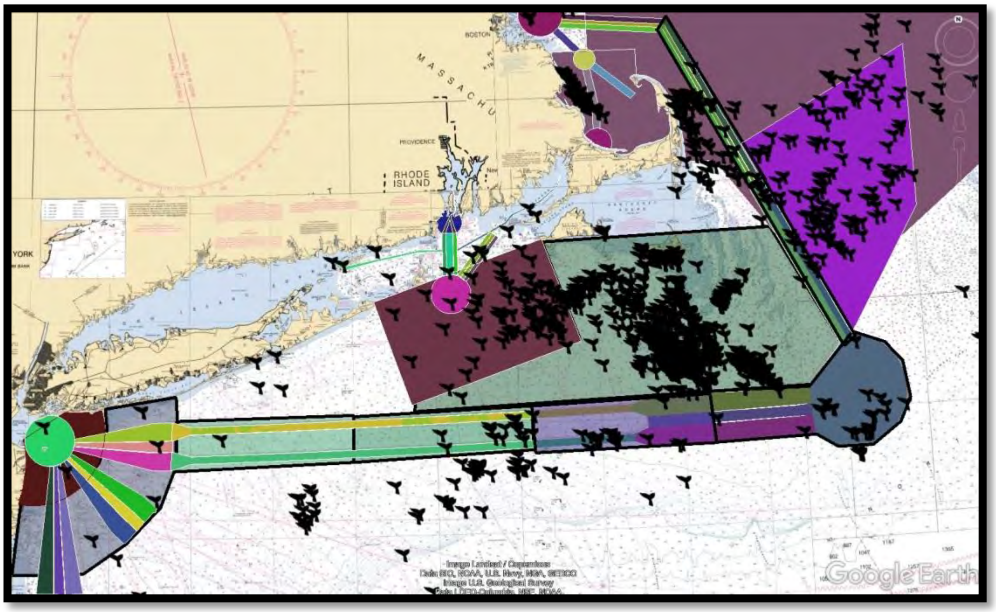

Figure 7. Representation of Petitioners' Request, right whale sightings 2015–2020 (NOAA SAS Data)

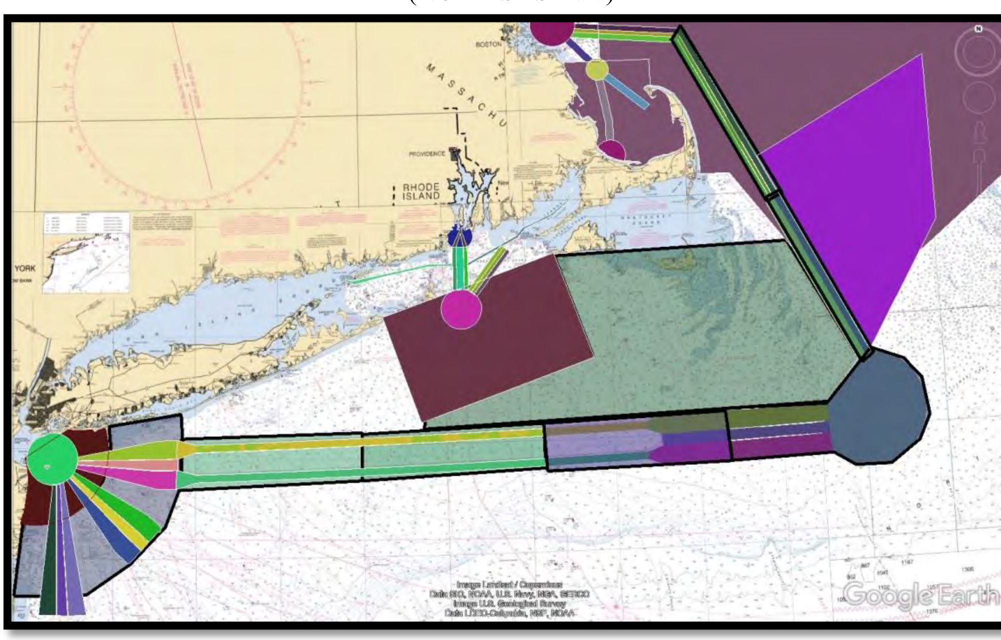

Figure 8. Representation of Petitioners' Request

Accordingly, we request that NMFS extend the Block Island SMA to the east to meet the boundaries of the corresponding Traffic Separation Scheme to the south and east and enact this as a year-round speed restricted area (as shown in Figure 8).

E. Expand the Seasonal Management Area off Virginia out to 45 Nautical Miles

The port of Virginia has consistently been ranked one of the busiest ports in the United States, and after the most recent dredging project is completed, it will be the deepest port on the East Coast.[87] Two of the Mid-Atlantic's largest wind projects are located off the coast of Virginia and the Outer Banks of North Carolina, which will likely increase vessel traffic in this area during the construction and operation phases.

While visual survey effort to detect right whales is limited in this area, passive acoustic monitoring has detected right whales in all months of the year off the coast of Virginia with a peak between November and April.[88] This habitat appears to serve as more than just a migratory corridor and may be a foraging habitat for right whales. NMFS's Northeast Fisheries Science Center's own plankton data indicate that *Centropeges spp.* aggregations form off the coast of Virginia in the winter (Figure 9).

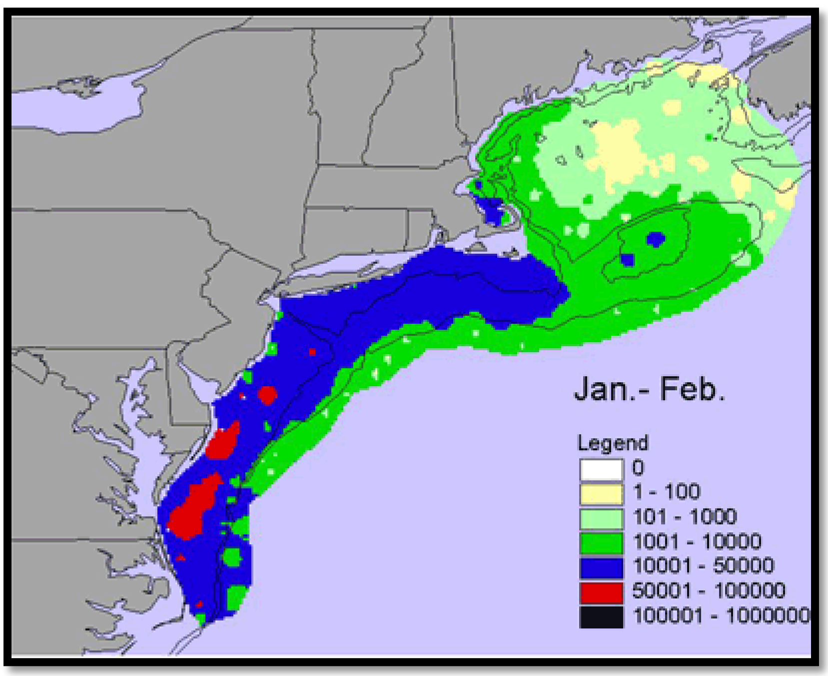

Figure 9. Distribution of *Centropages typicus* (*Ecology of the Northeast US Continental Shelf*, NMFS (July 16, 2018), https://www.nefsc.noaa.gov/ecosys/ecosystem-ecology/zooplankton.html)

[87] Patricia Kirk, *East Coast Ports May Benefit from Tariffs on Chinese Imports*, National Real Estate Investor (June 1, 2018), https://www.nreionline.com/industrial/east-coast-ports-may-benefit-tariffs-chinese-imports.
[88] Bureau of Ocean Energy Management, *Understanding Marine Mammal Presence in the Virginia Offshore Wind Energy Area*, OCS-BOEM Study 2019-007 (Sept. 2018), *available at* https://espis.boem.gov/final%20reports/BOEM_2019-007.pdf.

As a result, we request that NMFS extend the current SMA off Virginia an additional 25 miles (Figure 10). While this extension does not capture the entire habitat likely used by right whales in this area, it covers the area where vessel traffic is heaviest and risk of vessel strike is highest.

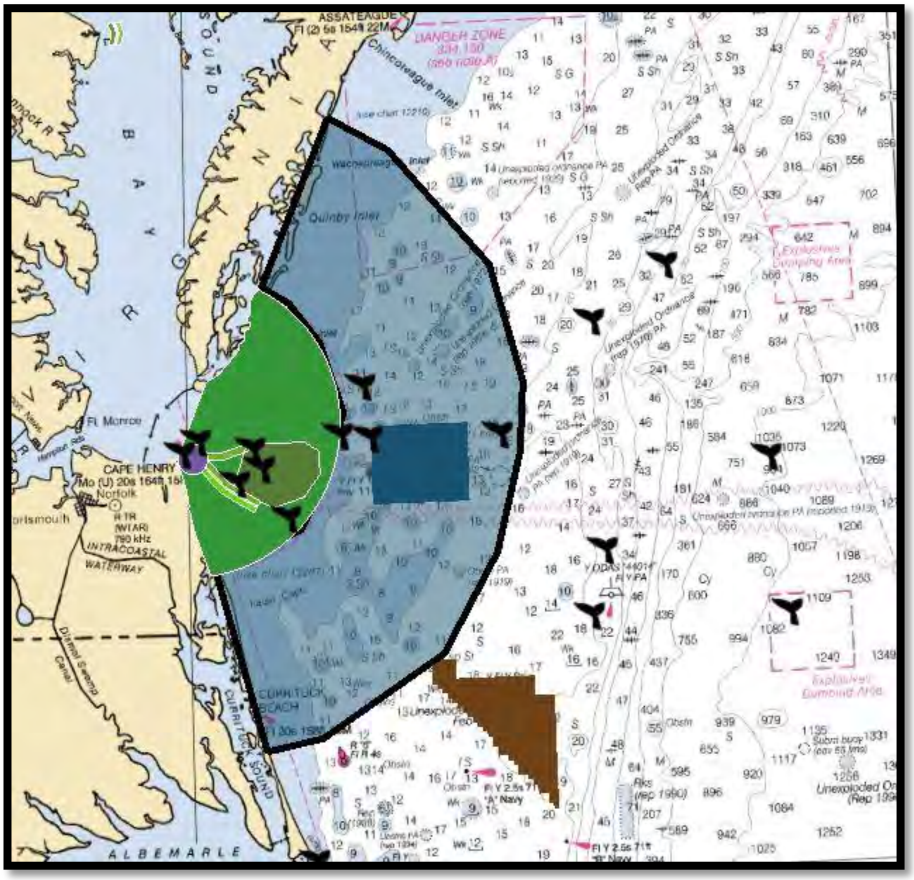

Figure 10. Representation of Petitioners' Request

F. Expand All Other Mid-Atlantic and Southeast Seasonal Management Areas Out to 30 Nautical Miles from Shore

Currently the SMAs in the Mid-Atlantic and Southeast extend out to 20 nautical miles from shore. In the 2006 proposed ship speed rule and accompanying environmental analysis, NMFS proposed instituting a radial buffer around ports from Block Island to Savannah, Georgia that would extend out to 30 nautical miles from shore, but ultimately chose not to do so in the final rule to reduce the economic burden on industry.[89] NMFS's original proposal was consistent with the best available scientific literature at the time, which demonstrated that 94 percent of right whales are sighted within the 30 nautical mile buffer.[90] Since that time, additional studies, representing the best available science, have shown that this distance is the *minimally protective*

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[89] *See* 73 Fed. Reg. at 60,179.

[90] A.J. Knowlton et al., *Right Whale Sightings and Survey Effort in the Mid- Atlantic Region: Migratory Corridor, Time Frame and Proximity to Port Entrances* (July 2002).

distance, and that there is evidence that right whales can be found even further offshore when migrating.

In fact, NMFS's 2012 analysis states that:

> Schick *et al*., 2009 concluded that hypothetical SMAs that extended to 30 nm from shore and around port entrances would provide more protection for migrating right whales than do the existing SMAs with 20 nm radii. Such studies and other sources, such as an evaluation of right whale sighting information obtained since implementation of the rule should be important assets in making determinations of the locations, timing, and size of SMAs . . . in future rulemaking.[91]

Similarly, a 2014 study concluded:

> The possibility that some of those whales were struck in waters adjacent to SMA boundaries underscores the importance of expanding SMA boundaries along the species' migratory corridor (i.e. from Georgia to New York) to the 30 nmi limit originally proposed by the NMFS based on its past assessment of the width of the right whale migratory corridor and relevant new information.[92]

These findings were corroborated by van der Hoop et al.'s 2014 conclusion that "specifically, increasing the spatial and temporal extent of SMAs in the mid-Atlantic, should be considered,"[93] and more recently by Sharp et al. 2019's summary: "If mitigation efforts such as more effective gear modifications, extended fishery closures, and expanded vessel speed restrictions are not implemented imminently, human activities will cause an inhumane and certain extinction of this species in the all-too near future."[94]

Accordingly, we request that NMFS extend the Mid-Atlantic and Southeast SMAs to 30 nautical miles from shore, rather than the current distance of 20 nautical miles.

G. Expand the Scope of the Seasonal Management Area Off Race Point

We also formally request that NMFS combine the Off Race Point and Cape Cod Bay SMAs into a single management area that would provide protection from January 1 through April 30. NMFS has recognized the importance of protecting right whales in Cape Cod Bay as early as January 1 but has not accounted for migration into Cape Cod Bay, which is enclosed on three sides by land (see Figure 11).

[91] 2012 Ship Speed Rule Analysis at 42.
[92] Laist et al. 2014 at 144.
[93] van der Hoop et al. 2014 at 31.
[94] S. Sharp et al. 2019 at 27.

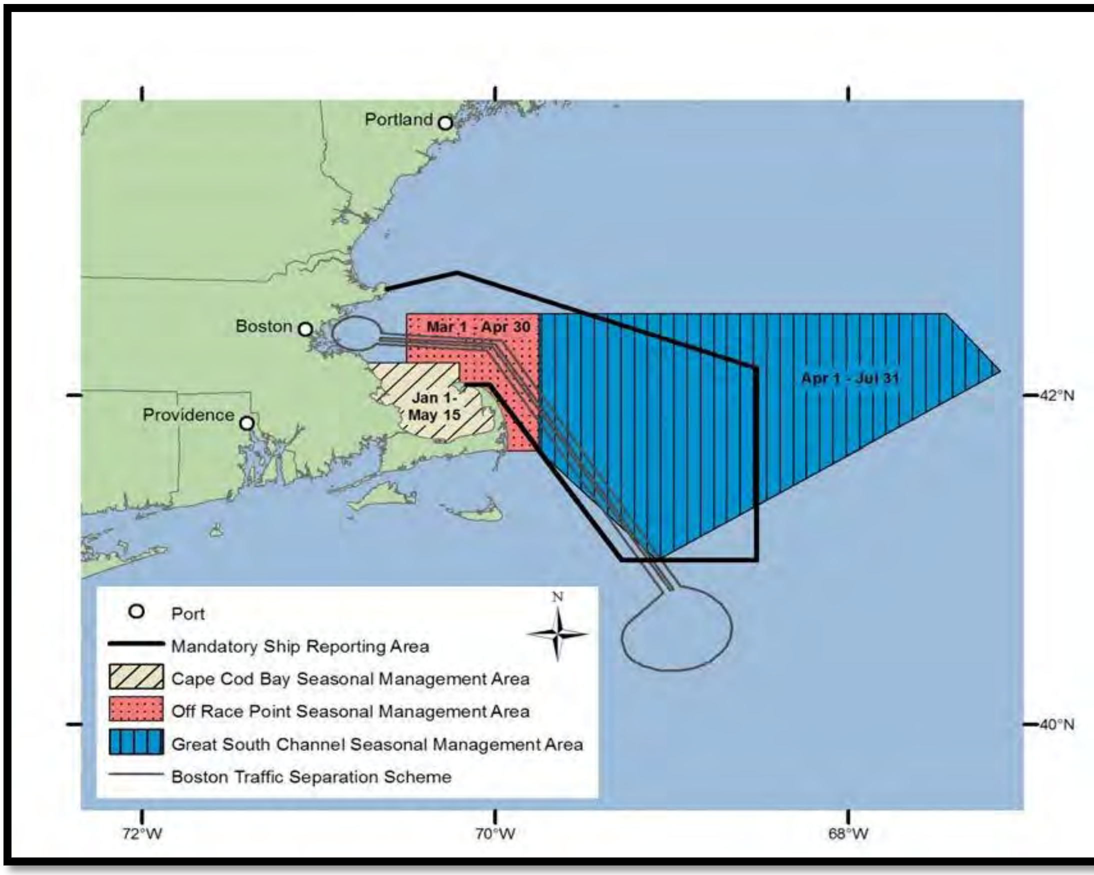

Figure 11. (NMFS, *Compliance Guide for Compliance Guide for Right Whale Ship Strike Reduction Rule*, *available at* http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/compliance_guide.pdf)

Between May 1 and May 15, 2018, numerous right whale sightings were reported in the Off Race Point restricted area even *after* the speed restriction had been lifted. Given the number of right whales using the waters south of the Cape, it is highly likely that at least some right whales leaving Cape Cod Bay after April 30 are moving through the Off Race Point area as they move south.

Thus, to address the risk of vessel strikes in this area, we request that NMFS combine the SMAs for Off Race Point and Cape Cod Bay into a single SMA that would mandate that ships travel at speeds of no more than 10 knots in this area from January 1 through May 15 each year.

Monitoring and Enforcement

We remind NMFS that monitoring and enforcement are key to ensuring full compliance with the rule. We note that the current rule grants an exemption from compliance to ensure vessel operational safety. We agree that the safety of vessel operations is paramount, and that this exemption is consistent with the International Regulations for Preventing Collisions at Sea 1972. However, we ask that NMFS, working with the U.S. Coast Guard, continue to investigate vessels or regions where requests for exemptions are used consistently to ensure that they are being used legitimately and not simply for the purposes of evading speed restrictions.

Conclusion

NMFS is legally obligated under the ESA and MMPA to protect North Atlantic right whales from further take resulting from vessel strikes. Information that has come to light since promulgation of the 2008 and 2013 ship speed rules demonstrates that mandatory vessel speed limits in areas where right whales and vessels overlap is the only mechanism likely to effectively address such threats. Accordingly, it is imperative that NMFS take the actions requested in this petition to prevent and mitigate the significant and continuing threat of vessel strikes. We request that the agency expedite its response to this petition and act quickly to propose, evaluate, and finalize an amended ship speed rule to ensure that the species has the best chance to survive and recover.

Respectfully submitted,

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ATTACHMENT 13

Marine Mammal Science

MARINE MAMMAL SCIENCE, **(*): ***–*** (*** 2017)

DOI: 10.1111/mms.12386

Vessel collision injuries on live humpback whales, *Megaptera novaeangliae*, in the southern Gulf of Maine

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ABSTRACT

North Atlantic humpback whales (*Megaptera novaeangliae*) in the Gulf of Maine overlap with both recreational and commercial vessel activity. Vessel strikes are one source of anthropogenic impact that has the potential to inhibit the recovery of this protected species. There are currently no regulations or guidelines specifically devised to reduce the likelihood of collisions for vessels transiting in the vicinity of humpback whales, except for vessels actively engaged in whale watching. To understand interactions between vessels and humpback whales better, we analyzed injuries on 624 individuals photographed in the southern Gulf of Maine from 2004 to 2013. Multiple reviewers evaluated 210,733 photos for five categories of injury consistent with a vessel strike. In total, 14.7% (n = 92) of individuals photographed showed injuries consistent with one or more vessel strikes. These results likely underestimate vessel collision rates and impacts because multiple events, events resulting in mortality, and those that involved only blunt force trauma could not be detected. Nevertheless, our results indicate that vessel strikes are underreported and that healing is dependent on the severity and location of the injury. We recommend that a management strategy be developed for all classes of vessels transiting in the vicinity of whales.

Key words: vessel strike, humpback whale, Gulf of Maine, Stellwagen Bank National Marine Sanctuary, marine conservation, scar, photo-identification, wound, healing.

The Gulf of Maine (GoM) is the southernmost primary feeding ground for humpback whales in the North Atlantic Ocean. and individuals overlap with both recreational and commercial vessel activity. At the time of this study, humpback whales were listed as endangered under the U.S. Endangered Species Act and considered a strategic stock under the U.S. Marine Mammal Protection Act. Strategic stocks are

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defined as those for which the rate of direct human-caused mortality exceeds the designated potential biological removal (PBR) level (16 U.S.C. § 1362 [19]). Observed mortalities and injuries from anthropogenic causes may be inhibiting recovery of this protected species (Waring *et al.* 2014), and these events are likely underestimated due to undetected events, limited carcass recovery and necropsy effort, and difficulty in assessing cause of death when carcasses are examined. Cause of death was determined for less than half of all reported humpback whale carcasses observed on the U.S. East Coast between 1970 and 2009 (van der Hoop *et al.* 2013). When cause of death was determined, 74% were attributed to human activities, including ship strikes (van der Hoop *et al.* 2013).

In 2008 the National Marine Fisheries Service (NMFS) implemented speed restrictions to reduce the threat of ship collisions with North Atlantic Right whales (U.S. Federal Register 2008), codified at 50 C.F.R. § 224.105 (2008). These seasonal management areas, which require vessels greater than 20 m to travel at ≤10 knots, were designed for North Atlantic right whales, but proposed to provide ancillary benefit to other large whales, including humpback whales. While the seasonally managed areas covered by the "Speed Rule" were found to reduce collision risk with North Atlantic right whales, Laist *et al.* (2014) found that humpback whales did not significantly benefit. Similarly, van der Hoop *et al.* (2015) did not detect significant reduction in ship strikes of large whales either spatially or temporally following the implementation of the seasonally managed ship speed rule. Currently, in NOAA's Greater Atlantic Region (Maine through Virginia), there are guidelines for vessels engaged in whale-watching to avoid harassment and possible injury (U.S. Federal Register 1999). These voluntary guidelines were developed in 1985 (revised in 1998) as a result of vessel strikes by commercial whale-watching vessels and included input from the commercial whale-watching owners and managers. Wiley *et al.* (2008) found that commercial whale-watching vessels did not fully comply with the speed portion of the guidelines, yet also concluded that no whales were struck by commercial whale-watch vessels during the study period. However, the latter depends entirely on reporting by vessels involved in strikes and by those that witness events. Limitations on event detection and reporting have prompted injury-based studies of entanglement rates (Robbins and Mattila 2001, 2004; Robbins 2009, 2012). However, to date, there has been no systematic effort to quantify nonlethal vessel-related injuries on Gulf of Maine humpback whales.

This study analyzes images for injuries consistent with vessel strikes in order to address the following objectives: (1) to estimate the percentage of humpback whales in the southern GoM that have apparent vessel-strike injuries, (2) to analyze the apparent vessel-strike data in conjunction with demographic data to identify any particularly vulnerable demographic component of the population, (3) to characterize the body location and severity of observed injuries and to monitor healing and clarify definitions on healing, and (4) to review management efforts and outreach for vessels transiting in the vicinity of whales in the southern GoM and recommend modifications to monitoring and management.

Methods

Data Sources

This study focused on 210,733 high-resolution digital images of 624 individual humpback whales. Images were collected by Whale and Dolphin Conservation aboard commercial whale-watching boats and research vessels in and around the Stellwagen Bank National Marine Sanctuary, in the southwest GoM, from 2004 through 2013. They were obtained primarily for photo-identification purposes with an emphasis on ventral fluke and dorsal fin images, but other body parts were also documented opportunistically. Individual identifications and data on sex and age class were facilitated by the Gulf of Maine Humpback Whale Catalog curated by the Center for Coastal Studies (Provincetown, MA).

Vessel-strike Injury Analysis

Protocols for detecting and assessing vessel-strike injuries were adapted from studies of North Atlantic right whales (Knowlton and Costidis 2013) and gray whales (Bradford *et al.* 2009). The body was divided into 26 body regions for coding purposes (Fig. 1). A scoring opportunity was defined as the ability to code a body zone in a given photograph. Photographic coverage was determined to be "full," "partial," or "none" for each of the body regions, given all photos available for the individual. In order for coverage of a given zone to be considered "full," the entire zone must have been clearly visible in photographs of adequate quality (reasonable distance and clarity). Anything less than full coverage of a zone was deemed "partial" coverage. Zones rated with "full" coverage were used to determine whether a vessel-strike injury existed in that zone (yes/no) and "partial" coverage zones were rated as either yes or unknown for scar presence. Body zones could potentially have more than one vessel-strike injury in or across multiple body zones. Cases in which there were vessel-strike injuries across multiple zones did not automatically qualify the injury as resulting from a separate vessel-strike event. These injuries, if not obvious by continuity of the wound/scar, were then scored for state of healing appearance.

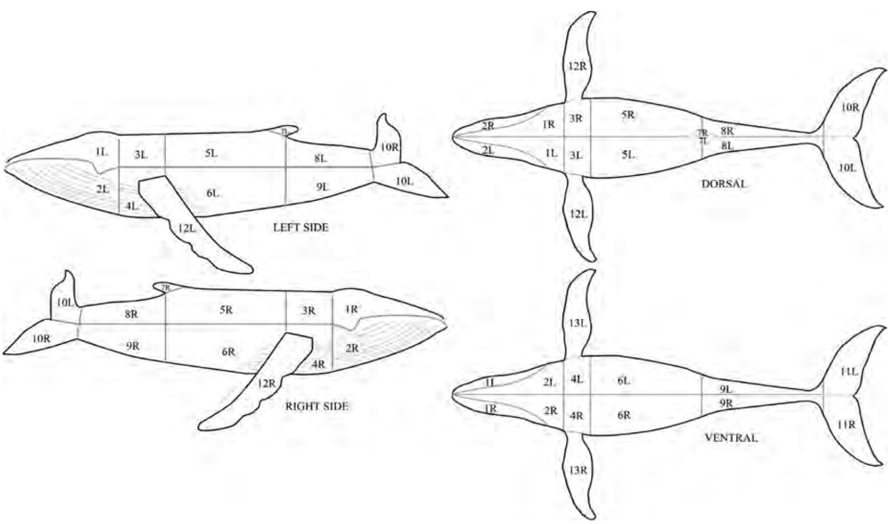

Figure 1. Twenty-six body zones used when coding for vessel interactions, adapted from Bradford *et al.* 2009 and Knowlton *et al.* 2013.

Vessel-strike Injury Definitions

In order for the injury to be attributed to a vessel strike, the wound had to meet one of five mutually exclusive categories: (1) consistent with propeller; (2) probably due to propeller; (3) consistent with skeg + propeller; (4) other physical vessel trauma; or (5) other possible vessel-strike injuries, defined as follows:

Consistent with propeller and probably due to propeller—Relatively parallel wound pattern with evenly spaced incisions; these injuries can vary in size, appearance, and severity depending on the size of the vessel, the speed of the boat, and the position of the animal in the water column (Fig. 2A).

Consistent with propeller + skeg—An injury with relatively parallel evenly spaced incisions with a singular straight wound/scar adjacent to the propeller incisions. The singular straight injury (skeg wound/scar) will be nearly perpendicular to the parallel evenly spaced incisions (propeller wound/scar) and may extend the full or partial length of the propeller incisions (Fig. 2B).

Other physical vessel trauma—Other injuries that appear to be the result of physical trauma from either a pointed object or a sharp edge or from a blunt force, other than those described above. Wounds inflicted from other physical trauma are often "lumpy" in appearance with irregular edges once healed (Fig. 2C).

Other possible vessel strike injuries—Other injuries that could not be confidently assigned to one of the previous definitions, but were not consistent with social, foraging, or entanglement injuries and may have been the result of a vessel strike (Fig. 2D).

After the injury type was categorized, its severity and healing states were evaluated. Severity was determined by the body layers affected as follows: (1) penetration only of the skin, (2) penetration of the skin and blubber, and (3) penetration into muscle or deeper. State of healing was categorized at each observation as fresh/recent, healing, or healed, as defined in Table 1.

For each of the 26 body zones, dates were noted for when the scar/wound was first sighted and the date on which each photo was taken. The age class of the animal at the time the vessel-strike injury was determined following previous humpback whale studies in the GoM (*e.g.*, Clapham 1993, Robbins 2007). Age classes were defined as follows: dependent calves (<1 yr old), independent juveniles (known to be 1–4 yr old), and adults (≥5 yr old). Cases in which wounds had healed prior to the first

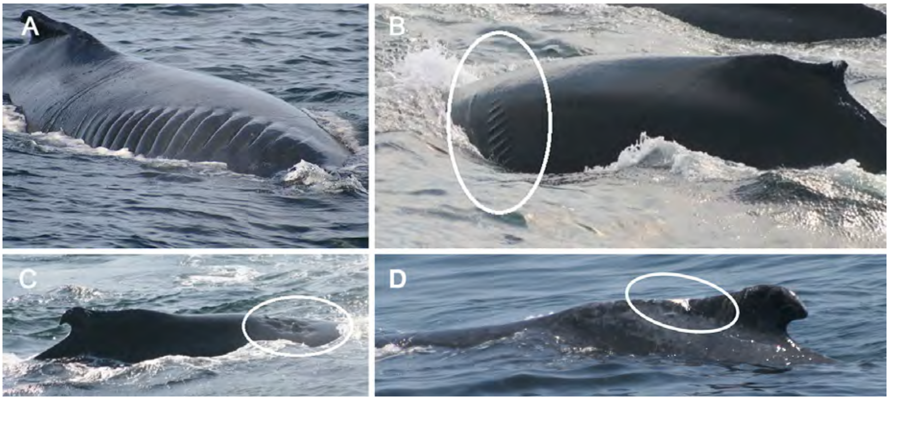

Figure 2. (A) Consistent with propeller and probably due to propeller, (B) consistent with propeller + skeg, (C) other physical vessel trauma, (D) other possible vessel strike injuries.

Table 1. Definition of healing states.

Phase of wound healing	Physical appearance description	Physiological description
"Fresh/Recent" = Inflammatory Phase	Wound site is often deep red or variations of pink in color. Blubber or muscle layers may be exposed.	Blood clot is formed; blood vessels dilate to allow for antibodies, white blood cells, and nutrients to reach the wound. Autolysing of necrotic tissue (Leaper and Harding 1998).
"Healing" = Proliferation and Maturation phases[a]	Growth band of new tissue begins to form and grow inwards from the edges of the wound site, pigment ranging from variations of pink to white/gray. Later stages of healing may present "normal" pigmentation of the skin matching the uninjured regions; however the shape of the wounded site may continue to evolve.	Proliferation: Wound is "rebuilt" with new granulation tissue combined of collagen and extracellular matrix. The color and condition of the tissue is an indicator of healing (Leaper and Harding 1998). Maturation: The final phase in healing occurs once the wound has closed. Collagen is remodeled and realigned along tension lines where the wound is contracting. This phase can last a year or longer depending on the size of the wound (Mercandetti and Cohen 2005).
"Healed"	Raised or indented ranging from black to white in color (Robbins 2012); stretched, smooth and glossy tissue in appearance (Bloom and Jager 1994, Rommel *et al.* 2007). Appearance of the wound site has remained unchanged over a consistent period of time.	Postmaturation.

[a]Wound healing is a complex process and can be divided three stages: an inflammatory reaction, a proliferative process leading to tissue restoration, then tissue remodeling (Li *et al.* 2007). For the purposes of coding healing stages, no differentiation was made between the proliferation and remodeling phases of healing; both phases were categorized as "healing."

sighting of the injury, or the age of the individual was not known, categorized as age class "unknown" for this analysis.

Statistical Analyses

A chi-square test for independence was used to determine whether vessel-strike injury presence differed among the factors sex, age class, and body region.

Interrater Agreement

A primary and secondary reviewer independently coded all suitable photos collected from 2004 to 2011 using the vessel-strike injury analysis protocols as outlined above. Both reviewers had previous marine mammal photo-identification experience. Images for 2012–2013 were analyzed by the same primary reviewer and three secondary reviewers (reviewers 2a, 2b, and 2c) with photo-identification experience ranging from <1 to >2 yr. All reviewers were trained using the same techniques and protocols as outlined above for the study. This technique was used to test the agreement and ability to have multiple researchers analyzing data in the future and to test the strength of the injury-type definitions developed for this study.

Krippendorff's alpha (α) was used to measure the agreement between the reviewers. This statistic is a reliability coefficient developed to measure agreement between independent coders (Krippendorff 2007). Krippendorff's alpha is a generalization of several known reliability indices and enables a variety of data with the same reliability standard to be ranked. Krippendorff's alpha can be used for both large and small sample sizes, any number of categories, levels of measurement, and accounts for incomplete or missing data (Hayes and Krippendorff 2007). The basic form of the equation is $\alpha = 1 - \frac{D_o}{D_e}$, where D_o is the observed disagreement and D_e is the disagreement one would expect when the coding of units is attributable to chance. When observers agree perfectly, $D_o = 0$ and $\alpha = 1$, (Krippendorff 2007). Krippendorff suggests the following for interpreting his coefficient: "It is customary to require $\alpha \geq .800$. Where tentative conclusions are still acceptable, $\alpha \geq .667$ is the lowest conceivable limit" (Krippendorff 2004, p. 241).

Following interrater agreement tests, reviewers discussed all disagreements of injuries and injury type. The reviewers defended the rating they gave and referred back to definitions for support. The primary reviewer and second reviewer(s) came to consensus for the final calculations of the data analysis.

Results

Interrater Agreement

The data analyzed included 624 individuals, resulting in 16,224 scoring opportunities for both the primary reviewer and the second reviewer. Overall, reviewer 1 and reviewer 2 agreed 83.5% of the time for vessel-strike injury presence ($\alpha = 0.707$; *n* agreements = 13,539; *n* disagreements = 2,685). As more than one reviewer 2 was used for the analysis of the 2012–2013 data, each reviewer 2 was analyzed independently against reviewer 1. Reviewer 2a agreed 83.1% ($\alpha = 0.704$), reviewer 2b agreed 83.4% ($\alpha = 0.705$) and reviewer 2c agreed 84.0% ($\alpha = 0.712$) with reviewer 1 for the presence of vessel-strike injuries. Agreement of vessel-strike injury presence for the rating of "yes" was particularly strong with 99.3% agreement between the primary and all secondary reviewers combined.

Overall, reviewer 1 and reviewer 2 agreed 99.3% of the time on the decision of injury type ($\alpha = 0.627$; *n* agreements = 16,116; *n* disagreements = 108). Reviewer 2a agreed 99.5% ($\alpha = 0.651$) with reviewer 1. Reviewer 2b agreed 99.3% ($\alpha = 0.70$) and reviewer 2c agreed 99.2% ($\alpha = 0.514$) for the decision of injury type against reviewer 1.

Photographic Coverage of Body Zones

Of the 624 analyzed individuals, 11.8% ($n = 53$) had full photographic coverage of all dorsal and ventral regions while 64.8% ($n = 398$) had full photographic coverage of all dorsal zones posterior to the blowhole through the tailstock (Fig. 3). Photographic coverage was most complete for dorsal regions and both the dorsal and ventral fluke. The ventral fluke was the most photographed zone, due to it being the primary photo-identification feature. The ventral tail stock was the predominant zone rated "partial" coverage (Fig. 4). Photo coverage was consistently limited for the pectoral fins and all ventral regions except the ventral flukes. The dorsal side of the pectoral fin was the only dorsal zone that was not partially or fully photographed in at least 50% of the individuals. Full photographic coverage was available for 4,427 scoring opportunities on the left side body zones *vs.* 4,462 scoring opportunities for the right side body zones. Partial photographic coverage was determined for 538 scoring opportunities for the left side body zones *vs.* 513 scoring opportunities for the right side body zones. No photos were recorded for 3,134 scoring opportunities on the left side body zones *vs.* 3,124 scoring opportunities on the right side body zones.

Vessel-Strike Injuries

Out of the 624 individuals reviewed, 14.7% ($n = 92$) of whales had injuries consistent with at least one vessel strike, with a total of 149 injuries documented. The number of vessel-strike injuries per individual ranged from zero to four. Of the individuals showing evidence of vessel strikes, most exhibited either one ($n = 46$) or two ($n = 37$) injuries, however, seven individuals had three vessel-strike injuries and two showed evidence of four vessel-strike injuries. In most cases it could not be determined whether multiple injuries in different body zones were caused by one or more event. However, one individual, a dependent calf, was confirmed to have injuries from two separate events. The two events were discriminated based on the presence of new fresh injuries in different body regions within weeks of when the calf was most recently documented with its initial healing injuries.

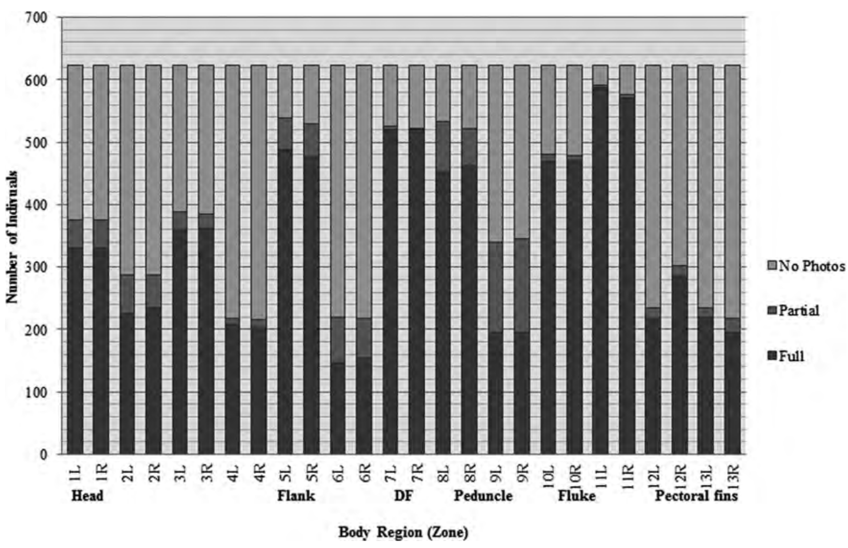

Figure 3. Frequency of photo coverage: full, partial, and no photos of each body region (zone) ($n = 624$).

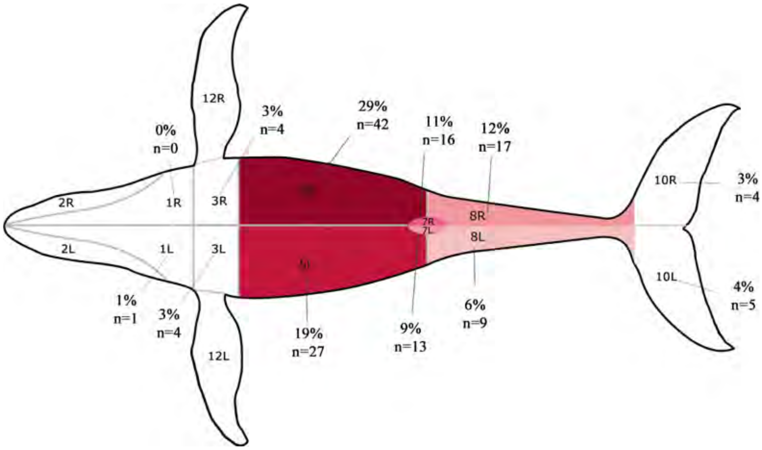

Figure 4. Relative percentage of vessel strike injuries occurring in each dorsal zone. The number of individual injuries are also noted (n = 142). Zones with the highest incidence of vessel strike are highlighted darkest.

State of Healing

The 149 vessel-strike injuries were each categorized into one of the three healing states based on definitions in Table 1. In total, 10% (n = 15) were classified as fresh/recent at first sighting, 29% (n = 43) as healing, and 61% (n = 91) as healed. A total of 15 fresh/recent injuries were observed on nine individuals; of these nine individuals, five individuals (all calves) were documented in the study area without injuries between 6 d and 1 mo prior to the first date of detection. Fresh injuries were documented in 2008 (n = 4), 2009 (n = 4), 2011 (n = 3), 2012 (n = 1) and 2013 (n = 3).

Severity of Injuries

Injuries were categorized as 29% (n = 43) penetrating skin only, 66% (n = 98) extending into blubber, and 5% (n = 8) extending into muscle.

Vessel-strike Injury Type

Vessel-strike injuries were assigned to one of five injury types based on definitions above and Figures 2A–2D: 12% (n = 18) were consistent with propeller wounds, 9% (n = 14) were consistent with skeg + propeller wounds, 8% (n = 12) were probable propeller wounds, 38% (n = 56) were deemed other physical vessel trauma and 33% (n = 49) were considered other probable vessel-strike injuries (Fig. 4).

Body Region

A total of 58% (n = 86) of vessel-strike injuries were located on the right side of the individual, 42% (n = 63) had injuries on the left side of the body. In addition, 21% (n = 32) had vessel-strike injuries on both sides of the body. A chi-squared test showed there was no significant difference in the number of right side *vs*. left side injuries (χ^2_1, n = 149) = 3.550, P = 0.059).

Zones 5R and 5L, comprising the flank region, were the body zones sighted most frequently with injuries from a vessel strike. Forty-six percent (n = 69) of all vessel wounds/scars were observed in zone 5 with 28% (n = 42) in 5R and 18% (n = 27) in 5L. Including only vessel-strike injuries consistent with propeller and consistent with skeg + propeller (excluding "probable" vessel-related injuries and other vessel-related injuries), zones 5 and 8 ranked highest with 62% and 16% respectively. Using a chi-squared test, we found significant differences between the locations of injuries between all zones ($P < 0.001$), with the highest percentage of injuries documented in zone 5. Zone 1R (right side of head) and 12L and 12R (pectoral fins), were the only observed dorsal zones where no vessel-strike injuries were observed (Fig. 5).

Identification of Vulnerable Demographics of the Population

Sex

Sex was known for approximately 68% of the individuals studied (n = 422) with a bias toward females. The frequency of vessel-strike injuries for females 19.0% (48/252) was not significantly different from males 16.5% (28/170) (χ^2_1, n = 76) = (3.16, P = 0.57).

Age Class

Of the 92 individuals with injuries consistent with vessel strikes, the age class at which they acquired the injury could be determined for 56 individuals: 55% were acquired when the whale was an adult (n = 31), 13% (n = 7) as a juvenile, 32% (n = 18) as a calf. Two mothers sustained injuries while accompanied by a dependent calf.

A chi-squared test indicated statistically significant differences in overall vessel-strike injury frequency (χ^2_2, n = 56) = 15.4, $P < 0.0001$) among adults (55%, n = 31), juveniles (13%, n = 7), and calves (32%, n = 18).

Discussion

Injury-based assessments have been used to evaluate the frequency of entanglement among Gulf of Maine humpback whales (Robbins and Mattila 2001, 2004; Robbins 2009, 2012); however, this study is the first to analyze vessel-strike injuries systematically through photographs of humpback whales in this region.

Similar to a previous study (Bradford *et al.* 2009), two reviewers were used for interrater agreement to determine reliability of the findings and to determine whether protocols may be used by more than one qualified researcher and achieve similar results. This study also tested the methodology by using multiple second reviewers with varying degrees of photo-identification experience to assess the strength of the definitions developed for the study. Interrater agreement results indicated that once an individual has been trained, the level of prior research experience was not a factor in the ability to determine presence or absence of vessel-strike injuries and to rate types of scarring based on the definitions used in this study. This implies that more than one trained researcher may be used to produce comparable results if study protocols and definitions are followed.

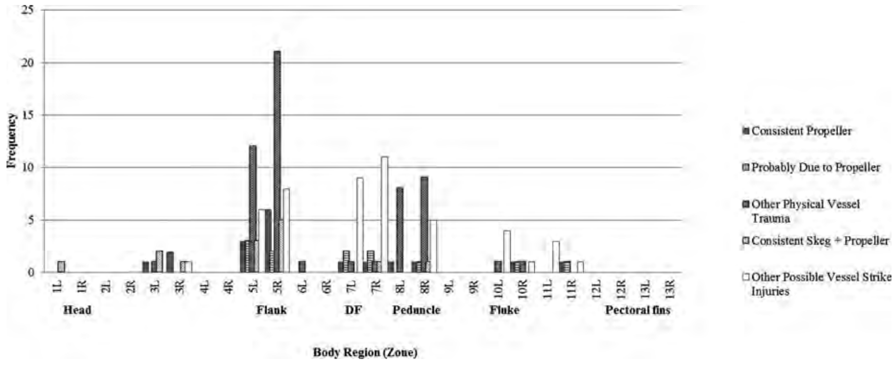

Figure 5. Frequency of appearance of injury by body region ($n = 149$).

The dorsal body regions that were most frequently observed with sublethal vessel-strike injuries were posterior to the pectoral fins through the tail stock. It is likely that surface exposure of the back, combined with the tendency to raise the tail stock prior to a dive, leave these regions most vulnerable. Because data were obtained opportunistically, it is possible that images of body parts, other than those used for photo-identification, were photographed more frequently if wounds were observed. However, as most (63.8%) of the individuals examined in this study had full photographic coverage of the dorsal region (posterior to the blowhole through the tail stock) it is unlikely that these data are biased by wound presence. The results of this study indicate that whales can be struck in any dorsal region. However, the frequency of injuries in the dorsal back and tail stock regions, and the high likelihood of these areas being photographed highlight the importance of these body regions. This suggests that in the absence of full body documentation, vessel-strike injury monitoring of these regions in particular could be beneficial in assessing the impacts of vessel-strikes in future studies.

Definitions of injury type and healing state used in this study were developed from and generally consistent with previous marine mammal anthropogenic injury studies (Bloom and Jager 1994, Visser 1999, Rommel *et al.* 2007, Bradford *et al.* 2009, Robbins 2012). According to Rommel *et al.* 2007, the skin over healed injuries should be stretched, smooth, and glossy tissue in appearance. However, our results indicate that smooth epidermal coverage is not in all cases an adequate indicator of a "healed" injury. In one documented case, the underlying shape of a vessel-strike injury to a caudal peduncle continued to change over a 47 mo time frame, even though full epidermal coverage with smooth tissue was noted within 15 mo of the injury. In this case, smooth, glossy tissue was not a good indicator because tissue continued to modify at the injury site. It is possible that deep injuries to the caudal peduncle, or other areas with flexure and movement, will take longer to heal (Zogaib and Monte-Alto-Costa 2011). Healing likely varies with the severity of the injury, placement of the injury, and the age of the animal. We recommend that a vessel-strike injury not be assumed to have healed until the appearance of the wound site remains unchanged. In the referenced case above, "healed" status was determined after the individual was documented with no changes in healing over a 2 yr period (see Appendix S1 and associated figures). However, future longitudinal studies of humpback whale vessel-strike injuries are needed to better quantify criteria for healing status.

As with healing, the severity of the injury cannot easily be determined by images alone. In this study, the majority (66%) of the injuries observed appeared to penetrate the blubber layer, with very few (5%) cases known to involve muscle. The few observed incidences of the latter may be due to a higher mortality from these types of injuries. As this was a systematic study of photographs of live animals, analyses were limited to those that the individuals were able to survive the vessel-strike injury. According to Laist (2001), most severe and lethal injuries result from collisions with large ships, whereas our sample set is most likely biased towards encounters with smaller vessel size classes. However, initially surviving a vessel strike does not guarantee that injury will not result in mortality later in the animal's life (Moore *et al.* 2007). Although the wound site might appear to be healing/healed or superficial, chronic exposure to stress in cetaceans may cause an imbalance in metabolic regulation which can lead to death (Angliss and Demaster 1998). In at least one mortality case, a humpback whale succumbed to an apparent infection from a vessel-strike injury that was documented as healed[2] and would likely have been classified as moderate in severity when the injury was first detected. This was known only because the whale was necropsied to determine its cause of death. Studies have shown that necropsies are necessary to accurately determine blunt force trauma (Wiley *et al.* 1995; Moore *et al.* 2004, 2013), but this case in particular provides an example of a mortality resulting from an injury that appeared to be superficial, or healed. Long-term studies underway on this population will help to clarify the ultimate fate of the individuals in this study relative to those that have not been exposed to a vessel strike.

At least 14.7% of southern Gulf of Maine humpback whales showed evidence of at least one injury consistent with a vessel strike. Because these data were largely based on opportunistic sightings taken from whale-watching vessels, it is conceivable that individuals that are more likely to interact with boats were photographed more frequently and these may also have a higher likelihood of vessel strikes. Alternatively, it is conceivable that these individuals have greater experience with vessels and so are more adept at avoiding collisions. In the future, the techniques used in this study can be applied to data from systematic population surveys to evaluate this question and to examine vessel-strike injuries at the population level in the GoM.

This study found that adult humpback whales are significantly more likely to acquire injuries from vessel strikes and have an overall higher frequency of such injuries. While we cannot definitively determine that risk is higher for adults, it may be a result of foraging behavior. Weinrich *et al.* (1997) found that adult humpback whales preferentially exploit prey in the upper water column, which may result in increased exposure to vessel activity. It is also important to consider that previous studies of humpback whales have shown no detectable reactions to vessels when whales were engaged in surface feeding or social behaviors (Krieger and Wing 1984, Baker and Herman 1989, Neilson *et al.* 2012). Furthermore, Friedlander *et al.* (2009) noted that humpback whale surface feeding behavior in the southern GoM was most likely to occur during daylight hours, a time when prey are more likely to be at the surface and, as supported by acoustic data, vessel density in the region is also likely to be highest (SBNMS). In contrast, when considering only fresh/recent

[2]Personal communication from David Rotstein, Marine Mammal Pathology Services, 19117 Bloomfield Road, Olney, MD 20832, September 2014.

injuries evaluated in the study, calves were more likely (56%) to exhibit wounds from vessel strikes, consistent with the findings of Laist *et al.* (2001).

Ten percent of the injuries were rated as fresh and were assumed to have occurred in the study region, as these individuals were documented in the study area without injuries between 6 d and 1 mo prior to the first date of detection. Because the images were not taken at standardized distance, photogrammetry scales could not be applied to estimate propeller wound dimensions and, therefore, vessel class sizes. Similarly, the activities in which the vessels were engaged when the strikes occurred cannot be determined. However, it is unlikely that the injuries were caused by either sovereign vessels, vessels engaged in commercial whale watching, or vessels carrying paying passengers as these vessel types have been shown to be more likely to report their strikes than other vessel types (Jensen and Silber 2003). Other vessels that could account for the unreported events documented in this study include commercial fishing, recreational vessels, and other small boaters. According to the Stellwagen Bank National Marine Sanctuary, more than 400 commercial fishing vessels operate in the southern GoM year round along with recreational boating and fishing vessels (SBNMS 2007). With more than 64 harbors and 80 yacht clubs in Massachusetts alone, the Sanctuary estimates that hundreds of small boaters operate within the Sanctuary waters daily during the summer, a time when humpback whales are most likely to be present (SBNMS 2007).

Between 2004 and 2013, NOAA's Northeast Region's Office of Law Enforcement had only received one report of a vessel strike (initially reported as harassment) involving a humpback whale.[3] This collision did not result in sharp force trauma and, as a result, was not part of this study. Therefore, none of the injuries analyzed in this study were reported to NOAA. Laist *et al.* (2001) found that for vessels <24 m in length it is highly unlikely that the collisions go undetected by the operator, as vessel damage tends to be significant for this size class. A study of reported whale-vessel collisions in Alaskan waters by Neilson *et al.* (2012) further supports these claims; the study reports one-third of collisions resulted in some kind of human toll and/or property damage. This raises the question of whether the lack of reporting a vessel collision with a whale is due to the fact that boaters are unaware they have struck a whale, perceived legal consequences, or ignorance of the requirement and method to report.

The 1998 revisions of the Northeast Regional Whale-Watching Guidelines included the development of "speed rings" specifically designed to reduce the risk of collisions when whale-watching vessels approach and leave large whales. The development and monitoring of these guidelines has focused exclusively on commercial whale-watching vessels (SBNMS Behavioral Disturbance Working Group Plan 2004, Wiley *et al.* 2008). According to NOAA (2010), recreational boaters are numerous and often aggressive in the Stellwagen Bank National Marine Sanctuary from May to September, the major portion of the whale-watch season. A public education program, "See a Spout, Watch out!" was developed by Whale and Dolphin Conservation, in conjunction with NOAA, in an attempt to educate private recreational boaters that whale watch in the sanctuary. SBNMS recognizes that this is largely a land-based outreach program and an on-the-water program is needed to successfully increase outreach to vessels in the vicinity of whales (SBNMS 2007). The concern for vessels

[3]Personal communication from Todd Nickerson, Special Agent, NOAA NMFS Northeast Region Office of Law Enforcement, 53 N 6th Street, New Bedford, MA 02740, September 2014.

operating in the vicinity of whales (not including commercial whale-watching vessels) has been acknowledged by the SBNMS Advisory Council and the council has formally recommended that the Sanctuary support and develop research programs to reduce the risk of vessel strikes (SBNMS 2007). In August of 2015, the SBNMS piloted its Whale Outreach and Education Project with the specific purpose of conducting outreach and educating private boaters and whale watchers regarding the Northeast Regional Whale Watching Guidelines and best practices.[4] Continued monitoring of vessel-strike injuries will help to evaluate whether these management and outreach approaches will reduce the number of ship strikes or the reporting rates.

This study provides a minimum estimate of vessel strikes for humpback whales in the southern Gulf of Maine and provides evidence that these events are underreported. Further efforts should be focused on defining the vessel classes involved in these strikes, increasing rates of reporting, and analyzing the potential for impacts from injuries that are not immediately fatal. We believe that long-term studies of injuries on whales can be useful in monitoring the efficacy of existing guidelines/regulations. Results from wound studies can assist managers in evaluating their ability to meet the statutory goals put forward for protected species. We recommend that future guideline/regulation development should consider all vessels operating or transiting in the vicinity of whales, not only those engaged in whale watching.

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Supporting Information

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Appendix S1. Case study: NA8988 "Rapier's 2009 Calf."

Figure S1. 10 June 2009; state of healing: Fresh.

Figure S2. 25 June 2009; state of healing: Healing.

Figure S3. 14 July 2009; state of healing: Healing.

Figure S4. 28 September 2010; state of healing: Healing.

Figure S5. 20 July 2011; state of healing: Healing.

Figure S6. 16 August 2011; state of healing: Healing.

Figure S7. 27 May 2012; state of healing: Healing.

Figure S8. 9 September 2012; state of healing: Healing.

Figure S9. 11 May 2013; state of healing: Healing.

ATTACHMENT 14

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Vessel operator response to a voluntary measure for reducing collisions with whales

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ABSTRACT: Voluntary programs have been used with varying degrees of success to address a variety of environmental issues. The goal of the present study was to assess mariner response to a voluntary program to reduce the threat of vessel collisions with the endangered North Atlantic right whale *Eubalaena glacialis*. The program involves the creation of temporary zones, dynamic management areas (DMAs), in which vessel operators are requested, but not required, to either navigate around the area or travel through at speeds of 10 knots or less. Using remotely sensed automatic identification system data, we analyzed 3324 transits made by 1100 individual vessels, the majority of which belong to the international commercial shipping industry utilizing east coast ports of the USA. In general, we observed very little change in vessel operations in response to the DMAs. The mean transit speeds for cargo, tanker, and passenger vessels within the DMAs exceeded the requested maximum of 10 knots and differed little from speeds used outside DMAs. In addition, few transits appeared to involve efforts to navigate around the DMAs. Therefore, we conclude that the program likely had only a modest consequence in reducing vessel collisions with whales, at least as measured by vessel operations. These results may have application to other settings where voluntary programs are contemplated or implemented.

KEY WORDS: Vessel–whale collisions · Voluntary conservation programs · Right whale

INTRODUCTION

The use of voluntary programs to address environmental issues has grown dramatically (e.g. EEA 1997, Barde 2000, Alberini & Segerson 2002, NRC 2002, Morgenstern & Pizer 2007). They are often preferable to regulatory actions because they can be implemented relatively quickly (Morgenstern & Pizer 2007); do not require the development of potentially costly monitoring, policing, and penalty regimes; are less prone to litigation; and can promote innovation within the affected community (Khanna 2001, Rivera & de Leon 2004). However, public participation is essential to voluntary programs achieving their intended goals. Voluntary environmental protection programs have been used in such diverse areas as improvement of air quality and reduction of various industrial chemical emissions (Khanna & Damon 1999, Gamper-Rabindran 2006), adoption of energy-efficient technologies and reduction of carbon dioxide emissions (Morgenstern & Pizer 2007), and waste management (Lyon & Maxwell 2007). They have also been used in protection of ecosystem diversity and endangered species (e.g. FWS/NMFS 1997, Smith & Shogren 2002, Mönkkönen et al. 2009).

Various attempts have been made to address a specific environmental issue involving endangered marine species: the threat of at-sea vessel collisions with large whale species (Wiley et al. 2008, Vanderlaan et al. 2009, Silber et al. 2012). Vessel collisions

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with whales occur in all oceans. They can involve all large whale species and nearly all vessel classes, and are often fatal to the whale (Laist et al. 2001, Jensen & Silber 2003). Nearly 800 records of vessel collisions with large whale species are described in the scientific literature (Van Waerebeek et al. 2007). These counts should be regarded as minima, as many collisions go undetected or unreported (Kraus et al. 2005), the cause of death cannot always be determined in a beach-stranded carcass (Glass et al. 2010), and reporting is inconsistent in many areas.

Efforts to reduce the threat of vessel collisions with whales have included both mandatory and recommended changes in vessel-routing practices, including the establishment of 'Areas To Be Avoided' in both Canadian (Vanderlaan & Taggart 2009) and US waters (Silber & Bettridge 2006, Silber et al. 2012), and the modification of vessel traffic separation schemes in US and Mediterranean waters (Tejedor et al. 2007, Silber et al. 2012). The goal of these vessel-routing modifications is to reduce the threat of collisions by reducing the overlap of high density vessel traffic and whale aggregation areas. Mandatory and recommended restrictions of vessel speed have also been employed to minimize the threat of collisions with whales (NPS 2006, NOAA 2008a,b, Tejedor Arceredillo et. al. 2008). Studies have indicated that as vessel speeds diminish so does the likelihood of serious injury or death when a whale is struck by a vessel (Laist et al. 2001, Pace & Silber 2005, Vanderlaan & Taggart 2007).

For the highly depleted North Atlantic right whale *Eubalaena glacialis*, which is listed as Endangered under the US Endangered Species Act (ESA) and as depleted under the Marine Mammal Protection Act (MMPA), collisions with ships (or 'ship strikes') is one of the species' greatest threats to recovery (Kraus et al. 2005). In a population containing only several hundred individuals, an average of about 2 *known* (others almost certainly go undetected) vessel collision-related right whale deaths have occurred annually over the last decade (Glass et al. 2008, 2010, Waring et al. 2010). To address this threat, the US National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) issued a final rule requiring vessels 65 feet (ca. 20 m) or greater in length to travel at 10 knots or less during certain times of the year in locations (termed 'seasonal management areas' [SMAs]) along the US eastern seaboard that are characterized by right whale occurrence and concentrated maritime activity (NOAA 2008b). In combination with these mandatory restrictions, the NMFS also established a program whereby temporary zones, called 'dynamic management areas' (DMA), can be established quickly in locations throughout the species' range when right whales are observed outside of the geographic extent or effective period of the SMAs (NOAA 2008b). The SMA and DMA programs provide complementary protective mechanisms responsive to both the predictable, as well as the unexpected and transitory presence of right whales.

Because the range of the right whale includes all coastal waters of eastern North America, DMAs might be created in any location along the US eastern seaboard (Asaro 2012). They are established when reliable sightings are obtained (derived primarily from systematic aircraft surveys for marine mammals using trained observers) of 3 or more right whales in US waters within a 75 square nautical mile (n mile^2) (138.9 km^2) area, such that right whale density was ≥0.04 right whales n miles^{-2}. This is consistent with protocol suggested by Clapham & Pace (2001), and is based on the assumption that whale groups at those densities would persist for an extended period. Additional (15 n miles^2) areas are then delineated around the sighting location to account for potential whale movement and are incorporated into a single polygon that encompasses both the sighting location and its surrounding zone. Each DMA is established immediately (i.e. <24 h) upon confirmation of right whale sighting locations and automatically set to expire 15 d after the initiation date. If whale aggregations persist beyond this period, the DMA may be extended for an additional 15 d. Maritime communities are notified of the existence of a DMA via: NOAA Weather Radio broadcasts on a regular basis for the full duration of the DMA; US Coast Guard (USCG) broadcast notices to mariners; an email distribution list (605 recipients of shipping industry liaisons and industry representatives, pilot associations, harbor masters, marine exchanges, etc.); postings on the NMFS' Office of Protected Resources ship strike web site and the Northeast Fisheries Science Center's web-based interactive right whale sightings system; and an automatic return message via electronic mail is sent to mariners who seek information on whale-sighting locations. Mariners are requested, but not required (i.e. voluntary compliance is encouraged), to either navigate around DMAs or travel through them at 10 knots or less. Given the geographic scope of the DMA program and the number of vessels routinely transiting the US eastern seaboard, this voluntary conservation measure can potentially affect the activities of a sizable portion of the commercial shipping industry and other maritime interests including passenger vessels, recreational boaters, and fishing vessels that utilize US east coast ports and waterways.

The goal of the present study was to assess vessel operators' responses to the DMAs. We examined vessel speeds to determine the degree to which vessels were adhering to the requested speed restriction and to detect any changes in speed as they entered the DMAs. We also examined vessel routes to determine the extent to which vessels may have been altering their course to navigate around the DMAs.

MATERIALS AND METHODS

Automatic identification system

We assessed mariner response to the DMAs using automatic identification system (AIS) data. Designed as a safety of navigation tool, AIS transponders send global positioning system (GPS)-linked, very high frequency (VHF) (161.975 and 162.025 MHz) radio signals providing ship-to-shore and ship-to-ship information transfer. The International Convention for the Safety of Life at Sea (SOLAS), an international agreement that specifies minimum standards for the construction, equipment, and operation of vessels, requires that all ships 300 gross tons and greater engaged in international voyages, cargo ships of 500 gross tons and greater not engaged in international voyages, and passenger ships irrespective of size carry AIS equipment. Participating nations are responsible for ensuring that ships operating under their jurisdiction comply with SOLAS requirements. The USCG has codified these requirements domestically by requiring that all vessels 65 feet (ca. 20 m) or greater traveling in US waters carry AIS transponders. The AIS signal normally has a range of about 20 to 30+ n miles (essentially line of sight), but this range may be extended (e.g. depending on the height of the receiving antenna) or diminished in certain circumstances (e.g. electrical storms or certain atmospheric conditions).

AIS transponders send multiple signals each minute that provide a suite of information, both dynamic (unique to a particular voyage) and static (constant for a given vessel). Dynamic information includes the vessel's position (in latitude/longitude coordinates), speed over ground, course over ground, heading, and position accuracy, all of which are determined by continuous GPS-linked updates. Static information includes the vessel's: name, call sign, type, length, country of origin, and maritime mobile service identity (MMSI) number (a number unique to each vessel assigned for the purposes of navigational safety). All static information is entered by the operator upon initializing the system.

The AIS network operates continuously and autonomously, updates as often as every 2 s, and is capable of handling >4500 reports min^{-1}, making it a highly precise means to track vessel operations. The USCG established a network of AIS receivers that covers nearly all US waters. The NMFS's Office of Protected Resources, in cooperation with the USCG and the Department of Transportation's Volpe National Transportation Systems Center, makes use of data feeds from this system (see Silber & Bettridge 2010 for a detailed description of our AIS data acquisition and analysis).

Vessel operations in DMAs

We analyzed operations in 66 DMAs that were established between December 2008 and June 2011. Of these, 59 occurred in waters off New England and 7 off the states of Georgia and Florida (Table 1). All but one of the DMAs in New England waters were rectangular in shape, while those occurring in waters off Georgia and Florida tended to be irregular in shape due to their juxtaposition to already in-effect SMAs or broadly distributed whale sighting locations. The locations and frequency of DMAs were influenced not only by the seasonal occurrence of right whales *Eubalaena glacialis*, but also by a varying amount of aircraft survey effort throughout the year and the DMA protocol itself, which indicates that DMAs not be overlain with established SMAs. DMAs ranged in size from 404 to 4391 n $miles^2$ (Table 1). The 59 DMAs in northeastern US waters occurred in all months of the year, with most occurring in November (n = 6), December (n = 9), and January (n = 8) (Table 1, Fig. 1). All US southeast Atlantic coast DMAs occurred in January and February, the period of high right whale occurrence in that region.

We quantified the number and types of vessels travelling through the DMAs during their effective period. These counts included only those transits that consisted of at least 1 n mile of travel within an active DMA. Information on 'vessel type' is encoded in the AIS message itself as established by the International Maritime Organization protocol and as entered by the operator. The operator is limited to a finite num-

Table 1. Characterization of the 66 dynamic management areas (DMAs) analyzed, including: number of whales that prompted the DMA, total area (in square nautical miles, n miles^2), start and end date (month/day/year) of DMAs active period, and number of vessel transits (that consisted of at least 1 n mile of travel within the DMA) by vessel type that were detected within the DMAs during their active period

DMA	No. of whales	Area (n miles^2)	Start date	End date	Tanker	Cargo	Passenger	Pilot	Sovereign	Tow	Tug	Other	Total
NE_01	11	1767	12/11/2008	12/25/2008	11	1	0	1	0	11	11	8	43
NE_02	43	1576	12/11/2008	12/28/2009	6	0	0	0	0	0	0	0	6
NE_03	3	1356	12/11/2008	12/25/2009	21	3	0	0	0	0	0	0	24
NE_04	28	1997	1/13/2009	2/10/2009	39	14	0	0	0	23	32	17	125
NE_05	3	1605	1/16/2009	1/29/2009	32	21	3	0	0	20	19	10	105
NE_06	6	1448	2/11/2009	2/25/2009	14	6	0	0	0	5	7	3	35
NE_07	5	1456	2/11/2009	2/25/2009	27	18	0	0	1	3	5	5	59
NE_08	12	2419	2/11/2009	2/25/2009	12	18	0	0	1	0	0	5	36
NE_09	3	1592	3/17/2009	3/28/2009	1	0	0	0	0	0	0	0	1
NE_10	5	1764	4/13/2009	4/25/2009	0	1	0	0	0	0	0	0	1
NE_11	15	1926	5/12/2009	5/27/2009	13	4	0	0	0	0	0	6	23
NE_12	3	1602	5/13/2009	5/27/2009	22	1	0	0	0	0	1	3	27
NE_13	44	4391	6/2/2009	6/29/2009	41	30	8	0	1	1	0	21	102
NE_14	3	4391	7/9/2009	7/21/2009	20	22	3	0	3	0	0	24	72
NE_15	5	1644	9/2/2009	9/16/2009	8	2	4	0	0	2	0	15	31
NE_16	26	2124	10/15/2009	11/11/2009	18	5	11	0	0	17	17	30	98
NE_17	24	1918	10/22/2009	12/1/2009	49	2	1	0	2	1	0	4	59
NE_18	16	2441	10/27/2009	11/10/2009	9	2	2	0	0	2	0	0	15
NE_19	41	3661	11/10/2009	12/17/2009	71	15	6	0	2	7	10	37	148
NE_20	47	3403	11/10/2009	11/24/2009	19	9	0	0	0	0	0	1	29
NE_21	27	4198	12/4/2009	12/19/2009	7	0	0	0	0	0	0	0	7
NE_22	37	3768	1/4/2010	1/15/2010	3	0	0	0	0	0	0	0	3
NE_23	13	1887	1/5/2010	1/28/2010	34	6	0	0	0	10	13	10	73
NE_24	3	1527	2/1/2010	2/15/2010	0	0	0	0	1	4	0	2	7
NE_25	14	1922	3/8/2010	3/22/2010	1	0	5	0	0	1	0	1	8
NE_26	6	1697	3/12/2010	3/24/2010	7	11	0	0	0	0	0	3	21
NE_27	8	1941	3/22/2010	4/4/2010	15	19	10	0	1	1	0	1	47
NE_28	3	1566	4/14/2010	4/28/2010	0	0	15	0	1	1	0	5	22
NE_29	18	886	4/22/2010	5/5/2010	25	16	2	0	5	9	33	25	115
NE_30	80	1682	4/30/2010	5/5/2010	8	9	3	0	3	7	16	15	61
NE_31	11	2460	5/24/2010	6/5/2010	20	10	2	0	0	0	2	12	46
NE_32	3	1591	7/27/2010	8/9/2010	21	22	5	3	1	7	16	50	125
NE_33	4	1591	8/9/2010	8/23/2010	26	19	9	4	3	8	11	55	135
NE_34	10	1591	8/18/2010	9/1/2010	24	22	6	2	2	9	14	52	131
NE_35	6	1591	9/1/2010	9/14/2010	16	15	11	4	1	8	12	30	97
NE_36	4	1707	9/13/2010	9/25/2010	5	1	8	0	0	0	0	0	14
NE_37	7	1591	9/13/2010	9/27/2010	27	19	20	8	1	10	20	16	121
NE_38	10	2308	10/14/2010	10/28/2010	13	1	6	0	0	0	0	7	27
NE_39	8	1818	10/14/2010	10/28/2010	14	10	14	2	0	3	13	14	70
NE_40	4	1471	10/14/2010	10/28/2010	1	2	1	0	0	0	0	0	4
NE_41	14	1818	10/28/2010	11/8/2010	10	4	2	0	3	2	6	6	33
NE_42	10	3754	11/16/2010	11/27/2010	24	24	1	0	0	3	20	8	80
NE_43	14	2760	11/16/2010	11/27/2010	7	9	0	0	0	0	0	2	18
NE_44	12	2447	11/16/2010	11/27/2010	0	1	0	0	0	0	0	1	2
NE_45	7	2299	11/29/2010	12/14/2010	15	2	0	0	2	5	9	8	41
NE_46	16	2413	12/1/2010	12/14/2010	4	0	0	0	0	0	0	0	4
NE_47	4	1683	12/1/2010	12/14/2010	9	0	0	0	0	0	0	1	10
NE_48	28	4032	12/21/2010	1/2/2011	24	13	0	0	0	1	0	0	38
NE_49	5	1561	12/21/2010	1/2/2011	2	1	0	0	0	0	0	1	4
NE_50	3	1579	1/4/2011	1/15/2011	15	5	0	0	1	2	6	2	31
NE_51	4	1680	1/4/2011	1/15/2011	1	0	0	0	0	0	0	0	1
NE_52	8	2108	1/4/2011	1/15/2011	2	0	0	0	0	0	0	0	2
NE_53	3	1592	1/10/2011	1/23/2011	86	196	13	0	3	33	23	18	372
NE_54	5	1612	2/25/2011	3/11/2011	11	28	21	0	2	0	1	1	64
NE_55	5	1813	3/15/2011	3/29/2011	3	6	0	0	0	0	0	1	10
NE_56	3	899	4/27/2011	5/10/2011	0	1	18	0	1	5	6	8	39

Table 1 (continued)

DMA	No. of whales	Area (n miles^2)	Start date	End date	Tanker	Cargo	Passenger	Pilot	Sovereign	Tow	Tug	Other	Total
NE_57	13	1995	5/2/2011	5/15/2011	8	12	10	0	3	13	19	18	83
NE_58	21	648	5/3/2011	5/17/2011	13	22	0	0	6	1	0	10	52
NE_59	21	1163	5/3/2011	5/17/2011	8	18	0	0	2	0	0	9	37
SE_01	16	693	1/12/2010	2/5/2010	0	0	0	0	0	2	2	3	7
SE_03	19	774	2/1/2010	3/24/2010	0	0	0	0	0	3	6	3	12
SE_05	33	1476	2/22/2010	3/15/2010	12	35	29	0	1	34	14	13	138
SE_07	8	673	1/12/2011	1/27/2011	0	2	0	0	0	0	0	1	3
SE_08	4	635	1/31/2011	2/15/2011	0	1	0	0	0	1	1	1	4
SE_09	5	404	2/24/2011	3/11/2011	0	1	0	0	0	1	1	1	4
SE_10	5	845	2/28/2011	3/15/2011	7	44	0	0	0	3	4	4	62
Totals	905				961	781	249	24	53	279	370	607	3324

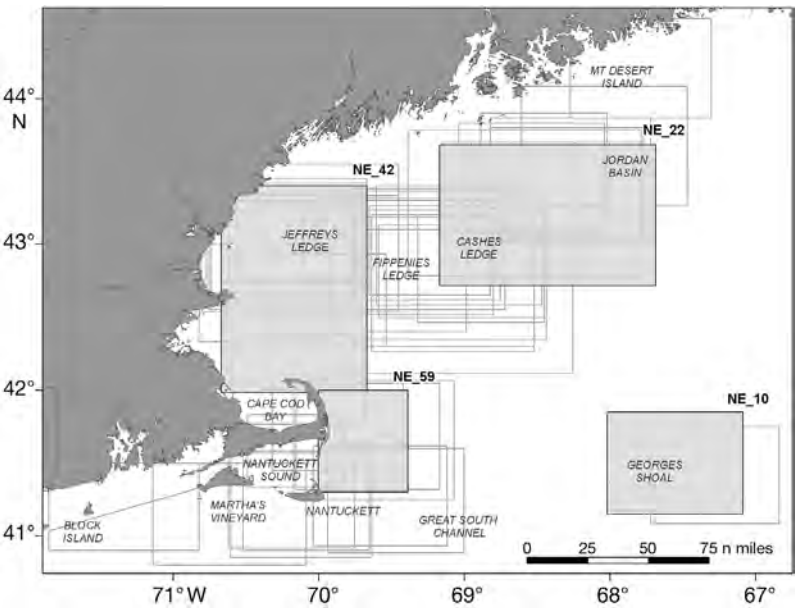

Fig. 1. Boundaries of dynamic management areas (DMAs) located in waters off New England. DMAs NE_10, NE_22, NE_42, and NE_59 have been labeled and shaded to illustrate variation in size and shape

ber of designations, such as cargo, tanker, passenger, tow, pilot, tug, and sovereign (i.e. those owned or operated by a national government), and we used these same designations in our analysis. For characterization of use of the areas by vessel type, we developed an 'other' category that included, for example, fishing vessels, sailing or pleasure craft, sovereign, dredging, and diving vessels when these were indicated by the operator.

For comparative purposes, we studied operations within the 66 DMAs relative to operations in 10 n mile 'buffer' areas surrounding the DMAs. We also compared operations in periods when the DMAs were active relative to 2 wk periods directly preceding and immediately following the active DMA times. Vessel speeds were examined to determine if basic vessel operations changed in response to the DMAs. We calculated mean and median speeds within DMAs and compared speeds within DMAs to those in 10 n mile buffer areas surrounding DMAs to determine if vessel operators changed at-sea speeds in response to the DMAs. To ensure representative travel speeds, we limited the speed analyses to those trips that consisted of at least 5 n miles of uninterrupted travel at speeds of 5 knots or greater both inside the DMAs and in the 10 n mile buffers around them. Shipping industry consultations indicated that any anticipated course or speed modifications would occur within 5 n miles of a management area. We (arbitrarily) doubled the size of this study area to 10 n miles. Vessels may continue to transmit AIS signals while at anchor or in port. Therefore, to reduce the amount of unneeded data (e.g. those indicating a speed of 0 knots) and to consider vessels actually underway, we analyzed speed data for only those vessels traveling >5 knots. Our use of vessel speed throughout refers to the vessel's 'speed over ground' (SOG) as provided in the AIS signal. Vessel speeds within the DMAs were compared to those in the corresponding 10 n mile buffer areas using a Wilcoxon signed-rank test. This comparison was made for all vessels combined, as well as for the following 3 vessel types: cargo, tanker, and passenger. Center, spread, outliers, and interquartile range, or middle 50% of the transit speeds, were also determined for the transits. Transit speeds greater than the 75th percentile plus 3 times the interquartile range were represented as outliers.

We also examined vessel routes to determine if vessel operators altered course to avoid a DMA. For vessels with transits that were located entirely within the 10 n mile buffer, a hypothetical shortest-possible route was created using the vessel's first and last positions. If the hypothetical shortest-possible route intersected the DMA, we considered the transit a potential avoidance transit (Fig. 2). We conducted this analysis for transits initiated during the effective periods, as well as for the 2 wk periods directly preceding and following the effective periods.

RESULTS

A total of 3324 trips consisting of at least 1 n mile were made by 1100 individual vessels through active DMAs. The average number of transits per DMA was 50 and ranged from 1 to 372. The majority of transits were made by tankers (n = 961), followed by cargo vessels (n = 781) and tugs (n = 370). Of the 1100 unique vessels, 769 were foreign-flagged.

Of the 3324 transits analyzed, 1799 included at least 5 n miles of uninterrupted travel at speeds of 5 knots or greater both inside the DMAs and 10 n mile buffers outside DMAs and thus were included in the vessel speed analyses. The 1799 transits were made by 745 individual vessels, 557 of which were foreign-flagged. On average, speeds in active DMAs were greater than the requested limit of ≤10 knots (mean = 12.0, SD = 3.91). Differences in median speeds in DMAs (Mdn = 11.4) as compared to their adjoining buffer areas (Mdn = 12.0) were statistically significant ($Z = 5.96$, $p < .001$) (Fig. 3); however, the differences were small, and reductions in speeds were not great enough to universally comply with the requested 10 knot limit. We found similar relationships among cargo, tanker, and passenger vessel types. Mean speeds by tanker and cargo vessels were <0.5 knots lower inside DMAs than in their respective buffer areas. The largest difference in speeds was observed for passenger vessels, whose mean speeds in the 10 n mile buffer areas and DMAs were 16.05 and 14.10 knots, respectively. Considering individual trips, however, 599 of the 1799 analyzed had mean speeds equal to or below the requested maximum of 10 knots; of those, 166 had mean speeds above 10 knots prior to entering the DMA.

Potential avoidance transits were observed in the active periods of only 18 of the 66 DMAs analyzed (Table 2). In 7 of these 18 (all of which occurred off New England), potential avoidance transits were observed only during the active period and not in the 2 wk periods before and after the DMA went into effect. However, in the remainder (i.e. 11 of 18) of the DMAs in which apparent course changes were made, we also detected avoidance transits in the 2 wk period directly preceding and/or following the DMA active period. This suggests that other factors likely played a role in determining routes chosen by operators that we attributed to 'avoidance', regardless of whether a DMA had been established. For example, vessel operators may have been responding instead to other navigational measures lying adjacent to or near those areas in which DMAs were imposed, including the existence of recommended routes in waters off Georgia/Florida and a traffic separation scheme and an 'Area To Be Avoided' off New England (see www.nmfs.noaa.gov/pr/shipstrike/ for descriptions of locations of each of these) immediately adjacent to a DMA.

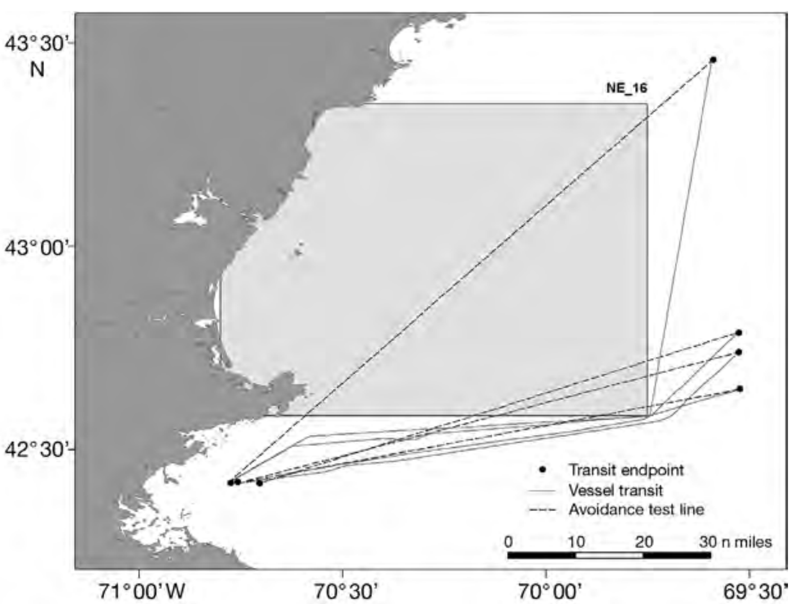

Fig. 2. Four vessel transits around dynamic management area (DMA) NE_16 in which courses may have been altered to avoid travel through the management area. See 'Vessel operations in DMAs' in 'Materials and methods'

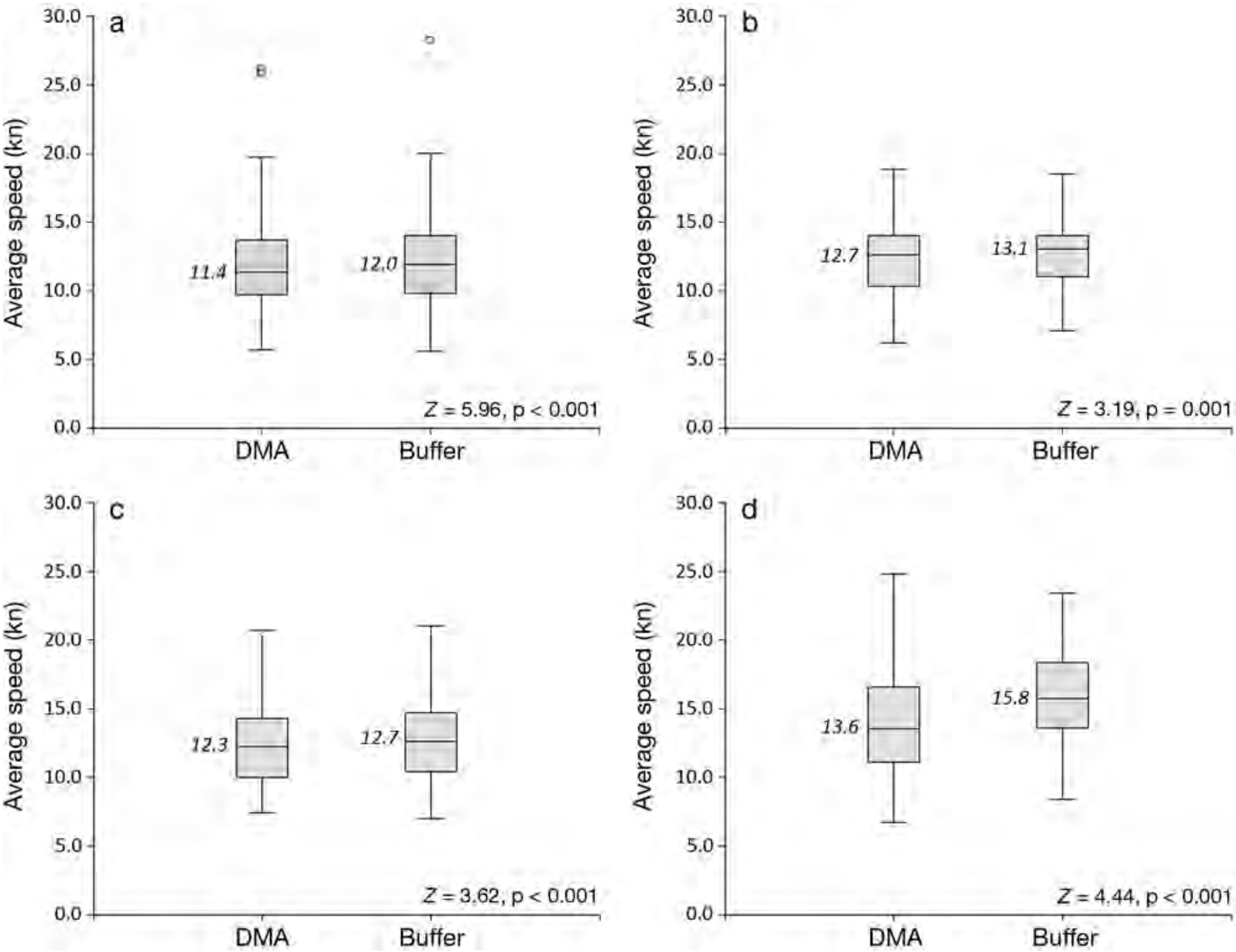

Fig. 3. Box plots of average vessel transit speeds within the dynamic management areas (DMAs) and 10 nautical mile buffers located outside of the DMAs for (a) all vessels combined, (b) tanker vessels, (c) cargo vessels, and (d) passenger vessels. Median speeds, represented by bars inside of the box plots, are provided along with the results from the Wilcoxon signed-rank tests. Data values greater than the 75th percentile plus 3.0 times the interquartile range are shown as outliers (⊙)

DISCUSSION

A number of measures involving changes in vessel operations have been implemented in various regions around the world to reduce the threat of vessel collisions with endangered large whale species. These include both mandatory and voluntary vessel speed restrictions and changes to vessel routes. Levels of vessel operator participation in heeding these measures appeared to be mixed. For example, mariner adherence with voluntary measures that include an 'Area To Be Avoided' (e.g. Vanderlaan et al. 2009), 3 modified traffic separation schemes (Tejedor et al. 2007, Vanderlaan et al. 2008, Silber et al. 2012), and recommended routes (Lagueux et al. 2011) tended to be high. In contrast, Wiley et al. (2008) found that adherence to guidelines for whale-watch vessels was low, and compliance with both voluntary and mandatory vessel speed restrictions has also been low, at least initially (Silber & Bettridge 2010). The relative success of some measures may depend upon their being endorsed by the International Maritime Organization (Silber et al. 2012), the efficacy of outreach or monitoring and mariner notification programs, or may suggest vessel operators are more likely to adhere to voluntary routing measures than those involving vessel speed reductions.

We made the assumption that vessel operators were adequately notified about the management areas, but we were not able to confirm this. Therefore, a better understanding is needed about why the outcome of this program was less than expected. Factors may include, for example, that notification of the management areas was not universally received by

Table 2. Number of 'avoidance transits' (see 'Results' for a definition of this term) detected for the dynamic management areas (DMAs) during their respective active periods and during the 2 wk immediately preceding and following their active periods. Only those DMAs in which avoidance transits were detected are listed

DMA	Vessel type	Avoidance transits Before	During	After
NE_04[a]	Tanker	0	4	0
NE_07	Tug	1	1	1
NE_08	Tanker	1	1	0
NE_11[a]	Tanker	0	1	0
NE_13	Tanker	0	1	1
NE_14[a]	Tanker	0	1	0
NE_15	Passenger	0	3	1
	Tanker	0	1	1
NE_16[a]	Passenger	0	2	0
	Tanker	0	2	0
NE_17[a]	Passenger	0	1	0
NE_18	Passenger	0	1	0
	Tanker	0	0	2
NE_31	Other	0	1	0
	Tanker	0	0	1
NE_33[a]	Tanker	0	1	0
NE_38[a]	Passenger	0	1	0
NE_57	Cargo	1	0	0
	Other	0	0	1
	Pleasure	0	0	1
	Sailing	0	0	2
	Tanker	5	2	1
NE_58	Sailing	1	0	0
	Tug	0	2	2
SE_03	Towing	0	0	1
SE_05	Cargo	0	1	0
	Pleasure	0	0	1
	Tug	0	1	1
SE_10	BigTow	1	0	0
	Cargo	7	5	7
	Dredging	1	0	0
	Tanker	0	1	0

[a]Avoidance transits were not detected in the 2 wk periods directly before and after the DMA was in effect

vessel operators, they were received but ignored, at-sea conditions precluded slowing to 10 knots, or other factors. However, the studies needed to make these determinations are beyond the scope of this one.

We analyzed and presented these data in rather broad terms (e.g. mean speeds) to assess the overall effectiveness of the program at an affected population level, but this approach may obscure some changes in behavior (e.g. changes in speeds) made by individual vessels or segments of the population. It appears, for example, that operators of passenger vessels made somewhat greater attempts than those operating other vessel types to alter their operations in response to DMAs. Additional analysis is likely needed to determine, with greater specificity, if individual vessel operators or certain segments of this community were aware of and made attempts to comply with the requests made through this program. Such analysis is advisable to further assess the utility of the program or specific aspects of it.

Voluntary conservation measures are generally preferable to those that are mandated because the former are more readily implemented and have fewer administrative costs (Alberini & Segerson 2002), do not require development of enforcement programs, and have various benefits derived from willing participation. However, data are not always available to determine if compliance with such initiatives is actually occurring, and we herewith add to the handful of studies in which compliance has been measured in regards to reducing vessel-strikes. We found that, when taken in the aggregate, mariners exhibited real and detectable, but generally low levels of adherence with requests to alter speed or course. Therefore, this program likely had only a modest consequence in reducing the occurrence of vessel collisions with right whales *Eubalaena glacialis*.

Public voluntary programs may have the tacit benefits of improved environmental protection that results from community-wide dissemination of information even if changes in behavior are not quantified (Lyon & Maxwell 2007), and it is possible this is an unintended benefit of the program we studied. However, the lackluster response of vessel operators to DMAs suggests only moderate success of the program in achieving its goals and that the NMFS may want to re-evaluate the utility of the program and consider, for example, doing away with it to devote energy to more effective ship-strike reduction measures, or altering it to enhance its effectiveness perhaps by making certain actions within DMAs mandatory and enforceable.

Our findings may have application to other settings where voluntary environmental conservation actions are contemplated or undertaken. If they are used, consideration should be given to establishing realistic, agreed-upon baselines (Morgenstern & Pizer 2007) and reasonable expected outcomes; developing means to engage, notify, and ensure adherence by the affected communities; and creating monitoring programs that enable periodic assessment the program's overall conservation value (Alberini & Segerson 2002, Vanderlaan & Taggart 2009, Silber et al. 2012).

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Oceana Comment
Attachments

NORTH ATLANTIC RIGHT WHALE (*Eubalaena glacialis*): Western Atlantic Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

The western North Atlantic right whale population ranges primarily from calving grounds in coastal waters of the southeastern U.S. to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence. Mellinger *et al.* (2011) reported acoustic detections of right whales near the nineteenth-century whaling grounds east of southern Greenland, but the number of whales and their origin is unknown. However, Knowlton *et al.* (1992) reported several long-distance movements as far north as Newfoundland, the Labrador Basin, and southeast of Greenland. In addition, resightings of photographically identified individuals have been made off Iceland, in the old Cape Farewell whaling ground east of Greenland (Hamilton *et al.* 2007), in northern Norway (Jacobsen *et al.* 2004), and in the Azores (Silva *et al.* 2012). The September 1999 Norwegian sighting represents one of only two published sightings in the 20th century of a right whale in Norwegian waters, and the first since 1926. Together, these long-range matches indicate an extended range for at least some individuals and perhaps the existence of important habitat areas not presently well described. A few published records from the Gulf of Mexico (Moore and Clark 1963; Schmidly *et al.* 1972; Ward-Geiger *et al*. 2011) likely represent occasional wanderings of individuals beyond the sole known calving and wintering ground in the waters of the southeastern U. S. The location of much of the population is unknown during the winter. Davis *et al.* (2017) recently pooled together detections from a large number of passive acoustic devices and documented broad-scale use of much more of the U.S. eastern seaboard than previously believed. Further, there has been an apparent shift in habitat use patterns (Davis *et al*. 2017). Surveys flown in an area from 31 to 160 km from the shoreline off northeastern Florida and southeastern Georgia since 1996 report the majority of right whale sightings occur within 90 km of the shoreline. One sighting occurred ~140 km offshore (NMFS unpub. data) and an offshore survey in March 2010 observed the birth of a right whale in waters 75 km off Jacksonville, Florida (Foley *et al.* 2011). Although habitat models predict that right whales are not likely to occur farther than 90 km from the shoreline (Gowan and Ortega-Ortiz 2015), the frequency with which right whales occur in offshore waters in the southeastern U.S. remains unclear.

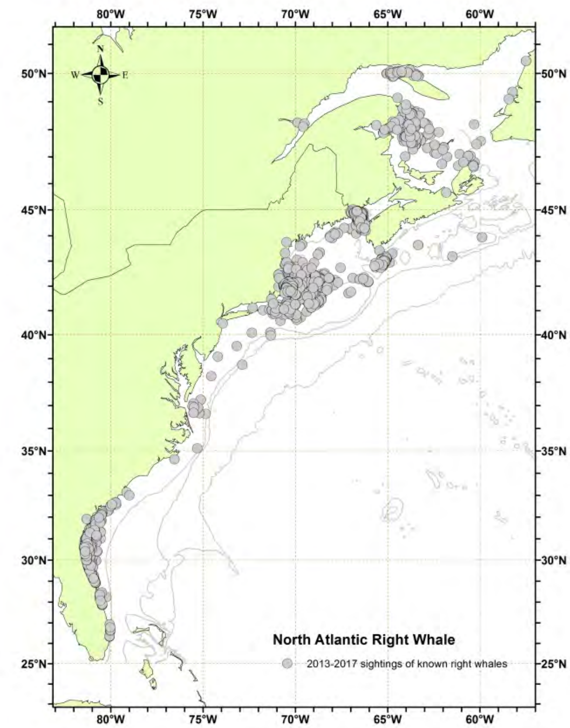

Figure 1. Distribution of sightings of known North Atlantic right whales, 2013-2017. Isobaths are the 100-m, 1000-m and 4000-m depth contours.

Visual and acoustic surveys have demonstrated the existence of seven areas where western North Atlantic right whales aggregate seasonally: the coastal waters of the southeastern U.S.; the Great South Channel; Jordan Basin; Georges Basin along the northeastern edge of Georges Bank; Cape Cod and Massachusetts Bays; the Bay of Fundy; and the Roseway Basin on the Scotian Shelf (Brown *et al*. 2001; Cole *et al.* 2013). Since 2013, increased detections and survey effort in the Gulf of St. Lawrence indicate right whale presence in late spring through early fall (Cole *et al.* 2016, Khan *et al.* 2016, 2018). Passive acoustic studies of right whales have demonstrated their year-round presence in the Gulf of Maine (Morano *et al.* 2012; Bort *et al.* 2015), New Jersey (Whitt *et al.* 2013), and Virginia (Salisbury *et al*. 2016). Additionally, right whales were acoustically detected off Georgia and North Carolina in 7 of 11 months monitored (Hodge *et al*. 2015). All of this work further demonstrates the highly mobile nature of right whales. Movements within and between habitats are extensive, and the area off the mid-Atlantic states is an important migratory corridor. In 2000, one whale was photographed in Florida waters on 12 January, then again 11 days later (23 January) in Cape Cod Bay, less than a month later off Georgia (16 February), and back in Cape Cod Bay on 23 March, effectively making the round-trip migration to the Southeast and back at least twice during the winter season (Brown and Marx 2000). Results from satellite-tagging studies clearly indicate that sightings separated by perhaps two weeks should not necessarily be assumed to indicate a stationary or resident animal. Instead, telemetry data have shown rather lengthy excursions, including into deep water off the continental shelf (Mate *et al.* 1997; Baumgartner and Mate 2005). Systematic visual surveys conducted off the coast of North Carolina during the winters of 2001 and 2002 sighted 8 calves, suggesting the calving grounds may extend as far north as Cape Fear (W.A. McLellan, Univ. of North Carolina Wilmington, pers. comm.). Four of those calves were not sighted by surveys conducted farther south. One of the females photographed was new to researchers, having effectively eluded identification over the period of its maturation. In 2016 the Southeastern U.S. Calving Area Critical Habitat was expanded north to Cape Fear, North Carolina. There is also at least one case of a calf apparently being born in the Gulf of Maine (Patrician *et al*. 2009) and another newborn was detected in Cape Cod Bay in 2012 (Center for Coastal Studies, Provincetown, MA USA, unpub. data).

Right whale calls have been detected by autonomous passive acoustic sensors deployed between 2005 and 2010 at three sites (Massachusetts Bay, Stellwagen Bank, and Jeffreys Ledge) in the southern Gulf of Maine (Morano *et al*. 2012, Mussoline *et al*. 2012). Comparisons between detections from passive acoustic recorders and observations from aerial surveys in Cape Cod Bay between 2001 and 2005 demonstrated that aerial surveys found whales on approximately two-thirds of the days during which acoustic monitoring detected whales (Clark *et al*. 2010). These data suggest that the current understanding of the distribution and movements of right whales in the Gulf of Maine and surrounding waters is incomplete. Additionally, the aforementioned apparent shift in habitat use patterns since 2010, highlighted by Davis *et al.* (2017), includes increased use of Cape Cod Bay (Mayo *et al.* 2018) and decreased use of the Great South Channel.

New England waters are important feeding habitats for right whales, where they feed primarily on copepods (largely of the genera *Calanus* and *Pseudocalanus*). Right whales must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx 1990). These dense zooplankton patches are likely a primary characteristic of the spring, summer, and fall right whale habitats (Kenney *et al.* 1986, 1995). While feeding in the coastal waters off Massachusetts has been better studied than in other areas, right whale feeding has also been observed on the margins of Georges Bank, in the Great South Channel, in the Gulf of Maine, in the Bay of Fundy, and over the Scotian Shelf (Baumgartner *et al.* 2007). The characteristics of acceptable prey distribution in these areas are beginning to emerge (Baumgartner *et al.* 2003; Baumgartner and Mate 2003). The National Marine Fisheries Service (NMFS) and Center for Coastal Studies aerial surveys during the springs of 1999–2011 found right whales along the Northern Edge of Georges Bank, in the Great South Channel, in Georges Basin, and in various locations in the Gulf of Maine including Cashes Ledge, Platts Bank, and Wilkinson Basin. Analysis of the sightings data has shown that the utilization of these areas has a strong seasonal component (Pace and Merrick 2008). Although right whales are consistently found in these locations, studies also highlight the high interannual variability in right whale use of some habitats (Pendleton *et al.* 2009, Ganley *et al.* 2019). In 2016, the Northeastern U.S. Foraging Area Critical Habitat was expanded to include nearly all U.S. waters of the Gulf of Maine (81 FR 4837, 26 February 2016).

An important shift in habitat use patterns in 2010 was highlighted in an analysis of right whale acoustic presence along the U.S. Eastern seaboard from 2004 to 2014 (Davis *et al.* 2017). This shift was also reflected in visual survey data in the greater Gulf of Maine region. Between 2012 and 2016, visual surveys have detected fewer individuals in the Great South Channel and the Bay of Fundy. In addition, late winter use of a region south of Martha's Vineyard and Nantucket Islands was recently described (Leiter *et al.* 2017). A large increase in aerial surveys of the Gulf of St. Lawrence documented at least 34, 105, and 131 unique individuals using the region, respectively, during the summers of 2015, 2017, and 2018 (NMFS unpublished data).

Genetic analyses based upon direct sequencing of mitochondrial DNA (mtDNA) have identified 7 mtDNA haplotypes in the western North Atlantic right whale, including heteroplasmy that led to the declaration of the seventh haplotype (Malik *et al.* 1999, McLeod and White 2010). Schaeff *et al.* (1997) compared the genetic variability of North Atlantic and southern right whales (*E. australis*), and found the former to be significantly less diverse, a finding broadly replicated by Malik *et al.* (2000). The low diversity in North Atlantic right whales might indicate inbreeding, but no definitive conclusion can be reached using current data. Modern and historic genetic population structures were compared using DNA extracted from museum and archaeological specimens of baleen and bone. This work suggested that the eastern and western North Atlantic populations were not genetically distinct (Rosenbaum *et al.* 1997, 2000). However, the virtual extirpation of the eastern stock and its lack of recovery in the last hundred years strongly suggest population subdivision over a protracted (but not evolutionary) timescale. Genetic studies concluded that the principal loss of genetic diversity occurred prior to the 18th century (Waldick *et al.* 2002). However, revised conclusions that nearly all the remains in the North American Basque whaling archaeological sites were bowhead whales (*Balaena mysticetus*) and not right whales (Rastogi *et al.* 2004; McLeod *et al.* 2008) contradict the previously held belief that Basque whaling during the 16th and 17th centuries was principally responsible for the loss of genetic diversity.

High-resolution (i.e., using 35 microsatellite loci) genetic profiling has been completed for >75% of all North Atlantic right whales identified through 2006. This work has improved our understanding of genetic variability, the number of reproductively active individuals, reproductive fitness, parentage, and relatedness of individuals (Frasier *et al.* 2007, 2009). One emerging result of the genetic studies is the importance of obtaining biopsy samples from calves on the calving grounds. Between 1990 and 2010, only about 60% of all known calves were seen with their mothers in summering areas when their callosity patterns are stable enough to reliably make a photo-ID match later in life. The remaining 40% were not seen on a known summering ground. Because the calf's genetic profile is the only reliable way to establish parentage, if the calf is not sampled when associated with its mother early on, then it is not possible to link it with a calving event or to its mother, and information such as age and familial relationships is lost. From 1980 to 2001, there were 64 calves born that were not sighted later with their mothers and thus unavailable to provide age-specific mortality information (Frasier *et al.* 2007). An additional interpretation of paternity analyses is that the population size may be larger than was previously thought. Fathers for only 45% of known calves have been genetically determined; yet, genetic profiles were available for 69% of all photo-identified males (Frasier 2005). The conclusion was that the majority of these calves must have different fathers that cannot be accounted for by the unsampled males, therefore the population of males must be larger (Frasier 2005). However, a recent study compared photo-identification and pedigree genetic data for animals known or presumed to be alive during 1980-2016 and found that the presumed alive estimate is similar to the actual abundance of this population, which indicates that the majority of the animals have been photo-identified (Fitzgerald 2018).

POPULATION SIZE

The western North Atlantic right whale stock size is based on a published state-space model of the sighting histories of individual whales identified using photo-identification techniques (Pace *et al.* 2017). Sightings histories were constructed from the photo-ID recapture database as it existed in October 2018. Using a hierarchical, state-space Bayesian open population model of these histories produced a median abundance value. The best abundance estimate available for the North Atlantic right whale stock is 428 individuals (95% credible intervals 406-447). As with any statistically-based estimation process, uncertainties exist in the estimation of abundance because it is based on a probabilistic model that makes certain assumptions about the structure of the data. Because the statistically-based uncertainty is asymmetric about N, the credible interval is used above to characterize that uncertainty (as opposed to a CV that may appear in other stock assessment reports).

Historical Abundance

The total North Atlantic right whale population size pre-whaling is estimated between 9,075 and 21,328 based on extrapolation of spatially explicit models of carrying capacity in the North Pacific (Monserrat *et al.* 2015). Basque whalers were thought to have taken right whales during the 1500s in the Strait of Belle Isle region (Aguilar 1986), however, genetic analysis has shown that nearly all of the remains found in that area are, in fact, those of bowhead whales (Rastogi *et al.* 2004; Frasier *et al.* 2007). This stock of right whales may have already been substantially reduced by the time colonists in Massachusetts started whaling in the 1600s (Reeves *et al.* 2001, 2007). A modest but persistent whaling effort along the coast of the eastern U.S. lasted three centuries, and the records include one report of 29 whales killed in Cape Cod Bay in a single day in January 1700. Reeves *et al*. (2007) calculated that a minimum of 5.500 right whales were taken in the western North Atlantic between 1634 and 1950, with nearly 80% taken in a 50-year period between 1680 and 1730. They concluded "there were at least a few thousand whales present in the mid-1600s." The authors cautioned, however, that the record of removals is incomplete, the results were preliminary, and refinements are required. Based on back calculations using the present population size and growth rate, the population may have numbered fewer than 100 individuals by 1935 when international protection for right whales came into effect (Hain 1975; Reeves *et al.* 1992; Kenney *et al.* 1995). However, little is known about the population dynamics of right whales in the intervening years.

Minimum Population Estimate

The minimum population estimate is the lower limit of the two-tailed 60% credible interval about the median of the posterior abundance estimates using the methods of Pace *et al*. (2017). This is roughly equivalent to the 20th percentile of the log-normal distribution as specified by Wade and Angliss (1997). The median estimate of abundance for western North Atlantic right whales is 428. The minimum population estimate as of January 2017 is 418 and stands as Nmin. The 17 known mortalities from 2017 are not accounted for in this estimate.

Current Population Trend

The population growth rate reported for the period 1986–1992 by Knowlton *et al.* (1994) was 2.5% (CV=0.12), suggesting that the stock was recovering slowly, but that number may have been influenced by discovery phenomenon as existing whales were recruited to the catalog. Work by Caswell *et al.* (1999) suggested that crude survival probability declined from about 0.99 in the early 1980s to about 0.94 in the late 1990s. The decline was statistically significant. Additional work conducted in 1999 was reviewed by the IWC workshop on status and trends in this population (IWC. 2001); the workshop concluded based on several analytical approaches that survival had indeed declined in the 1990s. Although capture heterogeneity could negatively bias survival estimates, the workshop concluded that this factor could not account for the entire observed decline, which appeared to be particularly marked in adult females. Another workshop was convened by NMFS in September 2002, and it reached imilar conclusions regarding the decline in the population (Clapham 2002). At the time, the early part of the recapture series had not been examined for excessive retrospective recaptures which had the potential to positively bias the earliest estimates of survival as the catalog was being developed.

Examination of the abundance estimates for the years 1990–2011 (Figure 2) suggests that abundance increased at about 2.8% per annum from posterior median point estimates of 270 individuals in 1990 to 481 in 2011, but that there was a 99.99% chance that abundance declined from 2011 to 2017 when the final estimate was 428 individuals. As noted above, there seems to have been a considerable change in right whale habitat use patterns in areas where most of the population has been observed in previous years exposing the population to additional anthropogenic threats (Hayes *et al.* 2018). This apparent change in habitat use has the effect that, despite relatively constant effort to find whales, the chance of seeing an individual that is alive has decreased. However, the methods in Pace *et al.* (2017) account for changes in capture probability.

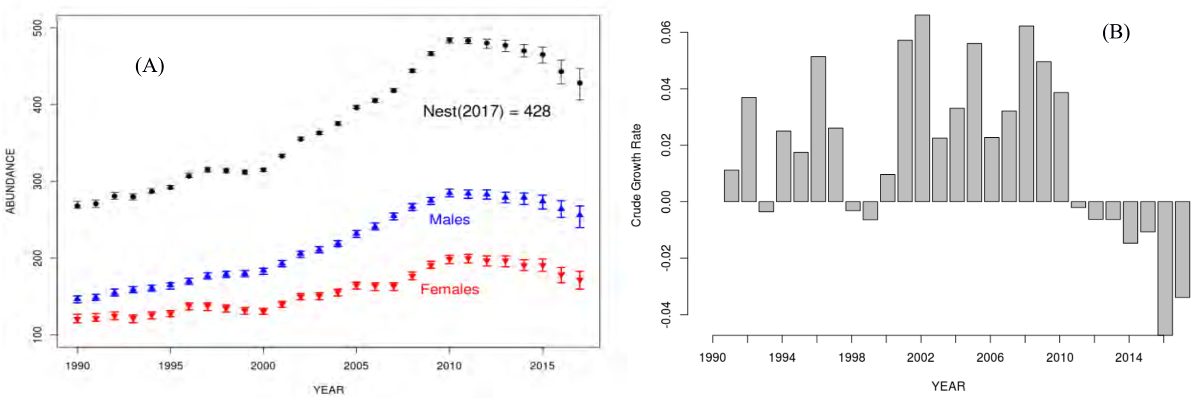

Figure 2. (A) Abundance estimates for North Atlantic right whales. Estimates are the median values of a posterior distribution from modeled capture histories. Also shown are sex-specific abundance estimates. Cataloged whales may include some but not all calves produced each year. (B) Crude annual growth rates from the abundance values.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

During 1980–1992, at least 145 calves were born to 65 identified females. The number of calves born annually ranged from 5 to 17, with a mean of 11.2 (SE=0.90). The reproductively active female pool was static at approximately 51 individuals during 1987–1992. Mean calving interval, based on 86 records, was 3.67 years. There was an indication that calving intervals may have been increasing over time, although the trend was not statistically significant (P=0.083) (Knowlton *et al.* 1994). Since 1993, calf production has been more variable than a simple stochastic model would predict.

During 1990–2017, at least 447 calves were born into the population. The number of calves born annually ranged from 1 to 39, and averaged 16 but was highly variable (SD=8.9). The fluctuating abundance observed from 1990 to 2017 makes interpreting a count of calves by year less clear than measuring population productivity, which we index by the number of calves detected/estimated abundance (Apparent Productivity Index or API). Productivity for this stock has been highly variable over time and has been characterized by periodic swings in per capita birth rates (Figure 3). Notwithstanding the high variability observed, and expected for a small population, productivity in North Atlantic right whales lacks a definitive trend. Corkeron *et al.* (2018) found that during 1990–2016, calf count rate increased at 1.98% per year with outlying years of very high and low calf production. This is approximately a third of that found for three different southern right whale (*Eubalaena australis)* populations during the same time period (5.3-7.2%). Their projection models suggest that this rate could be 4% per year if female survival was the highest recorded over the time series from Pace *et al.* (2017). Reviewing the available literature, Corkeron *et al.* (2018) showed that female mortality is primarily anthropogenic, and concluded that anthropogenic mortality has limited the recovery of North Atlantic right whales. In a similar effort, Kenny (2018) projected a series of scenarios that varied entanglement mortality from observed to zero. Using a scenario with zero entanglement mortality, which included 15 'surviving' females, and a five year calving interval, the projected population size including 26 additional calf births would be 588 by 2016.

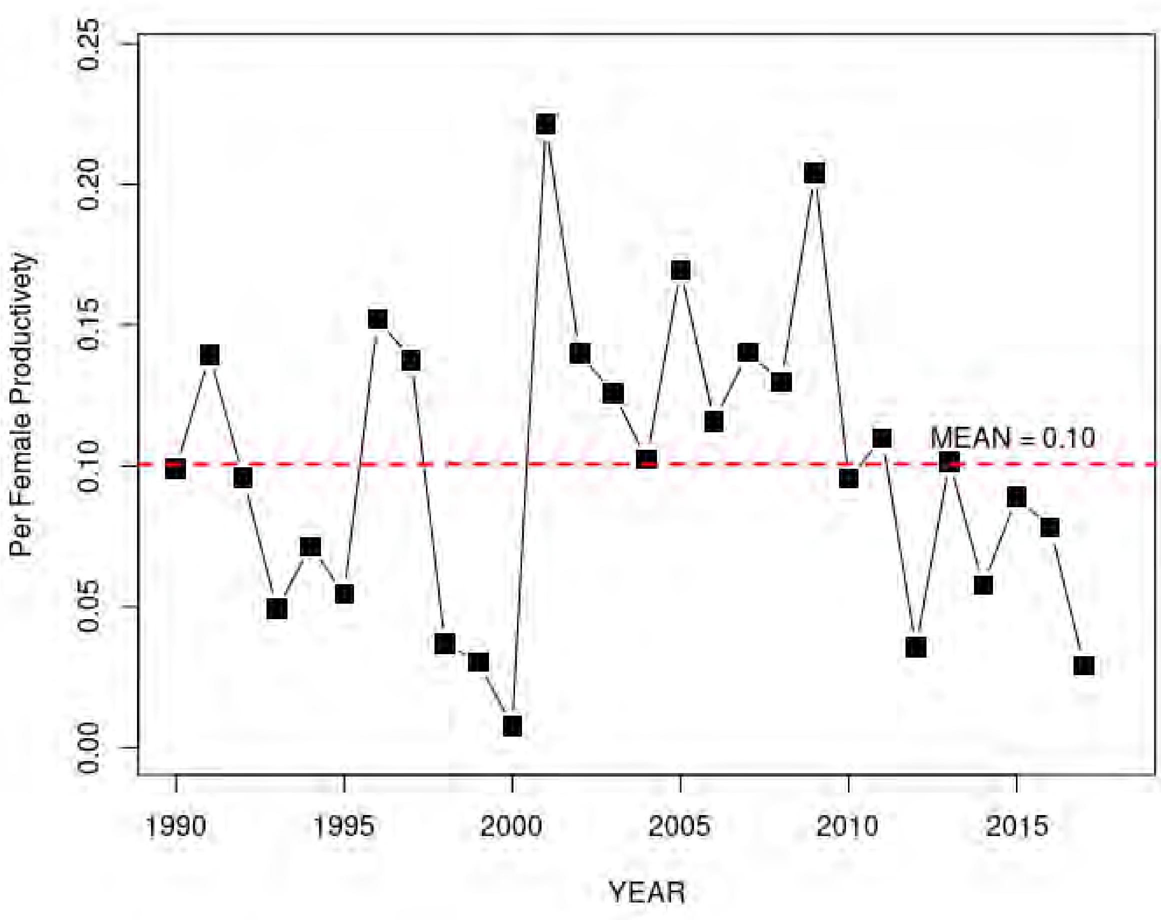

Figure 3. Productivity in the North Atlantic right whale population as characterized by calves detected/(estimated number of females).

North Atlantic right whales have thinner blubber than southern right whales off South Africa (Miller *et al.* 2011). Blubber thickness of male North Atlantic right whales (males were selected to avoid the effects of pregnancy and lactation) varied with *Calanus* abundance in the Gulf of Maine (Miller *et al.* 2011). Sightings of North Atlantic right whales correlated with satellite-derived sea-surface chlorophyll concentration (as a proxy for productivity), and calving rates correlated with chlorophyll concentration prior to gestation (Hlista *et al.* 2009). On a regional scale, observations of North Atlantic right whales correlate well with copepod concentrations (Pendleton *et al*. 2009). The available evidence suggests that at least some of the observed variability in the calving rates of North Atlantic right whales is related to variability in nutrition (Fortune *et al.* 2013) and possibly increased energy expenditures related to non-lethal entanglements (Rolland *et al.* 2016; Pettis *et al.* 2017; van der Hoop 2017).

An analysis of the age structure of this population suggests that it contains a smaller proportion of juvenile whales than expected (Hamilton *et al.* 1998; IWC 2001), which may reflect lowered recruitment and/or high juvenile mortality. Calf and perinatal mortality was estimated by Browning *et al.* (2010) to be between 17 and 45 animals during the period 1989 and 2003. In addition, it is possible that the apparently low reproductive rate is due in part to an unstable age structure or to reproductive dysfunction in some females. However, few data are available on either factor and senescence has not been documented for any baleen whale.

The maximum net productivity rate is unknown for this stock. For purposes of this assessment, the maximum net productivity rate was assumed to be the default value of 0.04. This value is based on theoretical modeling showing that cetacean populations may not grow at rates much greater than 4% given the constraints of their reproductive life history (Barlow *et al.* 1995). Single year production has exceeded 0.04 in this population several times, but those outputs are not likely sustainable given the 3-year minimum interval required between successful calving events and the small fraction of reproductively active females. This is likely related to synchronous calving that can occur in capital breeders under variable environmental conditions. Hence, uncertainty exists as to whether the default value is representative of maximum net productivity for this stock, but it is unlikely that it is much higher than the default.

POTENTIAL BIOLOGICAL REMOVAL

Potential biological removal (PBR) is the product of minimum population size, one-half the maximum net productivity rate and a recovery factor for endangered, depleted, threatened stocks, or stocks of unknown status relative to OSP (MMPA Sec. 3. 16 U.S.C. 1362; Wade and Angliss 1997). The recovery factor for right whales is 0.1 because this species is listed as endangered under the Endangered Species Act (ESA). The minimum population size is 418. The maximum productivity rate is 0.04, the default value for cetaceans. PBR for the Western Atlantic stock of the North Atlantic right whale is 0.8.

ANNUAL HUMAN-CAUSED SERIOUS INJURY AND MORTALITY

For the period 2013 through 2017, the minimum rate of annual human-caused mortality and serious injury to right whales averaged 6.85 per year. This is derived from two components: 1) incidental fishery entanglement records at 5.55 per year, and 2) vessel strike records at 1.3 per year. Early analyses of the effectiveness of the ship strike rule were reported by Silber and Bettridge (2012). Recently, van der Hoop *et al.* (2015) concluded that large whale mortalities due to vessel strikes decreased inside active seasonal management areas (SMAs) and increased outside inactive SMAs. Analysis by Laist *et al.* (2014) incorporated an adjustment for drift around areas regulated under the ship strike rule and produced weak evidence that the rule was effective inside the SMAs. When simple logistic regression models fit using maximum likelihood-based estimation procedures are applied to previously reported vessel strikes between 2000 and 2017 (Henry *et al.* 2020), there is no apparent trend (Fig 4). However, the odds of an entanglement event are now increasing by 6.3% per year.Although PBR analyses in this SAR reflect data collected through 2016, There were 17 right whale mortalities in 2017 (Daoust *et al.* 2017). This number exceeds the largest estimated mortality rate during the past 25 years. Further, despite high survey effort, only 5 and 0 calves were detected in 2017 and 2018, respectively. Therefore, the decline in the right whale population will continue for at least an additional 2 years.

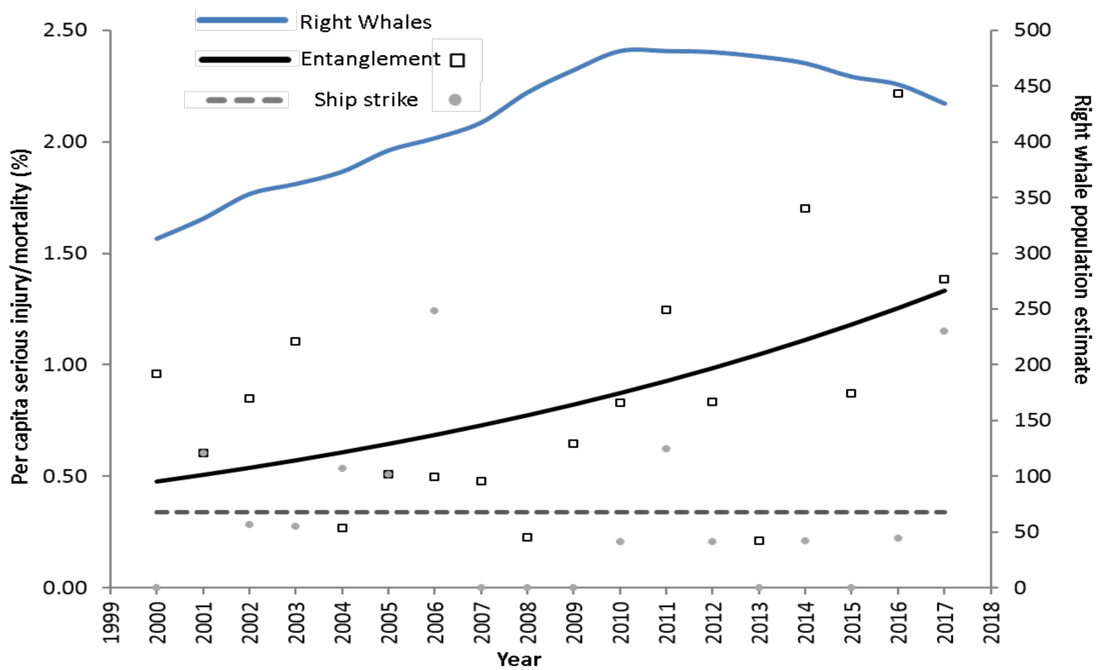

Figure 4. North Atlantic right whale serious injury/mortality rates from known sources 2000-2017. The right whale population trend is overlaid and referenced to right y-axis

Beginning with the 2001 Stock Assessment Report, Canadian records have been incorporated into the mortality and serious injury rates to reflect the effective range of this stock. It is important to stress that serious injury determinations are made based upon the best available information; these determinations may change with the availability of new information (Henry *et al.* 2020). For the purposes of this report, discussion is limited to those records considered confirmed human-caused mortalities or serious injuries. Annual rates calculated from detected mortalities should be considered a low-biased accounting of human-caused mortality; they represent a definitive lower bound. Detections are irregular, incomplete, and not the result of a designed sampling scheme. A key uncertainty is the fraction of the actual human-caused mortality represented by the detected serious injuries and mortalities. Research on small cetaceans has shown the actual number of deaths can be several times higher than that observed (Wells and Allen 2015; Williams *et al.* 2011). For North Atlantic right whales, estimates of the total mortality exceed or equal the number of detected serious injuries and mortalities (Figure 5) and currently 72% of mortalities since 2000 are estimated to have been observed. Because annual population estimates are now available (Pace *et al.* 2017), it is possible to estimate total annual mortality (and the number of undetected mortalities) by applying the basic population dynamic formula (Williams *et al.* 2002):

$N_{t+1} = N_t + B_t - D_t$

Where N_t is the number of animals in a population in year *t*, N_{t+1} is the number of animals in the population in year *t+1*, B_t is the number of births in the population in year *t*, and D_t is the number of deaths in the population in year *t*.

Solving for D_t yields: $D_t = N_t + B_t - N_{t+1}$ which can then be used to estimate undetected mortality as: D_t- observed deaths= undetected deaths.

The total mortality estimated described above is based on the assumption that all animals that exit from the population in the model are actual deaths and that all entries into the population are births. If immigration were occurring, new mature animals would be documented and captured in the estimate of B_t. There is a lack of any evidence for permanent emigration from the population. Temporary emigration (*e.g.* the animal is not observed in the survey area for multiple years) only adds to individual capture heterogeneity, which is accommodated by the model given the longevity of the data sets. Importantly, these assumptions are not novel to the total mortality estimate, but a core part of the published Pace *et al.* (2017) population estimate. A method to assign cause to these undetected mortalities is currently under development; as such these additional mortalities are not counted towards PBR at this time. Another uncertainty is assigning many of the detected entanglements to country of origin. Gear recovered is often not adequately marked and whales have been known to carry gear for long periods of time and over great distances before being detected.

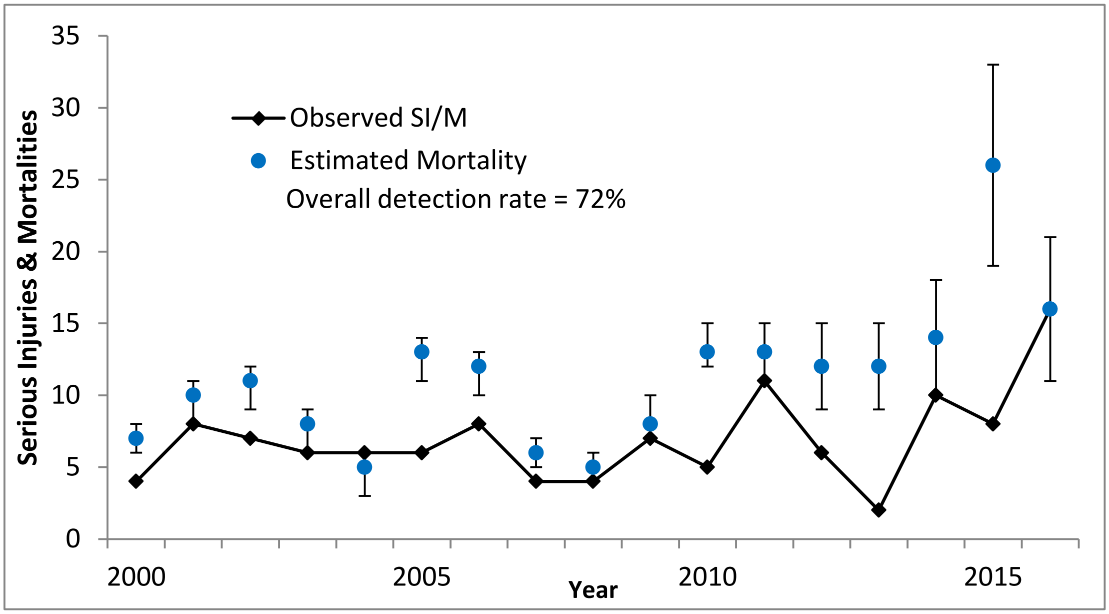

Figure 5. Time series of observed annual total serious injuries and mortalities (SI/M; black line) versus estimated total mortalities (blue points with associated error bars).

Background

The details of a particular mortality or serious injury record often require a degree of interpretation (Moore *et al.* 2005; Sharp *et al.* 2019). The assigned cause is based on the best judgment of the available data; additional information may result in revisions. When reviewing Table 1 below, several factors should be considered: 1) a vessel strike or entanglement may have occurred at some distance from the location where the animal is detected/reported; 2) the mortality or injury may involve multiple factors; for example, whales that have been both vessel struck and entangled are not uncommon; 3) the actual vessel or gear type/source is often uncertain; and 4) in entanglements, several types of gear may be involved.

Further, the small population size and low annual reproductive rate of right whales suggest that human sources of mortality have a greater effect relative to population growth rates than for other whales (Corkeron *et al.* 2018). The principal factor believed to be retarding growth and recovery of the population is entanglement with fishing gear (Kenny 2018). Between 1970 and 2018, a total of 124 right whale mortalities was recorded (Knowlton and Kraus 2001; Moore *et al.* 2005; Sharp *et al.* 2019). Of these, 18 (14.5%) were neonates that were believed to have died from perinatal complications or other natural causes. Of the remainder, 26 (21.0%) resulted from vessel strikes, 26 (21.0%) were related to entanglement in fishing gear, and 54 (43.5%) were of unknown cause. At a minimum, therefore, 42% of the observed total for the period and 43% of the 102 non-calf deaths was attributable to human impacts (calves accounted for six deaths from ship strikes and two from entanglements). One should be cautious in applying these percentages as more than minimum rates as they only represent carcasses, and exclude serious injury which is highly skewed towards entanglement. A recent analysis of human-caused serious injury and mortality during 2000–2017 (Figure 4) shows that entanglement injuries have been increasing steadily over the past twenty years while injuries from vessel strikes have shown no specific trend despite several reported cases in 2017 (Hayes *et al.* 2018).

Finally, entanglement or minor vessel collisions may not kill an animal directly, but may weaken or otherwise affect it so that it is more likely to become vulnerable to further injury. Serious injury determinations for large whales commonly include animals carrying gear when these entanglements are constricting or appear to interfere with foraging (Henry *et al*. 2020).

Fishery-Related Mortality and Serious Injury

Not all mortalities are detected, but reports of known mortality and serious injury relative to PBR as well as total human impacts are contained in the records maintained by the New England Aquarium and the NMFS Greater Atlantic and Southeast Regional Offices (Table 1). From 2013 through 2017, 28 of those examined records of mortality or serious injury (including records from both U.S. and Canadian waters, prorated to 27.75 using serious injury guidelines) involved entanglement or fishery interactions. For this time frame, the average reported mortality and serious injury to right whales due to fishery entanglement was 5.55 whales per year. Information from an entanglement event often does not include the detail necessary to assign the entanglements to a particular fishery or location.

Although disentanglement is often unsuccessful or not possible for many cases, there are several documented cases of entanglements for which the intervention of disentanglement teams averted a likely serious-injury determination. Seven serious injuries were prevented by intervention during 2013–2017 (Henry *et al.* 2020). Sometimes, even with disentanglement, an animal may die of injuries sustained from fishing gear. A female yearling right whale, #3107, was first sighted with gear wrapping its caudal peduncle on 6 July 2002 near Briar Island, Nova Scotia. Although the gear was removed on 1 September by the New England Aquarium disentanglement team, and the animal seen alive during an aerial survey on 1 October, its carcass washed ashore at Nantucket on 12 October 2002 with deep entanglement injuries on the caudal peduncle. Additionally, but infrequently, a whale listed as seriously injured becomes gear-free without a disentanglement effort and is seen later in reasonable health. Such was the case for whale #1980, listed as a serious injury in 2008 but seen gear-free and apparently healthy in 2011.

Incidents of entanglements in waters of Atlantic Canada and the U.S. east coast were summarized by Read (1994) and Johnson *et al.* (2005). Despite the long history of known fishing interactions, the only bycatch of a right whale observed by the Northeast Fisheries Observer Program was in the pelagic drift gillnet fishery in 1993. No mortalities or serious injuries have been documented by fisheries observers in any of the other fisheries monitored by NMFS.

Whales often free themselves of gear following an entanglement event, and as such scarring may be a better indicator of fisheries interaction than entanglement records. A review of scars detected on identified individual right whales over a period of 30 years (1980–2009) documented 1,032 definite, unique entanglement events on the 626 individual whales identified (Knowlton *et al*. 2012). Most individual whales (83%) were entangled at least once, and over half of them (59%) were entangled more than once. About a quarter of the individuals identified in each year (26%) were entangled in that year. Juveniles and calves were entangled at higher rates than were adults. Scarring rates suggest that entanglements occur at about an order of magnitude more often than detected from observations of whales with gear on them. More recently, analyses of whales carrying entangling gear also suggest that entanglement wounds have become more severe since 1990, possibly due to increased use of stronger lines in fixed fishing gear (Knowlton *et al*. 2016).

Knowlton *et al.* (2012) concluded from their analysis of entanglement scarring rates over time that efforts made since 1997 to reduce right whale entanglement have not worked. Working from a completely different data source (observed mortalities of eight large whale species, 1970–2009), van der Hoop *et al*. (2012) arrived at a similar conclusion. Vessel strikes and entanglements were the two leading causes of death for known mortalities of right whales for which a cause of death could be determined. Across all 8 species of large whales, there was no detectable change in causes of anthropogenic mortality over time (van der Hoop *et al*. 2012). Pace *et al.* (2015) analyzed entanglement rates and serious injuries due to entanglement during 1999–2009 and found no support that mitigation measures implemented prior to 2009 had been effective at reducing takes due to commercial fishing. Since 2009, new entanglement mitigation measures (72 FR 193, 05 October 2007; 79 FR 124, 27 June 2014) have been implemented as part of the Atlantic Large Whale Take Reduction Plan, but their effectiveness has yet to be evaluated. Assessment efforts are underway but rely on a statistically-significant time series to determine effectiveness.

Other Mortality

Vessel strikes are a major cause of mortality and injury to right whales (Kraus 1990; Knowlton and Kraus 2001, van der Hoop *et al.* 2012). Records from 2013 through 2017 have been summarized in Table 1. For this time frame, the average reported mortality and serious injury to right whales due to vessel strikes was 1.3 whales per year.

An Unusual Mortality Event was established for North Atlantic right whales in June 2017 due to elevated stranding along the Atlantic coast, especially in the Gulf of St. Lawrence region of Canada (https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2018-north-atlantic-right-whale-unusual-mortality-event).

Table 1. Confirmed human-caused mortality and serious injury records of right whales: 2013–2017[a]

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
07/12/2013	Prorated Injury	3123	off Virginia Beach, VA	EN	.75	XU	NR	Constricting gear cutting into mouthline; Partially disentangled; final configuration unknown. No resights post Jul/2013
01/15/2014	Serious Injury	4394	off Ossabaw Island, GA	EN	1	XU	NP	No gear present but new ent. injuries indicating prior constricting gear on both pectorals and at fluke insertion. Injury to left ventral fluke. Evidence of health decline. No resights post Feb/2014.
04/01/2014	Serious Injury	1142	off Atlantic City, NJ	EN	1	XU	NR	Constricting rostrum wrap with line trailing to at least mid-body. Resighted in 2018. Health decline evident.
04/09/2014	Prorated Injury	-	Cape Cod Bay, MA	VS	.52	US	-	Animal surfaced underneath a research vessel while it was underway (39 ft at 9 kts). Small amount of blood and some lacerations of unknown depth on lower left flank.
06/29/2014	Serious Injury	1131	off Cape Sable Island, NS	EN	1	XC	NR	At least 1, possibly 2, embedded rostrum wraps. Remaining configuration unclear but extensive. Animal in extremely poor condition: emaciated, heavy cyamid coverage, overall pale skin. No resights.
09/04/2014	Serious Injury	4001	off Grand Manan, NB	EN	1	XC	NR	Free-swimming with constricting rostrum wrap. Remaining configuration unknown. No resights post Oct/2014.
09/04/2014	Mortality	-	Far south of St. Pierre & Miquelon, off the south coast of NL	EN	1	XC	NR	Carcass with constricting line around rostrum and body. No necropsy conducted, but evidence of extensive, constricting entanglement supports entanglement as COD.
09/17/2014	Serious Injury	3279	off Grand Manan, NB	EN	1	XC	NR	Free-swimming with heavy, green line overhead cutting into nares. Remaining config. unk. In poor overall condition: heavy cyamids on head and blowholes. Left blowhole appears compromised. No resights.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
09/27/2014	Mortality	-	off Nantucket, MA	EN	1	US	NR	Fresh carcass with multiple lines wrapping around head, pectoral, and peduncle. Appeared to be anchored. No necropsy conducted, but extensive, constricting entanglement supports entanglement as COD.
12/18/2014	Serious Injury	3670	off Sapelo Sound, GA	EN	1	XU	NP	No gear present but new, healing entanglement injuries. Severe injuries to lip, peduncle and fluke edges. Poss. damage to right pectoral. Resights indicate health decline.
04/06/2015	Serious Injury	CT04CCB14	Cape Cod Bay, MA	EN	1	XU	NP	Encircling laceration at fluke insertion with potential to affect major artery. Source of injury likely constricting entanglement. No gear present. Evidence of health decline. No resights.
06/13/2015	Prorated Injury	-	off Westport, NS	EN	.75	XC	NR	Line through mouth, trailing 300-400m ending in 2 balloon-type buoys. Full entanglement configuration unknown. No resights.
09/28/2015	Prorated Injury	-	off Cape Elizabeth, ME	EN	.75	XU	NR	Unknown amount of line trailing from flukes. Attachment point(s) and configuration unknown. No resights.
11/29/2015	Serious Injury	3140	off Truro, MA	EN	1	XU	NR	New, significant ent. injuries indicating constricting wraps. No gear visible. In poor cond. with grey skin and heavy cyamid coverage. No resights.
1/29/2016	Serious Injury	1968	off Jupiter Inlet, FL	EN	1	XU	NP	No gear present, but evidence of recent entanglement of unknown configuration. Significant health decline:emaciated, heavy cyamid coverage, damaged baleen. Resighted in April 2017 still in poor cond.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
5/19/2016	Serious Injury	3791	off Chatham, MA	EN	1	XU	NP	New entanglement injuries on peduncle. Left pectoral appears compromised. No gear seen. Significant health decline: emaciated with heavy cyamid coverage. No resights post Aug/2016.
5/03/2016	Mortality	4681	Morris Island, MA	VS	1	US	-	Fresh carcass with 9 deep ventral lacerations. Multiple shorn and/or fractured vertebral and skull bones. Destabilized thorax. Edema, blood clots, and hemorrhage associated with injuries. Proximate COD=sharp trauma. Ultimate COD= exsanguination.
7/26/2016	Serious Injury	1427	Gulf of St Lawrence, QC	EN	1	XC	NP	No gear present, but new entanglement injuries on peduncle and fluke insertions. No gear present. Resights show subsequent health decline: gray skin, rake marks, cyamids.
8/1/2016	Serious Injury	3323	Bay of Fundy, NS	EN	1	XC	NP	No gear present, but new, severe entanglement injuries on peduncle, fluke insertions, and leading edges of flukes. No gear present. Significant health decline: emaciated, cyamids patches, peeling skin. No resights.
8/13/2016	Serious Injury	4057	Bay of Fundy, NS	EN	1	CN	PT	Free-swimming with extensive entanglement. Two heavy lines through mouth, multiple loose body wraps, multiple constricting wraps on both pectorals with lines across the chest, jumble of gear by left shoulder. Partially disentangled: left with line through mouth and loose wraps at right flipper that are expected to shed. Significant health decline: extensive cyamid coverage. Current entanglement appears to have exacerbated injuries from previous entanglement (see 16Feb2014 event). No resights.
8/16/2016	Prorated Injury	1152	off Baccaro, NS	EN	0.75	XC	NR	Free-swimming with line and buoy trailing from unknown attachment point(s). No resights.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
8/28/2016	Serious Injury	2608	off Brier Island, NS	EN	1	XC	NR	Free-swimming with constricting wraps around rostrum and right pectoral. Line trails 50 ft aft of flukes. Significant health decline: heavy cyamid coverage and indication of fluke deformity. No resights.
8/31/2016	Mortality	4320	Sable Island, NS	EN	1	CN	PT	Decomposed carcass with multiple constricting wraps on pectoral with associated bone damage consistent with chronic entanglement.
9/23/2016	Mortality	3694	off Seguin Island, MA	EN	1	XC	PT	Fresh, floating carcass with extensive, constricting entanglement. Thin blubber layer and other findings consistent with prolonged stress due to chronic entanglement. Gear previously reported as unknown.
12/04/2016	Prorated Injury	3405	off Sandy Hook, NJ	EN	0.75	XU	NE	Lactating female. Free-swimming with netting crossing over blowholes and one line over back. Full configuration unknown. Calf not present, possibly already weaned. No resights. Gear type previously reported as NR.
04/13/2017	Mortality	4694	Cape Cod Bay, MA	VS	1	US	-	Carcass with deep hemorrhaging and muscle tearing consistent with blunt force trauma.
06/19/2017	Mortality	1402	Gulf of St Lawrence, QC	VS	1	CN	-	Carcass with acute internal hemorrhaging consistent with blunt force trauma.
06/21/2017	Mortality	3603	Gulf of St Lawrence, QC	EN	1	CN	PT	Fresh carcass found anchored in at least 2 sets of gear. Multiple lines through mouth and constricting wraps on left pectoral. Glucorticoid levels support acute entanglement as COD.
06/23/2017	Mortality	1207	Gulf of St Lawrence, QC	VS	1	CN	-	Carcass with acute internal hemorrhaging consistent with blunt force trauma.
07/04/2017	Serious Injury	3139	off Nantucket, MA	EN	1	XU	NP	No gear present, but evidence of recent extensive, constricting entanglement and health decline. No resights.

Date[b]	Fate	ID	Location[b]	Assigned Cause	Value against PBR[c]	Country[d]	Gear Type[e]	Description
07/06/2017	Mortality	-	Gulf of St Lawrence, QC	VS	1	CN	-	Carcass with fractured skull and associated hemorrhaging. Glucorticoid levels support acute blunt force trauma as COD.
07/19/2017	Serious Injury	4094	Gulf of St Lawrence, QC	EN	1	CN	PT	Line exiting right mouth, crossing over back, ending at buoys aft of flukes. Non-constricting configuration, but evidence of significant health decline. No resights.
07/19/2017	Mortality	2140	Gulf of St Lawrence, QC	VS	1	CN	-	Fresh carcass with acute internal hemorrhaging. Glucorticoid levels support acute blunt force trauma as COD.
08/06/2017	Mortality	-	Martha's Vineyard, MA	EN	1	XU	NP	No gear present, but evidence of constricting wraps around both pectorals and flukes with associated tissue reaction. Histopathology results support entanglement as COD.
09/15/2017	Mortality	4504	Gulf of St Lawrence, QC	EN	1	CN	PT	Anchored in gear with extensive constricting wraps with associated hemorrhaging.
10/23/2017	Mortality	-	Nashawena Island, MA	EN	1	XU	NP	No gear present, but evidence of extensive ent involving pectorals, mouth, and body. Hemorrhaging associated with body and right pectoral injuries. Histo results support entanglement as COD.

Assigned Cause	**Five-year mean (US/CN/XU/XC)**
Vessel strike	01.3 (0.50/ 0.80/ 0.00/ 0.00)
Entanglement	5.55 (0.20/ 1.20/ 2.45/ 1.70)

a. For more details on events please see Henry *et al.* 2020.
b. The date sighted and location provided in the table are not necessarily when or where the serious injury or mortality occurred; rather, this information indicates when and where the whale was first reported beached, entangled, or injured.
c. Mortality events are counted as 1 against PBR. Serious injury events have been evaluated using NMFS guidelines (NOAA 2012).
d. CN=Canada, US=United States, XC=Unassigned 1st sight in CN, XU=Unassigned 1st sight in US.
e. H=hook, GN=gillnet, GU=gear unidentifiable, MF=monofilament, NP=none present, NR=none recovered/received, PT=pot/trap, WE=weir.

STATUS OF STOCK

The size of this stock is considered to be extremely low relative to OSP in the U.S. Atlantic EEZ. This species is listed as endangered under the ESA and has been declining since 2011 (see Pace *et al.* 2017). The North Atlantic right whale is considered one of the most critically endangered populations of large whales in the world (Clapham *et al.* 1999, NMFS 2017). The total level of human-caused mortality and serious injury is unknown, but the reported (and clearly biased low) human-caused mortality and serious injury was a minimum of 6.65 right whales per year from 2013 through 2017. Given that PBR has been calculated as 0.8, human-caused mortality or serious injury for this stock must be considered significant. This is a strategic stock because the average annual human-related mortality and serious injury exceeds PBR, and also because the North Atlantic right whale is an endangered species. All ESA-listed species are classified as strategic by definition; therefore, any uncertainties discussed above will not affect the status of stock.

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Reducing Vessel Strikes to North Atlantic Right Whales

The purpose of this information is to reduce the likelihood of deaths and serious injuries to these endangered whales that result from collisions with vessels.

Right Whale Speed Rule Assessment

In 2013, NOAA Fisheries committed to publish a report evaluating the conservation value and economic and navigational safety impacts of the 2008 North Atlantic right whale vessel speed regulations (50 CFR § 224.105). The report was finalized in June 2020 and evaluates four aspects of the right whale vessel speed rule: biological efficacy, mariner compliance, impacts to navigational safety, and economic cost to mariners. It also provides a detailed assessment of the rule's effectiveness, and assesses general trends in vessel traffic characteristics within Seasonal Management Areas over time.

- Right Whale Vessel Speed Rule Assessment, June 2020 (PDF, 53 pages)
- Appendix A: Figures and Tables (PDF, 77 pages)
- Appendix B: Economic Impact Assessment (PDF, 87 pages)

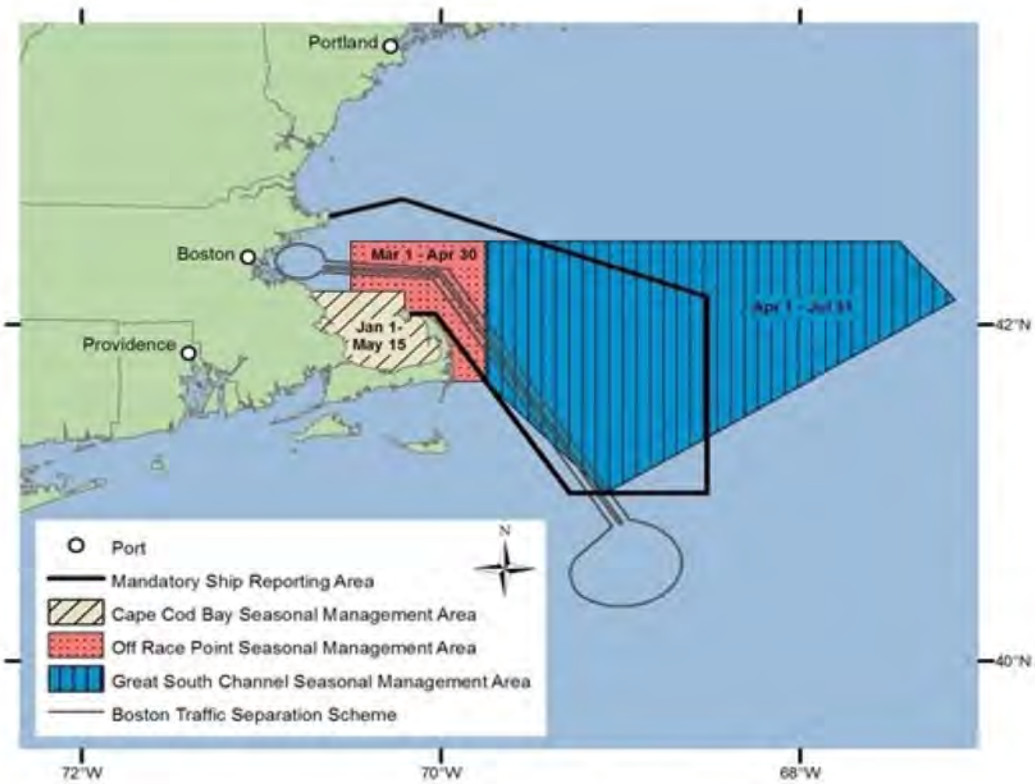
Although the report is final, we welcome comments for consideration as we evaluate the need for future actions or modifications to our vessel strike reduction efforts. Please provide any written comments to Dr. Caroline Good, Office of Protected Resources at narw.vesselstrike@noaa.gov. We have extended the comment deadline to March 26, 2021.

Vessel Speed Restrictions

All vessels 65 feet (19.8 meters) or longer must travel at **10 knots or less** in certain locations (called Seasonal Management Areas or SMAs) along the U.S. east coast at certain times of the year to reduce the threat of vessel collisions with endangered North Atlantic right whales. The purpose of this mandatory regulation is to reduce the likelihood of deaths and serious injuries to these endangered whales that result from collisions with vessel.Because vessels of all sizes can strike a whale, NOAA Fisheries also encourages vessels less than 65 feet in length to help protect right whales by slowing to 10 knots of less within active SMAs as well.

- Compliance Guide (PDF, 2 pages)
- Final Rule to eliminate sunset provision on speed restrictions (12/09/13, 78 FR 73726)
- Proposed rule to eliminate sunset provision on speed restrictions (06/06/2013, 78 FR 34024)
- Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule (2012, PDF 49 pages)
- Final rule to implement speed restrictions (10/10/2008, 73 FR 60173)

Seasonal Management Areas - Northeast



Cape Cod Bay, January 1 - May 15

Includes all waters of Cape Cod Bay with Northern Boundary of 42º04'56.5"N, 070º12'W to 42º12'N, 070º12'W then due west back to shore.

Off Race Point, March 1 - April 30

Waters Bounded by:

42º04'56.5"N, 070º12'W

42º12'N, 070º12'W

42º12'N, 070º30'W

42º30'N, 070º30'W

42º30'N, 069º45'W

41º40'N, 069º45'W then due west back to shore.

Great South Channel, April 1 - July 31

Waters Bounded by:

42º30'N, 069º45'W

42º30'N, 067º27'W

42º09'N, 067º08'24"W

41º00'N, 069º05'W

41º40'N, 069º45'W then back to starting point.

Seasonal Management Areas - Mid-Atlantic

Migratory Route and Calving Grounds, November 1 - April 30

Block Island Sound waters bounded by:

40º51'53.7" N 070º36'44.9" W

41º20'14.1" N 070º49'44.1" W

41º04'16.7" N 071º51'21.0" W

40º35'56.5" N 071º38'25.1" W then back to starting point.

Within a 20-nm (37 km) radius of the following (as measured seaward from the COLREGS lines):

-Ports of New York/New Jersey:

40º29'42.2"N 073º55'57.6"W

-Entrance to the Delaware Bay

(Ports of Philadelphia and Wilmington):

38º52'27.4"N 075º01'32.1"W

-Entrance to the Chesapeake Bay

(Ports of Hampton Roads and Baltimore):

37º00'36.9"N 075º57'50.5"W

-Ports of Morehead City and Beaufort, NC: 34º41'32.0"N 076°40'08.3"W

Within a continuous area 20-nm from shore between Wilmington, North Carolina, to Brunswick, Georgia, bounded by the following:

A- 34º10'30"N, 077º49'12"W

B- 33º56'42"N, 077º31'30"W

C- 33º36'30"N, 077º47'06"W

D- 33º28'24"N, 078º32'30"W

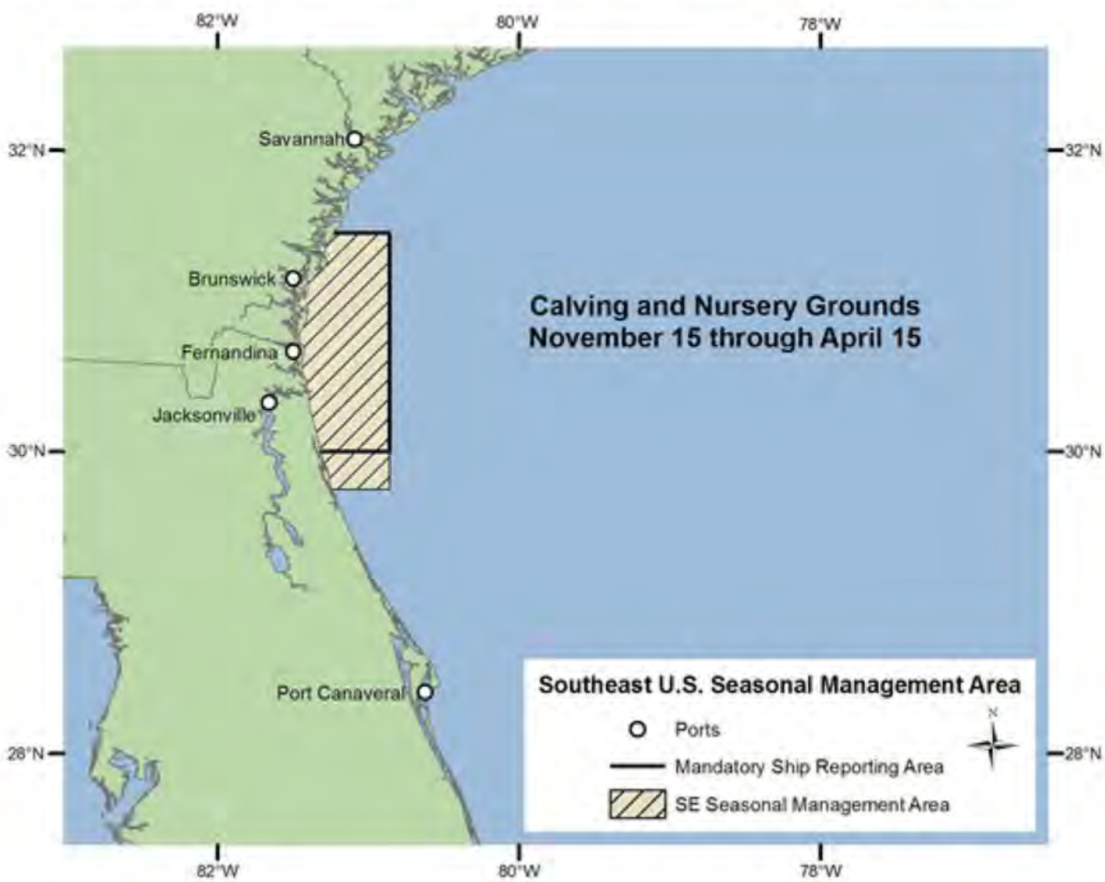
E- 32º59'06"N, 078º50'18"W

F- 31º50'00"N, 080º33'12"W

G- 31º27'00"N, 080º51'36"W

and west back to the shore.

Seasonal Management Areas - Southeast



Calving and Nursery Grounds, November 15 - April 15

Vessel speed is restricted in the area bounded to the north by latitude 31º27'N; to the south by latitude 29º45'N; to the east by longitude 080º51'36"W.

Right Whale Slow Zones

Right Whale Slow Zones is a program that notifies vessel operators of areas where maintaining speeds of 10 knots or less can help protect right whales from vessel collisions. Under this program, NOAA Fisheries provides maps and coordinates to vessel operators indicating areas where right whales have been detected. Mariners are encouraged to avoid these areas or reduce speeds to 10 knots or less while transiting through these areas for 15 days.

Right Whale Slow Zones are established around areas where right whales have been recently seen or heard; these areas are identical to Dynamic Management Areas (DMA) when triggered by right whale visual sightings but, they will also be established when right whale detections are confirmed from acoustic receivers.

NOAA Fisheries announces Right Whale Slow Zones to mariners through its customary maritime communication media and displays any active zones below, with the most recent designation first.

All boaters, or interested parties, can sign up for email notifications by clicking here and selecting "Right Whale Slow Zones" under the Regional New England/Mid-Atlantic subscription topics. You can also follow us on Facebook (@NOAAFisheriesNEMA) and Twitter (@NOAAFish_GARFO) for announcements.

You can check for Right Whale Slow Zones on our online right whale sightings map. Or, you can download the free Whale Alert app, which will automatically notify you when you enter one of these areas.

South of Nantucket, Massachusetts, February 26 - March 31, 2021

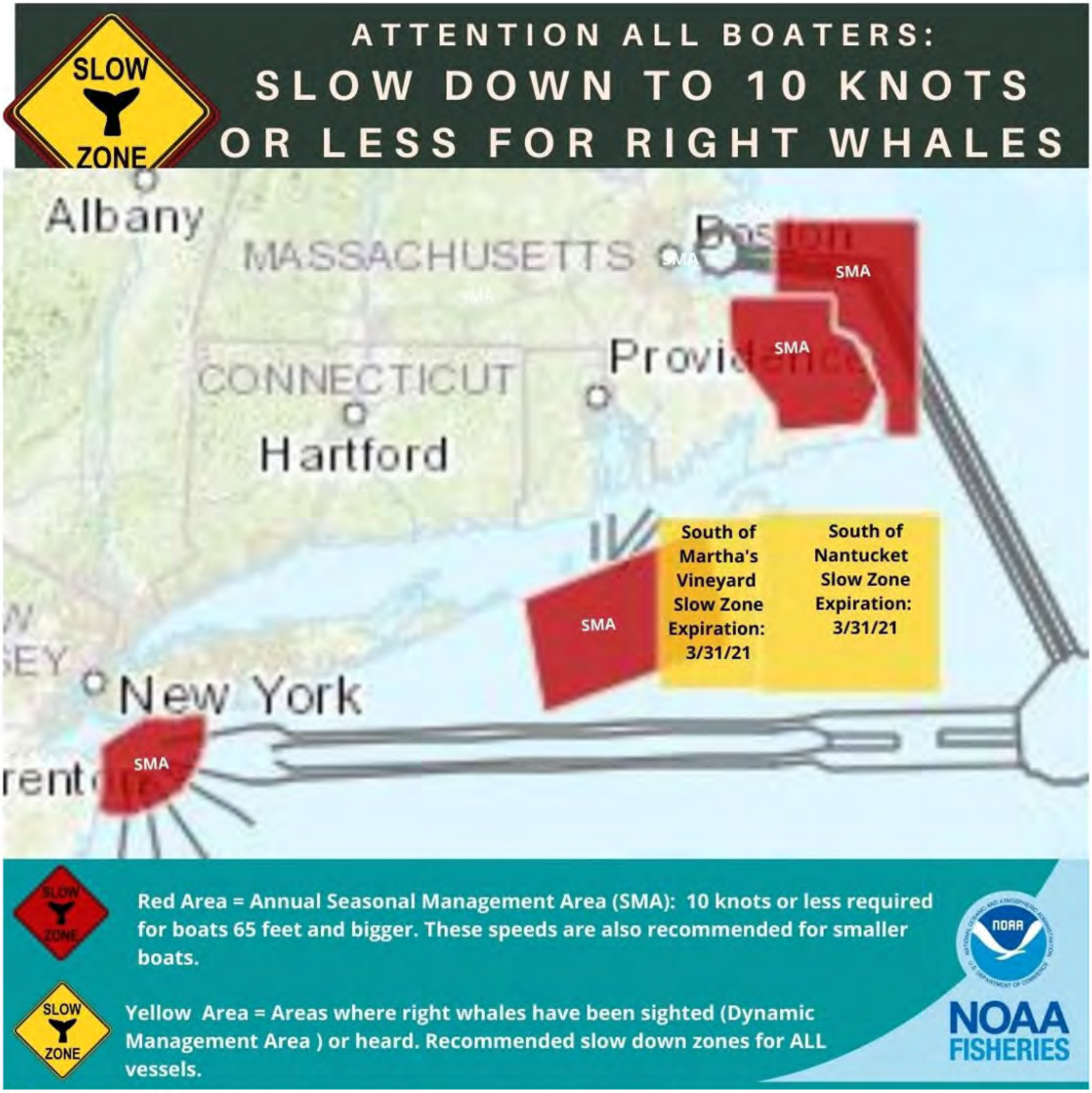
Waters bounded by:

41 23 N
40 40 N
069 39 W
070 35 W

South of Martha's Vineyard, Massachusetts, March 7 - 31, 2021

Waters bounded by:

41 21 N
40 41 N
070 15 W
071 06 W



Dynamic Management Areas

Voluntary Dynamic Management Areas (DMAs) may be established by NOAA Fisheries based on visual sightings documenting the presence of three or more right whales within a discrete area. Mariners are encouraged to avoid these areas or reduce speeds to 10 knots or less while transiting through these areas. DMAs are announced to mariners through its customary maritime communication media and display any active ones, with the most recent designation first.

Vessel Routing

Vessel routing recommendations to reduce collisions with North Atlantic right whales will soon be available on all NOAA Electronic Navigation Chart products.

Great South Channel Area to Be Avoided

For ships weighing 300 gross tons or more, a voluntary seasonal Area To Be Avoided (ATBA) is in effect each year from April 1 to July 31, when right whales face their highest risk of ship strikes in this area.

Boston, Massachusetts Traffic Separation Scheme

The North-South lanes of the Traffic Separation Scheme servicing Boston were narrowed from 2 miles to 1.5 miles (consistent with the East-West Boston Traffic Separation Scheme lanes) to reduce vessel collisions with whales.

Charts of Approaches to Boston Traffic Separation Scheme and Area to be Avoided:

- 13200: Georges Bank and Nantucket Shoals
- 13203: Georges Bank Western Part
- 13006: West Quoddy Head to New York

Recommended Routes in Key Right Whale Habitats

NOAA established recommended vessel routes in four locations to reduce the likelihood of ship collisions in key right whale habitats in Massachusetts, Georgia, and Florida.

- Recommended Routes (PDF, 2 pages)

Mandatory Ship Reporting System

When ships greater than 300 gross tons enter two key right whale habitats—one off the northeast U.S. and one off the southeast U.S.—they are required to report to a shore-based station.

In return, ships receive a message about right whales, their vulnerability to ship strikes, precautionary measures the ship can take to avoid hitting a whale, and locations of recent sightings.

Mandatory Ship Reporting System areas will soon be available on all NOAA Electronic Navigation Chart products.

- Mandatory Ship Reporting System Placard (PDF, 2 pages)
- Final Rule (11/20/2001, 69 FR 58066)

Mariner Training Resources

We're working on making our materials available online. In the interim, if you'd like a copy of our Prudent Mariner's Guide to Right Whale Protection CD please contact Peter Kelliher.

Report a Vessel Strike

Report vessel strikes to the National Marine Mammal Stranding Network.

Where Are Right Whales?

- Northeast U.S. Right Whale Sightings
- Southeast U.S. Right Whale Sightings
- Acoustic detections in Cape Cod Bay and the Boston TSS
- Download the Whale Alert app for iPad and iPhone

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ARTICLE

Marine Mammal Science

Assessing the lethality of ship strikes on whales using simple biophysical models

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Abstract

Studies of ship strikes on whales often focus on large vessels (>20 m), with attention to their speeds and the resulting risk of lethality. Smaller coastal vessels also co-occur with whales, resulting in collisions that merit study. To cast light on injuries caused by vessels of all sizes, we used knowledge of right whale anatomy and Newtonian mechanics to construct simple models that predict the mechanical stresses experienced by whales during collisions. By comparing our predictions with published models and with data from ship strikes on various whale species, we developed a model for lethal injury as a function of several vessel and whale properties, finding that collisions that create stresses in excess of 0.241 MPa were likely to cause lethal injuries to large whales. Furthermore, this model has revealed that (1) vessels of all sizes can yield stresses higher than this critical level, and (2) large vessels produce stresses much larger than this even when travelling at reduced speeds (i.e., 10 knots). The model is fast enough to power an interactive GUI-based tool (in R) and flexible enough to simulate strikes by vessels of different masses and speeds upon whales of different species, sizes, and physical conditions.

KEYWORDS

biophysical model, lethality, mechanical stress, North Atlantic right whale, policy, ship strikes, shipping, speed restrictions, whales

1 | INTRODUCTION

Collisions with whales by ocean-going vessels (i.e., ship strikes) have been widely studied (Conn & Silber, 2013; Gende et al., 2019; Kite-Powell, Knowlton, & Brown, 2007; Laist, Knowlton, Mead, Collet, & Podesta, 2001; Schoeman, Patterson-Abrolat, & Plön, 2020; van der Hoop, Vanderlaan, & Taggart, 2012; Vanderlaan, Taggart, Serdynska, Kenney, & Brown, 2008). The observations compiled by Laist et al. (2001) suggest that the most severe injuries occur as a result of ship strikes by large vessels, and accordingly both the United States and Canada have made efforts to mitigate this problem by altering traffic patterns and restricting the speeds of large vessels (length > 20 m; e.g., Transport Canada, 2018; U.S. Federal Register, 2008). There are, however, many smaller vessels (length < 20 m) that can also be involved in ship strikes, and some observations indicate that injuries from these collisions can be serious (Jensen & Silber, 2004; Neilson, Gabriele, Jensen, Jackson, & Straley, 2012; Ritter, 2012; Wiley, Mayo, Maloney, & Moore, 2016). These smaller vessels generally do not use automatic identification systems (AIS), thus producing less track-data compared to larger vessels and they are not subject to the regulations to mitigate ship strike lethality (Transport Canada, 2018). This suggests it is a mistake to focus solely on large vessels, particularly given recent observations of right whales in coastal eastern Canadian waters, where smaller vessels are used in local fisheries that are active at times while the whales are present (Davies & Brillant, 2019; Simard, Roy, Giard, & Aulanier, 2019).

It can be difficult to diagnose the trauma responsible for the death of whales killed by ship strikes without a forensic necropsy because external indicators of the injury may be few or subtle (Campbell-Malone et al., 2008). A further complication is that there is no single indicative condition that signifies mortality by blunt trauma. For example, necropsies of whales killed by blunt trauma typically report extensive subcutaneous hemorrhages that can extend through the blubber and the underlying tissues (Moore et al., 2013), but the occurrence of broken bones is neither universal, nor diagnostic. Campbell-Malone et al. (2008) report that the mandibles of North Atlantic right whales (*Eubalaena glacialis*; hereafter, right whales) were fractured in one-third of the necropsies they examined where blunt trauma was identified as cause of death. Sharp et al. (2019) reported that 8 of 10 right whales killed by blunt trauma had fractured bones. Similarly, three of the four right whales determined to have died as a result of blunt trauma in Canada in 2017 had acute internal hemorrhages, but, importantly, just one of these animals had bone fractures that were attributable to the blunt trauma that resulted in the death of the animal (Daoust, Couture, Wimmer, & Bourque, 2018). These observations indicate that the stresses experienced by whales during ship strikes do not need to exceed the breaking strength of bones to kill the animal.

Motivated by the desire to investigate the potential for serious injury by small vessels, and to reduce uncertainties in the mode of injury by vessels of all sizes, we set out to quantify the reactive forces that arise during ship strikes with large whales. By demonstrating the relationship between strikes and the reactive forces of the collision, our goals were to provide a more complete evaluation of the threat that vessels of all sizes pose to whales, and to identify the physical factors that influence this threat. Many species of whales are struck by vessels (Jensen & Silber, 2004; Neilson et al., 2012; van der Hoop et al., 2013) and so we set out to create models that could deal with whales and vessels of all sizes and types. The particular focus was, however, on right whales, which puts our work in the context of a growing body of knowledge about right whale ship strikes, the biophysical studies of right whales (e.g., Raymond, 2007), and the relationship of vessel speeds and lethality (e.g., Conn & Silber, 2013; Vanderlaan & Taggart, 2009).

2 | METHODS

2.1 | Model formulation

2.1.1 | One-layer scaling model

The main tool used in the present study is a four-layer model that will be described in the next section. However, we begin by describing a simpler model, to establish the notation and to cast some light on the basic dynamical principles. This system involves the collision of a large object of mass M_s moving at velocity V_s until it collides with a much lighter stationary object of mass M_w. Here, the subscripts *s* and *w* stand for ship and whale, respectively. Supposing both ship and whale to be point masses separated by a compressible layer of thickness *l* that has linear elastic modulus of compression *E*, the force resisting collision may be written $F = AE\Delta l/l$, where *A* is the impact area and Δl measures the compaction at any given time. Denoting positions of the ship and whale as X_s and X_w, and setting $t = 0$ as the time of initial contact of the ship with the compressible layer, we may write $\Delta l = l - (X_w - X_s)$, during the interaction interval. According to Newton's second law, the momentum equations for ship and whale are

$$M_s \frac{dV_s}{dt} = -F \tag{1}$$

and

$$M_w \frac{dV_w}{dt} = F \tag{2}$$

where ship and whale velocities are $V_s = dX_s/dt$ and $V_w = dX_w/dt$, respectively, and a positive value of *F* indicates a force in the direction of increasing *x* coordinate. For the case of a large ship and a much smaller whale, we have $M_s \gg M_w$, so that combining Equations 1 and 2 reveals that $\left|\frac{dV_s}{dt}\right| \ll \left|\frac{dV_w}{dt}\right|$. This means that the ship is too massive to be slowed appreciably during the collision. In this limit, Δl may be approximated as $l + Vt - X_w$ where *V* denotes the nearly constant ship speed. Thus, the whale's momentum equation can be written

$$\frac{d^2 X_w}{dt^2} = \frac{AE}{M_w}\left(\frac{l + Vt - X_w}{l}\right) \tag{3}$$

It is convenient to define a new variable $\zeta = X_w - l - Vt$, which is the negative of Δl in this limiting case of a constant-velocity ship. With this definition, Equation 3 becomes

$$\frac{d^2\zeta}{dt^2} + \omega^2\zeta = 0 \tag{4}$$

where $\omega = \sqrt{AE/(lM_w)}$. This is an oscillation equation, with solution

$$\zeta \propto \sin \omega t \tag{5}$$

given the initial condition $\zeta = 0$ at $t = 0$. The absolute value of this function reaches a local maximum when $\omega t = \frac{\pi}{2}$ so a time scale for the penetration of the ship into the body of the whale is

$$t_* = \frac{\pi}{2}\sqrt{\frac{lM_w}{AE}} \tag{6}$$

Thus, ignoring whale movement to first order, so that $d\zeta/dt = 0$ at $t = 0$ can be approximated as $-V$, we may derive

$$\zeta_* = V\sqrt{\frac{lM_w}{AE}} \tag{7}$$

as a length scale for the penetration of the ship into the body of the whale.

Although limited by approximations that will be relaxed in the next section, these simple formulas may still be useful for building intuition. As might have been expected, both the impact time, t^*, and the depth of penetration, ζ^*, are predicted to increase with whale length, since larger whales have larger mass and also thicker regions of blubber and other compressible materials. However, and perhaps not so intuitively, the square root implies that neither of these dependencies is linear. The square root dependence also applies, inversely, to the relationship of impact time and penetration to the area of impact, A, and the stiffness of the compressible material, E. Thus, the formulas back up and extend the intuition that a sharply pointed ship prow will penetrate further than a blunt one, and that penetration will be deeper for more compressible material.

More insight on the penetration depth can be gathered by focussing on ζ^*/l, the fractional compaction of the compressible layer. It might be hypothesized that high values of this quantity may correlate with high potential for injury. It is instructive to write this as

$$\frac{\zeta_*}{l} = \frac{V}{V_0} \tag{8}$$

whereupon

$$V_0 = \sqrt{\frac{AEl}{M_w}} \tag{9}$$

may be interpreted as a scale for critical ship speed, as it corresponds with complete tissue compaction. With reasonable values (explained and refined below) $A = 1.32$ m^2, $E = 0.6 \times 10^6$ Pa (section 2.2.5 in Raymond, 2007), $l = 1.3$ m (sum of thickness of skin, blubber, and sublayer) and $M_w = 20 \times 10^3$ kg, we find that $V_0 = 7.2$ m/s (or 14 knots). This speed is comparable to the Vanderlaan & Taggart (2007) estimate of a critical speed of 6.1 m/s (or 11.8 knots) for increased likelihood of lethality of large-ship impacts. Even so, the assumptions underneath this calculation are so crude that the results should be considered mostly as a scaling relationship that provides context for a more realistic model. The next section provides such a model, in which the dynamical approximations are less restrictive, and the biomechanical model of whale tissue is more realistic.

2.1.2 | Four-layer model

A simple way to extend the previous model is to replace its single layer of compressive material with a sequence of layers that have distinct thicknesses and material properties. Our tests with a variety of configurations revealed that a simple but reasonable arrangement is to consider four such layers: a skin layer, a blubber layer to its interior, a region further to the interior that we will call the sublayer, and bone to the interior of that. The literature provides direct or indirect guidance as to the material properties of each of these layers except the sublayer, and so in this treatment we will follow Raymond (2007) in taking the sublayer material properties to be similar to those of the blubber, although the model is constructed to permit distinct sublayer properties.

The notation already established for ship and whale mass, position, velocity and acceleration will be retained in this model. The forces considered during the impact event are the resistance of the whale's body to compression (although now in four layers), the resistance of the whale's skin to extension across the deformed impact zone, water drag on both ship and whale, and the ship's thrust. Importantly, (1) no assumptions are made on the ratio of whale acceleration to ship acceleration, so the model will handle a range of ship masses and (2) the assumption of a linear stress–strain relationship is dropped, to improve the accuracy of force calculations.

In the interests of simplicity of this initial study, only normal (i.e., not oblique) impacts are considered, and the shearing effects of propeller blades on skin are ignored. Ship deformation is ignored on the assumption that it will be negligible compared to deformation of the whale. That deformation is assumed to be confined to a particular impact area that is modelled as rectangular, while retaining the ability to address actual prow shapes by geometric calculations. For the present purpose, the key material property of the constituent whale layers is the stress–strain relationship. (The model also tracks material strength, but this is mainly for future work as, at present, the literature provides few constraints on this property.) Water drag forces are expressed in a standard quadratic form that involves the wetted areas of the vessel and whale, and the square of the speeds of each with respect to the surrounding water, which is assumed to be motionless relative to an assumed nonaccelerating coordinate system.

With these assumptions, the dynamical system may be expressed as a small set of algebraic and ordinary differential equations.

Prior to contact, the ship momentum equation is expressed as

$$M_s \frac{dV_s}{dt} = T_s - D_s \tag{10}$$

where T_s is the ship thrust (i.e., propulsive force) and D_s, the drag force, is parameterized with

$$D_s = -\frac{1}{2}\rho S_s C_s V_s |V_s| \tag{11}$$

where ρ is water density, S_s is the vessel's wetted surface area, and C_s is a nondimensional factor that accounts for frictional and other forms of drag on the ship (van Manen & van Oossanen, 1988). The default value of C_s is taken to be four times the purely frictional value of $CF = 2.5 \times 10^{-3}$ given in fig. 4 of van Manen & van Oossanen (1988), for the Reynolds Number appropriate to fishing boats moving at 10 knots, on the assumption that friction typically accounts for about a quarter of the total drag on low-speed vessels (MAN Diesel & Turbo, 2011). As a test, the drag force as formulated was used to predict the power consumption of a typical Cape Islander fishing boat, using reasonable values for engine and propeller efficiency. The results matched to within a factor of 2, and since this is comparable with the variation in hull resistance caused by biofouling through the course of a season (Woods Hole Oceanographic Institution, 1952), this was taken as confirmation of the acceptability of the drag formulation.

During contact, we must account for forces resulting from deformation of the whale. Denoting the sum of such forces as F (with positive values meaning that the whale will be accelerated in the X direction), Equation 10 may be extended to

$$M_s \frac{dV_s}{dt} = T_s - D_s - F. \tag{12}$$

The model takes the ship thrust T_s to be a constant value implied by the thrust-friction balance for the velocity prior to the collision, on the assumption that the vessel operator will be unable to cut engine power in the subsecond timescale of a collision. However, the drag force D_s is taken to vary with ship speed according to the quadratic drag law discussed above.

On the assumption that an initially motionless whale will not be able to respond during the brief interval of a collision event, its swimming thrust T_w can be set to zero, yielding the momentum equation

$$M_w \frac{dV_w}{dt} = F - D_w \tag{13}$$

where D_w, which accounts for water drag, is formulated with a quadratic law similar to that of the ship, but with drag coefficient C_w of 2.5×10^{-3}, on the assumption that the whale drag will not involve the

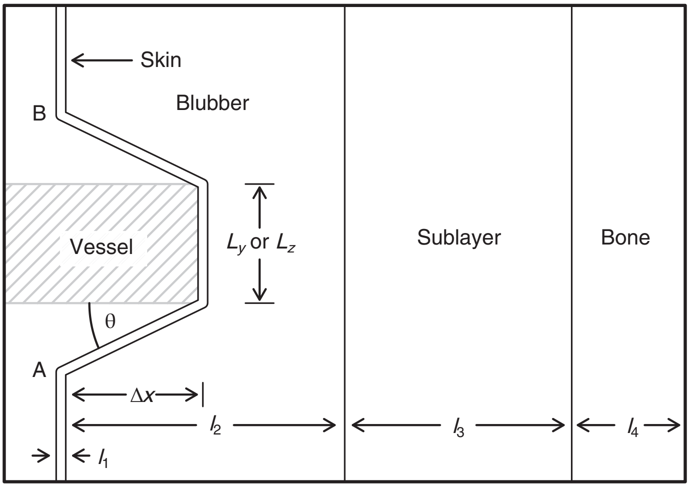

FIGURE 1 Definition sketch (not to scale) showing the cross-sectional geometry of four-layer model of a whale being impacted by a moving vessel.

wave-making and form-drag components that apply to ships moving under power. Sensitivity experiments with the model (Appendix A), suggest that the overall results depend very little on the details of the drag parameterizations, simply because these forces are very small (by factors exceeding 100), compared with the impact forces.

The reactive force, F, is broken down into two components, viz.

$$F = F_C + F_E \tag{14}$$

where F_C is a compression force resulting from the thinning of whale skin, blubber, sublayer, and bone, and F_E is an extension force resulting from the stretching of skin over the depression made by the ship as it protrudes into the animal. Figure 1 illustrates the geometry of the deformation, and also details some further notation about whale properties.

The core of the model formulation lies in the expression of F_C and F_E in terms of the penetration of the ship into the whale. The compression force is perhaps the most straightforward, so it will be discussed first. A nonlinear stress–strain relationship is assumed for the compression of skin, blubber, sublayer, and bone. In this, the engineering stress σ (i.e., the normal force per unit area) is related to the engineering strain (i.e., the fractional reduction in thickness) with

$$\sigma_i = a_i\left(e^{b_i\epsilon} - 1\right) \tag{15}$$

where subscript i is 1 for skin, 2 for blubber, 3 for sublayer, and 4 for bone. The exponential form of this proposed relationship is consistent with the approximately linear dependence of local modulus (i.e., $\partial\sigma/\partial\epsilon$) on stress σ for Cuvier's beaked whale (*Ziphius cavirostris*), shown in fig. 8 of Soldevilla *et al*. (2005). Furthermore, this form works well as a regression model for the stress–strain relationship shown in fig. 2.13 of Raymond (2007). Some insight on this formulation is gained by noting that the b_i values indicate the nonlinearity of the stress–strain relationship in each layer, and that the product $a_i b_i$ approaches the linear modulus E_i in the limit of low strain, since $e^{b_i\epsilon} \approx 1 + b_i\epsilon$ for small values of $|b_i\epsilon|$.

The key variable in the formulation of the reactive force is the penetration Δx of the ship into the whale (again, see Figure 1). Denoting the strains within the individual layers ε_1 through ε_4, we may write this penetration distance as

$$\Delta x = \sum_i \epsilon_i l_i \tag{16}$$

Limiting the sum to just those layers that have nonzero thickness (i.e., to layers that have compression strain $\varepsilon_i < 1$) enables the model to handle cases of fast vessels or strikes on parts of the whale that have little cushioning between skin and bone.

Combining Equations 15 and 16 yields

$$\Delta x = \sum_i (l_i/b_i)(1 + \ln(\sigma/a_i)) \tag{17}$$

as the key link between force and vessel-whale separation. The meaning of this equation is revealed by considering the case of σ and a_i of the same order, because then $\ln(\sigma/a_i) \approx (\sigma/a_i - 1)$, so that the right-hand side of Equation 17 becomes $\sigma\sum_i l_i/a_i b_i$. With a linear approximation to the stress–strain relationship, this becomes $\sigma\sum_i l_i/E_i$, revealing that layers that are much thinner than others can be neglected, as can layers that are much stiffer than others. This applies to both skin and bone, and so the thickness and the stiffness of these components do not affect the compression force F_C greatly, provided that the intermediate layers have been compressed only slightly. However, this assumption of slight compression fails during a strong collision, during which bone compression can suddenly yield large forces that greatly overwhelm the forces created by the compression of the softer materials during the earlier stages of the impact. (This sudden force is analogous to the jolt that may be felt when an automobile's suspension spring bottoms out over a large bump in the road.)

As an aside on computational aspects, it is worth pointing out that Equation 17 is not easily inverted, and so it is solved in the model by using a root-finding method. Since this is a computationally expensive calculation that would be needed at every time-step in the simulation, the model computes the $\sigma = \sigma(\Delta x)$ relationship just once, at the start of the simulation, caching the results in a piecewise-linear approximating function that can be computed quickly as the simulation proceeds.

Returning to the dynamics of ship and whale, the compression force is found by multiplying stress σ by the impact area, which in the model is the product of a horizontal extent L_y and a vertical extent L_z (again, see Figure 1), i.e.,

$$F_C = L_y L_z \sigma \tag{18}$$

This leaves a single force to be discussed, namely that resulting from the extension of skin over the dimpled region of impact. There is little guidance in the literature for formulating this force, so a simple model is constructed here. The area of direct contact is assumed to be surrounded by a linearly beveled region that makes angle θ to the direction normal to the skin surface. The stretching is assumed to be constant throughout the depressed region (including the bevel), i.e., the skin that originally extended along a line from A to B in the definition sketch of Figure 1 becomes stretched from its original length along a line connecting the points to the longer path indicated by the three line elements on the diagram. The strain in the y-direction can therefore be written

$$\epsilon_y = 2\frac{\Lambda - \lambda}{L_y + 2\lambda} \tag{19}$$

where $\Lambda = \Delta x/\cos\theta$ and $\lambda = \Delta x \cdot \tan\theta$, after which an analog to Equation 15 can be used to compute along-layer tensile stress σ_y in the y-direction. Analogous steps lead to σ_z for skin stress in the z-direction. Multiplying these stresses by the nominal skin thickness l_1 along the perimeter of the impact zone, and then by the lengths of the corresponding sides, yields net force

$$F_E = 2l_1(L_y\sigma_z + L_z\sigma_y)\cos\theta \qquad (20)$$

in the x-direction, with forces in the y- and z-directions cancelling by symmetry.

Taken together, Equations 10 to 20 form the basis of the four-layer numerical model that is the centerpiece of the present study. The integrations of the differential equations are carried out with the "lsoda" function in the R language (R Core Team, 2020), which is supplied as part of the "deSolve" package for numerical integration of differential equations (Soetaert, Petzoldt, & Setzer, 2010). This function is well-suited to the present application because of its high accuracy in mathematically stiff problems, i.e., problems with rapidly changing temporal behaviors, as can occur with a bone compression, as explained above. Appendix B explains how the simulation code is made available to readers as an R package named "whalestrike" and Appendix C explains the choice of default values for a_i, b, θ, etc., used in that package, and in most of the following.

2.2 | Comparison with Raymond's (2007) simulations

The model was configured to represent a mid-body strike of a 13.7 m North Atlantic right whale weighing 30 tonnes (i.e., 30,000 kg; Fortune et al., 2012), and the thicknesses of the layers l_1 through l_4 (i.e., skin, blubber, sublayer, and bone) set to 0.025 m, 0.16 m, 1.12 m, and 0.1 m respectively. These values were selected to match the values used by Raymond (2007), and the thicknesses of the layers reasonably match values measured during necropsies of adult right whales (Daoust et al., 2018; Leighfield, 2003).

The simulations used a ship of mass 311 tonnes with a bulb at the bow, as detailed in the finite-element calculations of Raymond (2007). Examination of Raymond's diagrams of whale deformation, together with calculations of the geometry of intersecting shapes, suggests representing the ship's bulb-shaped impact zone with L_y = 1.24 m and L_z = 0.71 m in the present framework. As in Raymond (2007), it was assumed that the biomechanical properties of the sublayer matched those of the blubber layer. The sublayer thickness was increased from the default model value of l_3 = 1.12 m to 1.47 m, to account for the unexpectedly high mass of the Raymond (2007) simulated whale, which Raymond (and the present authors) took to indicate an error in inferred girth. The default values were used for the other layers of the model whale.

2.3 | Estimating the lethality of the reactive forces of a whale strike

We examined published historical records of observed whale strikes for which we could determine (or reasonably assume) the variables needed to set up collision simulations with the four-layer model (i.e., vessel size, vessel speed, whale size, fate of the whale; Table 1). We limited our analysis to those observations where the fate of the whale was recorded as "no injury," "minor injury," "serious injury," or "killed." Some observations of whales that have been struck by ships report that the animal was swimming or acting "normally" following the ship strike (Laist et al., 2001), but there are also many observations to support the notion that animals may ultimately die as a result of earlier injuries (Campbell-Malone et al., 2008; Kraus et al., 2005; Moore et al., 2013; Neilson et al., 2012; Sharp et al., 2019). Lacking definitive results in the literature, we chose to simplify matters, categorizing reports of both "no injury" and "minor injuries" as nonlethal outcomes and both "serious injuries" and "killed" as lethal outcomes, in the same manner as previous studies (Conn & Silber, 2013; Neilson et al., 2012; Vanderlaan & Taggart, 2007). In total, we uncovered 34 observations that had the information required for comparison with model simulations. For each observation, the four-layer model was used to estimate the maximal reactive forces during collision, and these results were linked to the fate of the whale (i.e., nonlethal or lethal). The resulting relationship was used to infer a function linking the inferred probability of lethality, P(lethal), to the modeled collision stresses on the whale. Since those stresses are controlled by ship speed, mass, and contact area, along with whale biomechanical properties, the result of a successful linkage will be a tool that may be used to predict the outcomes of arbitrary whale strikes.

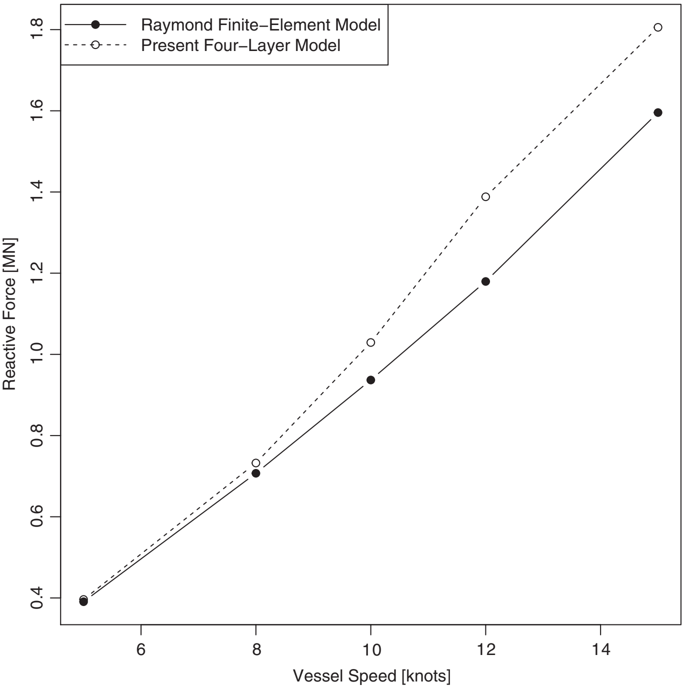

FIGURE 2 Comparison of the predicted dependence of collision stress (force per unit area) for impacts by a 311-tonne ship moving at selected speeds. The solid curve represents the results of the finite-element simulations of Raymond (2007) as reported in his Figure 6.1, and the dashed curve represents the results of the present four-layer simulation, showing the sum of compression and extension forces.

3 | RESULTS

Before moving on to the main results of the analysis, it should be noted that comparisons of the predictions between the four-layer model and the one-layer model were done throughout the analysis. This comparison relied on the fact that these simulations assumed equal biomechanical properties for blubber and sublayer, so computation of the equivalent thickness in a one-layer model was direct. As expected, the model predictions diverged most for the simulations involving a small vessel, for which it is unreasonable to assume that the vessel will maintain constant speed during a collision. The differences in predictions are significant in practical terms. For example, critical speeds for a 45-tonne boat (discussed later) differ by up to 26% between the one-layer and the four-layer models, and by 9% for a 311-tonne ship. Since a prime motivation for the present work was to study collisions with small vessels, and since we hope to establish a foundation for further studies with distinct biomechanical properties in each layer, we will focus entirely on the four-layer model in the remainder of this paper.

3.1 | Comparison with Raymond (2007)

Raymond (2007) produced a summary diagram (his fig. 6.1) showing maximum compression stress within the whale, as a function of ship speed, and this provides a convenient way to test the present model. Overall, the root-mean-square difference between the stress predictions of the finite-element and four-layer models was 0.14 MN, or 9.4% of the signal, with the results being nearly identical at low speeds (Figure 2). Since no "tuning" had been done by adjusting material properties to match the models, this agreement serves as a practical validation of the four-layer model.

TABLE 1 Reported ship strikes used to produce the lethality curve, where L (m) is length in meters, and Wt (t) is mass in tonnes. Fate is a description of the reported state of the whale after the ship strike; Uninjured and Killed are self-explanatory, and Minor and Serious each refer to the reported severity of the injury to the whale. Type is the reported description of the vessel where "HS Ferry" is a high-speed ferry, "USCG" is a US Coast Guard vessel, and "WW" is a whale watching vessel. Sp (kn) is the reported speed in knots of the vessel when the strike occurred. Max. stress is the maximum value of stress in megapascals computed during a numerical simulation with the four-layer model, based on the other properties listed in this table.

		Whale				Vessel					
Case	Date	Species	L (m)	Wt (t)[a]	Fate	Type	L (m)	Wt (t)[b]	Sp (kn)	Max. stress (MPa)	Reference
1	1885-01-01	Large whale	–	40	Minor	Pilot	–	60	13	0.92	Laist et al. 2001
2	1935-01-01	Large whale	–	40	Killed	Steamship	131	30,000	15	114.24	Laist et al. 2001
3	1953-11-01	Large whale	–	40	Killed	Navy	169	11,100	20	819.23	Laist et al. 2001
4	1955-03-22	Sperm whale	14	29	Killed	Steamship	144	30,000	17	1.78	Laist et al. 2001
5	1961-09-01	Large whale	–	40	Serious	Cargo	–	8,000	14	1.67	Laist et al. 2001
6	1972-12-01	Right whale	13	26	Killed	Container	207	24,182	22	647.77	Laist et al. 2001
7	1974-04-23	Large whale	–	40	Serious	Yacht	18	15	10.5	0.34	Laist et al. 2001
8	1974-12-01	Large whale	–	40	Serious	Ferry	–	4,000	17	540.24	Laist et al. 2001
9	1975-01-22	Gray whale	14	31	Killed	Navy	–	72	51	822.51	Laist et al. 2001
10	1980-07-05	Blue whale	30	183	Killed	Tanker	203	80,000	21	824.46	Laist et al. 2001
11	1984-08-01	Fin whale	24	80	Serious	WW	28	70	16	289.14	Laist et al. 2001
12	1988-09-07	Right whale	13	26	Killed	Ferry	171	8,000	12.5	0.92	Laist et al. 2001
13	1991-06-21	Humpback whale	15	49	Minor	WW	14	60	7.5	0.40	Laist et al. 2001
14	1991-07-06	Right whale	4.6	1	Killed	USCG	84	3,500	22	0.17	Laist et al. 2001
15	1992-02-01	Sperm whale	14	29	Killed	HS Ferry	20	5	45	17.88	Laist et al. 2001
16	1992-04-04	Large whale	–	40	Serious	Research	89	3,500	14	1.66	Laist et al. 2001
17	1992-05-15	Bryde's whale	12	12	Killed	Container	121	50,000	14	0.58	Laist et al. 2001
18	1993-09-09	Fin whale	24	80	Killed	Ferry	159	40,000	20	820.53	Laist et al. 2001
19	1995-06-01	Large whale	–	40	Minor	Fishing	27	60	9	0.49	Laist et al. 2001
20	1996-01-16	Humpback whale	15	49	Uninjured	WW	25	10	9	0.22	Jensen & Silber 2004
21	1996-05-16	Large whale	–	40	Serious	USCG	115	3,300	15	47.32	Laist et al. 2001
22	1997-01-01	Sperm whale	14	29	Killed	Ferry	100	11,000	25	819.40	Laist et al. 2001

TABLE 1 (Continued)

		Whale				Vessel					
Case	Date	Species	L (m)	Wt (t)[a]	Fate	Type	L (m)	Wt (t)[b]	Sp (kn)	Max. stress (MPa)	Reference
23	1997-10-12	Sperm whale	14	29	Uninjured	Fishing	–	30	6	0.18	Jensen & Silber 2004
24	1998-04-24	Gray whale	9	7	Killed	Navy	172.8	9,800	14	0.37	Jensen & Silber 2004
25	1998-04-28	Gray whale	6	2	Killed	Navy	153.9	9,800	22	0.28	Jensen & Silber 2004
26	1998-08-01	Minke whale	11	13	Killed	HS Ferry	36	3,500	25	1.73	Laist et al. 2001
27	1998-08-11	Humpback whale	15	49	Uninjured	WW	23.8	10	2	0.03	Jensen & Silber 2004
28	1998-09-12	Minke whale	6	3	Killed	WW	24	65	25	0.46	Laist et al. 2001
29	1999-07-28	Humpback whale	12	25	Killed	Cruise	243.8	50,000	19	130.12	Laist et al. 2001
30	2000-01-11	Bryde's whale	12.4	13	Killed	Cruise	214	50,000	22	1.37	Laist et al. 2001
31	2000-02-01	Humpback whale	15	49	Serious	Passenger	118	14,000	14.3	355.08	Laist et al. 2001
32	2001-02-26	Humpback whale	15	49	Uninjured	Inflatable	5.8	2	14	0.14	Jensen & Silber 2004
33	2001-06-18	Sperm whale	14	29	Killed	Navy	154	8,000	27	819.64	Jensen & Silber 2004
34	2001-06-29	Minke whale	7.6	5	Killed	Navy	253	10,000	15	0.32	Jensen & Silber 2004

[a]Masses for the whales were estimated to the nearest tonne based on their lengths using the equations from Fortune et al. (2012) for North Atlantic right whales and Lockyer (1976) for all other species. Where the length of the whale was not reported, we used the lengths for each species reported by NOAA (https://www.fisheries.noaa.gov/whales), rounded to the nearest meter. Where they report a range of lengths, we used the average, and where they reported a maximum length, we used the maximum length less 3 m. Where a ship strike record only reported "Large whale," we used 40 tonnes for its mass.

[b]Masses for vessels (i.e., displacement, not tonnage) were determined either by online searches for the named vessel, or by assuming the mass based on displacements of known vessels of the same type and length.

3.2 | Critical stress during ship strikes

A regression model of logistic form

$$P(\text{lethal}) = \left[1 + \exp\left(-\frac{\log_{10}\tau - c_1}{c_2}\right)\right]^{-1} \quad (21)$$

was chosen to represent the dependence of probability of lethality on the base-10 logarithm of compression stress (Figure 3, Table 1). Here, c_1 is the value of $\log_{10}\tau$ that yields P(lethal) = 0.5, and c_2 relates to the slope of the curve at the midpoint of the curve. A nonlinear least-squares method was used to infer c_1 and c_2, using the "nls" function in the R language, with related functions being used to calculate statistical characteristics of the fit. The resultant inferred value for c_1 was 5.38, SE = 0.15, p < .001, 95% CI [4.83, 5.65] while that for c_2 was 0.349, SE = 0.179, p = .061, 95% CI [0.123, 1.064]. The residual standard error of the regression was 0.326 with 32 df. Thus, the stress τ_{50} experienced by a whale during a ship strike that yields P(lethal) = .5 was estimated to be 0.241 MPa, 95% CI [0.067, 0.450].

The relationship between vessel speed and the modeled reactive stresses as a result of the ship strike are shown in Figure 4 for three different vessels. The masses (i.e., displacement, not tonnage) of the vessels were 45, 311, and 30,000 tonnes, representing plausible values for a typical coastal fishing boat in Atlantic Canada, a "large" vessel of the same mass used by Raymond (2007), and a still larger, more typical, container ship. The bow of the model coastal fishing vessel was patterned on the Cape Islander style that is typically used in Atlantic Canada, while the large vessels were modeled to have bulbs at their bow, as for the ship modeled by Raymond (2007). Accordingly, the areas of impact were set to 1.32, 0.88, and 0.88 m^2 for the three vessel types, respectively. The default values for whale biomechanical properties were used in the simulations, representing a mid-body strike of an adult right whale.

The resultant velocity that led to P(lethal) = .5 was 6.6 knots for the modeled 45-tonne fishing boat, 4.7 knots for the 311-tonne ship, and 4.5 knots for the 30,000-tonne ship. At 10 knots, the estimates of P(lethal) for a mid-body collision with a right whale were 0.69, 0.83, and 0.85 for these three vessel types. The simulations at 10 knots reveal that the whale would experience <5 g of acceleration during strikes by any of these vessels. These 10-knot simulations also indicate that the compressive forces on the bones are below the bone-breaking threshold, at least for mid-body strikes, where soft tissues are relatively thick.

The issue of the location of a ship strike along the body of the whale was addressed by calculating and plotting the critical velocity for various thicknesses of blubber and sublayer (Figure 5). The thickness of the blubber and

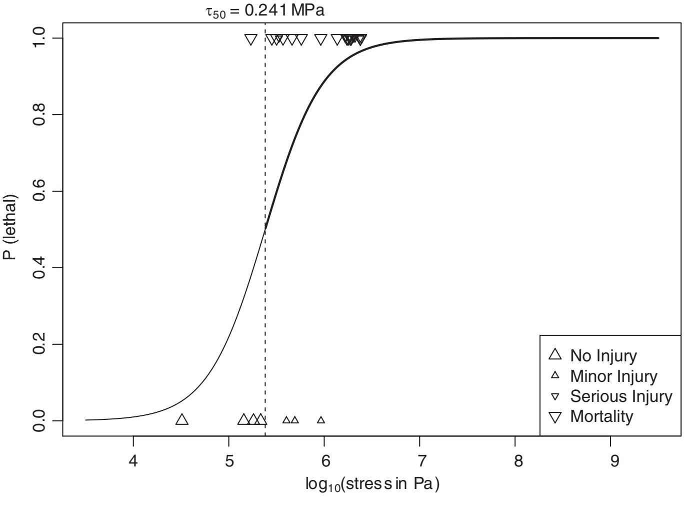

FIGURE 3 Probability of a lethal injury to a large whale in relation to the maximum compression stress incurred during a ship strike. The triangles represent literature results of ship strikes, with lethality characteristics as explained in the text, and with stresses inferred with model simulations that used the published ship and whale conditions. These points were fitted to a logistic function (solid line) to infer the probability of lethality, denoted P (lethal) in the text. The vertical dashed line indicates the stress, τ_{50}, that corresponds to the inflection of the logistic, i.e., the stress at which P (lethal) = .5, or the probability of lethality is 50%.

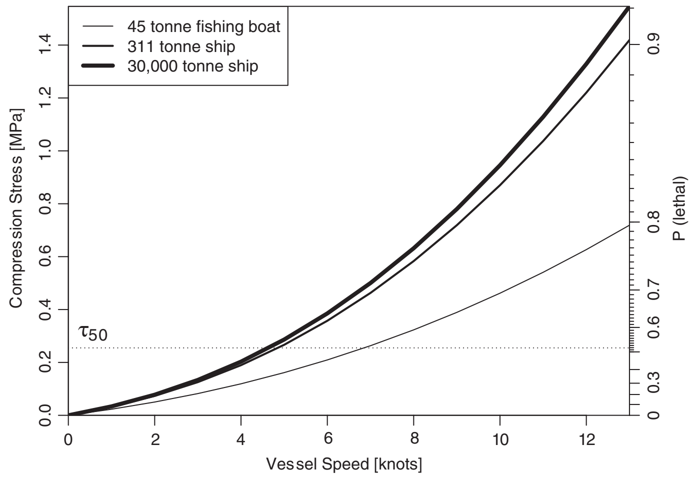

FIGURE 4 Variation of maximum compression stress with ship speed according to the four-layer model, for vessels of mass 45, 311, and 30,000 tonnes. The impact area for the 45-tonne fishing boat was set to 1.32 m^2, while for the larger ships, with protruding bulbous bows, it was set to 0.88 m^2. Default values are used for all other parameters. The horizontal line shows τ_{50}, the stress yielding a 50% probability of lethality.

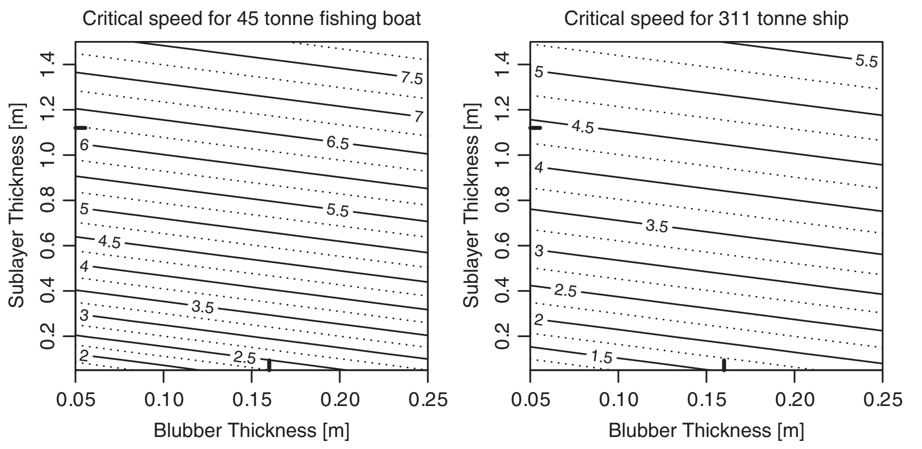

FIGURE 5 Dependence of the critical vessel speed, in knots, on the thickness of blubber and sublayer, for a 45-tonne fishing boat with impact area 1.32 m^2 (left) and a 311-tonne ship with impact area 0.88 m^2 (right). The contours show the collision speed that yields a compression stress that corresponds with *P*(lethal) = .5. The tick marks inside the axes show the default layer thickness values of the model, which are intended to represent a mid-body ship strike of a right whale. The velocities at the intersections of these tick marks match those at stress τ_{50} in Figure 4.

sublayer vary predictably along the length of the animal, with larger thicknesses corresponding to strikes nearer the middle of the body (the top right area of each plot panel in Figure 5) and smaller thicknesses corresponding to strikes in areas with thinner tissue layers over the bone, such as the head or mandible (lower left area of each plot in Figure 5). For each of the vessels modeled in these plots (45-tonne and 311-tonne), critical velocities were higher in areas where these layers were thicker and lower where blubber and sublayer were thin.

4 | DISCUSSION

The good agreement between the predictions of the four-layer model and the finite-element model of Raymond (2007) is of high practical significance, given the difficulty of setting up finite-element models and the simplicity of setting up (and extending) models such as those presented here.

An observational comparison of our models with the statistical studies of Vanderlaan & Taggart (2007) and Conn & Silber (2013) is also warranted. Both studies used a form of logistic function to model whale lethality as a function of vessel speed, and although there is overlap with the predictions of the four-layer model and these previous studies, the detailed results of the present study differ in several important ways. First, estimates in the present study for *P*(lethal) of a ship strike at 10 knots by small (45 tonne) and large (>300 tonne) vessels were each much larger (0.69 and > 0.83 respectively) than the estimate of >0.32 for vessels of all sizes by Vanderlaan & Taggart (2007) and approximately 0.57 by Conn & Silber (2013; based on their fig. 3). Second, our estimates of critical velocities, which yield *P*(lethal) = .5, were 6.6 knots and 4.5–4.7 knots for small (45 tonne) and large (>300 tonne) vessels respectively, while Vanderlaan & Taggart (2007) estimated the critical velocity for vessels of all sizes was 11.8 knots (95% confidence interval approximately 6.5 to 14 knots), and fig. 3 of Conn & Silber (2013) suggests a critical velocity of 9 knots, with a credible interval of approximately 2.6 knots to 11.4 knots.

Several factors may account for the differences between the predicted lethalities and critical speeds of the present study with those of previous studies. To begin with, these are very different analyses, ours being based on Newtonian dynamics and biomechanical properties of whale tissue, and these other studies taking a more statistical approach. These previous studies modelled whale lethality only as a function of vessel speed, while the present study modeled whale lethality as a function of the mechanical stresses of the strikes, incorporating several other factors absent from previous studies such as vessel mass, impact area, and whale biomechanical properties. There were also differences in data selection; our model required more details from the data (e.g., vessel and whale masses) and so the available data set was winnowed compared to these other studies, though all studies examining the lethality of ship strikes on whales, including the present study, are limited by relatively few observations of adequate information. The models of the present study were based on physical laws and biomechanical information from all sources known to us, and were constructed with an eye to future data and dynamical refinements. The goal was not just to advance our knowledge of the mode and consequences of injury to whales as a result of ship strikes, but also to create a framework that can be further elaborated in future investigations.

An important result of the present study, especially in the context of whales migrating between regions with different shipping traffic, is that whales can be seriously (i.e., lethally) injured as a result of collisions by vessels of a wide range of sizes. Intuition and simple theory both suggest that the precise value of ship mass may become unimportant for sufficiently large ships (because the ship will not slow down greatly during collision with a much less massive whale), and the four-layer model simulations verify this, revealing little dependence of compression stress on ship mass, once the latter exceeds a few hundred tonnes (Figure 4). Serious injury is, therefore, not a surprising result for strikes by large vessels, which can be orders of magnitude more massive than a whale. Even small fishing vessels (e.g., 45-ft Cape Islanders) have sufficient mass (approximating or exceeding the mass of even large whales) to lethally injure whales if they strike them, despite their typically slower speeds relatively to large cargo vessels. This is particularly likely for strikes on whales where the tissue layers are thin (Figure 5).

The simulations also shed light on the mode of injury. For example, although the inferred probability of lethality from mid-body strikes by large vessels at typical transiting velocities (e.g., 16–24 knots; Hatch et al., 2008; Wiley, Thompson, Pace, & Levenson, 2011) exceeds 0.9 and approaches 1, these simulations do not routinely involve compression stresses that are comparable to bone strength. The same was found with midbody strikes by small vessels at typical transiting velocities (e.g., 10.7 knots; Wiley et al., 2011). As a result, our simulations are in line with reports that not all whales killed by blunt trauma have fractured bones (Campbell-Malone et al., 2008; Sharp et al., 2019). The precise nature of such injuries deserves further study of whale biology. For example, it may be that strikes that yield relatively small stresses in the dorsal region may still cause lethal hemorrhages within the extensive vascular system that exists in the layers below the blubber in that location of right whales (Daoust et al., 2018). Similarly, a small-stress ship strike could damage structures important for life functions (e.g. baleen) and therefore also produce a mortality. In the meantime, the present model permits a first-order simulation of strikes at various body parts through predictions of compression stress for given a strike, as a function of blubber and sublayer thickness. Thus, for example, our simulations reveal that compression stress may exceed bone strength if the vessel strikes a region of the animal with thin blubber and sublayer cover, such as the head.

The simulations with the four-layer model reveal that the area of impact is another important factor, as was suspected from the scaling derived in the one-layer model. Determining this area is collision-specific, involving the profile of the vessel bow and the whale size and shape. The simulations in this study used relatively standard impact areas (see Appendix B), but the model takes the geometry of the impact zone as an adjustable parameter, which permits simulation of a wide range of collisions, from the fishing boats and container ships of the test cases shown here, to the case of low-mass, high-velocity oceanic racing vessels, which may present a serious hazard to whales because of the small impact area of their narrow keels and daggerboards (Ritter, 2012).

Although the models presented in this research incorporate some of the most important factors in estimating the reactive forces of a ship strike, there are other variables that ought to be considered in more advanced models. These include the angle of the collision, the articulation and architecture of the whale body (i.e., the separation of the body parts into separate but connected masses), whale behaviors such as evasion, and the possibility of skin lacerations caused by shearing forces exerted across small areas, such as may be caused by ship propellers (Campbell-Malone et al., 2008; Sharp et al., 2019; Wiley et al., 2016).

4.1 | Conclusions

We have shown that a four-layer dynamical model of ships striking whales produces results that are in good agreement with a more sophisticated finite-element model. This is important because the present model is so simple and efficient that it can be used within a GUI-based application (to be described separately) that can run simulations quickly enough to respond to a user's interactive explorations of the effects of altering relevant variables (e.g., vessel size and speed, whale size, and blubber thickness). The calibration of the model with observations of whale injuries from known strikes gives us the ability to identify critical speeds for vessels of any given mass, colliding with a whale of any given properties. This may prove beneficial in the context of species at risk of extinction such as the North Atlantic right whale, as these simulations offer guidance immediately, thus avoiding delays inherent in statistical prediction that must be based on the collection of data from prior collision events involving animals that are already at risk.

We used this tool to investigate the likely injuries incurred for two important classes of vessel that are of great concern to the conservation of North Atlantic right whales. The results suggest that (1) there is no reasonable transiting speed at which large vessels could strike a whale without a large risk of lethally injuring the animal, and that (2) vessels of all sizes pose a threat to seriously injure or kill whales.

The analysis for large vessels reveals that the speed limits commonly under discussion in the research and management communities (i.e., 10 knots) will provide only small reductions in the probability of lethal ship strikes. Thus, for large vessels, the only practical way of reducing the risk of lethal collisions is to reduce the co-occurrence of these vessels with whales. Mechanisms to do this include establishing exclusion areas for vessels (e.g., International Maritime Organization Areas to be Avoided), altering shipping lanes, and revising traffic separation schemes. Implementing these tools will require knowledge of where and when elevated probabilities for ship strikes exist. Work to provide this knowledge is currently being undertaken by numerous researchers (e.g., M. K. Carr, personal communication, July 2020).

By contrast, there may be more opportunities available for small vessels to mitigate their risk of causing a lethal ship strike. Owing to the proximity of the crew to the ocean surface on small vessels, along with the maneuverability and responsiveness of such craft (Schoeman et al., 2020; Wiley et al., 2016), collisions may be avoided by a combination of last-minute detection and evasive action. Therefore, for small vessels at least, there is a reason to hope that a combination of speed restrictions and having crew posted to watch for surfacing whales may be an effective way to reduce the incidence of whale injury and mortality.

ACKNOWLEDGMENTS

The work we present here benefitted from discussions with our Dalhousie University colleagues M. K. Carr and C. T. Taggart. In addition, we are grateful for the very detailed and helpful comments made by two anonymous reviewers.

AUTHOR CONTRIBUTIONS

Dan Kelley: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; software; supervision; visualization; writing-original draft; writing-review and editing. **James Vlasic:** Investigation; methodology; validation; writing-original draft. **Sean Brillant:** Conceptualization; funding acquisition; methodology; project administration; supervision; writing-original draft; writing-review and editing.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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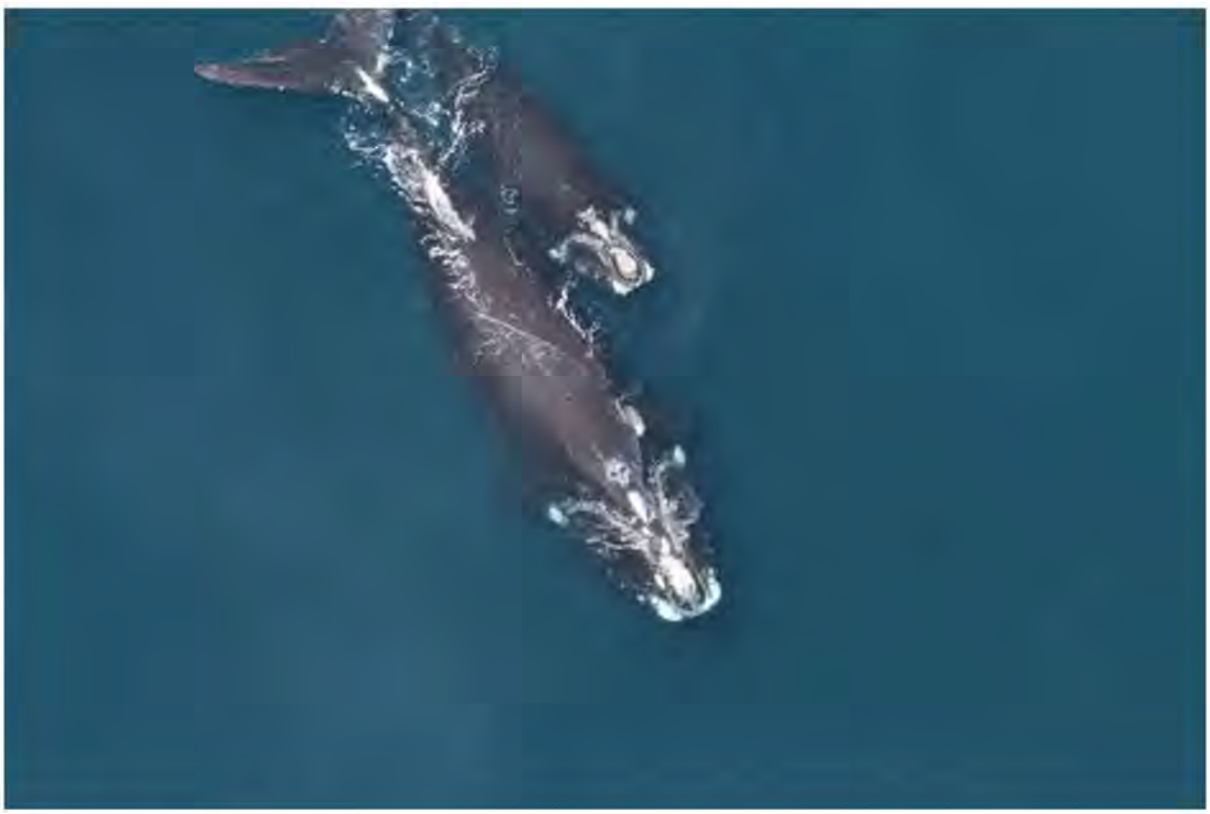
NOAA FISHERIES 150TH ANNIVERSARY 1871-2021

Team Reaches Nearly Unanimous Consensus on Right Whale Survival Measures

April 26, 2019

The Atlantic Large Whale Take Reduction Team met to develop additional measures to reduce impacts from fishing gear in Providence between April 23-26, 2019.



April 26 Update:

After many hours of intense discussion over four days, the Team was able to reach nearly unanimous consensus on a package of measures that would achieve at least a 60 percent serious injury and mortality reduction goal in each of the lobster management areas. Two general risk reduction approaches emerged as the Team's preferred options: line reduction and gear modification.

"This is hard work. The Team members brought not only their expertise but also their passion for the people and communities they represent to the table. Everyone understands that there are real and difficult consequences to fishermen as a result of the choices made in this room," said Sam Rauch, NOAA Fisheries deputy assistant administrator for regulatory programs. "I am confident that the meaningful measures supported by the majority of the Team today present a substantial opportunity to reduce the impacts of U.S. fisheries on right whales and an opportunity to support the recovery of this species."

The measures in the package include reductions in vertical buoy lines as well as gear modifications to reduce the strength at which lines will break. Reduced breaking strength lines would allow entangled whales to more easily break free of gear. Additionally, an expansion of gear marking to create larger and more frequent marks on U.S. trap/pot fishery buoy lines throughout U.S. East Coast waters was supported by most Team members. This expansion should improve the ability of large whale scientists and managers to better determine the source of gear seen on or retrieved from endangered large whales.

On April 23, a group of approximately 60 fishermen, scientists, conservationists, and state and federal officials will come together to discuss ways to further reduce serious injury and mortality of endangered North Atlantic right whales caused by trap/pot fishing gear. The group will meet in Providence, Rhode Island for four days. At the end of the meeting, they hope to agree on a suite of measures that will reduce right whale serious injuries and deaths in fishing gear in U.S. waters from Maine to Florida to less than one whale per year, the level prescribed by the Marine Mammal Protection Act.

"Tackling entanglements is critical to the recovery of the North Atlantic right whale population, and we can't do it without the assistance and cooperation of those who know best how the fishing industry interacts with large whales," says Mike Pentony, regional administrator for NOAA Fisheries Greater Atlantic Region. "The continued participation and dedication of our industry, science, NGO, and agency partners is absolutely necessary to future success.

About Right Whales

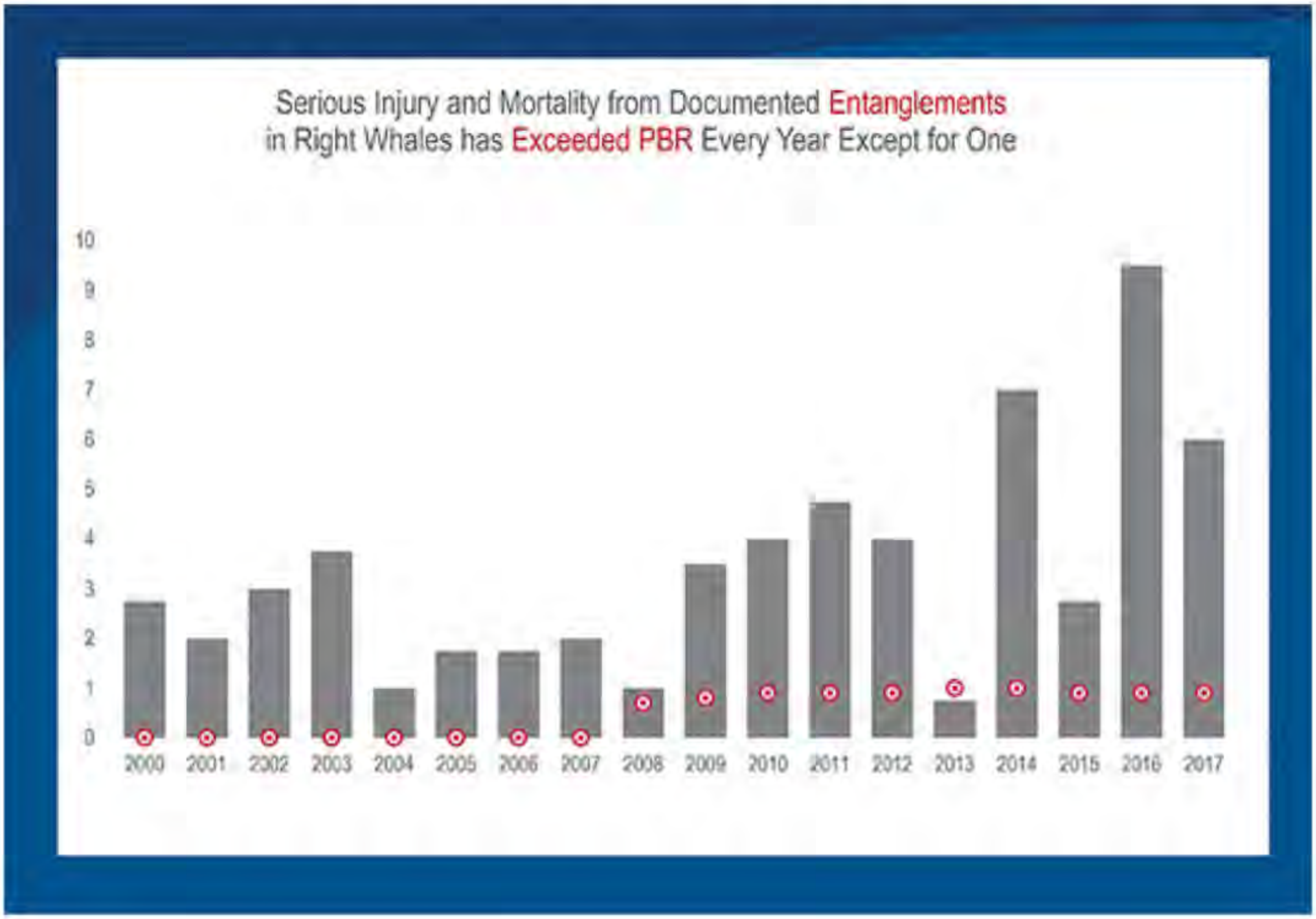
These whales, which got their name from being the "right" whales to hunt because they floated when they were killed, have never recovered to pre-whaling numbers. Due in part to conservation measures put in place to protect these whales from incidental entanglements in fishing gear and vessel strikes, we saw steady population growth from about 270 right whales in 1990 to about 480 in 2010. But in 2010, another downward trajectory began. This downward trend, exacerbated by an unprecedented 17 mortalities (particularly in the Gulf of St. Lawrence snow crab fishery) in 2017, brought a new urgency to modify the existing Atlantic Large Whale Take Reduction Plan.

That Plan, developed by the Team of stakeholders meeting next week, identifies a number of conservation measures from area closures to gear modifications that U.S. fixed gear fishermen have already implemented. Despite these efforts, today the population is estimated to be fewer than 411 whales. Only twelve births have been observed in the three calving seasons since the winter of 2016/2017, less than one third the previous average annual birth rate for right whales. This accelerates the trend that began around 2010, with deaths outpacing births in this population.

Take Reduction Planning

The Marine Mammal Protection Act requires that if serious injuries and mortalities to a population of marine mammals due to U.S. commercial fisheries is above a level that the stock can sustain, NOAA Fisheries convene Take Reduction Team to develop consensus recommendations on how to reduce this threat.

The immediate goal of a Take Reduction Team is to develop a Plan is to reduce incidental mortality and serious injury to a level, known as the "potential biological removal" level, that allows the stock to stabilize or grow, rather than decline. Although it's been in existence since 1997, the Atlantic Large Whale Take Reduction Plan has not been able to consistently reduce serious injuries and mortalities to below the potential biological removal level.



Cost of Entanglement

Entanglements are currently the leading cause of known right whale mortality. More than 80 percent of right whales carry scars that indicate that they have been entangled in fishing lines , and nearly 60 percent of those are entangled more than once. Not all entanglements drown whales. Some prevent a whale from feeding, increase the energy a whale needs to swim and feed, and cause pain and stress to the animal, which weakens it. Biologists believe that the additional stress of entanglement is one of the reasons that females are calving less often; females used to have calves every 3-5 years, and now are having calves every 6-10 years.

In recent years, most documented fishing gear entanglements of large whales (like right and humpback whales) that result in serious injury and mortality come from trap/pot gear. The traps lie on the ocean floor and are connected to buoys at the surface by long vertical buoy lines.

Many whales that are entangled are discovered after the event, with no gear attached. In some instances, gear is retrieved, analyzed, and stored for future analysis; much of this retrieved rope is consistent with buoy lines. That said, 71 percent of all recovered/observed gear (2009-2018) from right whales cannot be matched to a specific fishery or site.

Strategies for Reducing Risk

In Providence next week, the Team will be developing and discussing potential measures to modify the Take Reduction Plan, including updates to the current gear marking strategy, seasonal area closures, and reducing the risk of vertical lines through the use of weak rope. Many of these measures were proposed by Team members during an October 2018 meeting to discuss possible options to discuss at the April 2019 meeting. In advance of this meeting, the team particularly requested two things: 1. Clarification of a target percent reduction in serious injury and mortality, and 2. An ability to evaluate and compare different risk reduction elements from Team proposals.

A Target Reduction Level

Based on the 2016 population estimate, the Northeast Fisheries Science Center's North Atlantic right whale stock assessment establishes a potential biological removal level of 0.9 whales per year -- i.e. slightly less than one whale suffering human caused mortality or serious injury from any source in a given year.

Currently, NOAA Fisheries estimates that U.S. fisheries are responsible for 2.5 to 2.6 observed serious injuries and mortalities each year. Scientists estimate that we only observe 60 percent of the serious injuries and mortalities, which would bring the U.S. total to about 4.3. To get to 0.9 will require a reduction of 60-80 percent of serious injuries and mortalities.

A Risk Analysis Decision Tool

Determining how to judge the expected conservation value of any particular measure is a complicated task. To create a model to assess risk reduction, the model needs to first identify the current risk landscape, overlaying information on the density of trap/pot vertical lines, the distribution of whales, and the relative risk of the gear configuration associated with the lines (strengths/diameters of lines, lengths of trawls). Working collaboratively, the model combines Industrial Economics Inc.'s improved trap/pot vertical line model and the Duke Marine Spatial Ecology Lab's marine mammal density model, as well as risk assessment weights provided by Take Reduction Team members, Agency large whale scientists and managers, and permitted whale disentanglers. With these data sets, scientists at NOAA's Northeast Fisheries Science Center developed a risk assessment tool that will be used at next week's meeting. This tool represents a substantial leap forward and provides the Team with the best available information to determine risk and support their deliberations.

Next Steps

After this meeting, we will use recommendations from the Team to begin rulemaking in May. At various points during rulemaking there will be continued opportunity for public comment.

"I'm confident we have the right people around the table to tackle this problem," says Mike Asaro, Acting Protected Resources Assistant Regional Administrator. "This is a complex issue but with the cooperation and active engagement from the people who know this issue best, I have hope that following the meeting, we will have a solid set of conservation measures to proceed to rulemaking that will allow the fishing industry and whales to coexist and thrive."

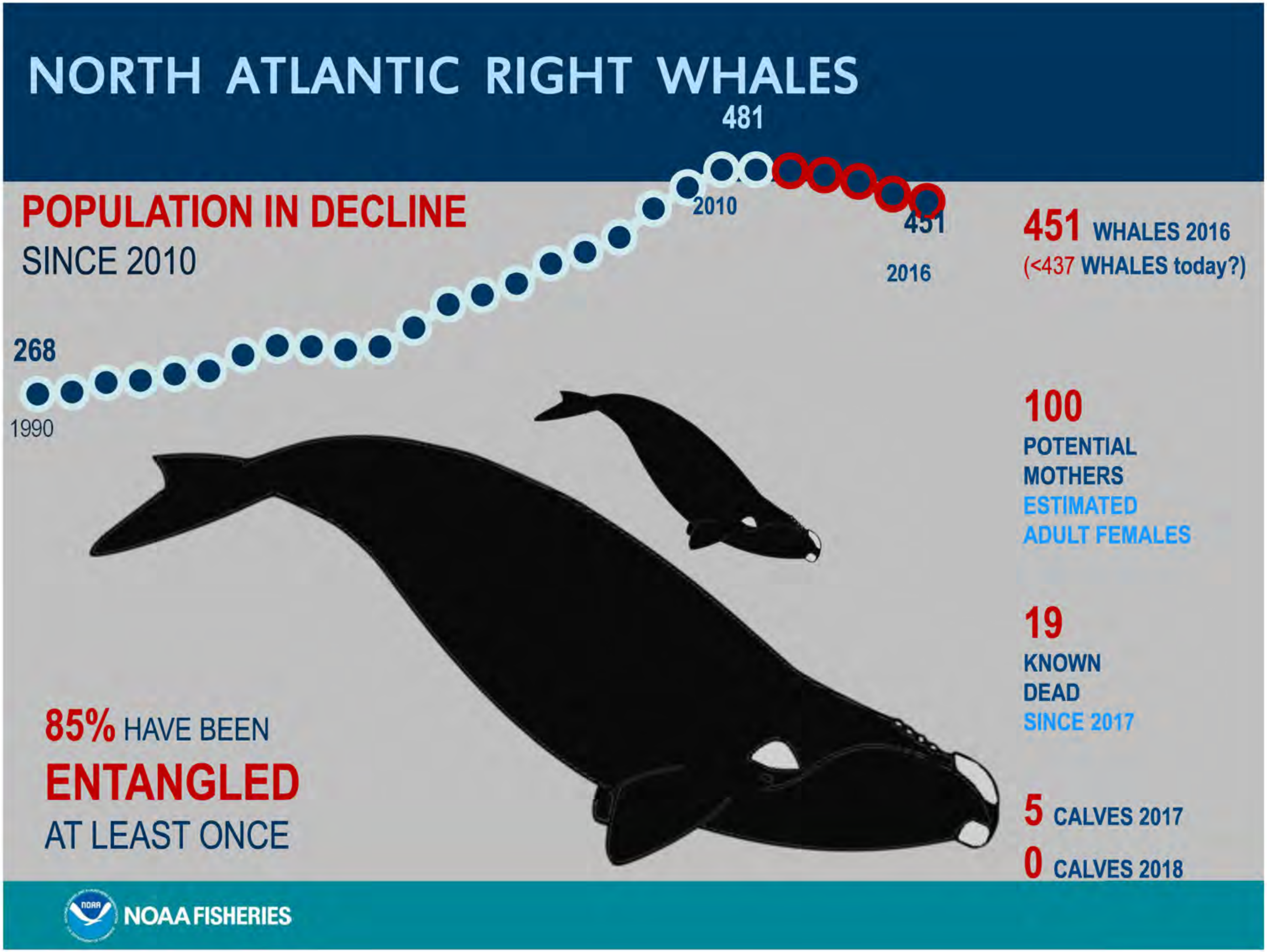
Last updated by Greater Atlantic Regional Fisheries Office on February 03, 2021

North Atlantic Right Whales: A Summary of Stock Status and Factors Driving Their Decline

Sean A Hayes, NEFSC Protected Species Branch

Presentation for Atlantic Large Whale TRT

Sept 18, 2018


NORTH ATLANTIC RIGHT WHALES
481
POPULATION IN DECLINE
SINCE 2010
2010
451
2016
268
1990
451 WHALES 2016
(<437 WHALES today?)
100
POTENTIAL
MOTHERS
ESTIMATED
ADULT FEMALES
19
KNOWN
DEAD
SINCE 2017
85% HAVE BEEN
ENTANGLED
AT LEAST ONCE
5 CALVES 2017
0 CALVES 2018
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July 22, 1997
- Establish TRP
- Weak link requirements
- Effective November 15,1997

December 2000
- Gear marking requirements
- Effective February 2001

January 9, 2002
- Establish SAM and DAM program
- DAM effective February 8, 2002
- SAM effective March 2002

June 25, 2007
- Seasonal gillnet closures in Southeast
- Effective July 2007

October 5, 2007
- Expand weak link requirements
- Implement sinking groundline requirements
- Effective April 2009
- Replaced SAM and DAM program

June 27, 2014
- Vertical line rule
- Additional gear marking requirements
- Effective June 2015

December 12, 2014
- Modification to time/area of closure area
- Effective immediately

May 28, 2015
- Modification to vertical line rule. Effective immediately
- Additional gear marking requirements

What Happened?-

1. Ecosystem shift
2. Fishery behavioral change
3. Whale behavioral change

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Today's challenges

Environment change contributed to increased exposure to

- **Changing US fisheries**
- **Canadian fisheries**
- **Canadian vessel traffic**

Impacts:

1. **Increased Serious Injury & Mortality**
2. **Sublethal entanglement costs**
3. **Potentially reduced food**
4. **Increased migration distance/costs**

} Contributes to reduced calving

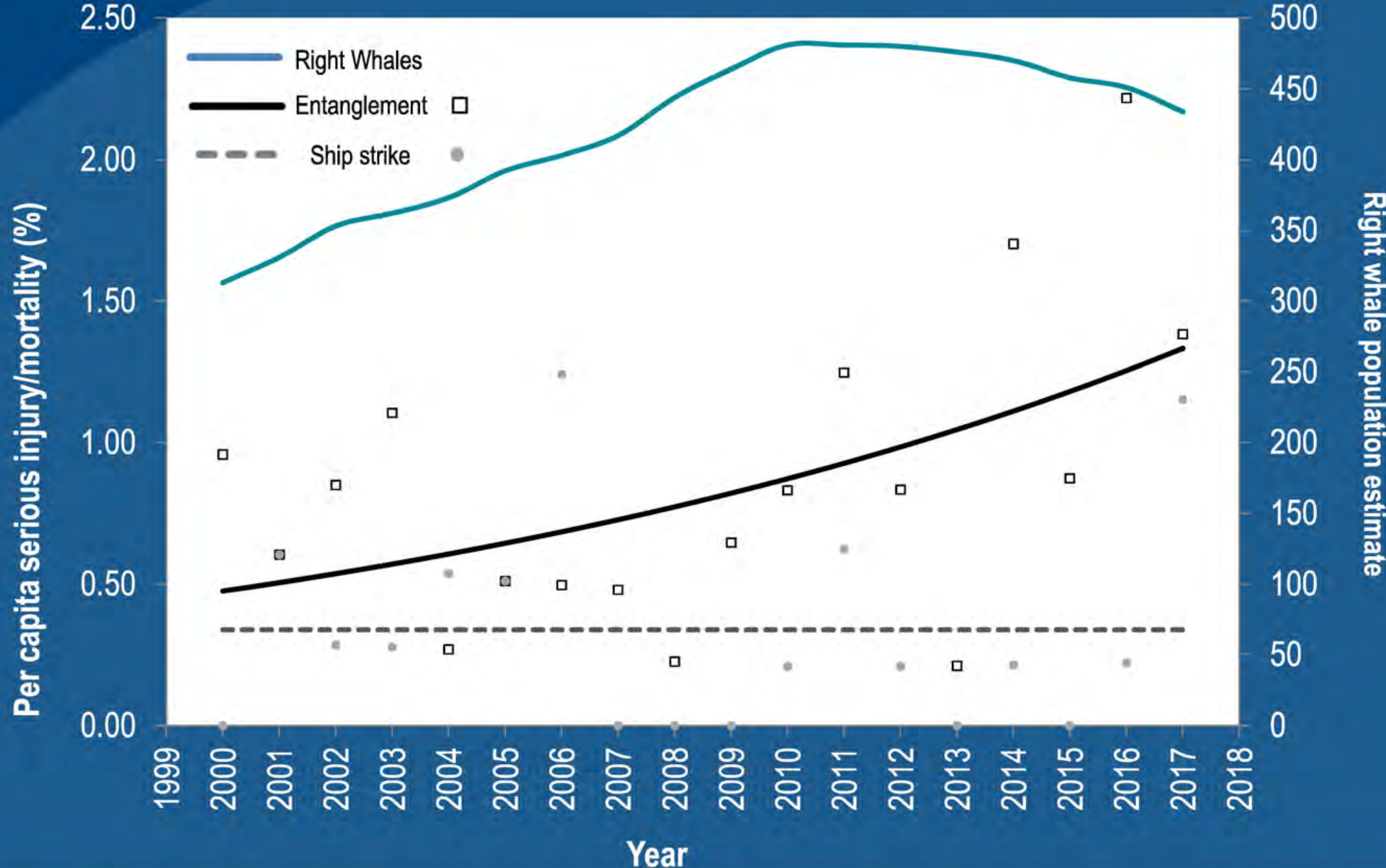
Demography at its most basic

If more animals die in a year than are born in a year, a species will decline

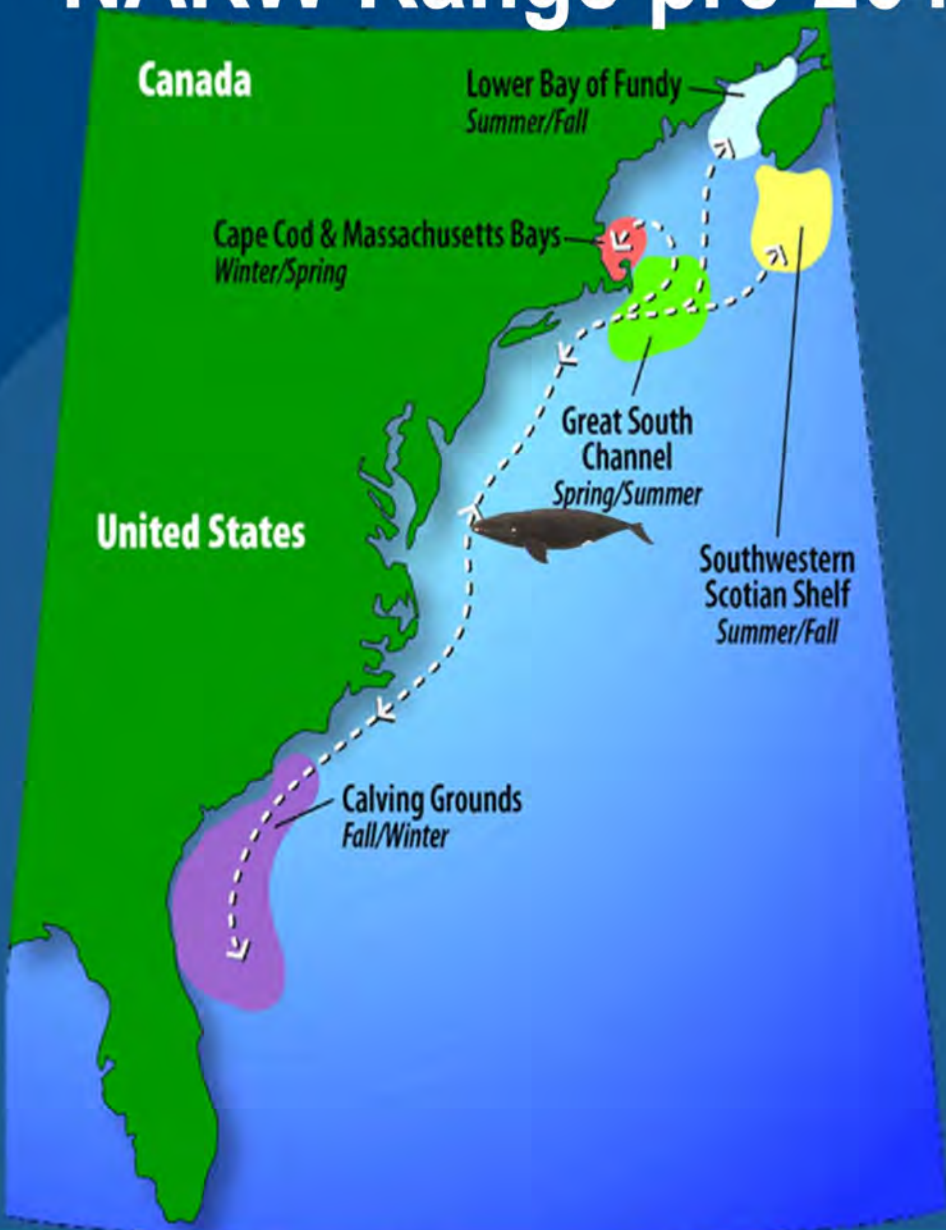
Demography is about deaths and births….

NOAA FISHERIES

Sources of Serious Injury and Mortality



NARW Range pre-2010

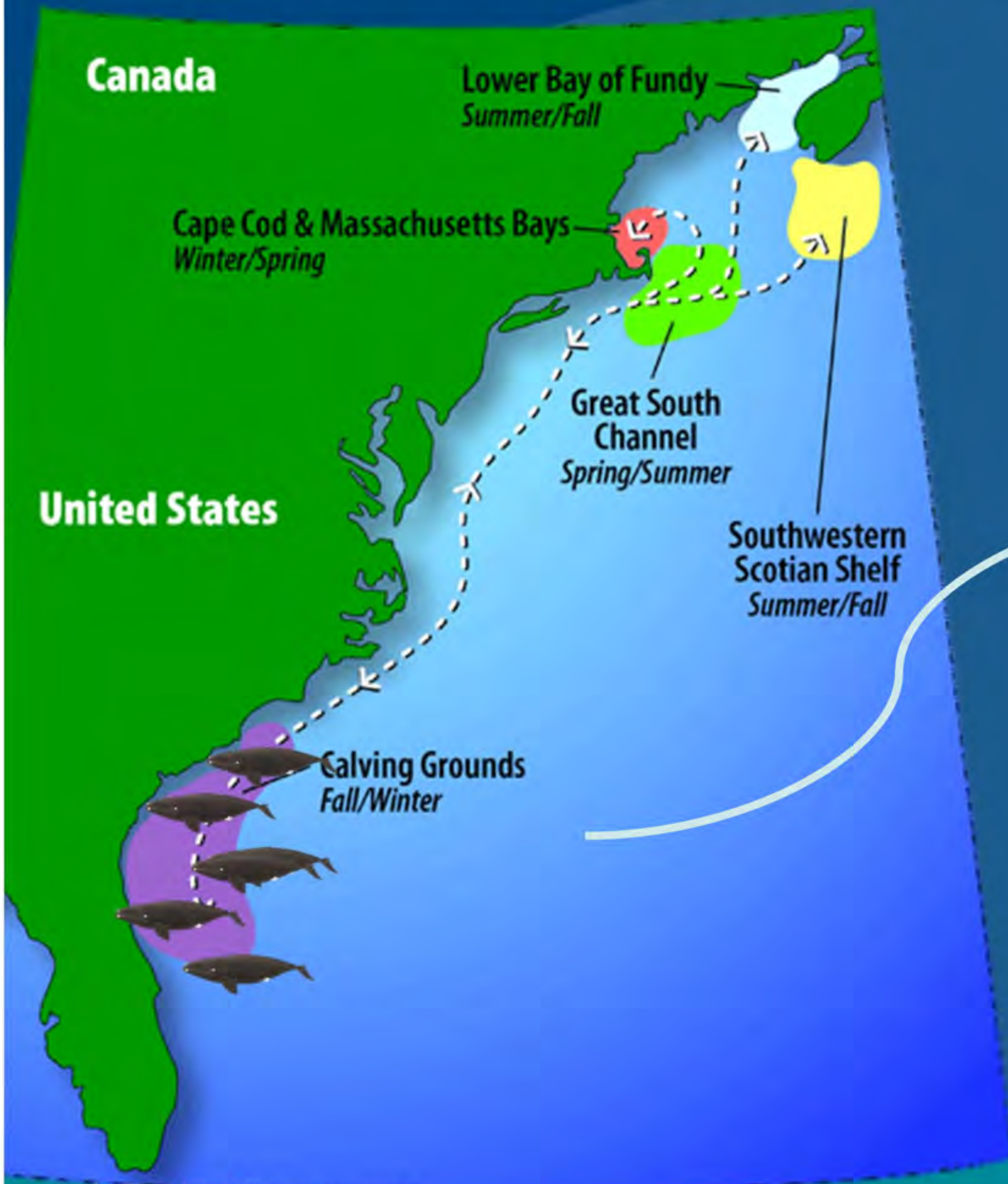


Females

- Need 2-3 years to prepare for breeding
- forgo breeding when in poor condition to conserve energy for survival

Figure from https://www.whoi.edu/oceanus/v2/article/images.do?id=2482

So what happened to whales?

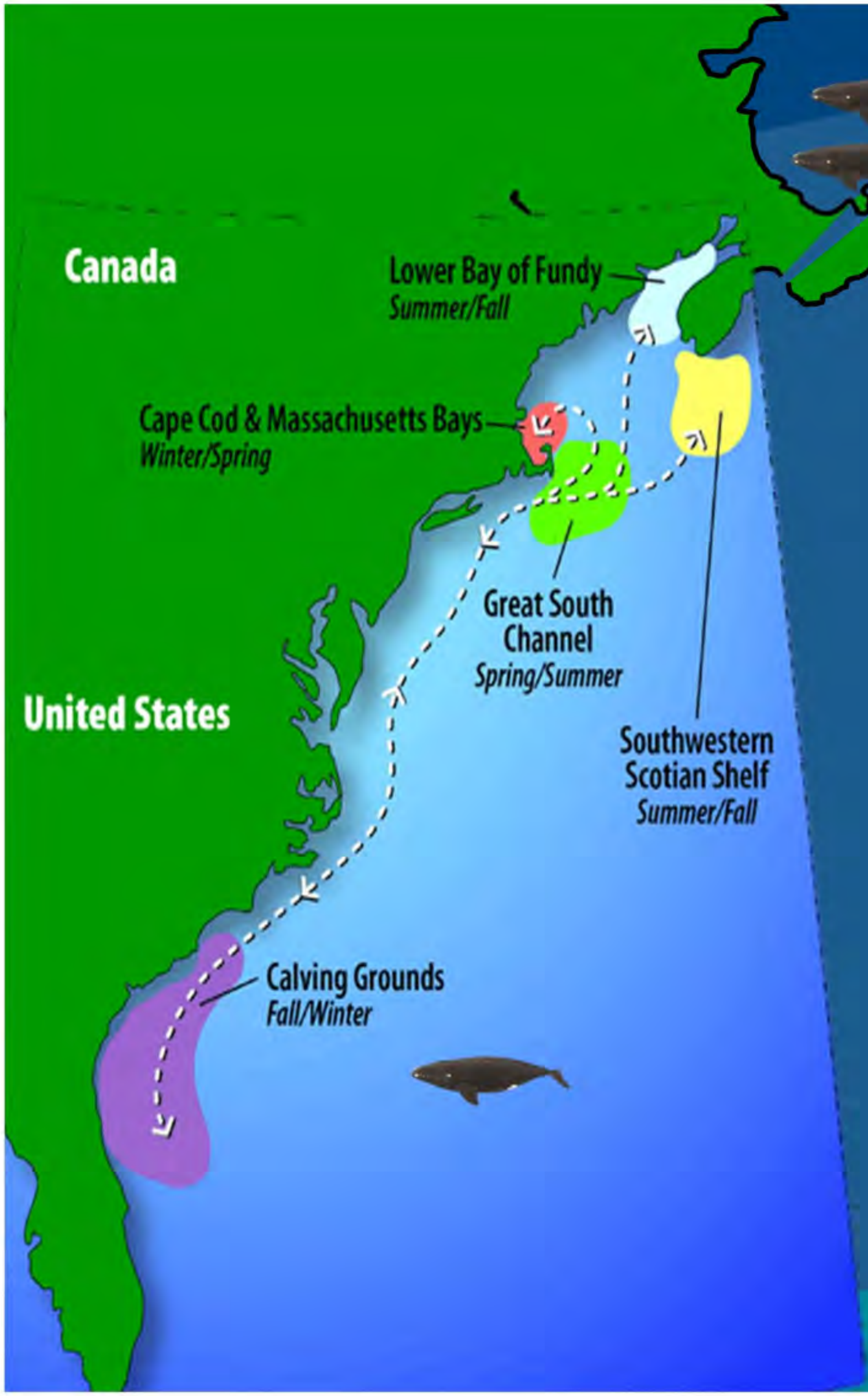


"Distributional shift?"

NARW Atlantis! (?)

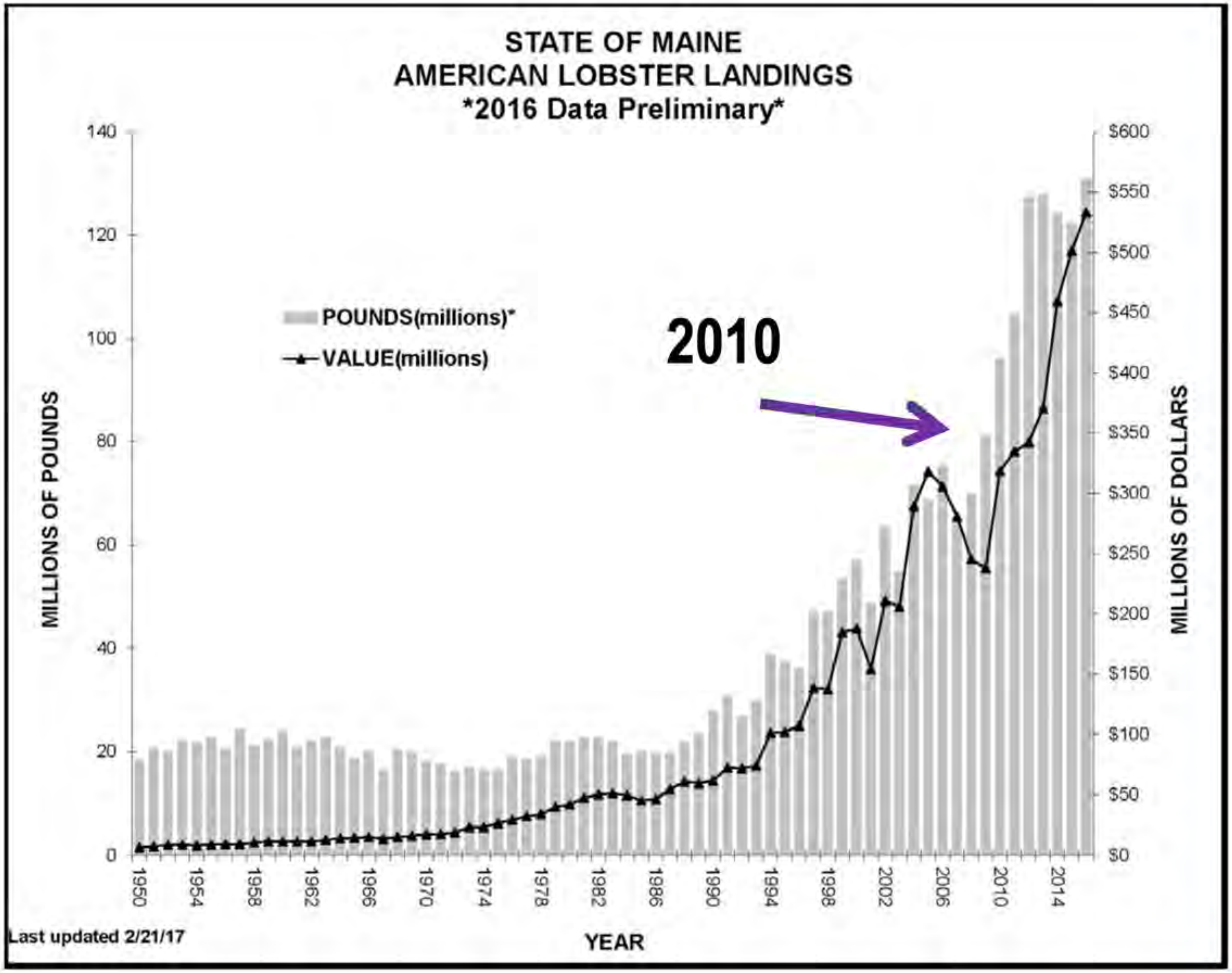
Implies a 'one-way' trip…

This is not what we are seeing



Like many species in NW Atlantic, NARW are expanding range north

- Historic movement pattern/speed also increases



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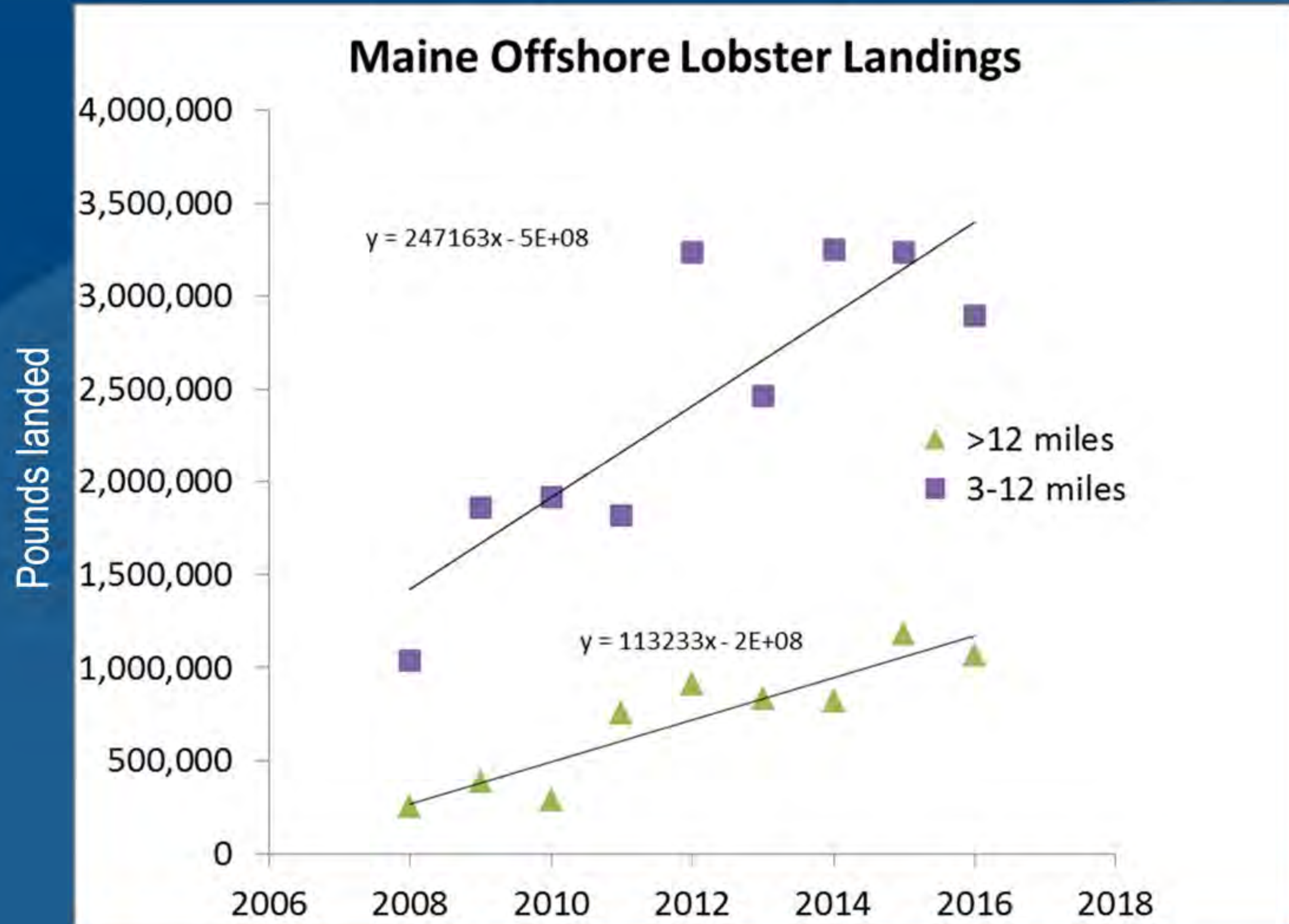
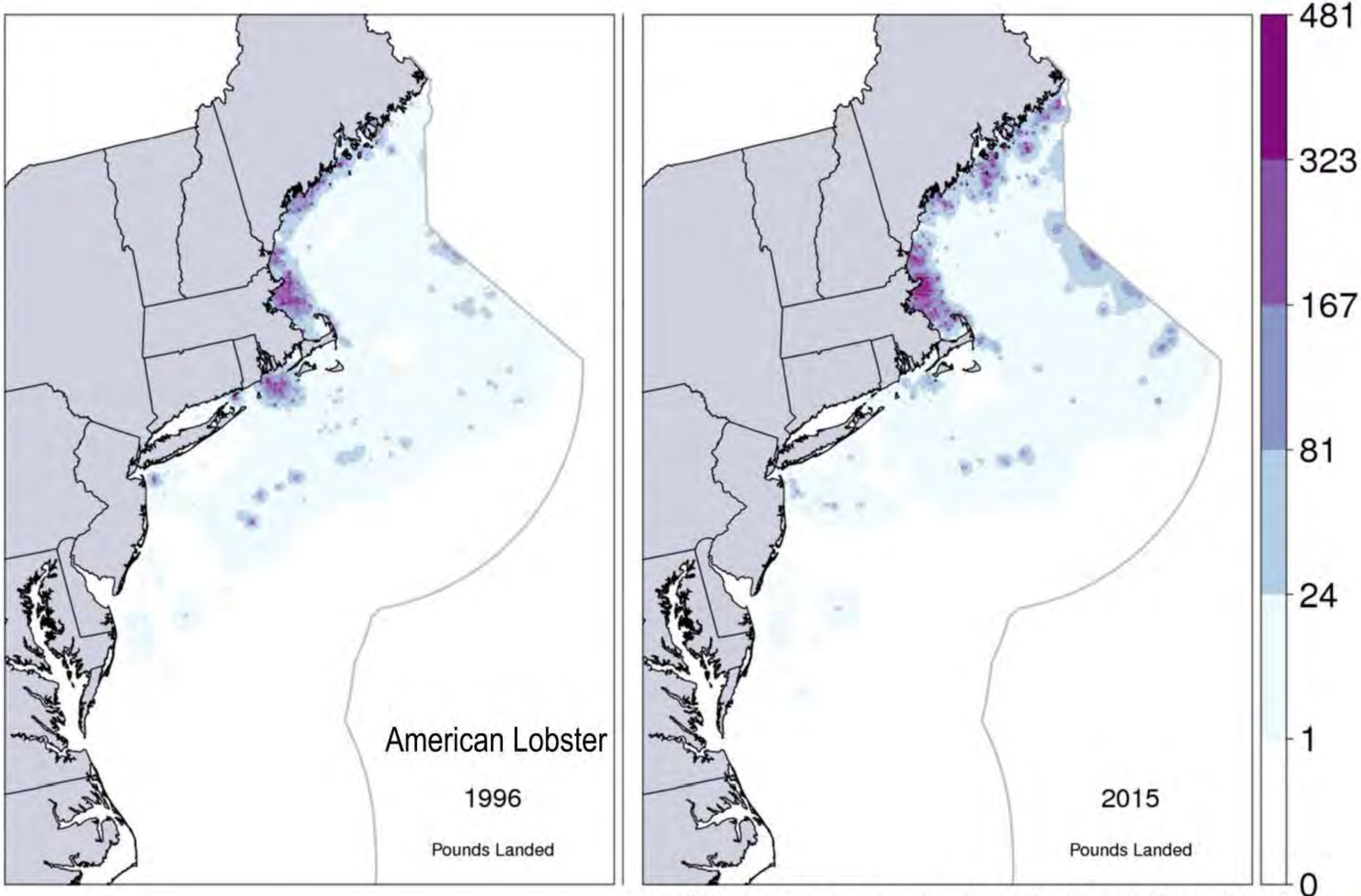
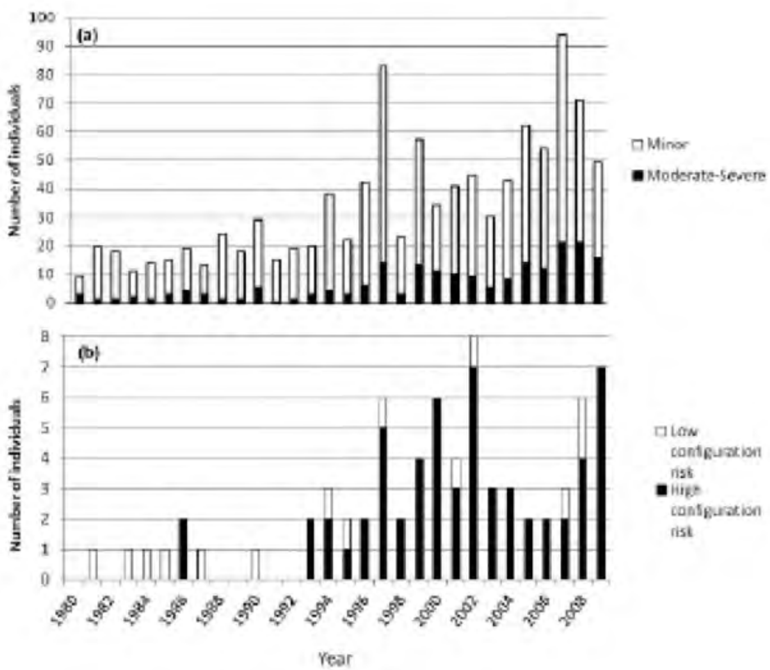


- **Offshore landings increasing by ~350,000 lbs/year**
- **That part of the fishery growing ~1.5%/year**



https://www.nefsc.noaa.gov/read/socialsci/fishing-footprints.php

Entanglements: rope has become stronger



- Knowlton et al 2015 Cons Biol
- 1994-2010
  - Rope got stronger
  - Injury severity got worse

Effects of fishing rope strength on the severity of large whale entanglements

Amy R. Knowlton,* ¶ Jooke Robbins,† Scott Landry,† Henry A. McKenna,‡ Scott D. Kraus,* and Timothy B. Werner*§

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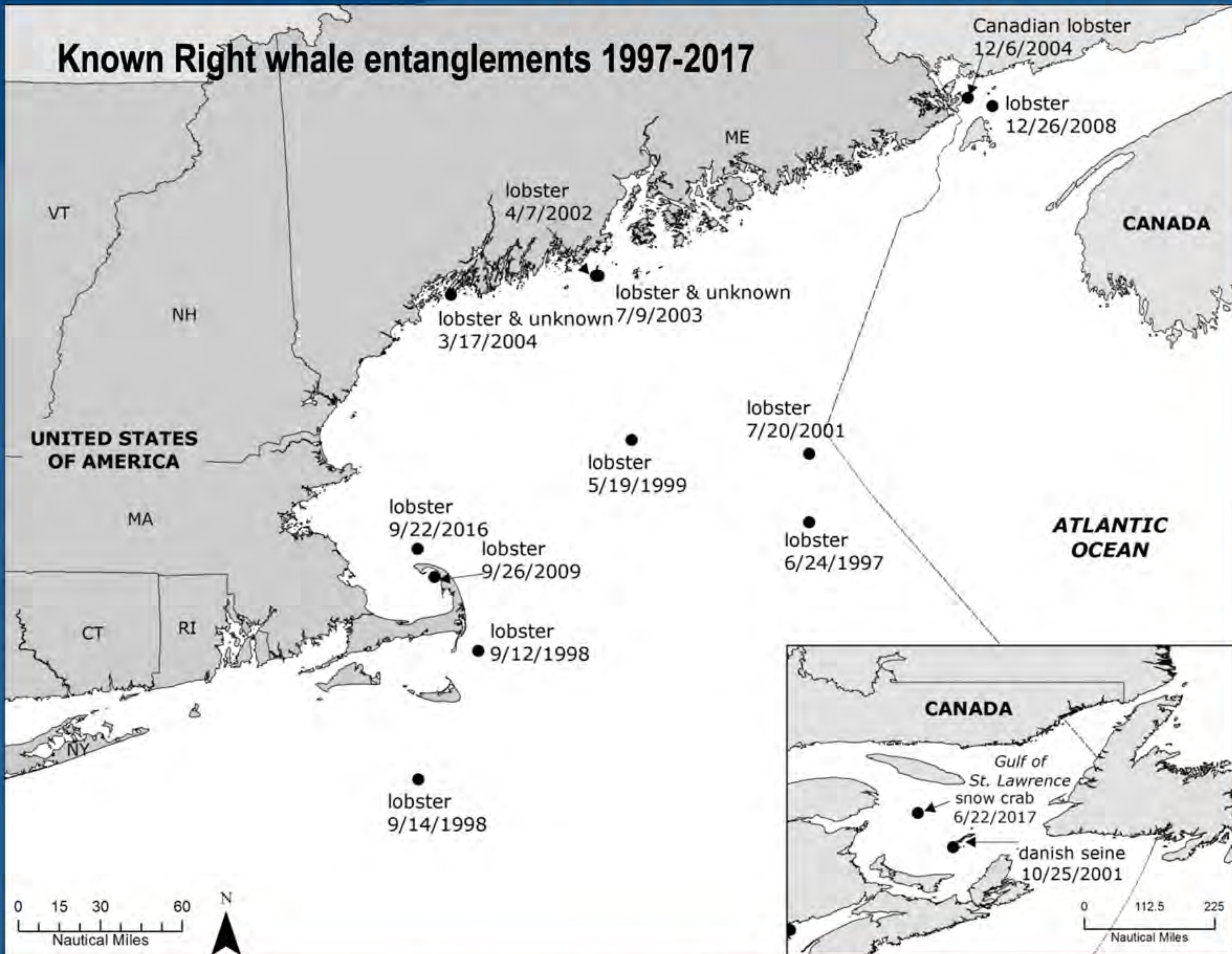
Where does entanglement happen?



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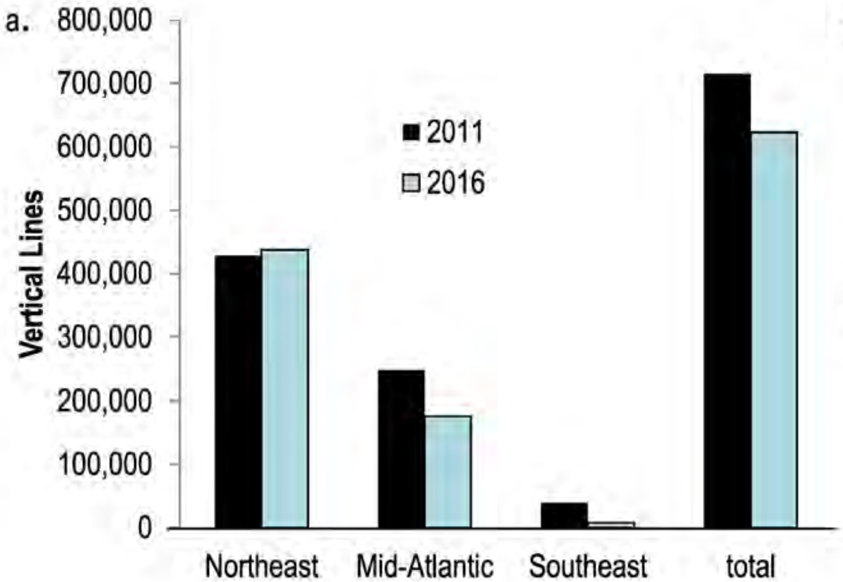
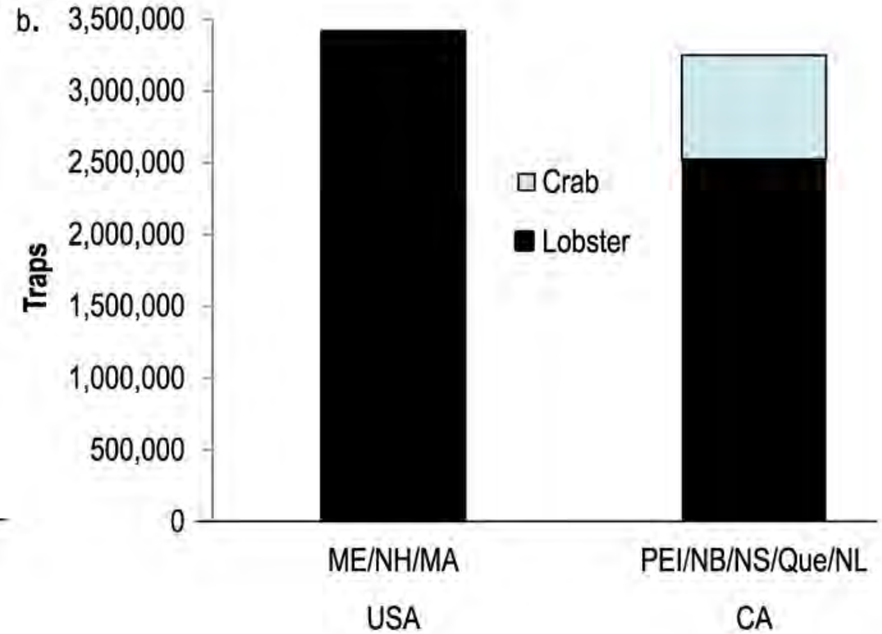
Anywhere there is a vertical line….

Index of fishing efforts.

a) The change in number of vertical lines in US waters from 2011 to 2016
b) The approximate number of traps in USA Northeastern states and Canadian provinces.





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*US lines counts from IEC, Canadian trap counts estimated from # license multiplied by trap limits

The lottery…

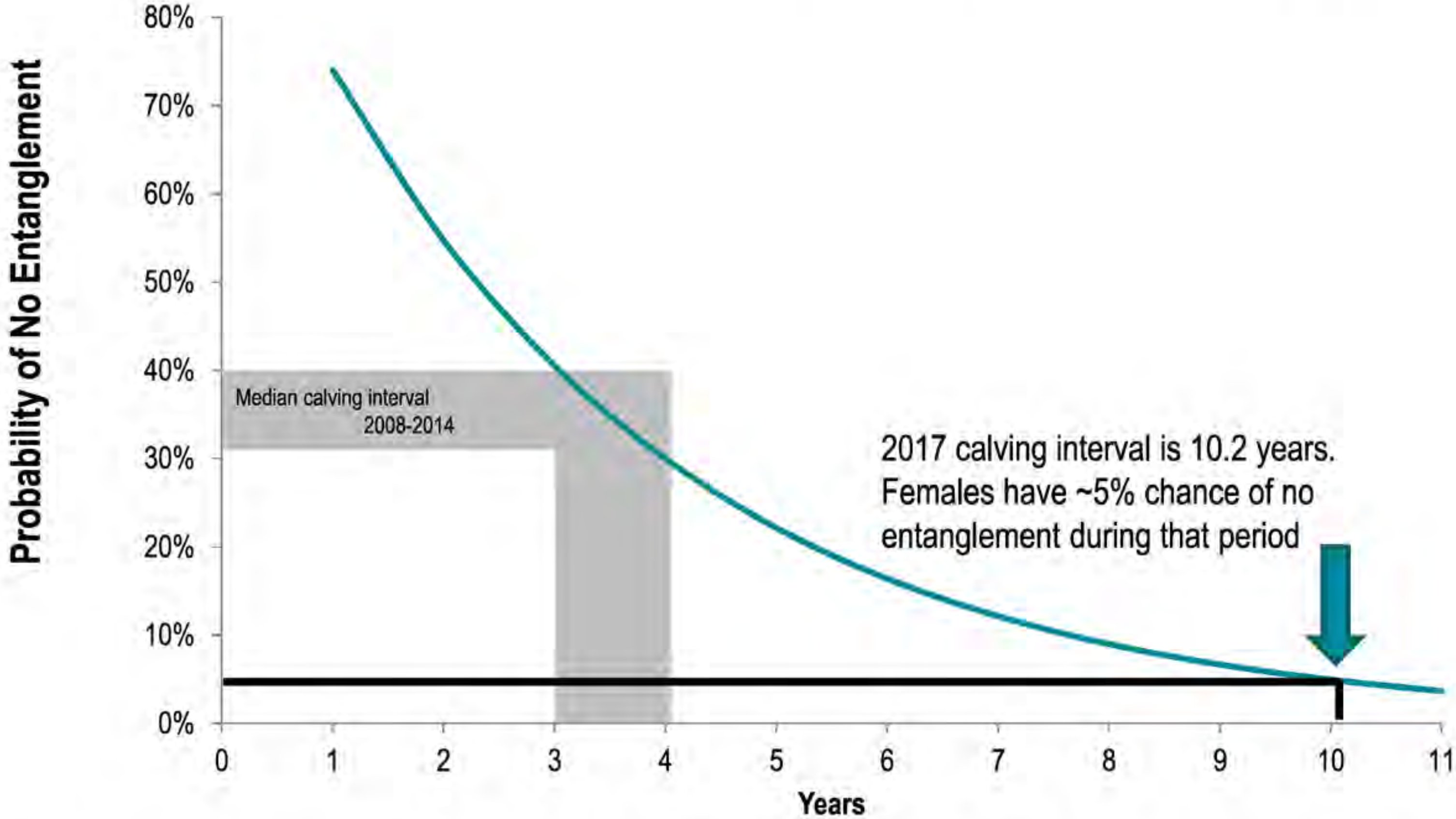
Even though your chances of winning are not high.. Someone always wins…

Sadley- winning is not a good thing..

The point is entanglement can be happening exactly where you fish and odds are you will never see it.

But from the whales perspective…

Cumulative annual probability of no entanglement (annual rate = 74%)



- If a female gets entangled and survives, strong chance she will delay calving several years
- The odds of her not getting entangled again during that delay are low

What could recovery look like?

Corkeron MMC 2017 and Corkeron et al in review

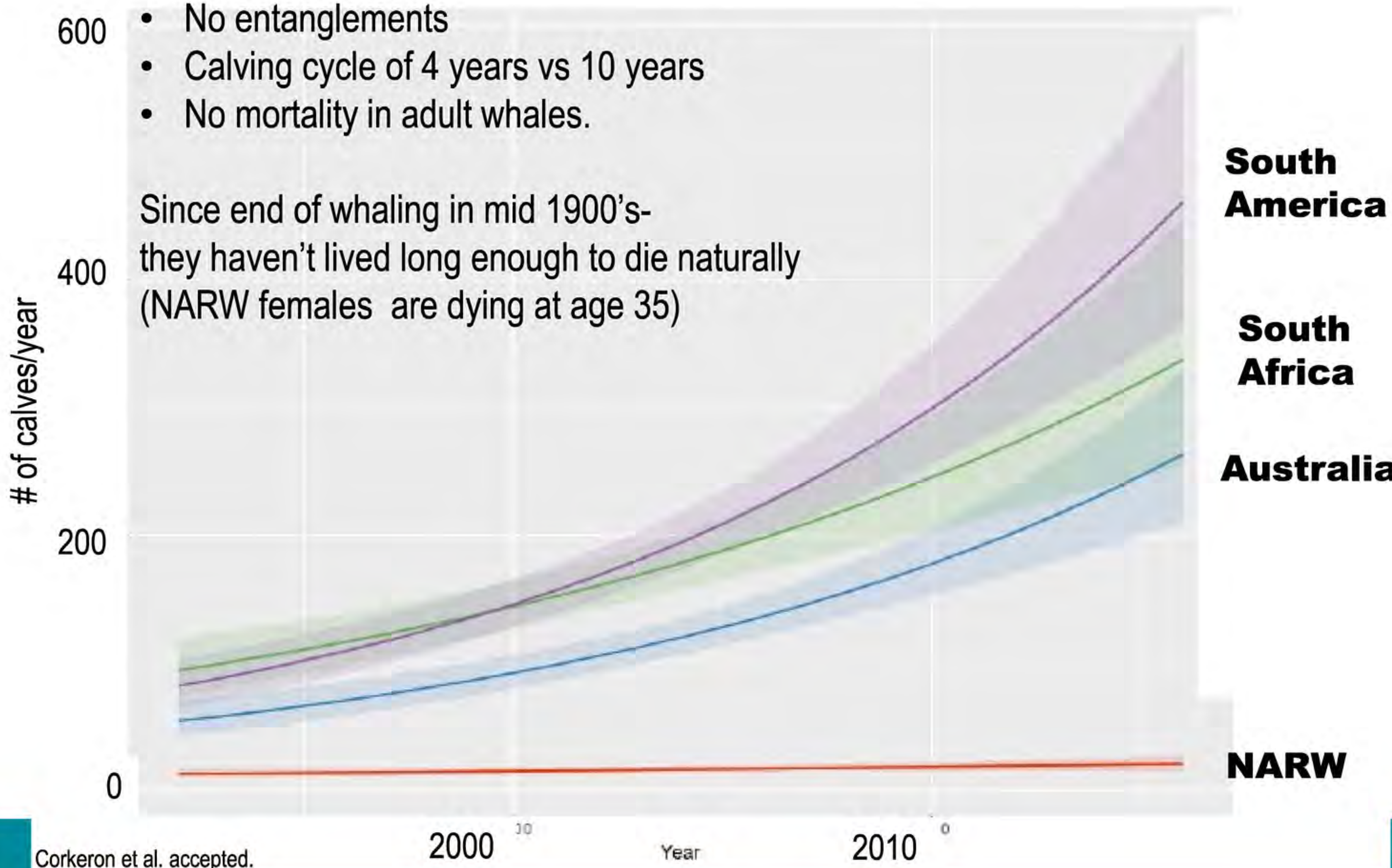
Imagine a world where after decades of recovery Right whales…

- had not aged long enough to die..
- No ship strike or entanglement..
- They were fat and happy
- Calving rates of 5-7% and hundreds born/year…

Southern Right Whales- What's different?

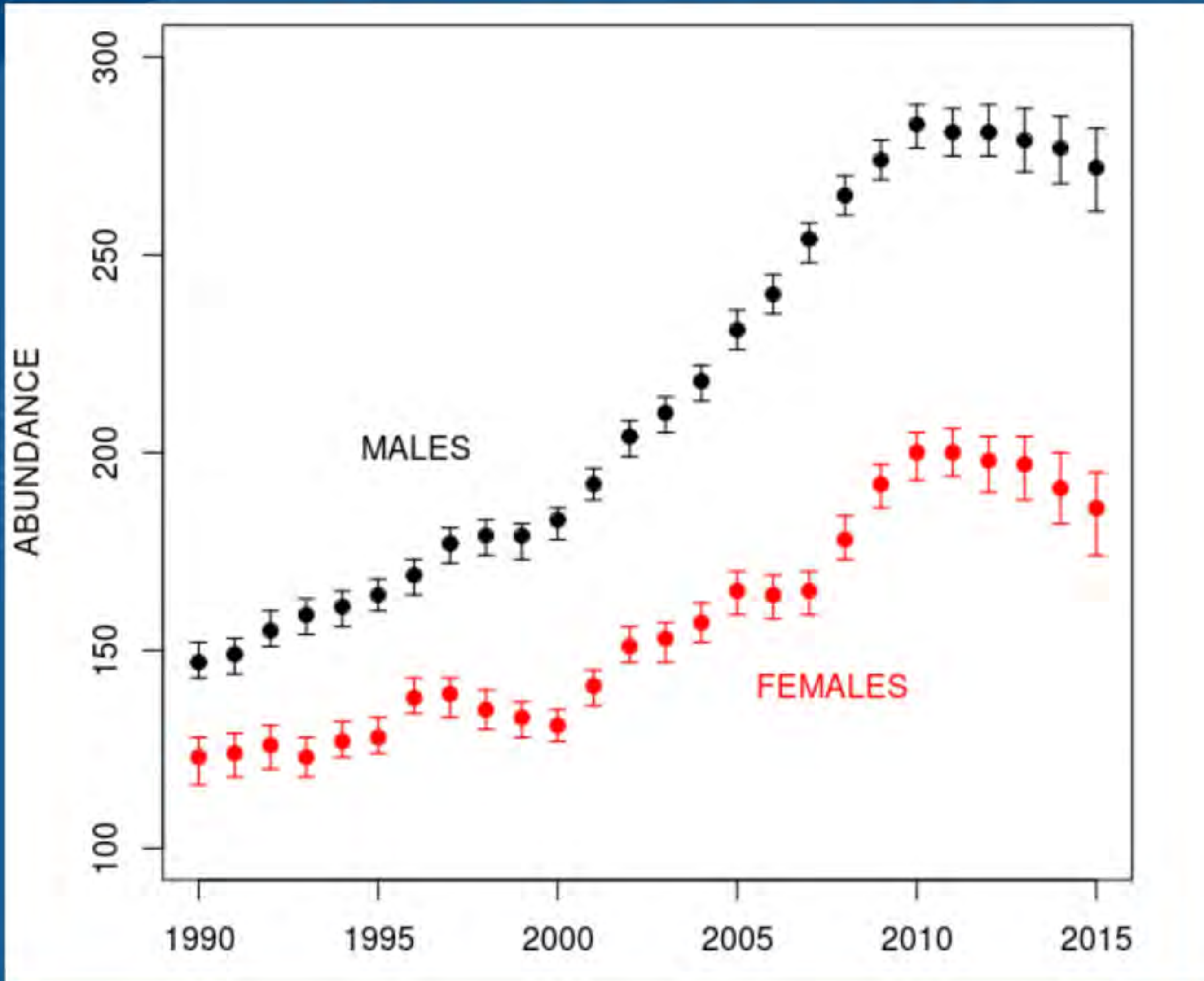
- No ship strikes
- No entanglements
- Calving cycle of 4 years vs 10 years
- No mortality in adult whales.

Since end of whaling in mid 1900's-
they haven't lived long enough to die naturally
(NARW females are dying at age 35)



Corkeron et al. accepted.

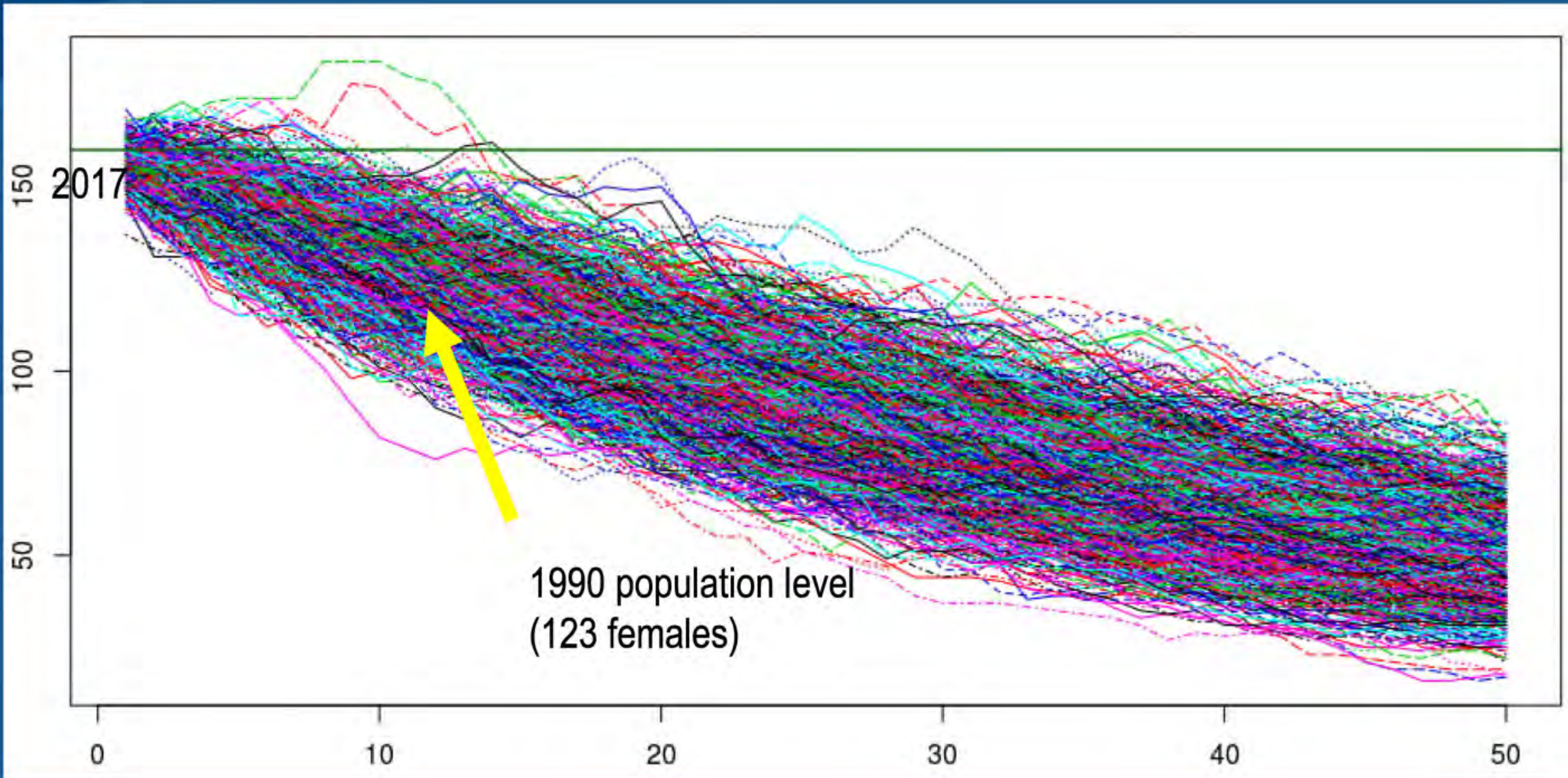
Sex bias- the problem is worse



NOAA FISHERIES

Pace et al. 2017

NARW Females- current rate of decline back to 1990 population in 12 years

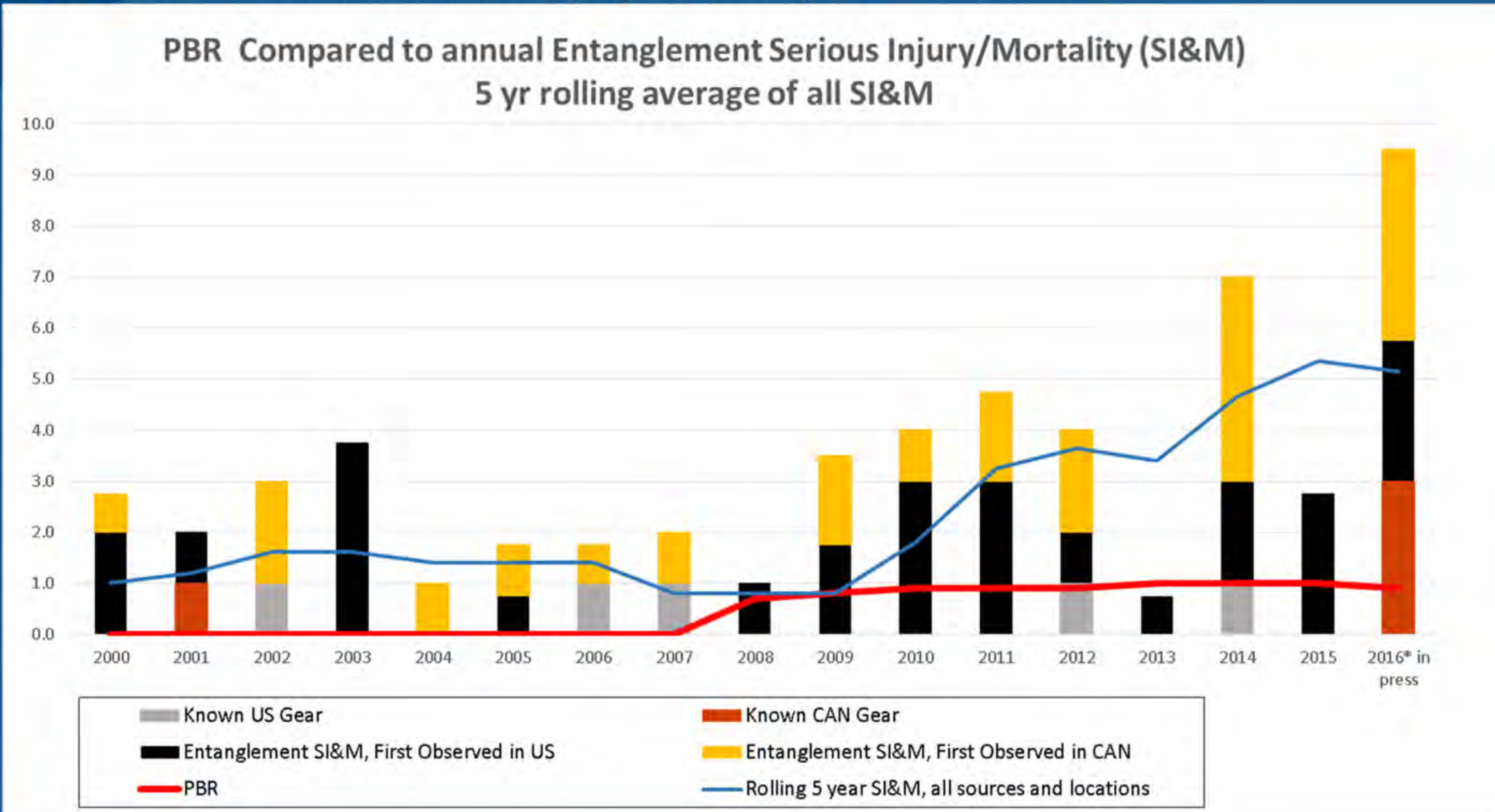


NOAA FISHERIES

NARW are exposed to ~2x the gear after 2010

The Charge to the TRT-

How do we reduce serious injury/mortality to below PBR



Websites for the paper

https://www.nefsc.noaa.gov/publications/tm/tm247/

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Questions?

Image collected under MMPA Research permit number 17355
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FINAL REPORT

Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule

Update of Economic Impact and Scoping Assessment for Study of Potential Modifications

SUBMITTED TO
National Oceanic & Atmospheric Administration (NOAA)
National Marine Fisheries (NMFS)
Office of Protected Resources

SUBMITTED BY
Nathan Associates Inc.
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NATHAN
ASSOCIATES INC.

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1. Introduction

Background

On December 9, 2008, the Right Whale Ship Strike Reduction Rule (Rule) issued by the U.S. National Marine Fisheries Service (NMFS) went into effect. The rule requires certain vessels to travel at 10 knots or less in certain areas of right whale aggregation and near several key port entrances along the U.S. eastern seaboard.

The U.S. National Marine Fisheries Service's (NMFS) Final Rule to reduce the severity and likelihood of vessel strikes to North Atlantic right whales went into effect on 9 December 2008 (73 FR 60173; 10 October 2008). The stated goal of the rule was "*to reduce or eliminate the threat of ship strikes [of North Atlantic right whales] - the primary source of mortality in the endangered population*." It requires that vessels 65 feet and greater in length travel at speeds of 10 knots or less near several key port entrances and in certain areas of right whale aggregation and along the U.S. eastern seaboard, known as "Seasonal Management Areas" (SMA) (Figure 1- 1).

As indicated in the preamble to the rule, a program of "Dynamic Management Areas" (DMA) was also established whereby temporary zones (15 days in duration, generally) are created around aggregations of right whales occurring outside of SMAs. Mariners are asked, but not required, to either avoid established DMAs altogether or travel through them at speeds of 10 knots or less.

The rule is set to expire five years from the date of its publication. NMFS indicated that it would develop ways to monitor the effectiveness of the rule. This report presents an updated assessment of the estimated economic impact of the Rule. In large measure, the economic impact assessment is based on the approach and analysis presented in the FEIS Report, Economic Analysis for the Final Environmental Impact Statement of the North Atlantic Right Whale Ship Strike Reduction Strategy prepared by Nathan Associates Inc. for NMFS in August 2008.

Whereas the economic analysis included in the FEIS report were based on assumptions regarding the impact on vessel operations, this updated assessment is based on actual vessel operations recorded during periods when the rule was in effect and not in effect. There are also several important data and analytical improvements that are incorporated in the present assessment that are further described herein.

Figure 1-1. Locations of Vessel Speed Restriction Seasonal Management Areas

General Approach

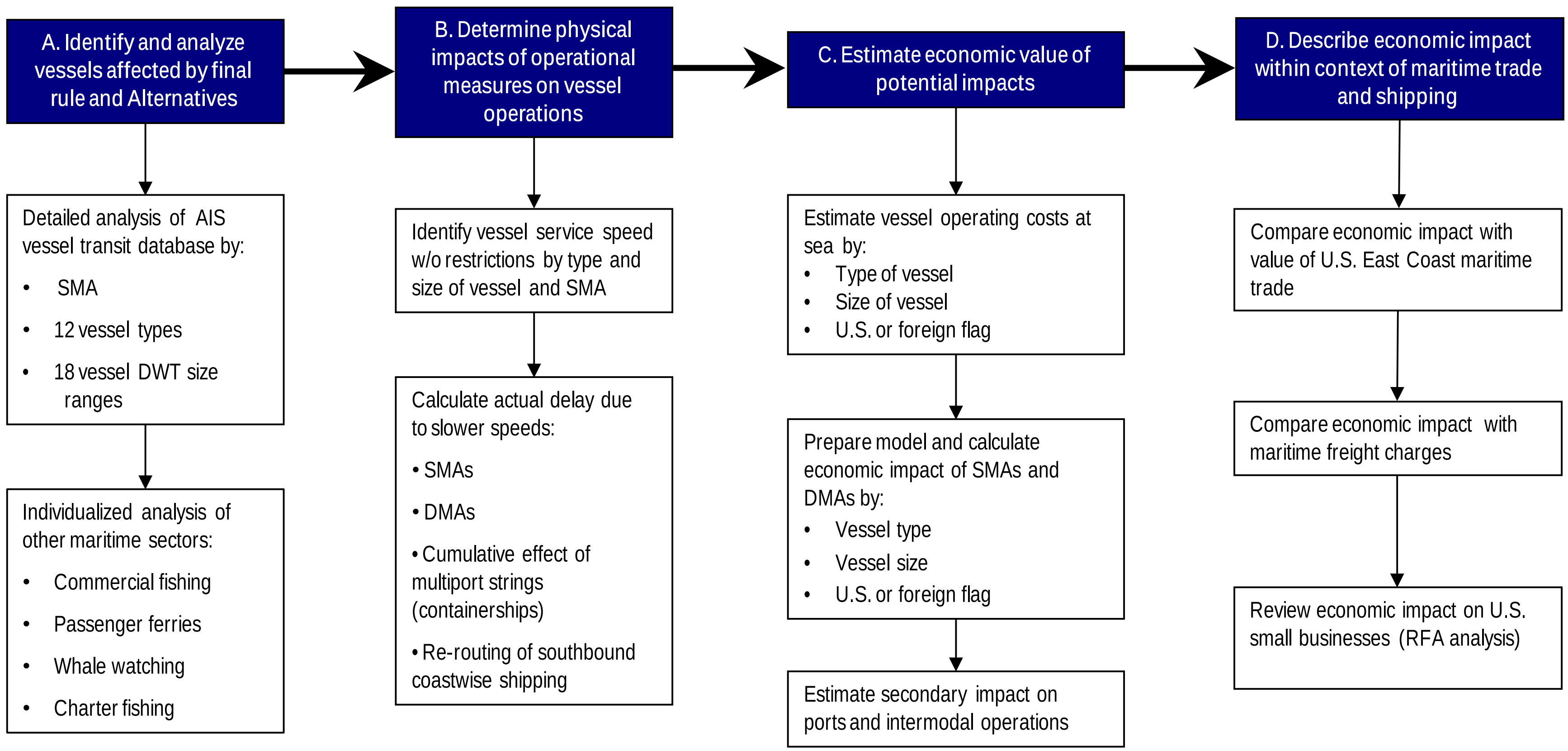
Our approach for the estimation of the potential economic impact of the proposed operational measures of the Rule has been designed so that results can be identified and analyzed at a summary level or disaggregated by port area, vessel type, vessel size, and vessel flag. An ancillary benefit of this approach is that it also enhances the accuracy and rigor of the analysis. Key factors such as vessel operating speed vary significantly by vessel type and size; vessel operating costs vary by those vessel characteristics as well as flag of registry. For this study, we have used 10 knots as the base case.

As depicted in Figure 1-2, our general approach is organized into the following four principal tasks:

> **Task A. Identify and analyze vessels affected by the final rule.** Detailed information regarding vessels transiting SMAs during 2009 was obtained from the U.S. Coast Guard's Automatic Identification System (AIS) database. Vessel transits were analyzed for 10 SMAs on the U.S. East Coast, 12 vessel types, 18 vessel DWT size ranges and U.S. and foreign flag registration.
>
> **Task B. Determine physical impacts of operational measures on vessel operations.** Key information include vessel service speed by type and size of vessel for periods when the SMAs were not in effect as compared to when they were in effect. Similar information was analyzed for DMAs. Results of this task include estimate of minutes of delay per vessel transit for SMAs and DMAs.
>
> **Task C. Estimate economic value of potential impacts.** Key data include vessel operating costs at sea by type and size of vessel and whether U.S. or foreign flag registry. Results include detailed estimates of economic impact of speed restrictions by SMA, vessel type, vessel DWT size range, and flag of registration.
>
> **Task D. Describe economic impact within context of U.S. East Coast maritime trade and shipping.** The estimated economic impact is assessed relative to the value of maritime trade and relative to maritime freight charges. We also conducted separate economic impact analyses for sectors not sufficiently included in the AIS database such as whale watching vessels, passenger ferries, commercial fishing and charter fishing.

Chapter 2 provides a detailed assessment of the impact of the rule on the shipping industry, while Chapter 3 presents the assessment on other maritime sectors. Chapter 4 presents a summary of the total direct and indirect economic impact. Chapter 5 presents the updated analysis of the impact of the rule on small business entities, consistent with a Regulatory Flexibility Act (RFA) threshold assessment. Chapter 6 provides a scoping analysis of the approach, data requirements and issues for the conduct of an economic analysis of potential modifications of the current rule.

Figure 1-2. General Approach



2. Economic Impact on Shipping Industry

Direct Economic Impact

AIS DATA AND APPROACH

A key data improvement is the availability of Automatic Identification System (AIS) that uses a Global Positioning System-linked, very high frequency radio signal that provides for ship-to-ship and ship-to-shore information transfer. It transmits the ship's name, call sign, position, dimensions, speed, heading and other information multiple times each minute. The AIS signal provides a suite of information, both dynamic (that is unique to a particular voyage) and static (that is consistent for a given vessel). Dynamic information includes the vessel's position, speed over ground, course over ground, heading, rate of turn, and position accuracy (< or > 10 m) which are determined by continuous GPS linked updates. Static information includes the vessel name, call sign, type, cargo, and its Maritime Mobile Service Identity (MMSI) number. Given the rate at which it provides this information, AIS is a precise means to remotely track vessel speeds and other vessel operations.

AIS transponders are required on certain vessel types that transit U.S. waters. These include: 1) all commercial tugs, barges, tow and similar vessels that are 26 feet in length or greater; 2) all passenger vessels (such as ferries and cruise ships) 150 gross tonnage or more; and 3) any commercial self-propelled vessel that is 65 feet in length or greater, which consists of commercial fishing vessels, tankers, cargo ships, etc.

The goal of the economic impact analysis is to estimate the impact on the shipping industry and overall economy from the actual implementation of the Rule. For these reasons, the economic impact analysis uses actual speeds of vessel transiting areas when the rule is not in effect by vessel type, size and flag compares those speeds with those from transits when the rule is in effect

We obtained access to the AIS for the areas relevant to the Rule for the full year of 2009 from the NOAA Office of Protected Resources. We then spent a significant effort to review the data and fill-in critical missing information for the economic analysis on vessel type and size. This was accomplished by matching various vessel identifiers such as the Maritime Mobile Service Identity (MMSI) number, call sign, and IMO number. In some instances, information on the type and size of vessel were confirmed based on the name of the vessel, length and cargo type. For vessels that the vessel type was known as well as the gross registered tonnage, the deadweight tonnage was estimated using the regression analysis described in the 2008 FEIS Report, Appendix A, Attachment 5.

As a result of the AIS data review and analysis, we were able to obtain for 2009, operating information for 62,765 vessel transits through areas affected by the Rule[1]. Table 2-1 presents the distribution of the total vessel transits through SMA areas by type and size of vessel. Containerships accounted for 18,540 transits followed by towing vessels with 14,425 transits and tank ships with 10,002 transits.

Table 2-1. Total Vessel Transits through SMAs by Type and Size of Vessel, 2009 (includes periods when Rule is in effect and not in effect)

	DWT Size Range																		
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	0-100	00-120	0-150	150+	Total
Bulk Carrier	1	276	257	206	134	312	239	565	258	297	380	251	767	177	3		22	20	4,165
Combination Carrier (e.g. OBO)		6						44					6	13		2			71
Container Ship	139	610	964	352	712	506	1,221	888	1,450	1,078	3,704	6,616	79	221					18,540
General Dry Cargo Ship	371	559	510	322	347	311	116	123	258	100	8	1							3,026
Industrial Vessel	1,270	125	13				6												1,414
Passenger Ship a/	3,143	933	159																4,235
Refrigerated Cargo Ship	4	225	265	54	1	2	96		5		26								678
Ro-Ro Cargo Ship	138	201	962	1,627	988	804	176	79	211	24	317	22							5,549
Tank Barge										2									2
Tank Ship	13	389	403	501	116	193	317	891	786	2,284	695	567	774	282	525	531	448	287	10,002
Towing Vessel	14,425																		14,425
Other b/	1,900	148	18	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	2,072
Total	20,134	3,347	3,538	3,062	2,298	2,128	2,171	2,590	2,968	3,785	5,130	7,457	1,626	693	528	533	470	307	62,765

a/ Includes recreational vessels.
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.
Source: Nathan Associates Inc.

Of total 62,765 transits, 28,543 vessel transits (45.5%) occurred during periods when the Rule was in effect and 34,222 vessel transits (54.5%) occurred during periods when the Rule was not in effect (Table 2-2).

[1] The data file received from NOA had a total of 78,757 transit records. However, we excluded 15,992 records due to vessels less than 65 feet LOA, non-commercial shipping vessels and where the vessel type or size could not be determined.

Table 2-2. Percent of Vessel Transits through SMAs during Effected Periods by Type of Vessel, 2009

Vessel Type	Rule in Effect	Rule Not in Effect	Total	% Rule in Effect
Bulk Carrier	2,193	1,972	4,165	52.7
Combination Carrier (e.g. OBO)	46	25	71	64.8
Container Ship	8,634	9,906	18,540	46.6
General Dry Cargo Ship	1,310	1,716	3,026	43.3
Passenger Ship	1,244	2,991	4,235	29.4
Refrigerated Cargo Ship	390	288	678	57.5
Ro-Ro Cargo Ship	2,648	2,901	5,549	47.7
Tank Barge	2		2	100.0
Tank Ship	4,494	5,508	10,002	44.9
Towing Vessel	6,751	7,674	14,425	46.8
Other b/	831	1,241	2,072	40.1
Grand Total	28,543	34,222	62,765	45.5
a/ Includes recreational vessels.				
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.				
Source: Nathan Associates Inc.				

Table 2-3 presents the number of transits through SMA areas in 2009 by SMA and type of vessel. The New York SMA had the largest number of transits at 15,180 transits followed by the SMA from North Carolina to Georgia with 13,437 transits and Norfolk with 9,549 transits. Each of these areas had a large number of containership transits.

Table 2-3. Total Vessel Transits through SMAs by Type of Vessel, 2009 (includes periods when Rule is in effect and not in effect)

SMA	Bulk Carrier	Combination Carrier (e.g. OBO)	Container Ship	General Dry Cargo Ship	Passenger Ship a/	Refrigerated Cargo Ship	Ro-Ro Cargo Ship	Tank Barge	Tank Ship	Towing Vessel	Other b/	Total
Off Race Point	177		341	51	192	2	92		672	446	53	2,026
Cape Cod Bay	44		17	27	69		21		166	1,633	107	2,084
Great South Channel	246		353	78	173	2	89		618	24	32	1,615
Block Island	326	4	55	138	109	25	237		605	826	141	2,466
New York	592	27	4,850	266	478	20	1,056	2	3,173	4,294	422	15,180
Philadelphia	430	5	870	532	1,308	567	333		1,779	2,687	189	8,700
Norfolk	1,424	27	3,988	632	235	10	1,198		622	1,130	283	9,549
Morehead City	50		15	49	40		8		72	429	54	717
North Carolina to Georgi	533	6	6,668	735	981	14	843		1,707	1,338	612	13,437
Southeast	343	2	1,383	518	650	38	1,672		588	1,618	179	6,991
Grand Total	4,165	71	18,540	3,026	4,235	678	5,549	2	10,002	14,425	2,072	62,765
a/ Includes recreational vessels.												
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.												
Source: Nathan Associates Inc.												

In terms of transits during periods when the SMAs were in effect, the Mid-Atlantic region registered the highest percentage of transits, generally between 45-50 percent of total transits (Table2-4). This is consistent with the 181-day period that the SMAs were in effect in these areas from November 1 through April 30. Other areas also generally had the percentage of transits through active SMAs matching the percent of the days of the year that they were in effect.

Table 2-4. Percent of Vessel Transits through SMAs by Type of Vessel during Effected Periods, 2009

SMA	Rule in Effect	Rule Not in Effect	Total	% Rule in Effect
Off Race Point	316	1,710	2,026	15.6
Cape Cod Bay	882	1,202	2,084	42.3
Great South Channel	477	1,138	1,615	29.5
Block Island	1,121	1,345	2,466	45.5
New York	7,520	7,660	15,180	49.5
Philadelphia	3,979	4,721	8,700	45.7
Norfolk	4,652	4,897	9,549	48.7
Morehead City	182	535	717	25.4
North Carolina to Georgia	6,499	6,938	13,437	48.4
Southeast	2,915	4,076	6,991	41.7
Grand Total	28,543	34,222	62,765	45.5
Source: Nathan Associates Inc.				

AVERAGE OPERATING SPEEDS BY VESSEL TYPE AND SIZE

Accurate information on current vessel operating speeds is clearly an important element for the determination of the economic impact of the speed restriction required by the Rule. The AIS information provides the most detailed and accurate information of vessels operating speeds for the areas subject to the Rule. For each area subject to the Rule, we have computed the average operating speeds by type and size of vessel for periods in 2009 when the Rule was not in effect. This provides the most robust estimate for actual vessel operations and average operating speeds without the influence of the Rule. In Table 2-5 below, we present the data by vessel type and size but summarized across all of the areas affected by the Rule. The fastest average vessel operating speed in these areas observed in 2009 was 14.0 knots for containerships and 13.9 knots for refrigerated cargo ships. The overall weighted average speed was 11.9 knots.

Table 2-5. Average Vessel Operating Speed through SMAs by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule Is Not in Effect, 2009 (knots)

	DWT Size Range																		
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	4.6	11.1	11.2	11.9	9.6	11.4	11.1	10.7	11.2	11.9	12.3	11.3	11.4	10.8			12.6	10.6	11.3
Combination Carrier (e.g. OBO)		13.9						10.1					9.8			12.7			10.6
Container Ship	12.4	12.9	14.1	13.7	13.2	14.9	14.5	13.9	14.0	13.9	14.4	13.9	13.6	14.1					14.0
General Dry Cargo Ship	11.4	11.6	13.5	12.3	12.4	11.5	12.3	11.2	11.8	12.9	12.8								12.1
Passenger Ship	10.7	15.7	14.8																12.4
Refrigerated Cargo Ship	11.0	14.4	14.6	15.0			11.3		13.4		13.7								13.9
Ro-Ro Cargo Ship	8.4	13.3	13.6	14.2	13.7	13.2	13.9	15.3	13.4	14.3	13.6	13.4							13.6
Tank Ship	9.6	12.3	11.6	12.7	11.0	12.4	12.1	12.3	11.9	11.9	11.8	11.8	11.3	11.1	10.9	11.3	10.3	11.2	11.7
Towing Vessel	8.2																		8.2
Total	9.3	13.7	13.4	13.6	12.9	13.0	13.5	12.5	13.0	12.6	13.9	13.7	11.5	12.0	10.9	11.3	10.3	11.2	11.9

Source: Nathan Associates Inc.

Average vessel operating speeds through SMAs in 2009 during period when the Rule was in effect declined to an overall average of 10.0 knots (Table 2-6). Containerships slowed from an average of 14 knots to 10.6 knots. Ro-ro vessels slowed from 13.6 knots to 10.5 knots. The fastest average vessel speed through SMA active areas was by refrigerated cargo ships at 13.1 knots just slightly slower than the 13.9 knots recorded during non-active SMA periods.

Table 2-6. Average Vessel Operating Speed through SMAs by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule Is in Effect, 2009 (knots)

	DWT Size Range																		
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier		10.5	10.4	11.4	9.1	10.6	10.3	9.9	10.3	10.3	10.7	9.6	10.4	10.8	9.6		10.6	9.2	10.3
Combination Carrier (e.g. OBO)		10.6						6.8					8.5	10.0					8.2
Container Ship	12.3	11.1	10.7	10.6	10.3	10.2	11.1	11.1	11.0	10.1	10.6	10.5	10.7	10.4					10.6
General Dry Cargo Ship	10.5	11.4	11.6	11.1	11.5	10.6	11.2	10.8	11.0	10.5	9.2	9.9							11.2
Passenger Ship	9.1	10.7	11.5																9.7
Refrigerated Cargo Ship		13.4	13.8	11.8	12.9	9.4	11.7		9.9		9.9								13.1
Ro-Ro Cargo Ship	9.3	10.8	10.3	10.5	10.7	10.6	10.3	10.4	11.1	10.9	10.2	10.8							10.5
Tank Barge										10.6									10.6
Tank Ship	9.2	10.1	10.5	10.8	10.3	10.9	10.3	10.4	10.5	10.3	10.5	10.0	9.9	9.8	9.6	10.6	9.7	10.9	10.3
Towing Vessel	8.2																		8.2
Total	8.6	10.9	11.0	10.7	10.5	10.5	10.9	10.5	10.8	10.2	10.6	10.4	10.2	10.4	9.6	10.6	9.8	10.7	10.0

Source: Nathan Associates Inc.

AVERAGE DELAYS DUE TO RULE BY TYPE AND SIZE OF VESSEL

The primary operational impact of the Rule on the shipping industry is the extra sailing time incurred caused by vessels having to slow down within the restricted areas. Estimates of the extra sailing time were calculated by subtracting the time required to sail through each restricted area using the detailed average vessel operating speeds for that restricted area during periods when the Rule was not in effect from the time required at a sailing speed of 10 knots. Only average vessel speeds of greater than 10 knots during non-Rule periods were used for these calculations. A summary across all restricted areas of the average extra time per vessel transit by vessel type and size is presented in Table 2-7. The average delay for all vessels is 0.37 of an hour or 22 minutes. The highest average delay by vessel type is 37minutes (0.62 hours) for combination carriers followed by 34 minutes for Ro-Ro carriers and 32 minutes for containerships. Refrigerated cargo ships only experienced an average delay of 5 minutes.

Table 2-7. Average Delays per Vessel Transit through SMAs due to Rule by Type and Size of Vessel, 2009 (hours)

	DWT Size Range																	
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	.00-12(	.20-15(	150+	Total
Bulk Carrier		0.12	0.17	0.08	0.12	0.16	0.18	0.16	0.21	0.37	0.33	0.39	0.19	0.00			0.34	0.31	0.20
Combination Carrier (e.g. OBO)		0.75						0.93					0.50						0.62
Container Ship	0.02	0.36	0.61	0.46	0.47	0.78	0.49	0.45	0.45	0.64	0.59	0.55	0.53	0.59					0.54
General Dry Cargo Ship	0.19	0.04	0.29	0.20	0.17	0.16	0.19	0.08	0.16	0.44	0.62								0.17
Passenger Ship	0.17	0.84	0.42																0.35
Refrigerated Cargo Ship		0.11	0.08	0.32			-0.06		0.54		0.62								0.08
Ro-Ro Cargo Ship	0.00	0.46	0.64	0.66	0.51	0.48	0.60	0.72	0.35	0.43	0.54	0.49							0.56
Tank Ship	0.14	0.45	0.23	0.33	0.12	0.28	0.30	0.36	0.29	0.36	0.27	0.38	0.29	0.27	0.27	0.13	0.12	0.07	0.29
Total	0.19	0.55	0.42	0.49	0.42	0.45	0.41	0.36	0.37	0.46	0.54	0.54	0.25	0.29	0.27	0.13	0.12	0.09	0.37
Source: Nathan Associates Inc.																			

VESSEL OPERATING COSTS AT SEA BY TYPE AND SIZE OF VESSEL

The U.S. Army Corps of Engineers (USACE) prepares estimates of vessel operating costs to be used by planners in studies to determine the potential benefits of harbor improvement projects. Vessel operating costs include annual capital costs as determined by the replacement cost of the vessels and application of capital recovery factors; estimates of fixed annual operating costs such as for crew, lubricating materials and stores (supplies), maintenance and repair, insurance and administration; the number of operational days per year; and fuel costs at sea and in port.

The type and DWT size of vessels for which operating costs are reported by the USACE is shown in Table 2-8 below. Vessel operating costs are presented separately for U.S. flag and foreign flag vessels, for five vessel types, and up to 14 vessel DWT sizes within a vessel type.

Table 2-8. Type and Size of Vessels for which USACE Reports Vessel Operating Costs (DWT)

Foreign flag					U.S. flag				
General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull	General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull
11,000	9,000	15,000	20,000	20,000	11,000	9,000	15,000	20,000	20,000
14,000	14,000	25,000	25,000	25,000	14,000	14,000	25,000	25,000	25,000
16,000	17,000	35,000	35,000	35,000	16,000	17,000	35,000	35,000	35,000
20,000	20,000	40,000	50,000	50,000	20,000	20,000	40,000	50,000	50,000
24,000	23,000	50,000	60,000	60,000	24,000	23,000	50,000	60,000	60,000
30,000	28,000	60,000	70,000	70,000	30,000	28,000	60,000	70,000	70,000
	31,000	80,000	80,000	80,000		31,000	80,000	80,000	80,000
	35,000	100,000	90,000	90,000		35,000	100,000	90,000	90,000
	39,000	120,000	120,000	120,000		39,000	120,000	120,000	120,000
	42,000	150,000	150,000	150,000		42,000	130,000	150,000	150,000
	49,000	175,000	175,000	175,000		49,000		175,000	175,000
	55,000	200,000	200,000	200,000		55,000		200,000	200,000
	66,000		265,000	265,000		66,000		265,000	265,000
	82,000		325,000	325,000					

Source: U.S. Army Corps of Engineers, Economic Guidance Memorandum 02-06, Deep Draft Vessel Operating Costs

As the USACE data includes more vessel size ranges than necessary for this economic impact analysis We applied regression techniques to the USACE vessel operating cost data in order to match with the vessel size categories with thoase used in this analysis of U.S. East Coast vessel arrivals. A logarithmic equation was specified relating hourly operating costs at sea with vessel DWT for each of the vessel types used in this economic impact analysis.

A concern over the use of the USACE operating cost estimates is the variability of actual vessel operating costs due to the fluctuations in the price of bunker fuel. The USACE estimates include the assumed fuel consumption per day at sea for the primary propulsion and auxiliary propulsion for each vessel type and DWT size. The primary propulsion is assumed to use heavy viscosity oil while the auxiliary propulsion is assumed to use marine diesel oil. We updated the USACE vessel operating costs to reflect the average bunker fuel prices per ton for New York for using an annual average 2009 calculated from data reported by Bunkerworld. The average price for heavy viscosity oil for 2009 was $347 per metric ton and marine diesel oil was $685 per metric ton. The resulting estimates of vessel operating costs by type and size of vessel for 2009 are presented for foreign flag and U.ZS.-flag vessels in Table 2-9 and Table 2-10, respectively. These estimated vessel operating costs for 2009 represent the best method to value the actual impact on the shipping industry of the Rule that year.

It is important to distinguish between foreign flag and U.S. flag vessels as their costs structures differ considerably. Overall, U.S.-flag vessels have operating costs 40-70 percent higher than foreign flag vessels. This is principally due to higher costs for U.S. crews, vessel maintenance and insurance requirements that U.S.-flag vessels have to satisfy[2].

Table 2-9. Hourly Vessel Operating Costs at Sea for Foreign Flag Vessels by Type Size of Vessel Using Average 2009 ($000s)

	DWT Size Range (000s)																	
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+
Bulk Carrier	786	805	825	845	865	886	907	929	951	974	1,010	1,059	1,110	1,164	1,221	1,311	1,477	1,703
Combination Carrier (e.g. OBO)	826	846	866	887	908	930	952	975	999	1,023	1,060	1,112	1,166	1,223	1,282	1,377	1,551	1,789
Container Ship	788	888	1,000	1,126	1,267	1,427	1,607	1,809	2,037	2,294	2,740	3,474	4,405	5,584	7,080	10,107	-	-
Freight Barge	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
General Dry Cargo Ship	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
Passenger Ship a/	3,551	5,069	7,237	10,962	13,897	-	-	-	-	-	-	-	-	-	-		-	-
Refrigerated Cargo Ship	1,774	1,997	2,249	2,532	2,851	3,211	3,615	4,071	4,583	5,161	6,166	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	867	977	1,100	1,238	1,394	1,570	1,767	1,990	2,241	2,523	3,014	3,822	4,845	-	-	-	-	-
Tank Ship	960	978	996	1,015	1,034	1,053	1,073	1,093	1,113	1,134	1,166	1,210	1,256	1,304	1,353	1,431	1,570	1,755
Towing Vessel	960	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-

a/ Includes recreational vessels.

b/ Includes fishing vessels, industrial vessels, research vessels, and school ships.

Source: Prepared by Nathan Associates Inc. as decribed in text from data provided in U.S. Army Corps of Engineers, Economic Guidance Memorandum 05-01, Deep Draft Vessel Operating Costs and adjusted for bunker fuel prices reported by Bunkerworld for IFO380 and MDO for New York.

Table 2-10. Hourly Vessel Operating Costs at Sea for U.S. Flag Vessels by Type Size of Vessel Using Average 2009 ($000s)

	DWT (000s)																	
Vessel type anf flag	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+
Bulk Carrier	1,321	1,358	1,396	1,435	1,476	1,517	1,559	1,603	1,648	1,694	1,766	1,866	1,972	2,084	2,203	2,393	2,748	3,243
Combination Carrier (e.g. OBO)	1,387	1,426	1,466	1,507	1,549	1,593	1,637	1,683	1,730	1,779	1,854	1,960	2,071	2,189	2,313	2,513	2,885	3,405
Container Ship	1,064	1,194	1,340	1,503	1,687	1,894	2,125	2,385	2,676	3,003	3,571	4,497	5,664	7,133	8,984	12,698	-	-
Freight Barge	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-
General Dry Cargo Ship	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-
Passenger Ship a/	4,775	6,749	9,539	14,283	17,989	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigerated Cargo Ship	2,393	2,686	3,014	3,383	3,796	4,260	4,781	5,366	6,022	6,758	8,034	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	1,170	1,313	1,474	1,654	1,856	2,083	2,337	2,623	2,944	3,304	3,928	4,947	6,230					
Tank Barge	1,784	1,818	1,853	1,888	1,924	1,960	1,998	2,036	2,074	2,114	2,174	-	-	-	-	-	-	-
Tank Ship	1,784	1,818	1,853	1,888	1,924	1,960	1,998	2,036	2,074	2,114	2,174	2,258	2,344	2,434	2,528	2,675	2,939	3,291
Towing Vessel	1,784	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-

Source: Prepared by Nathan Associates Inc. as decribed in text from data provided in U.S. Army Corps of Engineers, Economic Guidance Memorandum 05-01, Deep Draft Vessel Operating Costs and adjusated for bunker fuel prices reported by Bunkerworld for IFO380 and MDO for New York.

DIRECT ECONOMIC IMPACT OF SMAS

The estimated direct economic impact on the shipping industry of the Rule in 2009 is presented in Table 2-11. Across all SMAs, the total direct economic impact is estimated $19.6 million. More than 63 percent of the total direct impact incurred by containerships at $12.4 million followed distantly by Ro-Ro cargo ships at $2.2 million, tank ships at $1.6 million and passenger at $1.5 million.

[2] Some studies report a much higher differential (up to 2.7 times) between U.S.-flag and foreign flag vessel operating costs. However, those studies do not include fuel and capital costs in their comparisons.

Table 2-11. Direct Economic Impact of SMAs on Shipping Industry by Type and Size of Vessel, 2009 ($000s)

Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	-	17	21	7	9	27	24	81	25	49	62	60	82	-	-	-	7	6	476
Combination Carrier (e.g. OBO)	-	3	-	-	-	-	-	16	-	-	-	-	2	-	-	-	-	-	21
Container Ship	1	90	267	78	203	286	446	353	625	668	2,881	6,128	70	295	-	-	-	-	12,392
General Dry Cargo Ship	24	3	53	27	19	14	19	9	42	60	-	-	-	-	-	-	-	-	271
Passenger Ship a/	405	806	245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,455
Refrigerated Cargo Ship	-	28	28	28	-	-	-	-	7	-	23	-	-	-	-	-	-	-	114
Ro-Ro Cargo Ship	-	54	352	665	355	303	95	61	86	12	244	11	-	-	-	-	-	-	2,239
Tank Ship	0	73	39	85	7	22	51	227	116	438	127	118	122	24	68	49	32	19	1,616
Towing Vessel	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194
Other b/	563	263	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	826
Total	1,187	1,336	1,005	889	594	651	634	746	902	1,227	3,338	6,318	277	319	68	49	39	26	19,604

a/ Includes recreational vessels.
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.
Source: Nathan Associates Inc.

The direct economic impact on the shipping industry by SMA is presented in Table 2-12. The largest impact is recorded for the SMA from North Carolina to Georgia at $5.9 million followed by New York at $5.5 million and Norfolk at $4.2 million. As previously mentioned these areas have the majority of containership transits along the U.S. East Coast. These three SMAs account for nearly 80 percent of the direct econom,ic impact of the Rule on the the shipping industry.

Table 2-12. Direct Economic Impact of SMAs on Shipping Industry by SMA and Type of Vessel, 2009 ($000s)

SMA	Bulk Carrier	Combination Carrier (e.g. OBO)	Container Ship	General Dry Cargo Ship	Passenger Ship a/	Refrigerated Cargo Ship	Ro-Ro Cargo Ship	Tank Ship	Towing Vessel	Other b/	Total
Off Race Point	9	-	74	2	4	-	7	37	3	0	136
Cape Cod Bay	7	-	2	1	1	-	3	25	20	6	65
Great South Channel	15	-	139	4	185	0	12	60	0	0	416
Block Island	55	1	37	11	27	5	84	129	10	4	362
New York	73	11	3,631	27	349	16	473	593	62	271	5,506
Philadelphia	48	-	375	43	169	73	137	229	38	26	1,138
Norfolk	174	8	2,830	61	187	8	505	111	16	267	4,166
Morehead City	5	-	8	2	4	-	2	7	2	87	117
North Carolina to Georgi	55	1	4,805	79	123	8	382	321	24	101	5,897
Southeast	37	-	490	41	406	5	634	103	20	64	1,800
Total	476	21	12,392	271	1,455	114	2,239	1,616	194	826	19,604

a/ Includes recreational vessels.
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.
Source: Nathan Associates Inc.

DIRECT ECONOMIC IMPACT OF DMAS

The Rule specifies that voluntary dynamic management areas would be implemented along the U.S. Exclusive Economic Zone when right whale sightings occur. Triggers for implementing a DMA are based on those specified for the Atlantic Large Whale Take

Reduction Plan (ALWTRP) Dynamic Area Management fishing restrictions.[3] A DMA action would be triggered by a single reliable report from a qualified individual of an aggregation of three or more right whales within 75 square nautical miles (nm^2) (257 km^2), such that right whale density is equal to or greater than 0.04 right whales per nm^2 (3.43 km^2), equivalent to four right whales per 100 nm^2 (343 km^2). Once a DMA is triggered, NMFS would use the following procedures and criteria to establish a DMA:

- A circle with a radius of at least 2.8 nm (5.2 km) would be drawn around the location of each individual sighting. This radius would be adjusted for the number of observed whales, so as to size the DMA to maintain a density of four right whales per 100 nm^2 (343 km^2). Information on how to calculate the length of the radius can be found in the Proposed Rule to amend the regulations that implement the ALWTRP (67 FR 1133). For a group of three whales the DMA would consist of a core area with a radius of 4.8 nm (8.9 km).

- If any circle or group of contiguous circles includes three or more right whales, this core area and its surrounding waters would be a candidate DMA zone.

Once NMFS identifies a core area containing three or more whales, the agency would expand this initial core area to provide a buffer in which the whales could move and still be protected. NMFS will determine the extent to the DMA zones as follows:

- A large circular zone would be drawn extending 15 nm (27.8 km) from the perimeter of a circle around each core area.

- The DMA would be a polygon drawn outside, but tangential to, the circular buffer zone(s), defined by the latitudinal and longitudinal coordinates of its corners.

Hence each DMA consists of the core area with a radius of 4.8 nm (for a group of three whales) plus the buffer with a radius of 15 nm for a total radius of 19.8 nm. The diameter of the DMA is thus 39.6 nm. The DMA zone would automatically expire after 15 days from the day of the original sighting, unless subsequent surveys within the 15-day period demonstrated (a) whales are present in the zone, or (b) the aggregation had persisted, in which case the period would be extended 15 days from the date of any subsequent sightings in the zone.

Impact on Vessel Operations

In all regions, mariners have the option of either routing around the DMA or proceeding through it at a restricted speed. The measures are voluntary and vessel operators are not

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[3] See the January 9, 2002 Federal Register Proposed Rule (as amended by the October 28, 2002 technical amendment to the final rule) for the definition of Procedures and Criteria to Establish a DAM Zone, Criteria to Determine the Extent of the DAM Zone, and Duration of DAM Zones.

currently required to take either measure. For this analysis we have compared the average speeds for each vessel type passing through areas where DMAs were implemented in 2009 with speeds for same types of vessel through those same areas when the DMA was not in effect. The direct impact of a DMA on vessel operations is the increased time required to transit through the DMA when it is in effect.

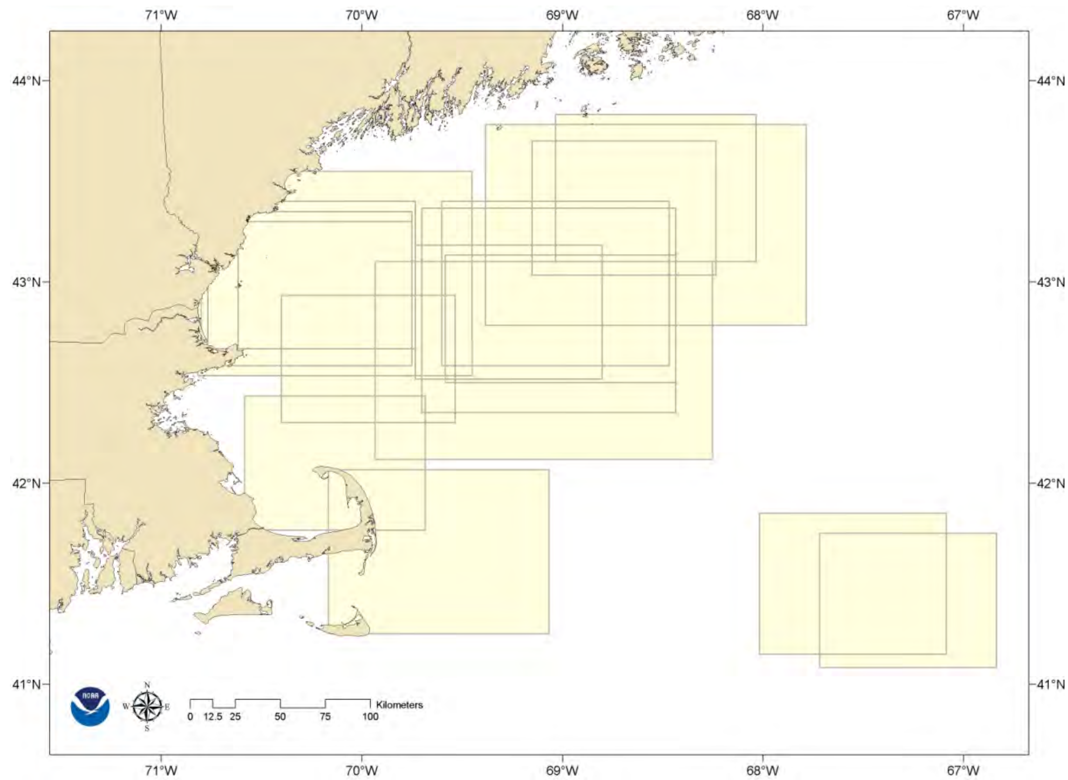
In 2009, there were18 DMAs implemented based on the sightings of right whales. Information on each of these DMAs is presented in Table 2-11 and the locations of the DMAs are shown in Figure 2-1. The average duration of the DMAs in 2009 was 18.6 days. The DMAs range in size from 1448 nm^2 to 4391 nm^2.

Table 2-13. DMAs Implemented in 2009

DMA No.	No. of Whales	Area (nm^2)	Start date	End date	Duration Days
NE_04	28	1997	1/13/2009	2/10/2009	28
NE_05	3	1605	1/16/2009	1/29/2009	13
NE_06	6	1448	2/11/2009	2/25/2009	14
NE_07	5	1456	2/11/2009	2/25/2009	14
NE_08	12	2419	2/11/2009	2/25/2009	14
NE_09	3	1592	3/17/2009	3/28/2009	11
NE_10	5	1764	4/13/2009	4/25/2009	12
NE_11	15	1926	5/12/2009	5/27/2009	15
NE_12	3	1602	5/13/2009	5/27/2009	14
NE_13	44	4391	6/2/2009	6/29/2009	27
NE_14	3	4391	7/9/2009	7/21/2009	12
NE_15	5	1644	9/2/2009	9/16/2009	14
NE_16	26	2124	10/15/2009	11/11/2009	27
NE_17	24	1918	10/22/2009	12/1/2009	40
NE_18	16	2441	10/27/2009	11/10/2009	14
NE_19	41	3661	11/10/2009	12/17/2009	37
NE_20	47	3403	11/10/2009	11/24/2009	14
NE_21	27	4198	12/4/2009	12/19/2009	15

Source: NOAA, Office of Protected Resources, National Marine Fisheries Service.

Figure 2-1. Locations of DMAs in 2009



The average vessel operating speeds by vessel type during periods when DMA were in effect and not in effect in 2009 are presented in Table 2-14. There were 11,924 transits recorded in the DMA areas at times when the DMAS were not in effect and 1,937 transits during the DMAs. The overall weighted average speed during the non-active periods was 8.0 knots whereas an average of 8.5 knots was recorded for the period when DMAs were in effect. Interestingly, only six vessel types had average speeds greater than 10 knots through the DMA areas, and of these only two vessel types, bulk carriers and passenger ships actually recorded a reduction in speed during active DMAs. For bulk carriers the reduction was minor from 10.1 knots to 9.8 knots and for passenger vessels the speed reduction was from 12.0 knots to 9.0 knots.

Table 2-14. Average Vessel Operating Speed through DMAs by Type of Vessel, 2009 (knots)

Vessel type	Number of transits: Not in effect	In effect	Total	Average speed: Not in effect	In effect	Speed reduction
Bulk Carrier	396	97	493	10.10	9.80	0.29
Container Ship	528	91	619	14.90	15.00	
Freight Barge	86	9	95	8.90	9.54	
General Dry Cargo Ship	163	26	189	11.36	11.67	
Industrial Vessel	42	7	49	6.09	9.23	
Passenger Ship	544	72	616	12.00	9.00	3.00
Recreational	120	6	126	6.88	9.77	
Research Vessel	44	14	58	9.88	11.18	
Ro-Ro Cargo Ship	155	19	174	13.52	13.60	
School Ship	62	15	77	5.66	7.31	
Tank Ship	1,697	431	2,128	11.34	11.53	
Towing Vessel	2,075	310	2,385	7.53	7.60	
#N/A	5,995	840	6,835	5.93	6.10	
Total	11,924	1,937	13,861	8.01	8.49	

Source: Nathan Associates Inc.

As previously mentioned, the speed restrictions under DMAs are voluntary. As such, a large segment of the shipping industry did not reduce speeds through active DMAs in 2009. For this reason, there was no or minimal economic impact of DMAs on the shipping industry in 2009.

OTHER DIRECT IMPACTS ON SHIPPING INDUSTRY

Cumulative Effect of Multi-Port Strings for Containerships

Many of the vessels calling at U.S. East Coast ports occur as part of a "string" of port calls by the vessel. For containerships, Ro-Ro cargo ships and some specialty tankers these multi-port calls constitute a scheduled cargo service offered by the shipping lines. Other types of vessels may have multiple U.S. East Coast port calls as part of a coastwise cabotage service, for delivery of specialty chemicals or other products, or to lighten or top off in order to maximize vessel utilization. There are several reasons why the cumulative effect of multiple port calls at restricted ports could impact a vessel more than the sum of the individual direct impacts presented in the prior sections. First, the delays incurred from speed restrictions at one port when combined with speed restrictions at a subsequent port may diminish the ability of the vessel to maintain its schedule and could result in missed tidal windows. Second, even brief delays at arrival at the second port could result in increased costs for scheduled, but unused, port labor. Third, some shipping lines felt that the cumulative impact of three or four port calls at port areas with restrictions could cause them to rework vessel itineraries and could result in dropping of one of the port calls in order to maintain a weekly service without having to add an additional vessel to the service.

However, these cumulative factors will not affect every vessel making multiple port calls at restricted ports. Also the impact may vary from an 8-hour delay due to a missed tidal window to incurring charges for unused labor if a vessel is late arriving at the port.[4] It is realistic to assume that the shipping industry will revise their itineraries to account for the delays imposed by the speed restrictions and that occurrences of missed tidal widows will be rare. From the calculations described in detail in the 2008 FEIS Report, we have used the same average additional delay of 11 minutes for each containership transit that is part of a multi-port string to account for this cumulative impact.[5] The economic value of this additional time has been calculated based on the average 2009 vessel operating and the 2009 vessel operating costs for containerships. The estimated impact for 2009 is $3.1 million.

Re-routing of Southbound Coastwise Shipping

Coastwise shipping or cabotage trade along the U.S. East Coast has always been an important segment of our nation's maritime heritage. In recent years, attention has been focused on the further development of coastwise shipping (also referred to as short-sea shipping) as a means of reducing highway congestion on the Eastern Seaboard. Benefits of coastwise shipping also include lowering transport and environmental costs and reducing our demand for imported fuel. For these reasons, it is important that the speed restrictions not unduly affect the development of increased coastwise shipping.

However, for commercial and navigation purposes, it appears unlikely that the speed restriction would significantly affect coastwise shipping. Northbound vessels prefer to use Gulf Stream further offshore and benefit from the enhanced operating speed and fuel efficiency. Southbound traffic routes closer to the U.S. East Coast; generally within 7-10 nautical miles of the shoreline. However, during the proposed seasonal management periods, masters of southbound vessels would likely route outside of seasonal speed restricted areas incurring an overall increase in distance. This affects southbound vessels between the entrance to the Chesapeake Bay and Port Canaveral.

The speed restrictions in the mid-Atlantic region are implemented for a radius of 20 nautical mile buffer around each port area for port areas north of Wilmington, NC.[6] A continuous 20-mile buffer was implemented from Wilmington, NC through Savannah to the northern boundary of the Southeastern SMA. The additional distance incurred by southbound vessels would be 56 nautical miles. The economic impact for this extra sailing distance is estimated at $1.1 million using 2009 vessel operating costs.

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[4] While tides occur on 12-hour cycle, it is assumed that a tidal window is open for 2 hours before and after high tide. This results in an 8-hour waiting period between tidal windows.

[5] Only a small portion of vessel arrivals should be affected by this additional delay. It is assumed that 7.5 percent of vessels could be affected by as much as an additional 8-hour delay due to missing the tidal window. This results in an average additional delay per vessel of 36 minutes.

[6] The exception is the Block Island Sound speed restriction area that is configured as a rectangle with a width of 30 nautical miles.

TOTAL DIRECT ECONOMIC IMPACT ON SHIPPING INDUSTRY

The total direct economic impact on the shipping industry consists of the various impacts analyzed above. These are the SMAs, DMAs, cumulative effect of multi-port strings and the re-routing of southbound coastwise shipping. The total direct economic impact on the shipping industry in 2009 is estimated at $23.8 million as shown in Table 2-15.

Table 2-15. Direct Economic Impact on Shipping Industry, 2009 ($millions)

Impact	Amount
Seasonal Management Areas (SMAs)	19.6
Dynamic Management Areas(DMAs)	-
Cumulative Effect of multi-port strings	3.1
Re-routing of southbound coastwise shipping	1.1
Total	23.8

Source: Prepared by Nathan Associates as described in text.

Direct Economic Impact Relative to Trade Value and Freight Costs

The U.S. Census Bureau data on U.S. imports of merchandise is compiled primarily from automated data submitted through the U.S. Customs' Automated Commercial System.[7] Data are compiled also from import entry summary forms, warehouse withdrawal forms and Foreign Trade Zone documents as required by law to be filed with the U.S. Customs Service. Information on U.S. exports of merchandise is compiled from copies of Shipper's Export Declarations (SEDs) and data from qualified exporters, forwarders or carriers. Copies of SEDs are required to be filed with Customs officials at the port of export.

For this study, the following data items have been used from the U.S. Census Bureau Foreign Trade Statistics:

- **Customs import value –** the value of imports appraised by the U.S. Customs Services in accordance with the legal requirements of the Tariff Act of 1930, as amended. This value is generally defined as the price actually paid or payable for merchandise when sold for exportation to the U.S. excluding U.S. import duties, freight, insurance and other charges incurred in bringing the merchandise to the U.S.

- **Import charges** – the aggregate cost of all freight, insurance and other charges (excluding U.S. import duties) incurred in bringing the merchandise from alongside the carrier at the port of exportation and placing it alongside the carrier at the first port of entry in the U.S.

- **F.A.S. export value** – the free alongside ship value of exports at the U.S. seaport based on the transaction price, including inland freight, insurance and other

[7] The description and definition of information from the U.S Census Bureau Foreign Trade Statistics is based on the Guide to Foreign Trade Statistics: Description of the Foreign Trade Statistical Program available on the U.S. census Bureau website.

charges incurred in placing the merchandise alongside the carrier at the U.S. port of exportation. The value, as defined, excludes the cost of loading the merchandise aboard the exporting carrier and also excludes freight, insurance and any other charges or transportation costs beyond the port of exportation.

- **Shipping weight** – the gross weight in metric tons including the weight of moisture content, wrappings, crates, boxes and containers.

- **District of exportation** – the customs district in which the merchandise is loaded on the vessel which takes the merchandise out of the country.

- **Import district of unlading**- the district where merchandise is unloaded from the importing vessel.

Table 2-18 presents data collected by the U.S. Census Bureau on volume and value of goods carried by vessels calling at U.S. East Coast ports.

Table 2-16. U.S. East Coast Maritime Trade, 2005-2011 Value ($ millions)

Year	Vessel Import Custom Value	Vessel Export Value	Total
2005	296,478	96,861	393,339
2006	327,804	113,955	441,759
2007	347,337	140,728	488,065
2008	381,869	173,475	555,344
2009	272,445	126,884	399,329
2010	329,035	153,977	483,012
2011	390,148	190,803	580,952

Note: Includes Custom districts 1,4,5,10,11 and 13 through 18

Source: Prepared by Nathan Associates Inc. from U.S. Census Bureau, Foreign Trade Statistics for 2005 to 2011.

To measure the significance of the operational measures on the shipping industry, it is interesting to compare the estimated direct economic impact with ocean freight costs associated with U.S. East Coast trade. Ocean freight costs are considered as a conservative proxy for shipping industry revenues. In 2009, ocean freight charges averaged 4.6 percent of the value of imports. Given the composition of our trade, it is reasonable to assume that ocean freight charges would represent no less than the same percentage of the value of our exports.

Table 2-17 US. East Coast Vessel Import Charges as Percent of Vessel Import Customs Value ($ millions)

Year	Vessel Import Custom Value	Vessel Import Charges	Percent
2005	293,065	14,921	5.1%
2006	324,220	16,509	5.1%
2007	344,068	16,558	4.8%
2008	378,250	17,745	4.7%
2009	269,814	12,418	4.6%
2010	326,126	14,242	4.4%
2011	386,358	15,171	3.9%

Note: Includes Custom districts 4,5,10,11 and 13 through 18. The Customs District of Portland has been excluded due to incongruences between the customs and the CIF value.
Source: Prepared by Nathan Associates Inc. from U.S.

Table 2-18 presents the significance of the estimated economic impact of the operational measures relative to the value of U.S. East Coast trade in 2009. This comparison is useful to determine whether increased shipping costs associated with the proposed operational measures would significantly affect the price and volume of traded goods via U.S. East Coast ports. In 2009, the total annual direct economic impact on the shipping industry is $23.8 million while the value of U.S. East Coast trade is $399.3 billion. Thus the direct economic impact represents six thousandth of one percent of the value of traded merchandise in 2009.

Table 2-18 also shows the direct economic impact on the shipping industry represents less than two-tenths of one percent of the ocean freight costs for U.S. East Coast trade. These results indicate that the implementation of the proposed operational measures had a minimal impact on the financial revenues and hence the financial performance of the vessel operators calling at U.S. East Coast ports.

Table 2-18. Economic Impact as a Percent of Value of U.S. East Coast Maritime Trade and Ocean Freight Costs, 2009

Item	Amount
Direct economic impact ($millions)	23.6
East Coast trade merchandise value ($ millions)	399,329
Direct economic impact as a percent of trade value (%)	0.0059
Ocean freight costs ($ millions)	15,973
Direct economic impact as a percent ofocean freight costs (%)	0.148

Source: Prepared by Nathan Associates as described in text.

Estimated Indirect Economic Impact

Depending on the nature and significance of the direct economic impact, it is possible that implementation of the proposed operational measures could have indirect economic impacts. Potential indirect economic impacts include:

- Increased intermodal costs due to missed rail and truck connections
- Diversion of traffic to other ports
- Impact on local economies of decreased income from jobs lost due to traffic diversions

There are many factors that influence a shipping line's decision to call at specific ports. These include the adequacy and suitability of port facilities and equipment, the ability of the terminal operator to quickly turnaround the vessel, overall cargo demand, efficiency of intermodal transportation, port charges, and the port location relative to other ports and cargo markets. If cargo is to divert to other ports this would be because the total additional costs associated with those routes are less than the cost of vessel time due to delays at the current port. Hence it would be double-counting to also include any additional overland transport costs to the estimated impact already presented.

A good portion of a port's traffic is often considered captive to that port. For cargoes that are destined for the port's immediate hinterland, it does not make economic sense to call at a distant port and then to ship back to the port via expensive land transport. However, most ports also accommodate traffic that is not destined for its immediate hinterland but is through traffic that may have economically attractive routing alternatives. Port areas in the Northeast and northern parts of the mid-Atlantic region serve as gateways to the inland population centers and industrial areas such as western New York, western Pennsylvania, Ohio, Indiana, Illinois and Michigan. These areas may be served via the Canadian ports of Halifax and Montreal without incurring delays caused by the right whale ship strike reduction measures.[8] These Canadian ports currently compete with Northeast U.S. ports for cargo destined for the mid-eastern U.S. and the speed restrictions implemented in the U.S. and not in Canada could shift the current competitive balance to the advantage of Canadian ports.

The Maritime Administration (MARAD), an agency of the U.S. Department of Transportation has developed a Port Economic Impact Kit that allows users to assess the economic impact of port activity on a region's economy. The MARAD Port Economic Impact Kit uses an adaptation of input-output analysis that is a widely established tool for undertaking economic impact assessments. The model calculates the total economic impacts or multiplier effect of

[8] Vessels may divert to other U.S. ports in addition to those diverting to Canada. While this is possible, for the total economic impact analysis only diversions to non-U.S. ports are included. For diversion to ports within the U.S. the negative economic impact for one U.S. port are offset by gains in another U.S. port.

deep-draft port industry and includes an indirect effect that reflects expenditures made by the supplying firms to meet the requirements of the deep-draft port industry as well as expenditures by firms stocking the supplying firms. The model also includes an induced effect that corresponds to the change in consumer spending that is generated by changes in labor income accruing to the workers in the deep-draft port industry as well as employment in the supplying businesses.

We have estimated the indirect economic of port diversions based on the detailed methodology described in the 2008 FEIS adjusted for the actual observed delays incurred in 2009 from the AIS data analysis and using the updated vessel operating costs for 2009. The estimated indirect economic impact of port diversion for 2009 is $15.8million.

3. Economic Impact of Rule on Other Market Segments

The AIS data captures the vast preponderance of commercial maritime activity that would be subject to the speed restrictions and other operational measures. However, there are some market segments that may be impacted by the speed restrictions and other operational measures whose maritime activities are not adequately captured in the AISA data. In this section, we identify the most relevant of these market segments and discuss the potential economic impact. Those market segments or potential impacts include:

- Commercial fishing
- Charter fishing
- Passenger ferries
- Whale watching

The economic impact for each of these elements is presented below.

Commercial Fishing

Commercial fishing is a multimillion dollar industry along the U.S. East Coast. In 2011, commercial fish landings at U.S. East Coast ports totaled $934 million (Table 3-1). The port of New Bedford, MA is the leading U.S. port in terms of value of commercial fish landings with $369.0 million in 2011.

Table 3-1. U.S. East Coast Commercial Fishery Landings by Port, 2002 through 2011 (millions of dollars)

Port	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
New Bedford, MA	168.6	176.2	207.7	282.5	281.4	268.0	241.3	249.2	306.0	369.0
Cape May-Wildwood, NJ	35.3	42.8	60.2	68.4	37.6	58.8	73.7	73.4	81.0	103.0
Hampton Roads Area, VA	69.5	79.6	100.8	85.2	51.0	70.2	12.3	68.1	75.0	88.0
Gloucetser, MA	41.2	37.8	42.8	45.9	47.3	46.8	54.2	50.4	57.0	59.0
Stonington, ME	21.7	20.5	22.4	32.3	34.3	23.5	15.4	26.5	45.0	48.0
Point Judith, RI	31.3	32.4	36.0	38.3	46.8	36.7	36.9	32.4	32.0	40.0
Point Pleasnat, NJ	19.7	22.8	19.2	21.6	22.6	23.1	22.1	20.2	23.0	37.0
Reedville, VA	24.2	24.2	26.1	27.1	23.7	27.3	23.9	25.9	34.0	36.0
Long Beach-Barnegat, NJ	14.6	16.4	20.6	26.7	24.5	23.1	22.9	21.7	26.0	34.0
Portland,ME	40.4	28.7	34.6	34.6	27.8	24.1	22.6	16.6	19.0	28.0
Provincetown-Chatham, MA	15.2	13.5	14.2	19.8	20.6	18.3	18.3	20.0	20.0	27.0
Rockland, ME	4.3	4.1	2.7	7.4	n.a.	n.a.	n.a.	n.a.	11.0	24.0
Wanchese-Stumpy Point, NC	23.2	21.0	20.6	19.6	21.7	20.6	22.4	23.1	22.0	22.0
Montauk, NY	11.1	11.0	13.1	16.5	16.8	15.7	14.3	14.6	18.0	19.0
Newport, RI	n.a.	n.a.	n.a.	n.a.	20.8	12.4	n.a.	n.a.	n.a.	n.a.
Boston, MA	8.6	8.9	8.8	10.6	n.a.	n.a.	n.a.	11.9	15.1	n.a.
Beaufort- Morehead City, NC	19.1	15.0	16.9	9.7	n.a.	n.a.	11.1	23.1	n.a.	n.a.
Atlantic City, NJ	22.4	20.8	17.7	18.5	24.2	27.5	24.1	22.2	17.3	n.a.
Other	76.2	74.9	55.2	51.1	-	-	-	-	-	-
Total	646.6	650.6	719.6	815.8	701.1	696.1	615.5	699.3	801.4	934.0
Source: NOAA Fisheries.										

The right whale ship strike reduction operational measures apply to vessels with a length of 65 feet and above. Because the AIS data lacks adequate records on commercial fishing vessels[9], we also evaluated data which included fishing vessels which are over 65 feet in length and weigh less than 150 tons, using information provided by NMFS' database of commercial fishing permits.

Table 3-2 shows that for the Southeast region nearly 80 percent of the fishing vessels over 65 feet are less than 150 tons. For the Northeast region, 63 percent of the fishing vessels over 65 feet are less than 150 tons.

[9] Commercial fishing vessels greater than 65 are required to have AIS transponders. However, the data set we received only included 147 transits of fishing vessels on the entire US East Coast during 2009 which was felt to be too small to be accurate.

Table 3-2. Fishing Vessel Permits Issued to Vessels 65 Feet and Above in LOA by Region, 2009-2011

		2009		2010		2011	
Region	Vessel size	Fishing permits	%	Fishing permits	%	Fishing permits	%
Southeast Region	All vessels	279	100%	260	100%	247	100%
	Vessels less than 150 GRT	220	79%	204	78%	195	79%
Northeast Region	All vessels	807	100%	773	100%	722	100%
	Vessels less than 150 GRT	523	65%	496	64%	453	63%

Source: Prepared by Nathan Associates Inc. from data provided by NOAA Fisheries Service, Southeast Regional Office (SERO) and Northeast Regional Office (NERO).

The estimated economic impact of the operational measures on commercial fishing vessels in 2003 is presented in Table 3-3. The analysis assumes that the commercial fishing vessels are affected for an effective distance of 20 nautical miles each way as they steam to and from fishing areas.

Many commercial fishing vessels steam at 10 knots or below and will not be affected by the operational measures if they were implemented at the 10-knot speed restriction. The typical steaming speed for other commercial fishing vessels is assumed at 12 knots. Average operating costs per hour of $400 includes fuel costs of June 2009. The duration of the speed restrictions vary from 181 days per year for the mid-Atlantic to 61 days per year for the Northeastern US. For purposes of the economic analysis, we have assumed that the speed restrictions were in effect for 181 days for commercial fishing..

Table 3-3. Estimated Economic Impact on Commercial Fishing Vessels by Region, 2009

Item	Northeast Region	Southeast Region	Total
Commercial fishing permits for vessels over 65 ft LOA and under 150	523	220	743
Percent with steaming speed over 10 knots	40%	40%	40%
Vessels potentially affected by speed restrictions	209	88	297
Typical steaming speed of affected vessels (knots)	12	12	12
Number of trips per year per vessel	25	25	25
Minutes of delay per trip with restricted speed of 10 knots	38.0	38.0	38.0
Operating cost per hour of steaming (dollars)	400	400	400
Estimated impact per year (dollars)	657,022	276,376	933,398

Source: Prepared by Nathan Associates Inc.

The estimated impact in 2009 on commercial fishing vessels is estimated at $0.7 million for the Northeast Region and $0.3 million for the Southeast Region. The combined Northeast and Southeast regional economic impact of $0.9 million is only one-tenth of one percent of the value of U.S. East Coast commercial fishery landings of $699 million in 2009.

These results indicate that the implementation of the operational measures will not have an undue adverse impact on the commercial fishing industry along the U.S. East Coast.

Charter Fishing

In some areas, charter vessels travel up to 50 nautical miles offshore to reach prime fishing areas. At vessel speeds of up to 17 knots they can reach their fishing areas in less than 3 hours. Under the Rule, speed restrictions of 10 knots for 20 nautical miles add about 100 minutes to the roundtrip steaming time, and could severely affect client demand.

The charter fishing industry is active along the U.S. East Coast with concentration in the Carolinas, Virginia, Florida, New Jersey and Massachusetts. The industry consists of half-day charters of about 6 hours that typically go up to 20 nautical miles offshore; full-day charters of 11-12 hours that can go up to 40 nautical miles offshore; and extended full day charters that can be from 18-24 hours and go up to 50 miles offshore. The vast majority of the charter fishing industry consists of modern and well-equipped fishing boats of less than 65 feet LOA and thus would not be subject to the speed restrictions and other operational measures.

A small segment of the industry referred to as head boats often uses vessels of 80 feet LOA and above that can accommodate 60 to 100 passengers. These vessels go up to 50 miles offshore stop and anchor over wreck and rock formations for fishing species as red snapper, grouper, trigger fish, amberjack. The charter fee for a head boat is typically $50- $80 per person.

As described above an increase of 100 minutes roundtrip steaming time would reduce the competitiveness of the larger head boats (more than 65 foot LOA) particularly for the half-day and full-day charters. It is likely that vessels of less than 65 foot LOA would increase their share of those market segments, partially offsetting the economic impact incurred by the larger head boats. For extended full-day charters, head boats of LOA in excess of 65 feet would incur additional costs associated with the 100 minutes increase in roundtrip steaming time. It is estimated that annual economic impact of the speed restriction of 10 knots for these vessels over 20 nautical miles is approximately $1.0 million.[10]

Passenger Ferries

The vast majority of passenger vessels operating along the U.S. East Coast sail within the COLREGS line and as such will not be affected by the Rule. However, in the southern New England area, there is a well-developed passenger ferry sector that operates beyond the COLREGS line and hence is subject to the Rule's operational measures. A list of major New

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[10] This calculation assumes 50 head boat vessels with 30 roundtrips during the off-season months of November through April and an hourly steaming operating cost of $400. These calculations do not include any offsetting impact of revenue gains by operators of smaller charter fishing vessels.

England passenger ferry operators, routes served and service characteristics are presented in Table 3-4.

Table 3-4. New England Ferry Operators, 2011

Operator	Route	Max Vessel Speed (knots)	Distance (nm)	Summer Schedule	Non-summer schedule	Travel Time (minutes)	Summer Season Adult Fare ($) Round trip
SOUTHERN NEW ENGLAND							
Fast Ferries							
Bay State Cruise Company	Boston, MA-Provincetown, MA	30	50	6 trips daily	none	90	85
Boston Harbor Cruises	Boston, MA-Provincetown, MA	40	50	4 trips daily	none	90	83
Boston Harbor Cruises	Boston, MA-Salem, MA	33	25	8 trips daily	none	60	27
Cross Sound Ferry Sevices	New London, CT-Orient Point LI, NY	30	16	12 trips daily	All year long	45	34.25
Block Island Express	New London, CT-Block Island, RI	35	30	6 - 8 daily trips	none	75	45
Freedom Cruise Line	Harwich, MA-Nantucket, MA	24	30	6 trips daily	Spring, Fall	80	74
Hy-Line Cruises	Hyannis, MA- Nantucket, MA	30	27	12 trips daily	10 trips daily	60	77
Hy-Line Cruises	Hyannis, MA-Martha's Vineyard, MA	24	20	10 trips daily	4-6 trips daily	55	71
Block Island Ferry	Point Judith, RI-Block Island, RI	30	11	12 trips daily	Spring, Fall 8-10 trips daily	30	36
Seastreak	New Bedford, MA- Martha's Vineyard, MA	30	30	12 trips daily	Spring, Fall 4-10 trips daily	60	68
Seastreak	New York City, NY- Martha's Vineyard, MA	42	150	2 trips per weekend	Holidays	315	155
The Steamship Authority	Hyannis, MA- Nantucket, MA	35	26	10 trips daily	8 trips daily	60	67
Vineyard Fast Ferry	Quonset Point, RI-Martha's Vineyard, MA	33	50	6 trips daily	Srping, fall 4 daily trips	95	79
Regular Ferries							
Bay State Cruise Company	Boston, MA-Provincetown, MA	16	50	2 trips Sat and Sun	none	180	46
Express Ferry	Plymouth, MA-Provincetown, MA	16	25	2 trips daily	none	100	43
Cross Sound Ferry Service	New London, CT-Orient Point LI, NY	15	16	30 trips daily	All year long	80	27
Hy-Line Cruises	Hyannis, MA- Nantucket, MA	15	26	6 trips daily	1-2 trips daily	110	45
Hy-Line Cruises	Hyannis, MA-Martha's Vineyard (Oak Bluffs), MA	12	20	2 trips daily	2 trips daily	100	45
Hy-Line Cruises	Nantucket, MA-Martha's Vineyard (Oak Bluffs), MA	16	20	2 trips daily	2 trips daily	70	70
Block Island Ferry	Point Judith, RI-Block Island, RI	16.5	11	18 trips daily	All year long	55	19
Block Island Ferry	Point Judith, RI- Newport, RI	13	10	2 trips daily	none	60	13
Block Island Ferry	Newport, RI-Block Island, RI	13	22	2 trips daily	none	120	17
Patriot Party Boats	Falmouth, MA- Martha's Vineyard (Oak Bluffs), MA	15	5	16 trips daily	All year long	20	20
Falmouth Ferry	Falmouth, MA-Martha's Vineyard (Edgadtown), M	12	9	8 trips daily	Spring 6 daily trips each weekend	60	50
Island Queen	Falmouth, MA-Martha's Vineyard (Oak Bluffs), MA	12	5	14 trips daily	Spring, Fall 4-10 daily trips	35	20
The Steamship Authority	Woods Hole-Martha's Vineyard	16	7	32 trips daily	28 trips daily	35-45	16
The Steamship Authority	Hyannis, MA- Nantucket, MA	14	26	12 trips daily	6 trips daily	135	33
MAINE							
Casco Bay Lines	Portland, ME - Peaks Island, ME	12.5	3	14 trips daily	All year long	20	8
Casco Bay Lines	Portland, ME - Little Diamond Island, ME	12.5	3	18 trips daily	All year long	20	8
Casco Bay Lines	Portland, ME - Great Diamond Island, ME	12.5	4	18 trips daily	All year long	25	9
Casco Bay Lines	Portland, ME - Diamond Cove, ME	12.5	5	22 trips daily	All year long	30	10
Casco Bay Lines	Portland, ME - Long Island, ME	12.5	6	24 trips daily	All year long	35	10
Casco Bay Lines	Portland, ME - Chebeague Island, ME	12.5	12	12 trips daily	All year long	70	11
Casco Bay Lines	Portland, ME - Cliff Island, ME	12.5	10	10 trips daily	All year long	60	12
Casco Bay Lines	Portland, ME - Bailey Island, ME	12.5	20	2 trips daily	none	105	25

Source: Prepared By Nathan Associates Inc. from data on operator websites and selected interviews.

Passenger ferry operations in southern New England generally fall into two categories - fast ferry service with vessel speeds ranging from 24-39 knots and regular ferry service with vessel speeds from 12-16 knots. As shown in Table 3-4 there are ten operators providing fast ferry service on 12 routes. Key destinations include Provincetown, Block Island, Nantucket, and Martha's Vineyard, while important origins include Boston, New London, Hyannis, Harwich, Point Judith and Quonset Point.

Regular ferry service in southern New England is provided by nine operators on eleven routes. Vessel speeds range from 12-16 knots and serve many of the same origins and destinations as the fast ferry service. Additional origins served by regular ferries include Plymouth, Falmouth and Woods Hole.

Regular ferry service also operates in Southern Maine with 120 trips daily to eight destinations served by Casco Bay Lines from Portland. Service is provided to local islands including Peaks Island, Great Diamond Island, Cliff Island and Bailey Island.

IMPACT ON FERRY OPERATORS

Passenger ferry service generally is not impacted by the SMAs as they are not effective during the summer season. Speed restrictions for Cape Cod Bay are implemented from January 1 through May 15. Speed restrictions for Block Island Sound are from November 1 through April 30. In addition, the speed restricted area for Block Island Sound does not extend to the shoreline and hence does not impact fast ferry operations.[11]

However, voluntary DMAs established during the summer season could have an impact, especially if they became mandatory. Interviews with passenger ferry operators identified their particular concern of the situation where a DMA were to be implemented during the peak summer season. For a fast ferry operator, a DMA implemented directly along their route would result in the suspension of service for the entire period that the DMA is in effect[12]. There are several reasons for this conclusion. First, the demand for fast ferries that normally operate between 24-39 knots would virtually disappear if the ferries were restricted to a speed of 10 knots. Second, any remaining demand would not be sufficient to cover vessel operating costs, and third, many of the handling and comfort characteristics of fast ferries would suffer at these reduced speeds.

As reported in earlier in Table 2-11, there were 18 DMAs established in 2009. Figure 3-1 below shows the seven DMAs in 2009 that are in locations relevant for ferry operations. However

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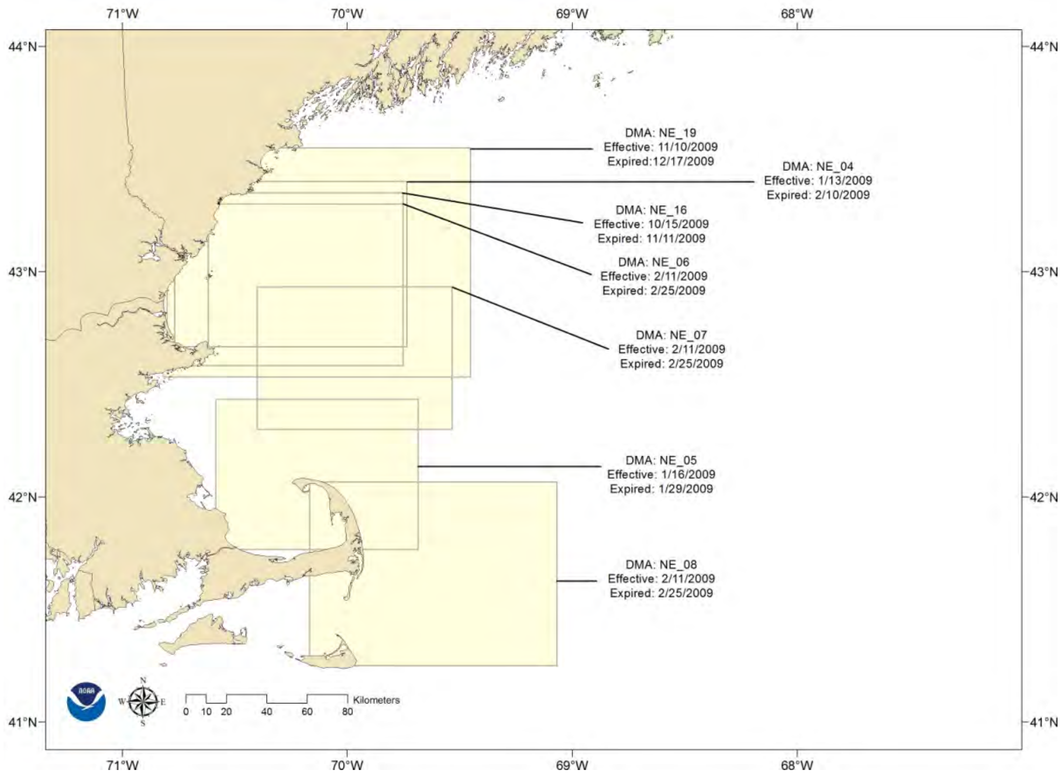
[11] The rectangular area proposed has its northern limits running approximately in a line from Montauk to the southwestern coast of Block Island.

[12] If a DMA were to be implemented say over a 15-day summer period, the two fast ferry operators on the Boston-Provincetown route would lose net revenues of over $500,000, nearly 10 percent of their annual sales and wipe out their annual profit. Multiple DMAs in one year or in consecutive years could force the shutdown of these services.

each of these DMAs occurred in the winter months and did not affect ferry operations. Hence, in 2009 there was no or minimal economic impact of DMAs on fast ferry operators.

Figure 3-1 DMAs in Areas Relevant for Passenger Ferry Operators



New England Whale Watching Industry

The New England whale watching industry also can be categorized into operations that deploy high-speed vessels with speeds ranging from 25-38 knots; and operations that deploy regular speed vessels with speeds from 16-20 knots. Table 3-5 presents information for the major whale watching operators in Massachusetts Bay. There are nine operators of high-speed vessels; three are based in Gloucester, three in Boston, one in Barnstable, one in Bar Harbor and one in Boothbay Harbor. These operators make 18 daily trips during the summer months. There are fifteen operators of regular speed vessels that have operations based in Massachusetts (eight operators), New Hampshire (four), Maine (two) and Rhode Island (one). Altogether these operators make 21 daily whale watching trips during the summer months.

Table 3-5. Massachusetts Bay Whale Watching Operators, 2012

Operator	Location	# Daily Trips (per Vessel)	Trip Duration (hr)	Adult Fare per Trip ($)	Max Vessel Speed (knots)	Number of Vessels
Regular-Speed Vessel						
Yankee Fleet	Gloucester, MA	1	4	n.a.	20	2
Coastal Fishing Charters	Gloucester, MA	1	4-5	100	20	1
Newburyport Whale Watch	Newburtyport, MA	2	4 - 4 1/2	48	20	1
Captian John Whale Watching and Fishing Tours	Plymouth, MA	4	3 1/2-4 1/2	45	17	4
Provincetown Whale Watches	Provincetown, MA	1	n.a.	37	20	1
The Dolphin Fleet of Provincetown	Provincetown, MA	8	3-4	44	16	4
Shearwater Excursions	Nantucket Island, MA	1	6	115	20	1
Al Gauron Whale Watching	Hapton Beach, NH	1	5	36	20	3
Atlantic Whale Watch	Rye Harbor, NH	1	4 - 4 1/2	36	20	1
Eastman's Docks	Seabrook Beach, NH	1	4 1/2	33	20	4
First Chance WhaleWatch	Kennebunk, ME	1	4 1/2	48	18	1
Odyssey Whale Watch	Portland, ME	2	4	48	20	1
Capt. Bill & Sons Whale Watch	Gloucester, MA	2	3 1/2	48	20	1
Granite State Whale Watch	Rye Harbor, NH	2	4-5	36	18	1
Frances Fleet Whale Watching	Narragansett, RI	1	4 1/2	n.a.	18	2
Subtotal		21				28
High-Speed Vessels						
Capt'n Fish's Whale Watch	Boothbay Harbor, ME	2	3-3 1/2	48	33	3
Boston Best Cruises	Boston, MA	2	4	45	33	2
Bar Harbor Whale Watch Company	Bar Harbor, ME	3	3-3 1/2	59-56	33	3
New England Aquarium Whale Watch	Boston, MA	1	3-4	45	30	1
Boston Harbor Cruises	Boston, MA	4	3	45	35	2
7 Seas Whale Watch	Gloucester, MA	2	3 1/2-4	48	35	1
Cape Ann Whale Watch	Gloucester, MA	2	3-4	48	25	1
Yankee Fleet	Gloucester, MA	1	4	n.a.	33	1
Hyannis Whale Watcher Cruises	Barnstable, MA	1	3 1/2-4	47	38	1
Subtotal		18				15

Source: Prepared by Nathan Associates from data on operator websites and selected interviews.

Speed restrictions for Cape Cod Bay are implemented from January 1 through May 15. Hence, the peak summer whale watching season are not affected for high-speed or regular speed vessels. Similarly, the speed restrictions for an extended Off Race Point from March through April would not impact the whale watching season.

As shown earlier in Figure 3-1, there were no DMAs implemented in 2009 that were during periods that affected whale watching operations. Further, if a DMA were to be established, a whale watching operator will select an alternative location where humpback whales are present and not right whales. The whale watching community has developed an informal communications network to advise them of whale sightings. As State and Federal regulations restrict any vessel from approaching closer than 500 yards to a right whale, they would avoid right whale as a matter of course.

4. Total Direct and Indirect Economic Impact

In the sections above we have presented the analysis of individual components of the economic impact analysis of the Rule in 2009. The total direct and indirect economic impact of is $44.7 million in 2009 (Table 4-1). This cosists of $23.8 million of direct impact on the shipping industry, 1.9 million on commercial fishing and charter fishing combined, and $19.0 million of indirect impacts.

Table 4-1 Total Direct and Indirect Economic Impact, 2009 ($ millions)

Impact	Amount
Direct iimpact on shipping industry	
Seasonal Management Areas (SMAs)	19.6
Dynamic Management Areas(DMAs)	-
Cumulative Effect of multi-port strings	3.1
Re-routing of southbound coastwise shipping	1.1
Subtotal	23.8
Direct impact on other other market segments	
Commercial fishing	1.0
Charter fishing	0.9
Passenger ferries	-
Whale watching	-
Subtotal	1.9
Indirect impact	19.0
Total impact	44.7

Source: Prepared by Nathan Associates as described in text.

5.Impact on Small Business

Size Standards for Small Entities

According to the U.S. Small Business Administration[13], a small business is a concern that is organized for profit, with a place of business in the United States, and which operates primarily within the United States or makes a significant contribution to the U.S. economy through payment of taxes or use of American products, materials or labor. Further, the concern cannot be dominant in its field, on a national basis. Finally, the concern must meet the numerical small business size standard for its industry. SBA has established a size standard for most industries in the U.S. economy.

Size standards for the industries potentially affected by the final rule are presented in Table 5-1. For international and domestic commercial shipping operators, the SBA size standard for a small business is 500 employees or less. The same threshold applies for international cruise operators and domestic ferry service operators. For whale watching operators and charter fishing operators the SBA threshold is $7.0 million of average annual receipts. For commercial fishing operators, the SBA threshold is $4.0 million of average annual receipts.

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[13] United States Small Business Administration, Frequently Asked Questions About Small Business Size Standards, www.sba.gov/size/indexfaqs.html

Table 5-1. Small Business Size Standards and Firms by Employment Size and NAICS Code, 2008

Type of entity	NAICS Code	NAICS U.S. Industry Title	Size Standard ($ millions)	Size Standard Employees	Firms Employment size Total	< 20	< 500	500+
International commercial shipping operator	483111	Deep Sea Freight Transportation	n.a.	500	230	120	96	14
International cruise operator	483112	Deep Sea Passenger Transportation	n.a.	500	64	29	30	6
Domestic commercial shipping operator	483113	Coastal and Great Lakes Freight Transportation	n.a.	500	379	207	136	36
Domestic ferry service operator	483114	Coastal and Great Lakes Passenger Transportation	n.a.	500	155	103	48	4
Whale watching operators	487210	Scenic & sightseeing transportation, water	7	n.a.	1,704	1,540	152	12
Charter fishing operators	487210	Scenic & sightseeing transportation, water	7	n.a.	1,704	1,540	152	12
Commerical fishing	114111	Finfish Fishing	4	n.a.	1,060	1,017	41	2
	114112	Shellfish Fishing	4	n.a.	877	858	19	-
	114119	Other Marine Fishing	4	n.a.	34	31	3	-

Source: U.S. Small Business Administration,Table of Small Business Size Standards matched to North American Industry Classification System Codes, October 24, 2012 and SBA Office of Advocacy, Firm Size Data provided by U.S. Census Bureau on Employer Firms and Employment by Employment Size of Firm by NAICS Codes, 2008.

Table 5-1 also presents information on the total number of firms in the U.S. in 2008 by employment size ranges for these industries. The preponderance of firms involved in these industries is considered as small entities by the SBA size standards. In 2008, there were 230 firms involved in deep sea freight transportation industry of which 216 firms had 500 employees or less. In the deep sea passenger transport industry, 58 firms of the total 64 firms had 500 or fewer employees. In the Coastal and Great Lakes freight transportation industry, 343 firms of the total 379 firms had 500 or fewer employees. In the Coastal and Great Lakes passenger transportation industry, all but four firms of the 155 total firms had 500 or fewer employees.

There were 1,704 firms providing scenic and sightseeing water transportation in 2008 of which 1,692 firms had 500 or fewer employees. For the finfish fishing industry 1,058 firms of the total 1,060 firms had 500 or fewer employees; while all 877 firms involved in shellfish fishing had 500 or fewer employees.

Number of Small Entities Affected

For the FEIS Report of 2008, Nathan Associates conducted a detail analysis to determine the number of small entities involved in commercial shipping along the U.S. East Coast. Many of the firms operating within the international commercial shipping industry and international cruise industry have foreign ownership and have their primary place of business outside the U.S. and hence would not qualify as a U.S. small entity.

To identify vessel owned by U.S. entities, we analyzed information provided by the U.S. Coast Guard regarding parties owning vessels that had arrivals at the U.S. East Coast in 2004.

We were able to identify the vessel owner and/or managing owner for 99.6 percent of the vessels that had U.S. East Coast vessel arrivals in 2004.[14] The USCG data provides information on the address of the vessel owner and/or managing owner in terms of zip code, state and country. Using that information we identified vessels with U.S. East Coast arrivals in 2004 that were owned by U.S. entities or foreign entities.

Of the 27,385 U.S. East Coast vessel arrivals in 2004, 6,540 arrivals or 23.9 percent were recorded by vessels owned by parties with U.S. address (Table 5-2). The U.S. East Coast arrivals were made by 4,114 vessels of which 620 or 15.1 percent were by vessels owned by parties with a U.S. address. In terms of number of parties, the 2004 vessel arrivals were made by 3,505 parties of which 432 or 12.3 percent had a U.S. address.

Table 5-2. U.S. East Coast Vessel Arrivals by Vessels with U.S. or Foreign Parties, 2004

	Party address		
Item	U.S	Foreign	Total
Number of vessel arrivals	6,540	20,845	27,385
Percent	23.9%	76.1%	100.0%
Number of vessels	620	3,494	4,114
Percent	15.1%	84.9%	100.0%
Number of parties	432	3,073	3,505
Percent	12.3%	87.7%	100.0%

Source: Prepared by Nathan Associates Inc. from analysis of U.S. Coast Guard as described in text.

We then conducted an analysis of the entire U.S. Coast Guard vessel characteristics database to identify the number and type of vessels owned by the U.S. parties with U.S. East Coast arrivals in 2004.[15] Approximately 71 percent of the U.S.-based parties owned only one vessel and 90.7 percent owned 4 or less vessels (Table 5-3).

[14] We were not able to match party information for 198 vessels of the 4,114 vessels that had U.S. East Coast arrivals in 2004. These vessels accounted for 3.8 percent of 2004 U.S. East Coast arrivals (1,004 of the 27,385 arrivals). However using information on U.S. or foreign flag of registry, we assigned these vessels by country of ownership.

[15] For this analysis, we included all vessels owned by the party, not just those with vessel arrivals at U.S. East Coast ports in 2004.

Table 5-3. U.S-Based Parties with U.S. East Coast Arrivals by Number of Vessels Owned, 2004

Number of Vessels Owned	Number of Parties	Percentage of Parties	Number of Vessels	Percentage of Vessels
1	306	70.8	306	30.6
2	49	11.3	98	9.8
3	24	5.6	72	7.2
4	13	3.0	52	5.2
5	6	1.4	30	3.0
6	7	1.6	42	4.2
7	6	1.4	42	4.2
8	3	0.7	24	2.4
9	4	0.9	36	3.6
10	1	0.2	10	1.0
11	3	0.7	33	3.3
12	1	0.2	12	1.2
15	1	0.2	15	1.5
16	1	0.2	16	1.6
17	2	0.5	34	3.4
20	1	0.2	20	2.0
24	1	0.2	24	2.4
35	1	0.2	35	3.5
38	1	0.2	38	3.8
61	1	0.2	61	6.1
Total:	432	100	1,000	100

Source: Prepared by Nathan Associates inc. from U.S. Coast Guard data as described in text.

The next step was to determine which of these U.S. based parties should be considered a small-business for the RFA analysis. Information on the number of employees is not readily available for U.S.-based parties that own vessels with arrivals at the U.S. East Coast. However, we reviewed the list of U.S-based parties and removed the 53 parties that obviously do not qualify as a small business such as Carnival Cruise Lines, Chevron, Maersk, Holland America Line, BP Oil Shipping, etc. A further classification was made to exclude an additional 17 parties that own 5 or more vessels from the set of small businesses on the assumption that a business with 5 or more capital intensive commercial cargo vessels would employ at least 500 employees throughout its organization. We assume that the remaining set of 362 US-based parties that own vessels that had U.S. East Coast arrivals in 2004 be assumed to be small businesses for the purposes of the RFA analysis. Table 5-4 presents information on vessels and vessel arrivals for this set of vessels assumed to be operated by U.S.-based small entities.

Table 5-4. U.S. East Coast Vessel Arrivals by U.S.-Based Small Entities, 2004

Vessel Type	Number of 2004 Vessel Arrivals	Number of vessels	Number of parties
Bulk Carrier	142	25	24
Container Ship	502	30	28
Freight Barge	77	13	12
General Dry Cargo Ship	99	24	22
Multiple	435	49	31
Passenger Ship	463	33	31
Refrigerated Cargo Ship	51	6	6
Ro-Ro Cargo Ship	433	25	22
Tank Barge	702	61	51
Tank Ship	784	83	79
Towing Vessel	209	44	43
Other a/	65	14	13
Total:	3,962	407	362

a/ Other includes fishing vessels, industrial vessels, and research vessels.
Source: Prepared by Nathan Associates Inc. from U.S. Coast Guard data as described in text.

The 362 parties assumed to be small businesses operated 407 vessels that had 3,962 vessel arrivals at U.S. East Coast ports in 2004. Tank ships and tank barges are the vessel types with the most parties, vessels and vessel arrivals for the set of vessels assumed to be owned by U.S. based small businesses.

Other Industries

In Chapter 3, we presented information on entities involved in other maritime industries that would potentially be affected by the operational measures of the final rule. For purposes of this RFA analysis we have assumed that all U.S. East Coast entities involved in commercial fishing industry, domestic ferry service industry, and charting fishing industry are considered as small entities. In the whale watching industry all entities (except the New England Aquarium) are considered as small entities.

Thus as shown in Table 5-5, we estimate that there are 373 small entities potentially affected Rule. Of these, 209 entities are involved in commercial fishing in the Northeast Region and 88 entities in the Southeast region. There are 14 entities identified involved in Southern New England passenger ferry service[16], 8 entities providing whale watching services in Massachusetts Bay and 40 entities providing charter fishing service along the U.S. East Coast. Note that only the subset of charter fishing entities operating larger head boats that accommodate 60 to 100 passengers is included in this analysis. The majority of charter fishing

[16] In Table 3-4, ten entities are listed as operating fast ferries in Southern New England and eight entities that operate regular ferries. However, four of the entities operate both fast ferries and regular ferries and hence, there are only 14 entities involved in Southern New England passenger ferry service.

entities operates fishing boats of less than 65 LOA and thus are not subject to the operational measures of the Rule.

Table 5-5. Number of Small Entities in Other Industries Potentially Affected, 2009

Industry	Number of Small Entities Potentially Affected
Commercial Fishing	
Northeast Region	209
Southeast Region	88
Southern New England Passenger Ferries	14
Massachusetts Bay Whale Watching	22
Charter Fishing	40
Total	373

Source: Prepared by Nathan Associates Inc. as described in Section 3, and presented in Table 3-2, Table 3-4 and Table 3-7.

Economic Impact on Small Entities

In this section, we first present the economic impact on the small entities involved in the commercial shipping industry[17] followed the estimated impact on small entities in other maritime industries.

COMMERCIAL SHIPPING

All of the operational measures of the final rule described in Section 3 are assumed to apply to commercial shipping vessel operated by small entities. Table 5-6 presents the number of vessel arrivals by U.S. small entities in 2004 and total vessel arrivals by all U.S. entities. Those figures are used to calculate the percent of U.S. vessel in 2004 that were made by small entities. The resulting percentages are then applied to the current analysis of the 2009 economic impact on all U.S.- flagged vessels to determine the economic impact on U.S. small entities[18].

The economic impact of the Rule on U.S. small entities in the commercial shipping industry is estimated at $2.2 million in 2009. This estimate includes the direct economic impact of speed restrictions during seasonal management periods and dynamic management periods plus the cumulative effect of multi-port strings and the re-routing of southbound coastwise shipping. Containerships ($0.8 million) ro-ro cargo ships ($0.4 million) and passenger ships ($0.3 million) together account for 68 percent of the economic impact on small entities in the commercial shipping industry.

[17] Passenger cruise vessels are included in this section as the data sources, approach and methodology applied for this market segment is same as those of the commercial shipping industry.
[18] The 2004 data and relationships were used because there wass no information on the transits in 2009 by U.S. small entities within the shipping industry.

Table 5-6. Economic Impact on U.S. Small Entities by Vessel Type, 2009

	2004 Vessel Arrivals			2009 Economic Impact		
Vessel type	Arrivals by U.S. Small Entities	Arrivals by All U.S. Entities	Percent by US Small Entities	On all U.S. Entities ($000s)	On U.S. Small Entities ($000s)	As a % of Annual Revenues
Bulk Carrier	142	150	94.7	99.1	93.8	0.044%
Container Ship	502	874	57.4	1,449.6	832.6	0.106%
Freight Barge	77	270	28.5	398.4	113.6	0.307%
General Dry Cargo Ship	99	124	79.8	18.1	14.5	0.008%
Passenger Ship	272	310	87.7	319.7	280.6	0.037%
Refrigerated Cargo Ship	51	51	100.0	-	-	0.000%
Ro-Ro Cargo Ship	433	450	96.2	404.3	389.0	0.063%
Tank Barge	702	1,474	47.6	199.2	94.9	0.010%
Tanker	731	784	93.2	220.5	205.6	0.021%
Towing Vessel	209	691	30.2	194.2	58.8	0.012%
Other a/	65	65	100.0	199.2	199.2	0.267%
Total	3,283	5,243	62.6	3,502.4	2,193.1	0.042%

a/ Other includes fishing vessels, industrial vessels, research vessels, school ships. -

Note: Annual revenue estimated as average of daily operating cost at sea and daily operating cost in port by vesel type and size for 365 days for vessels accounting for 2009 SMA transits.

Daily operating cost in port was assumed at 60 percent of daily operating cost at sea.

Source:Nathan Associates Inc.

Table 5-6 also presents the economic impact on small entities as a percent of annual revenues by vessel type. For vessels operated by small entities it was assumed that they spend equal amounts of days at sea and in port.

Overall, the economic impact of the Rule represents about 4 one-hundredth of one percent of the annual revenues of vessels operated on the U.S. East Coast by small entities. For small entities operating containerships, the economic impact increases to up to one-tenths of one percent.

Based on these findings, we conclude that the operational measures of the final rule would not have a significant economic impact on a substantial number of small entities involved in commercial shipping along the U.S. East Coast.

Other Industries

The estimated economic impact on small entities in other maritime industries is presented in Section 3. The impact on small entities in the charter fishing industry in 2009 is estimated at $1.0 million (Table 5-7). The estimated economic impact on small entities in the commercial fishing industry is $0.9 million. There was no or minimal impact in 2009 on ferry operators and whale watching operators.

Table 5-7. Estimated Economic Impact of Rule on Small Entities in Other Industries, 2009 ($000s unless otherwise specified)

Industry	Estimated Economic Impact ($000s)	No. of Small Entities	Average Economic Impact per Small Entity ($000s)	Economic Impact as a % of Annual Revenues
Commercial fishing	933.4	307	3.0	0.4%
Charter fishing	1,000.0	40	25.0	4.3%

Source: Prepared by Nathan Associates Inc.

The economic impact on commercial fishing vessels is estimated at $3,000 per vessel per year and constitutes less than one-half of one percent of their annual revenues. This is not considered to be a significant economic impact.

The annual revenue of a small entity operating a charter fishing head boat is estimated at $504 thousand based on an average of 80 passenger paying $80 for 90 charters. The estimated economic impact of the final rule at is 4.3 percent of their estimated annual revenue and for purposes of the FRFA determination is not considered to be a significant economic impact.

6. Scoping Assessment of Economic Analysis of Potential Rule Modifications

As initially mandated, the Rule is due for renewal or modification in 2013. In this section, we assess the data requirements and level of analyses that would be needed to estimate the economic impact of some issues.

Update Analysis for 2010, 2011 and 2012

The economic impact analysis presented in this report is based on 2009 AIS data. By early 2013, it should be possible to obtain AIS data for 2010 through 2012. It is most efficient for data cleaning and review if the data for these years are provided together rather than at separate times. The key issue for using the additional years of AIS data is the matching of newly appearing vessels with our detailed twelve categories of vessel types and 18 deadweight ton ranges.

We have been provided AIS data for the first 11 months of 2010. Based on a review of that data, an additional year would require matching more than 2,000 newly appearing vessels, requiring about 7 days for an analyst and 4 days for a senior economist. If the three years of 2010 through 2012 were analyzed at the same time, this work could be completed with 14 days for an analyst and 8 days for a senior economist.

Reduce 65-Foot Vessel Length Threshold

The current Rule applies to vessels that are 65 feet and above in overall length (LOA). For 2009, we have worked with the AIS for vessels that are affected by the current Rule. If the length threshold was reduced to say 30 feet, this would require matching additional vessels with our detailed twelve categories of vessel types and 18 deadweight ton ranges. In terms of the conduct of the economic impact analysis, this modification would be difficult and costly to undertake as less information is available on smaller vessels. Lowering the length threshold will also require renewed and expanded analyses for commercial fishing, ferry boats, whale watch vessels and charter fishing vessels. It is estimated that this would require 15 days for an analyst and 10 days for a senior economist.

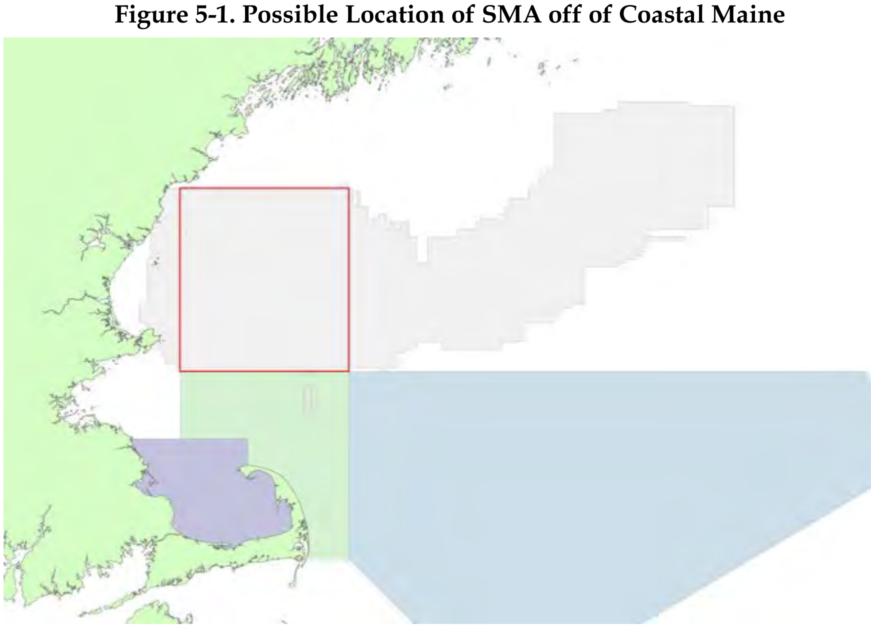
Expansion of Off-Race Point and Great South Channel SMAs

Under this modification, the existing Off-Race Point SMA and the Great South Channel SMA would be expanded to incorporate areas where DMAs regularly occur. As the vessel transits through DMAs have already been analyzed for 2009, the characteristics of those vessels have already been matched and identified. We would need to receive from NOAA a revised SMA database incorporating transits that would applicable to the newly defined geographic boundaries of the expanded SMAs. Since there would little need for matching of vessels, the economic impact for 2009 could be determined with 5 days for an analyst and 2 days for a senior economist. Other years could be conducted with the time already included for 2010-2012 update described above.

Establishment of SMAs in Waters of Coastal Maine

The current Rule does not include a SMA for waters off of Maine's coast. However, this has been an active area for right whales in recent years, as evidenced by the number of DMAs that have been implemented. The possible location of the SMA which would be effective from October 1 through February 28 is shown in Figure 5-1.

Figure 5-1. Possible Location of SMA off of Coastal Maine



We have been provided by NOAA, an AIS database that shows transits in 2009 for this possible SMA. Of the 1,734 transits made through this area in 2009 by 404 vessels, we have been able to match 1,397 transits by 305 vessels. Matching of the remaining vessels and determining the economic impact will require 3 days for an analyst and 1 days for a senior economist.

Make all DMAs Mandatory

As the vessel transits through DMAs have already been analyzed for 2009, the characteristics of those vessels have already been matched and identified. That analysis compared the amount of time needed to transit a DMA based on actual recorded speeds for the DMA areas when they were in effect and not in effect. However, since this data only corresponds to voluntary speed restrictions, it does not provide the impact for a mandatory DMA. The best estimate of the average observed speeds would be those recorded in SMAs in 2009 for each type/ size of vessel. Those speeds could b used to then calculate the impact of a mandatory DMA.

The analysis described in the paragraph above applies to the shipping industry vessels. However, making all DMAs mandatory will also require renewed and expanded analyses for commercial fishing, ferry boats, whale watch vessels and charter fishing vessels. It is estimated that this entire task would require 5 days for an analyst and 10 days for a senior economist.

An Assessment of the Final Rule to Implement Vessel Speed Restrictions to Reduce the Threat of Vessel Collisions with North Atlantic Right Whales

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NOAA Technical Memorandum NMFS-OPR-48
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EXECUTIVE SUMMARY

On 10 October 2008 the U.S. National Marine Fisheries Service (NMFS) published a "Final rule to implement speed restrictions to reduce the threat of ship collisions with North Atlantic right whales" (73 FR 60173). The rule requires that vessels 65 feet and greater in length travel at 10 knots or less near key port entrances and in certain areas of right whale aggregation along the U.S. eastern seaboard, known as "Seasonal Management Areas". Text in the preamble of the rule indicated NMFS's intention to also develop a "Dynamic Management Area" program to protect unpredictably occurring aggregations of right whales whereby mariners would be requested, but not required, to avoid temporarily established areas or travel through them at 10 knots or less. This "ship strike" reduction rule is set to expire five years from its effective date on 9 December 2013, before which NMFS was expected to develop ways to monitor and assess the rule's effectiveness at reducing ship strikes of right whales.

To this end, NMFS convened a workshop in November 2008 to determine ways to measure the rule's effectiveness. Among other things, the workshop concluded that regardless of the metrics developed to assess effectiveness, detecting meaningful biological effects of the restrictions would be difficult prior to the five-year expiration. This conclusion, notwithstanding, the workshop developed four metrics, that when combined, might provide a characterization of a possible reduction in ship strike deaths, as well as mariner response to, and economic impacts of, the vessel speed restrictions. The workshop also indicated that given the time needed for the agency to consider actions prior to the expiration of the rule, a report assessing the effectiveness of the regulations should be developed for NOAA leadership by December 2011. This is that report.

The four areas of assessment identified in the 2008 workshop report, and discussed in this report are (1) possible changes in ship strike death rates (*i.e.*, biological effectiveness); (2) changes in vessel operations in response to the regulations (*i.e.*, mariner response); (3) a quantification of mariner outreach and education efforts, and (4) economic impacts resulting from the rule. Results of a separate study on voluntary mariner response to Dynamic Management Areas are also discussed.

Results herein are based on statistical analyses of the occurrence of 55 large whale (all species of large whale) ship strike deaths or serious injuries over the course of 10 years. We also analyzed literally hundreds of millions of remotely-sensed vessel Automatic Identification System data points used to characterize vessel operations and to assess the economic impacts represented in over one hundred thousand passages made by over 6,000 individual vessels within both Seasonal and Dynamic Management Areas. We also evaluated maritime community awareness-raising efforts that were coordinated by a number of NMFS personnel and mediated through hundreds of contacts using various print and broadcast media.

Summary of conclusions:

- Although these data sets (including both vessel operations and biological data) were substantial and the analyses thorough, our findings are inconclusive regarding the biological effectiveness of the rule in achieving its objectives, because the time allotted (based on a sampling period of only two years given the timing of the expiration of the rule and to allow sufficient time to develop this report) to determine its biological effectiveness was simply too brief.
- A statistical assessment of the time needed to detect a change in the rate of ship strikes indicated that two years was an insufficient period to make a meaningful determination regarding a reduction in ship strikes. However, based on three separate statistical analyses, there may be "a meager amount of evidence" in support of a reduction in ship strike deaths and serious injuries of large whales; and at least five years are needed to detect substantial biological effects.
- Mariner compliance with the requirements of the rule was relatively low in 2009 and 2010, but it exhibited a marked improvement in 2011. Compliance was consistently low in "foreign-flagged" vessels.
- The outreach program used to inform the maritime community about vessel speed restrictions appeared to "blanket" the affected communities rather well. Although it was extensive in scope and a variety of communications outlets were employed, improvements in the program, particularly with regard to "non-domestic" vessel operators, appears warranted.
- The maximum estimated total (*i.e.,* direct and indirect) economic impacts resulting from the vessel speed restrictions were $52.4M and $79.0M using 2009 and 2012 bunker fuel prices, respectively. These are revisions to the 2008 projected economic impact of $137.3M. The new estimates assumed 100% compliance with the provisions of the rule and as such represent maximum economic impacts.
- Mariner adherence to voluntary speed restrictions within or avoidance of Dynamic Management Areas was minimal.
- The justification and reasoning for initially establishing vessel speed restrictions still stand. In addition, independent studies conducted since the rule was enacted indicate that the probability of a struck whale being killed or seriously injured is reduced as vessel speed diminishes and further that NMFS' vessel speed restrictions, in particular, are reducing the risk of fatal ship strikes or right whales. Therefore, the reasons for establishing speed limits and these more recent findings strongly suggest that the use of vessel speed restrictions should continue.
- Last, we provide suggestions about steps to improve the vessel-strike reduction program, including possible modifications to the provisions of the rule itself and various related aspects of the program that will enhance their value to right whale conservation.

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TERM AND ACRONYM LIST

ACOE	United States Army Corps of Engineers
AIS	Automatic Identification System
BI	Block Island
CCB	Cape Cod Bay
COPPS	Community Oriented Policing and Problem Solving Letters
CSA	Chamber of Shipping of America
DMA	Dynamic Management Area
GPS	Global Positioning System
GSC	Great South Channel
IMO	International Maritime Organization
ITU	International Telecommunications Union
MMSI	Maritime Mobile Service Identity
MOA	Memorandum of Agreement
MOR	Morehead City, South Carolina
MSR	Mandatory Ship Reporting
NAIS	National Automatic Identification System
NMFS	National Marine Fisheries Service
NC-GA	Wilmington, North Carolina to Savannah, Georgia

NEUS	Northeast United States
NOAA	National Oceanic and Atmospheric Administration
NOAA OLE	NOAA Office of Law Enforcement
NOR	Norfolk
NOVA	Notices of Violation
NY-NJ	Port of New York and New Jersey
ORP	Off Race Point
PHI	Ports of Philadelphia
SEUS	Southeast United States
SMA	Seasonal Management Area
SOG	speed over ground
SOLAS	[International Convention for the] Safety of Life at Sea
USCG	United States Coast Guard
USN	United States Navy
VHF	very high frequency
WSC	World Shipping Council

TABLE OF CONTENTS

INTRODUCTION

The greatest known anthropogenic threat to the recovery of the highly depleted North Atlantic right whale (*Eubalaena glacialis*) is at-sea collisions with vessels (for the purposes of the report, also called "ship strikes") (Clapham *et al*., 1999; Kraus *et al*., 2005, NMFS, 2005; Knowlton and Brown, 2007). In a population believed to be comprised of 350-550 individuals, any mortality caused by human activity is cause for concern, especially if these threats are preventing the population from recovering from potential extinction. Over the 20-year period from 1986-2005, 50 documented right whale deaths occurred, 19 of which were attributed to vessel strikes (the cause of death could not be determined in the majority of the other of the cases) (Knowlton and Kraus, 2001; Kraus *et al*., 2005; Glass *et al*., 2010). These are likely minimum counts because not all dead whales are detected particularly in offshore waters, and some detected carcasses are never recovered while those that are recovered may be in advanced stages of decomposition that preclude a definitive cause of death determination (Glass *et al*., 2010).

There is no evidence that the number of human-caused right whale deaths has diminished in recent years. An average of about two known North Atlantic right whale deaths and serious injuries from vessel strikes occurred annually in 2004 through 2008 (2008 being the most recent years for which peer-reviewed mortality counts are available) (Glass *et al*., 2010; Waring *et al*., 2010).

Right whales are more likely, per capita, to suffer a vessel strike than any other large whale species (Vanderlaan and Taggart, 2007). The factors contributing to their vulnerability to vessel strikes, although not fully clear, most likely relate to the species' coastal distribution that exposes them to high density vessel traffic, their tendency to spend considerable amounts of time at the surface, and that they tend to exhibit little or no vessel avoidance behavior (Terhune and Verboom, 1999; Nowacek *et al*., 2004). Avoiding an advancing ship, even if it was perceived as a threat (and there is no evidence for this), is not likely an inherent behavioral response for right whales (Ford and Reeves, 2008).

The endangered status of the right whale and the magnitude of vessel-strike threat to the species in the Northwest Atlantic Ocean has prompted the National Oceanic and Atmospheric Administration (NOAA) to develop and implement a number of management actions to reduce this threat (Bettridge and Silber, 2008; Silber *et al*., submitted). Among these actions were mandatory or recommended changes in vessel-routing practices (Silber *et al*., submitted), and mandatory or recommended vessel speed restrictions (NMFS, 2004; NMFS, 2008). In particular, NOAA instituted regulations that restrict vessel speeds in certain areas and at certain times along the U.S eastern seaboard where right whales feed, migrate, socialize, and rear their young (NMFS, 2008).

The U.S. National Marine Fisheries Service's (NMFS) Final Rule to reduce the severity and likelihood of vessel strikes to North Atlantic right whales went into effect on 9 December 2008 (73 FR 60173; 10 October 2008). The stated goal of the rule was "*to reduce or eliminate the threat of ship strikes [of North Atlantic right whales] - the primary source of mortality in the endangered population*." It requires that vessels 65 feet and greater in length travel at speeds of

10 knots or less near several key port entrances and in certain areas of right whale aggregation and along the U.S. eastern seaboard, known as "Seasonal Management Areas" (SMA) (Fig. 1). These SMAs are in effect during certain times of the year that correspond to right whale seasonal movement and aggregation patterns (Fig. 2). NMFS's Office of Law Enforcement (OLE) is responsible for enforcing the provisions of the vessel speed restriction rule. The U.S. Coast Guard (USCG) and others have taken a number of steps to assist in these efforts.

As indicated in the preamble to the rule, a program of "Dynamic Management Areas" (DMA) was also established whereby temporary zones (15 days in duration, generally) are created around aggregations of right whales occurring outside of SMAs. Mariners are asked, but not required, to either avoid established DMAs altogether or travel through them at speeds of 10 knots or less. This approach provides NMFS with complimentary measures aimed at protecting both predictable and recurring seasonal right whale presence as well as the option to react quickly to the occurrence of unexpected aggregations. The latter may be linked, for example, to shifting presence of right whale prey.

Vessel speed has been implicated as a principal causal factor in both the occurrence and severity of vessel-whale collisions, and therefore formed the basis for NMFS's ship strike reduction measures. Studies indicate that vessel speed restrictions can reduce the probability of serious injury or death resulting from a vessel strike (Pace and Silber, 2005; Vanderlaan and Taggart, 2007). Recent studies also indicate that the likelihood of occurrence of a strike is also lowered by reduced vessel speed (Gende *et al*., 2011); and that the size of the area around a ship's hull in which a whale is drawn to the vessel (thereby increasing the exposure to a strike) and the magnitude of the impact involved in a whale-vessel collision is diminished by reduced vessel speed (Campbell-Malone, *et al*., 2008; Silber *et al*., 2010). Studies conducted since establishment of the vessel speed rule have contributed to a growing body of literature on this subject (Vanderlaan *et al*., 2009; Vanderlaan and Taggart, 2009; Gende *et al*., 2011; Lagueux *et al*., 2011; Wiley *et al*., 2011) indicating that lowered vessel speeds reduce the risk of fatal whale strikes. Of these, Lagueux *et al*. (2011) and Wiley *et al*. (2011) concluded that NMFS's 2008 10-knot vessel speed restrictions, in particular, reduced the risk of lethal strikes of right whale by 38.5% and 56.7% in waters off the southeast U.S. coast and New England, respectively. Therefore, the arguments used to establish vessel speed restrictions to reduce fatal strikes of right whales – and as backed by more recent studies – still support continued use of the restrictions.

The rule is set to expire five years from the date of its publication. NMFS indicated that it would develop ways to monitor the effectiveness of the rule. Therefore, NMFS committed to (a) developing means to monitor the rule's effectiveness, (b) assessing its overall effectiveness, and (c) preparing a report of the findings, which have been compiled as this report This is that report.

Workshop to Assess the Effectiveness of the Final Rule

Given the need to monitor the relative success of the rule, NMFS's Office of Protected Resources convened a workshop in November 2008 to determine ways to assess the effectiveness of the vessel speed restrictions in achieving their goals (Silber and Bettridge, 2009;

excerpts of this report (*i.e*., the Executive Summary, only, for the sake of brevity) are provided in Appendix A). The goal of the workshop was to:

> "*develop a strategy, involving multiple components, to monitor and assess whether vessel speed regulations are achieving the rule's intent of reducing the occurrence of ship strikes in right whales (i.e., whether the rule is "effective")*."

Among other things, the workshop concluded that:

> "*The final rule contains a provision that the regulations would expire five years after implementation. With regard to the expiration, the workshop concluded that at that time, NMFS would (a) re-issue the regulations, (b) modify the regulations, or (c) allow them to expire. Therefore, if the regulations are to be modified or re-issued by the December 2013 expiration date through the rulemaking process, it will be necessary to have conclusions regarding effectiveness in hand for National Oceanic and Atmospheric Administration (NOAA) leadership by December 2011. As a result, data collection should start immediately and summaries and reports regarding the rule's effectiveness should be available by December 2011."*
>
> *"Workshop participants agreed that the timeframe for implementing adequate and rigorous metrics is quite short. In fact, given the suite of variables contributing to ship strikes, detecting meaningful biological effects of the regulations would be difficult. Variables complicating a rigorous assessment of effectiveness include maritime commerce, oceanographic features contributing to shifts in whale distribution, and the rarity of a ship strike event. Much longer time series are typically needed to detect statistically meaningful effects. Nonetheless, within these rather arbitrary time constraints, workshop participants understood the charge to develop metrics, as possible."*
>
> *"Workshop participants agreed that NOAA will use four basic parameters to monitor effectiveness*."

These parameters are:

- ***Biological studies*** -- Assess the rate (using the time elapsed between) of known large whale ship strike deaths;
- ***Human behavior*** -- Quantify human response to provisions of the Rule using Automatic Identification System (ideally, relying on a centralized network) to monitor vessel operations;
- ***Mariner awareness*** -- Enhance and quantify mariner awareness-raising efforts through education and outreach programs; and
- ***Economics*** – To the extent possible, quantify economic impacts resulting from the conditions of the Rule.

Following the workshop, NMFS established programs to gather and analyze information in these areas. Results of these analyses are presented here.

The goals of this report are to present the results of assessment studies conducted in the years since implementation of the Rule (December 2008 – 2011); to present summary conclusions from the studies; and to provide recommendations for possible future action with regard to ship strike reduction.

Content and Organization of the Report

Here, we present the results of five independent, but interrelated, studies. Findings are provided in four sections corresponding to the assessment tools identified by the 2008 workshop, and in one additional area: a characterization and assessment of industry response to the establishment of 66 DMAs. While the results of each of these studies have, or may also be, presented elsewhere by various authors as stand-alone papers, reports, or conference presentations, overview summaries of each are presented here. Each summary "chapter" is intended as a self-contained analysis with various contributing authors that correspond to their particular expertise or their having conducted or contributed to a specific type of analysis.

We also include a "Conclusions and Recommendations" section that provides a discussion, in general terms, of ways to improve seasonal and dynamic vessel speed restriction management areas as conservation measures as well as recommendations about ways to improve aspects of the program such as monitoring and compliance, raising the awareness of maritime communities, and data collection. Taken collectively, this is an attempt to assess NMFS's vessel speed restrictions, and the results may be applicable to other settings in which vessel strike reduction of whales is sought or related living marine resource conservation measures.

Specifically, this report contains the following summary papers:

I. Biological Metric
"*Assessment of the frequency of whale and vessel collisions on the U.S. eastern seaboard in the two years following implementation of the ship strike reduction rule*"

II. Human Behavior: Automatic Identification System Monitoring of Vessel Compliance
"*Characterization of vessel operations in, and compliance with, vessel speed restriction Seasonal Management Areas in 2009 and 2010*"

III. Mariner Awareness: Education and Outreach
"*Summary of actions to notify maritime communities about the vessel speed restriction rule*"

IV. Economic Impacts
"Initial estimate of economic impact of the right whale ship strike reduction vessel speed restrictions"

V. Dynamic Management Areas
"*Vessel operations in and around Dynamic Management Areas*"

I. Biological Studies: Assessment of the frequency of whale and vessel collisions on the U.S. eastern seaboard in the two years following implementation of the ship strike reduction rule

Gregory K. Silber and Richard M. Pace, III

The ultimate goal of the vessel speed restriction action is to enable population recovery by reducing deaths and serious injuries of whales resulting from vessel strikes. And, the goal of any assessment is to directly quantify a reduction – ideally, determined by direct counts – in actual or averted deaths from ship strikes. However, as noted above and elsewhere (*e.g.*, Silber and Bettridge, 2009), quantification of trends in the occurrence of anthropogenic whale deaths using direct counts can be difficult if not impossible particularly when constrained by short sampling periods.

A number of alternative means conceivably may be used to assess a reduction in ship strike deaths. One is quantifying visual observations of imminent collisions that are somehow averted. However, recording such incidents will be few and would not be systematic because it involves observers being located near the interaction at the time it occurs. A second means would be to directly quantify known whale ship strike death rates both before and after a measure is implemented. However, this, too, is difficult to measure directly because other unrelated and difficult to quantify processes may be at play (*e.g.,* shifts in whale distribution, changes in numbers or locations of vessel transits) that may affect the number and rate of known ship strike-related deaths (Silber *et al*., submitted).

Although ship strikes are a significant fraction of the total number of annual large whale deaths and are a legitimate threat to the North Atlantic right whale population, they are actually relatively rare events and, therefore, sample sizes will always be small. This is compounded by an inability to reliably detect and ascertain the cause of *all* ship strike-related deaths. Therefore, long time series' are needed to identify any trends in the occurrence of ship strike deaths. And, even if changes in the rate of ship strike deaths are detected, it may be difficult to attribute that outcome to a specific ship strike reduction action. Several studies have assessed the effectiveness of various ship strike reduction measures by evaluating likely correlates to risk, risk of lethality, and in determining probabilities associated with collisions and steps taken to reduce collisions (Vanderlaan and Taggart, 2007; Vanderlaan *et al*., 2009; Wiley *et al*., 2011), and whereas the studies are highly useful particularly in the absence of direct counts, they remain indirect assessments.

The limitations identified above notwithstanding, NOAA recognized the need to assess the biological affect of the vessel speed restrictions (NMFS, 2008; Silber and Bettridge, 2009). The 2008 workshop participants concluded that assessing the effectiveness of the rule was not possible in a relatively short period if it were based solely on detecting changes in the number of annual right whale deaths, so other means were sought. An alternative metric was developed and presented to the 2008 workshop, namely:

(a) Comparing periods both before and after the rule's implementation by using a 100% sample of known ship strike deaths of *all baleen whale species* (*i.e*., not only right whales to which the rule was targeted) occurring along the U.S. east coast (*i.e*., not only those geographic areas within the rule's SMAs); and

(b) Conducting a statistical analysis of *time elapsed* between subsequent ship strike mortality events.

Known ship strike deaths of all baleen whale species occurring in all areas (not only within SMAs) were to be examined to increase the overall sample size, accompanied by the reasoning that some species might, to some degree, also benefit from U.S. east coast ship strike reduction measures.

The workshop participants agreed that the proposed metric should be used, noting that this approach would to some extent avoid the pitfalls identified above (*e.g*., brief sampling period, relatively infrequent occurrence of actual ship strike events). However, this metric has limitations of its own. As noted in a report of the results (Pace, 2011; Appendix B), a statistical assessment of this approach was undertaken and the conclusion was that the two-year post-rule sampling period was simply too brief to detect a significant change in large whale ship strike deaths. The limited sampling period resulted primarily from the five-year "sunset" of the rule, and the need to generate this report.

Nonetheless, given that the rule went into effect in December 2008, the analysis described here included only U.S. east coast large whale ship strike deaths and serious injuries from 1 January 2000 through 31 December 2010 (n = 58). The results of the analysis are provided in Appendix B; we provide a summary here.

Some central conclusions from a "Frequency of whale and vessel collisions on the US eastern seaboard two years post ship strike rule" (Pace, 2011) are:

- With regard to assessing overall effectiveness of the rule, the results are inconclusive. The time series is too brief;
- A standard classical statistical assessment of the time needed to detect a change in the rate of ships strikes indicates that two years (the selected sampling period given the timing of the expiration of the Rule) was an insufficient period to detect a change. For example,
    - There is a 2.5% probability of detecting a 50% change in ship strike rates after two years (6.1% chance of detecting a 66% change);
    - After 5 years, there is an 80% probability of detecting a 50% change (93% of detecting a 50% reduction after 7 years);
- These critical limitations notwithstanding, statistical testing was done using three separate tests. The results were:
    - Largely inconclusive;
    - A simple plot of the data indicates that 2005 was a very bad year for ship strikes, but statistical analysis do not support this; and

- In considering three separate analytical approaches, there is "a meager amount of evidence for an increase in the time between events post rule implementation."

As for right whale deaths since the rule went into force, no right whale deaths or serious injuries are known to have occurred in times and locations in which SMAs were in effect or by vessels subject to the rule. Some, and as yet not peer-reviewed, observations indicate that one suspected ship strike-related right whale death occurred in the northern Gulf of Maine when SMAs were not in effect; another was struck and likely seriously injured by a sovereign vessel which was not subject to the rule.

II. Human Behavior: Characterization of vessel operations in, and compliance with, vessel speed restriction Seasonal Management Areas in 2009, 2010, and 2011

Shannon Bettridge and Gregory K. Silber

Introduction

This section provides a description of vessel operation patterns in Seasonal Management Areas (SMA). We collected and analyzed data on vessel types, speeds, number of trips and other features obtained from the USCG's National Automatic Identification System (AIS) network – a system of shore-based receivers and relayers that provide information on vessel operations in nearly all U.S. coastal waters.

This serves as a partial update and expansion of a 2010 report on the same subject (Silber and Bettridge, (2010); accessible at: http://www.nmfs.noaa.gov/pr/pdfs/fr/fr73-60173.pdf), in this case evaluating vessel operations in 2009, 2010, and 2011. A number of the findings (*e.g.*, number of vessel transits, proportions of trips by vessel type and flag state) and conclusions presented here are similar to the ones in the Silber and Bettridge (2010) report, notably, that adherence to the vessel speed restriction by maritime communities was not as strong as what might be expected in 2009 and 2010, although compliance appears to have markedly improved in 2011. The reasons for the early low compliance levels are not readily apparent and we only briefly address them here, leaving treatment of this to a later time and/or to be presented in subsequent publications. Instead, our goal here is to characterize vessel operations in SMAs. Except where otherwise indicated, all the AIS data acquisition, storing, parsing, and analyzing used in this study are the same as previously described in the 2010 report (Silber and Bettridge, 2010). The reader is referred to that report for descriptions of data acquisition and analytical methods used.

Automatic Identification System (AIS): Its Purpose and Our Data Analysis

Originally conceived as a safety of navigation technology, the AIS sends Global Positioning System (GPS)-linked signals that provide for ship-to-ship and ship-to-shore information transfer. A ship's name, call sign, position, dimensions, speed, heading and other information are transmitted multiple times each minute via very high frequency (VHF) radio signals. The AIS network that we utilized works in an autonomous and continuous mode and is capable of handling more than 4,500 reports per minute and updating as often as every two seconds. The rate at which it provides this information (*e.g.*, multiple location fixes and speed indications each minute) makes the AIS networks and its components a highly precise and cost effective means to track vessel speeds and other vessel operations and to remotely sense activities of various maritime communities.

A suite of information, both dynamic (unique to a particular voyage) and static (constant for a given vessel), is embedded in the AIS signal. Dynamic information includes the vessel's position, speed over ground, heading, and position accuracy, which are determined by continuous GPS-linked updates. Static information includes the vessel's name, call sign, type, cargo, and Maritime Mobile Service Identity (MMSI) number (a unique number assigned to each vessel for safety at sea purposes). This information is entered by the operator upon initializing the system.

NMFS Headquarters' Office of Protected Resources has been acquiring AIS data feeds from the USCG National AIS. Data are downloaded and processed, under a Memorandum of Agreement (MOA), by the Department of Transportation's Volpe National Transportation Systems Center (Volpe Center) and provided to NMFS as raw data and in summaries.

While providing a wealth of information about vessel operations, the system is not without limitations. For example, the range is limited. AIS vessel transponders typically operate with a range of coverage of about 20-40 nautical miles, but perhaps more in certain circumstances (*e.g*., up to hundreds of miles in ideal conditions), or essentially "line of sight". Reception distances are influenced by the height of the receiving antenna, and the signal may be momentarily compromised, or enhanced, by local meteorological conditions (*e.g.*, electrical storms), atmospheric bounce, or other possible interferences (*e.g.*, other radio signals). In addition, not all transmitted messages are flawless, mostly due to operator error in entering required information into the transponder. We have developed various ways of detecting and eliminating faulty transmissions (Silber and Bettridge, 2010) and a substantial number have been removed from the data set.

Although our analytical approaches are defined in the 2010 report, we provide some basic information here to help orient the reader for the purpose of interpreting our results. Every mention of vessel speed refers to the vessel's "speed over ground" (SOG) as explicitly stated in the rule itself (as opposed to speed through the water) and as provided by the AIS signal itself. Information on "country of origin" and "vessel type" is encoded in the AIS message as established by International Maritime Organization (IMO) protocol and as entered by the operator. As to vessel type, the operator is limited to a finite number of designations, such as cargo, tanker, passenger, tow, pilot, tug, and sovereign. We also developed an "other" category that might include, for example, fishing vessels, sailing or pleasure craft, dredging, and diving vessels. Our reporting of vessel type information below correspond to these categories provided by the vessel operator (with the exception of "tow" and "big tow" which we combined into the single category "tow"). Sovereign vessels (those owned or operated by, or under contract with Federal entities) are not included in our analysis because these vessels are excluded from the provisions of the vessel speed rule. This vessel category may be the subject of subsequent analysis.

This monitoring program involves a substantial data set. As noted, vessels' AIS transponders send a signal multiple times each minute; tens of vessels may be moving through active SMAs at any given time, representing several thousands of coastal transits per month. Given that AIS equipment is required by the IMO's International Convention for the Safety of Life at Sea (SOLAS) for most vessels and by the USCG for vessels in U.S. waters, we assume we are acquiring a full record of all vessels traveling in active SMAs, but we have no way to determine if all vessels with AIS carriage requirements adhered to those requirements. Given, however, AIS's primary function is that of navigational safety, it is reasonable to assume that vessel operators would use the system; the USCG may also assess penalties if the system is not used.

We therefore regard these as minimum, but reliable, counts of the number of vessel transits. And, because this data set is quite large we believe it enables us to accurately portray vessel operations in SMAs.

Thus, we provide a characterization of vessel operations in SMAs by summarizing information on vessel country of origin, speeds, by type, and overall compliance rates with the speed restrictions. This summary is for the period of January 1, 2009 through December 31, 2011.

By any measure (the number of records removed from analysis notwithstanding), we present information on a formidable fleet that traverses areas vital to the longevity of the right whale population. It appears that large vessels are nearly ubiquitous throughout the range of North Atlantic right whales, and a given individual whale may encounter tens of vessels each day, hundreds each year.

Results and Summaries

A total of 135,057 vessel transits were recorded and analyzed in active SMAs in 2009, 2010, and 2011, comprising of tens of millions of individual location and speed data points. Of these, 46,143 transits were removed from further analysis because they contained (primarily operator) errors. Thus, a total of 88,914 vessel trips were further analyzed and discussed here (Table 1).

Country of Origin

Considering all transits in all active SMAs, the ratio of foreign flagged to domestic vessels was 1.7:1. This is generally consistent across all months except July when only the Great South Channel (GSC) SMA (see Terms and Acronyms List, and Table 1 for lists of acronyms for each of the SMAs) was active, where the ratio was 5:1. The majority of cargo and tanker vessels were foreign-flagged, while not surprisingly all tow and nearly all tug and pilot vessels were U.S. owned and operated. The highest proportion of foreign versus domestic vessels occurred in the GSC SMA, followed by the ORP SMA perhaps reflecting trans-Atlantic passages destined for Boston or New York; and the lowest number of foreign flag relative to domestic vessels occurred in the CCB and MOR SMAs (Fig. 3).

Vessel Type

Cargo vessels constituted the overwhelming majority of ship passages in all SMAs, comprising over 51% of all vessel transits, (and not including the “other” category, for the moment, were) followed by tanker vessels (14%), and tug and tow type vessels (10% each) (Table 2; Fig. 4). Cargo vessels were strongly represented in the NY-NJ, NOR NC-GA and SEUS SMAs, with the NC-GA complex having the highest number of cargo transits of all SMAs (Fig. 5).

The number of tanker vessel transits was higher, proportionally, in northern SMAs than in more southern SMAs, perhaps reflecting the propensity of refineries in the northeast region. The NC-GA complex encompasses the primary ports supporting movement of goods to the U.S. south, which accounts in part for the volume represented here over single-port entrance SMAs.

Composition of Vessel Traffic in SMAs

Overall, the greatest vessel traffic volumes were in the NY-NJ, NC-GA and NOR SMAs (Table 1). The NY-NJ SMA had the greatest number of transits (n = 22,989) followed by the NC-GA complex and the NOR SMA (n = 19,649 and n = 14,838 transits, respectively). The number of transits through the NY-NJ port complex dwarfs the others, despite the fact that the NC-GA SMA encompasses a number of large ports, including Savannah and Charleston; and considering the NOR SMA includes vessels servicing Baltimore, Hampton Roads, and other destinations within the Chesapeake Bay.

Tow-type vessels were common in the CCB SMA, reflecting the tug-and-barge industry utilizing the Cape Cod Canal as well as those vessels providing heating oil and other materials to Cape Cod communities and elsewhere in the northeast. These are typically slow moving vessels, a fact that is partly reflected in slower speeds in this area relative to other SMAs where other vessel types and higher speeds were observed.

Relative to the other SMAs, there were proportionally low numbers of vessels transiting through the ORP, GSC, and MOR SMAs. The ORP SMA is active for a relatively short period, which likely accounts for this pattern; but, overall, MOR appears to be one of the smaller volume ports inside SMAs. The relatively low numbers reflected in the GSC SMA are more difficult to interpret given it is the largest (in area) of all the SMAs and is used by international vessels making port calls in Boston, New York, and elsewhere. Volume in this area may indicate that (a) vessels are utilizing the Traffic Separation Scheme servicing Boston, which lies outside the GSC SMA and/or they are routing around the Area To Be Avoided established in this area; (b) the relatively higher vessel volumes in SMAs other than the GSC is indicative of the level of many coast-wide (*e.g.*, port-to-port) transits along the eastern seaboard, as opposed to trans-Atlantic passages; or (c) not all transmissions from vessels in the area are being captured given the limitations of the transmission ranges of the AIS signal (GSC is the farthest SMA from shore). Regardless, this is a key feeding area for right whales, which may involve relatively long residency times for the whales, and it is fortuitous that the traffic volume may be low in this area.

Vessel Speeds

There are a number of ways to characterize vessel speeds within SMAs. We examined the *portion* of each transit for which speeds were both below and above 10.0 knots and 12.0 knots as thresholds for characterizing speeds used on a particular trip. This approach provides a means for examining the relative "egregiousness" of violations of the speed restrictions (*i.e.*, was the violator exceeding the speed limit for the majority of the trip or only a portion?). We assessed the "percent of the transit (distance) >10.0 knots" and "percent of the transit (distance) >12.0 knots" of each transit. We then determined, for each transit, whether most of the trip (>50%) was below or above these two speed thresholds. Thus, as general measures of "compliance", we provide the distribution of vessels traveling (a) at or less than 10.0 knots/12.0 knots for the entire transit, (b) above 10.0 knots/12.0 knots for up to half of the transit, and (c) above 10.0 knots/12.0 knots more than half of the transit distance (Fig. 6). We then used this metric as a means to compare mariner compliance between years.

We also quantified the "maximum speed over ground" achieved during each vessel transit through active SMAs. Although other types of metrics might more accurately capture the nature of the speeds used in these trips, this is a readily accessible metric and it does represent one measure of each transit. And, in the strictest interpretation of the rule, any speed in excess of 10.9 knots within an active SMA constitutes a violation of the speed limit. We recognize that maximum speed may represent only a fraction of the entire transit, thus this measure may overestimate the overall speed of a given transit and upwardly bias summaries of speeds in all transits. However, to the extent that enforcement actions, or monitoring efforts for that matter, rely on any excessive speed above, say, 12 or 13 knots, as an indicator of "non-compliance", maximum speed still serves as a measure of relative adherence to the restrictions.

In 2009, 32% (n = 9,198) of recorded transits exhibited maximum speeds at or below 10.9 knots for the entire transit; 58% (n = 16,363) were at or below 12.9 knots for the entirety of the transit. This increased slightly in 2010, when 36% (n = 10,584) transits had maximum speeds at or below 10.9 knots for the entire transit; 62% (n = 18,281) were at or under 12.9 knots for the duration of the transit. In 2011, 53% (n = 16,417) of recorded transits exhibited maximum speeds at or below 10.9 knots for the entire transit; 74% (n = 23,098) were at or below 12.9 knots for the entirety of the transit (Fig. 7). The most common maximum speed category represented was 10.0 (*i.e.*, 10.0 - 10.9) knots; and the majority of all transits had maximum speeds between 10.0 and 14.0 (*i.e.*, 10.0 - 14.9) knots (Fig. 7).

Cargo and pilot vessels exhibited the highest aggregate maximum speeds (with the most traveling in the 15-16 knot range) (Fig. 8). The majority of vessels in the "tug, tow, dredge", and "other" categories exhibited peak aggregate speeds around 10 knots. With regard to those in the tug, tow, and dredge categories, such vessels travel around 10-12 knots routinely and regardless of vessel speed restrictions. Generally, domestic vessels had lower aggregate maximum vessel speeds than did foreign-flagged vessels; the latter tended to travel at maximum speeds of 12 knots or greater (Fig. 9).

Another way to characterize vessel transits is by calculating mean speeds, although we acknowledge that there are inherent potential biases involved with this approach. For example, vessels may slow down to board a pilot or anchor within an SMA while waiting to enter port. Typically, vessels transmit AIS data throughout the entire voyage; therefore, in such instances the number of records with lower speeds would dominate the particular transit and average vessel speeds would be biased downward. A vessel may not have traveled at the mean speed for much of the transit, and even brief periods of elevated speeds would bias average speeds upward. Thus, average speeds may not always accurately characterize actual speeds for the entire trip.

These considerations notwithstanding, we decided to quantify aggregate mean speeds to assess general trends. Overall, passenger vessels had the highest mean speeds (11 knots) when travelling through SMAs, followed by cargo vessels (10.9 knots) and tankers (10.8 knots). Tow vessels had the slowest mean speeds (9.1 knots) (Fig. 10). The highest aggregated mean vessel speeds were recorded in the PHI and GSC SMAs, with an average above 11 knots per transit. The slowest aggregate mean speeds were recorded in the CCB SMA, with an average speed of

9.9 knots in 2009 and 9.4 knots in 2010 – an area that is dominated by tug and tow vessels, which travel at lower speeds than other vessel types.

Trends in Vessel Speeds

We were interested in determining if aggregated vessel speeds diminished with time as awareness of the restrictions (including late 2010 enforcement actions -- see section III, below) increased. When considering the *portion* of transits at or below 10.0 knots, we found that 21% of transits in 2009 were completely at or below 10.0 knots for the entire SMA transit. This rate increased slightly to 22% in 2010 and to 33% in 2011. In 2009, 41% of transits were above 10.0 knots for over half of the trip, declining to 37% in 2010 and to 22% in 2011. Thus, for this metric we observed an increase in compliance and perhaps an overall lowering of speeds by the entire fleet between the three years.

When considering the *maximum vessel speed* attained during one transit, 68% of the trips in 2009 exceeded 10.9 knots at some point. This figure decreased slightly to 64% in 2010 and decreased further to 47% in 2011. In general, we see an increase from 2009 to 2011 in the number of trips in which the maximum speed for each trip was below 13 knots, and a decrease in the number of trips in which the maximum speed for all or a portion of the trip was at 14 knots or greater.

Compliance with Vessel Speed Restrictions

It is not clear why initial "compliance" with these regulations was relatively low. Contributing factors may be a lack of public recognition of the rule, disregard for it, or inadequate early enforcement. On the other hand, marked improvement in compliance in 2011 is likely attributable, at least in part, to 2010 enforcement actions. Regardless, there are almost certainly learning and acquisition phases to a requirement that substantially alters standard practices. With regard to foreign-flagged vessels and their operators infrequent port calls, language barriers, or simple lack of familiarity with domestic requirements may hamper acquisition and understanding of the significance and requirements of the rule.

NMFS developed and implemented an extensive mariner awareness-raising campaign that should have been adequate to notify every mariner transiting U.S. Atlantic coast waters about the requirements of this rule (see Chapter III for a description). Also, NMFS' Office of Law Enforcement issued 149 outreach letters notifying vessel owners and operators of specific violations detected and informing them of the regulations and NOAA's Office of General Counsel issued civil penalties to another 18 vessel owners and operators (7 were issued in late-2010, the balance coming in late 2011). In collaboration with two large shipping industry associations, NMFS developed a program in which over 400 individual vessels were provided with monthly summaries of specific information (*e.g.*, times, dates, locations, speeds) about their recent vessel operations in SMAs. This program began in 2010 and is ongoing. NOAA's Stellwagen National Marine Sanctuary developed a system of notifying mariners about vessel speeds in the sanctuary. Collectively, these actions almost certainly have had a substantial effect on vessel activities and compliance with restrictions in SMAs. We expect to examine these efforts more closely in subsequent analyses and will present the results elsewhere.

III. Mariner Awareness, Education and Outreach: Summary of actions to notify maritime communities about the vessel speed restriction rule

Shannon Bettridge, Cheryl Bonnes, Barb Zoodsma, and Gregory K. Silber

To effectively reduce the likelihood and lethality of vessel collisions, compliance with the ship speed regulations must be high. In turn, compliance with the regulations cannot be anticipated without first ensuring mariner awareness of the requirements of the regulations. In other words, before expecting high compliance rates with the vessel speed rule, information must be clearly delivered and correctly understood by affected maritime communities. To achieve this, NMFS and its partners launched an extensive outreach campaign in advance of the ship speed rule going into effect and while the regulations were in effect. We developed a program geared specifically to distributing information about the provisions of the regulation through as many outlets and media as possible. The goal was to provide information about the requirements of the rule to as many of the various affected elements of the maritime industry as possible, even if redundant.

While these actions to communicate the provisions of the rule to mariners were undertaken prior to establishing the rule and during the period it was in effect, we do not describe outreach efforts that began in 2006 including public scoping meetings, solicitation of public comment, Federal Register notices, coast-wide presentations in key ports, and other actions associated with NMFS's Advanced Notice of Proposed Rulemaking, Proposed Rulemaking, the draft and final Environmental Impact Statements, and related actions. Descriptions of these can be found in the Final Environmental Impact Statement to Implement the Vessel Operational Measures to Reduce Ship Strikes to the North Atlantic Right Whale (Anonymous, 2008; and at http://www.nmfs.noaa.gov/pr/shipstrike/archive.htm).

Characterization of outreach efforts

Although not a direct assessment of effectiveness, the 2008 workshop participants agreed it was essential to not only develop and implement an extensive program to inform all potentially affected entities about the requirements, but also to quantify NMFS's efforts to do so. The workshop report recommended that NMFS monitor outreach efforts by quantifying, for example, the amount of material distributed and numbers of broadcasts made, and attempt to estimate the extent of the audience reached.

Heeding the workshop recommendations, NMFS tracked awareness-raising efforts since October 2008 directed at domestic and foreign flagged vessels, recreational boaters, fishermen, Federal agencies, whale watch vessels, passenger ferries, and other affected entities since October 2008. These actions are described below.

<u>Navigational Aids</u>

Beginning in the early 2000s, NMFS routinely published information in relevant U.S. *Coast Pilot* books on the threat of vessel strikes to sea turtles and large whales (right whales in particular), and other matters. The information is updated annually and information on the vessel speed restrictions was added in 2008/2009 and runs currently. The U.S. *Coast Pilot* is a series of nautical books that cover a range of information important to navigators of coastal and intra-coastal waters and the Great Lakes. Issued in nine volumes, they contain supplemental information that is difficult to portray on a nautical chart, including Federal regulations applicable to navigation. Routinely updated by NOAA's Office of Coast Survey readily available, each volume contains sections on local operational considerations and navigation regulations, followed by chapters that contain detailed discussions of coastal navigation.

It is important to note that knowledge of requirements, precautions, and safety at sea provisions contained in U.S. *Coast Pilots* is a requirement for all vessels sailing in U.S. waters. Because carrying *Coast Pilots* is mandated and enforced by the USCG and NMFS Office of Law Enforcement (OLE), reason might suggest that these outlets, *alone* (perhaps as coupled with the rulemaking itself, accompanying changes in the U.S. Code of Federal Regulations, and notification by shipping company parent organizations), would be sufficient to ensure mariner adherence to the requirements of U.S. law. Nonetheless, in the following sections, we identify additional steps taken to inform mariners and the general public about U.S. regulations.

As to those vessels sailing internationally, details of the ship speed rule are also articulated in *Sailing Directions*, a 42-volume American navigation publication prepared by the National Geospatial-Intelligence Agency (NGA), and a companion document, *Notice to Mariners*. These publications, used by mariners to plan international voyages, describe general features of ocean basins and country-specific information (such as military operational areas, pilotage requirements, regulations, search and rescue information, ship reporting systems) as well as features of coastlines, ports, and harbors. NMFS provides annual updates to these publications. Information appearing in *Notice to Mariners* and *Sailing Directions* is also generally incorporated into another international sailing guide, the United Kingdom's *Admiralty Publications*. While these three publications are not required for passage in U.S. waters, they are widely distributed and highly regarded as an essential source of information on safety of navigation at sea.

SMA boundaries are not depicted on NOAA-produced paper or electronic navigational charts. Having this information shown directly on nautical charts would almost certainly further mariner knowledge of, and improve compliance with, the provisions of these regulations. This is a key shortcoming toward improving compliance. Although special notes to mariners about the vessel speed restrictions appear on the charts and are provided on the NOAA electronic navigational charts, these certainly are no substitute for the potency of chart-depicted speed requirements for inbound vessels in U.S. waters particularly those owned and operated by foreign entities.

Notices to Mariners

Information about vessel speed restrictions and locations of right whales is also provided to mariners through various official broadcast media, including Broadcast and Local Notices to Mariners, satellite-linked marine safety broadcasts, and NOAA Weather Radio. The NGA, in collaboration with NOAA and the USCG, publishes weekly Notices to Mariners, which provide corrections to navigational publications and nautical charts. The U.S. Notice to Mariners officially amends NGA and NOAA nautical charts with new information collected from many sources, among them the Local Notice to Mariners published by the various U.S. Coast Guard districts. The need to adhere to ship speed regulations are announced regularly via Local and Broadcast Notices to Mariners, particularly as they come into force seasonally. Periodic announcements about the rule are also made on NOAA Weather Radio broadcasts on specifically designated maritime radio frequencies. Broadcasts containing information about the speed rule are issued hourly (or as time permits) from Brunswick, GA, to Melbourne, FL, from 15 November to 15 April, annually; and from Mamie, NC to Hardeeville, SC from 1 November to 30 April, annually.

Here again, *all* mariners are responsible for adhering to any information regarding navigational safety contained in the above-listed notices. Given that they are tailored regionally, the broadcasts would be received when mariners are in, near, or approaching SMAs. Thus, because this information is delivered by regionally-specific broadcasts that are routinely monitored by nearly all mariners and contain information that is required as a matter of port entry for safe navigation in particular waters, one might argue that these requirements, alone, would suffice in ensuring all mariners entering these areas are cognizant of what is required. (A significant gap is the omission of SMAs on NOAA's nautical charts.) In addition, most mariners routinely monitor NOAA Weather Radio to assess local conditions while at sea and would, therefore, be expected to receive information about the requirements from that source.

<u>Mandatory Ship Reporting Systems</u>

Information is also provided to mariners on the ship speed rule via the Mandatory Ship Reporting systems (MSR). The MSR systems, jointly funded and operated by NMFS and the USCG, are aimed at increasing mariners' awareness of the problem of ship strikes of right whales. Beginning July 1999, all commercial ships 300 gross tons and greater are required to report to a shore-based station when they enter two areas off the east coast of the United States: one in waters off Massachusetts and one off Georgia and Florida (Silber *et al*., submitted). The reporting system off Massachusetts operates year round, while the one off Georgia and Florida operates annually from 15 November to 15 April, which corresponds with periods of right whale occurrence in the region. Ship operators are required to report their vessel name, call sign, course, speed, location, destination, and route. In return, the vessel receives an automated message that provides specific (< 24 hours old) right whale sighting locations and guidance on sources for the latest information about and avoidance procedures that may prevent a collision. Thus, mariners receive updated information immediately and in real-time at the same time they enter areas of right whale aggregations. A total of 2,000-3,000 of these return messages are sent to vessels annually.

When SMAs are in effect the MSR systems advise mariners to refer to navigational publications such as the U.S. *Coast Pilot*, *Sailing Directions*, and nautical charts for information on relevant regulations, and the boundaries of right whale critical habitats and SMAs. Because these systems are mandatory and the return message goes immediately and directly to mariners entering right whale aggregation areas, mariners are reminded in real-time of active SMAs. For more information on the MSR systems, see: http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/msr.

Unlike the information contained in the U.S. *Coast Pilot* and Local and Broadcast Notice to Mariners, which includes precautions mariners are required to heed, information contained in the

MSR outgoing message is advisory in nature (*e.g*., based on this information, mariners may or may not choose to alter their actions based on locations of recent right whale sightings). However, reporting into the system is required. Because reporting is mandatory, the USCG has cited, and will cite, mariners who fail to report into the systems. Therefore, each ship that reports (hundreds per year) receives the information directed to that specific vessel and in real-time in the same locations and times that some SMAs are in effect. For these reasons, one might reasonably expect mariners in these waters to be knowledgeable of the vessel speed restriction requirements, and might also expect these messaging systems to influence their actions in subsequent voyages into U.S. ports.

National Buoy Data Center Weather Buoy Web Sites

Notices regarding SMAs are also posted via National Buoy Data Center web sites for 90-100 weather buoys stationed in waters off all eastern seaboard states and extending into some Canadian waters. Messages available to mariners seeking regionally-specific weather data are tailored regionally and may read something like "*Caution: Right whales may be active in northeast waters year-round. Mandatory speed restrictions of 10 knots apply to vessels 65 feet or greater in specific areas and times along the US east coast. Voluntary speed restrictions may be in effect in other areas and times. For current information on speed-restricted areas, go to: http://www.nmfs.noaa.gov/pr/shipstrike*".

Community Oriented Policing and Problem Solving (COPPS) Letters

NOAA recognized that mariners may not have been fully aware of the speed restrictions immediately after the rule took effect. Therefore, for approximately one year after enactment of the restrictions, NOAA's Office of Law Enforcement (OLE) sent outreach letters, rather than citations, to vessels observed traveling in excess of the specified speeds. These letters (Appendix C) were part of OLE's Community Oriented Policing and Problem Solving (COPPS) program. The letters were informative rather than punitive but contained specific information on where and when violations occurred. Between September 2009 and March 2011, OLE issued 149 COPPS letters (to over 57 companies or vessel owners).

Separate analysis is underway to determine if the COPPS letter program and other actions, including some of those identified here, have had a specific and discernable effect on mariner compliance with the speed rule.

Notices of Violation (NOVA)

Following the first year of the rule's implementation, NOAA's Office of General Counsel began issuing Notices of Violation and Assessment of civil penalties (NOVAs), to some of the more egregious (by distance, speed, or frequency) violators. Between November 2010 and November 2011, the owners and operators of 18 vessels were issued NOVAs with penalties ranging from $11,500 to $92,000 depending on the number of violations charged. NOAA's Office of General Counsel anticipates issuing additional NOVAs as soon as investigations are completed and case packages are forwarded from NMFS' OLE.

At-Sea Hailings
Through a program that ran from 2009-2011, USCG cutters directly hailed 46 vessels in SMAs that were exceeding the speed restrictions. Using VHF radio, cutter crews notified vessel operators of speed restrictions and requested that the vessel slow to appropriate speeds.

Electronic Mail Notifications and Monthly Summaries to Individual Vessels
Each time the various SMAs went into effect, NMFS and its partners sent numerous electronic mail reminders to mariners and a host of related or interested parties. Regular e-mail announcements were sent to distribution lists of 605 and 546 recipients maintained by NMFS Northeast and Southeast Regional Offices, respectively. These distribution lists include shipping agents, port authorities, scientists, non-governmental organizations, owners and operators of cruise lines, passenger vessel operators, pilots, among others. In addition, the State of Massachusetts, the Chamber of Shipping of America (CSA), the World Shipping Council (WSC), the Maritime Administration (the Administration has jurisdiction over hundreds of commercial vessels), and Lloyd's Registry sent electronic reminders to their members and distribution lists. NMFS also maintains a "rwsightings" e-mail address and when messages are sent to it, an automatic return e-mail is sent providing information on currently active SMA and DMAs. Collectively, these messages were routinely distributed to several thousand recipients.

In a separate program initiated by the shipping industry, NMFS worked collaboratively with the World Shipping Council and the Chamber of Shipping of America to directly provide feedback to shipping companies on the behavior of their individual ships in SMAs. This program, jointly developed by NMFS and these industry associations, enlisted specific companies who were given the option, and then voluntarily agreed, to participate in the program. In December 2010, NMFS began sending, once each month, reports to interested shipping companies (13 WSC and 4 CSA companies, representing a total of ca. 400 vessels that regularly use U.S. east coast SMAs) providing the dates, locations, and speeds of their vessels as they traveled within SMAs. Vessel operations data were acquired through AIS and provided to companies in the form of an Excel spreadsheet, with one worksheet per vessel. Data fields, each line representing one trip through a SMA, included:

- Vessel name
- SMA name
- Speed over ground (in knots) upon entry
- SMA Entry time
- Maximum speed over ground (in knots) while in SMA
- Date and time when maximum speed over ground was reached
- Speed over ground (in knots) upon exit
- SMA Exit time
- Distance traveled within SMA (in nautical miles)
- Percent of SMA distance traveled at >10 knots
- Percent of SMA distance traveled at >12 knots

Between December 2010 and July 2011, 141 summary reports were sent by electronic mail to shipping companies (see Appendix D for a sample email). Although analysis of this program and other specific steps to improve compliance is underway and will be presented elsewhere, we believe that providing rapid turnaround information on individual transits to specific vessel operators will be an important means to improve compliance and might serve as a model in other settings. Overall, NMFS has received positive response from the industry on this program, and NMFS intends to continue the program for the foreseeable future, as resources allow.

Transit Speed Summaries provided by the Stellwagen Bank National Marine Sanctuary
Starting in 2009, the Stellwagen Bank National Marine Sanctuary and NMFS worked with the US Coast Guard, NOAA's OLE, International Fund for Animal Welfare, and the maritime industry to provide information directly to shipping company owners about the speeds of their vessels transiting the Off Race Point and Cape Cod Bay SMAs, each of which overlap a portion on the sanctuary. In addition to highlighting the provision of the vessel speed restriction rule, each letter contained a map showing:

- Vessel Name
- Date(s) and track of that vessel's SMA transit(s),
- speed histogram(s) for each of the vessel's transits showing distance traveled in the SMA at speeds of <10 knots, 10.1-11 knots and >11 knots,
- percent of distance traveled in an SMA during which the vessel transit was out of compliance with the rule, and
- an analysis of the vessel's least compliant transit (if one existed) calculating how much time it would have taken for the vessel to transit the SMA at compliant speed (10 knots).

Data were compiled using AIS data collected by receivers located around the sanctuary. Letters (192 in 2009 and 227 in 2010) were sent to company addresses provided by the USCG and the Massachusetts Port Authority.

Compliance Guides
In advance of the speed rule going into effect, NMFS developed and widely distributed a "Compliance Guide for Mariners" (Appendix E and http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/compliance_guide.pdf). This two-sided brochure includes maps, coordinates, and dates for the SMAs prescribed in the rule. It also provides relevant text from the rule, as well as website addresses for more information. The Compliance Guide is laminated to provide waterproof protection while at sea.

In addition to posting on its ship strike reduction website, NMFS distributed nearly 3,000 laminated Compliance Guides to mariners through a number of outlets. The guides have also been distributed via electronic mail, downloaded from the NMFS website, and printed in other publications. These outlets included, among others:

- NOAA Office of Law Enforcement
- NOAA's shipping and maritime liaisons, including its Navigational Managers program and industry liaisons working under contract with NMFS
- U.S. Coast Guard, including Local Notices to Mariners
- U.S. Army Corps of Engineers

- U.S. DOT Maritime Administration (MARAD), reaching maritime labor unions (>50 companies) and a fleet of commercial vessels under contract to the Administration
- Harbor and bar pilot associations
- Marine Exchanges, these are companies that work in conjunction with ports to facilitate safe and efficient activities in individual ports
- Lloyd's Register (including ca. 2,000 companies, ca. 7,000 ships internationally)
- Maritime academies
- State police and natural resources agencies
- Shipping companies
- Shipping agents
- Whale watch companies
- Environmental organizations
- Local, regional, and national print and electronic news media
- Right whale protection notebook

Computer Training Resources

NOAA, in conjunction with the USCG and the North Atlantic Right Whale Recovery Plan Southeast Implementation Team and with input from the shipping industry, produced a computer-based, interactive guide and training resource for shipboard operations as they relate to avoiding ship-strike interactions with North Atlantic right whales. The guide, titled "A Prudent Mariner's Guide to Right Whale Protection," is available in CD-ROM format or for free download from the Internet (http://www.nero.noaa.gov/shipstrike/doc/mtr.html). It was updated in April 2009 to include information specific to the ship speed rule. Since spring 2009, NOAA has distributed more than 2,500 "Prudent Mariner" CD-ROMs.

This interactive CD program provides educational and support information intended to raise awareness of shipboard operators in areas where North Atlantic right whales may be present. Focused on operations along the U.S. Atlantic coast, the program delivers crew training information about right whales, including an introduction to right whales, recommended navigational actions when operating in right whale habitat, a guide to reporting sightings of dead or injured right whales, an informative video presentation, and a short follow-up quiz. The program also includes guidelines for compliance with the Mandatory Ship Reporting systems and a tool for submitting a report to the Mandatory Ship Reporting system. Review and knowledge of this information and having taken the follow-up quiz are required for all captains and crew of the entire cruise line industry.

Right Whale Notebooks and Merchant Mariner Education Module

NMFS has designed and distributed Shipboard Right Whale Protection Program Notebooks, which are binders of information for mariners about North Atlantic right whales. The binders contain: (a) Crew and Watchstander Training; (b) Sighting Information Sources and Collection; (c) Precautionary Measures for the Prudent Mariner; (d) "A Prudent Mariner's Guide to Right Whale Protection" dvd, and (e) Mandatory Ship Reporting Requirements, Guidelines for Mariners Placards, and Compliance Guide for Right Whale Ship Strike Reduction Rule. Between January 2009 and August 2011, NMFS distributed 544 notebooks via 10 industry, trade, or private organizations and 18 federal or state agencies or their affiliates (Appendix F).

(In addition, NMFS personnel and shipping industry liaisons distribute materials (compliance guides and notebooks) at industry specific events and conferences which accounts for an additional 250 notebooks not included in Appendix F.) Notebooks are available upon request and at no cost.

The North Atlantic Right Whale Recovery Plan Northeast Implementation Team and a contractor developed a merchant mariner education module on large whale ship strikes for maritime academy instructors in mariner safety, certification, licensing, or licensing upgrade courses to educate ship's captains. The self-contained, multi-unit module includes a Right Whale Ship Strike Curriculum Package with an Instructor's Manual and two PowerPoint education modules intended to provide Federal, state, and international maritime academic and training institutions and fleet managers with, discussion notes, implementation strategies, resource materials, and student assessments on the prevention of ship strikes of North Atlantic right whales.

The modules' lessons are geared toward use in courses on Voyage Planning, Bridge Management, Terrestrial and Coastal Navigation, Social Responsibility, Safety and Environmental Training, and Certification, Re-certification, and License Testing for mariners operating in coastal waters of the United States and Canada. The modules may also be used in sea semester training and fleet training scenarios. To date, the curricula were implemented at six mariner academies, including the USCG Academy, Maine Maritime Academy, Massachusetts Maritime Academy, Texas A&M University at Galveston, SUNY Maritime College, and the U.S. Merchant Marine Academy. These curricula are available free of charge upon request.

Trade Journal and On-line Articles

NMFS staff prepared and published articles explaining the threats to right whales and the provisions of the rule. These were submitted to 31 different trade journals in the U.S. Of these, ten journals published a total of 23 articles about the rule between December 2008 and December 2009. The target audiences of the journals included maritime industry professionals, recreational power boaters and sailors, marine engineers, and commercial and recreational fishermen. The journals are published in the U.S., in English, and circulation was primarily to U.S. residents.

The vessel speed rule was also publicized through online media. At least 63 articles about the rule were published on the Internet by numerous news groups between October 2008 and March 2011 (Appendix G). For many of these articles, NMFS staff was contacted by the authors to provide interviews.

Press Releases

NMFS, NOAA's OLE, and USCG issued 7 press releases in advance of the rule's effectiveness and again annually when SMAs were set to resume (Appendix H). These resulted in a number of stories on local and national broadcast and print media.

Events and Oral Presentations
NMFS and NOAA OLE staff took numerous opportunities to raise awareness about the rule, including providing oral presentations at conferences and public events. Public events included boat shows, whale festivals, industry meetings, conferences, and training sessions.

Between September 2008 and June 2011, NMFS staff gave at least 66 oral presentations on the rule to a combined audience of more than 2,500 individuals. Audiences included port operators, harbor safety committees, maritime associations, maritime exchanges, environmental organizations, and FM radio audiences, among others (Appendix I).

NMFS Ship Strike Reduction Web Pages
NMFS Office of Protected Resources regularly updated its ship strike reduction website with maps of active SMAs and DMAs (www.nmfs.noaa.gov/pr/shipstrike). Among other things, the ship strike reduction and large whale conservation website (Appendix J) provides links to the *Federal Register* notice announcing and explaining the final rule, the Compliance Guide, maps of all SMAs and DMAs, contact information for reporting a ship strike, information on other ship strike reduction efforts (such as routing measures and the Mandatory Ship Reporting systems) and related supporting documents.

Two additional NMFS websites relay information about the speed rule: the Northeast Regional Office and Southeast Regional Office websites each contain web pages specific to right whale conservation and the prevention of ship strikes, http://www.nero.noaa.gov/shipstrike/ and http://sero.nmfs.noaa.gov/pr/mm/rightwhales/rwconservation.htm, respectively.

Summary

In sum, in addition to providing annual updates in the U.S. *Coast Pilot,* international navigational publications, *e.g.*, *Sailing Directions* and *Notice to Mariners*, and USCG Local and Broadcast Notice to Mariners – which contain precautions and announcements for which mariners must heed as a matter of U.S. port entry - NMFS and its partners provided information about vessel speed restrictions through:

- Periodic, timely, and regionally-focused announcements issued on NOAA weather radio and NOAA weather buoy web sites;
- 149 NMFS Office of Law Enforcement's Community Oriented Policing and Problem Solving (COPPS) advisory letters going directly to vessel owners;
- 18 NOVAs (containing multiple counts of violations) issued by NOAA's Office of General Counsel;
- Annually, 2,000-3,000 automated outgoing messages sent directly to mariners entering right whale aggregation areas via the Mandatory Ship Reporting system;
- Several thousand recipients of reminders via e-mail distribution lists maintained by the World Shipping Council (WSC), the Chamber of Shipping of America (CSA), Maritime Administration, Lloyds List, NMFS's Northeast and Southeast Regional Offices and shipping liaison officers;

- Monthly summaries reporting specific vessel operations (*e.g*., dates, times, and vessel speeds) in SMAs to WSC and CSA companies representing about 400 individual vessels;
- Reminder e-mails about DMAs and the opening of SMAs are sent to a distribution list of hundreds of maritime interest groups and individual recipients;
- Nearly 3,000 compliance guides distributed by harbor pilot associations, marine exchanges, maritime academies, shipping companies, environmental groups, whale watch companies, Lloyd's Register, and several federal agencies;
- 2,500+ interactive training CDs distributed;
- Over 550 Right Whale Protection Program notebooks distributed;
- Merchant Marine training curricula modules implemented in six merchant marine academies and provided free of charge via the Internet;
- Over 20 articles published in industry trade journals;
- Seven press releases;
- Over 60 oral presentations at meetings of, for example, port authorities, harbor safety committees, maritime associations, marine exchanges, environmental organizations, schools with total estimated audiences of over 2,500 individuals;
- Numerous spots, interviews, or stories appearing on local or national television or radio media;
- At least nine oral presentations or exhibits maintained at boat shows, public events, or scientific meetings; and
- Updates and reminders provided on several ship strike related web sites.

As discussed above, the effectiveness of the speed rule at reducing ship strikes is directly dependent upon compliance with its provisions, and compliance with the rule is in turn dependent upon mariner awareness. Given the inherent relationship between compliance with the rule and an awareness/understanding of it, NMFS and its partners distributed information about the ship speed rule as broadly, as often, and as clearly stated as possible. NMFS staff has solicited recommendations from the shipping industry on outreach venues and media and has pursued or developed modified outreach efforts accordingly.

We believe the mariner awareness program and actions taken within it to be quite comprehensive, in part because it includes outlets (*e.g*., U.S. *Coast Pilots*, the USCG's Local and Broadcast Notice to Mariners) providing information that mariners are required to know and understand and to which they are expected to adhere, as well as a broad range of ancillary outlets, media, and targeted recipients. Given the breadth of this effort, we believe that a lack of knowledge about the restrictions can be ruled out as a source of observed low mariner compliance with the rule. We also believe aspects of this program may be a useful model for outreach programs contemplated for other maritime regulations. Nonetheless, we believe there are ways to improve this program (as identified in the "Recommendations" section, below). And, as noted in other sections of this report, compliance with the provisions of the rule has not been strong -- the reasons for this are not obvious.

NMFS and its partners expect to continue to distribute outreach materials related to the vessel speed restrictions through as many media as possible and continue to seek opportunities to educate mariners about the rule. The agency will also ensure that messages and materials are kept updated and accurate, while also quantifying outreach and education efforts. Many NMFS and OLE staff in the Northeast Region, Southeast Region, and Headquarters carefully tracked outreach efforts associated with the speed rule. Without their assistance in maintaining these records, this summary would not have been possible.

IV. Economic Impacts: Initial[1] estimate of economic impact of the right whale ship strike reduction vessel speed restrictions

Gregory K. Silber, Shannon Bettridge, Richard Blankfeld[2], and Gerardo Ayzanoa

Issuance of the 2008 vessel speed restriction rule was accompanied by an Environmental Impact Statement (Anonymous, 2008) and an "Economic analysis for the Final Environmental Impact Statement of the North Atlantic right whale ship strike reduction strategy" (Nathan Associates, Inc., 2008). These reports provided estimates of expected direct and indirect costs as a result of the ship strike reduction rule as it affects the shipping industry, commercial whale watch entities, passenger and fishing vessels, and associated maritime communities. These estimates also considered potential impacts to such things as intermodal (*i.e.*, land-based) transport, ports, and associated businesses.

The 2008 workshop participants recognized that any action (*e.g*., continuation or modification) regarding the provisions of the rule needed to be accompanied by an updated analysis of the 2008 economic analysis. They also recognized the value of any retrospective analysis of the impacts of the rule (as opposed to projections), because in the years following enactment of the rule, new data would be available from actual observation (or, at a minimum, updated and refined information) that would enhance any conclusions regarding economic effects. Further, whereas many aspects of the transport of goods and other elements of maritime activities may have remained relatively consistent since implementation of the rule, others may have changed. Thus, the workshop participants recommended that economic impacts be re-assessed because right whale conservation efforts should realistically be weighed against possible negative consequences.

Assessments made in 2007/2008 (Nathan Associates, Inc., 2008) relied on 2003/2004 USCG data on vessel port calls, 2004 vessel operating costs, and 2008 fuel costs. The latter two, in particular, have changed in recent years and new data information was needed to revise the estimates.

An update to the 2008 estimates was performed under contract by the same analytical team. A report of their initial assessments of direct and indirect economic impacts is provided in Appendix K and a summary is provided here. A key data improvement is the availability of Automatic Identification System (AIS) vessel operation information. These data enable analysis of *actual* vessel speeds used rather than reliance on assumptions about expected at-sea speed capabilities (actual speed data were not available for the 2008 analysis), and a quantification of

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[1] NMFS regards these as "initial estimates" because they may be subject to some refinement. For example, additional or updated information on passenger ferries may be added at a later date, and some values may change as new data are acquired. However, these changes, if any, are expected to have little overall effect on the estimates provided here. Therefore, NMFS regards these estimates as the best available at this time.

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the actual number and frequency of trips through SMAs in 2009, rather than estimates prepared from 2004 USCG port-call data. The analysis described here includes all of 2009 which provided operating information for 58,459 vessel transits through areas affected by the rule. Of these, 30,669 transits (52.5%) occurred during periods when the rule was in effect and 27,790 transits (47.5%) in times when the rule was not in effect (Appendix K, Table 1).

The goal was to estimate the economic impact to the shipping industry and overall economy from the full implementation of the rule. The analysis assumes 100% compliance with the rule (see Section II for a discussion of compliance rates). That is, the analysis assumes that all vessels subject to the rule sail at a maximum speed of 10 knots within the restricted areas when they are in effect -- and as such represents the *maximum* economic impact on the shipping industry and general economy.

The primary operational impact of the rule on the shipping industry is the extra sailing time caused when vessels limit their speed within SMAs. To make this estimate, the 10-knot speed limit was compared with the actual sailing speeds of vessels in 2009, by vessel type and size, for each area when speed restrictions were not in effect (

Table 3 and Appendix K, Table 2). Thus, estimates of the extra sailing time were calculated by subtracting the time required to sail through each restricted area in periods when the rule was not in effect from the time required at a sailing speed of 10 knots. This provides the most robust estimate for actual vessel operations and operating speeds without the influence of the rule. Only average vessel speeds of greater than 10 knots during non- rule periods were used for these calculations.

The overall weighted average delay for all vessels was 0.30 hours (18 min) and ranged from 0.03 hours (2 min) for towing vessels to 0.43 hours (26 minutes) for refrigerated cargo ships (Appendix K, Table 3). Consultant updates to the U.S. Army Corps of Engineer vessel operating costs (Appendix K, Table 4) were prepared using the retrospective annual average price of bunker fuels for 2009 and current 2012 bunker fuel prices (Appendix K, Table 5). These estimates were then used to calculate the cost of the delays for each of the vessel types and sizes.

The total estimated direct cost of the rule (assuming 100% compliance and thus the maximum estimated impact) was $22.0M and $34.8M for 2009 and 2012 bunker fuel costs, respectively (Appendix K, Tables 6 and 7).

The AIS data captures the vast preponderance of commercial maritime activity that would be subject to the speed restrictions and other operational measures. However, there are some market segments that also may be impacted by the speed restrictions. Those market segments or potential impacts include cumulative effect of multi-port strings for containerships; re-routing of southbound coastwise shipping, passenger time on ferries, and indirect economic impact of port diversions. Estimates of direct economic impacts to these segments or operations have been included in the analysis (Appendix K, Table 8). In addition, depending on the nature and significance of the direct economic impact, it is possible that implementation of the operational measures could have indirect economic impacts, including increased intermodal costs due to missed rail and truck connections, diversion of traffic to other ports, impact on local economies of decreased income from jobs lost due to traffic diversions. Estimates of these indirect costs have also been considered and included here in overall estimates of economic impact (Appendix K, Table 8), using both 2009 and 2012 bunker fuel prices.

Therefore, the maximum overall estimated direct and indirect economic impacts are $52.4M and $79.0M for 2009 and 2012 bunker fuel prices, respectively (Table 4). By way of comparison, the 2008 estimates (based on a number of assumptions[3] and less precise vessel speed information) of economic impact was $137.3M (Nathan Associates, Inc., 2008).

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[3] Among other things, the 2008 estimates assumed a 100% compliance rate with DMAs which are voluntary. See Section V for a description of the DMA program.

V. Dynamic Management Areas Compliance Analysis: Vessel operations in and around Dynamic Management Areas

Jeffrey D. Adams, Gregory K. Silber, Michael J. Asaro, and Shannon Bettridge

Voluntary conservation measures have been used in a variety of marine living resource conservation efforts, including for the reduction of vessel collisions with endangered large whale species (Vanderlaan and Taggart, 2009; Wiley *et al*., 2011; Silber *et al*., submitted). These have included voluntary vessel routing measures (Vanderlaan and Taggart, 2009; Silber *et al*., submitted), voluntary speed advisories (M. McKenna, pers. comm.; Tejedor Arceredillo, *et al*., 2008), and avoidance guidance for whale watch vessels (Wiley *et al*., 2008).

As indicated earlier in this report, as a counterpart to its mandatory vessel speed restrictions, NMFS developed a program whereby it could quickly respond with protective measures for right whale aggregations that occurred outside of historically predictable areas of occurrence by establishing Dynamic Management Areas (DMAs) that were finite in geographic scope and duration. The purpose was to provide protection to these whales, while also minimizing economic impacts to the maritime community imposed by areas in which vessel speed limits are required. Mariners were advised, but not required (*i.e*., voluntary compliance was encouraged) to either avoid DMAs or travel through them at 10 knots or less. By definition, these areas would be established immediately upon confirmation of right whale sighting locations and would expire 15 days after the date they were established. At the same time, NMFS created a program to monitor vessel operations in both required (in effect seasonally) and voluntary (in effect temporarily) vessel speed restriction zones using vessel AIS technologies. Here, we provide a brief summary of the results of a study of vessel operations within DMAs. The full results will be , or have been, provided elsewhere (Adams *et al*., 2011) and in submissions to the peer-reviewed literature (*e.g.*, Asaro, 2012).

Establishing DMAs

The onset of a DMA was triggered by a reliable sighting (derived primarily from systematic aircraft surveys for marine mammals) of three or more right whales in U.S. waters within a 75 square nautical mile (nm) (138.9 km^2) area, such that right whale density was greater than or equal to 0.04 right whales per nm^2. This is consistent with a protocol suggested by Clapham and Pace (2001), and based on the assumption that whale groups at these densities would persist for an extended period. Additional (15 nm) buffer areas were then developed around the sighting location to account for potential whale movement and incorporated into a single polygon encompassing both the sighting location and its surrounding zone. Each DMA expired 15 days after the date of being established; however, if whale aggregations that met the density threshold persisted into the DMA's second week, the DMA was extended for an additional 15 days. DMAs were not established in, and therefore did not overlap, with SMAs.

The maritime community was notified about the creation of a DMA in these ways: NOAA Weather Radio broadcast on a regular basis for the full duration of the DMA; USCG broadcast notice to mariners; an email distribution list (605 recipients of shipping industry liaisons and industry representatives, pilots associations, harbor masters, marine exchanges, etc); the

Mandatory Ship Reporting automatic return message to vessels; postings on NMFS' Office of Protected Resources ship strike web site and Northeast Fisheries Science Center interactive right whale sightings "mapper"; and an automatic return message sent to mariners requesting information by electronic mail.

Vessel Operations in DMAs

A total of 69 DMAs were established between December 2008 and June 2011 (we limited our analysis to those DMAs enacted prior to June 2011). Of these, 59 occurred in waters off New England and 10 off the southeast U.S. coast. All but one of the 59 DMAs established in New England waters were rectangular in shape, while those occurring in waters off Georgia and Florida tended to be irregular in shape due to their juxtaposition to existing SMAs, broadly distributed whale sighting locations, or other (*e.g.*, oceanographic) features. Three of the 10 DMAs off the southeast U.S. were omitted from the analyses due to their proximity to active SMAs, because the presence of an SMA might skew results with regard to the behavior (*e.g.*, vessel speed) of vessel operators. The areas encompassed a combined estimated total of 905 individual whale sightings, although these included repeat sightings of the same individual whales that recurred in the same areas between or within the same years (Appendix L).

The 59 DMAs analyzed in northeast U.S. waters occurred in all months of the year, and most were established in November (n = 6), December (n = 9), and January (n = 8). The relative frequency of the occurrence of DMAs throughout the year were influenced not only by the seasonal occurrence of right whales, but also by a varying amount of aircraft survey effort throughout the year and the DMA protocol itself which indicates that DMAs would not be overlain with established SMAs. Thus, the locations of DMAs may not necessarily be a true reflection of right whale occurrence in all locations and times, but they do reflect a substantial amount of right whale occurrence outside SMA boundaries.

We used vessel positions gathered from the USCG's National AIS program to assess vessel operations within 66 DMAs. Vessel position information was aggregated into individual transits using methods similar to those described in Chapter II, above, and in Silber and Bettridge (2010). Unlike the SMA analysis, we did not limit the analysis to vessels over 65 feet (19m) because the 2008 rule did not stipulate a vessel size or class. All speeds reported here refer to "speed over ground."

Vessel transit speeds and routes were examined to determine if basic vessel operations changed in response to the DMAs. Specifically, transit speeds were analyzed to detect whether vessels altered speed as they entered the DMAs. We limited analysis to transits that included at least 5 nautical miles (nm) of travel both inside of the DMAs and in 10 nm buffers drawn around the DMAs. To ensure representative travel speeds, we limited the analysis to transits that had minimum speeds of 5 knots or greater. Vessel speeds inside DMAs and outside DMAs (*i.e.*, buffers) were compared using paired t-tests for all vessels combined, as well as for cargo, tanker, and passenger vessels.

Vessel routes were also examined to quantify the number of transits that may have involved course alterations to avoid traveling through the DMAs. For vessels whose transits were located entirely within the 10 nm buffer, the first and last points of the transit were used to create line features. If the line features intersected the DMA, the transit was considered a potential avoidance transit (Appendix M). This analysis was conducted for transits initiated during the effective periods as well as the two-week periods directly preceding and following the effective periods.

Results and Discussion

A total of 3,324 transits that consisted of at least one nautical mile occurred within the DMAs during their respective effective periods. These transits were made by 1,100 individual vessels. The majority of the trips were made by tankers (n = 961), cargo vessels (n = 781), and tugs (n = 370) (Appendix L).

We observed lower mean speeds in the active DMAs relative to the 10 nm buffer areas surrounding the active DMAs, but the differences were small (Appendix N). The largest difference was observed for passenger vessels, whose mean speed was 16.1 knots in the 10 nm buffers and 14.1 knots in DMAs (Appendix O). Mean speeds for all analyzed vessel types were above the requested maximum speed of 10 knots. Avoidance transits during the active periods of DMAs were detected for 18 of the 66 DMAs analyzed (Appendix P). For 11 of 18 DMAs with avoidance transits during the active period, avoidance transits were also detected in either the two-week period directly preceding and/or following the active period, suggesting that other factors (*e.g.*, recommended vessel routes, traffic separation schemes, etc.) most likely play a role in the routes of the avoidance transits.

Although the DMA program may have had some tacit benefit in raising the awareness of mariners to the problem of right whale vulnerability to ship strikes, when measured by vessels either avoiding an area or restricting speed while in it, the DMA program likely had little or no impact in reducing the occurrence of ship strikes. The nuances of these data (*e.g.*, perhaps with regard to adherence to the provisions of DMAs by certain vessels or certain vessel types, or in certain times or locations) will be explored further in subsequent analysis.

Voluntary measures have received considerable use in a variety of environmental issues (National Research Council, 2002; Morgenstern and Pizer, 2007). As a means to alter human behavior, voluntary approaches are generally preferable to regulatory actions (at least as a first tier approach), because the former do not require the development of potentially costly monitoring, policing, and penalty regimes, are less prone to litigation, and can promote innovation and solutions by the affected community (Khanna, 2001; Rivera and de Leon, 2004). However, in many cases in which voluntary approaches have been tried, they have not attained their intended goals.

As to large whale vessel strike reductions, voluntary measures appear to have been successful in some situations and relatively unsuccessful in others (Wiley *et al*., 2008; Vanderlaan and Taggart, 2009; Lagueux *et al*., 2011; Silber *et al*., submitted; M. McKenna[4], *pers. comm.* 2011)

[4] Megan McKenna, U.S. Marine Mammal Commission, Bethesda, MD.

at least as success is measured by vessel operator adherence to the requested actions. Based on this study, we conclude that DMAs, as measured by mariner response to the voluntary measure, likely had only modest, if any, consequence in lowering the risk of vessel collisions with right whales.

VI. Conclusions and Recommendations

Conclusions

Vessel speed restrictions were established in certain times and locations to reduce the likelihood of ship strikes of the highly depleted North Atlantic right whale. The restrictions were set to expire five years from the date of issuance (*i.e.*, 9 December 2013) and in issuing the restrictions, NMFS indicated it would assess the effectiveness of the rule. It convened a workshop in 2008 to determine the means for doing so. NMFS has completed the analysis and herewith presents findings and considerations for next steps.

These results are based on statistical analyses of 55 large whale ship strike deaths or serious injuries having occurred over the course of 10 years; literally hundreds of millions of AIS data points used to characterize vessel operations and economic impacts represented in hundreds of thousands of passages taken by thousands of individual vessels both within and outside Seasonal and Dynamic Management Areas; and maritime community awareness-raising efforts organized by a number of NMFS personnel and through hundreds of contacts using various print and broadcast media. Although these data sets were substantial, it is not possible at this time to make definitive statements about the biological effectiveness of the rule. The time allotted to determine the biological effectiveness was simply too brief.

Participants in the 2008 workshop indicated that several years was almost certainly too brief a period to determine if the vessel speed restrictions were effective in substantially reducing ship strikes – and that several years would not be sufficient to determine if recovery was being influenced at a population level. Nonetheless, NMFS set out to assess various aspects of the program although some of these (*e.g.*, vessel monitoring) are only indirect measures of "effectiveness." These constraints notwithstanding, we have found that certain conclusions, summarized below, can be made from these assessments.

Known ship strikes – Changes in the rate of whale ship strike deaths cannot be detected in two or three years. Using the method identified here, it may be possible to detect some rather large (*e.g.*, a reduction of 30-60%) changes in five to seven years. Therefore, based on results presented here, definitive statements cannot be made about the effectiveness of reducing the occurrence of vessel strikes using vessel speed restrictions – longer time series are needed to better make such an assessment.

Vessel operations – Strict adherence to 10 knot speed restrictions was unacceptably low, but it improved through time and there are signs that an across-the-board lowering of vessel speeds will continue. The improvements are most probably due to upgraded enforcement efforts and other specifically targeted efforts to improve compliance. Foreign-flagged vessels exhibited lower compliance rates than did domestically owned and operated vessels.

Outreach – Overall, hundreds of individual efforts were made to communicate or provide material to mariners and the maritime community. We believe this to be a highly comprehensive outreach effort (and may serve as a model for other programs), but there are ways in which it might be improved, more effectively reaching foreign flagged vessels, for example.

Economics – Actual economic impacts were substantially lower than projected in 2008. Revisions to the original estimates based on updates to such things as actual bunker fuel costs (in 2009) and the use of 2009 AIS data to quantify (rather than estimate) vessel operations indicate that the economic impact was $52.4M ($79.0M using 2012 bunker fuel prices). The 2008 projected economic impact was $137.3M. The revised estimates also assume 100% compliance (*i.e*., all trips in all active SMAs did not exceed 10 knots) and therefore should be regarded as the maximum economic impact on the shipping industry and general economy.

Dynamic Management Areas - Mariner observation of voluntary speed restrictions or voluntary avoidance of DMAs was minimal. NOAA made extensive efforts to notify mariners about DMAs, and although it is beyond the scope of our study to determine why adherence was low, we believe that the lack of adherence to the DMAs was due more to their voluntary nature than to a lack of awareness of the management zones.

Recommendations and considerations for reducing vessel strikes of right whales through a vessel speed restriction program

The purpose of this section is to offer generalized suggestions about agency considerations if modifying the provisions of the vessel speed restriction rule and its related programs is warranted. Based on the results presented here, "lessons learned" in implementing the program, and other observations, we offer a number of recommendations about next steps and ways to improve the program to further right whale ship strike reduction. They are actions for consideration to further the goal of maximizing protection of right whales using the best available science while also considering economic impacts to the shipping industry and other maritime communities. These suggestions will require proper vetting, in some cases further analysis, may require rulemaking, and will be subject to adequate funding. Some components of this program (*e.g*., outreach efforts, vessel monitoring) likely should be continued with only small modifications; while others (*e.g*., dimensions of SMAs) may need re-evaluation. Because a number of aspects of this program -- regulating vessel speed in large geographic areas; monitoring a regulation using AIS; and use of a precise and remotely-sensed technology to assess vessel compliance and economic impacts -- were novel and heretofore not attempted, they are not flawless, and we therefore also provide thoughts on ways to improve these systems and programs.

A list of recommendations below is followed by a section that provides a discussion of, further information about, or justification for each recommendation.

List of Recommendations

Recommendations regarding modification of the vessel speed restriction rule

- *Vessel speed – While it is not possible to make definitive statements about the biological effectiveness of the vessel speed regulations at this time, existing evidence (based on studies appearing in the scientific literature both before and after enactment of the rule) is persuasive in indicating that vessel speed restrictions should continue as a means to reduce ship strikes of right whales. Therefore, NMFS should continue to use this tool as a means to reduce lethal vessel collisions with whales.*
- *Modification of the rule – Consideration should be given to modifying certain aspects of the regulation to enhance its capacity to reduce vessel strikes, while also giving strong consideration to economic and other impacts to various maritime communities.*
- *Size of SMAs – Consideration should be given to either expanding the sizes of the SMAs to encompass a large portion, if not all, of the recurring DMAs, or to establishing new SMAs.*
- *Vessel size – Consideration should be given to means to include smaller vessels in speed restrictions or other means to reduce strikes inflicted by small vessel classes.*
- *Dynamic Management Areas and Mandatory vs. Voluntary Measures*
    - To improve the conservation value of the DMA program, *NMFS should consider (a) doing away with it altogether and focus these efforts on more pragmatic and effective means of reducing ship strikes, (b) making the conditions of dynamically managed areas mandatory for vessel operators, or (c) expanding mandatory SMAs into areas and in times where DMAs are predictably recurring*.
    - *Possible limitations of both voluntary and mandatory measures as briefly addressed here should be considered when these types of measures are contemplated in the future*.
- *Sovereign Vessels – Exemptions for sovereign vessels should be retained in any subsequent rulemaking for the reasons indicated in the rule, namely due to the need to avoid hindering efforts with regard to such things as national security, safety of life at sea, and other vital missions. However, all vessel operations under control of federal entities should be the subject of consultation under section 7 of the ESA if not already subject to an existing Biological Opinion.*

- *Requested deviations from vessel speed restrcitions – In developing modifications to the vessel speed rule, the Office of Protected Resources should work with the Office of Law Enforcement, General Counsel, the shipping industry, and others to review and evaluate existing exemptions in the rule (including for state law enforcement vessels) to determine if they should re-instated, modified, and/or streamlined in any way.*

Recommendations regarding monitoring and compliance

- *Monitoring –*
    - *Maintain strong monitoring programs.*
    - *Continue use of AIS, or a related system, preferably through a single, centralized system, for monitoring vessels*.

- *Anticipate and plan for analysis of reasonably long time series to monitor the rate of ship struck right whales – possibly using the metric used here. An assessment should be done and a report provided every five years regarding trends in right whale ship strike deaths and serious injuries and to assess elements of this program.*
- *Efforts to detect and necropsy right whale ship strike deaths should continue at appropriate levels to ensure adequate sample sizes for ongoing analysis.*
- *Aerial and shipboard right whale surveys should continue at appropriate levels to ensure proper notification to mariners of right whale locations (i.e., through the aircraft survey programs, MSR system) and to determine when and where to establish (or extend) DMAs.*

- *Improving compliance –*
  - *It is likely that enforcement programs are key to the success of this or any regulation, and adequate resources and plans for execution are essential.*
  - *Emphasis should be placed not only on attempting to determine the causes of discrepancies in compliance between domestic- and foreign-flagged vessels, but in finding ways to improve compliance among international communities, in particular.*
- *Raising mariner awareness –*
  - *An examination should be conducted, likely through a set of surveys of maritime communities, to determine whether outreach efforts are reaching their intended audiences, whether they have in fact resulted in a change in behavior of the recipient, and to ensure outreach efforts are cost-effective.*

Discussion of Recommendations

Vessel speed
The use of vessel speed restrictions to reduce lethal vessel strikes of right whales was based largely on analysis by Laist *et al*. (2001), Pace and Silber (2005), and Vanderlaan and Taggart (2007). These studies, alone, indicate that the likelihood of serious injury and death in whales struck by vessels is diminished by reduced vessel speed. The latter two analyses indicate that the probability of death or a serious injury to a struck whale is rapidly when vessel speeds are below 12 knots diminished (and the probability decreases as speed decreases). Using this logic, vessel speed restrictions are being used in other locations to reduce the threat of ship strikes to large whale species (*e.g*., humpback whales in Glacier Bay, AK; fin and sperm whales in the Mediterranean Sea).

Based on probability analysis alone (*e.g*., Pace and Silber, 2005; Vanderlaan and Taggart, 2007), the vessel speed restrictions are expected to reduce lethal ship strikes – and they, alone, likely justify continuation of the restrictions – although it is not possible to demonstrate this statistically in restricted time frames. The original ideas and findings have been backed by additional, more recent studies.

Since enactment of the vessel speed rule, several studies have appeared in the peer-reviewed literature on this topic that appear to confirm these conclusions. Among them, Vanderlaan *et al*.

(2009; right whales along the U.S. and Canadian eastern seaboard), Vanderlaan and Taggart (2009; right whales in Canadian waters), and Gende *et al*. (2011; humpback whales in Alaskan waters) concluded that vessel speed restrictions are effective in reducing the occurrence or severity of vessel strikes of right and other large whale species in various geographic locations. More specific to the context of this report, Lagueux *et al*. (2011) and Wiley *et al*. (2011) reported that implementation of NOAA's 2008 vessel speed restrictions have reduced the probability of lethal vessel strikes of North Atlantic right whales by 39% and 57% in waters off the southeast U.S. and off New England, respectively. In addition, Silber *et al*. (2010) found that both the size of the zone of influence (*i.e*., the area in which a whale is vulnerable to a strike or might be drawn into a strike) around the hull of a vessel, and acceleration (*i.e*., impact force) experienced by the whale, increases as vessel speed increases.

Therefore, based on these original results and conclusions having appeared in the peer-reviewed literature since the rule was enacted, we *recommend that vessel speed restrictions be maintained as a means to reduce ship strikes*. *We further recommend that consideration be given to modifying certain aspects of the regulation to enhance its capacity to reduce vessel strikes, perhaps by increasing the scope, while also giving strong consideration to economic and other impacts to various maritime communities*.

Modification of the rule
*Provisions of the vessel speed rule include certain variables (*e.g.*, vessel length, vessel speed) that, if modified, may increase their overall conservation value. For example, in its November 2008 rulemaking, NMFS indicated that*

> "Based on available data, NMFS will consider adjusting the regulations. Such actions would be taken through additional rulemaking. Measures that NMFS could consider may involve vessel size, vessel routing (*e.g*., making recommended routes mandatory), vessel speed, making dynamically managed areas mandatory, and the size and duration of the areas where the restrictions apply."

Therefore, in keeping with the thinking that adjusting one or more of these variables may be used to further limit ship strikes, NMFS might consider *modifying certain aspects of the regulation to enhance its capacity to reduce vessel strikes, while also considering economic impacts and related factors.*

Dimensions of Seasonal Management Areas
With regard to SMA sizes and the locations of their boundaries, NMFS indicated in the Rule's preamble that it would

> "…continue to monitor right whale sighting locations relative to these boundaries and may modify [the size of SMAs], as appropriate, if changes are warranted based on shifts in right whale occurrence or additional analysis."

While such analysis has not been conducted for the purposes of this report, NMFS should evaluate the size and locations of the SMAs to determine if modifying their dimensions to enhance the extent of their protection is warranted. Establishment of these management zones was predicated on encompassing areas where right whales could reliably and predictably occur, while also limiting their size to minimize economic impacts to maritime communities.

Analysis of the number, timing, and locations of DMAs (Asaro, 2012; Adams *et al*., this report) indicate that a relatively large number of DMAs have occurred regularly in certain locations in waters off New England. These studies suggest that to include a large number of right whale observations that have occurred incidentally outside SMAs, *consideration should be given to either expanding the sizes of the SMAs to encompass a large portion, if not all, of the recurring DMAs, or to establishing new SMAs*. In addition, Schick *et al*., 2009 concluded that hypothetical SMAs that extended to 30 nm from shore and around port entrances would provide more protection for migrating right whales than do the existing SMAs with 20 nm radii. Such studies and other sources, such as an evaluation of right whale sighting information obtained since implementation of the rule should be important assets in making determinations of the locations, timing, and size of SMAs, as counterbalanced against economic impacts, in future rulemaking.

Vessel Size

Decisions regarding the size of vessels to which the vessel speed restrictions would apply were based, in large part, on conventions adopted by the USCG, the International Maritime Organization, and the maritime community whereby many regulations and guidelines are based on vessel sizes of either 300 gross tons or 65 feet in length. Nonetheless, in its rulemaking, NMFS acknowledged the occurrence of vessel strikes of right whales by vessels less than 65 feet in length and that these vessels may pose a threat to right whales. Indeed, since implementation of the rule, one known vessel strike of a right whale occurred by a (sovereign) vessel that was 50 feet in length. In its rulemaking, NMFS, therefore, indicated that it would

> "…continue to consider means, including future rulemaking, to address vessel classes below 65 ft (19.8 m). Additionally, in collaboration with other organizations, NMFS will continue to engage in education and outreach programs regarding right whale vulnerability to ship strikes specific to the recreational, fishing, and other coastal maritime activities that involve vessels less than 65 ft (19.8 m)."

As noted in the "Education and Outreach" paper contained in this report, NMFS has engaged in a number of awareness- raising efforts in regard to small vessels operation. These efforts may or may not be sufficient to limit strikes occurring in these vessel classes. Therefore, *NMFS should consider means to include smaller vessels, if possible, in speed restrictions or other means to reduce strikes in such vessels*.

One significant consideration in this regard is that adherence to rules and other activities by such vessel classes may be difficult to monitor. As noted, NMFS is currently monitoring vessel operations using AIS technologies; however, by international convention and USCG requirements, only vessels 65 feet or greater are required to carry AIS transmitters. Therefore, if smaller vessel classes are included, monitoring adherence to rules affecting these vessels would be difficult, and means to do so would need to be developed. In addition, smaller vessel classes include a wide variety of vessel types including self-, wind-, jet-propelled craft. Therefore, whereas these vessels may pose a threat to right whales, means to include them, including the consideration about, for example, appropriate vessel lengths and classes and means of propulsion, in ship strike reduction measures may be challenging.

Dynamic Management Areas and Voluntary vs. Mandatory Measures
In efforts to reduce lethal vessel strikes of whales, NMFS has taken a number of management actions – some requesting voluntary changes in vessel operations, some mandatory (*e.g*., vessel speed restrictions). Although the virtues of voluntary measures are not being specifically addressed here, some studies have indicated that voluntary changes to vessel operations to reduce strikes have been adhered to (in the case of recommended routes (Lagueux *et al*., 2011)) and an International Maritime Organization-endorsed Area To Be Avoided (Vanderlaan and Taggart, 2009); while others have not (in the case of whale watch boats avoiding whales (Wiley *et al*., 2008)).

In its 2008 rulemaking, NMFS indicated it would:

> "…monitor voluntary compliance with designated DMAs. If adherence is not satisfactory, NMFS will consider making them mandatory, through a subsequent rulemaking."

The analysis of DMAs contained in this report (Adams, *et al*., above) about vessel operations and the relatively low adherence to vessel speed advisories within DMAs should be an important consideration in assessing whether DMAs should be made mandatory and whether the DMA program should continue at all. Bearing in mind, too, that our analysis indicates that even requisite changes in vessel operations (*i.e*., required vessel speed restrictions) are no guarantee that they will be adhered to and compliance will be automatic. Therefore, *the limitations of both voluntary and mandatory measures should be considered when required or voluntary measures are contemplated in the future*.

Adherence to the conditions of DMAs is voluntary, and the number of vessels avoiding or traversing these areas at 10 knots or less, as recommended, is low. Therefore, to improve the conservation value of this program, *NMFS should consider (a) doing away with the DMA program and focus these efforts on more pragmatic and effective means of reducing ship strikes, (b) making the conditions of dynamically managed areas mandatory for vessel operators, or (c) expanding mandatory SMAs into areas and in times where DMAs are predictably recurring*.

Deviations from Requirements of the Rule
The existing Rule provides certain deviations from the provisions of the rule to those vessels subject to the vessel speed restrictions under adverse meteorological or oceanographic conditions that might jeopardize navigational safety. A ship's captain can, based on local conditions and his or her judgment of those conditions and the safety of the vessel, deviate from the 10 knot speed restriction. Any such deviations and the justification for doing so must be properly documented in the ship's logbook. NMFS continues to believe that allowing such deviations is necessary for the safety of life at sea, but NMFS also has reason to believe some vessel operators regularly deviate from the required ten knot speed limit when conditions do not require it. Therefore, in

developing modifications to the vessel speed rule, *the Office of Protected Resources should work with the Office of Law Enforcement, General Counsel, the USCG, the shipping industry, and others to review existing exceptions in the rule to determine if they should be re-instated, modified, and/or streamlined in any way* and in such a manner to ensure navigational safety while also enhancing the conservation value of the restrictions. While some exceptions are probably necessary, there may be ways to improve how these are implemented and recorded.

Sovereign Vessels

Sovereign vessels – those vessels owned or operated by Federal agencies or through contract with Federal agencies – are not required to comply with provisions of the existing rule. This includes vessels operated by the U.S. Navy (USN) (and foreign sovereign vessels when they are engaging in joint exercises with the USN), the USCG, the Army Corps of Engineers (ACOE), NOAA, and several other agencies. The reasons for this, as stated in the 2008 rule, are

> "the national security, navigational, and human safety missions of some agencies may be compromised by mandatory vessel speed restrictions."

NMFS indicated further that:

> "[h]owever, this exemption will not relieve Federal agencies of their obligations to consult, under section 7 of the ESA, on how their activities may affect listed species. NMFS acknowledges that a number of agencies already provide guidance to vessel operators and fleets with regard to conservation measures to protect right whales and other endangered species, as well as contribute to conservation efforts generally."

We recommend that exemptions for sovereign vessels remain in place if subsequent rulemaking that is contemplated. The reasons for the exceptions remain. In addition, some federal entities such as the USN, USCG, and the ACOE either consult with NMFS under section 7 of the Endangered Species Act (ESA) in regard to their vessel operations, or operate under the provisions of existing ESA Section 7 Biological Opinions. In addition, for years, the USN and USCG have had standing orders for their Atlantic fleets to adhere, to the extent possible, to right whale ship strike reduction measures. These programs should be updated, if needed, and continued.

However, as noted above, text in the preamble of the rule indicates that NMFS would recommend that all federal entities operating in U.S. east coast waters to initiate consultations under the ESA. In large part, these consultations have not occurred. Perhaps most notable is that vessel operations housed in various NOAA programs have not undergone consultation. A case in point is a right whale struck and perhaps seriously injured by a vessel operated under a NOAA National Marine Sanctuary program did not result in the initiation of a consultation. This track record needs to be improved. Therefore, we recommend, as previously indicated in the 2008 Rule, that *all vessel operations undertaken under control of federal entities (i.e., operations of all sovereign vessels) be the subject of consultation under Section 7 of the ESA if not already subject to an existing Biological Opinion*, or re-initiated as new information related to the Opinion is received.

Monitoring
Strong monitoring programs provide mechanisms for improving conservation programs. We, therefore, recommend that *attention be given to maintaining a strong vessel monitoring program* for both voluntary and mandatory measures.

Monitoring -- Vessels
With regard to monitoring vessel operations, and therefore compliance with the speed restrictions, we have found that the use of AIS has provided a comprehensive, cost-effective, and precise means to monitor vessel operations and we *highly recommend AIS, or a related system, be maintained for monitoring vessel operations* (although new monitoring technologies should also be considered as they are developed), *preferably in a single, centralized network.* In addition to providing a platform for a detailed analysis of vessel operations, this system has been compatible with the development of programs that provide feedback directly to vessel operators about their actions to improve compliance (this has been done in both conjunction with this program and by Wiley *et al*., 2011), and a means to supplement enforcement actions. In another program initiated by the World Shipping Council, NMFS has been working in collaboration with the Council and USCG in an attempt to use existing AIS outgoing messaging capabilities to provide immediate feedback to mariners that exceed 10 knot speed restrictions. Although initiated, the program may take several years to develop.

An AIS-based program has had a number of virtues. Data were collected remotely and cost-effectively. For the analysis presented here and in a host of related analyses, NMFS relied heavily on the USCG's established network of receiving stations. Although aspects of the USCG's system are still under development (and some may be becoming obsolete and others unfunded), it has been an invaluable resource to this program and any effort to continue or enhance it should be encouraged. Given the rate at which data are transmitted and the wealth of information they contain, the AIS is highly precise in assessing vessel positional and speed operations. And, as the 2008 workshop participants recommended, such a system would logically be *based on a centralized AIS network*. There are, nonetheless, downsides to this system as well: the amount of incoming data for archiving, processing and analyzing is formidable and not all transmissions are flawless due primarily to operator error.

Monitoring -- Whale deaths and serious injuries
As noted above, one to five years is not an adequate time to assess whether ship strike deaths have been lowered. Therefore, NMFS should *anticipate and plan for analysis of reasonably long time series to monitor the rate at which right whales are struck by vessels*. The metric described and used here (time elapsed between subsequent large whale ship strike deaths) is one very good possibility for ongoing monitoring, and there may be other related means to conduct this type of assessment. In addition, NMFS should plan on continuing these monitoring efforts and *should provide a report every five years of right and large whale ship strike death and serious injury rates and trends*. Related to this, *efforts to detect and necropsy right whale ship strike deaths should continue at appropriate levels*.

Improving Compliance and Improving Awareness

Compliance with the restrictions generally has been low – but, indications are that speeds across all vessels sampled were trending lower by 2011 (see Bettridge and Silber, above). It is not clear why compliance rates were low and this matter should be the subject of additional study. This, and analysis that will be presented elsewhere, indicates that compliance improved among certain sectors of the shipping industry particularly when NMFS' Office of General Counsel began to issue citations. (At the time of this writing more citations are being processed). Therefore, it is likely that *enforcement programs are key to the success of this or any regulation, and adequate resources and plans for execution are essential*.

Our analysis (Bettridge and Silber, above) also indicates that compliance was notably lower in foreign-flagged vessels than was exhibited by those owned and operated by domestic entities. Here, again, the reasons for this are not clear and factors may include infrequent or irregular U.S. port calls, notifications having never reached operators of foreign flagged vessels, communications were received but not well understood possibly due to language barriers, a lack of understanding of U.S. regulations, or other reasons. Whatever the reason, *emphasis should be placed on not only attempting to determine the causes of these discrepancies, but in finding ways to improve compliance in these segments of the shipping community*.

One clear first step toward improving compliance is that NOAA should work, immediately, to *ensure vessel speed SMAs are depicted on NOAA's paper and/or electronic charts*. In addition, consideration should be given to the translation of some materials into other languages and/or the consideration of new outlets for distribution. Another approach to consider is wider distribution of articles in foreign trade magazines. As a related matter, *federal agencies that own or operate vessels (including those under contract) should consult, or be encouraged to consult, with NMFS under the provisions of the Endangered Species Act regarding the operation of their vessels*.

As noted above, NMFS has made efforts to communicate the requirements of the vessel speed restrictions to various maritime communities and through a variety of media. The goal was to blanket the affected communities as completely as possible. Viewed in terms of quantity and amount of coverage, we regard this program as highly successful. Indeed, the structure and scope of this effort may be a model for outreach programs for other regulatory actions. Although extensive in scope and coverage, one shortcoming of this effort is an assessment of whether the efforts have achieved desired outcomes.

Although not known with certainty, it is possible that compliance was improved by the extensive outreach program undertaken, and inasmuch as most material and broadcasts are produced and distributed relatively inexpensively, these may be highly cost-effective ways to alter vessel operations. Intuitively, among these, steps taken through customary or required media for those navigating in U.S. waters, U.S. *Coast Pilots*, Broadcast and Local Notices to mariners, for example, are likely the most effective in directly reaching the shipping industry. Mailings going directly to shipping companies with information about the operations of their vessels, specifically, likely were also strong motivators for vessel operators to understand and abide by the restrictions.

The agency has tracked and quantified its outreach efforts; however, the impacts of these efforts have had on relevant entities have not been determined and there may be ways to improve the program. NMFS has not conducted an analysis of whether (a) these various media outlets reached their intended targets, (b) once distributed, they reached actual vessel operators; or (c) they actually resulted in changes in behavior. Nor has an assessment been done to determine which of the individual outreach efforts have had the most (or most cost-effective) impact. The participants of the 2008 workshop discussed the possibility of performing a marketing survey to assess awareness about the rule. To date, no such survey has been conducted, but doing so (subject to funding availability) would be useful in determining whether outreach efforts were successfully targeting relevant affected entities, whether they were prompted in some way to respond, and if so, whether behavior actually changed; or conversely, whether the materials, approach, or outlets should be modified. Therefore, we believe it advisable to conduct a set of surveys to answer these questions as a means to improve the effectiveness and cost-effectiveness of outreach efforts.

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FIGURES

Fig. 1. Locations of vessel speed restriction Seasonal Management Areas (NMFS 2008)

Fig. 2. Dates of active SMAs. Shaded cells represent SMA in effect.

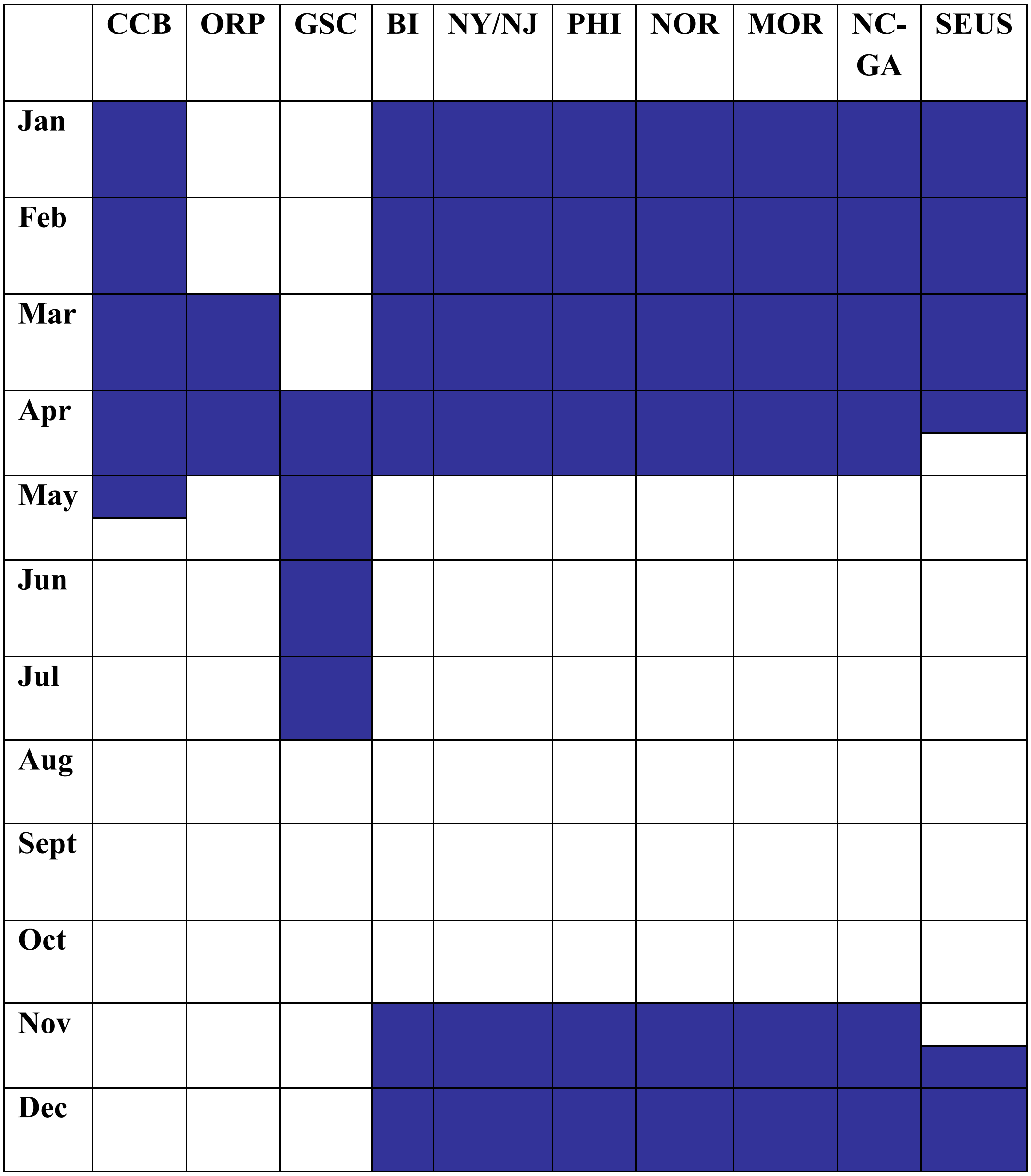


Fig. 3. Proportion of use of each SMA by domestic and foreign flag vessels in 2009, 2010, and 2011.

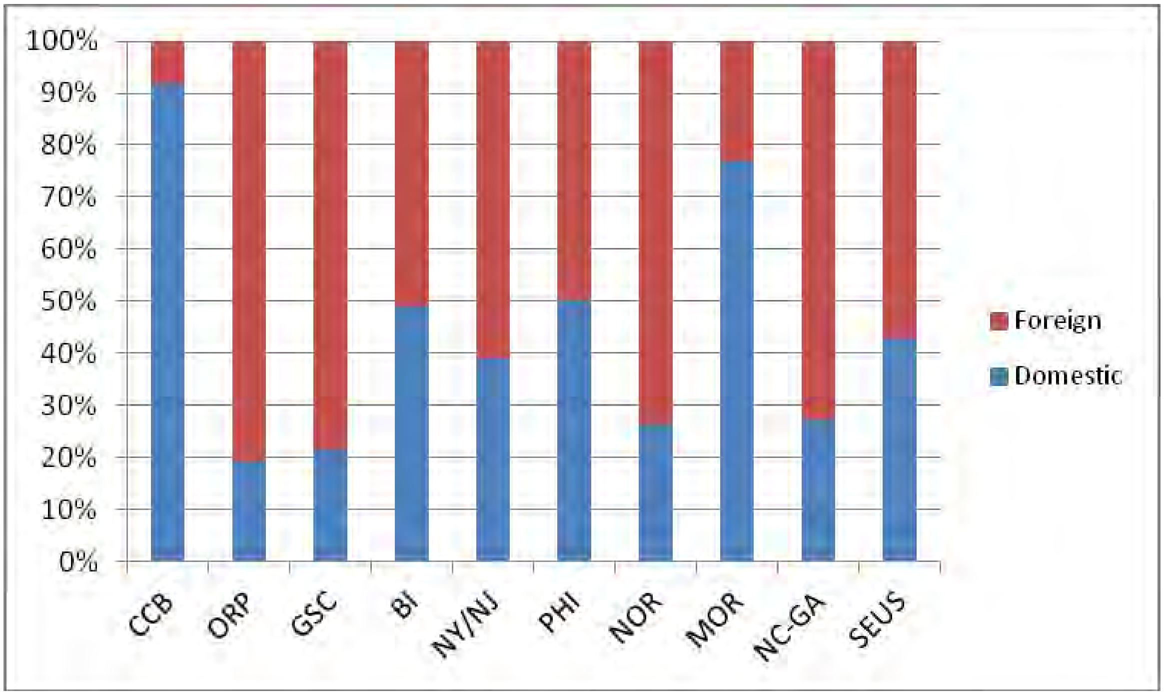


Fig. 4. Distribution of vessel types transiting all SMAs in 2009, 2010, and 2011.

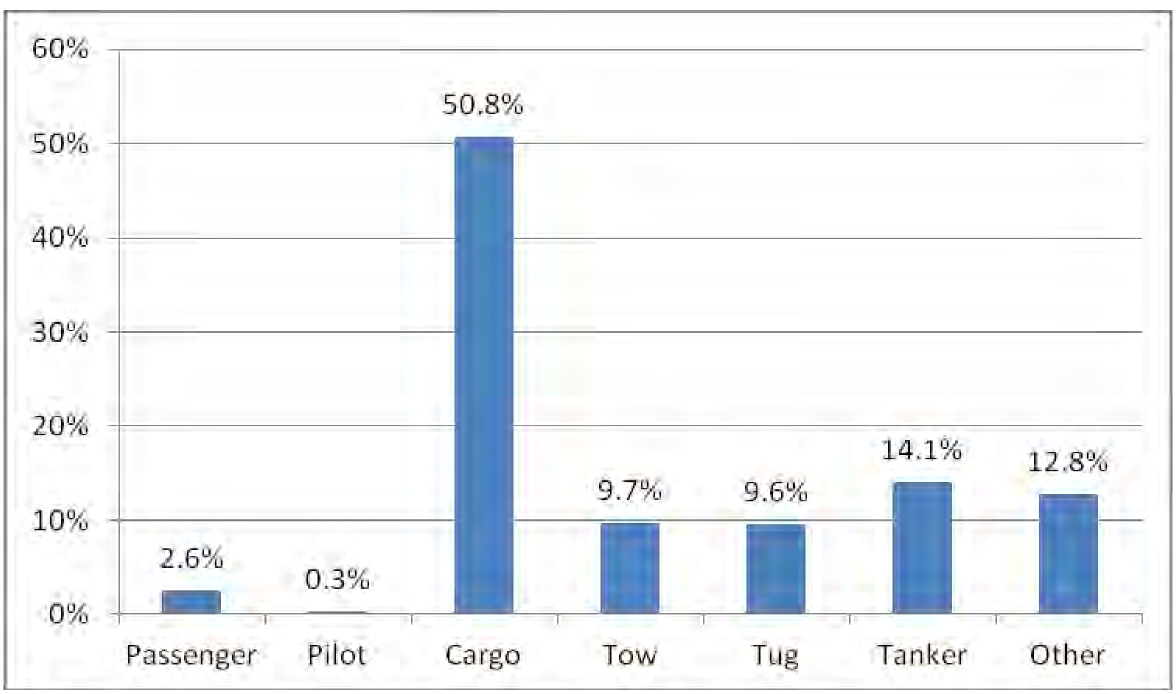


Fig. 5. Number of transits in each SMA by vessel type in 2009, 2010, and 2011. (Note: CCB, GSC, and ORP SMAs were collapsed into "NEUS" category for this figure because the numbers of transits in each of these SMAs were imperceptible given the scale of this graph.)

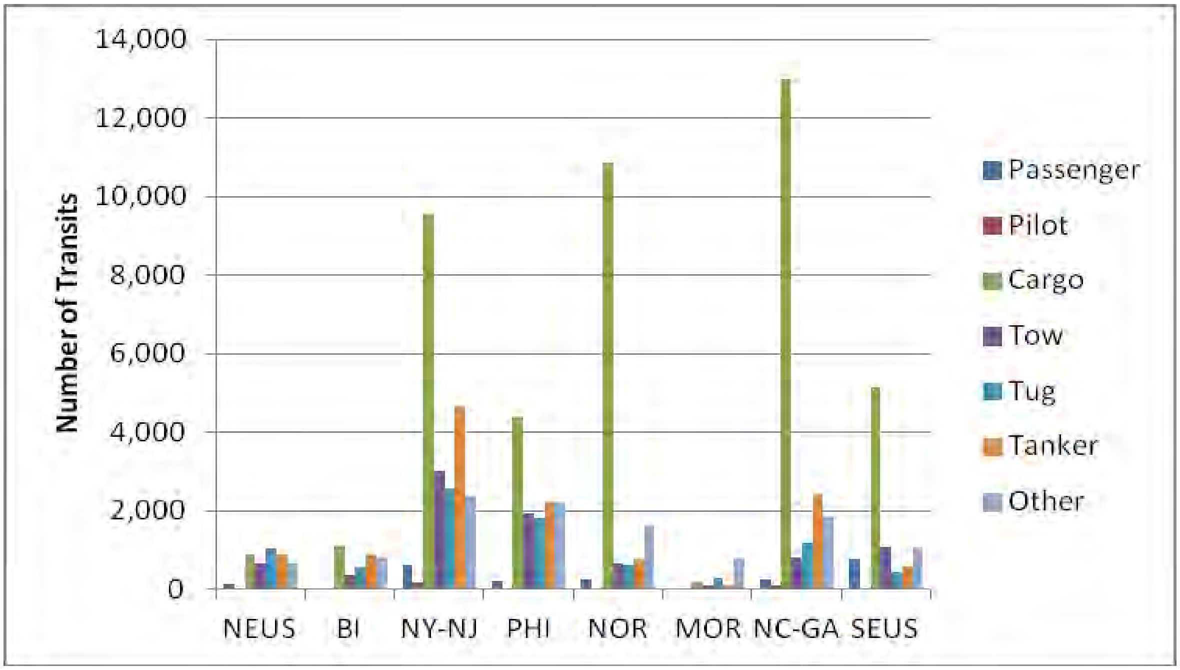


Fig. 6a. Proportion of transits in which vessel speed was at or below 10.0 knots for the entire distance; above 10.0 knots for 1-50% of the distance; or above 10.0 knots for 51-100% of the distance, for all SMAs in 2009, 2010, and 2011.

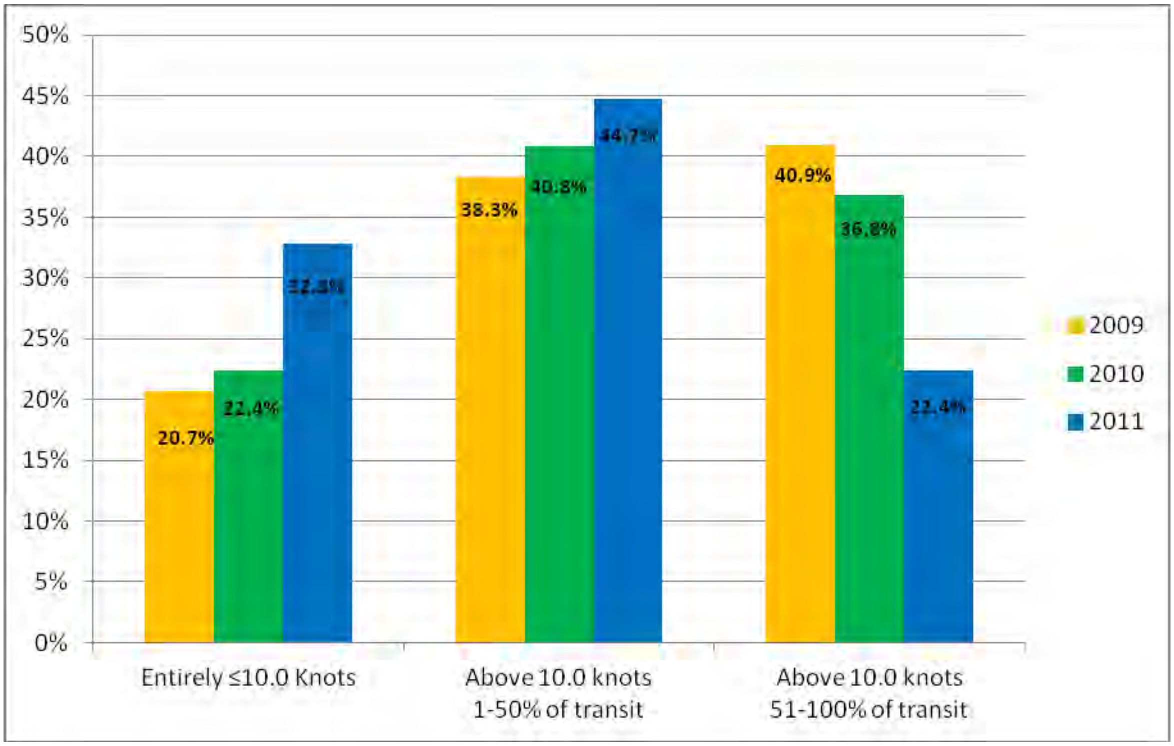


Fig. 6b. Proportion of transits in which vessel speed was at or below 12.0 knots for the entire distance; above 12.0 knots for 1-50% of the distance; or above 12.0 knots for 51-100% of the distance, for all SMAs in 2009, 2010, and 2011.

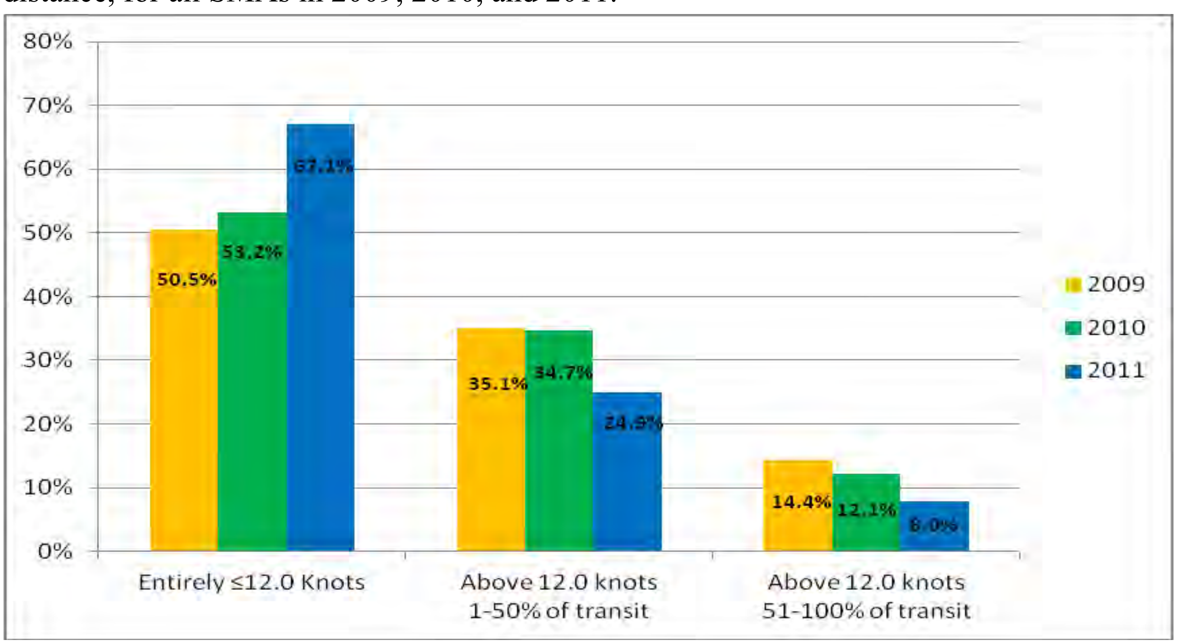


Fig. 7. Distribution of vessel speeds, as described by "maximum speed over ground" in all SMAs in 2009, 2010, and 2011.

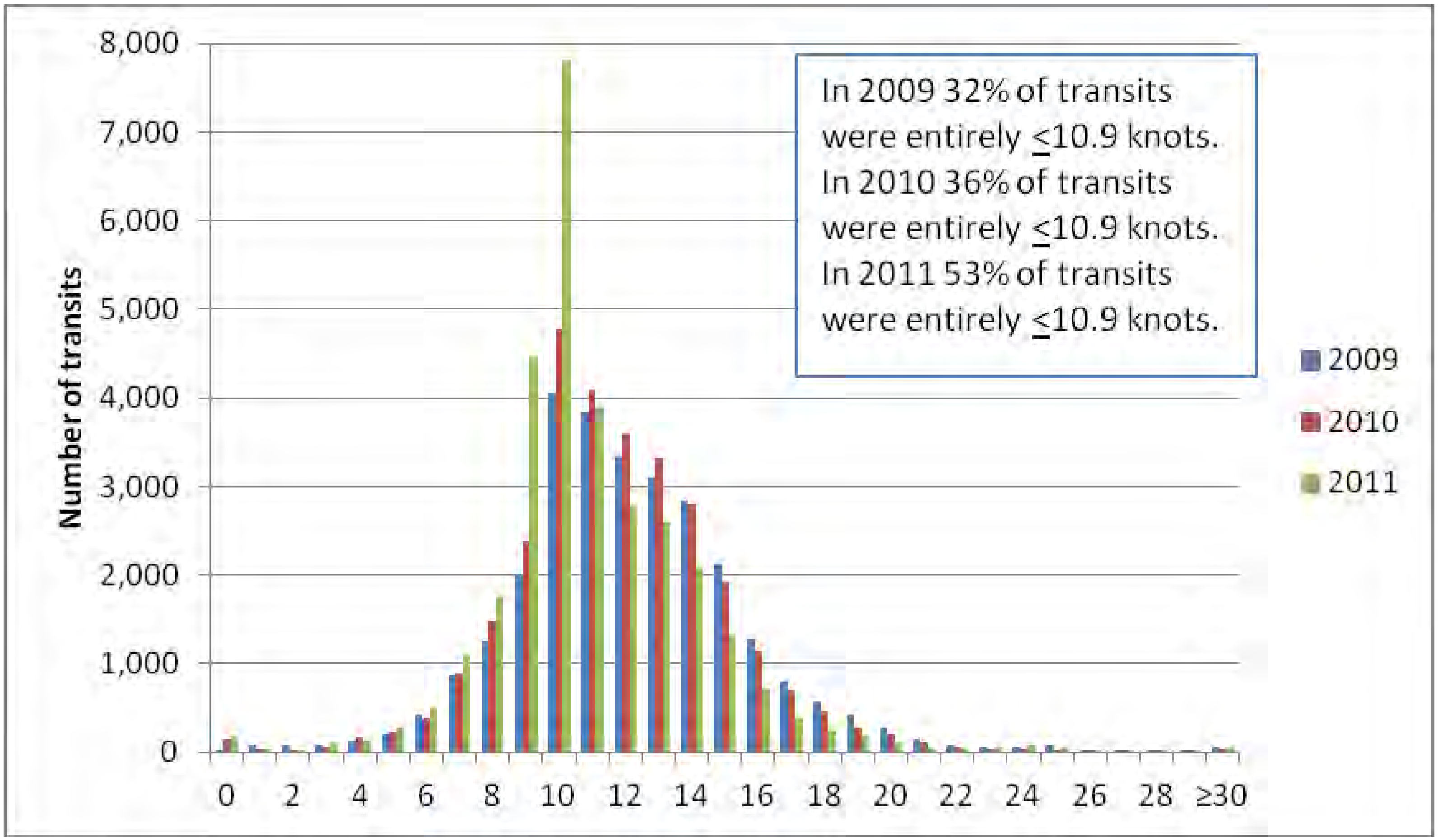


Fig. 8. Distribution of vessel speeds through SMAs, displayed as a percent of the total transit, as a function of "maximum speed over ground" by vessel type.

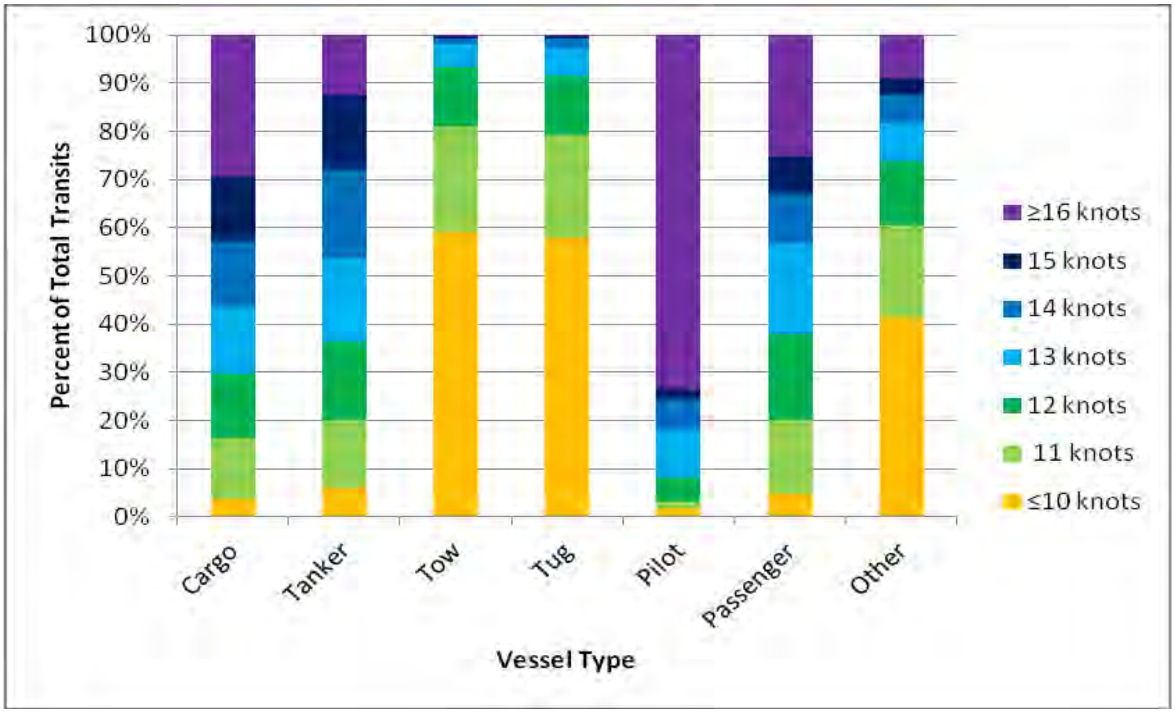


Fig. 9. Maximum vessel speed as a function of country of origin, 2009, 2010, and 2011.

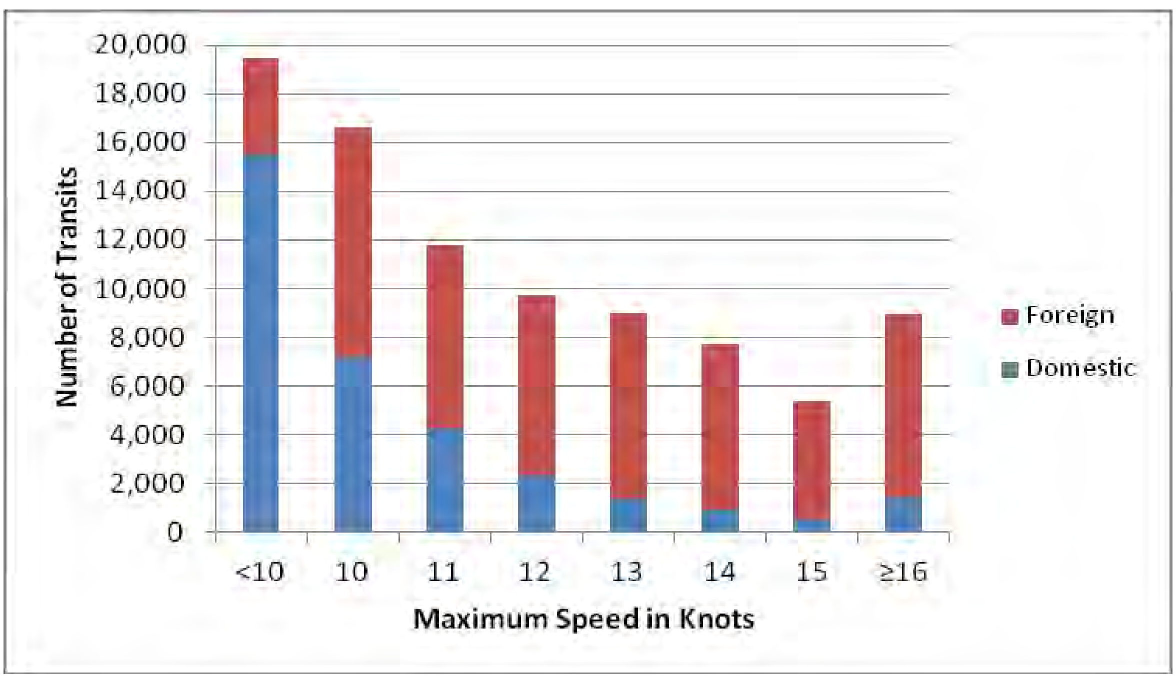
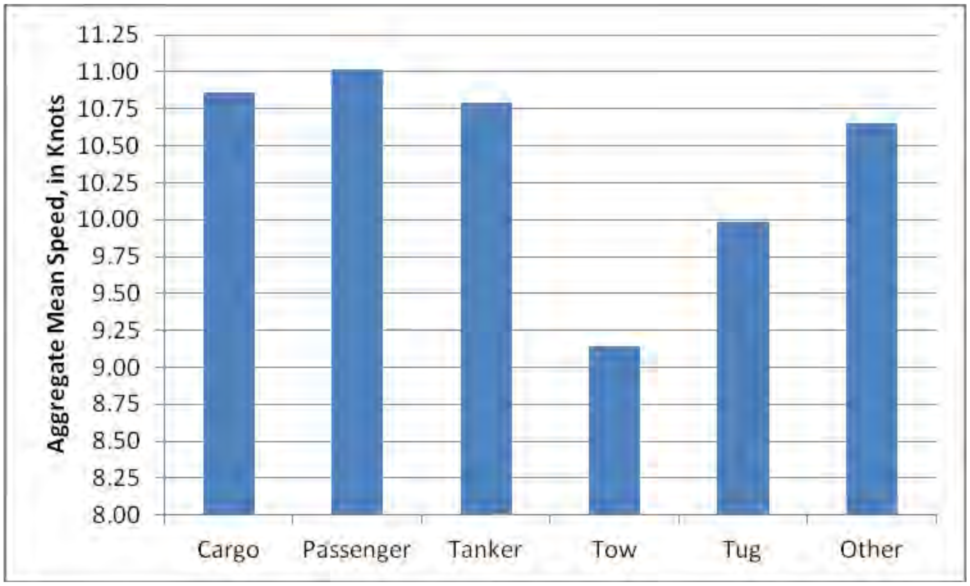


Fig. 10. Aggregate mean vessel speeds within all SMAs, 2009 and 2010.



TABLES

Table 1. Dates of active SMAs, number of days analyzed in each, and number of transits analyzed in each in 2009, 2010 and 2011.

Region	Acronym	Times "Active"	Number of SMA days	Number of SMA transits analyzed 2009	Number of SMA transits analyzed 2010	Number of SMA transits analyzed 2011	Total number of transits analyzed
Cape Cod Bay	CCB	1 January – 15 May	135	718	748	594	2,060
Off Race Point	ORP	1 March – 30 April	61	217	235	214	666
Great South Channel	GSC	1 April – 31 July	122	410	539	632	1,581
Block Island	BI	1 November – 30 April	181	1,240	1,256	1,242	3,738
New York	NY	1 November – 30 April	181	7,651	7,660	7,678	22,989
Philadelphia	PHI	1 November – 30 April	181	3,857	3,910	5,068	12,835
Norfolk	NOR	1 November – 30 April	181	4,790	4,720	5,328	14,838
Morehead City	MOR	1 November – 30 April	181	475	424	572	1,471
North Carolina to Georgia	NC-GA	1 November – 30 April	181	6,172	6,743	6,734	19,649
Southeast U.S.	SEUS	15 November – 15 April	152	2,773	3,209	3,105	9,087
TOTAL			**5,636**	**28,303**	**29,444**	**31,167**	**88,914**

Table 2. Number of transits analyzed, by vessel type, in each of the SMAs in 2009, 2010, and 2011.

SMA	Passenger	Pilot	Cargo	Tow	Tug	Tanker	Other	Total
CCB	4	0	61	601	992	143	259	2,060
ORP	12	0	276	47	53	243	35	666
GSC	108	0	564	20	10	489	390	1,581
BI	17	0	1,101	357	536	897	830	3,738
NY-NJ	631	165	9,570	3,020	2,579	4,647	2,377	22,989
PHI	203	31	4,409	1,927	1,839	2,247	2,179	12,835
NOR	254	9	10,857	673	640	774	1,631	14,838
MOR	15	0	194	94	279	115	774	1471
NC-GA	262	99	12,981	831	1,193	2,432	1,851	19,649
SEUS	768	2	5,161	1,071	434	577	1,074	9,087
Total	2,274	306	45,174	8,641	8,555	12,564	11,400	88,914

Table 3. Average Vessel Operating Speed by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule is Not in Effect, 2009 (knots)

	DWT Size Range (000s)																		
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	-	11.1	11.2	11.9	9.6	11.4	11.0	10.7	11.2	11.9	12.4	11.3	11.5	10.8	-	-	12.8	10.8	11.3
Combination Carrier (e.g. OBO)	-	13.9	-	-	-	-	-	10.1	-	-	-	-	9.8	-	-	12.7	-	-	10.6
Container Ship	12.5	13.0	14.1	13.6	13.1	14.9	14.5	13.9	14.0	13.9	14.4	13.9	13.6	14.1	-	-	-	-	14.0
Freight Barge	9.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.4
General Dry Cargo Ship	11.5	11.4	13.8	12.3	12.9	12.2	12.6	11.2	12.3	12.9	10.7	-	-	-	-	-	-	-	12.3
Passenger Ship a/	10.6	15.9	14.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.4
Refrigerated Cargo Ship	-	14.8	14.7	15.0	-	-	11.3	-	13.4	-	13.7	-	-	-	-	-	-	-	14.0
Ro-Ro Cargo Ship	8.3	13.3	13.6	14.3	13.7	13.2	13.9	15.3	13.4	14.3	13.6	13.4	-	-	-	-	-	-	13.6
Tank Ship	-	12.3	11.6	12.7	10.8	12.2	12.1	12.4	12.0	12.0	11.8	12.0	11.2	11.3	10.6	11.3	10.2	11.2	11.8
Towing Vessel	8.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.2

a/ Includes recreational vessels.

Source: Prepared by Nathan Associates Inc. from AIS data as described in text.

Table 4. Total Economic Impact of Rule Using 2009 and 2012 Bunker Fuel Prices, ($000s).

	Bunker fuel prices of	
Impact	2009	2012
Direct economic impact		
Shipping industry vessels	21,976	34,776
Cumulative effect of multi-port strings	3,593	5,685
Re-routing of southbound coastwise shipp	1,298	2,054
Pasengers' time on passenger ferries	5,191	5,191
Whale watching vessels	1,336	1,336
Subtotal direct economic impact	33,393	49,041
Indirect economic impact of port diversions	18,970	30,019
Total economic impact	52,363	79,061

Source: Prepared by Nathan Associates as described in text.

APPENDICES

Appendix A Conclusions excerpted from "*Report of a workshop on assessing the effectiveness of the right whale ship strike reduction rule*" (Silber and Bettridge, 2009)

Report of a Workshop on Assessing the Effectiveness of the
Right Whale Ship Strike Reduction Rule
November 19-20, 2008
Silver Spring, Maryland
Gregory Silber
Shannon Bettridge
Office of Protected Resources
National Marine Fisheries Service, NOAA

March 2009

Introduction

The U.S. National Marine Fisheries Service's (NMFS) final rule to reduce the severity and likelihood of vessel strikes to North Atlantic right whales went into effect on 9 December 2008 (73 FR 60173; 10 October 2008). The stated goal of the rule is "*to reduce or eliminate the threat of ship strikes [of North Atlantic right whales] - the primary source of mortality in the endangered population*". The rule requires certain vessels to travel at 10 knots or less in certain areas of right whale aggregation and near several key port entrances along the U.S. eastern seaboard. One provision of the rule is that NMFS will develop ways to monitor its effectiveness in attaining its intended goal. The rule expires in 5 years. Therefore, within a few years, NMFS will need to (a) devise a way to monitor the rule's effectiveness, (b) assess its overall effectiveness, and (c) generate a report of the findings.

On November 19-20, 2008, NMFS' Office of Protected Resources convened a Workshop on Assessing the Effectiveness of the Right Whale Ship Strike Reduction Rule. The goal of the workshop was to develop a strategy, involving multiple components, to monitor and assess whether vessel speed regulations are achieving the rule's intent of reducing the occurrence of ship strikes in right whales (*i.e.*, whether the rule is "effective"). Appendix 1 is a list of workshop participants and the workshop Terms of Reference are provided in Appendix 2.

Workshop Conclusions

By way of summary, key workshop conclusions are provided here; background information and descriptions of principal discussions follow.

The final rule contains a provision that the regulations would expire five years after implementation. With regard to the expiration, the workshop concluded that at that time, NMFS would (a) re-issue the regulations, (b) modify the regulations, or (c) allow them to expire. Therefore, if the regulations are to be modified or re-issued by the December 2013 expiration date through the rulemaking process, it will be necessary to have conclusions regarding effectiveness in hand for National Oceanic and Atmospheric Administration (NOAA) leadership by December 2011. As a result, data collection should start immediately and summaries and reports regarding the rule's effectiveness should be available by December 2011.

Workshop participants agreed that the timeframe for implementing adequate and rigorous metrics is quite short. In fact, given the suite of variables contributing to ship strikes, detecting meaningful biological effects of the regulations would be difficult. Variables complicating a rigorous assessment of effectiveness include changes in maritime commerce, oceanographic features contributing to shifts in whale distribution, and the rarity of a ship strike event. Much longer time series are typically needed to detect statistically meaningful effects. Nonetheless, within these rather arbitrary time constraints, workshop participants understood the charge to develop metrics, as possible.

Workshop participants agreed that NOAA will use four basic parameters to monitor effectiveness.

1. Biological data

Only one metric can be used to statistically evaluate the rule's effectiveness given the short time constraints: through assessments of observed time lapses between known ship strike related deaths of all large whale species. Thus, the rates of known ship strike deaths and serious injuries, both before and after implementation of the regulations, will be compared statistically to determine whether the regulations have resulted in a reduced rate (as opposed to the actual number) of known ship strikes. Although the rule focuses geographically on waters inhabited by right whales, adequate sample sizes can only be obtained by using data on all large whale species ship strike deaths. Certain assumptions (*e.g.*, constancy of detection effort) need to be assured. Other measures, *e.g.*, whale demographics, relative abundance, number of ship strike deaths, and scarring were discussed and considered not appropriate because much longer time series and larger sample sizes would be needed for sufficient statistical rigor. As a second component, NMFS will continue to collect and synthesize right whale sighting data to confirm that elements of the regulations (*e.g*., the size, time periods, and dimensions of Seasonal Management Areas (SMAs)), are on appropriate scales, or modify them as appropriate. Thus, NMFS might determine that the regulations could be more effective if dimensions of the SMAs were changed.

Other measures, discussed below, constitute indirect assessments of effectiveness.

2. Human behavior

Mariner compliance rates are one measure of effectiveness. Therefore, NMFS will quantify mariner compliance with the regulations using Automated Identification System (AIS). Receipt and analysis of ship-transmitted AIS data will allow precise quantification of the number of mariners that are exceeding 10 knots; NMFS will develop periodic summary reports of compliance. As a corollary to this, NMFS will use the same means to quantify mariner compliance with voluntary measures, such as Dynamic Management Areas and recommended routes established as protective measures for right whales.

3. Mariner awareness

To be effective, all segments of affected entities and industries need to be fully aware of the regulations. Therefore, NMFS will quantify the number of outgoing messages, printed material distributed, press releases, and direct communications with maritime industries and estimate the audiences reached and potential receivers of the information.

4. Economics

NMFS will assess potential economic impacts of the regulations by confirming, updating, and possibly improving economic impacts estimations made prior to implementation of the regulations. Conditions affecting shipping and other economic activities will be subject to many factors, including global and domestic economics. We will try to filter the effects of the regulation within the overall economic scenario.

Therefore, in sum:

NMFS's program to assess the effectiveness of the ship strike reduction rule will consist of these components and conditions.

- Data collection should start immediately and synthesis and reports regarding the rule's effectiveness should be available by December 2011.

- Biological:
    - Ensure consistency of monitoring efforts
    - Continue ongoing efforts to monitor large whale deaths known to have resulted from ship strikes
    - Conduct statistical analysis of changes in rate of time elapsed between known large whale ship strike deaths
- Human behavior:
    - Seek to develop or utilize a coast-wide centralized AIS monitoring system
    - Provide periodic reports of mariner compliance
- Education and Outreach
    - Monitor outreach efforts by quantifying, for example, the amount of material distributed, numbers of broadcasts made, and attempt to estimate audience reached
- Economic
    - Gather data on economic impact of rule
    - Conduct economic analysis for Environmental Impact Statement
- Related analysis
    - Continue to gather and analyze right whale sightings and ship strike records to assess appropriateness of SMA dimensions; and number, size and compliance with DMAs

Frequency of Whale and Vessel Collisions on the US Eastern Seaboard: Ten Years Prior and Two Years Post Ship Strike Rule

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US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration National Marine Fisheries Service
Northeast Fisheries Science Center Woods Hole, Massachusetts

August 2011

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INTRODUCTION

Protected species science programs are frequently asked to provide management advice based on imperfect data associated with occurrence rates of rare events such as strandings, road kills or other rarely detected mortalities. Ship strikes of large whales and right whales are such settings, and they are of particular interest because economically significant management actions have been enacted to hopefully reduce their occurrence. These measures are of unknown effectiveness while possibly causing annual industry costs ranging from tens of thousands to exceeding $100 million (shipping regulations). Following implementation of what have been termed "the Ship Strike Rules" (Federal Register 2006) which became effective 9 December 2008, the National Marine Fisheries Service (NMFS) will likely be challenged to demonstrate the recovery benefits of these expensive conservation measures in terms of effectiveness measures (e.g. whales saved). An added question on the minds of managers, industry representatives and conservation organizations is, "How long need actions be in place before we know if they are effective?" For the analyst, this entails evaluating a Poisson process of relatively rare events for significant decreases in rates of occurrence. Data on ship strikes include a highly scrutinized time series of dates when whale mortalities that resulted from whale-ship collisions were detected during 2000-2010. With only 8 years of data prior to implementation of the Ship Strike Rule, uncertainty about the *status quo* rate will still be large. Further, whale-ship collisions that produce whale deaths will likely not be eliminated by management actions. Therefore, it is the amount by which they may have been reduced concomitant with adherence to regulations that must be investigated. Herein, I examine the timing of detected ship strikes of large whales to see whether there has been any reduction in their rate of occurrence detected ship-strike related mortalities. I also provide some advice on increasing the length of the time series after rule enactment to detect different effect sizes.

METHODS

Serious injury and mortality data for large whale stocks in the US Atlantic were evaluated for evidence of collisions with ships from necropsy and gross observations reported to the Northeast Fisheries Science Center (NEFSC) (see Glass et al. 2009 for a description). From these data, I included all reports judged to be mortalities or serious injuries (hereafter mortalities) to fin (*Balaenoptera physalus*), sei (*B. borealis*), right (*Eubalaena glacialis*) and humpback (*Megaptera novaeangliae*) whales during the period 1 January 1999-31 December 2010. Strikes of each species should resemble a Poisson process, each with its own inherent rate, and because Poisson processes are summable, events pooled across species should also resemble a Poisson process. Using the discovery date associated with each strike, I calculated the time elapsed since the previous event, which I refer to as "waiting time," and I refer to the times since the Ship Strike Rule went into effect as event times (events occurring prior to the rule were coded as negative event times). I first examined the waiting time data relative to fits of models of exponential waiting times. Competing models included, in descending order of complexity:

1 Variable rates among years (*i.e.,* 12 rates, 1 per year 1999-2010),

2 2 rates, one prior to the rule and one after, and

3 A single rate.

Preliminary evaluations of similar data suggested that a more powerful approach at detecting changes may be to develop regressions of event times against order of occurrence, and to compare models with and without change points. I fit both classical linear models and their Bayesian counterparts to examine the evidence for a change in the rate of ship strikes since the implementation date of the Ship Strike Rule. Competing models included:

1 a single slope (a constant ship strike rate)

2 a fixed change point having 2 slopes on either side of the implementation date

3 2 distinct regression models for before and after the rule, and

4 a free-floating, single change point analysis with 2 slopes on either side of an arbitrary change date, where that date was also allowed to vary and achieve the bit fit.

The latter 2 models were only evaluated in the Bayesian framework. All Bayesian models were evaluated using WinBugs (ver. 1.4.3) (Lunn, et al. 2000) and were structured with broad flat priors on all parameters (Carlin and Louis 2000). Model Selection was based on DIC, an information criterion similar to AIC for likelihood models (Spiegelhalter 2002).

In addition to examining the available data on detected ship strike mortalities, I examined the potential to detect a change in rates of ship strikes using a set of simulation trials. Specifically, I estimated the mean of the exponential distribution that best fit the pre-Rule waiting times. I simulated sets (1000 each) of waiting times that would occur, if the estimated rate of occurrence of ship strikes were 66, 50 and 33% of the pre-Rule rate for 2, 5 and 7 years post implementation. I then tested the hypothesis that a change point model with rates differing before and after implementation of the rule (model 5 above) fit these simulated data better than a constant regression model (model 4 above). The percent rejections (alpha=0.05) were taken as measure of power to detect a true change for the 9 combinations of 3 study durations and 3 effect sizes.

RESULTS

A total of 58 ship strikes of large whales that were deemed to be serious injuries or mortalities were included in NEFSC data during 1 Jan 1999 – 31 December 2010. These included 17 humpback, 16 fin, 21 northern right, and 4 sei whales. The most consistent evaluation of these data occurred beginning in 2000 (TVN Cole, Pers. Comm.), so I limited analysis to event times starting with the first strike in 2000 (n=55). A simple plot of the data gives an appearance of heterogeneity among years with 2005 appearing as a particularly nasty one (Figure 1). However, there was no statistical support for heterogeneity in event waiting times among years (Appendix A). As with most biological data, waiting times between detected ship strikes appear somewhat more variable than those associated with a simple Poisson process (ship strikes per year).

Comparing change point models for these data offered a meager amount of evidence for an increase in the time between events after rule implementation, which equates to fewer ship strike mortalities detected per annum. Based on AICc, the classical regression model with a fixed change after the rule (model 5 above) received weight of 0.75 vs. the single rate regression (model 4 above) weight of 0.25, with an estimated effect size of only 3 days longer between strikes after rule implementation (Appendix B). Similarly, only weak distinctions were possible among Bayesian change point models with DIC values of 64.7, 63.0, 63.2, and 53.3 (Appendix C) for single slope (model 4 above), two slopes on either side of the implementation date (model 5 above), 2 distinct regression models (model 6 above), and a free-floating, single change point analysis (model 7 above), respectively (smaller values are better). The one exception was the free-floating change point model, which rather convincingly suggested that, if one change occurred in these data, it was a significant decrease in time between strikes starting in early 2004 (Appendix C; Figure 2). Using the Bayesian framework to evaluate the before and after rule model (fixed change point referred to as model 5 above), the estimated times between ship strikes were 62 days before the rule and 88 days after the rule (Figure 3). Although this effect size differed considerably from the classical framework estimates, the posterior distribution for the rate of mortalities after the ship strike rule was enacted included a relatively large amount of variance (Figure 3).

Clearly there would be more power to detect change the large that change is and the longer the period of evaluation after the rule is enacted. In my simulations, correct detections of significant changes in times between ship strikes ranged from 1% when a 33% reduction in the rate of ship strikes occurred and post-rule monitoring existed for only 2 years to a 99.7 correct detection rate when a 66% reduction in ship strikes occurred and monitoring included 7 years of data after the ship strike rule was enacted (Table 1).

CONCLUSIONS

Based on the analysis of change points, there was only weak evidence to support an increase in the time between detected ship strike mortalities of large whales on the eastern U.S. seaboard after enactment of the Ship Strike Rule. Rates of detected serious injuries and mortalities of large whales resulting from ship-whale collisions appeared to show somewhat greater variability during the 11 years evaluated than what might be expected by chance alone. The estimated size of the effect, if one existed, depended heavily on the frame work (classical regression or Bayesian MCMC) in which the time series of ship strike dates were evaluated. Due to the lack of a clear outcome from the evaluation of ship strike event times when coupled with the results of the simulation study, I suggest at least 5 years of data be evaluated prior to passing judgment on the biological effectiveness of the Ship Strike Rule.

ACKNOWLEDGEMENTS

Data used in this paper come from numerous sources. A. G. Henry and T.V. N. Cole are largely responsible for collating and often evaluating the level of evidence from a report to determine if it warrants a serious injury and were it not for their diligence and consistent treatment of reports, my evaluation would have little meaning. Determinations of causes of mortality are due in large part to a few highly skilled biologists that form a part of the stranding network and were essential in developing these data.

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Federal Register. 2006. Endangered Fish and Wildlife; Proposed Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales. 71:36299-36313.

Glass, A.H, T.V.N. Cole, M. Garron. 2009. Mortality and serious injury determinations for baleen whale stocks along the United States eastern seaboard and adjacent Canadian Maritimes, 2003-2007 (2nd Edition). U.S. Department of Commerce, Northeast Fish Science Center Reference Document 09-04, 19 pp.

Lunn, DJ, Thomas A, Best N, and Spiegelhalter D. 2000. WinBUGS -- a Bayesian modelling framework: concepts, structure, and extensibility. Statistics and Computing 10:325--337.

Spiegelhalter, D. J., N. G. Best, B. P. Carlin, A. van der Linde. 2002. Bayesian measures of model complexity and fit (with discussion). Journal of the Royal Statistical Society, Series B (Statistical Methodology) 64: 583–639.

Table 1. Detection rates (%) of false null hypotheses for simulated times between ship strikes assuming that the rates estimated for serious injuries and mortalities detected between 1 January 2000 and 8 December 2008 were reduced as indicated.

	YEARS OF POST RULE MONITORING		
REDUCTION IN RATE	2	5	7
33%	1	50.8	65.9
50%	2.5	80.5	92.8
66%	6.1	94.6	99.7

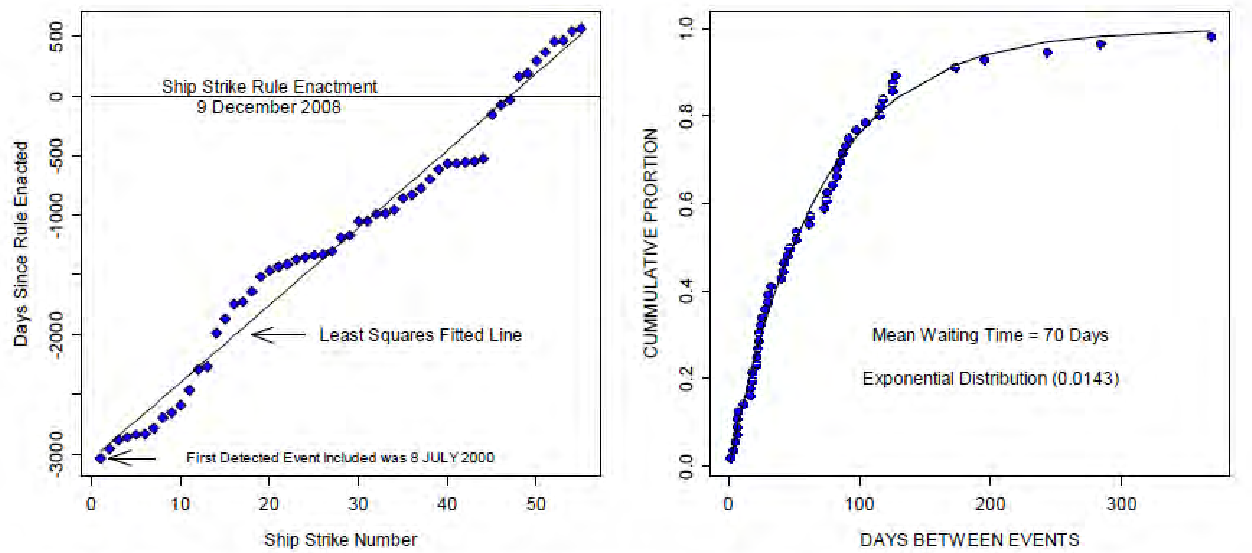


Figure 1. Whale and ship collisions resulting in serious injuries or mortalities detected along the US Eastern seaboard 2000-2010. Graphs represent timing of events in chronological order (A) and the cumulative distribution (B) resulting from the best generalized linear model fit to time between events (model 4 above).

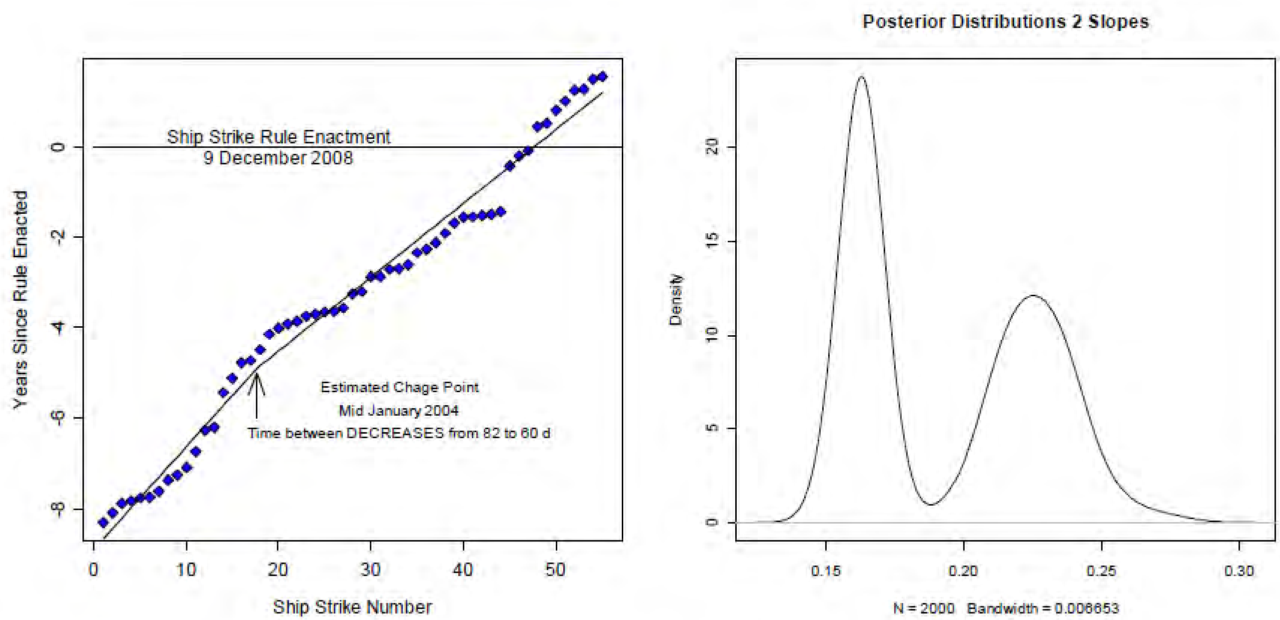


Figure 2. Whale and ship collisions resulting in serious injuries or mortalities detected along the US Eastern seaboard 2000-2010. Graphs depict fit resulting from a Bayesian framework used to estimate a free floating change point for the timing of events in chronological order (A) and the posterior distributions of estimated of rates (1/years between events) for change point model (model 7 above).

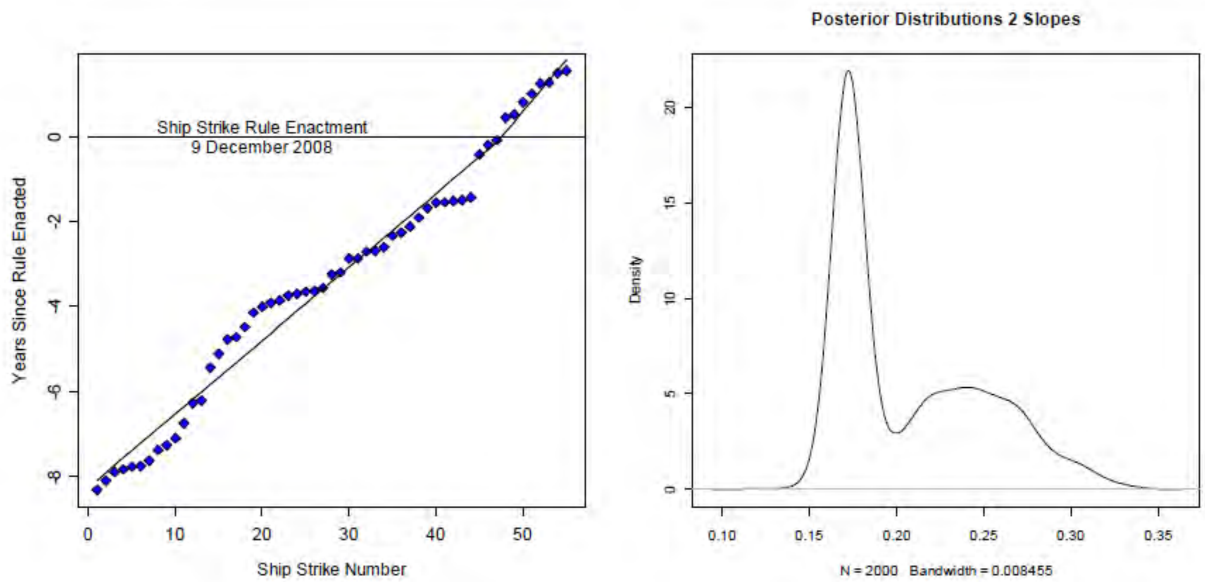


Figure 3. Whale and ship collisions resulting in serious injuries or mortalities detected along the US Eastern seaboard 2000-2010. Graphs depict Bayesian model fit of rate of events that included a change point fixed at Ship Strike Rule enactment date estimated for the timing of events in chronological order (A) and the posterior distributions of estimated of rates (1/years between events) for change point model (model 5 above).

APPENDIX A. CLASSICAL STATISTICAL COMPARISONS

```
summary(model 1, dispersion=1)

Call:
glm(formula = TimeBetween ~ as.factor(Year), family = Gamma,
   data = LW_00)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.4383  -0.6774  -0.2990   0.4531   1.5846

Coefficients:
                     Estimate  Std. Error z value Pr(>|z|)
(Intercept)          0.007576   0.004374   1.732   0.0833 .
as.factor(Year)2001  0.016562   0.010118   1.637   0.1016
as.factor(Year)2002  0.001770   0.006946   0.255   0.7989
as.factor(Year)2003 -0.002576   0.005624  -0.458   0.6470
as.factor(Year)2004  0.006154   0.007110   0.866   0.3867
as.factor(Year)2005  0.022959   0.011648   1.971   0.0487 *
as.factor(Year)2006  0.011614   0.007749   1.499   0.1339
as.factor(Year)2007  0.026907   0.014741   1.825   0.0680 .
as.factor(Year)2008 -0.001453   0.005624  -0.258   0.7961
as.factor(Year)2009  0.002424   0.006643   0.365   0.7152
as.factor(Year)2010  0.012626   0.011007   1.147   0.2513
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 1)

    Null deviance: 59.892  on 54  degrees of freedom
Residual deviance: 41.073  on 44  degrees of freedom
AIC: 577.83

Number of Fisher Scoring iterations: 6
```

```
summary(model 2, dispersion=1)

Call:
glm(formula = TimeBetween ~ as.factor(Rule), family = Gamma,
    data = LW_00)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.5103  -0.9778  -0.2913   0.3310   2.0157

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       0.016006   0.002413   6.633 3.28e-11 ***
as.factor(Rule)1 -0.005896   0.003888  -1.516    0.129
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
(Dispersion parameter for Gamma family taken to be 1)

    Null deviance: 59.892  on 54  degrees of freedom
Residual deviance: 57.864  on 53  degrees of freedom
AIC: 581.3

Number of Fisher Scoring iterations: 6
```

summary(model_3, dispersion=1)

```
Call:
glm(formula = TimeBetween ~ 1, family = Gamma, data = LW_00)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.5532  -0.9853  -0.3895   0.2659   2.2856

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) 0.014334   0.001933   7.416 1.20e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 1)

    Null deviance: 59.892  on 54  degrees of freedom
Residual deviance: 59.892  on 54  degrees of freedom
AIC: 581.51
Number of Fisher Scoring iterations: 6
```

Confidence set for the best model

Method: raw sum of model probabilities

95% confidence set:

	Model	K	AICc	Delta AICc	AICcWt
intercept only	3	2	581.74	0.00	0.46
Before and After Rule	2	3	581.77	0.04	0.46
All Years	1	12	585.26	3.52	0.08

Model probabilities sum to 1

Conclusion --- Note that the AICc for intercept only model and 2 rate model are the same even though 1 parameter was added: only one rate is supported

APPENDIX B. CLASSICAL CHANGE POINT ANALYSIS

summary(model.oneslope) (Model 4)

```
Call:
glm(formula = DaysSince2 ~ count, data = LW_00)

Deviance Residuals:
    Min        1Q    Median       3Q       Max
-328.93   -112.88   -15.83    98.70   299.95

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -3041.774     41.798  -72.77   <2e-16 ***
count          64.675      1.299   49.80   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

    Null deviance: 59213198  on 54  degrees of freedom
Residual deviance:  1238754  on 53  degrees of freedom
AIC: 713.31
```

summary(model.change) (Model 5)

```
Call:
glm(formula = DaysSince2 ~ 1 + count:as.factor(Rule), data = LW_00)

Deviance Residuals:
    Min        1Q    Median       3Q       Max
-258.13    -88.46   -29.35    72.82   306.03

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)            -2998.680     45.336  -66.14   <2e-16 ***
count:as.factor(Rule)0    62.087      1.756   35.36   <2e-16 ***
count:as.factor(Rule)1    65.025      1.269   51.24   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

    Null deviance: 59213198  on 54  degrees of freedom
Residual deviance:  1140740  on 52  degrees of freedom
AIC: 710.78
```

AICc Comparison --- Confidence set for the best model

Method: raw sum of model probabilities
95% confidence set:

	K	AICc	Delta AICc	AICcWt
Change After Rule	4	711.58	0.0	0.75
One Slope	3	713.78	2.2	0.25

Conclusion – with an evidence ratio of 3:1, the change point is somewhat preferred, but the estimated difference in rates before and after the Rule (62 vs 65 days between) was small.

APPENDIX C. BAYESIAN CHANGE POINT ANALYSIS

(smaller DIC indicate BETTER fit)

Model	DIC
Free Change point	53.287
Fixed Change point	63.012
2 Regressions	63.170
1 Slope	64.706

Conclusion - Fixed change point is slightly preferred over a constant rate. Free change point is much preferred over the rest which indicates some unidentified heterogeneity is dominant over any rate change that might have occurred post-Rule.

Appendix C. Sample Community Oriented Policing and Problem Solving (COPPS) letter.

On (insert date) your vessel (insert name) was allegedly operating in excess of the 10 knot speed limit inside the (insert SMA here).

This letter is an official reminder of regulations regarding the Ship Strike Reduction Rule found at 50 CFR 224.105 promulgated under the authority of the Endangered Species Act and the Marine Mammal Protection Act. All vessels greater than or equal to 65 feet operating in the (insert SMA and applicable dates here) must slow to speeds of 10 knots or less. Vessels may operate at a speed greater than 10 knots only if necessary to maintain a safe maneuvering speed in an area where conditions severely restrict vessel maneuverability.

Atlantic large whales are protected under the Marine Mammal Protection Act (16 USC 1361) and the Endangered Species Act (16 USC 1531). Violations of either act can result in civil penalties, criminal fines and/or imprisonment. The NOAA Fisheries Service Office of Law Enforcement investigates reported violations of the Marine Mammal Protection Act and the Endangered Species Act.
Additional information about the Ship Strike Reduction Rule can be obtained online at www.nero.noaa.gov/shipstrike or by calling Special Agent (name) at (phone)
Sincerely,

Name
Special Agent-in-Charge
NOAA Fisheries Service Office of Law Enforcement
(Name) Enforcement Division

Appendix D. Sample Email to Shipping Companies.

Dear _______:

Attached is an Excel file that includes individual spreadsheets for each (Ship company) ship recorded in "Seasonal Management Areas" (SMA) along the US eastern seaboard in (month, year). The National Oceanic and Atmospheric Administration (NOAA) established vessel speed restriction zones in certain locations and times to reduce the threat of vessel collisions with North Atlantic right whales (http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/compliance_guide.pdf). NOAA's National Marine Fisheries Service (NMFS) is using AIS technologies to track vessel operations in these SMAs and has compiled monthly summaries of (Ship company) vessels that have transited through the active SMAs..

Appendix E. Compliance Guide for Right Whale Ship Strike Reduction Rule (available at http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/compliance_guide.pdf)

Science, Service, Stewardship

NOAA FISHERIES SERVICE

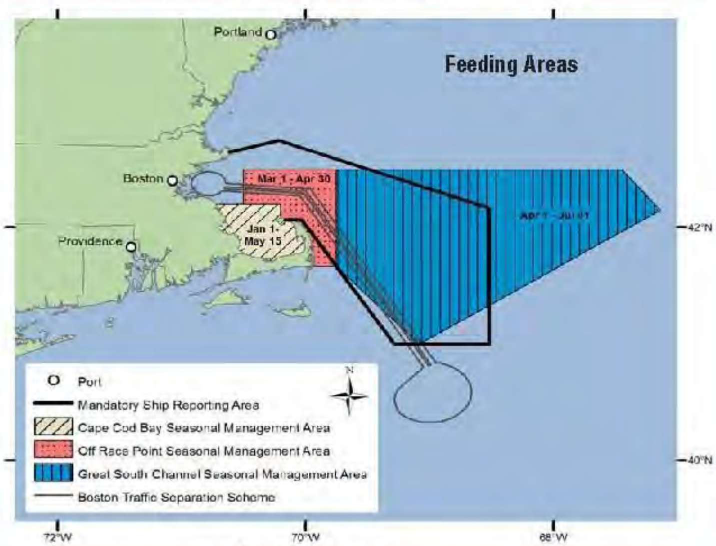
Compliance Guide for Right Whale Ship Strike Reduction Rule (50 CFR 224.105)

ATTENTION: All vessels greater than or equal to 65 ft (19.8 m) in overall length and subject to the jurisdiction of the United States and all vessels greater than or equal to 65 ft in overall length entering or departing a port or place subject to the jurisdiction of the United States.

YOU MUST SLOW TO SPEEDS OF 10 KNOTS OR LESS IN SEASONAL MANAGEMENT AREAS

Mandatory speed restrictions of 10 knots or less are required in Seasonal Management Areas along the U.S. East Coast during times when right whales are likely to be present. The purpose of this regulation is to reduce the likelihood of deaths and serious injuries to these endangered whales that result from collisions with ships.

Northeast U.S. Seasonal Management Areas



Feeding Areas

Cape Cod Bay
January 1 - May 15
Includes all waters of Cape Cod Bay with Northern Boundary of 42°04'56.5"N, 070°12'W to 42°12'N, 070°12'W then due west back to shore.

Off Race Point
March 1 - April 30
Waters Bounded by:
42°04'56.5"N 070°12'W
42°12'N, 070°12'W
42°12'N, 070°30'W
42°30'N, 070°30'W
42°30'N, 069°45'W
41°40'N, 069°45'W
then due west back to shore.

Great South Channel
April 1 - July 31
Waters Bounded by:
42°30'N, 069°45'W
42°30'N, 067°27'W
42°09'N, 067°08'24"W
41°00'N, 069°05'W
41°40'N, 069°45'W
then back to starting pt.

The rule does not apply to waters inshore of COLREGS lines.

Vessels may operate at a speed greater than 10 knots only if necessary to maintain a safe maneuvering speed in an area where conditions severely restrict vessel maneuverability as determined by the pilot or master.

If a deviation from the 10 knot speed restriction is necessary, the following information must be entered into the logbook:

- Reasons for deviation
- Speed at which vessel is operated
- Latitude and longitude at time of deviation
- Time and duration of deviation
- Master of the vessel shall sign and date the logbook entry

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

Migratory Route

November 1 through April 30

Vessel speed is restricted in the following areas:

- Block Island Sound waters bounded by:

  40°51'53.7" N 070°36'44.9" W
  41°20'14.1" N 070°49'44.1" W
  41°04'16.7" N 071°51'21.0" W
  40°35'56.5" N 071°38'25.1" W
  then back to starting point.

- Within a 20-nm (37 km) radius of the following (as measured seaward from the COLREGS lines):
  - -Ports of New York/New Jersey:
    40°29'42.2"N 073°55'57.6"W
  - -Entrance to the Delaware Bay (Ports of Philadelphia and Wilmington):
    38°52'27.4"N 075°01'32.1"W
  - -Entrance to the Chesapeake Bay (Ports of Hampton Roads and Baltimore):
    37°00'36.9"N 075°57'50.5"W
  - -Ports of Morehead City and Beaufort, NC:
    34°41'32.0"N 076°40'08.3"W

- Within a continuous area 20 nm from shore between Wilmington, NC, to Brunswick, GA, bounded by the following:

Point	Latitude	Longitude
A	34°10'30"N	077°49'12"W
B	33°56'42"N	077°31'30"W
C	33°36'30"N	077°47'06"W
D	33°28'24"N	078°32'30"W
E	32°59'06"N	078°50'18"W
F	31°50'00"N	080°33'12"W
G	31°27'00"N	080°51'36"W

and west back to the shore.

Calving and Nursery Grounds

November 15 through April 15

Vessel speed is restricted in the area bounded to the north by latitude 31°27'N; to the south by latitude 29°45'N; to the east by longitude 080°51'36"W.

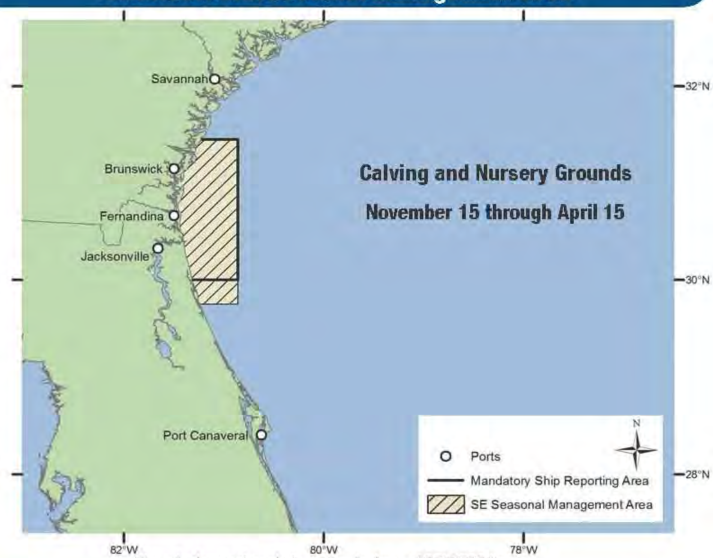
For more information, visit:
http://www.nmfs.noaa.gov/pr/shipstrike
http://nero.noaa.gov/shipstrike
http://rightwhalessouth.nmfs.noaa.gov

Right Whale Ship Strike Reduction Rule expires on December 9, 2013

Page 2 of 2

Mid-Atlantic U.S. Seasonal Management Areas

Southeast U.S. Seasonal Management Area



The rule does not apply to waters inshore of COLREGS lines.

Voluntary Dynamic Management Areas (DMAs) may also be established by NOAA Fisheries Service. Mariners are encouraged to avoid these areas or reduce speeds to 10 knots or less while transiting through these areas. NOAA Fisheries Service will announce DMAs to mariners through its customary maritime communication media.

This serves as NOAA's small entity compliance guide. OMB Control #0648-0580

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

Appendix F. Shipboard Right Whale Protection Program Notebooks Distributed January 2009 – August 2011.

Affiliation	# Sent	Date Sent
New York Maritime Outreach	2	1/15/2009
OMAO's Marine Operations Center	12	5/19/2009
US Shipping	14	6/1/2009
Georgia Ports Authority	5	6/19/2009
US Army Corps of Engineers	16	6/23/2009
(Individual)	1	7/17/2009
Sapelo Island National Estuarine Research Reserve	1	7/21/2009
Moran Shipping Agency	8	9/21/2009
Savannah Maritime Association	48	10/23/2009
Maritime Association of South Carolina	48	10/23/2009
Coast Guard Marine Safety Unit	48	10/30/2009
APL Maritime	8	11/1/2009
Stolt Tankers	107	11/4/2009
USACE- South Atlantic Division	1	12/22/2009
USACE- Wilmington District	1	12/22/2009
USACE- Savannah District	1	12/22/2009
USACE- Charleston District	1	12/22/2009
Liberty Marine Services Inc.	1	12/22/2009
JMTX Agents and Operators Comm	18	1/6/2010
Savannah Maritime Association	12	1/20/2010
JMTX Harbor Safety Committee	8	3/10/2010
Savannah Maritime Association	12	12/15/2010
SC Maritime Assn Operations	24	6/23/2011
Hapag-Lloyd (America) Inc.	20	6/27/2011
Meditarrian Shipping Company	50	7/11/2011
Merritt Island NWR	2	7/11/2011
Riverwalk	2	7/11/2011
Wild Treasure	13	7/11/2011
TFMarine, Inc.	12	8/15/2011
Jacksonville Marine Transportation Exchange	36	8/15/2011
(Individual)	12	8/15/2011

Appendix G. Articles published about the ship speed rule, October 2008 – March 2011.

Publication	Title	Date
High Beam Research	Ship Strike Reduction Rule Aims to Protect North Atlantic Right Whales	10/8/2008
Defenders of Wildlife	Groups applaud new rules to protect right whales, but condemn premature phase-out of rules after only five years	10/8/2008
gCaptain	Reducing Speed to Protect Right Whales	10/9/2008
Marine Log	NOAA sets speed limit to protect right whales	10/9/2008
Bangor Daily News	New rules to protect North Atlantic right whales	10/11/2008
Marine Link	Speed Kills Whales: Restrictions for East Coast	10/16/2008
The Maritime Executive	A Snapshot into the Future: Voyage 231 of the Containership "Compliance"	10/16/2008
The Maritime Executive	Speed Restrictions to Reduce Threat of Ship Collisions With North Atlantic Right Whales to Take Effect	10/16/2008
Science Daily	Ship Strike Reduction Rule Aims to Protect North Atlantic Right Whales	10/20/2008
Journal of Commerce	Whale Rule to Slow Ships	10/30/2008
New England Aquarium	Ship speed limits take effect as whales begin dangerous migration along East Coast	11/1/2008
Trade Only	East Coast Speed Limits Start Next Week	11/19/2008
Professional Mariner	NOAA proposes speed limits to protect North Atlantic right whales	12/1/2008
Trade Only	Right Whale Restrictions Now in Effect	12/3/2008
The Maritime Executive	New Vessel Speed Regulations for U.S. East Coast Ports	12/4/2008
The Maritime Executive	New Vessel Speed Regulations for U.S. East Coast Ports	12/4/2008
Sail Magazine	Save the Whales	12/5/2008
Coosa Valley News	Right Whales Has Hope in Georgia	12/8/2008
Star News	Ships slow down to spare rare whales	12/8/2008
Softpedia	Ships Must Now Avoid Right Whale Paths	12/8/2008
The Boston Globe	Caution! Whale Crossing: Slow to 11 miles per hour	12/8/2008

Publication	Title	Date
The Boston Herald	New speed limit designed to protect rare whales	12/8/2008
Central Maine Morning Sentinel	Ships slow down to save whales	12/8/2008
NOAA	Ships Must Slow Down to Protect North Atlantic Right Whales	12/8/2008
Atlanta Journal-Constitution	Ancient visitors follow instincts to Georgia	12/8/2008
High Beam Research	Ships Must Slow Down to Protect North Atlantic Right Whales	12/8/2008
The Boston Globe	As of today, right whales gain a right of way at sea, US rule takes effect to reduce ship speed	12/9/2008
Conservation Report	MARINE MAMMALS: Right whale shuts down Cape Cod Canal	12/9/2008
Jacksonville Marine Transportation Exchange Website	NOAA Releases Compliance Guide for Speed Rule	12/9/2008
hamptonroads.com and pilotonline.com	Large ships must slow down to limit risk to endangered whales	12/10/2008
Georgia Dept. of Natural Resources	Press Release	12/11/2008
National Data Buoy Center website	Right whales active off the coast	12/22/2008
NGIA Special Notice to Mariners	Notice to Mariners 01/09	1/1/2009
The Post and Courier	Harbor pilots seek exemption from federal slow-down rule	2/18/2009
Village Soup (The Rockland Herald Gazette)	Right whale rule sinks cruise ship visit	3/2/2009
USA Today (blog)	Whales force Royal Caribbean cruise ship to abandon port call in Maine	3/4/2009
Bunkerworld.com	US ports: Speed restrictions to protect whales	3/9/2009
Newsday.com	Monitoring of rare whales near NY harbor ends	3/16/2009
Mariners Weather Log, April 2009:	New Vessel Speed Regulations for U.S. East Coast Ports	4/1/2009
Port World	US ports: Speed restrictions to protect whales	4/9/2009
The Maritime Executive	NOAA Says Changes in Vessel Operations May Reduce Risk of Endangered Whale Shipstrikes	5/28/2009
Georgia Dept. of Natural Resources	Ship Strike Reduction Regulation Information	5/29/2009

Publication	Title	Date
Marine Link	CG Reminder, Slow for Right Whales	5/29/2009
Soundings	Vessels Operations Altered to Prevent Right Whale Strike	6/3/2009
Earth System Monitor	New Regulations and Routing Measures to Protect Endangered Right Whales	7/1/2009
Professional Mariner	Ship speed limit to protect whales goes into effect Sunday	10/30/2009
Marine Link	Waters Changes in Vessel Operations Protects Whales	11/1/2009
Environmental Service News	Ships Sailing U.S. Atlantic Coast Must Slow for Whales	11/2/2009
Soundings	Right Whale Restrictions Now in Effect	11/3/2009
Trade Only	NOAA Puts Whale Compliance Rules Online	11/3/2009
The Maritime Executive	U.S. Coast Guard Reminds Mariners to Slow Down to Protect Right Whales	11/4/2009
Saving Seafood	Ships Sailing U.S. Atlantic Coast Must Slow for Whales	11/6/2009
Action News 9	Chilly Now But Soon to Change Again... "Crafternoon"... Mariners & Right Whales	11/9/2009
NBC New York	Ship Speed Limit Again Proposed to Aid Endangered Whales	1/7/2010
BIMCO	NOAA gets serious with issue of violation notices to Ships in Voluntary Right Whale Speed Restriction Zone	11/1/2010
Port World	NOAA announces vessel speed restrictions to protect endangered right whales	11/4/2010
Examiner.com	Right Whale seasonal management is in effect	11/3/2010
Inchcape Shipping Services	North Atlantic Right Whale Migration and Calving Season	11/4/2010
Live Better Magazine	Southeastern U.S. Right Whale Education and Conservation	11/7/2010
gCaptain	Seven Vessels Accused of Violating Right Whale Rule	11/16/2010
Defenders of Wildlife	Right Whale Protection Has Teeth	11/17/2010
West of England	USA - Right Whale Ship Strike Reduction Rule	11/24/2010
Mondaq	United States: No Speeding—You May Be Subject to a Whale of a Penalty!	3/9/2011

Appendix H. Ship Speed Rule Press Releases Issued December 2008 – November 2010.

Organization	Title	Date	URL
NOAA	Ships must slow down to protect North Atlantic right whales	12/8/2008	http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/pressrelease_effective.pdf
NOAA	Ship strike reduction rule aims to protect North Atlantic right whales	8/8/2008	http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/finalrule_pressrelease.pdf
USCG	Right Whale Ship Strike Reduction Rule Takes Effect Sunday	10/30/2009	http://coastguardnews.com/right-whale-ship-strike-reduction-rule-takes-effect-sunday/2009/10/30/
NOAA- OLE	NOAA Office of Law Enforcement reminds mariners to slow down	11/9/2009	http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/speed_restrictions_southeast.pdf
NOAA	NOAA: Ship Speed Restrictions to Protect Endangered North Atlantic Right Whales	11/1/2010	http://www.noaanews.noaa.gov/stories2010/20101101_shipstrike.html
NOAA	Heightened Mariner Awareness Requested During Right Whale Birthing Season	1/10/2010	NA
NOAA- OLE	NOAA Enforces Right Whale Ship Strike Reduction Rule	11/16/2010	http://www.noaanews.noaa.gov/stories2010/20101116_rightwhale.html

Appendix I. Presentations on ship speed rule given November 2008 through June 2011.

Presenter	Date	Title of Presentation	Name of Event	# of Attendees	Audience
Shannon Bettridge	9/1/2008	Ship Strikes and North Atlantic Right Whales Final Environmental Impact Statement and Ship Strike Reduction Measures	Boston Port Operators Group	50	Ship operators in Boston
Shannon Bettridge	10/1/2008	North Atlantic Right Whale Ship Strike Reduction Efforts	SEIT meeting October 2008	40	Southeast Implementation Team
Greg Silber	11/7/2008	Right Whale Ship Strike Rule	North Atlantic Right Whale Consortium Meeting	100	Right Whale Conservationist
Shannon Bettridge	11/7/2008	North Atlantic Right Whale Ship Strike Reduction Efforts	NGO Constituents Meeting	25	Environmental NGO groups in DC
Kristen Koyama	11/19/2008	Right Whale Update	Boston Port Operators Group meeting	25	Pilots, harbor masters, MASSPORT, USCG, fed/state agencies, tug companies, etc.
Kristen Koyama	12/9/2008	Right Whale Update	Southeastern MA port safety meeting	50	Pilots, harbor masters, passenger vessel industry, fed/state agencies, USCG, local law enforcement, etc.
Don Lewis	12/9/2008	Discussed implementation of Speed rule	Meeting with Cumberland Sound Pilots	75	Cumberland Sound Pilots
Don Lewis	12/9/2008	Discussed implementation of Speed rule	Meeting with Amelia Maritime, Green Island Maritime, and Seaboard Line Agents	75	Commercial shipping companies
Don Lewis	12/10/2008	Discussed implementation of Speed rule	Jacksonville Harbor Safety Committee	75	Jacksonville shipping agents, St Johns Bar Pilots

Presenter	Date	Title of Presentation	Name of Event	# of Attendees	Audience
Michael Henderson	12/11/2008	Right Whale Ship Strike Rule - 2 pg PDF	CG Sector San Juan Harbor Safety Mtg	30	Harbor pilots, port authority, city/commonwealth officials, USCG, CBP, ACOE
Kristen Koyama	12/11/2008	Right Whale Update	Rhode Island port safety meeting	50	Pilots, harbor masters, passenger vessel industry, fed/state agencies, USCG, local law enforcement, etc.
Michael Henderson	12/12/2008	Right Whale Ship Strike Rule - 2 pg PDF	USCG Sector San Juan Harbor Safety Mtg	40	Harbor pilots, port authority, city/commonwealth officials, USCG, CBP, ACOE
Michael Henderson	12/16/2008	Right Whale Ship Strike Rule - 2 pg PDF	Emailed PDF to distribution list for PR & USVI	65	My Navigation Mgr distribution list for PR & USVI
Barb Zoodsma	12/18/2008		R/W presentation to USCG Sector Jacksonville personnel	75	USCG
Don Lewis	1/7/2009	Update of R/W season and new rule	Jacksonville Agents and Operators Meeting	75	Jacksonville Agents and Operators
Don Lewis	1/8/2009	Update of R/W season and new rule	Fernandina Maritime Exchange	75	Port Mariners and Vessel Operators
Michael Henderson	1/21/2009	Right Whale Ship Strike Rule - 2 pg PDF	Savannah Maritime Assn monthly mtg	25	Pilots, port authority, GA DNR, USCG, CBP, ACOE, commercial shipping
Michael Henderson	1/22/2009	Right Whale Ship Strike Rule - 2 pg PDF	CG Sector Charleston Harbor Safety Mtg	35	Pilots, port authority, GA DNR, USCG, CBP, ACOE, commercial shipping

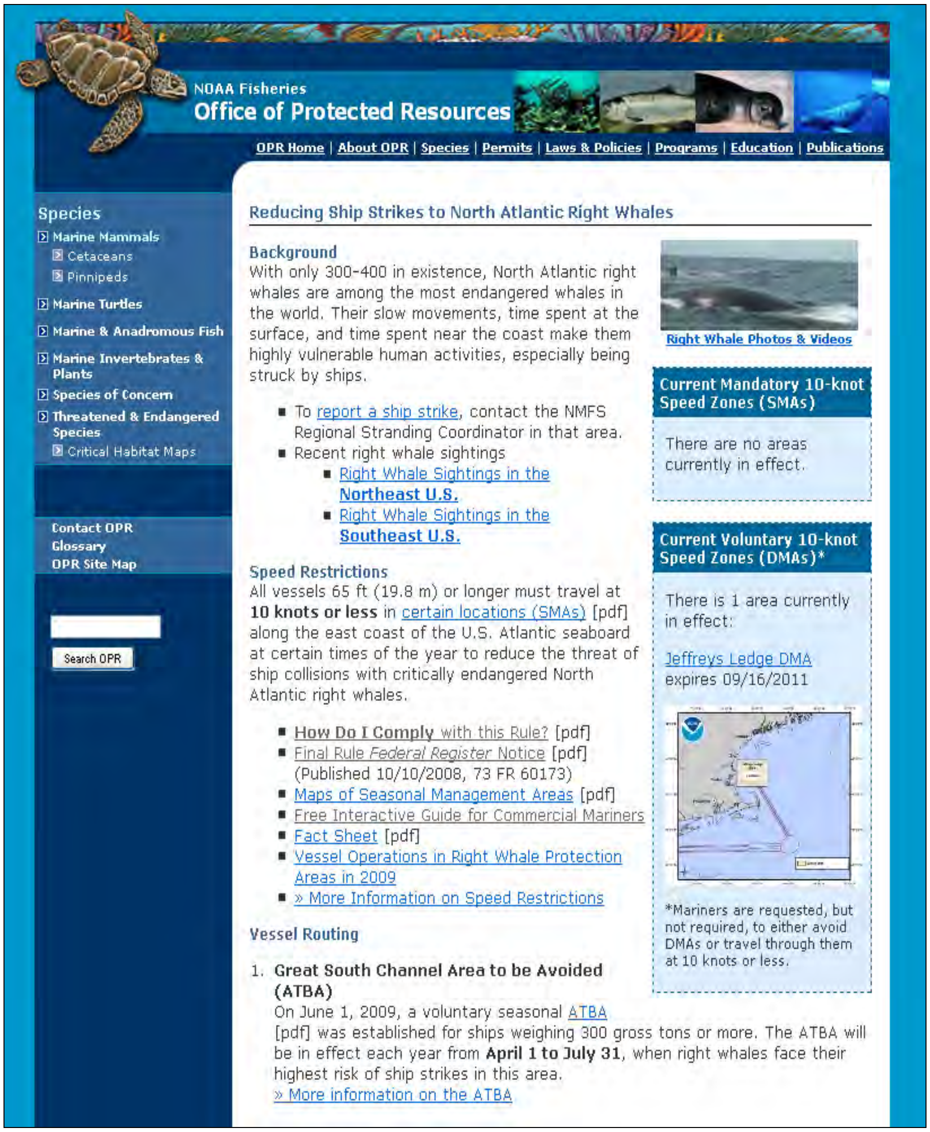
Presenter	Date	Title of Presentation	Name of Event	# of Attendees	Audience
Kristen Koyama	1/23/2009	Right Whale Update	ME/NH Port Safety Forum	30	Pilots, harbor masters, fed/state agencies, passenger vessels, port authority, etc.
Michael Henderson	1/26/2009	Right Whale Ship Strike Rule - 2 pg PDF	Tampa Bay Harbor Safety Mtg	40	Pilots, Ports of Tampa, Manatee, St. Pete, USCG, ACOE Cruise shipping & commercial
Michael Henderson	1/26/2009	Right Whale Ship Strike Rule - 2 pg PDF	Board of Directors - Tampa Propeller Club	18	Senior Tampa Bay maritime officials
Don Lewis	2/7/2009	Seasonal Update and Speed rule	JMTX Board of Directors Meeting	20	Senior Maritime officials in Jacksonville
Michael Henderson	2/11/2009	Right Whale Ship Strike Rule - 2 pg PDF	Key West Maritime Mtg	75	
Shannon Bettridge	2/18/2009	North Atlantic Right Whale Ship Strike Reduction Efforts	MISNA	20	Marine Exchanges, Nationwide
Kristen Koyama	2/18/2009	Right Whale Update	Boston Port Operators Group Meeting	25	Pilots, harbor masters, MASSPORT, USCG, fed/state agencies, tug companies, etc.
Michael Henderson	2/19/2009	Right Whale Ship Strike Rule - 2 pg PDF	Port Everglades (FL) Harbor Safety Mtg	75	Harbor pilots, port authority, city/commonwealth officials, USCG, ACOE
Michael Henderson	2/20/2009	Right Whale Ship Strike Rule - 2 pg PDF	Port of Miami Harbor Safety Mtg	75	Harbor pilots, port authority, city/commonwealth officials, USCG, ACOE
Kristen Koyama	2/25/2009	Right Whale Update	Thames Maritime Coalition meeting	15	Port interests, fed/state reps

Presenter	Date	Title of Presentation	Name of Event	# of Attendees	Audience
Don Lewis	2/25/2009	Seasonal Update and Speed rule	Jacksonville Maritime Strategic Planning Comm	10	Select maritime exchange members
Kristen Koyama	3/10/2009	Right Whale Update	Southeastern MA port safety meeting	50	Pilots, harbor masters, passenger vessel industry, fed/state agencies, USCG, local law enforcement, etc.
Don Lewis	3/11/2009	Seasonal Update and Speed rule	JMTX Harbor Safety Committee	30	Port Mariners and Vessel Operators
Kristen Koyama	3/12/2009	Right Whale Update	Rhode Island port safety meeting	50	Pilots, harbor masters, passenger vessel industry, fed/state agencies, USCG, local law enforcement, etc.
Shannon Bettridge and Todd Nickerson and Frank Sprtel	3/18/2009	Right Whale Ship Strike Rule	NY Harbor Safety, Navigation and Operations Committee Meeting, Staten Island, NY	75	Pilots, Shipping Cos., Port Authorities, NY DEC, Academia, USCG, etc.
Kristen Koyama Todd Nickerson	3/26/2009	Right Whale Ship Strike Reduction Rule	USCG Industry Day - Small Passenger Vessels	100	Small passenger vessel industry reps, incl. ferries, whale watch, charters, etc
Don Lewis	4/1/2009	Seasonal Update and Speed rule	JMTX Agents and Operators Committee	25	Vessel Agents and Vessel Operators
Don Lewis	4/9/2009	Seasonal Update and Speed rule	Port of Fernandina Maritime Exchange	20	Port Mariners and Vessel Operators
Don Lewis	5/14/2009	Update and new Outreach Materials	Board of Governors, Propeller Club Jacksonville	20	Senior Maritime officials in Jacksonville
Don Lewis	5/20/2009	Update and new Outreach Materials	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	7/1/2009	Update and new Outreach Materials	JMTX Agents and Operators Committee	25	Vessel Agents and Vessel Operators
Don Lewis	7/9/2009	General Briefing and Outreach	Florida Association of Environmental Professionals	20	Environmental Compliance Professionals

Presenter	Date	Title of Presentation	Name of Event	# of Attendees	Audience
Don Lewis	9/9/2009	Season Preparation and Outreach	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	10/4/2009	Season Preparation and Outreach	JMTX Agents and Operators Committee	25	Vessel Agents and Vessel Operators
Don Lewis	11/4/2009	General Briefing and Outreach	Marine Information Services of North America	10	Marine Exchanges and Assn from around nation
Don Lewis	11/10/2009	General Briefing and Outreach	San Jose Rotary Club - Jacksonville	60	Jacksonville Business People
Don Lewis	12/9/2009	Seasonal Update and Compliance	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	1/6/2010	Seasonal Update and Compliance	JMTX Agents and Operators Committee	22	Vessel Agents and Vessel Operators
Don Lewis	1/20/2010	Seasonal Update and Compliance	Savannah Maritime Association	40	Port Mariners and Vessel Operators
Don Lewis	2/3/2010	Seasonal Update and Compliance	JMTX Board of Directors Meeting	20	Senior Maritime officials in Jacksonville
Rich Chesler	3/2/2010	Right Whale and the Ship Strike Rule	Lagoon House in Palm Bay, FL	15	General Public
Don Lewis	3/10/2010	Seasonal Update and Compliance	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	4/7/2010	Seasonal Update and Compliance	JMTX Agents and Operators Committee	20	Vessel Agents and Vessel Operators
Don Lewis	5/19/2010	Seasonal Wrap-Up and Compliance	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	6/2/2010	Seasonal Wrap-Up and Compliance	Port of Fernandina Maritime Exchange	20	Port Mariners and Vessel Operators
Don Lewis	7/7/2010	Seasonal Wrap-Up and Compliance Discussion	JMTX Agents and Operators Committee	20	Vessel Agents and Vessel Operators
Don Lewis	9/8/2010	Season Preparation and Outreach	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	10/6/2010	Season Preparation and Outreach	JMTX Agents and Operators Committee	20	Vessel Agents and Vessel Operators

Presenter	Date	Title of Presentation	Name of Event	# of Attendees	Audience
Don Lewis	12/8/2010	Season Update Intro Greg Schweitzer	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	12/15/2010	Season Update Intro Greg Schweitzer	Savannah Maritime Association	35	Port Mariners and Vessel Operators
	1/10/2011	Ship Strike Rule/ SMA Public Service Announcement	WAMU Radio	?	General public
Don Lewis	1/12/2011	Seasonal Update and Compliance	JMTX Agents and Operators Committee	20	Vessel Agents and Vessel Operators
Michael Asaro	2/16/2011	Presentation- RW Ship Strike Rule	Port of Boston Terminal/USCG Industry Day Event, Boston, MA	50	Vessel Agents and Vessel Operators
Michael Asaro	2/24/2011	Presentation- RW Ship Strike Rule	Maine/New Hampshire Port Safety Forum, Portsmouth, NH-	50	Vessel Agents and Vessel Operators
Don Lewis	3/9/2011	Season Update with Barb Zoodsma	JMTX Harbor Safety Committee	25	Port Mariners and Vessel Operators
Don Lewis	4/13/2011	Seasonal Update and Compliance	JMTX Agents and Operators Committee	20	Vessel Agents and Vessel Operators
Don Lewis	4/21/2011	General Briefing and Outreach	Leadership Nassau - Community Dev.	25	Fernandina Beach Business Leaders
Don Lewis	6/23/2011	Seasonal Wrap-Up and Compliance Discussion	Maritime Association of South Carolina Operations Committee	30	Port Mariners and Vessel Operators Charleston

Appendix J. Screen shot of NMFS Office of Protected Resources Ship Strike Reduction Page. www.nmfs.noaa.gov/pr/shipstrike.



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Reducing Ship Strikes to North Atlantic Right Whales

Background
With only 300-400 in existence, North Atlantic right whales are among the most endangered whales in the world. Their slow movements, time spent at the surface, and time spent near the coast make them highly vulnerable human activities, especially being struck by ships.

- To report a ship strike, contact the NMFS Regional Stranding Coordinator in that area.
- Recent right whale sightings
  - Right Whale Sightings in the **Northeast U.S.**
  - Right Whale Sightings in the **Southeast U.S.**

Speed Restrictions
All vessels 65 ft (19.8 m) or longer must travel at **10 knots or less** in certain locations (SMAs) [pdf] along the east coast of the U.S. Atlantic seaboard at certain times of the year to reduce the threat of ship collisions with critically endangered North Atlantic right whales.

- How Do I Comply with this Rule? [pdf]
- Final Rule *Federal Register* Notice [pdf] (Published 10/10/2008, 73 FR 60173)
- Maps of Seasonal Management Areas [pdf]
- Free Interactive Guide for Commercial Mariners
- Fact Sheet [pdf]
- Vessel Operations in Right Whale Protection Areas in 2009
- » More Information on Speed Restrictions

Vessel Routing

1. **Great South Channel Area to be Avoided (ATBA)**
   On June 1, 2009, a voluntary seasonal ATBA [pdf] was established for ships weighing 300 gross tons or more. The ATBA will be in effect each year from **April 1 to July 31**, when right whales face their highest risk of ship strikes in this area.
   » More information on the ATBA

Right Whale Photos & Videos

Current Mandatory 10-knot Speed Zones (SMAs)
There are no areas currently in effect.

Current Voluntary 10-knot Speed Zones (DMAs)*
There is 1 area currently in effect:
Jeffreys Ledge DMA
expires 09/16/2011

*Mariners are requested, but not required, to either avoid DMAs or travel through them at 10 knots or less.

Appendix K. Initial Estimate of Economic Impact of the Right Whale Ship Strike Reduction Vessel Speed Restrictions

NATHAN
ASSOCIATES INC.

Memorandum

February 6, 2012

To: Greg Silber and Shannon Bettridge

NOAA/ NMFS/Office of Protected Resources

From: Richard Blankfeld and Gerardo Ayzanoa

Nathan Associates Inc.

Subject: Initial Estimate of Economic Impact of the Right Whale Ship Strike Reduction Vessel Speed Restrictions

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1. Introduction

On December 9, 2008, the Right Whale Ship Strike Reduction Rule (Rule) issued by the U.S. National Marine Fisheries Service (NMFS) went into effect. The rule requires certain vessels to travel at 10 knots or less in certain areas of right whale aggregation and near several key port entrances along the U.S. eastern seaboard.

This memorandum presents an initial assessment of the estimated economic impact of the Rule. In large measure, the economic impact assessment is based on the approach and analysis presented in the FEIS Report, Economic Analysis for the Final Environmental Impact Statement of the North Atlantic Right Whale Ship Strike Reduction Strategy prepared by Nathan Associates Inc. for NMFS in August 2008.

There are several important data and analytical improvements; however that are incorporated in the present assessment that are further described herein.

2. AIS Data and Approach

A key data improvement is the availability of Automatic Identification System (AIS) that uses a Global Positioning System-linked, very high frequency radio signal that provides for ship-to-ship and ship-to-shore information transfer. It transmits the ship's name, call sign, position, dimensions, speed, heading and other information multiple times each minute. The AIS signal provides a suite of information, both dynamic (that is unique to a particular voyage) and static (that is consistent for a given vessel). Dynamic information includes the vessel's position, speed over ground, course over ground, heading, rate of turn, and position accuracy (< or > 10 m) which are determined by continuous GPS linked updates. Static information includes the vessel name, call sign, type, cargo, and its Maritime Mobile Service Identity (MMSI) number. Given the rate at which it provides this information, AIS is a precise means to remotely track vessel speeds and other vessel operations.

AIS transponders are required on certain vessel types that transit U.S. waters. These include: 1) all commercial tugs, barges, tow and similar vessels that are 26 feet in length or greater; 2) all passenger vessels (such as ferries and cruise ships) 150 gross tonnage or more; and 3) any commercial self-propelled vessel that is 65 feet in length or greater, which consists of commercial fishing vessels, tankers, cargo ships, etc.

The goal of the economic impact analysis is to estimate the impact on the shipping industry and overall economy from the full implementation of the Rule; it is not designed to identify actual industry compliance with the Rule. As such, the economic analysis assumes 100 percent compliance with the Rule and as such represents the maximum economic impact on the shipping industry and general economy. For these reasons, the economic impact analysis assumes that all vessels subject to the Rule sail at a maximum speed of 10 knots within the restricted areas and time periods. Using the AIS data, the 10-knot speed limit is then compared with the actual sailing speeds of vessels for each area during periods when the speed restrictions are not in effect.

We obtained access to the AIS for the areas relevant to the Rule for the full year of 2009 and for the first 11 months of 2010 from the NOAA Office of Protected Resources. We then spent a significant effort to review the data and fill-in critical missing information for the economic analysis on vessel type and size. This was accomplished by matching various vessel identifiers such as the Maritime Mobile Service

Identity (MMSI) number, call sign, and IMO number. In some instances, information on the type and size of vessel were confirmed based on the name of the vessel, length and cargo type. For vessels that the vessel type was known as well as the gross registered tonnage, the deadweight tonnage was estimated using the regression analysis described in the 2008 FEIS Report, Appendix A, Attachment 5.

As a result of the AIS data review and analysis, we were able to obtain for 2009, operating information for 58,459 vessel transits through areas affected by the Rule. Of these, 30,669 vessel transits (52.5%) occurred during periods when the Rule was in effect and 27,790 vessel transits (47.5%) occurred during periods when the rule was not in effect. Table 1 presents the distribution of the total vessel transits by type and size of vessel.

Table 1. Total Vessel Transits by Type and Size for Areas Subject to Rule, 2009 (includes periods when Rule is in effect and not in effect)

	DWT Size Range (000s)																	
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier		274	248	206	134	312	229	559	251	277	351	235	699	161	3		20	18	3,977
Combination Carrier (e.g. OBO)		6						44					6	13		2			71
Container Ship	136	571	921	338	684	506	1,172	805	1,379	1,017	3,485	6,308	79	221					17,622
Freight Barge	112	13																	125
General Dry Cargo Ship	351	454	415	265	223	102	82	117	186	100	4								2,299
Passenger Ship a/	2,267	851	159																2,899
Refrigerated Cargo Ship		215	262	54	1	2	96		5		26								661
Ro-Ro Cargo Ship	131	201	928	1,516	931	778	176	79	211	24	317	22							5,314
Tank Ship	12	368	340	481	106	164	298	881	648	2,034	656	474	760	116	424	440	424	287	8,913
Towing Vessel	14,298																		14,298
Other b/	1,743	133	18	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	1,900
Total	19,050	3,086	3,291	2,860	2,079	1,864	2,059	2,485	2,680	3,452	4,839	7,039	1,544	511	427	442	444	305	58,459

a/ Includes recreational vessels.
b/ Includes fishing vessels, industrial vessels, research vessels, and school ships.
Source: Prepared by Nathan Associates Inc. from AIS data as described in text.

3. Average Operating Speeds by Vessel Type and Size

Accurate information on current vessel operating speeds is clearly an important element for the determination of the economic impact of the speed restriction required by the Rule. The AIS information provides the most detailed and accurate information of vessels operating speeds for the areas subject to the Rule. For each area subject to the Rule, we have computed the average operating speeds by type and size of vessel for periods in 2009 when the Rule was not in effect. This provides the most robust estimate for actual vessel operations and average operating speeds without the influence of the Rule. In Table 2 below, we present the data by vessel type and size but summarized across all of the areas affected by the Rule. The fastest average vessel operating speed in these areas observed in 2009 was 14.0 knots for containerships and refrigerated cargo ships. Within some vessel size categories, faster average speeds of 15.9 knots (passenger ships) and 15.3 knots (Ro-Ro cargo ships) were recorded.

Table 2. Average Vessel Operating Speed by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule is Not in Effect, 2009 (knots)

	DWT Size Range (000s)																		
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	-	11.1	11.2	11.9	9.6	11.4	11.0	10.7	11.2	11.9	12.4	11.3	11.5	10.8	-	-	12.8	10.8	11.3
Combination Carrier (e.g. OBO)	-	13.9	-	-	-	-	-	10.1	-	-	-	-	9.8	-	-	12.7	-	-	10.6
Container Ship	12.5	13.0	14.1	13.6	13.1	14.9	14.5	13.9	14.0	13.9	14.4	13.9	13.6	14.1	-	-	-	-	14.0
Freight Barge	9.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.4
General Dry Cargo Ship	11.5	11.4	13.8	12.3	12.9	12.2	12.6	11.2	12.3	12.9	10.7	-	-	-	-	-	-	-	12.3
Passenger Ship a/	10.6	15.9	14.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.4
Refrigerated Cargo Ship	-	14.8	14.7	15.0	-	-	11.3	-	13.4	-	13.7	-	-	-	-	-	-	-	14.0
Ro-Ro Cargo Ship	8.3	13.3	13.6	14.3	13.7	13.2	13.9	15.3	13.4	14.3	13.6	13.4	-	-	-	-	-	-	13.6
Tank Ship	-	12.3	11.6	12.7	10.8	12.2	12.1	12.4	12.0	12.0	11.8	12.0	11.2	11.3	10.6	11.3	10.2	11.2	11.8
Towing Vessel	8.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.2
a/ Includes recreational vessels.																			
Source: Prepared by Nathan Associates Inc. from AIS data as described in text.																			

4. Average Delays due to Rule by Type and Size of Vessel

The primary operational impact of the Rule on the shipping industry is the extra sailing time incurred caused by vessels having to slow down within the restricted areas. Estimates of the extra sailing time were calculated by subtracting the time required to sail through each restricted area using the detailed average vessel operating speeds for that restricted area during periods when the Rule was not in effect from the time required at a sailing speed of 10 knots. Only average vessel speeds of greater than 10 knots during non-Rule periods were used for these calculations. A summary across all restricted areas of the average extra time per vessel transit by vessel type and size is presented in Table 3. The highest average delay by vessel type is 0.43 hours (26 minutes) for refrigerated cargo ships.

Table 3. Average Delays per Vessel Transit due to Rule by Type and Size of Vessel, 2009 (hours)

	DWT Size Range (000s)																		
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	-	0.16	0.15	0.29	0.11	0.19	0.19	0.10	0.18	0.22	0.26	0.12	0.17	0.17	-	-	0.20	0.01	0.17
Combination Carrier (e.g. OBO)	-	0.38	-	-	-	-	-	0.05	-	-	-	-	0.02	0.13	-	-	-	-	0.10
Container Ship	0.34	0.25	0.20	0.17	0.11	0.13	0.24	0.24	0.24	0.15	0.17	0.16	0.20	0.15	-	-	-	-	0.18
Freight Barge	0.01	0.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05
General Dry Cargo Ship	0.14	0.27	0.32	0.23	0.31	0.21	0.25	0.20	0.24	0.18	0.22	-	-	-	-	-	-	-	0.25
Passenger Ship a/	0.07	0.13	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
Refrigerated Cargo Ship	-	0.52	0.46	0.26	0.39	0.04	0.28	-	0.05	-	0.06	-	-	-	-	-	-	-	0.43
Ro-Ro Cargo Ship	0.13	0.16	0.14	0.17	0.21	0.19	0.10	0.11	0.24	0.14	0.09	0.22	-	-	-	-	-	-	0.17
Tank Ship	0.05	0.12	0.19	0.20	0.16	0.21	0.13	0.20	0.18	0.17	0.21	0.14	0.14	0.11	0.12	0.20	0.10	0.23	0.17
Towing Vessel	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
Total	0.12	0.48	0.43	0.43	0.37	0.41	0.42	0.33	0.41	0.37	0.42	0.40	0.26	0.31	0.17	0.25	0.14	0.25	0.30
a/ Includes recreational vessels.																			
Source: Prepared by Nathan Associates Inc. from AIS data as described in text.																			

5. Vessel Operating Costs at Sea by Type and Size of Vessel

The USACE prepares estimates of vessel operating costs to be used by planners in studies to determine the potential benefits of harbor improvement projects. Vessel operating costs include annual capital costs as determined by the replacement cost of the vessels and application of capital recovery factors; estimates of fixed annual operating costs such as for crew, lubricating materials and stores (supplies), maintenance and repair, insurance and administration; the number of operational days per year; and fuel costs at sea and in port.

The type and DWT size of vessels for which operating costs are reported by the USACE is shown in Table 4 below. Vessel operating costs are presented separately for U.S. flag and foreign flag vessels, for five vessel types, and up to 14 vessel DWT sizes within a vessel type.

Table 4. Type and Size of Vessels for which USACE Reports Vessel Operating Costs (DWT)

Foreign flag					U.S. flag				
General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull	General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull
11,000	9,000	15,000	20,000	20,000	11,000	9,000	15,000	20,000	20,000
14,000	14,000	25,000	25,000	25,000	14,000	14,000	25,000	25,000	25,000
16,000	17,000	35,000	35,000	35,000	16,000	17,000	35,000	35,000	35,000
20,000	20,000	40,000	50,000	50,000	20,000	20,000	40,000	50,000	50,000
24,000	23,000	50,000	60,000	60,000	24,000	23,000	50,000	60,000	60,000
30,000	28,000	60,000	70,000	70,000	30,000	28,000	60,000	70,000	70,000
	31,000	80,000	80,000	80,000		31,000	80,000	80,000	80,000
	35,000	100,000	90,000	90,000		35,000	100,000	90,000	90,000
	39,000	120,000	120,000	120,000		39,000	120,000	120,000	120,000
	42,000	150,000	150,000	150,000		42,000	130,000	150,000	150,000
	49,000	175,000	175,000	175,000		49,000		175,000	175,000
	55,000	200,000	200,000	200,000		55,000		200,000	200,000
	66,000		265,000	265,000		66,000		265,000	265,000
	82,000		325,000	325,000					

Source: U.S. Army Corps of Engineers, Economic Guidance Memorandum 02-06, Deep Draft Vessel Operating Costs

We applied regression techniques to the USACE vessel operating cost data in order to match with the vessel size categories used in our analysis of U.S. East Coast vessel arrivals. A logarithmic equation was specified relating hourly operating costs at sea with vessel DWT for each of the vessel types used in this economic impact analysis.

A concern over the use of the USACE operating cost estimates is the variability of actual vessel operating costs due to the fluctuations in the price of bunker fuel. The USACE estimates include the assumed fuel consumption per day at sea for the primary propulsion and auxiliary propulsion for each vessel type and DWT size. The primary propulsion is assumed to use heavy viscosity oil while the auxiliary propulsion is assumed to use marine diesel oil. We updated the USACE vessel operating costs to reflect the average bunker fuel prices per ton for New York for using an annual average 2009 calculated from data reported by Bunkerworld. The average price for heavy viscosity oil for 2009 was $347 per metric ton and marine diesel oil was $685 per metric ton. The resulting estimates of vessel operating costs by type and size of vessel for 2009 are presented in Table 5. These estimated vessel operating costs for 2009 represent the best method to value the actual impact on the shipping industry of the Rule that year.

Table 5. Hourly Vessel Operating Costs at Sea for Foreign Flag Vessels by Type Size of Vessel Using Average 2009 and January 2012 Bunker Fuel Prices

	DWT Size Range (000s)																	
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+
Foreign Flag 2009 Hourly Operating Costs at Sea																		
Bulk Carrier	786	805	825	845	865	886	907	929	951	974	1,010	1,059	1,110	1,164	1,221	1,311	1,477	1,703
Combination Carrier (e.g. OBO)	826	846	866	887	908	930	952	975	999	1,023	1,060	1,112	1,166	1,223	1,282	1,377	1,551	1,789
Container Ship	788	888	1,000	1,126	1,267	1,427	1,607	1,809	2,037	2,294	2,740	3,474	4,405	5,584	7,080	10,107	-	-
Freight Barge	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
General Dry Cargo Ship	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
Passenger Ship a/	3,551	5,069	7,237	10,962	13,897	-	-	-	-	-	-	-	-	-	-		-	-
Refrigerated Cargo Ship	1,774	1,997	2,249	2,532	2,851	3,211	3,615	4,071	4,583	5,161	6,166	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	867	977	1,100	1,238	1,394	1,570	1,767	1,990	2,241	2,523	3,014	3,822	4,845	-	-	-	-	-
Tank Ship	960	978	996	1,015	1,034	1,053	1,073	1,093	1,113	1,134	1,166	1,210	1,256	1,304	1,353	1,431	1,570	1,755
Towing Vessel	960	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
Foreign Flag Jan 2012 Hourly Operating Costs at Sea																		
Bulk Carrier	1,180	1,209	1,238	1,269	1,300	1,332	1,364	1,398	1,432	1,467	1,522	1,597	1,677	1,760	1,847	1,987	2,242	2,593
Combination Carrier (e.g. OBO)	1,239	1,269	1,300	1,332	1,365	1,398	1,433	1,468	1,504	1,541	1,598	1,677	1,760	1,848	1,940	2,086	2,355	2,723
Container Ship	1,166	1,325	1,506	1,712	1,946	2,212	2,514	2,858	3,249	3,693	4,476	5,783	7,472	9,655	12,475	18,323	-	-
Freight Barge	710	871	1,068	1,311	1,608	1,972	2,419	2,967	3,640	4,465	-	-	-	-	-	-	-	-
General Dry Cargo Ship	710	871	1,068	1,311	1,608	1,972	2,419	2,967	3,640	4,465	-	-	-	-	-	-	-	-
Passenger Ship a/	5,299	7,784	11,432	17,902	23,132	-	-	-	-	-	-	-	-	-	-		-	-
Refrigerated Cargo Ship	2,622	2,981	3,388	3,852	4,378	4,977	5,657	6,431	7,310	8,309	10,070	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	1,282	1,457	1,657	1,883	2,140	2,433	2,766	3,144	3,574	4,062	4,923	6,361	8,219	-	-	-	-	-
Tank Ship	1,347	1,373	1,400	1,427	1,454	1,483	1,512	1,541	1,571	1,601	1,648	1,713	1,780	1,850	1,922	2,037	2,242	2,516
Towing Vessel	1,347	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	710	871	1,068	1,311	1,608	1,972	2,419	2,967	3,640	4,465	-	-	-	-	-	-	-	-

a/ Includes recreational vessels.
b/ Includes fishing vessels, industrial vessels, research vessels, and school ships.
Source: Prepared by Nathan Associates Inc. as decribed in text from data provided in U.S. Army Corps of Engineers, Economic Guidance Memorandum 05-01, Deep Draft Vessel Operating Costs and adjusted for bunker fuel prices reported by Bunkerworld for IFO380 and MDO for New York for the year 2009 and as of January 20, 2012.

Table 5 also presents estimated hourly vessel operating costs using bunker prices of January 2012. Given that the future of bunker fuel prices is unknown, the January 2012 may represent the best estimate for vessel operating costs in future years. The price for heavy viscosity oil in New York for January 20, 2012 was $672 per metric ton and marine diesel oil was $998 per metric ton.

6. *Estimated Direct Economic Impact on Shipping Industry Vessels*

The estimated direct economic impact on the shipping industry of the Rule in 2009 is presented in Table 6. Across all restricted areas, the total direct economic impact is estimated $22.0 million. More than 62 percent of the total direct impact incurred by containerships at $13.7 million, followed distantly by refrigerated cargo ships at $2.5 million and Ro-Ro cargo ships and passenger ships each at $1.8 million.

Table 6. Direct Economic Impact of Rule on Shipping Industry by Type and Size of Vessel, 2009 Using Average 2009 Bunker Fuel Prices ($000s)

	DWT Size Range (000s)																		
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-12(	120-15(	150+	Total
Bulk Carrier	-	29	38	24	8	39	27	75	59	52	89	49	135	21	-	-	12	4	663
Combination Carrier (e.g. OBO)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Container Ship	18	153	332	93	207	247	617	503	854	646	3,072	6,551	76	314	-	-	-	-	13,682
General Dry Cargo Ship	35	57	102	51	62	25	40	29	103	76	-	-	-	-	-	-	-	-	580
Passenger Ship a/	471	901	406	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,777
Refrigerated Cargo Ship	-	170	215	45	-	-	64	-	7	-	21	-	-	-	-	-	-	-	522
Ro-Ro Cargo Ship	4	56	361	676	441	350	99	65	147	18	286	12	-	-	-	-	-	-	2,514
Tank Ship	-	74	50	108	13	39	46	236	131	454	147	104	121	12	69	93	46	75	1,817
Towing Vessel	279	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	279
Other b/	132	8	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	142
Total	939	1,450	1,503	997	731	700	895	908	1,300	1,246	3,615	6,715	332	347	69	93	59	78	21,976

a/ Includes recreational vessels.
b/ Includes fishing vessels, industrial vessels, research vessels, and school ships.
Source: Prepared by Nathan Associates Inc. from AIS data as described in text.

Table 7 presents the impact for 2009 vessel but using the average vessel operating costs based on January 2012 bunker fuel prices. The total direct economic impact increases to $34.8 million with containerships accounting for $22.4 million or 64.2 percent of the total.

Table 7. Direct Economic Impact of Rule on Shipping Industry by Type and Size of Vessel, 2009 Using 2012 Bunker Fuel Prices, ($000s)

	DWT Size Range (000s)																		
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	-	44	58	36	12	58	41	114	89	79	134	74	204	32	-	-	19	5	1,000
Combination Carrier (e.g. OBO)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Container Ship	26	228	500	141	318	383	966	794	1,362	1,040	5,017	10,903	129	542	-	-	-	-	22,351
General Dry Cargo Ship	51	84	149	74	91	37	59	43	153	112	-	-	-	-	-	-	-	-	853
Passenger Ship a/	702	1,383	641	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,725
Refrigerated Cargo Ship	-	254	324	69	-	-	100	-	10	-	34	-	-	-	-	-	-	-	791
Ro-Ro Cargo Ship	5	83	544	1,028	677	542	155	102	234	28	467	20	-	-	-	-	-	-	3,887
Tank Ship	-	104	71	152	19	54	64	332	185	642	207	147	171	18	98	132	66	107	2,567
Towing Vessel	392	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	392
Other b/	194	12	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	208
Total	1,370	2,195	2,285	1,501	1,117	1,076	1,388	1,385	2,032	1,900	5,860	11,144	504	592	98	132	85	112	34,776

a/ Includes recreational vessels.
b/ Includes fishing vessels, industrial vessels, research vessels, and school ships.
Source: Prepared by Nathan Associates Inc. from AIS data as described in text.

7. *Total Economic Impact of Rule Including Other Market Segments and Indirect Economic Impact*

The AIS data captures the vast preponderance of commercial maritime activity that would be subject to the speed restrictions and other operational measures. However, there are some market segments that may be impacted by the speed restrictions and other operational measures whose maritime activities are not adequately captured in the AISA data. In this section, we identify the most relevant of these market segments and discuss the potential economic impact. Those market segments or potential impacts include:

- Cumulative effect of multi-port strings for containerships
- Re-routing of southbound coastwise shipping
- Passenger time on ferries
- Indirect economic impact of port diversions

The economic impact for each of these elements is presented below[5].

Cumulative effect of Multi-Port Strings for Containerships

Many of the vessels arrivals at U.S. East Coast ports occur as part of a “string” of port calls by the vessel. For containerships, ro-ro cargo ships and some specialty tankers these multi-port calls constitute a scheduled cargo service offered by the shipping lines. Other types of vessels may have multiple U.S. East Coast port calls as part of a coastwise cabotage service, for delivery of specialty chemicals or other products, or to lighten or top off in order to maximize vessel utilization. There are several reasons why the cumulative effect of multiple port calls at restricted ports could impact a vessel more than the sum of the individual direct impacts presented in the prior sections. First, the delays incurred from speed restrictions at one port when combined with speed restrictions at a subsequent port may diminish the ability of the vessel to maintain its schedule and could result in missed tidal windows. Second, even brief delays at arrival at the second port could result in increased costs for scheduled, but unused, port labor. Third, some shipping lines felt that the cumulative impact of three or four port calls at port areas with restrictions could cause them to rework vessel itineraries and could result in dropping of one of the port calls in order to maintain a weekly service without having to add an additional vessel to the service.

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[5] In the 2008 FEIS, other market segments such as commercial fishing, charter fishing and whale watching vessels were analyzed separately. However for this economic impact assessment, the availability of the AIS data permitted those market segments to be analyzed as part of the overall shipping industry analysis.

However, these cumulative factors will not affect every vessel making multiple port calls at restricted ports. Also the impact may vary from an 8-hour delay due to a missed tidal window to incurring charges for unused labor if a vessel is late arriving at the port.[6] It is realistic to assume that the shipping industry will revise their itineraries to account for the delays imposed by the speed restrictions and that occurrences of missed tidal widows will be rare. We have used an average additional delay of 11 minutes for each containership transit that is part of a multi-port string to account for this cumulative impact.[7] The economic value of this additional time has been calculated for each port area based respectively on the average 2009 vessel operating and the January 2012 vessel operating costs for containerships. As shown in Table 8, the estimated impact for 2009 is$3.6 million and in 2012 $5.7 million.

<u>Re-routing of Southbound Coastwise Shipping</u>

Coastwise shipping or cabotage trade along the U.S. East Coast has always been an important segment of our nation's maritime heritage. In recent years, attention has been focused on the further development of coastwise shipping (also referred to as short-sea shipping) as a means of reducing highway congestion on the Eastern Seaboard. Benefits of coastwise shipping also include lowering transport and environmental costs and reducing our demand for imported fuel. For these reasons, it is important that the speed restrictions not unduly affect the development of increased coastwise shipping.

However, for commercial and navigation purposes, it appears unlikely that the speed restriction would significantly affect coastwise shipping. Northbound vessels prefer to use Gulf Stream further offshore and benefit from the enhanced operating speed and fuel efficiency. Southbound traffic routes closer to the U.S. East Coast; generally within 7-10 nautical miles of the shoreline. However, during the proposed seasonal management periods, masters of southbound vessels would likely route outside of seasonal speed restricted areas incurring an overall increase in distance. This affects southbound vessels between the entrance to the Chesapeake Bay and Port Canaveral.

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[6] While tides occur on 12-hour cycle, it is assumed that a tidal window is open for 2 hours before and after high tide. This results in an 8-hour waiting period between tidal windows.

[7] Only a small portion of vessel arrivals should be affected by this additional delay. It is assumed that 7.5 percent of vessels could be affected by as much as an additional 8-hour delay due to missing the tidal window. This results in an average additional delay per vessel of 36 minutes.

The speed restrictions in the mid-Atlantic region are implemented for a radius of 20 nautical mile buffer around each port area for port areas north of Wilmington, NC.[8] A continuous 20-mile buffer was implemented from Wilmington, NC through Savannah to the northern boundary of the Southeastern SMA. The additional distance incurred by southbound vessels would be 56 nautical miles. The economic impact for this extra sailing distance is estimated at $1.3 million using 2009 vessel operating costs and $2.1 million using January 2012 vessel operating costs.

Impact on Ferry Passengers

The proposed operational measures will have a direct economic impact on ferry passengers whose travel time will be increased due to the speed restrictions. As recognized by the U.S. Department of Transportation, time saved from travel may be devoted to other activities, such as remunerative work or recreation.[9] The USDOT guidelines recommend hourly values of travel-time savings to be used in all economic analysis of transportation regulatory actions. Specific values of travel time are recommended for local travel and intercity travel and whether the travel is for business or personal purposes.

The USDOT guidelines recommend using the median household income (divided by 2000 hours) as the basis for valuation of intercity business travel time, and 70 percent of that value for intercity personal travel time. Hence, based on the 2000 Census data, they recommend hourly values of $21.20 for intercity business travel and $14.80 for intercity personal travel. We have updated the USDOT recommended values using 2005 data for median household income reported by the U.S. Census Bureau.[10] Based on that data, the hourly value of intercity business travel time is $23.16 and intercity personal travel time is $16.21.

The estimated economic impact of proposed operational measures on Southern New England ferry passengers is presented in Table 8. The estimates are the same as those presented in the 2008 FEIS, as a

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[8] The exception is the Block Island Sound speed restriction area that is configured as a rectangle with a width of 30 nautical miles.

[9] U.S. Department of Transportation, Office of the Secretary of transportation, The Value of Travel Time: Departmental Guidance for Conducting Economic Evaluations, April 9, 1997 http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf and Revised Departmental Guidance, Valuation of Travel Time in Economic Analysis, February 11, 2003 http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf.

[10] U.S. Census Bureau, Income, Poverty and Health Insurance Coverage in the United States: 2005, issued August 2006. http://www.census.gov/prod/2006pubs/p60-231.pdf

separate analysis of the impact on ferry passengers was not conducted for this initial estimate of the economic impact of the Rule.

Estimated Indirect Economic Impact

Depending on the nature and significance of the direct economic impact, it is possible that implementation of the proposed operational measures could have indirect economic impacts. Potential indirect economic impacts include:

- Increased intermodal costs due to missed rail and truck connections
- Diversion of traffic to other ports
- Impact on local economies of decreased income from jobs lost due to traffic diversions

There are many factors that influence a shipping line's decision to call at specific ports. These include the adequacy and suitability of port facilities and equipment, the ability of the terminal operator to quickly turnaround the vessel, overall cargo demand, efficiency of intermodal transportation, port charges, and the port location relative to other ports and cargo markets. If cargo is to divert to other ports this would be because the total additional costs associated with those routes are less than the cost of vessel time due to delays at the current port. Hence it would be double-counting to also include any additional overland transport costs to the estimated impact already presented.

A good portion of a port's traffic is often considered captive to that port. For cargoes that are destined for the port's immediate hinterland, it does not make economic sense to call at a distant port and then to ship back to the port via expensive land transport. However, most ports also accommodate traffic that is not destined for its immediate hinterland but is through traffic that may have economically attractive routing alternatives. Port areas in the Northeast and northern parts of the mid-Atlantic region serve as gateways to the inland population centers and industrial areas such as western New York, western Pennsylvania, Ohio, Indiana, Illinois and Michigan. These areas may be served via the Canadian ports of Halifax and Montreal without incurring delays caused by the right whale ship strike reduction measures.[11] These Canadian ports currently compete with Northeast U.S. ports for cargo destined for

[11] Vessels may divert to other U.S. ports in addition to those diverting to Canada. While this is possible, for the total economic impact analysis only diversions to non-U.S. ports are included. For diversion to ports within the U.S. the negative economic impact for one U.S. port are offset by gains in another U.S. port.

the mid-eastern U.S. and the speed restrictions implemented in the U.S. and not in Canada could shift the current competitive balance to the advantage of Canadian ports.

The Maritime Administration (MARAD), an agency of the U.S. Department of Transportation has developed a Port Economic Impact Kit that allows users to assess the economic impact of port activity on a region's economy. The MARAD Port Economic Impact Kit uses an adaptation of input-output analysis that is a widely established tool for undertaking economic impact assessments. The model calculates the total economic impacts or multiplier effect of deep-draft port industry and includes an indirect effect that reflects expenditures made by the supplying firms to meet the requirements of the deep-draft port industry as well as expenditures by firms stocking the supplying firms.The model also includes an induced effect that corresponds to the change in consumer spending that is generated by changes in labor income accruing to the workers in the deep-draft port industry as well as employment in the supplying businesses.

We have estimated the indirect economic of port diversions based on the detailed methodology described in the 2008 FEIS adjusted for the actual observed delays incurred in 2009 from the AIS data analysis and using the updated vessel operating costs for 2009 and January 2012. As shown in Table 8, the estimated indirect economic impact of port diversion for 2009 is $19.9 million and for January 2012 it is $30.0 million.

Table 8. Total Economic Impact of Rule Using 2009 and 2012 Bunker Fuel Prices, ($000s)

	Bunker fuel prices of	
Impact	2009	2012
Direct economic impact		
Shipping industry vessels	21,976	34,776
Cumulative effect of multi-port strings	3,593	5,685
Re-routing of southbound coastwise shipp	1,298	2,054
Pasengers' time on passenger ferries	5,191	5,191
Whale watching vessels	1,336	1,336
Subtotal direct economic impact	33,393	49,041
Indirect economic impact of port diversions	18,970	30,019
Total economic impact	52,363	79,061

Source: Prepared by Nathan Associates as described in text.

The total economic impact of the Rule including direct and indirect impacts is estimated at $52.4 million using 2009 vessel operating costs and $79.1 million using January 2012 vessel operating costs.

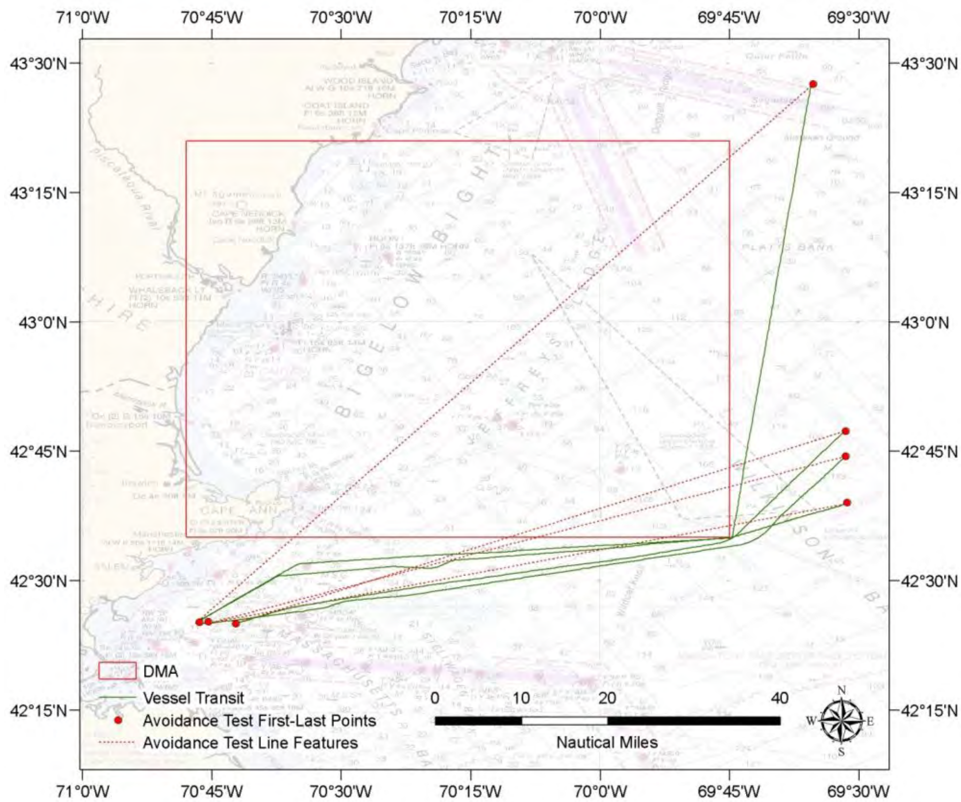
Appendix L. Number of transits by vessel type that had at least 1 nautical mile of travel within the DMAs during their respective effective periods.

DMA	# Whales	General Location	Area (nm^2)	Start Date	End Date	Tanker	Cargo	Pass.	Pilot	Tow	Tug	Other	Total
NE_01	11	Jeffreys Ledge	1767	12/11/2008	12/25/2008	11	1	0	1	11	11	8	43
NE_02	43	Jordan Basin	1576	12/11/2008	12/28/2009	6	0	0	0	0	0	0	6
NE_03	3	Cashes Ledge	1356	12/11/2008	12/25/2009	21	3	0	0	0	0	0	24
NE_04	28	Jeffreys Ledge	1997	1/13/2009	2/10/2009	39	14	0	0	23	32	17	125
NE_05	3	Jeffreys Ledge	1605	1/16/2009	1/29/2009	32	21	3	0	20	19	10	105
NE_06	6	Northern Jeffreys Ledge	1448	2/11/2009	2/25/2009	14	6	0	0	5	7	3	35
NE_07	5	Southern Jeffreys Ledge	1456	2/11/2009	2/25/2009	27	18	0	0	3	5	5	59
NE_08	12	Great South Channel	2419	2/11/2009	2/25/2009	12	18	0	0	0	0	5	36
NE_09	3	Georges Shoal	1592	3/17/2009	3/28/2009	1	0	0	0	0	0	0	1
NE_10	5	Georges Shoal	1764	4/13/2009	4/25/2009	0	1	0	0	0	0	0	1
NE_11	15	Cashes Ledge	1926	5/12/2009	5/27/2009	13	4	0	0	0	0	6	23
NE_12	3	Jordan Basin	1602	5/13/2009	5/27/2009	22	1	0	0	0	1	3	27
NE_13	44	Cashes Ledge	4391	6/2/2009	6/29/2009	41	30	8	0	1	0	21	102
NE_14	3	Cashes Ledge	4391	7/9/2009	7/21/2009	20	22	3	0	0	0	24	72
NE_15	5	Fippenies Ledge	1644	9/2/2009	9/16/2009	8	2	4	0	2	0	15	31
NE_16	26	Jeffreys Ledge	2124	10/15/2009	11/11/2009	18	5	11	0	17	17	30	98
NE_17	24	Jordan Basin	1918	10/22/2009	12/1/2009	49	2	1	0	1	0	4	59
NE_18	16	Cashes Ledge	2441	10/27/2009	11/10/2009	9	2	2	0	2	0	0	15
NE_19	41	Jeffreys Ledge	3661	11/10/2009	12/17/2009	71	15	6	0	7	10	37	148
NE_20	47	Cashes Ledge	3403	11/10/2009	11/24/2009	19	9	0	0	0	0	1	29
NE_21	27	Jordan Basin	4198	12/4/2009	12/19/2009	7	0	0	0	0	0	0	7
NE_22	37	Jordan Basin	3768	1/4/2010	1/15/2010	3	0	0	0	0	0	0	3
NE_23	13	Jeffreys Ledge	1887	1/5/2010	1/28/2010	34	6	0	0	10	13	10	73
NE_24	3	Nantucket MA	1527	2/1/2010	2/15/2010	0	0	0	0	4	0	2	7
NE_25	14	Nantucket MA	1922	3/8/2010	3/22/2010	1	0	5	0	1	0	1	8

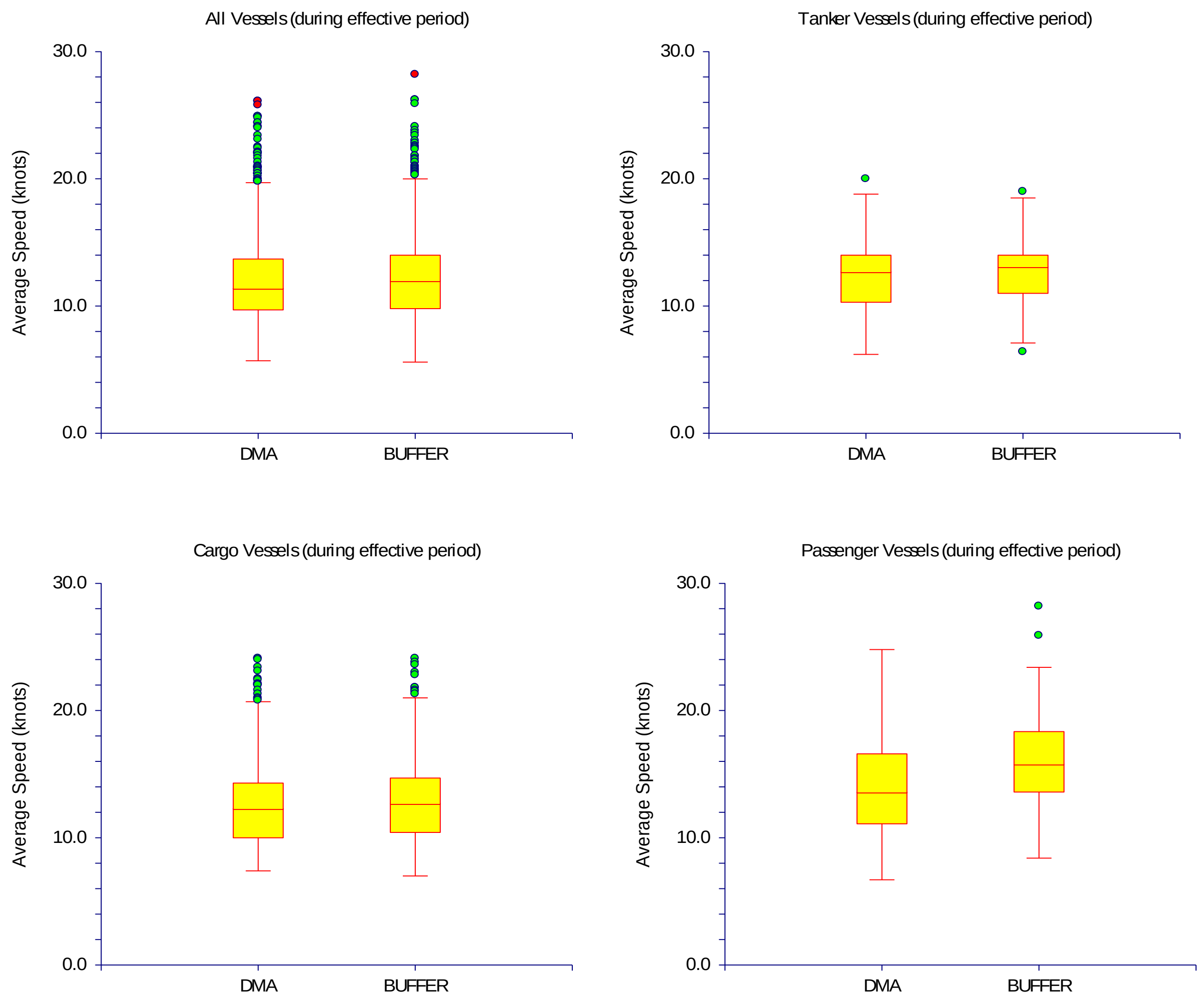
DMA	# Whales	General Location	Area (nm^2)	Start Date	End Date	Tanker	Cargo	Pass.	Pilot	Tow	Tug	Other	Total
NE_26	6	Great South Channel	1697	3/12/2010	3/24/2010	7	11	0	0	0	0	3	21
NE_27	8	Great South Channel	1941	3/22/2010	4/4/2010	15	19	10	0	1	0	1	47
NE_28	3	Nantucket MA	1566	4/14/2010	4/28/2010	0	0	15	0	1	0	5	22
NE_29	18	Block Island	886	4/22/2010	5/5/2010	25	16	2	0	9	33	25	115
NE_30	80	Block Island	1682	4/30/2010	5/5/2010	8	9	3	0	7	16	15	61
NE_31	11	Cashes Ledge	2460	5/24/2010	6/5/2010	20	10	2	0	0	2	12	46
NE_32	3	Jeffreys Ledge	1591	7/27/2010	8/9/2010	21	22	5	3	7	16	50	125
NE_33	4	Jeffreys Ledge	1591	8/9/2010	8/23/2010	26	19	9	4	8	11	55	135
NE_34	10	Jeffreys Ledge	1591	8/18/2010	9/1/2010	24	22	6	2	9	14	52	131
NE_35	6	Jeffreys Ledge	1591	9/1/2010	9/14/2010	16	15	11	4	8	12	30	97
NE_36	4	Mount Desert Island	1707	9/13/2010	9/25/2010	5	1	8	0	0	0	0	14
NE_37	7	Jeffreys Ledge	1591	9/13/2010	9/27/2010	27	19	20	8	10	20	16	121
NE_38	10	Cashes Ledge	2308	10/14/2010	10/28/2010	13	1	6	0	0	0	7	27
NE_39	8	Jeffreys Ledge	1818	10/14/2010	10/28/2010	14	10	14	2	3	13	14	70
NE_40	4	Jordan Basin	1471	10/14/2010	10/28/2010	1	2	1	0	0	0	0	4
NE_41	14	Jeffreys Ledge	1818	10/28/2010	11/8/2010	10	4	2	0	2	6	6	33
NE_42	10	Jeffreys Ledge	3754	11/16/2010	11/27/2010	24	24	1	0	3	20	8	80
NE_43	14	Cashes Ledge	2760	11/16/2010	11/27/2010	7	9	0	0	0	0	2	18
NE_44	12	Jordan Basin	2447	11/16/2010	11/27/2010	0	1	0	0	0	0	1	2
NE_45	7	Jeffreys Ledge	2299	11/29/2010	12/14/2010	15	2	0	0	5	9	8	41
NE_46	16	Jordan Basin	2413	12/1/2010	12/14/2010	4	0	0	0	0	0	0	4
NE_47	4	Cashes Ledge	1683	12/1/2010	12/14/2010	9	0	0	0	0	0	1	10
NE_48	28	Cashes Ledge	4032	12/21/2010	1/2/2011	24	13	0	0	1	0	0	38
NE_49	5	Jordan Basin	1561	12/21/2010	1/2/2011	2	1	0	0	0	0	1	4
NE_50	3	Jeffreys Ledge	1579	1/4/2011	1/15/2011	15	5	0	0	2	6	2	31
NE_51	4	Cashes Ledge	1680	1/4/2011	1/15/2011	1	0	0	0	0	0	0	1
NE_52	8	Jordan Basin	2108	1/4/2011	1/15/2011	2	0	0	0	0	0	0	2

DMA	# Whales	General Location	Area (nm^2)	Start Date	End Date	Tanker	Cargo	Pass.	Pilot	Tow	Tug	Other	Total
NE_53	3	Sandy Hook	1592	1/10/2011	1/23/2011	86	196	13	0	33	23	18	372
NE_54	5	East of Cape Cod	1612	2/25/2011	3/11/2011	11	28	21	0	0	1	1	64
NE_55	5	East of Nantucket	1813	3/15/2011	3/29/2011	3	6	0	0	0	0	1	10
NE_56	3	Nantucket Sound	899	4/27/2011	5/10/2011	0	1	18	0	5	6	8	39
NE_57	13	Martha's Vineyard	1995	5/2/2011	5/15/2011	8	12	10	0	13	19	18	83
NE_58	21	East of Cape Cod	648	5/3/2011	5/17/2011	13	22	0	0	1	0	10	52
NE_59	21	East of Cape Cod	1163	5/3/2011	5/17/2011	8	18	0	0	0	0	9	37
SE_01	16	Ponce de Leon Inlet	693	1/12/2010	2/5/2010	0	0	0	0	2	2	3	7
SE_03	19	Ponce de Leon Inlet	774	2/1/2010	3/24/2010	0	0	0	0	3	6	3	12
SE_05	33	Cape Canaveral	1476	2/22/2010	3/15/2010	12	35	29	0	34	14	13	138
SE_07	8	Palm Coast	673	1/12/2011	1/27/2011	0	2	0	0	0	0	1	3
SE_08	4	Palm Coast	635	1/31/2011	2/15/2011	0	1	0	0	1	1	1	4
SE_09	5	Palm Coast	404	2/24/2011	3/11/2011	0	1	0	0	1	1	1	4
SE_10	5	Brunswick	845	2/28/2011	3/15/2011	7	44	0	0	3	4	4	62
Totals	905					961	781	249	24	279	370	607	3324

Appendix M. Map depicting four avoidance transits that were detected during the active period of DMA NE 16.



Appendix N. Box plots of mean average vessel transit speeds within the Dynamic Management Areas (DMA) and a 10 nautical mile buffer located outside of the DMAs. Red bars within the box plots represent the median of mean speeds and the green and red dots are mild and extreme outliers, respectively.



Appendix O. Mean vessel transit speeds (± standard errors) inside of active DMAs and 10 nautical mile buffers located outside of DMAs.

Vessel Types	n	Buffers	DMAs
All	1799	12.33±0.10	12.00*±0.09
Tanker	615	12.63±0.08	12.31*±0.09
Cargo	525	13.21±0.21	12.89*±0.19
Passenger	93	16.05±0.39	14.10*±0.39
Other	566	10.57±0.20	10.49±0.18

**mean speeds in DMAs were significantly lower ($p < 0.05$) than mean speeds in 10 nautical mile buffers*

Appendix P. Counts of avoidance transits detected in DMAs during their active period and two-week periods directly before and after the active periods. Only DMAs in which avoidance transits were detected during the active periods are included, and shading is used to highlight DMAs where avoidance transits were not detected in the two-week periods directly before and/or after the active periods.

DMA	Vessel Type	Avoidance Transits		
		Before DMA	**During DMA**	**After DMA**
NE_04	Tanker	0	4	0
NE_07	Tug	1	1	1
NE_08	Tanker	1	1	0
NE_11	Tanker	0	1	0
NE_13	Tanker	0	1	1
NE_14	Tanker	0	1	0
NE_15	Passenger	0	3	1
	Tanker	0	1	1
NE_16	Passenger	0	2	0
	Tanker	0	2	0
NE_17	Passenger	0	1	0
NE_18	Passenger	0	1	0
	Tanker	0	0	2
NE_31	Other	0	1	0
	Tanker	0	0	1
NE_33	Tanker	0	1	0
NE_38	Passenger	0	1	0
NE_57	Cargo	1	0	0
	Other	0	0	1
	Pleasure	0	0	1
	Sailing	0	0	2
	Tanker	5	2	1
NE_58	Sailing	1	0	0
	Tug	0	2	2
SE_03	Towing	0	0	1
SE_05	Cargo	0	1	0
	Pleasure	0	0	1
	Tug	0	1	1
SE_10	BigTow	1	0	0
	Cargo	7	5	7
	Dredging	1	0	0
	Tanker	0	1	0

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FEATURE ARTICLE

Gross and histopathologic diagnoses from North Atlantic right whale *Eubalaena glacialis* mortalities between 2003 and 2018

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ABSTRACT: Seventy mortalities of North Atlantic right whales *Eubalaena glacialis* (NARW) were documented between 2003 and 2018 from Florida, USA, to the Gulf of St. Lawrence, Canada. These included 30 adults, 14 juveniles, 10 calves, and 16 of unknown age class. Females represented 65.5% (19/29) of known-sex adults. Fourteen cases had photos only; 56 carcasses received external examinations, 44 of which were also necropsied. Cause of death was determined in 43 cases, of which 38 (88.4%) were due to anthropogenic trauma: 22 (57.9%) from entanglement, and 16 (42.1%) from vessel strike. Gross and histopathologic lesions associated with entanglement were often severe and included deep lacerations caused by constricting line wraps around the flippers, flukes, and head/mouth; baleen plate mutilation; chronic extensive bone lesions from impinging line, and traumatic scoliosis resulting in compromised mobility in a calf. Chronically entangled whales were often in poor body condition and had increased cyamid burden, reflecting compromised health. Vessel strike blunt force injuries included skull and vertebral fractures, blubber and muscle contusions, and large blood clots. Propeller-induced wounds often caused extensive damage to blubber, muscle, viscera, and bone. Overall prevalence of NARW entanglement mortalities increased from 21% (1970–2002) to 51% during this study period. This demonstrates that despite mitigation efforts, entanglements and vessel strikes continue to inflict profound physical trauma and suffering on individual NARWs. These cumulative mortalities are also unsustainable at the population level, so urgent and aggressive intervention is needed to end anthropogenic mortality in this critically endangered species.

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§Corrections were made after publication. For details see www.int-res.com/abstracts/dao/v135/n1/c_p1-31/
This corrected version: July 3, 2019

North Atlantic right whale carcass found chronically entangled in fishing gear ~60 miles off the Virginia coast, and later towed to shore for necropsy. Investigating whale carcasses to determine cause of death requires specialized skills, logistics, and dedicated funding.

Photo: Sea to Shore Alliance (NOAA permit #20556)

KEY WORDS: North Atlantic right whale · *Eubalaena glacialis* · Mortality · Entanglement · Vessel strike · Necropsy · Pathology · Morphology

1. INTRODUCTION

The North Atlantic right whale *Eubalaena glacialis* (NARW) is one of the most endangered large whale species in the world (listed as 'Endangered' on the IUCN Red List; Cooke 2018). NARWs are found primarily within the northwest Atlantic Ocean from Florida, USA, to the Gulf of St. Lawrence, Canada (Knowlton et al. 1992, Khan et al. 2016). By the early

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20th century, all 3 right whale species (North Atlantic, North Pacific, and southern) had been hunted to near extinction by the commercial whaling industry (Reeves 2001). International protections for all right whale species were first instituted over 80 yr ago. NARWs have been legally protected under the US Endangered Species Act and Marine Mammal Protection Act for nearly 50 yr and the Canadian Species at Risk Act for 15 yr (DFO 2014). Despite this long-term protection, NARWs have experienced no appreciable recovery, in contrast to their southern hemisphere counterpart, southern right whales *E. australis* (Cooke et al. 2015, Bannister et al. 2016, Findlay et al. 2017, Corkeron et al. 2018).

While a period of population growth for NARWs was documented around the turn of this century, in 2010 NARWs started to decrease in number once again (Pace et al. 2017, Pettis et al. 2018). This decline has been attributed to a variety of factors, primarily low reproductive rates (Kraus et al. 2001, Pettis et al. 2018) and high mortality rates caused by entanglement in fishing gear and vessel strikes (Kraus 1990, Caswell et al. 1999, Knowlton & Kraus 2001, Moore et al. 2004, van der Hoop et al. 2013, Corkeron et al. 2018, Kenney 2018). At the end of 2017, between 392 and 433 (95% confidence range; best estimate = 411) NARWs remained in the population (Pettis et al. 2018, based on the methodology of Pace et al. 2017). Among them, only 90 were likely adult females (Hayes et al. 2018a), the most crucial demographic for reproduction. If the present downward trend continues, the population could become functionally extinct within a few decades. Additionally, NARW reproductive success has been linked to climate-associated ecosystem regime shifts, which are currently unfavorable for the species (Meyer-Gutbrod & Greene 2018). Neither the current environmental conditions nor the unpredictability of future climate trends were accounted for in the most recent population models (Pace et al. 2017), suggesting that population decline may proceed even more rapidly than projected.

NARW reproductive trends demonstrate increasing calving intervals, declining numbers of first-time dams (calving females), and declining percentage of available dams that calve (Kraus et al. 2001, Pettis et al. 2017a). In fact, the annual rate of increase of the NARW population between 1990 and 2016 was 2% (including the decline in abundance observed since 2010), which is only one-third that of their southern-hemisphere counterparts (Corkeron et al. 2018). While the etiology of poor population recovery in the NARW population, including factors such as reproductive failure, is uncertain, anthropogenic stressors such as sub-lethal chronic entanglement and ocean noise are suspected to be contributing factors (Tyack 2008, Rolland et al. 2012, van der Hoop et al. 2016). Climate-associated changes in prey availability (Meyer-Gutbrod & Greene 2014, Meyer-Gutbrod et al. 2015) and poorer overall health and body condition in adult females (Rolland et al. 2016, Pettis et al. 2017b) may also be reducing fecundity.

In an effort to mitigate direct anthropogenic mortalities, the US and Canadian governments have implemented large-scale management efforts over the past 20 yr. Measures to reduce vessel strike mortalities included shifts in traffic separation schemes in the Bay of Fundy (2003) and Boston, MA (2007); the designation of the Roseway Basin (2007) and Great South Channel (2009) Areas to be Avoided; and the US ship speed restriction rule (2008), which established seasonal and dynamic management areas (NMFS 2008, van der Hoop et al. 2013). The latter effort resulted in decreased vessel-strike mortalities within seasonal management areas in the USA, but increased vessel strikes outside of them (Laist et al. 2014, van der Hoop et al. 2015). In addition, fishing gear modifications have been implemented in the USA by the Atlantic Large Whale Take Reduction Plan since 1997 in an effort to better understand and reduce large whale entanglements. These measures include the incorporation of weak links into fishing gear configurations, seasonal fishery closures, gear marking, sinking groundline (2009), establishment of a minimum number of traps per trawl (vertical line rule, 2015), and ghost gear clean ups (NMFS 2014, Hayes et al. 2018a). Unfortunately, these mitigations have not been effective in reducing the number of entanglement events for large whales (Pace et al. 2014, Hayes et al. 2018a), and the severity of entanglements has actually increased in recent years (Knowlton et al. 2012). The Government of Canada also recently implemented shipping and fishing regulations in response to the unprecedented deaths of 12 NARWs in Canadian waters in 2017. These cases are part of an ongoing unusual mortality event (NMFS 2019).

NARW mortality data from 1970–2002 were previously summarized by Moore et al. (2004). During that 32 yr period, 54 NARW mortalities were documented, and cause of death was established in 19 cases. Of those, 14 deaths were due to vessel strikes (74%), 4 to entanglements (21%), and 1 to perinatal death (5%). The current review summarizes gross and histopathologic findings from NARW deaths that occurred in the subsequent 16 yr period, i.e. 2003–2018.

2. METHODS

Between 2003 and 2018, NARW mortalities were reported to marine mammal stranding network agencies, government officials, and whale researchers in the USA and Canada (see Acknowledgements). Data were entered into standardized fields in a dedicated Microsoft Access necropsy database for the North Atlantic Right Whale Consortium (NARWC 2018a). Varying levels of data were available on each case due to sighting circumstance, location of carcass, environmental conditions, available personnel, and carcass condition. To be considered a confirmed NARW death, a minimum of carcass location and photograph(s) enabling species identification were required. Drift analyses, condition code timeline, and distinguishing marks were employed to avoid double-counting carcasses that were not able to be brought to shore for necropsy and disposal.

2.1. Carcass documentation and necropsy

In some cases, NARW carcasses were confirmed but never relocated after the initial report. In other cases, documentation of floating carcasses was limited to an at-sea examination, with or without limited sampling. When carcasses stranded or were towed ashore, a thorough examination was conducted barring adverse environmental or logistical conditions. A decomposition code of 1–5 was assigned based on the definitions in Geraci & Lounsbury (2005). Morphometrics were obtained and a necropsy was conducted following the protocol outlined by McLellan et al. (2004) whenever feasible. A correction factor of −9% of the measured length (Fortune et al. 2012) was employed to obtain a corrected total straight length for animals that were measured after being towed at sea and/or hauled onto a beach. Weights of the whale carcasses were obtained in a variety of ways: by using a vessel travel lift to weigh the whale as it was hauled out of the water; by net weight determination of whales placed on a flatbed truck and transported to a weigh station prior to necropsy by subtracting the weight of the empty vehicle/trailer from the weight with the whale; or by corrected weight determination when the soft tissues and skeleton were weighed separately after the necropsy by adding 6.8% to that measurement to account for un-weighed fluid losses (calculated from McLellan et al. 2004, Moore et al. 2004). In one case, the post-necropsy tissues and skeleton were weighed without the baleen racks and an additional estimated 250 kg was added to the total weight to account for this missing tissue. Body condition in stranded right whales has not been documented in a standardized format over the years. The most frequently used descriptive terms in necropsy reports were 'robust/good,' 'thin/poor,' and 'emaciated.' In some cases, only blubber thickness measurements were recorded, with no subjective body condition assessment included in the gross necropsy report.

Identification photographs were obtained when available for comparison to the NARWC identification database (NARWC 2018b) enabling carcasses to be matched to previously documented or known living individuals. Samples (most often skin, post-cranial, or occipital condyle bone core) were obtained to assist with individual identification on a molecular level to support photographic identification or in lieu of it when identification images were not available. Genetic samples were analyzed though combined efforts at Trent University (Peterborough, Ontario, Canada) and Saint Mary's University (Halifax, Nova Scotia, Canada). When sample quality allowed, individual-specific genetic profiles were obtained for each sample based on high-resolution genetic profiling protocols (sequencing a portion of the mitochondrial control region, molecular sex determination, and genotype analysis at 35 microsatellite loci) as described by Frasier et al. (2013). For samples where the DNA was highly degraded, mitochondrial sequencing and molecular sexing were still conducted, but only the 5 most polymorphic loci were typed, using modified protocols specific for the analysis of highly degraded DNA (McLeod et al. 2010). More loci were added until adequate resolution was obtained for individual identification, or if it was deemed that the DNA was too degraded to obtain reliable results. These results were then compared to the NARW genetic database, which contains genetic profiles for more than 75% of all identified NARWs (Frasier et al. 2009) and is curated through Trent and Saint Mary's Universities.

Age classes were defined as follows for cataloged whales; calf: 1 d to 1 yr; juvenile >1 to <9 yr or until the year before they calve if it occurs before they are 10; and adult ≥9 yr (Hamilton et al. 1998, Rolland et al. 2005). For carcasses of unknown ages, age class was assigned based on necropsy findings (mature/immature status of gonads) and/or actual or corrected total straight length according to Moore et al. (2004), where calf: <900 cm; juvenile: >1000 and ≤1200 cm; and adult >1400 cm; for any lengths falling outside these ranges, age class cannot be determined (CBD).

Comprehensive internal and external sampling was performed to the extent possible on examined whales, but was occasionally limited by advanced decomposition and/or logistical constraints. Various tissues were collected for analyses including advanced diagnostic imaging (CT), histopathological examination (preserved in 10% neutral buffered formalin), bacterial and viral testing (frozen at −80°C dry and/or stored in RNA stabilizing solution), contaminant, stress hormone, and biotoxin analyses (frozen at −20 or −80°C), and life history information (frozen at −20 or −80°C).

Table 1. Standardized list of pathophysiologic cause of death (COD) categories and associated sub-categories assigned to North Atlantic right whale mortality cases 2003–2018. COD categories with no applicable sub-categories are listed as not applicable (NA)

Pathophysiologic COD	COD sub-categories
Degenerative	NA
Developmental	NA
Autoimmune	NA
Metabolic	NA
Neonatal (still birth or dystocia)	NA
Neoplastic	NA
Nutritional	Maternal abandonment, other
Immunological	Failure of passive transfer
Infectious	Bacterial, fungal, parasitic, viral, multiple etiologies, cause unknown
Inflammatory (non-infectious)	NA
Ischemic or vascular	NA
Trauma	Blunt force trauma vessel strike, propeller trauma vessel strike, entanglement, predation, acoustic, drowning/asphyxia, foreign body ingestion, hemorrhage/hypovolemic shock, neurologic, cause unknown, other
Toxin	NA
Euthanasia	NA
Other	NA
Undetermined	NA

2.2. Case reviews

This retrospective case review study included all available data from confirmed NARW mortalities between 2003 and 2018, which were entered into standardized fields in the NARWC necropsy database (NARWC 2018a) and distilled into short case summaries with representative gross images. Each summary includes a brief case history (date reported, location of initial sighting, towed at sea/hauled on beach), necropsy geographic location, brief carcass description (decomposition code, % skin present, evidence of bloating, presence of baleen), signalment (age or age class, sex), major gross and histopathologic findings, ancillary diagnostic findings, ultimate and proximate cause of death, relevant incidental findings, and a discussion regarding timeline and interpretation of findings. Each case summary was reviewed by the primary case prosector for accuracy.

In many cases, primary prosectors had assigned a cause of death (COD) for the whale in the final necropsy report. All CODs were standardized based on a commonly used veterinary pathophysiological categorization of diseases (adapted DAMNIT-V categorization; Table 1). Proximate COD is defined as the underlying condition(s) that started the chain of events leading to death (e.g. 'Trauma — propeller trauma vessel strike'). Ultimate COD is defined as the condition that caused the animal to die at that place and time (e.g. 'Trauma — hemorrhage/hypovolemic shock' as a result of a proximate COD of 'Trauma — propeller trauma vessel strike'). In many instances, ultimate COD is inferred from the severity and location of lesions rather than as a morphological diagnosis. For cases where the established COD was not specified to be proximate or ultimate or was not assigned, the primary author categorized proximate and ultimate CODs based on the available data and submitted them to the primary prosector for approval. Degree of confidence for ultimate and proximate CODs were scored according to definitions developed by Moore et al. (2013). Moore et al. (2004, 2013) classified propeller trauma as 'sharp' and trauma from hull parts as 'blunt.' However, a recent discussion of propeller trauma (Semeraro et al. 2012) suggests that propeller blade edges are not truly sharp, and that the resulting trauma can be both 'sharp' and 'blunt' at times. Thus, we describe any trauma inflicted by a propeller as 'propeller-induced trauma.'

2.3. Analysis

For all morphometric analyses, only whales with actual or corrected total straight lengths (not estimated), actual or corrected weights (not estimated), and known actual or minimum age (based on sightings history) were included. All morphometric data were validated against the original datasheets for accuracy, including whether the weights and lengths were actual or estimated. Total straight length, weight, and age were compared to establish length–weight curves, age–length curves, and age–weight curves. Fluke width and anterior flipper edge length, as defined in the morphometrics data sheet, were regressed on total straight length to facilitate length extrapolations for future decomposed or incomplete carcasses where total straight length is not available. All curves were graphed and regressed in MedCalc for Windows, version 18.10.2 (MedCalc Software), using logarithmic, exponential, or geometric equations as best-fit analysis indicated for each dataset. In order to increase sample size, all regressions were performed with the complete NARW mortality dataset from 1970–2018 archived in the NARWC necropsy database (NARWC 2018a) established by the Woods Hole Oceanographic Institution (WHOI) and currently maintained by the International Fund for Animal Welfare (IFAW). The mortality plots were generated using ArcMap 10.6.1 and the Albers Equal Area Conic projection (ESRI).

3. RESULTS

Between 2003 and 2018, 70 confirmed NARW mortalities were reported in US and Canadian waters (see Supplement 1, Table S1 for a complete list of carcasses). The average annual number of mortalities over the 16 yr study period was 4.4, with an outlier peak in 2017 of 17 (range 1–17, SD 3.6) that was related to an ongoing unusual mortality event (see Section 4.3). Excluding the outlier year, the annual mean was 3.5 reported NARW deaths (range 1–6, SD 1.25). The majority of these cases were initially sighted floating at sea (n = 51), while 16 were found stranded dead on shore and the remaining 3 cases stranded alive (2 calves and 1 juvenile). Of the 70 confirmed mortalities, 13 whales were not examined (only photographs and location data were available due to poor field conditions, offshore location, or other logistical limitations), 1 had an initial exam with no sampling, 1 had initial sampling with no exam, 11 were minimally examined and sampled (these included floating carcasses that were examined from vessels with no towing option, and stranded carcasses with minimal viscera due to advanced state of decomposition and/or in a remote location; data collected varied), and 44 were necropsied. Necropsied whales were fresh dead (Code 2, n = 3), moderately decomposed (Code 3, n = 20), or in advanced decomposition (Code 4, n = 21).

Sex was identified in 59/70 (84.3 %) cases and age class in 54/70 (77.1 %) cases; in 10 cases, neither age class nor sex could be determined either due to decomposition, scavenger damage, or lack of exam. There were 31 females, 28 males, and 11 whales of undetermined sex. More adult mortalities were documented (n = 29) than juveniles (n = 14) and calves (n = 10) combined. Adult females represented the largest overall demographic, comprising 19/29 (65.5 %) of the known-sex adult mortalities. Table 2 presents a summary of age class and sex. The majority of calves stranded prior to 2010 (9/10, 90 %) while the majority of adults (20/30, 66.7 %) and juveniles (10/15, 66.7 %) stranded between 2010 and 2018.

NARW mortalities were documented from the Atlantic coast of northeastern Florida (southernmost part of calving grounds, frequented in winter) to the northwestern coast of Newfoundland in the Gulf of St. Lawrence (northernmost part of commonly used feeding grounds, frequented in summer). A map of confirmed NARW mortalities from 2003 through 2018 with associated causes of death is provided in Fig. 1. Of the 70 confirmed mortalities, 23 occurred in Canada, 1 at the Canada/US border, and 46 in the USA. Four spatial mortality aggregations are subjectively evident, including 11 deaths in the southeastern USA (Georgia and Florida), 10 off North Carolina and Virginia, 17 off Massachusetts, and 15 deaths in the Gulf of St. Lawrence. It is also important to remember that location of entanglement death does not necessarily reflect the location where the whale became entangled, since whales are able to carry gear over long distances. Across all years, seasonal mortality peaks occurred in summer (June–August, n = 27) and winter (December–February, n = 20) with spring (March–May, n = 12) and fall (September–November, n = 11) having lower overall mortalities (Table 3). Deaths only occurred in the calving grounds (Florida

Table 2. Summary of age class and sex for all confirmed North Atlantic right whale mortalities 2003–2018 (n = 70)

Age class	Sex			
	Male	Female	Undetermined	Total
Adult	10	19	1	30
Juvenile	5	9	0	14
Calf	8	2	0	10
Undetermined	5	1	10	16
Total	28	31	11	70

Fig. 1. North Atlantic right whale mortalities between 2003 and 2018, highlighting proximate cause of death. Entanglement deaths do not necessarily occur where the whale was initially entangled

and Georgia) during winter months, the majority of which were calves (7/11, 64%). The remaining 3 calves stranded in North Carolina (March and December) and Cape Cod (May). The majority of summer deaths occurred in Canadian waters (n = 19), and the majority of spring deaths occurred in mid-Atlantic waters (New York to South Carolina, n = 7). Mortalities documented between Massachusetts and Maine were nearly equivalent in each season (n = 4 in winter, 5 in spring, 5 in summer, 6 in fall). A map of mortalities by season is provided in Fig. A1 in the Appendix.

Table 3. Temporospatial North Atlantic right whale mortality data 2003–2018 (n = 70). Mid-Atlantic includes New York through South Carolina. Seasons are defined as winter: December–February; spring: March–May; summer: June–August; fall: September–November

Season	Florida/ Georgia	Mid-Atlantic	Massachusetts to Maine	Canada
Winter	11	5	4	0
Spring	0	7	5	0
Summer	0	3	5	19
Fall	0	1	6	4

3.1. Causes of mortality

COD was determined in 43/70 (61.4%) cases. The cause of the remaining 27 mortalities was undetermined due to advanced state of decomposition (n = 10) or inability to fully examine the carcass (n = 17). Four whales that were not available for necropsy were determined through photographic evidence to have active, severe, and extensive line entanglements sufficient to assign entanglement-related CODs.

Natural CODs were found in 5/43 (11.6%) cases, and only in calves (5/10 calves, 50%). These CODs were largely attributed to perinatal complications such as stillbirth, dystocia, failure of passive transfer (immune compromise, diagnosed by low globulins on serum electrophoresis), and malnutrition due to either presumed maternal abandonment or developmental abnormalities within the gastrointestinal tract including a colic-like disorder (or both). The gross necropsy report of 1 young calf concluded that it died due to hemorrhage and hypovolemic shock as sequelae to shark predation (EgNEFL0904 / 3910), but the histopathology report was not available to provide further support for this conclusion (confidence level was limited to 'suspect'). Proximate and ultimate CODs are summarized in Table 4 for all 43 cases in which COD could be determined.

All 38 of the remaining cases for which COD could be determined died due to anthropogenic trauma. This includes all adults (n = 18), all juveniles (n = 9), 4 calves, and all NARWs of undetermined age class (n = 7). Sixteen NARWs died as a result of collisions with vessels (9 females, 7 males, see Sections 3.3.1 and 3.3.2), and 22 died due to entanglement in line (9 females, 10 males, and 3 undetermined sex, see Section 3.3.3). Six of the vessel strike cases had evidence of propeller-induced trauma, and 10 had blunt force trauma consistent with the impact of a vessel. Deaths due to vessel strike (blunt or propeller-induced

Table 4. Proximate and ultimate causes of death (CODs) and incidental findings in the 43 North Atlantic right whale mortalities from 2003−2018 for which COD was determined. Ages from sightings history are actual unless noted (min.: minimum age, indicating the whale was never observed as a calf; est.: estimate; CBD: cannot be determined). NA: not applicable

Report year	Field ID / catalog ID	Age (yr)	Sex	Proximate COD Category (subcategory)	Proximate COD Confidence	Ultimate COD Category (subcategory)	Ultimate COD Confidence	Incidental findings
2003	MJM03-01Eg / 2150	12 (min.)	F	Trauma (blunt force trauma)	Confirmed	Trauma (neurologic), Trauma (hemorrhage / hypovolemic shock)	Probable	Trauma (entanglement)
2004	RKB 1457	<1	M	Perinatal (immunological: failure of passive transfer), Nutritional (maternal abandonment)	Probable	Undetermined	NA	Infectious (bacterial)
2004	VMSM20041004 / 1004	29 (min.)	F	Trauma (blunt force trauma)	Probable	Trauma (hemorrhage / hypovolemic shock)	Probable	Trauma (entanglement)
2004	KMS 374 / 1909	15	F	Trauma (propeller strike)	Confirmed	Trauma (hemorrhage / hypovolemic shock)	Confirmed	Trauma (entanglement)
2005	EgNEFL0501 / 2143	14	F	Trauma (propeller strike)	Suspect	Undetermined	NA	Other
2005	VAQS20051008Eg / 2301	12	F	Trauma (entanglement, chronic)	Confirmed	Nutritional	Probable	Undetermined
2005	CCSN05-134Eg / 2617	9	F	Trauma (blunt force trauma)	Probable	Undetermined	NA	Undetermined
2006	EgNEFL0602	<1	M	Trauma (propeller strike)	Confirmed	Trauma (hemorrhage / hypovolemic shock)	Confirmed	Infectious (parasitic)
2006	EgNEFL0603 / 3602	<1	F	Trauma (entanglement, acute), Trauma (predation)	Probable	Undetermined	NA	Infectious (parasitic)
2006	DVS 2006-04745 / 3595	1	F	Trauma (propeller strike)	Confirmed	Trauma (hemorrhage / hypovolemic shock)	Suspect	Other
2006	MJM9406Eg / 1267	24	F	Trauma (blunt force trauma)	Confirmed	Trauma (hemorrhage / hypovolemic shock)	Probable	Undetermined

Continued on next page

Table 4 (continued)

Report year	Field ID / catalog ID	Age (yr)	Sex	Proximate COD Category (subcategory)	Proximate COD Confidence	Ultimate COD Category (subcategory)	Ultimate COD Confidence	Incidental findings
2006	GA2006025Eg / 3508	2	M	Trauma (propeller strike)	Confirmed	Trauma (hemorrhage / hypovolemic shock), Trauma (pneumothorax)	Probable	Trauma (predation)
2007	EgNEFL0704	<1	M	Perinatal (still birth, dystocia, other)	Probable	Perinatal (still birth, dystocia, other)	Probable	Other
2007	BRF134	<1 (est.)	M	Trauma (entanglement, acute)	Probable	Undetermined	NA	Developmental
2008	HUBBS0803Eg	<1	M	Perinatal (still birth, dystocia, other)	Probable	Trauma (hemorrhage / hypovolemic shock)0	Probable	Developmental
2008	KLC022	<1	M	Developmental, Nutritional	Probable	Euthanasia	Confirmed	Developmental, Nutritional
2009	CALO 0901 / 3710	2	M	Trauma (entanglement, acute), Trauma (post-traumatic scoliosis, chronic)	Probable	Euthanasia	Confirmed	Undetermined
2009	EgNEFL0904 / 3910	<1	F	Trauma (predation)	Suspect	Trauma (hemorrhage / hypovolemic shock)	Probable	Developmental
2010	MJM070110Eg / 1124	30 (min.)	M	Trauma (entanglement, chronic)	Confirmed	Undetermined	NA	Nutritional, other
2010	CWHC X22447-10 / 1113	29 (min.)	M	Trauma (entanglement, acute)	Suspect	Undetermined	NA	Undetermined
2011	EgNEFL1103 / 3911	2	F	Trauma (entanglement, chronic), Trauma (predation)	Confirmed	Nutritional, Trauma (hemorrhage / hypovolemic shock)	Probable	Trauma (iatrogenic)
2011	SC1118	CBD	M	Trauma (entanglement, chronic)	Probable	Undetermined	NA	Undetermined
2011	NCARI006 / 1308	28	F	Trauma (blunt force trauma)	Probable	Trauma (neurologic)	Probable	Trauma (entanglement, chronic)
2012	CWHC Incident #86957	CBD	F	Trauma (entanglement, acute)	Confirmed	Trauma (drowning/asphyxia)	Suspect	Undetermined
2012	EgNEFL1235 / 4193	2	M	Trauma (entanglement, chronic)	Confirmed	Nutritional	Suspect	Trauma (shark scavenging)

2013	NCUR130811 /1311	30	M	Trauma (entanglement, CBD)	Suspect	Undetermined	NA	Undetermined
2014	MARS 2014-113 / CBD	CBD	CBD	Trauma (entanglement, CBD)	Suspect	Undetermined	NA	Undetermined
2014	IFAW14-156Eg	CBD	CBD	Trauma (entanglement, acute)	Probable	Trauma (drowning/asphyxia)	Probable	Undetermined
2016	IFAW16-082Eg / 4681	<1	M	Trauma (propeller strike)	Confirmed	Trauma (neurologic), Trauma (hemorrhage / hypovolemic shock)	Probable	Infectious (viral)
2016	MARS 2016-175 / 4320	3	M	Trauma (entanglement, acute)	Probable	Undetermined	NA	Undetermined
2016	MME-16-249Eg / 3694	10 (min.)	F	Trauma (entanglement, chronic)	Confirmed	Nutritional	Probable	Trauma (entanglement)
2017	IFAW17-182Eg / 4694	1	F	Trauma (blunt force trauma)	Probable	Trauma (drowning/asphyxia)	Suspect	Infectious (viral)
2017	MARS 2017-141, EG2017-02 / 1402	33	M	Trauma (blunt force trauma)	Suspect	Trauma (hemorrhage)	Suspect	Infectious (viral)
2017	MARS 2017-143, EG2017-04 / 3603	11	F	Trauma (entanglement, acute)	Confirmed	Nutritional, Trauma (drowning/asphyxia)	Suspect	Trauma (entanglement)
2017	MARS 2017-142, EG2017-06 / 1207	37 (min.)	M	Trauma (blunt force trauma)	Probable	Trauma (hemorrhage / hypovolemic shock)	Probable	Infectious (parasitic), Trauma (entanglement)
2017	MARS 2017-145, EG2017-07	CBD	M	Trauma (blunt force trauma)	Probable	Trauma (hemorrhage / hypovolemic shock)	Probable	Undetermined
2017	MARS 2017-146, EG2017-08 / 2140	26	M	Trauma (blunt force trauma)	Suspect	Trauma (hemorrhage / hypovolemic shock)	Suspect	Other
2017	IFAW17-320Eg	CBD	M	Trauma (entanglement, acute)	Probable	Undetermined	NA	Undetermined
2017	MARS2017-312, EG2017-09 / 4504	2	F	Trauma (entanglement, acute)	Confirmed	Trauma (drowning/asphyxia)	Probable	Trauma (entanglement)
2017	IFAW17-375Eg	CBD	M	Trauma (entanglement, acute)	Suspect	Trauma (drowning/asphyxia)	Suspect	Trauma (blunt force trauma)
2018	VAQS20181005Eg / 3893	10	F	Trauma (entanglement, chronic)	Confirmed	Nutritional	Probable	Undetermined
2018	IFAW18-244Eg	1 (est.)	M	Trauma (entanglement, acute)	Probable	Trauma (drowning/asphyxia)	Suspect	Undetermined
2018	IFAW18-281Eg / 3515	13	F	Trauma (entanglement, acute)	Probable	Undetermined	NA	Undetermined

trauma) occurred in 7/16 (43.8%) study years (2003–2006, 2011, 2016, and 2017; Fig. 2).

Of the 22 entanglement cases, 12 (54.5%) were classified as acute (hours to days) and 7 (31.8%) as chronic (weeks to months) based on gross and histopathologic lesion characteristics (see Section 3.3.3 for details). Another case involved a suspected acute entanglement occurring when the whale was a calf with chronic complications that led to the animal's demise 1.5 yr later (CALO 0901). Two additional cases were examined only through photos and video from which it was not possible to determine entanglement chronicity. Of the NARWs that died from acute entanglement, 7/12 (58.3%) were 3 yr old or younger (or <1000 cm total straight length) compared to only 2/8 (25.0%) that died from chronic entanglement. Two cases that died due to entanglement trauma also showed evidence of perimortem shark predation that likely contributed to the animals' deaths (EgNEFL0603 / 3602, EgNEFL1103 / 3911, acute and chronic entanglement, respectively). Of the 8 whales with healed incidental scars from previous entanglements, 3 died due to a subsequent new entanglement and 5 to ship strikes. Confirmed NARW deaths attributed to entanglement occurred in 12/16 (75.0%) study years (2005–2007, 2009–2014, 2016–2018; Fig. 2).

Although not directly related to COD, 2 NARWs in this dataset (IFAW17-182Eg / 4694 and MARS2017-141, EG2017-02 / 1402) were found to have multifocal ulcerations of the glossal mucosa, which were revealed to be erosions or ulcerations of the epithelium (Fig. 3). No infectious agents were observed microscopically. Viral PCR in 1 case was negative for morbillivirus, calicivirus, and herpesvirus.

3.2. Morphometrics

Fig. 4 shows the logarithmic relationships between total straight length and minimum age for all NARW carcasses from 1970–2018 with measured lengths and known minimum ages (Fig. 4a; $R^2 = 0.9239$, $p < 0.001$), and for only female NARWs that fit the same criteria (Fig. 4b; $R^2 = 0.9488$, $p < 0.0001$). Fig. 5 shows the relationships between weight and total straight length (Fig. 5a; exponential, $R^2 = 0.9562$, $p < 0.0001$) and weight and minimum age (Fig. 5b; geometric, $R^2 = 0.9680$, $p < 0.0001$) for NARW carcasses 1970–2018. Fig. 6 shows the geometric relationships between fluke width and total straight length (Fig. 6a; $R^2 = 0.9078$, $p = 0.0001$) and anterior flipper edge length and total length (Fig. 6b; $R^2 = 0.9505$, $p < 0.0001$) for all NARW carcasses from the same time period.

3.3. Traumatic lesions

Due to the large number of NARW mortality cases included in this study, individual case summaries and representative gross images are not included here but are reported in Supplement 2. Highlights of notable gross and histopathologic findings will be

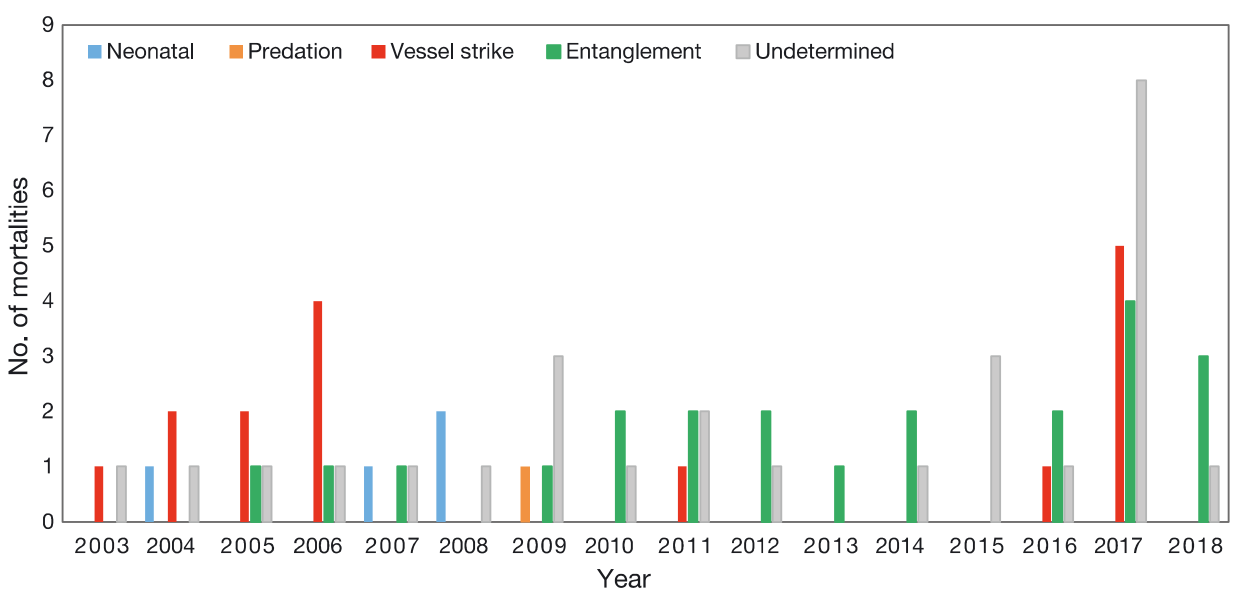


Fig. 2. North Atlantic right whale proximate causes of death by year 2003–2018. Proximate cause of death categories include neonatal mortalities, predation, entanglement, and unknown. A total of 70 mortalities occurred during the study period

Fig. 3. North Atlantic right whale (IFAW17-182Eg / 4694; see Table 4) tongue; cause of death probable vessel strike blunt force trauma. Multifocal to coalescing glossal erosions and ulcerations were negative on PCR for herpesvirus, morbillivirus, and calicivirus. No infectious etiology was identified microscopically. Image credit: International Fund for Animal Welfare

presented here to emphasize frequently observed lesions, novel findings, and extent of trauma.

3.3.1. Vessel strike — blunt trauma

Of the NARWs that died due to vessel strike blunt trauma, bone fractures were a common finding, occurring in 8/10 (80.0%) cases. Skull fractures occurred in 6 NARWs, 2 of which (MJM03-01Eg and NCAR1006Eg) had fractures that penetrated the

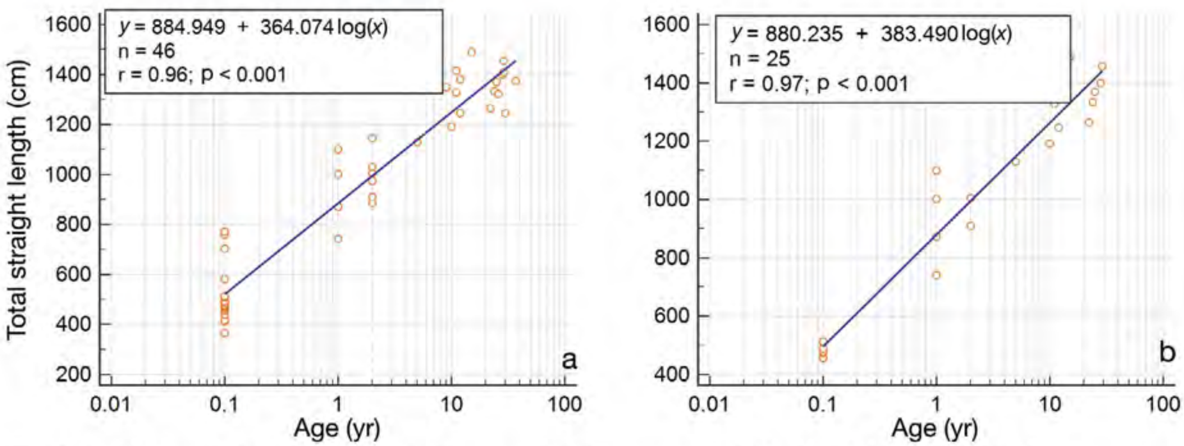


Fig. 4. Total straight length (actual or corrected) vs. age (minimum or actual) for North Atlantic right whale carcasses with measured (not estimated) lengths and known ages from 1970–2018 fitted with a logarithmic equation for (a) all whales (n = 46) and (b) only female whales (n = 24)

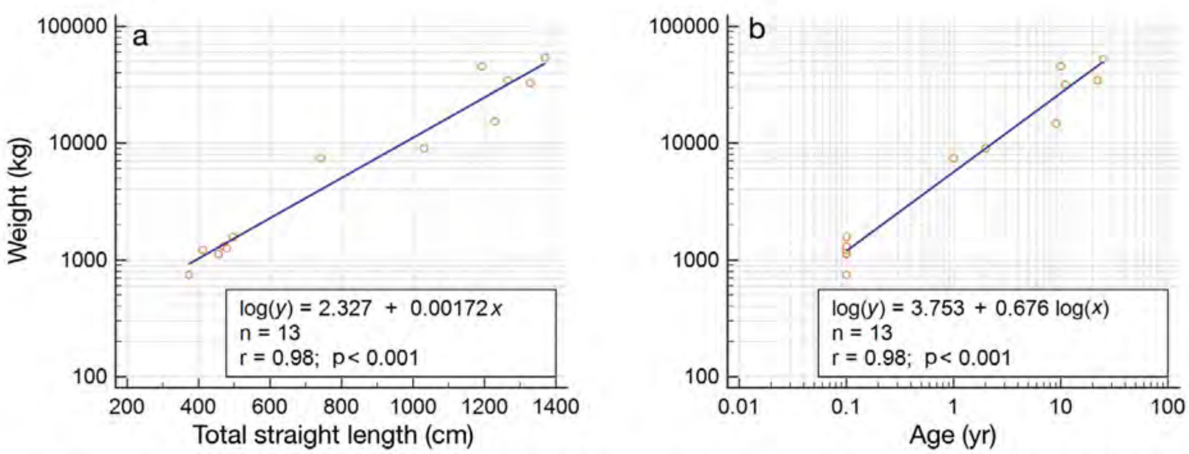


Fig. 5. (a) Weight (actual or corrected) vs. total straight length (actual or corrected) for all North Atlantic right whale carcasses with available data 1970–2018 (n = 13) fitted with an exponential equation. (b) Weight (actual or corrected) vs. age (minimum or actual) for all whales with available data from 1970–2018 (n = 14) fitted with a geometric equation

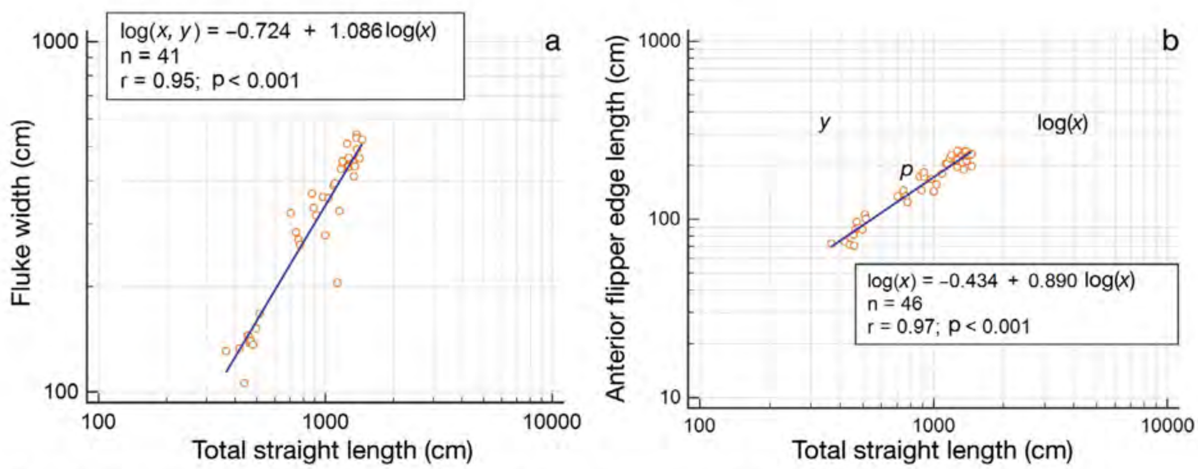


Fig. 6. (a) Fluke width (actual) vs. total straight length (actual or corrected) for all North Atlantic right whale carcasses with available data from 1970–2018 (n = 41) fitted with a geometric equation. (b) Anterior flipper edge length (actual) vs. total straight length (actual or corrected) for all whales with available data from 1970–2018 (n = 46) fitted with a geometric equation

neurocranium (brain case), likely resulting in nearly immediate death from catastrophic central nervous system injury (Fig. 7a). In 3 cases, the oral vascular retia (corpus cavernosum maxillaris; see Ford et al. 2013) were lacerated from the trauma, likely leading to fatal hemorrhage and hypovolemic shock (MARS 2017-145/EG2017-07, MJM03-01Eg / 2150, VMSM 2004 1004 / 1004). Fractured petrotympanic complexes (ear bones; Fig. 7b) were also common, although sometimes they were attributed to postmortem causes when other supportive evidence of blunt trauma was not present. Vertebral fractures occurred in 3 cases, with transverse and/or spinous process fractures in all cases (Fig. 8a), and vertebral centrum (body) fractures in 2 cases (Fig. 8b). Vertebral process fractures were often present in multiple contiguous vertebrae and were associated with black putty-like material consistent with antemortem blood that had coagulated and lysed due to postmortem heat and pressure (Fig. 8). Large perimortem blood clots were present in 9/10 (90%) blunt trauma cases in various locations including along fracture sites (as just mentioned), adjacent to intact vertebrae, and

Fig. 7. (a) North Atlantic right whale (MJM03-01Eg / 2150; see Table 4); cause of death: confirmed vessel strike blunt trauma. Large basilar skull fracture just to the left of the occipital condyles (knife is shown entering the foramen magnum at the arrow and visible through the fracture). Skull is inverted in image. (b) MARS 2017-145, EG2017-07; cause of death: probable vessel strike blunt trauma. Petrotympanic complexes (ear bones) fractured at their base. Image credits: (a) Woods Hole Oceanographic Institution; (b) Gilbert Boyer (Canadian Wildlife Health Cooperative)

Fig. 8. North Atlantic right whale (MJM9406Eg / 1267; see Table 4); cause of death: confirmed vessel strike blunt force trauma. (a) Vertebrae displaying multiple contiguous fractured transverse processes. Note the black, putty-like substance surrounding the fracture sites (oval), consistent with clotted blood from hemorrhage. (b) Fractured vertebral centrum with fractures of the spinous process and vertebral arch. Image credits: Woods Hole Oceanographic Institution

free within body cavities (Fig. 9). These clots presented as dark brown to black putty-like substance with no obvious cells or structure microscopically.

Another common gross finding in vessel strike blunt trauma cases was a well-demarcated region of muscle and overlying blubber contusion. The texture of contused muscle was more gelatinous (presumptive perimortem edema and hemorrhage from ruptured capillaries) and the color was darker compared to adjacent muscle (Fig. 10). Blubber contusions were often superficial to the muscle contusions and included patchy to undulating regions of hemorrhage in some cases (Figs. 10–12). In order to be considered significant and rule out lividity, these changes were restricted to a well-delineated region and not diffusely distributed on the dependent surface of the animal (keeping in mind that the dependent surface may have changed over time between floating at sea, stranding, and necropsy). Histopathologic lesions in vessel strike blunt trauma cases included erosion, ulceration, edema, congestion, and hemorrhage in the blubber and skin. Myofiber degeneration with fibrin exudation and erythrocyte extravasation were also observed. However, in many blunt trauma cases, the state of decomposition was advanced, making gross findings more instrumental in establishing the COD than histopathologic lesions.

Fig. 9. North Atlantic right whale (MARS 2017-142, EG2017-06 / 1207; see Table 4); cause of death: probable blunt force trauma vessel strike. Abundant black putty-like material (arrows), consistent with clotted blood, was present in the thoracic cavity. Image credit: Marine Animal Response Society/Canadian Wildlife Health Cooperative

3.3.2. Vessel strike — propeller-induced trauma

All 6 propeller-struck whales suffered deep lacerations (Semeraro et al. 2012), evidenced by torn and crushed soft tissue in a curvilinear, S- or Z-shaped pattern (indicating a left-handed or right-handed propeller, respectively) (Rommel et al. 2007), often (but not always) having multiple parallel wounds. The depth and number of wounds varied among cases. GA2006025Eg / 3508 sustained at least 20 relatively short lacerations and chop wounds, some deep into muscle and the thoracic cavity, the latter of which caused a fatal pneumothorax (Fig. 13). IFAW16-082Eg / 4681 sustained fewer longer lacerations and chop wounds, one of which penetrated deep into the abdominal cavity likely lacerating viscera (Fig. 14). Three propeller trauma cases also had associated skull fractures (KMS 374 / 1909, GA2006025Eg / 3508, IFAW16-082Eg / 4681), 1 had vertebral shearing and fractures (IFAW16-082Eg / 4681), and 1 calf had a complete peduncle and fluke amputation (Eg-

Fig. 10. North Atlantic right whale (IFAW17-182Eg / 4694; see Table 4); cause of death: probable vessel strike blunt trauma. (a) Left lateral body with reflected blubber showing a focal patchy blubber contusion (lower arrows) overlying a focal muscular contusion/hematoma (upper arrows). (b) Close-up showing blubber contusion (arrows) and underlying gelatinous (contused) muscle. Image credits: International Fund for Animal Welfare

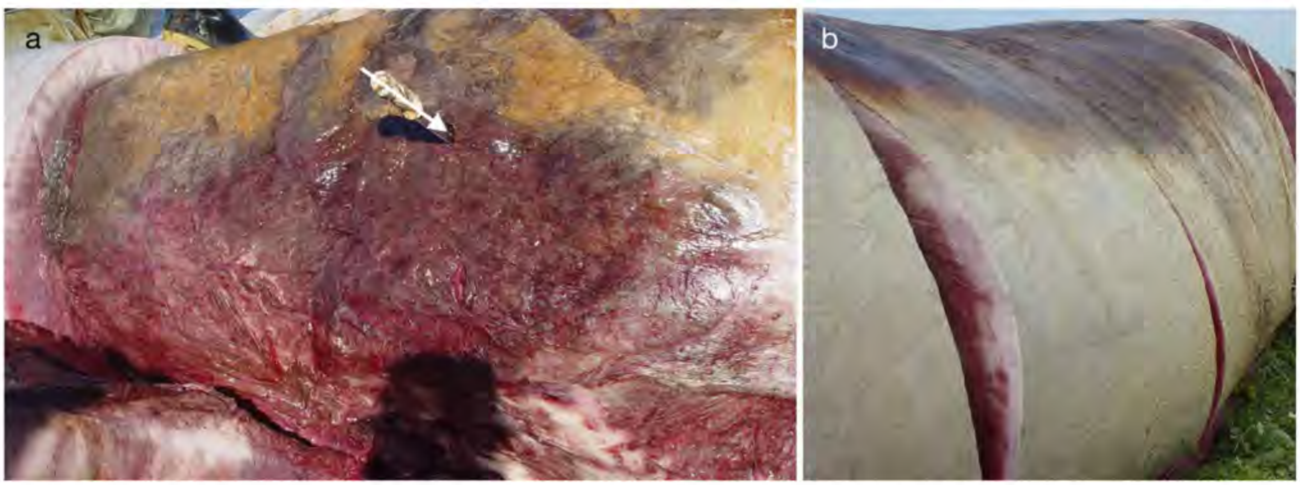


Fig. 11. (a) North Atlantic right whale (MJM03-01Eg / 2150; see Table 4); cause of death: confirmed blunt trauma vessel strike. Muscle contusion superficial to a mandibular fracture. Knife (arrow) probes the fracture site. Reflected contused blubber can also be seen overlying the muscle contusion. (b) MJM9406 / 1267; cause of death: confirmed blunt trauma vessel strike. Undulating pattern of hemorrhage in blubber (foreground) on the left lateral abdomen just cranial to genital aperture. Image credits: Woods Hole Oceanographic Institution

NEFL0602, Fig. 15). In 1 of the 6 propeller trauma cases (KMS 374 / 1909), a Navy vessel reported striking a live NARW and observed the whale immediately after the collision, bleeding and missing a fluke blade; the carcass was found 1 wk later (Fig. 16). Another vessel strike case (NEFL0501Eg / 2143) involved a whale with healed scars from a propeller interaction that occurred 14 yr earlier when she was a calf (Fig. 17). This individual subsequently became pregnant and died with a full-term fetus *in utero*. Based on gross and histopathologic findings, increased intra-abdominal pressure caused by the increased volume of the developing fetus exceeded the reduced tensile strength of the propeller scars, leading to splitting of the deposited collagen, subsequent entry of bacteria into the open scar, abscess formation, and presumed sepsis. In propeller trauma cases, the ultimate causes of death were most often hypovolemic and/or neurogenic shock from hemorrhage and/or central nervous system trauma, respectively. Associated histopathologic lesions included hemorrhage and edema in blubber, muscle, and bone. Myofiber degeneration characterized by sarcoplasmic clumping and granularity with loss of cross-striations (myofiber disruption) was occasionally observed. However, the wash-out effect observed in floating carcasses may affect the ability to detect acute hemorrhage, edema, and inflammation at the site of injury (i.e. cellular evidence is washed away by the aquatic environment prior to sampling).

3.3.3. Entanglement

Notable gross soft tissue entanglement lesions included lacerations caused by constrictive wraps of line primarily around the axilla/flippers, flukes/peduncle, and the head/mouth. In acute cases, corresponding histopathologic lesions included superficial compression, epidermal erosion and ulceration, dermal and hypodermal edema and hemorrhage, and little to no evidence of inflammation or fibrosis. Chronic soft tissue entanglement lesions had evidence of fibrosis

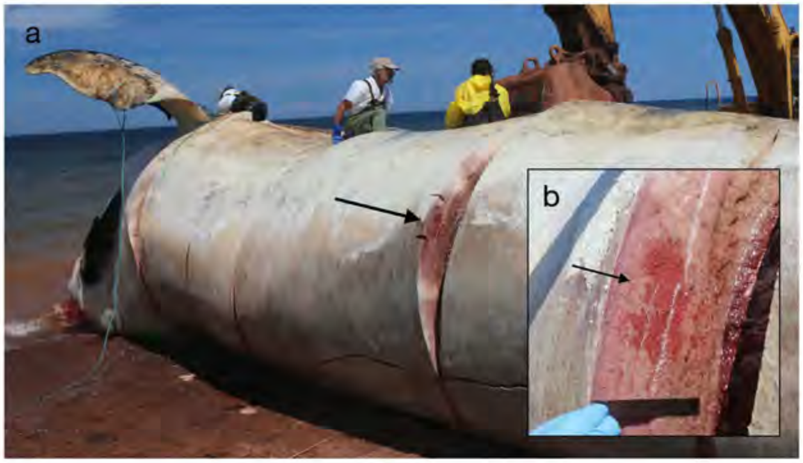


Fig. 12. (a) North Atlantic right whale (MARS 2017-142, EG2017-06 / 1207; see Table 4); cause of death: probable blunt force trauma vessel strike. Distinct region of focal blubber contusion in right lateral body wall. (b) Close-up of region shown in (a). The arrow in each photo points to the same area. Image credit: Marine Animal Response Society

Fig. 13. North Atlantic right whale (GA2006025 / 3508; see Table 4); cause of death: confirmed vessel strike propeller trauma. Right lateral head and body showing 20 Z-shaped penetrating chop wounds (numbered 1–20) consistent with a right-handed propeller interaction. A linear non-penetrating abrasion coursing parallel to the wound axis is also visible dorsal to the propeller wounds (above and parallel to dashed line) suggestive of a skeg or rudder interaction. Image credit: Florida Fish and Wildlife Conservation Commission

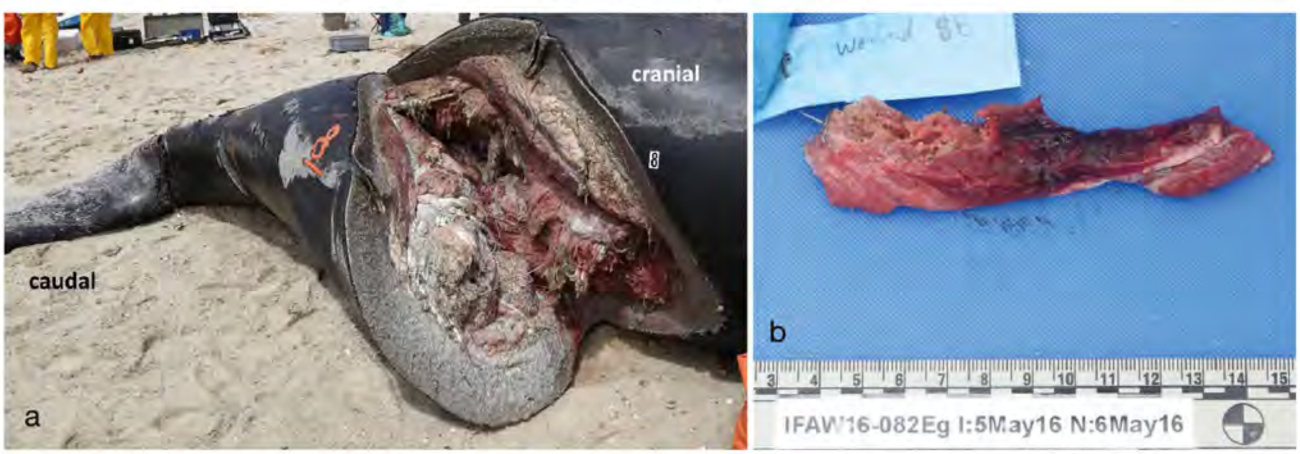


Fig. 14. North Atlantic right whale (IFAW16-082Eg / 4681; see Table 4); cause of death: confirmed propeller strike. (a) Deep transecting oblique chop wound on the caudal left ventrolateral body consistent with a left-handed propeller interaction, extended deep through blubber and muscle and into the abdominal cavity. Numerous lumbar and caudal vertebrae were also fractured and shorn by the impact. (b) Lesion hemorrhage and washout as observed at necropsy. Image credits: International Fund for Animal Welfare

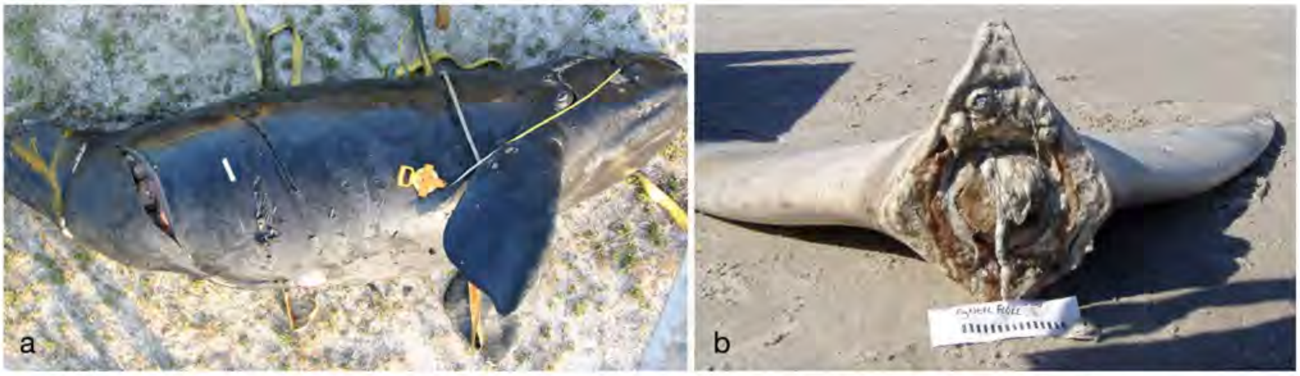


Fig. 15. North Atlantic right whale calf (EgNEFL0602; see Table 4); cause of death: confirmed vessel strike, propeller trauma. (a) Right lateral body with S-shaped lacerations consistent with left-handed propeller strike. (b) Caudal peduncle and flukes from the same whale that were severed by the propeller and later washed ashore. Image credits: Florida Fish and Wildlife Conservation Commission

Fig. 16. North Atlantic right whale (KMS 374 / 1909; see Table 4); cause of death: confirmed propeller strike. (a) Right fluke blade severed by propeller, tearing large vessels and severing the terminal 3–4 caudal vertebrae. (b) Close-up of the injury. Image credits: Virginia Aquarium & Marine Science Center / University of North Carolina at Wilmington

in the epidermis, dermis, and hypodermis, with myofiber atrophy in some flipper entanglements. Inflammation was notably absent in chronic lesions as well, perhaps due to decreased vascularity in these regions. In some cases, chronically entangling line was deeply embedded within an envelope of soft tissue fibrosis and scarring (Fig. 18b). Of the 7 whales with evidence of chronic entanglement (1 died due to vessel strike blunt trauma, see Table 4), all exhibited osteopathic lesions due to chronically impinging line including periosteal proliferation (n = 6, Figs. 19 & 20), osteopenia (n = 3, Fig. 21), and lytic lesions (n = 2, Figs. 20c & 22b). Periosteal proliferation was often exuberant in response to the repetitive injury caused by the line (Figs. 19 & 20). Despite the avid new bone growth in many of these cases, the line passively (and likely slowly) inflicted a partial amputation of the affected flipper (Figs. 19 & 20). Another case (CALO 0901) previously documented as a live calf with scars from a (presumed acute) peduncle/fluke entanglement, live-stranded >1 yr later with entanglement-induced osteolysis, sclerotic and proliferative changes in the caudal vertebrae, unilateral dystrophic mineralization of the surrounding soft tissues, and resultant traumatic scoliosis (Fig. 22). A different case with an extensive and chronic fluke entanglement had osseous metaplasia of the peduncle soft tissue (EgNEFL1235 / 4193). In many chronically entangled whales, poor body condition and widespread epidermal cyamid ('whale louse') infestations were present (Fig. 18a), indicating overall compromised health.

Baleen plate separation and/or mutilation due to entangling line was observed in 5 cases (VAQS2005-1008Eg, EgNEFL1103, MME16-249Eg, MARS2017-312/EG2017-09, VAQS2018-1005Eg; Fig. 23a), in-

Fig. 17. North Atlantic right whale (EgNEFL0501 / 2143; see Table 4) showing (a) old propeller wounds at time of necropsy. (b) Dissection of caudal-most wound in (a) showing abscessed granular tissue and necrosis associated with the old propeller wound. Image credits: University of North Carolina at Wilmington

Fig. 18. North Atlantic right whale (EgNEFL1103 / 3911; see Table 4); cause of death: confirmed chronic entanglement. (a) View of right axilla from the caudal perspective showing extensive orange cyamid coverage on the affected flipper. The embedded entangling line can be seen at the arrow. (b) Right lateral lip in cross-section showing embedded line (arrow) and surrounding hemorrhagic edema. Image credits: Florida Fish and Wildlife Conservation Commission

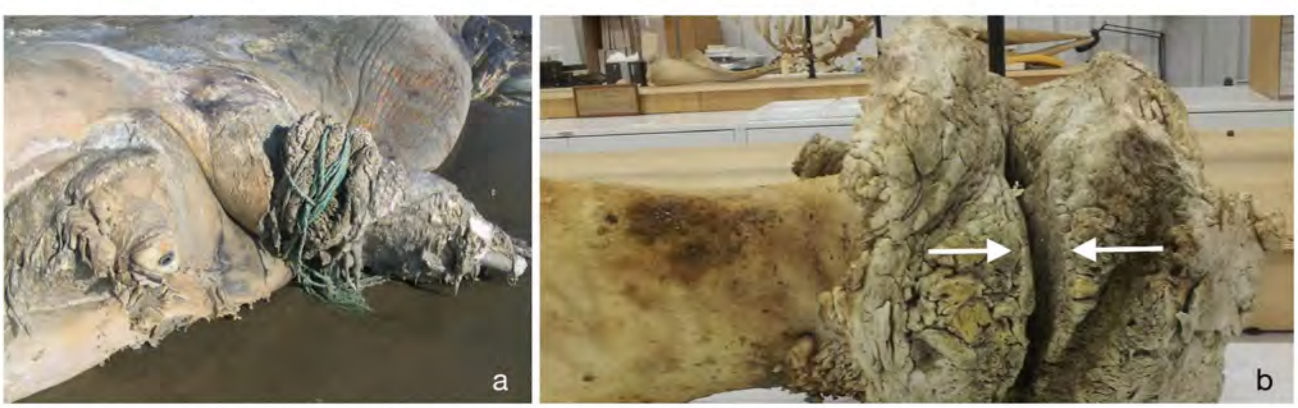


Fig. 19. North Atlantic right whale (SC1118; see Table 4); cause of death: probable chronic entanglement (entanglement confirmed, role in death is probable). (a) 13 wraps of entangling line were found around the right pectoral flipper. (b) Flensed humerus showing exuberant proliferative periosteal reaction (new bone formation) near the humeral head and a furrow caused by the chronically impinging line (arrows). Image credits: NOAA National Ocean Service Center for Coastal Environmental Health and Biomolecular Research Coastal Marine Mammal Strandings and Assessments Project

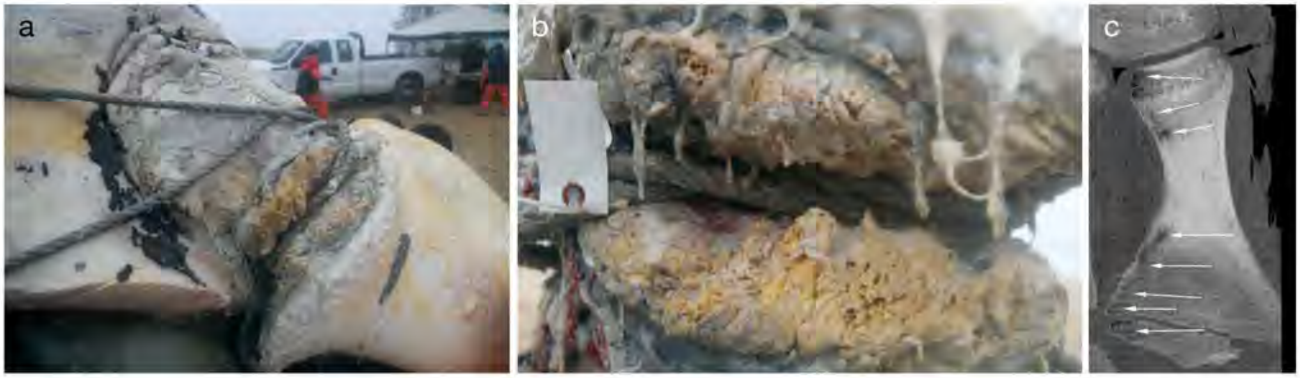


Fig. 20. North Atlantic right whale (VAQS20181005Eg / 3893; see Table 4); cause of death: confirmed chronic entanglement. (a,b) Chronically entangling line embedded into the base of the right flipper (humerus) creating a partial amputation of the limb with surrounding exuberant soft tissue proliferation visible in (b). (c) CT of right radius with arrows indicating areas of bone lysis. Image credits: Virginia Aquarium & Marine Science Center; CT scan interpretation (arrows) courtesy of S. Dennison

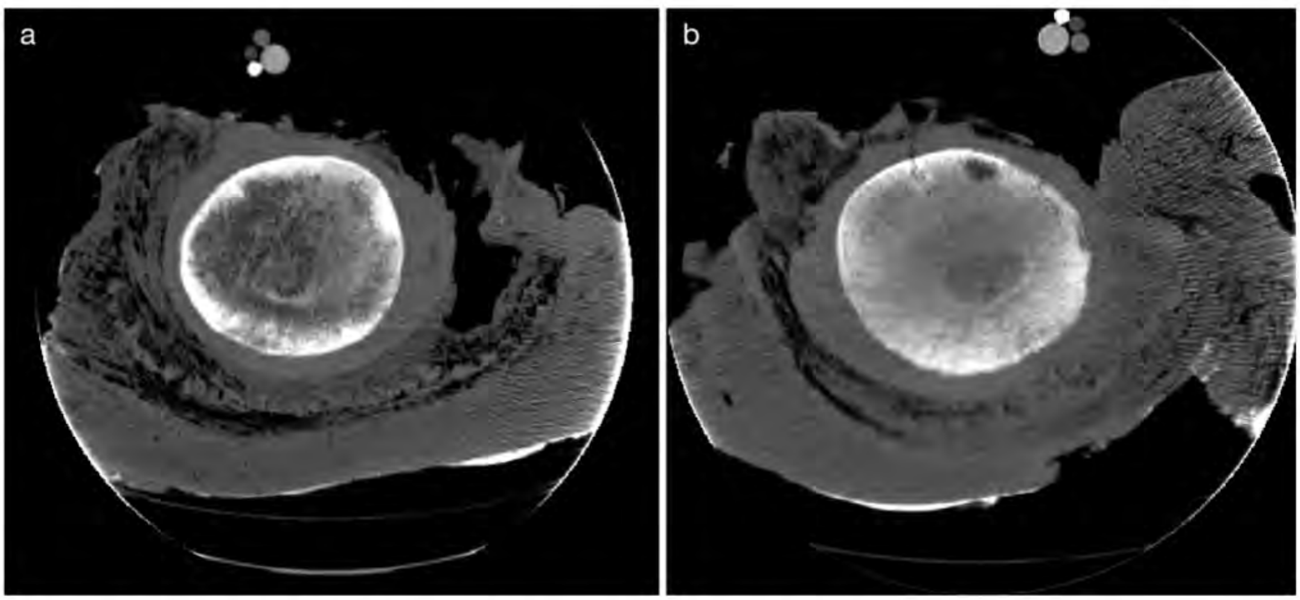
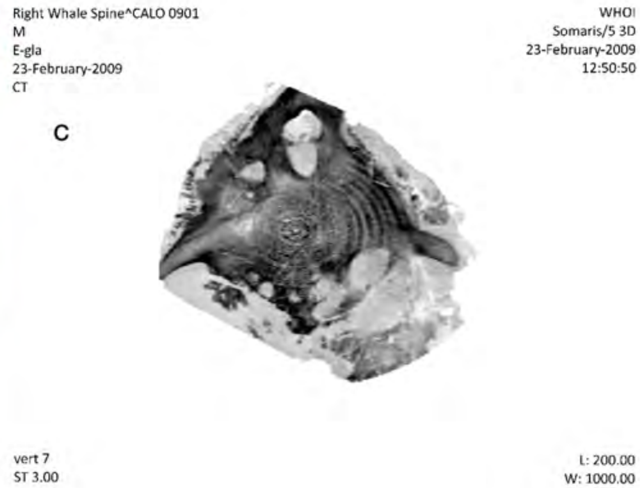


Fig. 21. North Atlantic right whale (EgNEFL1103 / 3911; see Table 4); cause of death: confirmed chronic entanglement. Comparative CT images of right and left humeri at the same level. (a) Entangled flipper shows diminished opacity within the trabecular bone of the diaphysis compared to (b) the unaffected flipper. Image credits: Virginia Aquarium & Marine Science Center; CT scan interpretation courtesy of S. Dennison

cluding gingival lacerations in some cases. In some of these affected whales, the entanglement configuration would have created a major feeding impediment through physical obstruction of the oropharynx (VAQS2018-1005Eg), decreased efficiency of baleen plate filter feeding (all cases), or entanglement-induced trismus, restricting the ability of the mouth to open when lines to the rostrum were cinched at the flippers (MME16-249Eg). In 1 case, entangling lines created a laceration on the dorsal head, directly into the left naris (blowhole), likely affecting the animal's ability to breathe and possibly its ability to create a water-tight blowhole seal for diving (VAQS2005-1008Eg; Fig. 23b).

Fourteen carcasses, or 63% of those with entanglement as the proximate COD, were found entangled in gear (Table 5). All of these cases were entangled in multifilament twisted lines or ropes, occasionally with attached polyballs (n = 4), bullet buoys (n = 1), and traps or portions of traps (n = 2). Identifying the gear origin was possible in 5/14 (35.7%) cases, all of which were recognized as Canadian snow crab fishing gear. Two of those cases were traced back to a specific region, the Gulf



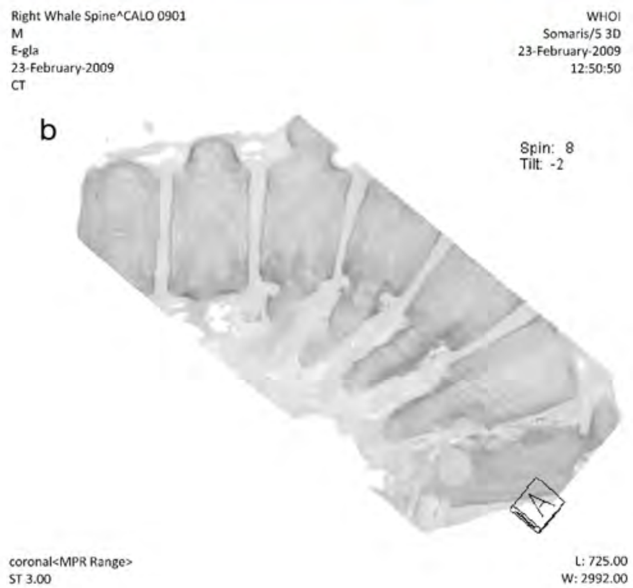


Fig. 22. North Atlantic right whale (CALO 0901 / 3710; see Table 4); cause of death: probable entanglement. (a) Traumatic scoliosis (abnormal curvature of the spine) *in situ* due to prior entanglement. (b,c) CT scans of affected vertebrae showing significant chronic, predominantly ipsilateral lytic, sclerotic, and proliferative changes of the intervertebral discs, cranial and caudal vertebral end-plates, and vertebral subchondral bone. Image credits: (a) University of North Carolina at Wilmington, (b,c) Woods Hole Oceanographic Institution; CT scan interpretation courtesy of S. Dennison

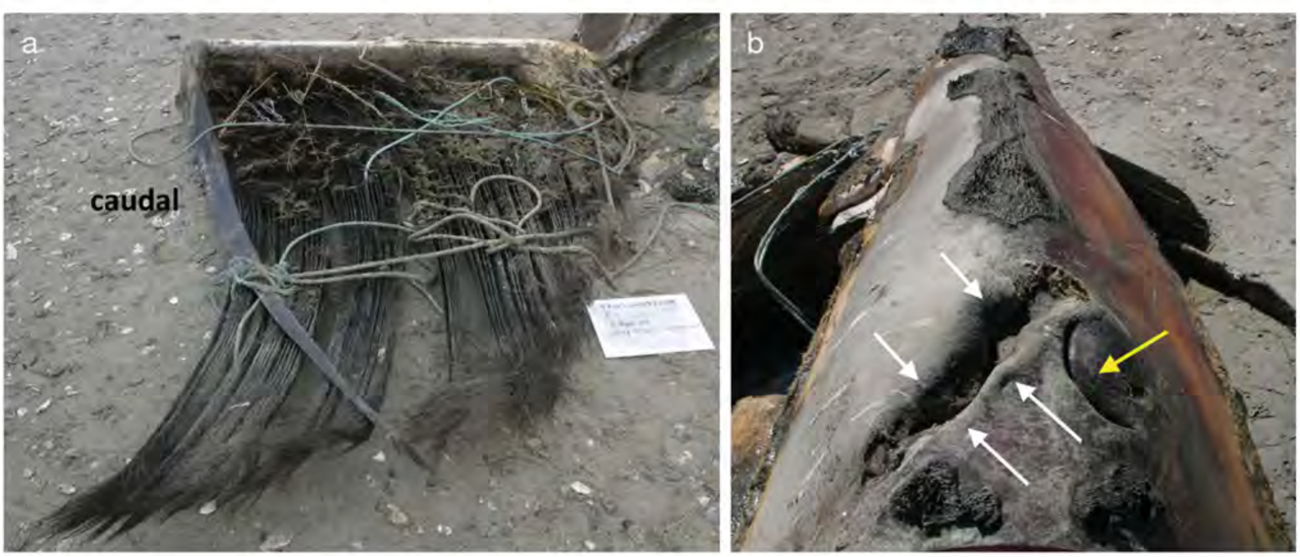


Fig. 23. North Atlantic right whale (VAQS20051008Eg / 2301; see Table 4); cause of death: confirmed chronic entanglement. (a) Anterior half of left baleen rack after gingiva was excised and baleen was reflected to reveal the medial aspect of the baleen and the entangling lines *in situ*. (b) Deeply abraded laceration (white arrows) directly over the left naris (blowhole) on the dorsal head of the same whale caused by the entangling line. Yellow arrow points to the unaffected right naris (blowhole). Photo credits: Virginia Aquarium & Marine Science Center

of St. Lawrence. One additional case was identified as having unknown trap/pot gear of US origin (EgNEFL1235 / 4193) and another case was identified as having unknown trap/pot gear of unknown origin (EgNEFL1103 / 3911). Three cases where only rope was found entangling the whale were not identified to origin at all (SC1118, VAQS2005-1008Eg, CWHC Incident 86957). Entangling gear from MJM070110Eg / 1124 was lost while under tow to the necropsy site, and 3 additional entangled whales could not be examined or sampled. One of the unexamined entangled whales (IFAW14-156Eg) was possibly entangled and anchored in fixed gear south of Nantucket, MA, USA, based on the presence of a line of floats lying along its body, 2 endlines present in the initial report images, and a stationary position at sea for multiple days. This carcass could not be examined by responders due to poor weather. When conditions improved, fixed gear with large polyballs similar to that documented on the entangled whale were identified at the coordinates of the carcass, but the whale was no longer present. The remaining 9 carcasses listed in Table 5 were not found with gear present; however, the lesions observed at examination were consistent with entanglement in line (based on previously documented cases where line and similar lesions were present), and were sufficiently significant to warrant COD assignation in 8 of those cases. Due to lack of entangling gear available for examination, source of the entangling lines could not be identified in any of these 9 cases.

A whale entangled in gear with attached bullet buoys (EgNEFL1235 / 4193) had weak links present near the base of the buoys, neither of which separated as designed. There were no other intact or broken weak links present in any other gear entangling NARWs documented in this study. The line involved in entanglements was often 5/8″ (15.9 mm) and a combination of leaded and unleaded line in many cases. In 9 cases, lines were wrapped multiple (up to 30–50) times around an appendage (Fig. 19), the rostrum, or through the baleen (Fig. 23). Of animals with unidentified gear origins, 1 case had a portion that comprised floating trap/pot groundline (EgNEFL1103 / 3911), and both trap/pot floating and sinking lines were identified in another case (VAQS2005-1008Eg / 2301).

Table 5. Presence and origin of entangling gear in all dead entangled North Atlantic right whale cases 2003–2018. NA: not applicable; DFO: Fisheries and Oceans Canada

Report year	Field ID / catalog ID	Gear present?	Gear origin
2005	VAQS20051008Eg / 2301	Yes	Rope of unknown origin
2006	EGNEFL0603 / 3602	No	NA
2007	BRF134	No	NA
2009	CALO 0901 / 3710	No	NA
2010	MJM070110Eg / 1124	Yes	Entangling lines lost during tow, unable to examine
2010	CWHC X22447-10 / 1113	No	NA
2011	EgNEFL1103 / 3911	Yes	Unknown trap/pot of unknown origin with floating groundline
2011	SC1118	Yes	Unknown gear origin
2011	NCARI006 / 1308	No	NA
2012	CWHC Incident #86957	Yes	Large-diameter rope examined by DFO, unable to determine gear origin
2012	EgNEFL1235 / 4193	Yes	Unknown trap/pot of US origin
2013	NCUR130811 /1311	Yes	Floating carcass; not sampled/examined
2014	MARS 2014-113 / CBD	Yes	Floating carcass; not sampled/examined, but a thick entangling line is evident in images
2014	IFAW14-156Eg	Yes	Found in fixed gear in US waters
2016	MARS 2016-175 / 4320	Yes	Canadian snow crab fishery
2016	MME-16-249Eg / 3694	Yes	Canadian snow crab fishery
2017	MARS 2017-143, EG20170-04 / 3603	Yes	Canadian snow crab fishery (Gulf of St. Lawrence)
2017	IFAW17-320Eg	No	NA
2017	MARS2017-312, EG2017-09 / 4504	Yes	Canadian snow crab trap (Gulf of St. Lawrence)
2017	IFAW17-375Eg	No	NA
2018	VAQS2018-1005Eg / 3893	Yes	Canadian snow crab fishery
2018	IFAW18-244Eg	No	NA
2018	IFAW18-281Eg / 3515	No	NA

4. DISCUSSION

The 3 most significant findings in this study were that (1) the relative prevalence of entanglement-related NARW deaths increased compared to vessel strike deaths with respect to previously published mortality data (Moore et al. 2004), (2) no natural mortalities were identified in adult or juvenile NARWs, and (3) gross and histopathologic features of the traumatic entanglement and vessel strike lesions were consistent and severe. For the purposes of this discussion, we will first explore CODs and other mortality trends over time, then briefly cover the unusual mortality event of 2017. We will then discuss the significance of the anthropogenic traumatic lesions and the manner in which the affected NARWs died.

4.1. COD

During the last 16 yr, anthropogenic trauma was the leading cause of mortality in NARWs, similar to the antecedent 32 yr period (Moore et al. 2004). However, the predominant type of anthropogenic trauma shifted from vessel strikes to entanglements in the current dataset (see Table 6 for a comparison of anthropogenic trauma incidence between Moore et al. 2004 and this study). Of the 54 NARW mortalities reported between 1970 and 2002, COD was established in 19 cases: 14 were due to vessel strikes, 4 to entanglements, and 1 perinatal death. Thus, for that time period, 73.7% (14/19) of NARWs died due to vessel strikes while the majority of NARWs with determined CODs from the last 16 yr died due to entanglement (51.2%, 22/43). The etiology of this shift in the principal anthropogenic COD for NARWs is likely multifactorial, consisting of changes within the shipping and fishing industries as well as whale distribution. Additionally, changes in response effort, diagnostic capabilities, and improvements in image quality in recent years have facilitated additional COD determinations that would not have been possible during the earlier time period.

Potentially contributing to this observed trend, vessel speed restrictions went into effect on 9 December 2008 within US waters. When pre- (1970–2008) and post-ship strike rule cases (2009–2018) were compared for carcasses found in US waters, 75% (18/24) of anthropogenic mortalities were due to vessel strikes (25% to entanglement) prior to the rule implementation, compared to only 23.5% (4/17) due to vessel strikes afterwards (76.5% due to entanglement). Previous studies showed the ship strike rule to be moderately effective at decreasing vessel strike mortalities within active seasonal management areas (SMAs), but vessel strike mortalities just outside inactive SMAs actually increased (van der Hoop et al. 2015). The general recommendation from that study and another (Laist et al. 2014) was to increase the coverage of active SMAs in order to improve the rule's efficacy. The reduced number but continued occurrence of NARW deaths in US waters due to vessel strikes reported in this study supports this recommendation as well, indicating that the ship strike rule may have helped to reduce NARW vessel strike mortalities in US waters, but it did not prevent them completely. The spatiotemporal data presented in Table 3 and carcass locations in Table S1 can help inform future geographically and seasonally based management schemes. Moving forward, it is unclear how the new generation of super container ships and the associated trend of wider and deeper ports and channels may impact the whales or the efficacy of the ship strike rule. These larger vessels may require more time and space to execute response maneuvers, which may increase the likelihood of interactions with whales, and (due to reduced maneuverability) they may also have higher navigational safe speeds (an exemption in the ship strike rule), which may increase the likelihood of those interactions being fatal for the whale.

Unlike the observed decrease in NARW vessel strike mortalities, the incidence of entanglement deaths increased since 2008, with 13 documented NARW entanglement deaths discovered in US waters over the last 10 yr (1.3 yr^{-1}), compared to 6 in the prior 38 yr (0.16 yr^{-1}). When Canadian NARW deaths are included, total entanglement deaths increase to 19 from 2009–2018 (1.9 yr^{-1}) and 7 from 1970–2008 (0.18 yr^{-1}). A portion of this marked recent increase in entanglement deaths may be due to improved efforts in surveillance, reporting, carcass retrieval, and forensic investigations. However, this order of magnitude change in annual entanglement mortality rate is likely

Table 6. Comparison of diagnosed North Atlantic right whale vessel strike (VS) and entanglement (EN) incidence between this study and Moore et al. (2004)

Period	Diagnosis (n) VS	Diagnosis (n) EN	Incidence (cases yr^{-1}) VS	Incidence (cases yr^{-1}) EN	Reference
1970–2002	14	4	0.4	0.1	Moore et al. (2004)
2003–2018	16	22	1	1.4	Present study

not due to increases in effort and diagnostic capability alone. In fact, considering the declining NARW population numbers since 2010, the actual risk of entanglement mortality for a given NARW may have increased even more substantially. In agreement with previous studies (Knowlton et al. 2012, Pace et al. 2014, McDonald et al. 2016), these data elucidate the fact that entanglement mitigation measures undertaken by the USA since 1997 as part of the Atlantic Large Whale Take Reduction Plan (NMFS 2014), including gear modifications (weak links, sinking groundlines, minimum trap number per string, gear marking) and seasonal closures, have failed to decrease the number of whale entanglement deaths. While these efforts likely prevented some mortalities (by reducing line suspended in the water column near whales, sinking groundline and seasonal closures are likely worthwhile efforts), they are not sufficient to reduce entanglement-related NARW deaths to the required levels under the US Marine Mammal Protection Act and the Endangered Species Act. In Canadian waters, the Canadian Recovery Strategy and proposed Action Plan (DFO 2016) for this species identifies reducing the threat of fishing gear interactions as one of the highest priority actions to recover this species. Despite this being identified for decades, there have been very limited actions undertaken in Canada to address this threat, and most by non-government, industry, or academic stakeholders. Mandated measures to reduce this threat were only introduced by the federal government in 2018. It is also important to reiterate concerns raised by Moore et al. (2004), about weight loss in chronically entangled whales, who can become negatively buoyant and can be under-represented in the case analysis. Thus, the preponderance of acute entanglement cases in this case series is likely strongly biased by that phenomenon.

Weak links were found in the gear attached to a dead entangled whale in this report (EgNEFL1235); both were intact (did not release). The cause of their release failure was not clear, but could have been due to poor execution (improper configuration when employed at sea), inherent design deficiencies, or insufficient strain being applied at the site of the weak link. Given that the weak links in this case were not located at a point of strain within the entanglement configuration at the time of necropsy, the likelihood that they would have been effective in preventing the entanglement even if they had separated properly was minimal. Another gear modification, the 2015 vertical line rule that established a minimum number of traps per trawl, may have had unintended detrimental consequences for whales by causing fishermen to employ stronger ropes in order to sustain the increased load of hauling multiple traps per trawl (Hayes et al. 2018a). Entanglement injury severity in NARWs has been shown to increase with stronger ropes (Knowlton et al. 2016). Thus, while this modification did reduce overall line in the water column, by replacing it with fewer stronger lines, it may have actually increased related mortalities. These challenges with line modifications illustrate that any line in the water column poses a threat to whales, and mitigation efforts would be more appropriately focused on eliminating ropes from whale habitat entirely (Johnson et al. 2005).

The specific origin of entangling gear was identified in 5/14 cases (Canadian snow crab fishery) while trap/pot gear of either US or unknown origin was identified in 2 additional cases, and a fixed-gear fishery in US waters was suspected in another case. In general, when identified, the entanglements were found to be from fixed fishing gear set within the range of the species. These findings are consistent with a previously published study wherein the main types of gear entangling whales were identified as pot and gill net gear, with NARWs more commonly entangled in the former (Johnson et al. 2005). Gear marking to indicate fishery of origin was not evident in the majority of the 14 cases where gear was present. Improvements in coordinated gear marking locations and redundancies within both Canadian and US fisheries could provide significant insight into proper target fisheries for management efforts. However, the highest fisheries management priority must be minimizing exposure to and interaction of whales with fishing gear altogether.

Management changes not only did not decrease NARW entanglement deaths, but an apparent increase thereof was observed over the study period. This recent entanglement mortality escalation could be partially explained by altered geographic distributions for both NARWs and pot/trap fishing gear, resulting in an increased spatial overlap of the 2 entities. NARWs have been shifting their distribution northward in recent years, with decreased sightings in the southeastern USA and increased sightings in the Gulf of St. Lawrence (Davis et al. 2017, Meyer-Gutbrod et al. 2018). Changes in whale distributions are largely driven by shifts in prey availability, which in turn are linked to environmental parameters (Meyer-Gutbrod & Greene 2014, 2018, Meyer-Gutbrod et al. 2015). American lobster distribution has also shifted to the north and offshore in recent years into deeper, cooler waters as previously suitable habitat has warmed (Le Bris et al. 2018). Not surprisingly, the lobster fishing industry followed (Pinsky & Fogarty 2012), increasing the amount of gear in offshore whale habitats. Fishing operations in these harsher environments require more durable fishing gear, resulting in the deployment of stronger, thicker line, the consequences of which have already been discussed.

Knowlton et al. (2012) showed that the annual percentage of NARWs observed with rope present on the body increased significantly over their study period (1980–2009), while the rate of new entanglement wounds did not, suggesting that whales more recently experienced increasing difficulty freeing themselves from entanglement (but not necessarily a higher rate of new entanglement). This finding could be correlated with more durable gear being employed by the fishing industry. The present study shows clearly that the entanglement mortality rate has increased in recent years, but further investigation is warranted to better understand whether this is due to increased rates of entanglement events and/or increased risk of death from entanglement due to changes in gear or other factors. Regardless of the exact mechanism, the efficacy of entanglement mitigation efforts must be improved. As climate change is expected to introduce more variability in the coming years, it is becoming increasingly important to consider environmental parameters during mitigation planning. This is especially true with regards to frequently employed spatially and temporally fixed protection strategies such as 'critical habitat' and 'seasonal management areas.' The efficacy of these approaches may decrease with increased variability in environmental conditions and whale habitat use patterns.

Whales are at risk of becoming entangled any time line is present within the water column in their proximity. Expanding seasonal closures to include a larger percentage of NARW habitat may be part of a more efficacious solution, as would a more dynamic fisheries management strategy based on whale presence (as was employed in the Gulf of St. Lawrence snow crab fishery during the summer of 2018). Ropeless fishing, which either completely eliminates the presence of buoy lines or limits them to when the traps are actively being hauled is also a promising potential solution (Moore 2019). Its success depends upon developing affordable technologies and the willingness and feasibility of the industry to employ it. Knowlton et al. (2016) postulated that widespread adoption of fishing ropes with a breaking strength of ≤1700 lbsf (~7.56 kN) could reduce life-threatening entanglements in all large whales by 72% by reducing the rope strength to below swimming whale force production (Arthur et al. 2015). While weaker lines may help to decrease entanglement mortalities in adult NARWs, they would likely still have negative impacts on their reproductive health, energetic costs, and chronic stress levels. Additionally, reduced breaking strength line would likely not significantly reduce entanglement mortalities in smaller marine species, specifically endangered leatherback sea turtles (James et al. 2005), minke whales, juvenile humpback whales (Knowlton et al. 2016), and even potentially young NARWs.

4.2. Other mortality trends

Over the past 16 yr, there were no documented natural mortalities for adult or juvenile NARWs, and more adult NARWs died than juveniles and calves combined. These demographics are in stark contrast to those published by Kraus (1990), who showed that between 1977 and 1985, only 4/25 (16.0%) mortalities occurred in whales >12 m (adults) and that most mortalities occurred in whales under 4 yr of age. While these high mortality rates in young whales were detrimental to population growth, adult females are the most important reproductive demographic and in recent years have experienced the highest mortality rate. This unfortunate statistic likely contributed to the observed poor population growth in this critically endangered species and will continue to do so unless effective mitigation measures are implemented. Additionally, anecdotal data suggesting that NARWs are growing more slowly in the current decade could not be supported here due to small sample size since 2010 (n = 2). However, for the 2 young whales with available data that died during this decade (885 cm at 2 yr and 1130 cm at 5 yr), their straight lengths were shorter than anticipated for their age based on the age–length curves from the prior decades of data.

The calculated potential biological removal (PBR) is the estimated maximum number of animals that can be removed from a marine mammal stock by human activities each year while allowing the stock to reach its optimal sustainable population level. For NARWs, PBR has ranged from 0 to 0.9 over the study period (Hayes et al. 2018b). Over the past 16 yr, we documented an annual minimum average of 2.4 known NARWs killed by human-induced trauma (38 deaths in 16 yr), which is unsustainable for this population. While both entanglement and vessel strike deaths are unintentional, they are no less fatal than commercial whaling is, and in many cases, are far less humane (Moore 2014). This exceedance of PBR also does not take into account the additional 27 dead NARWs during that time period for which a COD could not be determined, suggesting that the human-induced mortality rate within this population could be up to 4 whales annually. It also does not include those NARWs determined to have a serious anthropogenic injury that would likely lead to death that are not represented in this dataset (Henry et al. 2017), again indicating that these numbers are a gross underestimation of the human-induced mortality in this endangered species.

Finally, reported whale carcasses likely represent only a portion of those that actually occur due to the low likelihood of finding carcasses at sea and the reluctance and/or unawareness of various parties to report mortalities to the proper authorities when found (Henry et al. 2013). Knowlton & Kraus (2001) suggested that the number of unreported NARW deaths is likely equal to the number reported, suggesting that the 70 deaths documented here were likely closer to 140 deaths over 16 yr (8.8 dead NARWs yr^{-1}), a grossly unsustainable mortality rate for a population of 411 whales. Further, it is likely that the unreported deaths are biased towards entanglements. Often, vessel-struck animals are in robust condition and their carcasses float and can therefore be detected. In contrast, whales that have been chronically entangled tend to be thinner and their carcasses are more likely to sink, as discussed in Section 4.1.

4.3. Unusual mortality event 2017–2018

The year with the highest number of NARW mortalities was 2017 (n = 17), with 12 of the deaths documented in the Gulf of St. Lawrence, Canada, and the other 5 in the USA. Five of the 2017 deaths were attributed to vessel strikes and 4 to entanglements (Daoust et al. 2017, NMFS 2019). NOAA declared an unusual mortality event (UME) for NARWs from 1 January 2017, which was ongoing during the preparation of this manuscript in 2019 (NMFS 2019). The current total number of mortalities included in the event at the time of publication was 20 whales, including 3 NARW carcasses documented off Massachusetts in 2018. Of these 20 whales, 12 were examined by necropsy. The preliminary cause of the event was attributed to human interactions from vessel strikes (n = 5) or rope entanglement (n = 7). An additional NARW skull fragment uncovered on Martha's Vineyard, MA, in 2018 had not been included in the UME at the time of publication due to its undetermined timeline. The increase in Canadian NARW deaths in 2017 compared to other years likely reflects the northerly NARW distributional shift into unprotected waters, but increased surveillance effort may have also played a role in amplifying mortality reporting. Active monitoring of NARW habitat shifts through aerial and vessel-based surveys and passive acoustic monitoring is imperative to ensure that mitigation measures are adaptive, dynamic, and implemented in the most impactful locations.

4.4. Necropsy effort

The majority of cases in this dataset (51/70, 73%) were found floating offshore, compared to Moore et al. (2004) in which only 30% (16/54) were. While this trend may in large part be due to increased offshore surveillance effort, a possible shift to more offshore whale distributions or mortality factors may also be partially responsible. Regardless, these data strongly support continued and expanded efforts to survey offshore habitat for NARW carcasses in order to obtain more accurate mortality statistics. The efforts put forth to document and when possible, tow, land, transport, and necropsy these whales have been substantially improved in recent years. The ability of stranding networks to prioritize the collection of event, animal, necropsy, and ancillary diagnostics data from this endangered species is evident in the quantity and quality of data available for this study. Increased federal funding in both the USA and Canada for stranding networks engaged in these activities has been, and will continue to be, a critical factor in the ability to monitor NARW mortality events.

Significant improvements in the quality and standardization of data and sample collection since the prior necropsy summary by Moore et al. (2004) are largely due to the NARW necropsy protocol established by McLellan et al. (2004) and the dedicated efforts of Necropsy Team Leaders and stranding organizations along the North American eastern seaboard. As a result of these monumental efforts on the part of all involved, a significant series of NARW trauma cases was able to be compiled here, including the discovery of severe and consistent gross and histopathologic lesions derived from anthropogenic trauma. Efforts to standardize diagnostic procedures, nomenclature, and training should continue to be supported in order to maintain and improve the current state of NARW forensic investigations. Specifically, a standardized method for evaluating body condition in right whale carcasses should be developed. Pettis et al. (2017b) used a scale of good, fair, or poor body condition in free-swimming right whales based on the dorsal profile posterior to the blowholes. This approach may be adaptable to floating and stranded whales but is likely limited by carcass recumbency and postmortem bloating. More preferably, a 5-point numerical scale based on multiple anatomical locations, as is commonly used on other species, should be developed to better evaluate body condition in these cases. McLellan et al. (2004) also stressed that a comprehensive collection of blubber thicknesses across the entire body surface provides the best description of a whale's nutritional status and body condition.

4.5. Traumatic lesions

Histopathologic lesions observed in some propeller strike cases (discoid and segmental disintegration of myofibers) were consistent with lesions observed in experimentally traumatized skeletal muscle exposed to seawater (Stacy et al. 2015) and with those reported in large whales by Sierra et al. (2014), indicating that perimortem propeller injuries can be identified in whale carcasses even when wounds have been washed out by seawater. In fact, the study by Stacy et al. (2015) illustrated that seawater exposure increases detectability of discoid and segmental disintegration in muscle injuries caused during the perimortem/supravital period. These results indicate that washout areas may be the best region to sample for myofiber damage evidence, and it is strongly encouraged that prosectors prioritize washout regions of suspect propeller-induced lesions for histopathology in future cases. Fat emboli, which are commonly associated with traumatic (especially orthopedic) injuries (Hulman 1995) and have been observed in whales with evidence of barotrauma (Fernández et al. 2005), were not observed in any of the carcasses in this study. The significance of their absence is unclear, as fat emboli are usually released from the marrow (which is largely absent in whales) exposed in long-bone fractures, and barotrauma fat emboli are likely associated with gas embolus formation within fatty tissues. Techniques such as oil red O and Sudan black staining, osmium tetroxide postfixation, and paraffin embedding were also not regularly employed to detect fat emboli.

The focal patchy to undulating pattern of blubber contusion observed in a portion of the vessel strike blunt trauma cases could have a few different etiologies: (1) shearing forces from the vessel impact may tear cutaneous trunks of vessels crossing through the subdermal sheath; (2) compressive forces due to vessel hull features may result in focal extravasation along pressure points; or (3) the undulating pattern is similar to that made when experimental shock waves travel through tissues with varying densities and thus variable resulting wave velocities (Clemedson & Jönsson 1961, Cernak 2017). If focal regions of patchy or undulating blubber contusions are documented during a necropsy, the prosector should look for other supportive evidence of blunt trauma. Efforts to understand vascular supply patterns (e.g. angiosomes) of different regions may help reduce conflation of livor mortis and postmortem marbling with perimortem traumatic edema and hemorrhage.

The putty-like substance observed in many blunt trauma cases as described in this study was reported in 1 NARW carcass previously (Moore et al. 2004); this animal was also a victim of severe blunt trauma. Suggestive of massive internal hemorrhage, the substance's origin is consistent with blood clots that have coagulated and lysed under the heat and increased internal body pressure resulting from decomposition within a carcass of large mass. However, caution must be undertaken not to over-interpret this finding on necropsies of animals in advanced decomposition, since severely autolyzed muscle and other tissues may have a similar appearance and consistency, and decomposition or environmental effects (e.g. mechanical trauma from waves) may cause postmortem organ rents and release of blood into cavities. Dependent surface changes from death to bloating to stranding and necropsy are also important to consider in the differentiation of true perimortem hemorrhage patterns from postmortem lividity. While NARW carcasses tend to float in dorsal or lateral recumbency, vessel interactions, especially propeller trauma, can affect the orientation of floating whales after death. Presence of 'putty' is supportive of perimortem hemorrhage from blunt trauma when present along fracture lines, in discrete interstitial pockets (e.g. intramuscularly), or in conjunction with other traumatic lesions but should not be used as the sole indicator of blunt trauma in whale carcasses. Efforts should also be made not to confuse clots of vascular origin with 'putty.' In a case with advanced decomposition and an undetermined COD (MARS 2017-144/EG2017-03), degraded muscle and connective tissue were found within a portion of similar-looking putty-like substance, making it impossible to determine the etiology of the material (muscle or a combination of blood and muscle) and thus hindering the interpretation of this finding in that particular case. This case highlights the challenges of drawing diagnostic conclusions from gross and microscopic examinations of NARW carcasses in advanced decomposition. In many of these cases, the gross lesions will be the most helpful in determining COD, especially when there are multiple gross lesions in support of the same etiology (see Moore et al. 2013 for anthropogenic trauma case criteria definitions). While histopathologic investigation is hindered by autolysis in cases of advanced decomposition, it can provide supportive evidence for gross conclusions and is still a valuable tool to employ in these important cases. Another noteworthy limitation of necropsies on animals in advanced decomposition is that underlying toxicoses and infectious diseases may be more difficult to rule out. While samples were analyzed for presence of biotoxins in some NARW cases, associated gross and histopathologic lesions may not have been evident due to decomposition. Conditions such as encephalitis, hippocampal atrophy, or other CNS pathologies are nearly impossible to diagnose in large whales due to how rapidly these tissues degrade after death. While this does not detract from the severity of the observed traumatic lesions, it does limit our understanding of other potential co-morbidity factors in this species.

Previous publications have reported rope embedded in bones of entangled large whales, similar to our findings (Moore et al. 2004, 2006, Cassoff et al. 2011). Moore et al. (2004) also reported 2 chronic entanglement cases in NARWs with diffuse soft tissue ossification around the site of flipper entanglement, but lesions in both cases were lost during museum preparation. Ours is the first study to present a case series of osteopathic lesions indicative of chronic entanglement-induced trauma in NARWs to include periosteal proliferation (exuberant new bone growth in response to relentless insult), osteopenia (due to presumed flipper disuse), lytic lesions (potentially from osteomyelitis or osteonecrosis), and osseous metaplasia (formation of bone-like material in soft tissues). Osteopenia and lytic bone lesions were most readily identified with bone imaging (CT scanning), which was only performed in 2 entanglement cases (CALO 0901 and VAQS20181005Eg). Retrieval of entangled flippers and the unaffected contralateral control specimens should be a priority for future necropsies to provide an age-appropriate 'normal' for comparison in advanced diagnostic imaging to more accurately evaluate the severity of the induced lesions in the affected flipper. Additionally, continued sampling of colonic contents to determine overall stress hormone levels (Rolland et al. 2017) aids in providing an endocrine-based context for the necropsy results.

This compilation of significant gross and histopathologic findings in NARW trauma cases indicates that despite some loss of evidence in the interval between death and carcass recovery, diagnoses are still possible if a careful examination and sampling are undertaken. Obtaining and labeling detailed samples of suspected traumatic injuries will offer the opportunity to categorize these lesions as antemortem, perimortem, or postmortem. However, experience with prosection and gross pathologic interpretation are invaluable due to previously mentioned challenges related to interpreting histopathologic samples with significant autolysis. Additionally, better understanding of wound vitality characteristics may help improve sampling locations and inform interpretations of perimortem interval. These efforts will enable prosectors to more frequently and accurately establish a COD and estimate time of injury relative to death.

While not necessarily traumatic lesions, the multifocal glossal ulcers observed in 2 cases in our study were interestingly observed in a previously reported case (Catalog Eg #1014 'Staccato') that died from vessel strike in 1999. Prosectors are encouraged to sample and perform full diagnostics on such lesions (pan-viral screening and/or electron microscopy) in the future in order to better understand the etiology of these lesions and any potential impact on NARW health.

4.6. Manner of death

Trauma was severe in the 38 NARWs that died due to human activities. Some mortalities were likely acute, such as vessel strike blunt trauma cases where massive skull fractures likely caused loss of consciousness and rapid death. Other vessel-struck whales died due to exsanguination and resultant hypovolemic shock or traumatic pneumo- or hemothorax. While not extremely protracted, these mechanisms of death are not considered humane according to the AVMA Guidelines for the Euthanasia of Animals (Leary et al. 2013). One propeller-struck whale with a completely severed caudal peduncle and flukes (EgNEFL0602) presumably lost its ability to locomote efficiently if not altogether, and either drowned as a result of its inability to remain at the surface or died from hypovolemic shock due to exsanguination. As previously described by Moore et al. (2013) and Cassoff et al. (2011), peracute underwater entrapment occurring when animals entangled in gear could not reach the surface to breathe was likely a relatively acute death. The necropsies of many of these cases showed evidence of a significant antemortem struggle, including marked contusions and edema from thrashing against the entangling gear and fluid within the lungs from either terminal aspiration or asphyxia. Based on these findings, it is reasonable to assume that a considerable amount of stress and pain would be experienced by the whale prior to its demise from peracute underwater entrapment in entangling gear.

Chronic injuries were sustained by whales that carried entangling gear for long periods of time. Over time, the impinging line on flippers, peduncle, head, and body created deep lacerations into the underlying soft tissue and bone, often with surrounding hemorrhage and edema. In some chronic cases where rope movement against the body surface was minimal, scar tissue formed over the entangling line, encasing it as a potential nidus of infection within the surrounding tissue. Both the soft tissue and osteopathic lesions observed in chronically entangled whales would be profoundly painful and debilitating over time (Moore et al. 2006, Cassoff et al. 2011, Moore 2013).

The poor health of many of these chronically entangled whales was also reflected in their increased cyamid burden and poor body condition. Furrows created by entanglement lesions and poor skin condition provide protective habitat for these obligate parasites, and it has been postulated that whales debilitated by the sequelae from a long-term entanglement may swim slower, increasing the available low-flow habitat for cyamids on the whale's body (Osmond & Kaufman 1998, Pettis et al. 2004). Lower swim speeds in these whales would also impact their ability to consume sufficient calories in any given period of time. Additionally, the direct impediments of baleen plate separation, mutilation, and oral cavity obstruction due to entangling line are unquantified to date, but likely have a substantial impact on the ability of a filter-feeding animal to forage and thermoregulate efficiently (Werth 2004, Lambertsen et al. 2005, Kot et al. 2009, Ford et al. 2013).

Finally, the chronic implications of even acute traumatic events, especially in young growing animals, are evident from the cases presented here. Despite never being observed carrying gear, CALO0901 / 3710 had protracted traumatic insults (traumatic scoliosis) from a prior entanglement event that compromised his mobility and ability to feed over a year after its apparent resolution, eventually leading to his live stranding and necessary euthanasia (Harms et al. 2014). Both this case and that of the NARW (NEFL0501Eg / 2143) with healed propeller lacerations whose subsequent pregnancy re-opened her wounds and led to her death 14 yr after the instigating injury, are morbid reminders that even seemingly resolved traumatic events caused by human activities can have unseen and profound impacts on this species' survival.

5. CONCLUSION

If the recent trends presented here are not sufficient to instigate meaningful change within NARW habitat, their extinction is almost certain. This dataset agrees with Corkeron et al. (2018) that adult NARWs are not dying from geriatric conditions because they are instead suffering premature deaths due to human-induced trauma. Young whales are also dying from anthropogenic trauma at an alarming rate, further limiting the number of NARWs reaching sexual maturity and reducing the potential for population recovery. Some of the deaths caused by human activities inflict painful acute deaths, while others are much more protracted, causing a profound amount of suffering for each affected whale. It is essential that measures to reduce anthropogenic NARW mortality be undertaken immediately, as was previously called for nearly 14 yr ago by Kraus et al. (2005). If mitigation efforts such as more effective gear modifications, extended fishery closures, and expanded vessel speed restrictions are not implemented imminently, human activities will cause an inhumane and certain extinction of this species in the all-too near future.

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Appendix

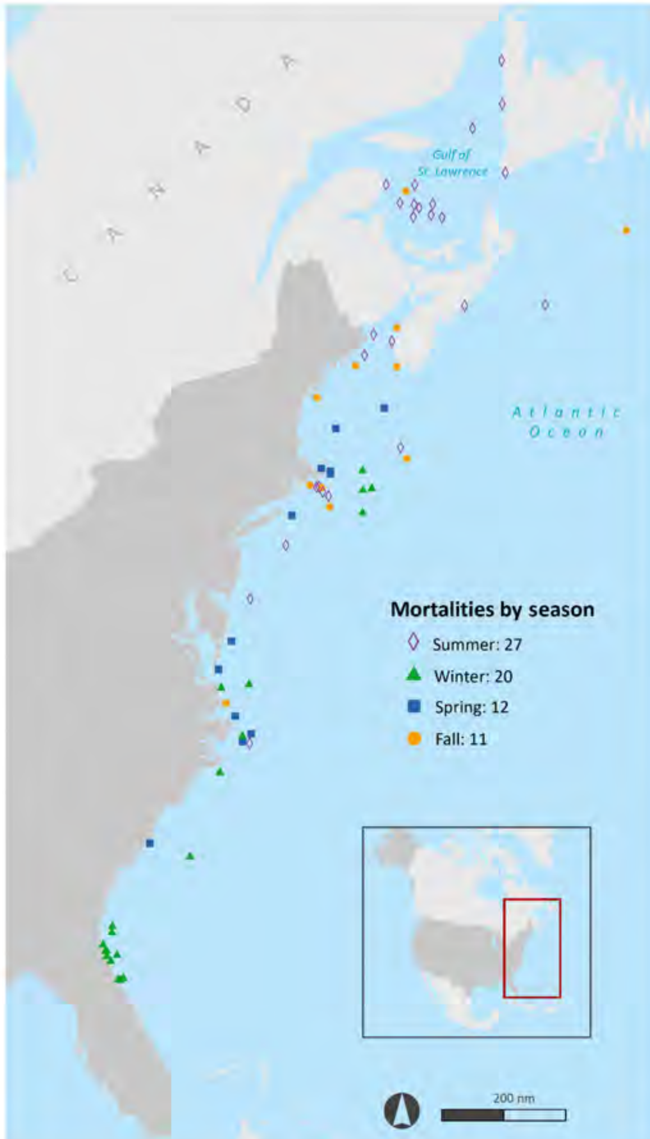

Fig. A1. North Atlantic right whale mortalities (n = 70) between 2003 and 2018 by season. Seasons are defined as follows: spring: March–May; summer: June–August; fall: September–November; winter: December–February

Editorial responsibility: Stephen Raverty, Abbotsford, British Columbia, Canada

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North Atlantic Right Whale

North Atlantic Right Whale

Eubalaena glacialis

Protected Status

ESA ENDANGERED
Throughout Its Range

CITES APPENDIX I
Throughout Its Range

MMPA PROTECTED
Throughout Its Range

MMPA DEPLETED
Throughout Its Range

Quick Facts

WEIGHT	Up to 140,000 pounds
LIFESPAN	Up to 70 years
LENGTH	Up to 52 feet
THREATS	Entanglement in fishing gear, Vessel strikes, Habitat degradation, Ocean noise, Climate change, Changes in distribution and availability of prey, Small population size
REGION	New England/Mid-Atlantic,

Southeast

About The Species

The North Atlantic right whale is one of the world's most endangered large whale species, with less than 400 individuals remaining. Two other species of right whales exist: the North Pacific right whale, which is found in the North Pacific Ocean, and the Southern right whale, which is found in the southern hemisphere. Right whales are baleen whales, feeding on copepods (tiny crustaceans) by straining huge volumes of ocean water through their baleen plates, which act like a sieve.

By the early 1890s, commercial whalers had hunted right whales in the Atlantic to the brink of extinction. Whaling is no longer a threat, but human interactions still present the greatest danger to this species. Entanglement in fishing gear and vessel strikes are the leading causes of North Atlantic right whale mortality. Increasing ocean noise levels from human activities are also a concern since the noise may interfere with right whale communication and increase their stress levels.

NOAA Fisheries and our partners are dedicated to conserving and rebuilding the North Atlantic right whale population. We use a variety of innovative techniques to study, protect, and recover these endangered whales. We engage our partners, including the fishing and shipping industries, as we develop regulations and management plans that foster healthy fisheries and reduce the risk of entanglements, slow down vessel traffic, and reduce ocean noise.

Status

North Atlantic right whales have been listed as endangered under the Endangered Species Act since 1970. Researchers estimate there are fewer than 400 North Atlantic right whales, with fewer than 100 breeding females left. The number of new calves born in recent years has been below average. Since 2017, right whales have experienced an ongoing Unusual Mortality Event (UME), with 46 individual right whales dead (n=32) or seriously injured (n=14). This represents more than 10% of the population, which is a significant impact on such a critically endangered species where deaths are outpacing births.

Protected Status

ESA Endangered

- Throughout Its Range

CITES Appendix I

- Throughout Its Range

MMPA Protected

- Throughout Its Range

MMPA Depleted

- Throughout Its Range

Appearance

North Atlantic right whales have stocky black bodies with no dorsal fins, and their blow spouts are shaped like a “V.” Their tails are broad, deeply notched, and all black with a smooth trailing edge. Their bellies may be all black or have irregularly shaped white patches. Pectoral flippers are relatively short, broad, and paddle-shaped. Calves are about 14 feet at birth and adults can grow to lengths of 52 feet.

Their heads have knobby white patches of rough skin, called callosities, which appear white because of whale lice (cyamids) covering their otherwise black skin. Each right whale has a unique pattern of callosities that scientists use to identify individual whales, an invaluable tool in tracking population size and health. Aerial and ship-based surveys and the North Atlantic Right Whale Consortium’s photo-identification database maintained by our partners at the New England Aquarium help track individuals over the years.

Behavior and Diet

When viewing right whales, you might see these enormous creatures breaching and then crashing back down with a thunderous splash. You might also see them swimming along with their rostrum out of the water as they skim feed on dense patches of plankton. Right whales feed by opening their mouths while swimming slowly through large patches of copepods and other zooplankton. They filter out these tiny organisms from the water through their baleen, where the copepods become trapped in a tangle of hair-like material that acts like a sieve. Right whales feed anywhere from the water’s surface to the bottom of the water column.

Groups of right whales may be seen actively socializing at the water's surface, known as surface-active groups, or SAGs. Mating and socializing occurs in SAGs, which are observed during all seasons and in all habitats.

Right whales communicate using low-frequency moans, groans, and pulses, which may maintain contact between individuals, communicate threats, signal aggression, or be used for other social reasons.

Where They Live

World map providing approximate representation of the North Atlantic right whale's range.

North Atlantic right whales primarily occur in Atlantic coastal waters on the continental shelf, although they also are known to travel far offshore, over deep water.

Right whales migrate seasonally and may travel alone or in small groups. In the spring, summer, and into fall, many of these whales can be found in waters off New England and further north into Canadian waters, where they feed and mate.

Each fall, some right whales travel more than 1,000 miles from these feeding grounds to the shallow, coastal waters of their calving grounds off of South Carolina, Georgia, and northeastern Florida, though migration patterns vary.

NOAA Fisheries has designated two areas as critical habitat for North Atlantic right whales. These areas provide important feeding, nursery, and calving habitat:

- Off the coast of New England (foraging area).
- Off the southeast U.S. coast from Cape Fear, North Carolina, to below Cape Canaveral, Florida (calving area).

Lifespan & Reproduction

Right whales can probably live for at least 70 years, but data on their average lifespan is limited since scientific monitoring of the species is fairly recent. Ear wax can be used to estimate age in right whales after they have died. Another way to determine life span is to look at groups of closely related species. There are indications that some species closely related to right whales may live more than 100 years. However, female North Atlantic right whales are now only living to around 45 years old and males only to around 65 years old. Such reduced lifespans are due to human-caused mortality, not old age.

In recent years, researchers have recorded more deaths among adult females than adult males, leading to a population with more males than females, a bias that is increasing over time. Females that undergo energetic stress from reproduction may be more susceptible than males to dying from chronic injuries such as those from entanglement or vessel strikes.

Female right whales become sexually mature at about age 10. They give birth to a single calf after a year-long pregnancy. Three years is considered a normal or healthy interval between right whale births. But now, on average, females are having calves every 6 to 10 years. Biologists believe that the additional stress caused by entanglement is one of the reasons that females are calving less often.

Threats

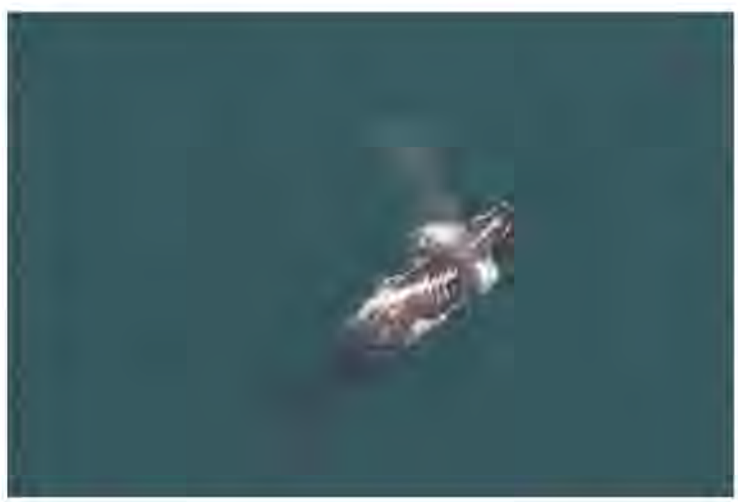
Climate Change

The changing climate, and more specifically oceanographic changes in the Northwest Atlantic, are key factors contributing to reduced reproduction and higher susceptibility to human-caused threats. Over the past decade, right whales have changed their distribution patterns, likely in response to changes in prey location and availability due to warming oceans. As their prey moved, the whales began spending more time in areas with fewer protections from vessel strikes and entanglements.

A dip in right whale births and lengthened calving intervals (from 3-5 years to 6-10 years) indicates that reproductively active females have struggled in recent years to find sufficient food resources to support pregnancy. As their environment changes, right whales will likely continue to modify their distribution and behavior to adapt, resulting in a more uncertain and unpredictable future for the species.

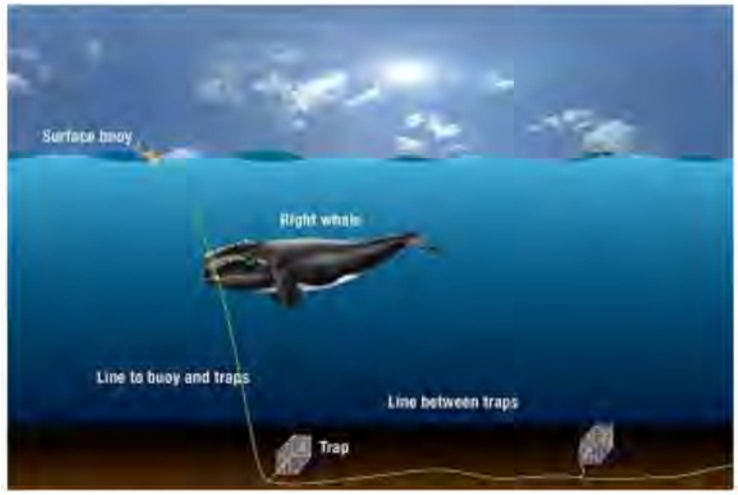
Vessel Strikes

Vessel strikes are a major threat to right whales. Their habitat and migration routes are close to major ports along the Atlantic coastline and often overlap with shipping lanes, making right whales vulnerable to collisions with vessels. These collisions can cause broken bones and massive internal injuries or cuts from propellers. Vessels of nearly any size can injure or kill a right whale. The faster a vessel is traveling when it hits a whale, the higher the likelihood of serious injury or death.



Entanglements

A North Atlantic right whale with propeller scars. Credit: NOAA



Entanglement in fishing gear is one of the greatest threats to North Atlantic right whales. NOAA Fisheries and our partners estimate that over 85 percent of right whales have been entangled in fishing gear at least once. Fishing gear can cut into a whale's body, cause serious injuries, and result in infections and mortality. Even if gear is shed or removed through disentanglement efforts, the time spent entangled can severely stress a whale, weaken it, prevent it from feeding, and sap the energy it needs to swim, feed, and reproduce. Chronic entanglements are one reason scientists think that female right whales are having fewer calves and are taking longer to have calves.

Ocean Noise

Ocean noise from human activities such as shipping, boating, construction, and energy exploration and development has increased in the Northwest Atlantic. Noise from these activities can interrupt the normal behavior of right whales and interfere with their communication. It may also reduce their ability to detect and avoid predators and human hazards, navigate, identify physical surroundings, find food, and find mates.

Scientific Classification

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Cetacea
Family	Balaenidae
Genus	*Eubalaena*
Species	*glacialis*

What We Do

Conservation & Management

We are committed to the protection and recovery of the North Atlantic right whale through implementation of various conservation, regulatory, rescue, and enforcement measures. Our work includes:

- Protecting habitat and designating critical habitat.
- Rescuing entangled right whales.
- Reducing the threat of vessel collisions.
- Reducing injury and mortality by fishing gear.
- Minimizing the effects of vessel disturbance and noise.

Learn more about our conservation efforts ›

Science

We conduct various research activities on the biology, behavior, and ecology of the North Atlantic right whale. The results of this research are used to inform management decisions and enhance recovery efforts for this critically endangered species. Our work includes:

- Identifying habitat and when it is used by right whales.
- Investigating unusual mortality events.
- Performing stock assessments to gather population information.
- Tracking individuals over time to monitor important population traits.

Learn more about our research ›

How You Can Help

Report a Right Whale Sighting

Please report all right whale sightings from Virginia to Maine at (866) 755-6622, and from Florida to North Carolina at 877-WHALE-HELP (877) 942-5343. Right whale sightings in any location may also be reported to the U.S. Coast Guard via channel 16 or through the **Whale Alert app**.

Stay 500 Yards Away

To protect right whales, NOAA Fisheries has regulations that prohibit approaching or remaining within 500 yards (1,500 feet) of a right whale—500 yards is the length of about five football fields. These regulations apply to vessels and aircraft (including drones), and to people using other watercraft such as surfboards, kayaks, and jet skis. Any vessel within 500 yards of a right whale must depart immediately at a safe, slow speed.

Call the NOAA Fisheries Enforcement Hotline at **(800) 853-1964** to report a federal marine resource violation. This hotline is available 24 hours a day, 7 days week for anyone in the United States.

Learn more about our marine life viewing guidelines ›

Report Marine Life in Distress

Report a sick, injured, entangled, stranded, or dead animal to make sure professional responders and scientists know about it and can take appropriate action. Numerous organizations around the country are trained and ready to respond. Never approach or try to save an injured or entangled animal yourself—it can be dangerous to both the animal and you.

Learn who you should contact when you encounter a stranded or injured marine animal >

Be Informed and Get Involved

Stay updated on right whale take reduction and other conservation measures. For accurate information, check your sources or confirm them by reviewing our news and announcements. Participate in public meetings and share your perspectives with Take Reduction Team members who represent your constituency.

In the Spotlight

North Atlantic Right Whale

The North Atlantic right whale is NOAA Fisheries' newest Species in the Spotlight. This initiative is a concerted, agency-wide effort to spotlight and save marine species that are among the most at risk of extinction in the near future.

North Atlantic right whales, which got their name from being the "right" whales to hunt because they floated when they were killed, have never recovered to pre-whaling numbers. These whales have been protected since 1935, when the international prohibition on whaling went into effect. North Atlantic right whales have been listed as endangered under the Endangered Species Act since it was enacted in 1973, and have been experiencing a steady population decline for nearly a decade. NOAA and our partners are continuing to prioritize stabilizing and preventing extinction of this species, and the ***Species in the Spotlight*** designation helps focus resources on these many efforts.

North Atlantic Right Whales' Role in a Balanced Ecosystem

The majority of the Earth's oxygen is produced by marine phytoplankton. These tiny ocean inhabitants also help to absorb CO2, so healthy phytoplankton levels also help to combat climate change. When marine mammals such as right whales defecate at the surface, they provide essential nitrogen and phosphorus to those phytoplankton. Phytoplankton form the base of the food web in many ocean ecosystems, providing nutrition to zooplankton, small fish and invertebrates, and large fish, sea turtles, sea birds, and marine mammals, like North Atlantic right whales.

When whales die and their bodies sink, they also provide essential nutrient resources to the ocean floor ecosystems. Scavengers consume the soft tissue of a sunken carcass in a matter of months. Organic fragments, or detritus, enrich the sediments nearby for over a year, and the bones of the whale's skeleton can provide habitat for invertebrate communities for decades.

Better understanding North Atlantic right whale behavior and biology also provides us with information about changing ocean conditions, giving us insight into larger environmental issues that could have implications for human health.

Sometimes we don't know how vital a species' role is in maintaining this balance until it's too late, and those unforeseen impacts can have a direct effect on our own existence. The Marine Mammal Protection Act and Endangered Species Act recognize that conserving species to ensure they fulfill their role in the broader ecosystem is to everyone's benefit. A diverse environment is a healthier environment. It's part of our responsibility as stewards of the nation's living marine resources to make sure that we protect North Atlantic right whales for generations to come.

NOAA's Commitment to Right Whale Recovery

As the federal agency charged with recovering the North Atlantic right whale, we are committed to recovering the species by significantly reducing risks from entanglement and vessel strikes. The Marine Mammal Protection Act provides a structure, through the Take Reduction Process, for stakeholder voices to be heard and the opportunity for entanglement risk reduction innovation to come from the people who will be most affected by future regulatory action. Under the Endangered Species Act, we manage the threats that North Atlantic right whales face, including the risks of vessel strikes, to facilitate their recovery.

Learn more about NOAA's commitment to saving North Atlantic right whales ›

Threats

North Atlantic right whales face many threats, including climate change which may alter their migratory patterns and feeding areas, vessel strikes, entanglement in fishing gear, and the impacts of ocean noise on their ability to communicate, find food, and navigate. Two of these threats, entanglement in fishing gear and vessel strikes, are the causes of the majority of the serious injuries and mortalities in the ongoing North Atlantic Right Whale Unusual Mortality Event.

Learn more about these threats ›

Priority Actions Plan

We are currently developing a Species in the Spotlight 5-Year Priority Actions plan that builds on the recovery plan and details the focused efforts that are needed from 2021–2025.

For information on our many efforts, including our recovery plan, implementation teams, critical habitat designations, vessel strike reduction, fishing gear entanglement reduction, and stranding responses, to help North Atlantic right whales recover, visit our conservation and management page.

2019 Partner in the Spotlight Award

The North Atlantic Right Whale Consortium is dedicated to the conservation and recovery of the North Atlantic right whale. Its 200 members represent research and conservation organizations, shipping and fishing industries, technical experts, U.S. and Canadian government agencies, and state and provincial authorities. The Consortium has made substantial contributions to the efforts to protect and recover these whales.

NARWC
THE NORTH ATLANTIC RIGHT WHALE CONSORTIUM

Learn more about the Consortium's work ›

Management Overview

Right whales are protected under both the Endangered Species Act (ESA) and the Marine Mammal Protection Act. They have been listed as endangered under the ESA since 1970 and are in danger of extinction throughout all of their range. NOAA Fisheries is working to recover this species in many ways.

Recovery Planning and Implementation

Recovery Plan

Under the ESA, NOAA Fisheries is required to develop and implement recovery plans for the conservation and survival of listed species. The ultimate goal of the North Atlantic right whale plan is to recover the species, with an interim goal of down-listing its status from endangered to threatened.

The major actions recommended in the plan are:

- Reduce or eliminate injury and mortality caused by vessel collisions and fishing gear.
- Protect habitats essential to the survival and recovery of the species.
- Minimize effects of vessel disturbance.
- Continue international ban on hunting and other directed take.
- Monitor the population size and trends in abundance of the species.
- Maximize efforts to free entangled or stranded right whales and acquire scientific information from dead specimens.

Read the recovery plan for the North Atlantic right whale ›

Implementation

The ESA authorizes NOAA Fisheries to appoint recovery teams to assist with the development and implementation of recovery plans. Two regional North Atlantic right whale recovery plan implementation teams were established to assist with issues related to the status and conservation of right whales

Learn more about the Southeast U.S. Implementation Team ›

Learn about the Northeast U.S. Implementation Team ›

Critical Habitat Designation

Once a species is listed under the ESA, NOAA Fisheries evaluates and identifies whether any areas meet the definition of critical habitat. Those areas may be designated as critical habitat through a rulemaking process. The designation of an area as critical habitat does not create a closed area, marine protected area, refuge, wilderness reserve, preservation, or other conservation area; nor does the designation affect land ownership. Rather, federal agencies that undertake, fund, or permit activities that may affect these designated critical habitat areas are required to consult with NOAA Fisheries to ensure that their actions do not adversely modify or destroy designated critical habitat. NOAA Fisheries designated critical habitat for the North Atlantic right whale in 1994 (59 FR 28805) and revised the designation in 2016 (81 FR 4838). Critical habitat for the North Atlantic right whale includes two areas—a foraging area in the Northeast and a calving area in the Southeast:

- North Atlantic Right Whale critical habitat map and GIS data
- Final rule establishing critical habitat for North Atlantic Right whales

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Conservation Efforts

Reducing Vessel Strikes

The most common vessel-related threats to right whales are blunt force trauma and propeller cuts. Collisions between whales and large vessels often go unnoticed and unreported, even though whales can be injured or killed and vessels can sustain damage.

Reducing vessel speeds where whales are present, developing recommended shipping lanes outside of specific ports, making mariners aware when whales are around, and implementing a 500-yard "no-approach" safety zone around right whales are among the measures we use to reduce these threats.

Specifically, we have taken both regulatory and non-regulatory steps to reduce the threat of vessel collisions to North Atlantic right whales, including:

- Requiring vessels to slow down in specific areas during specific times (Seasonal Management Areas).
- Advocating for voluntary speed reductions in Dynamic Management Areas and Right Whale Slow Zones.
- Recommending alternative shipping routes and areas to be avoided.
- Modifying international shipping lanes.
- Developing right whale alert systems.
- Developing mandatory vessel reporting systems.
- Increasing outreach and education.
- Improving our stranding response.

Implementing Vessel Speed Restrictions for North Atlantic Right Whales

The most effective way to reduce collision risk is to keep whales and vessels apart. If that is not possible, the next best option is for vessels to slow down and keep a lookout. There are several areas, known as Seasonal Management Areas, along the U.S. East Coast where most vessels 65 feet or longer must slow to 10 knots or less during times of the year when right whales are likely to be in the area. The idea behind the 10-knot limit is that the more slowly a vessel goes, the more time the whale has to get out of the way, and a strike at that speed is less likely to be fatal. We have fined companies for violating these speed reductions.

Outside of these areas, if three or more right whales are sighted within close proximity to each other, we implement a short-term voluntary speed reduction area around those whales called a Dynamic Management Area (or DMA) and do our best to get the word out to all vessels to reduce their speed in these areas. In the Northeast, we also implement analogous Right Whale Slow Zones when right whales are detected by acoustic receivers. Unfortunately, studies have found that these voluntary measures are not sufficiently effective in modifying vessel speed or direction of travel, and therefore likely do little to reduce vessel collisions.

Learn more about reducing vessel strikes to North Atlantic right whales

Implementing a Mandatory Vessel Reporting System for North Atlantic Right Whales

To further reduce the number of vessel strikes, NOAA Fisheries and the U.S. Coast Guard developed and implemented a mandatory vessel reporting system for North Atlantic right whales. When large vessels enter one of two key right whale habitats—one off the U.S. northeast coast and one off the U.S. southeast coast—they must report to a shore-based station. In return, the vessel receives a message about right whales, their vulnerability to vessel strikes, precautionary measures to avoid hitting a whale, and locations of recent sightings.

Learn more about the mandatory ship reporting system for North Atlantic right whales

Implementing Right Whale Sighting and Notice Systems

To reduce vessel collisions with right whales, mariners are urged to use caution and proceed at safe speeds in areas where right whales occur. NOAA Fisheries and our partners developed an interactive mapping application that provides real-time information on North Atlantic right whale sightings along the East Coast of the United States.

Learn more about reducing vessel strikes to North Atlantic right whales

Addressing Ocean Noise

Underwater noise threatens marine animal populations, interrupting their normal behavior and driving them away from areas important to their survival. NOAA Fisheries is investigating all aspects of acoustic communication and hearing in marine animals, including the effects of sound on whale behavior and hearing. In 2016, we issued technical guidance or assessing the effects of anthropogenic sound on marine mammals' hearing.

Learn more about ocean noise

Marine Mammal Unusual Mortality Events

There is an ongoing Unusual Mortality Event for North Atlantic Right Whale. Under the Marine Mammal Protection Act, an unusual mortality event is defined as "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." Scientists carefully study unusual mortality events, to determine the cause of these events and better understand the health of marine mammal populations.

Get information on active and past UMEs

Get an overview of marine mammal UMEs

Reducing Entanglement in Fishing Gear

Entanglement in fishing gear is a primary cause of serious injury and mortality for many whale species, including the North Atlantic right whale. With the help of the Atlantic Large Whale Take Reduction Team—a group of advisors consisting of fishermen, scientists, and state and federal officials—we have developed management measures to reduce whale entanglements. We require commercial fishermen to use certain gear modifications that are less harmful to North Atlantic right whales, and have established areas where fishing cannot take place during certain times when North Atlantic right whales are present. Specifically, we have taken both regulatory and non-regulatory steps to reduce the threat of entanglement to North Atlantic right whales, including:

- Implementing seasonal closures to fixed gear commercial fisheries in a number of areas of predictable aggregations of right whales .
- Requiring weak links in fixed gear fisheries fishing to increase the likelihood that right whales can break free of buoy lines and gillnet panels.
- Requiring sinking line (versus floating) between trap/pots on the bottom of the ocean.
- Mandating gear marking to improve our understanding of where and how right whales become entangled
- Increasing outreach and education.
- Improving our stranding response.

We are currently developing management measures to reduce the number and strength of buoy lines in the water column in an effort to further reduce the risk of entanglement in fishing gear. In addition, we are actively working with fishermen to test ropeless fishing gear systems which we anticipate will provide future options to prevent large whale entanglement.

In addition, when entangled whales are reported anywhere along the U.S. East Coast, the NOAA-funded Atlantic Large Whale Disentanglement Network is called upon to try to help. The network is made up of emergency responders from 20 public and private organizations who have extensive training in how to disentangle large whales and increase their odds of surviving. The Network has successfully disentangled close to 30 North Atlantic right whales over the years. Examining gear removed from entangled animals is one of the key ways for us to determine whether regulations are working and fishing gear modifications are effective.

Learn more about ropeless gear

Learn more about the Take Reduction Team's efforts to reduce whale entanglements

Learn more about bycatch and fisheries interactions

Overseeing Marine Mammal Health and Stranding Response

We work with volunteer networks in all coastal states to respond to marine mammal strandings. When stranded animals are found alive, NOAA Fisheries and our partners assess the animal's health. When stranded animals are found dead, our scientists work to understand and investigate the cause of death. Although the cause often remains unknown, scientists can sometimes identify strandings due to disease, harmful algal blooms, vessel strikes, fishing gear entanglements, pollution exposure, and underwater noise. Some strandings can serve as indicators of ocean health, giving insight into larger environmental issues that may also have implications for human health and welfare

Learn more about the Marine Mammal Health and Stranding Response Program ›

International Collaboration

NOAA Fisheries is actively collaborating with Canada through ongoing bilateral negotiations on the science and management gaps that are impeding the recovery of North Atlantic right whales in both Canadian and U.S. waters.

Read our January 2020 Leadership Message ›

Key Actions and Documents

Actions & Documents | Incidental Take

Five-Year Reviews of North Atlantic and North Pacific Right Whales

NMFS announces a 5-year review of North Atlantic right whale (Eubalaena glacialis) and North Pacific right whale (Eubalaena japonica) under the Endangered Species Act of 1973 (ESA), as amended. A 5-year review is based on the best scientific and…

- Notice of Initiation (77 FR 16538, 03/21/2012)
- North Atlantic right whale 5-year review (08/2012)
- North Pacific right whale 5-year review (10/2012)

Notice

, Alaska, New England/Mid-Atlantic, West Coast, Foreign

PUBLISHED

March 21, 2012

Listing North Atlantic Right Whale Under the ESA

We, NMFS, completed a status review of right whales in the North Pacific and North Atlantic Oceans under the Endangered Species Act (ESA) in December 2006 and are listing the currently endangered northern right whale (Eubalaena spp.) as two…

- Final Rule

Final Rule
, New England/Mid-Atlantic
PUBLISHED
April 7, 2008

Regulations Governing the Approach to North Atlantic Right Whales

Disturbance is identified in the Final Recovery Plan for the Northern Right Whale (Recovery Plan) as among the principal human-induced factors impeding recovery of the northern right whale (Eubalaena glacialis) (NMFS, 1991). NMFS is issuing this interim…

- Final Rule, technical amendment (69 FR 69536)
- Final Rule (62 FR 6729)

Final Rule
, New England/Mid-Atlantic, Southeast
PUBLISHED
February 13, 1997

Science Overview

NOAA Fisheries conducts various research activities on the biology, behavior, and ecology of the North Atlantic right whale. The results of this research are used to inform management decisions and enhance recovery efforts for this endangered species.

We use a variety of methods to determine where right whales are located, including surveys with boats and planes, underwater acoustic listening devices, habitat modeling, and citizen science sighting reports. To better inform the public of the most recent right whale sightings, NOAA scientists maintain a database that displays real-time sightings on an interactive map. These data, along with those maintained by our partners at the New England Aquarium, includes more than 40 years of reliable sightings data, spanning the entire range of the species from Canada through Florida.

NOAA is working hard to develop a tag that will stay attached to right whales without compromising the health of these animals given their precarious state and poor condition. Right whales are especially challenging to keep long term tags attached since they often engage in physical contact with each other, putting tremendous stress on tags attached to their bodies. They also lack a dorsal fin which is a commonly used attachment point in other species.

Aerial Surveys

Scientists use small aircraft to spot North Atlantic right whales and photograph them to identify individuals and record their seasonal distribution. Understanding the whales' distribution patterns helps managers establish measures to reduce vessel strikes and fisheries interactions. NOAA Fisheries and our partners also use small unmanned aircraft systems (drones) to assess individual right whale size and body condition, as well as taking breath samples to analyze factors such as genetics and stress hormones.

North Atlantic right whale mother and calf as seen from a research drone called a hexacopter. Hexacopters allow researchers to conduct right whale photo identification and photogrammetry studies. Photogrammetry techniques allow scientists to get body measurements from aerial photographs. Photo: NOAA Northeast Fisheries Science Center/Lisa Conger and Elizabeth Josephson.

Shipboard Studies

In addition to aerial surveys, we conduct vessel surveys that investigate the whales' habitat preferences and feeding ecology, as well as collect photographic and genetic identification. Information from this research can be used to inform management actions that protect the North Atlantic right whale.

As with our aerial surveys, the goals of many shipboard surveys are to photograph as many individual right whales as possible, so we concentrate on places where we are most likely to find them at the surface, aggregating to feed or engage in social behaviors. This helps us accurately estimate the population size and monitor population trends. The photographs and other data collected (time, date, location, behavior) are used by researchers to investigate things like body condition, behavior, and life history. Over time, these data can also reflect changes in distribution.

If the whales aren't feeding or socializing at the surface, their behavior can make them hard to spot (for example, if they're engaged in deep dives or traveling while submerged). Sea state and weather also make it more challenging to spot whales.

Acoustics

Acoustics is the science of how sound is transmitted. This research involves increasing our understanding of the basic acoustic behavior of whales, dolphins, and fish; mapping the acoustic environment; and developing better methods using autonomous gliders and passive acoustic arrays to locate cetaceans.

We use underwater microphones to listen for right whale calls. This is another way to learn more about where and when these whales are present in different areas (at least during times they are vocalizing) where visual surveys are not likely to be effective. For example, acoustic detections have shown that at least some right whales can be detected year-round in locations we thought were once only seasonally used.

Other research is focused on the acoustic environment of cetaceans, including North Atlantic right whales.

Learn more about acoustic science ›

Stock Assessments

Determining the size of the North Atlantic right whale population—and whether it is increasing or decreasing from year to year—helps resource managers assess the success of the conservation measures enacted. Our scientists collect population information on right whales from various sources and present the data in an annual stock assessment report.

Learn more about marine mammal stock assessments ›

Documents

DOCUMENT

North Atlantic Right Whale (Eubalaena glacialis) Scenario Planning Summary Report

NOAA Fisheries published the North Atlantic Right Whale Scenario Planning Summary Report from an…

New England/Mid-Atlantic

DOCUMENT

Draft Biological Opinion on 10 Fishery Management Plans

This draft Biological Opinion on 10 Fishery Management Plans in the Greater Atlantic Region and the…

New England/Mid-Atlantic

DOCUMENT

Draft Environmental Impact Statement: ALWTRP Risk Reduction Rule

Draft Environmental Impact Statement, Regulatory Impact Review, and Initial Regulatory Flexibility…

New England/Mid-Atlantic

DOCUMENT

Report of the Health Assessment Workshop for North Atlantic Right Whales (Eubalaena glacialis), June 24-26, 2019

The primary purpose of this document is to summarize current information on health assessments for…

National

More Documents

Data & Maps

DATA

Recovery Action Database

Tracks the implementation of recovery actions from Endangered Species Act (ESA) recovery plans.

National

MAP

Other Southeast Gillnet Waters

New England/Mid-Atlantic

MAP

Sinking Groundline Exemption Contour

New England/Mid-Atlantic

MAP

Exempted Waters for Maine State Lobster Permits

New England/Mid-Atlantic

More Data and Maps ›

Outreach & Education

EDUCATIONAL MATERIALS

Fact Sheet: Summary of Proposed Risk Reduction Rule to Modify the Atlantic Large Whale Take Reduction Plan

Summary of the proposed “Risk Reduction Rule” to modify the Atlantic Large Whale Take Reduction…

New England/Mid-Atlantic

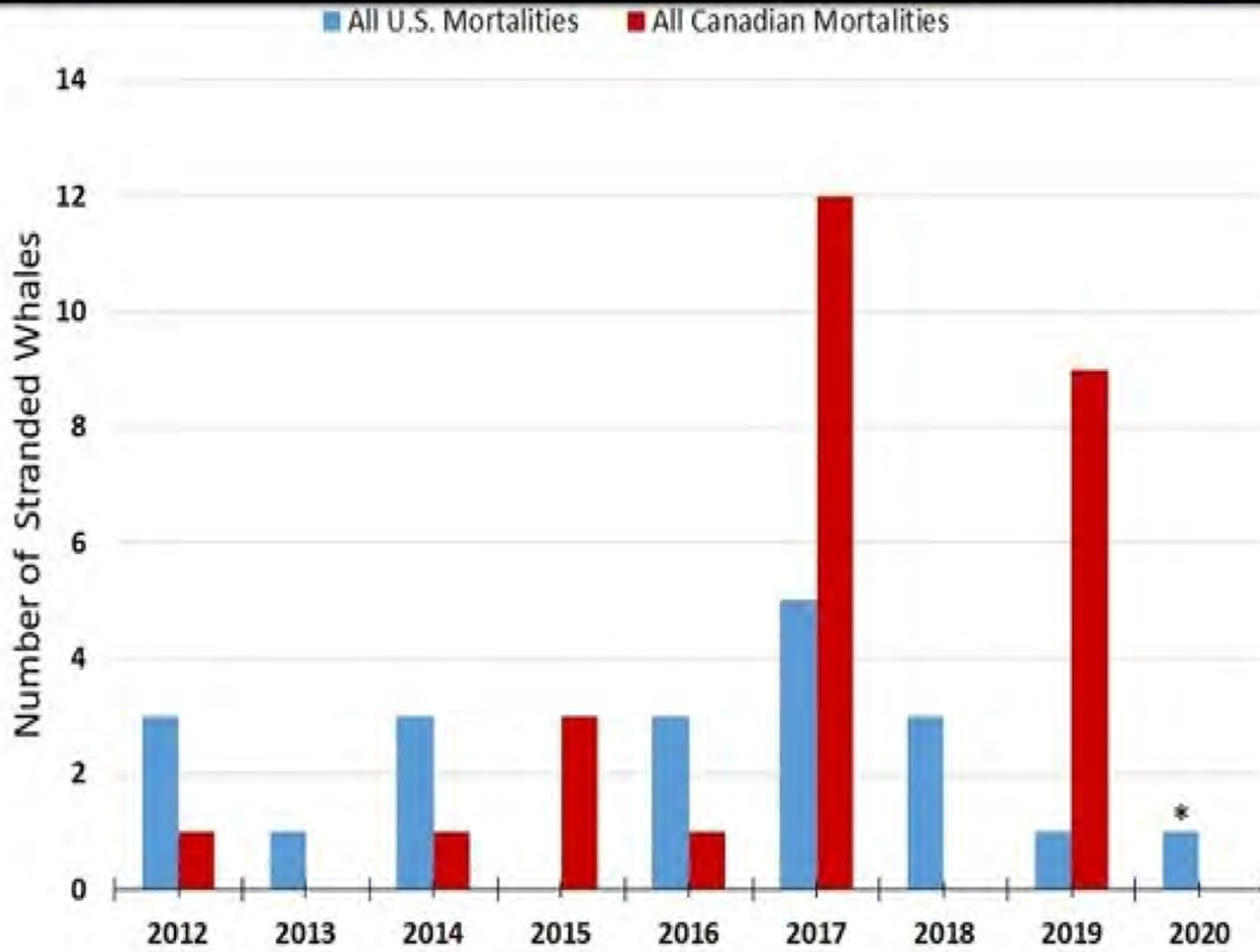
More Outreach and Education Materials ›

NOAA FISHERIES

2017–2020 North Atlantic Right Whale Unusual Mortality Event

Since June 7, 2017, elevated North Atlantic right whale (Eubalaena glacialis) mortalities have been documented, primarily in Canada and were declared an Unusual Mortality Event.

Since June 7, 2017, elevated North Atlantic right whale (*Eubalaena glacialis*) mortalities have been documented, primarily in Canada and were declared an Unusual Mortality Event. In 2017, there was a total of 17 confirmed dead stranded whales (12 in Canada; 5 in the United States) and in 2018, three whales stranded in the United States. In 2019, nine whales have stranded in Canada, and one whale has stranded in the United States. The current total mortalities for the UME is 30 dead stranded whales (21 in Canada; 9 in the United States).



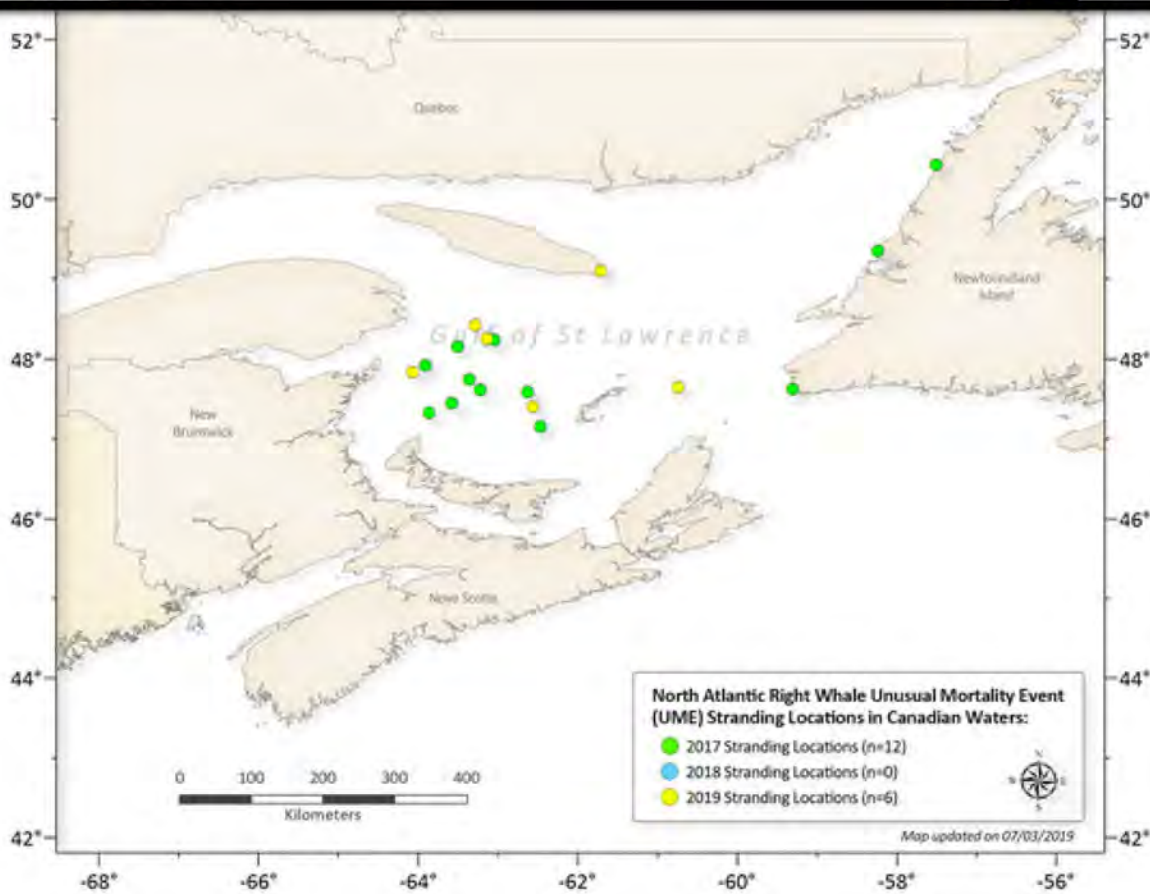
Annual North Atlantic Right Whale Mortalities, 2012-2019, U.S. and Canada. (presumed mortality of vessel struck NARW call)*

North Atlantic Right Whale Causes of Death

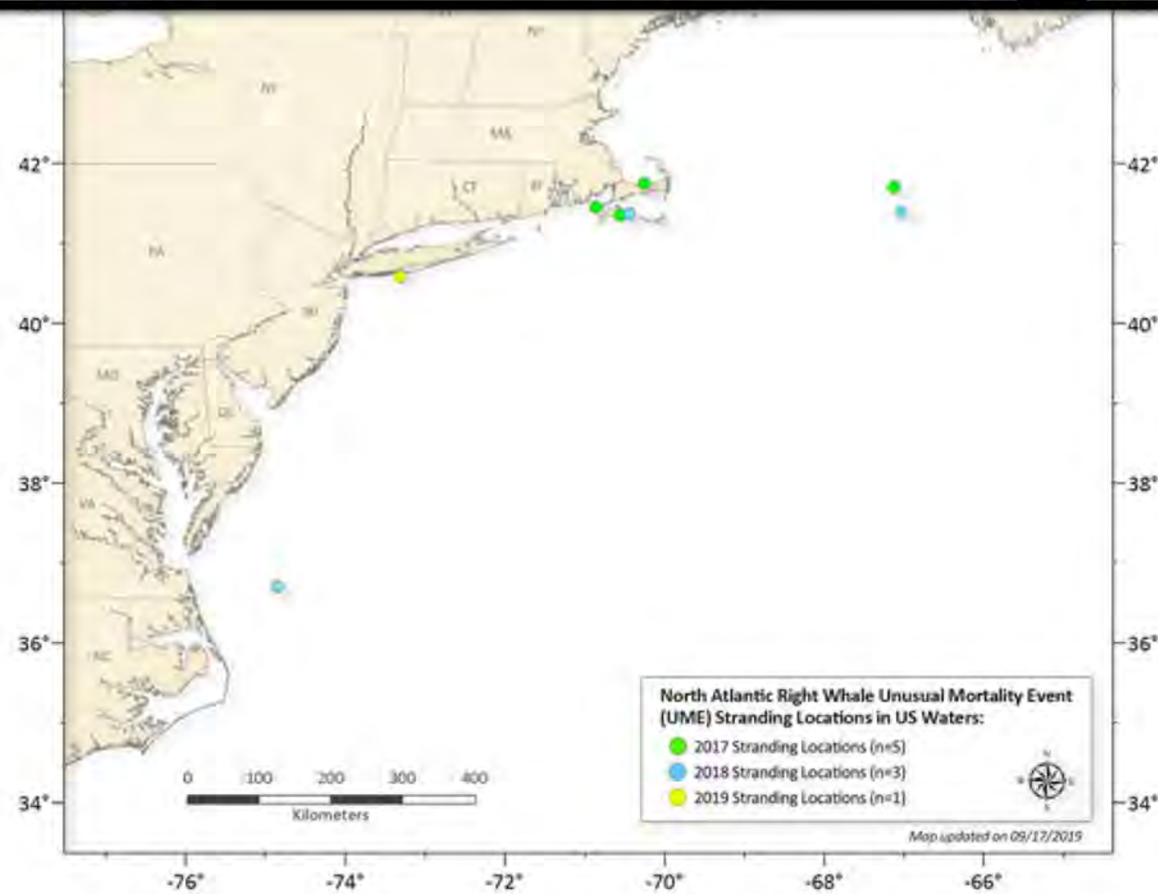
Year	Month	NARW ID	Sex	Location first observed	Preliminary Cause of Death
Canada					
2017	June	#3746	M	Gulf of St Lawrence	Undetermined; could not be examined
2017	June	#1402	M	Gulf of St Lawrence	Suspect blunt force trauma (vessel strike)

2017	June	#3190	M	Gulf of St Lawrence	Undetermined; advance decomposition
2017	June	#3603	F	Gulf of St Lawrence	Acute entanglement (gear present; anchored)
2017	June	#3512	F	Gulf of St Lawrence	Undetermined; could not be examined
2017	June	#1207	M	Gulf of St Lawrence	Probable blunt force trauma (vessel strike)
2017	July	Unk	M	Gulf of St Lawrence	Probable blunt force trauma (vessel strike)
2017	July	#2140	M	Gulf of St Lawrence	Suspect blunt force trauma (vessel strike)
2017	July	#2630	M	Newfoundland	Undetermined; could not be examined
2017	July	Unk	F	Newfoundland	Undetermined; could not be examined
2017	July	#1911	F	Newfoundland	Undetermined; could not be examined
2017	September	#4504	F	Gulf of St Lawrence	Acute entanglement (gear present)
2019	June	Wolverine	M	Gulf of St Lawrence	Pending
2019	June	Punctuation #1281	F	Gulf of St Lawrence	Compatible with sharp force trauma (vessel strike)
2019	June	Comet #1514	M	Gulf of St Lawrence	Highly compatible with blunt force trauma (vessel strike)
2019	June	#3815	F	Gulf of St Lawrence	Pending
2019	June	#3329	F	Gulf of St Lawrence	Pending
2019	June	Clipper #3450	F	Gulf of St Lawrence	Compatible with blunt force trauma (vessel strike)
2019	June	Unk	U	Gulf of St Lawrence	Undetermined; not examined
2019	July	#3421	M	Gulf of St Lawrence	Pending
2019	July	Unk	U	Gulf of St Lawrence	Undetermined; not examined

USA					
2017	April	#4694	F	Barnstable, MA	Blunt force trauma (vessel strike)
2017	August	Unk	M	Martha's Vineyard, MA	Probable entanglement
2017	August	#2123	F	Cape Cod, MA (offshore)	Undetermined; could not be examined
2017	October	Unk	M	Nashawena Island, MA	Suspect entanglement
2017	November	#2611	F	Martha's Vineyard, MA	Undetermined; advance decomposition
2018	January	#3893	F	Virginia Beach, VA (offshore)	Chronic entanglement (gear present)
2018	August	Unk	M	Monomoy, MA	Probable entanglement
2018	October	#3515	F	Nantucket, MA (offshore)	Probable acute entanglement
2019	September	#1226	M	Long Island, NY(offshore)	Pending
2020	January	Calf of 2360	U	Georgia (offshore)	Presumed mortality; Sharp force trauma (vessel strike)



North Atlantic right whale stranding locations along the Atlantic coast in Canadian waters



North Atlantic right whale stranding locations along the Atlantic coast in U.S. waters.

Note: Graph represents confirmed mortalities reported in each country and does not always reflect the location of the injury or death of the animal. Carcasses may drift across national boundaries; therefore, a carcass may be sighted or reported in one country even though the mortality occurred elsewhere. Species or stocks that migrate across national boundaries often carry their illnesses, injuries, or exposures to toxins with them. For mortality determinations in these species, transboundary collaboration is critical in determining the causes of injury, illness, and mortality for each animal.

Causes of the North Atlantic Right Whale UME

Full necropsy examinations have been conducted on 18 of the 30 whales and final results from the examinations are pending. Necropsy results from seven of the Canadian whales from 2017 can be found online.

As part of the UME investigation process, NOAA assembled an independent team of scientists to coordinate with the Working Group on Marine Mammal Unusual Mortality Events to review the data collected, sample stranded whales, and determine the next steps for the investigation. We are continuing to investigate these mortalities but preliminary findings support human interactions, specifically vessel strikes or rope entanglements, as the cause of death for the majority of the whales.

A dead right whale floating at the surface of the ocean.

Report a Stranding

The most important step that the public can take to assist investigators is to immediately report any sightings of injured or stranded whales (dead or alive). In the United States, make a report by calling the Greater Atlantic Marine Mammal Stranding Hotline at (866) 755-6622 or the Southeast Marine Mammal Stranding Hotline at (877) 433-8299. In Canada, call the Marine Animal Response Society at 1-866-567-6277 or the Quebec Marine Mammal Emergency Response Network at 1-877-722-5346. You can also contact the U.S. and Canadian Coast Guards on VHF Channel 16. Do not approach injured or dead animals.

More Information

- Frequent Questions: 2017 North Atlantic Right Whale UME
- Fisheries and Oceans, Canada
- Transport Canada
- Marine Animal Rescue Society, Canada
- Donate to the Unusual Mortality Event Contingency Fund
- Unusual Mortality Events

Last updated by Office of Protected Resources on 04/16/2020

December 31, 2020

NOAA FISHERIES

Greater Atlantic Regional Fisheries Office

Proposed "Risk Reduction Rule" to Modify the Atlantic Large Whale Take Reduction Plan

SUMMARY FOR PUBLIC COMMENTS

To reduce the impacts of entanglement in commercial fishing gear on right whales, we are requesting comments on proposed changes to the Atlantic Large Whale Take Reduction Plan (ALWTRP). These modifications are intended to achieve at least a 60 percent reduction in mortalities or serious injuries of right whales in the Northeast crab and lobster trap/pot fisheries, which deploy about 93 percent of the buoy lines fished in areas where right whales occur. In 2021, the Atlantic Large Whale Take Reduction Team will be asked to recommend risk reduction measures for other Atlantic trap/pot and gillnet fisheries.

The proposed rule and the Draft Environmental Impact Statement, as well as details on how to provide comments, can be found on the Plan website: **fisheries.noaa.gov/ALWTRP.**

The Proposed Rule would:

- Modify gear marking to introduce state-specific marking colors
- Increase the number of and area of marked lines
- Modify gear configurations to reduce the number of vertical buoy lines by requiring more traps between buoy lines and by introducing weak insertions or weak rope into buoy lines
- Modify existing seasonal restricted areas to restrict buoy lines (but allow ropeless fishing)
- Add up to two new seasonal buoy line closures

The tables on the following pages list the regulatory elements of the risk reduction alternatives in the proposed rule and considered in the preferred alternative within the Draft Environmental Impact Statement. Measures shaded in blue are those that will be managed under other state or fishery management rulemaking.

Comments are due by March 1, 2021.

For information on **public hearings** on the DEIS and proposed rule, as well as copies of the documents and background information, visit our website: **fisheries.noaa.gov/ALWTRP**.

Attendance at a public hearing is not necessary for commenting.

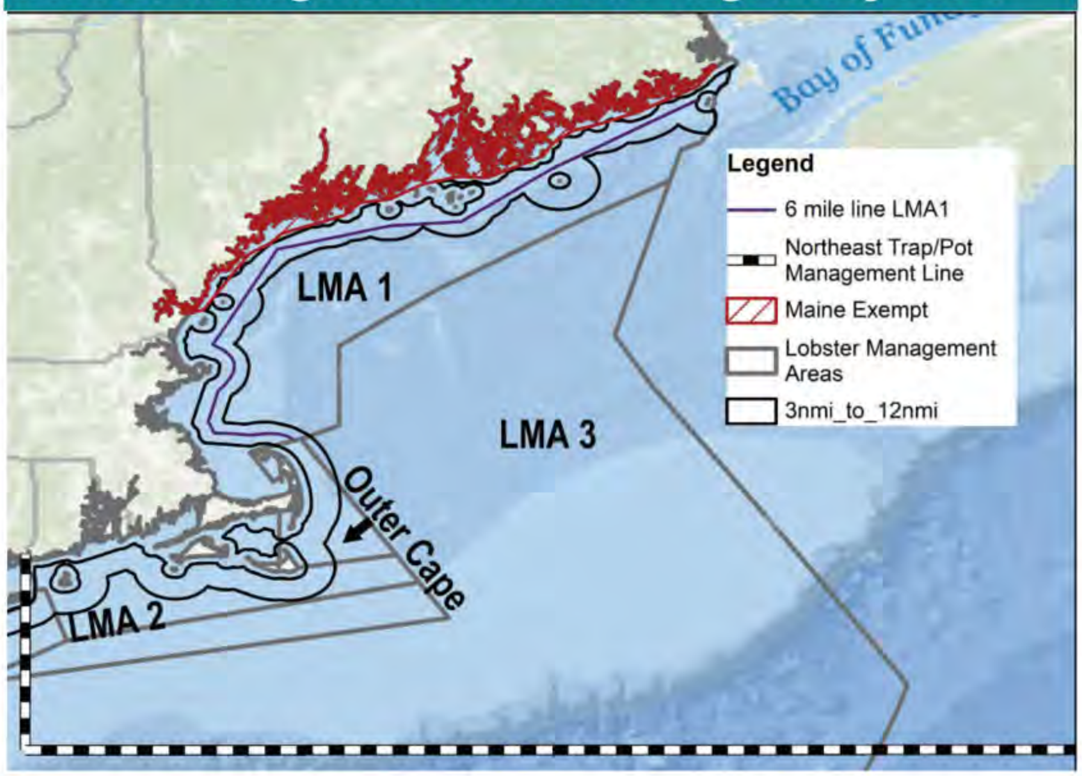
Comments may also be submitted in writing **through the online comment portal**.

To comment, go to: **regulations.gov.** Search for NOAA-NMFS-2020-0031.

Choose "Comment Now" to submit your comments.

Questions?
Contact Colleen.Coogan@noaa.gov, Marisa.Trego@noaa.gov or call (978) 281-9181.

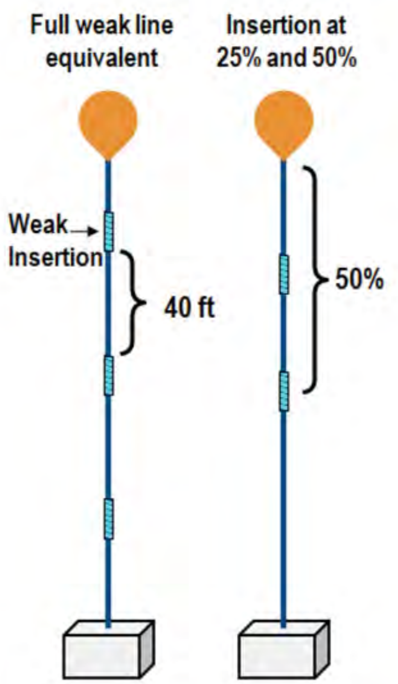
Lobster Management Areas and Regulatory Lines



Traps Per Trawl

Area	Current Regulations	Proposed Regulations
ME exempt area – 3 nm	2 traps/trawl	3 traps/trawl
ME 3–6 nm	3 traps/trawl	8 traps/trawl
LMA1, 6–12 nm	10 traps/trawl	15 traps/trawl
LMA 2, OC 3-12 nm	10 traps/trawl	15 traps/trawl
LMA1, 2 beyond 12 nm	15-20 traps/trawl	25 traps/trawl
MA state waters	1 or 2 traps/trawl	No singles on vessels longer than 29' (8.84 m) permits after 1/1/2020
LMA3	20 traps/trawl	Year-round: 45 traps/trawl, extend trawl length to 1.75 nm

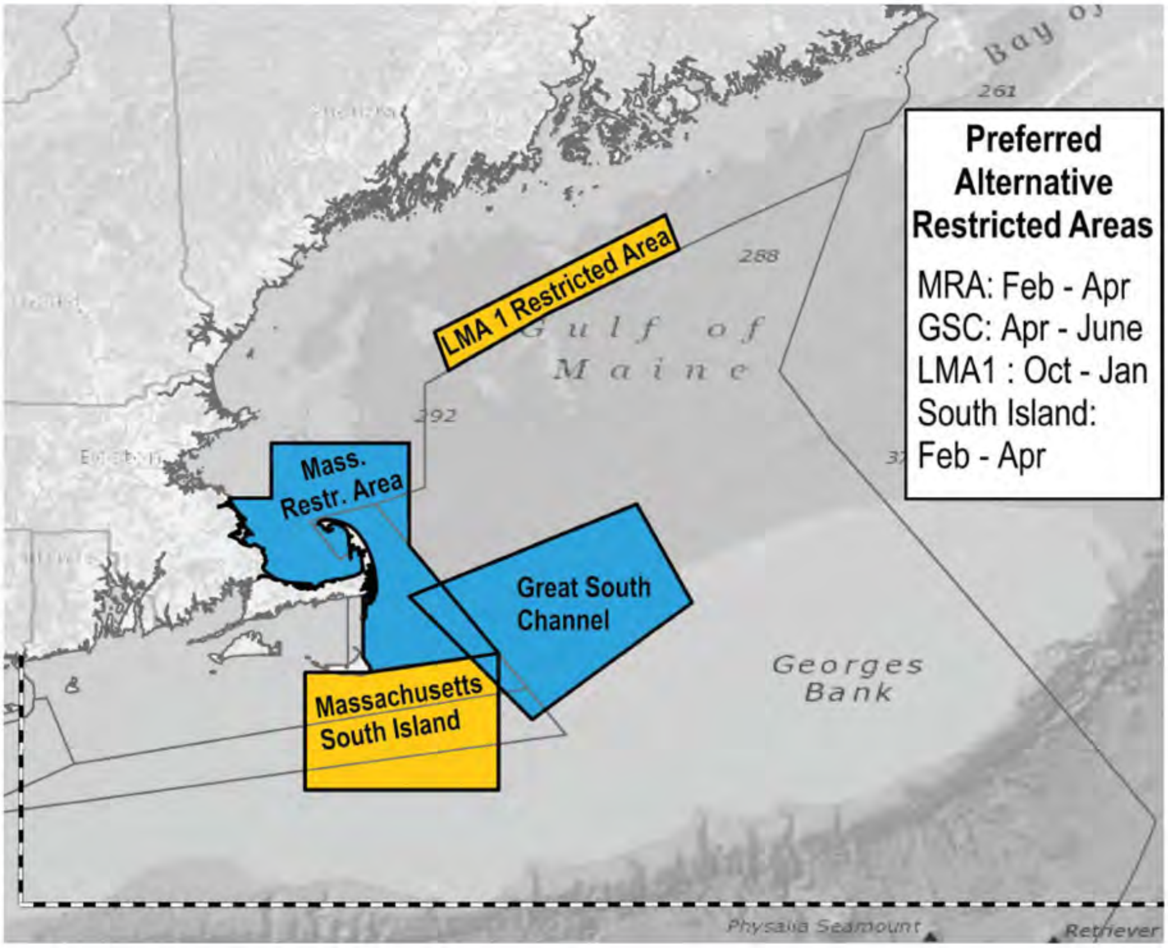
Weak Link and Weak Line Regulations



Component	Area	Current	Proposed
Weak Link Modification	Northeast Region	Weak link required attaching buoy to buoy line	Allow it to be at base of the surface system or, as currently required, at buoy
Weak Line	ME exempt area	None	1 weak insertion 50% down the line
	NH/MA/RI Coast–3 nm	None	1 weak insertion 50% down the line
	ME exempt area–3 nm, All areas 3–12 nm	None	2 weak insertions at 25% and 50% down line
	LMA 1, 2, OCC beyond 12 nm	None	1 weak insertion 35% down the line
	LMA 3	None	1 buoy line weak year-round to 75%

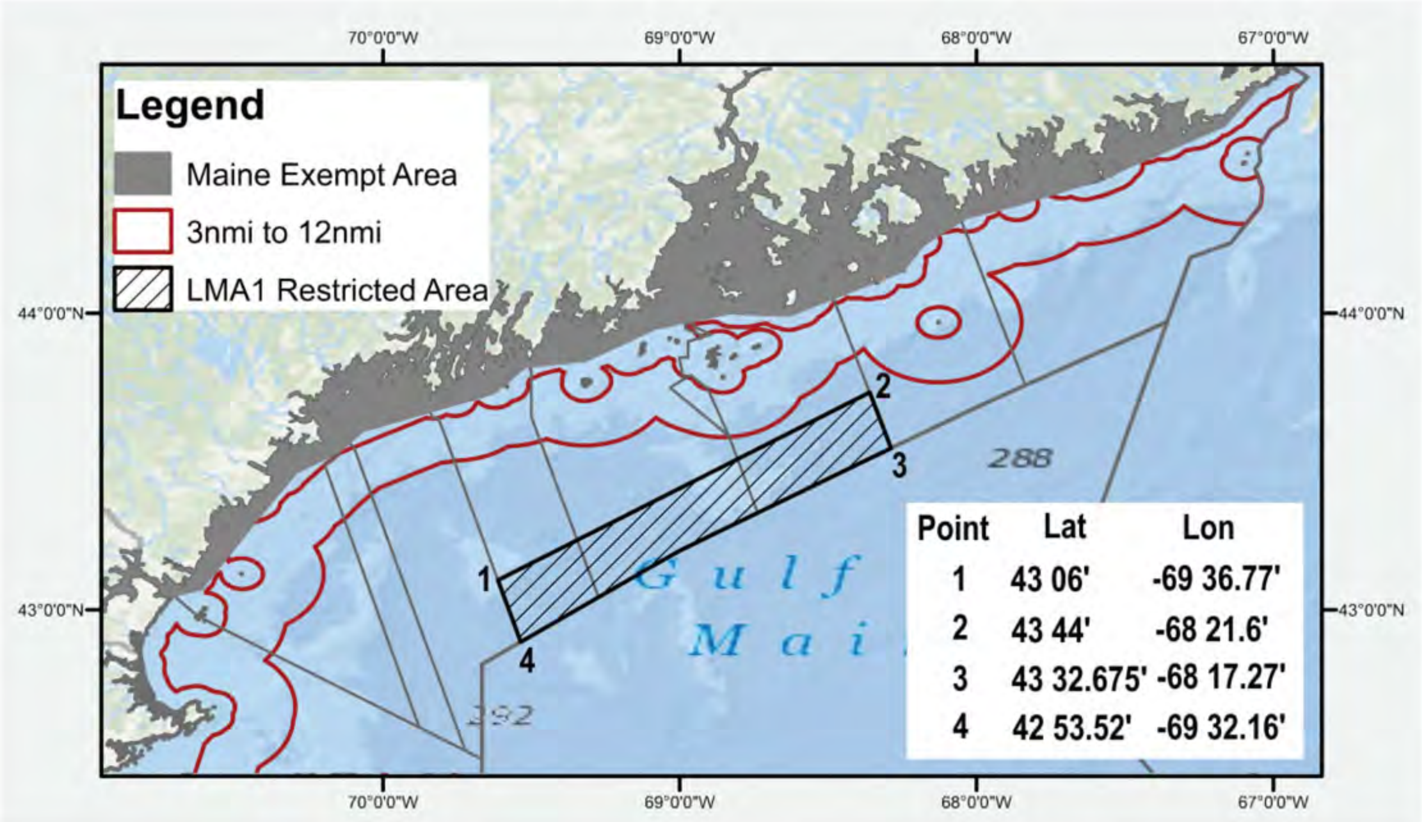
Blue shading indicates state regulations, including Maine gear marking, Massachusetts Restricted Area closure extension into May, and Massachusetts banning of single pots on vessels greater than 29 feet after permit transfers.

Restricted Areas

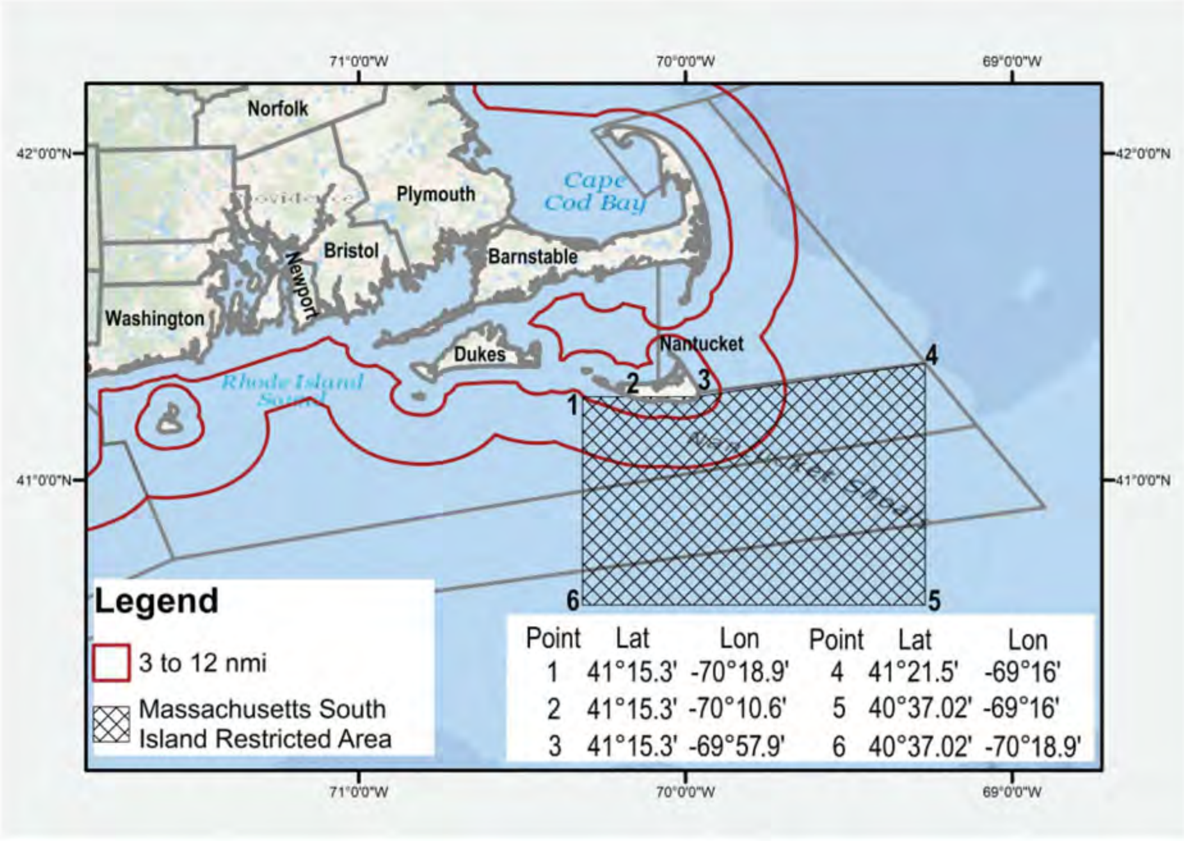


Area	Current Regulations	Proposed Regulations
All Restricted Areas	Closed to Fishing	Allow trap/pot fishing without buoy lines in existing and proposed restricted areas with an exempted fishing permit (EFP). EFP authorizations would likely include conditions to protect right whales (e.g. area restrictions, low vessel speed, observer monitoring, and reporting requirements.)
LMA1 Restricted Area	None	Restricted Oct-Jan Or 1-A no restriction Or 1-B restricted Oct-Jan based on future determinations
Massachusetts South Island Restricted Area	None	Restricted Feb-April
Massachusetts Restricted Area (MRA)	Closed Feb-April	Restricted Feb-April
	State waters closed through May until <3 whales remain (confirmed by surveys)	State waters closed through May until < than 3 whales remain (confirmed by surveys)
Great South Channel Restricted Area	Closed April-June	Restricted April-June

Restricted Areas - Detailed Maps



Point	Lat	Lon
1	43 06'	-69 36.77'
2	43 44'	-68 21.6'
3	43 32.675'	-68 17.27'
4	42 53.52'	-69 32.16'



Point	Lat	Lon	Point	Lat	Lon
1	41°15.3'	-70°18.9'	4	41°21.5'	-69°16'
2	41°15.3'	-70°10.6'	5	40°37.02'	-69°16'
3	41°15.3'	-69°57.9'	6	40°37.02'	-70°18.9'

Gear Marking

Federal Water Marks

Federal Waters

Area	Current	Proposed
Marks		
Entire Northeast Region	Three 12-inch marks, one at the top, middle, and bottom in the color below	One 3-foot long state-specific mark within two fathoms of the buoy (within the surface system) and three 12-inch marks at the top, middle and bottom of the buoy line (color below)
	No federal specific mark	6-inch green mark within the surface system within 12 inches of the 3-foot mark
Colors		
Maine	Red	Purple with 6-inch green mirroring state regulations effective 09/2020
New Hampshire	Red	Yellow with 6-inch green
Massachusetts	Red	Red with 6-inch green
Rhode Island	Red	Silver/Gray with 6-inch green
LMA 3	Black	Black with 6-inch green

State Water Marks

State Waters

Area	Current	Proposed
Marks		
Maine	None in TRP regs, state regulations as of 09/2020	One 3-foot long and one or two additional 1-foot marks (by depth) through state regulation
Massachusetts, Rhode Island, & New Hampshire	Three 12-inch marks, one at the top, middle, and bottom in the color below	One 3-foot long state-specific mark within two fathoms of the buoy (within the surface system) and two 12-inch marks in the top and bottom half of the buoy line in (color below)
Colors		
Maine	Purple (as of 09/2020)	Purple
New Hampshire	Red	Yellow
Massachusetts	Red & White (LMA1) Red & Black (LMA2) Red & Yellow (Outer Cape)	Red
Rhode Island	Red & Blue	Silver/Gray

Young Right Whale Likely Died from Entanglement

September 07, 2018

The whale most likely died as a result of being entangled in gear and drowning, according to the information scientists obtained from the necropsy.

The North Atlantic right whale carcass that was first reported floating off Marthaâ™s Vineyard on Monday, August 27, was necropsied on August 30 by IFAW. The whale most likely died as a result of being entangled in gear and drowning, according to the information scientists obtained from the necropsy.

The male right whale was approximately 9 meters (30 feet) in length, which would make the whale about a year and a half old, and likely was one of the five calves born over the 2016-2017 season.

IFAW's Brian Sharp and Dr. Sarah Sharp examine external wounds on the carcass. Credit: IFAW.

While this whale was moderately decomposed and parts of the carcass were missing, the necropsy team documented 11 lesions, including several linear depressions and bruises that are consistent with entanglement in line, particularly around the right flipper. There was also significant shark predation on the carcass, which appears to have happened post-mortem.

The team took samples from various tissues and organs for further analysis, including any signs of infection or disease. However, given the bruises on the body, the necropsy team concluded that this whale likely died as a result of entanglement. No gear was present on the whale.

Right Whales in Crisis

In 2017, NOAA confirmed 17 North Atlantic right whale deaths--about 4 percent of their population--an alarming number for an endangered species with a population estimated at about 450 animals. In 2018, there have been two confirmed right whale mortalities. There are currently only about 100 females of breeding age in the population and more females seem to be dying than males. Births have also been declining in recent years, and no new calves were spotted in the calving grounds off Florida this year.

In August 2017, NOAA Fisheries declared the increase in right whale mortalities an âœUnusual Mortality Event,â which helps the agency direct additional scientific and financial resources to investigating, understanding, and reducing the mortalities in partnership with the Marine

Mammal Stranding Network, Canadaâ™s Department of Fisheries and Oceans, and outside experts from the scientific research community.

Report a Stranded Marine Mammal

If you see a stranded marine mammal, please report it to our stranding hotline 866-755-NOAA (6622).

Questions?

Contact Jennifer Goebel, NOAA Fisheries, 978-281-9175 or Melanie Mahoney, IFAW, 508-815-7792.

Last updated by Greater Atlantic Regional Fisheries Office on September 07, 2018

Dead North Atlantic Right Whale Sighted off New Jersey

June 29, 2020

On June 25, 2020 we received a report of a floating North Atlantic right whale carcass off the coast of Elberon, New Jersey. We will update this web page as more information becomes available.

June 29, 2020 - Final Update

We are deeply saddened by the loss of the calf of North Atlantic Right whale #3560 and want to share the preliminary findings of yesterday's necropsy.

The male right whale calf had evidence of at least two separate vessel collisions. The whale had several propeller wounds across the head and chest, and a likely skeg or rudder injury on the back that may have occurred at the same time. Based on observed evidence of healing, those wounds were likely several weeks old, but were serious enough that they may have significantly impaired the whale. The second vessel collision resulted in a series of propeller wounds and a skeg or rudder wound across the tail stock. Evaluation of these wounds suggests they were inflicted shortly before the animal died and were likely the cause of death.

"Our hearts are broken by the news of the loss of this calf, which was the first calf observed this past season. The loss of every right whale is a detriment to this critically endangered species, but it is particularly hard when we lose a calf, given how few have been born in the last several years. The effort to secure this calf in order to determine the cause of death was herculean with many twists and turns," says Kim Damon-Randall, Deputy Regional Administrator for the Greater Atlantic Region. "We want to express our sincere appreciation to the many partners involved in this massive effort for your dedication and service towards the recovery of this critically endangered species. We are committed to continuing to work with our partners both in the United States and Canada to reduce threats to North Atlantic right whales in order to recover the species."

NOAA Fisheries is looking at the issue of vessel strikes from various perspectives. We recently completed an assessment of the right whale vessel speed rule and will soon be releasing a report detailing the conservation effectiveness, economic impacts, navigational safety, and compliance with the rule. We are also exploring new ways to use technology such as providing acoustic information to alert vessel operators that right whales are present in an area. The Whale Alert app currently provides real-time alerts to vessel operators about the presence of whales. We work with partners to support this tool and are working to expand communication to vessels.

An Unusual Mortality Event (UME) was declared for North Atlantic right whales in 2017 and is ongoing. Over the past three years, 31 whales in Canada and the U.S. have been documented dead and an additional 10 have been documented alive but with serious injuries (41 whales total). Most of the mortalities or injuries have been attributed to either vessel strikes or entanglements. Given there are only ~400 individual North Atlantic right whales remaining, those 41 individuals in the UME represent approximately 10% of the population, which is a significant negative impact on such a critically endangered species.

Thanks to our partners involved in this event, we were able to gather important information that will aid in determining the most effective measures needed to recover this species.

Agencies involved, in addition to NOAA Fisheries:

- National Park Service - For necropsy location and burial at Gateway National Recreation Area, Sandy Hook, New Jersey.
- Center for Coastal Studies - For aerial photos and assistance locating the whale after initial sighting.
- USCG Station Sandy Hook - For assistance towing carcass to Sandy Hook.
- USCG District 5 - For general operational support throughout the event.

USCG Sandy Hook and AMSEAS staff work together to tow calf to shore. Photo: Marine Mammal Stranding Center

- New England Aquarium (Anderson Cabot Center for Ocean Life) and Florida Fish and Wildlife Conservation Commission - For identifying the calf and providing background on the mother's life history.
- Atlantic Marine Conservation Society, Marine Mammal Stranding Center, International Fund for Animal Welfare, Virginia Aquarium - For coordinating and conducting the necropsy.
- Volunteers from University of Pennsylvania Veterinary School - For assistance with necropsy.
- Georgia Department of Natural Resources - For use of aerial photos of mother and calf obtained during initial sighting in December 2019.

June 28, 2020

Through a joint effort between the New England Aquarium and the Florida Fish and Wildlife Conservation Commission, the dead whale has been identified as the male calf of North Atlantic right whale #3560 (unnamed). He was the first of ten reported calves of the 2019/20 season. North Atlantic right whale #3560 and her calf were first spotted off the coast of Georgia in mid-December 2019, and were last sighted on April 6, 2020, off Cape Lookout, North Carolina. A necropsy has been completed and we hope to share preliminary results tomorrow (Monday, June 29).

The mom, #3560, was born in 2005, so is now 15 years old. She's been seen in all major right whale habitats over the years, from Canada to Florida, and frequented the Southeast, the only known calving area for this species, in the past but was not observed with a calf until this year. Sadly, this was her first calf. This is also the mother and calf pair that were documented in the Gulf of Mexico back in March. The status of the mom is unknown at this time.

"We were encouraged to learn of this right whale calf's birth last year, marking the first calf born of the season. The news of its death is distressing and yet another setback for an endangered species we are working tirelessly to protect," said Philip Hamilton, Research Scientist with the New England Aquarium who manages the North Atlantic Right Whale Catalog.

Another right whale calf was struck and seriously injured by a vessel earlier this year off the coast of Georgia. That mom and calf pair were last seen alive together on January 15, but the calf's current status is unknown.

NOAA urges everyone to please give these animals their space. Stay informed! Learn about recent right whale sightings through our Northeast Fisheries Science Center's Right Whale Sighting Advisory System. The law requires keeping a safe distance of at least 500 yards by sea and air (including drones) from North Atlantic right whales because of the dire status of the species. Get more information on how to safely view marine mammals in their habitats from our marine animal viewing guidelines.

If you see a sick, injured, stranded, or dead marine mammal please report it to your local stranding network. In New Jersey, please call (609) 266-0538.

June 27, 2020

With the assistance of the USCG, the whale has been towed to shore so that a full necropsy can be conducted starting this afternoon, and continued tomorrow morning. As we stated in yesterday's update, we have several partners in our northeast Marine Mammal Stranding Network assisting with the necropsy. We thank them for their continued support in this important effort.

Media contact: Allison Ferreira at 978-609-1604 or allison.ferreira@noaa.gov.

Dead right whale found floating off New Jersey on June 25 shows sign of a vessel collision. Photo: Center for Coastal Studies

June 26, 2020

Working closely with members of the stranding network, U.S. Coast Guard, and New York Department of Environmental Conservation to locate this right whale, we have confirmed that the carcass was floating off of Monmouth Beach, New Jersey as of 12:15 p.m.

We are now working on a plan to tow it to shore for a hands-on examination (necropsy).

Several partners in our northeast Marine Mammal Stranding Network are helping. Atlantic Marine Conservation Society, Marine Mammal Stranding Center, Virginia Aquarium, and International Fund for Animal Welfare are preparing to send biologists to assist with the necropsy, so we can learn more about this animal, its health, and possible cause of death.

Preliminary observations show a number of wounds along the head and body of the whale that are consistent with a vessel collision. It is too early to say whether this was the cause of death.

If you have information about this incident, please call the following number: (866) 755-6622 (select option "zero"). Any information will help us determine what happened to this whale, and contribute to our ongoing work to reduce threats to these endangered animals.

NOAA Fisheries uses multiple strategies to reduce the risks of collisions between ships and right whales. These include regulatory requirements, voluntary programs, and outreach. We require most vessels 65 feet or longer to transit at speeds of 10 knots or less in designated Seasonal Management Areas (SMAs) along the East Coast of the U.S. to reduce the risk of right whale vessel strikes. Since aggregations of right whales may also form outside of designated SMA boundaries, we established a voluntary Dynamic Management Area (DMA) program that encourages vessels greater than 65 feet in length either to avoid the area or to transit at speeds less than 10 knots.

June 25, 2020

This morning, we received a report of a deceased floating whale off the coast of Elberon, New Jersey. Based on the available photos, it has been confirmed to be a North Atlantic right whale.

The Marine Mammal Stranding Center (MMSC), Atlantic Marine Conservation Society, and NOAA are currently working with resources in the area to secure a necropsy location, and members of the stranding network are making plans to assist in this effort, so we can learn information about this animal.

The Center for Coastal Studies aerial survey team was flying on Long Island today and redirected their efforts. They were in the vicinity of the whale around 3 pm to document the animal, and confirmed that it was a right whale. MMSC is also headed out with U.S. Coast Guard to get additional photos from the water.

This is the first observed right whale death in U.S. waters in 2020. An unusual mortality event has been in effect for North Atlantic right whales since 2017, during which 31 whales (including this one) have been found dead in U.S. and Canadian waters, and an additional 10 live seriously injured whales have been documented, bringing the current total number of animals in the UME to 41.

The leading causes of death for this UME are entanglements or vessel strikes. Two of the 10 live whales reported as seriously injured in this UME were reported in 2020—one was a calf that had been struck by a vessel off the coast of Georgia, and the other was an adult female with an entanglement last seen off the coast of Massachusetts. Both of those individuals were last seen alive but their current status as of today is unknown.

North Atlantic right whales are endangered, with only about 400 remaining, of which only about 95 are breeding females.

We will share more information on this whale as we receive it.

NOAA Fisheries reminds the public to report sick, injured, stranded, or dead marine mammals to your local stranding network. In New Jersey, please call (609) 266-0538.

Insight

Understanding Marine Mammal Unusual Mortality Events

Scientists study and investigate unusual mortality events (UME) to understand the health of marine mammal populations. UMEs can serve as indicators of ocean health.

Read More

Last updated by Greater Atlantic Regional Fisheries Office on June 30, 2020

North Atlantic Right Whale Calf Injured by Vessel Strike

January 13, 2020

On January 8, the Florida Fish and Wildlife Conservation Commission spotted the fourth right whale calf of the season off Georgia, but the young whale was already injured.

A North Atlantic right whale calf was spotted off Georgia on January 8 with two roughly parallel and S-shaped injuries that experts say were consistent with the propeller of a vessel. The calf's mother is #2360, "Derecha," which means "right" in Spanish.

The injuries are concerning because of the severity and location of the wounds. One of the injuries appears to include damage to the calf's mouth which could hamper its ability to nurse and feed. Biologists estimate the newborn is just days old and the wounds were perhaps hours old.

Latest Updates

January 16

Team Administers Antibiotics to Injured North Atlantic Right Whale Calf

A team relocated Derecha and her injured right whale calf off Fernandina Beach, Florida yesterday afternoon. Biologists didn't want to get too close until verifying this was the mom/calf pair we were looking for. An aerial support crew soon provided confirmation and on-water assessment, giving the on-site veterinarian enough information to determine that antibiotics would benefit this whale. The team was able to remotely administer the drugs with the hopes of staving off infection. Now biologists will continue to monitor the calf during routine aerial surveys. The calf's prognosis remains poor.

Photos and video are allowing medical and whale experts a chance to examine changes in the wounds and assess the calf's overall behavior, condition, and health over time.


NOAA
HONDA

Photos: (Top) North Atlantic right whale mother, Derecha, swims with her injured calf. Credit: Florida Fish and Wildlife Commission. (Middle) The darting team prepares the antibiotic dart before administering it. Credit: NOAA Fisheries. (Bottom) Derecha and her calf at the water's surface. Credit: Florida Fish and Wildlife Commission. All photos taken under NOAA permit 18786-04.

This was a huge effort made possible by many experts from partner agencies all over the country including the field teams made up of FWC Fish and Wildlife Research Institute, the Wildlife Resources Division - Georgia DNR, Clearwater Marine Aquarium, SeaWorld, Blue World Research Institute and International Fund for Animal Welfare (IFAW) and external consultants from across the country that provided technical assessment of the injuries..

In the meantime we ask anyone with information regarding the calf's injuries and additional sightings to contact 1-877-WHALE-HELP (1-877-942-5343).

NOAA urges everyone to please give these animals their space. Mom/calf pairs spend the majority of their time at, or a few feet below the water's surface in the Southeast U.S. This is a critical and vulnerable time for right whale moms to bond with their calves - law requires staying away at least 500 yards by air (including drones) and by sea.

The protection of these animals is in the hands of all mariners on the water and all businesses that service those vessels. Stay educated, remain alert, and slow down while traveling through areas where right whales are found.

Administering the Drug

The video shows the injection from a close approach to the calf and the rapid recovery of the syringe.

A dose of antibiotic, a long acting cephalosporin that has been used in cetaceans (dolphins and whales), was administered to the calf intramuscularly using a ballistic syringe and needle to allow remote delivery via a Paxarms MK24C projector system.

An intramuscularly injection is a technique used to deliver a medication through the skin and blubber and into the muscles. This allows the medication to be absorbed into the bloodstream quickly.

The syringe holds 57 milliliters of antibiotic and is tethered for rapid post-injection recovery of the syringe and needle. The needle is 6 inches in length and has 3 side injection ports to ensure rapid (3 sec) delivery of the antibiotic. The mom and calf were assessed prior to delivery and were observed for some time after injection.

January 13

"Derecha's" injured right whale calf was last seen Friday afternoon by aerial survey and on-water teams with the Florida Fish and Wildlife Conservation Commission and the Georgia Department of Natural Resources. Medical experts and biologists spent the weekend reviewing images and video to continue assessments of the injury and prognosis and to determine potential next steps. Based on the images received, the calf's wounds are worse than originally thought - for example, some of the wounds are to the lip and may not be repairable, leading to impacts on feeding.

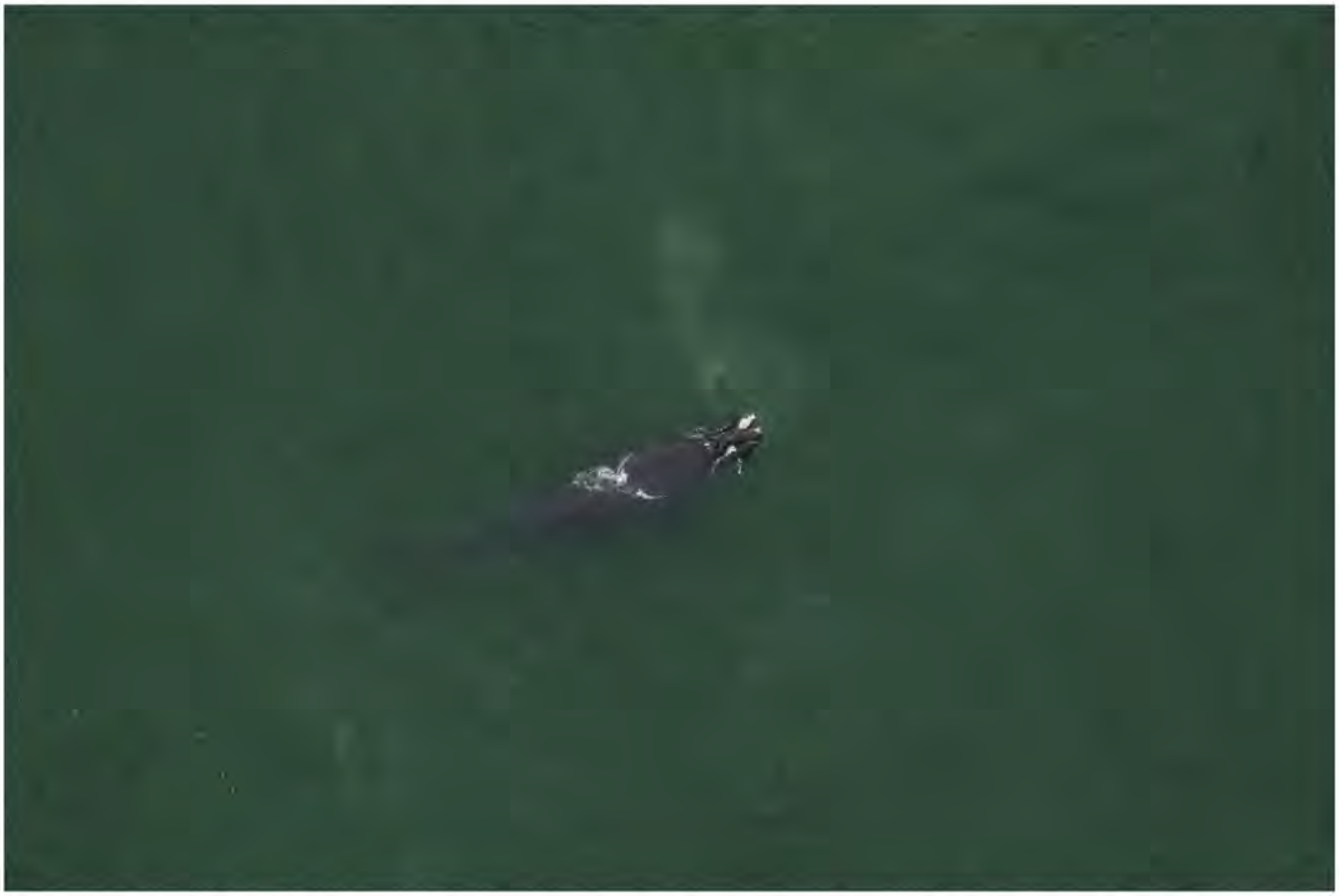
The calf's prognosis was downgraded from "guarded" to "poor". The current plan is to locate the mother and calf pair, obtain images in order to update our assessment of the calf's injuries, condition and behavior. Antibiotics may be delivered if warranted.

This is a huge effort made possible by many experts from partner agencies all over the country. The Florida Fish and Wildlife Conservation Commission, the Georgia Department of Natural Resources, Clearwater Marine Aquarium Research, SeaWorld, Blue World Research Institute, and IFAW.

In the meantime we ask anyone with information regarding the calf's injuries and additional sightings to contact 1-877-WHALE-HELP (1-877-942-5343).

NOAA urges everyone to please give these animals their space. Mom/calf pairs spend the majority of their time at, or a few feet below the water's surface in the Southeast U.S. This is a critical and vulnerable time for right whale moms to bond with their calves - law requires staying away at least 500 yards by air (including drones) and by sea.

The protection of these animals is literally in the hands of all mariners on the water and all businesses that service those vessels. Stay educated, remain alert, and slow down while traveling through areas where right whales are found.



Derecha's injured calf swims at the surface of the water with a visible injury on it's lip.

January 10

Biologists with Clearwater Marine Aquarium Research are heading out this morning in search of right whale mom "Derecha" and her injured newborn calf. Aerial and on-water survey teams from Georgia Department of Natural Resources and Clearwater Marine Aquarium Research were not able to find the pair yesterday. Biologists want to assess the calf's condition.

Mom and calf were first spotted Wednesday off the coast of Georgia by biologists with NOAA partner, the Florida Fish and Wildlife Conservation Commission. Experts say the calf's injuries were consistent with the propeller of a vessel. Biologists will continue to search; to get up and out as weather permits.

In the meantime we ask anyone with information regarding the calf's injuries and additional sightings to contact (877) WHALE-HELP (877-942-5343).

NOAA urges everyone to please give these animals their space. Mom/calf pairs spend the majority of their time at, or a few feet below, the water's surface in the Southeast U.S. This is a critical and vulnerable time for right whale moms to bond with their calves. Law requires staying away at least 500 yards by air (including drones) and by sea.

The protection of these animals is literally in the hands of all mariners on the water and all businesses that service those vessels. Stay educated, remain alert, and slow down while traveling through areas where right whales are found.

January 9

Teams with the Georgia Department of Natural Resources and Clearwater Marine Aquarium Research are out this morning (by air and sea) to try and find the mom/calf pair in order to assess the calf's condition.

NOAA is asking anyone with information regarding the calf's injuries and additional sightings to contact (877) WHALE-HELP (877-942-5343). The vessel that struck the animal may likely have propeller damage.

"Derecha" was first seen in December 1993. She is at least 27 years old. This is her fourth calf —she last gave birth in 2010.

Right whale mother, "Derecha" swimming with her injured calf.

Learn More About North Atlantic Right Whales

Facing a variety of man-made threats, North Atlantic right whales were listed under the Endangered Species Act in 1970. Once the right whale to hunt, these giants are now the right whales to save. Watch this video to learn more about endangered North Atlantic right whales:

North Atlantic right whales are one of the world's most endangered large whale species, with only about 450 remaining. NOAA has developed regulations for boaters and fishermen to help protect these whales from vessel collisions and entanglements. Learn more about regulations designed to protect right whales:

Insight

Understanding Vessel Strikes

Learn how NOAA Fisheries works to reduce the threat of vessel collisions with marine animals.

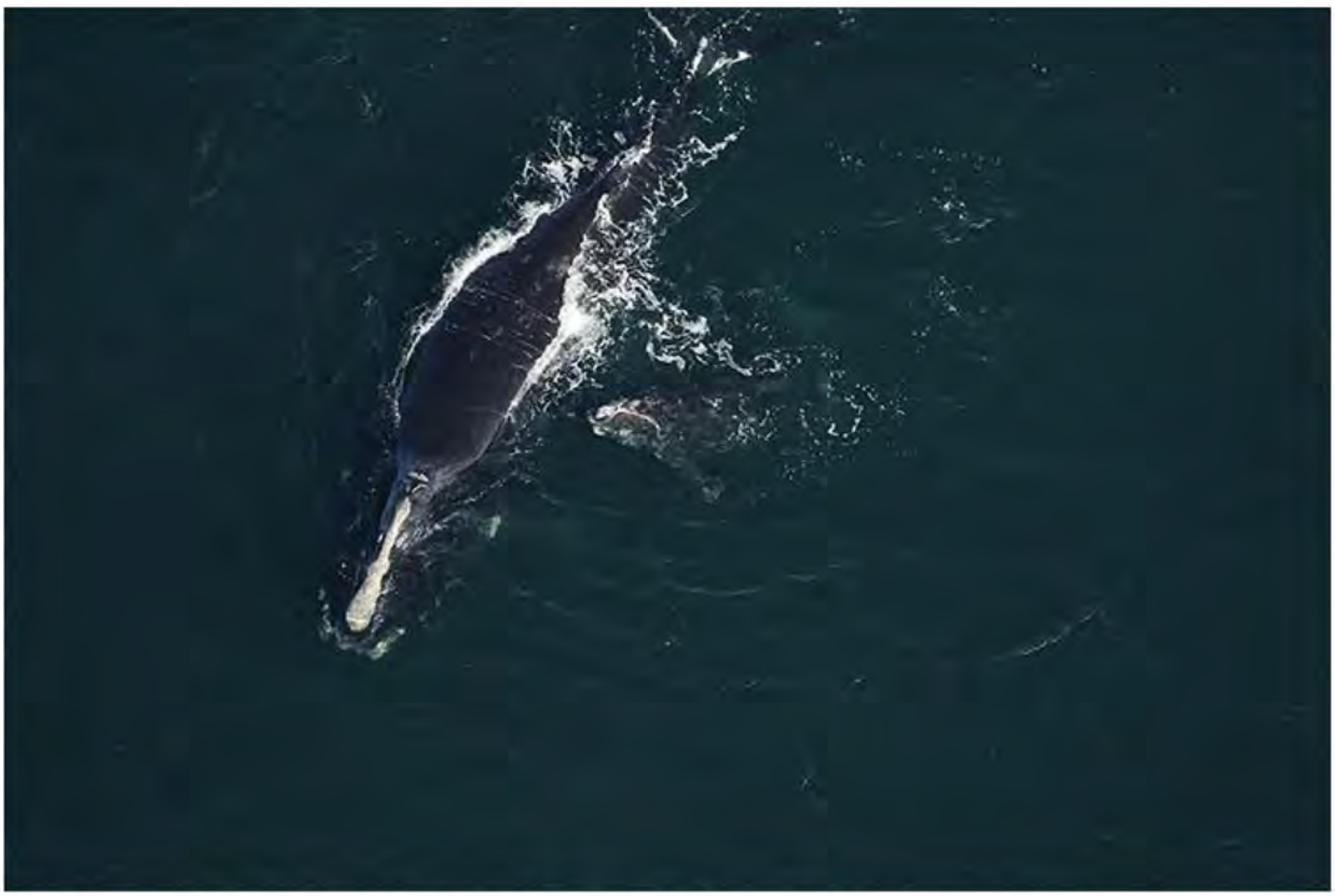
Read More

Last updated by Southeast Fisheries Science Center on February 21, 2020

North Atlantic Right Whale Calf Stranded Dead in Florida

February 14, 2021

On February 13, 2021, we received a report of a dead North Atlantic right whale off the coast of Florida. We will update this web page as more information becomes available.



North Atlantic right whale #3230 'Infinity' and calf when they were first sighted 16.5NM off Amelia Island, Florida on January 17, 2021. Catalog #3230 is 19 years old and this is her 1st calf. Credit: Florida Fish and Wildlife Conservation Commission, NOAA permit #20556-01

February 17, 2021

On February 16, 2021, the calf's mother "Infinity" (#3230) was found by a right whale aerial survey team alive but with new injuries. The Georgia Department of Natural Resources and Clearwater Marine Aquarium documented "Infinity" about 50 nautical miles north of St. Augustine Inlet, Florida, off the coast of Georgia. "Infinity" has two new cuts on her left side suggestive of a vessel strike.

February 14, 2021

A dead North Atlantic right whale calf was reported stranded on February 13, 2021, along the Florida coast. The animal is likely the calf of a 19-year old female named Infinity (#3230). The calf was first sighted on January 17, 2021, off Amelia Island, Florida. This is the first observed right whale death in U.S. waters in 2021. Regrettably, it is the second dead right whale calf of the 2020–2021calving season following the discovery of a dead calf in North Carolina in November 2020. NOAA's Office of Law Enforcement is investigating the incident.

In collaboration with our partners, we are organizing a necropsy (animal autopsy) of the calf to conduct a detailed evaluation of the cause of death, evaluate the calf's overall health prior to death, and generally learn more about this animal. We are working with our Marine Mammal Stranding Network partners, including:

- Florida Fish and Wildlife Conservation Commission
- Harbor Branch Oceanographic Institute
- Hubbs SeaWorld Research Institute
- University of Florida

The Ongoing Unusual Mortality Event

An Unusual Mortality Event (UME) has been ongoing for North Atlantic right whales since 2017. Since the UME was established, 33 whales (including this one) have been found dead in U.S. and Canadian waters. An additional 14 live seriously injured whales have been documented, bringing the current total number of animals in the UME to 47. The primary causes of the Unusual Mortality Event are entanglements or vessel strikes. North Atlantic right whales are a critically endangered species with fewer than 400 individuals estimated remaining. The 47 whales documented so far in the UME represent more than 10 percent of the population. This is a significant setback to the species' recovery.

Help Us Help Whales

The protection of these animals is in the hands of all mariners on the water. **Slow down and remain alert** while traveling through areas where right whales are found. It is difficult to see right whales, especially in poor light or weather conditions, so slowing down is the best prevention to avoid collisions. Allow plenty of time to slowly return to port—don't wait until you're racing to return before the sun goes down.

NOAA urges vessels of all sizes to please **slow down** and give these animals space. Mom-calf pairs spend the majority of their time at, or a few feet below, the water's surface in the Southeast United States. They can be surprisingly difficult to see, especially in poor light or weather conditions. The calving season is a critical and vulnerable time for right whale mothers as they nurse their young calves. Federal law requires everyone to stay at least 500 yards away from right whales by sea and by air (including drones).

We ask anyone with information on this event or if they see a dead or injured whale off Georgia or Florida, radio the U.S. Coast Guard via VHF Channel 16, or call (877) WHALE-HELP (1-877-942-5345).

Learn more about North Atlantic right whales

Species in the Spotlight: North Atlantic Right Whale

Facing a variety of threats from human activities, North Atlantic right whales were listed under the Endangered Species Act in 1970. Once the *right* whale to hunt, these giants are now the right whales to save.

With fewer than 400 individuals remaining, North Atlantic right whales are one of the world's most endangered large whale species. NOAA Fisheries has developed regulations to help protect these whales from vessel collisions and entanglements.

Regulations designed to protect right whales

Learn more about the North Atlantic right whale, a NOAA Fisheries Species in the Spotlight

Last updated by Southeast Regional Office on February 17, 2021

Laws & Policies: Marine Mammal Protection Act

Magnuson-Stevens Act
Endangered Species Act
Marine Mammal Protection Act
National Environmental Policy Act
More Laws
Policies

Magnuson-Stevens Act

The Magnuson–Stevens Fishery Conservation and Management Act (MSA) is the primary law that governs marine fisheries management in U.S. federal waters. First passed in 1976, the MSA fosters the long-term biological and economic sustainability of marine fisheries. Its objectives include:

- Preventing overfishing.
- Rebuilding overfished stocks.
- Increasing long-term economic and social benefits.
- Ensuring a safe and sustainable supply of seafood.

Under the MSA, U.S. fisheries management is a transparent and public process of science, management, innovation, and collaboration with the fishing industry.

Magnuson–Stevens Fishery Conservation and Management Act ›

U.S. Senators Ted Stevens (R-AK) and Warren Magnuson (D-WA), 1973. Photo credit: Ted Stevens Foundation.

History of the MSA

Prior to 1976, international waters began at just 12 miles from shore and were fished by unregulated foreign fleets. The MSA extended U.S. jurisdiction to 200 nautical miles and established eight regional fishery management councils with representation from the coastal states and fishery stakeholders. The councils develop fishery management plans that comply with the MSA's conservation and management requirements, including 10 national standards to promote sustainable fisheries management.

Congress has made two significant revisions to the MSA: first in 1996 with the passage of the Sustainable Fisheries Act, and in 2007 with the MSA Reauthorization Act.

Sustainable Fisheries Act:

- Strengthened requirements to prevent overfishing and rebuild overfished fisheries.
- Set standards for fishery management plans to specify objective and measurable criteria for determining stock status.
- Added three new national standards to address fishing vessel safety, fishing communities, and bycatch.
- Introduced fish habitat as a key component in fisheries management.

MSA Reauthorization Act:

- Established annual catch limits and accountability measures.
- Promoted market-based management strategies, including limited access privilege programs, such as catch shares.

- Strengthened the role of science through peer review, the scientific and statistical committees, and the Marine Recreational Information Program.
- Enhanced international cooperation by addressing illegal, unregulated, and unreported fishing and bycatch.

Under the MSA, we are ending overfishing and rebuilding stocks, which strengthens the value of fisheries to our economy and marine ecosystems.

Additional ongoing MSA reauthorization activities ❯

International Provisions of the Magnuson–Stevens Reauthorization Act:

The Magnuson–Stevens Fishery Conservation and Management Reauthorization Act of 2006, which amended the High Seas Driftnet Fishing Moratorium Protection Act, directs the United States to strengthen international fisheries management organizations and to address illegal, unreported, and unregulated fishing and bycatch of protected living marine resources. The Moratorium Protection Act was further amended in 2011 by the Shark Conservation Act to improve the conservation of sharks domestically and internationally.

The Moratorium Protection Act requires NOAA Fisheries to produce a biennial Report to Congress that lists nations the United States has identified for IUU fishing and/or bycatch of protected species and shark catches on the high seas for nations that do not have regulatory measures comparable to the United States.

Once a nation is identified, we enter a 2-year consultation process to encourage that nation to take necessary measures to address the issue for which it was identified. Following these consultations, NOAA Fisheries determines whether to negatively or positively certify the identified nation in the next Report to Congress.

NOAA Reports to Congress ›

A positive certification is issued if the nation has provided evidence of actions that address the activities for which it was identified. A negative certification may result in denial of U.S. port access for fishing vessels of that nation, and potential import restrictions on fish or fish products.

International provisions of the MSA reauthorization ›

Modernizing Recreational Fisheries Management Act

On December 31, 2018, the Magnuson–Stevens Act was amended by the Modernizing Recreational Fisheries Management Act. The Modern Fish Act focuses on improvements to recreational fishing data and management of mixed-use fisheries. The law includes requirements for new reports, studies, and guidance related to fisheries management and science.

Endangered Species Act

Congress passed the Endangered Species Act in 1973, recognizing that the natural heritage of the United States was of "esthetic, ecological, educational, recreational, and scientific value to our nation and its people." It was understood that, without protection, many of our nation's native plants and animals would become extinct.

Under the ESA, the federal government has the responsibility to protect:

- **Endangered species—**species that are in danger of extinction throughout all or a significant portion of their range.
- **Threatened species—**species that are likely to become endangered in the foreseeable future.
- **Critical habitat—**specific areas that are:
    - Within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection.
    - Outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation.

NOAA Fisheries and the U.S. Fish and Wildlife Service share responsibility for implementing the ESA. NOAA Fisheries is responsible for endangered and threatened marine and anadromous species—from whales and seals to sharks, salmon, and corals. The U.S. FWS is responsible for most terrestrial and freshwater species but also has responsibility over several marine mammal species like walrus, sea otters, manatees, and polar bears. We share jurisdiction over several other species such as sea turtles and Atlantic salmon.

"Nothing is more priceless and more worthy of preservation than the rich array of animal life with which our country has been blessed."

– *President Nixon, upon signing the Endangered Species Act*

We manage a number of endangered and threatened marine species. Under the ESA, species are listed as endangered or threatened regardless of where they are found.

If a species occurs only in areas beyond the U.S. exclusive economic zone and territorial waters, we refer to it as a "foreign species" in our counts of ESA-listed species (see the list of foreign species).

Learn more about terms related to the ESA ›

Protection, Conservation, and Recovery of Listed Species

The listing of a species as endangered makes it illegal for any person under U.S. jurisdiction to "take" that species—meaning harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to do any of these things. It is also illegal to import, export, or transport and sell endangered species in interstate or foreign commerce. Similar prohibitions may extend to species listed as threatened under the ESA.

NOAA Fisheries also does the following management actions for species listed under the ESA:

- Designates critical habitat for the conservation of the species (under section 4 of the ESA).
- Monitors and evaluates species status (under section 4 of the ESA).
- Develops and implements recovery plans for listed species (under section 4 of the ESA).
- Consults on federal actions that may affect a listed species, or its designated critical habitat, to minimize possible adverse effects (under section 7 of the ESA).
- Provides grants to states (under section 6 of the ESA) and grants to tribes for species conservation.
- Enters into bilateral and multilateral agreements with other nations to encourage conservation of listed species (under section 8 of the ESA).
- Investigates violations of the ESA (under section 9 of the ESA).

- Cooperates with non-federal partners to develop conservation plans, safe harbor agreements, and candidate conservation agreements with assurances for the long-term conservation of species (under section 10 of the ESA).
- Authorizes research to learn more about protected species (under section 10 of the ESA).
- Designates experimental populations of listed species to further the conservation and recovery of those species (under section 10 of the ESA).

The primary purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. To determine if an endangered or threatened species has recovered, we review the best available data about the species. We evaluate that data and progress towards meeting the species recovery criteria to determine whether the species still meets the definition of a threatened or endangered species.

Some factors that managers might consider when determining if a species is eligible for downlisting (e.g., from endangered to threatened) or delisting (e.g., removal from the list) are population increases, conservation efforts, regulatory mechanisms to conserve a species and its habitat, and reduction of threats. Once a species is determined to be recovered, it can then be removed from the list of endangered and threatened species.

Read the full text of the ESA ❯

Success Stories

The ESA has been successful in preventing species extinctions—less than 1 percent of the species listed under the ESA have gone extinct. While we have recovered and delisted a small percentage of listed species since 1973, we would likely have seen hundreds of species go extinct without the ESA.

Learn more about some of our success stories ›

Regulations, Policies, and Guidance

We have issued regulations, national policies, and guidance to promote efficiency and consistency in implementing the ESA to conserve and recover listed marine species.

Learn more about ESA regulations, policies, and guidance ›

Marine Mammal Protection Act

Congress passed the Marine Mammal Protection Act in 1972 in response to increasing concerns among scientists and the public that significant declines in some species of marine mammals were caused by human activities. The MMPA established a national policy to prevent marine mammal species and population stocks from declining beyond the point where they ceased to be significant functioning elements of the ecosystems of which they are a part. This was the first legislation to mandate an ecosystem-based approach to marine resource management.

Three federal entities share responsibility for implementing the MMPA:

- **NOAA Fisheries -** responsible for the protection of whales, dolphins, porpoises, seals, and sea lions.
- **U.S. Fish and Wildlife Service -** responsible for the protection of walrus, manatees, sea otters, and polar bears.
- **Marine Mammal Commission -** provides independent, science-based oversight of domestic and international policies and actions of federal agencies addressing human impacts on marine mammals and their ecosystems.

The Animal and Plant Health Inspection Service, a part of the Department of Agriculture, is responsible for regulations managing marine mammals at public display facilities (i.e., aquaria and zoos) under the Animal Welfare Act.

All marine mammals are protected under the MMPA. Some are also protected under the Endangered Species Act and the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Learn More: Glossary of Terms Used in the Marine Mammal Protection Act ›

Innovative Legislation

The MMPA was an innovative piece of legislation for the early 1970s. In addition to shifting the focus of conservation from species to ecosystems, the MMPA contains other features never before established in legislation. The MMPA:

- Included protection for population stocks in addition to species and subspecies—a population stock is a group of marine mammals of the same species or smaller taxa in a common spatial arrangement that interbreed when mature.
- Shifted the burden from resource managers to resource users to show that proposed taking of marine mammals would not adversely affect the resource or the ecosystem—"take" as defined in the MMPA means to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.
- Established the concept of "optimum sustainable populations" to ensure healthy ecosystems. Prior to the MMPA, the management of marine species was aimed at producing a "maximum sustainable yield" to ensure the species replenished itself for an adequate harvest in subsequent years.
- Directed federal agencies to seek changes in international agreements, such as the Convention for the Regulation of Whaling and the North Pacific Fur Seal Convention, so they corresponded to the protections outlined in the act.

Amendments of 1992

The MMPA was amended in 1992 to include Title IV, the Marine Mammal Health and Stranding Response Program, which mandates emergency responses to marine mammals in distress, monitoring health and health trends in marine mammal populations, and investigating marine mammal unusual mortality events. Title IV was subsequently amended in 2000 to include the John H. Prescott Marine Mammal Rescue Assistance Grant Program, which provides grants or cooperative agreements to eligible stranding network participants for: (1) recovery and treatment (i.e., rehabilitation) of stranded marine mammals; (2) data collection from living or dead stranded marine mammals, and (3) facility upgrades, operation costs, and staffing needs directly related to the recovery and treatment of stranded marine mammals and the collection of data from living or dead stranded marine mammals.

Amendments of 1994

The MMPA was substantially amended in 1994 to provide:

- A statutory definition of the term "harassment" which is a prohibited activity and means: "any act of pursuit, torment, or annoyance, which -- has the potential to injure a marine mammal or marine mammal stock in the wild (Level A harassment); or has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (Level B harassment)."
- Certain exceptions to the moratorium on take, including for takes of small numbers of marine mammals incidental to specified activities, when access by Alaska Natives to marine mammal subsistence resources can be preserved, and the general authorization for scientific research.
- A program to authorize and reduce the taking of marine mammals incidental to commercial fishing operations. Learn more about the Marine Mammal Authorization Program.
- A requirement to prepare stock assessments for all marine mammal stocks in waters under U.S. jurisdiction. Learn more about stock assessment reports.
- Studies of interactions between pinnipeds (seals and sea lions) and fisheries.

Protection, Conservation, and Recovery of Marine Mammals

To protect all marine mammals, the MMPA prohibits the "taking" of any marine mammal species in U.S. waters where "take" means to hunt, harass, capture, or kill any marine mammal or attempting to do so. It also prohibits the import and export of marine mammals and their parts or products.

Exceptions to these prohibitions include:

- Permitted incidental take (e.g., unintentional take) by commercial fisheries managed through the Marine Mammal Authorization Program.
- Authorized incidental take that may occur during non-fishing activities including oil and gas development, military readiness activities, renewable energy projects, construction projects, and research.
- Permitted directed take and import for scientific research, enhancement, commercial or educational photography, and public display.
- Permitted import, export, and receipt of parts for scientific research.
- Pre-act determinations for marine mammal parts taken before December 21, 1972.
- Take by Alaska natives for subsistence use or to create and sell authentic articles of handicrafts and clothing.

In addition to managing the taking of marine mammals, NOAA Fisheries also performs the following conservation and management actions:

- Develops and implements conservation plans for species designated as depleted.
- Develops and implements take reduction plans to minimize dead and seriously injured marine mammals in commercial fishing gear.
- Coordinates the National Marine Mammal Stranding Network to support the mandates of the Marine Mammal Health and Stranding Response Program.
- Partner with other nations to ensure that international trade does not threaten species.
- Investigates and prosecutes violations of the MMPA.

Read the full text of the MMPA

Co-Management with Alaska Native Organizations

Co-management involves collaboration between the federal government and Alaska Native Organizations to conserve marine mammal populations in Alaska.

Co-management efforts have integrated the field skills and traditional/indigenous knowledge of Alaska Native hunters with the scientific and technological expertise of agency scientists to enhance understanding of marine mammals including their stock structure, status, trends, movement and habitat-use patterns, responses to climate change, animal health and condition, contaminants, and disease. Sampling of Native-harvested animals for scientific purposes (e.g., biosampling) has provided tissues for a variety of studies. Education and outreach efforts have trained hunters in good hunting practices and biosampling and familiarized Alaska Native youth with cultural and subsistence traditions. Such efforts contribute significantly to marine mammal conservation and the maintenance of subsistence cultures.

Indigenous People's Council for Marine Mammals

Find Memoranda of Agreement between NOAA Fisheries, the U.S. Fish and Wildlife Service, the Geological Survey, and the Indigenous People's Council for Marine Mammals that provide direction for developing MMPA Section 119 agreements to promote the sustained health of marine mammal species:

- 2006 Agreement (PDF, 9 pages)
- 1997 Agreement (PDF, 23 pages)

Learn more about the co-management of marine mammals in Alaska

Regulations, Policies, and Guidance

We have issued regulations, national policies, and guidance to promote efficiency and consistency in implementing the MMPA to conserve and recover marine mammal species.

Find MMPA policies and guidance ›

National Environmental Policy Act

The National Environmental Policy Act, enacted in 1969, requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their major proposed actions. Its primary goal is to foster better decision making that takes into account all of the environmental impacts of an action and involves the public in that decision making.

The range of actions covered by NEPA is broad and includes:

- Making decisions on permit applications.
- Adopting federal land management actions.
- Constructing highways and other publicly-owned facilities.

When NOAA Fisheries undertakes a federal action, the first thing we have to do is decide if the action is subject to NEPA environmental review. A federal action is an activity, such as a plan, project or program, which may be funded, regulated, conducted, or approved by a federal agency. If the action is subject to NEPA review, then we must document the environmental impacts at one of three levels of NEPA analysis:

- By preparing a brief memorandum to the administrative record documenting that the activity qualifies for a categorical exclusion.
- By preparing a concise environmental assessment, and if appropriate, a finding of no significant impact.
- By preparing a detailed environmental impact statement.

We also provide information for use in NEPA documents prepared by other federal agencies. When another federal agency comes to us to obtain a permit or authorization, we review and provide comments on these documents. Once they are complete, we can adopt them as our own analysis for our permitting or authorization action. Through this process, we seek to ensure that impacts to marine wildlife resources are adequately described and that needed mitigation is provided.

We are responsible for implementing and enforcing more than 40 laws and policies to protect living marine resources. These include laws to deal with illegal, unreported, and unregulated fishing;

illegally trading fish and wildlife; and even the National Marine Sanctuaries Act, which designates and protects areas of the marine environment with special national significance.

More Laws

American Fisheries Act

Signed into law in 1998, the purpose of the act was to tighten U.S. ownership standards that had been exploited under the Anti-Reflagging Act, and to provide the Bering Sea and Aleutian Islands pollock fleet the opportunity to conduct their fishery in a more rational manner while protecting non-AFA participants in other fisheries. The AFA established sector allocations in the BSAI pollock fishery, determined eligible vessels and processors, allowed the formation of cooperatives, set limits on the participation of AFA vessels in other fisheries, and imposed special catch weighing and monitoring requirements on AFA vessels.

Learn more about the AFA and pollock fisheries management ›

Read the AFA as signed in 1998 ›

Read AFA amendments in the Coast Guard Authorization Act of 2010 ›

Read the AFA, current, statutory note to MSA, 16 USC 1851, "Bering Sea Pollock Fishery" ›

Animal Welfare Act

The Animal Welfare Act ensures humane care and treatment for certain animals that are exhibited to the public, bred for commercial sale, used in medical research, or transported commercially. Marine mammals on public display at aquariums fall under this act.

Facilities using regulated animals for regulated purposes must provide their animals with adequate housing, sanitation, nutrition, water and veterinary care, and they must protect their animals from extreme weather and temperatures. U.S. Department of Agriculture Animal Care is the unit within the Animal and Plant Health Inspection Service that upholds and enforces the act.

Learn more about the Animal Welfare Act ›

Antarctic Marine Living Resources Convention Act

The Antarctic Marine Living Resources Convention Act of 1984 provides the legislative authority to establish the U.S. AMLR Program, implementing the United States’ strategic goal of managing Southern Ocean resources using an ecosystem approach.

The program (working with the U.S. Department of State) supports U.S. participation in the Commission and Scientific Committee for the Conservation of Antarctic Marine Living Resources, and conducts directed research toward achieving the conservation objectives of the Convention.

Learn more about our Antarctic research ›

Atlantic Tunas Convention Act

The Atlantic Tunas Convention Act of 1975 authorizes the Secretary of Commerce to administer and enforce all provisions of the International Convention for the Conservation of Atlantic Tunas to which the United States is a party. ICCAT conducts stock assessments on species of Atlantic tunas, swordfish, and billfish. Based on these stock assessments, member nations negotiate quotas and other management recommendations for these species. Ideally, the management recommendations rebuild overfished stocks and allow for sustainable fishing of these species across the Atlantic Ocean, including the Mediterranean Sea, the Caribbean Sea, and the Gulf of Mexico.

Learn more about the Atlantic Tunas Convention Act ›

Aquaculture Act

The National Aquaculture Act of 1980 is a U.S. federal law that is intended to promote and support the development of aquaculture. The act aims to encourage development of aquaculture in the United States because aquaculture has the potential to reduce the U.S. trade deficit in fisheries products, augment existing commercial and recreational fisheries, and produce other renewable resources.

Learn more about the National Aquaculture Act ›

Billfish Conservation Act

In passing the Billfish Conservation Act, Congress recognized the conservation challenges facing billfish populations in the Atlantic and Pacific Oceans. Section 4(a) of the act prohibits any person from offering billfish or billfish products for sale, selling them, or having custody, control, or possession of them for purposes of offering them for sale.

Learn more about our role in the Billfish Conservation Act ›

Coastal Zone Management Act

The Coastal Zone Management Act provides for the preservation, protection, development, restoration, and enhancement of our nation's coastal zone resources for current and future generations. Under the act, there is a state-federal consistency provision that requires federal actions undertaken by federal agencies be consistent with enforceable policies of approved state management plans.

Learn more about the Coastal Zone Management Act ›

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act requires that all federal agencies consult with NOAA Fisheries, U.S. Fish and Wildlife Service, and state wildlife agencies when proposed actions might result in modification of a natural stream or body of water. Federal agencies must consider effects that these projects would have on fish and wildlife development and provide for improvement of these resources.

Under this act, we provide comments to the U.S. Army Corps of Engineers during review of projects under section 404 of the Clean Water Act (concerning the discharge of dredged materials into navigable waters) and section 10 of the Rivers and Harbors Act of 1899 (obstructions in navigable waterways). Our comments aim to reduce environmental impacts to migratory, estuarine, and marine fisheries and their habitats.

Learn more about the Fish and Wildlife Coordination Act ›

Fur Seal Act

The Fur Seal Act prohibits the taking of North Pacific fur seals, except by Alaska natives for subsistence purposes or by permit from NOAA Fisheries.

Learn more about fur seal laws and treaties ›

High Seas Fishing Compliance Act

The High Seas Fishing Compliance Act requires that all commercial fishing vessels registered in the United States have a permit to fish on the high seas. The high seas are those waters extending beyond the exclusive economic zone, or seaward of 200 miles. Those holding this permit must comply with international living marine resource agreements, including any measure implementing such agreements. Permit holders are required to record all fishing efforts on the high seas.

Learn more about permitting, reporting, and requirements for vessel monitoring systems and fishery observers ›

Illegal, Unreported, and Unregulated Fishing Enforcement Act

The Illegal, Unreported, and Unregulated Fishing Enforcement Act was passed in 2015 to combat IUU fishing and seafood fraud internationally. IUU fishing undermines both the economic and environmental sustainability of our nation's fisheries. Combating IUU fishing and seafood fraud is critical to sustaining the resilience of our global ocean fisheries, to leveling the playing field for the U.S. fishing and seafood industries, and to protecting the United States' reputation as a leader in sustainable seafood.

The legislation includes several provisions designed to prevent illegally harvested fish from entering the United States and supports efforts to achieve sustainable fisheries around the world, including the Port State Measures Agreement. This agreement aims to prevent vessels carrying fish caught illegally from entering U.S. ports and keeping illegal product out of our markets.

Together, the IUU Fishing Enforcement Act and the Port State Measures Agreement protect domestic fishermen from unfair competition and ensure consumer confidence in the seafood supply chain.

Learn more about U.S. efforts to combat IUU Fishing

Lacey Act

The Lacey Act, passed in 1900 as the first federal law protecting wildlife, was originally created to protect game and wild birds by making it a federal crime to poach game in one state with the purpose of selling the animal in another state. Today, the act reinforces other federal, state, and foreign wildlife protection laws by making it an offense to take, possess, transport, or sell wildlife that has been taken in violation of any law. The act also prohibits the falsification of documents for most shipments of wildlife (a criminal penalty) and makes the failure to properly mark wildlife shipments an offense (civil penalty).

The Lacey Act has been amended several times since its inception in 1900. The most significant amendments were those of 1969, 1981, and 1988. Among other changes, the 1969 amendments expanded the act to include amphibians, reptiles, mollusks, and crustaceans. As it relates to NOAA Fisheries, the 1981 amendments expanded the scope of the act in response to an increase in the illegal trade of fish and wildlife, both domestically and internationally. Additionally, new language was adapted, and the penalties for civil and criminal violations were increased.

The Lacey Act is considered one of the broadest and most comprehensive federal laws that conservation enforcement personnel can employ to protect wildlife.

Learn more about the Lacey Act

Migratory Bird Treaty Act

The Migratory Bird Treaty Act makes it illegal to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts (feathers), nests, or eggs of such a bird except under the terms of a valid federal permit. The U.S. Fish and Wildlife Service issues permits for otherwise prohibited activities under the act.

Learn more about the act and the birds that are protected

National Invasive Species Act

The National Invasive Species Act is a U.S. federal law intended to prevent invasive species from entering inland waters through ballast water carried by ships. This act reauthorized and amended a previous measure, the Non-Indigenous Aquatic Nuisance Prevention and Control Act of 1990.

Learn more about invasive and exotic marine species

National Marine Sanctuaries Act

The primary objective of the National Marine Sanctuaries Act is to protect marine resources, such as coral reefs, sunken historical vessels, or unique habitats. The act authorizes the U.S. Secretary of Commerce to designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational or esthetic qualities as national marine sanctuaries.

The National Marine Sanctuary System includes 13 national marine sanctuaries and five marine national monuments. NOAA's Office of Law Enforcement is responsible for the compliance with and enforcement of sanctuary regulations.

Learn more the National Marine Sanctuary System

Northern Pacific Halibut Act

The Northern Pacific Halibut Act is the implementing legislation for the Convention between the United States and Canada for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and Bering Sea. The act was created to conserve, manage, and rebuild the halibut stocks in the Convention Area to those levels that would achieve and maintain the maximum sustainable yield from the fishery.

It authorizes the U.S. Secretary of State, with the concurrence of the U.S. Secretary of Commerce, to accept or reject on behalf of the United States the halibut fishery regulations and management recommendations developed by the International Pacific Halibut Commission. The act also authorizes the North Pacific Fishery Management Council and the Pacific Fishery Management Council to develop, and the U.S. Secretary of Commerce to implement, additional halibut fishery regulations governing the U.S. portion of Convention waters.

Learn more about the Northern Pacific Halibut Act

Oil Pollution Act of 1990

In response to the Exxon Valdez oil spill, the U.S. Congress passed the Oil Pollution Act of 1990. The act amended the Clean Water Act and addresses issues associated with preventing, responding to, and paying for oil pollution. Responsible parties are made accountable for the clean up costs. Parties that spill/discharge oil into the environment must also respond to impacted wildlife. In addition, responsible parties are required to have an Oil Spill Response Plan developed in consultation with NOAA Fisheries and the U.S. Fish and Wildlife Service.

Learn more about the Oil Pollution Act

Shark Conservation Act

The Shark Conservation Act allows for sustainably managed shark fisheries while eliminating the harmful practice of finning—a process of removing shark fins at sea and discarding the rest of the shark. The act requires that all sharks in the United States, with one exception, be brought to shore with their fins naturally attached.

Learn more about our role in the Shark Conservation Act

Whaling Convention Act

The Whaling Convention Act implements the United States' obligations under the International Convention for the Regulation of Whaling, which provides for the conservation of whale stocks and the management of whaling. Among other things, the act prohibits whaling in violation of the Convention. And under the act, we co-manage subsistence whale hunts regulated by the International Whaling Commission.

Learn more about co-management of subsistence hunts with Alaska Natives

Learn more about NOAA Fisheries and the International Whaling Commission

Policies

There are several policies that determine how we manage and study living marine resources. Policies are statements of and instructions for implementing high-level direction and positions that guide organizational decisions and actions. These written policies promote accountability and consistency in management and science practices. They also demonstrate our commitment to implementing identified priorities.

Aquaculture Policy

In the United States, marine aquaculture operates within one of the most comprehensive regulatory environments in the world. We play a central role in developing and implementing marine aquaculture policies. We work to ensure that aquaculture complies with existing federal laws and regulations that we enforce under our marine stewardship mission.

Projects that are sited in U.S. waters must meet a suite of federal, state, and local regulations. These regulations ensure environmental protection, water quality, food safety, and protection of public health. Science and adaptive management inform NOAA policy, regulatory, and management decisions regarding aquaculture in marine waters.

We are working with federal, state, and tribal partners on a variety of initiatives. These initiatives stem from the 2011 aquaculture policies, the recent National Ocean Policy Implementation Plan and its mandates under the Magnuson-Stevens Act, and the National Aquaculture Act.

Learn more about our Marine Aquaculture Policy ›

Ecosystem-Based Fishery Management Policy

Resilient, productive ocean fisheries are critical to our economy and way of life. Managing these fisheries over the long-term means taking into account more than just one species at a time. It requires a holistic, science-based approach that looks at the entire ecosystem. This approach is known as ecosystem-based fisheries management.

NOAA Fisheries has developed an agency-wide EBFM policy, which outlines a set of principles to guide our actions and decisions over the long-term. It directs continued progress toward development and implementation of EBFM approaches. It also ensures our commitment to incorporate EBFM into the agency's resource management decisions.

We developed a road map to guide implementation of the EBFM policy over the next five years. The road map outlines actions we can take now to further the policy's six guiding principles:

1. Implement ecosystem-level planning.
2. Advance our understanding of ecosystem processes.
3. Prioritize vulnerabilities and risks of ecosystems and their components.
4. Explore and address trade-offs within an ecosystem.
5. Incorporate ecosystem considerations into management advice.
6. Maintain resilient ecosystems.

Learn more about ecosystems-based management ›

National Habitat Policy

Healthy habitat is vital to protecting coastal and ocean ecosystems and communities. In turn, healthy habitat is important for achieving the NOAA mission. We are responsible for ensuring the nation has a strong network of healthy habitats. These habitats sustain resilient and thriving marine and coastal resources, communities, and economies. However, with widespread loss and deterioration of coastal and marine habitats, we are in danger of losing this natural infrastructure. We are committed to confronting these challenges for many years.

The NOAA National Habitat Policy acknowledges that healthy habitat is crucial to our agency programs and activities. This long-term policy outlines a set of guiding principles that applies to all of NOAA's habitat work. It will influence future actions and priorities related to habitat conservation, allowing us to be more efficient and effective. It's a clear statement of our dedication to habitat conservation and resilient ecosystems and communities.

Learn more about our National Habitat Policy ›

National Saltwater Recreational Fishing Policy

This national policy aims to better serve millions of our nation's recreational saltwater fishermen and their coastal communities. The policy reflects fishermen's voices on existing and emerging concerns, including public access, resource stewardship, regulatory education, science innovation, and better lines of communication between state and federal rulemakers and the community.

Learn more about our National Saltwater Recreational Fishing Policy ›

Ocean Noise Policy

Increasing human activity is contributing to rising levels of underwater noise. Due to the efficiency with which sound travels underwater, aquatic animals have evolved to use acoustic cues in a wide variety of contexts. These cues support their survival and reproductive success, including selecting mates, finding food, maintaining group structure and relationships, avoiding predators, and navigation. Increasing noise levels can impact the animals and ecosystems that inhabit these places including through acute, chronic, and cumulative effects.

The Ocean Noise Policy codifies our commitment to working to reduce the impacts of human-made noise on marine organisms. It outlines how we will implement the NOAA Ocean Noise Strategy—a ten year strategy that addresses scientific and management actions.

Learn more about our Ocean Noise Strategy ›

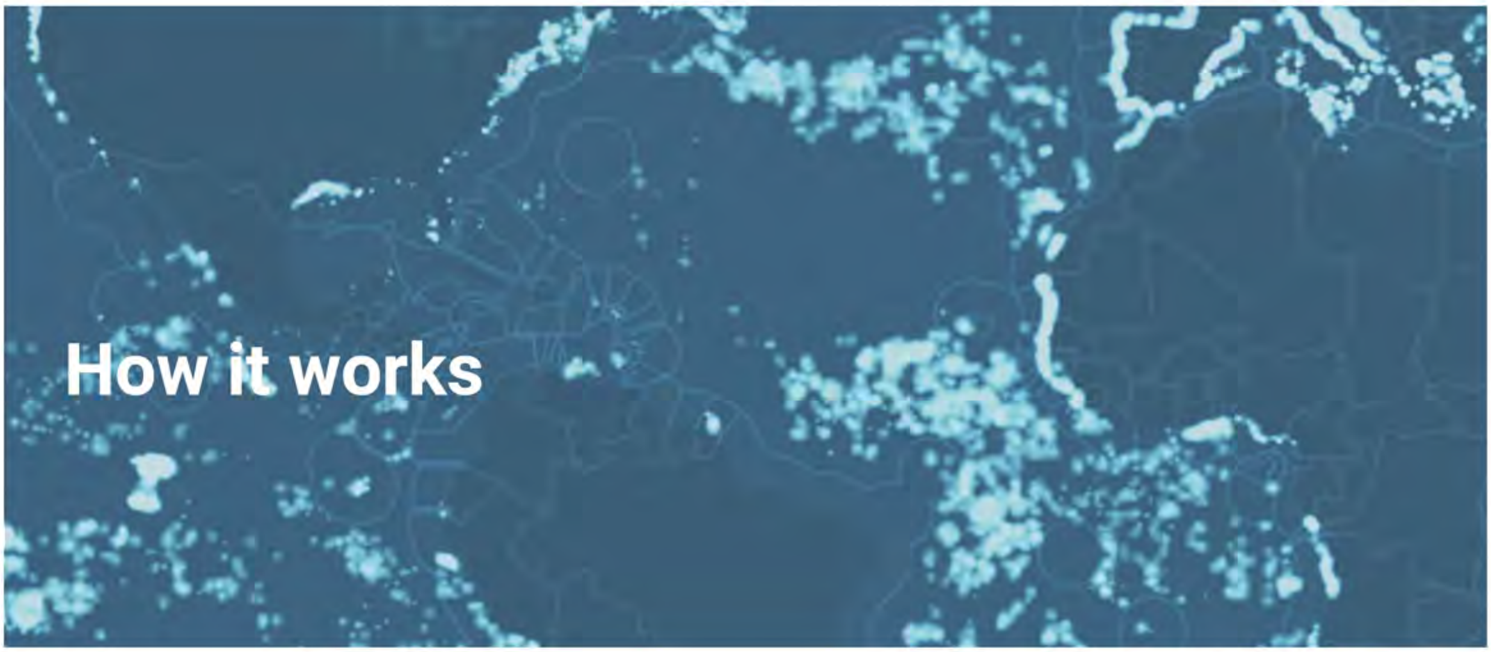
Other NOAA Fisheries Policy Directives

NOAA Fisheries policy directives undergo an extensive internal review across NOAA Fisheries offices around the country and reflect our organization's positions as a whole. They also provide specific instruction for how we implement key statutory requirements like the Marine Mammal Protection Act and the Endangered Species Act.

Explore our policy directives ›

Map & data

Donate



Transforming fishing through transparency and technology

Just a decade ago, building an accurate picture of the commercial fishing across the globe would have been impossible. Today, thanks to advances in satellite technology, cloud computing and machine learning, Global Fishing Watch is making it a reality. So how do we do it?

1. Harvesting the data

The process starts with vessel tracking data. While Global Fishing Watch uses

2. Processing the information

3. Sharing the results

Global Fishing Watch makes this vessel tracking information available to all

several vessel tracking systems, we start with the automatic identification system (AIS), a GPS-like device that large ships use to broadcast their position in order to avoid collisions. The International Maritime Organization and many national governments require larger boats including many commercial fishing vessels to use AIS. Each year, more than 300,000 unique AIS devices broadcast the location of a vessel along with other information showing its identity, course and speed. Ground stations and satellites pick up this information, meaning a ship's movements can be followed even in the remotest parts of the ocean.

While only a small fraction of the world's roughly 2.9 million fishing boats carry AIS, they are responsible for a disproportionate amount of the fish caught, especially far from shore. It's estimated vessels with AIS account for over half the fishing effort more than 100 nautical miles from shore, and as much as AIS provides vast amounts of publicly available data – it's far too much for any human being to make sense of, and only part of it is from fishing boats.

Global Fishing Watch runs this data through two neural networks using computer algorithms to learn and look for patterns in large data sets. More than 60 million points of information per day from more than 300,000 vessels are fed through machine-learning classifiers to determine the type of ship (e.g., cargo, tug, sail, fishing), its size, what kind of fishing gear (e.g. longline, purse seine, trawl) it's using, and where and when it's fishing based on its movement patterns. To do this, our research partners and fishery experts have manually classified thousands of vessel tracks to "teach" our algorithms what fishing looks like.

By using cloud computing to spread the load over thousands of machines in parallel, we're able to apply that learning to the entire through our interactive online map and downloadable data. Anyone with an internet connection can trace the movements of about 60,000 commercial fishing boats, along with their name and flag state, in near real time: our data shows all activity from 1 January 2012 until 72 hours ago.

You don't need to be an expert to use the platform, any more than you need to know about complex algorithms to use a search engine: it's aimed at members of the public and journalists as much as researchers, campaigners and governments.

Users can create heat maps to see patterns of commercial fishing activity, view tracks of individual vessels, and overlay information like the locations of marine protected areas or different countries' exclusive economic zones (EEZ).

80% of the fishing in the high seas.

dataset producing 37 billion points over five years.

Catching out the identity cheats

Most large fishing vessels are assigned a unique Maritime Mobile Service Identity (MMSI) number, but in practice some vessels use a number that is not assigned to them — either a false number (like 123456789) or the number of another vessel. This means that, throughout the ocean, multiple vessels are simultaneously broadcasting the same MMSI number making them indistinguishable from one another without closer inspection. Vessels can also manipulate their GPS location by tampering with the system ("spoofing").

Our machine-learning algorithms automatically separate signals coming from multiple vessels using the same MMSI, and also detect when the broadcast location is inconsistent with the location of the satellite that received the signal. We can't always determine the true identity of the spoofing vessel, but our algorithms can still detect the vessel's behaviour and put it on a map.

Making an impact

The technology powering the Global Fishing Watch map may be impressive, but the really exciting stuff happens when people use it:

- **Governments** can identify and take action against boats that aren't authorised to fish in their waters, or that are fishing illegally in protected areas
- **Seafood suppliers and retailers** can see where and how fish are caught and ensure they only source from boats that are operating legally and responsibly
- **Researchers** can study the impacts of fishing on ocean health, identify vulnerable areas, investigate how environmental changes influence where fish go, or

"Every time I show the live map to somebody, they tell me something I didn't know. In five seconds it can tell stories that never could have been told before."

evaluate the effectiveness of conservation and fisheries policies

- **NGOs and journalists** can identify and investigate suspicious vessels, and advocate for stronger protection for important ecosystems
- **Fishers** can show that they are operating legally and responsibly, giving them a market advantage by enabling them to sell their catch to customers who demand sustainable, traceable seafood

Brian Sullivan
Co-founder of Global Fishing Watch and Senior Program Manager for Google Earth Outreach

Founding Partners

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NOAA FISHERIES

Incidental Take Authorizations Under the Marine Mammal Protection Act

The Marine Mammal Protection Act requires that an incidental take authorization be obtained for the unintentional "take" of marine mammals incidental to activities including construction projects, scientific research projects, oil and gas development, and military exercises.

Overview

Authority
Marine Mammal Protection Act

Permit Type
For Marine Mammals

Estimated Processing Time
5-8 months (IHA) / 9-18 months (LOA)

About

The Marine Mammal Protection Act, and its implementing regulations, allows, upon request, the incidental take of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographic region. Incidental take is an unintentional, but not unexpected, "take". Taking is prohibited, with certain exceptions, under the MMPA.

The NOAA Fisheries Office of Protected Resources authorizes the incidental take of marine mammals under the MMPA to U.S. citizens and U.S.-based entities, if we find that the taking would:

- Be of small numbers;
- Have no more than a "negligible impact" on those marine mammal species or stocks; and
- Not have an "unmitigable adverse impact" on the availability of the species or stock for subsistence uses.

Most incidental take authorizations have been issued for activities that produce underwater sound. Some of these activities include:

- Military sonar and training exercises.
- Oil and gas development, exploration, and production activities.
- Other energy (renewable and LNG) activities.
- Scientific research projects.
- Construction projects.

What You Will Need

There are two types of incidental take authorizations: Incidental Harassment Authorization (IHA) and Letter of Authorization (LOA). You will need to determine which type of authorization is appropriate for your planned activity.

If your action has potential to:	Then you should:
Result in "harassment" only (i.e., injury or disturbance)	Apply for an IHA (effective up to 1 year)
Result in harassment only (i.e., injury or disturbance) AND is planned for multiple years	Apply for an LOA* (effective up to 5 years)
Result in "serious injury" or mortality	Apply for an LOA* (effective up to 5 years)

* For a Letter of Authorization, NOAA Fisheries must issue regulations. Regulations with an associated LOA may be issued for multi-year activities. These proposed actions must be well-planned with enough detailed information to allow for a robust analysis of the entire duration of your planned activity. Because LOAs can be valid for up to 5 consecutive years while an IHA can only be valid for 1 year, the rulemaking/LOA is often beneficial in reducing the administrative burden even when serious injury or mortality is not anticipated.

Please contact us for further info on determining which type of authorization is appropriate for your planned activity.

How to Apply

For more information on applying, please see the detailed application instructions. The collection of this information has been approved by the Office of Management and Budget, OMB Control Number 0648-0151.

Time frames for application:

For IHAs: apply **5-8 months** in advance of the intended project start date. Some IHAs may take longer to process. Contact us for more project specific recommendations.

For rulemakings/LOAs: apply **at least 9 months, preferably 15 months**, in advance of the intended project start date. Some rules and LOAs may take longer to process. Contact us for more project specific recommendations.

What Happens After You Submit

Actions in the IHA Process	Time
Review of application for adequacy and completeness (see details of adequacy and completeness determination)	3-7 weeks*
Preparation of proposed IHA, initiation of NEPA and ESA processes as necessary	1-2 months
Publication of proposed IHA in *Federal Register* for public comment period	30 calendar days
Review and addressing of public comments, finalization of ESA and NEPA compliance, making final determinations, and issuance or denial of IHA	1-2 months

Actions in the Rulemaking/LOA Process	Time
Review of application for adequacy and completeness (see details of adequacy and completeness determination)	4-9 weeks*
Publication of Notice of Receipt of Application in the *Federal Register* for public comment period	30 calendar days
Review and addressing of public comments, preparation of proposed rule, initiation of NEPA and ESA processes as necessary	2-5 months
Publication of proposed rule in *Federal Register* for public comment period	30-60 calendar days
Review and addressing of public comments, finalization of ESA and NEPA compliance, making final determinations, and publication of notice of issuance or denial of final rule	2-5 months
Issuance of LOA	30 calendar days after date of publication of final rule in the *Federal Register*

*If your application is incomplete, it will be returned to you with an explanation.

For activities that occur in Arctic waters where the activity has the potential to affect the availability of a species or stock of marine mammals for subsistence uses, your monitoring plan must be peer reviewed. We will typically conduct the peer review immediately before or during the public comment period for the proposed IHA or proposed rule (for LOAs).

Incidental Harassment Authorization Renewals

NOAA Fisheries is now implementing an expedited process (approximately 60 days) whereby the agency may, on a case-by-case basis, issue a one-year Renewal IHA, following notice to the public

- up to *another* year of identical, or nearly identical, activities as were covered by the initial IHA (or subset of those activities) or
- a subset of the activities covered by the initial IHA because the originally planned activities were not completed within the effective dates of the initial IHA and are planned for completion under the proposed Renewal.

This expedited process is designed for application to simple, relatively low-impact projects with little to no uncertainty regarding the impacts of the activity on marine mammals, including type and amount of expected take. Please consult with NOAA Fisheries prior to submitting a request for a Renewal to ensure the activity qualifies, as the process to obtain authorization will take longer if a Renewal is not appropriate.

NOAA Fisheries' purpose in providing for Renewals is two-fold. First and foremost, the efficiencies in dealing with these simple, low-impact projects (which have already been fully described and analyzed in the initial IHA) frees up limited staff resources to increase focus on more complex and impactful projects and improve our ability to conserve and protect marine mammals by even better evaluating and utilizing new science, evolving technologies, and potential new mitigation measures. In addition, while the agency has always striven for efficiency in regulatory processes, recent directives have called for agencies to put processes in place that reduce regulatory timelines and the regulatory burden on the public. The Renewal process reduces the effort needed by both applicants and NOAA Fisheries' staff for simple, relatively low impact projects with little to no uncertainty regarding effects that have already been fully analyzed by the agency and considered by the public – with no reduction in protection to marine mammals.

Learn More about conditions that must be met for an IHA Renewal and a description of the process. >

More Information

For more information on applying, please see the detailed application instructions.

An Interactive Map can be viewed that shows recent and in process authorizations.

Pending actions, issued authorizations, and other relevant documents related to Incidental Take Authorizations can be found on the following pages:

- Incidental Take Authorizations for military readiness activities
- Incidental Take Authorizations for oil and gas activities
- Incidental Take Authorizations for other energy (renewable and LNG) activities
- Incidental Take Authorizations for research and other activities

Find out more about marine mammal protection.

For more information on issued authorizations or applying for authorization, please contact us.

Last updated by Office of Protected Resources on 02/07/2020

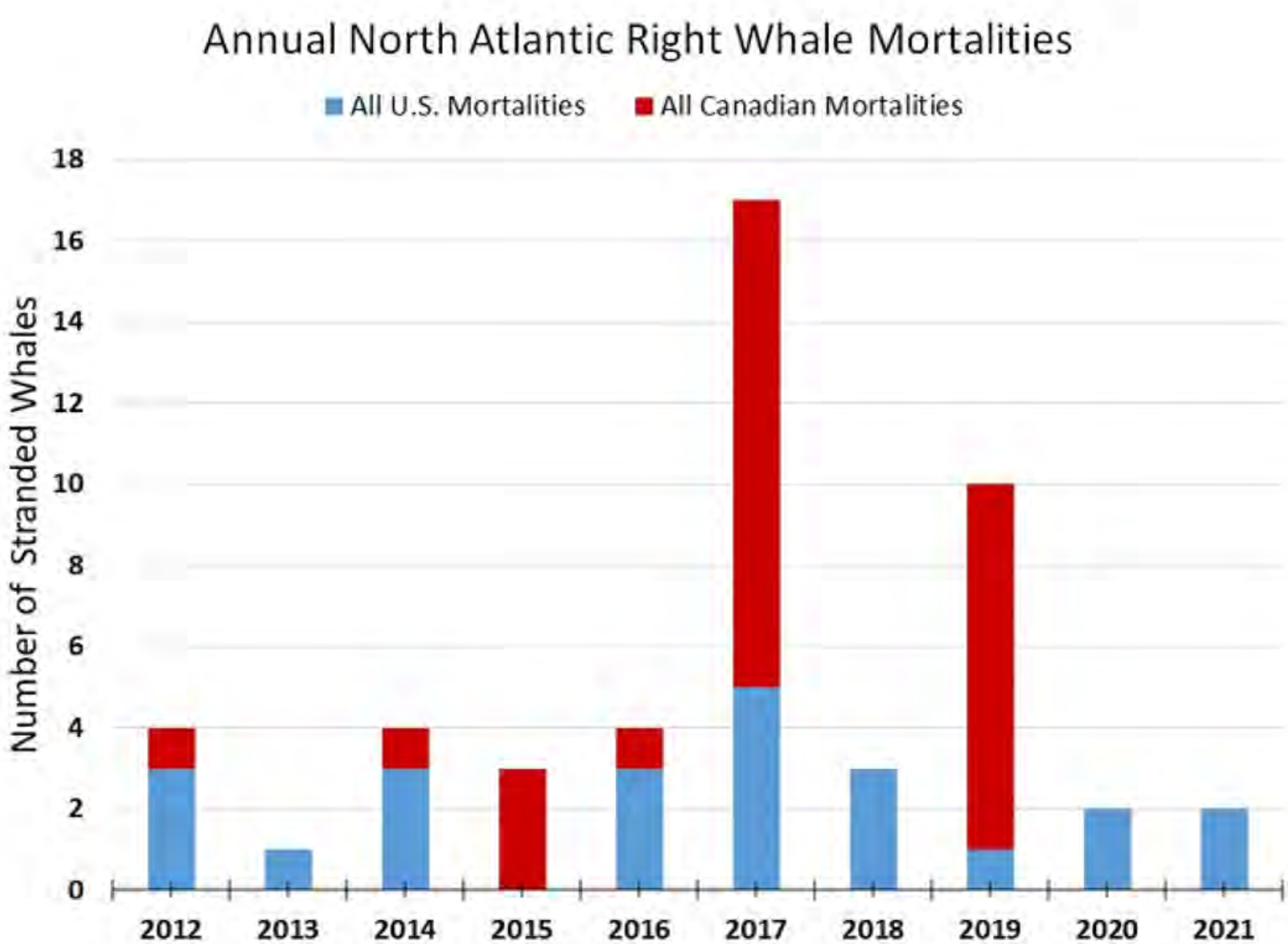
2017–2021 North Atlantic Right Whale Unusual Mortality Event

Since 2017, elevated numbers of dead or seriously injured North Atlantic right whales (Eubalaena glacialis) have been documented, necessitating an Unusual Mortality Event declaration and investigation.

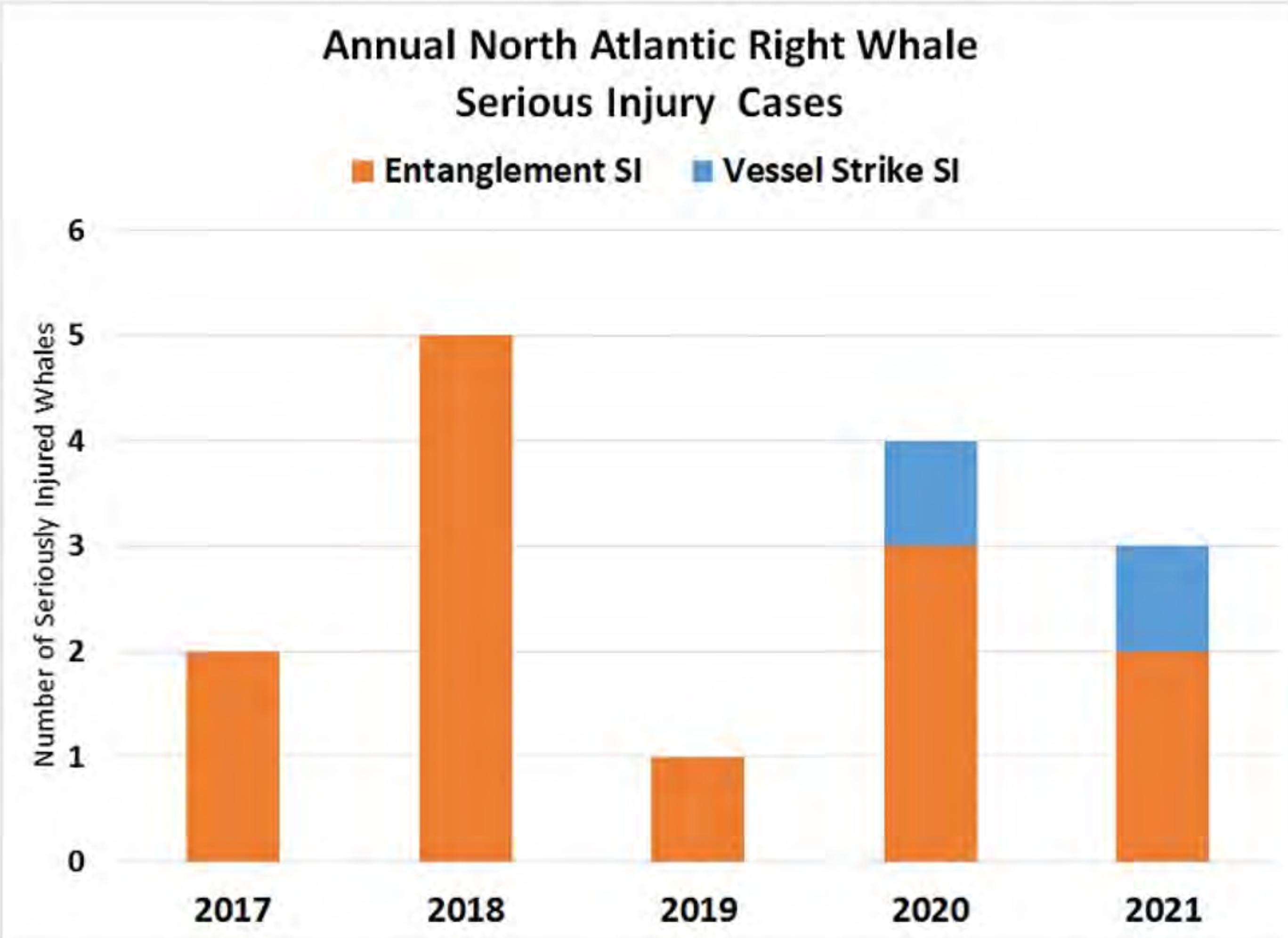
Beginning in 2017, elevated mortalities in North Atlantic right whales (*Eubalaena glacialis*) have been documented, primarily in Canada but some in the U.S., and were collectively declared an Unusual Mortality Event (UME). In 2017, there were a total of 17 confirmed dead stranded whales (12 in Canada; 5 in the United States) and in 2018, three confirmed dead stranded whales in the United States. In 2019, nine dead whales stranded in Canada, and one dead whale stranded in the United States. In 2020, two mortalities were documented. To date in 2021, two mortalities has been documented. The current total confirmed mortalities for the UME are 34 dead stranded whales (21 in Canada; 13 in the United States), and the leading category for the cause of death for this UME is "human interaction," specifically from entanglements or vessel strikes.

Additionally, since 2017, 15 live free-swimming non-stranded whales have been documented with serious injuries from entanglements or vessel strikes. The Marine Mammal Protection Act (MMPA) requires NOAA's National Marine Fisheries Service (NMFS) to distinguish between injuries to marine mammals that are serious and those that are non-serious (*e.g.*, MMPA Sections 101(a)(2)(4) and(5); 101(d); 108(a)(2); 117; 118; 120 (j)(2)). MMPA Sections 117 and 118 specifically direct NMFS to consider the human-caused mortality and serious injury to marine mammals for stock assessments and management of fisheries interactions. Serious injury determination is a detailed assessment process that uses data, such as body condition and parameters of the human-caused injury, collected from living whales to determine an individual whale's prognosis for survival. A serious injury designation indicates a whale is likely to die from those injuries (although it was alive at its last sighting). More recent serious injury determinations (*e.g.*, 2020 & 2021) are preliminary and subject to change as we receive additional information. Therefore, the preliminary cumulative total number of animals in the North Atlantic right whale UME has been updated to **49** individuals to include both the confirmed mortalities (dead stranded or floaters) (n=34) and seriously injured free-swimming whales (n=15) to better reflect the confirmed number of whales likely removed from the population during the UME and more accurately reflect the population impacts.

Thus, given there are less than 400 individual North Atlantic right whales remaining, these 49 individuals in the UME represent more than 10% of the population, which is a significant setback to the recovery of such a critically endangered species.



Annual North Atlantic Right Whale Mortalities, 2012-2021, U.S. and Canada



Annual North Atlantic Right Whale Serious Injury (SI) Cases of whales last seen alive, 2017-2021, U.S. and Canada

North Atlantic Right Whale Causes of Death for Confirmed Carcasses

Year	Month	NARW ID	Sex	Location First Observed Dead	Preliminary Cause of Death
Canada					
2017	June	#3746	M	Gulf of St Lawrence	Undetermined; could not be examined
2017	June	Glacier #1402	M	Gulf of St Lawrence	Suspect blunt force trauma (vessel strike)
2017	June	Panama #3190	M	Gulf of St Lawrence	Undetermined; advance decomposition
2017	June	Starboard #3603	F	Gulf of St Lawrence	Acute entanglement (gear present; anchored)

Year	Month	NARW ID	Sex	Location First Observed Dead	Preliminary Cause of Death
2017	June	Contrail #3512	F	Gulf of St Lawrence	Undetermined; could not be examined
2017	June	#1207	M	Gulf of St Lawrence	Probable blunt force trauma (vessel strike)
2017	July	Unk	M	Gulf of St Lawrence	Probable blunt force trauma (vessel strike)
2017	July	Peanut #2140	M	Gulf of St Lawrence	Suspect blunt force trauma (vessel strike)
2017	July	Alien #2630	M	Newfoundland	Undetermined; could not be examined
2017	July	Unk	F	Newfoundland	Undetermined; could not be examined
2017	July	Mystique #1911	F	Newfoundland	Undetermined; could not be examined
2017	September	#4504	F	Gulf of St Lawrence	Acute entanglement (gear present)
2019	June	Wolverine #4023	M	Gulf of St Lawrence	Suspect blunt force trauma (vessel strike)
2019	June	Punctuation #1281	F	Gulf of St Lawrence	Probable blunt force trauma (vessel strike)
2019	June	Comet #1514	M	Gulf of St Lawrence	Probable blunt force trauma (vessel strike)
2019	June	#3815	F	Gulf of St Lawrence	Undetermined; not examined
2019	June	#3329	F	Gulf of St Lawrence	Undetermined; not examined
2019	June	Clipper #3450	F	Gulf of St Lawrence	Probable blunt force trauma (vessel strike)
2019	June	Unk	U	Cape Breton	Undetermined; not examined
2019	July	#3421	M	Gulf of St Lawrence	Undetermined
2019	July	Unk	M	Cape Breton	Undetermined; not examined
USA					
2017	April	#4694	F	Barnstable, MA	Blunt force trauma (vessel strike)
2017	August	Unk	M	Martha's Vineyard, MA	Probable entanglement

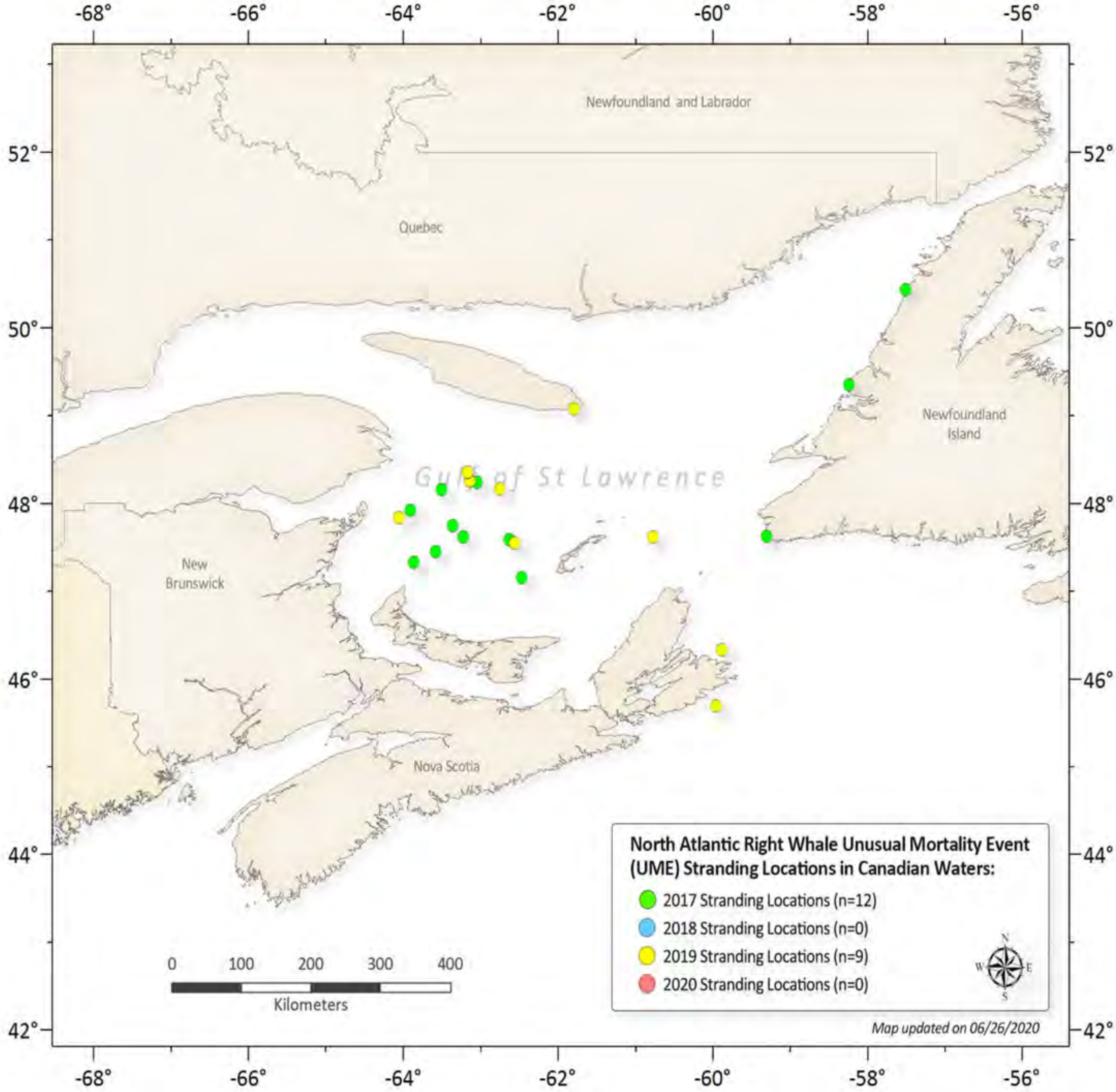
Year	Month	NARW ID	Sex	Location First Observed Dead	Preliminary Cause of Death
2017	August	Couplet #2123	F	Cape Cod, MA (offshore)	Undetermined; could not be examined
2017	October	Unk	M	Nashawena Island, MA	Suspect entanglement
2017	November	Picasso #2611	F	Martha's Vineyard, MA	Undetermined; advance decomposition
2018	January	#3893	F	Virginia Beach, VA (offshore)	Chronic entanglement (gear present)
2018	August	#4505	M	Monomoy, MA	Probable entanglement
2018	October	#3515	F	Nantucket, MA (offshore)	Probable acute entanglement
2019	September	Snake Eyes #1226	M	Long Island, NY(offshore)	Probable acute entanglement
2020	June	2020 Calf of #3560	M	Elberon, New Jersey (offshore)	Sharp and blunt force trauma (vessel strike)
2020	November	Unk	M	Core Banks, North Carolina	Perinatal mortality
2021	February	2021 Calf of #3230	M	St. Augustine, Florida	Pending
2021	February	Cottontail #3920	M	off Myrtle Beach, SC	Chronic entanglement (gear present)

North Atlantic Right Whales Determined to be Seriously Injured (Last seen alive)

Year	Month	NARW ID	Sex	Location First Observed	Initial Serious Injury Determination
Canada					
2017	July	Mayport #4094	F	off Sainte-Marie Saint-Raphael, New Brunswick	Entanglement
2018	July	#3312	M	off Miscou Island, New Brunswick	Entanglement

Year	Month	NARW ID	Sex	Location First Observed	Initial Serious Injury Determination
2018	July	#3843	M	off Grand Manan, New Brunswick	Entanglement
2019	July	#3125	M	off Perce, Quebec	Entanglement
USA					
2017	July	Diablo #3139	F	off Nantucket, MA	Entanglement
2018	February	#3296	M	off Jekyll Island, GA	Entanglement
2018	December	#2310	M	off Nantucket, MA	Entanglement
2018	December	#3208	M	off Nantucket, MA	Entanglement
2020	January	2020 Calf of #2360	U	Altamaha Sound, GA	Vessel Strike
2020	February	Dragon #3180	F	off Nantucket, MA	Entanglement
2020	March	Unk	U	off Georges Bank	Entanglement
2020	October	#4680	M	off Sea Bright, NJ	Entanglement
2021	January	#1803	M	off Georgia/Florida state border	Entanglement
2021	February	Infinity #3230	F	off St. Augustine, FL	Vessel Strike
2021	March	Snow Cone #3560	F	off Cape Cod Bay, MA	Entanglement

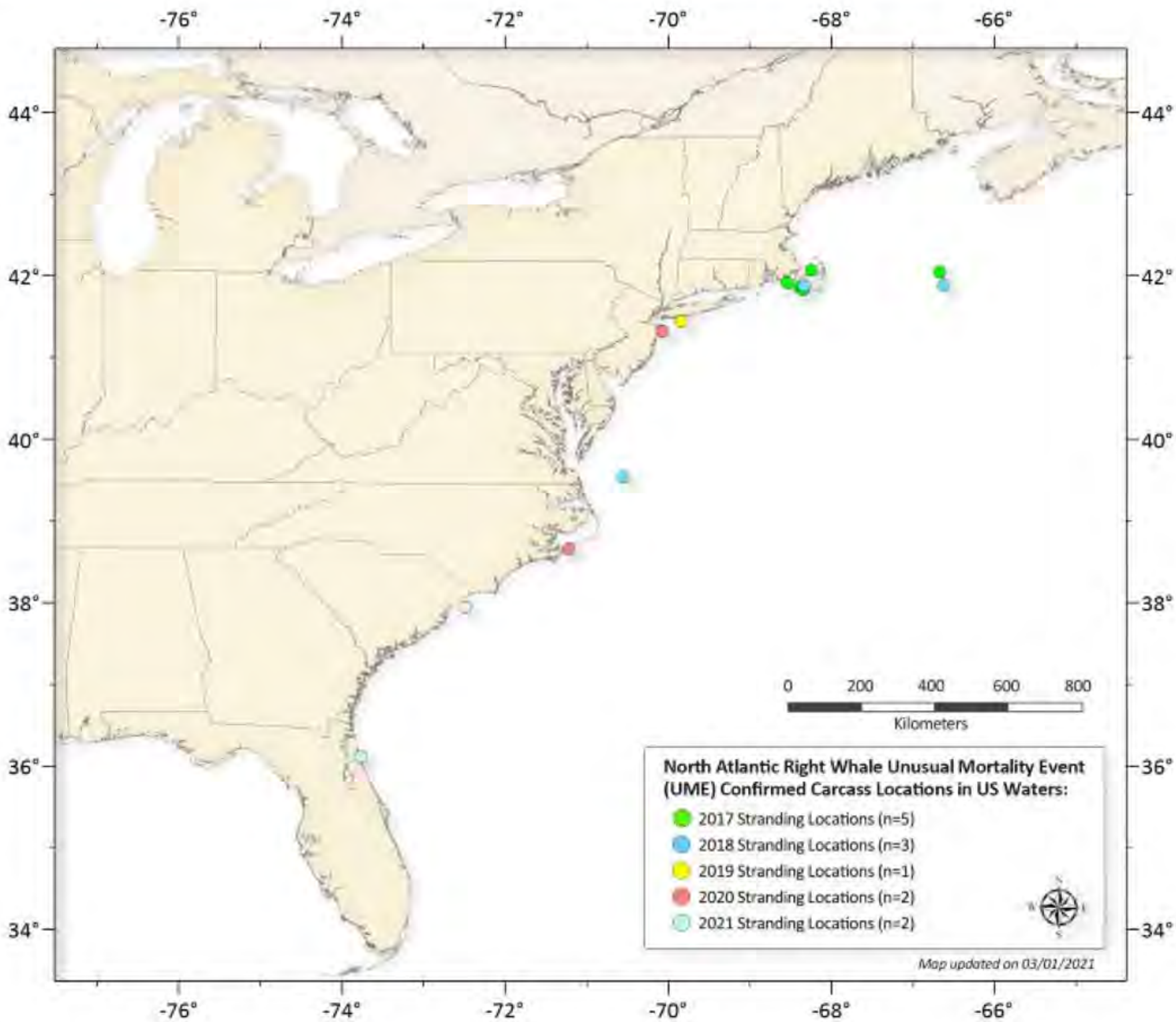
Note: Graphs and/or tables represent confirmed mortalities and injuries reported in each country and does not always reflect the location of the injury or death of the animal. Carcasses may drift across national boundaries; therefore, a carcass may be sighted or reported in one country even though the mortality occurred elsewhere. Species or stocks that migrate across national boundaries often carry their illnesses, injuries, or exposures to toxins with them. For mortality and serious injury determinations in these species, transboundary collaboration is critical in determining the causes of injury, illness, and mortality for each animal.



Map of NARW mortalities in Canada

Causes of the North Atlantic Right Whale UME

Full necropsy examinations have been conducted on 20 of the 32 dead whales and final results from some examinations are pending. Necropsy results can be found online from seven of the Canadian whales from 2017 and from five of the whales from 2019. Photos and other available documentation for the live whales were reviewed by the NMFS Northeast Fisheries Science Center



Map of NARW confirmed carcass locations in U.S. waters

as part of the serious injury determination process and those listed above were designated as seriously injured.

As part of the UME investigation process, NOAA assembled an independent team of scientists to coordinate with the Working Group on Marine Mammal Unusual Mortality Events to review and interpret the data collected, guide sampling of stranded whales, evaluate sighting effort, review logistical considerations, and determine the next steps for the investigation. We continue to investigate these mortalities, but preliminary findings support “human interactions” as the primary category of the cause of death for the majority of the dead stranded whales, specifically vessel strikes or rope entanglements. Additionally, 14 live whales have been documented as seriously injured either by vessel strikes or entanglements during the time frame of the current UME (2017-2021).

A dead right whale floating at the surface of the ocean.

Report a Stranding

The most important step that the public can take to assist investigators is to immediately report any sightings of injured or stranded whales (dead or alive). In the United States, make a report by calling the Greater Atlantic Marine Mammal Stranding Hotline at (866) 755-6622 or the Southeast Marine Mammal Stranding Hotline at (877) 433-8299. In Canada, call the Marine Animal Response Society at 1-866-567-6277 or the Quebec Marine Mammal Emergency Response Network at 1-877-722-5346. You can also contact the U.S. and Canadian Coast Guards on VHF Channel 16. Do not approach injured or dead animals.

More Information

- February 28, 2021 Adult North Atlantic Right Whale Found Dead off South Carolina
- February 14, 2021 North Atlantic Right Whale Calf Stranded Dead in Florida
- January 8, 2021 Report of the Health Assessment Workshop for North Atlantic Right Whales
- November 23, 2020 First Known North Atlantic Right Whale Calf of the Season Washes Up Dead off North Carolina
- October 20, 2020 Entangled North Atlantic Right Whale Spotted off Nantucket
- October 12, 2020 Entangled North Atlantic Right Whale Spotted off New Jersey
- June 25, 2020 North Atlantic Right Whale Carcass off New Jersey

- February 28, 2020 Emaciated Adult Female North Atlantic Right Whale Spotted Entangled off Nantucket
- January 13, 2020 North Atlantic Right Whale Calf Injured by Vessel Strike
- Frequent Questions: 2017 North Atlantic Right Whale UME
- Fisheries and Oceans, Canada
- Transport Canada
- Marine Animal Rescue Society, Canada
- Donate to the Unusual Mortality Event Contingency Fund
- Unusual Mortality Events
- Marine Mammal Health and Stranding Response Program

Last updated by
Office of Protected Resources
on 03/12/2021

SECOND PORT ACCESS ROUTE STUDY

TO

ANALYZE POTENTIAL VESSEL ROUTING MEASURES

FOR REDUCING VESSEL (SHIP) STRIKES

OF

NORTH ATLANTIC RIGHT WHALES

PREPARED BY THE

OFFICE OF WATERWAYS MANAGEMENT

NAVIGATION SYSTEMS DIVISION

NAVIGATION STANDARDS BRANCH

UNITED STATES COAST GUARD

I. REQUIREMENT

The Administration is developing measures to reduce ship strikes of right whales. The goal of these measures is to address the lack of recovery of the right whale by reducing the likelihood and threat of ship strikes.

Section 626 of the Coast Guard and Maritime Transportation Act of 2004 (the 2004 Act) (enacted August 9, 2004) mandated that the Coast Guard: (1) Cooperate with the National Oceanic and Atmospheric Administration "in analyzing potential vessel routing measures for reducing vessel strikes of North Atlantic Right Whales", and (2) provide a final report of the analysis to Congress within 18 months after the date of enactment of the Act.

The final report was delivered to Congress as required. The report contained possible future action items such as establishing a Great South Channel area to be avoided (ATBA). If the ATBA was proposed to be established, its location would require that the Boston traffic separation scheme (TSS) in the vicinity of Cape Cod be amended.

II. GENERAL

The North Atlantic right whale, *Eubalaena glacialis*, is considered one of the most endangered large whale species in the world. Right whales have been listed as endangered under the Endangered Species Act (ESA) since its passage in 1973 (35 FR 8495, June 2, 1970). Although precise estimates of abundance are not available, it appears that the eastern North Atlantic population is nearly extinct and the western North Atlantic population numbers approximately 300 whales. (*See* Ward-Geiger, Silber, and Baumstark, and Pulfer, 2005.) The status of North Atlantic right whales is a very serious issue, especially for the National Marine Fisheries Service (NMFS) and the United States Coast Guard. While calf production has increased somewhat in recent years, reproduction has been erratic over the last few decades, and recovery is seriously affected by fatalities and serious injury resulting from human activities, primarily from collisions with vessels (ship strikes) and entanglement in fishing gear.

The Coast Guard is charged with enforcing the Marine Mammal Protection Act (MMPA), ESA, and the regulations issued under those statutes. One of the Coast Guard's core missions and strategic goals is the protection of the marine environment, including the conservation of living marine resources and enforcement of living marine resource laws. The Coast Guard works in collaboration with NMFS to prevent ship strikes. The Coast Guard issues local and written periodic notices to mariners concerning ship strikes, issues NAVTEX messages alerting mariners to the location of right whales, and actively participates in the Mandatory Ship Reporting (MSR) Systems that provide information to mariners entering two specific areas, one in the northeastern United States and one in the southeastern United States. In addition, the Coast Guard provides patrols dedicated to enforcement of the ESA and the MMPA; limited vessel and aircraft support to facilitate right whale research and population monitoring; funding to support the Sighting Advisory (SAS)/Early Warning System (EWS); vessels and aircraft to assist in right whale disentanglements and strandings; and disseminates NMFS information packets to vessels boarded in or near right whale waters. As part of its Strategy development, and consistent with section 626 of the 2004 Act, NMFS asked the Coast Guard for assistance in its ship-strike rulemaking by conducting a Port Access Route Study (PARS).

Under the Ports and Waterways Safety Act (PWSA) (33 U.S.C. 1223(c)), the Commandant of the Coast Guard may designate necessary fairways and traffic separation schemes (TSSs) to provide safe access routes for vessels proceeding to and from U. S. ports. In addition, the PWSA provides that such designation of fairways and TSSs must recognize, within the designated areas, the paramount right of navigation over all other uses. The PWSA also allows the Coast Guard to adjust the location or limits of designated fairways or TSSs. Through the study process, the Coast Guard must consult with Federal, State, and foreign state agencies (as appropriate) and consider the views of maritime community representatives, environmental groups, and other interested stakeholders received through the public comment process. The Coast Guard must also take into account all other uses of the area under consideration including as appropriate:

- the exploration for, or exploitation of, oil, gas, or other mineral resources;
- the construction or operation of deepwater ports or other structures on or above the seabed or subsoil of the submerged lands or the Outer Continental Shelf (OCS) of the U. S.;
- the establishment or operation of marine or estuarine sanctuaries; and
- activities involving recreational or commercial fishing.

Designation shall, to the extent practicable, reconcile the need for safe access routes with the needs of all other reasonable uses of the area involved. Additionally, for the original PARS, Section 626 of the 2004 Act specifically required that routing measures be considered to reduce ship strikes of North Atlantic right whales.

Most commercial vessels calling at U.S. ports are foreign flag vessels. The United States, after Executive Branch review and clearance, may submit proposed routing measures recommended by a PARS--in particular traffic separation schemes (TSSs)--to the International Maritime Organization (IMO) for approval, adoption, and implementation. However, not all routing measures must be submitted to IMO. For instance, the routing measures analyzed by the original PARS for the southeastern United States and for Cape Cod Bay were not submitted to IMO, while the amendment to the northern portion of the Boston TSS (a previously IMO adopted measure) was submitted to IMO. A seasonal ATBA and the amending of the southern portion of the Boston TSS are being proposed for IMO submission. The International Convention for the Safety of Life at Sea (SOLAS) recognizes IMO as the competent international body for developing guidelines, criteria and regulations at the international level for ships' routing systems. Upon adoption of a routing measure, IMO issues a circular to its approximately 166 Member States to provide geographic coordinates of the adopted routing measure. The routing measure is then added to navigational charts issued by various entities worldwide, including National Oceanic and Atmospheric Administration (NOAA) navigational charts. As to the proposed amendment of the Boston TSS, the Coast Guard will begin the process of updating the list of offshore traffic separation schemes and precautionary areas at 33 C.F.R. Part 167 during or after IMO action on the proposal by the United States, including issuing a Federal Register notice and providing opportunity for public comment. The traffic separation schemes and other routing measures that have been adopted worldwide by IMO can be found at www.imo.org.

On November 19, 2007, the Coast Guard published a notice of study in the *Federal Register* (72 FR 64968) which provided the reason for this study, procedures by which the public could comment on the study, descriptions of the geographic areas to be studied, and a timetable and process that the Coast Guard was going to use in conducting its PARS.

III. BACKGROUND

DEFINITIONS

The following definitions are from the IMO's publication "Ships' Routeing" (except those marked by an asterisk, which are terms derived from Coast Guard regulations) and should help the reader to understand terms used throughout this document:

> Area to be avoided or ATBA means a routing measure comprising an area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by all vessels, or certain classes of vessels.
>
> Deep-water route means a route within defined limits, which has been accurately surveyed for clearance of sea bottom and submerged obstacles as indicated on nautical charts.
>
> Fairway* means a lane or corridor in which no artificial island or structure, whether temporary or permanent, will be permitted so that vessels using U.S. ports will have unobstructed approaches.
>
> Inshore traffic zone means a routing measure comprising a designated area between the landward boundary of a traffic separation scheme and the adjacent coast, to be used in accordance with the provisions of Rule 10(d), as amended, of the International Regulations for Preventing Collisions at Sea, 1972 (COLREGS).
>
> No anchoring area means a routing measure comprising an area within defined limits where anchoring is hazardous or could result in unacceptable damage to the marine environment. Anchoring in a no anchoring area should be avoided by all vessels or certain classes of vessels, except in case of immediate danger to the vessel or the persons on board.
>
> Precautionary area means a routing measure comprising an area within defined limits where vessels must navigate with particular caution and within which the direction of traffic flow may be recommended.

Recommended route means a route of undefined width, for the convenience of vessels in transit, which is often marked by centerline buoys.

Recommended track means a route which has been specially examined to ensure so far as possible that it is free of dangers and along which vessels are advised to navigate.

Regulated Navigation Area or RNA* means a water area within a defined boundary for which regulations for vessels navigating within the area have been established under 33 CFR part 165.

Roundabout means a routing measure comprising a separation point or circular separation zone and a circular traffic lane within defined limits. Traffic within the roundabout is separated by moving in a counterclockwise direction around the separation point or zone.

Separation Zone or separation line means a zone or line separating the traffic lanes in which vessels are proceeding in opposite or nearly opposite directions; or from the adjacent sea area; or separating traffic lanes designated for particular classes of vessels proceeding in the same direction.

Traffic lane means an area within defined limits in which one-way traffic is established. Natural obstacles, including those forming separation zones, may constitute a boundary.

Traffic Separation Scheme or TSS means a routing measure aimed at the separation of opposing streams of traffic by appropriate means and by the establishment of traffic lanes.

Two-way route means a route within defined limits inside which two-way traffic is established, aimed at providing safe passage of ships through waters where navigation is difficult or dangerous.

Vessel routing system means any system of one or more routes or routing measures aimed at reducing the risk of casualties; it includes traffic separation schemes, two-way routes, recommended tracks, areas to be avoided, no anchoring areas, inshore traffic zones, roundabouts, precautionary areas, and deep-water routes.

STUDY AREA

The study area is the area bounded to the west by a line drawn at longitude 070º W; bounded to the north by a line drawn at latitude 43º 00' N; bounded to the east by the boundary of the exclusive economic zone; and bounded to the south by a line drawn at latitude 40º 30' N. This area includes the northern right whale critical habitat, mandatory ship reporting system area, and the Great South Channel including Georges Bank out to the exclusive economic zone (EEZ) boundary.

ANALYSIS

During the course of a routine PARS, the Coast Guard reviews port data, which would include vessel types, vessel traffic density, types of cargo, economic impacts, port improvements, vessel safety, and overall environmental impacts. In addition, the Coast Guard reviews comments received on the PARS notice. Further, if meetings of any type are held, comments received at those meetings are also considered.

In analyzing potential vessel routing measures for reducing vessel strikes of North Atlantic right whales, and to be consistent with the original PARS, the Coast Guard and NOAA agreed that this PARS would be narrower in scope than a routine PARS because the Coast Guard did not consider economic impacts. These impacts would be considered by NMFS as part of an economic analysis it is doing as part of the implementation of its Strategy. The Coast Guard also reviewed research papers published and/or provided by NMFS which, in addition to advising on right whale habitat and migration patterns, also analyzed ship transit data, especially those studies that cite Mandatory Ship Reporting System data.

Six comment submissions were received on its PARS announcement in the *Federal Register* and were reviewed by the Coast Guard. All comments submitted were by individuals or organizations that want to see right whales protected. Comments were highly supportive of the Coast Guard's efforts to protect whales. No comments were submitted by vessel owners/operators or shipping companies.

NMFS advises that right whales tend to migrate seasonally in a corridor along the eastern seaboard of the U. S. and Canada between winter calving/nursing areas in the southern region (near the border between Georgia and Florida) and summer feeding grounds in the northern region (e.g. Cape Cod, Great South Channel, Bay of Fundy). In waters off the southeast U. S. and mid-Atlantic right whales are often found within 30 nautical miles of the coast. Their fall southward migration primarily occurs in November and December, and their spring northward migration primarily occurs in March and April. Accordingly, depending upon the time of the year, right whale sightings may occur within 30 nautical miles of the shore along much of the U. S. east coast, whereas in New England and Canadian waters this distance is greater. (*See* Ward-Geiger, et al., 2005.)

The following charts provided by NMFS (figures 1 through 3) provide summaries of right whale sighting information in the northeast region during the months indicated, show a possible depiction of a proposed seasonal ATBA, and provide background on the migration time period and distribution of right whales.

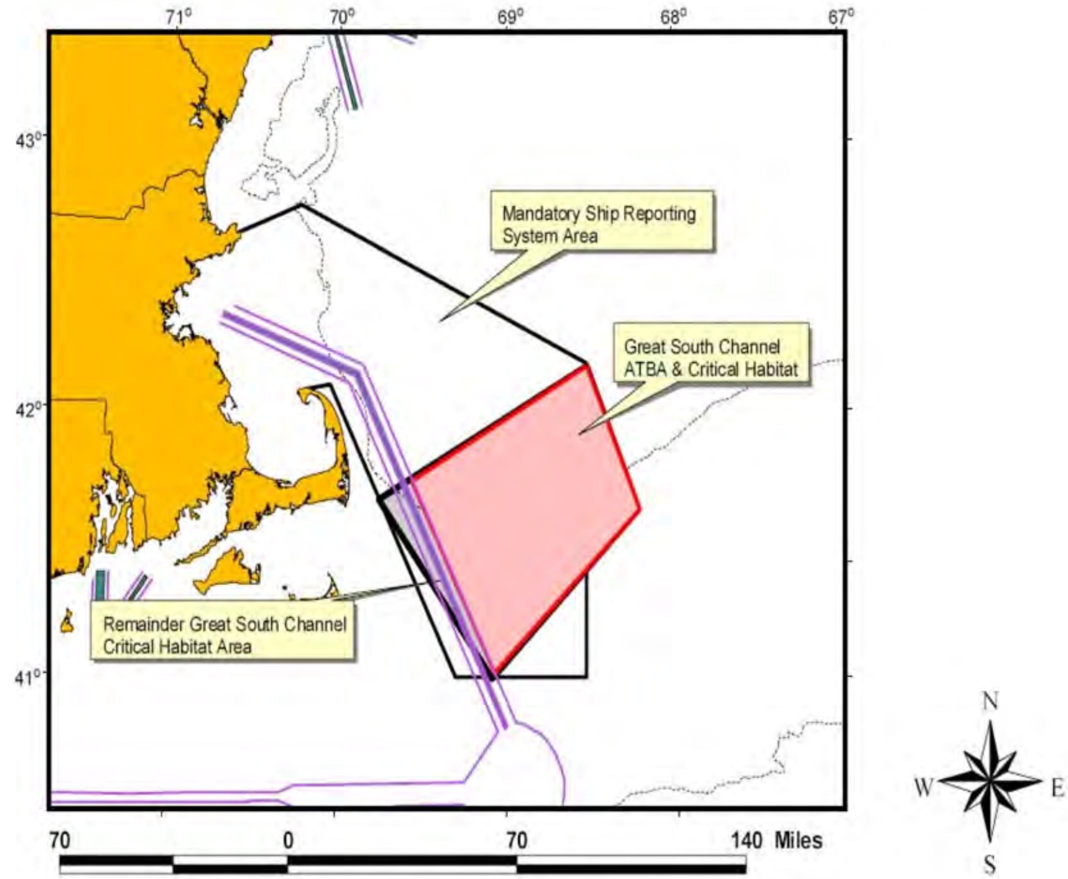


Figure 2. Mandatory Ship Reporting System, proposed Area To Be Avoided (ATBA) and Critical Habitat areas

Figure 1. (*See* Merrick, 2007)

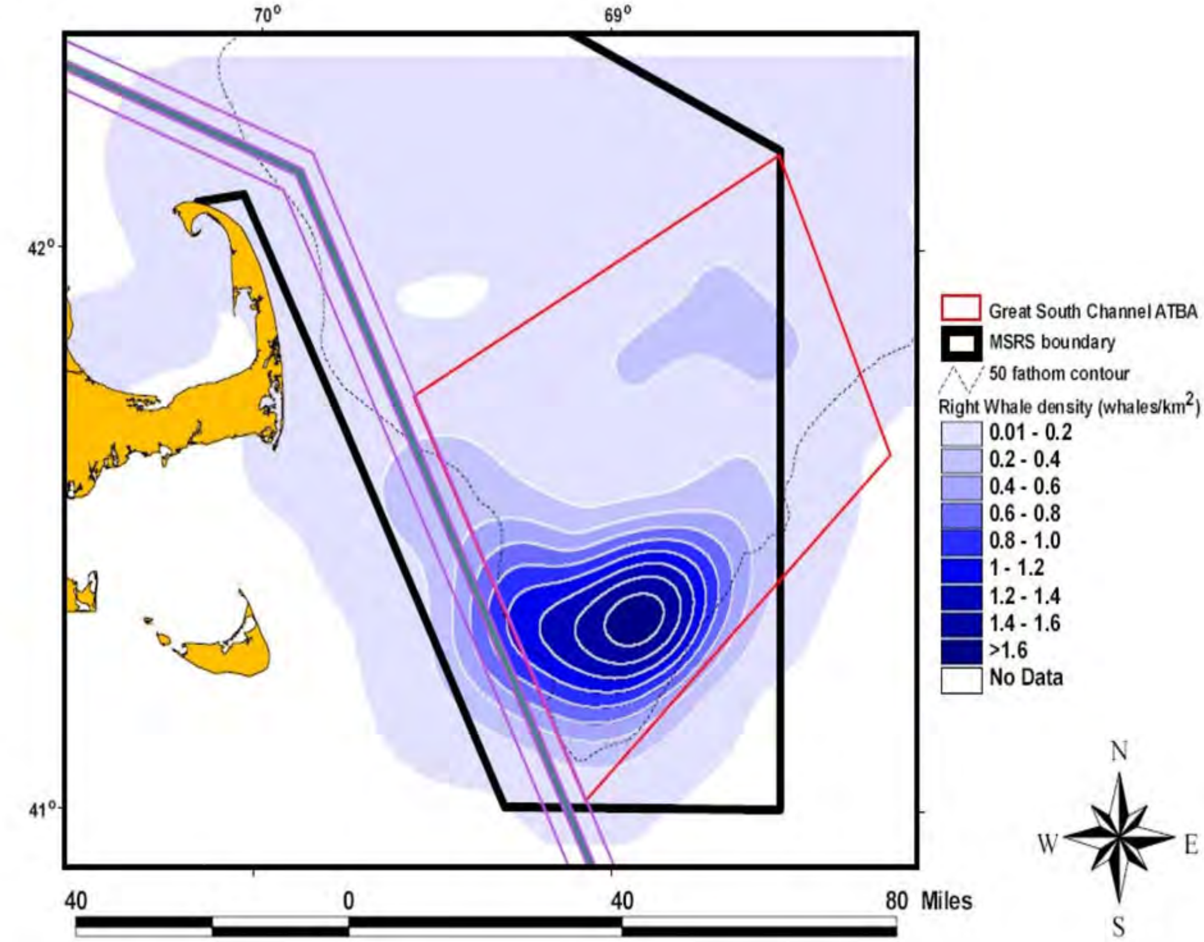


Figure 4. Northern right whale sighting densities (whales/km^2) in the Great South Channel during April–July, 1999–2005 shown with the Great South Channel Area To Be Avoided (ATBA) and Mandatory Ship Reporting System (MSRS) boundary.

Figure 2. (*See* Merrick, 2007)

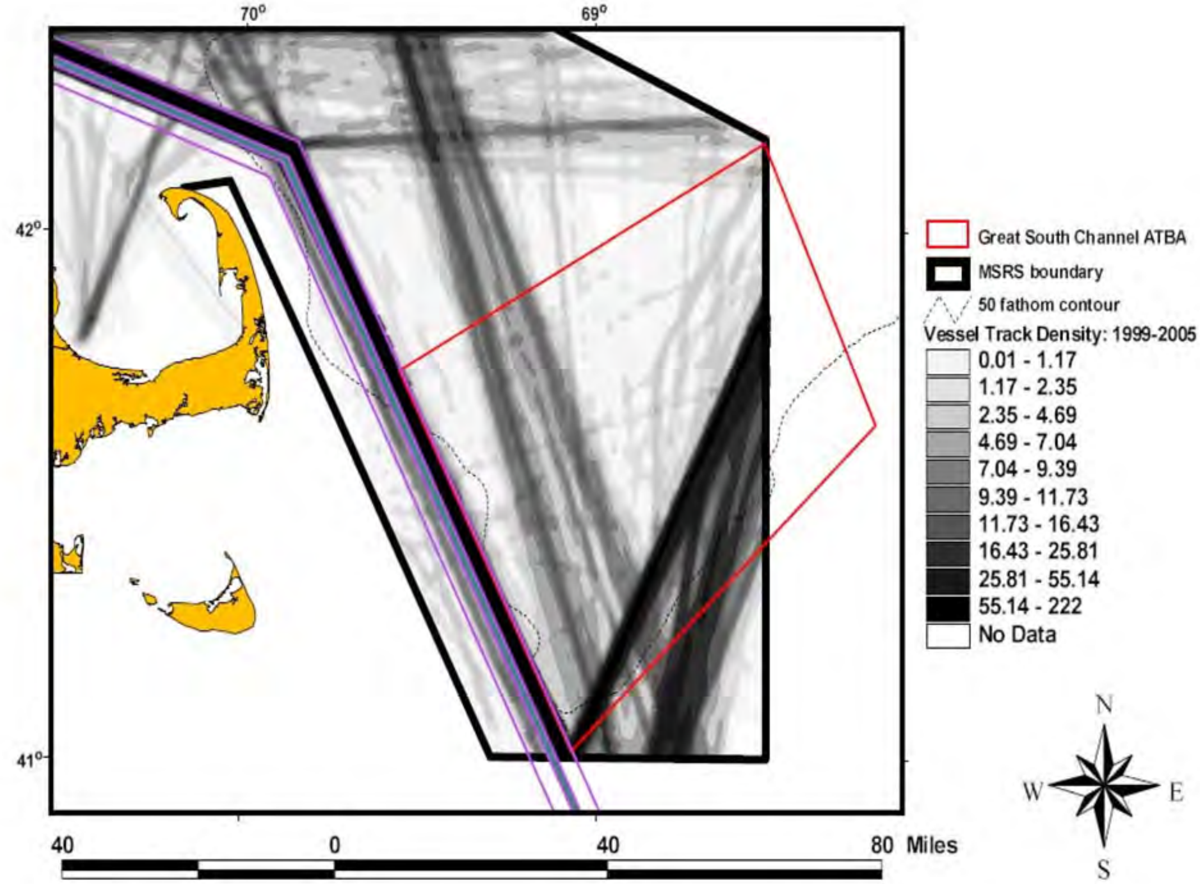


Figure 5. Mandatory ship reporting system (MSRS) boundaries and densities of ship track (km of ship track/km²) through the potential Great South Channel Area To Be Avoided (ATBA for April–July, 1999–2005.

Figure 3. (*See* Merrick, 2007)

IV. ROUTING MEASURES REVIEWED

NMFS considers the use of routing measures an essential component of its Ship Strike Reduction Strategy, because use of such measures by vessels could reduce exposure of right whales to ships and thus reduce the likelihood of a ship strike to the extent practicable, while minimizing adverse impacts on the shipping industry. During the consultation process between the Coast Guard and NMFS, two potential routing measures were discussed to determine applicability and usefulness in protecting right whales from ship strikes. These measures were defined previously and a discussion of their uses and applicability to prevent ship strikes are provided below:

A. *Area to Be Avoided* - is a routing measure that describes an area within defined limits in which vessels would be advised not to enter or avoid because of its vital importance to right whales. Right whales face their highest risk of ship strikes in this area during a four month period because of the significant seasonal whale aggregations that occur and their close proximity to ship traffic. Moreover, it is important to note that there are right whales in this area that are rarely, if ever, seen elsewhere. By "moving" ships away from the right whales' critical habitat and their normal summer feeding grounds, the risk of collision between ships and right whales would be reduced.

B. *Traffic separation scheme (TSS)* – is a measure that separates traffic by having vessels travel in a lane in a particular direction. In addition, the lanes are separated by a separation zone or line. A vessel in a TSS must comply with Rule 10 of the International Regulations for Preventing Collisions at Sea, 1972, as amended (COLREGS). Rule 10 requires that a vessel using a TSS stay within its lane and avoids crossing traffic lanes as far as practicable. TSSs are usually placed at the entrance of a harbor, especially if there is a large volume of vessel traffic that transits to and from the harbor. This measure provides a high level of predictability to ship movements and locations and, if used properly by all vessels in relative proximity to each other, can reduce the risk of collision. TSSs can potentially be located where studies indicate that the exposure of right whales to vessels is lower, thereby potentially reducing the risk of ship strikes.

V. RECOMMENDED RATHER THAN MANDATORY MEASURES

During the consultations between the Coast Guard and NMFS, the issue of whether the ATBA and the TSS should be recommended or mandatory was discussed.

One of the Coast Guard's primary missions is to promote safety at sea. The Coast Guard has found that a key factor in vessel safety is to maintain the ability and responsibility of the ship's master to operate (navigate) a vessel based on surrounding circumstances. Vessel operators must account for a multitude of variables and risks posed by continuously changing elements such as sea state, weather, visibility, vessel condition, and other vessel traffic. Constraining a vessel operator's discretion to act appropriate to circumstances can pose serious risks of collision, grounding, or other casualties with implications for both safety and the greater marine environment. Accordingly, the Coast Guard generally supports the establishment of recommended rather than mandatory routing measures.

NMFS agreed that recommended measures should be pursued, unless compliance with such measures is low. NMFS and the Coast Guard will develop proper monitoring methods and techniques to determine compliance with the measures. If there is non- or low compliance with the recommended measures, steps may be taken to pursue making them mandatory. The agreement by NMFS to proceed with recommended measures is based on an understanding that recommended measures are easier to implement, may be implemented more quickly, and that mariners generally accept and follow such measures.

VI. ROUTING MEASURES FOR THE STUDY AREA

As previously discussed in the original PARS, the Coast Guard noted that NMFS mentioned in its ANPRM that it is considering recommending the establishment of an Area to be Avoided (ATBA) off of Great South Channel. The potential impact of this ATBA is that vessels transiting north and south which previously avoided using the TSS may begin to use the TSS because they would be prohibited or advised to avoid passing through the ATBA and could potentially have a shorter voyage through the TSS than by going around the ATBA and George's Bank to the east. These vessels would leave the lanes once past the boundaries of the ATBA. Right whales occupy the area north of the ATBA. (*See* Merrick, 2005). Therefore, it may be necessary to create additional routing measures such as another TSS or two-way route that would break off to the north from the existing TSS where the risk of right whale and vessel interaction may potentially be lower. Both NMFS and the Coast Guard will continue to investigate this possible shift in vessel traffic patterns and determine the validity and necessity of creating additional routing measures.

Because the proposed seasonal ATBA would overlap the existing TSS, it would then become necessary to amend the Boston TSS in that section that runs parallel to Cape Cod (north – south orientation). The amended TSS would consist of traffic lanes 1.5 nautical miles wide vice their current 2 nautical mile width. Based on advances in vessel navigation, the Coast Guard believes that 1.5 mile lanes would provide a sufficient margin of safety. The separation zone dimensions would remain the same. These dimensions will now be uniform throughout the entire length of the TSS in the approaches to Boston. Also, the current western edge of the TSS remains where it is currently located (figures 4 through 6).

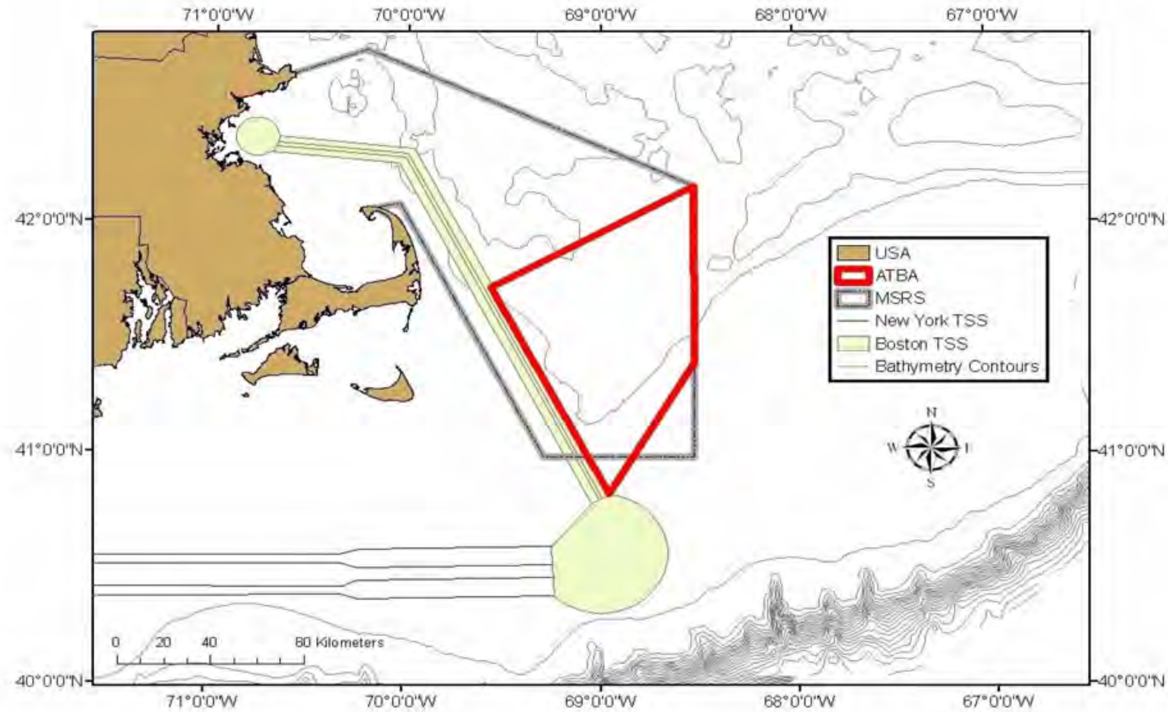


Figure 4. Proposed ATBA (in red). Note overlap with TSS.

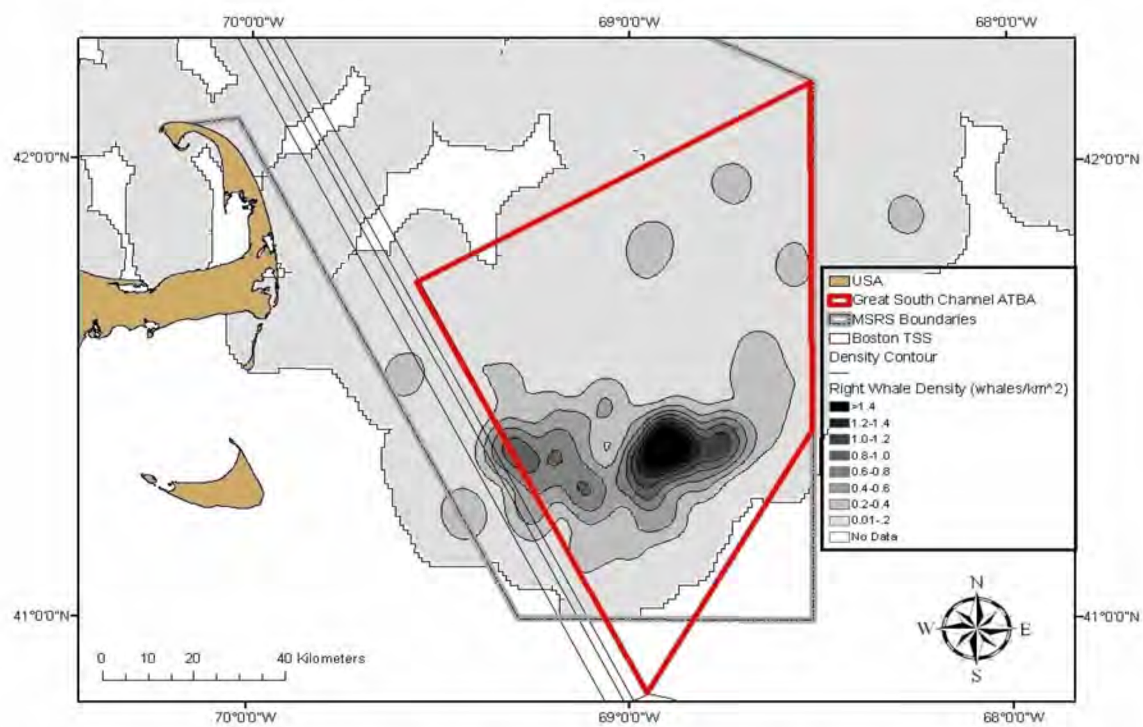


Figure 5. Proposed ATBA (in red) in relation to right whale density.

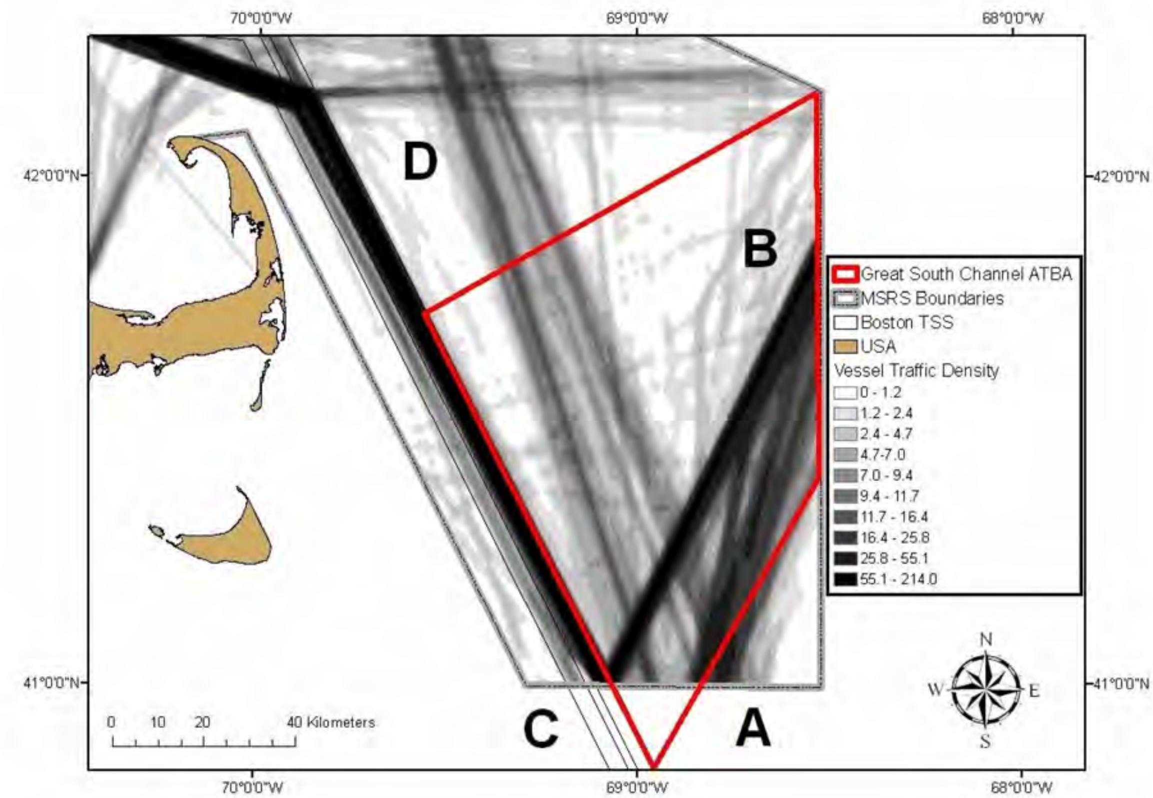


Figure 6. ATBA in relation to shipping tracks.

VIII. SUMMARY OF RECOMMENDATIONS

The Coast Guard summarizes its recommendations as:

- Create a seasonal Area To Be Avoided (ATBA) as shown, and
- Amend the TSS in the Approach to Boston, MA.

IX. FUTURE ACTION ITEMS

The following are action items that may be required as a result of this PARS:

- The U. S. Government will develop and submit to IMO documents for amending the Boston TSS and the establishing of the Great South Channel ATBA;
- USCG will publish a final notice of study results;
- Maritime community and other stakeholders to be advised of routing measures;
- Aids to navigation to be added, moved or removed to accommodate or mark new routing measures; and
- If any regulations are necessary, such regulations will be promulgated by the appropriate agency.

X. REFERENCES

Merrick, R. 2005. Seasonal management areas to reduce ship strikes of Northern right whales in the Gulf of Maine. Northeast Fisheries Science Center.

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Russell, B., A.R. Knowlton, J. B. Ring. 2003. Vessel traffic management scenarios based on recommended measures to reduce ship strikes of Northern right whales.

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THE PORT ACCESS STUDY PROCESS

A Port Access Route Study (PARS) is usually conducted at the District level. A Notice of Study (NOS) is first published in the Federal Register. Any such notice will identify the study area, provide the reasons for the PARS, and invite public comments and additional information. PARS can take from 1- 3 years to complete.
The following outlines the PARS process:

1. Determine if PARS is required. The District Commander must determine if a PARS is required. This decision may be made based on--

   a. A request from a private party. This request should propose a study in a particular area, identify problems due to the lack of vessel routing measures, identify problems with existing vessel routing measures, and provide possible solutions or alternatives to the present situation in the waterway;

   b. New information. The District Commander is made aware of the need for new or modified vessel routing measures due to increased Outer Continental Shelf (OCS) activities, port development or improvements, increase or decrease in vessel traffic flow and congestion, or any other factors or information deemed appropriate; and a

   c. Review of previous PARS. The District Commander will review any previous PARS for the identified study area and will determine if any conditions or information has significantly changed enough since the last PARS to justify a new study.

2. Identify the study area. The District Commander must identify the applicable geographic study area. The study area must be large enough to consider all activities that may affect or be affected by new or modified existing vessel routing measures.

3. Prepare a draft Notice of PARS. The District Commander will prepare a draft Notice of PARS. The notice will--

   a. Delineate the study area and provide a summary of the reasons for the PARS;

   b. Invite submission of public comments and additional information. Instructions will be provided on how and where to send comments and information;

   c. Present issues and ask specific questions for which we are seeking answers; and

   d. Explain any contemplated vessel routing measures and any associated legal effect of those measures.

4. Publication of the Notice of PARS. The District Commander will ensure publication of the notice in the Federal Register.

5. Conducting the Study. There are various methods to conduct a study. The following provides a basic framework for conducting the PARS. District Commanders are encouraged to modify or expand this framework as necessary and to direct any questions concerning the PARS process to Commandant (CG-NAV).

   a. Collect and analyze data and other information on—

      1) Vessel traffic characteristics and trends (both existing and potential), including traffic volume, size and types of vessels, potential interference with the flow of commercial traffic, presence of any unusual cargoes, and other similar information;

      2) Fishing activity;

      3) Recreational boating traffic;

      4) Commercial ferry traffic;

      5) Military activities;

      6) Existing and potential OCS resource development activities;

      7) Environmental information and factors which may be impacted by potential or amended vessel routing measures;

      8) Underway and projected dredging projects;

      9) Port development activities;

      10) Native American Tribal activities and impacts of potential or amended vessel routing measures;

      11) Economic (cost and benefit) effects and impacts; and

      12) Information that arises as a result of public comments.

   b. Notifications and consultations. The District Commander will notify and consult with all Federal, State, tribal and local government agencies located in or near the PARS study area that may be affected by the results of the PARS. If these actions are unsuccessful at the District level, then the District Commander will notify Commandant (CG-NAV) who will initiate contact and advise the applicable government agencies of the PARS. The District Commander should also notify and consult with representatives of the maritime community, port and harbor authorities/associations, pilot associations, and any other local customer or interest group deemed appropriate.

   c. Public meetings. The District Commander should conduct public meetings if deemed necessary or if requested by an interested party. A Notice of Meeting must be published in the Federal Register.

   d. Other uses. The District Commander will consider other uses of the marine environment in the PARS area such as:

1) The exploration for or exploitation of oil, gas, or other mineral resources.

2) The construction or operation of deepwater ports, renewable energy installations or other structures on or above the seabed or subsoil of the submerged lands or the OCS of the United States.

3) The establishment or operation of marine or estuarine sanctuaries.

4) Activities involving recreational or commercial fishing or diving.

6. Final PARS Report. The District Commander will publish a final PARS report and forward a copy of the report to Commandant (CG-NAV). The following provides a basic format for the report:

a. Introduction. This provides a general overview of the study.

b. Background. This may include such items as statutory authority, definition of terms, description of study area, and history.

c. Maritime trends and analysis. These may include statistics, projections, and any other pertinent data.

d. New Issues.

e. Summary and conclusion.

f. Recommendations.

g. Enclosures. These could be any supporting documents such as other studies.

h. Appendices. These could include spreadsheets and charts.

The public may be afforded another opportunity to comment on the Final PARS Report. The District Commander should make this determination based on the level of public participation in the study and the whether there was significant disagreement or controversy on possible outcomes of the study. If another public comment period is warranted, the input received could alter the study results.

7. Notice of Study Results. After the PARS is received and reviewed, Commandant (CG-NAV) will work with the District Commander to draft a Notice of Study Results, which will be published in the Federal Register. This completes the PARS process; no further public input will be considered.

8. Implementation. PARS results help program managers establish traffic routing measures, fairways, TSS, limited access areas, recommended routes and regulated navigation areas. They may provide justification for regulatory projects or submissions to the International Maritime Organization (IMO). If the PARS recommends vessel routing measures, Commandant (CG-NAV) will validate the recommendations and initiate the Federal rulemaking process and/or IMO's ships routing measures process.

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How does it work?

How does it work?

Global Fishing Watch processes data using machine learning to identify where and when fishing is occurring on a global scale. We're employing a class of machine learning models called neural networks (NNs) to help us process all those AIS or VMS messages and to help us determine commercial

How can we he

FAQs

fishing activity based on the vessel's movements on the water. To determine when vessels are fishing, we're using a NN to assign a "yes" score when vessels are actively fishing and a "no" score when they aren't. We also designed a NN to figure out what types of vessels we are seeing—whether they are longliners, purse seiners, trawlers, or other.

In both cases, we give the computer a huge amount of AIS data that we've already analyzed and labeled by fishing score or vessel classification depending on what we're training it to find. We call that the training data set. The computer sifts through it, finding patterns and determining which features are relevant and which aren't. The computer then creates an algorithm, a set of rules that can be used to evaluate other AIS data and tell us what we want to know.

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North Atlantic Right Whale (*Eubalaena glacialis*) Vessel Speed Rule Assessment

June 2020

NOAA Fisheries, Office of Protected Resources

EXECUTIVE SUMMARY

The North Atlantic right whale (*Eubalaena glacialis*) remains one of the most endangered large whales in the world with an estimated population size of about 400 individuals at the end of 2018 (Pace et al. 2017; Hayes et al. 2019). Despite decades of protection, a combination of anthropogenic impacts and a low calving rate continue to impede recovery of the species (Kraus et al. 2016; Corkeron et al. 2018; Hayes et al. 2019). The most pressing threats to right whale survival include entanglement in fishing gear and collisions with vessels, which combined are responsible for a minimum of 86 mortalities and serious injuries in the U.S. and Canada between 2000 and 2017 (Waring et al. 2004; Waring et al. 2009; Waring et al. 2013; Hayes et al. 2019) representing approximately 20% of the extant population.

In 2008, the National Marine Fisheries Service (NMFS) implemented a seasonal, mandatory vessel speed rule in certain areas along the U.S. East Coast to reduce the risk of vessel collisions with right whales. We conducted a review of the speed rule to evaluate how effective it is at reducing the incidence of right whale mortality and serious injury due to vessel strikes and where it could be improved. While it is not possible to determine a direct causal link, the number of documented vessel strike mortalities and serious injuries decreased from 12 during the 10 years prior to the rule's implementation to 8 in the 10 years since implementation. This overall decline demonstrates progress but also indicates additional action is warranted to further reduce the threat of vessel collisions.

The level of mariner compliance with the speed rule increased to its highest level (81%) during 2018-2019. In most Seasonal Management Areas (SMAs) more than 85% of vessels subject to the rule maintained speeds under 10 knots, but in some portions of SMAs mariner compliance is low, with rates below 25% for the largest commercial vessels outside four ports in the southeast.

Evaluations of vessel traffic in active SMAs revealed a reduction in vessel speeds over time, even during periods when SMAs were inactive. An assessment of the voluntary Dynamic Management Area (DMA) program found limited mariner cooperation that fell well short of levels reached in mandatory SMAs. An examination of AIS-equipped small vessel traffic (< 65 ft in length) in SMAs, not subject to the rule, found the densest activity in the Mid-Atlantic where less than 50% of transit distance was below 10 knots. Off New England, small vessel traffic was sparser with 83% of transit distance under 10 knots.

Our investigation of navigational safety revealed no indication of impacts from implementation of the speed rule. Finally, an economic impact assessment was conducted to evaluate the cost of compliance to the regulated community. The yearly cost to industry is estimated to be $28.3 to $39.4 million annually, with the majority of the cost (58 -70%) borne by the container ship sector.

Findings from this review include recommendations for further action, including addressing low compliance in some SMA port entrance areas and insufficient cooperation with voluntary DMAs. More attention is needed to further investigate the impact of non-lethal vessel collision injuries to right whales, assess conservation concerns with small vessel traffic and strengthen our ability to enforce the speed regulations.

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ACRONYM LIST

ATBA - Area To Be Avoided
AIS - Automatic Identification System
CVI - Clean Vessel Incentive
DWAS - Distance Weighted Average Speed
DMA - Dynamic Management Area
ECAs - Emission Control Areas
ESA - Endangered Species Act
FR - Federal Register
gt - gross tons
IEc - Industrial Economics, Inc.
IHS Markit - Information Handling Service Markit
IMO - International Maritime Organization
MARPOL - International Convention for the Prevention of Pollution from Ships
MMPA – Marine Mammal Protection Act
MSRS - Mandatory Ship Reporting System
NDBC - National Data Buoy Center
NGA - National Geospatial Intelligence Agency
NMFS - National Marine Fisheries Service
NMS - National Marine Sanctuary
nm - nautical miles
NOAA - National Oceanic and Atmospheric Administration
NOAA GC - NOAA Office of General Counsel
NOS – National Ocean Service
NOVA - Notices of Violation and Assessment of Administrative Penalty
OCS - NOAA Office of Coast Survey
OGV - Ocean Going Vessel
OLE - NOAA Office of Law Enforcement
OPR - Office of Protected Resources
SMA - Seasonal Management Area
TSS - Traffic Separation Scheme
USACE - United States Army Corps of Engineers
USCG - United States Coast Guard

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Cover photo: North Atlantic Right Whale (#3522); taken under NMFS/NOAA permit 655-1652-01 under the authority of the Marine Mammal Protection Act and the U.S. Endangered Species Act. Photo Credit: Brenna Kraus/New England Aquarium

A NOTE ON VESSEL TERMINOLOGY

The following definitions are provided to offer clarity and ensure that the reader understands the vessel terminology used in this report. For the purposes of this report we offer the following explanations:

1. **Ocean Going Vessels (OGVs)** are the largest vessels in operation and are subject to the speed rule. They include only the following vessel types: tankers, cruise ships, container ships, vehicle carriers (commonly referred to as "roll on-roll off" or Ro-Ros), general cargo vessels and bulk carriers.
    i. Within the OGV category, three size classes are commonly used based on terminology for vessels sized for travel through the Panama Canal. For the purposes of this report we use the following definitions:
        i. **Sub-Panamax Vessels**: maximum length overall = 676 feet (ft)
        ii. **Panamax Vessels**: maximum length overall = 966 ft
        iii. **Post-Panamax Vessels**: maximum length overall = 1,201 ft
2. **Mid-sized vessels** are equal to or greater than 65 ft in length and mostly less than 350 ft in length. These vessels are subject to the speed rule and include vessel types such as; towing and pushing, pleasure, fishing, sailboats, whale watching, and most passenger ferries.
3. **Small vessels** are any vessel less than 65 ft in length. These vessels are <u>not</u> subject to the speed rule.
4. **Exempted vessels** are those not subject to the speed rule due to an explicit exemption not related to vessel size. These exempted vessels include mostly military vessels, vessels owned, operated, or contracted by the federal government, and state law enforcement vessels engaged in enforcement or search and rescue activities.

PURPOSE OF THE REPORT

In an effort to reduce the threat of vessel collisions with right whales, the National Marine Fisheries Service (NMFS) implemented a novel rule requiring most vessels equal to or greater than 65 ft in length to transit at speeds of 10 knots or less in designated Seasonal Management Areas (SMAs) along the U.S. East Coast (73 FR 60173, October 10, 2008). The 2008 speed rule included the designation of ten SMAs between Massachusetts and Florida informed by the best available information regarding vessel traffic characteristics and right whale distribution at the time.

In 2013, NMFS published a final rule removing the “sunset clause” from vessel speed restrictions implemented in 2008 (78 FR 73726, December 9, 2013). As part of this action, NMFS committed to publish and seek comment on a report evaluating the conservation value and economic and navigational safety impacts of the rule (50 CFR § 224.105). This report evaluates four aspects of the right whale vessel speed rule: biological efficacy, mariner compliance, impacts to navigational safety, and economic cost to mariners. The report also assesses general trends in vessel traffic characteristics within SMAs over time, provides a detailed assessment of the speed rule’s effectiveness and offers recommendations for strengthening the rule based on these findings.

In addition to the assessment of the vessel speed rule, this report evaluates mariner cooperation with the Dynamic Area Management (DMA) program and investigates small vessel transits patterns through active SMAs.

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BACKGROUND ON RIGHT WHALES AND VESSEL COLLISIONS

The North Atlantic right whale (hereafter "right whale") remains one of the most endangered large whales in the world with an estimated population size of about 400 individuals at the end of 2018 (Pace et al. 2017; Hayes et al. 2019). Despite decades of protection, a combination of anthropogenic impacts and a low calving rate continue to impede recovery of the species (Kraus et al. 2016; Corkeron et al. 2018; Hayes et al. 2019). With fewer than 100 reproductive females, any mortality or serious injury hinders recovery. Currently, the most pressing threats to right whale survival include entanglement in fishing gear and collisions with vessels, which combined are responsible for a minimum of 86 mortalities and serious injuries in the U.S. and Canada between 2000 and 2017 (Waring et al. 2004; Waring et al. 2009; Waring et al. 2013; Hayes et al. 2019) representing approximately 20% of the extant population.

Right whales range widely across the Northwest Atlantic Ocean mostly along the U.S. and Canadian coasts, although some whales are known to travel to the northeast Atlantic periodically (Figure 1; Knowlton et al. 1992; Silva et al. 2012, Davis et al. 2017). Their primary foraging grounds include the greater Gulf of Maine region, Scotian Shelf, and the Gulf of St. Lawrence (Pershing et al. 2009; Davies et al. 2014; Simard et al. 2019). The species' only known winter calving ground lies within the South Atlantic Bight between northern Florida and North Carolina (Keller et al. 2012; Gowan et al. 2014).

Right whales inhabit U.S. waters year-round, but predominate during late fall through early summer. Right whale distribution changes seasonally, and over time the whales favor different foraging habitats based on the quality and abundance of available prey (Pendleton et al. 2012; Record et al, 2019; Davies et al. 2019). Since 2010, broad shifts in habitat preference have led to new high use areas in U.S. waters such as the region south of Martha's Vineyard and Nantucket, MA (Leiter et al. 2017) and increased the risk from anthropogenic threats as the whales moved into habitats with fewer protections in Canadian waters (Meyer-Gutbrod et al. 2018).

The whales' distribution includes seasonal coastal habitats characterized by extensive vessel traffic, which results in increased risk of collisions with vessels, or vessel "strikes". Since 2008, eight right whale mortalities and serious injuries from vessel collisions occurred in (or near) U.S. waters (for details see section "Right Whale Vessel Strikes in U.S. Waters Since 2008"). Right whales experience two main types of vessel interaction injuries: contact with the vessel hull leading to a blunt force trauma injury, and/or contact with the hull or propeller leading to sharp trauma and laceration injuries (Moore et al. 2013; Sharp et al. 2019). Hydrodynamic modeling of whale-vessel interactions indicates that when whale-vessel contact occurs at the surface, whales are more likely to experience blunt force trauma injuries, whereas when contact occurs sub-surface, whales are more likely to be pulled toward the propeller and suffer lacerations (Silber et al. 2010). Furthermore, modeling indicates the intensity of impact and risk of serious injury and/or mortality increases with higher vessel speed (Vanderlaan and Taggart, 2007; Silber et al. 2010; Conn and Silber, 2013).

Right whales are also susceptible to non-contact harassment by vessels which can include disturbance to essential behaviors such as feeding, nursing and communication. Vessel noise can be especially problematic for right whales. Studies indicate low-frequency vessel noise can mask the whales' vocalizations (Clark et al. 2009; Hatch et al. 2012) and that right whales have vocally adapted to noisy environments by modifying the duration and frequency of their vocalizations (Parks et al. 2009; Parks et al. 2011). The pervasiveness of vessel activity in and around right whale habitats can also cause disturbance. In the Bay of Fundy, right whales' stress hormone levels declined following a sudden reduction in vessel traffic and low-frequency vessel noise (Rolland et al. 2012).

Vessel traffic along the U.S. East Coast is extensive and overlaps substantially with important right whale habitats. This traffic includes thousands of the largest ocean going vessels (OGVs) and small/mid-sized recreational, fishing, and other commercial vessels (Table 1). Five of the largest ports in the U.S. are found in this area including the ports of New York/New Jersey, Savannah, Virginia, Charleston and Baltimore. The most common vessel types (> 65 ft) transiting SMAs include fishing boats, pushing/towing vessels and container ships which combined comprised the majority (56%) of total vessel transit distance in active SMAs in 2018-2019.

In most cases, OGVs cannot reasonably be expected to sight whales nor take evasive action to avoid striking whales due to the vessels' enormous size and restricted maneuverability. OGVs operate at night and in poor weather and can strike a whale without perception by those on board. This is best illustrated by instances when OGVs have unknowingly arrived in port with a large whale draped across their bows. Given these realities, spatial distancing and preventatively slowing the speed of OGVs are currently the best strategies to prevent vessels of this size striking whales.

Some mid-sized and small vessels possess the maneuverability to take evasive action if whales are sighted and are more likely to perceive a whale strike. Whale detectability and safe maneuverability, however, can impede a swift response to a sudden whale sighting. Vessel strikes can occur even when circumstances are seemingly optimal for avoidance as illustrated by two right whale vessel strikes involving small research vessels that occurred in Cape Cod Bay during daylight hours (Wiley et al. 2016). In both cases, the vessels (<65 ft) had experienced mariners and whale observers on board. In one case, the vessel was traveling at ~9 knots in excellent conditions, yet the whale was not seen prior to the collision. In the other case, the vessel was returning to port transiting at ~20 knots with winds > 20 knots and 1.3 m seas. The whale was sighted just prior to impact preventing evasive action by the vessel operator. These events illustrate the unpredictability of collisions and how strikes can occur when even vigilant mariners operate in the vicinity of large whales.

There are many cases from around the world of vessels sustaining significant damage, and even sinking, following collisions with whales. For example, in March of 2009 a 30-foot pleasure craft collided with a whale off Hilton Head, SC and sustained damage significant enough to require passenger rescue by the United States Coast Guard (USCG). The whale, of undetermined species, was also injured with large amounts of blood reported in the water. Sailing vessels are at particular risk of substantial damage due to their deliberately light construction (Ritter, 2012). For small and mid-sized vessels, whale awareness is a matter of safety for both mariners and whales.

Right whales are particularly vulnerable to vessel strike due to their penchant for coastal habitats and frequent occurrence at near surface depths. In some habitats, such as Cape Cod Bay, right whales often forage just below the water's surface, rendering them hidden to mariners but vulnerable to vessel collisions (Mayo and Marx, 1990; Parks et al. 2012). Mothers with newborn calves frequently rest and nurse in nearshore habitats at or near the water surface placing them at high risk of vessel interactions on southeast calving grounds, along the mid-Atlantic migratory corridor and in New England (Cusano et al. 2018).

Researchers lack a full understanding of how right whales perceive and react to vessel traffic. A whale's response to an approaching vessel may be influenced by its activity state, ability to detect the vessel, and position in the water column relative to the vessel. Studies of right whale reactions to vessel noise indicate a lack of response, possibly from habituation to vessel noise (Nowacek et al. 2004). Right whales' positive buoyancy near the ocean surface may also be problematic for risk avoidance. When diving at the surface, their buoyancy may slow descent and when passively ascending they may lack the maneuverability to take vertically evasive action to avoid a vessel at the surface (Nowacek et al. 2001). There is evidence, however, that some whales can and do take evasive action when encountering vessel traffic (Szesciorka et al. 2019) and that slowing vessel speeds assists whales with vessel avoidance (Gende et al. 2011; Conn and Silber, 2013).

Numerous modeling exercises have indicated that slowing the speed of vessels reduces the risk of lethal vessel collisions, particularly in areas where right whales are abundant and vessel traffic is common and otherwise traveling at high speeds (Vanderlaan and Taggert, 2007; Conn and Silber, 2013; Van der Hoop et al. 2014; Martin et al. 2015; Crum et al. 2019). Previous investigations indicate that the speed rule has effectively reduced the risk of vessel strikes to right whales (Conn and Silber, 2013; Laist et al. 2014; Crum et al. 2019). The increased use of recommended routes through SMAs may also be contributing to a reduction in vessel strike risk (Crum et al. 2019). These key management tools, reducing vessel speed and separating whales and vessels via routing measures, continue to offer the most effective options available to reduce vessel collisions with right whales in U.S. waters.

VESSEL STRIKE PREVENTION: REGULATIONS AND PROGRAMS

NMFS has implemented a multi-pronged approach towards mitigating vessel strike risk to right whales. These efforts rely on a combination of regulatory requirements, voluntary programs, and outreach efforts aimed at modifying mariner behavior and/or increasing mariner awareness of right whale presence. Together, these efforts address three aspects of reducing vessel strike risk: 1) reducing the spatial overlap of right whales and vessels, 2) reducing the speed of vessels transiting through right whale habitat, and 3) promoting mariner awareness of right whale presence. While we lack a full understanding of vessel strike risk and how right whales perceive vessel traffic, all agency programs are based on the best available data regarding the nature of vessel strike risk, right whale distribution, and vessel traffic patterns. Below is a summary of vessel strike reduction actions implemented by NMFS and other federal partners to date.

Statutory Protections

"Take" Prohibitions

Both the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA) generally prohibit the unauthorized "take" of North Atlantic right whales. Under the ESA, "take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." (16 USC § 1532(19)). Under the MMPA, "take means to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill." (16 USC § 1362(13)).

ESA Section 7 Consultations

As required by Section 7(a)(2) of the ESA, as amended (ESA; 16 U.S.C. §1531 et seq.), all U.S. Federal agencies must consult with NMFS to ensure that any actions they authorize, fund, or carry out that may affect ESA listed species under NMFS jurisdiction are not likely to jeopardize the continued existence of those species or adversely modify or destroy their designated critical habitat. As part of the Section 7 consultation process, NMFS and its federal partners regularly evaluate vessel strike risk to right whales and, where appropriate, NMFS recommends federal agencies implement reasonable and prudent measures to minimize such risk.

Regulatory Protections

500 Yard Minimum Approach Distance

In 1997, NMFS implemented a minimum approach distance for vessels in the vicinity of right whales in an effort to reduce harassment and risk of injury (62 FR 6729, February 13, 1997). It is illegal for a vessel to approach within 500 yards (1,500 ft) of a right whale and if a vessel finds itself within 500 yards it "must steer a course away from the right whale and immediately leave the area at a slow safe speed" (50 CFR § 224.103(c)(1-2)). Exceptions are made if "compliance would create an imminent or serious threat to a…..vessel". (50 CFR § 224.103(c)(3)). These regulations were promulgated under the authority of the ESA and MMPA.

Right Whale Vessel Speed Rule

In 2008, NMFS implemented a rule (hereafter "speed rule") requiring most vessels equal to or greater than 65 ft in length to transit at speeds of 10 knots or less in designated SMAs (73 FR 60173, October 10, 2008) pursuant to its authority under the MMPA and ESA. Some vessels are exempt from this requirement including military vessels, vessels owned, operated or contracted by the federal government, and vessels engaged in enforcement or search and rescue activities. (50 CFR § 224.105(a)). Although these vessels are exempt from the speed rule they are not exempt from consultation under Section 7 of the ESA. During consultations, mitigation measures, including speed restrictions, may be recommended to reduce the threat of vessels collisions with right whales. In addition, subject to specific requirements, vessels may deviate from the speed restriction (i.e., exceed the speed limit), under limited circumstances, to maintain safe maneuvering speeds (50 CFR § 224.105(c)). Vessels employing this safety deviation must make a notation in the vessel log detailing the event.

Ten SMAs were designated along the U.S. East Coast with seasonally active periods reflective of temporal trends in right whale habitat use (Figure 2), and are depicted on NOAA navigational charts. The location of the SMAs was informed by vessel traffic (i.e. port entrances were assumed high traffic areas relative to other areas) and right whale distribution data at the time the rule was established. NMFS selected the 10-knot speed limit based on analyses of large whale vessel strike events where the vessel speed at the time of impact was known. Researchers found the probability of whale mortality increased substantially with vessel speed, with the greatest increase occurring between speed of 10 to 14 knots (Vanderlaan and Taggert, 2007). Based on these findings, NMFS determined that the use of speed restrictions was an effective means to reduce the likelihood and severity of vessel collisions.

Mandatory Ship Reporting (MSR) System

In 1998, a mandatory reporting program for all vessels > 300 gross tons was introduced in important right whale habitat areas off New England and Florida/Georgia (66 FR 58066, November 20, 2001) under the authority of the Ports and Waterways Safety Act. Under the provisions of the MSR program, applicable vessels are required to report to the USCG when entering either of the two MSR areas. In response, reporting vessels receive an automated message that provides information about the latest right whale sightings, right whale vulnerability to vessel collisions, and actions mariners can take to avoid collisions. The MSR boundary is included on NOAA navigational charts.

Non-Regulatory Actions

Great South Channel Area To Be Avoided (ATBA)

An ATBA is an International Maritime Organization (IMO) established vessel routing measure within a specified area to avoid navigational hazards or environmentally sensitive areas. In June 2009, an ATBA was established in the Great South Channel to the east of Cape Cod, MA after gaining approval from the IMO. Due to frequent right whale foraging aggregations in the area, all vessels ≥ 300 gross tons (gt) are recommended to avoid this area between April 1 and July 31. The Great South Channel ATBA is included on NOAA navigational charts.

Recommended Routes

In 2006, a joint USCG/NOAA effort established recommended routes for vessels transiting across Cape Cod Bay and into/out of ports in Florida and Georgia. The routes are recommended between January and May in Cape Cod Bay and between November and April off Florida and Georgia. Mariners are recommended to follow the routes to minimize their transit distance through important right whale habitat areas. NMFS continues to monitor the routes and there is evidence of regular mariner use of routes in the southeast (Crum et al. 2019). If the routes are not routinely used, consideration may be given to making the routes mandatory. All recommended routes are included on NOAA navigational charts.

Modification to the Boston Traffic Separation Scheme (TSS)

In 2007, following a successful application to the IMO led by the Stellwagen Bank National Marine Sanctuary and NMFS, a modified TSS (commonly referred to as a shipping lane) was implemented to the north of Cape Cod, MA for vessel traffic navigating to and from the Port of Boston. The modification narrowed the TSS and shifted its route to the north around Cape Cod to reduce the overlap with large whale foraging grounds. The Boston TSS is included on NOAA navigational charts.

Dynamic Management Areas (DMA)

The agency acknowledged that right whale foraging aggregations may form outside of designated SMA boundaries, thus leaving these aggregations without protection from fast moving vessels. To address this, NMFS implemented a voluntary DMA program concurrently with the mandatory speed rule. A DMA is triggered when a group of 3 or more right whales are sighted in close proximity. Following the trigger, NMFS establishes a DMA boundary around the whales for 15 days and encourages vessels either to avoid the area or transit through at speeds less than 10 knots. DMAs may be extended if whales remain in the area. The agency alerts mariners to DMA declarations through emails to lists of interested parties, Local Notices to Mariners, and Broadcast Notices to Mariners.

Increasing Global Use of Vessel Speed Limits for Whale Protection

Since implementation of the speed rule in 2008, the use of mandatory, voluntary and incentive-based speed limits has become a core strategy to reduce the risk of large whale vessel strikes globally. The speed rule and associated SMAs have been cited as exemplar programs by other nations, including Canada, when they reviewed options to reduce vessel strike risk in Canadian waters in 2017 (DFO, 2017). Below are examples of voluntary and mandatory speed restrictions in place today:

1. In January 2007, Spain became the first nation to initiate a voluntary speed measure (< 13 knots) to protect whales in the Strait of Gibraltar shipping lanes (Silber et al. 2012).

2. NOAA has long encouraged vessels to reduce speed in whale habitat areas along the California coast. Starting in 2008 in the Santa Barbara Channel and 2014 off San

Francisco, NOAA formally introduced voluntary 10-knot speed restrictions for vessels 300 gt or larger. Vessels are requested to slow to 10 knots between May 1 - November 15 each year within the Vessel Speed Reduction Zone off San Francisco Bay and May 15 - November 15 in the Whale Advisory Vessel Speed Reduction Zone off southern California.

3. In June 2013, Canada implemented a voluntary 10-knot speed reduction zone in the Gulf of St. Lawrence Estuary to reduce the risk of vessel strikes for several whale species (Chion et al. 2017).

4. In September 2013, the Port of Auckland implemented the Hauraki Gulf Transit Protocol for Commercial Shipping, which included a voluntary speed restriction of 10 knots for vessels transiting the Hauraki Gulf to protect endangered Bryde's whales (Constantine et al. 2015). Cooperation with the speed reduction program is strong.

5. In 2014, a collaborative effort between NOAA's Channel Islands National Marine Sanctuary (NMS) and county level Air Pollution Control Districts called "Protecting Blue Whales and Blue Skies" began offering financial and positive public relations incentives to participating shipping companies that voluntarily slowed their vessels to 10 knots or less in designated areas along the California coast. This program is unique in having multiple goals of reducing the risk of large whale vessel collisions, reducing pollution emissions from Ocean OGVs along the California coast, and an additional benefit of reducing ocean noise. Since its inception, the program has expanded to include the central coast National Marine Sanctuaries (NMSs) and the Bay Area Air Quality Management District off San Francisco Bay.

6. In December 2014, the Panama Canal Authority implemented a mandatory 10-knot seasonal speed limit in designated areas within the Gulf of Panama from August 1 to November 30 each year to protect humpback whales and other cetaceans (IMO, 2016).

7. In the summer of 2017, following a series of right whale deaths in the Gulf of St. Lawrence, Canada introduced a large mandatory 10-knot speed zone for vessels > 65 ft in length in the Gulf (Davies and Brillant 2019b) and mandatory dynamic speed zones in major shipping lanes. Canada continues to renew and refine the details of the 10-knot speed regulations each year and in 2019 modified their rules to include vessels 42 ft or greater in length.

8. In 2019, the Commonwealth of Massachusetts announced a mandatory 10-knot speed limit in Cape Cod Bay during the months of March and April for most vessels under 65 ft in length (MA DMF, 2019). This state regulation compliments the federal speed rule in the Cape Cod Bay SMA, effectively requiring most vessels of any size to maintain speeds of 10 knots or less during these months. This was the first program in the U.S. to restrict the speed of small vessels to mitigate collisions with large whales, although programs limiting

small vessel speeds to protect other marine mammals, such as manatees, have been in place for many years.

EVALUATION OF VESSEL SPEED IN SEASONAL MANAGEMENT AREAS

Mariner Compliance with the Speed Rule: Goals and Methods

Mariner compliance with the vessel speed rule is critical to effectiveness. It is essential to evaluate mariner adherence with the rule across all SMAs to gain insight regarding the rule's effectiveness. Our evaluation of vessel activity focused on understanding differences and trends in compliance temporally, regionally, by vessel size class and by vessel type. This is a critical step in assessing how effective the rule is currently and whether the rule's effectiveness could be enhanced if higher levels of mariner compliance are achieved in the future.

We conducted a broad assessment of vessel traffic patterns in SMAs to evaluate compliance with the speed rule and changes in vessel traffic characteristics over time. We assembled and analyzed available data on vessel types, characteristics, speeds, and transits through SMAs using the USCG's National Automatic Identification System (AIS) network and other vessel databases.

AIS vessel tracking data are essential to monitor vessel transits through SMAs. AIS is an automatic vessel tracking system which uses data sent via onboard transponders to track vessel locations. USCG carriage requirements dictate that most (non-military) vessels greater than 65 ft in length carry and operate AIS units. If a vessel fails to follow these USCG AIS requirements, or unlawfully disengages their AIS equipment, we have no mechanism to track this undetected vessel traffic.

In 2016, updated carriage requirements came into effect adding all (commercial) fishing vessels (> 65 ft in length) to the regulations (80 FR 5281, January 30, 2015). This resulted in a large increase in fishing vessel AIS traffic data as hundreds of fishing vessels began using AIS for the first time. Additionally, many mariners not required to carry AIS units, such as pleasure boats and sailboats, increasingly do so voluntarily, as the cost of AIS units has fallen. As a result, the quality and comprehensiveness of AIS data available today far exceed that of earlier years.

Using AIS data from shore-based receivers, we established a set of decision rules to process the data, remove incomplete or error filled records, and classify vessel types. The AIS network relies on mariners to enter static information about their vessel characteristics, which is then transmitted to the AIS receiver stations. If a mariner makes a mistake entering a vessel's characteristics that error will be passed along to the USCG AIS database. Where possible, we linked AIS vessel identification records to the Information Handling Services (IHS) Markit database of vessels to confirm or correct vessel information entered into the AIS system. The IHS Markit database includes all OGVs and many mid-sized vessels (>100 gt) but not smaller vessels (< 65 ft). For smaller vessels, we lacked a secondary database to confirm the accuracy of reported information. Figure 3 presents the detailed decision tree used to process all AIS data to establish vessel type and length.

The AIS system classifies vessels by a combination of vessel type and vessel activity. These categories did not always align well with vessel type classifications of relevance for this assessment. Using the IHS Markit “Statcode 5 Shiptype Coding System” we reclassified vessels in the AIS data according to their alignment with this industry standard categorization of vessel types. This effort resulted in 26 vessel categories (Figure 4). For vessels subject to the rule we also assigned vessels into two overarching type categories: 1) OGVs and 2) mid-sized vessels (as defined at the beginning of the report).

Following the AIS data processing and re-classification, vessel transits through SMAs containing a minimum of two data records were compiled and used to calculate the following key indicators of vessel traffic characteristics and compliance with the speed rule:

1. Distance weighted average speed (DWAS). We used DWAS as a measure of vessel speed to correct for the bias introduced by the over-representation of AIS records at lower speeds and for differences in AIS signal transmission/reception rates between vessels. DWAS was calculated by first determining the total distance traveled by a vessel as the sum of individual transit segment distances at each unique speed. The speed of each transit segment was then multiplied by the fraction of the total distance traveled and summed to produce an average speed weighted by the contribution of each transit segment.

2. Proportion of total transit distance in each of the following speed bins: <10 knots, 10 -12 knots, 12.1 - 15 knots, >15 knots.

3. Transit Distance. Total transit distance allowed us to understand the total amount of vessel traffic present in each area of assessment and examine changes in traffic patterns over time. Along with vessel speed, transit distance is an important metric for understanding overall risk of vessel traffic to whales.

SMA transits were temporally organized by SMA “seasons” rather than by calendar year. This is due to the seasonality of the active SMA periods. SMAs become active starting in fall/winter/spring and become inactive the following spring and summer. For example, the SMA season 2012-2013 refers to SMAs active between November 1, 2012 and July 31, 2013.

Lastly, there is an important limitation to this assessment of compliance. Data detailing the number of safety deviations used on individual transits are not readily available so we are unable to determine what proportion of transits lawfully invoked the safety deviation clause. In general, any transit in excess of the 10-knot speed limit should be considered potentially non-compliant, recognizing that a vessel master may have invoked the safety deviation clause.

General Vessel Speed Characteristics in SMAs

Average vessel transit speeds have decreased in active SMAs since the speed rule was established. For those vessels subject to the rule, the DWAS in active SMAs fell from 10.05 knots during the 2008-2009 season to 8.52 knots during the 2018-2019 season (Figure 5). Interestingly, a decrease also occurred in inactive SMAs when no speed restriction was in effect. The DWAS in inactive SMAs declined from 11.94 knots during the 2008-2009 season to 8.43 knots during the 2018-2019 season. The same trend holds true for OGV with DWAS dropping from 11.41 knots to 9.45 knots in active SMAs and from 13.51 to 12.42 during inactive periods. This general trend towards slower vessel transit speeds in inactive SMAs indicates that factors other than the speed rule may be influencing vessel speed in these areas, but given changes in mid-size vessel AIS adoption over time we must be cautious about interpreting speed trends for this vessel size class.

While vessel speeds declined, the total distance transited by mid-sized vessels across all SMAs may have increased. The total distance transited by mid-sized vessels in active SMAs increased dramatically from 131,354 nautical miles (nm) in 2008-2009 to 584,424 nm in 2018-2019 (Figure 6). This increase in transit distance is partly an artifact of available AIS data and changes to AIS carriage requirements since the rule came into effect in 2008. The substantial jump in total transit distance in 2015-2016 coincides with new AIS requirements for all fishing vessels > 65 ft in length. The number of fishing vessels appearing in the AIS data during active SMAs increased substantially that season from 187 to 451 vessels (Table 1). Furthermore, the number of vessels voluntarily carrying AIS has increased over time. These factors have led to a greater number of vessels in the AIS data system and makes it challenging to separate out real increases in vessel traffic from artifacts of the data.

When looking only at OGVs, a different story emerges with the total transit distance generally remaining stable over time (Figure 6). OGV traffic accounted for less than half the total transit distance (43%) for all vessels within active SMAs for 2018-2019. This trend for OGVs is likely to be real and more accurate due to long standing and consistent AIS requirements for vessels of this size.

The size of OGVs has changed over time in SMAs, with the proportion of Post-Panamax sized OGVs increasing from <1% of OGV transits in active SMAs during the 2008-2009 season to a high of 24.7% in the 2017-2018 season (Figure 7). The proportion of Sub-Panamax vessel transits remains consistent over time with the proportion of Panamax vessel transits declining and replaced by Post-Panamax vessel traffic. In the 2018-2019 season Post-Panamax size vessels made up 37.2% of OGV transits in the North Carolina to Georgia SMA and > 20% of OGV transits in the Race Point, Great South Channel, New York and Chesapeake SMAs (Figure 8). The proportion of Post-Panamax size vessels transiting through SMAs is expected to increase further in the future.

Compliance in Seasonal Management Areas (SMAs)

Compliance with the vessel speed rule has increased across all SMAs each season since implementation in 2008 (Figure 9). Overall compliance, for vessels subject to the rule, reached a high of 81% during the 2018-2019 season but the proportion of vessel traffic exceeding 15 knots has increased to 3.99% after a low of 2.71% in 2012-2013. Furthermore, despite the overall high compliance rate in 2018-2019, vessels transited just under 200,000nm across active SMAs in excess of 10 knots.

The level of compliance varies across SMAs with the Cape Cod Bay, Race Point, and Great South Channel SMAs having compliance rates in excess of 80% over all years while the North Carolina to Georgia SMA had the lowest compliance rate at 63.05% (Figure 10). Looking at the most recent season (2018-2019), compliance in SMAs from Delaware northward exceeded 85% (Figure 11). Morehead City (87.47%) and Southeast (84.6%) also had high compliance in 2018-2019. The Chesapeake (78.08%) and North Carolina to Georgia (69.49) SMAs demonstrated notably lower compliance rates in 2018-2019. A very high proportion of vessel traffic exceeding 12 knots (20.73%) was noted in the North Carolina to Georgia SMA.

In 2018-2019, the total vessel transit distance was highest in the North Carolina to Georgia and Southeast SMAs with 588,374 and 392,633 nautical miles of vessel traffic recorded, respectively (Figure 11). The high amount of vessel traffic in this region is a function of the larger size and nearshore coverage of these SMAs. Examining vessel traffic relative to SMA size reveals the highest density of vessel traffic occurs in the Mid-Atlantic region within the New York, Delaware Bay, and Chesapeake SMAs (Figure 12). A similar pattern emerges when examining the subset of vessel traffic transiting at speeds in excess of 10 knots with the highest level of non-compliant vessel traffic occurring in the North Carolina to Georgia SMA (80,401nm) but the densest non-compliant traffic occurring in the Mid-Atlantic region (Figure 13).

Evaluating vessel traffic by type reveals the prevalence of certain vessel types in active SMAs. Fishing vessels, container ships and towing/pushing vessels accounted for the majority of vessel traffic in all SMAs during 2018-2019 (Figure 14). It is useful to note that the number of unique vessels operating in SMAs does not necessarily align with the distance transited by that vessel type through SMAs. In some cases, a small number of vessels are responsible for a large amount of transit distance (e.g., dredging vessels) while in other cases a large number of vessels (e.g., tankers) are responsible for a relatively moderate amount of transit distance (Figure 14).

Vessel compliance varied considerably by vessel type in active SMAs during 2018-2019 (Figure 15). Fishing vessels showed the highest level of compliant transit (93%) while other cargo (44%) and pleasure vessels (31%) had particularly low levels of compliance. Of the three most prevalent vessel types (fishing, container, and towing/pushing), container ships demonstrated the lowest level of compliance at 76%. Examining the total distance transited by vessels in excess of 10 knots demonstrates container ships, pleasure vessels and tankers had the longest non-compliant transit distances in active SMAs during 2018-2019 (Figure 16). Notably, the total transit distance in excess of 12 knots for container ships and pleasure vessels (47,585 nm) exceeded the same total for all other vessel types combined (44,388 nm).

Examining vessel metrics by individual SMA reveals key differences along the coast. The proportion of non-compliant transit distance generally decreased over time in each SMA (Figures 17-26) and the proportion of the highest speed traffic (> 15 knots) had declined to <1% in five SMAs by 2018-2019 (Figures 17-20 and Figure 21). However, in the North Carolina to Georgia SMA (Figure 25) the proportion of vessel traffic transiting at speeds in excess of 15 knots has increased in recent years reaching a high of 10.41% in the 2017-2018 season. Additionally, in the New York (Figure 21), Chesapeake (Figure 23), Morehead City (Figure 24), and Southeast (Figure 26) SMAs, the proportion of vessel traffic transiting at speeds in excess of 12 knots has varied in recent years or increased moderately.

The composition of vessel types transiting active SMAs and their rates of compliance varied substantially during the most recent 2018-2019 season (Figures 27-36). In the northern SMAs, mid-sized vessel traffic was most prevalent (Figures 27-30). In Race Point, Great South Channel and Block Island SMAs fishing vessels dominated the vessel traffic while in Cape Cod Bay towing/pushing vessels were dominant. Morehead City had a similar profile with fishing, dredging, and towing/pushing vessels most common (Figure 34).

For SMAs directly off major ports, vessel traffic included a greater mix of vessel types and size classes. Container ships made up the greatest proportion of transit distance in the New York, Chesapeake, and North Carolina to Georgia SMAs with towing/pushing, tanker, and fishing vessels also making up large proportions of total vessel transit distance (Figures 31, 33, and 35). Across all SMAs, pleasure vessels and passenger vessels (both other and cruise ships) were often the least compliant with particularly high percentages of high speed (> 15 knots) transit distance. In the Morehead City, North Carolina to Georgia, and Southeast SMAs pleasure vessels were both highly non-compliant and made up more moderate levels of total transit distance relative to other SMAs (Figures 34-36). In the Great South Channel, general cargo and bulk carrier vessels demonstrated low compliance levels (<60%) which were not observed in other SMAs (Figure 29).

In summary, the proportion of total vessel transit distance through active SMAs at speeds < 10 knots reached an all-time high (81%) in 2018-2019. However, compliance has generally leveled off over the past few years (~79-81%) and a significant amount of vessel traffic (nearly 200,000nm) continues to transit active SMAs at speeds in excess of 10 knots. Compliance is generally higher in the four most northern SMAs and particularly excessive vessel speeds (> 12 knots) are an issue in the North Carolina to Georgia SMA.

Ocean Going Vessel (OGV) Compliance in Port Entrance Areas within SMAs

Following implementation of the speed rule, NMFS was petitioned in 2013 to exclude federally maintained dredged channels and pilot boarding areas from the rule over concerns for navigational safety involving OGVs. NMFS denied the petition in 2015 (80 FR 62008, October 15, 2015), finding that the petitioners lacked “substantial information indicating that that exclusion of these areas is necessary”. The agency noted that the safety deviation provision provided mariners with an exemption to the rule if conditions existed that restricted vessel maneuverability preventing safe navigation at speeds of 10 knots or less. Given the interest in these entrance zones, we analyzed the characteristics of OGVs traffic in these areas specifically to gain a better understanding of compliance within these discrete portions of SMAs.

We identified 11 entrance channel areas accommodating OGV traffic within SMAs from Cape Cod, MA to Jacksonville, FL. Entrance channel zones that fell within SMAs included: Cape Cod Canal East, New York, Delaware Bay, Chesapeake Bay, Morehead City, Wilmington, Charleston, Savannah, Brunswick, Fernandina and Jacksonville (Figure 37). We evaluated vessel compliance in these zones using the same procedure used for SMAs overall.

OGV compliance varied dramatically between the 11 port entrance areas (Figure 38). Across all active "seasons" the proportion of total vessel transit distance < 10 knots was highest in the New York entrance area (75.73%) and lowest in Brunswick (12.62%). The New York and Savannah entrance areas had the densest vessel traffic and in Savannah 60.4% of the traffic (338,311nm of transit) exceed 10 knots. The total transit distance of vessels within these zones varied considerably but was unrelated to compliance rates. Vessel transit distance reflects a combination of vessel traffic density and the varying length of entrance channels with ports south of Cape Hatteras requiring longer entrance channels due to more naturally shallow bathymetry in port approaches. During the 2018-2019 season, the southern entrance areas (with the exception of Morehead City) revealed notably lower proportions of transit distance under 10 knots relative to the northern/Mid-Atlantic areas (Figure 39). Only 11.16% of transit distance through the Charleston entrance area was under 10 knots while compliance within Cape Cod Canal East reached 90.04%.

An assessment of compliance over time in each entrance area (Figures 40-50) demonstrated more variability. Compliance rates were highest overall in more northern areas with Delaware Bay, Chesapeake Bay, and Morehead City showing large improvements (Figures 42-44). Compliance in entrance areas outside the ports of Wilmington, Charleston, and Brunswick were exceptionally low, never reaching over 20% since 2008 except for the first season in Wilmington (Figures 45, 46 and 48). Rates of compliance were less than 30% for Savannah in recent years after achieving 66.5% during the 2012-2013 (Figure 47). The DWAS in entrance areas between Cape Cod and Morehead City ranged from 8.22 to 10.4 knots but increased outside more southern ports with DWAS ranging from 10.19 - 13.48 knots. Many entrance areas demonstrated improvements in compliance rates over time, but the ports south of Morehead City showed little change over time or a declining rate of compliance.

Lower compliance rates in some entrance channel areas may coincide with employment of the speed rule's safety deviation provision. However, low compliance rates in certain entrance areas demonstrated little change year to year, across all vessel types, which points to other causes for the low compliance rates.

Examination of port entrance areas within active SMAs revealed extremely low levels of compliance, particularly in Wilmington, Charleston, Savannah, and Brunswick. This is concerning in Charleston and Savannah given the higher levels of transit distance and longer entrance channels into these busy ports. In contrast, New York, with high levels of transit distance, has had compliance levels in excess of 75% since 2010-2011, although that level has slipped from a high of 87.34% in 2013-2014.

Other Considerations Regarding Vessel Speed

Operational Need to Slow Vessels

Mandatory and recommended maritime speed restrictions are commonplace and used in a number of contexts. For example, slowing vessels to speeds under 10 knots outside U.S. ports is a routine, and generally required, part of day-to-day operations for OGVs entering harbors. OGVs are required to use local harbor pilots to enter ports and must slow to speeds less than 10 knots in order to embark or disembark the local pilot. Depending on the port and the size of the OGV, designated pilot boarding areas may be as close as a few miles from an inner harbor or up to 15 miles offshore. Usually, a vessel slows to a safe speed and a pilot embarks or disembarks using an external ladder on the lee side of the ship. Pilot associations commonly recommend OGVs slow to speeds ranging from 5-10 knots for pilot boarding. For example, when boarding pilots OGVs are requested to slow to 5-7 knots outside Morehead City, 8-10 knots outside Charleston, 5-9 knots at Brunswick and 8-10 knots at Jacksonville (NOS, Coast Pilot Vol. 4, 2019). Additionally, the USCG has established vessel speed limits in certain port entrances and adjacent rivers for national security purposes (66 FR 53712, October 24, 2001; 67 FR 41337, June 18, 2002) and U.S. Army Corps of Engineers (USACE) requests certain vessel classes to maintain speeds under 10 knots when transiting the Cape Cod Canal.

Other Factors Influencing Vessels Transit Speeds

OGVs are a significant contributor to pollution emissions in the coastal region. In 2010, the IMO designated an Emission Control Area (ECA) along the East Coast of the U.S. (among many other regions) through amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL). Beginning in August of 2012, new vessel emissions standards were established for ECAs which became effective in 2013 and continue to be strengthened over time. OGVs usually achieve compliance with emission standards by switching to cleaner burning fuels within ECAs, such as marine diesel oil, slowing their speed and/or employing exhaust gas cleaning systems known as “scrubbers”. Most types of OGVs see substantial fuel consumption savings when steaming at lower speeds which in turn reduces pollution emissions. The extent of the savings and the speeds needed to achieve them vary according to the vessel size, design, and transit draft. Numerous sectors have recently urged the IMO to set speed limits for OGVs in an attempt to further reduce greenhouse gas emissions.

In 2013, the Port Authority of New York and New Jersey implemented a Clean Vessel Incentive (CVI) Program aimed at reducing air pollution from the many large vessels coming to the port.[1] One component of the CVI program provides financial incentives for participating vessels which maintain speeds of 10 knots or less within a 20 nm boundary seaward of the territorial sea line. Fortuitously, this outer boundary overlaps exactly with the New York SMA for right whales. As a result, vessels who transit this area under 10 knots during the active SMA period and register for the CVI program are both reducing emissions and helping to reduce the risk of vessel strike to whales.

Fuel costs make up a substantial portion of the operating costs for many vessel types, and transiting at a slower speeds can result in fuel savings (Maloni et al. 2013). Moreover, marine fuel prices can vary substantially from year to year, leading to large swings in vessel operating costs. There is no set definition for an optimal slow speed for fuel savings, rather it is usually a percentage reduction from a vessel's design or service speed. For a fast moving container vessel, this can mean 14 knots while for a slower oil tanker, it could mean 10 knots. OGVs may experience considerable fuel consumption savings by operating at slower speeds although the benefits may not extend to speeds as low as 10 knots for all vessel designs.

In light of possible cost savings, the NY/NJ CVI program, and more rigorous emissions standards in ECAs moving forward, OGVs in particular may have multiple incentives for transiting at slower speeds within SMAs whether they are active or not. This development is positive news for whales. Vessel traffic is increasing along the U.S. East Coast, so if external factors are ushering in a shift to slower vessel speeds, that may contribute to a lower risk of vessel collision for whales.

MARINER COOPERATION WITH VOLUNTARY DYNAMIC MANAGEMENT AREAS (DMAs)

Between December 2008 and May 2019, a total of 195 DMAs were declared in response to right whale sightings outside the boundaries of active SMAs. DMAs are triggered when aggregations of three or more right whales are detected and remain in effect for 15 days. During this period mariners are requested to avoid the DMA or slow all vessels to 10 knots or less to prevent collisions with right whales within DMAs. To investigate mariner cooperation with voluntary DMA slow down requests, we examined the DWAS of vessel transits (> 65 ft in length) and the proportion of vessel transit distance under 10 knots through designated DMAs.

DMAs were excluded from evaluation if they: 1) occurred during the first year of the program (2009), 2) overlapped with an active SMA, 3) included an error in the original DMA communication, or 4) the DMA notice was not included in the USCG Notice to Mariners. These exclusions were necessary to ensure that mariners had ample time to become aware of the DMA program (1 above) and had access to complete and accurate communications regarding DMA specifics (3 and 4 above). Additionally, DMAs overlapping active SMAs were removed (2 above) from the analysis to ensure that the presence of an active SMA did not influence mariner behavior in the DMA.

[1] https://www.panynj.gov/port/en/our-port/clean-vessel-incentive-program.html

Using vessel traffic data processed in the same manner as the SMA vessel traffic data, we examined vessel operations in 86 DMAs established between January 2010 and May 2019 (Figure 51). Of these, 76 occurred in waters off New England and the Mid-Atlantic and 10 off the coasts of Georgia and Florida. This geographic distribution is expected and comports with the prevalence of frequent right whale foraging aggregations in the New England area. When examining only OGV traffic, a subset of these DMAs (n=79) was used due to a lack of OGV traffic in 7 DMA areas.

To evaluate cooperation with DMAs, we compared vessel transits through each active DMA to vessel traffic in the same area during the week directly prior to the DMA declaration. We chose to evaluate a truncated time period within the active DMA (beginning 4 days from the original whale sighting trigger) to ensure that all mariners would have had ample time to learn about the DMA declaration. In some instances, DMAs were extended in time due to new right whale sightings in the same area. In these cases, DMAs were consolidated into one DMA analysis unit as long as the spatial extent of the DMA remained unchanged. We employed paired Wilcoxon signed-rank tests to compare vessel speeds and transit distance within active DMAs with those in the DMA area during the week prior to the DMA declaration.

The size of DMAs included in the analysis ranged from 404 nm^2 to 4953 nm^2 with total transit distances through individual DMAs ranging from 5.6 nm to 21,330 nm. Some DMAs had very light vessel traffic with only 1-2 applicable vessels transiting while others had in excess of 250 unique vessels transit during the analysis period.

Comparing the DWAS of vessels in active DMAs vs. the week before in the same area yielded significant but small differences ($Z = 3.28$, $p = 0.001$). During the study period, the mean DWAS declined from 11.83 knots to 11.52 knots with the median declining from 11.88 knots to 11.22 knots (Figure 52). While the change is significant and provides evidence of slower vessel speeds during DMAs, the degree of cooperation remains insufficient to bring down the DWAS to under 10 knots in the active DMAs.

A similar result was found when comparing only OGV traffic in DMAs, which again yielded small but significant differences in vessels' DWAS during active DMAs vs. the week earlier ($Z=3.88$, $p= 0.001$). The mean DWAS of OGVs declined from 13.6 knots to 12.53 knots with the median declining from 12.92 knots to 12.33 knots (Figure 53). Only four DMAs had OGV traffic with a DWAS equal to less than 10 knots.

The proportion of vessel traffic cooperating with the 10-knot speed request increased during DMA active periods. The mean increased from 39.8% to 46.9% and median increased from 35.55% to 50.62% (Figure 54) demonstrating a shift to lower speeds during the active DMA period. However, the increase in cooperative vessel traffic remains modest and fails to approach levels achieved in mandatory SMAs. Only a small portion of vessels are modifying their speed to less than 10 knots within active DMAs.

Comparing the transit distance of vessels in active DMAs vs. the week before in the same area resulted in no significant difference (Z=0.19, p= 0.846). If vessels were avoiding active DMAs, we would expect to see a decrease in vessel traffic. The lack of change in transit distance indicates mariners may not be modifying their routes to avoid active DMAs.

Cooperation from the mariner community is essential for any voluntary speed program. This assessment demonstrates that some mariners are cooperatively decreasing their speed in active DMAs but not to levels sufficient to be compliant if a 10-knot speed restriction were to be mandatory. These findings echo earlier assessments of DMA effectiveness which found similar patterns of modest cooperation that fell short of program goals (Silber, 2012a). OGVs, which made up 35% of the total distance transited through DMAs, are a particular concern given their higher overall average speeds. Vessels continue to transit thousands of nautical miles at speeds above 10 knots through active DMAs, where right whales are known to have aggregated.

SMALL VESSEL TRAFFIC IN SEASONAL MANAGEMENT AREAS (SMAs)

Given the number of small vessel collisions with whales documented during the past 20 years (see section below on Vessel Size Classes Involved in Right Whale Collisions), we undertook a review of small vessel traffic patterns in SMAs to better understand vessel strike risk associated with small vessels. USCG AIS carriage requirements do not apply to most vessels under 65 ft in length but many smaller vessels voluntarily carry AIS for safety or enjoyment. Because AIS use by small vessels is voluntary, the data are likely biased and not a representative sample of small vessel operations in SMAs. Bearing this in mind, we cannot draw holistic conclusions from this review of small vessel operations. Rather, this assessment provides a first level examination of AIS-equipped small vessel operations in active SMAs and their possible threat to right whales.

We focused on examining AIS data from the most recent SMA season available, 2018-2019. Since more small vessels adopt the use of AIS each year, more recent years are likely to have the most comprehensive data. The vessel transit data were processed in the same manner as described above for vessel type, speed, and transit distance. We applied three vessel size categories originally developed by the Florida Fish and Wildlife Conservation Commission's Marine Mammal Pathology Lab for the study of manatee vessel strikes. These categories include; category I vessels (<16 ft in length); category II (16-39 ft in length), and category III (40-65 ft).

During the 2018-2019 season, AIS-equipped small vessels transited 279,176 nm across all active SMAs. The majority of this traffic occurred in the North Carolina to Georgia (141,742 nm) and Southeast (49,509 nm) SMAs (Figure 55). Examining the amount of transit distance relative to the area of each SMA reveals the densest traffic in SMAs between New York and Georgia (Figure 56). Off New England, both the overall distance traveled and the density of traffic is much lower, possibly due to poor weather conditions during winter months in more northern areas.

The proportion of AIS-equipped small vessels transiting under 10 knots varied considerably between SMAs. In the four New England SMAs, more than 83% of all small vessel traffic transited at 10 knots or less, while in the New York, Delaware Bay, and Chesapeake SMAs, less than 50% of transit distance was below 10 knots. The southern SMAs were more mixed with 55-74% of small vessel transit distance at speeds under 10 knots.

The majority of AIS-equipped small vessel traffic in active SMAs came from four vessel types; pleasure, sailing, pilot and fishing vessels (Figure 57). Of these, sailing and fishing vessels traveled at lower speeds with nearly 100% of sailing vessel traffic traveling at speeds of under 10 knots. In contrast, more than 50% of pleasure vessel transit distance exceeded 10 knots and that number rose to more than 85% for pilot vessels. Given the ubiquity of small pleasure and pilot vessel traffic in some SMAs and the high speeds at which many travel, these vessel types may pose a particular threat to right whales.

Approximately 85% of small vessel traffic was made up of category III size vessels (40-65 ft in length), 15% were category II vessels and less than 1% were category I. This size breakdown must be regarded with some caution, however, as it likely underestimates the smallest vessel size classes active on the water during this period because they may lack adequate power supplies to operate AIS units and/or vessel operators may see no need for AIS if they make mostly short, daytime trips close to shore. Looking at the traffic breakdown by SMA again (Figure 58), the North Carolina to Georgia SMA has the most transit distance and the most category II and III vessel size traffic.

The best available AIS data indicate that a substantial amount of small vessel traffic traveling at speeds in excess of 10 knots is present in active SMAs particularly in the Mid-Atlantic and to a lesser degree in the southeast. Pleasure and pilot vessels account for the majority of traffic transiting over 10 knots. Most vessels fall within size category III, although this sample of small vessels may be biased. Vessels under 65 ft in length are known to cause mortalities and injuries in right whales. The speed and characteristics of the small vessel traffic detailed here warrant further assessment.

Vessel Size Classes Involved in Right Whale Collisions

In 2013, Costidis and Knowlton completed an assessment of vessel size classes involved in right whale collisions through 2012.[2] Based on photographs of propeller laceration injuries and some reports of vessel strikes, they evaluated a subset of these events and determined the likely size of vessels involved. From the 37 records between 1999 and 2012, sufficient information was available to evaluate 18 injury cases. Of these, 11 cases (61%) involved small vessels < 65 ft in length, three involved vessels either under or over 65 ft and four were the result of strikes by vessels > 65 ft in length. Furthermore, based on photo ID records they were

[2] Knowlton AF, Costidis A. Unpublished. 2013. Case Studies of Vessel Struck Right Whales (*Eubalaena glacialis*) documented off the East Coast of North America. Report prepared for The Volgenau Foundation. Available from the John H. Prescott Marine Laboratory, New England Aquarium, Central Wharf, Boston, MA.

able to narrow down the area where some of these vessel strikes occurred. Three collisions likely occurred on the southeast calving ground and one in Cape Cod Bay.

They were also able to identify the vessel size involved in eight mortality or serious injury cases either from photographs or vessel strike reports by mariners. In six cases these vessels were > 65 ft in length and in two cases the vessels were found to be under 65 ft. Of these small vessel cases, one was a March 2005 mortality off Georgia where a 43-ft vessel was involved and the other a serious injury from April 2006 in Cape Cod Bay where a right whale was struck by a 50-ft research vessel.

The proportion of small vessels involved in collisions with whales is concerning because the vessel speed rule does not apply to this vessel size class (< 65 ft in length). Small vessel collisions may be less likely to result in a serious injury or mortality, but at least one mortality and one serious injury were the result of small vessel collisions during this period.

NAVIGATIONAL SAFETY

Navigational safety is of paramount importance to NMFS. When the agency published the final rule implementing the 10-knot vessel speed restriction on October 10, 2008 (73 FR 60173, October 10, 2008) the rule included a provision allowing vessels to deviate from the speed rule under certain conditions for reasons of safety. Specifically, the rule states that “a vessel may operate at a speed necessary to maintain safe maneuvering speed instead of the required ten knots only if justified because the vessel is in an area where oceanographic, hydrographic and/or meteorological conditions severely restrict the maneuverability of the vessel” (50 CFR § 224.105 (c)).

It was always understood that there may be limited situations, such as inclement weather, in which operating at 10 knots or less may severely impact the maneuverability of a vessel. Notwithstanding the inclusion of this safety deviation provision, in 2012 a petition was made by the American Pilots’ Association to NMFS as part of comments to the proposed rule to eliminate the speed rule's sunset provision (78 FR 34024, June 6, 2013). The Association indicated that safe navigation could be hindered in certain areas by vessels traveling at or below 10 knots and recommended that NMFS “exclude federally-maintained dredged channels and pilot boarding areas (and the immediately adjacent waters) for ports from New York to Jacksonville” from the vessel speed restrictions. NMFS decided to accept this comment as a petition for rulemaking but later denied the petition finding it presented no “substantial information indicating that exclusion of these areas is necessary to address the concerns” (80 FR 62008, October 15, 2015). At the same time, USACE commented on the petition, indicating a potential increased risk of vessel grounding incidents in the Charleston entrance harbor due to diminished vessel maneuverability when operating at or below ten knots. Given these previous comments, and the agency’s ongoing commitment to safety at sea, we undertook additional efforts to review the navigational safety impacts of the speed rule to date.

Marine Casualty Events: Groundings

A vessel grounding is a type of marine casualty incident where a vessel has an impact with the seabed or side of a waterway. To investigate whether there was an increase in grounding incidents in any active SMAs since the speed rule went into effect, we reviewed the USCG "Marine Casualty & Pollution" database for groundings events along the east coast (United States Coast Guard, 2019).

The casualty database includes data on all marine casualty events reported to USCG from January 2002 through July 2015. Based on this data availability, we examined casualty data for a period of 6.5 years before and 6.5 years after the rule was enacted. We analyzed all grounding events within the current SMA boundaries and identified whether the incidents occurred during the active or inactive seasons for each SMA (Figure 59).

The analysis showed that 58 grounding events met this criteria, with 31 occurring prior to the speed rule and 27 occurring after it was implemented. Of the 31 earlier casualty grounding incidents, 71% occurred in the months when SMAs would have been active and 29% in the months when they would have been inactive. A different trend appeared after the speed rule was in effect. Of the 27 grounding incidents since December 2008, only 41% occurred when SMAs were active, while 59% occurred when SMAs were inactive. Thus, there was actually a reduction in grounding events within active SMAs following implementation of the vessel speed rule. There are insufficient data to draw any conclusion as to the cause of this decrease, but regardless, the initiation of the 10-knot speed rule is not associated with an increase in grounding incidents. Furthermore, USCG Sector Charleston has had no reports, to date, of a mariner citing the right whale speed rule as a causal factor in any type of marine casualty event.

Charleston Entrance Channel (Fort Sumter Range)

In May 2019, USACE released a navigation study detailing vessel simulations conducted to evaluate different widening alternatives proposed as part of the ongoing Charleston Harbor Deepening and Widening Project (USACE, 2019). Part of this assessment examined the Fort Sumter Range, a channel segment often referred to as the "entrance channel" to Charleston harbor. Only one alternative was considered for Fort Sumter Range, which included no widening to the existing 800 ft (1000 ft overall) channel. Simulations were run for this no-widening alternative to examine two-way traffic issues, based on an 800 ft wide channel deepened to 54 ft, and an overall 944 ft wide channel deepened to 49 ft along the sides (Figure 60). The simulations used an exemplar container ship with the following dimensions: length 1,201 ft, beam 160 ft and draft 49.9 ft. This is the maximum size for a Post-Panamax vessel.

Two-way traffic runs (i.e. two ships passing) in the channel were simulated on ebb and flow tides with a 30-knot crosswind under two speed conditions: 1.) unrestricted speeds, and 2.) speeds restricted to 10 knots in keeping with the vessel speed rule. The conditions were chosen to reflect "credible worst-case scenarios." Pilots conducting the simulations observed a decrease in steerage and an increase in the ship's "effective beam" during the restricted runs.

The pilots also experienced groundings on some runs while trying to pass each other in the channel. Two-way traffic was deemed viable at 10 knots but with poorer handling. In contrast, the pilots reported being able to better control ships at unrestricted speeds (typically 13-14 knots).

These simulations were designed to test the limits of safe navigation, using the largest vessels, under poor weather conditions, with two-way traffic in the channel. Fortunately, the simulated scenario described in the report is rare. During the active SMA period in this region (November 1 - April 30), 30-knot winds are an uncommon event. Based on wind data from the National Data Buoy Center (NDBC) between 2016 and 2018, wind speeds of 30 knots or higher never exceeded 3% of wind speed observations at the NDBC offshore buoy #41004 during any month the SMA was active. Of the 18 months of data we reviewed, 13 months had no observations of winds ≥ 30 knots. Wind speeds of 25 knots or higher were also infrequent and never exceeded 16% of wind speed observations at the offshore buoy during any month the SMA was active. At an inshore station (#FBIS1), closer to the harbor entrance, wind speeds of 30 knots or higher never exceeded 2% of wind speed observations during any active month and wind speed events of 25 knots or higher never exceeded 3% of wind speed observations during any active month.

Another key factor in the simulations is two-way vessel traffic in the entrance channel. Two-way entrance channel traffic is limited to some extent by certain inner harbor channels, which only permit one-way traffic. One report examining vessel traffic in the entrance channel during February 2019 found 13.7% of transits involved two-way (Post-Panamax) traffic in the channel and 33.1% of transits involved two-way traffic of any size OGVs.[3] Additional assessment is needed to more fully evaluate the prevalence of two-way Post-Panamax vessel traffic in the Charleston entrance.

The size of OGVs transiting the Charleston entrance channel during the active SMA period has changed substantially since the speed rule was implemented. During the 2008-2009 SMA season, only 1.4% of OGV transits in the channel were Post-Panamax vessels (Figure 61). By the 2017-2018 season, 59.2% of vessel transits were made by Post-Panamax vessels. Whether this proportion will continue to grow remains to be seen, but it is clear that Post-Panamax vessels now predominate OGV transits in Charleston.

Given the growing size of OGVs transiting the Charleston entrance channel and the episodic high wind events that occur during the SMA active period, it is reasonable to assume that mariners may need to use the safety deviation provision when encountering extreme wind combined with two-way Post-Panamax traffic in the channel. Based on our findings, the majority of transits should be able to maintain 10 knots in the channel given the generally favorable weather predominant during the SMA active months and the mostly one-way Post-Panamax vessel traffic in the entrance channel.

[3] Lang, J., Goldstein, N., Newman, O., and Goldstein, A. Unpublished 2020. Compliance with Speed Restrictions to Protect Right Whales from Ship Strikes. Rhode Island Marine Animal Patrol. 44p.

There is no indication that the vessel speed rule has negatively impacted navigational safety. Vessel grounding incidents have declined within SMAs since the speed rule went into effect. USACE simulated traffic runs into and out of the Port of Charleston highlighted some concerns regarding safe passage in the entrance channel for two-way traffic involving Post-Panamax vessels under high wind scenarios at slow speeds. Fortunately, the confluence of conditions detailed in the model simulations are uncommon and should not prevent routine safe transit at 10 knots in the entrance channel.

BIOLOGICAL EFFECTIVENESS

Minimizing right whale vessel strike mortalities and serious injuries remains the core objective of the right whale speed rule. As such, to evaluate the biological efficacy of the speed rule we examined the number of mortalities, serious injuries, and non-serious injuries of right whales related to vessel strikes both before and after implementation. In addition, as the speed rule may benefit other large whale species, despite being developed specifically for right whales, we examined mortality, serious injury, and non-serious injury data for humpback, sei, fin, and minke whales all of which have a history of vessel strike events inside SMAs.

NMFS defines a serious injury as “any injury that will likely result in mortality (50 CFR 229.2) and further interprets the word “likely” as presenting a “greater than 50 percent chance of death” (NMFS, 2012). This definition can also include dependent calves when the mother has died. Injuries not meeting this standard are considered non-serious injuries (hereafter injuries).

Right Whale Mortalities, Serious Injuries, and Injuries from Vessel Collisions (1999 - 2018)

NMFS examined available data on right whale vessel collisions over a 20-year span, including 10 years prior to the implementation of the vessel speed rule (1999-2008) and 10 years post implementation (2009-2018). Between 1999 and 2018 a total of 57 confirmed right whale vessel collisions were documented as U.S. events or first detected in U.S. waters (Table 2, Figure 62; Cole et al. 2005; Glass et al. 2008; Henry et al. 2015; Henry et al. 2019; Henry et al. in press). These include 14 mortalities, 6 serious injuries, and 37 non-serious injuries. Most of the individuals involved in these collisions were juveniles (age class 1-8 years; 45.6%; n=26), with adults making up 28.1% (n=16), calves 15.7% (n=9), and animals of unknown age 10.5% (n=6). Females comprised 54.4% (n=31) of the total, males 33.3% (n=19), and individuals of unknown sex 12.2% (n=7). Examining the mortality and serious injury incidents on a per capita basis suggests a downward trend in recent years (Figure 63).

Table 3. North Atlantic right whale vessel strike mortalities, serious injuries, and injuries 1999-2018 (n = 57). Data includes both confirmed U.S. events and events first sighted in U.S. waters but of unconfirmed geographic origin.

Time Period	US Mortalities	US Serious Injuries	US Injuries	First Seen US Mortalities	First Seen US Serious Injuries	First Seen US Injuries	Total
1999-2008	10	2	5	0	0	8	25
2009-2018	3	4	10	1	0	14	32
Total	13	6	15	1	0	22	57

We used chi-square tests to determine departures from expected vessel strike events for sex. Significantly higher female mortality, serious injury, and injury occurred during this period (total vessel strikes: 31 females and 19 males; $\chi 2 = 9.495$, $p = 0.002$) based on the 2015 estimated sex ratio of 59.4 males to 40.6 females (Pace et al. 2017). The proportion of calves in the population never exceeded 10% during this period (Pace et al. 2017) yet calves made up 17.6% (n=9) of individuals involved in collisions for which an age class could be determined. With juveniles, a similar result emerges. Juveniles comprise 50.9% (n=26) of collisions for which an age class could be determined but based on best available estimates they make up between 24.7 and 31.1% of the population (Hamilton et al.1998).

The high proportion of female, juvenile, and calf vessel collisions is consistent with other assessments of right whale vessel collisions (Laist et al. 2001, van der Hoop et al. 2013). Calves are particularly vulnerable to vessel strike likely due to their tendency to remain near the ocean surface. Cusano et al. (2018) found that 74% of a calf's day was spent resting at the surface or just subsurface on the southeast calving ground and 70% of the time was spent resting at the surface or just subsurface when in Cape Cod Bay. Mothers are also at heightened risk for vessel strikes in the southeast calving ground while tending to very young calves; they spend the majority of their time at or near the surface and were found to dive shallower and for shorter periods of times than other right whales in the same area (Cusano et al. 2018).

Juveniles' habitat use may differ from adults inadvertently increasing their risk of vessel strike. Juveniles have a higher probability of migration to the southeast calving grounds than other (non-reproductive) adults, possibly due to lower energetic demands releasing them from the need to forage all winter (Gowan et al. 2019). Research indicates that to maximize traveling efficiency right whales may utilize depth strata proportional to their body size, with smaller individuals found closer to the surface (Nousek McGregor, 2010). This behavior could render smaller whales at a higher risk of collision.

Of the 57 documented collisions, 25 occurred prior to implementation of the speed rule and 32 occurred after (Table 3, Figure 64). This increase in the total number of detected collisions may be cause for concern; however, it is important to consider the severity of these events. The number of right whale mortalities dropped after the speed rule came into effect but the number of serious injuries increased. Of the 14 documented U.S. mortalities, 10 occurred prior to implementation of the speed rule and four afterward (one first sighted in the U.S.). Two serious injuries occurred prior to the speed rule and four serious injuries (including two prorated injuries) occurred after implementation. Thirteen injuries were documented prior to the rule and 24 post-implementation.

Interpretation of apparent increases in serious injuries and injuries warrants some caution. Following implementation of the speed rule, NMFS conducted extensive mariner outreach. Part of these efforts included raising awareness about the problem of large whale vessel collisions and encouraging all mariners and members of the public to report vessel strike incidents. Additionally, the period between 2009 and 2018 has seen increasing levels of right whale monitoring and associated photographs of whales. It is possible that these factors have led to more comprehensive reporting and detection of vessel strike events.

Alternatively, it is possible that right whales are better able to avoid fatal vessel collisions due to slower vessel speeds and thus whales are now more frequently seriously or non-seriously injured by vessel interactions but more work is required to fully evaluate this likelihood. Another concern is that minor vessel collisions may not kill an animal directly, but may weaken or otherwise affect it so that it is more likely to become vulnerable to further injury (Hayes et al. 2019). Finally, confirmed collisions only reflect those that were detected.

The decrease in observed vessel strike mortality is a positive sign, and provides evidence that the speed rule may have helped to reduce mortality. Nonetheless, the increase in injuries (both serious and non-serious) needs to be monitored closely in the future. Furthermore, over the 20-year study period changes in whale monitoring efforts, protocols for determining serious injuries, as well as mariner awareness may have impacted vessel strike detection and injury classification.

Finally, NMFS should examine sub-lethal and delayed lethal effects of vessel strike injuries to better understand their impact on individual and population health. For example, a female right whale ("Lucky") survived lacerations from a 1991 vessel collision when she was a calf, only to die in January 2005 when she became pregnant for the first time and the old wounds reopened. Continued monitoring of whales with apparently non-serious vessel strike injuries remains essential to understanding the long-term health consequences of these events.

Right Whale Vessel Strikes in U.S. Waters Since 2008

It is critical to learn from vessel strike mortalities and serious injuries that have occurred since the speed rule went into effect. Below is a brief summary of the eight vessel collisions that resulted in mortalities or serious injuries since the speed rule was implemented (Henry et al. 2015; Henry et al. 2019):

1. Mortality: A dead juvenile female (ID #3901) was first sighted to the southwest of Grand Manan Island, Canada in U.S. waters on July 2, 2010 with two large ventral lacerations deeper than 10 cm. A necropsy was not performed and it was not possible to estimate the size of the vessel involved. This mortality is designated as "first sighted" in U.S. waters. Because of the close proximity of the carcass to Canada it was not possible to determine if the lethal vessel collision occurred in U.S. or Canadian waters.

2. Serious Injury: A live juvenile male (ID# 3853) was sighted offshore of Hunting Island, SC on January 20, 2011 with 16 deep (>10cm) lacerations across its back. Based on photographs of the lacerations the vessel involved was estimated to be longer than 65 ft. This individual was previously sighted uninjured on January 15th off Georgia narrowing the timing for this vessel strike to January 15-20, 2011. No resights of this individual have been reported.

3. Mortality: A dead adult female (ID #1308) stranded in Nags Head, NC on March 27, 2011. A necropsy was performed demonstrating evidence of a vessel strike, including a fractured skull. Scars from a previous entanglement were also visible. She was found to be lactating and was last sighted alive on the 31st of January 2011 with her calf.

4. Serious Injury: The dependent calf of the dead adult female (ID #1308) was declared a serious injury following the death of its mother in March 2011.

5. Serious Injury: On Dec 7, 2012 a recreational vessel (46 ft long, traveling 12-13 knots) reported a collision with a whale (later determined to be a right whale) off Ossabaw Island, Georgia. No whales were seen prior to the collision. The mariner did not see the injured whale; however, he believed two whales were present. A ~40 ft whale was observed swimming around a large pool of blood (65 ft diameter). The size and sex of the whale are unknown.

6. Serious Injury: On Apr 9, 2014, a research vessel (39 ft long traveling 9 knots) reported a right whale surfacing under it while underway in Cape Cod Bay. The vessel reported a small amount of blood in the water and some lacerations of unknown depth on the whale. The size and sex of the whale are unknown.

7. Mortality: A dead male calf (ID #4681) was first sighted on May 3, 2016 floating off Morris Island, Chatham, MA. A necropsy revealed 9 large deep lacerations and fractured/shorn bones. The calf was last sighted with its mother on April 28th 2016 in Cape Cod Bay, 7 miles east of Plymouth, MA. The calf was estimated to have died 2-5 days earlier and a hindcast[4] model was run to estimate the location of the vessel strike

[4] The term "hindcast modeling" refers to the process of modeling back in time where a dead whale may have drifted from using information on oceanographic and weather conditions. These estimates can help narrow down the location where a vessel strike occurred. Hindcast models are most helpful when a whale dies within 5-6 days of being sighted, otherwise the time between the strike and discovery of the carcass may be too long for useful modeling.

event. The hindcast modeling indicates (Figure 65) the calf was struck within the Off Race Point SMA possibly near the Boston shipping lanes. The SMA may or may not have been active when the strike occurred as this SMA becomes inactive on April 30th.

8. Mortality: A dead female juvenile (ID #4694) was first sighted in Cape Cod Bay north of Barnstable, MA on the 13th of April 2017. A necropsy revealed deep hemorrhage and muscle tearing consistent with blunt force trauma. She was last sighted alive on the 9th of April 2017 in Cape Cod Bay. She was estimated to have died 48 hours before being discovered so a hindcast model was run which indicated the strike may have occurred in Cape Cod Bay to the east of the entrance to the Cape Cod Canal (Figure 66). This vessel strike occurred within the active Cape Cod Bay SMA.

Since the implementation of the speed rule, vessel strikes have continued to occur along the east coast of the U.S. in habitats commonly used by right whales. The seasonality of these events (December - July) corresponds to the months when large numbers of right whales are known to be present in U.S. waters. There is no discrete spatial or temporal clustering that would indicate a new “hot zone” for vessel strikes, rather right whales continue to experience collisions in areas similar to before implementation of the speed rule. Additionally, blunt force trauma and propeller lacerations continue to cause right whale deaths and serious injuries.

The two mortalities off Cape Cod and the serious injury in Cape Cod Bay require further evaluation. The greater Cape Cod area includes major shipping lanes and is a preferred right whale habitat, particularly in winter and spring. It is also one of the most protected areas for right whales. To have had three significant collision events in this relatively small area, and within active SMAs is concerning.

Massachusetts has recently (2019) implemented a mandatory seasonal speed limit of 10-knots in Cape Cod Bay for most vessels less than 65 ft in length during the months of March and April each year. This new seasonal regulation is active during the time frame when all three of the events occurred (or likely occurred). Cape Cod may continue to require unique consideration as a region with large aggregations of right whales and reliable foraging habitats in U.S. waters.

Right Whale Mortalities of Undetermined Cause (1999 - 2018) and Unobserved Mortality

We also reviewed right whale mortalities of undetermined cause given the high number of these events during the study period. A mortality is considered undetermined when insufficient information is available to determine a cause of death. This often occurs when a carcass is unrecoverable or so decomposed as to prevent a cause of death determination. In many cases, these carcasses are able to be identified to species.

Between 1999 and 2018, 82 right whale mortalities were observed in the U.S. and Canada. Researchers were able to identify a cause of death in 59.7% (n=49) of cases, with 10.2% dying from natural causes, 38.8% from vessel collision, and 51.0% from entanglement (Moore et al.

2005, Sharp et al, 2019). In the remaining 40.2% (n=33) of cases, no cause of death could be determined. Despite this paucity of information, it is likely that some portion of these undetermined mortalities were due to vessel strikes. While we will never know the cause of death, it is important to acknowledge these additional right whale mortalities.

Unobserved mortality, serious injury and injury from vessel strike is a challenging factor to evaluate. Despite considerable efforts to detect dead or injured right whales, including public outreach to report whales in distress, many right whale mortalities go undetected. Efforts are underway to estimate the level of this "cryptic mortality". Additionally, unlike entanglement injuries which usually leave visible scars, blunt force trauma injuries from vessels are difficult or even impossible to detect visually by external assessment. Given that not all right whale mortalities can be assigned a cause of death and that unobserved mortalities clearly occur, the actual number of mortalities from vessel strikes will likely always be higher than those that are detected.

Other Large Whale Vessel Strike Mortality and Injury Data (1999 - 2017)

Vessel strike mortality, serious injury and injury data was available for four mysticetes between 1999-2017; humpback whales (*Megaptera novaeangliae*), fin whales (*Balaenoptera physalus*), sei whales (*Balaenoptera borealis*) and minke whales (*Balaenoptera acutorostrata*) (Cole et al. 2005; Glass et al. 2008; Henry et al. 2015; Henry et al. 2019; Henry et al. in press). There were no records of blue whale vessel strikes during this period but historically they have occurred along the U.S. East Coast. Unlike right whales, fin, sei, and minke whales are known to be periodically transported into ports, draped across the bulbous bows of large ships (Rockwood et al. 2017). The location of these vessel strikes may occur far out at sea and not in any proximity to where they were first discovered. Additionally, due to their lower buoyancy, these species may be more likely to sink than right whales following a vessel collision and thus go undetected (Rockwood et al. 2017).

Table 4. Large whale (not including known right whale) vessel strike mortalities, serious injuries and injuries 1999-2017 (n = 131). Data includes both confirmed U.S. events and events first sighted in U.S. waters but of unconfirmed geographic origin.

Species	Humpback			Fin		Minke	Sei	Unknown	Total
	Mortalities	Serious Injuries	Injuries	Mortalities	Injuries	Mortalities	Mortalities	Injuries	
1999 - 2008	13	1	11	11	2	2	4	0	44
2009 - 2017	25	4	22	12	2	10	6	6	87
Total	38	5	33	23	4	12	10	6	131

A total of 131 vessel collisions were documented between 1999-2017 (Figure 67) with collisions involving 27 fin whales, 76 humpback whales, 12 minke whales, 10 sei whales and 6 whales of unknown species. Nearly all vessel strikes recorded for fin, sei, and minke whales occurred in the Mid-Atlantic region between North Carolina and New York, although 17 of these were individuals found on the bows of ships or with injuries consistent with having been draped across a ship's bow. Of the 38 humpback whale mortalities, 9 occurred in New England and the rest (29) in the Mid-Atlantic region. Of the 53 mortalities that occurred after the speed rule implementation, 13.2% of carcasses (n = 7) were located within active SMAs with three found in the Chesapeake SMA.

In the 10 years prior to implementation of the speed rule, 13 humpback whale mortalities, 1 serious injury and 11 injuries were recorded, but in the nine years after implementation, 25 mortalities, 4 serious injuries and 22 injuries were identified (Table 4). For fin whales, 11 mortalities and two injuries were documented before and 12 mortalities and two injuries after implementation. Two minke whale mortalities were documented before and ten after implementation. Four sei whale mortalities were documented before implementation and six afterward.

Based on the limited data available, evidence suggests an increase in vessel strike mortalities for these species, especially in the mid-Atlantic region, though as noted earlier, this may be the result of increased awareness and reporting on whale-vessel interactions. Additionally, the increase in the humpback population (Hayes et al. 2019) may have also played a role in the higher numbers. Regardless, taken at face value, these data suggest that the speed restrictions put in place for right whales are not providing additional protection for other large whale species. As such, an in-depth assessment may be required to develop management options tailored to these species.

In conclusion, the reduction in observed right whale mortality since 2008 is a promising sign, but the increase in serious injuries and non-serious injuries is cause for concern. Assessment of the full extent of right whale vessel strike mortality and injury during the study period is stymied by the high number of undetermined mortalities and an unknown number of unobserved mortalities, serious injuries and injuries. Additionally, since 2010, there appears to have been a considerable change in right whale habitat use patterns in areas where most of the population has been observed in previous years (Hayes et al. 2019). It is important to recognize some limitations when considering the effectiveness of the speed rule as a standalone program. A number of vessel strike prevention measures are in effect that may have contributed to changes in the rates of vessel strikes and it is not possible to separate out the individual contribution of one vessel strike reduction program from another. The downward trend in detected right whale vessel strike mortality is encouraging and may be the result of the comprehensive suite of programs now in place.

ECONOMIC ASSESSMENT

An economic assessment of the vessel speed rule using the most up to date information available was conducted for NMFS by an outside consultancy, Industrial Economics, Inc. (IEc).

The complete report from IEc is provided in Appendix B. The following is a summary of the major findings.

The economic assessment used 2017 vessel data, provided by NMFS, detailing vessel transits through SMAs during both active and inactive periods. IEc focused on the impact of the speed restrictions on transit times, evaluating the additional time required to complete a transit during the active period due to the speed rule. Using information on distance-weighted average transit speeds for different vessel types when SMAs were active and inactive, IEc calculated the expected delay experienced for each individual transit when SMAs were active.

Using this approach, IEC used two different methods to evaluate the delays:

> Method 1: Comparison of mean vessel speeds
> This method assumes that in the absence of speed restrictions, the average distance weighted speed of vessels during the active period would be identical to the average distance weighted speed of vessels during the inactive period. This method treats all transits during the active period as affected by the speed rule.
>
> Method 2: Comparison of high-speed transits only
> This method assumes that only a portion of transits during the active period are affected by the speed restrictions. In this case, only transits that would have occurred at speeds in excess of 10 knots are considered. First, they calculated the proportion of vessel transits during the inactive period in excess of 10 knots. Next, assuming that the same percentage of transits during the active period would have occurred at speeds greater than 10 knots, they identified analogous transits during the active period starting with the highest speed transit until the same target proportion was reached.

Another consideration in the assessment was the treatment of non-compliant transits. It is important to take non-compliance into effect to evaluate the economic impact of the speed rule based on actual compliance. It can also be useful to understand the impact if full compliance were to be achieved. To this end, a full compliance scenario was evaluated using both methods to assess delay and is available in the report (Appendix B).

To determine the economic impact of delays, hourly vessel operating costs are required for each vessel type to ensure an accurate assessment. Given the extensive range of vessel types transiting the SMAs, IEc used a variety of data sources and methods to estimate vessel operating costs. For OGV's, fuel costs can make up a substantial proportion of a vessel's operating costs and vessel fuel consumption generally increases exponentially with increasing speed. Unfortunately, detailed fuel consumption data were unavailable so estimates were based on a vessel's service speed, usually well in excess of 10 knots. As a result, fuel consumption, and therefore also OGV operating costs, were likely overestimated given the reduced speeds at which OGVs transit active SMAs. Actual OGV operating costs would likely be lower at reduced speeds, with less fuel consumption.

Based on the methods described above and the best available data for 2017, IEc estimates the direct cost of the speed rule at approximately $28.3 million (method 1) to $39.4 (method 2) per year based on actual compliance (Table 5). A large proportion of the cost is attributable to commercial shipping which accounted for $24.8 million (method 1) to $29.2 million (method 2) each year, with container ships bearing most of the cost due to the high number of transits through active SMAs.

Trade data indicate that the value of goods entering and leaving East Coast ports recovered following the 2008 economic downturn and has remained relatively constant ever since. A review of the data suggest no impact from the speed rule on the volume or economic activity at potentially affected ports (Appendix B). Furthermore, the yearly direct cost estimates to commercial shipping as a percent of trade value at affected East Coast ports is approximately 0.005%.

ENFORCEMENT

The NOAA Office of Law Enforcement (OLE) and NOAA Office of General Counsel (NOAA GC) have primary responsibility for enforcement of the vessel speed rule. OLE is supported by the USCG, which works in close collaboration with NMFS to assist with mariner compliance of federal regulations. Working together, OLE, NOAA GC, and USCG spearhead a trio of enforcement contacts with mariners each year which include the following:

1. Notices of Violation and Assessment of Administrative Penalty (NOVAs) and Written Warnings

   Based on OLE's investigations, NOAA issues NOVAs or Written Warnings to vessels found to have exceeded the 10-knot speed limit in SMAs. NOVAs issued by NOAA GC assess a civil penalty commensurate with the charges involved, and are most often issued in cases where a vessel operator(s) has demonstrated a substantial or repeated failure to adhere to the speed rule. Written warnings may be issued by NOAA GC or OLE and are most often issued in less egregious cases.

2. Compliance Assistance Letters

   OLE sends out compliance assistance letters to mariners found to have exceeded the 10-knot speed limit. These letters address conduct that does not reach the level of a NOVA or a Written Warning but, rather, serve to educate mariners on the requirements of the speed rule and potential enforcement actions if the alleged conduct continues in the future.

3. Hail and Inform Efforts

   The USGC hails applicable vessel operators who they detect transiting in excess of 10 knots in active SMAs. Mariners are reminded of the speed rule and informed that they should reduce their speed accordingly. Vessel compliance with hail instructions is noted and reported to NMFS.

In recent years (2017-2019), NOAA GC, OLE, and USCG have had a total of 178 enforcement related contacts via these three avenues. There were 60 contacts in 2017, 54 in 2018 and 64 in 2019. Since most vessels transit repeatedly through SMAs, one enforcement contact may cover numerous transits in possible violation of the speed rule. When enforcement investigations commence, as allowed by the rule, vessel operators are given an opportunity to provide evidence that they deviated from the requirements of the rule to maintain safe maneuvering speed, specifically due to oceanographic, hydrographic and/or meteorological conditions on transits which were in alleged violation of the speed rule.

OUTREACH

Any successful vessel strike reduction strategy designed to achieve meaningful protection for right whales demands mariner awareness, comprehension, cooperation, and compliance. To this end, NMFS and its partners have developed a broad suite of initiatives to inform, educate, and hold vessel operators transiting through right whale habitat along the U.S. East Coast accountable. These include, real-time awareness of right whale sightings, engagement with the professional maritime community, regulatory reminders, notices of dynamic actions, and corporate responsibility programs. The goal of these efforts is to reach out to mariners through both established and innovative ways to promote a “whale aware” mariner environment and the adoption of prudent practices to reduce the likelihood of vessel strike events. Below are the descriptions of specific actions, programs and other initiatives carried out by NMFS, NOAA’s National Ocean Service (NOS), USCG and other partners in support of the agency’s vessel strike reduction strategy.

Corporate Responsibility Initiatives

Partnership with the Shipping Industry

Beginning in 2010, NMFS partnered with the World Shipping Council and the Chamber of Shipping of America to provide data to shipping companies on the performance of OGVs while transiting active SMAs. Shipping companies voluntarily participate, and receive a monthly report detailing the dates, locations, and speeds of their vessels while within SMAs. The complete list of data provided includes the following:

1. Vessel name
2. SMA name
3. Speed over ground (in knots) upon entry
4. SMA Entry time
5. Maximum speed over ground (in knots) while in the SMA
6. Date and time when maximum speed over ground was reached

7. Speed over ground (in knots) upon exit
8. SMA Exit time
9. Distance traveled within the SMA (in nautical miles)
10. Percent of SMA distance traveled at >10 knots
11. Percent of SMA distance traveled at >12 knots

This outreach program provides shipping companies with large fleets a mechanism by which to evaluate the operations of individual vessel compliance with the speed rule. This gives corporate shipping managers the ability to monitor which vessels in their fleet are consistently compliant and which may require intervention. Currently, summary reports are provided each month to 18 companies covering approximately 1,000 OGVs.

Right Whale Corporate Responsibility Project

The Right Whale Corporate Responsibility Project was launched in 2010 by NOAA's Stellwagen Bank National Marine Sanctuary (NMS), in collaboration with NMFS, the International Fund for Animal Welfare, the USCG, and the Massachusetts Port Authority.[5] The project team tracks vessels transiting the Stellwagen Bank NMS which overlaps with the Cape Cod Bay and Off Race Point SMAs. Vessels and operator companies are graded (A+ to F) based on compliance levels with the 10-knot speed limit in the NMS. Individual vessels and companies are then sent a "report card" package (Figure 68) detailing the vessel's transits, compliance levels, and information about right whales. If a vessel or company receives an A+ or A grade they are awarded a Certificate of Corporate Responsibility. In 2019, the program rated 258 vessels from 110 companies, with 85% of vessels and 86% of companies receiving A or A+ grades. This program is designed to acknowledge and applaud responsible corporate practices and environmental stewardship. Feedback on the report card approach is positive and the program is expected to continue into the foreseeable future.

Direct Engagement with the Mariner Community

All major ports maintain harbor safety committees that address port related issues such as safety, security and environmental concerns. Committee members may include government agencies, shipping agents, industry organizations, and public interest groups. Committee meetings provide updates on port issues to federal, state, commercial, and other stakeholders. Each year, liaisons from NMFS attend harbor safety committee meetings at ports adjacent to SMAs to provide seasonal updates, presentations, and reminders about federal regulations pertaining to right whales. Liaisons answer questions and listen to concerns from the maritime community. They often distribute informational documents to shipping agents to pass along to their shipping clients. NMFS representatives also attend meetings of port advisory groups, such as the Boston Port Operators Group, in a similar capacity, to discuss right whale vessel strike reduction regulations and programs.

[5] https://sanctuaries.noaa.gov/news/jun19/right-whale-corporate-responsibility-project-stellwagen-bank-national-marine-sanctuary.html

Navigation Aids

Professional mariners and recreational boaters commonly use official navigation reports to ensure safe transit at sea. NMFS has worked closely with government partners to ensure that details regarding the speed rule, SMAs, and DMAs are integrated into this stream of navigational information for the maritime community. Below is a list of these efforts.

1. Local Notices to Mariners, Broadcast Notices, and Marine Safety Information Bulletins

   The USCG issues several forms of regular updates to mariners including the weekly Local Notice to Mariners, Broadcast Notices to Mariners, and Marine Safety Information Bulletins. When SMAs or DMAs are active, local USCG districts will include related announcements in the "Special Notices" section of their Local Notice to Mariners. These announcements notify mariners to the declaration of, or changes to, voluntary DMAs, SMAs, and other management actions for right whales in relevant areas (Figure 69). They also list resources and websites that provide updated information about right whale training resources for mariners, recommended navigational actions when operating in whale habitat and instructions for reporting sightings of dead and injured right whales. The same information is provided in regionally tailored broadcasts that are routinely monitored by mariners. Some districts, such as Jacksonville, FL, also issue local Marine Safety Information Bulletins, explaining the endangered status of right whales, advising caution when transiting right whale habitat areas and detailing the speed rule requirements.

2. Special Notices to Mariners

   The National Geospatial-Intelligence Agency issues a Special Notice to Mariners each year, which includes a section providing information on protected species vulnerable to vessel strike, including right whales.

3. US Coast Pilot

   The U.S. Coast Pilot is a nautical reference book series that details a variety of navigational information of interest to mariners. NOAA's Office of Coast Survey (OCS) publishes the U.S. Coast Pilot, which is updated weekly and includes in-depth information about right whale regulations, how to identify right whales, and precautions to take when transiting right whale habitats. The Coast Pilot can be downloaded at the NOAA website.[6]

4. Nautical Charts

   OCS publishes Paper Nautical Charts, Electronic Navigational Charts, and Raster Navigational Charts that include detailed spatial information about right whale related spatial boundaries. These include SMAs, critical habitat, MSR boundaries, right whale

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[6] https://nauticalcharts.noaa.gov/publications/coast-pilot/index.html

ATBAs, and recommended two-way whale avoidance routes and tracks. These charting products are essential to mariners and are widely used throughout the professional and recreational marine world. The inclusion of right whale related spatial features in these charts is extremely helpful in ensuring mariner awareness and compliance.

Ongoing Outreach Programs

When the speed rule was first introduced in 2008, NMFS immediately launched a variety of efforts to inform mariners about the new rule, associated SMAs, and the problem of large whale vessel strikes. These activities included outreach to the press, publishing articles in maritime industry trade journals and presentations at relevant public events (festivals, boat shows, etc.) and industry meetings. NMFS developed a suite of outreach materials and mariner education modules. Hundreds of shipboard right whale outreach binders, filled with essential mariner training and educational resources, were handed out at events and made available upon request. Once the agency was confident of mariner awareness, and ongoing communications and education efforts were in place, NMFS refocused its outreach towards long term strategies.

Detailed information on right whale vessel strike reduction regulations and programs is now hosted on NMFS's comprehensive website Reducing Ship Strikes to North Atlantic Right Whales.[7] The website provides maps of the SMAs, information on mariner training and educational resources, links to the most recent right whale sightings, and instructions on how to report a vessel strike. The site is regularly updated and has proven to be a useful resource for vessel strike information.

Due to the seasonal nature of SMAs, mariners experience extended periods when SMAs are inactive. To ensure mariner awareness at the start of an SMA's active period, NMFS and its partners send out email notifications to a variety of distributions lists reminding mariners the SMAs are in effect. These distribution lists include industry associations, shipping agents, port authorities, passenger vessel operators, pilots, scientists, non-governmental organizations and other interested parties. NMFS also sends out notices to these lists when DMAs are declared.

Informational App

In 2012, a joint initiative by the Stellwagen Bank National Marine Sanctuary, USCG, Boston Port Operators Group, Massachusetts Port Authority, the International Fund for Animal Welfare, and other partners launched an innovative informational application (app) called Whale Alert.[8] The app's interactive mapping feature provides information on recent right whale sightings and acoustic detections, and allows users to report a right whale sighting. The app also features practical mariner information in the form of NOAA PORTS tides and currents data for stations along the coast and shows mapped boundaries of active SMAs and DMAs. Users of the app

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[7] https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales
[8] http://www.whalealert.org/

include mariners, recreational boaters, scientists, managers and members of the public. Whale Alert is currently active on the east and west coasts of the U.S.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This review evaluated the effectiveness, and impacts, of the right whale vessel speed rule as a tool to prevent right whale mortality and serious injuries. Since the speed rule was implemented, there has been a decline in the total number of documented right whale vessel strike mortalities but an increase in serious and non-serious injuries. This reflects progress made to date but also demonstrates that more effort is required to further reduce the incidence of vessel strikes. While we lack sufficient data to quantitatively demonstrate causality between the implementation of the speed rule and the decline in observed mortality, our assessment shows that the speed rule has had a positive effect in contributing to this change. The decline in mortality is promising and merits the continuation of, if not enhancement to, current management strategies.

Overall compliance with the speed rule continued to improve over the past decade and exceeds 80% collectively across all SMAs for the 2018-2019 season. However, certain discrete areas of poor compliance stand out and require enhanced attention. SMAs in the northeast demonstrated higher compliance rates than SMAs in the Mid-Atlantic and southeast. In particular, the ports of Wilmington, Charleston, Savannah, Brunswick and Jacksonville have compliance rates of less than 50% for OGV transiting into and out of the ports. (These conclusions reflect compliance without considering that some portion of apparently “non-compliant” transits may be covered by use of the safety deviation clause.)

Average (distance weighted) vessel speeds have slowed within SMAs both during active and inactive periods. This indicates factors other than the speed rule may be influencing a move to slower transit speeds including (possibly) emission pollution controls and fuel savings. The total transit distance of OGVs through active SMAs has remained fairly stable over the years, and represented between 41-43% of total vessel transit distance during the past three seasons.

Voluntary cooperation with DMAs has not proven to have a meaningful impact on vessel speed reduction. While there is evidence of mariners slowing down in DMAs, the degree of cooperation falls far short of levels reached in most parts of mandatory SMAs.

An assessment of small vessel traffic speeds in SMAs indicates regional differences in speed patterns. In the New England SMAs, > 80% of small vessel transit distance is below 10 knots, while in the Mid-Atlantic SMAs < 50% of transit distance is below 10 knots due mostly to fast pilot vessels. Most small vessel transits are made up of pilot, pleasure, sailing and fishing vessels, although this may constitute a biased sample. Small vessels in the U.S. are responsible for at least one right whale mortality in 2005 and one serious injury in 2006.

Between 1999 and 2012, small vessels were involved in at least 11 collisions with right whales resulting in injuries.

With regard to mariner impacts from the vessel speed rule, there was no indication that the rule has eroded navigational safety. Our economic impact assessment indicates a total yearly cost to industry of $28.3 to $39.4 million, with the majority of the cost (58 -70%) borne by the container ship sector. Container ships, cruise ships, and vehicle carriers (Ro-Ros) employ the greatest reductions in speed to comply with the rule and have the highest number of transits through active SMAs. As a result, they bear a large share of the total cost of the rule. Acknowledging differences in analysis techniques and variability in vessel traffic/fuel prices over time, when compared to earlier assessments of the direct costs of the speed rule, these estimates are substantially lower than the initial 2008 estimates ($87 million) and in line with the updated 2012 estimates ($19.6 - $34.8 million) (Nathan and Associates, 2008 and 2012; Silber and Bettridge, 2012). Additionally, the yearly direct cost to commercial shipping as a percent of trade value at affected East Coast ports is approximately 0.004%.

Recommendations

This review demonstrates that continued speed restrictions are warranted in light of the positive effect the speed rule has had in reducing the number of serious injuries and mortalities of right whales. Given the gravity of the whales' heath and population status and the continuing level of vessel collisions, we recommend that the rule be strengthened. The January 2020 vessel strike of a newborn right whale calf, recently presumed dead, best illustrates the urgent need for effective enhancements to the speed rule. It is necessary to modify some aspects of the rule to ensure levels of effectiveness consistent with right whale recovery needs. Based on the analyses and data presented in this report, the following specific recommendations are suggested:

- Modify SMAs:
    - NMFS should investigate the locations and timing of SMAs relative to current right whale distribution and vessel traffic patterns. Given what we know about changes in whale distribution, and vessel traffic patterns since development of the 2008 rule, we need to modify the location, timing, or duration of one or more SMAs to maximize their effectiveness.
        - During the past 10 years, at least 25% of DMAs were declared in the region south of Martha's Vineyard and Nantucket, Massachusetts. Right whale foraging activity has steadily increased in this area throughout the years. This zone warrants consideration for designation as an SMA.
        - Three significant vessel collisions have occurred in the area around Cape Cod, Massachusetts, including at least one mortality inside an active SMA. This is an area of particular concern and requires a re-assessment

of management actions required to reduce the risk of vessel strikes there.

- Enhance Enforcement and Outreach:
    - The agency currently lacks data on the full extent of vessels' reliance on the safety deviation but there are indications that some vessels may be claiming severe maneuverability constraints without reasonable grounds. There is no efficient mechanism by which the agency can collect such data from the logbook entries required for use of the safety deviation. To aid enforcement of the speed rule, and to better understand the extent of safety impacts, NMFS should investigate modifications to the regulatory language including possible contemporaneous electronic notification of safety deviations.

    - Vessels in certain SMAs exceed 10 knots at disproportionately high levels, especially OGVs in channel entrances. OGVs entering southern ports under pilotage, represent an outsized proportion of vessels traveling at excess speed. Additionally, container ships and pleasure vessels disproportionately operate at speeds in excess of 12 knots. Enforcement and outreach targeted to these industry sectors is needed to ensure compliance and meaningful vessel strike risk reduction across all vessel types.

- Address Vessel Strike Risk from Small Vessels: Small vessels (< 65 ft in length) transiting at speeds in excess of 10 knots are ubiquitous in portions of right whale habitat. The number of documented and reported small vessel collisions with whales necessitates further action both as it relates to potential regulations and outreach to this sector of the mariner community. For example, in 2019, Massachusetts placed seasonal limits on the speed of all vessels < 65 ft in length in Cape Cod Bay, and Canada expanded its Gulf of St. Lawrence speed restrictions to include vessels 42.6 ft (13 meters) in length.

- Modify or Terminate the DMA Program: Mariner cooperation with voluntary speed recommendations in DMAs is generally low and as such, likely does not provide a substantive reduction in vessel strike risk. NMFS should evaluate the DMA program to identify modifications to achieve more meaningful protections for right whales.

- Research Needs:

    - A large proportion of observed right whale vessel strikes between 1999 and 2018 involve females (54.4%) and when broken out by age class juveniles (45.6%) and calves (15.7%) are overrepresented. This finding requires additional investigation to determine if younger whales, and females, are at higher risk of vessel strike due to factors such as behavioral differences, smaller body size, difference in habitat use or inexperience with vessel traffic. A better understanding of the risks to these demographic groups may allow for more tailored management actions.

- Given the number of non-serious vessel collision injuries, an assessment of the sub-lethal impact of vessel strikes is warranted. Researchers have demonstrated that sub-lethal impacts from entanglements likely impeded reproduction. This has serious implications for population recovery. A more complete understanding of sub-lethal impacts from vessel collisions will better inform future right whale population recovery efforts.

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APPENDICES

- Appendix A: Tables and Figures
- Appendix B: IEC Economic Impact Analyses

Marine Mammal Stock Assessment Reports by Species/Stock

NOAA Fisheries annually prepares marine mammal stock assessment reports for all marine mammals in U.S. waters.

This page provides all marine mammal stock assessment reports by species/stock. We also provide this information as regional stock assessment reports.

Note: Individual reports are only posted when they are revised from a previous year.

Posting of the 508 compliant versions of the older years is in process. If there is a year that you need now, please contact us at 301-427-8400 or email pr.webmaster@noaa.gov to request it. Provide the species name and year that you need.

Cetaceans - Large Whales

All documents are in PDF format.

Blue Whale

- **Central North Pacific (*formerly called Western North Pacific (formerly Hawaii))**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Eastern North Pacific (*formerly called California/Mexico)**
  - Reports: 2019 | 2018 | 2017 | 2015 | 2013 | 2010 | 2009 | 2008 | 2007 | 2004 | 2003 | 2000
- **Western North Atlantic**
  - Reports: 2019 | 2010 | 2002 | 2001 | 2000 | 1999 | 1998 | 1995

Bowhead Whale

- **Western Arctic**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2000 | 1998

Bryde's Whale

- **Eastern Tropical Pacific**
  - Reports: 2015 | 2007 | 2000
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2017 | 2015 | 2012 | 2011 | 2009 | 2008 | 2005 | 2003 | 1995

Fin Whale

- **California-Oregon-Washington**
  - Reports: 2018 | 2016 | 2013 | 2010 | 2008 | 2003 | 2000
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Northeast Pacific**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2001 | 1998
- **Western North Atlantic**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001| 2000 | 1999 |1998 | 1997 |1995

Gray Whale

- **Eastern North Pacific**
  - Reports: 2018 | 2014 | 2013 | 2011| 2010 | 2008 | 2007 | 2005 | 2002 | 2000 | 1997
- **Western North Pacific Stock**
  - Reports: 2018 | 2014

Humpback Whale

- **American Samoa**
  - Reports: 2009
- **California-Oregon-Washington (*formerly called Eastern North Pacific and also formerly called California-Oregon-Washington-Mexico)**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2013 | 2010 | 2009 | 2008 | 2005 | 2004 | 2003 | 2002 | 2001 | 2000 | 1999
- **Central North Pacific**
  - Reports: 2019 | 2018 | 2017 | 2016 |2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998
- **Gulf of Maine (*formerly called Western North Atlantic)**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2000 | 1999 | 1998 | 1997 | 1995
- **Western North Pacific**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2001 | 2000 | 1999 | 1998

Minke Whale

- **Alaska**
  - Reports: 2018 | 2017 | 2015 | 2012 | 2010 | 2006 | 2001 | 1997
- **Canadian Eastern Coastal**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995
- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2007 | 2003 | 2000 | 1998
- **Hawaii**
  - Reports: 2013 | 2010 | 2004

Right Whale, North Pacific (formerly called Northern Right Whale)

- **Eastern North Pacific (*formerly called North Pacific)**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2000 | 1998

Right Whale, North Atlantic (formerly called Northern Right Whale)

- **Western Stock (*formerly called Western North Atlantic)**

Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995

Sei Whale

- **Eastern North Pacific**
  - Reports: 2018 | 2016 | 2010 | 2008 | 2007 | 2003 | 2000
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004
- **Nova Scotia (*formerly called Western North Atlantic)**
  - Reports: 2019 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2005 | 2003 | 2002 | 2000 | 1999
- **Western North Atlantic**
  - Reports: 1998 | 1995

Sperm Whale

- **California-Oregon-Washington**
  - Reports: 2019 | 2017 | 2014 | 2012 | 2010 | 2008 | 2007 | 2003 | 2001 | 2000 |1999
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **North Pacific**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 1998
- **North Atlantic**
  - Reports: 2019 | 2014 | 2013 | 2012 | 2007 | 2005 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995
- **Northern Gulf of Mexico**
  - Reports: 2015 | 2012 | 2010 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Puerto Rico and U.S. Virgin Islands**
  - Reports: 2010

Cetaceans - Small Whales

All documents are in PDF format.

Beaked Whale, Baird's

- **Alaska**
  - Reports: 2017 | 2013 | 2010 | 2005 | 1999 | 1997
- **California-Oregon-Washington**
  - Reports: 2018 | 2017 | 2013 | 2010 | 2008 | 2007 | 2003 | 2000

Beaked Whale, Blainville's

- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2005 | 2003 | 2000
- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2012 | 2009 | 1995
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995

Beaked Whale, Cuvier's

- **Alaska**
  - Reports: 2017 | 2013 | 2010 | 2005 | 1999 | 1997
- **California-Oregon-Washington**
  - Reports: 2017 | 2013 | 2010 | 2008 | 2007 | 2003 | 2000
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2003 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Puerto Rico and U.S. Virgin Islands**
  - Reports: 2011
- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2012 | 2009 | 2008 | 2005 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995

Beaked Whale, Gervais'

- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995

- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2012 | 2009 | 1995

Beaked Whale, Longman's

- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004

Beaked Whale, Mesoplodont

- **Western North Atlantic**
  - Reports: 2008 | 2007 | 2005 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997
- **California-Oregon-Washington**
  - Reports: 2017 | 2013 | 2010 | 2008 | 2007 | 2003 | 2000 | 1998

Beaked Whale, Sowerby's

- **Western North Atlantic**
  - Reports: 2019 | 2014 | 2013 | 2012 | 2009 | 1995

Beaked Whale, Stejneger's

- **Alaska**
  - Reports: 2017 | 2013 | 2010 | 2005 | 1999 | 1997

Beaked Whale, True's

- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2012 | 2009 | 1995

Beluga Whale

- **Beaufort Sea**
  - Reports: 2017 | 2014 | 2011 | 2008 | 2005 | 2002 | 1999 | 1997
- **Bristol Bay**
  - Reports: 2017 | 2014 | 2011 | 2008 | 2005 | 2002 | 1999 | 1997
- **Cook Inlet**

- Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2000 | 1999 | 1998

- **Eastern Bering Sea**
  - Reports: 2017 | 2014 | 2011 | 2005 | 2002 | 1999 | 1997
- **Eastern Chukchi Sea**
  - Reports: 2017 | 2014 | 2011 | 2008 | 2005 | 2002 |1999 | 1997

Dwarf Sperm Whale

- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2007 | 2003
- **Hawaii**
  - Reports: 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 2000 | 1999 | 1995
- **Western North Atlantic**
  - Reports: 2019 | 2016 | 2013 | 2012 | 2007 | 2005 | 2003 | 2002 | 2000 | 1999 | 1998 | 1997 | 1995

False Killer Whale

- **American Samoa**
  - Reports: 2010
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Hawaiian Islands Stock Complex (*formerly called Pacific Islands Region Stock Complex and formerly only Hawaii)**
  - Reports: 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 | 2002 | 2001 | 2000
- **Palmyra Atoll Stock (*formerly included in Pacific Islands Region Stock Complex)**
  - Reports: 2012 | 2011 | 2010 | 2009 | 2008 | 2007
- **Western North Atlantic**
  - Reports: 2019 | 2014

Killer Whale

- **AT1 Transient**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2005
- **Eastern North Pacific:**
  - **Alaska Resident**
    - Reports: 2017 | 2016 | 2013 | 2010 | 2007 | 2006 | 2005
  - **Northern Resident**
    - Reports: 2019 | 2017 | 2013 | 2010 | 2005 | 2001 | 1998
  - **Offshore**
    - Reports: 2018 | 2010 | 2008 | 2007 | 2003 | 2000 | 1999
  - **Transient (*currently part of the West Coast Transient stock)**
    - Reports: 2000 | 1999 | 1998
  - **Southern Resident**
    - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 | 2002 | 2001 | 2000 | 1999
- **Gulf of Alaska, Aleutian Islands, and Bering Sea Transient**
  - Reports: 2017 | 2016 | 2013 | 2010 | 2006 | 2005
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2010 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **West Coast Transient (*formerly called the Eastern North Pacific Transient stock)**
  - Reports: 2017 | 2013 | 2010 | 2005
- **Western North Atlantic**
  - Reports: 2014 | 2000 | 1995

Melon-Headed Whale

- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2005 | 2003 | 1995
- **Western North Atlantic**
  - Reports: 2019 | 2007 | 2005 | 2003

Narwhal

- **Unidentified**
  - Reports: 2017 | 2016 | 2013 | 2010

Northern Bottlenose Whale

- **Western North Atlantic**
  - Reports: 2014 | 2008 | 2007 | 1998 | 1995

Pilot Whale, Long-Finned

- **Western North Atlantic**
  - Reports: 2019 | 2018 | 2016 | 2015 | 2014 | 2013 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 |1995

Pilot Whale, Short-Finned

- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2007 | 2005 | 2003 | 2000 | 1999
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2006 | 2004 | 2003 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2015 | 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Puerto Rico and U.S. Virgin Islands**
  - Reports: 2011
- **Western North Atlantic**
  - Reports: 2019 | 2018 | 2016 | 2015 | 2014 | 2013 | 2011 | 2010 | 2009 | 2007 | 2006 | 2005 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995

Pygmy Killer Whale

- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Western North Atlantic**

- Reports: 2019 | 2007 | 2005 | 2003 | 1995

Pygmy Sperm Whale

- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2007 | 2003 | 2000
- **Hawaii**
  - Reports: 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1999 | 1995
- **Western North Atlantic**
  - Reports: 2019 | 2016 | 2013 | 2012 | 2007 | 2005 | 2003 | 2002 | 2000 | 1999 | 1998

Cetaceans - Dolphins

All documents are in PDF format.

Bottlenose Dolphin

- **Pacific Bottlenose Dolphin:**
  - **California Coastal**
    - Reports: 2016 | 2008 | 2006 | 2003 | 2001 | 2000
  - **California-Oregon-Washington Offshore**
    - Reports: 2016 | 2013 | 2010 | 2007 | 2003 | 2000
  - **Hawaiian Islands Stock Complex (Kauai/Niiahu, Oahu, 4-Island, Hawaii Island, Hawaii Pelagic)**
    - Reports: 2017 | 2013 | 2010 | 2006 | 2004 | 2000
- **Atlantic Bottlenose Dolphin:**
  - **Biscayne Bay**
    - Repots: 2013 | 2009
  - **Charleston Estuarine System**
    - Reports: 2015 | 2013 | 2009
  - **Florida Bay**
    - Reports: 2013 | 2009
  - **Indian River Lagoon Estuarine System**
    - Reports: 2015 | 2013 | 2009

- **Jacksonville Estuarine System**
  - Reports: 2015 | 2013 | 2009
- **Northern Georgia/Southern South Carolina Estuarine System**
  - Reports: 2015 | 2013 | 2009
- **Northern North Carolina Estuarine System**
  - Reports: 2017 | 2015 | 2013 | 2012 | 2010 | 2009
- **Northern South Carolina Estuarine System**
  - Reports: 2015 | 2013
- **Puerto Rico and U.S. Virgin Islands**
  - Reports: 2011
- **Southern Georgia Estuarine System**
  - Reports: 2015 | 2013 | 2009
- **Central Georgia Estuarine System**
  - Reports: 2015 | 2014
- **Southern North Carolina Estuarine System**
  - Reports: 2017 | 2015 | 2013 | 2010 | 2009
- **W.N. Atlantic Central Florida Coastal (*formerly part of Western North Atlantic Coastal stock)**
  - Reports: 2017 | 2015 | 2013 | 2010
- **W.N. Atlantic Northern Florida Coastal (*formerly part of Western North Atlantic Coastal stock)**
  - Reports: 2017 | 2015 | 2013 | 2010
- **W.N. Atlantic Northern Migratory Coastal (*formerly part of Western North Atlantic Coastal stock)**
  - Reports: 2017 | 2015 | 2013 | 2010
- **W.N. Atlantic South Carolina-Georgia Coastal (*formerly part of Western North Atlantic Coastal stock)**
  - Reports: 2017 | 2015 | 2013 | 2010
- **W.N. Atlantic Southern Migratory Coastal (*formerly part of Western North Atlantic Coastal stock)**
  - Reports: 2017 | 2015 | 2013 | 2010
- **W.N. Atlantic Offshore**
  - Reports: 2019 | 2016 | 2015 | 2014 | 2013 | 2008 | 2007 | 2005 | 2003 | 2002 | 2000 | 1999 | 1998 | 1997 | 1995
- **Western North Atlantic Coastal (*in 2009, split into multiple stocks)**
  - Reports: 2008 | 2007 | 2006 | 2005 | 2002 | 2001 | 2000 | 1999 | 1997 | 1995

- **Gulf of Mexico Bottlenose Dolphin:**
  - **Northern Gulf of Mexico Bay, Sound, and Estuary Stocks (*note that NOAA Fisheries is in the process of writing individual stock assessment reports for each of the 31 Bay, Sound, and Estuary stocks -- until this effort is completed, some of the information presented in the individual reports will also be included in the Bay, Sound, and Estuarine report)**
    - Reports: 2018 | 2016 | 2015 | 2014 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2005 | 1999 | 1995
  - **Choctawhatchee Bay**
    - Reports: 2015 | 2012 | 2011
  - **Terrebonne-Timbalier Bay Estuarine System Stock**
    - Reports: 2018
  - **St. Joseph Bay**
    - Reports: 2019 | 2015 | 2012 | 2011
  - **Barataria Bay Estuarine System**
    - Reports: 2017 | 2015 | 2014 | 2012 | 2011
  - **Mississippi Sound, Lake Borgne, Bay Boudreau Stock**
    - Reports: 2017 | 2015 | 2014
  - **Northern Gulf of Mexico Continental Shelf (formerly called Outer Continental Shelf)**
    - Reports: 2015 | 2014 | 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
  - **Gulf of Mexico Eastern Coastal (formerly part of Northern Gulf of Mexico Coastal Stocks (2005-2009) and Eastern Gulf of Mexico Coastal (1995-1997) - see below)**
    - Reports: 2015 | 2014 | 2012 | 2010
  - **Gulf of Mexico Northern Coastal (formerly part of Northern Gulf of Mexico Coastal Stocks (2005-2009) and Northern Gulf of Mexico Coastal (1995-1997) - see below)**
    - Reports: 2015 | 2014 | 2012 | 2010
  - **Gulf of Mexico Western Coastal (formerly part of Northern Gulf of Mexico Coastal Stocks (2005-2009) and Western Gulf of Mexico Coastal (1995-1997) - see below)**
    - Reports: 2015 | 2014 | 2012 | 2010
  - **Northern Gulf of Mexico Oceanic (formerly called Continental Shelf Edge and Continental Slope)**
    - Reports: 2014 | 2013 | 2012 | 2011 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
  - **Eastern Gulf of Mexico Coastal**
    - Reports: 1997 | 1995
  - **Northern Gulf of Mexico Coastal**
    - Reports: 1997 | 1995

- **Western Gulf of Mexico Coastal**
  - Reports: 1997 | 1995
- **Northern Gulf of Mexico Coastal Stocks**
  - Reports: 2009 | 2008 | 2007 | 2005

Clymene Dolphin

- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2007 | 2005 | 2003

Common Dolphin

- **Western North Atlantic (*in 2008, this stock was determined to be Short-Beaked Common Dolphin Western North Atlantic stock - see below)**
  - Reports: 2019 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995

Common Dolphin, Long-Beaked

- **California**
  - Reports: 2016 | 2012 | 2010 | 2008 | 2007 | 2003 | 2000

Common Dolphin, Short-Beaked

- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2007 | 2003 | 2000
- **Western North Atlantic (*formerly called Common Dolphin Western North Atlantic stock - see above)**
  - Reports: 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008

Fraser's Dolphin

- **Hawaii**
  - Reports: 2017 | 2010 | 2004
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995

- **Western North Atlantic**
  - Reports: 2019 | 2007 | 2005 | 2003

Northern Right Whale Dolphin

- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2003 | 2001 | 2000

Risso's Dolphin

- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2007 | 2003 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2015 | 2014 | 2013 | 2012 | 2010 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Western North Atlantic**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2002 | 2001 | 2000 | 1999 | 1998 | 1995

Rough-Toothed Dolphin

- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2016 | 2012 | 2008 | 2007 | 2005 |2003 | 1995
- **Western North Atlantic**
  - Reports: 2018 |2013 | 2008

Spinner Dolphin

- **American Samoa**
  - Reports: 2010
- **Hawaiian Islands Stock Complex**
  - Reports: 2018 | 2013 (corrected report) | 2012 | 2010 | 2004 | 2003 | 2000
- **Northern Gulf of Mexico**

  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Puerto Rico and U.S. Virgin Islands**
  - Reports: 2011
- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2007 | 2005 | 1998 | 1995

Spotted Dolphin, Atlantic

- **Northern Gulf of Mexico**
  - Reports: 2015 | 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Puerto Rico and U.S. Virgin Islands**
  - Reports: 2011
- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2012 | 2007 | 2005 | 2000 | 1999 | 1998 | 1997 | 1995

Spotted Dolphin, Pantropical

- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2003 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2015 | 2014 | 2012 | 2011 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2007 | 2005 | 2002 | 2000 | 1999 | 1998 | 1997 | 1995

Striped Dolphin

- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2003 | 2000
- **Hawaii**
  - Reports: 2017 | 2013 | 2010 | 2004 | 2000
- **Northern Gulf of Mexico**
  - Reports: 2012 | 2009 | 2008 | 2007 | 2005 | 2003 | 1995
- **Western North Atlantic**
  - Reports: 2019 | 2013 | 2012 | 2007 | 2005 | 2000 | 1998 | 1997 | 1995

White-Beaked Dolphin

- **Western North Atlantic**
  - Reports: 2019 | 2007 | 2006 | 2003 | 1997 | 1995

White-Sided Dolphin, Atlantic

- **Western North Atlantic**
  - Reports: 2019 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995

White-Sided Dolphin, Pacific

- **California-Oregon-Washington, Northern, and Southern**
  - Reports: 2016 | 2013 | 2010 | 2008 | 2007 | 2003 | 2000
- **North Pacific (*formerly called Central North Pacific)**
  - Reports: 2018 | 2017 | 2015 | 2012 | 2009 | 2006 | 2003 | 2000 | 1997

Cetaceans - Porpoises

All documents are in PDF format.

Dall's Porpoise

- **Alaska**
  - Reports: 2018 | 2017 | 2015 | 2012 | 2009 | 2007 | 2006 | 2003 | 2000 | 1997
- **California-Oregon-Washington**
  - Reports: 2016 | 2010 | 2008 | 2007 | 2003 | 2000

Harbor Porpoise

- **Bering Sea**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2006 | 2003 | 2000 | 1997
- **Gulf of Alaska**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2006 | 2003 | 2000 | 1997
- **Gulf of Maine-Bay of Fundy**

  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 | 1995
- **Monterey Bay (*formerly part of Central California - see below)**
  - Reports: 2019 | 2013 | 2009 | 2004 | 2003 | 2002
- **Morro Bay (*formerly part of Central California - see below)**
  - Reports: 2019 | 2013 | 2009 | 2004 | 2003 | 2002
- **Northern California-Southern Oregon (*formerly called Northern California)**
  - Reports: 2019 | 2013 | 2009 | 2002 | 2001 | 2000 | 1999
- **Northern Oregon-Washington Coast (*formerly called Oregon-Washington Coast)**
  - Reports: 2013 | 2011 | 2009 | 2006 | 2003 | 2002 | 2000 | 1999 | 1998
- **San Francisco-Russian River**
  - Reports: 2019 | 2013 | 2009 | 2004 | 2003 | 2002
- **Southeast Alaska**
  - Reports: 2019 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2006 | 2003 | 2000 | 1997
- **Washington Inland Waters (*formerly called Inland Washington)**
  - Reports: 2016 | 2011 | 2006 | 2003 | 2002 | 2000 | 1999 | 1998
- **Central California (*split into Monterey Bay stock and Morro Bay stock in 2002 - see above)**
  - Reports: 2001 | 2000 | 1999

Pinnipeds - Phocids (Earless Seals or True Seals)

All documents are in PDF format.

Bearded Seal

- **Alaska**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2011 | 2009 | 2006 | 2005 | 2002 | 2001 | 1997

Gray Seal

- **Western North Atlantic**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1995

Harbor Seal

- **Alaska stocks (*previously separated as Bering Sea, Gulf of Alaska, and Southeast Alaska stocks - see below)**
  - Reports: 2019 | 2017 | 2015 | 2012 | 2011
- **California**
  - Reports: 2014| 2011 | 2005| 2003 | 2001 | 2000
- **Oregon-Washington Coastal**
  - Reports: 2013 | 2010 | 2007 | 2003 | 2002 | 2000 | 1998
- **Washington Inland**
  - Reports: 2013 | 2010 | 2003 |2002 | 2000 |1998
- **Western North Atlantic**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005| 2003 | 2002 | 2001 | 2000| 1999 | 1998 | 1995
- **Bering Sea (*in 2011, combined into one Alaska stock report - see above)**
  - Reports: 2009 | 2007 | 2006 | 1998
- **Gulf of Alaska (*in 2011, combined into one Alaska stock report - see above)**
  - Reports: 2009 | 2007 | 2006 | 1998
- **Southeast Alaska (*in 2011, combined into one Alaska stock report - see above)**
  - Reports: 2009 | 2007| 2006| 1998

Harp Seal

- **Western North Atlantic**
  - Reports: 2019 | 2018 | 2017 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1995

Hawaiian Monk Seal

- **Hawaii**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2008 | 2007 | 2006 | 2005 | 2000 | 1999

Hooded Seal

- **Western North Atlantic**
  - Reports: 2018 | 2007 | 2006 | 2005 | 2003 | 1999 | 1998 | 1995

Northern Elephant Seal

- **California Breeding**
  - Reports: 2014 | 2007 | 2002 | 2000

Ribbon Seal

- **Alaska**
  - Reports: 2018 | 2017 | 2015 | 2014 | 2013 | 2009 | 2007 | 2006 | 2005 | 2002 | 2001| 1997

Ringed Seal

- **Alaska**
  - Reports: 2019 | 2017 | 2016 | 2015 | 2014 | 2013 | 2011 | 2009 | 2006 | 2005 | 2002 | 2001| 1997

Spotted Seal

- **Alaska**
  - Reports: 2017 | 2014 | 2011 | 2009 | 2006 | 2005 | 2002 | 2001 | 1997

Pinnipeds - Otariids (Eared Seals or Fur Seals and Sea Lions)

All documents are in PDF format.

Guadalupe Fur Seal

- **Mexico**
  - Reports: 2019 | 2016 | 2000

Northern Fur Seal

- **California (*formerly called San Miguel Island)**
  - Reports: 2015 | 2013
- **Eastern Pacific**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1998

- **San Miguel Island (*in 2013, combined into California stock report)**
  - Reports: 2010 | 2006 | 2003 | 2000 | 1998

California Sea Lion

- **United States**
  - Reports: 2018 | 2014 | 2011 | 2007 | 2003 | 2000

Steller Sea Lion

- **Eastern**
  - Reports: 2019 | 2017 | 2016 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998
- **Western**
  - Reports: 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2003 | 2002 | 2001 | 2000 | 1999 | 1998

Marine Mammals Under the Jurisdiction of U.S. Fish and Wildlife Service (Manatees, Polar Bears, Sea Otters, and Walruses)

West Indian Manatee

- **Antillean (Puerto Rico)**
- **Florida**

Polar Bear

- **Alaska Chukchi/Bering Seas**

Sea Otter, Southern

- **California**

Sea Otter, Northern

- **Southcentral Alaska**

- **Southeast Alaska**
- **Southwest Alaska**
- **Washington**

Pacific Walrus

- **Alaska**

More Information

- Marine Mammal Stock Assessment Reports by Region
- Marine Mammal Stock Assessments Overview
- Policy for Distinguishing Serious from Non-Serious Injuries of Marine Mammals
- Population Assessments
- Marine Mammal Protection

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Endang Species Res

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Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales

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[2]New England Aquarium, 1 Central Wharf, Boston, Massachusetts 02110, USA

ABSTRACT: To reduce right whale *Eubalaena glacialis* deaths caused by ship collisions along the US East Coast, a rule was implemented on 8 December 2008 requiring all vessels ≥65 feet (19.8 m) to travel 10 knots (18.5 km h^{-1}) or less in 10 seasonal management areas (SMAs). To evaluate the effectiveness of this rule, we plotted the locations of all right whale and humpback whale *Megaptera novaeangliae* carcasses attributed to ship-strikes since December 1990 in US waters to determine their proximity to SMAs. In the 18 yr pre-rule period, 13 of 15 (87%) right whales and 12 of 26 (46%) humpback whales killed by ships were found inside later SMA boundaries or within 45 nmi (83 km) of their perimeters during later active dates. In the first 5 yr after the rule became effective, no ship-struck right whales were found inside or within 45 nmi of any active SMA. This was nearly twice as long as the longest pre-rule period without discovery of a ship-struck carcass in those areas during effective time periods. Based on the 18 yr pre-rule period, bootstrap resampling analyses revealed that the probability of finding no ship-struck whales in or near SMAs during the first 5 yr post-rule period would be a statistically significant reduction in such deaths ($p = 0.031$). The results suggest the rule has been effective at reducing right whale deaths. We suggest enlarging SMAs to include additional parts of the right whale migratory corridor.

KEY WORDS: North Atlantic right whales · Humpback whales · Ship strikes · Conservation · Vessel speed limits

INTRODUCTION

The North Atlantic right whale *Eubalaena glacialis* was hunted nearly to extinction by 1000 yr of whaling that ended in the early 1900s (Reeves et al. 2007). Now one of the world's most endangered large whales (Marine Mammal Commission 2008), the species currently occurs almost exclusively over the continental shelf off the eastern USA and Canada. As of late 2013, it was estimated to number about 500 whales (www.narwc.org/papers.php?mc=3). The principal threats to its survival — vessel collisions and entanglement in fishing gear (Knowlton & Kraus 2001, Moore et al. 2004, Knowlton et al. 2012, van der Hoop et al. 2013) — are the main constraints to its recovery (Kraus et al. 2005, National Marine Fisheries Service 2005). From 1990 through 2012, more than half of all dead right whales found stranded or floating at sea (39 of 73) were attributable to ship collisions (n = 23) or entanglement (n = 16) (Knowlton & Kraus 2001, Moore et al. 2004, Marine Mammal Commission 2013). With no apparent progress in reducing entanglement deaths (Knowlton et al. 2012, van der Hoop et al. 2013), reducing vessel collisions has become even more important.

Several early studies indicated that reducing ship speed in key right whale habitats could reduce vessel-related whale deaths. Knowlton et al. (1995) modeled hydrodynamic forces around ships traveling at different speeds and concluded that objects the size and density of a whale can be pulled towards hulls and propellers of large ships with a force that increases as

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speeds increase above 10 knots. Clyne (1999) also simulated risks of collisions with vessels traveling at various speeds and found that collisions with the bow were more likely when speeds increased above 10 knots. Laist et al. (2001) examined accounts of accidental collisions with whales by vessels travelling at known speeds and concluded that lethal collisions increase sharply between speeds of 10 to 14 knots (18.5 to 15.9 km h^{-1}) and were rare at speeds below 10 knots. Based on those findings the seasonal distribution of right whales, the location of ship-struck carcasses, and input from the shipping industry, Russell et al. (2001) recommended seasonal management areas with 10 knot speed limits off major ports and in key habitats along the eastern US coast. Assuming whale deaths due to ships are strictly a function of impact force and vessel hydrodynamics, Vanderlaan & Taggart (2007) concluded that the greatest rate of change in the probability of lethal collisions was between vessel speeds of 8.6 to 15 knots (15.9 to 27.8 km h^{-1}) and that the probability of death declined by 50% at speeds of <11.8 knots (21.9 km h^{-1}).

Based largely on those findings and their own analyses, the National Marine Fisheries Service (NMFS) adopted a rule to limit vessel speeds in key US right whale habitats as part of its 'right whale ship-strike reduction strategy' (NMFS 2008a). The rule became effective on 8 December 2008 for a 5 yr period (i.e. until 8 December 2013). Although intended to protect right whales, the measure was also expected to provide some protection to humpback whales *Megaptera novaeangliae* and other large whales whose ranges overlap with those of right whales (NMFS 2008b). The rule requires all vessels 65 feet (19.8 m) or longer (also herein referred to as 'ships') to use speeds of 10 knots or less when transiting 10 Seasonal Management Areas (SMAs) along the US East Coast during periods of peak right whale occurrence (Fig. 1). The 10 SMAs comprise 6 that extend 20 nautical miles (nmi; 37 km) from shore, off major ports along the species' coastal migratory corridor between southern New England and Georgia (effective 1 November to 30 April); 3 in feeding areas off Massachusetts (i.e. Cape Cod Bay, effective 1 January to 15 May; the Great South Channel, effective 1 April to 31 July; and an area immediately east and north of Cape Cod, effective 1 March to 30 April); and 1 in the core of the species' calving grounds off the southeastern US coast of Georgia and Florida (effective 15 November to 15 April).

In addition to SMAs, the NMFS ship-strike reduction strategy included new vessel routing measures for the port of Boston in Massachusetts and 3 ports in the southeastern US right whale calving grounds, and established 2 other types of management areas: Dynamic Management Areas (DMAs) and a seasonal 'Area To Be Avoided' (ATBA). DMAs are temporary 15 d management areas established on short notice to protect aggregations of 3 or more right whales found at unpredictable locations outside of active SMAs. When DMA boundaries are announced through customary maritime communication media (e.g. voice radio and local notices to mariners) ships are asked, but not required, to limit speeds to 10 knots or to steer clear of those areas. ATBAs, established under the authority of coastal nations after approval of the International Maritime Organization, are areas where ship operators are asked, but not required, to avoid transits. Such an area off Nova Scotia, Canada, has been shown to be effective at reducing the risk of lethal vessel strikes in right whale habitats (Vanderlaan et al. 2008). The ATBA for right whale protection lies principally within the boundary of the Great South Channel SMA, east of the shipping lanes that run along that SMA's western edge (Fig. 1). The new routing measures: (1) narrowed and shifted the

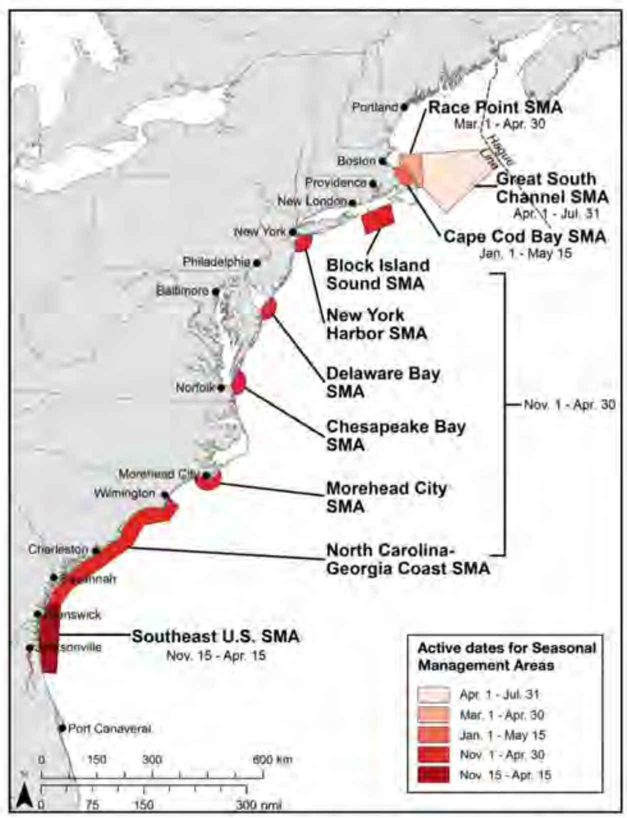

Fig. 1. *Eubalaena glacialis*. Locations and effective dates of Seasonal Management Areas (SMAs) requiring 10 knot ship speed limits after 8 December 2008 to protect North Atlantic right whales

east–west leg of track of vessel traffic separation lanes leading into Boston Harbor to reduce overlap with right whale habitat in Cape Cod Bay (Silber et al. 2012a) and (2) recommended routes through Cape Cod Bay and off the ports of Jacksonville, Fernandina, and Brunswick to minimize transit distances through areas used least intensively by right whales (Lagueux et al. 2011).

Initially proposed in June 2006 (NMFS 2006), the rule finally adopted in 2008 was subject to a protracted review by high-level officials in the US government. Concerned about its economic impacts and skeptical of the measure's effectiveness, several changes were imposed on the action preferred by the NMFS. In part, the width of SMAs along the species' migratory corridor was reduced from 30 to 20 nmi (55 to 37 km), and a sunset provision was added requiring the rule to expire 5 yr after its effective date (i.e. 8 December 2013). During the 5 yr period the NMFS was to evaluate effectiveness of the speed requirement for reducing whale deaths and decide whether to extend, modify, or allow it to lapse. Another required change was making the 10 knot speed limit in DMAs voluntary instead of mandatory. On 9 December 2013, the rule was extended indefinitely subject to further review to determine if dredged channels through SMAs should be exempted from its provisions as requested by petition (NMFS 2013).

After the 2008 rule was adopted, the NMFS developed a plan to evaluate its effectiveness (Silber & Bettridge 2009). Based on the first 3 yr of post-rule experience, the NMFS examined vessel compliance rates and economic impacts using data from an Automatic Identification System for ships (Silber & Bettridge 2012) and evaluated its biological effectiveness based on intervals between all documented collisions with large whales along the east coast 2 yr before the rules went into effect versus 2 yr afterwards (Pace 2011). From those analyses, the NMFS concluded that biological data were not yet sufficient to reach statistically meaningful conclusions, but that „…there may be 'a meager amount of evidence in support of a reduction in ship-strike deaths and serious injuries of large whales'" (Silber & Bettridge 2012, p. iv).

Several other studies have investigated compliance with the new speed restrictions in both SMAs (Silber & Bettridge 2010, Lagueux et al. 2011, Mueller et al. 2011, Wiley et al. 2011) and DMAs (Asaro 2012, Silber et al. 2012b). Initial compliance in SMAs was poor, but improved after warnings began to be issued in late 2009 and improved further after notices of violations with speed limits were issued in late 2010 (Silber & Bettridge 2012). Most ships, however, reduced their speed to varying degrees, although not necessarily to 10 knots. Compliance in DMAs was very poor. This result was similar to a voluntary request asking vessels to travel at 10 knots off Southern California to protect blue whales, which resulted in almost no change in vessel speeds (McKenna et al. 2012). Still other studies have recently provided further evidence that collision risks increase as vessel speeds increase above 10 knots due to hydrodynamic effects (Silber et al. 2010), and whale deaths are correlated with vessels traveling at increasing speeds (Conn & Silber 2013).

The reason why slow speeds are thought to reduce lethal collisions is subject to debate. Some suggest it is due solely to reduced impact and hydrodynamic forces (Vanderlaan & Taggart 2007, Vanderlaan et al. 2009, Silber et al. 2010); others suggest it provides added time for whales to avoid oncoming ships (Laist et al. 2001, Gende et al. 2011). Regardless of the mechanism and its intuitive rationale for reducing speed to reduce collision risks, the effectiveness of speed requirements remains poorly documented and is still subject to doubt by some. To further explore whether speed restrictions have been effective at reducing lethal whale collisions, we examined information on known and possible ship-strike deaths of right and humpback whales found in and near SMAs before and after the NMFS implemented its rules limiting ship speeds along the US East Coast.

Specifically, we examined the locations and discovery dates of all right whale and humpback whale carcasses attributed to ship strikes or unknown causes to determine their proximity to SMA boundaries and their occurrence relative to SMA effective dates before and after the rule went into effect on 8 December 2008. We did not include fin whales because, unlike right whales and humpback whales, they can be carried 1000s of kilometers into ports on the bows of ships making it unclear where they were struck (Laist et al. 2001). We also did not consider other large whales (i.e. sperm, blue, sei, or minke whales), because they occur infrequently in areas where SMAs have been designated and because lethal collisions with those species along the US East Coast have been rare over the past 25 yr (Laist et al. 2001). We hypothesized that the average annual tally of right whale carcasses, and possibly also humpback whale carcasses, attributable or possibly attributable to ships discovered in or near SMA boundaries during SMA time frames would be lower after the ship-strike reduction rule went into effect.

MATERIALS AND METHODS

We searched the National Marine Mammal Stranding Database maintained by the NMFS for records of all known right whale and humpback whale deaths attributed to ship strikes along the eastern US and Canadian coasts after 8 December 1990. For right whales, we also examined the Right Whale Photo-identification Catalogue maintained by the New England Aquarium for such deaths. Because the NMFS ship-strike reduction strategy is focused on US waters, our analyses of SMA effectiveness used only records of dead whales found within the US Exclusive Economic Zone. We sought records from Canada (i.e. waters north and east of the Hague Line that serves as the boundary between the US and Canadian Exclusive Economic Zones; Fig. 1), the only other area where North Atlantic right whales are known to have been killed by ships, to indicate what proportion of the ship-collision problem occurs in US waters. For right whales, our study period extended through 8 December 2013, the latest date for which records were available from the Right Whale Photo-identification Catalogue. Because of delays in entering stranding data into the national database, analyses of humpback whales extended only through 8 July 2011.

We also searched for records of all right whale deaths after 8 December 1990 that were attributed to unknown causes, because some of those whales may have been killed by ship strikes (e.g. some whales were documented floating offshore, but were not examined closely). We selected 8 December 1990 as the start of our study period because: (1) that date generally corresponds with the time when East Coast carcass recovery efforts for right whales were expanded and necropsy teams began flensing carcasses to the bone to look for internal ship-collision injuries not always apparent externally, and (2) it was statistically convenient to use the same day and month as the 8 December 2008 effective date for the NMFS rule. Data recorded for each dead whale in the national stranding database include the date, latitude and longitude, and general description of where the carcass was first seen; the cause of death, if it can be determined; the whale's decomposition state; and a summary of necropsy results (if conducted) or other findings explaining the assigned cause of death. When those data for right whales were missing, supplemental information was obtained when available from the Right Whale Photo-identification Catalogue.

Carcass locations were mapped using ArcGIS Version 10.0. SMA boundaries were added using coordinates available from the NMFS. Separate maps showing carcass discovery locations before and after the rule went into effect on 8 December 2008 were prepared for right whales killed by ships and for right whales that died of unknown causes that might have involved ship collisions. To identify carcasses of whales possibly killed by ships, we narrowed the list of carcasses attributed to unknown causes by eliminating those that were thoroughly necropsied and had no signs of ship-collision injuries. We also prepared a map for humpback whales, but only for deaths attributed to ship strikes; 275 humpback whale carcasses attributed to unknown causes were not plotted. Much less effort is made to retrieve and necropsy dead humpback whales than right whales; thus, unlike the situation for right whales, almost no records of humpback whales could be ruled out as possibly being collision related. Because of the large number of humpback whale carcasses attributed to unknown causes and the inability to exclude any that were clearly not caused by ship collisions, we concluded that for this species it would not be possible to distinguish meaningful trends relative to ship collisions and implementation of SMAs from such carcasses.

From plotted locations we identified all right whale carcasses attributed to ship strikes and to unknown causes potentially involving ship strikes found inside SMA boundaries during effective time frames before and after the ship-strike reduction rule went into effect. For all other right whale carcasses in US waters, we calculated their distance to the nearest SMA boundary. To account for carcasses that may have drifted outside SMA boundaries after whales were struck and before they were found dead, we considered any carcasses inside SMAs or within 45 nmi (74 km) of SMA boundaries during their active time frames (hereafter referred to as 'in or near active SMAs') to be potential victims of collisions inside SMA boundaries. We did the same for humpback whale carcasses, but only for those attributed to ship strikes. We then calculated the average annual number of ship-struck carcasses found in or near active SMAs for each species during the 18 yr pre-rule period and for post-rule periods of 5.0 yr (1826 d) for right whales and 2.5 yr (942 d) for humpback whales (i.e. the latest dates for which data were available).

The drift distance of 45 nmi was based on estimates of carcass degradation and drift rates. Almost all right whale deaths attributed to ship collisions in this study were found moderately decomposed (Code 3) or fresher according to the 5 category ranking system (with Code 5 representing the most degraded) used to describe carcass degradation states (Geraci & Lounsbury 2005). We estimated it would take a maximum of 6 d for a right whale carcass to become moderately decomposed. This was based on a right whale named Staccato (Catalogue No. 1014) that was photographed alive and uninjured on 15 April 1999 and next seen 5 d later floating dead off Cape Cod, Massachusetts, after being struck by a ship. Its carcass was towed ashore the day it was sighted and it was necropsied the following day (i.e. 21 April), at which time it was recorded as being moderately decomposed (i.e. Code 3). Although carcass degradation can proceed at different rates depending on temperature, because right whales along the US East Coast almost always occur in cool water similar to temperatures in Cape Cod Bay in April, we considered the April 1999 case to be the best available estimate of the time needed for a right whale to degrade to a Code 3 condition.

Average carcass drift rate was estimated from the distances of movements reported for 5 right whale carcasses seen drifting in US waters and later re-sighted at another location. These carcasses were first seen floating on the following dates: 3 September 2002, 6 September 2002, 7 February 2004, 27 June 2010, and 2 March 2012. Coordinates for initial and resighting locations documented drift distances of at least 77 nmi (143 km) in 22 d, 112 nmi (204 km) in 8 d, 54 nmi (100 km) in 2 d, 21 nmi (39 km) in 3 d, and 27 nmi (50 km) in 5 d, respectively, giving an average drift distance of 7.3 nmi (13.5 km) per day or 43.8 nmi (81.1 km) in 6 d, which we rounded off to 45 nmi (83.3 km) for mapping convenience. Although these records do not reflect all possible conditions that could influence carcass drift rates, they reflect at least some range of conditions in different seasons and areas and are the best available data at this time.

We conducted a bootstrap resampling analysis (Efron & Tibshirani 1993) to test the hypothesis that the average annual number of ship-struck whale carcasses found after the speed rule went into effect would be less than the average number during the 18 yr before the speed rule went into effect. This hypothesis was tested separately for right whale carcasses found in or near active SMAs and for right whale carcasses found >45 nmi from SMAs (Table 1). We did the same for ship-struck humpback whale carcasses. For right whales, annual carcass totals from the 18 yr pre-rule period were resampled one million times, with each sample consisting of a random selection of 5 annual carcass totals to match the number of years in the post-rule period. After each annual total was selected, it was returned to the pool of eligible years so that each draw in a 5 yr sample had 18 annual totals from which to select (i.e. random selection with replacement). We followed the same procedure for humpback whales, but had only 2.5 yr of post-rule data. Therefore, each bootstrap sample for humpback whales consisted of a random selection of 3 annual pre-rule carcass totals. The mean of each bootstrap sample was calculated, and those values were sorted in ascending order. The limits of the upper 95% of values were used as the confidence interval. The percentage of mean values less than the lower bound constituted the p-value.

To investigate the hypothetical probability of discovering ship-struck right whale carcasses in or near SMAs in the sixth post-rule year, we did an additional bootstrap resampling as described above, but drew 6 values instead of 5 from the pool of 18 pre-rule annual ship-strike carcass totals in or near SMAs. From those samples we calculated the probability of discovering zero whales in the first 5 yr, followed by discovering ≤1 and ≤2 carcasses in the sixth year. We considered only 0, 1, or 2 carcass discoveries because these were the only values observed in any given year during the pre-rule period and, thus, were the only values possible in the bootstrap samples.

We also compared maximum waiting times between discovery of ship-struck right whale and humpback whale carcasses found in or near active SMAs during pre- and post-rule periods to determine the extent to which intervals between recorded ship-collision deaths differed.

RESULTS

Over the entire study period, 23 of 72 confirmed right whale deaths (31.9%) were attributed to ship collisions. Three-fourths of those deaths were in US waters (17 deaths including 15 pre-rule and 2 post-rule) and one-fourth (6 deaths) were in Canadian waters (Table 1, Fig. 2). During the 18 yr pre-rule period, 10 of the 15 carcasses in US waters were inside SMAs, and 3 others were within 45 nmi of SMA boundaries (including 2 within just 6 nmi) during later SMA active dates. Together, those 13 carcasses comprised 87% of all known ship-strike deaths (Table 2) in US waters during the pre-rule period for an average carcass discovery rate of 0.72 right whales yr^{-1} in or near active SMAs.

The decomposition state of all ship-struck right whale carcasses found in or near later SMA boundaries in the pre-rule period was moderate or fresher,

Table 1. *Eubalaena glacialis*. Date and distance from Seasonal Management Areas (SMAs) of all North Atlantic right whale carcasses attributed to ship collisions along the US East Coast: 1 January 1990 to 8 December 2013, before (pre-rule) and after (post-rule) the SMA implementation on 8 December 2008. Decomposition (Decomp.) codes — 1: alive; 2: fresh; 3: moderate decomposition; 4: advanced decomposition; Unk: unknown condition; nmi: nautical mile

Date (mm/dd/yy)	Nearest SMA	Inside SMA dates?	Inside SMA boundary?	Distance from SMA (nmi/km)	Decomp. code
Pre-rule					
03/12/91[a]	Calving grounds SMA	Yes	Yes	0	3
01/05/93[a]	Calving grounds SMA	Yes	Yes	0	1
12/06/93[a]	Chesapeake Bay SMA	Yes	No	2.6/4.8	Unk
01/30/96[a]	Calving grounds SMA	Yes	Yes	0	3
03/09/96[a]	Cape Cod Bay SMA	Yes	Yes	0	Unk
04/20/99[a]	Cape Cod Bay SMA	Yes	Yes	0	3
03/17/01[a]	Delaware Bay SMA	Yes	No	36/66.7	3
06/18/01	New York Harbor SMA	No	Yes	0	3
08/22/02	Delaware Bay SMA	No	No	15.4/28.5	4
02/07/04[a]	Chesapeake Bay SMA	Yes	Yes	0	3
11/17/04[a]	Chesapeake Bay SMA	Yes	Yes	0	3
01/12/05[a]	Calving grounds SMA	Yes	Yes	0	2
04/28/05[a]	Outer Cape Cod SMA	Yes	No	5.9/10.9	3
01/10/06[a]	Calving grounds SMA	Yes	Yes	0	2
12/30/06[a]	Calving grounds SMA	Yes	Yes	0	3
Post-rule					
07/02/10	Great South Channel SMA	Yes	No	112/207	3
03/27/11	Chesapeake Bay SMA	Yes	No	47/86	4

[a]Carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames

suggesting they may have drifted up to 45 nmi between the time of death and carcass discovery. The 3 longest waiting times between finding such carcasses in the pre-rule period were 2.8 yr (i.e. 1057 d between 17 March 2001 and 7 February 2004), 2.2 yr (i.e. 785 d between 6 December 1993 and 30 January 1996), and 1.9 yr (i.e. 709 d between 30 December 2006 and 8 December 2008). Only 2 pre-rule ship strikes were found outside the potential reach of eventual SMA protection provisions; both were inside or within 45 nmi of SMA boundaries, but were discovered 7 wk or more outside later SMA active dates. During the first 5.0 post-rule years, no ship-struck right whales were found in or near any active SMAs, giving a carcass discovery rate of 0 yr^{-1}. During that period, 2 ship-struck right whales were found in US waters; both were found within the active dates of the nearest SMA, but were >45 nmi away from the nearest SMA boundary (one 47 nmi away in Code 4 condition, the other 112 nmi away in Code 3 condition).

Thirty-three right whale deaths were attributed to unknown causes over the entire study period; 29 in US waters and 4 in Canadian. Eight of the 29 in US waters were recovered in moderate to fresh condition (mostly neonates) and were ruled out as possible ship-collision victims based on necropsy results that found no evidence of collision injuries. Therefore, 25 of all mortalities attributed to unknown cause might have been due to ship strikes; 21 in US waters (14 pre-rule and 7 post-rule) and 4 in Canadian waters (Table 3, Fig. 3). During the 18 yr pre-rule period, 8 of the 14 possible ship-strike carcasses in US waters (57.1%) were found either inside (n = 5) or within 45 nmi (n = 3) of SMA boundaries during their later effective dates for an annual pre-rule discovery rate of 0.44 right whale carcasses yr^{-1} in or near active SMAs. During the first 5.0 yr after the rule's effective date, 4 of 7 carcasses (57.1%) found in US waters attributed to unknown causes that may have included ship strikes were inside (n = 1) or within 45 nmi (n = 3) of active SMAs for an average discovery rate of 0.80 carcasses yr^{-1} (Table 2).

Over the entire study period, 32 humpback whale ship-strike deaths were discovered. They were all in US waters (Table 4, Fig. 4) and included 26 during pre-rule years and 6 during the first 2.5 post-rule years. During the pre-rule period 12 of 26 ship-struck humpback whales (46%) were found inside (n = 6) or within 45 nmi (n = 6) of SMA boundaries during later SMA effective dates, giving a discovery rate of 0.66 carcasses yr^{-1} (Table 4). The longest waiting time between finding at least one such carcass in pre-rule years was 5.6 yr (i.e. 2064 d between 14 April 1992

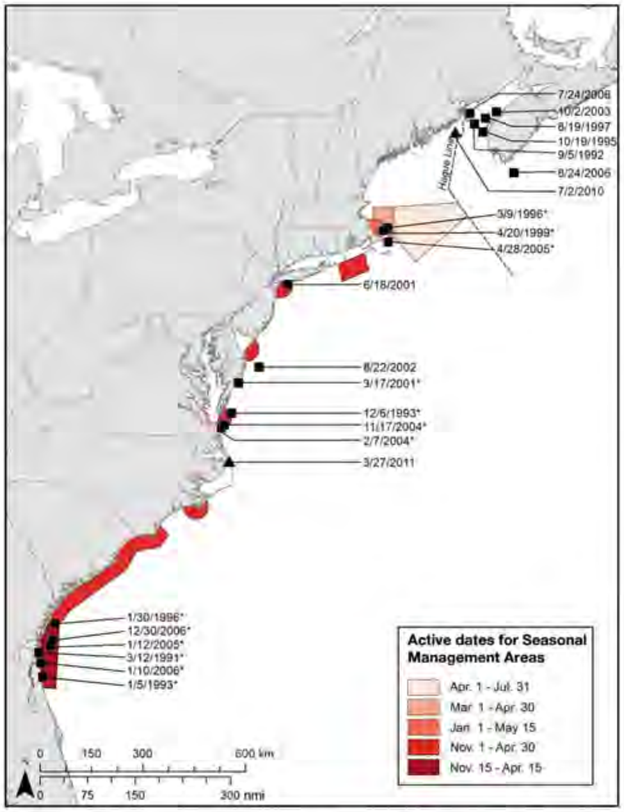

Fig. 2. *Eubalaena glacialis*. Locations and dates where all North Atlantic right whales killed by ships were found before and after Seasonal Management Areas (SMAs) were established on 8 December 2008. *: carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames; ■: carcass locations during pre-rule years, 1990 to 2008; ▲: carcass locations during post-rule years, 9 December 2008 through 8 December 2013

and 10 December 1997), 2.9 yr (i.e. 1090 d between 10 December 1997 and 4 December 2000), and 2.8 yr (i.e. 1045 d between 8 February 2002 and 19 December 2004). During the 2.5 yr (912 d) post-rule period, no ship-struck humpback whales were found inside active SMAs, but 2 were within 45 nmi of active SMAs, giving a post-rule discovery rate of 0.80 humpback whale carcasses yr^{-1}.

From our bootstrap resampling analysis, the upper 95% confidence interval around the annual pre-rule mean number of right whale ship-strike deaths in or near SMAs (0.72 carcasses yr^{-1}) was 0.2 to 2.0 (Fig. 5). As of 5.0 yr after the rule's adoption, the post-rule annual mean number of ship-strike deaths in or near SMAs was 0. The probability of a 5 yr post-rule carcass discovery rate of 0 is significantly lower (p = 0.031) than the pre-rule mean. An additional bootstrap resampling analysis was conducted to estimate the probabilities of finding 0, ≤1, or ≤2 carcasses in the sixth post-year rule after 5 consecutive years of no deaths. Those probabilities were estimated to be $p = 0.012$, $p = 0.024$, and $p = 0.031$, respectively.

We found no other significant or borderline significant differences between pre- and post-rule carcass discovery rates. For right whales, there were no apparent differences for (1) ship-struck carcasses found >45 nmi from active SMAs ($p = 0.99$) or (2) carcasses attributed to unknown causes that might have included ship strikes either in or near active SMAs ($p = 0.92$) or beyond 45 nmi of the nearest active SMA ($p = 0.87$). For humpback whales, there was no significant difference in discovery rates for ship-struck carcasses either within or near active SMAs ($p = 0.68$) or beyond 45 nmi of the nearest active SMAs ($p = 0.85$).

Table 2. *Eubalaena glacialis*, *Megaptera novaeangliae*. Number of known right whale and humpback whale deaths along the US East Coast attributed to ship strikes and unknown causes, possibly including ship strikes, inside or within 45 nmi of active Seasonal Management Area (SMA) boundaries or beyond 45 nmi of SMA boundaries, before and after the SMA implementation on 8 December 2008 (i.e. 8 December 1990 through 8 December 2013 for right whales and through 8 June 2011 for humpback whales)

	Pre-rule	Post-rule
Right whales — ship strikes		
Inside or within 45 nmi of SMA boundaries	13	0
Beyond 45 nmi of nearest SMA	2	2
Right whales — unknown cause		
Inside or within 45 nmi of SMA boundaries	8	4
Beyond 45 nmi of nearest SMA	6	3
Humpback whales — ship strikes		
Inside or within 45 nmi of SMA boundaries	12	2
Beyond 45 nmi of nearest SMA	14	4

DISCUSSION

Right whales

Results of this study indicate that the locations and time frames of SMAs were well-chosen to protect North Atlantic right whales from ship strikes. During the 18 yr before SMAs were implemented, 87% (13 of 15) of all right whales known to have been killed by ships in US waters were found inside or within 45 nmi of SMAs during later SMA effective dates. Indeed, most of those carcasses (i.e. 12 of 15 or 80%) were inside or within 6 nmi of SMA boundaries. It therefore appears that most right whales killed by ships before December 2008 were found in or near

Table 3. *Eubalaena glacialis*. Date and distance from Seasonal Management Areas (SMAs) of all North Atlantic right whale carcasses attributed to unknown causes, possibly including ship strikes, along the US East Coast: 1 January 1990 to 8 December 2013, before (pre-rule) and after (post-rule) the SMA implementation on 8 December 2008. Decomposition (Decomp.) codes — 1: alive; 2: fresh; 3: moderate decomposition; 4: advanced decomposition; Unk: unknown condition; NC: North Carolina; GA: Georgia

Date (mm/dd/yy)	Nearest SMA	Inside SMA dates?	Inside SMA boundary?	Distance from SMA (nmi/km)	Decomp. code
Pre-rule					
01/15/93	Calving grounds SMA	Yes	No	62/115	Unk
12/06/93[a]	Chesapeake Bay SMA	Yes	No	1.2/2.2	Unk
02/08/96[a]	Calving grounds SMA	Yes	Yes	0	4
02/19/96[a]	Calving grounds SMA	Yes	Yes	0	3
10/07/98	Chesapeake Bay SMA	No	No	8.5/15.7	4
01/19/00[a]	Block Island Sound SMA	Yes	Yes	0	Unk
01/27/01[a]	Calving grounds SMA	Yes	No	15/28	Unk
03/17/01[a]	NC-GA Coast SMA	Yes	No	3/5.6	4
06/10/02[a]	Great South Channel SMA	Yes	Yes	0	4
09/03/02	Chesapeake Bay SMA	No	No	38/70.3	3
09/06/02	Chesapeake Bay SMA	No	No	65/120.3	4
12/09/04	Great South Channel SMA	No	No	38/70.3	Unk
01/09/05	Great South Channel SMA	No	No	21/38.9	4
02/14/08[a]	Calving grounds SMA	Yes	Yes	0	4
Post-rule					
02/17/09[a]	Calving grounds SMA	Yes	Yes	0	3
02/25/09	Great South Channel SMA	No	Yes	0	3
08/18/09	New York Harbor SMA	No	No	44/81.5	4
12/19/09	Great South Channel SMA	No	No	6.1/11.3	2
02/19/11[a]	NC-GA SMA	Yes	No	34/63.0	4
03/17/11[a]	Delaware Bay SMA	Yes	No	40/74.1	3
03/02/12[a]	Race Point SMA	Yes	No	24/44.5	3

[a]Carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames

areas where SMAs were later established and also during their eventual effective dates.

The results also suggest that SMAs have effectively reduced the number of whale deaths due to ships. Average annual discovery rates of ship-struck right whale carcasses in or near active SMAs declined significantly from 0.72 to 0 carcasses yr^{-1} for at least the first 5.0 yr after the rule went into effect. This measure of reduction is likely to be conservative given that estimates of the size of the North Atlantic right whale population increased over the study period from about 295 whales in 1992 (Knowlton et al. 1994) to about 500 whales in 2013, with the addition of about 80 whales from 2008 through 2013 (New England Aquarium unpubl. data). Thus, the number of whales available to be struck has increased in post-rule years. In addition, the 5.0 yr post-rule period during which no ship-struck right whales carcass were discovered in or near any acitve SMAs is almost twice as long as the longest gap (i.e. 2.8 yr) between such discoveries during the pre-rule period.

These results are encouraging, but require a longer time period to confirm if the apparent effectiveness holds up over time. The recommended routing changes off Boston, the new recommended routes in Cape Cod Bay and the southeastern US calving grounds, and new ATBA also may have contributed to the apparent reduction in right whale ship-strike deaths by directing traffic through habitats used somewhat less frequently by whales. For example, a 58% reduction in collision risks was predicted by shifting a segment of the Boston shipping lanes (www.scimaps.org/maps/map/realigning_the_bosto_88/), and Fonnesbeck et al. (2008) predicted as much as a 44% reduction with new shipping lanes through the calving grounds. However, the new routes must still cross key right whale habitats, and no useful routing alternatives exist for mid-Atlantic ports along the right whale's coastal migratory corridor, where nearly half of all vessel-related right whale deaths have been discovered. Thus, although there should be some uncertain amount of risk reduction from new routes now in place, we believe speed restrictions are likely to be a more important factor in reducing collision risks along the US East Coast.

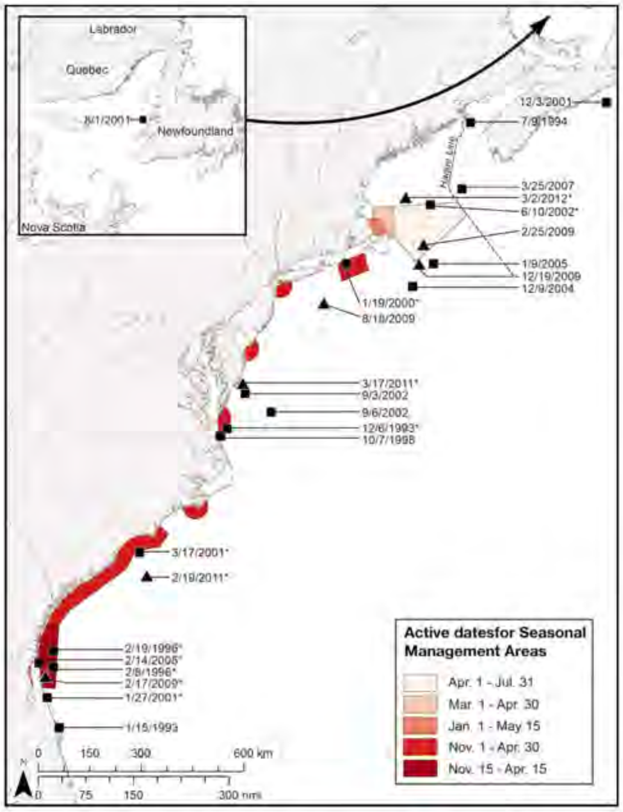

Fig. 3. *Eubalaena glacialis.* Locations and dates where all North Atlantic right whales killed by unknown causes, possibly including ship strikes, were found before and after Seasonal Management Areas (SMAs) were established on 8 December 2008. *: carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames; ■: carcass locations during pre-rule years, 1990 to 2008; ▲: carcass locations during post-rule years, 9 December 2008 through 8 December 2013

We found no indication that SMAs have reduced the number of right whale deaths attributed to unknown causes. The percentages of such deaths in or near active SMAs in the pre-rule (57.1%, 8 of 14) and post-rule (57.1%, 4 of 7) periods were identical, and the average annual carcass recovery rate actually increased from 0.44 to 0.80 carcasses yr^{-1} during the post-rule period. The most parsimonious interpretations for the increase in deaths due to unknown causes are that (1) all or most right whale deaths that may have been attributed to unknown causes but were actually due to ship strikes occurred >45 nmi from the nearest active SMA, (2) most right whale deaths attributed to unknown causes were not caused by ship collisions, and the increase reflects stochastic variability. As indicated below, an example of the first possibility may be the cluster of 4 carcasses attributed to unknown causes found in the southern Great South Channel area in winter. This is an area with high ship traffic and limited winter survey effort. The second possibility has some support from past experience. During a 4 yr period between 1993 and 1996, the annual discovery rate for right whale carcasses attributed to unknown causes in or near later active SMAs was 0.75 carcasses yr^{-1} (3 of 4 carcasses), which approaches the post-rule rate of 0.80 (Table 3).

Other studies have found little or no evidence that recent management measures have reduced vessel-related right whale deaths along the US East Coast. Analyses to date, however, have been too broad in scope, or involved time frames ill-suited for assessing effectiveness of the SMA network. For example, van der Hoop et al. (2013) found no noticeable reduction in large whale vessel- and entanglement-related deaths from 2003 through 2009 (when a number of management actions were implemented, including outreach efforts to advise mariners of collision risks), compared to earlier years. That study, however, was not designed to assess the effectiveness of site-specific measures or specifically of SMA vessel-speed restrictions. In particular, it included only 1 yr of data after SMAs were established.

Similarly, Pace (2011) found no significant reduction in ship-collision deaths after the rule went into effect. However, his analysis was based on only 2 yr of post-rule data, measured intervals between collisions involving all species of large whales (i.e. humpback, right, fin, and sei whales), considered all types of vessels (including those <65 ft in length that are not subject to regulation), and included all US and Canadian waters (including those not near SMAs). Furthermore, it did not distinguish between collisions inside versus outside SMA time frames. In contrast, our analysis focuses on those collisions most likely to have occurred within SMA boundaries, during effective dates, on the species of greatest concern (i.e. right whales), and on the vessels most likely to have been subject to management (i.e. all carcasses considered in this analysis had large wounds or contusions indicative of collisions with vessels that likely were >65 feet long). Therefore, we believe this analysis provides a more direct and useful measure of the rule's effectiveness for right whales.

Humpback whales

Our results suggest that SMAs have not provided a significant benefit for humpback whales. Whereas 87% of all ship-struck right whales were found in or near SMAs during effective dates in the pre-rule period, less than half (46%) of all such humpback

Table 4. *Megaptera novaeangliae*. Date and distance from Seasonal Management Areas (SMAs) of all humpback whale carcasses attributed to ship strikes along the US East Coast: 1 January 1990 to 8 June 2011, before (pre-rule) and after (post-rule) the SMA implementation on 8 December 2008. Decomposition (Decomp.) codes — 1: alive; 2: fresh; 3: moderate decomposition; 4: advanced decomposition; Unk: unknown condition; NC: North Carolina; GA: Georgia

Date (mm/dd/yy)	Nearest SMA	Inside SMA dates?	Inside SMA boundary?	Distance from SMA (nmi/km)	Decomp. code
Pre-rule					
11/08/91[a]	New York Harbor SMA	Yes	No	22.6/41.9	Unk
02/14/92[a]	Chesapeake Bay SMA	Yes	Yes	0	3
04/16/92[a]	Delaware Bay SMA	Yes	No	22.7/42.0	4
06/04/95	Chesapeake Bay SMA	No	No	0.1/0.2	3
05/09/96	Delaware Bay SMA	No	No	0.5/0.9	3
11/03/96[a]	Chesapeake Bay SMA	Yes	No	42.9/79.5	3
12/10/97[a]	Morehead City SMA	Yes	Yes	0	3
12/04/00[a]	Morehead City SMA	Yes	Yes	0	
01/25/01	Chesapeake Bay SMA	Yes	No	51.6/95.6	2
04/08/01[a]	NC-GA Coast SMA	Yes	Yes	0	2
07/29/01	New York Harbor SMA	No	No	6.8/12.6	3
08/18/01	Delaware Bay SMA	No	No	22.5/41.7	2
10/01/01	Cape Cod Bay SMA	No	Yes	0	3
02/08/02[a]	Chesapeake Bay SMA	Yes	No	4.8/8.9	Unk
05/30/02	Race Point SMA	No	No	51.7/95.7	3
08/01/02	New York Harbor SMA	No	No	0	4
06/06/03	Chesapeake Bay SMA	No	No	4.6/8.5	2-3
12/19/04[a]	Delaware Bay SMA	Yes	Yes	0	3
01/09/06[a]	NC-GA Coast SMA	Yes	Yes	0	3
03/17/06[a]	Chesapeake Bay SMA	Yes	No	1.5/2.8	3
09/27/06	Delaware Bay SMA	No	Yes	0	4
10/15/06	Delaware Bay SMA	No	No	6.2/11.5	4
05/10/07	Chesapeake Bay SMA	No	No	21.6/40.0	4
05/13/07	Race Point SMA	No	No	9.2/17.0	4
06/24/07	Race Point SMA	No	Yes	0	3
11/04/08[a]	Delaware Bay SMA	Yes	No	20.1/37.2	2
Post-rule					
07/27/09	New York Harbor SMA	No	Yes	0	3
03/13/10[a]	Delaware Bay SMA	Yes	No	12.8/23.7	3
06/10/10	New York Harbor SMA	No	No	0.1/0.2	3
07/04/10	Delaware Bay SMA	No	No	12.0/22.2	4
03/07/11[a]	Morehead City SMA	Yes	No	15/27.8	1
05/28/11	New York Harbor	No	No	23.9/44.3	4

[a]Carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames

whales were in or near those areas during active dates. However, it is notable that 12 of the other 15 pre-rule humpback whales killed by ships were found in or near SMA boundaries, but were outside of SMA active dates (Table 5). This pattern persisted in post-rule years when all 6 of the ship-struck humpback whale carcasses were found in or near SMA boundaries, but only 2 were within their active dates. Thus, it would seem that SMAs could be beneficial for humpback whales if their effective dates were expanded to better reflect the timing of their seasonal occurrence in SMA boundaries. The occurrence of humpback whale collisions outside of active dates is understandable given that SMA time frames were developed specifically for right whale protection.

Uncertainties in the time and location of collisions

In addition to constraints due to the small sample size of ship-struck carcasses on the statistical power of our analyses, 2 other limitations led to uncertainties: (1) the precise dates of collisions and (2) the precise locations of collisions relative to SMA dates and boundaries. Because the length of time between a collision and the discovery of collision-related carcasses is unknown and variable, there is some uncertainty about whether those whales were struck during SMA active dates. In most cases, we believe carcass discovery dates can be related with reasonable accuracy to active SMA dates. All ship-struck right whale carcasses found in or near SMAs during

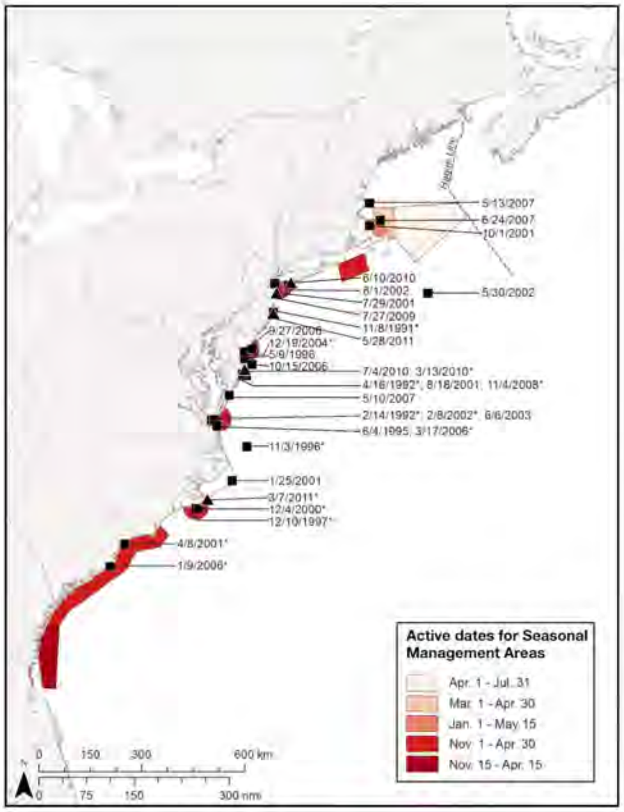

Fig. 4. *Megaptera novaeangliae*. Locations and dates where all humpback whales killed by ships were found before and after Seasonal Management Areas (SMAs) were established on 8 December 2008. *: carcass found in or within 45 nmi (83 km) of SMA boundaries during active time frames; ■: carcass locations during pre-rule years, 1990 to 2008; ▲: carcass locations during post-rule years, 9 December 2008 through 8 June 2013

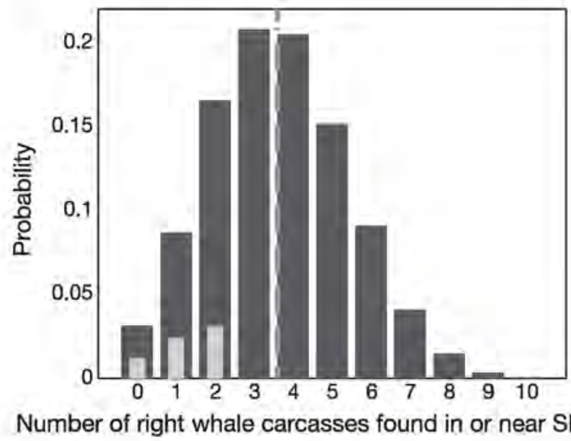

Fig. 5. *Eubalaena glacialis*. Probabilities of finding 0 to 10 right whale carcasses in or near Seasonal Management Areas (SMAs) over the 5 yr post-rule period (8 December 2008 to 8 December 2013) based on bootstrap resampling of discovery records during the 18 yr pre-rule period (8 December 1990 to 7 December 2008). Dark gray bars show probabilities of 5 yr totals assuming whales could be found in any year during the 5 yr period; light gray bars show probabilities assuming no whales were found in years 1 to 5 and 0, ≤1, or ≤2 whales were found in Year 6; gray dashed line shows the annual mean pre-rule discovery rate of 0.72 (equivalent to 3.6 carcasses over 5 yr)

pre-rule years with information on their decomposition state (i.e. 11 of 13) were moderately decomposed (Code 3) or fresher. Similarly, all but 1 ship-struck humpback whale found in or near SMAs with information on decomposition condition (7 of 8) were Code 3 or fresher. As noted above, right whale carcasses can degrade to a Code 3 condition within a week or less. Because most right whale carcasses attributed to ship strikes along the US East Coast have involved massive injuries, such as fractured skulls or vertebrae, severed tail stocks, and long, deep propeller wounds (Moore et al. 2004), it seems reasonable to assume that most victims die within a day or 2, if not hours, of being hit. By adding those pre- and post-mortem times together, it seems likely that most ship-collision deaths reported in this study occurred no more than about 7 to 8 d before the discovery dates. Only 1 ship-struck whale found in or near an SMA was found <9 d after the beginning or end dates of the nearest active SMA (i.e. a humpback whale with no information on its decomposition state was found 8 d after the start of the nearest SMA 22.6 nmi away). Thus, it seems reasonable to believe that most, if not all, carcasses considered to have been struck in or near SMAs during active SMA dates were in fact struck during those periods.

Far less clear is whether ship-strike victims found in or near SMA boundaries were in fact struck within SMA boundaries. Complicating factors include the possibility of whales swimming some distance after being struck and before they die and drift an additional distance from collision locations. Because of those possibilities, some dead whales discovered outside SMA boundaries may have been struck inside SMA boundaries and vice versa. In general, it seems unlikely that lethally struck whales would swim long distances after being hit. Even if whales do not die instantly or within a few hours, massive injuries typical of collision deaths are likely to leave them moribund or highly immobile. Transport of moribund or dead whales by wind and currents is more difficult to gauge. As noted above, resighted right whale carcasses drifted an average of 7 nmi d^{-1}, and 1 drifted 112 nmi (204 km) in 8 d, for an average of 14 nmi (26 km) d^{-1}. Thus, it is possible that some ship-struck carcasses could have drifted into SMAs from adjacent areas. Indeed, given that 5 of 8 right whale carcasses found inside SMA boundaries during pre-rule years were moderately decomposed, it would seem likely that at least some drifted 45 nmi before being found, which could have put them outside but near SMA boundaries.

A detailed analysis of carcass drift for ship-strike victims found in the past was beyond the scope of this study. To improve understanding of where ship-strike victims are actually struck relative to SMA boundaries in the future, we recommend conducting a retrospective drift analysis as a routine part of investigations for future ship-struck right whale carcasses. Where possible, estimates should be made during necropsies of the time between death and the discovery of all carcasses attributed to ship strikes. That time span should then be used to trace the possible drift path back to a predicted location at the time of death based on prevailing winds and currents over that period.

Despite uncertainty about precisely where past ship-strike victims were struck, the pattern of carcass recovery shown in Fig. 2 strongly suggests that nearly 90% of all right whale deaths attributed to ship strikes in US waters since 8 December 1990 and before the rule became effective were struck in or near SMAs during the periods in which these were in effect. The possibility that some of those whales were struck in waters adjacent to SMA boundaries underscores the importance of expanding SMA boundaries along the species' migratory corridor (i.e. from Georgia to New York) to the 30 nmi limit originally proposed by the NMFS based on its past assessment of the width of the right whale migratory corridor and relevant new information. In addition, we recommend that further studies be undertaken to better define the distances from shore that most right whales travel during their migrations in spring and fall between Georgia and New York.

SMA boundaries

With half of all known right whale deaths in US waters since 1990 due to ship strikes found along the species' migratory corridor — which is thought to extend to approximately 30 nmi from shore (Schick 2009, Keller et al. 2012) — failure to include waters between 20 and 30 nmi in SMA boundaries leaves a potentially significant gap in protection of right whales from ship collisions. Its lack of inclusion also complicates evaluations of SMA effectiveness. With current SMA boundaries along the migratory corridor set as 20 nmi arcs around port entrances, it is possible that vessels entering or leaving port may hit whales in the offshore third of the species' presumed migratory corridor (i.e. 20 to 30 nmi from shore), where speed limits do not apply. Those carcasses may drift into SMAs and be assumed incorrectly to have been struck by ships complying with speed restrictions inside an SMA. Also, because carcass detection and retrieval becomes more difficult as distance from shore increases, whales struck and killed in this offshore zone that do not drift towards shore may be underestimated.

To more rigorously protect right whales and reduce uncertainty about whether ship-strike victims are struck just beyond SMA boundaries where speed restrictions do not apply, we recommend that (1) the boundaries of the SMAs along the species' migratory corridor be extended to 30 nmi from shore, as initially proposed by the NMFS; (2) the configuration of SMAs be modified from an arc to a rectangle, with boundaries extending perpendicular from the points where current SMA perimeters intersect with land out to 30 nmi offshore, to cover a greater portion of vessel tracks across core migratory areas; and (3) SMAs be made effective indefinitely, with a view towards retaining them unless further analyses demonstrate they are ineffective or should be modified. Changing SMA boundaries along the migratory corridor from arcs to rectangles that extend 20 (or 30) nmi from shore would increase their size by about 25%. This change would increase the probability that ships entering or leaving port along routes that are not perpendicular to the coast would travel at speeds safe for whales when transiting areas where migrating whales are most likely to be encountered.

It is also interesting that several right whale deaths due to unknown causes, possibly including ship strikes, were found offshore at distances and/or at times of the year when retrieval was more difficult. In this regard, 4 of 15 right whale deaths of unknown cause were clustered in or near the southern tip of the Great South Channel SMA from December through February, when that SMA was not in effect (Fig. 2). Those deaths, which occurred at a time of year with poor weather conditions and where carcass retrieval is very difficult, lie near an area where several heavily used vessel traffic corridors intersect (Ward-Geiger et al. 2005). That area may, therefore, be an additional site where ship collision risks are high and where the designation of an SMA should be considered. In general, carcasses are less likely to be found farther offshore, because of reduced survey effort. We do not, however, believe this bias would alter our conclusions, because, with the exception of waters in the Gulf of Maine, right whale occurrence is believed to decrease in waters beyond 30 nmi from shore. In addition, those areas were not subject to regulation either before or after the rules went into effect, and thus right whale occurrence in or near SMAs should not differ in either period. The whales' distance from shore may also make it less likely they would drift into SMAs.

CONCLUSIONS

Analyses of the locations where ship-struck whale carcasses are found provide useful methods for evaluating the biological effectiveness of SMAs established to protect North Atlantic right whales. The overall pattern of carcass discovery locations shown in Fig. 2 strongly suggests that a large majority of ship-collision victims found in pre-rule years were struck by ships entering and leaving ports where the 10 SMAs were later designated and also on dates that coincided with periods in which the later SMAs were in effect. The increased waiting time between discovery of ship collisions in or near active SMAs after the December 2008 implementation (i.e. 5.0 yr as of the date of this analysis) also suggests that the seasonal 10 knot speed limit has been effective, although additional time is needed to confirm long-term trends. When the rule was adopted, it was thought it would also benefit humpback whales, but there is no evidence from this analysis that this has been true. Numerous collisions involving humpback whales were found within or near SMA boundaries, but most were not during active SMA dates.

Based on these results, speed restrictions and the existing SMAs are tools that should be kept in place indefinitely. Dredged channels passing through SMAs should not be exempted from restrictions, as requested by petition, because whales must travel across those channels and are at no less risk of being struck in those channels. The rules appear to have been effective and remain necessary to prevent ship-related right whale deaths. However, to better cover areas where right whales are at greatest risk, SMA boundaries along the right whale migratory corridor should be extended from 20 to 30 nmi from shore, as originally proposed by the NMFS. In addition, consideration should be given to: (1) changing the configuration of SMA boundaries off ports in mid-Atlantic states from arcs to rectangles, to better protect whales migrating farther offshore; (2) establishing a new winter SMA along a segment of designated shipping lanes south of the Great South Channel SMA, where 4 unretrieved right whale carcasses possibly struck by ships were found in the months of December through February; and (3) extending the dates of SMAs, to better cover times when humpback whales are likely to occur in SMA boundaries. Given the apparent effectiveness of reduced speed limits and experience indicating a lack of compliance with voluntary requests to use reduced speeds (McKenna et al. 2012, Silber et al. 2012b), we also recommend that speed limits in short-term DMA zones be made mandatory, rather than voluntary, to protect periodic right whale aggregations found outside of active SMAs. Our study provides encouraging evidence that 10 knot speed restrictions are effective for reducing vessel-related right whale deaths. Such restrictions should be considered as an option for mitigating vessel strikes of large whales in other parts of the world where this problem is considered significant.

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Vessel Strikes to Large Whales Before and After the 2008 Ship Strike Rule

Correction(s) for this article >

Erratum to "Vessel Strikes to Large Whales Before and After the 2008 Ship Strike Rule"

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Abstract

To determine effectiveness of Seasonal Management Areas (SMAs), introduced in 2008 on the U.S. East Coast to reduce lethal vessel strikes to North Atlantic right whales, we analyzed observed large whale mortality events from 1990–2012 in the geographic region of the "Ship Strike Rule" to identify changes in frequency, spatial distribution, and spatiotemporal interaction since implementation. Though not directly coincident with SMA implementation, right whale vessel-strike mortalities significantly declined from 2.0 (2000–2006) to 0.33 per year (2007–2012). Large whale vessel-strike mortalities have decreased inside active SMAs, and increased outside inactive SMAs. We detected no significant spatiotemporal interaction in the 4-year pre- or post-Rule periods, although a longer time series is needed to detect these changes. As designed, SMAs encompass only 36% of historical right whale vessel-strike mortalities, and 32% are outside managed space but within managed timeframes. We suggest increasing spatial coverage to improve the Rule's effectiveness.

Introduction

Vessel strikes contribute significant mortality to large whale stocks in the Northwest Atlantic despite mitigation efforts (van der Hoop *et al.* 2013). In 2008, the United States regulated to reduce vessel-strike mortalities in U.S. waters to North Atlantic right (*Eubalaena glacialis*; hereafter right) whales, mandating speeds <10 knots (18.5 km/hour) for commercial vessels ≥65 ft (20 m) long in 10 spatially and temporally defined Seasonal Management Areas (SMAs; Figure 1; Table 1; NOAA 2008).

Table 1. Location and active time periods of Seasonal Management Areas implemented annually, since December 9, 2008

Seasonal Management Area (SMA)		Active time period
Southeast United States:	Coastal Florida and Georgia	November 15 to April 15
Mid-Atlantic United States:	Brunswick, GA to Wilmington, NC	November 1 to April 30
	Ports of Morehead City and Beaufort, NC	November 1 to April 30
	Entrance to Chesapeake Bay: Ports of Hampton Roads, VA, and Baltimore, MD	November 1 to April 30
	Delaware Bay: Ports of Philadelphia, PA, and Wilmington, DE	November 1 to April 30
	Ports of New York/New Jersey	November 1 to April 30
	Block Island Sound	November 1 to April 30
Northeast United States:	Cape Cod Bay	January 1 to May 15
	Off Race Point	March 1 to April 30
	Great South Channel	April 1 to July 31

Figure 1

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Map of Seasonal Management Areas (SMAs; blue) implemented on December 9, 2008 as part of the United States' vessel-strike reduction strategy (the "Ship Strike Rule") and existing vessel-strike reduction measures in Canada in the Bay of Fundy (2003) and Roseway Basin (2007) (red).

This "Ship Strike Rule" also established Dynamic Management Areas (DMAs), recognizing interannual variability in whale distribution and habitat use (Winn *et al.* 1986; Patrician *et al.* 2009). DMAs provide 15-day voluntary speed limits for right whale aggregations ($n \geq 3$) detected outside active SMAs. In addition, mariners are requested to avoid DMAs (NOAA 2008). SMA sites and seasons consider (1) right whale movement, distribution, and aggregation patterns from sightings and telemetry data; (2) vessel-strike distribution and occurrence; and (3) regions with predictable vessel traffic (Merrick 2005; NOAA 2006). Although its design was right-whale specific, it was expected that the Ship Strike Rule should benefit other large whales (NOAA 2006; NMFS 2008), as the effect of speed on the lethality of a vessel collision is not species specific (Vanderlaan & Taggart 2007).

The 2008 Ship Strike Rule included a 5-year sunset clause to relieve any affected entities, and enable the National Marine Fisheries Service (NMFS) to assess and report on its efficacy (NOAA 2008). Although this clause has been eliminated (NOAA 2013), Rule assessment remains critical to determine whether amendments are required to meet its goals.

We evaluate the Rule's effectiveness with a series of indicators against specific objectives (Hockings *et al.* 2006). Here, indicators are observed vessel-strike mortalities, and the objective is reduced likelihood of death to right whales from vessel collisions (NOAA 2008). We test the null hypothesis that SMAs introduced by the Ship Strike Rule were not effective in reducing observed vessel-strike mortalities to right whales specifically, and other large whale species generally. If effective, we expect the Rule to have yielded significant changes in the spatial distribution and a decrease in the rate of observed vessel-strike mortalities. We expect significant spatiotemporal interaction, whereby observed vessel-strike mortality rates are reduced in managed areas during managed times. By including additional large whale species other than right whales, we assess whether SMAs provide mutual benefit to other species (as expected; NMFS 2008), and calculate the degree of protection SMAs offer these populations.

Methods

We obtained information on 1,198 mortality events (hereafter, mortalities) from 1990 to 2012 to blue (*Balaenoptera musculus*), Bryde's (*B. edeni*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*), minke (*B. acutorostrata*), right, sei (*B. borealis*), sperm (*Physeter macrocephalus*), and unidentified large whales in the Northwest Atlantic between the southern tip of Florida (25.4083° N, 80.3° W) and Cape Sable, Nova Scotia, Canada (43.5087° N, 65.69° W), from the coast to continental shelf. This geographic range encompasses numerous vessel-strike related management schemes introduced since 1997 in Canada and the United States (see e.g., Mullen *et al.* 2013 for a review) and envelops the Gulf of Maine allowing for carcass drift and coastline geography.

We obtained records (on shore and floating at sea) collected by stranding responders in the Canadian Maritime provinces from the Maritime Marine Animal Response Network, and American records from (1) National Oceanic and Atmospheric Administration (NOAA) Southeast and Northeast U.S. Marine Mammal Stranding Network Databases, and local response programs therein, and (2) NOAA's Northeast Fisheries Science Center (NEFSC).

The presumed cause of death, provided by the stranding responders or agency, was categorized as entanglement, vessel strike, other human cause (e.g., marine debris), nonhuman cause (e.g., perinatal), and undetermined (due to decomposition or where no cause of death was provided). Data were qualified through the mortality determinations of NOAA's NEFSC (e.g., Henry *et al.* 2013).

We included records of dead animals only, though previous studies include "serious injuries" that would likely result in death (Vanderlaan & Taggart 2007; NOAA 2011; Cole & Henry 2013). Estimates herein are therefore lower than in van der Hoop *et al.* (2013) and are a greater underestimation of the true number of mortalities.

We examined opportunistic and survey (aerial and vessel) sightings of all large whales, maintained within the North Atlantic Right Whale Consortium database (NARWC 2008) from 1990 to 2008 to assess their percent occurrence within SMAs.

Temporal analyses

To determine whether SMA implementation affected observed mortality rates, we used Webster's method (Webster 1973) with $y_i + y_i$ window sizes of $y = 3$ and 4 years to detect discontinuities in the time series of vessel-strike mortalities per year to right whales and, separately, to all other (including unidentified large whale) species. Discontinuities separate periods over which mortality rates are consistent, or stationary. We calculated Student's t-statistic for Webster's method with the standard deviation of the entire data series as window sizes are small (Legendre & Legendre 2012), and considered discontinuities significant at $\alpha = 0.1$.

We calculated Poisson cumulative distribution functions (CDFs) with bootstrap estimated 95% confidence intervals (CIs) based on the average number of observed vessel-strike mortalities per year (μ) as in Vanderlaan *et al.* (2009) for the stationary time periods detected with Webster's method.

Spatial analyses

Spatial coordinates reflect the location where a mortality was first detected or reported. We estimated location for 33 cases where coordinates were not provided but location information was descriptive (e.g., an address). We created a 1-D spatial coordinate system, selecting all mortalities observed within 20 nmi (37 km, i.e., the distance to which most SMAs extend) of the coastline (n = 934) and assigning them a coordinate for the closest location along the coastline. We then calculated the distance from the southern tip of Florida (our spatial origin), to each coastline location. We calculated smoothed (200 km bandwidth) normal kernel density distributions of these locations in two pre-Rule (19 year, January 1, 1990 to December 8, 2008; 4 year, December 8, 2004 to December 8, 2008) and one post-Rule (4 year, December 9, 2008 to December 31, 2012) period, all inclusive. To determine whether these distributions for all causes of death or attributed to vessel strike (n = 140) differed between each pre-Rule period and the post-Rule period, we used a two-sample Kolmogorov-Smirnov test (H_0 = no difference).

Spatiotemporal interaction

We assigned two binomial indicators (space, S; time, T) to all observed vessel-strike mortalities: S = 1 if the mortality was observed inside and 0 if outside SMAs, and T = 1 if the mortality was observed when the closest SMA was active and 0 if not active (Table 1). For example, for a vessel-strike mortality observed inside an SMA during the inactive period (e.g., Delaware Bay; September): S = 1, T = 0. For a vessel-strike mortality observed outside an SMA when nearby SMAs were active (e.g., Cape Hatteras, NC; March): S = 0, T = 1. Active times were applied to pre-Rule and post-Rule periods to test for interaction before Rule implementation. Because of SMA geometry, Great South Channel and Off Race Point SMAs were combined, yielding an active period of March 1 through July 31.

To examine whether SMAs were designated in appropriate areas, we calculated the percentage of (1) observed vessel-strike mortalities and (2) opportunistic and survey sightings for each species in the four different binomial combinations (S = 0, T = 0; S = 1, T = 0; S = 0, T = 1; and S = 1, T = 1) before implementation, 1990–2008.

To test for an interaction between space and time on the observed number of vessel-strike mortalities we performed an approximate permutation test for an analysis of variance (Anderson 2001). To remove the effects of each factor, space and time, we subtracted the appropriate mean from each observation (the number of vessel-strike mortalities within a year either pre- or postimplementation of the Ship Strike Rule) to obtain corresponding residuals that were used in the approximate permutation test (10,000 replications).

Results

From 1990 to 2012, 1,198 mortalities were observed. We identified 975 cases to one of eight large whale species; 223 cases involved unidentified large whales. Consistent with previous findings over the last 40 years (van der Hoop *et al.* 2013), the leading diagnosed causes of death (determined in 458 cases, 38%) were entanglement (n = 169), nonhuman causes (n = 147), and vessel strike (n = 135). Since Rule implementation (cause of death determined in 67/204 cases, 33%), entanglement has remained the leading diagnosed cause of death (n = 29) for all large whales over this geographic range, followed by vessel-strike (n = 25), and nonhuman-caused mortalities (n = 10).

Based on sightings data, 17% of right whale sightings, 1990–2008, were outside of what would become active SMAs following implementation (Table 2). In contrast, 27% of pre-Rule right whale mortalities occurred outside, and only 36% occurred fully inside, these spatiotemporal boundaries (Table 3). Comparable proportions of pre-Rule mortalities are observed inside future active SMA boundaries for right (36%), humpback (25%), minke (27%) and sei (40%) whales, and higher proportions for fin (53%) whales (Table 3).

Table 2. Percentage of opportunistic and survey sightings per species, 1990–2008 (pre-Rule implementation), located inside and outside (bold text) what would become 10 active Seasonal Management Areas (SMAs) following implementation of the Ship Strike Rule (NOAA 2008)

Species (n total sightings)	Blue (5)	Fin (6,717)	Humpback (9,503)	Minke (1,806)	Sei (3,006)	Sperm (570)	Right (21,749)
Area							
Southeast United States	–	–	0.31	0.0046	–	–	26
South Carolina Area	–	0.0046	0.083	–	–	–	2.9
Morehead City	–	–	0.023	–	–	–	0.10
Chesapeake Bay	–	–	–	–	–	–	0.092
Delaware Bay	–	–	–	–	–	–	0.014

Species (*n* total sightings)	Blue (5)	Fin (6,717)	Humpback (9,503)	Minke (1,806)	Sei (3,006)	Sperm (570)	Right (21,749)
Block Island Sound	–	0.060	0.0046	0.028	–	–	0.11
Cape Cod Bay	–	5.3	2.5	0.65	0.0046	–	26
Off Race Point	–	1.5	1.2	0.38	–	–	3.2
Great South Channel	–	12	21	2.8	11	0.028	25
Outside	**100**	**81**	**75**	**96**	**89**	**100**	**17**

Table 3. Total number (*n*) and percentage of observed vessel-strike mortalities per species, 1990–2008, during combinations of active (= 1) and inactive (= 0) space (*S*) and time (*T*) of Seasonal Management Areas before being implemented by the Ship Strike Rule (NOAA 2008)

Species (total *n* svessel-strike mortalities)	Blue (1)	Fin (34)	Humpback (28)	Minke (11)	Sei (5)	Sperm (3)	Right (22)
S = 0, *T* = 0 (inactive space, inactive time)	–	15	21	9.1	40	100	27
S = 0, *T* = 1 (inactive space, active time)	100	8.8	32	–	–	–	32
S = 1, *T* = 0 (active space, inactive time)	–	23	21	64	20	–	4.6
S = 1, *T* = 1 (active space, active time)	–	53	25	27	40	–	36

Temporal

We detected three discontinuities with Webster's method, where right whale vessel-strike mortality rates were consistent from 1990 to 2000, 2001 to 2006, and 2007 to 2012 (inclusive; Figure 2). Bootstrapped 95% CIs around Poisson-aggregated CDFs indicate no difference in the right whale vessel-strike mortality rate between 1990–2001 (0.91 per year) and 2001–2006 (2.0 per year), followed by a significant decrease to 0.33 per year during 2007–2012. We detected no significant discontinuities for all other species of large whale over the entire data series. No significant discontinuities were detected for either right whales or all other large whale species between 2008 and 2009, immediately following Rule implementation.

Figure 2

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Total number of observed vessel-strike mortalities per year to North Atlantic right whales (black bars), and eight other, including unidentified, large whale species (white bars). Horizontal lines represent the average number of vessel-strike mortalities per year for right whales (grey) over periods separated based on discontinuities detected using Webster's method (see text).

Spatial

The smoothed kernel density distribution of vessel-strike mortalities for all species post-Rule differed significantly from the 19-year ($P = 0.013$, Kolmogorov-Smirnov Test Statistic [KS] = 0.22) and 4-year pre-Rule ($P = 0.0018$; KS = 0.26) periods. Postimplementation, increases in mortality occurred from Delaware to New York, and decreases from the Great South Channel, northward (Figure 3). In contrast, no significant differences were observed in the density distributions of mortalities for all other causes of death between either pre-Rule or the post-Rule periods (1990–2008: $P = 0.89$, KS = 0.080; 2004–2008: $P = 0.34$, KS = 0.13).

Figure 3

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Smoothed kernel density estimates of all (black) and vessel-strike related (red) mortalities to large whales, including unidentified to species, before (1990 to December 8, 2008, dash; December 8, 2004–December 8, 2008, dot-dash) and after (December 9, 2008 to December 31, 2012, solid line) enactment of the "Ship Strike Rule" along the coastline from the southern tip of the Florida Peninsula, USA, to Cape Sable, Nova Scotia, Canada. Vertical lines indicate the location of all (black) and vessel strike (red) mortalities. Horizontal lines indicate the spatial extent of mandated Seasonal Management Areas (SMAs; SEUS, Southeast United States; M-A, Mid-Atlantic; MC/B, Morehead City/Beaufort, NC; CB, Chesapeake Bay; DB, Delaware Bay; NY/NJ, New York/New Jersey; BIS, Block Island Sound; GSC, Great South Channel; ORP, Off Race Point, MA; CCB, Cape Cod Bay, MA) in U.S. waters and voluntary regulations in Canadian waters (BOF, Bay of Fundy; ROS, Roseway Basin).

Spatiotemporal

We detected no significant interaction between space and time on the observed number of vessel-strike mortalities for all species in the 4-year pre- ($P = 0.82$) and post-Rule implementation periods ($P = 0.48$; Figure 4). There was a significant interaction in the 19-year pre-Rule period ($P = 0.040$), indicating that sample size or short time series may preclude the determination of significant interactions in 4-year periods. Observations suggest that following Rule implementation, fewer vessel-strike mortalities have occurred inside active SMAs, whereas their prevalence has increased outside inactive SMAs (Figures 4 and 5).

Figure 4

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The number of vessel-strike mortalities per year to large whales (including unidentified to species) observed inside (dashed lines) and outside (solid lines) inactive and active Seasonal Management Areas (SMAs) before (blue) and after (red) their implementation on December 9, 2008.

Figure 5

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Spatial and temporal distribution of vessel-strike mortalities to North Atlantic right (red) and other (including unidentified) species of large whale (black) before (open circle) and after (closed circle) the enactment of the "Ship Strike Rule" on December 9, 2008. Boxes illustrate the spatial and temporal extents of mandated Seasonal Management Areas (SMAs; solid line; SEUS, Southeast United States; M-A, Mid-Atlantic; MC/B, Morehead City/Beaufort, NC; CB, Chesapeake Bay; DB, Delaware Bay; NY/NJ, New York/New Jersey; BIS, Block Island Sound; GSC, Great South Channel; ORP, Off Race Point, MA; CCB, Cape Cod Bay, MA) and concurrent regulations in Canadian waters (dashed lines) active since 2003 (BOF, Bay of Fundy) and 2007 (ROS, Roseway Basin).

Discussion

Given the continued interest in implementing speed restrictions around the world (Silber *et al.* 2012b), it is essential that existing measures be assessed for their ability to achieve their objectives, and to determine what factors may contribute to their success or failure (Hockings *et al.* 2006). The significant reduction in right whale vessel-strike mortality between 2001–2006 and 2007–2012 observed here is not directly coincident with the implementation of the Ship Strike Rule alone (which would be 2008–2012), but likely reflects the combined effect of numerous measures introduced since 2006 (see e.g., Mullen *et al.* 2013 for a review). Voluntary and mandatory routing changes in the Bay of Fundy (since 2003), and in the Southeast United States and Cape Cod Bay (since 2006); and an Area to be Avoided (ATBA) in Roseway Basin (since 2008) have provided significant decreases in relative (Fonnesbeck *et al.* 2008; Vanderlaan *et al.* 2008; Vanderlaan & Taggart 2009) and absolute (van der Hoop *et al.* 2012) vessel-strike risk to right whales.

Though spatial and temporal trends are often analyzed separately, their interaction must be considered when testing the effectiveness of a regulation with specific extents in space and time. The lack of significant interaction following Rule implementation suggests that SMAs have been ineffective in reducing vessel-strike mortality in managed areas during managed times. We attribute our inability to detect many of the intended effects of the Ship Strike Rule to three issues of rule design and implementation: (1) low vessel compliance with the SMAs; (2) insufficient time and/or monitoring to examine effectiveness; and (3) SMAs may be inappropriately located, or may be too short in duration and/or too small (Schick *et al.* 2009).

The rule's perceived ineffectiveness could be due to compliance, which has been low (20.7%–32.8%, 2009–2011; Silber & Bettridge 2012) and is in many areas unknown. Although automatic identification system data have been used to determine changes in relative vessel-strike probabilities since Rule implementation (Wiley *et al.* 2011; Conn & Silber 2013), these studies do not report on compliance or vessel traffic distributions. Rule awareness by mariners likely increased following implementation, as outreach (e.g., through compliance guides, Mandatory Ship Reporting Systems) and enforcement programs (e.g., through violation notices, at-sea hailings) developed and particularly strengthened in 2010 (Silber & Bettridge 2012). How these efforts have influenced operator compliance, and how the Rule has influenced vessel distribution remains unknown.

The detection of a significant spatiotemporal interaction in the 19-year pre-Rule period, but not the 4-year pre-Rule period suggests the second issue, that the Rule likely imposed an insufficient time frame for monitoring to detect an effect. Indicators available to assess the Ship Strike Rule (i.e., observed mortalities) occur with relatively low frequency, and require long periods to accumulate adequate sample sizes (Pace 2011). If the rule does not include sufficient monitoring provisions or support to test its own efficacy, then that is a failure in its design and implementation.

Finally, SMAs may not be appropriately located or timed. The SMAs only protect 23% of our study area and the active boundaries of SMAs encompass only 36% of historical right whale vessel-strike mortalities (Table 3). Although they overlap critical habitat and calving areas, SMAs do not provide protection in the mid-Atlantic migratory corridor where mortality density and incidence is greatest (Figures 3 and 5). Further, SMAs may be too short in duration and/or too small (Schick *et al.* 2009). A large proportion (32%) of pre-Rule right whale vessel-strike mortalities occurred outside SMAs during their active times, suggesting that the spatial extent is insufficient in certain seasons.

From Delaware to New York, SMAs are small and protect only port entrances (Figures 1 and 5). Here, visual survey data are sparse (Russell *et al.* 2001), and acoustic survey data are available but have not been used to design regulations. Increasing the size of SMAs could mitigate this high-risk area (overlapping high vessel and whale densities), maximizing conservation gain, while minimizing industry cost. Similar strategies (e.g., the shipping lanes in the Bay of Fundy or ATBA in Roseway Basin) have been extremely successful in reducing vessel-strike risk and incidence to right whales (Vanderlaan *et al.* 2008; Vanderlaan & Taggart 2009; van der Hoop *et al.* 2012), though effectiveness still relies on compliance.

Laist *et al.* (2014) conclude SMAs are properly located, as 87% of right whale vessel-strike mortalities in U.S. waters were found in or near SMAs during what would become effective dates. This large difference (87% vs. 36% reported here) is likely due to a 45 nmi (74 km) buffer zone around SMAs in their analysis. This increases SMA size by a relatively arbitrary amount, especially given that the authors recommend a 10-nmi extension of SMAs, which would fall within the managed area, under their definition.

Although low sample size and limited power precluded the determination of some significant effects of the Rule (see also Pace 2011; Silber & Bettridge 2012), it appears that vessel-strike mortality to large whales has decreased inside active SMAs (Figure 4). Otherwise, vessel-strike mortalities have increased outside of active SMA (Figures 4 and 5), contrary to expectation. If effective, DMAs should have contributed to decreased vessel-strikes outside of SMA time periods and regions, which does not appear to be the case. Unfortunately, DMAs have not been found to result in any changes in vessel speeds or routing (Silber *et al.* 2012a), which would explain these observations.

It was expected that SMAs should benefit other whales (NMFS 2008). Pre-Rule sightings and mortalities (Tables 2 and 3) suggest SMAs provide little-to-no benefit to blue and sperm whales, but offer similar (though low) protection to humpback, minke, sei, and fin whales as they do for right whales.

The number of observed vessel-strike mortalities is affected by many variables that change through time (van der Hoop *et al.* 2013). The exact detection location is not necessarily where death, or the vessel strike, occurred; however, there is a limited amount of drift data available for vessel-struck animals, drift will differ with location, and thus designating a limit of potential drift would remain subjective. Whale distribution may have changed throughout the study period, though we believe that it has remained fairly constant because the distribution of whale mortalities for other causes of death has not changed. The factors that then likely affected vessel-strike mortality distributions are related to vessels (abundance, distribution, and speed).

Conclusions

Lethal vessel-strikes to right whales appear to be less common than before SMAs and other mitigation strategies were implemented, and the spatial density of vessel-strike mortality to all large whales has changed. However, measures of spatiotemporal interaction are required to directly assess whether SMAs have been effective in reducing mortality inside managed areas during managed times. It would be optimistic to expect that changes in rare events could be detected in the short time period imposed by a sunset clause; rules should include adequate time periods to evaluate their own efficacy with sufficient statistical power. The Ship Strike Rule has been extended indefinitely (NOAA 2013). These and other methods should be applied as part of NMFS's agreement to periodically review the Rule as implementation continues. Suggested improvements to the Rule, specifically, increasing the spatial and temporal extent of SMAs in the mid-Atlantic, should be considered.

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Caution Urged After Dozens Of Right Whales Spotted Near Nantucket

February 05, 2020 | By The Associated Press

A baby right whale swims with its mother in Cape Cod Bay in 2019. (Amy James/Center for Coastal Studies/NOAA permit 19315-1 via AP)

This article is more than 1 year old.

The federal government is asking vessels to slow down in an area south of Nantucket because approximately one eighth of the worldwide population of an endangered whale has been spotted nearby.

The National Oceanic and Atmospheric Administration says 50 North Atlantic right whales were seen in the area on Jan. 31. The agency has enacted a voluntary speed restriction until Feb. 15.

The government is encouraging mariners not to travel faster than 10 knots, The Boston Globe reported. Collisions with vessels are a major concern for the animals, which are also threatened by entanglement in fishing gear.

There are only about 400 of the whales left in the world. Their population was decimated by whaling, which is now illegal. Their population remains in jeopardy because of recent high mortality and poor reproduction.

Related:

- This Surveillance Team In The Sky Tracks Endangered North Atlantic Right Whales In Cape Cod Bay
- Can Feces Save A Species? Boston Has The World's Largest Collection Of Right Whale Poop

NOAA FISHERIES

Reducing Ship Strikes to North Atlantic Right Whales

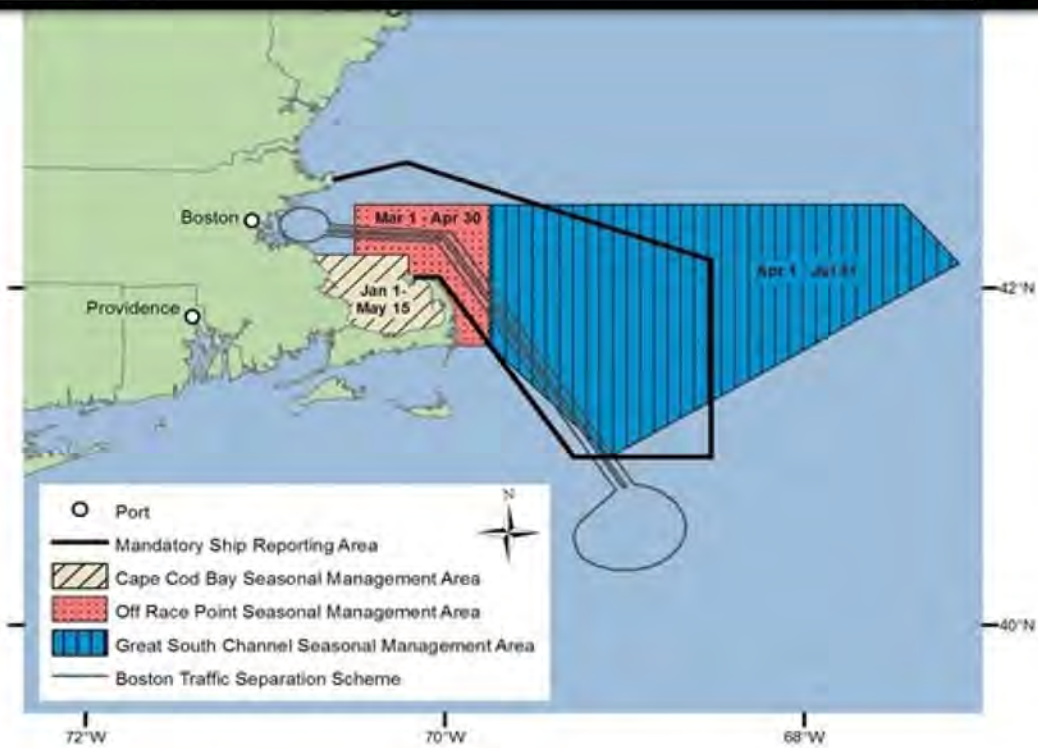
The purpose of this information is to reduce the likelihood of deaths and serious injuries to these endangered whales that result from collisions with ships.

Vessel Speed Restrictions

All vessels 65 feet (19.8 meters) or longer must travel at **10 knots or less** in certain locations (called Seasonal Management Areas or SMAs) along the U.S. east coast at certain times of the year to reduce the threat of ship collisions with endangered North Atlantic right whales. The purpose of this regulation is to reduce the likelihood of deaths and serious injuries to these endangered whales that result from collisions with ships.

- Compliance Guide (PDF, 2 pages)
- Final Rule to eliminate sunset provision on speed restrictions (12/09/13, 78 FR 73726)
- Proposed rule to eliminate sunset provision on speed restrictions (06/06/2013, 78 FR 34024)
- Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule (2012, PDF 49 pages)
- Final rule to implement speed restrictions (10/10/2008, 73 FR 60173)

Seasonal Management Areas - Northeast



Cape Cod Bay, January 1 - May 15

Includes all waters of Cape Cod Bay with Northern Boundary of 42º04'56.5"N, 070º12'W to 42º12'N, 070º12'W then due west back to shore.

Off Race Point, March 1 - April 30

Waters Bounded by:

42º04'56.5"N, 070º12'W

42º12'N, 070º12'W

42º12'N, 070º30'W

42º30'N, 070º30'W

42º30'N, 069º45'W

41º40'N, 069º45'W then due west back to shore.

Great South Channel, April 1 - July 31

Waters Bounded by:

42º09'N, 067º08'24"W

41º00'N, 069º05'W

41º40'N, 069º45'W then back to starting point.

Seasonal Management Areas - Mid-Atlantic

Migratory Route and Calving Grounds, November 1 - April 30

Block Island Sound waters bounded by:

40º51'53.7" N 070º36'44.9" W

41º20'14.1" N 070º49'44.1" W

41º04'16.7" N 071º51'21.0" W

40º35'56.5" N 071º38'25.1" W then back to starting point.

Within a 20-nm (37 km) radius of the following (as measured seaward from the COLREGS lines):

-Entrance to the Delaware Bay

(Ports of Philadelphia and Wilmington):

38º52'27.4"N 075º01'32.1"W

-Entrance to the Chesapeake Bay

(Ports of Hampton Roads and Baltimore):

37º00'36.9"N 075º57'50.5"W

-Ports of Morehead City and Beaufort, NC: 34º41'32.0"N 076°40'08.3"W

Within a continuous area 20-nm from shore between Wilmington, North Carolina, to Brunswick, Georgia, bounded by the following:

A- 34º10'30"N, 077º49'12"W

B- 33º56'42"N, 077º31'30"W

C- 33º36'30"N, 077º47'06"W

D- 33º28'24"N, 078º32'30"W

E- 32º59'06"N, 078º50'18"W

F- 31º50'00"N, 080º33'12"W

G- 31º27'00"N, 080º51'36"W

and west back to the shore.

Seasonal Management Areas - Southeast

Calving and Nursery Grounds, November 15 - April 15

Vessel speed is restricted in the area bounded to the north by latitude 31º27'N; to the south by latitude 29º45'N; to the east by longitude 080º51'36"W.

Dynamic Management Areas

Voluntary Dynamic Management Areas (DMAs) may also be established by NOAA Fisheries. Mariners are encouraged to avoid these areas or reduce speeds to 10 knots or less while transiting through these areas. NOAA Fisheries will announce DMAs to mariners through its customary maritime communication media and display any active ones below, with the most recent designation first.

Nantucket, MA DMA -- in effect between March 3, 2020 and March 18, 2020

NOAA Fisheries announces an extension of a voluntary vessel speed restriction zone (Dynamic Management Area - DMA) along with a new observed sighing of right whales in a location where no previous protection were in place, both DMAs have now been triggered. On March 3, 2020 the NOAA aerial survey team observed two separate aggregations of right whales, one 31 nm South of Nantucket MA and the second 47nm SE of Nantucket. The DMAs are in effect immediately, through

41 11 N

40 22 N

069 32 W

070 37 W

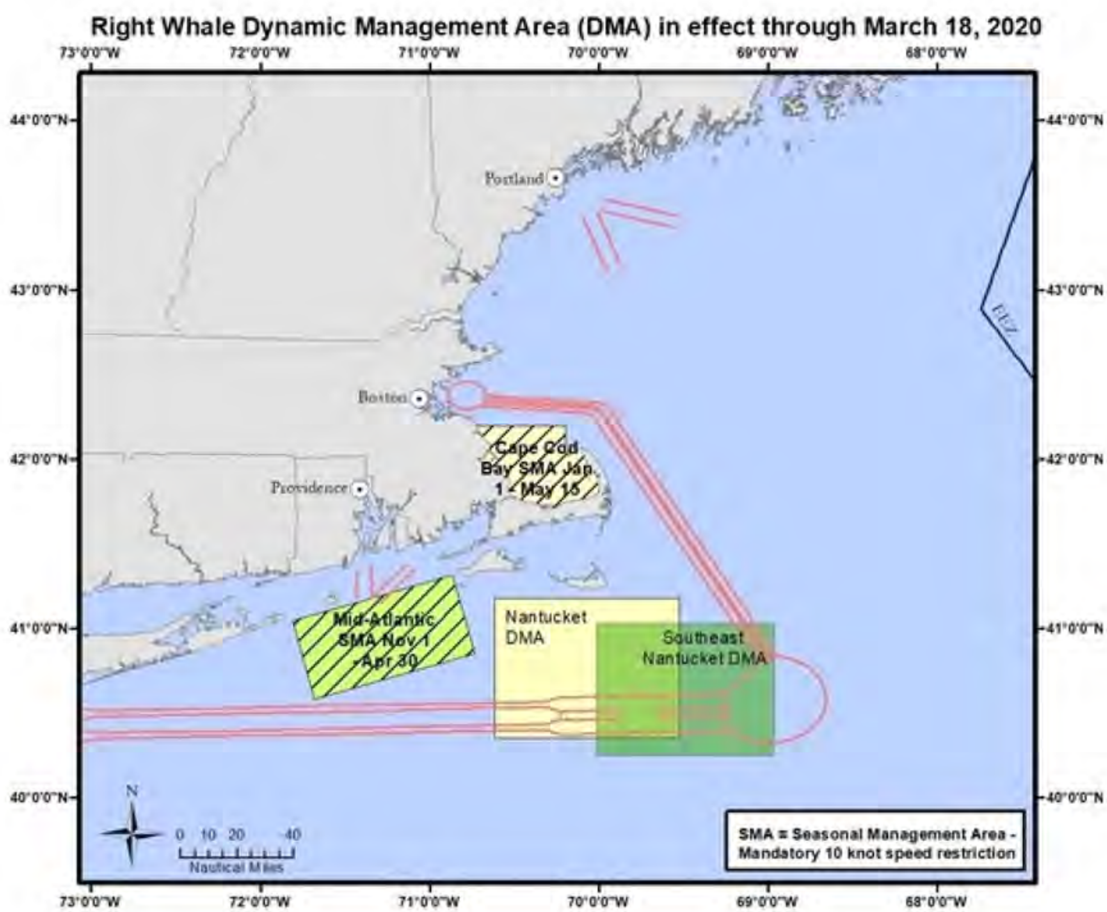
Southeast of Nantucket, MA DMA -- in effect through March 18 , 2020

41 02 N

40 15 N

068 58 W

070 01 W



Map of active DMA of Nantucket, Massachusetts available on all NOAA Electronic Navigation Chart products.

Great South Channel Area to Be Avoided

For ships weighing 300 gross tons or more, a voluntary seasonal Area To Be Avoided (ATBA) is in effect each year from April 1 to July 31, when right whales face their highest risk of ship strikes in this area.

Boston, Massachusetts Traffic Separation Scheme

The North-South lanes of the Traffic Separation Scheme servicing Boston were narrowed from 2 miles to 1.5 miles (consistent with the East-West Boston Traffic Separation Scheme lanes) to reduce vessel collisions with whales.

Charts of Approaches to Boston Traffic Separation Scheme and Area to be Avoided:

- 13200: Georges Bank and Nantucket Shoals
- 13203: Georges Bank Western Part
- 13006: West Quoddy Head to New York

Recommended Routes in Key Right Whale Habitats

NOAA established recommended vessel routes in four locations to reduce the likelihood of ship collisions in key right whale habitats in Massachusetts, Georgia, and Florida.

- Recommended Routes (PDF, 2 pages)

Mandatory Ship Reporting System

When ships greater than 300 gross tons enter two key right whale habitats—one off the northeast U.S. and one off the southeast U.S.—they are required to report to a shore-based station.

In return, ships receive a message about right whales, their vulnerability to ship strikes, precautionary measures the ship can take to avoid hitting a whale, and locations of recent sightings.

Mandatory Ship Reporting System areas will soon be available on all NOAA Electronic Navigation Chart products.

- Mandatory Ship Reporting System Placard (PDF, 2 pages)
- Final Rule (11/20/2001, 69 FR 58066)

Mariner Training Resources

Report a Ship Strike

Report ship strikes to the National Marine Mammal Stranding Network.

Where Are Right Whales?

- Northeast U.S. Right Whale Sightings
- Southeast U.S. Right Whale Sightings
- Acoustic detections in Cape Cod Bay and the Boston TSS
- Download the Whale Alert app for iPad and iPhone

Last updated by Office of Protected Resources on 03/04/2020

NOAA FISHERIES

Extended: Slow Speed Zone South of Nantucket to Protect Right Whales

NOAA Fisheries sent this bulletin at 10/20/2020 12:12 PM EDT

Having trouble viewing this email? View it as a Web page.

October 20, 2020

Extended: Vessel Slow Speed Zone South of Nantucket to Protect Right Whales

In Effect Through November 3

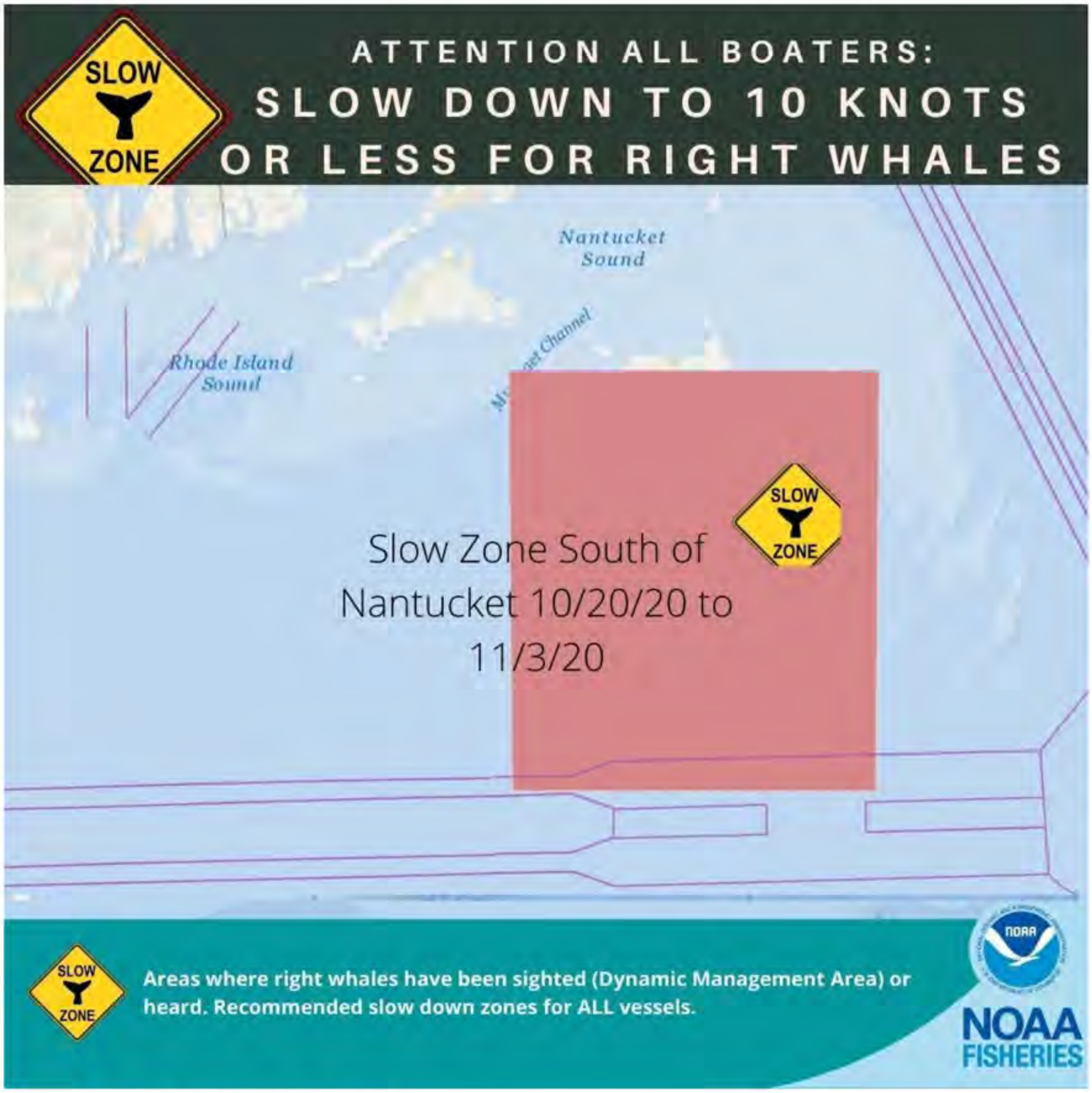
NOAA Fisheries announces an extension to the previously triggered voluntary vessel speed restriction zone (Dynamic Management Area or DMA) south of Nantucket.

This DMA was originally triggered by an August 31, 2020, sighting of an aggregation of right whales and previously extended until October 20, 2020. A Center for Coastal Studies aerial survey observed an aggregation of whales in this area on October 19. Since the current DMA is set to expire we are extending it through November 3.

Mariners, please go around this areas or go slow (10 knots or less) inside this area where groups of right whales have been sighted.

South of Nantucket DMA is in effect through November 3.

070 28 W



Give Right Whales Room

North Atlantic right whales are on the move along the Atlantic coast of the U.S. NOAA is cautioning boaters and fishermen to give these endangered whales plenty of room. We are also asking all fishermen to be vigilant when maneuvering to avoid accidental collisions with whales and remove unused gear from the ocean to help avoid entanglements. Commercial fishermen should use vertical lines with required markings, weak links, and breaking strengths.

Right Whales in Trouble

North Atlantic right whales are protected under the U.S. Endangered Species Act and the Marine Mammal Protection Act. Scientists estimate there are only about 400 remaining, making them one of the rarest marine mammals in the world.

In August 2017, NOAA Fisheries declared the increase in right whale mortalities an "Unusual Mortality Event," which helps the agency direct additional scientific and financial resources to investigating, understanding, and reducing the mortalities in partnership with the Marine Mammal Stranding Network, Canada's Department of Fisheries and Oceans, and outside experts from the scientific research community.

More Information

Recent right whale sightings

Find out more about our right whale conservation efforts and the researchers behind those efforts.

Download the Whale Alert app for iPad and iPhone

Acoustic detections in Cape Cod Bay and the Boston TSS

Details and graphics of all vessel strike management zones currently in effect.

Reminder: Approaching a right whale closer than 500 yards is a violation of federal and state law.

Spread the Word!

All boaters, or interested parties, can sign up for email notifications by clicking here and selecting "Right Whale Slow Zones" under the Regional New England/Mid-Atlantic subscription topics. You can also follow us on Facebook (@NOAAFisheriesNEMA) and Twitter (@NOAAFish_GARFO) for announcements.

Watch our video on Right Whale Slow Zones.

Recent Feature Stories about Right Whales

Listening for Right Whales in the Gulf of Maine

Make Way for Right Whales

10 Things You Should Know About Right Whales

Questions?

Media: Contact Jennifer Goebel, Regional Office, 978-281-9175

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ANOTHER RECORD DAY! 40% of right whale population seen in Cape Cod Bay

Apr 15, 2017 | PRESS

On Friday, April 15 the Center for Coastal Studies Aerial Survey team identified 206 individual rare North Atlantic right whales in Cape Cod Bay during a 10+ hour flight. This new record number represents about 40% of the entire population.

Right whale #1711 with her 2017 calf.

Among the animals spotted was right whale #1711 and her new calf, the last of the four 2017 mother/calf pairs to complete their 800+ mile journey from the birthing grounds off Florida and Georgia to the feeding grounds off Cape Cod.

Other species documented during the flight included 25 fin whales, 24 humpback whales, 40 sei whales, 9 minke whales, 3 unidentified large whales, and 13 unidentified dolphins.

The volume of whales in the Bay has raised concern for the safety of the animals, particularly that of the endangered North Atlantic right whale. Colleagues at IFAW and New England Aquarium confirmed that a [illegible] whale found dead in the Bay earlier this week died as a result of blunt trauma, most likely from a boat strike. That individual has been identified by researchers at NEAq as the 2016 calf of #4094.

Mariners in and around Cape Cod Bay and Race Point are urged to keep their speed below less than 10 knots and to post a lookout to reduce the risk of further collisions.

It is illegal to approach within 500 yards of a North Atlantic right whale without a research permit, but whale watchers can often see whales close to the bayside beaches and off Herring Cove and Race Point, Provincetown.

CCS right whale research and response operations are conducted in partnership with the Massachusetts Division of Marine Fisheries and NOAA under federal permits issued by the National Marine Fisheries Service. Support also comes from the Massachusetts Environmental Trust, CCS aviation contractor New England Specialized Aviation Services, and **contributions from CCS members.**

Fin whale feeding in Cape Cod Bay.

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Rare North Atlantic right whales return to Cape Cod Bay

Dec 12, 2018 | PRESS

On Tuesday, December 11 the Center for Coastal Studies' aerial surveillance team spotted seven critically endangered North Atlantic right whales in Cape Cod Bay, the first confirmed sighting of the species in the Bay this season.

Right whale #1403, Meridian, feeding in Cape Cod Bay on December 11, 2018. The white marks on the tail and white line in front of the blowholes are entanglement scars. CCS image, NOAA permit #19315-01

Among the whales photographed during the survey flight were individuals identified by natural markings as Arpeggio, Marble, and Meridian, whales that have visited Cape Cod Bay in the past.

One of the rarest of the world's large mammals, North Atlantic right whales visit Cape Cod Bay every winter and spring to feed on rich blooms of microscopic zooplankton. Starting in January each year since 1998, CCS has surveyed Cape Cod waters in collaboration with the Massachusetts Division of Marine Fisheries. This year, with special funding from several foundations, local businesses and individuals, CCS started its aerial and boat s DONATE ate November.

Dr. Charles "Stormy" Mayo, Senior Scientist at CCS said "With today's sighting we now know that whales enter the area earlier than previously thought, information important to the effort to protect the species."

CCS researchers identified 246 individual whales in Cape Cod Bay between January and May 2018, more than half of the estimated 411 whales in the population. No new calves were recorded in 2018 and only five were spotted in 2017, while three dead right whales have been found over the last year, down from 17 in 2017. The most common causes of death for those whales were entanglement and ship strike.

The dramatic decrease in the right whale population resulting from the low birth rate and high mortality prompted CCS to expand the aerial survey area to encompass the recently designated right whale Critical Habitat on Jeffreys Ledge (off the coast of Massachusetts and New Hampshire), and extend the survey season by two months, from November through June. This increased effort – the Right Whale Emergency Initiative – will improve the capacity for CCS to find and free entangled right whales and will expand the ability of federal and state agencies to protect the remnant population. Real-time sighting reports from the survey team will also allow managers to take swift action to regulate fishing and shipping activities in areas not previously known to be frequented by the right whales.

"With very low and declining population the future of the right whale is in great jeopardy and it's up to us to do everything we can to protect them in Cape Cod waters, one of their most critical feeding areas." said Dr. Mayo.

Members of the public are reminded that it is illegal for watercraft or aircraft of any kind to approach within 500 yards (1500 feet) of a North Atlantic right whale without a federal research permit.

CCS right whale research and response operations are conducted in partnership with the Massachusetts Division of Marine Fisheries and NOAA under federal permits issued by the National Marine Fisheries Service. Support also comes from the Massachusetts Environmental Trust, the Bruce J. Anderson Foundation, Bonnell Cove Foundation, Disney Conservation Four DONATE ller Family Foundation, Arthur & Elaine Johnson Foundation, Ramlose Foundation, Towle Ocean Conservation Fund, Nauset Disposal, and contributions from CC members.

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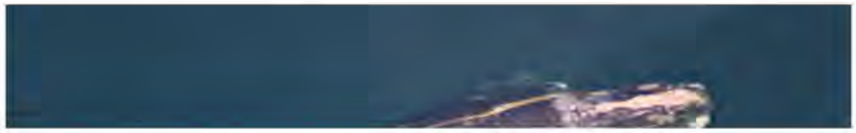

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NEWS

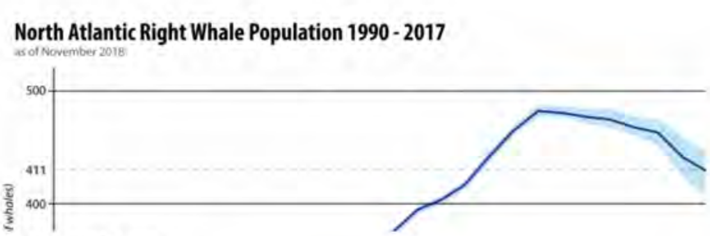
Right Whale Consortium Releases 2018 Report Card Update

411.

That's all scientists believe remains of the North Atlantic right whale population. Due primarily to human impacts, the population of these endangered whales has been in decline since 2010. North Atlantic right whales were once called the "right whales to hunt" because they swam close to shore, produced high yields of whale oil and baleen, and—thanks to their thick blubber—floated when killed. But now, rather than whalers, the population faces threats from vessel strikes and entanglement in fishing gear.

This week at its annual conference, the [North Atlantic Right Whale Consortium] (NARWC) released its annual "report card" on the status of this endangered population. Population numbers are reported at the end of the year once numbers are analyzed, so the most recent complete report available is for the end of 2017.

The best estimate for the population at the end of 2017 was 411, and there have been an additional three documented mortalities in 2018.



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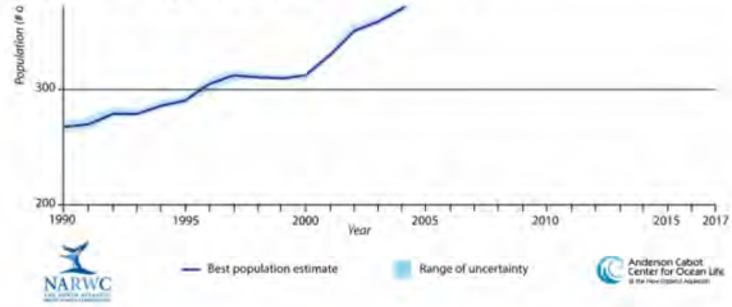
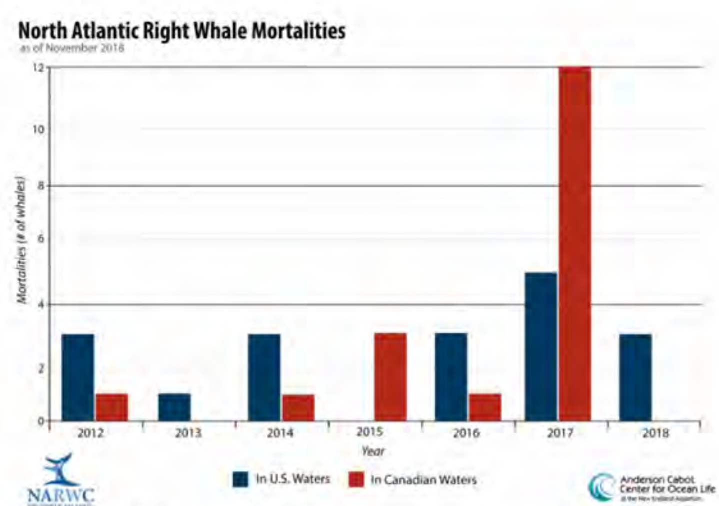


A graph of estimated North Atlantic right whale populations from 1990 to 2017. The dark blue line represents scientists' best estimate for the population number, where the light blue area represents the range of uncertainty. With 95 percent confidence, scientists report a right whale population between 392 and 433 at the end of 2017, with a best estimate of 411. Data from the 2018 NARWC Report Card.

From 2000 to 2010, the species seemed to be on the right track—its population was growing. By 2007, the population had increased from about 350 to 419, reaching a high of fewer than 500 whales in 2010.

"We're eroding that population growth," Mark Baumgartner of Woods Hole Oceanographic Institution said at the Consortium meeting.

The last few years have been desperate for right whales. The unprecedented 20 right whale deaths over 2017 and 2018 represented a loss of more than 4 percent of the struggling population. In 2017, 12 deaths were reported in Canadian waters and five in U.S. waters. So far in 2018, there have been three reported mortalities, all in the United States.



Right whales have a range from the east coast of Florida in the United States to the Gulf of St. Lawrence in Canada. Mortalities are reported either in U.S. waters (dark blue) or Canadian waters (red). Data from NOAA Fisheries.

This spring, Canada implemented new measures to help mitigate both entanglements and vessel strikes in areas right whales are frequently seen. The Canadian measures included vessel speed reductions, the establishment of different types of fisheries management areas and closures, and increased reporting. Under the new measures, the Canadian government increased reporting requirements for fishing activity, lost gear, and interactions with marine mammals.

While there haven't been any right whale mortalities reported in Canadian waters this year, there were three reported entanglements in Canada. Additionally, all three of the 2018 mortalities, which were in U.S. waters, were attributed to entanglement. One of those entanglement deaths was from Canada snow crab gear.

> **"Continued timely and effective efforts to reduce both entanglements and vessel strike mortalities must be a priority for both the U.S. and Canada if the species is to survive.**
>
> *- 2018 NARWC Report Card*

An important note: This is a preliminary release of the report card. Any additional data through the end of 2018 will be updated in January, if necessary.

Entanglements and vessel strikes have plagued the right whale population. According to the NARWC Report Card, "It is clear that current management regulations have not been effective at reducing serious entanglement injuries." Between 2010 and 2016, 85 percent of right whale mortalities were related to entanglement.

When a whale is entangled, it doesn't die instantly. Instead, entanglements in fishing gear—mostly the heavy ropes and traps of snow crab and lobster gear—reduce the survival probability for whales by exhausting and slowly starving them. Some whales, thankfully, manage to shed their gear, but their brush with entanglement leaves literal scars that

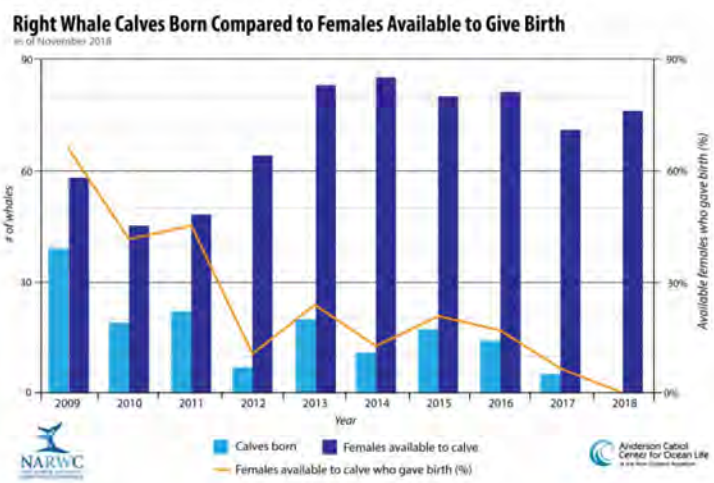
scientists use to identify the whales. A total of 83 percent of right whales have been entangled at least once.

"Human-caused mortality is unsustainable in this species," said Baumgartner.

Or, as Anderson Cabot Center Research Scientist Philip Hamilton put it, "This population can survive and flourish again if we can just stop killing them."

No right whale calves

The fewer documented mortalities in 2018 doesn't make up for a big issue within the population. Right whales aren't having babies. In 2018, for the first time in the 38 years Aquarium scientists have been studying the population, there were no calves reported.



Number of calves born (light blue) compared to known reproductive females available to calve (dark blue). The orange line is the percentage of females available to calve that gave birth from 2009 to 2018. Data from the 2018 NARWC Report Card.

Of the 411 individuals in the right whale population at the end of 2017, the report card says there were 71 female right whales available to calve. "Available females" are females who have given birth to at least one previous calf, were presumed to be alive, and who had not not given birth in the last two years. The amount of available females has been either steady or increased, but the percentage of those females giving birth has dropped. There are fewer right whales giving birth.

Anderson Cabot Center Senior Scientist Amy Knowlton studied the effects of severe entanglement on the females of the population. She found that within three years of a severe entanglement, only about 33 percent of females survive. Across the entire population, moderate and severe injuries from entanglements are on the rise.

At the Consortium meeting, there were calls for working with industry representatives to help save these whales. The thought is that fishermen are worried about reporting entanglements they see because they're afraid it could negatively impact their livelihoods.

"If we're going to solve this problem, we need the data," said Moira Brown, Anderson Cabot Center Senior Scientist.

What are we doing to help?

Since 2004, the Consortium's annual report has included updates on this beleaguered population, information on mortalities and injury events, a summary of management and research efforts that occurred that year, and—perhaps most important—recommendations for the future.

Over the last several years, the distribution of right whales and their patterns of habitat use have been shifting, likely due to their prey shifting in response to climate change. According to the report card, these shifts have "direct implications on research and management activities."

The NARWC said that identifying new critical habitats and developing alternative survey efforts to respond to these distribution changes needs to be a priority.

"These strategies should include efforts to not only locate and identify individual right whales, but also to ensure that information critical to important monitoring and management efforts ... is effectively and efficiently collected," according to the report card.

The Role of the Anderson Cabot Center

The Anderson Cabot Center is a critical component of the North Atlantic Right Whale Consortium, which is led by our very own Heather Pettis. For nearly than 40 years, the New England Aquarium's Right Whale Team has been leading research on and advocacy for the species. The team conducts vital work, including cataloging right whales in its extensive DIGITS database, tracking pregnancies and birth rates, investigating fishing gear adaptations to prevent entanglements, working to reroute shipping lanes to prevent deadly vessel strikes, and conducting groundbreaking stress hormone research in whales.

The day before the Consortium meeting, Anderson Cabot Center scientists joined industry leaders, engineers, scientists, and policymakers at the Ropeless Consortium Meeting. This group has a simple though not easy goal—a future with no ropes in the water column and, therefore, no whale or turtle entanglements. Thanks to a recent federal grant of $225,000, Senior Scientist Dr. Tim Werner and his team will begin testing a type of "ropeless" gear that replaces vertical rope lines with a large floating spool.

Together, we are working to ensure the long-term conservation and recovery of the endangered North Atlantic right whale.

Tags: 2018, North Atlantic Right Whale Consortium, publication, report card, right whales

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Oceana Exposes Ships Ignoring Voluntary Speed Zone Designed to Protect Endangered Right Whales

High Speeds Put North Atlantic Right Whales at Risk, Showing Need for Mandatory Speed Limits and Enforcement

Press Release Date
Friday, March 20, 2020
Location: Washington, DC
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Oceana today released the results of an analysis finding ships ignoring a voluntary speed zone in an area south of Nantucket designed to protect endangered North Atlantic right whales, of which only about 400 remain. Between January 22 and March 6, 2020, more than 41% of the 446 ships in the area exceeded the voluntary speed limit of 10 knots, which was established by the National Oceanographic and Atmospheric Administration (NOAA) to reduce the risk of injury and death to these whales.

Studies have found that the speed of a ship is a major factor in ship-related collisions with North Atlantic right whales and that slowing ship speeds to less than 10 knots in areas where these whales may be encountered can reduce the risk of collisions by 86%.

NOAA uses two different types of management tools to help protect North Atlantic right whales from the dangers of ship strikes: mandatory Seasonal Management Area (SMA) speed zones in places where whales are expected to be, and voluntary Dynamic Management Area (DMA) speed zones where whales are seen. DMAs suggest that ships avoid the area and have a voluntary speed limit of 10 knots. In contrast, SMAs require ships to slow down to 10 knots.

In November 2019, NOAA established a voluntary DMA to protect an aggregation of North Atlantic right whales south of Nantucket and Martha's Vineyard, which is currently in effect until March 29, 2020. In recent months, this area has contained up to 60 North Atlantic right whales.

Of the 183 ships exceeding the voluntary speed limit in this DMA, Oceana found that:

- Most (92%) were large cargo and tanker ships, including one that was more than 1,100 feet long, going as fast as 18.4 knots.
- Nearly all (96%) were flagged to foreign countries such as Panama and Liberia.
- One ship reported a speed over 22 knots, more than twice the voluntary speed limit.

Conversely, Oceana found 88.4% of the ships transiting through the mandatory SMA near Block Island, Rhode Island were complying with the speed restriction.

Last year, Oceana launched a campaign in the U.S. and Canada to reduce risks to North Atlantic right whales. Oceana senior campaign manager Gib Brogan released the following statement:

"While we appreciate NOAA's efforts, our data shows that ships simply aren't complying with voluntary speed zones. In this case, more than 40% of the ships in the area were ignoring these voluntary speed limits and putting North Atlantic right whales in harm's way. But when there are mandatory speed limits, ships actually slow down. NOAA must do more to protect North Atlantic right whales, including mandating that ships slow down when and where these whales are present, and increasing on-the-water enforcement to make sure they do so."

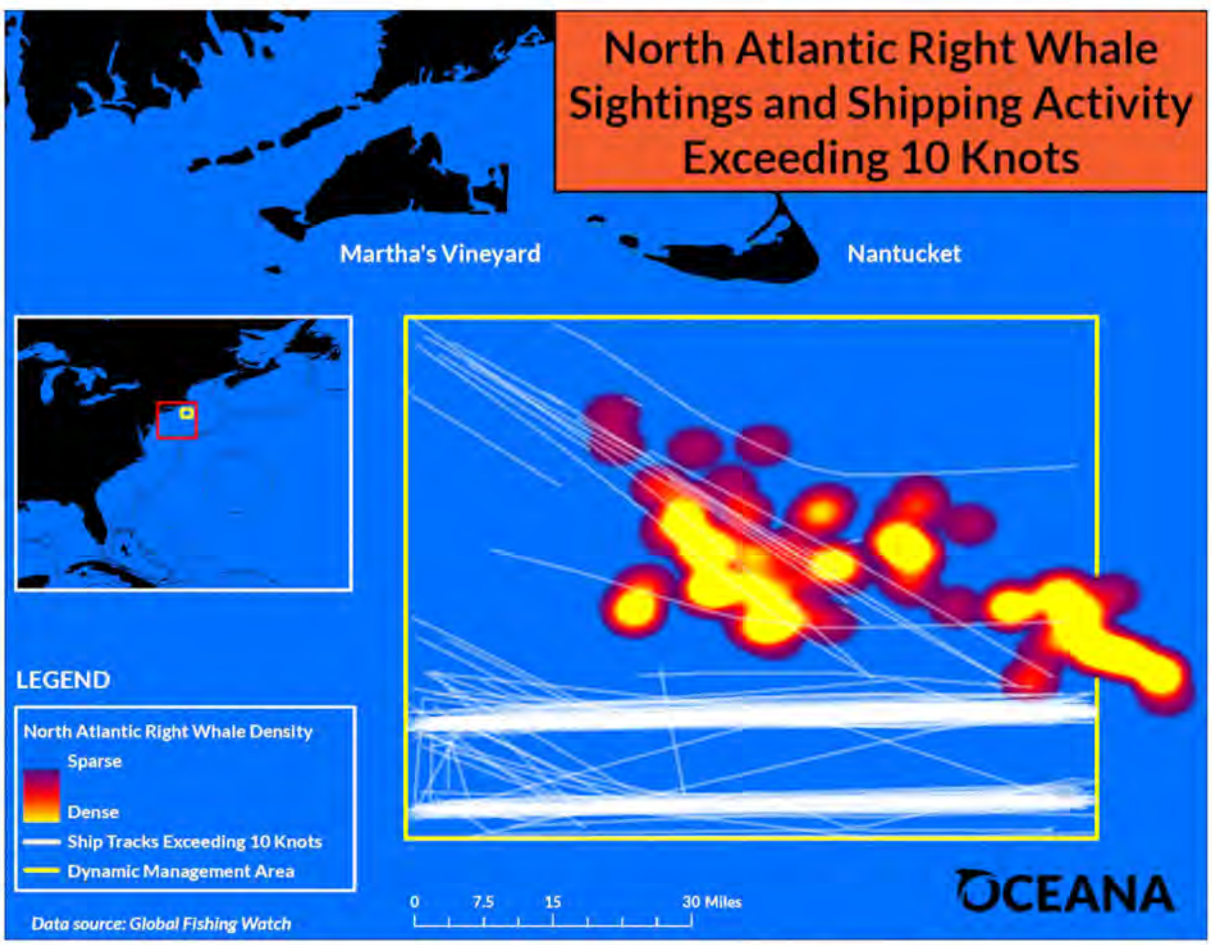

*Figure: Map of vessel traffic over 10 knots in the Nantucket Dynamic Management Area (DMA) between January 22 and March 6, 2020. North Atlantic right whale density information provided by NOAA Interactive North Atlantic Right Whale Sightings Map (**https://www.nefsc.noaa.gov/psb/surveys/MapperiframeWithText.html**).*

Oceana's analysis used the Global Fishing Watch platform, a tool developed by Oceana in partnership with Google and Skytruth, which utilizes machine learning to interpret data from various ship tracking sources like the Automatic Identification System, to monitor ship speed and positions in North Atlantic right whale conservation areas.

Background

North Atlantic right whales were named for being the "right" whale to hunt because they were often found near shore, swim slowly and tend to float when killed. They were aggressively hunted, and their population dropped from peak estimates of up to 21,000 to perhaps fewer than 100 by the 1920s. After whaling of North Atlantic right whales was banned in 1935, their population increased to as many as 483 individuals in 2010. Unfortunately, that progress has reversed.

Collisions with ships is one of two leading causes of North Atlantic right whale injury and death. North Atlantic right whales are slow, swimming around six miles per hour, usually near the water's surface. They are also dark in color and lack a dorsal fin, making them very difficult to spot. Studies have found that the speed of a ship is a major factor in ship-related collisions with North Atlantic right whales. At normal operating speeds, ships cannot maneuver to avoid them, and North Atlantic right whales swim too slowly to be able to move out of the way. This puts them at great risk of being struck, which can cause deadly injuries from blunt-force trauma or cuts from propellers.

Entanglement in fishing gear used to catch lobster, snow crab and bottom-dwelling fish like halibut, flounder and cod is the other leading cause of North Atlantic right whale deaths. Fishing gear from the U.S. and Canada entangles an estimated 100 North Atlantic right whales each year, and about 83% of all North Atlantic right whales have been entangled at least once. Ropes have been seen wrapped around North Atlantic right whales' mouths, fins, tails and bodies, which slows them down, making it difficult to swim, reproduce and feed, and can cause death. The lines cut into the whales' flesh, leading to life-threatening infections, and are so strong that they have severed fins and tails, and cut into bone.

DOI: 10.3354/ESR00335 • Corpus ID: 53968314

Response by vessel operators to protection measures for right whales Eubalaena glacialis in the southeast US calving ground

K. Lagueux, M. Zani, +1 author S. Kraus • Published 2011 • Biology • Endangered Species Research

Vessel strikes are the leading cause of mortality for the endangered North Atlantic right whale Eubalaena glacialis. Prior to a December 2008 implementation of a mandatory, seasonally based vessel-speed rule (10 knots, 18.5 km h−1) along the eastern US seaboard, voluntary recommended speeds and routes were established. We used Automatic Identification System (AIS) data to evaluate and compare the compliance rates between the mandatory and voluntary measures to protect right whales in the… CONTINUE READING

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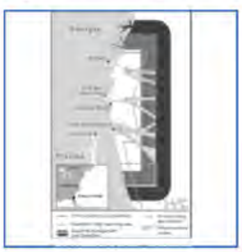
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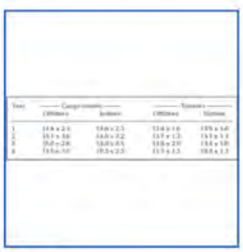
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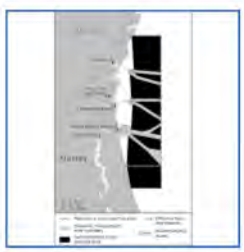
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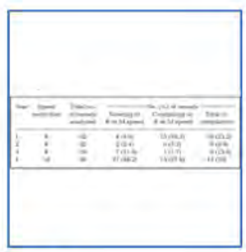
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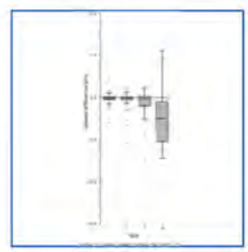
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FINAL REPORT

Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule

Update of Economic Impact and Scoping Assessment for Study of Potential Modifications

SUBMITTED TO
National Oceanic & Atmospheric Administration (NOAA)
National Marine Fisheries (NMFS)
Office of Protected Resources

SUBMITTED BY
Nathan Associates Inc.
www.nathaninc.com

December 2012

NATHAN
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1. Introduction

Background

On December 9, 2008, the Right Whale Ship Strike Reduction Rule (Rule) issued by the U.S. National Marine Fisheries Service (NMFS) went into effect. The rule requires certain vessels to travel at 10 knots or less in certain areas of right whale aggregation and near several key port entrances along the U.S. eastern seaboard.

The U.S. National Marine Fisheries Service's (NMFS) Final Rule to reduce the severity and likelihood of vessel strikes to North Atlantic right whales went into effect on 9 December 2008 (73 FR 60173; 10 October 2008). The stated goal of the rule was "*to reduce or eliminate the threat of ship strikes [of North Atlantic right whales] - the primary source of mortality in the endangered population*." It requires that vessels 65 feet and greater in length travel at speeds of 10 knots or less near several key port entrances and in certain areas of right whale aggregation and along the U.S. eastern seaboard, known as "Seasonal Management Areas" (SMA) (Figure 1- 1).

As indicated in the preamble to the rule, a program of "Dynamic Management Areas" (DMA) was also established whereby temporary zones (15 days in duration, generally) are created around aggregations of right whales occurring outside of SMAs. Mariners are asked, but not required, to either avoid established DMAs altogether or travel through them at speeds of 10 knots or less.

The rule is set to expire five years from the date of its publication. NMFS indicated that it would develop ways to monitor the effectiveness of the rule. This report presents an updated assessment of the estimated economic impact of the Rule. In large measure, the economic impact assessment is based on the approach and analysis presented in the FEIS Report, Economic Analysis for the Final Environmental Impact Statement of the North Atlantic Right Whale Ship Strike Reduction Strategy prepared by Nathan Associates Inc. for NMFS in August 2008.

Whereas the economic analysis included in the FEIS report were based on assumptions regarding the impact on vessel operations, this updated assessment is based on actual vessel operations recorded during periods when the rule was in effect and not in effect. There are also several important data and analytical improvements that are incorporated in the present assessment that are further described herein.

Figure 1-1. Locations of Vessel Speed Restriction Seasonal Management Areas

General Approach

Our approach for the estimation of the potential economic impact of the proposed operational measures of the Rule has been designed so that results can be identified and analyzed at a summary level or disaggregated by port area, vessel type, vessel size, and vessel flag. An ancillary benefit of this approach is that it also enhances the accuracy and rigor of the analysis. Key factors such as vessel operating speed vary significantly by vessel type and size; vessel operating costs vary by those vessel characteristics as well as flag of registry. For this study, we have used 10 knots as the base case.

As depicted in Figure 1-2, our general approach is organized into the following four principal tasks:

Task A. Identify and analyze vessels affected by the final rule. Detailed information regarding vessels transiting SMAs during 2009 was obtained from the U.S. Coast Guard's Automatic Identification System (AIS) database. Vessel transits were analyzed for 10 SMAs on the U.S. East Coast, 12 vessel types, 18 vessel DWT size ranges and U.S. and foreign flag registration.

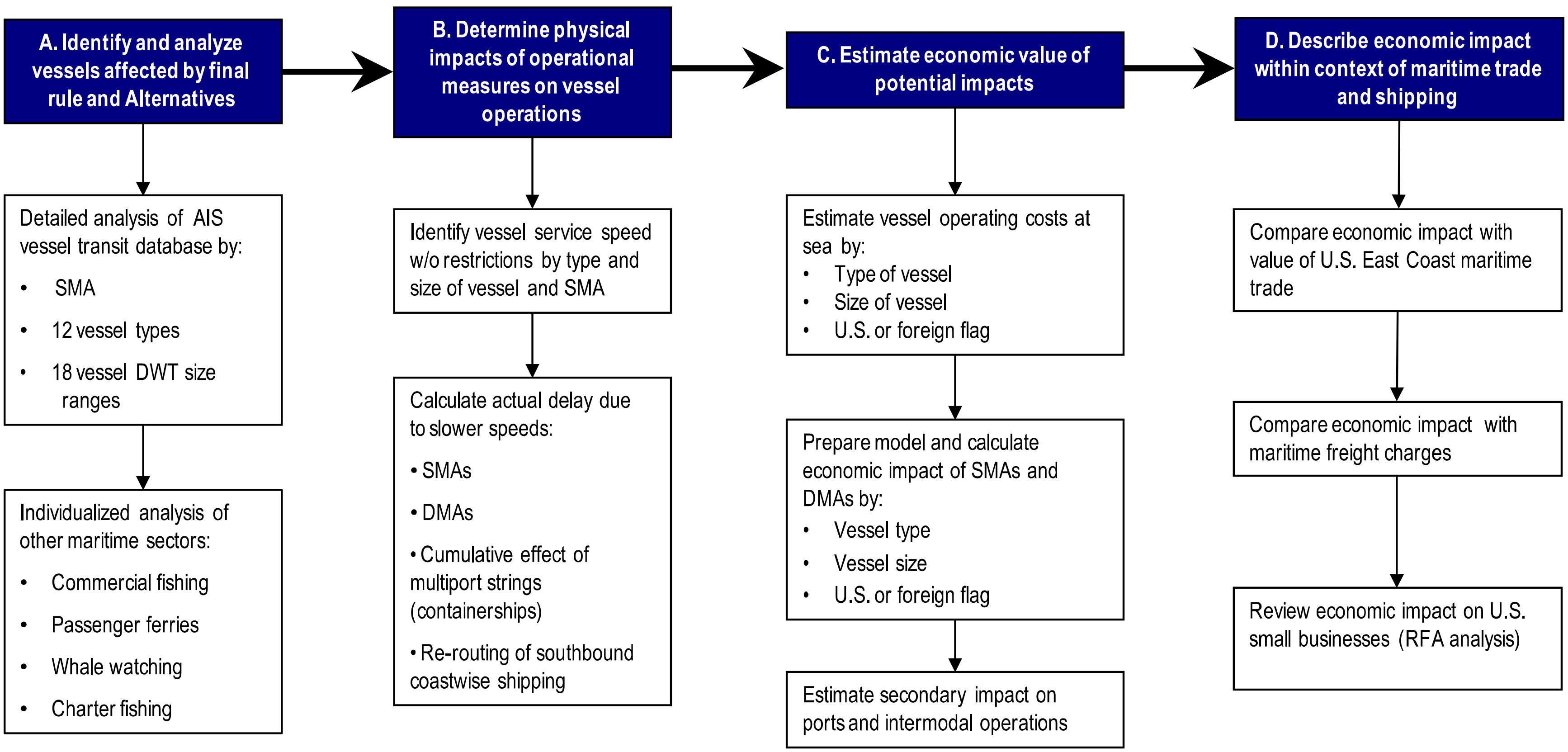
Task B. Determine physical impacts of operational measures on vessel operations. Key information include vessel service speed by type and size of vessel for periods when the SMAs were not in effect as compared to when they were in effect. Similar information was analyzed for DMAs. Results of this task include estimate of minutes of delay per vessel transit for SMAs and DMAs.

Task C. Estimate economic value of potential impacts. Key data include vessel operating costs at sea by type and size of vessel and whether U.S. or foreign flag registry. Results include detailed estimates of economic impact of speed restrictions by SMA, vessel type, vessel DWT size range, and flag of registration.

Task D. Describe economic impact within context of U.S. East Coast maritime trade and shipping. The estimated economic impact is assessed relative to the value of maritime trade and relative to maritime freight charges. We also conducted separate economic impact analyses for sectors not sufficiently included in the AIS database such as whale watching vessels, passenger ferries, commercial fishing and charter fishing.

Chapter 2 provides a detailed assessment of the impact of the rule on the shipping industry, while Chapter 3 presents the assessment on other maritime sectors. Chapter 4 presents a summary of the total direct and indirect economic impact. Chapter 5 presents the updated analysis of the impact of the rule on small business entities, consistent with a Regulatory Flexibility Act (RFA) threshold assessment. Chapter 6 provides a scoping analysis of the approach, data requirements and issues for the conduct of an economic analysis of potential modifications of the current rule.

Figure 1-2. General Approach



2. Economic Impact on Shipping Industry

Direct Economic Impact

AIS Data and Approach

A key data improvement is the availability of Automatic Identification System (AIS) that uses a Global Positioning System-linked, very high frequency radio signal that provides for ship-to-ship and ship-to-shore information transfer. It transmits the ship's name, call sign, position, dimensions, speed, heading and other information multiple times each minute. The AIS signal provides a suite of information, both dynamic (that is unique to a particular voyage) and static (that is consistent for a given vessel). Dynamic information includes the vessel's position, speed over ground, course over ground, heading, rate of turn, and position accuracy (< or > 10 m) which are determined by continuous GPS linked updates. Static information includes the vessel name, call sign, type, cargo, and its Maritime Mobile Service Identity (MMSI) number. Given the rate at which it provides this information, AIS is a precise means to remotely track vessel speeds and other vessel operations.

AIS transponders are required on certain vessel types that transit U.S. waters. These include: 1) all commercial tugs, barges, tow and similar vessels that are 26 feet in length or greater; 2) all passenger vessels (such as ferries and cruise ships) 150 gross tonnage or more; and 3) any commercial self-propelled vessel that is 65 feet in length or greater, which consists of commercial fishing vessels, tankers, cargo ships, etc.

The goal of the economic impact analysis is to estimate the impact on the shipping industry and overall economy from the actual implementation of the Rule. For these reasons, the economic impact analysis uses actual speeds of vessel transiting areas when the rule is not in effect by vessel type, size and flag compares those speeds with those from transits when the rule is in effect

We obtained access to the AIS for the areas relevant to the Rule for the full year of 2009 from the NOAA Office of Protected Resources. We then spent a significant effort to review the data and fill-in critical missing information for the economic analysis on vessel type and size. This was accomplished by matching various vessel identifiers such as the Maritime Mobile Service Identity (MMSI) number, call sign, and IMO number. In some instances, information on the type and size of vessel were confirmed based on the name of the vessel, length and cargo type. For vessels that the vessel type was known as well as the gross registered tonnage, the deadweight tonnage was estimated using the regression analysis described in the 2008 FEIS Report, Appendix A, Attachment 5.

As a result of the AIS data review and analysis, we were able to obtain for 2009, operating information for 62,765 vessel transits through areas affected by the Rule[1]. Table 2-1 presents the distribution of the total vessel transits through SMA areas by type and size of vessel. Containerships accounted for 18,540 transits followed by towing vessels with 14,425 transits and tank ships with 10,002 transits.

Table 2-1. Total Vessel Transits through SMAs by Type and Size of Vessel, 2009 (includes periods when Rule is in effect and not in effect)

	DWT Size Range																		
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	0-100	00-120	0-150	150+	Total
Bulk Carrier	1	276	257	206	134	312	239	565	258	297	380	251	767	177	3		22	20	4,165
Combination Carrier (e.g. OBO)		6						44					6	13		2			71
Container Ship	139	610	964	352	712	506	1,221	888	1,450	1,078	3,704	6,616	79	221					18,540
General Dry Cargo Ship	371	559	510	322	347	311	116	123	258	100	8	1							3,026
Industrial Vessel	1,270	125	13				6												1,414
Passenger Ship a/	3,143	933	159																4,235
Refrigerated Cargo Ship	4	225	265	54	1	2	96		5		26								678
Ro-Ro Cargo Ship	138	201	962	1,627	988	804	176	79	211	24	317	22							5,549
Tank Barge										2									2
Tank Ship	13	389	403	501	116	193	317	891	786	2,284	695	567	774	282	525	531	448	287	10,002
Towing Vessel	14,425																		14,425
Other b/	1,900	148	18	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	2,072
Total	20,134	3,347	3,538	3,062	2,298	2,128	2,171	2,590	2,968	3,785	5,130	7,457	1,626	693	528	533	470	307	62,765

a/ Includes recreational vessels.
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.
Source: Nathan Associates Inc.

Of total 62,765 transits, 28,543 vessel transits (45.5%) occurred during periods when the Rule was in effect and 34,222 vessel transits (54.5%) occurred during periods when the Rule was not in effect (Table 2-2).

[1] The data file received from NOA had a total of 78,757 transit records. However, we excluded 15,992 records due to vessels less than 65 feet LOA, non-commercial shipping vessels and where the vessel type or size could not be determined.

Table 2-2. Percent of Vessel Transits through SMAs during Effected Periods by Type of Vessel, 2009

Vessel Type	Rule in Effect	Rule Not in Effect	Total	% Rule in Effect
Bulk Carrier	2,193	1,972	4,165	52.7
Combination Carrier (e.g. OBO)	46	25	71	64.8
Container Ship	8,634	9,906	18,540	46.6
General Dry Cargo Ship	1,310	1,716	3,026	43.3
Passenger Ship	1,244	2,991	4,235	29.4
Refrigerated Cargo Ship	390	288	678	57.5
Ro-Ro Cargo Ship	2,648	2,901	5,549	47.7
Tank Barge	2		2	100.0
Tank Ship	4,494	5,508	10,002	44.9
Towing Vessel	6,751	7,674	14,425	46.8
Other b/	831	1,241	2,072	40.1
Grand Total	28,543	34,222	62,765	45.5

a/ Includes recreational vessels.

b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.

Source: Nathan Associates Inc.

Table 2-3 presents the number of transits through SMA areas in 2009 by SMA and type of vessel. The New York SMA had the largest number of transits at 15,180 transits followed by the SMA from North Carolina to Georgia with 13,437 transits and Norfolk with 9,549 transits. Each of these areas had a large number of containership transits.

Table 2-3. Total Vessel Transits through SMAs by Type of Vessel, 2009 (includes periods when Rule is in effect and not in effect)

SMA	Bulk Carrier	Combination Carrier (e.g. OBO)	Container Ship	General Dry Cargo Ship	Passenger Ship a/	Refrigerated Cargo Ship	Ro-Ro Cargo Ship	Tank Barge	Tank Ship	Towing Vessel	Other b/	Total
Off Race Point	177		341	51	192	2	92		672	446	53	2,026
Cape Cod Bay	44		17	27	69		21		166	1,633	107	2,084
Great South Channel	246		353	78	173	2	89		618	24	32	1,615
Block Island	326	4	55	138	109	25	237		605	826	141	2,466
New York	592	27	4,850	266	478	20	1,056	2	3,173	4,294	422	15,180
Philadelphia	430	5	870	532	1,308	567	333		1,779	2,687	189	8,700
Norfolk	1,424	27	3,988	632	235	10	1,198		622	1,130	283	9,549
Morehead City	50		15	49	40		8		72	429	54	717
North Carolina to Georgia	533	6	6,668	735	981	14	843		1,707	1,338	612	13,437
Southeast	343	2	1,383	518	650	38	1,672		588	1,618	179	6,991
Grand Total	4,165	71	18,540	3,026	4,235	678	5,549	2	10,002	14,425	2,072	62,765

a/ Includes recreational vessels.

b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.

Source: Nathan Associates Inc.

In terms of transits during periods when the SMAs were in effect, the Mid-Atlantic region registered the highest percentage of transits, generally between 45-50 percent of total transits (Table2-4). This is consistent with the 181-day period that the SMAs were in effect in these areas from November 1 through April 30. Other areas also generally had the percentage of transits through active SMAs matching the percent of the days of the year that they were in effect.

Table 2-4. Percent of Vessel Transits through SMAs by Type of Vessel during Effected Periods, 2009

SMA	Rule in Effect	Rule Not in Effect	Total	% Rule in Effect
Off Race Point	316	1,710	2,026	15.6
Cape Cod Bay	882	1,202	2,084	42.3
Great South Channel	477	1,138	1,615	29.5
Block Island	1,121	1,345	2,466	45.5
New York	7,520	7,660	15,180	49.5
Philadelphia	3,979	4,721	8,700	45.7
Norfolk	4,652	4,897	9,549	48.7
Morehead City	182	535	717	25.4
North Carolina to Georgia	6,499	6,938	13,437	48.4
Southeast	2,915	4,076	6,991	41.7
Grand Total	28,543	34,222	62,765	45.5
Source: Nathan Associates Inc.				

AVERAGE OPERATING SPEEDS BY VESSEL TYPE AND SIZE

Accurate information on current vessel operating speeds is clearly an important element for the determination of the economic impact of the speed restriction required by the Rule. The AIS information provides the most detailed and accurate information of vessels operating speeds for the areas subject to the Rule. For each area subject to the Rule, we have computed the average operating speeds by type and size of vessel for periods in 2009 when the Rule was not in effect. This provides the most robust estimate for actual vessel operations and average operating speeds without the influence of the Rule. In Table 2-5 below, we present the data by vessel type and size but summarized across all of the areas affected by the Rule. The fastest average vessel operating speed in these areas observed in 2009 was 14.0 knots for containerships and 13.9 knots for refrigerated cargo ships. The overall weighted average speed was 11.9 knots.

Table 2-5. Average Vessel Operating Speed through SMAs by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule Is Not in Effect, 2009 (knots)

	DWT Size Range																	
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	4.6	11.1	11.2	11.9	9.6	11.4	11.1	10.7	11.2	11.9	12.3	11.3	11.4	10.8			12.6	10.6	11.3
Combination Carrier (e.g. OBO)		13.9						10.1					9.8			12.7			10.6
Container Ship	12.4	12.9	14.1	13.7	13.2	14.9	14.5	13.9	14.0	13.9	14.4	13.9	13.6	14.1					14.0
General Dry Cargo Ship	11.4	11.6	13.5	12.3	12.4	11.5	12.3	11.2	11.8	12.9	12.8								12.1
Passenger Ship	10.7	15.7	14.8																12.4
Refrigerated Cargo Ship	11.0	14.4	14.6	15.0			11.3		13.4		13.7								13.9
Ro-Ro Cargo Ship	8.4	13.3	13.6	14.2	13.7	13.2	13.9	15.3	13.4	14.3	13.6	13.4							13.6
Tank Ship	9.6	12.3	11.6	12.7	11.0	12.4	12.1	12.3	11.9	11.9	11.8	11.8	11.3	11.1	10.9	11.3	10.3	11.2	11.7
Towing Vessel	8.2																		8.2
Total	9.3	13.7	13.4	13.6	12.9	13.0	13.5	12.5	13.0	12.6	13.9	13.7	11.5	12.0	10.9	11.3	10.3	11.2	11.9
Source: Nathan Associates Inc.																			

Average vessel operating speeds through SMAs in 2009 during period when the Rule was in effect declined to an overall average of 10.0 knots (Table 2-6). Containerships slowed from an average of 14 knots to 10.6 knots. Ro-ro vessels slowed from 13.6 knots to 10.5 knots. The fastest average vessel speed through SMA active areas was by refrigerated cargo ships at 13.1 knots just slightly slower than the 13.9 knots recorded during non-active SMA periods.

Table 2-6. Average Vessel Operating Speed through SMAs by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule Is in Effect, 2009 (knots)

	DWT Size Range																	
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier		10.5	10.4	11.4	9.1	10.6	10.3	9.9	10.3	10.3	10.7	9.6	10.4	10.8	9.6		10.6	9.2	10.3
Combination Carrier (e.g. OBO)		10.6						6.8					8.5	10.0					8.2
Container Ship	12.3	11.1	10.7	10.6	10.3	10.2	11.1	11.1	11.0	10.1	10.6	10.5	10.7	10.4					10.6
General Dry Cargo Ship	10.5	11.4	11.6	11.1	11.5	10.6	11.2	10.8	11.0	10.5	9.2	9.9							11.2
Passenger Ship	9.1	10.7	11.5																9.7
Refrigerated Cargo Ship		13.4	13.8	11.8	12.9	9.4	11.7		9.9		9.9								13.1
Ro-Ro Cargo Ship	9.3	10.8	10.3	10.5	10.7	10.6	10.3	10.4	11.1	10.9	10.2	10.8							10.5
Tank Barge										10.6									10.6
Tank Ship	9.2	10.1	10.5	10.8	10.3	10.9	10.3	10.4	10.5	10.3	10.5	10.0	9.9	9.8	9.6	10.6	9.7	10.9	10.3
Towing Vessel	8.2																		8.2
Total	8.6	10.9	11.0	10.7	10.5	10.5	10.9	10.5	10.8	10.2	10.6	10.4	10.2	10.4	9.6	10.6	9.8	10.7	10.0
Source: Nathan Associates Inc.																			

AVERAGE DELAYS DUE TO RULE BY TYPE AND SIZE OF VESSEL

The primary operational impact of the Rule on the shipping industry is the extra sailing time incurred caused by vessels having to slow down within the restricted areas. Estimates of the extra sailing time were calculated by subtracting the time required to sail through each restricted area using the detailed average vessel operating speeds for that restricted area during periods when the Rule was not in effect from the time required at a sailing speed of 10 knots. Only average vessel speeds of greater than 10 knots during non-Rule periods were used for these calculations. A summary across all restricted areas of the average extra time per vessel transit by vessel type and size is presented in Table 2-7. The average delay for all vessels is 0.37 of an hour or 22 minutes. The highest average delay by vessel type is 37minutes (0.62 hours) for combination carriers followed by 34 minutes for Ro-Ro carriers and 32 minutes for containerships. Refrigerated cargo ships only experienced an average delay of 5 minutes.

Table 2-7. Average Delays per Vessel Transit through SMAs due to Rule by Type and Size of Vessel, 2009 (hours)

	DWT Size Range																		
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	00-12(	20-15(	150+	Total
Bulk Carrier		0.12	0.17	0.08	0.12	0.16	0.18	0.16	0.21	0.37	0.33	0.39	0.19	0.00			0.34	0.31	0.20
Combination Carrier (e.g. OBO)		0.75						0.93					0.50						0.62
Container Ship	0.02	0.36	0.61	0.46	0.47	0.78	0.49	0.45	0.45	0.64	0.59	0.55	0.53	0.59					0.54
General Dry Cargo Ship	0.19	0.04	0.29	0.20	0.17	0.16	0.19	0.08	0.16	0.44	0.62								0.17
Passenger Ship	0.17	0.84	0.42																0.35
Refrigerated Cargo Ship		0.11	0.08	0.32			-0.06		0.54		0.62								0.08
Ro-Ro Cargo Ship	0.00	0.46	0.64	0.66	0.51	0.48	0.60	0.72	0.35	0.43	0.54	0.49							0.56
Tank Ship	0.14	0.45	0.23	0.33	0.12	0.28	0.30	0.36	0.29	0.36	0.27	0.38	0.29	0.27	0.27	0.13	0.12	0.07	0.29
Total	0.19	0.55	0.42	0.49	0.42	0.45	0.41	0.36	0.37	0.46	0.54	0.54	0.25	0.29	0.27	0.13	0.12	0.09	0.37
Source: Nathan Associates Inc.																			

VESSEL OPERATING COSTS AT SEA BY TYPE AND SIZE OF VESSEL

The U.S. Army Corps of Engineers (USACE) prepares estimates of vessel operating costs to be used by planners in studies to determine the potential benefits of harbor improvement projects. Vessel operating costs include annual capital costs as determined by the replacement cost of the vessels and application of capital recovery factors; estimates of fixed annual operating costs such as for crew, lubricating materials and stores (supplies), maintenance and repair, insurance and administration; the number of operational days per year; and fuel costs at sea and in port.

The type and DWT size of vessels for which operating costs are reported by the USACE is shown in Table 2-8 below. Vessel operating costs are presented separately for U.S. flag and foreign flag vessels, for five vessel types, and up to 14 vessel DWT sizes within a vessel type.

Table 2-8. Type and Size of Vessels for which USACE Reports Vessel Operating Costs (DWT)

Foreign flag					U.S. flag				
General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull	General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull
11,000	9,000	15,000	20,000	20,000	11,000	9,000	15,000	20,000	20,000
14,000	14,000	25,000	25,000	25,000	14,000	14,000	25,000	25,000	25,000
16,000	17,000	35,000	35,000	35,000	16,000	17,000	35,000	35,000	35,000
20,000	20,000	40,000	50,000	50,000	20,000	20,000	40,000	50,000	50,000
24,000	23,000	50,000	60,000	60,000	24,000	23,000	50,000	60,000	60,000
30,000	28,000	60,000	70,000	70,000	30,000	28,000	60,000	70,000	70,000
	31,000	80,000	80,000	80,000		31,000	80,000	80,000	80,000
	35,000	100,000	90,000	90,000		35,000	100,000	90,000	90,000
	39,000	120,000	120,000	120,000		39,000	120,000	120,000	120,000
	42,000	150,000	150,000	150,000		42,000	130,000	150,000	150,000
	49,000	175,000	175,000	175,000		49,000		175,000	175,000
	55,000	200,000	200,000	200,000		55,000		200,000	200,000
	66,000		265,000	265,000		66,000		265,000	265,000
	82,000		325,000	325,000					

Source: U.S. Army Corps of Engineers, Economic Guidance Memorandum 02-06, Deep Draft Vessel Operating Costs

As the USACE data includes more vessel size ranges than necessary for this economic impact analysis We applied regression techniques to the USACE vessel operating cost data in order to match with the vessel size categories with thoase used in this analysis of U.S. East Coast vessel arrivals. A logarithmic equation was specified relating hourly operating costs at sea with vessel DWT for each of the vessel types used in this economic impact analysis.

A concern over the use of the USACE operating cost estimates is the variability of actual vessel operating costs due to the fluctuations in the price of bunker fuel. The USACE estimates include the assumed fuel consumption per day at sea for the primary propulsion and auxiliary propulsion for each vessel type and DWT size. The primary propulsion is assumed to use heavy viscosity oil while the auxiliary propulsion is assumed to use marine diesel oil. We updated the USACE vessel operating costs to reflect the average bunker fuel prices per ton for New York for using an annual average 2009 calculated from data reported by Bunkerworld. The average price for heavy viscosity oil for 2009 was $347 per metric ton and marine diesel oil was $685 per metric ton. The resulting estimates of vessel operating costs by type and size of vessel for 2009 are presented for foreign flag and U.ZS.-flag vessels in Table 2-9 and Table 2-10, respectively. These estimated vessel operating costs for 2009 represent the best method to value the actual impact on the shipping industry of the Rule that year.

It is important to distinguish between foreign flag and U.S. flag vessels as their costs structures differ considerably. Overall, U.S.-flag vessels have operating costs 40-70 percent higher than foreign flag vessels. This is principally due to higher costs for U.S. crews, vessel maintenance and insurance requirements that U.S.-flag vessels have to satisfy[2].

Table 2-9. Hourly Vessel Operating Costs at Sea for Foreign Flag Vessels by Type Size of Vessel Using Average 2009 ($000s)

	DWT Size Range (000s)																	
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+
Bulk Carrier	786	805	825	845	865	886	907	929	951	974	1,010	1,059	1,110	1,164	1,221	1,311	1,477	1,703
Combination Carrier (e.g. OBO)	826	846	866	887	908	930	952	975	999	1,023	1,060	1,112	1,166	1,223	1,282	1,377	1,551	1,789
Container Ship	788	888	1,000	1,126	1,267	1,427	1,607	1,809	2,037	2,294	2,740	3,474	4,405	5,584	7,080	10,107	-	-
Freight Barge	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
General Dry Cargo Ship	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
Passenger Ship a/	3,551	5,069	7,237	10,962	13,897	-	-	-	-	-	-	-	-	-	-		-	-
Refrigerated Cargo Ship	1,774	1,997	2,249	2,532	2,851	3,211	3,615	4,071	4,583	5,161	6,166	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	867	977	1,100	1,238	1,394	1,570	1,767	1,990	2,241	2,523	3,014	3,822	4,845	-	-	-	-	-
Tank Ship	960	978	996	1,015	1,034	1,053	1,073	1,093	1,113	1,134	1,166	1,210	1,256	1,304	1,353	1,431	1,570	1,755
Towing Vessel	960	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-

a/ Includes recreational vessels.
b/ Includes fishing vessels, industrial vessels, research vessels, and school ships.
Source: Prepared by Nathan Associates Inc. as decribed in text from data provided in U.S. Army Corps of Engineers, Economic Guidance Memorandum 05-01, Deep Draft Vessel Operating Costs and adjusted for bunker fuel prices reported by Bunkerworld for IFO380 and MDO for New York.

Table 2-10. Hourly Vessel Operating Costs at Sea for U.S. Flag Vessels by Type Size of Vessel Using Average 2009 ($000s)

	DWT (000s)																	
Vessel type anf flag	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+
Bulk Carrier	1,321	1,358	1,396	1,435	1,476	1,517	1,559	1,603	1,648	1,694	1,766	1,866	1,972	2,084	2,203	2,393	2,748	3,243
Combination Carrier (e.g. OBO)	1,387	1,426	1,466	1,507	1,549	1,593	1,637	1,683	1,730	1,779	1,854	1,960	2,071	2,189	2,313	2,513	2,885	3,405
Container Ship	1,064	1,194	1,340	1,503	1,687	1,894	2,125	2,385	2,676	3,003	3,571	4,497	5,664	7,133	8,984	12,698	-	-
Freight Barge	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-
General Dry Cargo Ship	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-
Passenger Ship a/	4,775	6,749	9,539	14,283	17,989	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigerated Cargo Ship	2,393	2,686	3,014	3,383	3,796	4,260	4,781	5,366	6,022	6,758	8,034	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	1,170	1,313	1,474	1,654	1,856	2,083	2,337	2,623	2,944	3,304	3,928	4,947	6,230					
Tank Barge	1,784	1,818	1,853	1,888	1,924	1,960	1,998	2,036	2,074	2,114	2,174	-	-	-	-	-	-	-
Tank Ship	1,784	1,818	1,853	1,888	1,924	1,960	1,998	2,036	2,074	2,114	2,174	2,258	2,344	2,434	2,528	2,675	2,939	3,291
Towing Vessel	1,784	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-

Source: Prepared by Nathan Associates Inc. as decribed in text from data provided in U.S. Army Corps of Engineers, Economic Guidance Memorandum 05-01, Deep Draft Vessel Operating Costs and adjusated for bunker fuel prices reported by Bunkerworld for IFO380 and MDO for New York.

DIRECT ECONOMIC IMPACT OF SMAS

The estimated direct economic impact on the shipping industry of the Rule in 2009 is presented in Table 2-11. Across all SMAs, the total direct economic impact is estimated $19.6 million. More than 63 percent of the total direct impact incurred by containerships at $12.4 million followed distantly by Ro-Ro cargo ships at $2.2 million, tank ships at $1.6 million and passenger at $1.5 million.

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[2] Some studies report a much higher differential (up to 2.7 times) between U.S.-flag and foreign flag vessel operating costs. However, those studies do not include fuel and capital costs in their comparisons.

Table 2-11. Direct Economic Impact of SMAs on Shipping Industry by Type and Size of Vessel, 2009 ($000s)

Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	-	17	21	7	9	27	24	81	25	49	62	60	82	-	-	-	7	6	476
Combination Carrier (e.g. OBO)	-	3	-	-	-	-	-	16	-	-	-	-	2	-	-	-	-	-	21
Container Ship	1	90	267	78	203	286	446	353	625	668	2,881	6,128	70	295	-	-	-	-	12,392
General Dry Cargo Ship	24	3	53	27	19	14	19	9	42	60	-	-	-	-	-	-	-	-	271
Passenger Ship a/	405	806	245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,455
Refrigerated Cargo Ship	-	28	28	28	-	-	-	-	7	-	23	-	-	-	-	-	-	-	114
Ro-Ro Cargo Ship	-	54	352	665	355	303	95	61	86	12	244	11	-	-	-	-	-	-	2,239
Tank Ship	0	73	39	85	7	22	51	227	116	438	127	118	122	24	68	49	32	19	1,616
Towing Vessel	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194
Other b/	563	263	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	826
Total	1,187	1,336	1,005	889	594	651	634	746	902	1,227	3,338	6,318	277	319	68	49	39	26	19,604

a/ Includes recreational vessels.

b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.

Source: Nathan Associates Inc.

The direct economic impact on the shipping industry by SMA is presented in Table 2-12. The largest impact is recorded for the SMA from North Carolina to Georgia at $5.9 million followed by New York at $5.5 million and Norfolk at $4.2 million. As previously mentioned these areas have the majority of containership transits along the U.S. East Coast. These three SMAs account for nearly 80 percent of the direct econom,ic impact of the Rule on the the shipping industry.

Table 2-12. Direct Economic Impact of SMAs on Shipping Industry by SMA and Type of Vessel, 2009 ($000s)

SMA	Bulk Carrier	Combination Carrier (e.g. OBO)	Container Ship	General Dry Cargo Ship	Passenger Ship a/	Refrigerated Cargo Ship	Ro-Ro Cargo Ship	Tank Ship	Towing Vessel	Other b/	Total
Off Race Point	9	-	74	2	4	-	7	37	3	0	136
Cape Cod Bay	7	-	2	1	1	-	3	25	20	6	65
Great South Channel	15	-	139	4	185	0	12	60	0	0	416
Block Island	55	1	37	11	27	5	84	129	10	4	362
New York	73	11	3,631	27	349	16	473	593	62	271	5,506
Philadelphia	48	-	375	43	169	73	137	229	38	26	1,138
Norfolk	174	8	2,830	61	187	8	505	111	16	267	4,166
Morehead City	5	-	8	2	4	-	2	7	2	87	117
North Carolina to Georgi	55	1	4,805	79	123	8	382	321	24	101	5,897
Southeast	37	-	490	41	406	5	634	103	20	64	1,800
Total	476	21	12,392	271	1,455	114	2,239	1,616	194	826	19,604

a/ Includes recreational vessels.

b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.

Source: Nathan Associates Inc.

DIRECT ECONOMIC IMPACT OF DMAS

The Rule specifies that voluntary dynamic management areas would be implemented along the U.S. Exclusive Economic Zone when right whale sightings occur. Triggers for implementing a DMA are based on those specified for the Atlantic Large Whale Take

Reduction Plan (ALWTRP) Dynamic Area Management fishing restrictions.[3] A DMA action would be triggered by a single reliable report from a qualified individual of an aggregation of three or more right whales within 75 square nautical miles (nm^2) (257 km^2), such that right whale density is equal to or greater than 0.04 right whales per nm^2 (3.43 km^2), equivalent to four right whales per 100 nm^2 (343 km^2). Once a DMA is triggered, NMFS would use the following procedures and criteria to establish a DMA:

- A circle with a radius of at least 2.8 nm (5.2 km) would be drawn around the location of each individual sighting. This radius would be adjusted for the number of observed whales, so as to size the DMA to maintain a density of four right whales per 100 nm^2 (343 km^2). Information on how to calculate the length of the radius can be found in the Proposed Rule to amend the regulations that implement the ALWTRP (67 FR 1133). For a group of three whales the DMA would consist of a core area with a radius of 4.8 nm (8.9 km).

- If any circle or group of contiguous circles includes three or more right whales, this core area and its surrounding waters would be a candidate DMA zone.

Once NMFS identifies a core area containing three or more whales, the agency would expand this initial core area to provide a buffer in which the whales could move and still be protected. NMFS will determine the extent to the DMA zones as follows:

- A large circular zone would be drawn extending 15 nm (27.8 km) from the perimeter of a circle around each core area.

- The DMA would be a polygon drawn outside, but tangential to, the circular buffer zone(s), defined by the latitudinal and longitudinal coordinates of its corners.

Hence each DMA consists of the core area with a radius of 4.8 nm (for a group of three whales) plus the buffer with a radius of 15 nm for a total radius of 19.8 nm. The diameter of the DMA is thus 39.6 nm. The DMA zone would automatically expire after 15 days from the day of the original sighting, unless subsequent surveys within the 15-day period demonstrated (a) whales are present in the zone, or (b) the aggregation had persisted, in which case the period would be extended 15 days from the date of any subsequent sightings in the zone.

Impact on Vessel Operations

In all regions, mariners have the option of either routing around the DMA or proceeding through it at a restricted speed. The measures are voluntary and vessel operators are not

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[3]See the January 9, 2002 Federal Register Proposed Rule (as amended by the October 28, 2002 technical amendment to the final rule) for the definition of Procedures and Criteria to Establish a DAM Zone, Criteria to Determine the Extent of the DAM Zone, and Duration of DAM Zones.

currently required to take either measure. For this analysis we have compared the average speeds for each vessel type passing through areas where DMAs were implemented in 2009 with speeds for same types of vessel through those same areas when the DMA was not in effect. The direct impact of a DMA on vessel operations is the increased time required to transit through the DMA when it is in effect.

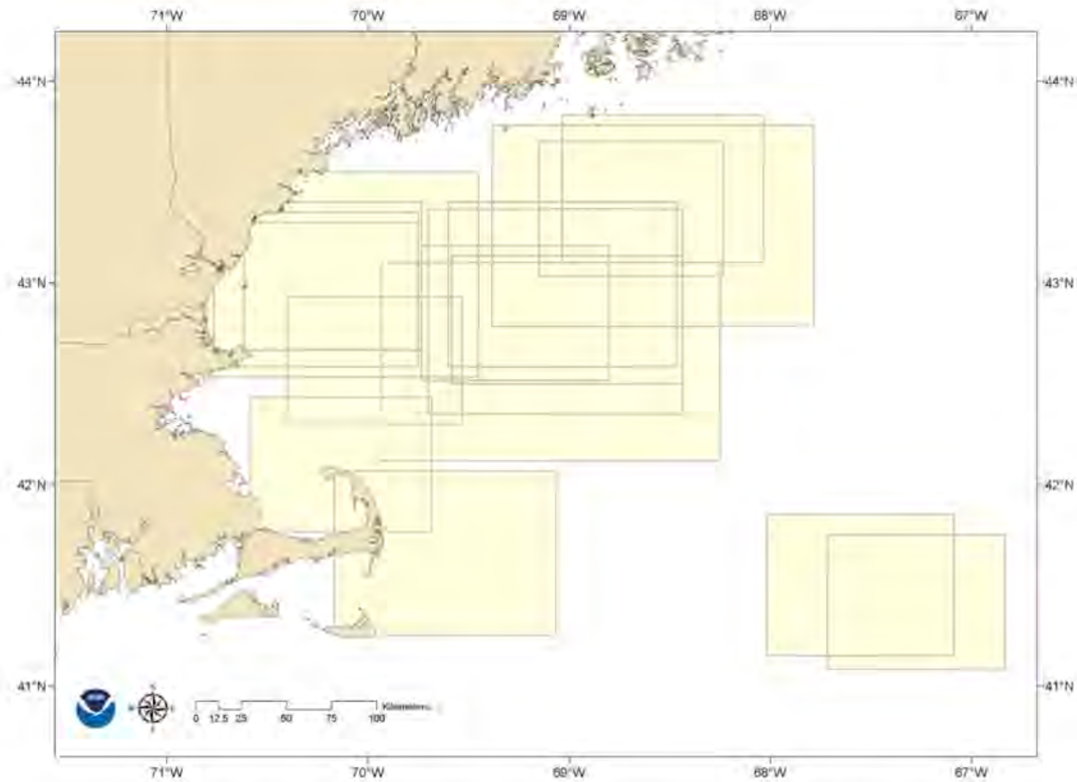
In 2009, there were18 DMAs implemented based on the sightings of right whales. Information on each of these DMAs is presented in Table 2-11 and the locations of the DMAs are shown in Figure 2-1. The average duration of the DMAs in 2009 was 18.6 days. The DMAs range in size from 1448 nm^2 to 4391 nm^2.

Table 2-13. DMAs Implemented in 2009

DMA No.	No. of Whales	Area (nm^2)	Start date	End date	Duration Days
NE_04	28	1997	1/13/2009	2/10/2009	28
NE_05	3	1605	1/16/2009	1/29/2009	13
NE_06	6	1448	2/11/2009	2/25/2009	14
NE_07	5	1456	2/11/2009	2/25/2009	14
NE_08	12	2419	2/11/2009	2/25/2009	14
NE_09	3	1592	3/17/2009	3/28/2009	11
NE_10	5	1764	4/13/2009	4/25/2009	12
NE_11	15	1926	5/12/2009	5/27/2009	15
NE_12	3	1602	5/13/2009	5/27/2009	14
NE_13	44	4391	6/2/2009	6/29/2009	27
NE_14	3	4391	7/9/2009	7/21/2009	12
NE_15	5	1644	9/2/2009	9/16/2009	14
NE_16	26	2124	10/15/2009	11/11/2009	27
NE_17	24	1918	10/22/2009	12/1/2009	40
NE_18	16	2441	10/27/2009	11/10/2009	14
NE_19	41	3661	11/10/2009	12/17/2009	37
NE_20	47	3403	11/10/2009	11/24/2009	14
NE_21	27	4198	12/4/2009	12/19/2009	15

Source: NOAA, Office of Protected Resources, National Marine Fisheries Service.

Figure 2-1. Locations of DMAs in 2009



The average vessel operating speeds by vessel type during periods when DMA were in effect and not in effect in 2009 are presented in Table 2-14. There were 11,924 transits recorded in the DMA areas at times when the DMAS were not in effect and 1,937 transits during the DMAs. The overall weighted average speed during the non-active periods was 8.0 knots whereas an average of 8.5 knots was recorded for the period when DMAs were in effect. Interestingly, only six vessel types had average speeds greater than 10 knots through the DMA areas, and of these only two vessel types, bulk carriers and passenger ships actually recorded a reduction in speed during active DMAs. For bulk carriers the reduction was minor from 10.1 knots to 9.8 knots and for passenger vessels the speed reduction was from 12.0 knots to 9.0 knots.

Table 2-14. Average Vessel Operating Speed through DMAs by Type of Vessel, 2009 (knots)

Vessel type	Number of transits			Average speed		
	Not in effect	In effect	Total	Not in effect	In effect	Speed reduction
Bulk Carrier	396	97	493	10.10	9.80	0.29
Container Ship	528	91	619	14.90	15.00	
Freight Barge	86	9	95	8.90	9.54	
General Dry Cargo Ship	163	26	189	11.36	11.67	
Industrial Vessel	42	7	49	6.09	9.23	
Passenger Ship	544	72	616	12.00	9.00	3.00
Recreational	120	6	126	6.88	9.77	
Research Vessel	44	14	58	9.88	11.18	
Ro-Ro Cargo Ship	155	19	174	13.52	13.60	
School Ship	62	15	77	5.66	7.31	
Tank Ship	1,697	431	2,128	11.34	11.53	
Towing Vessel	2,075	310	2,385	7.53	7.60	
#N/A	5,995	840	6,835	5.93	6.10	
Total	11,924	1,937	13,861	8.01	8.49	

Source: Nathan Associates Inc.

As previously mentioned, the speed restrictions under DMAs are voluntary. As such, a large segment of the shipping industry did not reduce speeds through active DMAs in 2009. For this reason, there was no or minimal economic impact of DMAs on the shipping industry in 2009.

Other Direct Impacts on Shipping Industry

Cumulative Effect of Multi-Port Strings for Containerships

Many of the vessels calling at U.S. East Coast ports occur as part of a "string" of port calls by the vessel. For containerships, Ro-Ro cargo ships and some specialty tankers these multi-port calls constitute a scheduled cargo service offered by the shipping lines. Other types of vessels may have multiple U.S. East Coast port calls as part of a coastwise cabotage service, for delivery of specialty chemicals or other products, or to lighten or top off in order to maximize vessel utilization. There are several reasons why the cumulative effect of multiple port calls at restricted ports could impact a vessel more than the sum of the individual direct impacts presented in the prior sections. First, the delays incurred from speed restrictions at one port when combined with speed restrictions at a subsequent port may diminish the ability of the vessel to maintain its schedule and could result in missed tidal windows. Second, even brief delays at arrival at the second port could result in increased costs for scheduled, but unused, port labor. Third, some shipping lines felt that the cumulative impact of three or four port calls at port areas with restrictions could cause them to rework vessel itineraries and could result in dropping of one of the port calls in order to maintain a weekly service without having to add an additional vessel to the service.

However, these cumulative factors will not affect every vessel making multiple port calls at restricted ports. Also the impact may vary from an 8-hour delay due to a missed tidal window to incurring charges for unused labor if a vessel is late arriving at the port.[4] It is realistic to assume that the shipping industry will revise their itineraries to account for the delays imposed by the speed restrictions and that occurrences of missed tidal widows will be rare. From the calculations described in detail in the 2008 FEIS Report, we have used the same average additional delay of 11 minutes for each containership transit that is part of a multi-port string to account for this cumulative impact.[5] The economic value of this additional time has been calculated based on the average 2009 vessel operating and the 2009 vessel operating costs for containerships. The estimated impact for 2009 is $3.1 million.

Re-routing of Southbound Coastwise Shipping

Coastwise shipping or cabotage trade along the U.S. East Coast has always been an important segment of our nation's maritime heritage. In recent years, attention has been focused on the further development of coastwise shipping (also referred to as short-sea shipping) as a means of reducing highway congestion on the Eastern Seaboard. Benefits of coastwise shipping also include lowering transport and environmental costs and reducing our demand for imported fuel. For these reasons, it is important that the speed restrictions not unduly affect the development of increased coastwise shipping.

However, for commercial and navigation purposes, it appears unlikely that the speed restriction would significantly affect coastwise shipping. Northbound vessels prefer to use Gulf Stream further offshore and benefit from the enhanced operating speed and fuel efficiency. Southbound traffic routes closer to the U.S. East Coast; generally within 7-10 nautical miles of the shoreline. However, during the proposed seasonal management periods, masters of southbound vessels would likely route outside of seasonal speed restricted areas incurring an overall increase in distance. This affects southbound vessels between the entrance to the Chesapeake Bay and Port Canaveral.

The speed restrictions in the mid-Atlantic region are implemented for a radius of 20 nautical mile buffer around each port area for port areas north of Wilmington, NC.[6] A continuous 20-mile buffer was implemented from Wilmington, NC through Savannah to the northern boundary of the Southeastern SMA. The additional distance incurred by southbound vessels would be 56 nautical miles. The economic impact for this extra sailing distance is estimated at $1.1 million using 2009 vessel operating costs.

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[4] While tides occur on 12-hour cycle, it is assumed that a tidal window is open for 2 hours before and after high tide. This results in an 8-hour waiting period between tidal windows.

[5] Only a small portion of vessel arrivals should be affected by this additional delay. It is assumed that 7.5 percent of vessels could be affected by as much as an additional 8-hour delay due to missing the tidal window. This results in an average additional delay per vessel of 36 minutes.

[6] The exception is the Block Island Sound speed restriction area that is configured as a rectangle with a width of 30 nautical miles.

TOTAL DIRECT ECONOMIC IMPACT ON SHIPPING INDUSTRY

The total direct economic impact on the shipping industry consists of the various impacts analyzed above. These are the SMAs, DMAs, cumulative effect of multi-port strings and the re-routing of southbound coastwise shipping. The total direct economic impact on the shipping industry in 2009 is estimated at $23.8 million as shown in Table 2-15.

Table 2-15. Direct Economic Impact on Shipping Industry, 2009 ($millions)

Impact	Amount
Seasonal Management Areas (SMAs)	19.6
Dynamic Management Areas(DMAs)	-
Cumulative Effect of multi-port strings	3.1
Re-routing of southbound coastwise shipping	1.1
Total	23.8

Source: Prepared by Nathan Associates as described in text.

Direct Economic Impact Relative to Trade Value and Freight Costs

The U.S. Census Bureau data on U.S. imports of merchandise is compiled primarily from automated data submitted through the U.S. Customs' Automated Commercial System.[7] Data are compiled also from import entry summary forms, warehouse withdrawal forms and Foreign Trade Zone documents as required by law to be filed with the U.S. Customs Service. Information on U.S. exports of merchandise is compiled from copies of Shipper's Export Declarations (SEDs) and data from qualified exporters, forwarders or carriers. Copies of SEDs are required to be filed with Customs officials at the port of export.

For this study, the following data items have been used from the U.S. Census Bureau Foreign Trade Statistics:

- **Customs import value –** the value of imports appraised by the U.S. Customs Services in accordance with the legal requirements of the Tariff Act of 1930, as amended. This value is generally defined as the price actually paid or payable for merchandise when sold for exportation to the U.S. excluding U.S. import duties, freight, insurance and other charges incurred in bringing the merchandise to the U.S.

- **Import charges** – the aggregate cost of all freight, insurance and other charges (excluding U.S. import duties) incurred in bringing the merchandise from alongside the carrier at the port of exportation and placing it alongside the carrier at the first port of entry in the U.S.

- **F.A.S. export value** – the free alongside ship value of exports at the U.S. seaport based on the transaction price, including inland freight, insurance and other

[7] The description and definition of information from the U.S Census Bureau Foreign Trade Statistics is based on the Guide to Foreign Trade Statistics: Description of the Foreign Trade Statistical Program available on the U.S. census Bureau website.

charges incurred in placing the merchandise alongside the carrier at the U.S. port of exportation. The value, as defined, excludes the cost of loading the merchandise aboard the exporting carrier and also excludes freight, insurance and any other charges or transportation costs beyond the port of exportation.

- **Shipping weight** – the gross weight in metric tons including the weight of moisture content, wrappings, crates, boxes and containers.

- **District of exportation** – the customs district in which the merchandise is loaded on the vessel which takes the merchandise out of the country.

- **Import district of unlading**- the district where merchandise is unloaded from the importing vessel.

Table 2-18 presents data collected by the U.S. Census Bureau on volume and value of goods carried by vessels calling at U.S. East Coast ports.

Table 2-16. U.S. East Coast Maritime Trade, 2005-2011 Value ($ millions)

Year	Vessel Import Custom Value	Vessel Export Value	Total
2005	296,478	96,861	393,339
2006	327,804	113,955	441,759
2007	347,337	140,728	488,065
2008	381,869	173,475	555,344
2009	272,445	126,884	399,329
2010	329,035	153,977	483,012
2011	390,148	190,803	580,952

Note: Includes Custom districts 1,4,5,10,11 and 13 through 18

Source: Prepared by Nathan Associates Inc. from U.S. Census Bureau, Foreign Trade Statistics for 2005 to 2011.

To measure the significance of the operational measures on the shipping industry, it is interesting to compare the estimated direct economic impact with ocean freight costs associated with U.S. East Coast trade. Ocean freight costs are considered as a conservative proxy for shipping industry revenues. In 2009, ocean freight charges averaged 4.6 percent of the value of imports. Given the composition of our trade, it is reasonable to assume that ocean freight charges would represent no less than the same percentage of the value of our exports.

Table 2-17 US. East Coast Vessel Import Charges as Percent of Vessel Import Customs Value ($ millions)

Year	Vessel Import Custom Value	Vessel Import Charges	Percent
2005	293,065	14,921	5.1%
2006	324,220	16,509	5.1%
2007	344,068	16,558	4.8%
2008	378,250	17,745	4.7%
2009	269,814	12,418	4.6%
2010	326,126	14,242	4.4%
2011	386,358	15,171	3.9%

Note: Includes Custom districts 4,5,10,11 and 13 through 18. The Customs District of Portland has been excluded due to incongruences between the customs and the CIF value.
Source: Prepared by Nathan Associates Inc. from U.S.

Table 2-18 presents the significance of the estimated economic impact of the operational measures relative to the value of U.S. East Coast trade in 2009. This comparison is useful to determine whether increased shipping costs associated with the proposed operational measures would significantly affect the price and volume of traded goods via U.S. East Coast ports. In 2009, the total annual direct economic impact on the shipping industry is $23.8 million while the value of U.S. East Coast trade is $399.3 billion. Thus the direct economic impact represents six thousandth of one percent of the value of traded merchandise in 2009.

Table 2-18 also shows the direct economic impact on the shipping industry represents less than two-tenths of one percent of the ocean freight costs for U.S. East Coast trade. These results indicate that the implementation of the proposed operational measures had a minimal impact on the financial revenues and hence the financial performance of the vessel operators calling at U.S. East Coast ports.

Table 2-18. Economic Impact as a Percent of Value of U.S. East Coast Maritime Trade and Ocean Freight Costs, 2009

Item	Amount
Direct economic impact ($millions)	23.6
East Coast trade merchandise value ($ millions)	399,329
Direct economic impact as a percent of trade value (%)	0.0059
Ocean freight costs ($ millions)	15,973
Direct economic impact as a percent ofocean freight costs (%)	0.148

Source: Prepared by Nathan Associates as described in text.

Estimated Indirect Economic Impact

Depending on the nature and significance of the direct economic impact, it is possible that implementation of the proposed operational measures could have indirect economic impacts. Potential indirect economic impacts include:

- Increased intermodal costs due to missed rail and truck connections
- Diversion of traffic to other ports
- Impact on local economies of decreased income from jobs lost due to traffic diversions

There are many factors that influence a shipping line's decision to call at specific ports. These include the adequacy and suitability of port facilities and equipment, the ability of the terminal operator to quickly turnaround the vessel, overall cargo demand, efficiency of intermodal transportation, port charges, and the port location relative to other ports and cargo markets. If cargo is to divert to other ports this would be because the total additional costs associated with those routes are less than the cost of vessel time due to delays at the current port. Hence it would be double-counting to also include any additional overland transport costs to the estimated impact already presented.

A good portion of a port's traffic is often considered captive to that port. For cargoes that are destined for the port's immediate hinterland, it does not make economic sense to call at a distant port and then to ship back to the port via expensive land transport. However, most ports also accommodate traffic that is not destined for its immediate hinterland but is through traffic that may have economically attractive routing alternatives. Port areas in the Northeast and northern parts of the mid-Atlantic region serve as gateways to the inland population centers and industrial areas such as western New York, western Pennsylvania, Ohio, Indiana, Illinois and Michigan. These areas may be served via the Canadian ports of Halifax and Montreal without incurring delays caused by the right whale ship strike reduction measures.[8] These Canadian ports currently compete with Northeast U.S. ports for cargo destined for the mid-eastern U.S. and the speed restrictions implemented in the U.S. and not in Canada could shift the current competitive balance to the advantage of Canadian ports.

The Maritime Administration (MARAD), an agency of the U.S. Department of Transportation has developed a Port Economic Impact Kit that allows users to assess the economic impact of port activity on a region's economy. The MARAD Port Economic Impact Kit uses an adaptation of input-output analysis that is a widely established tool for undertaking economic impact assessments. The model calculates the total economic impacts or multiplier effect of

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8 Vessels may divert to other U.S. ports in addition to those diverting to Canada. While this is possible, for the total economic impact analysis only diversions to non-U.S. ports are included. For diversion to ports within the U.S. the negative economic impact for one U.S. port are offset by gains in another U.S. port.

deep-draft port industry and includes an indirect effect that reflects expenditures made by the supplying firms to meet the requirements of the deep-draft port industry as well as expenditures by firms stocking the supplying firms. The model also includes an induced effect that corresponds to the change in consumer spending that is generated by changes in labor income accruing to the workers in the deep-draft port industry as well as employment in the supplying businesses.

We have estimated the indirect economic of port diversions based on the detailed methodology described in the 2008 FEIS adjusted for the actual observed delays incurred in 2009 from the AIS data analysis and using the updated vessel operating costs for 2009. The estimated indirect economic impact of port diversion for 2009 is $15.8million.

3. Economic Impact of Rule on Other Market Segments

The AIS data captures the vast preponderance of commercial maritime activity that would be subject to the speed restrictions and other operational measures. However, there are some market segments that may be impacted by the speed restrictions and other operational measures whose maritime activities are not adequately captured in the AISA data. In this section, we identify the most relevant of these market segments and discuss the potential economic impact. Those market segments or potential impacts include:

- Commercial fishing
- Charter fishing
- Passenger ferries
- Whale watching

The economic impact for each of these elements is presented below.

Commercial Fishing

Commercial fishing is a multimillion dollar industry along the U.S. East Coast. In 2011, commercial fish landings at U.S. East Coast ports totaled $934 million (Table 3-1). The port of New Bedford, MA is the leading U.S. port in terms of value of commercial fish landings with $369.0 million in 2011.

Table 3-1. U.S. East Coast Commercial Fishery Landings by Port, 2002 through 2011 (millions of dollars)

Port	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
New Bedford, MA	168.6	176.2	207.7	282.5	281.4	268.0	241.3	249.2	306.0	369.0
Cape May-Wildwood, NJ	35.3	42.8	60.2	68.4	37.6	58.8	73.7	73.4	81.0	103.0
Hampton Roads Area, VA	69.5	79.6	100.8	85.2	51.0	70.2	12.3	68.1	75.0	88.0
Gloucetser, MA	41.2	37.8	42.8	45.9	47.3	46.8	54.2	50.4	57.0	59.0
Stonington, ME	21.7	20.5	22.4	32.3	34.3	23.5	15.4	26.5	45.0	48.0
Point Judith, RI	31.3	32.4	36.0	38.3	46.8	36.7	36.9	32.4	32.0	40.0
Point Pleasnat, NJ	19.7	22.8	19.2	21.6	22.6	23.1	22.1	20.2	23.0	37.0
Reedville, VA	24.2	24.2	26.1	27.1	23.7	27.3	23.9	25.9	34.0	36.0
Long Beach-Barnegat, NJ	14.6	16.4	20.6	26.7	24.5	23.1	22.9	21.7	26.0	34.0
Portland,ME	40.4	28.7	34.6	34.6	27.8	24.1	22.6	16.6	19.0	28.0
Provincetown-Chatham, MA	15.2	13.5	14.2	19.8	20.6	18.3	18.3	20.0	20.0	27.0
Rockland, ME	4.3	4.1	2.7	7.4	n.a.	n.a.	n.a.	n.a.	11.0	24.0
Wanchese-Stumpy Point, NC	23.2	21.0	20.6	19.6	21.7	20.6	22.4	23.1	22.0	22.0
Montauk, NY	11.1	11.0	13.1	16.5	16.8	15.7	14.3	14.6	18.0	19.0
Newport, RI	n.a.	n.a.	n.a.	n.a.	20.8	12.4	n.a.	n.a.	n.a.	n.a.
Boston, MA	8.6	8.9	8.8	10.6	n.a.	n.a.	n.a.	11.9	15.1	n.a.
Beaufort- Morehead City, NC	19.1	15.0	16.9	9.7	n.a.	n.a.	11.1	23.1	n.a.	n.a.
Atlantic City, NJ	22.4	20.8	17.7	18.5	24.2	27.5	24.1	22.2	17.3	n.a.
Other	76.2	74.9	55.2	51.1	-	-	-	-	-	-
Total	646.6	650.6	719.6	815.8	701.1	696.1	615.5	699.3	801.4	934.0
Source: NOAA Fisheries.										

The right whale ship strike reduction operational measures apply to vessels with a length of 65 feet and above. Because the AIS data lacks adequate records on commercial fishing vessels[9], we also evaluated data which included fishing vessels which are over 65 feet in length and weigh less than 150 tons, using information provided by NMFS' database of commercial fishing permits.

Table 3-2 shows that for the Southeast region nearly 80 percent of the fishing vessels over 65 feet are less than 150 tons. For the Northeast region, 63 percent of the fishing vessels over 65 feet are less than 150 tons.

[9] Commercial fishing vessels greater than 65 are required to have AIS transponders. However, the data set we received only included 147 transits of fishing vessels on the entire US East Coast during 2009 which was felt to be too small to be accurate.

Table 3-2. Fishing Vessel Permits Issued to Vessels 65 Feet and Above in LOA by Region, 2009-2011

		2009		2010		2011	
Region	Vessel size	Fishing permits	%	Fishing permits	%	Fishing permits	%
Southeast	All vessels	279	100%	260	100%	247	100%
Region	Vessels less than 150 GRT	220	79%	204	78%	195	79%
Northeast	All vessels	807	100%	773	100%	722	100%
Region	Vessels less than 150 GRT	523	65%	496	64%	453	63%

Source: Prepared by Nathan Associates Inc. from data provided by NOAA Fisheries Service, Southeast Regional Office (SERO) and Northeast Regional Office (NERO).

The estimated economic impact of the operational measures on commercial fishing vessels in 2003 is presented in Table 3-3. The analysis assumes that the commercial fishing vessels are affected for an effective distance of 20 nautical miles each way as they steam to and from fishing areas.

Many commercial fishing vessels steam at 10 knots or below and will not be affected by the operational measures if they were implemented at the 10-knot speed restriction. The typical steaming speed for other commercial fishing vessels is assumed at 12 knots. Average operating costs per hour of $400 includes fuel costs of June 2009. The duration of the speed restrictions vary from 181 days per year for the mid-Atlantic to 61 days per year for the Northeastern US. For purposes of the economic analysis, we have assumed that the speed restrictions were in effect for 181 days for commercial fishing..

Table 3-3. Estimated Economic Impact on Commercial Fishing Vessels by Region, 2009

Item	Northeast Region	Southeast Region	Total
Commercial fishing permits for vessels over 65 ft LOA and under 150	523	220	743
Percent with steaming speed over 10 knots	40%	40%	40%
Vessels potentially affected by speed restrictions	209	88	297
Typical steaming speed of affected vessels (knots)	12	12	12
Number of trips per year per vessel	25	25	25
Minutes of delay per trip with restricted speed of 10 knots	38.0	38.0	38.0
Operating cost per hour of steaming (dollars)	400	400	400
Estimated impact per year (dollars)	657,022	276,376	933,398

Source: Prepared by Nathan Associates Inc.

The estimated impact in 2009 on commercial fishing vessels is estimated at $0.7 million for the Northeast Region and $0.3 million for the Southeast Region. The combined Northeast and Southeast regional economic impact of $0.9 million is only one-tenth of one percent of the value of U.S. East Coast commercial fishery landings of $699 million in 2009.

These results indicate that the implementation of the operational measures will not have an undue adverse impact on the commercial fishing industry along the U.S. East Coast.

Charter Fishing

In some areas, charter vessels travel up to 50 nautical miles offshore to reach prime fishing areas. At vessel speeds of up to 17 knots they can reach their fishing areas in less than 3 hours. Under the Rule, speed restrictions of 10 knots for 20 nautical miles add about 100 minutes to the roundtrip steaming time, and could severely affect client demand.

The charter fishing industry is active along the U.S. East Coast with concentration in the Carolinas, Virginia, Florida, New Jersey and Massachusetts. The industry consists of half-day charters of about 6 hours that typically go up to 20 nautical miles offshore; full-day charters of 11-12 hours that can go up to 40 nautical miles offshore; and extended full day charters that can be from 18-24 hours and go up to 50 miles offshore. The vast majority of the charter fishing industry consists of modern and well-equipped fishing boats of less than 65 feet LOA and thus would not be subject to the speed restrictions and other operational measures.

A small segment of the industry referred to as head boats often uses vessels of 80 feet LOA and above that can accommodate 60 to 100 passengers. These vessels go up to 50 miles offshore stop and anchor over wreck and rock formations for fishing species as red snapper, grouper, trigger fish, amberjack. The charter fee for a head boat is typically $50- $80 per person.

As described above an increase of 100 minutes roundtrip steaming time would reduce the competitiveness of the larger head boats (more than 65 foot LOA) particularly for the half-day and full-day charters. It is likely that vessels of less than 65 foot LOA would increase their share of those market segments, partially offsetting the economic impact incurred by the larger head boats. For extended full-day charters, head boats of LOA in excess of 65 feet would incur additional costs associated with the 100 minutes increase in roundtrip steaming time. It is estimated that annual economic impact of the speed restriction of 10 knots for these vessels over 20 nautical miles is approximately $1.0 million.[10]

Passenger Ferries

The vast majority of passenger vessels operating along the U.S. East Coast sail within the COLREGS line and as such will not be affected by the Rule. However, in the southern New England area, there is a well-developed passenger ferry sector that operates beyond the COLREGS line and hence is subject to the Rule's operational measures. A list of major New

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[10] This calculation assumes 50 head boat vessels with 30 roundtrips during the off-season months of November through April and an hourly steaming operating cost of $400. These calculations do not include any offsetting impact of revenue gains by operators of smaller charter fishing vessels.

England passenger ferry operators, routes served and service characteristics are presented in Table 3-4.

Table 3-4. New England Ferry Operators, 2011

Operator	Route	Max Vessel Speed (knots)	Distance (nm)	Summer Schedule	Non-summer schedule	Travel Time (minutes)	Summer Season Adult Fare ($) Round trip
SOUTHERN NEW ENGLAND							
Fast Ferries							
Bay State Cruise Company	Boston, MA-Provincetown, MA	30	50	6 trips daily	none	90	85
Boston Harbor Cruises	Boston, MA-Provincetown, MA	40	50	4 trips daily	none	90	83
Boston Harbor Cruises	Boston, MA-Salem, MA	33	25	8 trips daily	none	60	27
Cross Sound Ferry Sevices	New London, CT-Orient Point LI, NY	30	16	12 trips daily	All year long	45	34.25
Block Island Express	New London, CT-Block Island, RI	35	30	6 - 8 daily trips	none	75	45
Freedom Cruise Line	Harwich, MA-Nantucket, MA	24	30	6 trips daily	Spring, Fall	80	74
Hy-Line Cruises	Hyannis, MA- Nantucket, MA	30	27	12 trips daily	10 trips daily	60	77
Hy-Line Cruises	Hyannis, MA-Martha's Vineyard, MA	24	20	10 trips daily	4-6 trips daily	55	71
Block Island Ferry	Point Judith, RI-Block Island, RI	30	11	12 trips daily	Spring, Fall 8-10 trips daily	30	36
Seastreak	New Bedford, MA- Martha's Vineyard, MA	30	30	12 trips daily	Spring, Fall 4-10 trips daily	60	68
Seastreak	New York City, NY- Martha's Vineyard, MA	42	150	2 trips per weekend	Holidays	315	155
The Steamship Authority	Hyannis, MA- Nantucket, MA	35	26	10 trips daily	8 trips daily	60	67
Vineyard Fast Ferry	Quonset Point, RI-Martha's Vineyard, MA	33	50	6 trips daily	Srping, fall 4 daily trips	95	79
Regular Ferries							
Bay State Cruise Company	Boston, MA-Provincetown, MA	16	50	2 trips Sat and Sun	none	180	46
Express Ferry	Plymouth, MA-Provincetown, MA	16	25	2 trips daily	none	100	43
Cross Sound Ferry Service	New London, CT-Orient Point LI, NY	15	16	30 trips daily	All year long	80	27
Hy-Line Cruises	Hyannis, MA- Nantucket, MA	15	26	6 trips daily	1-2 trips daily	110	45
Hy-Line Cruises	Hyannis, MA-Martha's Vineyard (Oak Bluffs), MA	12	20	2 trips daily	2 trips daily	100	45
Hy-Line Cruises	Nantucket, MA-Martha's Vineyard (Oak Bluffs), MA	16	20	2 trips daily	2 trips daily	70	70
Block Island Ferry	Point Judith, RI-Block Island, RI	16.5	11	18 trips daily	All year long	55	19
Block Island Ferry	Point Judith, RI- Newport, RI	13	10	2 trips daily	none	60	13
Block Island Ferry	Newport, RI-Block Island, RI	13	22	2 trips daily	none	120	17
Patriot Party Boats	Falmouth, MA- Martha's Vineyard (Oak Bluffs), MA	15	5	16 trips daily	All year long	20	20
Falmouth Ferry	Falmouth, MA-Martha's Vineyard (Edgadtown), M	12	9	8 trips daily	Spring 6 daily trips each weekend	60	50
Island Queen	Falmouth, MA-Martha's Vineyard (Oak Bluffs), MA	12	5	14 trips daily	Spring, Fall 4-10 daily trips	35	20
The Steamship Authority	Woods Hole-Martha's Vineyard	16	7	32 trips daily	28 trips daily	35-45	16
The Steamship Authority	Hyannis, MA- Nantucket, MA	14	26	12 trips daily	6 trips daily	135	33
MAINE							
Casco Bay Lines	Portland, ME - Peaks Island, ME	12.5	3	14 trips daily	All year long	20	8
Casco Bay Lines	Portland, ME - Little Diamond Island, ME	12.5	3	18 trips daily	All year long	20	8
Casco Bay Lines	Portland, ME - Great Diamond Island, ME	12.5	4	18 trips daily	All year long	25	9
Casco Bay Lines	Portland, ME - Diamond Cove, ME	12.5	5	22 trips daily	All year long	30	10
Casco Bay Lines	Portland, ME - Long Island, ME	12.5	6	24 trips daily	All year long	35	10
Casco Bay Lines	Portland, ME - Chebeague Island, ME	12.5	12	12 trips daily	All year long	70	11
Casco Bay Lines	Portland, ME - Cliff Island, ME	12.5	10	10 trips daily	All year long	60	12
Casco Bay Lines	Portland, ME - Bailey Island, ME	12.5	20	2 trips daily	none	105	25

Source: Prepared By Nathan Associates Inc. from data on operator websites and selected interviews.

Passenger ferry operations in southern New England generally fall into two categories– fast ferry service with vessel speeds ranging from 24-39 knots and regular ferry service with vessel speeds from 12-16 knots. As shown in Table 3-4 there are ten operators providing fast ferry service on 12 routes. Key destinations include Provincetown, Block Island, Nantucket, and Martha's Vineyard, while important origins include Boston, New London, Hyannis, Harwich, Point Judith and Quonset Point.

Regular ferry service in southern New England is provided by nine operators on eleven routes. Vessel speeds range from 12-16 knots and serve many of the same origins and destinations as the fast ferry service. Additional origins served by regular ferries include Plymouth, Falmouth and Woods Hole.

Regular ferry service also operates in Southern Maine with 120 trips daily to eight destinations served by Casco Bay Lines from Portland. Service is provided to local islands including Peaks Island, Great Diamond Island, Cliff Island and Bailey Island.

IMPACT ON FERRY OPERATORS

Passenger ferry service generally is not impacted by the SMAs as they are not effective during the summer season. Speed restrictions for Cape Cod Bay are implemented from January 1 through May 15. Speed restrictions for Block Island Sound are from November 1 through April 30. In addition, the speed restricted area for Block Island Sound does not extend to the shoreline and hence does not impact fast ferry operations.[11]

However, voluntary DMAs established during the summer season could have an impact, especially if they became mandatory. Interviews with passenger ferry operators identified their particular concern of the situation where a DMA were to be implemented during the peak summer season. For a fast ferry operator, a DMA implemented directly along their route would result in the suspension of service for the entire period that the DMA is in effect[12]. There are several reasons for this conclusion. First, the demand for fast ferries that normally operate between 24-39 knots would virtually disappear if the ferries were restricted to a speed of 10 knots. Second, any remaining demand would not be sufficient to cover vessel operating costs, and third, many of the handling and comfort characteristics of fast ferries would suffer at these reduced speeds.

As reported in earlier in Table 2-11, there were 18 DMAs established in 2009. Figure 3-1 below shows the seven DMAs in 2009 that are in locations relevant for ferry operations. However

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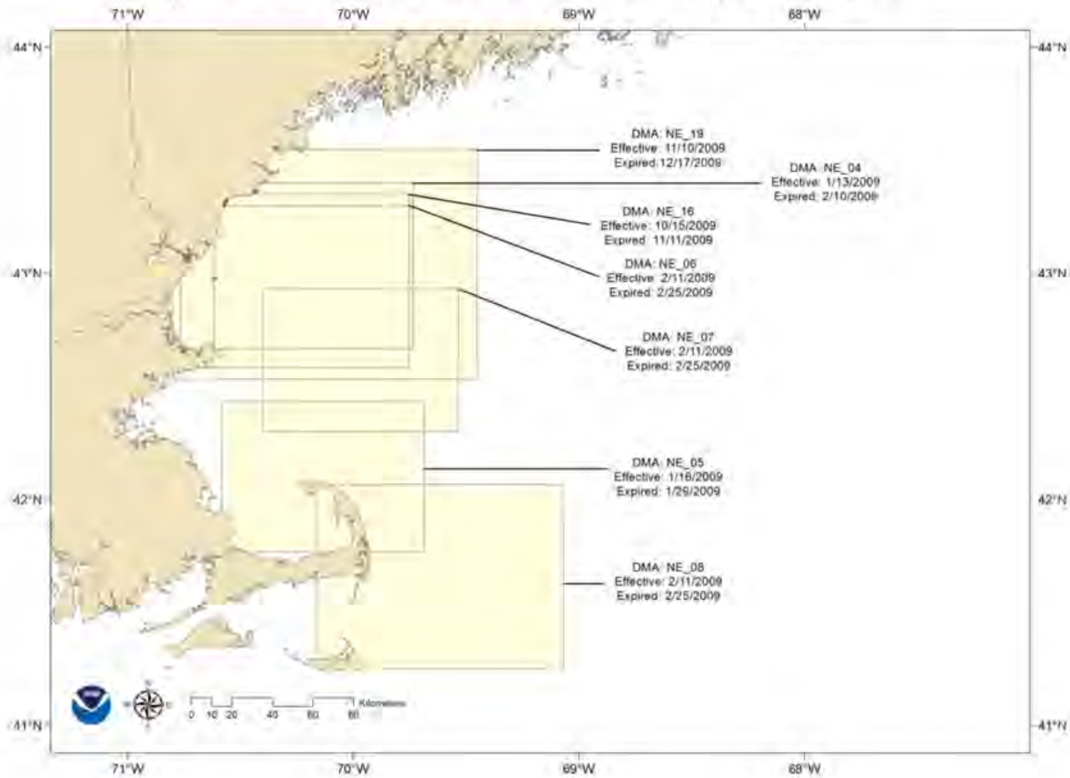
[11] The rectangular area proposed has its northern limits running approximately in a line from Montauk to the southwestern coast of Block Island.

[12] If a DMA were to be implemented say over a 15-day summer period, the two fast ferry operators on the Boston-Provincetown route would lose net revenues of over $500,000, nearly 10 percent of their annual sales and wipe out their annual profit. Multiple DMAs in one year or in consecutive years could force the shutdown of these services.

each of these DMAs occurred in the winter months and did not affect ferry operations. Hence, in 2009 there was no or minimal economic impact of DMAs on fast ferry operators.

Figure 3-1 DMAs in Areas Relevant for Passenger Ferry Operators



New England Whale Watching Industry

The New England whale watching industry also can be categorized into operations that deploy high-speed vessels with speeds ranging from 25-38 knots; and operations that deploy regular speed vessels with speeds from 16-20 knots. Table 3-5 presents information for the major whale watching operators in Massachusetts Bay. There are nine operators of high-speed vessels; three are based in Gloucester, three in Boston, one in Barnstable, one in Bar Harbor and one in Boothbay Harbor. These operators make 18 daily trips during the summer months. There are fifteen operators of regular speed vessels that have operations based in Massachusetts (eight operators), New Hampshire (four), Maine (two) and Rhode Island (one). Altogether these operators make 21 daily whale watching trips during the summer months.

Table 3-5. Massachusetts Bay Whale Watching Operators, 2012

Operator	Location	# Daily Trips (per Vessel)	Trip Duration (hr)	Adult Fare per Trip ($)	Max Vessel Speed (knots)	Number of Vessels
Regular-Speed Vessel						
Yankee Fleet	Gloucester, MA	1	4	n.a.	20	2
Coastal Fishing Charters	Gloucester, MA	1	4-5	100	20	1
Newburyport Whale Watch	Newburtyport, MA	2	4 - 4 1/2	48	20	1
Captian John Whale Watching and Fishing Tours	Plymouth, MA	4	3 1/2-4 1/2	45	17	4
Provincetown Whale Watches	Provincetown, MA	1	n.a.	37	20	1
The Dolphin Fleet of Provincetown	Provincetown, MA	8	3-4	44	16	4
Shearwater Excursions	Nantucket Island, MA	1	6	115	20	1
Al Gauron Whale Watching	Hapton Beach, NH	1	5	36	20	3
Atlantic Whale Watch	Rye Harbor, NH	1	4 - 4 1/2	36	20	1
Eastman's Docks	Seabrook Beach, NH	1	4 1/2	33	20	4
First Chance WhaleWatch	Kennebunk, ME	1	4 1/2	48	18	1
Odyssey Whale Watch	Portland, ME	2	4	48	20	1
Capt. Bill & Sons Whale Watch	Gloucester, MA	2	3 1/2	48	20	1
Granite State Whale Watch	Rye Harbor, NH	2	4-5	36	18	1
Frances Fleet Whale Watching	Narragansett, RI	1	4 1/2	n.a.	18	2
Subtotal		21				28
High-Speed Vessels						
Capt'n Fish's Whale Watch	Boothbay Harbor, ME	2	3-3 1/2	48	33	3
Boston Best Cruises	Boston, MA	2	4	45	33	2
Bar Harbor Whale Watch Company	Bar Harbor, ME	3	3-3 1/2	59-56	33	3
New England Aquarium Whale Watch	Boston, MA	1	3-4	45	30	1
Boston Harbor Cruises	Boston, MA	4	3	45	35	2
7 Seas Whale Watch	Gloucester, MA	2	3 1/2-4	48	35	1
Cape Ann Whale Watch	Gloucester, MA	2	3-4	48	25	1
Yankee Fleet	Gloucester, MA	1	4	n.a.	33	1
Hyannis Whale Watcher Cruises	Barnstable, MA	1	3 1/2-4	47	38	1
Subtotal		18				15

Source: Prepared by Nathan Associates from data on operator websites and selected interviews.

Speed restrictions for Cape Cod Bay are implemented from January 1 through May 15. Hence, the peak summer whale watching season are not affected for high-speed or regular speed vessels. Similarly, the speed restrictions for an extended Off Race Point from March through April would not impact the whale watching season.

As shown earlier in Figure 3-1, there were no DMAs implemented in 2009 that were during periods that affected whale watching operations. Further, if a DMA were to be established, a whale watching operator will select an alternative location where humpback whales are present and not right whales. The whale watching community has developed an informal communications network to advise them of whale sightings. As State and Federal regulations restrict any vessel from approaching closer than 500 yards to a right whale, they would avoid right whale as a matter of course.

4. Total Direct and Indirect Economic Impact

In the sections above we have presented the analysis of individual components of the economic impact analysis of the Rule in 2009. The total direct and indirect economic impact of is $44.7 million in 2009 (Table 4-1). This cosists of $23.8 million of direct impact on the shipping industry, 1.9 million on commercial fishing and charter fishing combined, and $19.0 million of indirect impacts.

Table 4-1 Total Direct and Indirect Economic Impact, 2009 ($ millions)

Impact	Amount
Direct iimpact on shipping industry	
Seasonal Management Areas (SMAs)	19.6
Dynamic Management Areas(DMAs)	-
Cumulative Effect of multi-port strings	3.1
Re-routing of southbound coastwise shipping	1.1
Subtotal	23.8
Direct impact on other other market segments	
Commercial fishing	1.0
Charter fishing	0.9
Passenger ferries	-
Whale watching	-
Subtotal	1.9
Indirect impact	19.0
Total impact	44.7

Source: Prepared by Nathan Associates as described in text.

5.Impact on Small Business

Size Standards for Small Entities

According to the U.S. Small Business Administration[13], a small business is a concern that is organized for profit, with a place of business in the United States, and which operates primarily within the United States or makes a significant contribution to the U.S. economy through payment of taxes or use of American products, materials or labor. Further, the concern cannot be dominant in its field, on a national basis. Finally, the concern must meet the numerical small business size standard for its industry. SBA has established a size standard for most industries in the U.S. economy.

Size standards for the industries potentially affected by the final rule are presented in Table 5-1. For international and domestic commercial shipping operators, the SBA size standard for a small business is 500 employees or less. The same threshold applies for international cruise operators and domestic ferry service operators. For whale watching operators and charter fishing operators the SBA threshold is $7.0 million of average annual receipts. For commercial fishing operators, the SBA threshold is $4.0 million of average annual receipts.

[13] United States Small Business Administration, Frequently Asked Questions About Small Business Size Standards, www.sba.gov/size/indexfaqs.html

Table 5-1. Small Business Size Standards and Firms by Employment Size and NAICS Code, 2008

Type of entity	NAICS Code	NAICS U.S. Industry Title	Size Standard ($ millions)	Size Standard Employees	Firms Employment size Total	< 20	< 500	500+
International commercial shipping operator	483111	Deep Sea Freight Transportation	n.a.	500	230	120	96	14
International cruise operator	483112	Deep Sea Passenger Transportation	n.a.	500	64	29	30	6
Domestic commercial shipping operator	483113	Coastal and Great Lakes Freight Transportation	n.a.	500	379	207	136	36
Domestic ferry service operator	483114	Coastal and Great Lakes Passenger Transportation	n.a.	500	155	103	48	4
Whale watching operators	487210	Scenic & sightseeing transportation, water	7	n.a.	1,704	1,540	152	12
Charter fishing operators	487210	Scenic & sightseeing transportation, water	7	n.a.	1,704	1,540	152	12
Commerical fishing	114111	Finfish Fishing	4	n.a.	1,060	1,017	41	2
	114112	Shellfish Fishing	4	n.a.	877	858	19	-
	114119	Other Marine Fishing	4	n.a.	34	31	3	-

Source: U.S. Small Business Administration,Table of Small Business Size Standards matched to North American Industry Classification System Codes, October 24, 2012 and SBA Office of Advocacy, Firm Size Data provided by U.S. Census Bureau on Employer Firms and Employment by Employment Size of Firm by NAICS Codes, 2008.

Table 5-1 also presents information on the total number of firms in the U.S. in 2008 by employment size ranges for these industries. The preponderance of firms involved in these industries is considered as small entities by the SBA size standards. In 2008, there were 230 firms involved in deep sea freight transportation industry of which 216 firms had 500 employees or less. In the deep sea passenger transport industry, 58 firms of the total 64 firms had 500 or fewer employees. In the Coastal and Great Lakes freight transportation industry, 343 firms of the total 379 firms had 500 or fewer employees. In the Coastal and Great Lakes passenger transportation industry, all but four firms of the 155 total firms had 500 or fewer employees.

There were 1,704 firms providing scenic and sightseeing water transportation in 2008 of which 1,692 firms had 500 or fewer employees. For the finfish fishing industry 1,058 firms of the total 1,060 firms had 500 or fewer employees; while all 877 firms involved in shellfish fishing had 500 or fewer employees.

Number of Small Entities Affected

For the FEIS Report of 2008, Nathan Associates conducted a detail analysis to determine the number of small entities involved in commercial shipping along the U.S. East Coast. Many of the firms operating within the international commercial shipping industry and international cruise industry have foreign ownership and have their primary place of business outside the U.S. and hence would not qualify as a U.S. small entity.

To identify vessel owned by U.S. entities, we analyzed information provided by the U.S. Coast Guard regarding parties owning vessels that had arrivals at the U.S. East Coast in 2004.

We were able to identify the vessel owner and/or managing owner for 99.6 percent of the vessels that had U.S. East Coast vessel arrivals in 2004.[14] The USCG data provides information on the address of the vessel owner and/or managing owner in terms of zip code, state and country. Using that information we identified vessels with U.S. East Coast arrivals in 2004 that were owned by U.S. entities or foreign entities.

Of the 27,385 U.S. East Coast vessel arrivals in 2004, 6,540 arrivals or 23.9 percent were recorded by vessels owned by parties with U.S. address (Table 5-2). The U.S. East Coast arrivals were made by 4,114 vessels of which 620 or 15.1 percent were by vessels owned by parties with a U.S. address. In terms of number of parties, the 2004 vessel arrivals were made by 3,505 parties of which 432 or 12.3 percent had a U.S. address.

Table 5-2. U.S. East Coast Vessel Arrivals by Vessels with U.S. or Foreign Parties, 2004

	Party address		
Item	U.S	Foreign	Total
Number of vessel arrivals	6,540	20,845	27,385
Percent	23.9%	76.1%	100.0%
Number of vessels	620	3,494	4,114
Percent	15.1%	84.9%	100.0%
Number of parties	432	3,073	3,505
Percent	12.3%	87.7%	100.0%

Source: Prepared by Nathan Associates Inc. from analysis of U.S. Coast Guard as described in text.

We then conducted an analysis of the entire U.S. Coast Guard vessel characteristics database to identify the number and type of vessels owned by the U.S. parties with U.S. East Coast arrivals in 2004.[15] Approximately 71 percent of the U.S.-based parties owned only one vessel and 90.7 percent owned 4 or less vessels (Table 5-3).

[14] We were not able to match party information for 198 vessels of the 4,114 vessels that had U.S. East Coast arrivals in 2004. These vessels accounted for 3.8 percent of 2004 U.S. East Coast arrivals (1,004 of the 27,385 arrivals). However using information on U.S. or foreign flag of registry, we assigned these vessels by country of ownership.

[15] For this analysis, we included all vessels owned by the party, not just those with vessel arrivals at U.S. East Coast ports in 2004.

Table 5-3. U.S-Based Parties with U.S. East Coast Arrivals by Number of Vessels Owned, 2004

Number of Vessels Owned	Number of Parties	Percentage of Parties	Number of Vessels	Percentage of Vessels
1	306	70.8	306	30.6
2	49	11.3	98	9.8
3	24	5.6	72	7.2
4	13	3.0	52	5.2
5	6	1.4	30	3.0
6	7	1.6	42	4.2
7	6	1.4	42	4.2
8	3	0.7	24	2.4
9	4	0.9	36	3.6
10	1	0.2	10	1.0
11	3	0.7	33	3.3
12	1	0.2	12	1.2
15	1	0.2	15	1.5
16	1	0.2	16	1.6
17	2	0.5	34	3.4
20	1	0.2	20	2.0
24	1	0.2	24	2.4
35	1	0.2	35	3.5
38	1	0.2	38	3.8
61	1	0.2	61	6.1
Total:	432	100	1,000	100

Source: Prepared by Nathan Associates inc. from U.S. Coast Guard data as described in text.

The next step was to determine which of these U.S. based parties should be considered a small-business for the RFA analysis. Information on the number of employees is not readily available for U.S.-based parties that own vessels with arrivals at the U.S. East Coast. However, we reviewed the list of U.S-based parties and removed the 53 parties that obviously do not qualify as a small business such as Carnival Cruise Lines, Chevron, Maersk, Holland America Line, BP Oil Shipping, etc. A further classification was made to exclude an additional 17 parties that own 5 or more vessels from the set of small businesses on the assumption that a business with 5 or more capital intensive commercial cargo vessels would employ at least 500 employees throughout its organization. We assume that the remaining set of 362 US-based parties that own vessels that had U.S. East Coast arrivals in 2004 be assumed to be small businesses for the purposes of the RFA analysis. Table 5-4 presents information on vessels and vessel arrivals for this set of vessels assumed to be operated by U.S.-based small entities.

Table 5-4. U.S. East Coast Vessel Arrivals by U.S.-Based Small Entities, 2004

Vessel Type	Number of 2004 Vessel Arrivals	Number of vessels	Number of parties
Bulk Carrier	142	25	24
Container Ship	502	30	28
Freight Barge	77	13	12
General Dry Cargo Ship	99	24	22
Multiple	435	49	31
Passenger Ship	463	33	31
Refrigerated Cargo Ship	51	6	6
Ro-Ro Cargo Ship	433	25	22
Tank Barge	702	61	51
Tank Ship	784	83	79
Towing Vessel	209	44	43
Other a/	65	14	13
Total:	3,962	407	362

a/ Other includes fishing vessels, industrial vessels, and research vessels.
Source: Prepared by Nathan Associates Inc. from U.S. Coast Guard data as described in text.

The 362 parties assumed to be small businesses operated 407 vessels that had 3,962 vessel arrivals at U.S. East Coast ports in 2004. Tank ships and tank barges are the vessel types with the most parties, vessels and vessel arrivals for the set of vessels assumed to be owned by U.S. based small businesses.

Other Industries

In Chapter 3, we presented information on entities involved in other maritime industries that would potentially be affected by the operational measures of the final rule. For purposes of this RFA analysis we have assumed that all U.S. East Coast entities involved in commercial fishing industry, domestic ferry service industry, and charting fishing industry are considered as small entities. In the whale watching industry all entities (except the New England Aquarium) are considered as small entities.

Thus as shown in Table 5-5, we estimate that there are 373 small entities potentially affected Rule. Of these, 209 entities are involved in commercial fishing in the Northeast Region and 88 entities in the Southeast region. There are 14 entities identified involved in Southern New England passenger ferry service[16], 8 entities providing whale watching services in Massachusetts Bay and 40 entities providing charter fishing service along the U.S. East Coast. Note that only the subset of charter fishing entities operating larger head boats that accommodate 60 to 100 passengers is included in this analysis. The majority of charter fishing

[16] In Table 3-4, ten entities are listed as operating fast ferries in Southern New England and eight entities that operate regular ferries. However, four of the entities operate both fast ferries and regular ferries and hence, there are only 14 entities involved in Southern New England passenger ferry service.

entities operates fishing boats of less than 65 LOA and thus are not subject to the operational measures of the Rule.

Table 5-5. Number of Small Entities in Other Industries Potentially Affected, 2009

Industry	Number of Small Entities Potentially Affected
Commercial Fishing	
Northeast Region	209
Southeast Region	88
Southern New England Passenger Ferries	14
Massachusetts Bay Whale Watching	22
Charter Fishing	40
Total	373

Source: Prepared by Nathan Associates Inc. as described in Section 3, and presented in Table 3-2, Table 3-4 and Table 3-7.

Economic Impact on Small Entities

In this section, we first present the economic impact on the small entities involved in the commercial shipping industry[17] followed the estimated impact on small entities in other maritime industries.

COMMERCIAL SHIPPING

All of the operational measures of the final rule described in Section 3 are assumed to apply to commercial shipping vessel operated by small entities. Table 5-6 presents the number of vessel arrivals by U.S. small entities in 2004 and total vessel arrivals by all U.S. entities. Those figures are used to calculate the percent of U.S. vessel in 2004 that were made by small entities. The resulting percentages are then applied to the current analysis of the 2009 economic impact on all U.S.- flagged vessels to determine the economic impact on U.S. small entities[18].

The economic impact of the Rule on U.S. small entities in the commercial shipping industry is estimated at $2.2 million in 2009. This estimate includes the direct economic impact of speed restrictions during seasonal management periods and dynamic management periods plus the cumulative effect of multi-port strings and the re-routing of southbound coastwise shipping. Containerships ($0.8 million) ro-ro cargo ships ($0.4 million) and passenger ships ($0.3 million) together account for 68 percent of the economic impact on small entities in the commercial shipping industry.

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[17] Passenger cruise vessels are included in this section as the data sources, approach and methodology applied for this market segment is same as those of the commercial shipping industry.

[18] The 2004 data and relationships were used because there wass no information on the transits in 2009 by U.S. small entities within the shipping industry.

Table 5-6. Economic Impact on U.S. Small Entities by Vessel Type, 2009

	2004 Vessel Arrivals			2009 Economic Impact		
Vessel type	Arrivals by U.S. Small Entities	Arrivals by All U.S. Entities	Percent by US Small Entities	On all U.S. Entities ($000s)	On U.S. Small Entities ($000s)	As a % of Annual Revenues
Bulk Carrier	142	150	94.7	99.1	93.8	0.044%
Container Ship	502	874	57.4	1,449.6	832.6	0.106%
Freight Barge	77	270	28.5	398.4	113.6	0.307%
General Dry Cargo Ship	99	124	79.8	18.1	14.5	0.008%
Passenger Ship	272	310	87.7	319.7	280.6	0.037%
Refrigerated Cargo Ship	51	51	100.0	-	-	0.000%
Ro-Ro Cargo Ship	433	450	96.2	404.3	389.0	0.063%
Tank Barge	702	1,474	47.6	199.2	94.9	0.010%
Tanker	731	784	93.2	220.5	205.6	0.021%
Towing Vessel	209	691	30.2	194.2	58.8	0.012%
Other a/	65	65	100.0	199.2	199.2	0.267%
Total	3,283	5,243	62.6	3,502.4	2,193.1	0.042%

a/ Other includes fishing vessels, industrial vessels, research vessels, school ships. -

Note: Annual revenue estimated as average of daily operating cost at sea and daily operating cost in port by vesel type and size for 365 days for vessels accounting for 2009 SMA transits.

Daily operating cost in port was assumed at 60 percent of daily operating cost at sea.

Source:Nathan Associates Inc.

Table 5-6 also presents the economic impact on small entities as a percent of annual revenues by vessel type. For vessels operated by small entities it was assumed that they spend equal amounts of days at sea and in port.

Overall, the economic impact of the Rule represents about 4 one-hundredth of one percent of the annual revenues of vessels operated on the U.S. East Coast by small entities. For small entities operating containerships, the economic impact increases to up to one-tenths of one percent.

Based on these findings, we conclude that the operational measures of the final rule would not have a significant economic impact on a substantial number of small entities involved in commercial shipping along the U.S. East Coast.

Other Industries

The estimated economic impact on small entities in other maritime industries is presented in Section 3. The impact on small entities in the charter fishing industry in 2009 is estimated at $1.0 million (Table 5-7). The estimated economic impact on small entities in the commercial fishing industry is $0.9 million. There was no or minimal impact in 2009 on ferry operators and whale watching operators.

Table 5-7. Estimated Economic Impact of Rule on Small Entities in Other Industries, 2009 ($000s unless otherwise specified)

Industry	Estimated Economic Impact ($000s)	No. of Small Entities	Average Economic Impact per Small Entity ($000s)	Economic Impact as a % of Annual Revenues
Commercial fishing	933.4	307	3.0	0.4%
Charter fishing	1,000.0	40	25.0	4.3%

Source: Prepared by Nathan Associates Inc.

The economic impact on commercial fishing vessels is estimated at $3,000 per vessel per year and constitutes less than one-half of one percent of their annual revenues. This is not considered to be a significant economic impact.

The annual revenue of a small entity operating a charter fishing head boat is estimated at $504 thousand based on an average of 80 passenger paying $80 for 90 charters. The estimated economic impact of the final rule at is 4.3 percent of their estimated annual revenue and for purposes of the FRFA determination is not considered to be a significant economic impact.

6. Scoping Assessment of Economic Analysis of Potential Rule Modifications

As initially mandated, the Rule is due for renewal or modification in 2013. In this section, we assess the data requirements and level of analyses that would be needed to estimate the economic impact of some issues.

Update Analysis for 2010, 2011 and 2012

The economic impact analysis presented in this report is based on 2009 AIS data. By early 2013, it should be possible to obtain AIS data for 2010 through 2012. It is most efficient for data cleaning and review if the data for these years are provided together rather than at separate times. The key issue for using the additional years of AIS data is the matching of newly appearing vessels with our detailed twelve categories of vessel types and 18 deadweight ton ranges.

We have been provided AIS data for the first 11 months of 2010. Based on a review of that data, an additional year would require matching more than 2,000 newly appearing vessels, requiring about 7 days for an analyst and 4 days for a senior economist. If the three years of 2010 through 2012 were analyzed at the same time, this work could be completed with 14 days for an analyst and 8 days for a senior economist.

Reduce 65-Foot Vessel Length Threshold

The current Rule applies to vessels that are 65 feet and above in overall length (LOA). For 2009, we have worked with the AIS for vessels that are affected by the current Rule. If the length threshold was reduced to say 30 feet, this would require matching additional vessels with our detailed twelve categories of vessel types and 18 deadweight ton ranges. In terms of the conduct of the economic impact analysis, this modification would be difficult and costly to undertake as less information is available on smaller vessels. Lowering the length threshold will also require renewed and expanded analyses for commercial fishing, ferry boats, whale watch vessels and charter fishing vessels. It is estimated that this would require 15 days for an analyst and 10 days for a senior economist.

Expansion of Off-Race Point and Great South Channel SMAs

Under this modification, the existing Off-Race Point SMA and the Great South Channel SMA would be expanded to incorporate areas where DMAs regularly occur. As the vessel transits through DMAs have already been analyzed for 2009, the characteristics of those vessels have already been matched and identified. We would need to receive from NOAA a revised SMA database incorporating transits that would applicable to the newly defined geographic boundaries of the expanded SMAs. Since there would little need for matching of vessels, the economic impact for 2009 could be determined with 5 days for an analyst and 2 days for a senior economist. Other years could be conducted with the time already included for 2010-2012 update described above.

Establishment of SMAs in Waters of Coastal Maine

The current Rule does not include a SMA for waters off of Maine's coast. However, this has been an active area for right whales in recent years, as evidenced by the number of DMAs that have been implemented. The possible location of the SMA which would be effective from October 1 through February 28 is shown in Figure 5-1.

Figure 5-1. Possible Location of SMA off of Coastal Maine

We have been provided by NOAA, an AIS database that shows transits in 2009 for this possible SMA. Of the 1,734 transits made through this area in 2009 by 404 vessels, we have been able to match 1,397 transits by 305 vessels. Matching of the remaining vessels and determining the economic impact will require 3 days for an analyst and 1 days for a senior economist.

Make all DMAs Mandatory

As the vessel transits through DMAs have already been analyzed for 2009, the characteristics of those vessels have already been matched and identified. That analysis compared the amount of time needed to transit a DMA based on actual recorded speeds for the DMA areas when they were in effect and not in effect. However, since this data only corresponds to voluntary speed restrictions, it does not provide the impact for a mandatory DMA. The best estimate of the average observed speeds would be those recorded in SMAs in 2009 for each type/ size of vessel. Those speeds could b used to then calculate the impact of a mandatory DMA.

The analysis described in the paragraph above applies to the shipping industry vessels. However, making all DMAs mandatory will also require renewed and expanded analyses for commercial fishing, ferry boats, whale watch vessels and charter fishing vessels. It is estimated that this entire task would require 5 days for an analyst and 10 days for a senior economist.

An assessment of the final rule to implement vessel speed restrictions to reduce the threat of vessel collisions with North Atlantic right whales

Published Date: 2012

Series: NOAA technical memorandum NMFS-OPR (/gsearch?ref=docDetails&related_series=NOAA%20technical%20memorandu OPR%20) ; 48

An Assessment of the Final Rule to Implement Vessel Speed Restrictions to Reduce the Threat of Vessel Collisions with North Atlantic Right Whales

Gregory K. Silber and Shannon Bettridge

Mammal Non-Lethal Deterrents, 10-12 February 2015, Seattle, Washington (/view/noaa/15852)

(/view/noaa/15852)

(/view/noaa/15852) [PDF - 498.09 KB]

Personal Author: Long, Kristy J.; DeAngelis, Monica; Engleby, Laura; Fauquier, Deborah; Johnson, Amanda J.; Kraus, Scott D.; Northridge, Simon P.;

Corporate Authors:

United States, National Marine Fisheries Service,

Conference Authors:

Technical Expert Workshop on Marine Mammal Non-Lethal Deterrents (2015 : Seattle, Wash.), sponsor.

Published Date:

2015

Series:

NOAA technical memorandum NMFS-OPR ; 50

Description:

"The NOAA's National Marine Fisheries Service (NMFS) Office of Protected Resources (OPR) hosted a workshop at the Alaska Fisheries Science Center (AFSC) in Seattle, Washington, February 10-12, 2015, to identify safe methods for deterring marine mamma...

File Type:

(/view/noaa/15852) [PDF - 498.09 KB]

Report of the Workshop to Assess Research and Other Needs and Opportunities Related to Humpback Whale Management in the Hawaiian Islands, 26-28 April 1995, Kaanapali, Maui, Hawaii (/view/noaa/15964)

(/view/noaa/15964)

(/view/noaa/15964) [PDF - 481.99 KB]

Personal Author: Payne, P. Michael; Phillips, Brady; Nitta, Eugene T.;

Corporate Authors:

United States, National Marine Fisheries Service., Office of Protected Resources,. United States, Office of Ocean and Coastal Resource Management., Sanctuaries and Reserves Division,.

Conference Authors:

Workshop to Assess Research and Other Needs and Opportunities Related to Humpback Whale Management in the Hawaiian Islands (1995 : Kaanapali, Hawaii)

Published Date:

1997

Series:

NOAA technical memorandum NMFS-OPR ; 11

File Type:

(/view/noaa/15964) [PDF - 481.99 KB]

Pinniped and cetacean oil spill response guidelines (/view/noaa/10479)

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Personal Author: Ziccardi, Michael H.; Wilkin, Sarah Margaret; Rowles, Teresa K.; Johnson, Shawn;

Corporate Authors:

United States, National Marine Fisheries Service,

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NOAA technical memorandum NMFS-OPR ; 52

Description:

"When oil spills occur in the marine environment, many species of wildlife in that ecosystem may be either directly or indirectly impacted. The impacts of spilled oil on birds have long been known (Jessup and Leighton, 1996 ; Leighton, 1993), with ef...

File Type:

(/view/noaa/10479) [PDF - 3.17 MB]

Protected Resources Program and the National Marine Sanctuary Program : strategic planning workshop final report : working together to conserve and recover protected resources in National Marine Sanctuaries : December 6-8, 2004, NOAA Fisheries Southwest Regional Office, Long Beach, California (/view/noaa/3624)

(/view/noaa/3624)

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2006

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NOAA technical memorandum NMFS-OPR ; 30

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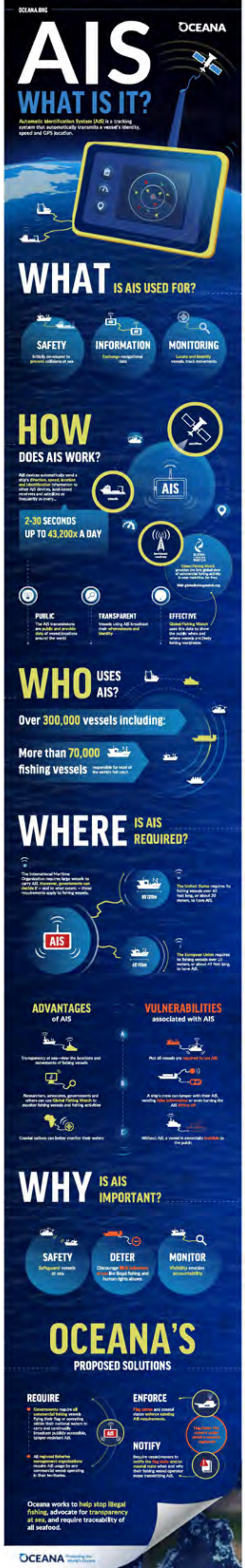
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WHAT IS IT?
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AIS
ADVANTAGES of AIS
VULNERABILITIES associated with AIS
WHY IS AIS IMPORTANT?
SAFETY
DETER
MONITOR
OCEANA'S
PROPOSED SOLUTIONS
REQUIRE
ENFORCE
NOTIFY
Oceana works to help stop illegal fishing, advocate for transparency at sea, and require traceability of all seafood.
OCEANA

Shipborne AIS Class Comparison	Class A	Class B-SO	Class B-CS
Primary Access Scheme	Self-Organizing Time-Division Multiple Access (SO-TDMA per ITU-R M.1371)		Carrier-Sense TDMA (CS-TDMA)
Frequency Range	156.025–162.025 MHz (25 kHz bandwidth)		161.500–162.025 MHz (25 kHz bandwidth)
Digital Selective Calling	Dedicated receiver	Time-shared with a TDMA receiver	
Transmit Power	12.5 Watts (1 W low-power)	5 Watts (2 W low-power)	2 Watts only
Positioning Source	Interfaced to vessel's primary Electronic Positioning Fixing System; Internal Global Navigation Satellite System (GNSS) as a fall-back	Internal GNSS only, interface to an external GNSS is optional	
Position Reporting {see adjoining table for distance travelled per speed per device class reporting rate}	Every 2 s if >23 kts; 3.33 s if >5° course change; 6 s if >14-23 kts; 10 s if 2-14 kts; 3 min. at anchored, moored, or =< 3 kts; via Message 1	Every 5 s if >23 kts; 15 s if 14-23 kts; 30 s if 2-14 kts; 3 min. if =< 2 kts; via Message 18	Every 30 s (±4 s), subject to slot availability; 3 min. if =< 2 kts; via Message 18
	Message 1 reports: MMSI, Time-stamp, Position, Position Accuracy flag, RAIM flag, COG, SOG, HDG, ROT, Navigation Status, Communication State	Message 18 omits ROT and Navigation Status, but, adds various Class B flags for: Type (SO/CS), Operating Mode, and, availability of a Display, DSC Receiver, Full/Limited Bandwidth, and Channel Management	
Static & Voyage Data Reporting	Every 6 min. via Message 5, which reports: MMSI, IMO#, Call-sign, Name, Ship Type, Dimensions, Static Draft, Destination, ETA, EPFS type, Data Terminal availability	Every 6 min. via Message 24A&B, which omits IMO#, Static Draft, Destination, ETA, Data Terminal availability, AIS version; but, adds a Vendor ID.	
Application & Safety Text Messaging	Receive & transmit	Receive optional, cannot transmit	
Display & Interfacing	Minimal Keyboard Display (MKD) required 2 input-output ports; multiple interfaces	Display optional; 1 input-output interface	Display optional; Input-output interfaces optional
Test Standard	IEC 61993-2	IEC 62287-2	IEC 62287-1
USCG Approval Nr.	USCG 165.155/x/x	USCG 165.157/x/x	USCG 165.156/x/x
Estimated Cost	$749-3,500	$750-1,600	$499-1,300

Meters Travelled / Knots / AIS Device Class Report Rate

Device Report Rate in Seconds / Knots ->	1	2	3	4	9	12	14	15	20	23	24	Device Class
2							14.4	15.4	20.6	23.7	24.7	A
3.3	1.7	3.4	5.1	6.8	15.3	20.4	23.8					A
6							43.2	46.3	61.7	71.0		A
10	5.1	10.3	15.4	20.6	46.3	61.7	72.0					A
5											61.7	B-SO
15							108.0	115.7	154.3	177.5		B-SO
30		30.9	46.3	61.7	138.9	185.2	216.1	231.5	308.7	355.0	370.4	B-SO/CS
180	92.6	185.2	277.8									A/B

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Compliance with vessel speed restrictions to protect North Atlantic right whales

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Abstract

Environmental regulations can only be effective if they are adhered to, but the motivations for regulatory compliance are not always clear. We assessed vessel operator compliance with a December 2008 regulation aimed at reducing collisions with the endangered North Atlantic right whale that requires vessels 65 feet or greater in length to travel at speeds of 10 knots or less at prescribed times and locations along the U.S. eastern seaboard. Extensive outreach efforts were undertaken to notify affected entities both before and after the regulation went into effect. Vessel speeds of 201,862 trips made between November 2008 and August 2013 by 8,009 individual vessels were quantified remotely, constituting a nearly complete census of transits made by the regulated population. Of these, 437 vessels (or their parent companies), some of whom had been observed exceeding the speed limit, were contacted through one of four non-punitive information programs. A fraction ($n = 26$ vessels/companies) received citations and fines. Despite the efforts to inform mariners, initial compliance was low (<5% of the trips were completely <10 knots) but improved in the latter part of the study. Each notification/enforcement program improved compliance to some degree and some may have influenced compliance across the entire regulated community. Citations/fines appeared to have the greatest influence on improving compliance in notified vessels/companies, followed in order of effectiveness by enforcement-office information letters, monthly summaries of vessel operations, and direct at-sea radio contact. Trips by cargo vessels exhibited the greatest change in behavior followed by tanker and passenger vessels. These results have application to other regulatory systems, especially where remote monitoring is feasible, and any setting where regulatory compliance is sought.

Keywords: Regulatory compliance, Vessel collisions, Ship strikes, Endangered whales, Remote monitoring, Large whale conservation, Vessel operations

Introduction

Natural resource conservation and management can take numerous forms, including through environmental regulations. However, environmental regulations are only effective if they are adhered to. A substantial body of socio-legal and economic literature has been devoted to the subject of regulatory compliance, but the factors that motivate individuals and businesses to comply are not always clear (Gunningham & Kagan, 2005; May, 2005). Compliance case studies have involved industrial pollution (Kagan, Gunningham & Thornton, 2011), hazardous waste (Stafford, 2012), agricultural practices (Winter & May, 2001), forestry (Purdy, 2010; Peterson & Diss-Torrance, 2012), fisheries (Hønneland, 1999; Ali & Abdullah, 2010), and endangered species conservation (Langpap, 2006; Innes & Frisvold, 2009), among others.

Some studies concluded that regulated communities may lack an understanding of the requirements or may lack the willingness or capacity to comply (Burby & Paterson, 1993; Brehm & Hamilton, 1996); others found that regulated entities may avoid complying because the consequences of noncompliance (i.e., enforcement actions) rarely outweigh the economic benefits of business as usual (Winter & May, 2001; Tyler, 2006). However, in many regulatory settings, limited resources may restrict enforcement actions and assessments of compliance to infrequent inspections (e.g., site visits), surveys, interviews, or self-reporting (Winter & May, 2001; Gunningham, Kagan & Thornton, 2004; Gray & Shimshack, 2011).

With regard to living marine resources, including endangered large whale protective measures, risk assessment estimates have been conducted (van der Hoop, Vanderlaan & Taggart, 2012; Redfern et al., 2013). But, there is also a need to ensure large whale conservation regulations are meeting their objectives through compliance.

The problem of vessel collisions with large whales

Hundreds of fatal vessel collisions (or "strikes") with large whales have been reported, worldwide (Laist et al., 2001; Van Waerebeek et al., 2007). In fact, the actual number of strikes is likely far greater than the reported number because many go undetected or unreported. Collisions with ships are a serious threat to the recovery of the highly depleted North Atlantic right whale (*Eubalaena glacialis*) (Kraus et al., 2005) and collisions along with incidental entanglement in commercial fishing gear, have retarded the recovery of this species (NMFS, 2005). A link has been established between vessel speed and the likelihood of death of a vessel-struck whale whereby the probability of death of a whale involved in a collision increases as vessel speed increases (Vanderlaan & Taggart, 2007; Conn & Silber, 2013).

To address the threat to the recovery of the North Atlantic right whale, the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) issued regulations in November 2008 requiring all vessels 65 feet (19.8 m) and greater in length to travel at 10 knots or less in areas where North Atlantic right whales and high vessel density co-occur (NMFS, 2008). These areas, called seasonal management areas (SMA), are located along the east coast of the U.S. Atlantic seaboard and are active for fixed periods of the year that correspond with seasonal North Atlantic right whale migration, feeding, calving and nursery activities (Fig. 1). The regulations are broad in geographic scope and affect a substantial number of entities, including nearly all tanker, cargo (e.g., container ships, vehicle transport vessels), passenger vessels, and ferries engaged in international and domestic transport of goods and people entering major U.S. ports.

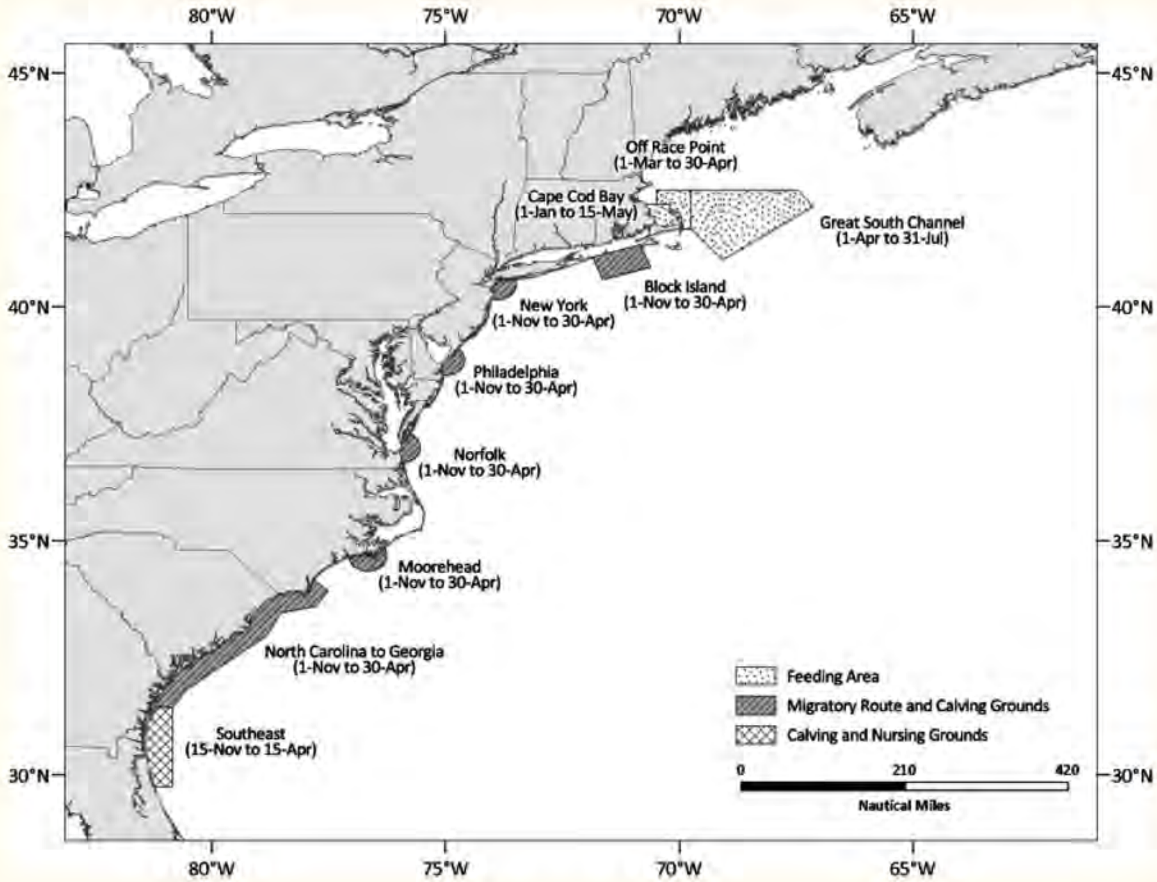

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Figure 1

Map depicting the location and active periods of the north Atlantic right whale seasonal management areas (SMAs).

Notifying the affected community

Extensive efforts by a number of agencies were made—both prior to the regulations going into effect and on an ongoing basis while they were in effect—to notify the affected community about the speed regulations that included an array of broadcast, print, and electronic media outlets (Appendix S1; Silber & Bettridge, 2012). Knowledge of, and adherence to, the requirements, precautions, and safety-at-sea provisions contained in a number of the print and broadcast notification outlets (e.g., U.S. Coast Pilot publications, Broadcast Notice to Mariners) is mandatory for any vessel sailing in U.S. waters. Most vessels studied here are engaged in regular and periodic domestic and international routes that would have resulted in repeated exposure to notification about the speed regulations. Given the breadth of the notification efforts, we believe vessel operators should have had ample knowledge of the requirements.

Compliance information and enforcement programs

After the restrictions went into effect, a subset of the regulated vessel operators or their companies received notifications and/or citations/fines under one of the information and/or enforcement programs described below when violations of the rule were detected. The programs were independently developed and carried out by four federal entities: two by NOAA's Offices of General Counsel and Law Enforcement, and one each by the United States Coast Guard (USCG) and NMFS's Office of

Protected Resources (OPR). There was no standardization or coordination between programs regarding protocols for notifying particular vessels/companies or the identity of operators being contacted. Each of these programs/activities is described immediately below in the chronological order in which they were first implemented.

Hailing at-sea In four periods during the first five years of the regulations (February–May 2009, January–July 2010, November 2010–July 2011, and January–March 2012), USCG personnel radioed vessels that were observed (detected via radar, Automatic Identification System (AIS), and/or visually) violating the speed restrictions and requested that the vessels slow to appropriate speeds. It was the only program involving real-time, verbal notification. It was also somewhat limited in scope, having been conducted in only six of 10 SMAs (the Great South Channel, Race Point, Cape Cod Bay, Philadelphia, Norfolk, and North Carolina to Georgia) and only when USCG cutters were on routine patrols or engaged in other missions.

Community oriented policing and problem solving (COPPS) letters As part of its Community Oriented Policing and Problem Solving (COPPS) Program, NOAA's Office of Law Enforcement (OLE) sent a total of 85 letters between September 2009 and January 2010 to companies whose vessel operators were determined by OLE agents (based on AIS data analysis) to have made at least one trip in an SMA that far exceeded the 10-knot limit. The letters were informative rather than punitive, and included detailed information regarding the observed violation(s) and a reminder about the speed restrictions.

Notice of violation and assessment of civil penalties (NOVA) To prosecute violations of the Endangered Species Act, NOAA's Office of General Counsel Enforcement Section can issue a Notice of Violation and Assessment of civil penalties (NOVA). A NOVA charges the respondent with a violation of laws and regulations, and assesses a civil monetary penalty in accordance with the agency's penalty policy for that violation (http://www.gc.noaa.gov/documents/031611_penalty_policy.pdf). Limited staff time required that attention be focused on a small number of vessels that exhibited numerous and flagrant breaches of the speed restrictions (as indicated by AIS), even though hundreds of violations were observed. Multiple offending trips were often cited in the NOVAs and fines were cumulative. Depending on the number of violations, penalties ranged from $5,750 to $92,000 (mean = $21,845) (www.gc.noaa.gov/enforce-office3.html). A total of 28 NOVAs were issued between November 2010 and September 2012 (and used to examine recipients' operations described below): seven in November 2010; two in December 2010 (those issued in November and December 2010 were defined as "season 3" for our purposes); eight in November 2011 (season 4); one in July 2012; three in August 2012; and seven in September 2012 (these latter three collectively were considered season 5). NOVAs issued in 2013 were not included in this analysis.

Monthly summaries of vessel operations In collaboration with the World Shipping Council (WSC) and Chamber of Shipping of America (CSA), two industry trade associations that represent more than 90% of the world's international commercial shipping fleet, NMFS's OPR developed a program to disseminate AIS-based vessel operations information to WSC and CSA member companies. A total of 17 shipping companies (13 WSC and 4 CSA members; ca. 400 vessels) participated in the program. Starting in December 2010, and monthly for the duration of the study, OPR sent reports directly to company officials containing spreadsheet summaries of every vessel transit within active SMAs (regardless of whether the trip was compliant with the regulation) during the previous month which included: vessel name; date/time of entry into the SMA; distance traveled within the SMA; speeds when entering and exiting the SMA; and the mean and maximum speeds within the SMA.

Study objectives

We sought to assess compliance by the regulated community by examining the response to the vessel speed restrictions. Using a remote monitoring program that provided a near-complete census of vessel operations, we quantified vessel operations in SMAs during the first five years of the regulations. In addition to quantifying overall compliance with the regulations, we assessed whether compliance with the regulations changed over time and whether attempts to improve compliance through the targeted notification and enforcement programs produced a change in behavior.

Materials and Methods

Monitoring vessel operations

We examined vessel behavior using AIS data. AIS is a navigational safety system that transmits very high frequency (VHF) radio signals several times each minute. Each transmission contains static information specific to a given vessel which allowed us to assess compliance by individual vessels and more generally by principal vessel types. The signal also includes dynamic Global Positioning System-linked data unique to a particular voyage including location, heading, and speed (Aarsæther & Moan, 2009). Functioning AIS capabilities are required by the International Maritime Organization on all vessels ≥300 gross tons, and the USCG requires AIS on nearly all vessels sailing in U.S. waters. The USCG has established a national network of AIS receivers that provides coverage of nearly all U.S. coastal waters, a continuously sampled record of operations and, for us, a nearly complete census of the community subject to the speed limits. The AIS's reporting rates provided hundreds of records per trip and resulted in a large and rather precise record of vessel speed and operations.

Assessing compliance

Using AIS data collected between November 1, 2008 and August 1, 2013, we analyzed all trips by vessels ≥65 feet in length that were located within the geographic boundaries of the SMAs (our analytical approach is described further in Silber & Bettridge, 2010). A trip located in an active SMA was considered compliant if all speeds were ≤10 knots. Because binning trips as compliant/noncompliant in this way may not fully capture more subtle responses to the regulations (e.g., vessel operators who were not fully compliant but may have modified their behavior when travelling through active SMAs), we also calculated the percent of total transit distance traveled within SMAs at speeds >10 knots (PDGT10), and average speeds when all or a portion of the trip exceeded 10 knots. With the exception of the average speeds >10 knots metric, we did not calculate mean trip speeds because AIS signals are transmitted at regular and frequent time intervals and, as such, slower speeds are more heavily represented than higher speeds. PDGT10 is not influenced by the distributions of speed values, provides a standard measure that is independent of trip length or duration, and, along with average noncompliant speeds, allowed us to quantify degrees of compliance (or noncompliance).

The above-mentioned metrics (compliance, PDGT10, and average noncompliant speed) were quantified for vessels by type (vessel type analyses were limited to those principally impacted by the regulations, which included cargo, tanker, and passenger), by association with the different notification/enforcement programs (USCG Hailing At-Sea, COPPs Letters, NOVA, WSC and CSA Monthly Summaries), before and after they had received these notification/enforcement actions and for periods when the restrictions were not in effect. Summary statistics were generated for each SMA active season, which we define as beginning on the first day of November (coinciding with the opening of the migratory and calving grounds SMAs) and ending on July 31 of the following year (closing of the Great South Channel SMA) (Fig. 1).

Statistical modeling

The observational design of the study made it difficult to directly associate changes in vessel behavior with any particular notification/enforcement program. The implementation of the suite of notification programs overlapped, confounding attempts to directly implicate any one action in the reduction of vessel speed. As such, we were limited to presenting summary statistics for the vessels associated with each notification/enforcement program.

We were, however, able to estimate the change in PDGT10 over time by examining the differences in its mean value across the sequence of the SMA active seasons during the first five years of the speed restrictions. A natural statistical model to describe the distribution of these values in a given season is the beta distribution, which is typically modeled as a function of scale (α) and shape (β) parameters:

$$f(x \mid \alpha, \beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha).\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1}.$$

We were interested in modeling the mean of this distribution (rather than the scale and shape specified above), so we reparameterized the beta distribution in terms of a mean μ and parameter v, which we interpret informally as a “sample size”. Here we used the scaled distance of each segment as this sample size parameter, so that segments are weighted according to their length; we included the scale parameter as an unknown in the model, by giving it a diffuse prior distribution. This reparameterization is:

$$\alpha = \mu v$$

$$\beta = (1-\mu)v.$$

We expected the mean PDGT10 to vary with several factors, including three variables of interest: SMA, vessel type, and season. Thus, we modeled μ using a mixed effects model:

$$\mu_{ijk} = \theta_i + \psi_j + \phi_{ik}$$

where θ_i is the mean for vessel type i, ψ_j is a random effect corresponding to SMA j, and ϕ_{ik} is the fixed effect of season k on vessel type i. The first season in any SMA (either 2008 or 2009, depending on the SMA’s location) is treated as the baseline; hence θ can be interpreted as the mean in the first season, and ϕ the effect of a subsequent season, relative to the first. It is these seasonal difference effects that are of primary interest. The random effect ψ_j where $j = 1\ldots, S$ is modeled as:

$$\psi_j \sim N(0, \tau_\psi).$$

To account for individual variation not attributable to vessel type, season or SMA, we also employed a random effect, which draws a θ value from a normal distribution for each unique vessel.

For each scale parameter in the model (τ_ψ, τ_θ, τ_v), we specified a half-Cauchy distribution in the inverse square-root of the parameter:

$$f(\sigma \mid \beta) = \frac{2}{\pi\beta\left[1+\left(\frac{\sigma}{\beta}\right)^2\right]}.$$

This results in a relatively diffuse, weakly-informative prior (after transforming by $\tau = \sigma^{-2}$) that is easily overwhelmed by the data (Gelman, 2006).

Because typical at-sea speeds vary widely for the different vessel types, models were fit for each of the three most common vessel types in the dataset: cargo, tanker and passenger vessels. Model parameters were estimated using Markov chain Monte Carlo (MCMC) methods as provided by the PyMC (version 2.3, Patil, Huard & Fonnesbeck, 2010) software package. Each model was run for 20,000 iterations, with the first 10,000 conservatively discarded as burn-in, leaving 10,000 samples for inference. Models were checked for lack of convergence using the Gelman–Rubin statistic (Gelman & Rubin, 1992) and for lack of fit using posterior predictive checks (Gelman et al., 2003).

Our Bayesian logistic mixed-effects model generated estimates of the differences among seasons for different vessel types across all SMAs, along with corresponding measures of uncertainty, 95% posterior credible intervals. Intervals that include zero may be interpreted as not statistically different from zero. Interpreting coefficients on the inverse-logit scale is challenging, since the underlying function is non-linear. For a given parameter value, the effect will be larger near the middle of the logistic curve (0.5), where it is steepest, and smaller near the boundaries (0 and 1), where it is flat. Thus, it is conventional to consider the upper bound on the parameter's effect by estimating its maximum influence. A useful rule of thumb is to divide the parameter value by four to get an approximate upper bound on the effect. For example, the estimated median of the difference between active periods 2 and 1 for cargo ships is −0.02, which corresponds to a maximum drop of 0.09 in PDGT10 (from 0.50 to 0.41); by comparison, the median value of −1.07 for the difference between active periods 5 and 1 would take an expected PDGT10 value of 0.50 down to 0.16.

Results

A total of 201,862 trips made by 8,009 individual vessels were analyzed. In the first two active seasons of the speed restrictions (i.e., the regulated community's initial response to the novel regulation), 4.0% and 4.2% of the trips were fully compliant and PDGT10 values averaged 57.3% and 55.5%, respectively (Table 1; Fig. 2). In comparison, when speed restrictions were not in effect during the first two years of the regulations, 1.7% and 2.3% of the trips within the geographic boundaries of the SMAs were conducted entirely with speeds ≤10 knots and PDGT10 values were 83.4% and 83.2%, respectively (Table 1).

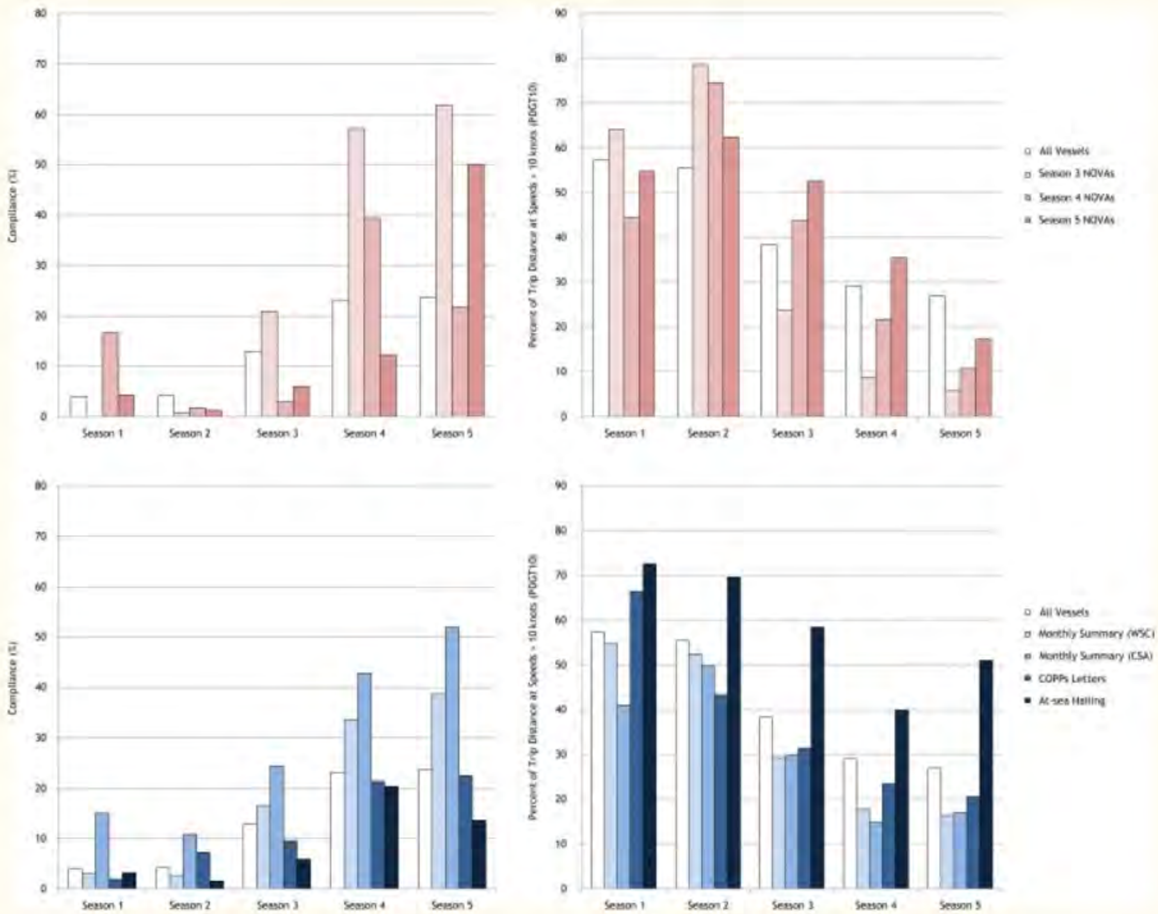

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Figure 2

Temporal changes in vessel speed restriction compliance metrics during the first five years of the regulations for vessels associated with the different notification/enforcement programs.

Compliance metrics for all vessels analyzed are also included for comparison and NOVA recipients have been further split based on when they received NOVAs (e.g. Season 3 NOVAs includes vessels that received their notices of violation shortly before or after the onset of Season 3) to better illustrate potential impacts associated with the enforcement action.

Table 1

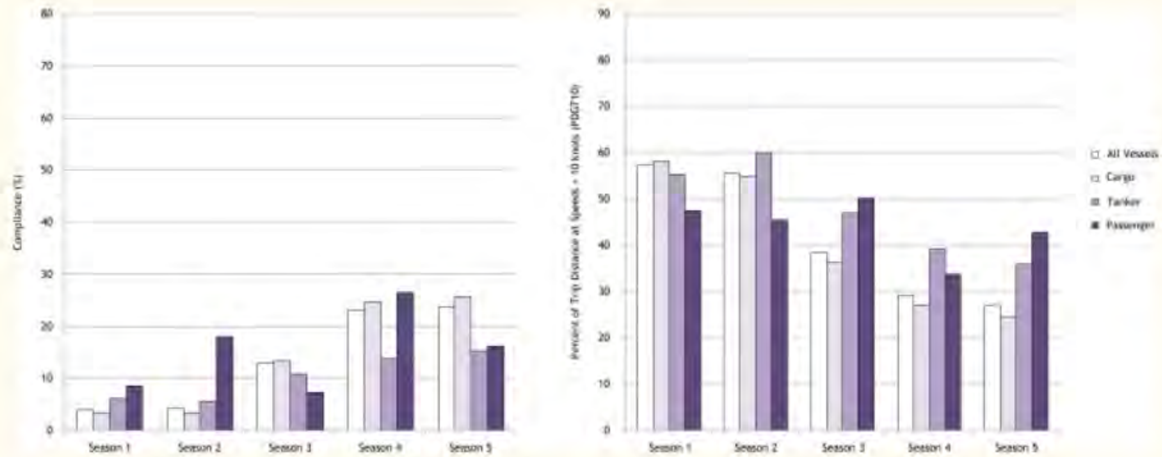
Compliance metric summary statistics for trips through the SMAs during active and inactive periods by all vessels (cargo, tanker, and passenger) for the first five years of the speed restrictions.

Season	SMA status	Trips	Vessels	Compliance[a]	PDGT10	Mean noncompliant speed[a]
1	Active	14907	1776	4.0	57.3	12.0
	Inactive	25974	2401	1.7	83.4	14.3
2	Active	19439	2019	4.2	55.5	12.0
	Inactive	22685	2065	2.3	83.2	14.3
3	Active	20782	2126	12.8	38.3	11.6
	Inactive	21408	2202	2.3	81.8	14.1
4	Active	18339	2097	23.1	29.1	11.7
	Inactive	20075	2092	2.1	80.9	14.1
5	Active	17927	2063	23.7	26.9	11.7
	Inactive	20326	2068	2.9	79.5	14.1

Notes.

[a]Compliance and mean noncompliant speed for inactive SMA trips refer to trips with all speeds ≤10 knots and mean of all speeds >10 knots, respectively.

The largest response in PDGT10 values over time among the three vessel types analyzed was for cargo ships (Table 2). The temporal effect of the second active season relative to the first for this vessel class was significantly negative, with a median value of −0.02 (95% BCI [−0.06, 0.01]). This effect increased 35-fold for the third active season to −0.70 (−0.72, −0.66), dropped further in the fourth active season to −1.20 (−1.24, −1.17), and then to −1.07 (−1.11, −1.03) in the fifth active season. For tankers, there was a notable drop in expected PDGT10 beginning in the third active season, with the median seasonal difference dropping to −0.25 (−0.31, −0.18), and further to −0.48 (−0.54, −0.41) and −0.62 (−0.69, 0.56) in seasons four and five, respectively (Table 2; Fig. 3). The change in vessel speed for passenger vessels was less consistent, showing little change in the first three active seasons (nominally higher in the third season) before becoming significantly negative in the fourth and fifth active season (Table 2; Fig. 3). None of the three models showed obvious lack of convergence, nor was there indication of lack of fit, based on the results of posterior predictive checks.



[Figure 3](#)

Temporal changes in vessel speed restriction compliance metrics during the first five years of the regulations for the three principal vessel types analyzed.

Compliance metrics for all vessels analyzed are also included for comparison.

Table 2

Model-based estimates of seasonal differences in PDGT10 for cargo, tanker and passenger vessels, along with posterior 95% credible intervals (highest posterior density intervals).

Each parameter represents the expected difference in PDGT10 in a specified season, relative to the first season, on the inverse-logit scale. Intervals that do not contain positive values are highlighted in bold.

Vessel type	Season	Median	Standard deviation	95% HPD interval
Cargo	2	−0.02	0.001	**(−0.06, 0.01)**
	3	−0.70	0.001	**(−0.74, −0.66)**
	4	−1.20	0.001	**(−1.24, −1.17)**
	5	−1.07	0.001	**(−1.11, −1.03)**
Tanker	2	0.18	0.002	(0.11, 0.25)
	3	−0.25	0.002	**(−0.31,−0.18)**
	4	−0.48	0.002	**(−0.54, −0.41)**
	5	−0.62	0.002	**(−0.69, −0.56)**
Passenger	2	0.12	0.008	(−0.07, 0.32)
	3	0.25	0.006	(0.07, 0.41)
	4	−0.56	0.007	**(−0.74, −0.39)**
	5	−0.48	0.007	**(−0.65, −0.31)**

Of the notification programs studied, vessels hailed by the USCG seemingly exhibited the smallest relative change in compliance following their notification (Table 3); and, transits by this group subsequent to their notification were consistently higher than the population as a whole (Fig. 2). The average PDGT10 values of COPPS letter recipients decreased from 66.3% to 33.3% after being notified (Table 3), representing a clear but modest response to the program.

Table 3

Compliance metric summary statistics for trips through active SMAs by vessels associated with notification/enforcement programs both before and after the notification/enforcement.

Program	Timing	Trips	Vessels[a]	Compliance	PDGT10	Mean noncompliant speed
At-sea hailing	Before	964	46	4.9	70.3	13.2
	After	1260	44	11.8	48.7	12.1
COPPs letter	Before	1572	85	2.6	66.3	12.8
	After	2743	62	14.3	33.3	11.9
Monthly summary (CSA)	Before	2197	40	29.5	35.8	10.9
	After	2119	30	55.6	12.3	10.6
Monthly summary (WSC)	Before	14203	317	3.3	51.7	11.8
	After	19416	303	29.0	20.8	11.7
NOVA	Before	1318	28	3.3	62.0	13.0
	After	562	14	40.4	14.5	11.7

Notes.

[a]Not all vessels with trips prior to (or associated with) the initiation of their respective notification/enforcement program made subsequent trips through active SMAs.

Vessels/companies that received NOVAs seemed to exhibit the greatest relative change in fully compliant trips and average PDGT10 after being cited. Average PDGT10 values went from 62.0% for trips prior to notification to 14.5% after fines were issued (Table 3). Average PDGT10 values for NOVA and monthly summary (both WSC and CSA) recipients declined in each successive active period following receipt of their respective enforcement/notification actions (Fig. 2). WSC monthly summary recipients made some of the largest relative adjustments in behavior (second only to NOVA recipients) with respect to full compliance (Table 3). Among the non-punitive programs, CSA monthly summary recipients had the greatest number of fully compliant trips (55.6%) and lowest average PDGT10 (12.3%) after being notified (Table 3).

Discussion

The U.S. Endangered Species Act (ESA) and related environmental legislation provide rather broad agency discretion for developing and implementing conservation regulations. However, without compliance, such regulations will be largely ineffective no matter how well they are designed or how important their mandates are perceived. In our study, substantial modifications to normal practices were expected of a large, multi-national community to a novel ESA-promulgated regulation.

We found that, while much of the regulated community responded when vessel speed restrictions were instituted, a substantial number of trips were not in total compliance and the 10-knot limit was routinely exceeded. This suggests that extensive initial and ongoing efforts to inform the regulated community about the speed restrictions provided no assurances that widespread compliance would necessarily follow, even though this information was provided using virtually every available conventional maritime communications system and requirements that mariners fully understand applicable regulations while sailing in U.S. waters. In addition, non-punitive notifications to violators (i.e., radio contact at sea, COPPS letters) by recognized enforcement authorities resulted in only modest changes in compliance rates.

Due to the number and diversity of entities affected by this rule, it is possible that several years were needed for the community to incorporate speed limits into their operating procedures. It is worth noting, for example, that some printed and broadcast information about the restrictions may have become available to "foreign-flagged" vessels (a large portion of ships entering U.S. ports) primarily after entering U.S. waters. However, most commercial vessels studied here, including foreign-flagged vessels, are engaged in repeated, scheduled routes and likely were exposed multiple times each year to broadcast and broadly-disseminated information about the restrictions.

Our results indicate that in response to the restrictions vessel operators tended to use speeds that while not always less than 10 knots for the duration of a transit were nonetheless slower than they might otherwise use. At-sea speeds typically range from 10–15, 15–25, and 20–25 knots for tanker, cargo, and passenger vessels, respectively. Accordingly, cargo vessels, the most numerous vessel type in our study and the type most named in enforcement actions, were required to make significant shifts in operations to comply with the speed regulation. Relative to cargo and passenger vessels, tankers needed to make the smallest changes in speeds to comply with the regulation, and it appears the approach taken by this vessel class was to reduce speeds when traveling through active SMAs (as reflected in their PDGT10 values), but, not to a point of full compliance.

The highest compliance rates were observed in the latter active periods, with notable changes occurring in the third season. Given the timing of the first set of NOVAs, these results suggest, but do not confirm, that the issuing of citations strongly influenced the behavior of notified vessels/companies. In addition, although they were issued to a fraction of the regulated community, citations appear to have improved compliance in the regulated population as a whole. This is consistent with findings by others whereby environmental monitoring and enforcement activities had a strong impact not only in reducing future violations (Gray & Shimshack, 2011), but also that deterrence resulting from these activities was almost as strong in affecting the compliance of others in the regulated community as it was on the sanctioned entity (Shimshack & Ward, 2005). Assessing internal business actions is beyond the scope of this study, but anecdotal reports to us indicate that there was broad knowledge among maritime industries that citations/fines were being issued. In addition, OLE press releases and industry trade publications notified readers about the issuing of fines and named the violator's company. Societal expectations, perceived social costs, and the importance of reputation have been identified as motivators in corporate compliance behavior (May, 2005; Gunningham, Thornton & Kagan, 2005), and these factors may have been at play in our study.

Each of the targeted notification programs appeared to have at least some effect on improved compliance in individual vessels. There are important distinctions between these programs that may be reflected in their relative effectiveness. An at-sea hailing incident may have been known only to the vessel operator and this program was limited geographically and temporally. Its modest influence on compliance suggests that when the perceived likelihood of detection is low (no visible enforcement entity present on the majority of trips) the threat of adverse consequences is also low. Receipt of NOVAs or monthly summaries of operations to association members (and perhaps COPPS letters) was almost certainly known throughout a given company (in most cases, company officials were the entities being notified) which may have led to company-wide directives regarding compliance. CSA members comprise a diverse set of vessel types, tankers being strongly represented; likely, minimal alteration of operations was needed for many of these vessels to comply. In addition, many CSA-member vessels are engaged largely in domestic trade and in making repeated U.S. port entries may have been exposed to a greater degree than other vessels to awareness-raising about the restrictions.

Multiple notification/enforcement programs can have an additive value in influencing compliance rates (Gray & Shimshack, 2011) and the threat of punitive actions may bolster the effectiveness of non-punitive measures (Abbot , 2009; Scholz & Gray, 1990). We note that shortly after NOVAs were issued the industry associations sought to develop regular non-compliance notification programs for their members. Therefore, these follow-up programs likely complimented enforcement actions and provided periodic reminders that operations were being routinely monitored.

Enforcement activities can be labor- and resource-intensive and may be difficult if the regulated population is large or widely dispersed (Abbot , 2009; Ali & Abdullah, 2010). Where feasible, remote-monitoring can be a cost-effective means to improve compliance (Purdy, 2010). Whereas we did not attempt to quantify agency costs involved in the monitoring/enforcement activities described here, by utilizing an existing infrastructure for remote monitoring and relying on electronic means or surface mail for nearly all enforcement and notification activities, costs were almost certainly considerably less than those involved in conventional inspection or law enforcement activities.

The vessel speed restrictions appear to be working as intended: no fatal vessel strike-related right whale deaths were reported in or near active SMAs since the rule went into effect, a period that is nearly twice the longest interval between subsequent known vessel collision fatalities in these same areas in an 18-year study period prior to adoption of the rule (Laist, Knowlton & Pendleton, 2014). Modeling studies have indicated that the risk of fatal vessel collisions of right whales has been reduced by the vessel speed restriction (Lagueux et al., 2011; Wiley et al., 2011). The probability (a 80–90% reduction in risk) of fatal vessel collisions was lowest in the latter part of the period in which the rule was in effect (Conn & Silber, 2013), during which improved compliance rates were observed.

Voluntary actions and incentives are approaches that have been widely used and can be effective in reducing environmental impacts (Dietz & Stern, 2002; Gunningham, Kagan & Thornton, 2004; Stafford, 2012). However, in regard to the conservation issue of vessel strikes of large whales, mandatory and enforced changes in vessel operations appear to have considerable conservation value while adherence to—and therefore effectiveness of—previously implemented voluntary measures to reduce whale disturbance (Wiley et al., 2008) and vessel/whale collisions (Silber, Adams & Bettridge, 2012) was low.

Costs incurred in issuing and enforcing living resource conservation regulations and costs to regulated entities might be assessed relative to societal benefits (Gren & Li, 2011). Economic impacts to the regulated community arising from vessel speed restrictions (including the effect of lost time, indirect impacts to intermodal transport systems etc.) are a fraction of the value of the goods and services provided by the affected maritime and associated industries (Nathan Associates Inc., 2012), and these might be weighed in the context of societal valuation studies of the virtues of preserving endangered and threatened species (e.g., Wallmo & Lew, 2011).

Summary and conclusions

This study provides information about the relative roles of punitive and non-punitive targeted actions designed to enhance compliance. Our findings, like those of others, appear to strongly suggest that citations/fines were motivators in improving compliant behavior and these may have been backed by targeted notifications of violation. Progressively improving compliance rates appeared to have been influenced, to varying degrees, by broad-scale notification programs and the threat (or reality) of enforcement activities. These results may help in formulating management strategies for this particular conservation concern and in improving compliance in virtually any setting in which regulatory compliance is sought.

Supplemental information

Appendix S1

Outreach used to notify mariners of the December 2008 vessel speed restrictions:

See Silber & Bettridge (2012) for more complete descriptions.

Click here for additional data file.(20K, docx)

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Additional Information and Declarations

Competing Interests

The authors declare there are no competing interests.

Author Contributions

Gregory K. Silber conceived and designed the experiments, wrote the paper, reviewed drafts of the paper, principal role in organizing the project and in securing data for analysis.

Jeffrey D. Adams performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.

Christopher J. Fonnesbeck performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, wrote the paper, reviewed drafts of the paper.

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Population of North Atlantic right whales dips again, to 366

October 27, 2020

PORTLAND, Maine (AP) — The population of North Atlantic right whales, an endangered species that has been the focus of conservation efforts for decades, has dipped to less than 370, officials said.

The whale numbers at only 366, the National Oceanic and Atmospheric Administration said Monday in an estimate that reflects the population as of January 2019. The previous estimate, gear.

The population was more than 480 in 2011, the Portland Press Herald reported. A NOAA team is working on a plan designed to reduce the risk the whales face due to fishing gear.

Conservation groups sounded the alarm about the drop in population Monday. Erica Fuller, an attorney with Conservation Law Foundation, said "the outlook is grim if we do not act today."

The population of North Atlantic right whales was devastated during the commercial whaling era. It has been a federally protected species since 1972.

3 Russian bomber pilots killed by ejection system glitch

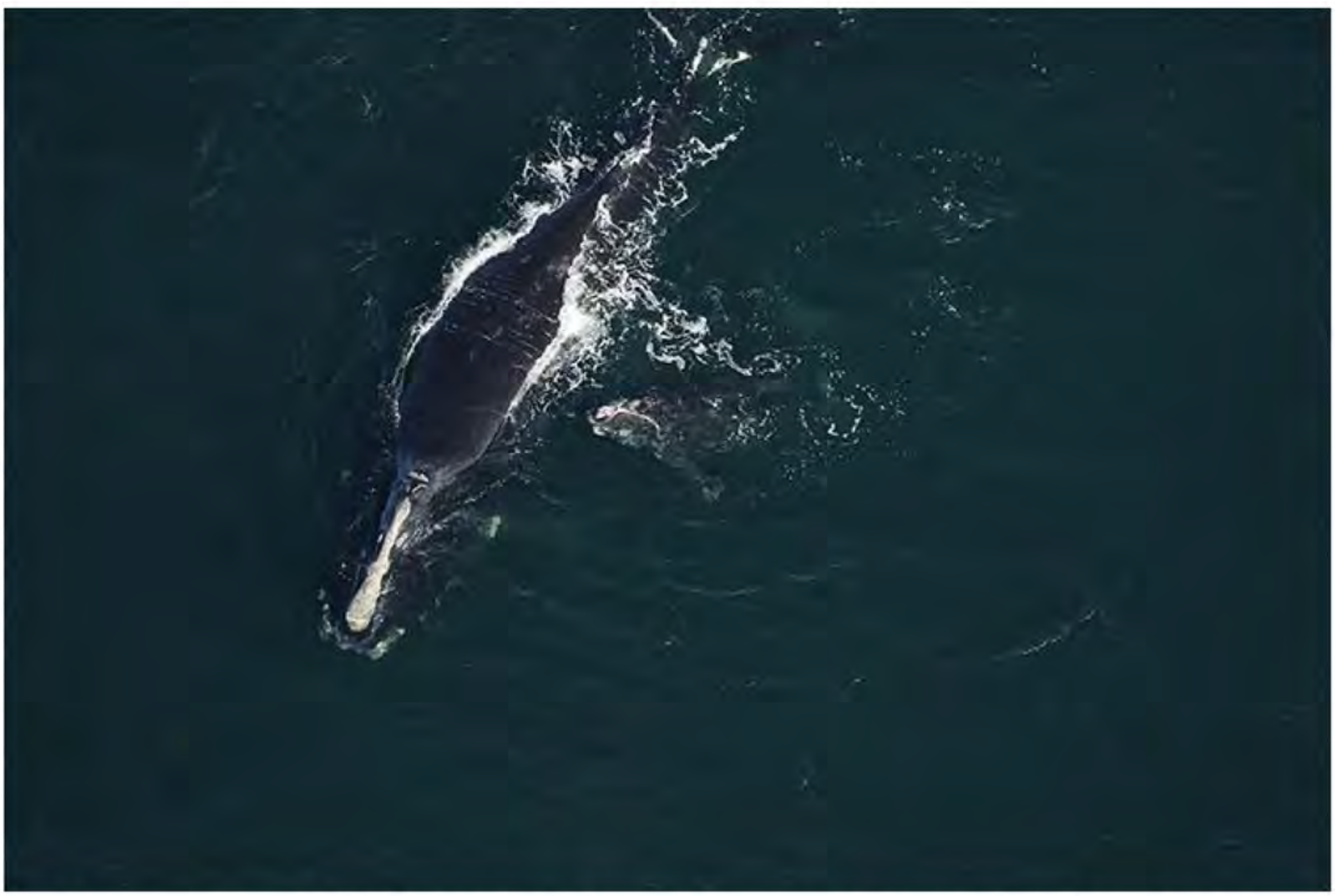
MOSCOW (AP) — Three members of a Russian bomber's air crew died Tuesday when their ejectio...

AP March 23, 2021

North Atlantic Right Whale Calf Stranded Dead in Florida

February 14, 2021

On February 13, 2021, we received a report of a dead North Atlantic right whale off the coast of Florida. We will update this web page as more information becomes available.



North Atlantic right whale #3230 'Infinity' and calf when they were first sighted 16.5NM off Amelia Island, Florida on January 17, 2021. Catalog #3230 is 19 years old and this is her 1st calf. Credit: Florida Fish and Wildlife Conservation Commission, NOAA permit #20556-01

February 17, 2021

On February 16, 2021, the calf's mother "Infinity" (#3230) was found by a right whale aerial survey team alive but with new injuries. The Georgia Department of Natural Resources and Clearwater Marine Aquarium documented "Infinity" about 50 nautical miles north of St. Augustine Inlet, Florida, off the coast of Georgia. "Infinity" has two new cuts on her left side suggestive of a vessel strike.

February 14, 2021

A dead North Atlantic right whale calf was reported stranded on February 13, 2021, along the Florida coast. The animal is likely the calf of a 19-year old female named Infinity (#3230). The calf was first sighted on January 17, 2021, off Amelia Island, Florida. This is the first observed right whale death in U.S. waters in 2021. Regrettably, it is the second dead right whale calf of the 2020–2021calving season following the discovery of a dead calf in North Carolina in November 2020. NOAA's Office of Law Enforcement is investigating the incident.

In collaboration with our partners, we are organizing a necropsy (animal autopsy) of the calf to conduct a detailed evaluation of the cause of death, evaluate the calf's overall health prior to death, and generally learn more about this animal. We are working with our Marine Mammal Stranding Network partners, including:

- Florida Fish and Wildlife Conservation Commission
- Harbor Branch Oceanographic Institute
- Hubbs SeaWorld Research Institute
- University of Florida

The Ongoing Unusual Mortality Event

An Unusual Mortality Event (UME) has been ongoing for North Atlantic right whales since 2017. Since the UME was established, 33 whales (including this one) have been found dead in U.S. and Canadian waters. An additional 14 live seriously injured whales have been documented, bringing the current total number of animals in the UME to 47. The primary causes of the Unusual Mortality Event are entanglements or vessel strikes. North Atlantic right whales are a critically endangered species with fewer than 400 individuals estimated remaining. The 47 whales documented so far in the UME represent more than 10 percent of the population. This is a significant setback to the species' recovery.

Help Us Help Whales

The protection of these animals is in the hands of all mariners on the water. **Slow down and remain alert** while traveling through areas where right whales are found. It is difficult to see right whales, especially in poor light or weather conditions, so slowing down is the best prevention to avoid collisions. Allow plenty of time to slowly return to port—don't wait until you're racing to return before the sun goes down.

NOAA urges vessels of all sizes to please **slow down** and give these animals space. Mom-calf pairs spend the majority of their time at, or a few feet below, the water's surface in the Southeast United States. They can be surprisingly difficult to see, especially in poor light or weather conditions. The calving season is a critical and vulnerable time for right whale mothers as they nurse their young calves. Federal law requires everyone to stay at least 500 yards away from right whales by sea and by air (including drones).

We ask anyone with information on this event or if they see a dead or injured whale off Georgia or Florida, radio the U.S. Coast Guard via VHF Channel 16, or call (877) WHALE-HELP (1-877-942-5345).

Learn more about North Atlantic right whales ›

Species in the Spotlight: North Atlantic Right Whale

Facing a variety of threats from human activities, North Atlantic right whales were listed under the Endangered Species Act in 1970. Once the *right* whale to hunt, these giants are now the right whales to save.

With fewer than 400 individuals remaining, North Atlantic right whales are one of the world's most endangered large whale species. NOAA Fisheries has developed regulations to help protect these whales from vessel collisions and entanglements.

Regulations designed to protect right whales ›

Learn more about the North Atlantic right whale, a NOAA Fisheries Species in the Spotlight ›

Last updated by Southeast Regional Office on February 17, 2021

North Atlantic Right Whales and the Dangers of Vessel Strikes and Entanglement

February 19, 2020

North Atlantic right whales are one of the most endangered whales. They are threatened by ship strikes and fishing gear entanglements throughout their range.

Today, there are only about 400 North Atlantic right whales left and it is estimated that only 85 are reproductively active females. The survival and reproductive success of these remaining females and their offspring is critical to right whale recovery.

Female North Atlantic right whales are not living as long as they once did and more females than males have been reported dead in recent years. Today, females make up approximately 40 percent of the population. It is thought that the energetic stress of reproduction makes female right whales more susceptible than males to dying from entanglement or ship strike injuries.

Biologists also believe that injuries and stress caused by long-term entanglements is one of the reasons that females are calving less often. Studies suggest that more than 85 percent of North Atlantic right whales have been entangled in fishing gear at least once. About 60 percent have been entangled multiple times.

Reducing Entanglements and the Future of Ropeless Gear

NOAA and partners have tried different approaches to reduce threats to North Atlantic right whales.

"Currently, gear modifications and seasonal fishery closures help protect North Atlantic right whales," said biologist Jessica Powell, an expert in marine mammal/fishery interactions at NOAA Fisheries' Southeast Regional Office. "We have a number of different measures and fishery regulations to help reduce entanglement. For example, fishermen in the Southeastern United States who are fishing the ocean during calving season use lines with low breaking strength, so an entangled animal could hopefully break free. In the future, we'd love to see ropeless gear."

Entanglement in fishing ropes attached to gillnets and traps on the ocean floor is one of the greatest threats to North Atlantic right whales. Becoming entangled in fishing gear can severely stress and injure a right whale. Being entangled slows down the whale, decreases its overall fitness, and can lead to a long and painful death.

Ropeless fishing gear is an emerging option that could alleviate a lot of this risk. There are different kinds of ropeless gear, Powell explained, but all are designed to reduce right whale interactions. "Some methods work with lift bags that float the gear to the surface; some have remote sensors that can deploy a buoy when the trap/pot receives an acoustic signal. There are a variety of ways they can work, and it's under development. That's part of the research and development phase—figuring out what works best for

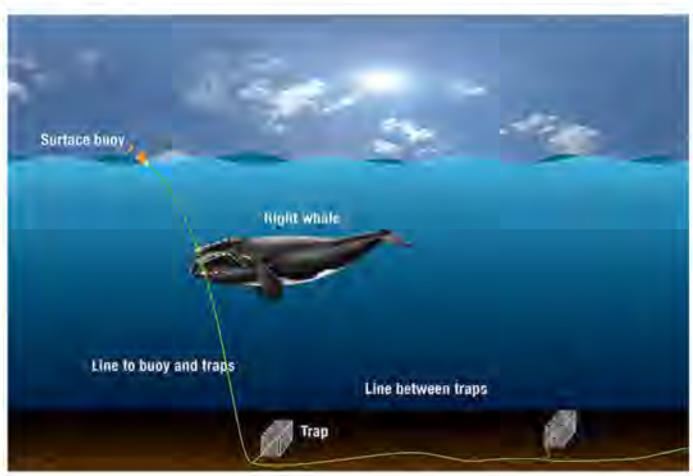


Illustration of how North Atlantic right whales get entangled in fishing gear. Entangled whales sometimes tow fishing gear for hundreds of fishermen without leaving ghost gear behind."

miles. Credit: WHOI Graphic Services, Woods Hole Oceanographic Institution.

Ecologist Caroline Good, who works on the Large Whale Team for NOAA Fisheries, agreed. "The ability to use gear retrieval devices that do not require the use of stationary buoy lines in the water column would be a truly game changing development for right whales," she said.

Entangled whales can tow fishing gear for hundreds of miles. Some fisheries with a history of entanglements are required to mark their gear. Identifying when, where, and in what fishery a whale was entangled is only possible when gear is marked or configured for a particular area and fishery.

Determining Dynamic and Seasonal Management Areas

Every year, North Atlantic right whales travel between calving grounds off the coast of Florida and Georgia to feeding grounds near New England and Canada. Along the way, they travel through many different fisheries and busy shipping lanes.

North Atlantic right whales prefer coastal waters making them susceptible to injury or death from ship strikes. To reduce interactions between ships and right whales, NOAA establishes seasonal and dynamic management areas along the East Coast.

Within seasonal management areas (SMAs), most vessels above 65 feet in length must transit at 10 knots or less during the active period. Some military and law enforcement vessels are exempt. The SMAs are inactive at certain times of the year. For the most part the mid-Atlantic and Southeast SMAs active from November to January and New England SMAs active January to July. The SMA periods and locations are based on what we know of right whale distribution, as well as high vessel traffic areas.

A map of the seasonal management areas off Massachusetts.

But North Atlantic right whales don't always go where we expect. We need to adapt to their changing distribution to protect them. Caroline Good explained that since the ship strike reduction rule went into effect in 2008, we have seen changes in right whale habitat use and distribution.

"The whales are now using the waters south of Nantucket and Martha's Vineyard as a foraging habitat," Good said. "That area was not heavily used prior to the 2008 rule. We're investigating that now to see if there needs to be additional protections as we also, undertake a broad evaluation of the speed rule and evaluate if action is needed to offer more protections against vessel strikes."

The Dynamic Management Area (DMA) program was created to supplement the speed rule. If three or more right whales are sighted in close proximity to each other outside an SMA, a DMA is declared in that area for 15 days. DMAs are voluntary speed restriction areas. DMA announcements are distributed via email announcements, Coast Guard broadcasts, and online.

A map showing an active DMA near Nantucket, Massachusetts.

International Collaboration with Canadian Partners

Starting in late spring, many North Atlantic right whales move into Canadian waters in search of foraging opportunities. We work closely with our Canadian partners to protect North Atlantic right whales across international boundaries.

"U.S. and Canadian researchers have been working together for years," Good said. "NOAA will hold a right whale workshop or coordination call and include participants from Canada's Department of Fisheries and Oceans. Canada is always invited to the table and vice versa. NOAA's Northeast Fisheries Science Center aerial survey team has been conducting extensive aerial surveys in the Gulf of St. Lawrence to assist with getting photos of whales and supplementing efforts of the Canadian survey teams."

At different times, the U.S. and Canada have pioneered methods to protect North Atlantic right whales that later were adopted by the other country. "Canada was first to modify a shipping lane in the Bay of Fundy to avoid a preferred North Atlantic right whale foraging spot," Good said. "We later modified the shipping lane going through Stellwagen Bank National Marine Sanctuary to Boston. Because Canada did it first, the precedent made it easier for us to do it."

"Later on, the United States implemented the first mandatory speed rule for right whales and in 2017 Canada followed with mandatory speed restrictions in the Gulf of St. Lawrence " Good explained. "In this instance, the existing U.S. rule made it easier for Canada to introduce the idea to their maritime community and present the benefits. Each country can help the other by implementing new strategies and observing what works."

Species in the Spotlight Initiative

You can help North Atlantic right whales too. Remember to give them space if you're out on the water. It's illegal to approach within 500 yards of a North Atlantic right whale. These regulations apply to vessels and aircraft (including drones), and to people using other watercraft such as surfboards, kayaks, and jet skis.

If you see injured, entangled, stranded, or dead whale or marine animal, immediately report it to your local stranding network. These networks are located around the country in all coastal states.

North Atlantic right whales are one of nine "Species in the Spotlight." These are species in need of immediate help due to their endangered status and declining populations.

Learn more about North Atlantic right whales and how you can help them ›

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Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014

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Abstract

Given new distribution patterns of the endangered North Atlantic right whale (NARW; *Eubalaena glacialis*) population in recent years, an improved understanding of spatio-temporal movements are imperative for the conservation of this species. While so far visual data have provided most information on NARW movements, passive acoustic monitoring (PAM) was used in this study in order to better capture year-round NARW presence. This project used PAM data from 2004 to 2014 collected by 19 organizations throughout the western North Atlantic Ocean. Overall, data from 324 recorders (35,600 days) were processed and analyzed using a classification and detection system. Results highlight almost year-round habitat use of the western North Atlantic Ocean, with a decrease in detections in waters off Cape Hatteras, North Carolina in summer and fall. Data collected post 2010 showed an increased NARW presence in the mid-Atlantic region and a simultaneous decrease in the northern Gulf of Maine. In addition, NARWs were widely distributed across most regions throughout winter months. This study demonstrates that a large-scale analysis of PAM data provides significant value to understanding and tracking shifts in large whale movements over long time scales.

Introduction

Understanding the distribution and movement patterns of marine mammals is essential for supporting their conservation[1,2]. Large whales undertake some of the longest of mammalian migrations, with some species traveling over 10,000 kilometers annually[3]. Several species of baleen whales are known to migrate from productive feeding grounds at higher latitudes in the summer to winter breeding grounds at lower latitudes[4], although not all individuals leave high latitudes each year[5,6]. The selective pressures driving these movements remain unresolved, including the relative importance of environmental influences and predator avoidance[7,8,9]. Some species, such as humpback (*Megaptera novaeangliae*) and gray (*Eschrichtius robustus*) whales, have relatively well-documented migration routes to and from known wintering grounds[10,11]. The migratory movements of other species, for example North Atlantic minke whales (*Balaenoptera acutorostrata*), have only been described recently[12], while those of others, like Antarctic blue whales (*B. musculus intermedia*), remain poorly known[13].

North Atlantic right whales (NARW; *Eubalaena glacialis*) are one of the least abundant, but intensively studied, species of baleen whales[14]. Centuries of whaling resulted in their near extinction by the time protection was introduced in 1935[15]. Their abundance increased from approximately 350 in 1990[16] to 476 in 2010[17], but has since shown evidence of decline[18]. The reasons for this decline are still unknown, but both widespread anthropogenic impacts from fishing and shipping, and climatic changes are likely. Much of the substantial research program that informs NARW conservation efforts is managed through the North Atlantic Right Whale Consortium (NARWC) formed in 1986. The NARWC curates an extensive catalog of geo-referenced photo identifications of individual whales, coupled with genetic, fisheries entanglement, and health-related data, that provides a detailed understanding of the status of the individuals comprising this species[19].

These data come primarily from decades of research that has been focused in areas that NARWs are known to use, including winter calving grounds off the coasts of Florida and Georgia, and more northerly feeding grounds off the coasts of New England and Atlantic Canada[15]. Although the general distribution of NARWs seemed fairly well known, recent surprises included discovering a potential mating ground in the Gulf of Maine in the winter[20,21]; acoustic detections and visual observations of whales in their historically-recorded habitats off Greenland and Iceland[15,22]; or year-round presence in locations previously thought of as migratory corridors[23,24,25]. Sporadic sightings of solitary NARWs in European waters[26,27,28], such as the 131 day round-trip made by one individual from U.S. waters to an old whaling ground off northern Norway[29], demonstrate that our understanding of their movement patterns remains incomplete.

Management to mitigate impacts of human threats to NARWs includes spatio-temporal measures, such as Seasonal Management Areas (SMAs) or Areas to be Avoided (ATBA), within which ships are required (SMA) or encouraged (ATBA) to reduce speed or avoid altogether during specified times when whales are known to use these areas[30,31]. For this reason, it is important to gain a better understanding of the seasonal distribution of NARWs, including how this distribution has changed in recent years. Since 2010, there has been a noticeable shift in the distribution of NARWs. Whales appear to visit some regions much less frequently, such as the Bay of Fundy, where they were regularly observed for at least two decades[32]. Likewise, there have been recent years with substantially reduced sightings of NARWs in the broader Gulf of Maine[33]. On the other hand, the proportion of the population that uses Cape Cod Bay, in the southern Gulf of Maine, appears to have increased as of late[34].

Until the early 2000s, data collection on NARWs mainly consisted of visual effort from ship-based or aerial surveys[35]. Visual surveys are limited by daylight, weather conditions, and the availability of suitable research platforms at appropriate times and in appropriate locations[36]. Emerging technologies, such as PAM, provide new ways to survey large areas. PAM can provide (1) continuous coverage of areas that are otherwise hard to observe for species presence, (2) data on multiple species simultaneously, and (3) information on the acoustic habitat, including natural and anthropogenic sounds[36,37]. Passive acoustic recorders deployed at different locations and over multiple years can comprise a novel, persistent, large-scale monitoring network that is impossible to replicate with other technologies. Such a network can provide detailed long-term information on multiple species to help inform management[38,39].

There have been numerous deployments of passive acoustic recorders along the eastern seaboard of North America from Florida, USA to Nunavut, Canada[25,40,41,42]. These deployments were designed to answer a variety of different individual research and management questions, but in combination, these data provide substantial coverage of the continental shelves off the western North Atlantic Ocean since 2004. A collaborative program across multiple institutions has brought these data together to assess the holistic occurrence of calling NARWs throughout this area. Here, we show how these acoustic data demonstrate changes in the distribution of NARWs across the eastern seaboard of North America during the past decade (2004–2014).

Results

A total of 35,600 days of acoustic recordings were processed with the Low Frequency Detection and Classification System (LFDCS)[43], and subsequent NARW upcall detections were manually reviewed, resulting in 2,527 days (7%) with confirmed NARW acoustic presence. NARWs were acoustically present along the entire eastern seaboard of North America from the western Scotian Shelf (region 3) to the waters off Jacksonville, Florida (region 10) throughout the winter months from late October through early April, with the exception of no detections on the Scotian Shelf from December through February (Fig. 1). A decrease in detections was seen in summer months in southern regions, reflecting the known movement of breeding individuals towards northern feeding grounds. NARWs were also detected near Iceland and Greenland (region 2) from July-October (see previous analysis by Mellinger, *et al.*[22]). Davis Strait (region 1) contained one day with possible NARW detections in both December and March. However, with high bowhead whale (*Balaena mysticetus*) and humpback whale calling also present, NARW presence could not be confirmed with confidence. There were no NARW detections in any recordings from Bermuda or the Caribbean (region 11), confirming the likelihood that NARWs do not currently venture into the waters surrounding Bermuda and the Caribbean.

Figure 1

Weekly Presence Summary: Boxplots representing the number of days per calendar week with confirmed North Atlantic right whale upcall acoustic presence in each region described in Fig. 4 and for all years of the study (2004–2014). Horizontal lines within the boxes indicate the median, box boundaries indicate the 25th (lower boundary) and 75th (upper boundary) percentiles, vertical lines indicate minimum and maximum values, and black dots represent outliers. Grey blocks indicate weeks where no data were available for that region.

Average weekly acoustic presence was broken up into two time periods representing before (2004–2010) and after (2011–2014) the described distribution shift starting in 2010 (Fig. 2)[33]. To test whether the occurrence of right whales in regions differed over the two time periods, we ran a Generalized Linear Model (GLM; see methods) with the number of days in which whale calls were detected as the dependent variable, and the time periods (2004–2010; 2011–2014) and regions as independent variables, with their interaction effects included in the model. There were too few data (in some time*region cells) available for Davis Strait, Iceland and Greenland, Georges Bank, Cape Hatteras, and

Bermuda and the Caribbean (regions 1, 2, 6, 9 and 11) for them to be included in the model.

Figure 2

Weekly Presence Comparison from 2004–2014: Boxplots representing the number of days per calendar week with confirmed North Atlantic right whale upcall acoustic presence in each region described in Fig. 4 and for each time period of interest (2004–2010 and 2011–2014). Horizontal lines within the boxes indicate the median, box boundaries indicate the 25th (lower boundary) and 75th (upper boundary) percentiles, vertical lines indicate minimum and maximum values, and black dots represent outliers. Grey blocks indicate time periods where no data were available for that region.

For all other regions, both factors and their interactions were significant (Table 1). Pairwise comparisons of time periods across individual regions (run using phia::testInteractions) demonstrated differences between the two time periods (Table 2), except for in Massachusetts Bay (region 5). Northern regions (3 and 4; Scotian Shelf and Gulf of Maine) saw a reduction in calls in 2011–2014, but mid-Atlantic regions (7 and 8; southern New England and the mid-Atlantic), and the Southeastern U.S. (region 10) saw increases (Table 3, produced using phia:interactionMeans). We used the False Discovery Rate[44] to adjust for alpha-value inflation.

Table 1 Results of the Poisson Generalized Linear Model (GLM) testing whether the occurrence of North Atlantic right whales in the regions differed over two time periods (2004–2010; 2011–2014).

Table 2 Results from the Poisson Generalized Linear Model (GLM) testing between the two time periods (A–B) for each region separately, using the False Discovery Rate[44] to correct for alpha-value inflation.

Table 3 Values for each region and time period individually from the Poisson Generalized Linear Model (GLM).

Spatial distribution of NARW acoustic occurrence was summarized from 2004–2014 by seasons in Fig. 3. Seasons were defined based on Roberts, *et al.*[45] with November to February as Winter, March to April as Spring, May to July as Summer, and August to October as Fall. Seasonal acoustic occurrence of NARWs reflected patterns seen in the daily presence plots (Figs 1 and 2), with NARW presence along the entire coast in both winter and spring seasons. Across all seasons, NARWs were detected from Cape Hatteras (region 9) to Nova Scotia (region 3), highlighting the expansive habitat of NARWs for most of the year (Fig. 3).

Figure 3

Seasonal Occurrence Maps: The number of days per season with confirmed North Atlantic right whale (NARW) upcall acoustic detections, summarized for all available recordings locations (2004–2014). Filled orange circles indicate NARW acoustic presence, and circle size indicates the number of days with NARW acoustic detections during a season. White dots indicate recorder locations with no NARW acoustic presence for any year during that season. Figure produced with ArcGIS 10.3.1 (http://www.arcgis.com); background map credits: Esri and GEBCO.

The LFDCS, with a Mahalanobis Distance (MD) threshold of 3.0, missed days with NARW upcalls at an estimated rate of 31%; if we used a threshold of one true upcall detection per day for daily presence, the rate of missed days with NARW upcalls would have been 25%. Manually tallied upcalls from the Gulf of Maine analysis[21] revealed that days where LFDCS detected true NARW upcalls had a median of 259 calls per day and ranged from 20–2770 calls per day, and days where LFDCS missed NARW upcalls had a median of 7 calls per day and ranged from 1–66 calls per day. It is important to note that detection rates, and therefore missed detection rates, will be highly variable due to variability in ambient noise levels, recorder types, habitat, bathymetry, and calling behavior of the animals. However, this analysis indicates that at greater calling rates, indicative of higher calling activity and potentially reflective of multiple calling individuals, daily NARW acoustic presence was most likely captured in areas where they were vocalizing. Sporadic calls, which may be produced by lone individuals passing through an area, were less likely to be detected in this analysis (note that lone animals can be missed by visual surveys, particularly aerial surveys, as well). Given the main goals of capturing broad-scale movements of the entire population with this analysis, failing to detect the presence of some individuals does not compromise the overall results.

Discussion

This study on acoustic presence of NARWs demonstrates this species' high mobility and broad geographic range. It also shows that the habitats NARWs frequent can change over time and that they are often distributed widely across their entire range. Previous understanding of NARW movements assumed the majority of the population migrated between the calving grounds in winter months and northern feeding grounds in summer months, where visual survey effort was therefore concentrated[27,46]. Little was known about the whereabouts of whales that did not frequent these habitats, or the exact timing and location of other important areas. This study demonstrates nearly continuous year-round NARW presence across their entire habitat range, particularly north of Cape Hatteras, suggesting that not all of the population undergoes a consistent annual migration. It is possible that the non-migrating whales could be mobile individuals occupying broader areas throughout the year, like some subspecies of blue whales in the Antarctic[47], or individuals that do not migrate annually, like a portion of the east Australian population of humpback whales[5]. Our data clearly demonstrate that NARWs occur along the entire eastern seaboard of North America for most of the year, even if that distribution has shifted within the past decade.

The acoustic data supports NARW distributional changes that have been recently observed during visual surveys. Furthermore, the acoustic data provide additional insights into where NARWs are located at times of the year when the poor weather and lack of light make visual surveys highly restricted (i.e., late fall to early spring). NARWs appear to have shifted from previously prevalent northern grounds, such as the Bay of Fundy and greater Gulf of Maine (regions 3 and 4), to spending more time in mid-Atlantic regions year-round (regions 7 and 8)[25,48]. In addition, improved visual survey effort in Canadian waters shows that NARWs have also been sighted more frequently further north in areas such as the Gulf of Saint Lawrence[35]. Acoustic data are currently being processed to allow further evaluation of this region, but were not available for this study. This is an area of extreme importance, with at least 10 linked NARW deaths this year alone[49]. Moving forward, it is crucial to have better available coverage for past and future monitoring efforts in such important regions where entanglement and ship strike threats are prominent. Likewise, we know of past NARW occurrence in historical habitat areas such as Greenland and Iceland, with acoustic presence in 2007[22], and it would be valuable to understand current usage of this region and confirm the northern extent of their range with more recent data. Therefore, this type of long-term, large-scale approach using PAM is invaluable for helping to track presence, and changes in presence, of key species to understand (1) how they have shifted their distribution and (2) whether these shifts puts them at increased risk from anthropogenic threats.

It remains unclear if these observed distribution shifts are due to environmental or anthropogenic effects, if they are a response to short-term changes in the environment, or part of a longer-term cycle in which NARWs shift their distribution. With recent studies finding the Gulf of Maine is the fastest warming body of water in the world[50], it is not surprising to see distributional changes across marine species. We suspect further changes in distributions will occur as water temperatures continue to rise, forcing movements towards both favorable oceanographic conditions and food sources elsewhere. Regardless of the factors influencing these changes in distribution, it is critical for management strategies to reflect new threats that may arise for this species as they move into regions outside of existing management areas[51].

The purpose of this study was to provide baseline information of NARW distributions across their current range. Here, PAM data was used for distributional analysis and assumes homogeneity in the probability of upcalls across all regions. We caution that this is not necessarily the case, as known calling rates vary among demographic groups, such as quieter mother-calf pairs[52], resulting in lower detection probabilities. Call rates are also lower with certain behaviors, such as foraging and logging[53], and therefore it is reasonable to suspect different calling rates over the different habitats and seasons summarized in this study. Additional variation exists across all the regions, with detection probabilities likely varying with different acoustic habitats, bathymetry and recorders. Risch, *et al.*[12] show that ambient noise levels varied across three sites included in this study (Massachusetts Bay, mid-Atlantic, and Southeastern U.S.; regions 5, 7, and 10) over each season, affecting detection probabilities and ranges; while Rice, *et al.*[54] provide detailed results on the varying acoustic environment at 10 different sites within the NARW range. These studies highlight the challenges with large-scale datasets, however, further analysis into detection ranges were beyond the scope and goal of this study. Thus, this work used an average range of detection distances based on published studies[55,56]. As such, it provides a minimum estimate of NARW presence, with the understanding that in some regions the detection ranges may have been slightly more constricted or wider than the average used.

This study integrates data from a suite of smaller-scale studies focused on the fine-scale occurrence of NARWs and other species. Comparing our results with these smaller-scale studies such as Hodge, *et al.*[48], Bort, *et al.*[21], Salisbury, *et al.*[25], Mellinger, *et al.*[22], Morano, *et al.*[23], and Whitt, *et al.*[57], there are time periods with discrepancies between the NARW acoustic detections presented in our study and these previous studies, with the previous studies finding right whale calls in some months that we did not find confirmed detections. This is likely due to a difference in detectors and analysis methodology. In order for this study to include and process such a large acoustic dataset, it was necessary to use an automated detector, LFDCS, and manually review these detections at a coarser level than may have been done in the smaller-scale studies. Our review of the LFDCS performance with a MD threshold of 3.0 at three sites found that 31% of days with right whales present were missed when compared to a full manual evaluation of the data, and that days with lower calling rates tended to be missed more often. Therefore, our results represent a minimum presence compared with these more detailed studies, and it is possible that NARWs have higher occurrence in some areas than is reported here. The missed detection rate could be reduced by lowering our classification threshold (i.e., increasing the maximum MD), but at the cost of increasing the time required to manually screen each detection, since increasing the maximum MD will result in more detections that must be reviewed by an analyst. As with all detection systems, there is a balance between accuracy and processing time that must be considered when choosing a detector within the context and scope of any study.

This is one of the first comprehensive, long-term passive acoustic studies to investigate an entire habitat range for a marine mammal at this temporal and spatial scale, and is made possible only by the cooperation and collaboration of an extensive research community. Even in areas where data were collected for alternate purposes, the combined contributed recordings provided crucial information to assess both the acoustic occurrence and changing distribution of the NARW population. This analysis demonstrates what can be accomplished for other poorly understood species, and encourages broad research collaborations in the future. All contributing data sets were combined for the common goal of understanding the distribution of a critically endangered species facing extreme threats from anthropogenic and environmental influences. In planning future large-scale studies, standardization of acoustic recorders and methods should be considered to improve the quality of datasets.

PAM is a powerful, cost-effective, long-term monitoring tool that can give a better understanding of temporal trends and reveal range expansion, decline, or distribution shifts in populations, as well as interannual changes. This information can be used to direct science and management to focal areas of interest. Most importantly, in an ocean where conditions are changing rapidly, adaptive management is needed to identify and protect areas that are crucial for species on the brink of extinction. Potential ways forward include setting up real-time passive acoustic monitoring systems (see NEPAN[39]), or thinking beyond the traditional means of classifying NARW critical habitat as static, confined areas. This is especially relevant when considering the mobile nature of this species whose distribution patterns may still be changing. It is imperative to continue effective surveys and timely conservation efforts to ensure the recovery of this endangered species.

Methods

Data collection

Passive acoustic data collected for a multitude of different research projects and goals were combined to examine a decade-long acoustic record of the spatial and temporal occurrence of NARWs throughout the western North Atlantic Ocean. This large area was divided into 11 regions, covering the main historical areas where the existing NARW population has been found since the late 1600s, ranging from Florida, USA to Cape Farewell, Greenland[58]. Recorders were assigned a region based on the biological and geographical importance of the area (Fig. 4). Region 3 was broken up to include subregion 3A, representing the Gulf of St. Lawrence: an area having an increase in NARW sightings and research effort over the last few years, but insufficient acoustic data available to contribute to this study. Data were examined across two time periods (2004–2010 and 2011–2014) representing before and after the observed distribution shift in 2010. Due to the ad hoc nature of this large-scale collaborative project, available data are patchy, a few recorders were duty cycled, and there are some regions or time-periods with no available data (Fig. 5).

Figure 4

Recorder Locations: Locations of available passive acoustic recorders used for this study spanning from Bermuda and the Caribbean (bottom right map inset) to the northernmost locations in Davis Straight (top left map inset). Yellow points indicate the locations of recorders available from 2004–2010; black points indicate the locations of recorders available from 2011–2014; and pink points indicate locations of recorders available for both time periods. Red boundaries outline the designated regions, which were defined by the historical distribution patterns of North Atlantic right whales across their range. Region numbers correspond to the following geographic areas: 1. Davis Strait; 2. Iceland and Greenland; 3. Scotian Shelf; 4. Northern Gulf of Maine; 5. Massachusetts Bay; 6. Georges Bank; 7. Southern New England; 8. Mid-Atlantic; 9. Cape Hatteras; 10. Southeastern U.S.; 11. Bermuda and the Caribbean. Figure produced with ArcGIS 10.3.1 (http://www.arcgis.com); background map credits: Esri and GEBCO.

Figure 5

Recording Effort: Figure indicating the proportion of year with available passive acoustic recordings in each region (see Fig. 1). Years are split into quarters from January 2004 to December 2014. Black indicates at least one recorder present for the entire quarter year for that region, lighter gray indicates a portion of that time period with recordings, and white indicates no available acoustic data for that region and time period.

Five types of bottom-mounted passive acoustic recorders were deployed from 2004 through 2014 (See Supplementary Table 1): the High-frequency Acoustic Recording Package (HARP)[59], the Marine Autonomous Recording Unit (MARU)[55], the Autonomous Multichannel Acoustic Recorder (AMAR)[60], the National Oceanic and Atmospheric Administration's (NOAA) Pacific Marine Environmental Laboratory's (PMEL) Moored Autonomous Hydrophones (HARU)[61], and the Guardbuoy (http://geospectrum.ca/guard-buoy). Data collected from each of these recorders varied from a minimum of 25 days to a maximum of 2 years (Supplementary Table 1). Some recorders (59 out of 324) were duty cycled, ranging in recording from 12–95% of the time, while most (265 out of 324) recorded continuously. The spatial configuration in which they were deployed varied from single units to lines and arrays of recorders; the configuration was determined by the original goal of the specific research project in question (Fig. 4). The majority of recordings were sampled at 2 kHz, with some ranging up to 250 kHz. All recordings were low-pass filtered and decimated to 2 kHz for analytical consistency across data in order to make them comparable.

Maximum detection ranges for NARWs can vary considerably, depending on recording equipment, location, and environmental conditions, as well as call type and behavioral context[62], but are estimated to range from 8 to 16 km[55,56]. Consequently, single recorders were selected for analysis from array configurations with units spaced less than 8 km apart, to ensure full coverage of the area while minimizing duplicative detections across recorders. We focused our analyses on data collected between January 2006 to December 2014, with the exception of data collected in 2004 and 2005 in the Bay of Fundy, Emerald Basin, and Roseway Basin, Canada, since these were the only long term recordings available for these areas that had previous well-known occurrence of NARWs. Data from a total of 324 recorders were analyzed, comprising 35,600 recording days of data. All government funded acoustic data are publicly available upon request from the data owner.

Detection and classification of NARW calls

All acoustic data were processed using the Low Frequency Detection and Classification System (LFDCS)[43] which creates conditioned spectrograms (Fig. 6) using the short-time Fourier transform with a data frame of 512 samples and 75% overlap resulting in a time step of 64 ms and frequency resolution of 3.9 Hz. After tracing contour lines, or "pitch tracks", through tonal sounds, the program uses multivariate discriminant analysis to classify the pitch tracks into call types. Calls were classified based on a user-developed call library; our library included four North Atlantic baleen whale species: NARW, fin (*Balaenoptera physalus*), sei (*B. borealis*), and humpback whales. Here, we focused only on the detections classified as NARW calls, specifically the low-frequency modulated upsweep known as the upcall. The upcall is a contact call used throughout the NARW range, produced by all ages and both sex classes, and is therefore the most reliable call to use for determining right whale presence[53,55].

Figure 6

A spectrogram example produced by the Low Frequency Classification and Detection System, showing four North Atlantic right whale upcalls with their corresponding pitch tracks (black and colored lines). Warmer colors on the selected (colored) pitch track indicate high amplitudes of sound, while cooler colors indicate lower amplitudes.

The call library described in Baumgartner and Mussoline[43] was expanded and improved for this analysis to include a wider variety of examples of NARW upcalls and increase detection probability. Each detection was assigned a MD, which measures the deviation of a detection from the assigned call type (see Baumgartner and Mussoline[43] for a more complete description). A lower MD indicates a closer match to the assigned call type. All NARW upcall detections with a MD less than or equal to 3.0 (after Baumgartner, *et al.*[63])

were manually screened by experienced analysts to determine which were correctly classified. For an ideal call type in the LFDCS (i.e., the seven attributes used in the discriminant function analysis are multivariate normal), 75% of actual calls will have a MD of 3.0 or less[63]; we chose this threshold to make the laborious process of manual screening manageable at the expense of sometimes missing genuine right whale upcalls (see below). This approach ensured that false detections were eliminated. The high degree of variability in NARW upcalls and the overlap with other species' vocalizations, such as upsweeps produced by humpback whales, necessitated this extra manual step in data processing[63].

For continuous data, a given day was marked as having NARWs present if three or more true upcall detections were found. Three upcalls were used to establish presence in order to be conservative and confident in stating NARW presence (we also conducted all analyses using a criterion of one upcall per day to indicate daily right whale presence, but neither our results nor conclusions changed). For duty-cycled data, the criteria was dropped to one true upcall detection signifying NARW presence so that presence was not underestimated due to a lower probability of recording vocalizing animals[64]. Weekly NARW acoustic presence per recorder was then summarized as the number of days per calendar week with daily presence.

To test whether the occurrence of right whales in regions differed over the two time periods, we ran a Generalized Linear Model (GLM) in R 3.4.1[65], using the libraries *ggplot2* [66], *MASS* [67], *car* [68], and *phia* [69]. This had the number of days in which whale calls were detected as the dependent variable, and the time periods (2004–2010; 2011–2014) and regions as independent variables, with their interaction effects included in the model. As the call data were counts, we ran the GLM with a Poisson distribution with log-link. The number of recording days was multiplied by the duty-cycle to correct for non-continuous data. Because effort (the number of days during which recorders were present) varied across time and region, we included the log of the number of days during which recorders were present plus 1 (as for some time*region cells, there were no recorders present) as an offset in the model.

The model formula in R was:

$$\begin{array}{c}{\rm{nDaysWithWhales}} \sim {\rm{timePeriod}}\ast {\rm{Region}}, {\rm{family}}= \mbox{`} {\rm{poisson}}\mbox{'},\\ \,{\rm{offset}}=\,\mathrm{log}({\rm{nDaysRecordings}}+1)\end{array}$$

Detector evaluation/missed detection rate

Detector performance was quantified to evaluate whether the missed detection rate for upcalls resulted in underestimating full days of NARW presence in our analysis. Three MARUs, manually reviewed for upcall presence in previous studies, were selected and used as ground-truth datasets to compare to our findings for days with NARW acoustic presence. These sites included year-round recordings from the Gulf of Maine (region 1); southern North Carolina (region 10); and Georgia (region 10)[21,48]. Selected days from each recorder were manually screened for NARW upcalls. Every third day of the Gulf of Maine recording was viewed and all upcalls for those days were counted (for detailed results on this analysis, see Bort, *et al.*[21]). Output from a detector[70] run on North Carolina and South Carolina units was manually reviewed for daily presence of at least one NARW upcall (for detailed results on this analysis, see Hodge, *et al.*[48]). The resulting data were combined and used to generate a ground-truthed dataset of days with NARW presence; this was then compared to the number of days estimated to have NARW presence based on the manually screened output of the LFDCS system.

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S.M.V.P., G.E.D., and M.F.B. designed the study. M.F.B. created the detection software. G.E.D. and J.M.B. conducted the acoustic analysis, and P.C. conducted the statistical analyses. J.B.T. and A.N.R. provided analysis for detector evaluation. G.E.D., S.M.V.P., and P.C. wrote the manuscript, and G.E.D. prepared the figures. J.B., C.B., J.B.T., G.B, R.A.C., D.C., C.W.C., J.D., K.D., L.Ha., J.H., L.Ho., H.K., S.K., B.M., D.K.M., H.M., S.N., D.P.N., S.P., A.J.R., A.N.R., D.R., A.S., M.S., K.S., J.E.S., E.S., S.T., A.W, and S.M.V.P. all provided the acoustic data. M.F.B., P.C., C.B., J.B.T., G.B., R.A.C., D.C., J.D., K.D., J.H., H.K., S.K., D.K.M., H.M., S.N., S.P., A.N.R., D.R., A.S., M.S., K.S., J.E.S., S.T. and S.M.V.P. all provided extensive edits to the manuscript. All authors reviewed and edited the manuscript.

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Ethics declarations

Competing Interests

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Oceana Exposes Ships Ignoring Voluntary Speed Zone Designed to Protect Endangered Right Whales

High Speeds Put North Atlantic Right Whales at Risk, Showing Need for Mandatory Speed Limits and Enforcement

Press Release Date
Friday, March 20, 2020
Location: Washington, DC
Contacts: Megan Jordan: mjordan@oceana.org +1.202.868.4061
Dustin Cranor, APR: dcranor@Oceana.org 954.348.1314

Oceana today released the results of an analysis finding ships ignoring a voluntary speed zone in an area south of Nantucket designed to protect endangered North Atlantic right whales, of which only about 400 remain. Between January 22 and March 6, 2020, more than 41% of the 446 ships in the area exceeded the voluntary speed limit of 10 knots, which was established by the National Oceanographic and Atmospheric Administration (NOAA) to reduce the risk of injury and death to these whales.

Studies have found that the speed of a ship is a major factor in ship-related collisions with North Atlantic right whales and that slowing ship speeds to less than 10 knots in areas where these whales may be encountered can reduce the risk of collisions by 86%.

NOAA uses two different types of management tools to help protect North Atlantic right whales from the dangers of ship strikes: mandatory Seasonal Management Area (SMA) speed zones in places where whales are expected to be, and voluntary Dynamic Management Area (DMA) speed zones where whales are seen. DMAs suggest that ships avoid the area and have a voluntary speed limit of 10 knots. In contrast, SMAs require ships to slow down to 10 knots.

In November 2019, NOAA established a voluntary DMA to protect an aggregation of North Atlantic right whales south of Nantucket and Martha's Vineyard, which is currently in effect until March 29, 2020. In recent months, this area has contained up to 60 North Atlantic right whales.

Of the 183 ships exceeding the voluntary speed limit in this DMA, Oceana found that:

- Most (92%) were large cargo and tanker ships, including one that was more than 1,100 feet long, going as fast as 18.4 knots.
- Nearly all (96%) were flagged to foreign countries such as Panama and Liberia.
- One ship reported a speed over 22 knots, more than twice the voluntary speed limit.

Conversely, Oceana found 88.4% of the ships transiting through the mandatory SMA near Block Island, Rhode Island were complying with the speed restriction.

Last year, Oceana launched a campaign in the U.S. and Canada to reduce risks to North Atlantic right whales. Oceana senior campaign manager Gib Brogan released the following statement:

"While we appreciate NOAA's efforts, our data shows that ships simply aren't complying with voluntary speed zones. In this case, more than 40% of the ships in the area were ignoring these voluntary speed limits and putting North Atlantic right whales in harm's way. But when there are mandatory speed limits, ships actually slow down. NOAA must do more to protect North Atlantic right whales, including mandating that ships slow down when and where these whales are present, and increasing on-the-water enforcement to make sure they do so."

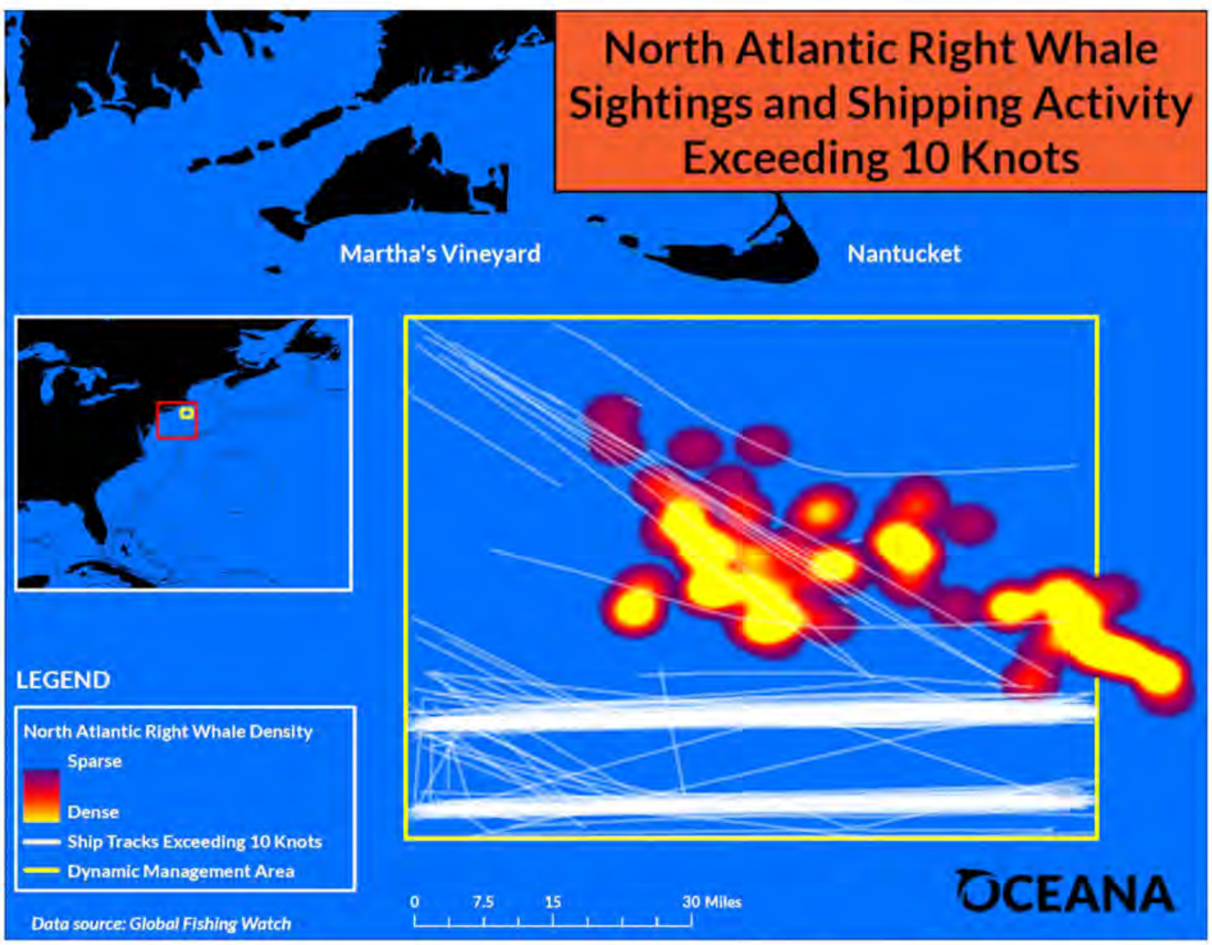

*Figure: Map of vessel traffic over 10 knots in the Nantucket Dynamic Management Area (DMA) between January 22 and March 6, 2020. North Atlantic right whale density information provided by NOAA Interactive North Atlantic Right Whale Sightings Map (**https://www.nefsc.noaa.gov/psb/surveys/MapperiframeWithText.html**).*

Oceana's analysis used the Global Fishing Watch platform, a tool developed by Oceana in partnership with Google and Skytruth, which utilizes machine learning to interpret data from various ship tracking sources like the Automatic Identification System, to monitor ship speed and positions in North Atlantic right whale conservation areas.

Background

North Atlantic right whales were named for being the "right" whale to hunt because they were often found near shore, swim slowly and tend to float when killed. They were aggressively hunted, and their population dropped from peak estimates of up to 21,000 to perhaps fewer than 100 by the 1920s. After whaling of North Atlantic right whales was banned in 1935, their population increased to as many as 483 individuals in 2010. Unfortunately, that progress has reversed.

Collisions with ships is one of two leading causes of North Atlantic right whale injury and death. North Atlantic right whales are slow, swimming around six miles per hour, usually near the water's surface. They are also dark in color and lack a dorsal fin, making them very difficult to spot. Studies have found that the speed of a ship is a major factor in ship-related collisions with North Atlantic right whales. At normal operating speeds, ships cannot maneuver to avoid them, and North Atlantic right whales swim too slowly to be able to move out of the way. This puts them at great risk of being struck, which can cause deadly injuries from blunt-force trauma or cuts from propellers.

Entanglement in fishing gear used to catch lobster, snow crab and bottom-dwelling fish like halibut, flounder and cod is the other leading cause of North Atlantic right whale deaths. Fishing gear from the U.S. and Canada entangles an estimated 100 North Atlantic right whales each year, and about 83% of all North Atlantic right whales have been entangled at least once. Ropes have been seen wrapped around North Atlantic right whales' mouths, fins, tails and bodies, which slows them down, making it difficult to swim, reproduce and feed, and can cause death. The lines cut into the whales' flesh, leading to life-threatening infections, and are so strong that they have severed fins and tails, and cut into bone.

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ARTICLE

Assessing the lethality of ship strikes on whales using simple biophysical models

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Abstract

Studies of ship strikes on whales often focus on large vessels (>20 m), with attention to their speeds and the resulting risk of lethality. Smaller coastal vessels also co-occur with whales, resulting in collisions that merit study. To cast light on injuries caused by vessels of all sizes, we used knowledge of right whale anatomy and Newtonian mechanics to construct simple models that predict the mechanical stresses experienced by whales during collisions. By comparing our predictions with published models and with data from ship strikes on various whale species, we developed a model for lethal injury as a function of several vessel and whale properties, finding that collisions that create stresses in excess of 0.241 MPa were likely to cause lethal injuries to large whales. Furthermore, this model has revealed that (1) vessels of all sizes can yield stresses higher than this critical level, and (2) large vessels produce stresses much larger than this even when travelling at reduced speeds (i.e., 10 knots). The model is fast enough to power an interactive GUI-based tool (in R) and flexible enough to simulate strikes by vessels of different masses and speeds upon whales of different species, sizes, and physical conditions.

Supporting Information

Filename	Description

Filename	Description
mms12745-sup-0001-Supinfo.pdf PDF document, 221.4 KB	**Appendix S1.** Supporting Information.

Please note: The publisher is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing content) should be directed to the corresponding author for the article.

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Large Whale Ship Strike Database

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-25
January 2004

Acknowledgments

We recognize the work of those in the field, notably members of the marine mammal stranding network, some of whom are listed on the first page. Much information on ship strikes to large whales would not be available were it not for the dedication and expertise of those who assess the condition of stranded and floating dead animals and maintain these data. Our appreciation also to the efforts of the many NOAA Fisheries staff who searched out ship strike records in response to a request for data. David Laist and colleagues' Marine Mammal Science paper on collisions between whales and ships was an invaluable source for ship strike records and provided a significant portion of reports in this database, as was the work by Peter Best and others on the same subject. Finally, the authors recognize those conscientious mariners who willingly report strike occurrences and communicate the details of such incidents to marine mammal protection agencies and organizations. Donna Wieting encouraged us to undertake this work and helped provide the time for us to complete it.

Literature citation should read as follows:

Jensen, A.S. and G.K. Silber. 2003. Large Whale Ship Strike Database. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR- , 37 pp.

Additional copies may be obtained from:

National Marine Fisheries Service
Office of Protected Resources
1315 East-West Highway, 13th Floor
Silver Spring, MD 20910
301-713-2322

This document can also be downloaded from NMFS website:
http://www.nmfs.noaa.gov/pr/overview/publicat.html

Introduction

Some human-related threats to endangered large whale species are diminishing, and a number of large whale populations are increasing in abundance. However, injuries and deaths resulting from ship collisions with whales remain a significant threat. In North Atlantic right whales, for example, ship strikes are a primary culprit in the slowed recovery of a highly depleted population.

Several papers provide accounts of mortality in large whales due to ship strikes (Laist et al., 2001; Best et al., 2001; Knowlton and Kraus, 2001). These papers review ship strike records through 2000, 1997 and 1999, respectively. We have built on these accounts by assembling a data base of all known ship strikes worldwide through 2002; a number of our records do not appear in previous accounts. Likely, many ship strikes go undetected or unreported as they may occur in remote areas or struck whales may drift out to sea. Thus, the actual number of strikes is undoubtedly much greater than reported here. Nonetheless, the information we provide is, to our knowledge, the most comprehensive set of data to date on this subject. In the geographic scope and in the range of species effected, the data base illustrates the extent of the threat to large whale species.

The intention of this report is to make accessible the known information on ship strikes to large whales world-wide. We have not attempted to provide an extensive analysis of such records herein, as a thorough discussion of a number of these records can be found in Laist et al. (2001). Rather, we have synthesized ship strike reports to large whales into a comprehensive database to centralize the knowledge base of such incidents. These records indicate that collisions between whales and ships are a world-wide phenomenon which warrants attention.

Materials and Methods

This database is based on a public request for information that NOAA Fisheries received for large whale ship strike records from 1975 to present (2002). Agency staff from NOAA Fisheries' Northeast, Southeast, Northwest, Southwest, Alaska, and Hawaii Fisheries Science Centers and Regional Offices contributed records to this report. In addition, NOAA Fisheries Office of Law Enforcement regional offices provided records of ship strike based on agency investigations (pending cases excluded). Many agency staff worked to the best of their abilities to fulfill this request, but it is possible that some records were overlooked and thus are not included.

In compiling this database, records of ship strikes were drawn from ship reports, marine mammal stranding reports, and NOAA Office of Law Enforcement reports. Following the initial set of data received, additional ship strike records were sought for the purposes of this synthesis through personal communications and a review of the literature on this issue (in particular, Laist et al., 2001; Best et al., 2001). Our records include information through October 2002.

Direct reports from ships, crew and captains are the most reliable source of information on an actual ship strike incident. In these cases, wherein the ship's crew was aware of the strike, it is often possible to obtain information on ship speed, damage to a ship, and relative degree of severity of the strike to the animal. Ship strike information can also be determined from stranded or floating dead whales in which definitive evidence of a massive internal or external trauma is documented (i.e., lacerations from propellers, fractures, hemorrhaging). However, these data are not always definitive as to whether the strike occurred pre- or post-mortem. In such cases, there generally is no information on how, when, or where the strike actually occurred. A dead stranded whale may drift considerable distance from the site of the actual impact. In the absence of a confirmed location for a ship strike incident, we have listed the site of stranding or site of discovery of the floating animal as the collision location in our database.

Another type of record is the occurrence of a ship entering port with a whale carcass draped across its bow. Generally, in these instances the ship's crew was unaware of the strike. Most often this occurs with large container, tanker and cruise ships, and a collision is only determined after the event when the whale is noticed pinned to a ship's bow by a pilot boarding the vessel or lookouts posted for harbor entry. In 42 of the known or probable cases of ship strike in our database, evidence of a collision was only noticed when a whale was brought into harbor on the bow of a large vessel. In certain rare instances, time and location of impact can be estimated by back-calculating to correlate with a previously unexplained decrease in vessel speed.

Given that crew of large vessels often do not detect the impact of striking a whale, animals may be hit and passed over without observation. Likewise, operators may be aware of a strike but choose not to report it. Therefore, as noted above, it is likely that far more collisions actually have occurred than the number reported here.

For the purposes of this report, evidence of injury or mortality is defined as blood noted in water; animal seen with cuts, propeller gashes or severed tailstock; animal observed sinking after strike indicating death; fractured skull, jaw, vertebrae; hemorrhaging, massive bruising or other injuries noted during necropsy of animal.

Results

The data base contains a total of 292 records of confirmed or possible ship strikes to large whales (Table 1). Where available, we have noted ancillary information such as vessel type, extent of injury, and vessel speed at time of impact.

Ship Strikes by Species

Eleven species were confirmed victims of ship strikes: blue, Bryde's, finback, gray, humpback, killer, minke, North Atlantic right, sei, southern right, and sperm whales (Figure 1). Finback whales are the most often reported species hit (75 records of strike), followed by humpback (44 records), North Atlantic right (38 records), gray (24 records), minke (19 records), southern right (15 records), and sperm whales (17 records). Far fewer reports exist of strikes to blue (8 records), Bryde's (3 records), sei (3 records) and killer whales (1 record). Several collision incidents were identified as general balaenopterid (3 records of strike), while a large proportion of reported strikes were not identified to species (42 unknown records). We note that coastal species (e.g., right and humpback whales) may be over represented in our data base, due to a greater likelihood of near-shore detection of a ship struck carcass than individuals that may have died at great distances from shore.

Geographic Distribution of Strikes

Ship strikes to large whales occur world-wide. In our records (and those compiled by others), large whale ship strikes were recorded in waters off Antarctica, Australia, Brazil, Canada, the Canary Islands, France, Japan, Mexico, New Zealand, Panama, Peru, Puerto Rico, and South Africa; in the Caribbean, Mediterranean, and Yellow Seas; and in the Indian and South Pacific Oceans. Our records indicate that ship strikes are most common in North America (Figure 2), but this is almost certainly biased due to sources of data from North American stranding records and enforcement reports. This finding may also be related to the volume of ship traffic along North American coasts. Furthermore, our (the authors) northern hemisphere location increases the likelihood that we learn of reports from North America more readily than elsewhere.

Collision incidents in waters off the United States are recorded from almost every coastal state: Alaska, California, Delaware, Florida, Georgia, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Rhode Island, South Carolina, Texas, Virginia, and Washington. Collisions also occurred in three National Marine Sanctuaries (NMS): Stellwagen Bank NMS (humpback, fin, and right whales), Channel Islands NMS (gray and several unidentified whales), and the Hawaiian Islands Humpback Whale NMS (humpback whales).

Records indicate that collisions between vessels and whales in U.S. waters are most common along the east coast, followed by the west coast and Alaska/Hawaii (Figure 3). Collisions were least common in the Gulf of Mexico.

Severity of Strike

Of the total 292 large whale ship strike reports, 48 (16.4%) resulted in injury to the animal and 198 (68.0%) were fatal. Thus, a total of 246 (84.3%) records indicate that whales that were hit or bear evidence of ship strike were in fact injured or killed by the interaction (Figure 4). In most cases the fate of injured whales is not known. Additionally, in 39 collision reports (13.3%), the impact to the whale was unknown, while in 7 reports (2.4%) there appeared to be no sign of injury.

It should be noted that the high injury and mortality figures for all whales in the database include numerous records of stranded or floating animals found dead. Injuries on a whale's dorsal side indicate that the animal was alive when hit, as dead whales generally float belly-up and are thus more likely to be injured ventrally if hit post-mortem. Although strong evidence indicates ship strike in the records included in this database (i.e., propeller marks, bruises, fractures, hemorrhaging, severed flukes), fatalities due to ship strike cannot always be confirmed because it is difficult or impossible to determine in some of these cases whether the strike occurred to the animal pre- or post-mortem. In addition, because many of our records come from dead stranded whales (as opposed to reports from mariners involved in or observing the striking), the database is weighted toward ship strikes resulting in death.

Vessel Type

Collisions between ships and whales are associated with a wide variety of vessel types. From our database, 134 of 292 cases of ship strike include information on vessel type, while in 158 cases the type of ship was unknown. Of the 134 cases of known vessel type, there are 23 reported incidents (17.1%) of Navy vessels hitting whales, 20 reports (14.9%) of ship strike for container/cargo ships/freighters, 19 (14.2%) reports of ship strike for whale-watching vessels, and 17 reports (12.7%) for cruise ships/liners (Figure 5). Sixteen reports of ship strike (11.9%) are attributed to ferries. Nine cases of ship strike (6.7%) are reported for Coast Guard vessels and eight cases (6.0%) for tankers. Recreational vessels and steamships were each responsible for seven collisions (5.2%) in the database, while fishing vessels were responsible for four records (3.0%) of strike. One collision (0.75 %) was reported from each of the following: dredge boat, research vessel, pilot boat, and whaling catcher boat.

Although these data provide valuable information regarding the wide range of vessels involved in collisions, care should be taken in interpreting these numbers. As noted earlier, captains of large ships, such as container ships, tankers, and cruise ships may not be aware that a collision with a whale has occurred and thus do not report the incident. It is also likely that captains of ships of all sizes who are under no obligation to report, in fact, do not, out of apathy or fear of enforcement consequences.

It should be carefully noted that the relatively high incidence of Navy and Coast Guard collision reports may be largely a factor of standardized military and government reporting practice rather than an actual higher frequency of collisions relative to other ship types. These two federal agencies are actively involved in large whale protection programs and reporting struck or dead whales to the National Marine Fisheries Service is now a part of standard operating practices.

Ship Speed

Vessel speed at the time of strike was reported for 58 (19.8%) of the 292 cases in our database (Figure 6). The range of speeds at which vessels were operating when a whale was hit was 2–51 knots; and the mean speed was 18.1 knots. The mean vessel speed which resulted in injury or mortality to the whale was 18.6 knots. Of the 58 cases, 19 (32.8%) resulted in injury to the whale and 20 (34.5%) resulted in mortality. Thus, a total of 39 incidents of ship strike (67.2%) with speed associated are known to have resulted in injury or mortality to the animal. When all 58 reports are grouped by speed, most vessels were traveling in the ranges of 13–15 knots, followed by speed ranges of 16–18 knots and 22-24 knots.

Vessel Damage and Mariner Safety

Thirteen records indicate damage to the vessel (as reported by the vessel), ranging from minor to extreme, as a result of impact with a whale. All of the incidents of vessel damage for which speeds were recorded were from collisions at an operating speed equal to or greater than 10 knots.

Many of these ships report cracked hulls or damaged propellers, propeller shafts and rudders. In one case, an 8 m recreational Bayliner traveling at 12 knots cracked its hull when it hit a humpback whale outside Juneau, Alaska. A 126 m Navy vessel sustained a 1.6 m tear in the leading edge of a propeller blade when it struck an undetermined whale species off southern California. By far the most extreme example was that of a 24 m high-speed Navy vessel, which hit an undetermined whale species at a speed over 40 knots off Key West, Florida, and reported severely damaged port and starboard aft strut actuators, broken steering arms, a warped hull, and ruptured seawater piping which flooded the gas turbine (pers. comm. T. Tucker in Laist *et al.* 2001).

In addition to vessel damage, ship strikes to large whales can also pose a hazard to human safety. In several cases, particularly with small vessels and fast-moving vessels (e.g., ferries), passengers have been knocked off their feet or even thrown from the boat upon impact with a whale. Hazards can be even more severe; Andre *et al.* (1997) in Laist *et al.* (2001) reports a case in the Canary Islands in which a high-speed ferry collided with a sperm whale at 45 knots, killing it and reportedly killing one passenger as well.

Discussion

Many ship strike fatalities almost certainly go undetected, so our database provides a minimum count of such occurrences. In fact, our records may represent only a fraction of the actual number of strikes. Nonetheless, they illustrate the scope and magnitude of the threat of ship strikes to endangered large whale species.

Ship strikes affect at least ten large whale species. Given the low abundance of North Atlantic right whales relative to other species, the frequency of occurrence of ship strikes to right whales suggests that the threat of ship strikes is proportionally greater to this species.

Ship strikes occur in all oceans and off nearly all continents. The small number of collision records from areas outside the United States is undoubtably due to the much reduced likelihood that such strikes were made known to us. The geographic distribution of our records from North America may, in part, be attributed to the disproportionate amount of collision reporting among different regions, as well as a function of high shipping traffic volume in some locations. All vessel classes are represented in our database, but it appears generally that relatively large and relatively fast moving vessels are most often involved.

For a variety of reasons, certain vessel classes are likely over-represented in our data. As noted, federal vessels are more likely to report a strike than commercial vessels due to their standardized reporting practice. In addition, awareness that an animal has been struck may depend upon the number of people on board. Federal ships carry substantial crew, a number of whom are generally on the bridge at any one time (bridge crew on Navy vessels often consists of a half dozen individuals or more). Such crews are more likely to spot a whale and/or register that a collision has occurred than a container ship or tanker with only one or two individuals at the helm. This may also be true for whale watch vessels that have passenger witnesses on board, and thus are more apt to report strikes than those vessels for which a collision may not be witnessed by parties other than captain and crew.

Numbers of ship strike reports in our database that appear high for Navy and Coast Guard vessels may also be factor of size and vessel configuration. A ship must register that a whale has been struck in order to report the incident. Most federal ships are smaller than those used for commerce and thus register impact when large ships may not (i.e., a 10,000 ton Naval ship has a greater likelihood of recognizing that a collision has occurred than does a 40,000 ton container ship). Smaller vessels are also more likely to notice collisions by nature of the location of a forward bridge. The bridges of tankers and container ships are generally located hundreds of feet aft and are high above the water; this can result in a line of sight well beyond the bow that obscures the direct view in the immediate path of the vessel.

Finally, reporting may also be a factor of geography. Navy operations, for example, are often conducted along continental shelf areas, in the same regions where large whale species are likely to aggregate in pursuit, for example, of prey concentrated there. Thus, the frequency of these reports may be more a factor of geographic overlap than vessel class or mariner behavior. The same is likely true for whale watching vessels which are generally the only vessel class in the vicinity of whales expressly because the whales are there.

Figures reported here for death and injury to whales as a result of ship strike may not accurately reflect the true results of impact. Death as a result of a strike was much more common than injury in our database, but this could be an artifact of most records originating with dead/stranded whales. Likewise, records may not indicate the final condition or status of an injured whale. As an example, if an animal was seen bleeding after impact, dove and was not re-sighted, it was classified as an 'injury' in our database. The whale, in fact, may have died subsequently from the injury, but a lack of information in such cases prevents a final assessment of collision impact. In any case, death or injury, such impacts are capable of delivering significant trauma to the animal.

The factors that contribute to ship strikes of whales are not clear, nor is it understood why some species appear more vulnerable than others. Nonetheless, the number of known ship strikes indicate that deaths and injuries from ships and shipping activities remain a threat to endangered large whale species, right whales in particular. We believe the compilation and presentation of these data will help in defining measures to reduce the incidence of such occurrences.

****

In an effort to use this database as an effective tool in its protection and stewardship of marine mammals, NOAA Fisheries intends to continue adding to the existing information contained in this report as additional ship strike incidents occur. If you have data to contribute relating to a large whale ship collision, please contact:

Large Whale Conservation and Recovery Program *or*
Marine Mammal Health and Stranding Program
Office of Protected Resources
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910
301-713-2322

Literature Cited

Best, P.B., J.L. Bannister, R.L. Brownell Jr. and G.P. Donovan (Eds). 2001. Report of the workshop on the comprehensive assessment of right whales: a worldwide comparison. J. Cetacean Res. Manage. (Special Issue) 2:1-60.

Knowlton, A.R. and S.D. Kraus. 2001. Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. J. Cetacean Res. Manage. (Special Issue) 2:193-208.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science, 17(1):35-75.

Figure 1. The occurrence of ship strikes in eleven whale species.

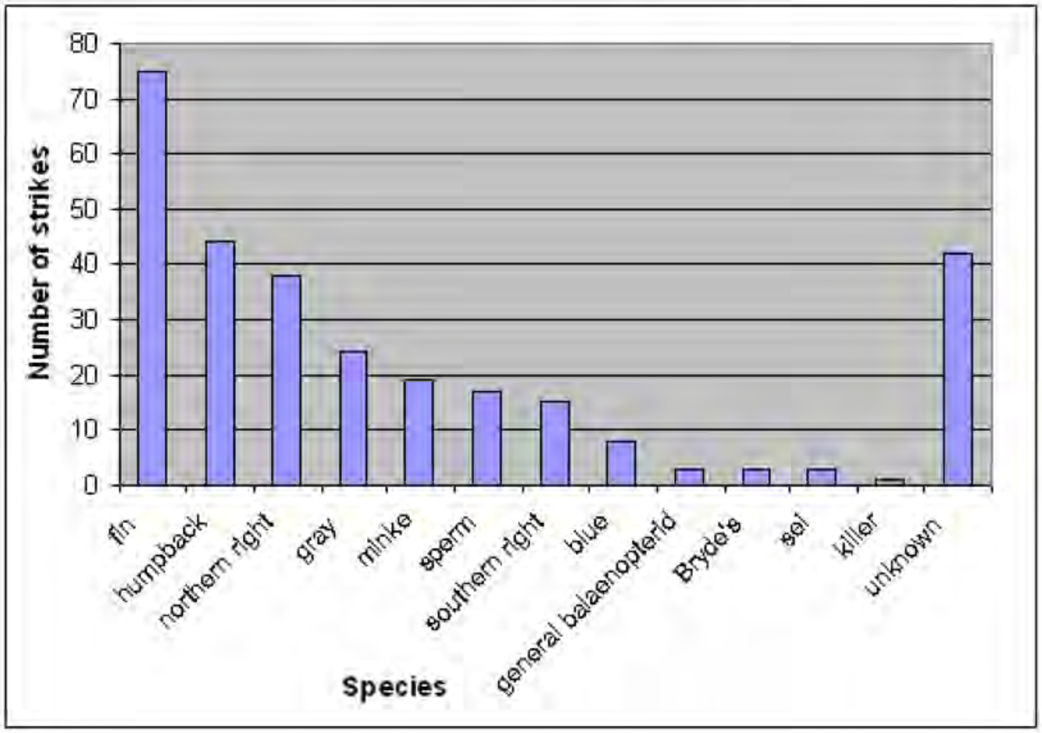


Figure 2. The geographic distribution of ship strikes to large whales world-wide.

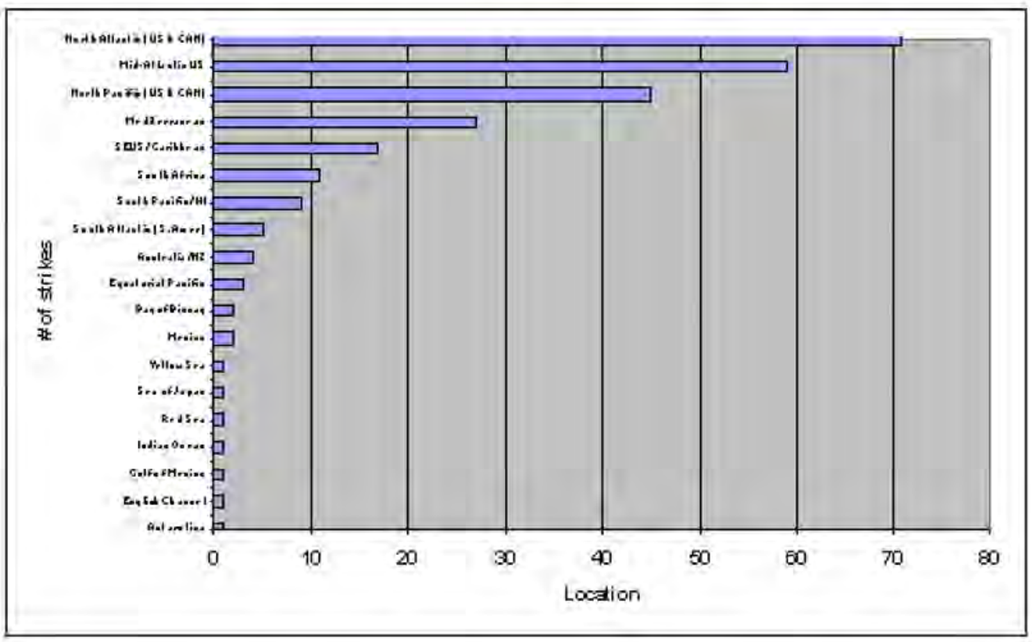


Figure 3. Distribution of vessel strikes to large whales in North America.

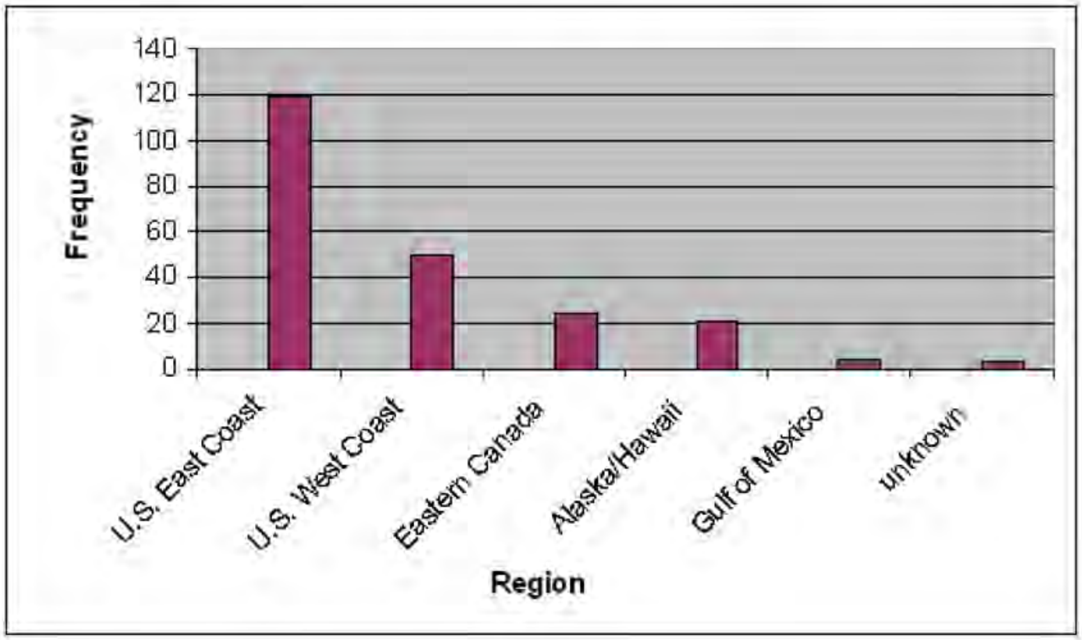


Figure 4. Result of ship strike to large whales.

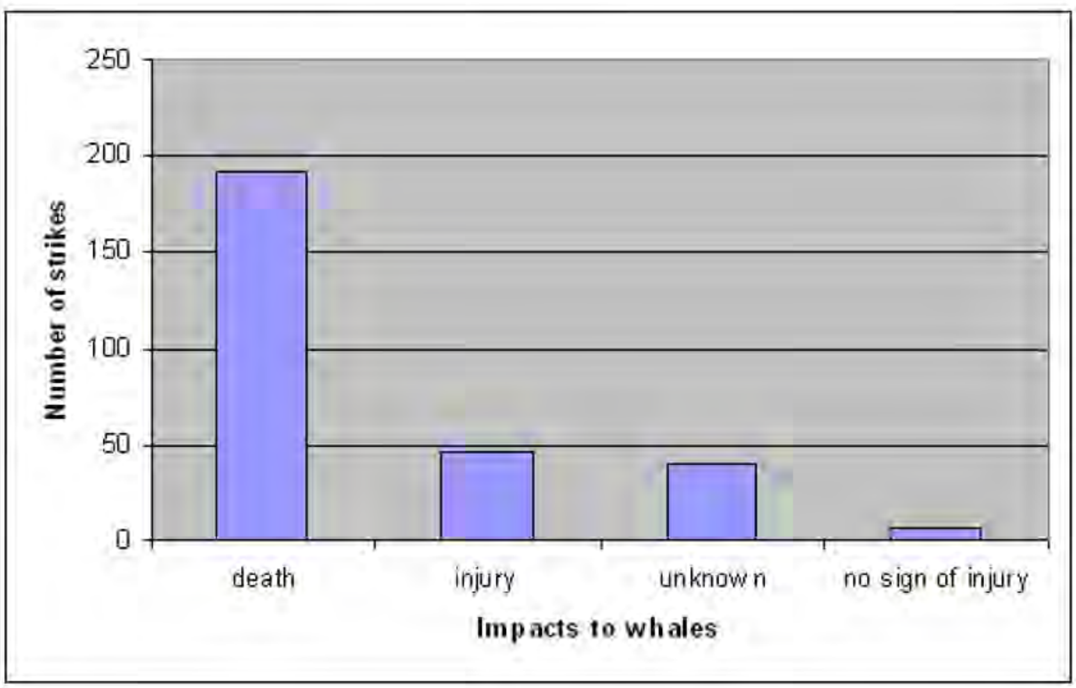
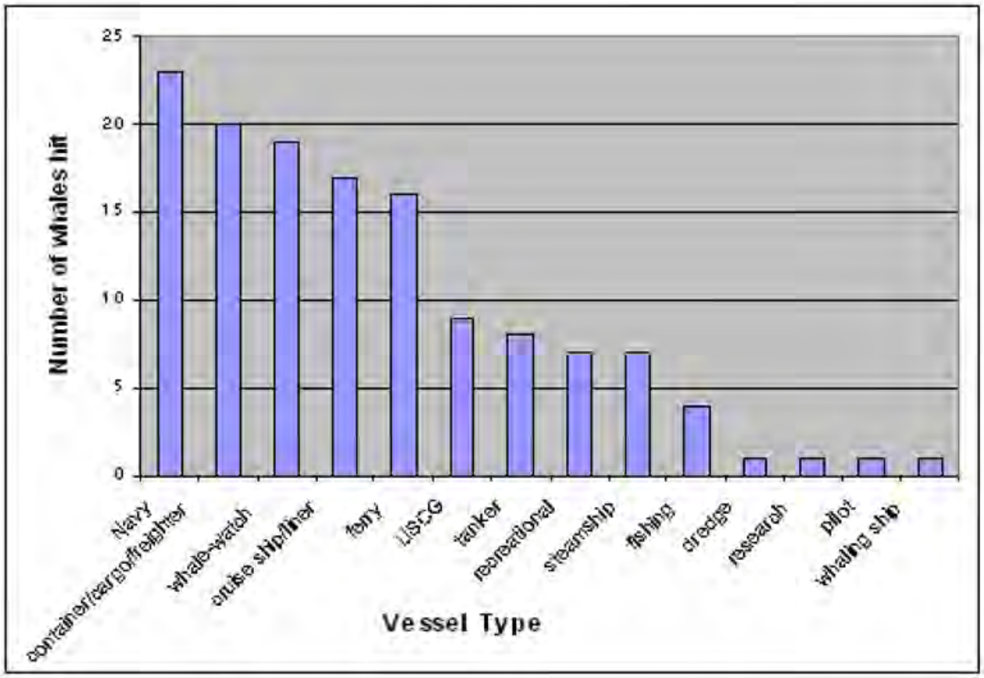
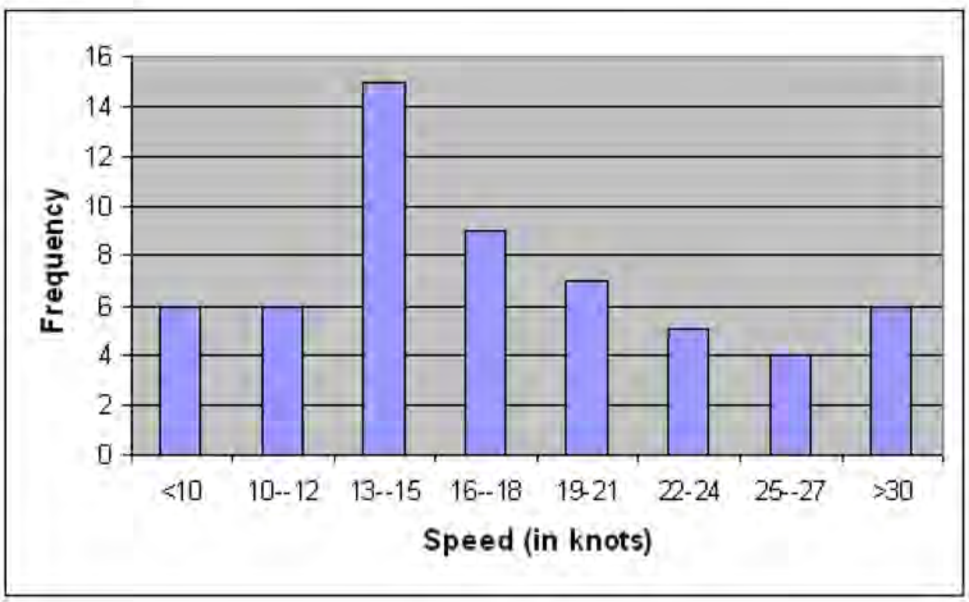


Figure 5. Types of vessel involved in collisions with large whales (where vessel type is reported).



Note: The high occurrence of Navy reports may reflect military and government reporting practice rather than an actual higher frequency of collisions relative to other ship types. Reporting struck or dead whales to NOAA Fisheries is now a part of standard operating practices for Navy and USCG.

Figure 6. The frequency of occurrence of ship speed in ship strike incidents in which ship speed was known.



Source codes and abbreviations for ship strike spreadsheet records:

* = from *Laist et al.* 2001
BO = NOAA Fisheries Biological Opinion
IML = Institute de la Mer et du Littoral, La Rochelle, France
kts = knots
MMC = Marine Mammal Commission
NEFSC = NOAA Fisheries Northeast Fisheries Science Center
nm = nautical miles
NMS = National Marine Sanctuary
NP = National Park
NWFSC = NOAA Fisheries Northwest Fisheries Science Center
NWR = National Wildlife Refuge
OLE = NOAA Fisheries Office of Law Enforcement
SICDD = Smithsonian Institute Cetacean Distributional Database
USCG = U.S. Coast Guard

Vessel names available upon request.

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
US East Coast							
02/08/02	humpback			Cape Henry, VA		mortality	
10/04/01	humpback			Approx. 5 nm NW of Stellwagen Bank, MA		injury	
06/29/01	minke/small sei		7.6	30 nm southeast of Cape Cod, inbound Boston traffic lane, MA	41-30N, 069-27.5W	mortality	
03/17/01	right			Assateague Is, VA		mortality	
02/01/01	finback			Port Elizabeth, NJ Berthing Channel		mortality	
01/02/01	finback			New York Harbor		mortality	
12/11/00	finback	F	10.8	New York Harbor		mortality	
12/04/00	humpback	M	8.5	0.5 nm offshore Cape Lookout, NJ		mortality	
07/29/00	humpback			Stellwagen Bank NMS, MA		unknown	
05/16/00	sperm			Block Canyon, NJ	39-45N, 71-07W	unknown	
05/14/00	humpback			Stellwagen Bank NMS, MA		unknown	
11/06/99	finback			Port Elizabeth, NJ		mortality	
06/23/99	minke		6 est	Near reserve channel, Boston Harbor, MA	42-19.8N, 70-60W	mortality	
04/20/99	right (Staccato)	F	13.7	6 miles N of Griffin Island, Wellfleet, MA	41-54.3N, 70-9.7W	mortality	
02/10/99	finback	M	15.5	False Cape State Park, VA	36-47N, 75.5W	mortality	
12/12/98	minke			Cape Cod Bay, MA		injury	
10/07/98	right			NC/VA state line		mortality	
09/12/98	minke		6	Barnstable, MA		mortality	
08/02/98	humpbacks			Stellwagen Bank NMS, MA		unknown	
06/07/98	2 humpbacks			Boston Harbor, MA		unknown	
05/24/98	minke			6 nm N of Race Pt, MA	42-14N, 70-10W	injury	
03/21/98	finback			Approx. 7.5 nm off Cape Henry, VA	36-5N, 75-48W	mortality	
03/21/98	finback	F	16.9	Salvo, NC	35-28.4N, 75-29W	mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
				OLE report	
whale-watch vessel		11.7		NEFSC	animal came up under keel of vessel, abrasion 1.5 ft long by 1 in wide seen anterior to dorsal fin
Navy	253	15	N	ship report	crew heard impact and felt shudder, gray and white whale observed lodged on bow, whale sank after ship backed up
				OLE report	
				OLE report	
				OLE report	
				NEFSC	from necropsy: abrasions, bruising, large hemotoma, 4 broken ribs and broken vertebral processes
				NEFSC	from necropsy: many focal hematomas on left side along ribs, but no pattern and no broken bones
				OLE report	
				OLE report	
				OLE report	
				OLE report	
				NEFSC	badly decomposed whale floating in harbor, carcass towed out to sea by MA Environmental Police
				NEFSC	mortality attributed to ship strike, necropsy points very strongly to traumatic incident that fractured the mandible
				NEFSC	from necropsy: large wound on dorsal peduncle ridge, hemorrhaging, fractured vertebrae indicative of ship strike
whale-watch vessel				NEFSC	body of whale seen in wake of whale watching vessel, blood reported
				OLE report	
whale-watch vessel	24	25	Y	NEFSC	whale swam under bow, impact felt, surfaced w/deep, bleeding gash, dead carcass sighted immediately afterward
whale-watch catamaran	36	18.3		NEFSC	whale surfaced in front of vessel, massive, fresh, bleeding wound across back from flipper to flipper
				OLE report	
				NEFSC	
				NEFSC	
				NEFSC	large hematoma evident from necropsy

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
03/03/98	blue			approaching Narragansett Bay, RI		mortality	
01/03/98	right			Georgia	30-50.7N, 81-9.6W	injury	
08/10/97	unknown			Stellwagen Bank NMS, MA		unknown	
12/10/97	humpback			Beaufort Inlet, NC	34-39N, 76-39W	mortality	
07/20/97	humpback			Cape Cod Bay, MA	42-09.6N, 069-12.9W	unknown	
06/07/97	minke			Sandy Hook Natl. Seashore, NJ	40-28N, 73-59.7W	mortality	
05/12/97	finback		12 est	Boston Harbor, MA	41-23N, 71-02.8W	mortality	
03/21/97	finback		12 est	7.5 nm off VA Beach, VA	36-50N, 75-48.3W	mortality	
11/03/96	humpback	M	8.4	Carrituk, NC	36-18N, 75-48W	mortality	
07/15/96	minke			Off Race Pt., MA		no sign of injury	
07/14/96	finback	M	13.5	Elizabeth Channel, NJ	40-41N, 74-09W	mortality	
05/09/96	humpback	F	7.3	Cape Henelopen State Park, DE	38-36.68N, 75-4.4W	mortality	
04/02/96	humpback	F	7	Cape Story Beach, VA Beach, VA	36-54N, 76-03W	mortality	
03/25/96	right	M		Wellfleet, MA		mortality, stranded	
03/09/96	right	M		MA		mortality	
02/26/96	finback	F	18 est	9 nm off Sandy Hook, NJ	40-18N, 73-46W	mortality	
01/30/96	right		13.7	10 nm east of Sapelo Island, GA		mortality	
11/14/95	finback	F	10	Below Old Cooper River, Charleston, SC	32-48N, 79-56W	mortality	
10/09/95	minke			185 km E of Cape Cod, MA		unknown	
08/13/95	right	F	adult	Gulf of Maine		unknown	
08/01/95	finback		17	48 km SE of Cape Cod, MA		mortality	
06/10/95	minke	F	3.7	Piney Point, MD	38-8N, 76-31.5W	mortality	
06/04/95	humpback	M	8.8	5 nm off Rudee Inlet, VA Beach, VA	36-49N, 75-52W	mortality	
02/01/95	unknown (right?)			Off NC		unknown	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
bulbous bow tanker	148			Ford, pers comm	whale found draped across vessel's bow by port pilot, hemorrhaging indicated whale was alive when struck
				NEFSC	entire left fluke lobe extending beyond dorsal notch severed by propeller, wound healed, status good
				OLE report	
				NEFSC	probable ship strike
USCG	82.3	20	N	USCG BO 6/8/98	humpback observed 5-10 ft under surface, thump heard, ship felt shudder, whale struck on starboard, not re-sighted
				NEFSC	from necropsy: severely decomposed, spine broken, likely ship strike
				NEFSC	floater, moderate decomposition, possible ship strike
				NEFSC	ship strike account in initial report
				NEFSC	acute trauma to skull, blunt trauma to left peduncle, likely ship strike
ferry (?)		15		NEFSC	whale hit, re-surfaced, no sign of injury
				NEFSC	ship strike (pre/post undetermined), adjacent to Maersk Shipping
				NEFSC	ship strike (pre/post undetermined)
				NEFSC	from necropsy: stranded, fractured left mandible, possible ship strike
				NEFSC	from necropsy: prop cuts along back, damaged baleen, thick area of skull broken indicating ship strike
				Best et al 2001	broken skull and 3.3 m long gash on back
				NEFSC	floater, possible ship strike
				Navy BO 5/15/97	hemorhagging, massive cranium fracturing, cervical vertebrae broken, indicates blunt trauma w/large vessel
				NEFSC	from necropsy: fractures to skull and hemorrhaging indicative ship strike
USCG	64	15	N	NEFSC	whale sighted off starboard, thud and shudder felt, not re-sighted
				Best et al 2001	cut 60-90 cm deep on right side of head below rostrum and into lower lip, orange cyamids on tail and lip edge
bulbous bow cruise ship	173			SICDD*	vibration felt while ship underway off Cape Cod, whale found on ship's bow in Bermuda with broken spine and extensive bruises
				NEFSC	stranding, large cut through skin on dorsal thorax, likely brought 12 mi up Potomac by ship
				NMFS memo	several major lacerations indicative of collision with a propeller, deepest 27cm., whale likely bled to death
Navy				Laist et al 2001	whale breached in front of submarine, struck bow, slid down vessel's starboard, may have been injured on right side

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
11/17/94	sei		15 est	Charlestown Harbor, Boston, MA		mortality	
08/15/94	minke		2	Hampton Roads, Chesapeake Bay, VA	37N, 76-21.4W	mortality	
08/04/94	right			Gulf of Maine		unknown	
07/19/94	humpback			Stellwagen Bank NMS, MA		unknown	
04/18/94	finback			Penns Grove, NJ		mortality	
04/10/94	humpback			Ocracoke, NC		mortality	
03/12/94	finback	F	16 est	Cape Henry, Chesapeake Bay, VA Beach	36-56N, 76-01.6W	mortality	
02/22/94	right whale calf			FL		mortality (presumed)	
12/31/93	right	F		East of Cape Charles, VA		mortality, floater	
12/06/93	right	M	12--22	NC/VA border, off False Cape		mortality, floater	
12/06/93	right	F		VA		mortality	
10/07/93	humpback			2 km off Atlantic City, NJ		injury	
10/01/93	minke			Sandbridge, VA		mortality	
09/27/93	minke	M	4.3	Ocean City, NJ	38-26N, 75-04.1W	mortality	
Aug-93	finback		15	Boston Harbor, MA	41-23N, 71-03W	mortality	
03/31/93	minke		7.5	New York Harbor, Staten Island, NY	40-39N, 74-03W	mortality	
01/05/93	right whale calf			In transit between Mayport and Ft. Pierce, FL	30-02.44N, 81-16.04W	mortality	
10/09/92	humpback	F	8.7	Metompkin Island, VA	37-46N, 75-32W	mortality	
07/31/92	finback	M	17	Port Newark, NJ	42N, 74.09W	mortality	
06/02/92	finback	F	15.6	Beach Haven Crest, NJ	39-36N, 74-12.5W	mortality	
04/22/92	humpback	F	9	Hatteras National Seashore, NC	35-11.4N, 75-46W	mortality	
04/16/92	humpback	F	9	Asseteague National Seashore, MD	38-10N, 75-10W	mortality	
03/15/92	minke	F	6.8	St. Johns River, FL	30-21.1N, 81-18W	mortality	
03/10/92	humpback	F	10.6	Hatteras Natl. Seashore, NC	35-20N, 75-21W	mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
container ship				NEFSC	vessel collision, came in on bow of container ship
				NEFSC	lower jaw broken, had begun to heal, possible ship strike
				OLE report	
				OLE report	
				Laist et al 2001	floating in Delaware River, broken vertebrae, blunt trauma to right pectoral fin and surrounding area
				Laist et al 2001	hemorrhaging in mandible and ventral to left pectoral
				NEFSC	flukes cut off, propeller marks in caudal area
				Best et al 2001	several deep cuts on head and lower lip regions, probable propeller cuts on both sides of dorsal flukes
				NEFSC	
				stranding report	scar on leading edge of fluke near tip and line scar along right side of mid-body, may have been pre-mortem
				Best et al 2001	carcass floating belly up w/large straight gash running from right ventral to right lateral surface anterior to flukes
sport-fishing vessel	10	>10	Y	SICDD*	animal hit while vessel accelerating, 15 min later animal observed "wobbling" while diving, blood seen in water
				Laist et al 2001	left mandible broken
				NEFSC	stranding, possible ship strike, pre/post mortem undetermined
				NEFSC	whale carried into harbor, likely ship strike
Navy				NEFSC	brought in on ship bow, reported to government as ship strike
USCG	25	15	N	Navy BO 5/15/97	calf hit, lacerations observed, carcass found 4 days later w/ 2 series of large propeller cuts from twin engine
				NEFSC	stranding, extensive bruising on right side, internal hemorraging on left flank, ship strike
				NEFSC	from necropsy: moderately decomposed, fractured vertebrae mid-section, death due to ship strike
				NEFSC	stranding, several fractured vertebrae, possible ship strike
				NEFSC	stranding, internal damage extensive, possible ship strike
				NEFSC	stranding, skull disarticulated, blunt trauma left side, possible ship strike
				NEFSC	propeller wounds from large vessel
				NEFSC	stranding, net scars on caudal peduncle, possible propeller wounds on fluke

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
02/14/92	humpback	M	8.6	Floating in mouth of Chesapeake Bay, Virginia Beach, VA	36-59N, 76-08W	mortality	
11/08/91	humpback	M	9	Island Beach State Park, NJ	39-50N, 74-05W	mortality	
08/08/91	unknown			25 nm south of Martha's Vineyard, MA		unknown	
07/06/91	right whale calf		4.6	East of Delaware Bay, DE	38-21.30N, 73-06.30W	mortality	
06/21/91	humpback			Stellwagen Bank NMS, MA		injury	
03/12/91	right	F	2 years	Off FL		mortality	
02/11/91	right	F	calf	Southeast US		injury	
11/25/90	finback	F	13	Curtis Bay, Baltimore, MD	39-40N, 76-40W	mortality	
06/08/90	humpback			Stellwagen Bank NMS, MA		unknown	
02/05/90	humpback		11	S of 18 m marker, Nags Head, NC	35-56.5N, 75-36.5W	mortality	
07/14/89	finback			North Kingstown, RI		mortality	
05/13/88	minke			Duxbury Beach, MA		mortality	
05/13/88	sei			Baltimore, MD		mortality	
05/04/88	finback			Deal, NJ		mortality	
01/15/88	finback			Marshfield, MA		mortality	
08/18/87	finback			Boston, MA		mortality	
02/14/87	right	F	calf	Southeast US		injury	
08/07/86	right	F	1 year	Massachusetts Bay, MA		mortality	
07/02/86	finback			Delaware River, NJ		mortality	
05/06/86	finback			Hoboken, NJ		mortality	
08/27/85	finback			Montauk, NY		mortality	
07/13/85	finback			Stellwagen Bank NMS, MA		unknown	
Aug-84	finback			Stellwagen Bank NMS, MA		injury	
03/07/84	finback			Baltimore, MD		mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
				NEFSC	floater, propeller wounds, fractured mandible and eye socket, possible ship strike
				NEFSC	3 propeller cuts observed on head, one cut fractured the right occipital condyle
				OLE report	
USCG	84	22	Y	Navy BO 5/15/97	2 whales 50 yds off bow, calf rolled out from ship w/propeller gashes on body, sank rostrum up, obviously dead
whale-watch vessel	14	5-10		Sullivan and Young*	bow struck and rode up over whale, fresh nick observed between nares and dorsal fin, subsequently re-sighted healthy
				Best et al 2001	from necropsy: shattered skull from ship strike
				Best et al 2001	series of 3 propeller cuts, maximum 1.2 m long x 15 cm deep on left flank
				NEFSC	apparent boat/ship collision, whale likely killed shortly before being found, ship strike mark mid-lateral left side
				OLE report	
				NEFSC	broken mandible, head damage
				SICDD*	stranding record, fractured lower jaw
				SICDD*	stranded, one large gash and three smaller gashes
				SICDD*	brought in on bow of ship, damaged skull
				SICDD*	boat hit, found floating
				SICDD*	identified as possible ship collision
				SICDD*	folded in half forward of dorsal fin on right side, likely brought into port on bow of ship
				Best et al 2001	series of 5 propeller cuts approx 30 cm long and 8 cm deep on left fluke tip
				Best et al 2001	2 propeller cuts, max. 4.5 m long x 1 m deep running longitudinally along body, severed spine
container ship				SICDD*	reported as struck by container ship
cruise ship				SICDD*	brought into port on bow of ship
				SICDD*	floating with propeller slashes, possible ship strike
				OLE report	
whale-watch vessel	28	16		Weinrich*	whale surfaced immediately in front of vessel, after collision whale was not resighted but blood seen in water
				SICDD*	brought into port on bow of ship, bruising evident

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
10/14/83	finback			Fire Island, NY		mortality	
07/31/83	finback			Manhattan, NY		mortality	
02/21/83	right	M	2 years	New Jersey		mortality	
01/24/83	finback			Norfolk, VA		mortality	
01/25/83	finback			Norfolk, VA		mortality	
08/02/82	finback			Elizabeth City, NJ		mortality	
03/31/81	finback			Norfolk, VA		mortality	
08/13/80	right	M		In transit between Mayport and Ft. Pierce, FL		injury	
05/25/80	right	M		Great South Channel, MA		injury	
10/18/79	finback			Baltimore, MD		mortality	
03/05/79	right	M	juv	NY		mortality	
11/05/76	right			ME		mortality	
04/15/76	right	M	calf	MA		mortality	
07/08/75	minke			Boothbay, ME		mortality	
winter 1972	right (possibly)			Approx 97 km E of Boston, MA		mortality	
Aug-52	unknown		15	139 km of Montauk, Long Island, NY		unknown	
1940-45	sperm			North Atlantic		mortality	
1940	baleen whale			Off Cape Hatteras, NC		mortality	
1926	unknown			North Atlantic		mortality	
1912-1915	unknown			Off U.S. East Coast		mortality	
1906	unknown			Off Chatham, MA		injured?	
1896	sperm whale?			Off Sandy Hook, NJ		mortality	
1885	unknown			32 km E of Nantucket, MA		injury	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
				SICDD*	slashes on ventral side, possible ship strike
				SICDD*	brought into port on bow of ship
				Best et al 2001	severed tail
				SICDD*	brought into port on bow of ship, bruising evident, reportedly hit off New York
				SICDD*	floating near harbor, bruising evident
				SICDD*	brought in on bow of ship, hit off Boston, MA
				SICDD*	brought into port on bow of ship, later determined to have been hit off Atlantic City, NJ
				Best et al 2001	series of 8 propeller cuts running along left flank and over back, max. 1.2 m length x 15 cm deep
				Best et al 2001	cut along back crossing spine, 1.5 m long x 15 cm deep
Russian cruise ship				SICDD*	brought into port of bow of ship
				Best et al 2001	tail severed
				Best et al 2001	severe lacerations observed on back
				Best et al 2001	large area of bruising observed behind skull, noted as probable ship collision
				Laist et al 2001	stranded, body heavily bruised
bulbous bow container ship	207	21-23		Murphy II*	noticed whale draped across ship's bow in harbor, realized slow speed during night due to impaled animal
Navy	93	14	Y	in Laist et al 2001	whale seen off port, submerged a few seconds before impact, severe damage to vessel
Navy				Slipjer 1962*	
tanker				Burgess 1940*	
ocean liner				Laist et al 2001	
steamship				Laist et al 2001	
steamship				Laist et al 2001	
ocean liner				Laist et al 2001	
pilot boat		13	N	Laist et al 2001	vessel's port bow collided w/whale, whale then seen rolling as if in distress

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
Eastern Canada							
09/27/97	humpback			St. Lawrence Estuary, Canada		injury	
08/19/97	right	F		Bay of Fundy, Canada		mortality	
09/27/00	right	F		Bay of Fundy		injury	
07/23/00	finback				41-52N, 71-22W	unknown	
07/08/00	right	M		Bay of Fundy, Canada		unknown	
10/19/95	right	M		Bay of Fundy, Canada		mortality	
09/26/95	minke			Bergeronnes, St. Lawrence Estuary, Canada		unknown	
09/16/95	right	M	4 years	Bay of Fundy, Canada		injury	
08/14/94	finback			Tadoussac, St Lawrence Estuary, Canada		injury	
07/29/93	finback			Bergeronnes, St. Lawrence Estuary, Canada		injury	
09/05/92	right	F	adult	Bay of Fundy, Canada		mortality	
06/20/92	finback			Tadoussac, St. Lawrence Estuary, Canada		injury	
08/28/87	right			Browns Bank, Canada		injury	
07/09/87	right	M	juv	Nova Scotia		mortality	
08/14/86	right	F		Bay of Fundy, Canada		mortality (presumed)	
08/05/84	right			Browns Bank, Canada		mortality	
10/09/67	unknown		15-18	Gaspe, Quebec, Canada		mortality	
Jul-67	unknown			South of Halifax, Canada		mortality	
1913	unknown			Off Newfoundland, Canada		unknown	
1910	unknown			North Atlantic		mortality	
1908	sperm			Off Newfoundland, Canada		mortality	
1908	unknown			Off Newfoundland, Canada		mortality?	
1904	unknown			Atlantic Ocean		mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
whale-watch vessel				Menard*	vessel struck humpback after it surfaced off bow, whale much less active and appeared injured after collision
				Best et al 2001	from necropy: 6 m long haematoma on left side and broken right mandible, no external sign of injury
				NEFSC	seen in July quite healthy, re-sighted in September with deep wound on left side of head
				OLE report	
				NEFSC	seen repeatedly w/ large deep gash on back, wound appears to be from ship strike between 09/99--07/00
				Best et al 2001	4.8 m long gash in back, broken vertebral disks
whale-watch vessel	11	>30		Laist et al 2001	rigid-hulled pneumatic craft collided w/whale, captain could not see directly in front due to high bow
				Best et al 2001	series of propeller cuts, max. 1 m long x 8 cm deep on tail stock and tail, fishing gear through mouth
whale-watch vessel				Laist et al 2001	vessel reported colliding w/whale, hull vibrated, wound seen on animal
whale-watch vessel				Menard*	whale surfaced and struck bow of vessel, wound subsequently observed on animal's back
				Best et al 2001	necropy revealed internal haemorrhaging from impact w/ship, no external sign of injury
whale-watch vessel				Menard*	vessel collided w/whale while whale-watching, wound visible on animal's back in front of dorsal
				Best et al 2001	1 m of right fluke tip missing, severed by propeller
				Best et al 2001	2-3 propeller cuts on left flank, 20-25 cm deep, shallow gash and swelling on right flank
				Best et al 2001	1 m diameter necrotic wound approx 1 m behind blowholes
				Best et al 2001	series of 5 propeller cuts, approx 60 cm long x 10 cm deep on left flank and near spine
passenger ship	232			in Laist et al 2001	whale observed impaled on ship's bow, animal nearly cut in half as vessel backed to dislodge
Navy	219			Cummings*	whale stuck on bow after vessel speed registered too slow, whale sank when vessel backed down to remove it
cargo ship				Laist et al 2001	
steamship				Laist et al 2001	
ocean liner				Laist et al 2001	
ocean liner				Laist et al 2001	
steamship				Laist et al 2001	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
1903	unknown			Placenta Bay, Newfoundland, Canada		unknown	
US and Canada West Coast							
11/04/02	finback	M	16	Off Waldron Island, WA		mortality	
10/02/02	finback		18.5	Cherry Point, WA		mortality	
08/09/02	finback		17	Elliot Bay, Seattle, WA		mortality	
07/17/02	blue		22-25	8 mi NW of Point Benito, San Fran, CA		mortality	
10/10/01	balaenopterid		15	4.5 mi south of San Nicolas Is., CA		mortality	
08/21/01	balaenopterid	F	15	Los Angeles Harbor		mortality, stranded	
08/20/01	unknown			Channel Islands, 25 nm off San Clemente Is., CA	32-23.5N, 118-50.3W	injury	
08/15/01	unknown			Channel Islands off San Clemente Island, CA	32-34N, 118-25W	injury	
07/28/01	unknown			10 mi off Solana Beach, San Diego, CA		unknown	
01/09/01	gray		3.6	3 mi offshore Montana de Oro State Park, CA	35-20N, 120-56W	injured	
05/28/00	humpback	F	12	Fiddler's Cove, south of Pescadero State Beach, CA		mortality, stranded	C 124
03/19/00	gray	M	12	2 mi W of Orick, Redwood National Park	41-15N, 124-00W	mortality, stranded	VM 2388
12/19/99	gray	M	12	Muir Beach, Golden Gate National Recreation Area		mortality	C 101
05/05/99	unknown			3 nm offshore, Davenport, CA	36-56.8N, 122-05.08W	unknown	
04/30/98	gray	F (juv	12	Stinson Beach, Marin County, CA		mortality, stranded	C 84
04/28/98	gray		6 est	En route to San Diego, CA	32-43N, 117-24W	mortality	
04/24/98	gray		9 est	CA	31-58N, 118-35W	mortality	
01/02/98	gray		12 est	San Pedro, LA county, CA	33-14N, 118-08W	injury	
01/23/99	gray		7.6	Off N Coronado Is, 5 mi from west end, CA		unknown	
01/07/98	gray calf	F	4.5	Crescent City Harbor, CA		injury	C 79
08/31/97	unknown			Dixon Entrance, Canadian waters		unknown	97045
03/25/97	gray		6 (w/o head)	Vandenberg Airforce Base, 1.5 mi N of Purisma Pt., CA		mortality, stranded	VAFB 97-01

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
steamship				Laist et al 2001	
				San Juan Islander	necropsy indicated blunt trauma through massive hemorrhaging, symmetrical fractures, displaced spine
tanker	46,100 gr tons			NWFSC	ship was en route from Valdez, AK, strike was pre-mortem
container ship	75			NWFSC	whale brought in on bow of ship, gored, strike was pre-mortem
				NOAA Fisheries	four dorsal propeller gashes, animal eviscerated by encounter
freighter				stranding report	animal initially sighted w/2 other whales prior to vessel collision w/freighter
				stranding report	carcass floating on back, 35 ventral grooves visible, large gash in gular region
Navy	57.3			stranding report	diving whale observed off starboard, shudder felt, blood observed in water, whale not resighted
Navy	153.9			stranding report	whale rolled over after collision, disappeared under ship, blood observed in water, whale not resighted
Navy	133	21		stranding report	prior to strike, whale observed 30 yds. off bow, after strike whale surfaced off port bow and swam away, no blood observed
				stranding report	animal sighted thrashing at surface, flukes completely severed, bleeding, final status unknown
				stranding report	skull smashed, suspect ship strike
				stranding report	large gouge on dorsal surface behind blowhole, blood on palate and coming from blowhole
				stranding report	carcass first found floating under Golden Gate Bridge on 12/18/99, rumor of boat strike
USCG				stranding report	ship hit whale and it breached 2-3 times, no blood observed, no animal found on revisitation of site
				stranding report	blood pouring from mouth in surf, then stranded on beach w/massive hemorhage in thoracic cavity
Navy	153.9	22	N	stranding report	whale sighted at 2000 yds, 10 min later ship shuddered, whale observed wrapped around upper bow stem, then sank
Navy	172.8	14		stranding report	whale sighted 1 nm off bow, 1.5 hrs later whale found wrapped around bow, ship backed down, whale sank
USCG	25			stranding report	collision resulted in six 1-ft gashes in animal's side, final status unknown
				stranding report	eyewitness account; animal appeared stunned after collision but no blood observed, animal swam away
				stranding report	calf bleeding profusely on dorsal side, believed to be propeller wound
cruise ship	214			stranding report	called in by passenger, audible sound of boat strike as whale surfaced directly in path of vessel
				stranding report	apparent clean cuts indicating vessel collision, head and left flipper missing

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
02/15/97	unknown			11 mi off Catalina Island, CA		injury	
02/11/97	finback		7.6	LA harbor, CA	33-44.30N, 118-17.00W	mortality	JEH 483
09/17/96	finback		14.5 est	Huntington Beach, CA		mortality	
03/07/95	gray			2.5 mi SE of Point Loma, San Diego, CA		unknown	
03/05/95	humpback		15	Westminster St., Venice, CA		mortality, stranded	JEH 465
01/02/95	gray			Off Anacapa Island, Channel Islands, CA		unknown	
05/14/94	gray		7.6 est	Pismo Beach, San Luis Obispo, CA	35-00N, 120-30W	mortality, stranded	MZH 0005
08/02/93	blue	F	24.4	San Nicolas Island, west end, Ventura County, CA		mortality, stranded	TDL 169
04/06/93	gray			En route from San Diego to Dana Pt, CA		injury	
08/12/91	finback	M	13.5	LA harbor, CA	33-44N, 118-16W	mortality	JEH 434
08/06/91	gray		10.7	8 mi off Oceanside, San Diego County, CA	33-08N, 117-31W	mortality	
04/13/91	gray	F (juv)	9.6 est	Point Richmond, East Bay Regional Park, CA	37-55N, 122-21W	mortality, stranded	JC 1
04/03/91	gray	M	12	Hamilton Air Force Base, Marin County, CA	38N, 122W	mortality, stranded	RLD 382
04/17/91	gray	F	11.4	San Francisco Bay NWR, north of Dunbarton Bridge, CA	37-31N, 122-06W	mortality, stranded	
06/15/90	unknown			Open water S of Clemente Island, Channel Islands, CA	32-39N, 117-47W	unknown	
05/31/90	unknown		12	Open water S of Clemente Island, Channel Islands, CA	32-48.2N, 118-44.7W	mortality	
late 1980's	finback		20	Seattle, WA		mortality	
06/11/89	blue		20	Tacoma, WA		mortality	
03/05/88	gray			Outside Los Angeles Harbor, CA		unknown	
01/11/88	gray	F	8 (juv)	Towed to NMFS dock, Marin County, CA		mortality	RLD 266
08/03/87	blue	F	14	Long Beach Pier J container terminal, CA		mortality	JEH 360
05/02/87	gray	F	11.5	Ft. Baker, Sausalito, Marin County, CA		mortality	RLD 187
02/14/87	gray	M	4.3	SE side of Ventura River, CA		mortality	87-2
01/24/85	unknown			Off southern CA		injury	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
rubber inflatable	6	34.8		stranding report	blood in water after collision, injury assumed
freighter or container				stranding report	carcass brought in on bow of unknown freighter or container ship, head and tail missing
freighter				stranding report	animal brought in to harbor on bow of freighter
24-ft runabout, private				stranding report	eyewitness account, animal hit in tail stock area, no apparent injuries
				stranding report	boat collision
whale-watch vessel				stranding report	eyewitness account, whale initially exhibited erratic behavior when hit, then swam away, no blood observed
				stranding report	possible propeller marks
				stranding report	large hematoma on lower right jaw & gular region, 3-5 cuts through ventral pleats indicated propellers, apparent ship strike
Navy	19.8	22	Y	OLE report	whale received 7 x 3-4 in slice along back, circled after collision, bleeding profusely, rolled over, stopped moving
American President Line				stranding report	whale hit by ship north of LA harbor and brought in draped across bow
Navy				stranding report	animal suffered 7 x 3 x 4 in gash on dorsal surface from propeller, bled profusely after collision, then floated belly-up
				stranding report	6-7 fresh cuts on back, appeared to have been made by propeller
				stranding report	5 cuts on right side and dorsal, appear to have been made by propeller
				stranding report	possible vessel collision
Navy				stranding report	vessel collided w/whale, large blood pool observed, survival not probable
Navy	133.5			stranding report	ship struck left side of whale, large portions of whale's remains floated at surface in large pool of blood, then sank
container ship				Ford, pers comm	ship en route from Japan arrived in harbor with whale draped across bow
container ship				Ford, pers comm	whale found draped across bow of ship arriving from southern California
tanker				Laist et al 2001	pod of whales seen directly ahead, dove to avoid ship, last whale to dive was hit, ship did not change course or speed
				stranding report	whale killed by large ship's propeller which severed spinal cord dorsally at skull's occipital
container ship	176			stranding report	hit in Santa Barbara Channel, pushed into harbor
				stranding report	evidence of vessel collision, wound from large ship's propeller
				stranding report	propeller lacerations (4) through dorsal vertabra and base of tail
Navy	126		Y	Tucker in Laist 2001	crew noted back and tail of large whale, large pool of blood astern, increase in aft vibration

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
10/24/80	blue		18	North Pacific		mortality	
01/22/75	gray			Off Pt. Loma, CA		mortality	
12/26/73	orca		calf	Strait of Georgia, B.C., Canada		injury	
11/29/65	sperm			200 km W of San Francisco, CA	37-30N, 123-31W	injury	
Alaska and Hawaii							
04/04/02	humpback			Several nm off Maalaea Harbor, Maui, HI		no sign of injury	
07/16/01	humpback	F		Glacier Bay NP, AK		mortality	
06/19/01	humpback			Dixon Entrance, AK	54-40N, 130-49W		
02/13/01	humpback		5--6	1.5 nm E of Olowalu Pt, Maui, HI	20-46.74N, 156-35.96W	injury	
02/08/01	humpback			2-3 nm S of Club Lanai, HI		injury	
08/16/00	finback			Uyak Bay, AK	57-38.5N, 153-55.9W	no sign of injury	
11/02/99	humpback			Metlakatla, AK		unknown	
07/28/99	humpback		10.6-13.7	Stephens Passage, 60 nm S of Juneau, AK		mortality	
06/04/99	finback		20	Vancouver, Canada		mortality	
03/06/99	humpback		calf	Waters between Maui and Lanai, HI		injury	
02/16/99	humpback		juv	2 mi S of Magregor Point, Maui, HI		injury	
09/24/98	humpback		18	North Pass, outside Juneau, SE AK		unknown	
08/11/98	humpback			North Pass, outside Juneau, SE AK		no sign of injury	
03/30/98	unknown		3.6	Near Pearl Harbor, HI	21-18.01N, 157-57.51W	unknown	EN-98-06-OH
10/12/97	sperm		12-15 est	60 mi SW of Middleton Is, Prince William Sound, AK		no sign of injury	
07/12/97	humpback			NW Shelter Is, outside Juneau, AK		injury	
05/30/97	unknown			Resurrection Bay, Prince William Sound, AK		unknown	
05/20/97	gray	F	10.9	1/4 mi S of Kah Shakes Cove, AK	55-02.00N, 13-00.00W	mortality	
05/16/96	unknown			Blying Sound, Gulf of Alaska, AK	59-23N, 145-09W	injury	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
bulbous bow freighter	174			Laist et al 2001	whale drifted free of bow upon arrival in harbor, thought to have been on bow for at least 5 days
Navy	72 tons	51	Y	Laist et al 2001	ship hit whale, vessel came to dead stop w/i 30 m, next day dead whale w/severed tail stranded near collision site
commercial ferry	152	15-18	N	Ford et al 1994*	crunch heard at ship's stern, blood in wake, bull, cow and 2 calves, 1 calf bleeding profusely from visible prop slashes
whale catcher boat	41		Y	Cummings*	vessel approached cow/calf pair, female dove and was hit while surfacing, thrashing whale seen in boat's wake
whale-watch catamaran	19.8		N	OLE report	vessel in neutral, whale surfaced underneath and lifted right stern of vessel several inches
				OLE report	
USCG	33.5	12		stranding report	whale surfaced 10 ft in front of vessel, ship backed down and came to all stop, crew heard thump
whale-watch catamaran	19.7	17	N	OLE report	bump felt on starboard, vessel heeled slightly, young whale surfaced 75 yds away in wake, no blood observed
whale-watch inflatable raft	13.2	15.6	N	OLE report	whale surfaced in front of vessel and was struck by keel, dove and swam away, blood seen in water
USCG	33.5	17		stranding report	whale surfaced and vessel came down on top of it, animal appeared to be uninjured and swam away
Bayliner pleasure craft				stranding report	vessel struck whale while underway, skin left on bow, status unknown
cruise ship	243.8	19	N	stranding report	vibration felt while underway, whale observed wrapped around ship's bow, came loose and sank when ship slowed down
cruise ship	259.7			Ford	ship arrived in harbor en route from Alaska, carcass draped across bow, captain and crew unaware of strike
high speed ferry	16.8			OLE report	vibration from strike felt on vessel, blood in wake as calf surfaced and disappeared, adult whale surfaced and dove
Bertram fishing charter	9.4	12	N	OLE report	boat made contact w/whale, animal surfaced w/blood in water then dove, cut observed on back behind dorsal fin
Bayliner	7.3	12	Y	stranding report	whale surfaced under bow as boat crossed its back, spasmed and dove, knocked vessel and cracked its hull
whale watch catamaran	23.8	2 (rev idle)		stranding report	whale surfaced under catamaran while idling, no evidence of injury
Navy	110.3	8	N	Navy report	whale crossed 20 ft in front of ship's bow back and forth, vessel struck animal on 2nd crossing, animal swam away
fishing vessel		6	N	stranding report	captain reported whale hit on tail, seemed unharmed, went back to feeding
skiff				stranding report	whale hit skiff, turning it over and dumping two people into water
whale-watch vessel	18	20	Y	NMFS memo	large whale surfaced in front of vessel, captain throttled down but whale hit hard, not seen after collision
				stranding report	deep gash on top of head indicative of vessel strike injury
USCG	115	15	N	NMFS memo	whale surfaced 50 yds off vessel, attempt to turn unsuccessful, impact felt, blood in water, no carcass

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
01/16/96	humpback			Off Kihei, Maui, HI		no sign of injury	
06/01/95	unknown			Summer Sound, Southeast AK		injury	
US Gulf Coast							
04/10/99	right			Unknown		unknown	
10/23/98	sperm			Ocean Shore Blvd, Ormond, FL	29-21.1N, 81-4.5W	mortality	
07/22/97	minke					unknown	
12/20/96	finback	M	14	Floating at port dock	32-07.3N, 81-07.9W	mortality	
02/19/94	humpback		8.2	Gulf, Gordon Pass, FL	26-8N, 81-48W	injury	
04/09/90	sperm	F	8.4 est	Grande Isle, LA	29-15N, 89W	mortality	
04/16/91	unknown			Off Key West, FL		unknown	
30-Jan	right		calf	Texas		mortality	
International							
08/07/02	sperm		9	30 nm south of Marquesas	23-56.3N, 82-06.5W	injury	
07/22/02	southern right	M	adult	Argentina		mortality	
06/18/01	sperm			20 mi south of Puerto Rico, Caribbean Sea		mortality	
02/28/01	humpback			Off Enterprise Island, Antarctic Peninsula, Southern Ocean		no sign of injury	
02/01/00	humpback	N/A		Off Antarctic Peninsula, Southern Ocean		injury	
01/11/00	Bryde's	N/A	12.4	SW of Bonaire, Caribbean Sea		mortality	
08/05/98	unknown	N/A		Mediterranean, Nice Harbor, France		unknown	
07/10/98	southern right	F	calf	Die Dam, Quoin Point, S. Africa		mortality	
1997	sperm	F	cow/calf pr	Canary Islands	28-11N, 15-32W	mortality	
08/09/97	sperm			Ischia, Campania, Italy		mortality	
07/31/97	minke			Genova, Liguria, Italy		mortality	
02/24/97	finback	M	5.2	Mediterranean Sea, Marseille		mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
whale-watch catamaran	25	9	N	OLE report	vessel came down on top of whale (three in close pod)
fishing vessel	27	9	N	Laist et al 2001	vessel struck whale head-on along port bow, whale observed swimming in circles before contact w/animal lost
				OLE report	
				NEFSC	head detached, possible boat propeller scar
Navy	169.5			Navy memo	
				NEFSC	found on ship's bow
				NEFSC	propeller wounds, seen from 2/19-2/21 swimming normally, likely ship strike
				NEFSC	deep cuts on dorsal surface indicate the ship strike was probably pre-mortem
Navy	24	<40	Y	Tucker*	ship struck whale, extensive damage to vessel, cost $1 million
				Best et al 2001	body severed approx 1 m forward of tail stock
				USCG	whale's pectoral fin cut in half, swimming slowly, fate unknown
				NMFS	
Navy	154	27	N	MMC letter	commanding officer felt shudder on impact, large blood slick in ship's wake, found dead whale upon circling back
inflatable zodiac	5.8	13-15	N	ship report	two whales surfaced immediately in front of zodiac, one hit just below dorsal fin, no sign of blood in water or injury
passenger ship	118	14.3	N	Wikander*	2 whales surfaced 14 m off bow, 1 came up directly under bow and was hit w/loud thud and shudder, blood in water
cruise ship	214	22	N	De Meyer*	harbor master observed whale on ship's bow, time/location of collision determined from decrease in speed during night
high-speed ferry		30	Y	Collet*	vessel hit unidentified whale
				Laist et al 2001	tail cut off
commercial ferry	100	25		Andre*	cow/calf pair resting at surface, loud sound heard, bodies of both animals observed behind vessel amidst blood
				Laist et al 2001	stranded, 3 deep wounds
				Laist et al 2001	stranded w/fractured skull
				Laist et al 2001	stranded, large hematoma on right side of thorax, possible ship strike

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
01/24/97	sperm			Messina, Sicily, Italy		mortality	
07/28/96	southern right		14.6	Scarborough, Cape Peninsula, S. Africa		mortality	
07/26/96	finback	M	14	Mediterranean Sea, between France and Corsica		mortality	
09/26/95	finback	F	18	Mediterranean Sea, Fos sur Mer		mortality	
05/25/95	finback			Livorno, Tuscany, Italy		mortality	
06/17/95	blue			Approaching Hauraki Gulf, New Zealand		mortality	
06/17/95	finback			Shearness Harbour, Kent, United Kingdom		mortality	
11/10/94	southern right		10.7 juv	Shell Bay, St. Helena Bay, S. Africa		mortality	
10/31/94	unknown			22 km W of Niigata, Japan, Sea of Japan		injury	
09/22/94	southern right		11 juv	Kabeljoubank, Breede River, S. Africa		mortality	
07/19/94	finback	M	14.5	Atlantic Ocean, English Channel, Le Havre		mortality	
05/20/94	finback			Cagliari, Sardinia, Italy		mortality	
1994	sei			Approaching Hauraki Gulf, New Zealand		mortality	
10/10/93	southern right	F	calf	Lekkerwater, De Hoop, S. Africa		mortality	
Oct-93	southern right			Rio Grande do Sul, Brazil		mortality	
09/09/93	finback			Mediterranean, St. Tropez, France		mortality	
09/09/93	finback	F		Mediterranean, Toulon Harbor, France		mortality	
08/16/93	southern right		calf	Between Long Beach and Koppie Alleen, S. Africa		mortality	
1992	southern right			Rio Grande do Sul, Brazil		unknown	
05/15/92	bryde's		12	Bass Strait, Australia		mortality	
04/04/92	unknown			19 km W of Callao, Peru		injury	
Feb-92	sperm			Canary Islands	27-56N, 14-34W	mortality	
1991	southern right			Rio Grande do Sul, Brazil		mortality	
05/13/91	finback	M	18.8	Atlantic Ocean, Bay of Biscay, Donges		mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
				Laist et al 2001	stranded w/propeller wounds, fractured skull
				Laist et al 2001	broken rostrum and missing skull bones
ferry				Laist et al 2001	brought into port on bow of ship
merchant ship				Laist et al 2001	brought into port on bow of ship
				Laist et al 2001	brought into port on bow of ship, fractured jaw and other wounds
container ship				Ford, pers comm	ship entered Auckland harbor with whale on bow
container ship				Ford, pers comm	whale found wrapped around bow in harbor, pre- or post-mortem strike undetermined
				Laist et al 2001	diagonal slashes across genital aperture
high speed jetfoil ferry	31			Honma et al. 1997*	after collision, tissue and bone indicative of marine mammal removed from waterjet suction pipe at vessel stern
				Laist et al 2001	cuts across back
merchant ship	190			Laist et al 2001	brought into port on bow of ship
				Laist et al 2001	stranded w/propeller wounds on right side, fractured right flipper
container ship				Ford	ship entered Auckland harbor with whale on bow
				Laist et al 2001	tail cut off
				Best et al 2001	whale stranded w/4 propeller cuts on tail stock
				Laist et al 2001	hit by ship, seen floating at sea
bulbous bow ferry	159	20		Collet*	crew felt shock and strong vibrations, decrease in vessel speed, 3 hrs later observed whale caught on bow in harbor
				Laist et al 2001	tail cut off
				Best et al 2001	trawler reported striking a right whale
bulbous bow container ship	121	14		Wapstra*	whale found draped around hull upon entering harbor, necropsy indicated whale alive when hit
research vessel	89	14	N	Ainley*	shudder was felt, blood seen in ship's wake, numerous whales seen in area nearby
high speed ferry	20	45		Andre et al. 1997*	collision resulted in death of one passenger
				Best et al 2001	two halves of right whale found approx 1/2 mile apart
tanker				Laist et al 2001	brought into port on bow of ship, broken jaw

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
04/30/91	finback			Genova, Liguria, Italy		mortality	
28-Apr	finback			Porto Torres, Sardinia, Italy		mortality	
1989	southern right		juv	Rio Grande do Sul, Brazil		mortality	
05/20/89	finback			Olbia, Sardinia, Italy		mortality	
09/07/88	southern right	M	14.1	7 km outside Port Elizabeth Harbor, S. Africa		mortality	
01/16/88	sperm			Cagliari, Sardinia, Italy		mortality	
05/22/87	finback			Olbia, Sardinia, Italy		mortality	
04/27/87	sperm			Savona, Liguria, Italy		mortality	
11/06/86	finback		16	Mediterranean Sea, Fos sur Mer		mortality	
06/28/86	finback			Livorno, Tuscany, Italy		mortality	
06/23/86	finback			Livorno, Tuscany, Italy		mortality	
01/21/85	finback	M	18	Mediterranean Sea, Port La Nouvelle La Franqui		mortality	
10/16/84	southern right		7.2 calf	East London Harbor, S. Africa		mortality	
02/08/84	southern right			Jakkalsfontein, S. Africa		mortality	
07/27/83	southern right		14.3 adult	Beachview, Port Elizabeth, S. Africa		mortality	
09/19/82	finback		13.5	Mediterranean Sea, Villeneuve les Maguelonnes		mortality	
07/05/80	blue			64 km W of Ensenada, Mexico		mortality	
10/19/76	finback	F	12.5	Atlantic Ocean, Bay of Biscay, France		mortality	
04/03/76	finback	M	14.3	Mediterranean Sea, Toulon		mortality	
1974	unknown			Cook Strait, N.Z.		injury	
09/10/74	finback		15	Mediterranean Sea, between Menton and Antibes		mortality	
04/23/74	unknown			<2 km off Baja Peninsula, Mexico		injury	
Oct-73	unknown			Bay of Bengal, Indian Ocean		mortality	
08/30/73	finback		15	Mediterranean Sea, between France and Corsica		mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
ferry				Laist et al 2001	brought into port on bow of ferry
				Laist et al 2001	struck by ship 1.5 mi from port, seen alive w/deep wound on back, found dead a day later
				Best et al 2001	stranded w/propeller cuts on head
ferry				Laist et al 2001	struck by ferry near entrance to harbor
twin screw ferry				Laist et al 2001	impact with whale felt, blood in water, three days later whale stranded w/propeller gashes and damaged rostrum
				Laist et al 2001	stranded w/propeller wounds
				Laist et al 2001	brought into port on bow of ship
				Laist et al 2001	stranded w/propeller wounds
tanker				Laist et al 2001	hit by tanker, brought into port on bow of ship
				Laist et al 2001	floating offshore with propeller wounds on back
				Laist et al 2001	floating 5 mi offshore with propeller wounds on back
				Laist et al 2001	stranded, large propeller cuts on back, probable ship strike
Hopper dredge	110			Best et al*	cow/calf pair surfaced in front of dredge, calf took full brunt of impact, struck by propeller as ship passed, stranded, died
				Laist et al 2001	major damage around midlength seen from air
				Laist et al 2001	five apparent propeller gashes
				Laist et al 2001	stranded, cut through middle of back, probable ship strike
tanker	203 m	21		Patten et al. 1980*	whale w/broken spine floated off ship's bow in LA harbor, collision location inferred from decrease in speed
				Laist et al 2001	stranded, large propeller cuts on back, probable ship strike
merchant ship				Laist et al 2001	brought into port on bow of ship, several ribs and cervical vertebra broken
commercial ferry	4,000 tons	17	N	in Laist et al 2001	struck and possibly killed whale, blood noticed in water after vessel passed
				Laist et al 2001	cut through middle, seen floating offshore
private motor yacht	18	10.5	N	in Laist et al 2001	boat shook & veered to port, large whale surfaced at stern w/deep propeller gashes down mid-section, pool of blood seen
Navy	133		N	Cummings*	vessel collided w/large whale at night and sustained no damage
ferry				IML*	brought into port on bow of ship

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Date	Species	Sex	Length (m)	Location (where struck, if known; if not, where found)	Coordinates	Mortality/ Injury	Field ID
09/03/72	finback	M	12.6	Mediterranean Sea, Nice		mortality	
07/05/72	finback	M	18	Mediterranean Sea, off Calvi		mortality	
Mar-72	unknown			Las Perlas Islands, Panama, Pacific Ocean		injury	
1963	unknown			Equatorial Pacific		injury	
Sep-61	unknown			Caribbean Sea		injury	
02/01/60	unknown			W of Cape Reinga, North Island, New Zealand		injury	
03/22/55	sperm		10	89 km W of Cape Gardafui, Canary Islands		mortality	
12/25/54	unknown			11 km off Kaikoura, South Island, New Zealand		unknown	
fall 1953	unknown			N Yellow Sea		mortality	
1950	Bryde's			Red Sea, Egypt		mortality	
1930's	unknown			Near Raratonga, South Pacific		mortality	

NOAA Fisheries Confirmed and Possible Ship Strikes to Large Whales

Vessel Type	Vessel Size(m)	Speed (kts)	Vessel Damage	Source	Comments
ferry				IML*	brought into port on bow of ship
ferry				Laist et al 2001	hit by ferry, seen floating at sea
Boston whaler	4	>25		Cummings*	boat struck whale and rode directly over the animal, after collision animal seen thrashing w/bloody wound
passenger ship	14,000 tons	18	N	Cummings*	whale in front of vessel was struck, small amount of blood in water, whale appeared to swim away slowly
cargo vessel	8,000 tons	14		Laist et al 2001	whale first sighted lying at surface, then seen thrashing in wake w/blood in water after collision
passenger ship	13,000 tons			Cummings*	vessel shuddered and slowed when propeller struck whale, animal then seen thrashing w/back sliced and bleeding
steamship	144	17		Slipjer 1979*	whale struck on head and body and became lodged on bow below water line
passenger ship	133	18	Y	Cummings*	vessel collided w/large whale and sustained damage
Navy	169	~20	N	Cummings*	shudder was felt, object on bow identified as whale, ship backed down to dislodge whale which then sank
tanker				Laist et al 2001	
steamer	131	15		Cummings*	ship collided w/large whale and almost cut it in half

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Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales

Correction(s) for this article >

ERRATUM

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Abstract

Collisions with vessels are a serious threat to a number of endangered large whale species, the North Atlantic right whale (*Eubalaena glacialis*) in particular. In late 2008, the U.S. National Oceanic and Atmospheric Administration issued mandatory time-area vessel speed restrictions along the U.S. eastern seaboard in an effort to mediate collision-related mortality of right whales. All vessels 65 feet and greater in length are restricted to speeds of 10 knots or less during seasonally implemented regulatory periods. We modeled mortality risk of North Atlantic right whale when the vessel restrictions were and were not in effect, including (1) estimation of the probability of lethal injury given a ship strike as a function of vessel speed, (2) estimation of the effect of transit speed on the instantaneous rate of ship strikes, and (3) a consideration of total risk reduction. Logistic regression and Bayesian probit analyses indicated a significant positive relationship between ship speed and the probability of a lethal injury. We found that speeds of vessels that struck whales were consistently greater than typical vessel speeds for each vessel type and regulatory period studied; a use-availability model fit to these data provided strong evidence for a linear effect of transit speed on strike rates. Overall, we estimated that vessel speed restrictions reduced total ship strike mortality risk levels by 80–90% with levels that were closer to 90% in the latter two of the four active vessel speed restriction periods studied. To our knowledge, this is the most comprehensive assessment to date of the utility of vessel speed restrictions in reducing the threat of vessel collisions to large whales. Our findings indicate that vessel speed limits are a powerful tool for reducing anthropogenic mortality risk for North Atlantic right whales.

Introduction

Violent collisions involving vessels and whales are a growing concern for marine resource managers. The outcome for the whale is often death or serious injury, including fractured bones, hemorrhaging, or propeller lacerations (Moore et al. 2004, Campbell-Malone et al. 2008). The occurrence of vessel strikes is a threat to a number of endangered large whale species (Clapham et al. 1999, Waring et al. 2011). In U.S. waters alone, tens of large whale deaths per year are ascribed to vessel strikes (Henry et al. 2012, van der Hoop et al. 2012), and globally the number may be in the hundreds of deaths each year (Laist et al. 2001, Jensen and Silber 2003, Van Waerebeek et al. 2007). Not all dead whales are detected (particularly in offshore waters), and the cause of death for carcasses that are recovered cannot always be determined due to decomposition (Henry et al. 2012). Thus, the actual number of whales that succumb to vessel collisions is likely far higher than reported.

The North Atlantic right whale (*Eubalaena glacialis*) is particularly vulnerable to vessel strikes. In a population that contains fewer than 500 individuals, an average of about two known deaths have been documented each year for at least the last decade (Waring et al. 2011, Henry et al. 2012). This anthropogenic threat has slowed the recovery of this highly depleted species (Knowlton and Kraus 2001, Kraus et al. 2005, NMFS 2005).

A number of approaches have been taken to reduce the threat of vessel strikes to right whales. These actions include mariner awareness-raising programs and modifications of customary vessel operation practices that include vessel speed reductions and changes in vessel routing patterns (Vanderlaan and Taggart 2009, Silber et al. 2012).

Vessel speed has been identified as a contributing factor in the occurrence and severity of vessel collisions with various marine vertebrates (Laist and Shaw 2006, Hazel et al. 2007), large whale species in particular (Laist et al. 2001, Jensen and Silber 2003, Pace and Silber 2005, Vanderlaan and Taggart 2007). Impact forces involved in a collision increase with increasing vessel speed (Wang et al. 2007, Campbell-Malone et al. 2008, Silber et al. 2010) and the probability of death or serious injury of a whale involved in a collision increases as vessel speed increases (Pace and Silber 2005, Vanderlaan and Taggart 2007, Wiley et al. 2011). Gende et al. (2011) found that the encounter distance between whale and vessel is also influenced by vessel speed such that higher vessel speeds may increase the probability of a strike occurring. These various findings have prompted the use of vessel speed restrictions as a means of diminishing the threat of vessel strikes to endangered marine mammal species in various locations (NPS 2003, Laist and Shaw 2006, Tejedor et al. 2007).

To address the threat of vessel strikes to North Atlantic right whales, the U.S. National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) issued regulations that limit vessel speeds in certain locations along the U.S eastern seaboard (NOAA 2008). The speed limits are in effect seasonally in prescribed areas ("seasonal management areas", or "SMAs"). The SMAs were designed to correspond with the timing and locations of right whale migration, feeding, and nursery activities where they co-occur with high vessel traffic densities (typically near sizable port entrances and vessel traffic bottlenecks), while also minimizing economic impact to the maritime transport industry (Fig. 1). While in a management zone, all vessels 65 feet and greater in length are required to travel at 10 knots or less (speed over ground). Sovereign (e.g., U.S. military) vessels are exempted from the regulations.

Figure 1

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Times and locations of vessel speed restriction seasonal management areas (SMAs) for North Atlantic right whales along the U.S. east coast.

It can be difficult to determine with certainty if vessel speed limits and related management actions are achieving their intended objective of reducing whale strikes, particularly in the relatively short period since their enactment (Pace 2011, Silber and Bettridge 2012). Studies have used risk reduction models to assess the relative effectiveness of various vessel routing measures (Vanderlaan and Taggart 2009, Vanderlaan et al. 2009, van der Hoop et al. 2012). Others have provided estimates of vessel strike risk reduction resulting specifically from NOAA's vessel speed restrictions (Lagueux et al. 2011, Wiley et al. 2011). However, estimates arising from the latter studies were obtained by examining only limited aspects of the restrictions both temporally and geographically. Further, most assessments of risk to date have been made by simulating whale and vessel movement to quantify strike rates. Although this approach is useful for determining how likely a whale is to come in close proximity to a vessel, it cannot be used to account for whale avoidance behavior that can prevent vessel collisions.

In this paper, we attempt to model the effect of mandatory vessel speed restrictions along the U.S. east coast on comprehensive North Atlantic right whale mortality risk. This includes an assessment of risk associated with different years and management regimes (i.e., vessel speed restrictions in/not in effect). Our analysis includes three components: (1) estimation of the probability of lethal injury given a ship strike at different vessel speeds; (2) estimation of the effect of transit speed on the instantaneous, per capita rate of ship strikes; and (3) a consideration of total risk reduction. The first component involves analyzing a dataset of ship strikes roughly twice the size as in previous work (e.g., Vanderlaan and Taggart 2007), while the second involves fitting a Bayesian model to describe the differences in observed ship speeds for vessels that struck whales from those which may or may not have struck whales. This latter approach differs conceptually from previous approaches to quantifying strike rates in that the effect of vessel speed on instantaneous strike rate is explicitly estimated via a statistical model. Finally, we jointly analyze all of these data sources to produce an estimate of mortality risk that simultaneously accounts for all sources of uncertainty.

Methods

Lethality of whale strikes

To explore the relationship between vessel speed and the lethality of vessel strikes, we examined records of known vessel strikes of whales in which sufficient information was provided to indicate with certainty both the speed of the vessel at the time of the strike and the severity of injury or fate (e.g., death resulted) of the whale involved in the collision. Records included all large whale species and all geographic areas worldwide.

In compiling vessel strike data for our analysis, we relied on the same data used in related studies by Pace and Silber (2005) and Vanderlaan and Taggart (2007). The latter study used published sources (Laist et al. 2001, Jensen and Silber 2003) that detailed the historical record of vessels striking large whales (*n* = 47). Pace and Silber (2005) used these same data in addition to unpublished records of vessel/whale strikes (*n* = 5) not used by Vanderlaan and Taggart (2007). We began our compilation with the data set (*n* = 52) used by Pace and Silber.

By reviewing scientific literature and canvassing information from various stranding programs and data sources, we then compiled additional vessel strike records that occurred after the Pace and Silber (2005) study had concluded in May 2005, or were not previously documented in the Pace and Silber analysis. We included only those cases in which both the vessel speed and the fate of the whale were known with certainty. This yielded a total of 38 records not analyzed in previous studies. Unique records that met criteria for evaluation were derived from Neilson et al. (2012) for Alaskan waters (*n* = 7); NMFS' National Marine Mammal Stranding databases for the U.S. northeast (*n* = 10), northwest (*n* = 2), and southwest (*n* = 7) regions, national program (*n* = 5), and the Hawaiian Islands Humpback Whale National Marine Sanctuary (*n* = 7). A total of 90 records meeting the criteria identified above were used in our analysis. These data included records through September 2012.

For each record we recorded a binary response variable for whether injuries were lethal/not lethal, using the same criteria as in previous studies (e.g., Vanderlaan and Taggart 2007, Andersen et al. 2008). Records in which the whale was known to have died (e.g., carcass observed) or a severe injury was described (e.g., blood in the water, open or bleeding wounds observed) were classified as "lethal" (Vanderlaan and Taggart 2007). Individuals that were known to have survived (for example, where there were subsequent sightings of the living whale), who exhibited no apparent injury, or only minor injuries (e.g., visible non-bleeding wound, or no report of blood) were recorded as non-lethal "0" responses (i.e., we assumed these whales did not die as a result of the encounter). In making these determinations, we adopted the same classification of records utilized by Pace and Silber (2005), Vanderlaan and Taggart (2007), and Neilson et al. (2012). This left $n = 30$ records for which we made new injury determinations.

In total, our data set consisted of roughly double the number of observations previously used to estimate the relationship between vessel speed and the lethality of ship strikes (see, e.g., Vanderlaan and Taggart 2007), so we hoped to substantially increase precision of parameters describing the strike speed-mortality relationship. Two different analyses were performed. First, we analyzed the data using a simple logistic regression model where severity of injury (Y_i = 1, lethal injury; Y_i = 0, non-lethal injury) is modeled as a Bernoulli response variable with success probability M_i, where

Here, M_i gives the probability of a lethal injury for strike i, and x_i gives the speed (in knots) of the vessel involved in the collision. We provide estimates from this approach for historical consistency; several authors have used this formulation when addressing mortality associated with ship strikes (Pace and Silber 2005, Vanderlaan and Taggart 2007, Lagueux et al. 2011). For this approach, we conducted analysis with the 'glm' function in the R statistical language (R Development Core Team 2012).

Second, to integrate the relationship between ship speed and mortality into our comprehensive mortality risk analysis, we conducted a Bayesian probit regression analysis, which is similar to a logistic regression but uses the probit link function in place of the logit. In particular, we considered the model

The probit link function leads to some computational advantages when conducting Bayesian analysis; in particular, one can construct a collapsed Gibbs sampler as suggested by Albert and Chib (1993) to sample regression parameters. Defining to be the design matrix where

and augmenting the parameter space with $\tilde{Y}_i$ values for each observation, the algorithm proceeds as follows:

(1) Update $\tilde{Y}_i$ values according to a truncated normal distribution. If $Y_i = 1$, sample $\tilde{Y}_i \sim \text{Normal}([\mathbf{X}\beta]_i, 1)$ with the constraint that $\tilde{Y}_i > 0$; if $Y_i = 0$, sample $\tilde{Y}_i \sim \text{Normal}([\mathbf{X}\beta]_i, 1)$ with the constraint that $\tilde{Y}_i < 0$.

(2) Update the vector of regression parameters (in this case $\boldsymbol{\beta}' = [\beta_0\ \beta_1]$) according to $\boldsymbol{\beta} \sim \text{MVN}((\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\tilde{\mathbf{Y}}, (\mathbf{X}'\mathbf{X})^{-1})$, where MVN denotes the multivariate normal distribution. This formulation implies a flat, improper prior distribution for the regression coefficients.

Posterior predictions of mortality probability at pre-specified vessel speeds can then be produced by sampling from

where $\Phi(Z)$ denotes the cumulative distribution function of the standard normal distribution evaluated at Z, and $\mathbf{X}_k$ gives the design vector associated with predictions (e.g., $\mathbf{X}_k = [1\ x_k]$). We used this algorithm to sample the posterior distribution of model parameters and make posterior predictions; 11,000 such values were simulated, and we discarded the first 1,000 as a burn-in. We provide R code to conduct this analysis as an online supplement.

Strike rate analysis

In an analysis of vessel encounter rates with humpback whales, Gende et al. (2011) provided evidence that the likelihood of vessel-whale encounters increases with vessel speed. Others have used simulation to model the likelihood of whale-vessel intersections given assumptions about whale and vessel movement (e.g., Vanderlaan and Taggart 2007, van der Hoop et al. 2012). However, the degree to which whales are likely or able to move to avoid vessels of varying speeds has heretofore been a subject of uncertainty.

To investigate the relationship between whale strike rates and vessel speeds, we compared the speeds of vessels that struck whales to a larger population of vessel speeds. From a statistical perspective, these data sources are similar to use-availability data as commonly modeled in animal resource selection studies (see, e.g., Manly et al. 2002), where speeds that resulted in whale strikes can be viewed as "use" and random vessel speeds can be viewed as "availability."

For this analysis, we obtained randomly selected vessel speeds in SMAs along the U.S. east coast summarized for analysis by speed and vessel type (i.e., cargo, passenger, sovereign vessel types). Vessel operations in SMAs were monitored using the Automatic Identification System (AIS), a safety-at-sea navigation tool that transmits very high frequency (VHF) radio signals. All vessels 300 gross tons or greater making international voyages are required by the International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea to maintain functioning and operational AIS capabilities. The same requirement applies to nearly all vessels 65 feet or greater sailing in U.S. waters. An AIS signal is transmitted several times per minute and contains both static (e.g., ship name, call sign, and hull specifications) and dynamic information that is unique to that particular voyage. Dynamic information includes vessel location, heading, and speed, and is automatically incorporated into the AIS signal by a global positioning system (GPS). Due to its signal transmission rate, AIS provides a detailed, continuously sampled, and precise record of vessel operations for a nearly complete census of vessels subject to the speed limits. Additional information about the function and characteristics of the AIS can be found in Aarsæther and Moan (2009) and Tetreault (2005); a description of methods used to acquire and parse AIS data for this study can be found in Silber and Bettridge (2010 and 2012).

Using the U.S. Coast Guard (USCG) network of AIS receivers, we obtained vessel operations data from 9 December 2008 to 31 July 2012. We randomly selected one speed value per SMA vessel transit. This sample was restricted to speeds that were >2 knots because AIS transmitters may continue to operate while vessels are at anchor or while in port. To generate a random population of such vessel speeds, we resampled these speeds with replacement, weighting each observation by the number of AIS records available per transit.

For analysis of instantaneous per capita strike rates, we limited strike records to the U.S. east coast and to vessel types that were comparable to the categories available in the AIS data. Strike records were derived from published large whale ship strike databases (Jensen and Silber 2003) and those maintained by NMFS stranding personnel. We restricted analysis to cargo vessels (n = 1 strike), passenger vessels (n = 1 strike), and to sovereign vessels (e.g., USCG operated vessels (n = 10 strikes)). Strike records were obtained over a wider time frame than AIS data; n = 6 were from 2000–2009, n = 4 were from 1990–1999, and n = 2 records came from 1950–1980. There is little indication that the speeds of vessels changed appreciably even over this relatively long horizon. We did not include strikes with small private vessels or whale watching vessels as these types of vessels were seldom identifiable in the AIS database. Although it may have been possible to isolate random transit speeds associated with particular whale watching vessels, we anticipated that these would not adequately represent the activities being conducted when whale strikes occurred (since whale watching vessels are actively searching for whales during portions of their transits). Since the fate of whales was not necessary for analysis of strike rates, we included records where the fate of the animal was unknown. A simple comparison of strike speeds from our vessel strike database to transit speeds randomly sampled from our AIS database in different regulatory periods suggested that strikes occurred when vessels, in each vessel category studied, were traveling faster than average vessel speeds (Fig. 2).

Figure 2

Open in figure viewer | PowerPoint

A comparison of randomly sampled ship speeds from our Automatic Identification System (AIS) database (black kernel densities) to speeds at which vessels struck whales (represented by X's). Data are partitioned by vessel type ("Cargo", "Passenger", or "Sovereign") and by whether the data point occurred during periods when Seasonal Management Area (SMA) speed restrictions were ("Y") or were not ("N") in effect. Each panel represents a distribution of 10,000 randomly sampled ship speeds which are used to define separate availability datasets in the strike rate analysis (strike rate itself is only modeled as a function of ship speed).

To formalize the relationship between vessel speed and strike rates, we start by defining the per capita, instantaneous rate at which whales are struck, λ_i. In particular, we express it as a function of vessel speed, x_i, with a log link. We considered both linear and quadratic functional forms for the effect of vessel speed on strike rate:

Letting $[X|Y]$ denote the conditional distribution of X given Y, we can describe the likelihood of observing strike speeds $\mathbf{x}$ for a particular combination of vessel type and regulatory period as where y = 1 if a particular vessel speed resulted in a strike. Here, [**y** = 1 | **x**, **α**] is the joint probability that the observed vessel strike speeds resulted in strikes, and can be given as

The component [**x**] denotes the probability density function for vessel speeds independent of whether or not those vessels struck whales. We follow Lele and Keim (2006) in approximating the denominator as

where , $j \in 1, 2, \ldots, B$ denotes a randomly sampled vessel speed from our transit database. This formulation has the advantage that we can use the empirical distribution of transit speeds as opposed to a fitted model, a desirable property since observed vessel speeds often were multimodal and/or bore little resemblance to parametric distributions. We set B = 10,000 in subsequent analysis.

The parameter α_0 controls the proportion of vessel speed observations that result in reported whale strikes. This parameter is not identifiable using the previous setup; however, inference can still be drawn regarding α_1, the effect of vessel speed on strike rates (Lele and Keim 2006). We used maximum likelihood to estimate parameters for the linear and quadratic models for strike rates, employing AIC (Burnham and Anderson 2002) for model selection. We then used the model with highest support in a Bayesian analysis of strike rates, imposing diffuse Normal(0,100) prior distributions on regression parameters (i.e., the α values). For this purpose, we used Markov chain Monte Carlo (Gelman et al. 2004) to sample from the joint posterior. When implementing this approach, we used separate data models for [**x**] for each combination of vessel type (cargo, passenger, sovereign) SMA speed restriction active/inactive period. An R script to conduct this analysis is provided in the Supplement.

Joint risk analysis

To estimate a total risk reduction value, we again sampled AIS data transmitted between 9 December 2008 and 31 July 2012 by cargo, tanker, and passenger vessels with lengths of 65 feet or greater (a total of tens of millions of individual speed records). We analyzed vessel speed information for 73,319 trips in SMAs at times in which speed restrictions were in effect and for 68,099 trips in the same geographic areas defined by SMAs when restrictions were not in effect. A single mean speed was computed for each trip. Vessel speed analyses were limited to transits that were at least one nautical mile in length, had at least five AIS records, and an average transit speed of >2 knots.

We formulated alternative expressions for relative mortality risk associated with R time periods with different management regulations. Assuming that the risk of mortality is temporally and spatially homogeneous within time period r, the probability that a single whale, chosen at random, is lethally injured can be given as

where T_r gives the time interval and h_r gives a constant hazard rate associated with period r. The hazard rate h_r is fundamental to survival analysis (cf. Cox and Oakes 1984) and measures instantaneous mortality risk. In practice, we expect variability in h_r over time and space, but little information exists to quantify changes in spatial distributions of whales over the entire east coast. Assuming that this distribution remains relatively constant, comparisons of constant h_r over different management regimes may still prove illuminating. In particular, the relative risk of morality in management period r relative to some reference period 0 may be written as

with values of $R > 1$ indicative of increased risk associated with a management action, and $R < 1$ indicative of reduced risk. In practice, there is considerable uncertainty in the hazards associated with each period because of uncertainty about mortality and strike rates, so that R is best viewed as a probability density function. Further, managers may be interested in different functional forms of h_r since these may provide different interpretations of the effect of management actions.

Ultimately, the mortality hazard throughout the management area (i.e., over all SMAs) in a given time interval is the sum of independent hazards associated with different transits (which are at different speeds and of different lengths). If we wish to directly compare the realized mortality risk in different management periods (i.e., speed regulation in effect/not in effect), we can approximate the mortality over each management period using a single, constant hazard during regulation period r:

Here, λ_{tr} is the instantaneous striking hazard for transit *t* in regulation period *r* (assumed here to be constant for the entire transit), D_{tr} is the duration of the transit, and M_{tr} gives the probability that a whale is lethally injured given that it is struck during transit *t* in period *r*. This formulation describes actualized change in mortality risk, but is dependent upon N_r, the number of transits in regulation period *r*, as well as the duration of such trips. Thus, changes in the total number of transits over time (or the duration of such transits) will affect interpretation of *R*. This formulation is also problematic for right whales because vessel speed regulations were temporally staggered based on location (Fig. 1) so T_r is not well defined.

Although absolute increases and decreases in risk can be of interest, managers may also be interested in standardized risk, or changes in risk associated with a management action while controlling for variables not under control of management. For instance, if the number and durations of transits varied markedly between regulation periods due to extrinsic factors, realized risk may give an unclear picture of the effects of regulations. In this case, managers may still be interested in changes in mortality risk that would have resulted had the number of transits remained constant. To make this estimate, we suggest calculating relative risk using

where , , and are random draws for strike rate, vessel transit duration, and mortality probability (see below). We refer to risk computed using this approach as standardized risk. Since we have empirical data on the length and speed of transits by management period and models for how whale mortality (*M*) and strike rate (λ) change as a function of transit speed (Eqs. 1 and 3) it is a relatively simple matter to calculate comprehensive risk reduction associated with speed restrictions. To properly account for uncertainty in these relationships, we computed a posterior distribution for the standardized risk ratio *R* (Eq. 4) by incorporating uncertainty in the estimated lethality-vessel speed relationship and the estimated strike rate-speed relationship. Again letting [X | Y] denote the conditional probability distribution of X given Y, and bold symbols denote vectors of parameters, we start by symbolically writing the joint posterior distribution of *R* and transit speed and mortality parameters given the data as

Here, **S** denotes vessel speed data for different management periods, **Z** denotes transit length data, and **Y** denotes strike/mortality data as analyzed in our Bayesian probit analysis. The posterior distribution depends on simulated vessel speed values , which are assumed to be distributed according to [**θ** | **S**], and simulated transit durations, . The latter depend upon both the empirical distribution of transit length values **Z** and upon vessel speed (given a particular transit length Z_i, and speed θ_i, duration can be calculated as Z_i/θ_i). Posterior predictions of lethality at different vessel speeds associated with the component [**M** | **θ**, **β**][**β** | **Y**] may be generated via Eq. 2, while posterior values of α_1 can be sampled from the strike rate analysis. Given these values, we express the standardized risk ratio as

Note that the non-identifiable strike rate parameter α_0 cancels out of the above expression. As correlation between transit lengths and vessel speeds was low (Pearson correlation coefficient $\rho = -0.03$), we used independent probability density functions for both quantities. In particular, we drew vessel speed values **θ** from the AIS-generated empirical distribution of vessel speeds within sampling regime *r*, and simulated based on draws from the empirical distribution of observed transit lengths **Z** over the whole study period. We selected the limits of summation, 19,345, because it was the average number of transits occurring within a six month period. As results were somewhat sensitive to high speeds outside the range of strike rate and/or mortality analyses, we replaced any randomly selected transit speed above the 99th percentile of transit speeds (22.5 knots) with a value of 22.5 knots.

To summarize comprehensive risk ratios, we generated 10,000 posterior predictions using Eq. 5. Separate predictions were made for each year (1–4) of the study and for control and treatment periods for each strike rate scenario. We also analyzed pooled control and treatment data (pooling over years).

Results

Using logistic regression analysis, we detected a significant positive relationship between ship speed and the probability of a lethal injury ($\beta_1 = 0.217$; SE 0.058; $p < 0.001$); the intercept was estimated as $\beta_0 = 1.905$ (SE 0.821). The Bayesian probit analysis produced an almost identical relationship to the logistic regression analysis (Fig. 3), with posterior means of $\beta_0 = -1.067$ (SE 0.452) and $\beta_1 = 0.124$ (SE 0.030). As with logistic regression, there was substantial evidence for a positive effect of vessel speed on strike lethality (the posterior sample for β_1 was greater than zero for all realizations). Owing to several new observations of serious injury vessel strikes at lower vessel speeds (e.g., one each at 2 and 5.5 knots), the relationship between lethality and strike speed was less extreme than the one produced by Vanderlaan and Taggart (2007) and used in previously published risk analyses (Fig. 3).

Figure 3

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Probability of a lethal whale strike given strike speed. The dashed line gives predictions from a logistic regression, the solid line gives posterior mean estimates from a Bayesian implementation of probit regression, and the dotted line gives logistic regression estimates reported by Vanderlaan and Taggart (2007). The gray area represents a 95% credible interval from the Bayesian analysis.

The speeds of vessels that struck whales were consistently greater than typical vessel speeds for each vessel type and regulatory period (Fig. 2). Accordingly, maximum likelihood fits of the use-availability model for strike speeds provided strong evidence for a linear effect of transit speed on strike rates (α_1 = 0.49, SE = 0.09); however, there was insufficient evidence to support a quadratic effect (ΔAIC = 1.1). We therefore used a linear formulation for the effect of transit speed on strike rates in our Bayesian analysis. The posterior distribution for α_1 was substantially greater than zero (Fig. 4), providing further evidence that strike rates increase as a function of vessel speed.

Figure 4

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Estimated posterior density function for α_1, the effect of vessel speed on the log of the instantaneous rate at which vessels strike whales. A value greater than zero indicates that instantaneous strike rate increases with vessel speed.

Estimates of comprehensive risk reduction suggest a large decrease in standardized mortality risk associated with vessel speed restrictions (Fig. 5). In particular, control periods (i.e., when SMAs were not in effect) all had similar risk levels, while treatment periods (i.e., when SMAs were in effect) resulted in a risk reduction of 80–90%. Examining individual years separately (Fig. 5), it appeared that risk reduction was on the order of 80% for the first 2 years of vessel speed restrictions, and closer to 90% for the final 2 years of regulation. Pooling over years and simply comparing risk between treatment periods when speed regulations were in effect versus control periods when regulations were not in effect, the posterior mean mortality risk level in treatment periods was 14% of that in control periods (95% credible interval 5.6–29.0%), representing an 86% reduction.

Figure 5

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Posterior predictive densities for comprehensive mortality risk ratio associated with transit speed restrictions in different years and management regimes. The left panel gives results for control periods ('N') while the right panel shows risk ratios when speed restrictions were in effect ('Y'). A ratio less than one indicates reduced risk relative to the control period in 2009.

Discussion

Various measures, focused primarily on changes in vessel routing patterns and reductions of vessel speed, have been employed to reduce the threat of vessel collisions with North Atlantic right whales. Routing changes that result in lowered co-occurrence of vessels and whales is the most desirable approach in most settings (Silber et al. 2012, van der Hoop et al. 2012), and several studies have provided estimates of vessel strike risk reduction afforded by established routing modifications (Firestone 2009, Vanderlaan and Taggart 2009, Vanderlaan et al. 2009, Lagueux et al. 2011). However, changing vessel routes is not always feasible due to navigational safety constraints, particularly in coastal waters.

Arguments for lowering vessel speed to limit the threat of fatal vessel collisions with both large whales (Laist et al. 2001) and manatees (*Trichechus manatus*) (Laist and Shaw 2006) first appeared in the early- and mid-2000s. These assertions were bolstered by risk reduction analyses (Pace and Silber 2005, Vanderlaan and Taggart 2007) and helped prompt use of speed restrictions in a number of locations (NPS 2003, Tejedor et al. 2007), the most extensive of which occur along the U.S. eastern seaboard. NOAA's vessel speed limits have been the subject of legal (Norris 2008, Firestone 2009), economic (Silber and Bettridge 2012), and risk reduction analyses (Lagueux et al. 2011, Wiley et al. 2011). Estimates of risk reduction to date have been applied to limited areas and times and relied on previously published logistic regression curves. Risk reduction values provided here include the full geographic scope of the vessel speed restrictions over a multi-year period using quantified vessel speeds, new whale strike data, and novel analyses. We believe this to be the most comprehensive assessment to date of the utility of vessel speed restrictions in reducing the threat of vessel collisions with large whales.

Our analysis highlights the importance of accounting for the combined effects of ship speed on (1) the rate at which vessels strike whales, and (2) the probability of mortality given that a whale is struck. In particular, we have shown that vessel speed is positively related to both components. To our knowledge, this is the first time that a use-availability model has been used to analyze the effect of vessel speed on the rate of whale strikes. Although simulation analyses (e.g., by modeling whale and vessel movement) can provide some guidance as to likely functional forms for the relationship between vessel speed and the likelihood of a whale coming into close proximity with a vessel, it is difficult to use these analyses to reliably predict the probability of a collision because of uncertainty about fine scale nature of whale avoidance behavior. For instance, little is known about whale reaction, if any, to approaching vessels, particularly in the near-field. We view our analysis as an improvement in this regard, in that it allows one to explicitly estimate the effect of vessel speed on instantaneous strike rate. The obvious limitation of this approach is the small sample size associated with whale strike speeds, particularly when limited to vessels for which we had reliable control (availability) data. Nevertheless, with just 12 data points there appeared to be ample indication that strike rates increased with vessel speed. By contrast, if one fixes strike rates to be constant and simply uses the mortality curve to account for changes in mortality risk, it is actually possible to arrive at an (erroneous) increase in mortality risk, simply because slower vessel speeds increase transit times (and thus exposure of whales to vessels). This emphasizes the importance of simultaneously accounting for the effects of vessel speed on whale mortality and on strike rates.

The present analysis does not account for potential reductions in whale mortality attributable to changes in vessel routing regimes. For instance, previous analysis of vessel routing measures designed to lessen vessel occurrence in or near right whale aggregation areas (Lagueux et al. 2011, van der Hoop et al. 2012) suggested that there were substantial decreases in strike rates in at least portions of the range of North Atlantic right whales. In fact, Areas To Be Avoided and modifications to Traffic Separation Schemes and other routing changes were made in the range of this species during the same period as vessel speed restrictions were introduced (Silber et al. 2012), albeit in targeted localized areas such as the Bay of Fundy, and waters off Georgia, Florida, and New England. We do not currently have data sufficient to account for the effects of management actions based on vessel routing across the entire east coast; however, we note that proportional changes to strike hazards result in an equivalent change to our risk ratio (Eq. 5). For instance, if vessel routing restrictions decreased the strike rate hazard by half, then the risk ratio in Eq. 5 would also be reduced by half. This suggests that our standardized risk ratio likely underestimates the true level of risk reduction accompanying the full suite of implemented management actions. However, we believe the risk ratios we provided here are valuable because it allows us to isolate the effects of a particular management action (in this case, transit speed regulations).

Our finding that vessel strike risk was lowest in the latter two of the four active periods studied is consistent with a measurable increase in vessel trips that comported with the required speed limits in years three and four, particularly as citations and fines were issued at the outset of year three (G. K. Silber, J. D. Adams, S. Bettridge, and B. Sousa, *unpublished manuscript*). This substantial shift in behavior observed across the entire regulated community helps explain, and contributes to, increased risk reduction in the latter two periods of our study.

We note the disparity of records of known vessel strikes by vessel type. Although cargo vessels represent the vast majority of vessels utilizing U.S. east coast ports and are the type most strongly represented in our AIS database, we were only able to obtain a single cargo vessel whale strike record for which strike speed was recorded. In contrast, sovereign vessels account, proportionally, for much higher numbers of recorded vessel strikes than other vessel types (Fig. 2). However, we wish to strongly emphasize that sovereign vessels are much more likely than other vessel types to report a struck whale because they are required to do so by internal protocol, and are obliged by conditions of U.S. Endangered Species Act Section 7 consultations to endeavor to reduce vessel strikes of whales by posting dedicated lookouts, traveling at reduced speeds when traversing active SMAs when and where feasible and when not jeopardizing vital or national security missions, and reporting when a whale strike has occurred. In addition, due to the sheer size of most commercial cargo and passenger vessels (which may be substantially larger than many sovereign vessel classes), these types of vessel operators are rarely aware that a collision with a whale has occurred. Nevertheless, it is important to note that our overall inference about the effect of ship speed on vessel strike rates could be biased if there were a statistical interaction between ship speed and ship type on vessel strike rates (that is, if whales respond to increasing ship speed differently among vessel types). Unfortunately, we do not have data sufficient to test this assumption, but believe it is the safest (and statistically parsimonious) to proceed with the assumption that transit speed affects strike rates similarly regardless of vessel type. A large number of additional reports of transit speed for non-sovereign vessel whale strikes would likely be necessary to relax this assumption.

Indications are that expansion will occur in the commercial maritime transport industry (Corbett 2004, Dalsøren et al. 2007), the cruise industry, offshore energy development, and other maritime sectors, thereby increasing risk of vessel strikes to whales. Conversely, factors such as restrictions on air-borne emissions from large vessels and the recent economic downturn may result in reduced vessel speeds (Khan et al. 2012) or fewer vessel trips (McKenna et al. 2012), which could reduce the likelihood of whale strikes. Nonetheless, the threat is likely to remain a concern as maritime transport and other activities increase and as whale populations grow in some locations. Our analysis suggests that vessel speed restrictions will likely remain a key tool for reducing anthropogenic mortality risk and promoting recovery of endangered large whale species.

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Supplemental Material

Supplement

R code to implement mortality risk analysis for North Atlantic right whales as a function of vessel speed (Ecological Archives C004-006-S1).

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Tracking Technology: The Science of Finding Whales

February 01, 2017

Whales can be very hard to find in Earth's vast seas. NOAA Fisheries' scientists and partners use a range of technologies and research techniques to locate whales and study their behavior. Some of these techniques are new and exploratory while others are tried and tested, but all are providing important data on protected whale species. Check out some of the ways we're watching for whales below.

Jessica Crance
Research Biologist, Alaska Fisheries Science Center

"This past summer, the Alaska Fisheries Science Center's National Marine Mammal Laboratory had the opportunity to collaborate with scientists on the 2016 Saildrone mission. Saildrones are a relatively new, autonomous technology that can stay out at sea for months, collecting continuous data that would otherwise be prohibitively expensive to gather through traditional methods.

Our interest in the project was to determine if the Saildrone would be a suitable platform for passive acoustic monitoring of marine mammals, in particular the critically endangered North Pacific right whale. We attached a small, autonomous acoustic recorder called the Acousonde to the keel of each Saildrone, and set it to record continuously up to 4 kHz, which covers the frequency band of most marine mammals in the Bering Sea.

The Saildrone has the advantage of covering a large area, while being able to stay out for months at a time, making it much more cost-efficient than a full-scale vessel survey. It also has the added benefit of being integrated with oceanographic and lower trophic instrumentation, allowing for the correlation of marine mammal data with oceanographic and prey variables.

Preliminary results from the passive acoustic data show some success in detecting higher frequency species like killer whales. There was masking of lower frequency signals due to water hitting the platform, which was not unexpected.

However, with planned modifications to reduce noise, and an increased sampling rate to include more high-frequency species (e.g., beaked whales), the incorporation of passive acoustics onto the Saildrone has great potential for monitoring large areas for the presence of vocalizing marine mammals."

Watch our broadcast of the 2016 Saildrone mission launch to learn more about the Saildrone program and how NOAA Fisheries scientists are utilizing the technology to study more than just whales.

Sofie Van Parijs
Zoologist, Northeast Fisheries Science Center

"In the Northeast Region, we have a network of passive acoustic recorders and autonomous gliders recording the presence of large whales from the shore to the shelf break, using archival recorders as well as in real time with our colleagues from Woods Hole Oceanographic Institution (WHOI) and Scripps Institution of Oceanography.

Passive acoustics allows us to record 24/7 in all weather conditions, so it is able to provide a continuous and long-term time series of how whales used different habitats and how their occupancy of these areas may be changing. Visual survey techniques are hampered by weather conditions and night time, but are essential because the photographs they take allow us to identify individuals and their health status. Combined together these techniques give a more complete picture of this species.

The long-term records of whale presence are enabling us to better understand changes in their distribution and behavior. Real-time detection using both autonomous gliders and stationary buoys is proving invaluable for mitigating human impacts and monitoring endangered species.

The next steps are to ensure that these technologies can be integrated into our standard monitoring protocols so their value can increase the efficiency of data collection for these species. Autonomous gliders are now able to go farther afield and explore areas that neither vessels nor planes can easily access, and can therefore provide information on unknown regions and evaluate whether species distributions are truly shifting."

NOAA Scientist Sofie van Parijs monitors acoustic data aboard a research vessel. Credit: NOAA

Learn more about passive acoustic research being done out of the Northeast Fisheries Science Center.

John Durban
Marine Mammal Biologist, Southwest Fisheries Science Center

"Unmanned aerial systems are changing the way we make observations of whale health. We can't put a live whale on a scale to check its body condition, but now we can use small UAS platforms to give them a checkup without any disturbance.

We have been flying a small hexacopter to hover 100 to 200 feet above whales to take overhead photographs: from these we can do photogrammetry (taking measurements from photographs) to monitor growth, assess body condition, and identify pregnancies. These metrics allow us to augment traditional stock assessments to not only focus on abundance trends of whales, but to also understand the underlying causes of population dynamics.

We are also flying our hexacopter through the exhaled blow of large whales to collect samples from which we can describe respiratory microorganisms and identify emerging diseases.

To date, we have flown more than 1,200 flights over more than a dozen species of whales and dolphins. The images and samples we are collecting are now forming the basis for key monitoring programs that can identify changes in whale health and population status over time to better inform management decisions aimed at recovering and sustaining protected whale populations."

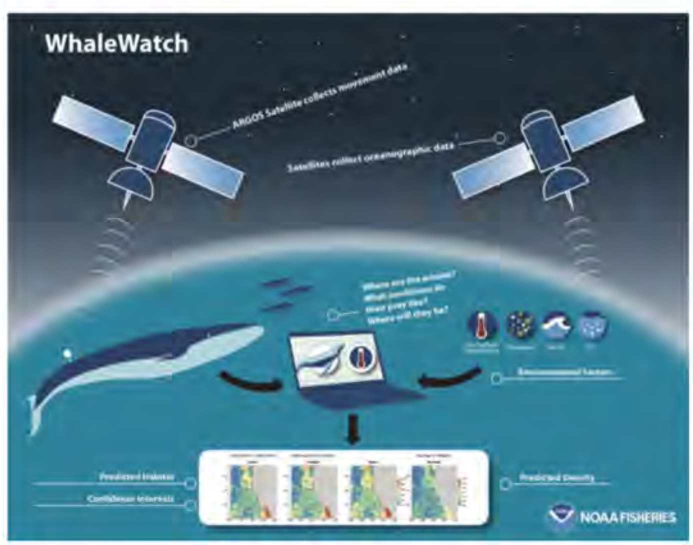
Durban and his colleague, Holly Fearnbach, are currently in Antarctica aboard the National Geographic *Explorer*. Learn more about their research in this video short from CBS News.

To see more photos of killer whales taken with unmanned aerial systems, check out this story from NOAA Fisheries.

Elliott Hazen
Research Ecologist, Southwest Fisheries Science Center

"Scientists have been using satellite tags to track blue whales along the West Coast since the early 1990s, learning how the largest animals on the planet find enough small krill to feed on to support their enormous size.

A collaboration of researchers from NOAA Fisheries, Oregon State University, and the University of Maryland have combined the wealth of tracking data with satellite observations of ocean conditions to develop the first system for predicting location and density of blue whales off the West Coast. The system, called WhaleWatch, produces monthly maps of blue whale "hotspots" to alert ships where there may be an increased risk of encountering these endangered whales.



This research provides a year-round predictive model. Most other models are confined to times when ships surveyed. Instead, this tool uses many years of tag data to let the whales tell us where they go, and what conditions drive aggregation and migration. WhaleWatch is an innovative combination of novel satellite technology and computer modeling approaches that can provide timely information to West Coast managers and the shipping industry. NASA also helped fund the project, which draws on ocean observations from both NASA and NOAA satellites.

Future planned developments of WhaleWatch would include more species as tag data become available, and ensemble models that combine multiple data types to provide a more complete view of whale habitat on the West Coast."

Learn more about WhaleWatch and how it can be used to predict and protect blue whale "hotspots."

Jessica Redfern
Marine Mammal Spatial Habitat and Risk Program Lead, Southwest Fisheries Science Center

"Whereas WhaleWatch uses tagging data to predict whale distributions for use in dynamic management, my research uses data from NOAA surveys to make predictions about long-term areas of higher and lower whale population densities. This information has proven critical in addressing the emerging problem of ships striking blue whales, and has informed the management of ship traffic to and from the busy ports of Los Angeles and Long Beach to mitigate this problem.

My most recent project used blue whale data from well-surveyed areas off the U.S. West Coast and in the eastern tropical Pacific Ocean to build blue whale habitat models. The models identify areas of upwelling and underwater topography that concentrate krill. The models were used to predict similar upwelling and feeding regions in the northern Indian Ocean that are likely to be important habitat for the endangered species.

Marine mammals face threats from human activities in most of the world's oceans, but we lack the data needed to address these threats in many areas. The data collected aboard our surveys allow us to predict species habitat in other parts of the world. Understanding species habitat allows us to address conservation problems that are often unexpected and critical to maintaining healthy populations."

Learn more about the Marine Mammal Spatial Habitat and Risk Program (SHARP).

Dave Weller
Marine Biologist, Southwest Fisheries Science Center

"Long-wave infrared video and software systems are being used off Central California to count eastern North Pacific gray whales during their southbound migration.

This system consists of: (1) three infrared cameras that monitor a fixed swath of the gray whale migration corridor 24 hours a day, (2) automated detection software for detecting whale blows, (3) whale-blow verification software for reviewing and removing false alarms, and (4) counting software that estimates the number of whales that have passed by the observation station.

A preliminary side-by-side comparison showed that the results of this infrared camera system compared favorably to results of a team of experienced NOAA visual observers. Benefits of this system include the ability to autonomously collect continuous data over long time windows (months), including periods of darkness when human observers are unable to work.

The use of this technology has other potential applications, such as mitigation of ship strikes and disturbance from underwater noise."

Learn more about the infrared camera systems being used on the West Coast.

Watch this video of the infrared camera system in action. The infrared camera detects thermal signatures from animals and objects that pass by the stationary cameras.

These thermal signatures are depicted in white so they stand out from the colder, surrounding waters (depicted in black). Birds, dolphins, and gray whales can all be seen in this video clip.

Last updated by Office of Communications on February 05, 2018

Why Scientists Are Counting Whales from Space

Hey, those blubber blobs aren't just going to count themselves.

// BY JENNIFER LEMAN JAN 6, 2020

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- **The New England Aquarium and Massachusetts-based engineering firm Draper are developing an algorithm to better monitor whales.**
- **The duo aims to use satellite imagery as well as sonar and radar data to track the whereabouts of vulnerable whale species.**
- **Whales are a critical part of the ocean food chain and can actually help mitigate the impacts of climate change.**

Scientists from the New England Aquarium and the Massachusetts-based engineering firm Draper are teaming up to save the whales. The researchers are weaving together a myriad of data in order to create a probability map of where whales might travel to and why. Knowing where whales go can help scientists better understand the environmental conditions that most impact the various species, reports 90.9 WBUR.

Changing water temperatures, for example, can shift where populations of krill, plankton, and fish—common food sources for whales—may go. Shipping lanes can also impact how whale populations travel: From 2010 to 2014, there were 37 reported ship strikes along the east coast of Canada and the U.S. and in the Gulf of Mexico, according to NOAA Fisheries data. Recent evidence has suggested that the ocean is getting noisier, which can stress whales and alter their behavior. (Luckily, groups like the U.S. Navy are taking note.)

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Why Do Whales Sing?

In order to track these whales, the team plans to tap reliable sources of sonar, radar and satellite data to keep a watchful eye on our planet's largest mammals. Eventually, the team hopes to input this data—collected from European Space Agency satellites to amateur radio operators—into an algorithm that will process that data and then track whales' movements.

Still, it won't be an easy task. "When we think about looking at the ocean from space, there are a couple of challenges to detecting whales," Draper's chief data scientist, John Irvine, tells WBUR. "One is how far into the water can you see? And the second is that the ocean is big. There are issues of how much can we look at it realistically."

Currently, scientists use aerial surveys to count and monitor whales, but there are a number of challenges involved with conducting aerial surveys. In some instances, gathering that data can be expensive and dangerous, and often, the counts are canceled due to adverse weather conditions. In most cases, the resolution is poor.

The team has pledged a total of $1 million toward the effort, and aim to have it up and running in the next few years. While the technology could, of course, be used around the world, the partners will begin testing their method in New England waters.

Whales are a critical component of the ocean ecosystem, working hard to ensure that the ocean food chain is balanced. But they're also vital in the fight against climate change, reports *National Geographic*.

LIKE THIS? YOU'LL LOVE THIS

Inside the Locked Rooms Where They Protect GPS

Whales are considered to be carbon sinks—think of them as swimming trees—and soak carbon up in the fat stored in their bodies. When they die and sink to the bottom of the ocean, all of that carbon, which would otherwise be released into the atmosphere, sinks with them. Their poop, too, plays an important role in battling the ill-effects of our changing climate by stimulating the growth of carbon dioxide-gulping phytoplankton.

A recent International Monetary Fund report noted that each carbon-sequestering whale may be worth *millions* of dollars—but only if they're left to go about their business in the world's oceans. The use of this new whale-watching technology could serve to identify key regions critical to the conservation of vulnerable whale species and their habitat.

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ORIGINAL RESEARCH ARTICLE

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Slocum Gliders Provide Accurate Near Real-Time Estimates of Baleen Whale Presence From Human-Reviewed Passive Acoustic Detection Information

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Mitigating the effects of human activities on marine mammals often depends on monitoring animal occurrence over long time scales, large spatial scales, and in real time. Passive acoustics, particularly from autonomous vehicles, is a promising approach to meeting this need. We have previously developed the capability to record, detect, classify, and transmit to shore information about the tonal sounds of baleen whales in near real time from long-endurance ocean gliders. We have recently developed a protocol by which a human analyst reviews this information to determine the presence of marine mammals, and the results of this review are automatically posted to a publicly accessible website, sent directly to interested parties via email or text, and made available to stakeholders via a number of public and private digital applications. We evaluated the performance of this system during two 3.75-month Slocum glider deployments in the southwestern Gulf of Maine during the spring seasons of 2015 and 2016. Near real-time detections of humpback, fin, sei, and North Atlantic right whales were compared to detections of these species from simultaneously recorded audio. Data from another 2016 glider deployment in the same area were also used to compare results between three different analysts to determine repeatability of results both among and within analysts. False detection (occurrence) rates on daily time scales were 0% for all species. Daily missed detection rates ranged from 17 to 24%. Agreement between two trained novice analysts and an experienced analyst was greater than 95% for fin, sei, and right whales, while agreement was 83–89% for humpback whales owing to the more subjective process for detecting this species. Our results indicate that the presence of baleen whales can be accurately determined using information about tonal sounds transmitted in near real-time from Slocum gliders. The system is being used operationally to monitor baleen whales in United States, Canadian, and Chilean waters, and has been particularly useful for monitoring the critically endangered North Atlantic right whale throughout the northwestern Atlantic Ocean.

Introduction

Human activities in the ocean have the potential to impact marine mammals, and if we are to act as responsible stewards of the ocean, we must find a way to mitigate those impacts, particularly in cases where human activities pose an existential threat to one or more species (Laist et al., 2001; Kraus et al., 2005, 2016; Read, 2008; Tyack, 2008). Banning all human activities in the ocean is untenable, as human society depends on the ocean for transportation and resources (e.g. food), so mitigation efforts must balance the needs of industry and conservation, while acknowledging the strengths and limitations of our ability to monitor both human activities and the abundance or occurrence of marine mammals simultaneously (Verfuss et al., 2018). The latter is a challenge, particularly over long time scales, over large spatial scales, and in real time. Visual and passive acoustic surveys are typically applied to this challenge, and each has its own strengths and limitations (Clark et al., 2010). Visual surveys are adept at positively identifying species and estimating animal abundance, but are limited by daylight and weather (e.g. fog, rain, snow, and high winds). Passive acoustic surveys can monitor continuously for sounds produced by nearby marine mammals, often for long periods of time, but species identification can sometimes be difficult, and for most species, only occurrence can be assessed (density estimation is currently possible for a limited number of marine mammals that are obligate vocalizers using very careful study design, but may be possible in the future for facultative vocalizers if our understanding of call rate variability for these species is substantially improved).

Passive acoustic monitoring from moored archival recorders has been an important tool for marine mammal research for a few decades (e.g. Mellinger et al., 2007; Van Parijs et al., 2009; Davis et al., 2017; Charif et al., 2019). More recently, archival passive acoustic monitoring has been conducted from mobile autonomous platforms, including surface drifters, profiling floats, electric gliders, and surface autonomous vehicles (Moore et al., 2007; Baumgartner and Fratantoni, 2008; Bingham et al., 2012; Klinck et al., 2012; Matsumoto et al., 2013; Griffiths and Barlow, 2016; Bittencourt et al., 2018). These platforms have the capability to range over tens to thousands of kilometers, and often the platform is quiet enough to allow excellent passive acoustic monitoring, particularly at higher frequencies. For mobile platforms, flow and wave wash noise present unique challenges for detecting the low-frequency calls typically made by baleen whales (wave wash includes both breaking waves and waves slapping against the platform hull). Platforms that passively drift, such as profiling floats, avoid flow noise altogether, and can avoid wave wash noise by placing the hydrophone sufficiently far from the surface (e.g. mounted on a profiling float that remains mostly at depth); however, they cannot control their lateral movement and therefore cannot be navigated. Surface autonomous vehicles typically move relatively fast (e.g. >0.5 m s^{-1}) and by definition have a component of the vehicle at the surface, so flow and wave wash noise are serious impediments to monitoring low audio frequencies (lead author's personal observation). The electric glider represents a convenient compromise between these other platforms. It can move slowly enough (0.15–0.2 m s^{-1}) that flow noise will not interfere with detecting low-frequency sounds, and it remains well below the surface much of the time so that wave wash is not an issue, yet it can be navigated over periods of weeks to months.

While archival passive acoustic recordings from autonomous vehicles have been useful for scientific applications (e.g. Baumgartner and Fratantoni, 2008), they are much less useful for mitigation applications because the audio recordings are not accessible to determine species presence until after recovery of the vehicle. Mitigation applications require real- or near real-time detections to immediately separate human activities from marine mammals in space or time. To date, near real-time passive acoustic systems have been developed for stationary installations, including moored buoys (Clark et al., 2005; Van Parijs et al., 2009; Baumgartner et al., 2019) and cabled hydrophones (André et al., 2011; Jarvis et al., 2014; Klinck et al., 2016). Klinck et al. (2012) describe a glider application for the detection and near real-time reporting of odontocetes, particularly beaked whales, and Matsumoto et al. (2013) used the same detection system to detect and report in near real time the clicks of Blainville's beaked whales from profiling floats. The only near real-time passive acoustic system developed to detect the low-frequency calls of baleen whales from long-endurance autonomous vehicles that we are aware of was described by Baumgartner et al. (2013). That system consisted of a digital acoustic monitoring instrument (DMON; Johnson and Hurst, 2007) programed with the low-frequency detection and classification system (LFDCS; Baumgartner and Mussoline, 2011) installed in a Slocum glider, and it was capable of detecting the calls of humpback (*Megaptera novaeangliae*), sei (*Balaenoptera borealis*), fin (*Balaenoptera physalus*), and North Atlantic right whales (*Eubalaena glacialis*) in real time, and relaying information about those calls to shore every 2 h via the glider's native Iridium satellite communication system.

Here, we evaluate the same system described by Baumgartner et al. (2013) (updated for the next generation of Slocum glider), but with a different approach to determining whale occurrence. Baumgartner et al. (2013) derived species-specific call rate thresholds from a logistic regression analysis of one glider dataset, and then applied those thresholds to a second independent glider dataset to automatically estimate occurrence from DMON/LFDCS call classification information. Over time scales of 15 min, this fully automated approach yielded false detection rates of 4, 23, and 0% and missed detection rates of 26, 62, and 27% for right, humpback, and fin whales, respectively (too little sei whale data were available to assess detector performance for this species). In this paper, we apply the human review methods described in Baumgartner et al. (2019) to evaluate DMON/LFDCS data relayed in near real time from Slocum gliders deployed in the southwestern Gulf of Maine during 2015 and 2016. We conducted this evaluation to determine if human review of detection information relayed in near real time could improve the accuracy of the system. We also compared the performance of three analysts reviewing the same glider dataset to understand between- and within-analyst variability in occurrence estimates after appropriate training to a formalized protocol. We believe these performance assessments are vital to our understanding of the strengths and limitations of near real-time passive acoustic monitoring systems for use in mitigation applications.

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Materials and Methods

The Slocum glider (Teledyne Webb Research) is a long-endurance autonomous underwater vehicle that is powered by alkaline or lithium batteries and can carry a variety of sensors to observe the ocean environment (Rudnick et al., 2004; Schofield et al., 2007). The vehicle moves slowly (nominally 0.65 km h^{-1}), but it can travel for weeks to months at a time covering hundreds to thousands of kilometers of survey track. The glider moves down and up in the water column by alternately becoming more and less dense than the surrounding water, respectively. It does this using a piston in the nose (called the buoyancy pump) to change its volume and therefore its density. Data from an integrated altimeter and depth sensor are used to determine when the glider should activate the buoyancy pump to descend or ascend. Short wings provide lift that propels the glider laterally, and an aft rudder and compass allow the vehicle to steer in a desired direction. Over the continental shelf, the glider typically descends to within several meters of the sea floor and ascends to within several meters of the sea surface repeatedly while steering toward a predetermined waypoint. At regular intervals (here every 2 h), the glider ascends to the surface where it acquires a position with a global positioning system (GPS) receiver and initiates a communication session with a shore-side server via Iridium satellite service. During the session, the glider sends engineering and science sensor data (including DMON data) and can receive new mission parameters and waypoints. At the end of the communication session, the glider resumes its descend/ascend sequence.

The DMON instrument Woods Hole Oceanographic Institution (WHOI) was integrated into the science bay of a Slocum glider model G2 for this study. The DMON has been described previously (Johnson and Hurst, 2007; Baumgartner et al., 2013, 2019) and was configured in an identical manner as in previous studies with one exception. Baumgartner et al. (2013) described the integration of the DMON in a Slocum glider model G1 where the hydrophones were mounted in an acoustically transparent urethane housing on the underside of the glider's science bay; in the G2 configuration, the hydrophones were mounted in a urethane housing on the topside of the glider's science bay (Figure 1).

FIGURE 1

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-g001.jpg)

Figure 1. Diagram of data flow from the DMON integrated in a Slocum glider to a shore-side server via the Iridium satellite service. These data are displayed on a website (dcs.whoi.edu (http://dcs.whoi.edu)), and pitch tracks and classification information are reviewed by an analyst to produce species-specific occurrence estimates for each monitored tally period. Occurrence estimates are then distributed to users via the same publicly accessible website as well as email and text messages. Web display in the figure shows a pitch track of a single North Atlantic right whale upcall.

The DMON consists of a programmable digital signal processor (Texas Instruments TMS320C55), flash memory, and integrated hydrophones that allow the instrument to record and process audio. The DMON for this study was programed with the low-frequency detection and classification system (LFDCS; Baumgartner and Mussoline, 2011; Baumgartner et al., 2013), which continuously recorded and processed audio from the attached low-frequency hydrophone (WHOI custom-built end-capped cylinders with Navy type II ceramics, 8–7500 Hz bandwidth, 36 dB re μPa/√Hz noise floor at 2 kHz, and −169 dB re V/μPa sensitivity at 2 kHz). The LFDCS sampled and recorded audio at 2000 samples per second, created spectrograms in real time (512 sample frame, Hann window and 75% frame-to-frame overlap, resulting in a spectrogram frequency resolution of 3.9 Hz and a time step of 64 ms), equalized the spectrograms, and identified and characterized tonal sounds using a pitch tracking algorithm (Baumgartner and Mussoline, 2011). Pitch tracks were classified by comparing attributes of each pitch track to the multivariate distribution of those same attributes for a variety of call types in a call library using quadratic discriminant function analysis. Pitch tracks and their associated classification information were transferred from the DMON to the Slocum glider via serial communications, but the amount of pitch track data sent each hour was limited to 8 kilobytes (kB) to constrain the cost of sending the data and the time and cost of reviewing those data back on shore (see below). As mentioned above, the glider transferred these data to shore during Iridium satellite communication sessions once every 2 h.

For this study, the presence of species-specific calls was taken as evidence of the occurrence of one or more whales of that species. Upcalls, a frequency-modulated upsweep from ~100 to 300 Hz (Schevill et al., 1962; Clark, 1982, 1983), were used to identify North Atlantic right whales, low-frequency downsweeps (34–82 Hz; Baumgartner et al., 2008) were used to identify sei whales, and 20-Hz pulses (17–25 Hz downsweeps; Watkins et al., 1987; Morano et al., 2012) were used to identify fin whales. Each of these species-specific calls had one or more call types in the LFDCS call library. No one call was used to identify humpback whales; instead, recognizable patterns of variable notes that comprise humpback whale song (e.g. Payne and McVay, 1971; D'Vincent et al., 1985; Clark and Clapham, 2004) were used to identify this species.

Near Real-Time Analysis

Pitch track data received from the glider by the shore-side server in near real time were ~~immediately posted~~ in graphical format on a publicly accessible website[1] (Figure 1). An analyst reviewed these data using a protocol that was developed jointly by scientists at WHOI and the National Oceanic and Atmospheric Administration's Northeast Fisheries Science Center (NEFSC), and is available at dcs.whoi.edu/ (http://dcs.whoi.edu/)#protocol. Details of the review process are described in Baumgartner et al. (2019). Briefly, pitch tracks from 15-min periods (called tally periods) were reviewed on a single web page where pitch tracks were displayed in stacked time-frequency plots (see time-frequency plot in Figure 1). The analyst considered the shape, amplitude, classification information and isolation from noise for each pitch track, as well as the context in which the pitch track occurred (i.e. pitch tracks in temporal proximity to a pitch track of interest) and any patterning in pitch tracks to determine if a pitch track was likely produced by a whale. Taking into account all of the information displayed in a 15-min tally period, the analyst scored the period as "detected," "possibly detected," or "not detected" for each of the monitored species (right, humpback, sei, or fin whale). A form on the pitch track webpage allowed the analyst to enter these scores as well as notes about what she/he had observed in the pitch tracks. For each species, a tally period was scored as "detected" when there was convincing evidence of a species' acoustic presence, "possibly detected" when there was some evidence of acoustic presence, but the evidence was not completely convincing, or "not detected" when there was no reasonable evidence of a species' acoustic presence (see Baumgartner et al., 2019 supporting information for further explanation). After the analyst's review was complete, occurrence information for each of the monitored species was displayed on the website[2] in tabular and graphical formats, sent directly to interested stakeholders by email or text, and was made available in several other applications, such as Whale Alert[3], the United States Coast Guard's CG1View situational awareness software, and WhaleMap[4].

Post-recovery Audio Analysis

After recovery of a glider, the continuous audio recordings were downloaded from the DMON and reviewed by an experienced analyst. The analyst reviewed audio for all 15-min tally periods for which at least 3.75 min of pitch track data had been sent and reviewed in near real time (note that tally periods that contained large numbers of pitch tracks from whales or other sources may have only a few minutes of pitch track data for review in near real time because of the 8 kB hr^{-1} limit). The analyst visually reviewed spectrograms and aurally reviewed audio for each of these 15-min tally periods to determine if the monitored species were "detected," "possibly detected," or "not detected" depending on how convincing the evidence was. Audio from the entire 15-min tally period was considered when scoring, not just the period when pitch tracks were available (e.g. for a tally period that had 5 min of pitch track data available in near real time, the audio analysis considered the entire 15 min of audio recordings).

Evaluation of the Accuracy of Near Real-Time Occurrence Estimates

Confusion matrices were used to compare occurrence estimates derived in near real time to occurrence estimates derived from review of the audio, where the audio analysis was considered the "truth." Only periods scored as either "detected," or "not detected" in both the near real-time and audio analyses were assessed with the confusion matrices (periods scored as "possibly detected" in either the near real-time or audio analyses were assessed separately). Performance metrics were calculated from the confusion matrices. Confusion matrices and performance metrics are presented below for 15-min and daily time scales, where the 15-min time scale refers to the comparison of individual tally periods and the daily time scale refers to the comparison of tally periods aggregated over 1 day. Daily data aggregation involved scoring a day as (1) "detected" if at least one tally period that day was scored as "detected," (2) "possibly detected" if no tally periods were scored as "detected" and at least one tally period was scored as "possibly detected," or (3) "not detected" if none of the tally periods were scored as "detected" or "possibly detected" (i.e. all tally periods were scored as "not detected"). Correlation analysis of daily percentages of tally periods scored as "detected" for the near real-time and audio analyses was also conducted for each of the monitored species. Daily percentages were transformed using the arcsine square-root transform: $\hat{X} = \sin^{-1}\left[\sqrt{\frac{X}{100}}\right]$ (Sokal and Rohlf, 1995). Axes of transformed values were back-transformed into percentages for clarity in the figures.

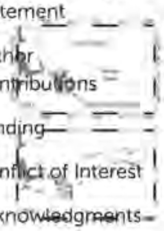
Evaluation of Between- and Within-Analyst Variability in Occurrence Estimates

For one of the glider deployments, the near real-time review of pitch tracks and classification information was conducted by three different analysts. One of the analysts (JB.; hereafter referred to as the experienced analyst) had significant experience identifying species-specific calls in both audio and pitch track data. The other two analysts (CH and JBT; hereafter referred to as the novice analysts) had significant experience reviewing audio for whale occurrence, but no experience evaluating pitch tracks. The two novice analysts were trained by the experienced analyst and the lead author using the analyst protocol (available at dcs.whoi.edu/ (http://dcs.whoi.edu/)#protocol). One year after they conducted the near real-time review, all three analysts repeated their review without access to their original scores. The scores of the two novice analysts were compared with the experienced analyst to assess how well the training and protocol reduced disagreement among the analysts. For each analyst, the original scores were also compared to scores determined 1 year later to evaluate within-analyst variability in occurrence estimates. Agreement was defined as the percentage of tally periods for which the two analysts' scores were identical, disagreement was defined as the percentage of tally periods for which the two analysts' scores were different (equivalently computed as 100 minus agreement), and serious disagreement was defined as the percentage of tally periods for which one analyst's score was "detected" and the other analyst's score was "not detected" (i.e. serious disagreement ignored differences among analysts that involved a "possibly detected" score).

Results

A single glider owned and operated by WHOI was deployed during spring 2015 in the southwestern Gulf of Maine in an area known as the Great South Channel (Figure 2). The Great South Channel was chosen for the study because of the high occurrence of all 4 species monitored by the DMON/LFDCS during late spring. The glider conducted 3 sets of east-west survey transects across the channel between deployment on 11 April and recovery on 31 July (Figure 2). During 2016, this same glider conducted 2 sets of east-west survey transects after deployment on 13 April, but then conducted a survey of the northern edge of Georges Bank and Georges Basin before being recovered on 8 August (Figure 2). East-west transects were influenced by strong north-south tides in the region, hence the survey transects were often not straight lines. Also during 2016, a second glider owned and operated by the U.S. Naval Oceanographic Office (NAVOCEANO) was equipped with a DMON and deployed on 13 April to conduct 1 set of east-west survey transects in the Great South Channel before recovery on 13 May. The DMON on the NAVOCEANO glider was not permitted to record audio, but sent pitch tracks to shore in near real time via Iridium satellite communications. Results of the 2015 and 2016 WHOI glider deployments were combined to evaluate the accuracy of near real-time occurrence estimates of right, humpback, sei and fin whales using audio simultaneously recorded by the DMON, while the 2016 NAVOCEANO glider deployment was used to evaluate between- and within-analyst variability in occurrence estimates.

FIGURE 2



(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-g002.jpg)
Figure 2. Track of the WHOI Slocum glider in the southwestern Gulf of Maine off the coast of Cape Cod, Massachusetts during 2015 and 2016. The 50-fathom isobath is shown in gray.

During the 112-day 2015 WHOI glider mission, 2,095,986 pitch tracks were generated by the DMON/LFDCS of which 412,980 (19.7%) were transmitted to shore. A total of 4,527 tally periods were analyzed in near real time, and audio analysis was conducted on 3,349 of those tally periods. The audio analysis focused on tally periods between 11 April and 31 July 2015 for which 3.75 min or more of pitch track data were analyzed in near real time. During the 118-day 2016 WHOI glider deployment, 2,196,583 pitch tracks were generated by the DMON/LFDCS of which 356,267 (16.2%) were transmitted to shore. A total of 4,974 tally periods were analyzed in near real time, and audio analysis was conducted on 2,072 of those tally periods. The audio analysis focused on tally periods between 25 April and 1 July 2016 for which 3.75 min or more of pitch track data were analyzed in near real time. During the 31-day 2016 NAVOCEANO glider deployment, 98,062 pitch tracks were generated by the DMON/LFDCS and transmitted to shore. The three analysts (1 experienced and 2 novice) analyzed 714 tally periods in near real time over the course of the entire glider deployment (13 April to 13 May), and repeated their analysis 1 year later. During the repeat analysis, an additional 185 tally periods were reviewed that were not available in near real time because of complications in data transfer from the NAVOCEANO Iridium server to WHOI's web processing system; thus, 899 tally periods were reviewed during the repeat analysis.

All 4 monitored species were detected during the WHOI glider surveys (Figures 3, 4, and Table 1). Right whales had the lowest occurrence; only 68 tally periods were scored as "detected" on 28 separate days during the audio analysis (Table 1). Humpback whales, in contrast, had the highest occurrence, with 1,731 tally periods being scored as "detected" (32% of all 5,421 analyzed tally periods) on 149 separate days during the audio analysis. Sei whales were detected during 1,060 tally periods (101 separate days), while fin whales were detected during 1,071 tally periods (135 separate days) of the audio analysis.

FIGURE 3

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-g003.jpg)
Figure 3. Track of the WHOI Slocum glider during 2015 and 2016 combined (black) and locations of the glider when **(A)** right, **(B)** humpback, **(C)** sei, and **(D)** fin whales were scored as "detected" (red filled circles). The 50-fathom isobath is shown in gray.

FIGURE 4

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(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-g004.jpg)
Figure 4. Time series of daily detections derived from the retrospective audio analysis (above zero line) and daily detections derived from the near real-time analysis (below zero line) for **(A)** right, **(B)** humpback, **(C)** sei, and **(D)** fin whales. Detections and possible detections are shown for both analyses. Scatterplots of near real-time versus retrospective audio detections for **(E)** right, **(F)** humpback, **(G)** sei, and **(H)** fin whales. Coefficients of determination (r^2) and associated p values are shown as well as a 1:1 line (solid) and simple linear regression line (dashed).

TABLE 1

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-t001.jpg)
Table 1. Confusion matrices comparing near real-time analysis to audio analysis for right, humpback, sei, and fin whales over 15-min and daily time scales.

Evaluation of the Accuracy of Near Real-Time Occurrence Estimates

Using the 2015 and 2016 WHOI glider deployments combined, near real-time occurrence estimates had low false detection rates for all species on both 15-min and daily time scales when using occurrence estimates from the audio analysis as the "truth" (Tables 1, 2). False detection rates were less than 0.3% on 15-min time scales, and were 0% on daily time scales. Missed detection rates ranged from 34 to 64% on 15-min time scales and 17 to 24% on daily time scales (Table 2). For humpback, sei, and fin whales, tally periods scored as "possibly detected" in near real time were most often scored as "detected" in the audio analysis (Table 3), suggesting that the analyst erred on the side of missing true detections rather than scoring false detections (as encouraged by the analyst protocol). For right whales, tally periods scored as "possibly detected" in near real time were nearly equally likely to be scored as "detected," "possibly detected," or "not detected" in the audio analysis (Table 3).

TABLE 2

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-t002.jpg)
Table 2. Performance metrics for the near real-time analysis (when treating the audio analysis as the "truth") over 15-min and daily time scales for right, humpback, sei, and fin whales based on the confusion matrices in Table 1.

TABLE 3

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-t003.jpg)
Table 3. Audio analysis scores for 15-min tally periods scored as "possibly detected" in near real time.

Temporal variability in near real-time detections mirrored that from the audio analysis for all species, but there tended to be fewer detections per day in near real time than in the audio analysis (Figures 4A–D). Scatterplots of daily percentages of detections (Figures 4E–H) confirm this observation with regression slopes that were less than 1. Daily near real-time detections of all species were strongly related to detections from the audio analysis ($p < 0.0001$ for all species).

Evaluation of Between- and Within-Analyst Variability in Occurrence Estimates

Using the 2016 NAVOCEANO glider deployment, agreement between the novice analysts and the experienced analyst was very high for right, sei, and fin whales; agreement was greater than 95% for these species and serious disagreement was less than 1.4% (Table 4). It is important to note that there were no right whale detections by the experienced analyst for the NAVOCEANO glider in 2016, a year of low right whale occurrence in the Great South Channel (there was only 1 right whale detection on the WHOI glider in the Great South Channel prior to 13 May, the date the NAVOCEANO glider was recovered). Agreement was lower for humpback whales, ranging from 83 to 89%, while serious disagreement for humpback whales was substantially higher than for the other species, ranging from 3.6 to 5.9% (Table 4). The analysts' original scores largely matched their scores determined 1 year later (Table 5). The experienced analyst had higher within-analyst agreement, but the novice analysts' agreement was still excellent, particularly for right, sei, and fin whales (within-analyst agreement for the novices was 96.5% or greater). As with the between-analyst comparisons, within-analyst comparisons showed lower agreement for humpback whales (agreement ranged from 87 to 94%, and serious disagreement ranged from 0.5 to 1.5%).

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TABLE 4

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-t004.jpg)
Table 4. Between-analyst agreement, disagreement, and serious disagreement for two novice analysts (A2 and A3) compared to an experienced analyst (A1).

TABLE 5

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-t005.jpg)
Table 5. Within-analyst agreement, disagreement, and serious disagreement (%) for one experienced (A1) and two novice analysts (A2 and A3).

Discussion

The Slocum gliders used in this study were able to successfully conduct surveys in a tidally energetic region for nearly 4 months at a time while detecting humpback, sei, fin, and North Atlantic right whales. False detection rates were extremely low for all 4 monitored species on both 15-min and daily time scales. Missed detection rates ranged from 34–64% on 15-min time scales and 17–24% on daily time scales. Compared to the automated method to estimate occurrence based on classified call counts described in Baumgartner et al. (2013), the human-review used here (after

Baumgartner et al., 2019) yielded lower false detection rates for right and humpback whales, while fin whale false detection rates were equivalent (sei whales could not be evaluated by Baumgartner et al., 2013). Missed detection rates were higher for right and fin whales during the human review, but lower for humpback whales. It is important to note that these performance statistics are derived from separate glider datasets (one in the northern Gulf of Maine in November and December 2012 and one in the southwestern Gulf of Maine during April–June 2015 and 2016), so it is very possible that the noise environment and interfering sounds were quite different between the two studies. Despite differences in the underlying datasets, these results suggest that false detection rates can be improved substantially with a human review of pitch tracks, perhaps at the cost of higher missed detections (as observed for right and fin whales).

A human review of pitch tracks was used by Baumgartner et al. (2019) to assess the performance of a moored buoy equipped with a DMON/LFDCS that sent detection information to shore every 2 h via Iridium satellite. An identical human review of pitch tracks using the same protocol was used in the present study; in fact, the same experienced analyst conducted the human review for both studies. False detection rates were extremely low (≤0.3%) for both the Slocum glider and the moored buoy at 15-min time scales (Table 6), and were 0% for both platforms on daily time scales. Missed detections varied by species between the platforms: missed detections on 15-min time scales were comparable between platforms for right and sei whales, lower on the glider for humpbacks, and lower on the buoy for fin whales. At daily time scales, missed detections were lower on the glider for right, humpback, and sei whales, but lower on the buoy for fin whales. Baumgartner et al. (2019) examined the reasons for missed detections on the moored DMON/LFDCS buoy and determined that low calling rates, data limitation (i.e. the 8 kB h^{-1} limit on transmitted pitch tracks), low amplitude calls, and interfering sounds contributed to missed occurrence. Both the glider and the buoy are subject to the same data limitation, so this should not contribute to the differences in missed call rates. It is likely that the variation in missed detections between the platforms may have more to do with differences in whale abundance and distribution around the platform at the two study sites, which would affect both calling rates and received amplitude. Missed detections can vary over time with the number of whales present, distance of the whales from the platform, whale calling behavior, and interfering noise, factors that have little to do with the platform and more to do with the study area or chance. Collocating the platforms would be a better study design for comparing differences in detection performance; the comparison, here, may be too confounded by variability in factors that are unrelated to the platforms themselves.

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TABLE 6

(https://www.frontiersin.org/files/Articles/502649/fmars-07-00100-HTML/image_m/fmars-07-00100-t006.jpg)
Table 6. Comparison of false and missed detection (occurrence) rates over 15-min time scales for a glider-mounted DMON/LFDCS using an automated detection method (data from Baumgartner et al., 2013) and a human review of pitch tracks (this study), as well as a moored DMON/LFDCS using a human review of pitch tracks (data from Baumgartner et al., 2019).

One of the challenges of detecting North Atlantic right whales with passive acoustics is that humpback whales often make an upsweep call that is very similar to the right whale upcall (e.g. Mussoline et al., 2012; Hodge et al., 2015; Charif et al., 2019). Despite very high humpback whale calling rates in the Great South Channel (Figure 4), right whale false detection rates were 0% on 15-min and daily time scales. The reason for such low false detection rates is that the analyst can evaluate the context in which low-frequency upsweeps are made (i.e. the sounds detected before and after a call of interest). The protocol urges the analyst to treat upsweeps that are accompanied by other pitch tracks attributable to humpback whales with skepticism and only consider upsweeps as coming from right whales if there is strong evidence to suggest the upsweeps are a different amplitude than the surrounding calls or are "off rhythm" (i.e. out of temporal sequence) with a known pattern of humpback whale calls (i.e. song notes).

Agreement among the three analysts reviewing the same set of detections was excellent for all species, particularly right, sei, and fin whales (Table 4). It is important to note that the evaluation of between- and within-analyst variability in occurrence estimates for right whales was incomplete because no right whales were detected during the 2016 NAVOCEANO glider deployment. We contend that having a documented protocol and using that protocol to train novice analysts was responsible for such strong agreement among the analysts. Agreement was lower for humpback whales, which reflects the greater subjectivity involved in identifying the varied calls that make up their song. In contrast to humpback whales, right, sei, and fin whales all have much more stereotypical calls for which the DMON/LFDCS can provide useful classification information, making identification more (but not completely) objective. There was also lower agreement for humpback whales than there was for right, sei, and fin whales for the same analyst reviewing the same dataset on two occasions 1 year apart (Table 5). Nevertheless, the analysts showed remarkable consistency in their scores after the 1-year interval, suggesting that the protocol effectively reduced both between- and within-analyst variability in occurrence estimates. This was encouraging, as it suggests that analysts with experience conducting aural reviews of audio and visual reviews of associated spectrograms can be trained over the course of only a few days to accurately review pitch track data as well. Moreover, it suggests that analysts can be "calibrated" with the protocol to produce the same results so that, for example, two analysts can conduct near real-time analysis on the same platform at different times (e.g. one analyst takes over reviewing data while the other is on vacation), and the detection process will remain consistent.

To date, Slocum gliders equipped with the DMON/LFDCS have been used for over 50 separate missions in the United States, Canada, and Chile. Deployments on the United States and Canadian east coasts have focused on right whale monitoring to provide scientists and managers information on distribution and occurrence in near real time. These observations have been used to direct aerial and shipboard surveys to whale locations to collect behavioral observations and photographs that are later used for individual identification and population estimation using mark-recapture methods (e.g. Pace et al., 2017). The United States government will soon use right whale passive acoustic detections to trigger dynamic management areas designed to reroute or slow ships in the vicinity of right whales on a voluntary basis to reduce ship strikes, and near real-time glider-based right whale detections will likely be an important data source for this management effort. Slocum gliders with the DMON/LFDCS have also been used to monitor bowhead, killer, beluga, humpback, and fin whales as well as bearded seals in the Chukchi Sea in the United States Arctic annually since 2013 (Baumgartner et al., 2014), and blue, humpback, and sei whales in the waters of northern Patagonia, Chile during 2018 and 2019 (unpublished data). The performance statistics reported, here, demonstrate that gliders are excellent platforms for near real-time passive acoustic monitoring of baleen whales, and that the technology has moved beyond the research and development phase and is now a viable operational tool for many monitoring and mitigation applications.

Data Availability Statement

The datasets generated for this study are available on request to the corresponding author.

Author Contributions

MB, SV, PC, and CH conceived the study. BH and SB prepared the WHOI and NAVOCEANO gliders, respectively. BH deployed all of the gliders and recovered the 2015 WHOI glider. MB oversaw all fieldwork, piloted the WHOI glider and recovered the 2016 WHOI and NAVOCEANO gliders, analyzed the data, and led the writing of the manuscript. BM oversaw piloting of the NAVOCEANO glider. SV and PC coordinated NOAA vessel access. SV and CH deftly managed grant funds and fund transfers among institutions. JuB reviewed all near real-time detection data and archived audio. CH and JaB analyzed the NAVOCEANO glider detection data. All authors contributed critically to the drafts and gave final approval for publication.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Footnotes

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2. ^ dcs.whoi.edu (http://dcs.whoi.edu)
3. ^ whalealert.org (http://whalealert.org)
4. ^ whalemap.ocean.dal.ca (http://whalemap.ocean.dal.ca)

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HOW TECHNOLOGY IS HELPING WHALE CONSERVATION

A guest blog by Josy O"Donnel

While many whale populations have been on the rise since hitting their low-point during the latter half of the last century, many species are faring less well. In all probabilities the vaquita porpoise will be extinct within a few decades. Population trends in other species/populations such as Maui's dolphin, the North Atlantic right whale, the Gulf of Mexico Bryde's whale and the Southern Ocean blue whale are equally disturbing. Consequently, conservation efforts are still crucial for ensuring the survival of many different species. Technologies like satellite imaging, which makes it easier to track and monitor groups of whales all across the globe, or sophisticated data analysis methods that can shed new insight on whale behaviors and human interactions have an important role to play. The following list showcases some of the most important conservation tools, resources and solutions made possible with technology.

Using Satellite Imagery to Track Whale Populations

The sheer size and unique nature of a maritime environment and habitat creates a number of problems that have often limited and interfered with conservation efforts. Satellites are often the only viable way to track, monitor and observe whales as well as their movement patterns, behavior and habits. The falling cost of satellite imaging has been a real boon for marine biologists who study whales as well as various conservation groups that are dedicated to protecting them. The spread of industrialization and the resulting increase of shipping traffic means that satellite tracking and images will continue to be a key resource in the fight to protect whales and other marine life.

Regulating Maritime Traffic

Shipping and boat traffic pose more than just a direct physical threat to whales and other large marine life. Poorly planned shipping lanes and heavy traffic can disrupt feeding habits, interfere with migratory patterns and may even cause damage to the sensitive hearing that is so critical for most species of cetacean. Enhanced communication and the ability to relay information from other sources, such as other vessels and even observation drones and satellites, makes it easier to minimize the negative impact of maritime traffic. Advanced warning systems that even include mobile applications can alert boat captains to the presence of whales along their route and allow them to make whatever changes or adjustments may be needed.

Aerial Drones and Remote Acoustic Monitoring Equipment

Satellites are not the only high-tech option for motioning and tracking whales. New resources like aerial drones that offer a flexible and low-cost alternative to observation aircraft and sophisticated underwater acoustical monitoring arrays have allowed for whale movements to be tracked, monitored and anticipated with greater accuracy than ever before. Accurate and timely information regarding whale locations, movements and behaviors is absolutely essential for identifying situations where conservation efforts can make a difference as well as assessing the impact that existing methods are having.

New Recycling Methods and Biodegradable Plastics

Pollution, refuse and other marine debris that impacts the marine ecology poses a serious risk to whales as well as all aquatic life. Plastics that find their way into the seas and oceans can be very harmful for

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whales that feed off plankton. Next-generation manufacturing and recycling methods that are helping to ensure less plastic finds its way into the food chain as well as new synthetics that are designed to biodegrade may play an important role in ensuring the survival of countless ocean species, including whales. Other environmental technologies that might one day make a difference also include strains of bacteria that have been specifically engineered in order to eat plastic and other synthetics as well as automated drones able to assist in collecting floating refuse for safe disposal.

Using Data Analytics to Promote Conservation
New methods that make it possible to collect, curate and assess large volumes of data in order to identify underlying patterns may have much to offer wildlife and marine conservationists. The ways and degrees in which our industrial society is impacting the natural world can be difficult to accurately measure or quantify. Data analytics is an ideal tool for uncovering and identifying potential threats to whale populations that might otherwise have escaped notice. Being able to produce greater insight on the ways in which humans may be damaging marine ecosystems helps to ensure that future conservation efforts may be directed with greater effectively.

Combating Ocean Acidification
Ocean acidification poses a dire threat to all marine life. Technology that offers new ways to curb greenhouse gas emissions can go a long way toward mitigating the damages and risks associated with acidification. While efforts to safeguard whale populations and species directly are often of critical importance, dealing with larger threats that might otherwise erode the entire ecosystem may prove to be just as important. While technologies like electric vehicles and solar energy may not seem related to whale conservation efforts, they could prove to be just as essential as the resources that make more direct efforts of preservation possible.

Future Technologies
In order to be effective, conservation efforts need to address both direct threats to whales as well as reducing the impact that humans are having on the oceans as a whole. Emerging technologies, such as smarter fishing nets that are less likely to pose a risk to other species and even sophisticated digital tagging methods that can provide even more insight on the needs and habits of whale populations may soon have an important role to play. Innovative new technologies are constantly providing conservationists with an ever expanding range of tools and solutions that may be used to help safeguard whales and other marine life.

Josy O'Donnel is the creator of [Conservation Institute](). While completing her bachelors degree, she developed an interest in the study of Earth's future and the conservation of Earth's natural resources. Years after, she is still immersed in these subjects. She wants to share her passion with an online community of people who are devoted to spreading awareness and attention to the most pressing threats to the diversity of life on Earth.

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Ship Speed Watch

Oceana's "Ship Speed Watch" allows users to monitor ship speeds in voluntary and mandatory speed restricted zones that were established to protect marine mammals like North Atlantic right whales along the East Coast of Canada and the United States in near real-time. When mandatory and enforced, speed restriction zones can help prevent collisions with ships, one of two leading causes of North Atlantic right whale injury and death. Ship Speed Watch was created using Automatic Identification System (AIS) data from Global Fishing Watch, an independent non-profit founded by Oceana in partnership with Google and SkyTruth, which uses cutting-edge technology to interpret data from various ship tracking resources. AIS was initially designed as a safety mechanism for ships to avoid collisions at sea. Using ship identifying information reported by operators, AIS can be used to monitor and track ship movements over time since it transmits a ship's identity, speed, and GPS location.

CLICK HERE TO LEARN HOW TO USE THIS MAP

Ship Speed Watch uses vessel information in the Global Fishing Watch database. This information is transmitted from a vessel's Automatic Identification System (AIS) device, which is collected via satellites and terrestrial receivers. Faulty AIS devices, user error, intentional manipulation, crowded areas, poor satellite reception, and transmission flaws are factors that contribute to noise and errors in AIS data, and sometimes those inaccuracies can be reflected in the speed and location of a vessel. Vessel operators can accidentally or purposefully enter false information into their ship's AIS thus concealing their identity or location. In crowded areas, such as ports, the massive number of radio transmissions can crowd the bandwidth of satellite and terrestrial receivers, leading to inaccuracies as well. For these reasons, Ship Speed Watch information must be relied upon solely at your own risk.

Background

In 2019, Oceana launched a campaign in the U.S. and Canada to help save the North Atlantic right whale, one of the most endangered large whales on the planet. They were named for being the "right" whale to hunt because they were often found near shore, swim slowly and tend to float when killed. North Atlantic right whale populations first crashed due to whaling until hunting this species was banned in 1935. Now the whales are on the brink of extinction mostly due to threats from marine vessel traffic and commercial fishing. Today, only about 400 North Atlantic right whales remain, including fewer than 100 breeding females, and the loss of even one animal a year is biologically devastating to the species' recovery. They could be the first large whale species to go extinct in the Atlantic Ocean in centuries. To reverse course, North Atlantic right whales must be protected from ship strikes and fishing gear entanglements.

North Atlantic right whales are slow, swimming around six miles per hour, usually near the water's surface. They are also dark in color and lack a dorsal fin, making them very difficult to spot. At normal operating speeds, ships cannot maneuver to avoid North Atlantic right whales, putting the whales at great risk of strikes, which can cause deadly injuries from blunt force trauma or cuts from the propellers. Slowing ship speeds to 10 knots or less in areas where these whales may be encountered can reduce death from collisions by 86%.

A 2020 Oceana analysis of ship speeds in an area south of Nantucket found that 41% of ships were ignoring the voluntary speed limit of 10 knots, which was established by the National Oceanographic and Atmospheric Administration (NOAA) to reduce the risk of injury or death to these whales. Oceana Canada also released a report with an analysis indicating that 67% of ships were ignoring a voluntary speed zone in the Cabot Strait designed to protect this species. **Requiring ships to slow down can help save North Atlantic right whales from extinction.**

To learn more about Oceana's binational campaign to save North Atlantic right whales, click here**.**

To make your voice heard and tell government officials to act now to protect North Atlantic right whales, click here**.**

To learn more about speed restriction zones in the U.S. click here **and in Canada** click here.

To see the scale of a North Atlantic right whale compared to a cargo vessel, click here**.**

To read the methodology of how this map was developed, click here.

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NOAA Technical Memorandum NMFS-NE-247

North Atlantic Right Whales- Evaluating Their Recovery Challenges in 2018

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
September 2018

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North Atlantic Right Whales - Evaluating Their Recovery Challenges in 2018

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ABSTRACT

The North Atlantic right whale (*Eubalaena glacialis*) population has been in decline for 8 years due to increased mortality and sublethal effects from multiple factors. Together these have contributed to a decrease in calving. Shifting ecosystem conditions have also changed North Atlantic right whale behavior and fishing patterns. For example:

- North Atlantic right whales have expanded their distribution farther into northern waters, and are visiting different foraging areas.
- Calanoid copepod distributions appear to be in a similar state of change and this may be affecting available forage for North Atlantic right whales
- The whales' range expansion has exposed them to vessel traffic and fisheries in Canadian waters, which did not have protections for right whales in place until late last summer (2017).
- American lobster (*Homarus americanus)* populations are also changing distribution, moving north and into deeper, cooler waters of the Gulf of Maine. The US fisheries are moving farther offshore to capitalize on this, increasing the overlap between their fishing activity and North Atlantic right whale foraging areas and migration corridors.

The net result of these events is that severe entanglements have increased among North Atlantic right whales. Animals are in poor body condition likely from a combination of repeated entanglement stress, potentially limited forage and increased migratory costs- all contributing to a decrease in female calving rate. Ship strikes are still a real threat to the population. At the current rate of decline, all recovery achieved in the population over the past three decades will be lost by 2029.

INTRODUCTION

Signs of Trouble

After several decades of recovery and years of collaboration among stakeholders, the North Atlantic right whale (*Eubalaena glacialis*), hereafter referred to as the right whale, began to decline (Pace et al. 2017). This trend was subtle at first, initially signaled by fewer sightings in traditional survey areas, but other warning signs began to emerge (Kraus et al. 2016). The number of documented mortalities increased markedly in 2016 and 2017 (Hayes et al. 2018; Hayes et al. 2017) and an improved way of modeling the population's numbers (Pace et al. 2017) revealed a clearer picture of the population size and decline in numbers. Concern further escalated throughout 2017 and 2018 when only 5 calves were born and there were 19 confirmed mortalities through August.

Taken together these signs meant that risks posed to right whales and associated management measures needed to be revisited for multiple US fisheries on the Atlantic coast. This occurs through the biological opinion process under the federal Endangered Species Act, which was reinitiated in October 2017, and through the take reduction team process under the federal Marine Mammal Protection Act.

Demographic Effects

Increased mortality rates and decreased calving have moved the population into a decline that has continued for at least the last 8 years. At present, right whale deaths attributable to human activity are mostly caused by ship strikes and entanglement in pot/trap and anchored gillnet fishing gear. An encounter with fishing gear is the most frequent cause of documented right whale serious injuries and deaths in recent years. The odds of an entanglement event are now increasing by 6.3% per year, while ship strikes events remain flat (Fig. 1). At the current rate of decline, the population will have returned to its 1990 numbers, likely with comparatively reduced genetic diversity, and could decline past a point of no return in just a few decades.

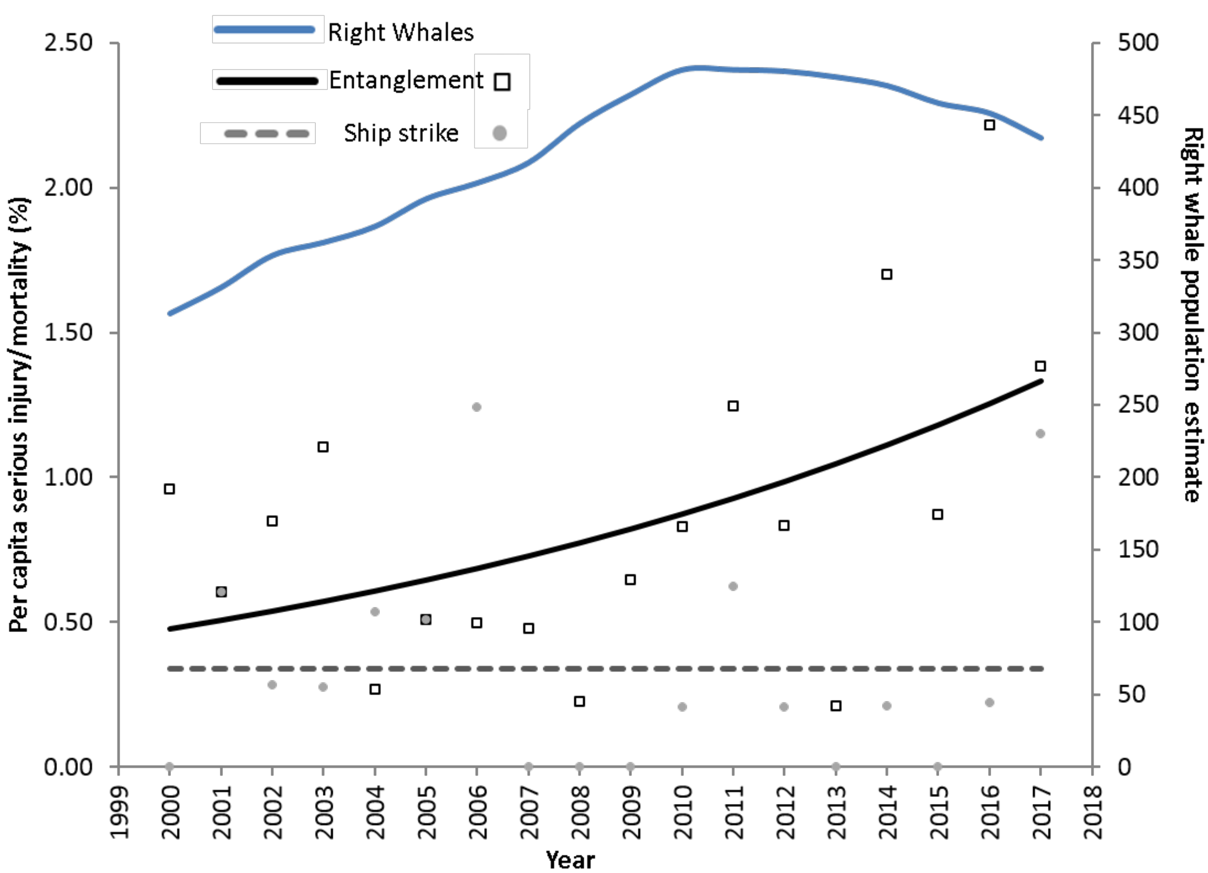

Fig. 1 North Atlantic right whale serious injury/mortality rates from known sources 2000-2017 (Henry et al 2017; 2016 & 2017 values preliminary). Models are simple logistic regressions fit using maximum likelihood-based estimation procedures available in R. The right whale population trend is overlaid and referenced to right y-axis (Hayes et al, 2018).

Distribution Change

Historically, right whales have returned to habitats in specific geographic locations annually, ensuring that a large portion of the population could be seen in each year. Therefore annual population estimates were conducted by simply sighting and counting as many animals as possible each year. Resulting estimates also assumed that an animal had died if it were not seen for 6 consecutive years.

Changes in this distribution pattern began around 2010 when the population peaked at 481 individuals. The whales were no longer using some of their established habitat areas in as great a number, and not staying within them for as long. This meant a new method was needed to account for animals, even those not sighted in a year. Once developed, this more advanced assessment tool, based upon mark recapture methods, enabled rapid assessment of the population with increased precision within one calendar year, much faster than the five or so years required to get good confidence on an annual estimate using the previous method. It also provided precise population estimates with greater resolution on the number of whales that likely died in any given year. Estimates made using the new method confirmed that in recent years, many deaths (around 10 to 20/yr) were going undetected annually and that by the end of 2016, the right whale population had declined to 451 individuals. A revised population estimate accounting for the many deaths and few births of 2017 is being developed and will be available later this year.

Increased Mortality

The large number of observed right whale mortalities in 2017 triggered an unusual mortality event (UME) to investigate the causes. The National Marine Fisheries Service (NMFS) is authorized to declare UMEs under the federal Marine Mammal Protection Act when an unanticipated significant die-off occurs in a marine mammal population, requiring an immediate response. Two other UMEs were declared that year due to 80 humpback whale and 40 minke whale deaths. Ongoing investigations for these two species have preliminarily identified causes of death that include entanglements, ship strikes, and disease.

In contrast to other large whale species, the problems of right whales are often more apparent because they are monitored more intensely and their coastal distribution means more opportunity for overlap with human activities, leading to it being nicknamed 'the Urban Whale' (Kraus et al. 2007).

While perhaps more attention is paid to the right whale given their more dire population status, it can be an indicator of more chronic problems that need addressing, not just for the sake of right whales but also for other populations of large whales. By example, although Gulf of Maine humpback whale status has improved, entanglement mortalities still remain high for this stock (Hayes et al. 2018).

There is considerable urgency to address the issues of mortalities that stem from human activities. Large whales, including right whales, are long-lived and can breed multiple times during their lives. This means these species can be resilient and able to recover after periods of poor reproduction. However, recovery for any species cannot take place if the number of deaths is more than the number of births in the population.

POTENTIAL CAUSES OF THE DECLINE

Ecosystem Dynamics

One of the constant challenges of resource management is that things change. While it is much easier to make management decisions if conditions are static, ecosystems are inherently dynamic and will change over time in response to a variety of influences. This is the case for the emerging story for right whales.

Sometime around 2010, ecosystem shifts occurred within their habitat that changed right whale movements and fishing practices in a way that has increased interaction between whales and fishing gear, and that potentially presents other environmental challenges.

Currently the Gulf of Maine is warming faster than 99.9% of all other ocean regions on the planet (Pershing et al. 2015). This is having dramatic impacts across the food web, from the middle and upper trophic level organisms such as American lobster (*Homarus americanus)*, Atlantic cod (*Gadus morhua)* and right whales (Greene 2016); to the zooplankton at the base of the food web such as calanoid copepods (Grieve et al. 2017; NEFSC 2018).

Whales and Fisheries Are On the Move

American lobster are experiencing strong population fluxes and redistributions with temperature warming. The southern New England lobster fishery has been severely limited by epizootic shell disease, which lobsters become susceptible to at warmer temperatures. In the Gulf of Maine, coastal waters remain cool enough and offshore, deeper waters have warmed enough for lobsters, and lobster fishing, to expand farther offshore. As a result, Maine lobster landings have increased steadily for the past 30 years, with an increasing portion of this caught 3 or more miles offshore over the past 10 years (Fig. 2). Note that Maine lobster landings did downturn sharply in 2017, and future trends are uncertain.

Prey Availability Drives Reproductive Success

It is essential to also recognize that environmental factors and lower trophic level dynamics also contribute to right whale birth and mortality rates. Changes in prey availability influence right whale health and reproduction. In particular, abundance of the copepod *Calanus finmarchicus* in the Gulf of Maine is a strong predictor of right whale reproductive success (Greene and Pershing 2004; Meyer-Gutbrod and Greene 2014; Meyer-Gutbrod et al. 2015).

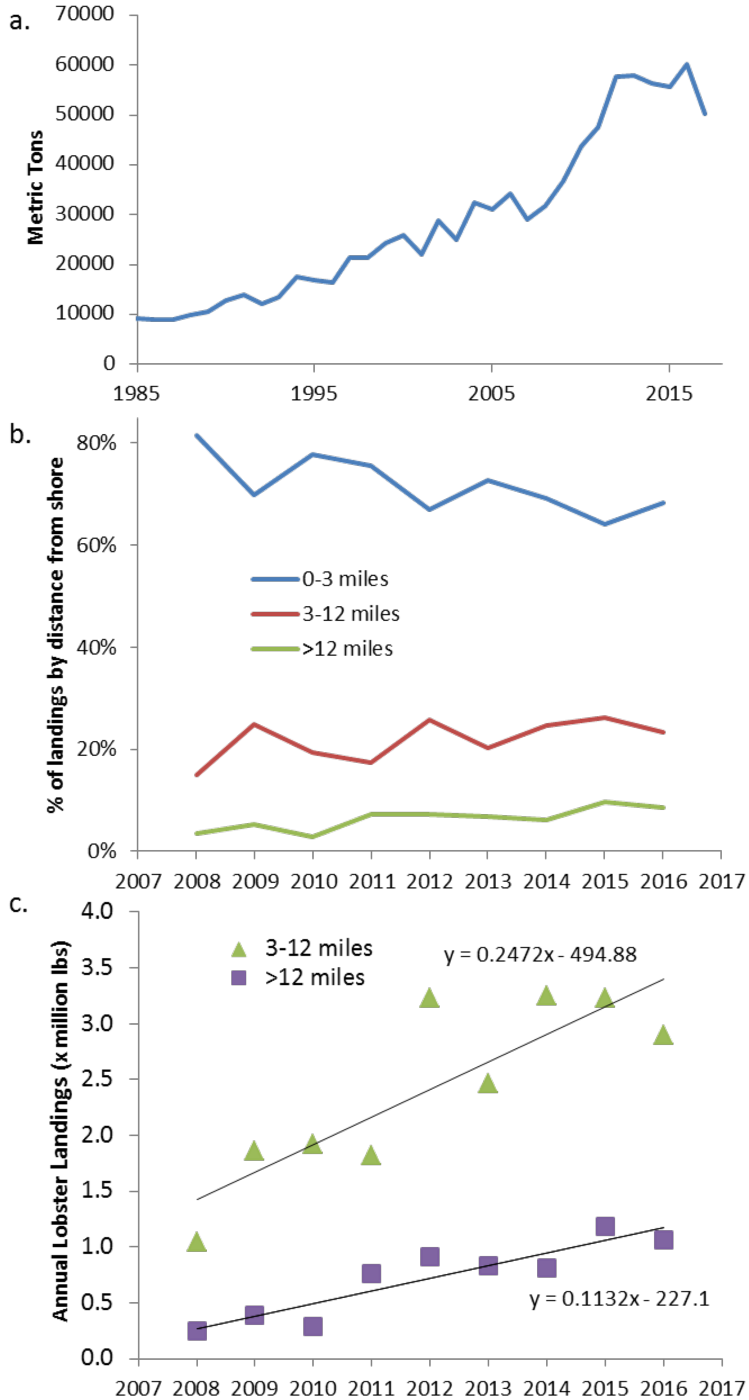

Fig 2. American lobster landings in Maine: a) total annual landings b) relative proportion of landing by distance from shore c) increase in landings from 3-12 and >12 miles offshore from Maine's 10% harvester reporting, no VTR data included. https://www.maine.gov/dmr/commercial-fishing/landings/

Meyer-Gutbrod and Greene (2018) followed individual whales over the past three decades to evaluate the relationship of calving and mortality rates to prey availability. They found that prey availability is a driver of decadal differences in the right whale population's recovery. Periods of low prey availability coincided with reduced birth rates (Meyer-Gutbrod and Greene 2018) and the interval between births has been observed to lengthen during periods when prey availability is low (Meyer-Gutbrod et al. 2015).

Similarly, years with few births contribute to years of decline or stagnation in population growth, indicating the pronounced effect of reproductive variability on species viability (Pace et al. 2017). That said, Meyer-Gutbrod and Greene (2018) modeled population growth rates under scenarios of high and low prey availability and found that the population should continue to grow even with poor prey availability and only fails to do so when whale mortalities reach 8 to 10 per year. It is worth noting natural mortality seems to be very rare in adult right whales: there has been no confirmed case of natural mortality in adult right whales in the past several decades (Corkeron et al. *Accepted with revision;* Henry et al. 2017; van der Hoop et al. 2013).

Right Whales Follow Prey in a Changing Ocean

The copepod *C. finmarchicus* has shifted in distribution and abundance in recent years due to unprecedented warming in the Gulf of Maine, and this is likely to impact the right whale population (Greene 2016; Mills et al. 2013; Reygondeau and Beaugrand 2011). It appears that in the last decade (~2005-2015), that there has been a general decline in *C. finmarchicus* in the Gulf of Maine (2009-2014, but 2015 was average abundance) and on Georges Bank (below average abundance since 2008) (NEFSC 2018) as well as the Scotian Shelf (Johnson et al. 2017).

Changes in plankton forage species abundance likely played a role in the changing movement patterns of right whales that began sometime in the past 10 years. There have been decreases in both acoustic detections and physical observations of right whales in the northern Gulf of Maine and the Bay of Fundy, and a concurrent increase in sightings of many of the same animals in the Canadian Gulf of St. Lawrence (Daoust et al. 2018; Davis et al. 2017; Meyer-Gutbrod et al. 2018; Meyer-Gutbrod and Greene 2018).

During winter, whales are spending more time offshore in the mid-Atlantic, and less time on the coastal calving grounds just off the southeastern U.S., where in 2017 and 2018 calving has been quite poor.

Reproduction Requires Robust Females

Reproduction depends on adequate adult female health and body condition. Reproductive females are particularly vulnerable to prey reductions because pregnancy and lactation increases caloric demand and they have less access to prey during migration to calving grounds (Fortune et al. 2013; Miller et al. 2012; Rolland et al. 2016).

Several of the ecosystem shifts mentioned earlier are likely to have negative consequences for reproduction in right whales. First, a reduction in prey will have energetics costs for females. Northward shifts in the right whales' feeding grounds, as a result of changes in prey availability, will increase energetic cost of the calving migrations from the southern calving grounds off the coast of Florida and Georgia, particularly if animals do not adapt to also calve farther north.

The cost of entanglement has also been shown to have direct and indirect consequences for right whales (van der Hoop et al. 2017b; van der Hoop et al. 2017c). This will be detailed next, but in the Gulf of Maine where ecosystem shifts are occurring more trap fishing is also occurring offshore, increasing the overlap with right whale foraging areas.

Whales have also expanded their range, foraging into the Gulf of St. Lawrence. This increased the whales' exposure to risk from fixed gear fisheries. Some of this risk has reduced by strong protections put in place by the Canadian government during the spring of 2018 (DFO/TC Canada 2018; DFO Canada 2018).

Anthropogenic Stressors

In a review of mortality sources for all large whales, entanglement in fishing gear was the number one cause, followed by natural causes and then vessel strikes. An exception to this is the right whale for which there is very little evidence of natural mortality in adult whales, likely due to shortened life spans associated with anthropogenic causes (Corkeron et al. *Accepted with revision*), as all confirmed causes of adult mortality and serious injury since 1970 have been due to fishing gear and vessel strike (Henry et al. 2017; van der Hoop et al. 2013).

The relative contribution from these two causes was approximately equal through the year 2000 (van der Hoop et al. 2013), but entanglement events resulting in death or serious injury have increased steadily since then, while ship strike frequency has remained lower with no specific trend (Fig. 1). For the recent 19 known right whale mortalities (17 in 2017 and 2 to date in 2018), the cause of death could be determined for 10. Ship strikes are implicated in five blunt force trauma cases and entanglement in the remaining five. In 2017, seven other entangled whales were observed: three were disentangled, three shed the gear, and one was not seen again.

Ship Strikes

Reducing Risk

Ship strikes are currently the second most frequently documented cause of mortality in right whales. The per capita mortality frequency has not varied much, hovering around 0.34% deaths or serious injury events per year (Fig. 1). Several management actions were implemented in U.S. and Canadian waters beginning in 2008 to reduce the risk of collisions between right whales and large vessels. Major actions include:

- Voluntary two-way routes for commercial vessels off the Southeast U.S. and in Cape Cod Bay
- Modification of the Boston, Massachusetts Traffic Separation Scheme
- Canada and the International Maritime Organization established the voluntary Area To Be Avoided concept in the Roseway Basin
- Seasonal Management Areas in habitats off of Massachusetts, ports along the Mid-Atlantic coast, and the southeastern U.S. where vessels are required to slow to speeds less than 10 knots during transits for vessels 65 ft in length or longer

- Intermittent implementation of voluntary speed restrictions in Dynamic Management Areas within which right whale aggregations are observed outside the boundaries of the Seasonal Management Areas

Several analyses have been conducted to evaluate the effectiveness of these management efforts (Conn and Silber 2013; Lagueux et al. 2011; Silber et al. 2014; van der Hoop et al. 2012). In general, while these analyses were based on a short time-series of available data, collectively they suggest that after ship-strike rules put in place, a reduction in right whale mortality from ship strikes followed, and in general were at the lowest on record per capita from 2010 through 2016.

Responding to Changing Risk

In 2017, right whale deaths by ship strike increased when 5 ship-strike mortalities were confirmed, 1 in U.S. and 4 in Canadian waters (Fig. 1), likely caused in part when right whales began to spend more time in new areas with high vessel traffic and no speed restrictions. Increased survey effort in these areas also made it more likely that these events would be observed and reported.

Entanglement

Reducing Risk

Management efforts to reduce entanglement risks in U.S. waters have focused on gear technology to make entanglements less likely to harm or kill whales, restricting where and when gear that poses a threat can be used when whales are likely to be present, and reducing the amount of gear in the water column (Fig 3). Measures are recommended through a take reduction team, as mandated under the federal Marine Mammal Protection Act. Each team comprises a variety of experts and stakeholders, who assist NOAA Fisheries in developing a take reduction plan when necessary.

Since 1997, a series of rules have been implemented based on the take reduction plan (Fig. 3). These include the sinking groundline (2009) and vertical line (2015) rules. While there appears to have been a subsequent reduction in entanglements caused by groundline (Morin et al. 2018), which moved 27,000 miles of line from the water column to the bottom (NMFS, 2014), absolute entanglement rates appear to be on the rise (Fig 1).

Increase in Entanglement Risk

Fewer but Stronger Lines in US Waters

There may also have been unintended consequences of the 2015 vertical line rule. The rule required ‘trawling up’ (using more traps per trawl) in some regions. While this reduced the number of lines, it also meant that lines had to be stronger to accommodate the increased load of multiple traps. This natural adaptation, and the fact that stronger rope was available, contributed to an increase in the severity of entanglements as found by Knowlton et al. (2016), who observed very little evidence of entanglement with ropes weaker than 7.56 kN (1700 lbsf).

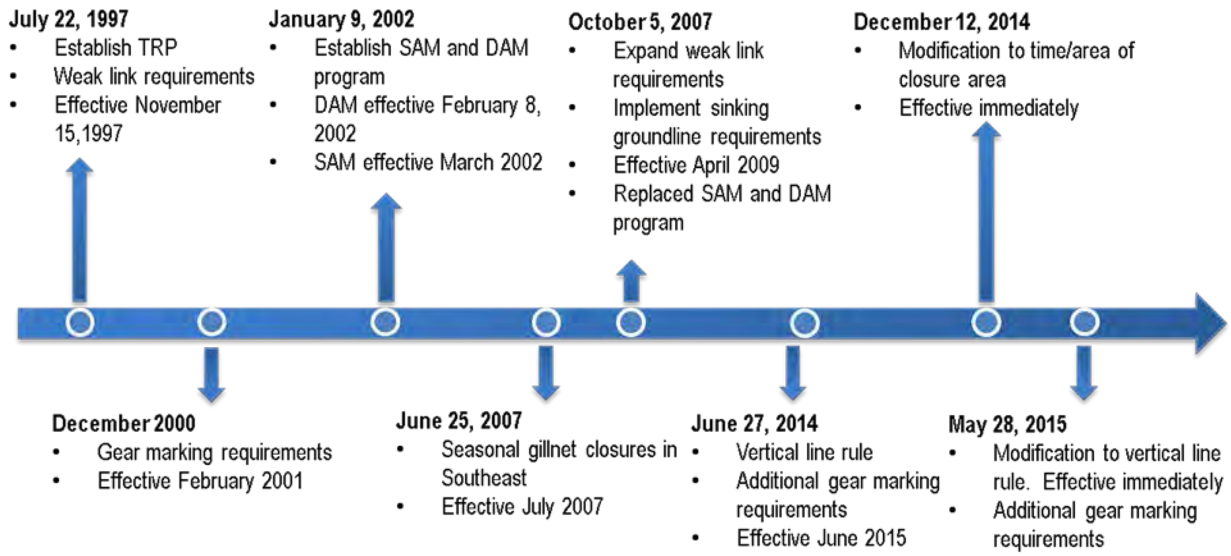

Fig 3. Timeline of significant management actions focused on reducing fishing entanglement

Entanglement Trends Upward

Knowlton et al.(2012) showed that nearly 85% of right whales have been entangled in fishing gear at least once, 59% at least twice, and 26% of the regularly seen animals are entangled annually. These findings represent a continued increase in the percentage of whales encountering and entangling in gear, which grew from to 61.5% in 1995 (Hamilton et al. 1998), to 75.6% in 2002 (Knowlton et al. 2005), confirming further the growing severity of the problem.

More Vertical Line in Right Whale Habitat

Rough estimates are that approximately 622,000 vertical lines are deployed from fishing gear in U.S. waters from Georgia to the Gulf of Maine. Notably until spring of 2018, very few protections for right whales were in place in Canadian waters. In comparison to recent decades, more right whales now spend significantly more time in more northern waters and swim through extensive pot fishery zones around Nova Scotia and into the Canadian Gulf of St. Lawrence *(Daoust et al. 2018).*

Taken together, these fisheries exceed an estimated 1 million vertical lines (100,000 km) deployed throughout right whale migratory routes, calving, and foraging areas. Figure 4 illustrates the scale of the challenge by providing fishery statistics for the various regions (data sources provided in Appendix 1).

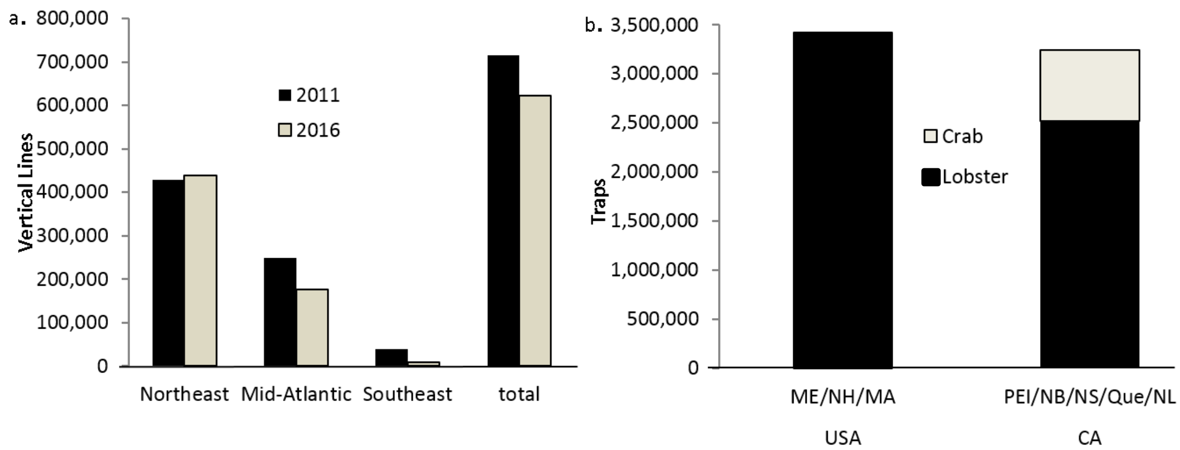

Fig 4. Index of fishing effort. a) The change in number of vertical lines in US waters from 2011 to 2016, b.) The approximate number of traps in USA Northeastern states and Canadian provinces. Data sources in Appendix 1.

Closures Are Effective, But May Not be Enough

A great deal of effort has been put into identifying entanglement 'hot-spots': relatively small areas where focused management measures can have minimal impact to fishing while providing great benefit to whales. Clear examples of this approach include the seasonal closure of Cape Cod Bay, and now the static closure within the Area 12 fishing zone of the Canadian Gulf of St. Lawrence. Both are relatively small areas where a significant portion (30 to 50+ %) of the right whale population has reliably occurred for several weeks to months over the past few years. Management actions have a population level benefit with impacts restricted to very local portions of fisheries. While still difficult choices, this has been the preferred management approach.

However, these closures, while likely very effective regionally, may not be enough. Each vertical line out there has some potential to cause an entanglement. With a 26% annual entanglement rate in a population of just over 400 animals, this translates to about 100 entanglements per year, which is significant for such a small population. But from the perspective of an individual fixed gear fisherman, they may never encounter a right whale. With more than 1 million lines out there, any single line has perhaps a 1 in 10,000 chance of entangling a whale in any one-year period. This can vary somewhat from regions with high to low densities of lines and/or whales.

However, in general, this means a fisherman and his or her descendants could go several generations without ever entangling of a right whale. Given this, it's easy to believe that *'all these entanglements are happening somewhere else'* regardless of where one fishes. Being able to directly link an entanglement with specific gear deployed at a specific place in time is rare, but by mapping known locations of gear that led to the entanglement of a right whale, one can see that there is no place within the fished area along the East Coast of North America for which entanglement risk is zero (Fig 5).

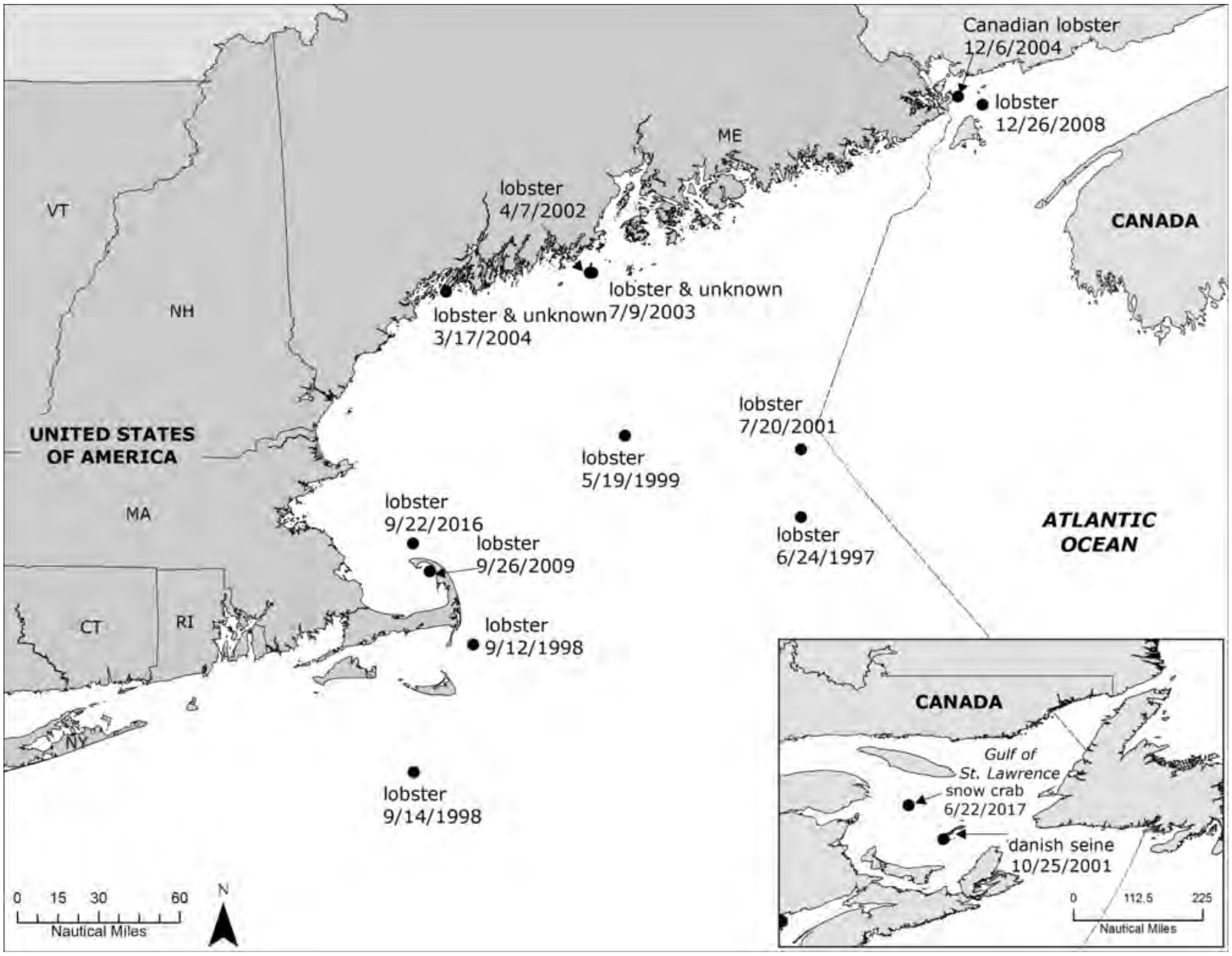

Fig 5. Right whale entanglements from 1997 through 2017 for which the set location and type of gear are known, and gear was recovered from a whale.

Sublethal Challenges- Skinny Whales and Few Calves

Fundamentally, a population increases when there are more births than deaths. Much attention has been paid to direct mortality caused by ship strikes and entanglement, but less focus has been put on the secondary effects of these and other variables where animals survive but fail to thrive because of the harm done. This is particularly evident in calving among mature females.

Biological Cost of Stressors

The abundance of photographs of known individual right whales taken over several decades have been used to develop health indicators associated with natural and human-caused stressors (Schick et al. 2013). This has been refined into a quantitative health score, including a predictive threshold below which females seem incapable of having a calf (Miller et al. 2012; Rolland et al. 2016).

We understand that right whales are exposed to numerous sublethal stressors, including fluctuating food resources (Meyer-Gutbrod and Greene 2014) and even underwater noise (Rolland et al. 2012). Several recent studies have also focused on sublethal effects of entanglement, the first of which includes increased swimming energy costs from dragging gear (van der Hoop et al. 2016). Even if disentangled, there are several injuries that can have costs lasting long after disentanglement. These include trauma wounds from rope cuts that may or may not eventually heal, and damage to baleen plates that can prevent efficient filter feeding for many years since these plates grow slowly.

Recent studies have also shown that even without accounting for injury, the drag from carrying rope and other gear for long periods of time can be energetically more expensive for a female than the migratory and developmental costs of a pregnancy (van der Hoop et al. 2017a; van der Hoop et al. 2017b; van der Hoop et al. 2017c).

Biological Demands of Right Whale Pregnancy

While serious injuries represent 1.2% of all entanglements, there are often sublethal costs to less severe entanglements. Should an entanglement occur but the female somehow disentangles and recovers, it still has the potential to reset the clock for this "capital" breeder. She now has to spend several years acquiring sufficient resources to get pregnant and carry a calf to term, the probability of a subsequent entanglement is fairly high, and this will create a negative feedback loop over time, where the interval between calving becomes longer. This is certainly a contributing factor in the longer calving interval for females, which has now grown from 4 to 10 years (Pettis et al. 2017).

Figure 6 demonstrates a simple model for estimating the probability that an animal will NOT become entangled over time. Similar to asking what are the odds of NOT getting 'heads' in 10 coin tosses, this model simply asks what are the odds of not getting entangled over time if there is a 74% chance of not getting entangled each year (Knowlton et al. 2012). Historically the median calving interval of a female right whale is 3 to 4 years (Pettis et al. 2017). The model estimates that animals have a about a 30 to 40% chance of not getting entangled during that period, or, conversely, a 60 to 70% chance of getting entangled.

With the calving interval now nearly twice as long as in the past, half as many calves are being born. So while entanglements often do not kill an animal, they may have a large impact by reducing or preventing births in the population. There is an additional variable, stress, which is much harder to quantify but known to have costs in mammals that are foraging in an environment with some mortality threat (Hernández and Laundré 2005).

It is difficult to tease out the relative effects of poor foraging conditions and the energetic costs of entanglement on the increased frequency of thin whales and the subsequent decrease in calving. Both are likely having some influence. While there are dozens of documented cases of ship strikes and entanglement linked to right whale mortality, to date there is no confirmed observation of a right whale starving to death from poor forage.

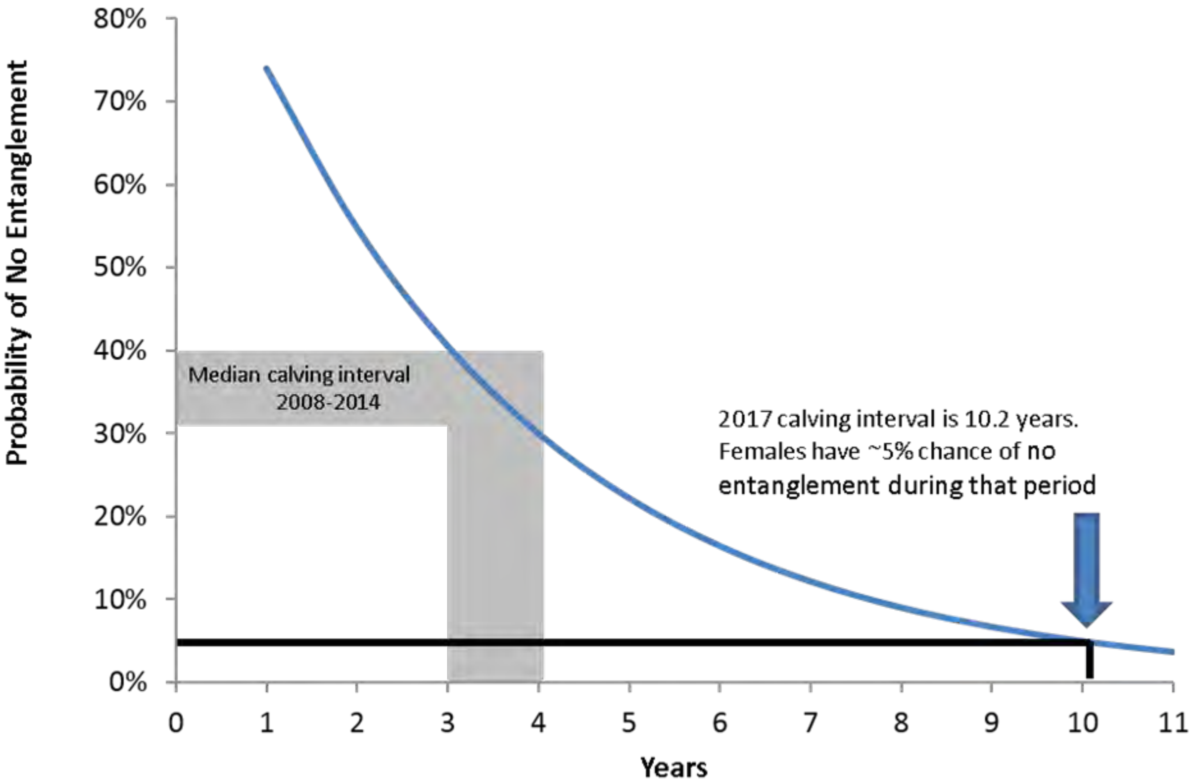

Fig 6. Cumulative annual probability of no entanglement (annual rate = 74%)

HOW LONG DO NORTH ATLANTIC RIGHT WHALES HAVE?

A Long-Lived Animal

Right whales have the potential to be a very long-lived species. In the southern hemisphere where shipping and fishing pressures are much lower, there is little evidence of human activities causing right whale mortality. There is also little evidence of natural mortality in adult animals (Corkeron et al. *Accepted with revision*). Since the ban on commercial whaling of Southern right whales in 1935 (Gambell 1993) these animals have not yet lived long enough to die of natural causes.

Meyer-Gutbrod and Greene (2018) demonstrated that even under poor foraging conditions, right whales should be able to recover if annual human-caused mortality is kept somewhere below 8-10 deaths per year. This means that in the absence of human-caused mortalities, right whales could potentially endure several decades under poor foraging conditions and still recover once environmental conditions improve. However, in the current situation in the northern hemisphere, where animals are living much shorter lives, there is great cause for concern that the risk of extinction is much higher than in the southern hemisphere, where animals are not regularly subject to human caused mortality.

An Illustration of Potential Decline, 2017-2067

A Matrix Model

In order to measure current population trends, we used a three-stage (calf, juvenile, adult) matrix population projection model (Caswell 2006) for female right whales, derived from Corkeron et al. (*Accepted with revision*), to project the future abundance of right whales. Survival values used for input into the population projection model were calculated using a Cormack-Jolly-Seber (Pace et al. 2017) variant of a mark-resight model (see Appendix 2 for details) and determined the population is declining at 2.33% per year.

We started the model estimating an abundance of 160 females alive at the end of 2017. With approximately 1.5 males per female (Pace et al. 2017), 160 females would result in an overall species abundance of about 400. It is possible that this abundance estimate may be marginally low, but since the model overestimates calving success, we assumed that these biases should cancel each other out.

Using the stage derived from the matrix model, we assumed that the 2017 starting population of 160 females was composed of 10 calves, 60 juveniles, and 90 adults. We ran 1000 stochastic projections forward 50 years (Fig. 7).We then extracted median and 95% quantile estimates of projected abundance from those projections, and estimates of the number of adult females remaining, for 5, 10, 15, 20, 25 and 50 years. Results are shown in the Table.

Results

The model projects that in 2067, 50 years from 2017, there would be 49 female North Atlantic right whales remaining, of which only 32 would be adults. In 20 to 25 years (2037-2042) there would be fewer than 50 adult females. In the near term, at the current rate of decline, all recovery in the population over the past 3 decades will be lost by 2029, with the population returning to the 1990 estimate of 123 females.

Notably, the model does not adjust for varying environmental conditions, which are known to fluctuate on a decadal time scale for North Atlantic Ecosystems (Nye et al. 2014) and are presently unfavorable. This approach may overestimate the rate of population decline but not the overall trajectory.

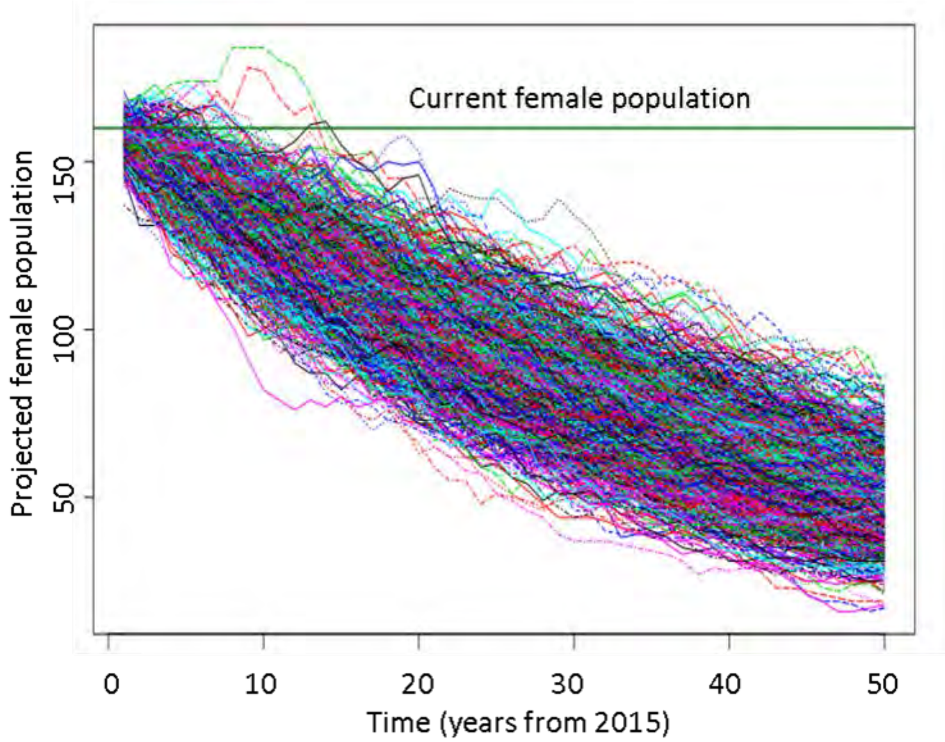

Fig. 7 Matrix population projection model output of North Atlantic right whale female population trend under current population conditions.

Table of matrix projection model output of female North Atlantic population trends for 5-year intervals, 2017-2067

Years from 2017	Number of females	Cis	Number of adult females
5	144	126 to 161	75
10	129	107 to 150	67
15	114	91 to 141	59
20	102	77 to 130	53
25	90	66 to 119	47
50	49	27 to 76	32

The threshold for functional extinction is very hard to define and likely varies by species. If the population declines to the 1990 level, there is a new threat: a repeated genetic bottleneck. Genetic bottlenecks happen when a population is so small that the genetic make-up of remaining group is not the same as that of the initial population. The effect of repeated bottlenecks is likely to mean that if the population returned to the 1990 level, that group would have less genetic diversity than the group that existed in1990. This can lead to reduced resilience and contribute to increased risk of extinction (Amos and Harwood 1998; Melbourne and Hastings 2008).

INDICATORS OF SUCCESSFUL MANAGEMENT MEASURES

Determining the management actions necessary to reverse the current population trend is beyond the scope of this document. However, the scale of the actions will need to be quite significant to be successful. Entanglement has increased dramatically and ship strikes continue to occur.

The population decline began in 2010 (Fig. 1), when entanglement was occurring at a rate of 26% among sited animals per year (Knowlton et al. 2012). Since then, the right whale range expansion has put them in the path of more shipping and more fishing gear – encountering almost twice the amount of gear owing to expansion of more fishing farther offshore in US waters and northward into Canadian waters (Fig. 4).

It is logical to conclude that to reverse the right whale decline, it may be necessary to reduce the impacts of entanglements and other harmful human interactions with right whales across their expanded range to pre-2010 levels. For recovery it may be necessary to go further, considering more modifications to fishing and shipping practices to compensate for potentially reduced forage opportunity and increased migratory costs.

Several biological indicators can be recommended for monitoring the short- and long-term effectiveness of any management actions that might be put in place to reduce the rate of both ship strikes and fishing gear entanglement.

Short-term indicators include fewer observed numbers of ship strikes and entanglements. These could be noticeable within 6 months to 1 year, but there is considerable variation around detectability of these events and the results will initially have a great deal of uncertainty. It takes approximately 1 year to conduct a population assessment and determine any changes in abundance. The assessment will alleviate some the uncertainty in detecting mortality risks that that might be mitigated by management actions. It should be noted that number of mortalities is the bluntest indicator of management success.

However, teasing the relative effects of management actions and natural variability on population size and condition will take several years of data and analysis. Metrics such as the frequency of scarring, improvements in body condition, and overall health scores could be detectable under stable environmental conditions in 2 to 3 years. Similarly, if environmental conditions are adequate for females to accumulate enough resources to calve, it will likely take at least 2 to 4 years to separate the impact of management action that reduced the frequency of, say, costly entanglements from the impact of natural variability. Ultimately, confidence in any estimate of population trajectory will emerge over 5 to 10 years.

In an ideal situation, evidence of human-caused injuries and mortality decreases, body condition improves, and the birth rate exceeds the death rate, resulting in more North Atlantic right whales.

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APPENDIX 1 Data Sources for Figure 4

Several data sources were used to construct Fig 4. All vertical line estimates in 4A were provided by Industrial Economics. Trap counts provided in 4B were acquired from a variety of sources. Raw trap counts were provided for Maine and Massachusetts. Trap counts for New Hampshire and all Canadian provinces were generated by multiplying license counts by trap limits. These were quite variable across regions, in which case the multiplier used is reported in the Table in the report.

Table 2. Data sources for trap counts and license numbers by country and regions.

Location	species	# traps	data year	Source
Maine	Lobster	2,901,000	2016	https://www.maine.gov/dmr/commercial-fishing/landings/documents/lobster.table.pdf
New Hampshire	Lobster	133,700	2010	https://www.greateratlantic.fisheries.noaa.gov/protected/whaletrp/trt/meetings/2012 meeting/Day%202/day_2_1c_new_hampshire_alwtrp_proposal.pdf
Massachussetts	Lobster	383,447	2011	http://www.lobstermen.com/wp-content/uploads/2009/10/MASS-LOBSTER-INDUSTRY-2012.pdf
Canada	**species**	**# license**	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Nova Scotia	lobster	3,249	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	748	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
New Brunswick	lobster	1,460	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	123	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Prince Edward Island	lobster	1,245	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	39	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Quebec	lobster	591	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	382	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Newfoundland	lobster	2,353	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	3,379	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Canada	**species**	trap limit range	trap multiplier used	**Source**
Nova Scotia- GOSL	lobster	225-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
Nova Scotia- GOSL	crab	75-150	150	neiges-en.html
Nova Scotia- east	crab	30-60		http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/snow-crab-neige/snow-crab-neiges2013-eng.htm
New Brunswick	lobster	240-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
	crab	75-150	150	neiges-en.html
Prince Edward Island	lobster	240-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
	crab	75-150	150	neiges-en.html
Quebec	lobster	235	235	http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/lobster-homard/index-eng.htm
	crab		200	
Newfoundland	lobster	185	235	https://thisfish.info/fishery/atlantic-lobster-canada-lfa11/
		100-425		http://waves-vagues.dfo-mpo.gc.ca/Library/282426.pdf
	crab	200	200	http://dfo-mpo.gc.ca/decisions/fm-2018-gp/atl-07-eng.htm

APPENDIX 2 Model Inputs and Methods used for Population Projection

In order to determine current rate of population decline we used a simple, three-stage matrix population projection model (Caswell 2006) for female right whales, derived from Corkeron et al. (*Accepted with revision*), to project the future abundance of North Atlantic right whales. The model's three stages are: calf, juvenile and adult. Survival values used for input into the population projection model are derived from survival estimates calculated using a Cormack-Jolly-Seber (as opposed to the published Jolly-Seber, Pace et al 2017) variant of a mark-resight model (see Appendix 1 for details). We used the lower 95% credibility intervals of the median estimates of survival for 2011-2015 from the model. These were: calves: 0.86137, juveniles: 0.92684, and adult females: 0.92684. The matrix projections also assume: a calving interval of 4.75 years (the mean of median inter-calf intervals for calving females 2011-2017, from the 2017 North Atlantic Right Whale Report Card (Pettis et al. 2017), ; females maturing at 11; and a current maximum longevity of 50. With no calves born this year, this calving estimate is arguably optimistic, but the inter-calf interval estimate for 2018 would be undefined, and so is unusable. Survival and transition probabilities for stages were calculated as described in Corkeron et al. (*Accepted with revision*).The model was run in R 3.4.3 (R_Core_Team 2017), using the libraries *diagram* (Soetaert 2017), *popbio* (Stubben and Milligan 2007) and *popdemo* (Stott et al. 2016).

The matrix used for analyses is:

	calf	immat	adlt
calf	0.00000	0.00000	0.10526
immat	0.86137	0.86254	0.00000
adlt	0.00000	0.06430	0.92443

This gives an intrinsic rate of increase of 0.9767, or a decline of 2.33% per year.

To develop a stochastic projection from this model, we took a starting abundance estimate of 160 females alive at the end of 2017, as the unusually high observed mortality of right whales that year (Meyer-Gutbrod and Greene 2018) meant that starting earlier would not capture one important recent anthropogenic impact on this species. With approximately 1.5 males per female North Atlantic right whale now (Pace et al. 2017), 160 females would give an overall species abundance of ~400. It is possible that this abundance estimate may prove to be marginally low, but as the model overestimates calving success, we assume that these biases should cancel each other out. When an abundance estimate for 2017 is available (by October-November 2018) the model can be revised.

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North Atlantic Right Whale Consortium
2019 Annual Report Card

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NORTH ATLANTIC RIGHT WHALE CONSORTIUM BACKGROUND

The North Atlantic right whale (*Eubalaena glacialis*) remains one of the most endangered large whales in the world. Over the past two decades, there has been increasing interest in addressing the problems hampering the recovery of North Atlantic right whales by using innovative research techniques, new technologies, analyses of existing databases, and enhanced conservation and education strategies. This increased interest demanded better coordination and collaboration among all stakeholders to ensure that there was improved access to data, research efforts were not duplicative, and that findings were shared with all interested parties. The North Atlantic Right Whale Consortium, initially formed in 1986 by five research institutions to share data among themselves, was expanded in 1997 to address these greater needs. Currently, the Consortium membership is comprised of representatives from more than 100 entities including: research, academic, and conservation organizations; shipping and fishing industries; whale watching companies; technical experts; United States (U.S.) and Canadian Government agencies; and state authorities.

The Consortium membership is committed to long-term research and management efforts, and to coordinating and integrating the wide variety of databases and research efforts related to right whales to provide the relevant management, academic and conservation groups with the best scientific advice and recommendations on right whale conservation. The Consortium is also committed to sharing new and updated methods with its membership, providing up-to-date information on right whale biology and conservation to the public, and maintaining effective communication with U.S. and Canadian Government agencies, state authorities, the Canadian Right Whale Network, the U.S. Southeast Right Whale Implementation Team, the Atlantic Large Whale Take Reduction Team, the Atlantic Scientific Review Group, and members of the U.S. Congress. The Consortium membership supports the maintenance and long-term continuity of the separate research programs under its umbrella, and serves as executor for database archives that include right whale sightings and photo-identification data contributed by private institutions, government scientists and agencies, and individuals. Lastly, the Consortium is interested in maximizing the effectiveness of management measures to protect right whales, including using management models from other fields.

The Consortium is governed by an Executive Committee and Board members who are elected by the general Consortium Membership at the Annual Meeting.

North Atlantic Right Whale Consortium members agreed in 2004 that an annual "report card" on the status of right whales would be useful. This report card includes updates on the status of the cataloged population, mortalities and injury events, and a summary of management and research efforts that have occurred over the previous 12 months. The Board's goal is to make public a summary of current research and management activities, as well as provide detailed recommendations for future activities. The Board views this report as a valuable asset in assessing the effects of research and management over time.

ESSENTIAL POPULATION MONITORING AND PRIORITIES

In the 2009 Report Card to the International Whaling Commission (IWC), the Consortium Board identified key monitoring efforts that must be continued and maintained in order to identify trends in the population, as well as assess the factors behind any changes in these trends (Pettis, 2009). The key efforts are: (1) Photographic identification and cataloging of right whales in historically and emerging high-use habitats and migratory corridors, including, but not limited to, the southeast United States, Cape Cod Bay, Gulf of St. Lawrence, Great South Channel, Bay of Fundy, Scotian Shelf, and Jeffreys Ledge, (2) Monitoring of scarring and visual health assessment from photographic data, (3) Examination of all mortalities, and (4) Continue using photo-ID and genetic profiling to monitor population structure and how this changes over time.

The Consortium Board regards the Consortium databases as essential to recovery efforts for the North Atlantic right whale population. In a review of the federal recovery program for North Atlantic right whales, the Marine Mammal Commission agreed with the Board's sentiment, stating that "both databases play critical roles in right whale conservation" and that the Identification Catalog "is the cornerstone of right whale research and monitoring" (Reeves et al. 2007). The review went on to recommend that both databases ("both" here and above refers to the Identification and Sightings databases; there are several Consortium databases available) be fully funded on a stable basis.

Over the last several years, right whale distribution and patterns of habitat use have shifted, in some cases dramatically. These shifts have been observed throughout the range of North Atlantic right whales and have direct implications on research and management activities, as well as on each of the key efforts identified above. As such, the Board believes that identifying potential extralimital and new critical habitats and developing alternative survey effort strategies to respond to the distributional changes should be a priority. These strategies should include efforts to not only locate and identify individual right whales, but also to ensure that information critical to important monitoring and management efforts (i.e. health assessment, injury and scarring assessments) is effectively and efficiently collected.

In 2019, **ten** right whale mortalities were detected, bringing the total detected mortalities for the last three years to **30**. Over the same time period, a total of **12** right whale calves were born. Given that detected mortalities likely under-represent actual mortalities by a significant amount (Kraus et al. 2005, unpub. data), the state of this population is dire. Anthropogenic factors, including entanglement in fixed fishing gear and vessel strikes, have been implicated in 13 of the 30 most recent mortalities (the remaining 17 have undetermined cause of death, though two of these are suspected as human impact – one entanglement and one vessel strike). Additionally, for all mortalities detected between 2003 and 2018 for which a cause of death could be determined, all juvenile and adult deaths were due to either entanglement or vessel strike (Sharp et al. 2019). Anthropogenic related deaths, which management measures have clearly not reduced (Pace et al. 2014; Sharp et al. 2019), are increasing the threat to the survival of this species.

In the spring of 2018, Canada announced new measures to mitigate both entanglements and vessel strikes in areas in which right whales frequent, including vessel speed reductions, temporary and fixed fisheries management areas and closures, and increased reporting requirements for fishing activity, lost gear, and interactions with marine mammals. There were no detected right whale mortalities in Canadian waters in 2018, though there were three entangled whales detected that year. In 2019, similar mitigation measures, though reduced in scope compared to 2018, were put into place in Canadian waters. Between 04 and 27 June 2019, seven right whale mortalities were detected in Canadian waters, three of which were attributed to vessel strikes. In response, vessel strike mitigation measures in the Gulf of St. Lawrence were expanded on 08 July 2019. Two additional right whale mortalities were detected in Canadian waters in July 2019 (causes of death undetermined) and a third whale who became severely entangled in the Gulf of St. Lawrence in August 2019, well after the snow crab fishery season was over, was discovered dead in waters off New York, U.S. in September 2019.

While there were no right whale mortalities detected in Canadian waters in 2018, three were detected in U.S. waters, all of which were entanglement related. One of these three entanglements was attributed to snow crab gear. Additionally, live entangled whales were detected in U.S. waters in both 2018 (1) and 2019 (2).

Ongoing discussions about reducing anthropogenic impacts on right whales in both Canadian and U.S. waters are encouraging. However, immediate, broad-based mitigation strategies that result in significant risk reduction throughout the right whale's range in light of changing distributions and habitat use must be a priority if this species is to survive.

POPULATION STATUS

The ability to monitor North Atlantic right whale vital rates is entirely dependent on the North Atlantic Right Whale Identification Database (Catalog), curated by the Anderson Cabot Center for Ocean Life at the New England Aquarium. As of September 4, 2019, the database consisted of over a million slides, prints, and digital images collected during the 78,399 sightings of 746 individual right whales photographed since 1935. Each year, 2,000 to 5,000 sightings consisting of 20-30,000 images are added to the identification database. Using Catalog data, a number of methods have been employed to estimate the number of North Atlantic right whales alive annually. Due to lag times in Catalog data submissions and data processing, only data through 2018 were available for these calculations. Here we describe four different estimate methods and present the Consortium's best estimate for 2018. The first two methods use the calendar year; the last two methods use the "whale" year which runs from December 1 to November 30. This latter definition was created to avoid "double counting" whales seen in the southeast US in December and January

Presumed Alive Method
The presumed alive method (PA) counts whales that have been seen at least once in the last six years (Knowlton et al. 1994). It is a consistently measureable and easily available value, but it assumes that whales remain alive for six years after their last sighting (which is often not the case) and the estimates for recent years may be artificially low due to delays in data processing. The PA number for 2018 is 462.

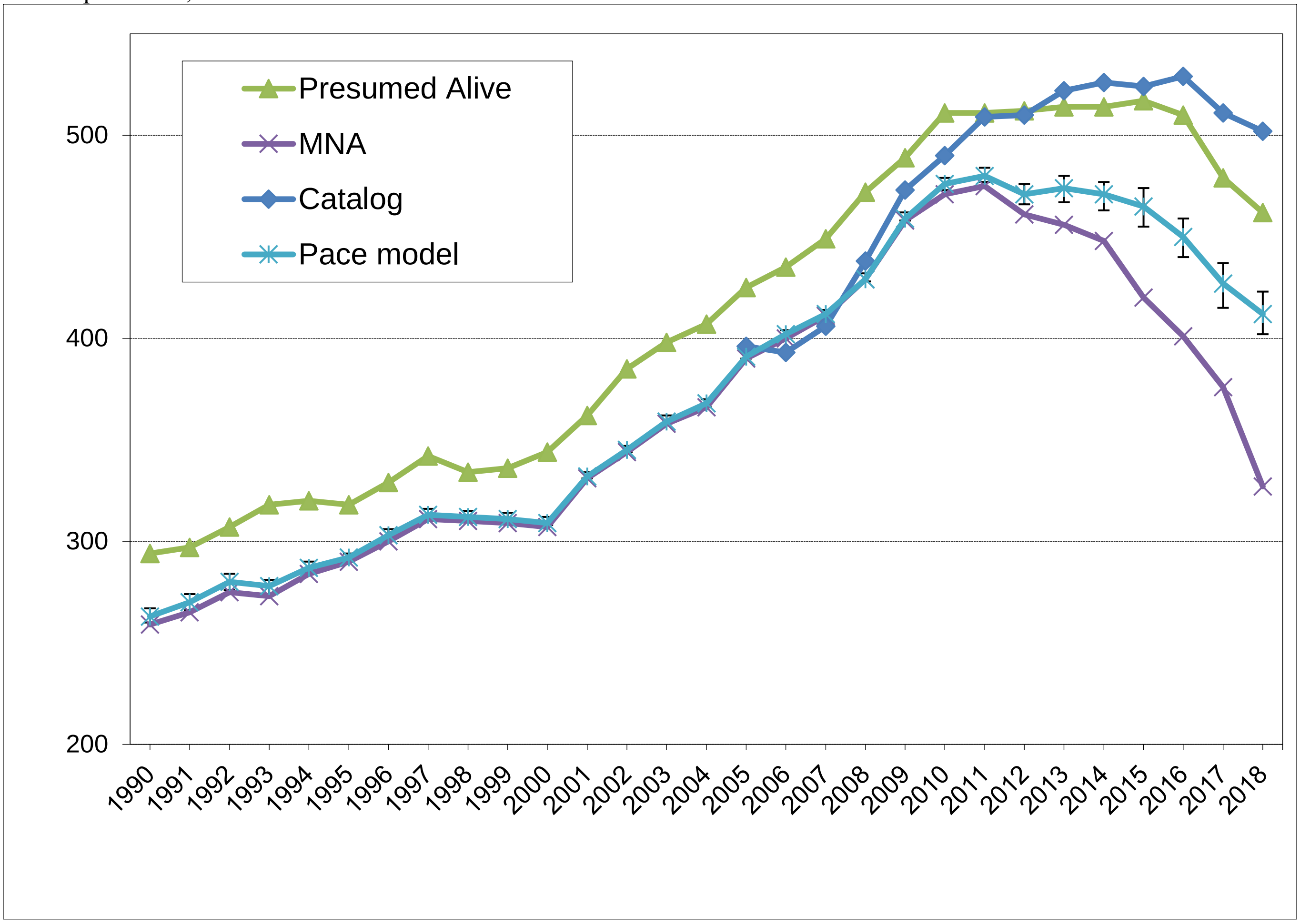
Catalog Method
The Catalog method (formerly referred to as the "Report Card" method) includes a low, middle and high estimate. A table with all of these estimates as well as a full description of the methodology is provided in Appendix 1 of this report card. The values are based upon the number of photographed whales only; they exclude potential unphotographed whales and therefore should not be considered a "population estimate". This method has the weakness of utilizing the PA methodology with its assumptions, but it does incorporate whales that have been photographed but not yet added to the Catalog. The Catalog estimates for 2018 range from a low of 343 to a high of 727 with a middle estimate of 502.

Minimum Number Alive Method
The Minimum Number Alive (MNA) is the number that was historically used in National Marine Fisheries Service stock assessment reports and counts whales seen in a given year, plus any whale not seen that year- but seen both before *and* after (see Hayes et al. 2017). The MNA number is more accurate than PA for older years, but is also not accurate for recent years for the same reason as the PA method, plus the fact that there have been fewer "after" years to detect a whale. The MNA number for 2018 is 327.

Pace Method
The Pace Method was added to the 2016 report card and has been included ever since. This analysis comes from the Pace et al. 2017 model which "adapted a state-space formulation with Jolly-Seber assumptions about population entry (birth and immigration) to individual resighting histories and fit it using empirical Bayes methodology." This model estimate accounts for whales that have not been photographed. The full methodology is available in the paper. It is important to note that the estimates provided by the Pace et al. 2017 methodology represent the estimated abundance at the *start* of the sample period plus all new entries into the population. That number for 2018 is 412. If one wanted an estimate at the end of the interval, one could subtract the number of known dead (or estimated number of dead if a detection rate for carcasses was available).

The full results for all four methods are presented in Figure 1**.** All numbers except the past Catalog method estimates were recalculated using data as of September 4, 2019 and therefore the numbers in this figure will differ from those in past report cards. The PA number is always artificially high as a comparison to the past year's MNA numbers attest. The difference is largely due to whales that have not been seen since before the year in question. For example, the 30+ animals that the PA number included in 1990 and the MNA did not are whales that have not been seen since 1990 and are thus very likely dead. From 1990 to 2010, the average difference between the PA number and the MNA number was 35 animals. If that difference remained consistent into this decade, the adjusted presumed alive number in 2018 would be 427 whales. The Pace method removes assumptions of when a whale is alive and is likely more accurate. The Catalog estimates are always higher than the other two methods for the most recent years. However, the fact that the old Catalog estimates for 2005 to 2009 were close to the eventual MNA numbers suggests that the methodology worked reasonably well through 2009. However, starting in 2010, the two numbers started to diverge. This is partially because fewer whales were seen so the MNA number may be artificially low. But it also appears that the six-year assumption for PA whales is increasingly erroneous; whales die sooner than six years after their last sighting. The Catalog estimate does however capture recent increase in calves that have not yet been cataloged. This delay in cataloging is largely due to the right whale distribution shift which has resulted in fewer calves being seen on the feeding grounds with their mothers, and fewer sightings of them as juveniles anywhere- both of which make cataloging recent calves challenging.

Figure 1. Assessments of the North Atlantic right whale population based on four available assessment methods. The Pace model shows a point "estimate" along with error bars which represent 95% of the posteriori probability. That model estimates the number of whale alive *at the start* of each year plus any new whales estimated to enter during that year. Data through 2018 as of September 4, 2019.



Best Right Whale Population Estimate 2018

We believe the Pace Method provides the best estimate for 2018. To get an estimate of whales alive *at the end* of 2018 using this methodology, we take the estimate at the start of 2018 (412, Figure 1) and subtract the observed deaths during 2018 (2 cataloged whales and one unidentified). Therefore, the best estimate for the end of 2018 is **409** right whales (95% confidence range +/- 11 and 10 respectively) using data as of September 4, 2019.

How Well Are We Monitoring?

Below is an annual count of sightings, unique individuals, whales presumed alive, kilometers of effort that have been submitted to the sightings database at the University of Rhode Island, and percent of the population that is identified each year from 2000 onward (Table 1). The shift in whale distribution has reduced both the number of sightings contributed to the Catalog and the percent of the population seen annually since 2011. Data as of September 4, 2019.

Table 1. Annual counts of sightings, unique individuals, presumed living whales, survey effort, and the percentage of the population seen. Survey effort from dedicated surveys only; opportunistic sightings do not record or report effort. None of the numbers for 2018 are final as not all of the data for that year have been submitted or analyzed. Data as of September 4, 2019.

Year	Sightings	Unique IDs	Presumed Living Population	Survey Effort (1,000 km)	% of population seen
2000	3087	236	344	125	69%
2001	3849	282	362	127	78%
2002	2718	303	385	252	79%
2003	2405	314	398	180	79%
2004	1811	286	407	287	70%
2005	3399	353	425	357	84%
2006	2801	347	436	316	80%
2007	3739	379	450	267	84%
2008	4147	390	473	254	83%
2009	4635	422	491	246	86%
2010	3224	421	512	271	82%
2011	3464	437	513	234	85%
2012	2127	375	512	271	73%
2013	1905	296	514	215	58%
2014	2399	369	513	200	72%
2015	1771	262	510	184	51%
2016	2199	319	499	155	64%
2017	3014	343	465	178	74%
2018	3453	343	462	135	74%

Reproduction

There were 7 documented calves born in 2019 (Table 2).

Table 2. Summary of calving events and associated inter-birth interval times for North Atlantic right whales from 2009-2019. The number of available cows, defined as females who have given birth to at least one previous calf, were presumed to be alive, and have not given birth in the last two years, are followed by the percentage of available cows to successfully calve. First time mothers are now included in the available to calve count.

Year	Calf Count	Available Cows/ % to calve	Average Interval	Median Interval	First time Moms
2009	39	66/59.1%	4.0	4	8
2010	19	49/38.8%	3.3	3	4
2011	22	51/43.1%	3.7	3	3
2012	7	66/10.7%	5.4	4	2
2013	20	90/22.2%	4.6	4	7
2014	11	86/12.8%	4.4	4.5	1
2015	17	84/20.2%	5.5	6	4
2016	14*	85/16.5%	6.6	7	4
2017	5	71/7.0%	10.2	8	0
2018	0	76/0	-	-	-
2019	7	87/8.0%	7	7	1

*There were 14 mothers seen with calves in the 2015/2016 season, however, due to a three-way calf switch that included the presumed loss of one calf that was never photographed, only 13 calves were photographed.

Mortalities
Between 01 January 2019 – 31 December 2019, ten right whale mortalities were documented. Nine were detected in Canadian waters and one in U.S. waters (Table 3). Cause of death was identified in four cases (three vessel strike and one entanglement). The Consortium Board recognizes necropsies as significant data collection events that provide valuable information on which management and conservation measures can be (and have been) based. The Board views consistent necropsy response and support (both financial and personnel) as critical to monitor both right whale recovery and the efficacy of management actions.

Live Vessel Strikes, Entanglements, and Entrapments
Vessel Strikes:
There were no non-lethal vessel strike injuries documented between 01 January 2019 – 31 December 2019.

Entanglement and Entrapments
There were eight active entanglement/entrapment cases reported between 01 January 2019 – 31 December 2019, of which five were new. Table 4 includes newly reported cases as well as pertinent updates to previously reported cases.

Table 3. Documented right whale mortalities 01 January 2019 – 31 December 2019.

Whale #	Date	Location	Sex	Age	Field #	Necropsied?	Cause	Comments
4023	06/04/2019	GSL	M	9		Yes	undetermined	Last sighted alive 08/21/2018 in the Gulf of St. Lawrence
1281	06/20/2019	GSL	F	38+		Yes	vessel strike	Last sighted alive on 05 and 07 June 2019 in the Gulf of St Lawrence
Unk	06/24/2019	Cabot Straight	Unk	Unk		No	undetermined	Carcass not recovered. Reported with images on 07/18/2019
1514	06/25/2019	GSL	M	34+		Yes	vessel strike	Last sighted alive 05 and 07 June 2019 in the Gulf of St. Lawrence
3815	06/25/2019	GSL	F	11		No	undetermined	Last sighted alive 05 and 07 June 2019 in the Gulf of St. Lawrence. Resighted floating dead in the GSL 07/18/2019
3329	06/26/2019	GSL	F	16		Yes	undetermined	Last sighted alive on 04/25/2019 in Cape Cod Bay
3450	06/27/2019	GSL	F	15+		Yes	vessel strike	Last sighted alive on 05 and 10 June 2019 in the Gulf of St. Lawrence
3421	07/18/2019	GSL	M	15		Yes	undetermined	Last sighted alive on 10 June 2019 in the Gulf of St. Lawrence
Unk	07/21/2019	Cape Breton	Unk	Unk		No	undetermined	Carcass not recovered. No conclusive evidence that this is the same carcass as was first seen on 06/24/2019.
1226	9/16/2019	NY	M	40+		Yes	entanglement	Was seen entangled and possibly anchored in the Gulf of St. Lawrence on 08/06/2019. Was not resighted prior to its death.

Table 4. Right whale entanglements and status updates 01 January 2019 – 31 December 2019. Newly reported entanglements (carrying gear) and updates to previously reported entanglements are in **bold**. Dead whales first sighted entangled at death are not included here. However, whales sighted alive as entangled and later dead are included.

Whale #	Date of First Entanglement Sighting	First location	Sex	Age (current)	Comments
4091	05/12/2018	60 miles ESE of Chatham, USA	F	8	The whale has line wrapped around its right flipper, at minimum, with about 50ft green line trailing. What appears to be a red, yellow and green buoy is near the right flipper. Due to weather forecast and distance, the CCS response team could not mount a response. **Resighted 12/31/2018 and 01/13/2019 south of Nantucket. Although the view of right flipper was not ideal, neither line nor the buoy were visible.**
3960	08/20/2018	Gulf of St. Lawrence	M	9	Whale observed with multiple wraps of the rostrum, damaged baleen, and no line trailing, although the sighting team felt that there was likely weight attached. Throughout the sighting the whale was thrashing at the surface and the configuration of the entanglement changed often. This behavior, the condition of the whale and changing entanglement configuration, led the team to believe that it was likely a new entanglement. As the team on scene was consulting and documenting the whale, its entanglement configuration continued to change and the whale picked up speed swimming at ~8kts. After more observations, the team felt that the whale might have shed the entanglement. No additional sightings of this whale have been reported. While observers noted that no gear was visible at the end of the sighting, they could not see all body areas and the whale was relatively distant and therefore the whale is considered still entangled. **Resighted in Cape Cod Bay on 03/20/2019 and confirmed to be gear free.**
2310	12/20/2018	Southeast of Nantucket	M	Adult, >24	The whale appears to have a short bitter end at the area of its left pectoral flipper that enters its left mouth. The line passes through the mouth and exits out the right side, trailing roughly 1-2 body lengths, at minimum, aft of the flukes. It appears as though the trialing line sinks into the water column due to the nature of the line, no bitter end was observed. There were no significant injuries associated with the entanglement documented. The whale was slightly thin. A response was not mounted. The whale may shed the line on its own. **Resighted on 02/3/2019 south of Nantucket and again on 4/25/2019 in Cape Cod Bay. Disentanglement attempt was unsuccessful and entanglement remains.**
4423	**04/25/2019**	**Great South Channel**	**M**	**5**	**Entanglement consists of thick line coming from depth approximately one whale length behind flukes that leads to a mass of rope and possibly submerged buoy. Whale is thin and grey. Resighted in July 2019 in the Gulf of St. Lawrence still entangled. A disentanglement attempt on 07/16/2019 appears to have cut part of the line on the right side of the whale and altered the tautness of the line configuration. Multiple resights in July and August show that the whale remains entangled with a bridle of heavy rope through its mouth and is trailing a ball of gear aft of the flukes. The condition of the whale remains poor. Resighted 10/28/2019 in the Gulf of St Lawrence and confirmed to be gear free. Condition is still poor with large lesions on both sides of the head and behind the blowholes. Whale does present as thin based on aerial images.**

Table 4 (cont'd). Right whale entanglements and status updates 01 January 2019 – 31 December 2019. Newly reported entanglements (carrying gear) and updates to previously reported entanglements are in **bold**. Dead whales first sighted entangled at death are not included here. However, whales sighted alive as entangled and later dead are included.

Whale #	Date of First Entanglement Sighting	First location	Sex	Age (current)	Comments
4440	**06/29/2019**	**Gulf of St. Lawrence**	**M**	**5**	**The whale was essentially hogtied with line from the mouth to the peduncle. Line exiting the left mouthline trails to peduncle and line exiting from the right mouthline and/or the right flipper leads there as well. At the peduncle there are at least two passes of line forming a tight wrap. Beneath the flukes is a heavily damaged Norwegian float and on top of the flukes there is a light knot and short bitter end. Wounds around the peduncle are extensive. A disentanglement effort on 07/16/2019 was successful in making a cut in the line exiting the left side of the mouth. The whale was resighted on 07/19/2019, at which time a survey team observed that the line in the mouth had been shed. At that time, there remained a line wrap and buoy at the peduncle and trailing line of approximately one length aft of the flukes. On 08/14/2019, the whale was sighted gear free in the Gulf of St. Lawrence.**
3125	**07/04/2019**	**Gulf of St. Lawrence**	**M**	**18**	**Last sighted gear free 03/20/2019 in Cape Cod Bay. Extensive entanglement through the mouth with multiple trailing lines. Rope may involve both flippers as well. A research team in the Gulf was able to attach a telemetry buoy to the entangling gear on 07/19/2019. The whale was tracked to the Scotian Shelf and intercepted by a disentanglement team from Newfoundland on 07/23/209 and 07/25/2019. The team believes they were able to cut one line of rope at the head and may have damaged others. Another disentanglement attempt was made on 08/2/2019 ~60miles east of Cape Cod. Multiple cuts to the entangling lines were made and the whale can now open its mouth. Remaining line on the whale includes embedded mid-rostrum wrap and wrap over the blowholes as well as line that is likely extensively woven in the baleen. The whale's condition is poor.**
1226	**08/06/2019**	**Gulf of St. Lawrence**	**M**	**Adult, >40**	**Last sighted gear free in the Gulf of St. Lawrence on 07/16/2016. Whale has at least two wraps around rostrum and a trailing bitter end. There appears to be extensive damage to the peduncle and the whale may be anchored. Whale was found floating dead off the coast of New York on 09/16/2019. See Table 3 above for details.**
3466	**12/21/2019**	**~20m south Nantucket**	**M**	**15**	**Last sighted gear free on 04/29/2019 in Cape Cod Bay. At the initial entanglement sighting, the whale had multiple passes of yellow line through its mouth. The line appeared to be buoyant and trails behind the whale to a jumble and at least one bitter end. There is no evidence of tackle or buoys and the flippers do not appear to be involved. No response was mounted due to the time of day and distance from shore. The large amount of line and the jumble indicate that the whale will have difficulty shedding the gear and the configuration may become more complicated.**

Monitoring Health of Injured Right Whales

Efforts to better track and monitor the health of anthropogenic injury of North Atlantic right whales were initiated in January 2013. These efforts aim to support annually mandated human induced serious injury and mortality determinations, to reduce the likelihood of undetected and unreported events, and to better assess both short and long term impacts of injury on right whale health. Previously and newly injured right whales with vessel strikes, attached fixed gear, or with moderate to severe entanglement injuries in the absence of attached gear (see Knowlton et al. 2016 for review of injury types) are flagged for monitoring biannually. Each whale's pre- and post-injury health conditions are evaluated using the visual health assessment technique (Pettis et al. 2004) and a determination of the impact of injury on health is made. Based on the available sighting and health information, whales are assigned to one of four categories: 1) Evidence of declining health coinciding with injury; 2) Inconclusive (this determination was assigned to animals when a: evidence of declining health exists but it was unclear whether or not it was linked to injury and/or b: images/information were inadequate to fully assess health condition visually; and/or c: condition has improved but remains compromised; 3) No indication of declining health caused by injury based on available images/information (these are removed from the monitoring list should subsequent sightings also show no impact of injury on health); and 4) Extended Monitor - no indication of declining health or whale's condition has improved but whale will remain on monitoring list because of injury severity and/or is still carrying gear. This last category was created to capture whales without current health impacts related to injury, but with injuries that have the potential to negatively impact future health condition (e.g. some severe vessel strikes, whales carrying gear, etc.).

Between 01 January and 31 December 2019, nine new injury of interest events were documented, all of which were entanglement related (four with attached gear and five with injuries but no gear attached). Of these nine, three exhibited declining condition coinciding with injury. The impact of injury on the health of five whales was inconclusive. There were no visual indicators of injury impact on health condition for the remaining newly injured whale. Seven whales previously on the monitoring list were removed, including one who was discovered dead on 6/4/2019 in the Gulf of St. Lawrence. The remaining seven whales exhibited stable health condition and wound healing. As of 31 December 2019, the Serious Injury/Human Impact list includes 72 whales with 80 injuries documented from March 2004 through 31 December 2019 (Table 5). The majority of the injuries are entanglement related (69/80, 86.3%) followed by vessel strikes (9/80, 11.3%). There are two whales on the list with injuries of unknown origin (Table 6).

Table 5. Since the inception of the injured right whale monitoring protocol, the number of injured whales and newly reported injuries has varied by year. The number of whales included on the injured whale list is given for each report and is followed parenthetically by how many of those were newly detected injuries. There are currently eight whales on the injured list with multiple injuries.

Year	June	December
2013	**33***	**32 (2)**
2014	**45 (16)**	**50 (6)**
2015	**51 (4)**	**59 (9)**
2016	**60 (4)**	**63(8)**
2017	**61 (4)**	**70 (10)**
2018	**74 (9)**	**70 (8)**
2019	******	**72 (9)**

*The first injured whale monitoring report was distributed in June 2013 and therefore does not include a comparative number of newly reported injuries.

**In 2019, reporting moved from a biannual to an annual basis.

Table 6. Impact of anthropogenic injury on right whale visual health by injury type based on assessments of photographs pre- and post-injury for all North Atlantic right whales on the Serious Injury/Human Impact list as of 31 December 2019.

	Entanglement		Vessel Strike	Other	Total
	Gear Present	No Gear Present			
Decline in Condition	9	14	2	1	26
Inconclusive	12	13	1	1	27
No Decline in Condition	5	9	3	0	17
Extended Monitor	1	1		0	2
Total	27	37	6	2	72*

*This represents the number of whales on the monitoring list. Eight of these whales have each had second injuries documented since their initial injury sighting. For purposes of this report, whales are included under the category representing their most recent injury.

Aerial and Vessel-based Sighting Summary: 2018

Prior to the 2017 Report Card, sighting information was reported for the time period following the previous NARWC Annual Meeting. However, that reporting included the current year for which not all data has necessarily been received and/or processed. Therefore, beginning with the 2017 Report Card, sighting summaries will be presented for the previous calendar year. Cataloged sighting information for the year 2018 (analysed 04 September 2019) is summarized below (Table 7) and includes survey, research, and opportunistic sightings. Months with sightings, survey types, and major contributing organizations (>10% total sightings for region) are listed.

Major Contributing Organizations

BHC: Boston Harbor Cruises
CCS: Center for Coastal Studies
CMARI: Clearwater Marine Aquarium Research Institute
CWI: Canadian Whale Institute
CWR: Campobello Whale Rescue
DFO: Fisheries and Oceans Canada
FWRI: Florida Fish and Wildlife Research Institute
GDNR: Georgia Department of Natural Resources
GMWSR: Grand Manan Whale and Seabird Research Station
NEAq: New England Aquarium
NEFSC: Northeast Fisheries Science Center
NWW; Newburyport Whale Watch
QLM: Quoddy Link Marine
TC: Transport Canada
WHOI: Woods Hole Oceanographic Institution

Table 7. Summary of 2018 right whale sightings by habitat region. Analyses for 2018 data are ongoing and therefore the data presented here should not be considered complete.

Area	# Sightings	Sighting Months	Survey types/activities	Contributing Organizations
Bay of Fundy	19	Jul-Sep	Vessel surveys, biopsy sampling	CWI, CWR, GMWSR, NEAq, QLM
East (Nova Scotian Shelf)	8	May	Aerial surveys	DFO/TC
Gulf of Maine	164	May, Oct, Dec	Aerial and Vessel surveys	NEAq, NEFSC
Great South Channel	150	Jan, Mar-Apr, May, Aug-Sep	Aerial and Vessel surveys	NEFSC
Jeffreys Ledge	9	Apr-May, Dec	Aerial surveys, whale watch	BHC, CCS, NWW
Mid-Atlantic (includes south of Cape Cod)	283	Jan-Apr, Jun-Sep, Nov-Dec	Aerial surveys	NEAq, NEFSC
New England (Massachusetts Bay/Cape Cod Bay)	1617	Jan-May, Nov-Dec	Aerial and Vessel surveys, biopsy and habitat sampling, drone photogrammetry	CCS, NEFSC, WHOI
North (Gulf of St. Lawrence)	1287	May-Sep	Aerial and Vessel surveys, biopsy sampling	NEAq, NEFSC
Southeast United States	46	Jan-Feb, Dec	Aerial and Vessel surveys, biopsy sampling	CMARI, FWRI, GDNR

Management and Mitigation Activities

United States

- NOAA called for 29 Dynamic Management Area (DMA) voluntary speed reduction zones between 01 January 2019 and 31 December 2019 (Table 8).

Table 8. Dynamic Management Area (DMA) voluntary speed reduction zones posted by NOAA between 01 January 2019 and 31 December 2019.

Event ID	**Trigger Date** (date of RW sightings)	**Number of Right Whales**	**Sightings Source**	**General Location**	**Boundaries**
163	1/2/2019	53	Aerial survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
164	1/15/2019	100	Aerial survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
165	1/27/2019	20	NEA aerial survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
166	2/4/2019	11	NEA aerial survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
167	2/17/2019	19	NEA aerial survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
168	3/1/2019	10	NEA/USCG Survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
169	3/13/2019	15	Research Vessel	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
170	3/28/2019	6	Aerial Survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
171	4/7/2019	15	NEA aerial survey	South of Nantucket	41 12 N 070 36 W 40 28 N 069 31 W
172	4/19/2019	11	Boston Harbor Cruises	East of Boston	42 40 N 070 20 W 42 02 N 071 15 W
173	4/23/2019	3	NEFSC aerial	Southwest Martha's Vineyard	40 39 N 070 56 W 39 59 N 071 47 W
174	4/29/2019	3	NEFSC survey	South of Martha's Vineyard	40 47 N 070 29 W 40 07 N 071 22 W
175	5/7/2019	4	NEFSC survey	SW Martha's Vineyard	40 39 N 070 56 W 39 59 N 071 47 W
176	5/14/2019	4	NEFSC aerial survey	South of Martha's Vineyard	40 47 N 070 29 W 40 07 N 071 22 W
177	5/16/2019	5	NEFSC ship survey	SE of Nantucket	40 48 N 068 24 W 40 05 N 069 20 W
178	5/15/2019	4	NEA aerial survey	South of Nantucket	40 44 N 070 01 W 40 04 N 070 51 W
179	5/22/2019	15	NEFSC Ship survey	SW Martha's Vineyard	40 39 N 070 56 W 39 59 N 071 47 W
180	5/22/2019	15	NEFSC Ship survey	South Martha's Vineyard	40 47 N 070 29 W 40 07 N 071 22 W
181	5/25/2019	9	NEA aerial survey	South of Nantucket	40 44 N 070 01 W 40 04 N 070 51 W
182	7/15/2019	3	NEA aerial survey	South of Nantucket	41 34 N 070 32 W 40 54 N 069 39 W
183	7/25/2019	7	NEA aerial survey	South of Nantucket	41 14 N 069 32 W 40 29 N 070 32 W
184	8/3/2019	10	NEFSC aerial survey	South of Nantucket	41 14 N 069 32 W 40 29 N 070 32 W
185	8/12/2019	9	NEFSC aerial survey	South of Nantucket	41 14 N 069 32 W 40 29 N 070 32 W
186	8/30/2019	19	NEFSC aerial survey	SE of Nantucket	41 23 N 068 14 W 40 43 N 070 10 W
187	9/9/2019	7	NEFSC aerial survey	SE of Nantucket	41 23 N 068 14 W 40 43 N 070 10 W
188	11/9/2019	3	NEFSC aerial survey	South of Nantucket	41 01 N 069 10 W 40 25 N 069 56 W
189	11/19/2019	?	NEFSC aerial survey	South of Nantucket	41 01 N 069 10 W 40 25 N 069 56 W
190	12/12/2019	8	NEFSC aerial survey	South of Nantucket	41 10 N 069 42 W 40 28 N 070 43 W
191	12/29/2019	14	CCS aerial survey	SE of Nantucket	41 35 N 069 35 W 40 52 N 070 37 W

- In 2019, NMFS conducted a number of management activities under the Endangered Species Act (ESA) related to recovery plan implementation specific to Section 4(f). This included:
    - Convened U.S. North Atlantic Right Whale Implementation Team (RWIT; composed of the Northeast U.S. Implementation Team (NEIT) and Southeast U.S. Implementation Team (SEIT)) to coordinate on coast wide issues. Regional teams also continued to meet and work independently on regional issues. The RWIT's Population Evaluation Tool Subgroup continued to meet and work towards development of a population viability analysis.
    - Announced the availability of the latest comprehensive report on Recovering Threatened and Endangered Species FY 2017-2018 and added the North Atlantic Right whale to the Species in the Spotlight. As part of the Species in the Spotlight campaign, NMFS will develop a five-year action plan. The 5-year action plan will build upon existing recovery and conservation plans and will detail the focused efforts needed over the next 5 years to reduce threats and stabilize the North Atlantic right whale population decline. NMFS sought input on the plan from the U.S. RWIT. With North Atlantic Right Whales now being added to the list, NMFS hopes that more focused attention will help stabilize the declining population. NMFS recognized the Right Whale Consortium as a *Species in the Spotlight Partner* which recognizes the efforts of over 200 partners dedicated to conserving and recovering the species.
- The Atlantic Large Whale Take Reduction Team continued their efforts to meet the requirements of the Marine Mammal Take Reduction Act, to develop recommendations to modify the Atlantic Large Whale Take Reduction Plan to reduce entanglement related serious injuries and mortalities to below the Potential Biological Removal Level of less than one per year. During a full Team meeting in April 2019, attendees came to near-consensus on recommendations to achieve risk reduction targets by jurisdictional/lobster management area to respect the diversity of the trap/pot fisheries. Two primary risk reduction measures were proposed:
    - Rope breaking at 1700 lbs or less via engineered weak rope or by introducing weaknesses regularly in rope, and
        - Less rope - reduce the number of buoy lines

    And the recommendation included strong support for:
        - Gear marking
        - Safety exemption
        - Monitoring post implementation: including whale numbers and distribution, endline numbers, outcomes on socioeconomics
        - Support for regulating in a way that allows regional gear innovations

    NMFS is working with the states and offshore lobster fishermen to develop take reduction measures for the Gulf of Maine and southern New England waters. Alternatives being developed are consistent with an agreement to achieve risk reduction across lobster and state management areas through a combination of line reductions and weak rope/weak insertions into rope. Scoping was conducted in August, 2019, with eight meetings held from Maine through Rhode Island. Alternatives and analyses that will be included in the Draft Environmental Impact Statement will reflect scoping comments received from over 800 people that attended scoping meetings, and nearly 27,000 pieces of correspondence received during scoping. The Draft Environmental Impact Statement and Proposed Rule are anticipated to be published for public comments in early 2020.
- NMFS convened two workshops related to NARW recovery and conservation:
    - NARW Health Assessment workshop from June 24-26, 2019 in Silver Spring, Maryland, held under the auspices of the Working Group on Marine Mammal Unusual Mortality Events. Workshop participants assessed current health information data, including associated data gaps, and identified appropriate available and needed tools and techniques for collecting standardized health data that can be used to understand health effects of environmental and human impacts (e.g. entanglement) and inform fecundity and survivorship models to ultimately guide NARW recovery.
    - NARW Monitoring and Surveillance workshop from October 22-24, 2019 in La Jolla, CA. NMFS working group members developed recommendations for prioritizing and integrating NARW monitoring and surveillance efforts range-wide across platforms (aerial, vessels, passive acoustic monitoring). NMFS will evaluate the recommendations and develop a comprehensive strategy to inform NARW conservation efforts and maximize NMFS' efficiency and ability to leverage resources to answer outstanding questions related to population and health status, as well as distribution and habitat use.
- In 2019, the NMFS Greater Atlantic Regional Fisheries Office had an increase in activity under the ESA related to the burgeoning offshore wind energy industry. With 15 active leases on the Outer Continental Shelf

(OCS) of the East Coast, much of this work was providing technical assistance about protected species to developers and the Bureau of Ocean Energy Management (BOEM, the lead Federal agency for authorizing the construction, operation, and eventual decommissioning of any offshore wind project). Many of the proposed projects are currently in the site assessment phase; effects of site assessment activities, including geotechnical and geophysical surveys, are assessed under the ESA and permits may also be necessary under the Marine Mammal Protection Act (MMPA). Effects of some survey activities are considered in a 2013 programmatic biological opinion (Data Collection and Site Survey Activities for Renewable Energy on the Atlantic Outer Continental Shelf). This Opinion is in the process of being updated. Additional activities in 2019 included:
    - Initiating an ESA section 7 consultation for the construction, operation, and decommissioning of Vineyard Wind 1, the first commercial scale offshore wind energy project in the United States in the northern portion of lease area OCS-501. Consultation is expected to be completed following the issuance of a Supplemental Environmental Impact Statement by BOEM.
    - Re-initiating the 2013 programmatic biological opinion on offshore wind energy survey activities to expand the geographic range to include actions south of North Carolina and to update relevant background information and complete updated analyses of effects to ESA listed species including NARWs.
- Following receipt of letters in the fall of 2018 from researchers both for and against invasive tagging of NARW, NMFS agency scientists and managers re-evaluated the risks and benefits of invasive tagging for this species. Following this review, in May 2019, NMFS instituted a temporary suspension of dart tagging of reproductive-age female NARW while tag improvements are being implemented and tagging reports are more closely reviewed. NMFS' current position on invasive tagging of NARW includes:
    - Prohibiting deep-implant tags designed to anchor in the fascia between muscle and blubber layers;
    - Allowing use of dart-style tags designed to anchor into the blubber layer, except on lactating females with neonates, and calves less than approximately 6 months old; and, temporarily suspending dart tagging of reproductive-age females; and
    - Requiring enhanced mitigation specific to dart tagging (including requiring the use sterile tags, prohibiting tagging of compromised individuals, requiring notification of tagging, and follow-up monitoring).
    - As part of an adaptive management plan, NMFS will annually re-evaluate use of dart tags on NARW, or earlier as needed, based on review of the following:
    - Monitoring reports submitted by researchers including information on efficacy of the tags (e.g., tag transmission duration) and effects of the tags (e.g., wound reaction and healing, animal health and behavior) for NARW and other cetacean species;
    - Tagging protocols and best practices developed by the International Whaling Commission, the International Union for the Conservation of Nature, and the Office of Naval Research;
    - The current status of and threats to the NARW population; and
    - Management needs to support conservation and recovery.
- NOAA Fisheries announced the availability of additional $1.6 million to support recovery actions for North Atlantic right whales
    - New federal funds will be available through the Atlantic States Marine Fisheries Commission for fishermen affected by pending right whale regulations.

Canada

- 2019 is the third year that the Government of Canada has implemented targeted management measures to help protect and recover NARW by addressing primary threats to the population: vessel strikes (Transport Canada lead) and entanglement in fishing gear (Fisheries and Oceans lead).
- The 2019 measures are focused on the prevention of entanglement and vessel strike by managing snow crab and lobster fisheries and all other non-tended fixed-gear fishing in Quebec and Atlantic Canada. Fisheries management measures include:
    - A season-long area closure (static zone) in the Gulf of St. Lawrence, covering 2,400km2;
    - If one or more right whales are detected anywhere in known foraging areas in the Gulf of St. Lawrence or the 2 critical habitats in the Roseway and Grand Manan Basins, 15 day closures (dynamic zone) of up to 2,100 km2 are implemented for snow crab and lobster fisheries (and all other non-tended fixed-gear fisheries); and
    - Outside these areas, in Quebec and Atlantic Canada sightings are reviewed on a case-by-case with special consideration given to sightings of 3 or more whales or a mother and calf pair.

- In response to the NARW mortalities in 2019, on July 9, DFO expanded the dynamic zone to the entire Gulf of St. Lawrence covering 227,940 km^2, stretching from the St. Lawrence Seaway, to the Cabot Strait and Strait of Belle-Isle. As a result, any sighting of a single NARW observed in the entire Gulf of St. Lawrence triggers a dynamic closure to all non-tended fixed gear fisheries. The number of flights by DFO were also doubled, from 5 to 10 per week.
- DFO has also implemented a range of fisheries measures to reduce the amount of rope in the water to lower the risk of NARW entanglement. Since 2017 they have adjusted opening and closing times in key fisheries, including in the Gulf of St. Lawrence. This minimizes the number of vertical lines and limits the number of traps, such as in the Gulf crab fishery.
- DFO also implemented requirements to identify and sequentially mark buoys, and are phasing in mandatory fishery-specific gear marking for all fixed-gear fisheries by 2020. Finally, they require all fishing licence holders to report lost gear and any interactions with marine mammals.
- Extensive surveillance of Quebec and Atlantic Canadian waters for NARW was achieved using multiple aircraft, vessels, and passive acoustic technology including hydrophones and gliders. Fisheries and Oceans, Transport Canada and partners are preparing plans for survey and surveillance efforts in 2020.
- As in 2019, DFO's Conservation and Protection branch continued to conduct extensive air and vessel patrols to verify compliance and enforce management measures related to NARW, including opening/closing of fishing areas and the removal of lost, abandoned, illegal or otherwise discarded fishing gear (i.e. "ghost gear"). Enforcement actions taken by fishery officers can lead to charges for violations under the *Fisheries Act*, *Species at Risk Act,* and other applicable laws and regulations.
- DFO has continued annual investment of over $1 million for marine mammal response organizations and investments in science to better understand threats to right whales, and to inform future management measures. They meet annually with our Marine Mammal Response partners to discuss the operational season and needs moving forward.
- DFO has implemented mandatory lost gear reporting for licence holders in all fixed-gear fisheries, as well as, mandatory reporting of any accidental contact between marine mammal and a vessel or fishing gear.
- From July 18-20, 2019, DFO also participated in a coordinated blitz with Canadian Coast Guard to retrieve ghost gear from five key areas in the Gulf of St. Lawrence. The five areas were identified based on the lost gear reports as well as areas of heaviest fishing in 2019. Over the course of the operation, 101 crab pots were recovered, over 10,000 lbs of crab were returned to the water, and 9.1 km of rope was removed from the water.
- DFO is supporting a number of industry trials of "whale safe" gear technologies that minimize or eliminate the risk of entanglement to whales and evaluating pilot projects using scientific expertise. The Department is hosting a Gear Innovation Summit in February 2020, which will include a stream focused on technological solutions to mitigate ghost gear.
- In 2019, Transport Canada once again implemented a large mandatory static speed restriction zone covering much of the Gulf of St. Lawrence, and dynamic speed restriction zones in the shipping lanes north and south of Anticosti Island to reduce the risk of vessel collisions with the NARW. These measures came into force on April 28, 2019 (see map HERE).
- On July 8, 2019, following the NARW mortalities, enhanced measures were announced, including expanding the speed restriction zones further east, increasing the number of vessels that speed restrictions apply to (all vessels over 13 m instead of just vessels 20m+), increasing the buffer zones around the dynamic speed zones, and increasing aerial surveillance (see map HERE).
- Transport Canada tested additional surveillance technologies to evaluate their effectiveness for possible integration into vessel traffic management in the Gulf of St. Lawrence, including a trial for a second year of Remotely Piloted Aircraft Systems (RPAS) and, in collaboration with the University of New Brunswick, a trial of acoustic monitoring to detect NARW in the dynamic speed zones using an underwater glider.
- Transport Canada began evaluating the 2019 measures before the conclusion of the season, and continues to engage with the marine transportation industry, scientists, and other stakeholders to refine and develop measures for 2020.
- Canada's National Marine Mammal Peer Review Committee met in October 2019 to review data and address question related to right whale distribution, habitat use, and risk of interactions with fishing gear and collision with vessels in Canadian waters.
- The Government of Canada consults with fishing and shipping industry representatives, Indigenous groups and other partners, for feedback on measures and to support the development of future measures. The NARW Roundtable meeting held on November 7th, 2019.

2019 North Atlantic Right Whale Publications/Reports

Reports and publications that utilized NARWC databases in 2019 and/or those of general interest to the right whale community are listed and hyperlinked (when available) below.

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Appendix 1

Catalog Assessment Method

We have developed standardized criteria that can be applied each year to get a low, middle (best estimate) and upper number of whales in the population as determined from Catalog data. One term needs to be explained to understand these numbers. Whales are given temporary intermatch codes if 1) two or more sightings match each other, and 2) neither have been matched to a catalog whale. Some of these whales will eventually be matched to existing cataloged whales and others will be determined to be "new" to the Catalog and assigned a number. Once an intermatch whale is given a Catalog number, or matched to another intermatch code whale, the intermatch code is made inactive. The results for 2018 are provided below in Table 1.

LOWER

To determine the lower bound, we simply count the number of unique cataloged whales identified the year before. Because of delays in processing data, this number is lower than the eventual total number of whales seen alive in that year.

MIDDLE

The middle bound is determined by summing three categories:

1) All whales presumed to be alive in that year (i.e. seen in the last six years),
2) Intermatch whales that are likely to be added to the Catalog. This is calculated by first finding all intermatch codes that span two or more years (both those that are active and those that were matched and made inactive), removing all calves and any SEUS whales whose sightings span two years only because they are seen in December and January of the same field season. Then, we determine which of those intermatch whales have Catalog numbers and what percent of those were new to the catalog (i.e. had not been matched to an existing cataloged whale). The remaining, unidentified intermatch whales are then multiplied by that fraction to determine how many are likely new to the Catalog (e.g. if only 20% of the matched intermatch whales were new, then 20% of the unmatched intermatch whales are likely new). That number is then added to the count of calves born more than two years earlier that are unmatched with active intermatch codes (indicating there is enough information to potentially match them in the future). Process changed Oct. 2009.
3) Calves from the last two years that have not been cataloged. We make an assessment of whether there is enough photographic information to likely be able to match them to future sightings and thus eventually assign them a Catalog number. We then sum those that will likely be cataloged.

UPPER

The upper bound is also the sum of three categories:

1) All Cataloged whales minus those whose carcasses were identified. Even whales missing for 30 years included.
2) All active intermatch whales minus calves from the last two years.
3) All calves from the last two years minus those known to be dead.

Table 1. The Catalog method of estimating the population represents an assessment of the number of photographed whales in the North Atlantic Right Whale Identification Database. Analysis completed 9/4/19.

Low: 343 individuals	
343	Cataloged whales seen in 2018
Middle: 502 individuals	
462	Cataloged whales presumed alive in 2018
37	Intermatch whales likely to be added to Catalog
3	Calves from 2017 and 2018 likely to be added to Catalog
High: 727 individuals	
684	All Cataloged whales in 2018 minus those known dead
39	All active intermatch codes without 2016 & 2017 calves
4	All uncataloged 2017 and 2018 calves minus dead

Alternative Arrangements Pursuant to 40 CFR Section 1506.11 – Emergencies

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
1. Release of HUD Section 108 loan guarantee funds to initiate land acquisition, relocation, site clearing and demolition activities.	Michigan governor declared City of Detroit to be in a state of emergency due to economic crisis. GM threatened to build a new plant outside the city unless a cleared site was delivered by May 1981.	City of Detroit, Michigan, under Section 104(h) of Community Development and Housing Act of 1974.	9/19/1980 Request: 9/22/1980 CEQ response: 9/24/1980	CEQ concurred in alternative arrangements proffered by HUD and the City which included substantial mitigation and notification efforts, and no demolition prior to discussion with Advisory Council on Historic Preservation. Upheld in Crosby v. Young, 512 F. Supp. 1363 (E.D. Mich. 1981).
2. Construct emergency regulating pond to stop sewage flow from Tijuana, Mexico, into the U.S.	Uncontrolled sewage flowing into U.S. would pose health risk and foul beaches.	International Boundary and Water Commission	3/8/1983	CEQ approved upon receipt of an environmental memorandum; preparation of EA followed.
3. Established boundary for an immediate separation between adjacent stone crab and shrimp fisheries.	Conflict escalated into physical violence between the two fisheries.	DOC / NOAA	3/9/1983	CEQ concurred in establishment of boundary, noting that fishery season would terminate shortly (and boundary issue would be fully addressed in the two 1983-84 fishery management plans.
4. Spray for mosquitoes with pesticides.	Outbreak of encephalitis in Yuma Proving Grounds, Arizona.	DOD /US Army	8/8/1983	CEQ approved arrangement to meet clear and present threat to human and animal health, noting that an EA or EIS might be necessary if long-term spraying were required.
5. Published an emergency temporary standard on asbestos.	Remove harmful asbestos materials.	DOL / OSHA	12/16/1983	CEQ agreed to publication of temporary asbestos standard on condition that OSHA assessment would be done on environmental effects prior to permanent standard hearings.
6. Aerial spraying of malathion pesticides in Idaho.	Infestation of migratory grasshoppers on Idaho cropland.	USDA / APHIS	8/3/1984	APHIS notified CEQ of the action, advising that 1979 Programmatic EIS found no adverse environmental effects.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
7. Stabilize the structural elements of a historic building prior to completion of the EIS process on the renovation.	Prevent the collapse of structure and exposure to hazardous asbestos.	Albany, NY Urban Renewal Agency under the Urban Development Action Grant program.	10/16/1984	CEQ agreed with the action considering that the asbestos removal qualified as an emergency circumstance and that stabilization would not cause environmental harm.
8. Clean up herbicide-contaminated material prior to the preparation of environmental documentation.	Herbicide-contaminated materials discovered at Fort A.P. Hill, Virginia (site of the 1981 Boy Scout Jamboree).	DOD /US Army	11/21/1984	CEQ agreed that environmental documents would be prepared concurrently with testing and clean- up at the site.
9. Issue a right-of way grant and allow the State of Utah to begin construction of the Great Salt Lake West Desert pumping project prior to the projected filing of the FEIS with EPA in July 1986.	Rising lake levels threatened extensive damage to surrounding industries, wildlife habitats, recreation areas, transportation systems, and personal and private property.	DOI / BLM	2/27/1985	CEQ approved the project in May 1986 (after Utah legislature authorized construction funds), provided that BLM complete the NEPA process, discussing the environmental impacts due to changes from the original EIS and that the state mitigate impacts as agreed to through the EIS process.
10. Issue a permit, based on a change to FWS policy, to capture the six remaining California condors and remove them from the wild.	Precipitous decline of species suggested that extinction was likely without enhancement of propagation.	DOI / FWS	12/20/1985	CEQ agreed to issuance of permit, noting 9/85 EA and 10/85 FONSI and that efforts were directed toward reentry of species in the wild. Upheld in National Audubon Society v. Hester, 801 F.2d 405 (D.C. Cir. 1986).

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
11. Destroy 1.3 million steelhead trout at Coleman National Fish Hatchery, California.	Spread of incurable whirling disease, classified as emergency by FWS.	DOI / FWS	1/31/1986	CEQ approved on basis of January 1986 EA.
12. Aerial spraying of pesticide malathion prior to signing ROD.	Grasshopper infestation on rangeland in Arizona.	USDA / APHIS	4/25/1986	CEQ approved action on condition that it was limited to acreage originally specified in request.
13. Destroy 5 million juvenile upright bright fall Chinook salmon at Little White Salmon National Fish Hatchery, WA.	Outbreak of untreatable viral Infectious Hematopoietic Necrosis (IHN).	DOI / FWS	5/19/1987	CEQ approved destruction, noting that the EA evaluated impacts and alternatives to proposed action.
14. Remove unexploded ordnance near Martha's Vineyard in MA.	Ordnance exposed by natural wave process posed hazard to beach users unaware of it.	DOD / US Army	8/29/1988	Consultation was concurrent with the removal action and prior to completion of an EA.
15. License a hydroelectric facility at Milner Dam in Idaho.	License issuance to allow money needed for immediate repairs to prevent dam failure due to seepage or earthquake.	FERC	10/25/1988	CEQ approved based on FERC's commitment to impose license conditions to mitigate any adverse impacts.
16. Destroy 3.42 million Pacific salmon and steelhead eggs and fish at Makah National Fish Hatchery, Washington.	Spread of untreatable virus: Viral Hemorrhagic Septicemia (VHS).	DOI / FWS	3/4/1989	CEQ approved after review of February 1989 EA.
17. Lower the water level behind Clear Creek Dam and Reservoir in Yakima, WA, to 2970 feet.	Potential dam failure which threatened both loss of life and property.	DOI / BLM	1/3/1990	CEQ approved with understanding that repairs or reconstruction thereafter would be conducted in compliance with NEPA.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
18. Aerial spraying of pesticide malathion over residential areas in Los Angeles, CA.	Threatened outbreak of Mediterranean fruit fly infestation resulting in economic losses of over $800 million to CA agricultural industry.	USDA / APHIS	1/19/1990	CEQ approved with 5 conditions: strict adherence to EPA quarantine exemption on malathion; vigorously pursue the NEPA process; employ monitoring program; provide monthly status reports to CEQ; and publish notices in affected counties.
19. Issue right-of-way for construction of Upper Flamingo Wash Detention Basin in Las Vegas, NV.	Frequent flooding that previously resulted in loss of life and millions dollars in damages.	DOI / BLM	12/4/1990	CEQ concurred with the understanding BLM would complete the NEPA process for the remainder of the project.
20. Allow night flights into and an increase in the overall number of flights from Westover Air Force Base in Massachusetts.	In response to hostilities in Kuwait, troops and military supplies had to be transported for use in Persian Gulf military operations (Operation Desert Shield) and the Air Force needed to change C-5A flight operations from those predicted in an EIS for the stationing of a unit of Air Force Reserve C-5A aircraft at Westover.	DOD / Air Force	11/21/1990 CEQ granted alternative arrangements 3/19/1991	The alternative arrangements required DOD/Air Force to immediately to implement five conditions: develop and complete, within 30 days, an EA documenting the environmental impacts of operations which exceeded the nature and number of flights occurring prior to Operation Desert Shield; provide for distribution, notice of availability, and a 30-day public comment period; provide Air Force responses to substantive comments; and continue efforts to remain alert to opportunities to lessen nighttime use over Westover. The Air Force committed to monitoring and publishing the results, and to preparing a supplemental EIS for the beddown of C-5A aircraft at Westover. Upheld in Valley Citizens for a Safe Environment v. Vest et al., (D. Mass. May 6, 1991) (WL330963 D. Mass., 1991).
21. Test aerial deactivation of land mine from the air at Tonopah Test Range in Nevada.	Preparation for war in Persian Gulf (Operation Desert Shield).	DOD / Air Force	1/16/1991	CEQ agreed to the testing considering the relatively short time needed for testing aerial deactivation of land mines (approximately 2 days), the military action in the Persian Gulf (Operation Desert Storm) and the service's expeditious consultation with DOI/ U.S. Fish and Wildlife Service and other government agencies with relevant expertise. Testing involved the use of fuel air explosives to clear buried land mines over a large area at the Department of Energy's Tonopah Test Range.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
22. Fund the Idaho Fish & Game Dept. and the Shoshone-Bannock tribe proposal to save the snake river Sockeye salmon.	Decline in salmon population. Migration of this sockeye salmon run had fallen to 4 adults in 1988, 1 adult in 1989 and no adults in 1990.	Bonneville Power Administration	5/1/1991	CEQ agreed to preparation of a special EA and conferencing with NMFS under ESA. CEQ participated in a conference call with representatives of 12 organizations to discuss issues of concern.
23. Drawdown of Par Pond, Savannah River Site.	Inspection of dam revealed depression in earth dam. Emergency drawdown to prevent possible life threatening failure of the dam and spread of sediment and contaminant.	DOE	7/9/1991	CEQ requested a special environmental analysis of the drawdown, repair and refilling of the Par Pond including discussion of mitigation measures. DOE entertained additional mitigation measures after public comment.
24. Allow the City of Portland, Oregon to pump down Bull Run Lake potentially reducing its volume down to 17 ft below normal minimal level.	City of Portland, Oregon, requested pumping additional water from Bull Run to meet emergency water needs of the City.	USDA / Forest Service	9/3/1992	CEQ agreed to allow the City to pump water from Bull Run Lake on condition that the City conduct an EA on the emergency action (distinguished from long-term use NEPA analysis for 20-year permit) as soon as possible. The alternative arrangements required the EA to: address the alternatives considered and their estimated impacts; explain the emergency conditions that support use of 40 CFR 1506.11 and the relationship of the EA to the ongoing long-term use analysis; discuss the limits of knowledge and the City's proposal for data gathering, monitoring and mitigation; and document whether the analysis supports a FONSI and, if not, identify requisite steps forward.
25. Reduce the bird-aircraft strike hazard at the JFK airport prior to APHIS completing a programmatic EIS for its gull-control program.	Severe bird-aircraft hazard conditions at the JFK airport prompted FAA to issue an emergency advisory.	USDA / APHIS	5/7/1993	CEQ issued recommendations regarding immediate actions, the programmatic EIS, and the ultimate decisions. These included: the definition of an acceptable risk, compliance by Secretaries with 16 U.S.C. §460; abstinence by FWS from processing permits under a categorical exclusion; the development of a program to plant and maintain tall grasses and wildflowers, and cooperation amongst Port authorities and FWS in preparing the programmatic EIS.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
26. Receive 144 spent fuel element from Belgium nuclear power plant prior to completing NEPA process.	Belgium nuclear reactor spent fuel element storage was filled to capacity. If the US did not accept the spent fuel elements, the spent fuel had the potential to be used for nuclear weapon production.	DOE	October 1993	Based on discussions with the Department of State, CEQ approved DOE proposal regarding alternative NEPA arrangements. However, Belgium refused the US offer to accept the fuel elements.
27. Block off streets around the White House complex to vehicular traffic.	Security was inadequate to protect the President, First Family and the White House complex.	Department of the Treasury	5/20-21/1995	CEQ concurred with the Department of the Treasury that an emergency situation existed that required immediate action. An EA was prepared after closure.
28. Form spur roads by blading old fire roads and fuel breaks. The total acreage disturbed by the proposed emergency measures constitutes no more than 2.5 acres of land in the Otay WSA. The roads would be closed to public access.	Sudden and dramatic increase in wildfires caused the County of San Diego to declare a state of emergency. Threats to human life and endangered and plant life were identified.	DOI / BLM	6/19/1996	CEQ concurred with BLM proposal to permit the State of California to begin construction of the proposed spur roads and heliports. Alternative arrangements included: FWS onsite review for heliports; BLM consulting FWS if the location of the proposed road or heliports changed; and a BLM archaeologist onsite during construction. Finally, the agency would use normal NEPA process for rehabilitation of disturbed areas after the emergency.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
29. Trench and terrace slopes that lost nearly all vegetation in a fire.	Fire burned 15,000 acres of federal, state and private land near Boise, Idaho. Conditions conductive to flooding, mudslides, and debris flows threatened human life and property, water quality and soil productivity.	DO I / BLM and USDA / Forest Service	9/19/1996	CEQ approved alternative arrangements that included: distributing additional copies of the interagency report to interested parties; implementing use of vegetative screening; developing monitoring plan, evaluating possibility of restoring natural grade; and notifying CEQ upon termination of emergency action.
30. Deviation from the normal operation procedures under test 7 of the Experimental Program of Water Deliveries to Everglades National Park.	High levels of rainfall created extreme flooding conditions which threaten endangered species and public safety.	DOD / US Army	January 1998	CEQ approved alternative arrangements that included: immediate distribution of a revised final emergency EA; developing comprehensive plan for public involvement; notifying CEQ if unanticipated impacts occur; formally consulting with FWS after emergency; alternative action to begin immediately and terminate after emergency at which time full NEPA requirements would resume; and providing CEQ with requested information.
31. Remove dead, drowned and severely root- sprung trees that were damaged by windstorm in the National Forests and Grasslands of Texas.	Windstorm caused destruction of habitat for red-cockaded woodpeckers; also gave rise to concerns about risk of high intensity fires and possible bark beetle infestation.	USDA / Forest Service	3/4/1998	CEQ approved alternative arrangements that included: Forest Service preparing an EA; only removing downed, dead or severely root-sprung trees; prioritizing tree removal by an interdisciplinary team; implementing long-term public involvement; not proceeding until emergency consultation under ESA is completed; maintaining records regarding tree removal priorities; establishing on-site monitoring team; and notifying CEQ if any modifications to these arrangements are necessary.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
32. Remove dead, downed and damaged trees in wake of 07/04/99 windstorm affecting 478,000 acres of Superior National Forest. Action proposed for Gunflint Corridor.	One area of affected forest - Gunflint Corridor - is a 2-lane winding, dead-end road with 600 structures, including homes. High risk to people and homes requiring treatment of 3,896 acres.	USDA / Forest Service	8/11/1999 CEQ response: 8/24/1999	CEQ agreed with alternative arrangements that included: preparation of programmatic EA; joint CEQ/FS public meeting; scoping meetings and site visits for particular projects within the Gunflint Corridor; consulting with other interested parties (agencies & tribes); and using on-site monitoring team.
33. Temporary, semipermanent, and permanent flood control measures following Cerro Grande Fire surrounding the Los Alamos National Laboratory in New Mexico.	High risk of soil erosion, flooding and debris flows threaten lives and property of the 10,000 residents in the communities of White Rock, the Pueblo of San Ildefonso and the Pueblo de Conchiti located downstream of Los Alamos National Laboratory.	DOE / National Nuclear Security Administration	May 2000 CEQ response: 6/15/2000	CEQ agreed on alternative arrangements that included: publication of FR notice outlining the emergency actions taken, being undertaken, and intended in the near term to address the effects of the fire as well as the potential impacts of emergency actions and proposed mitigation measures (dam construction); planning for continuing public involvement; preparing and publishing a Special Environmental Analysis; employing monitoring and adaptive mitigation measures; and reporting to CEQ.
34. Reduce wildfire fuel load in approximately 35,000 acres of 147,000 acre "high risk zone" of storm-damaged forest.	340,000 acres of Ouachita National Forest damaged by ice storm, blocked 1700 miles of road, and increasing ten-fold fuel load in forest stands located in close proximity to private property.	USDA / Forest Service	3/15/2001 CEQ response: 3/28/2001	CEQ concurred with alternative arrangements that included: preparing programmatic environmental analysis for highest priority fuel treatments areas; providing for expedited public comment before adopting a final programmatic environmental analysis; completing project-specific EAs before fuel reductions are authorized; and providing those EAs to the public for short comment periods.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
35. Commercial timber harvest on approx. 6200 acres and mechanical treatment of smaller fuels.	6,200 acres of Mark Twain National Forest land within two ¼ to ½ mile swaths of tornado damage (+80% of vegetation leveled) with fire risk to public safety and private property.	USDA / Forest Service	7/8/2002 CEQ Response: 7/12/2002	CEQ concurred with alternative arrangements that included: preparing programmatic environmental analysis for highest priority areas for fuel treatments; providing for expedited public comment before adopting a final programmatic environmental analysis; completing project-specific EA before fuel reductions are authorized that would be made public for short comment periods.
36. Transporting nuclear materials from Libya to the U.S. and within the U.S.	The shipment 55,000 pounds of nuclear material and other sensitive equipment were airlifted out of Libya as directed by the President. To expedite removal of four cylinders of uranium hexafluoride (UF_6) from Libya, the NNSA Administrator invoked the national security provisions of 49 CFR 173.7(b), allowing the shipment.	DOE / National Nuclear Security Administration	Shortly before 1/27/2004	CEQ and the Environmental Protection Agency were briefed in advance of the mission. CEQ found the NNSA's request for alternative arrangements was appropriately limited to the actions necessary to address the immediate impacts and risks associated with this emergency. Based on the briefing that DOE personnel provided, and their commitment to outreach to EPA and appropriate first responders, CEQ concluded that the NNSA's assessment of the environmental impact of the proposed action, including incorporation of an existing classified analysis of a similar scenario, provided sufficient alternative arrangements for NEPA compliance. The CEQ also was briefed following the completion of the mission. See: 69 FR 10440 (March 5, 2004)

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
37. Issue grants under the Stafford Act's Public Assistance Grant Program for the repair, replacement, or restoration of critical infrastructure in the New Orleans Metropolitan Area (NOMA). Although the restoration of eligible infrastructure substantially to its pre-disaster conditions is excluded from NEPA, FEMA anticipated applications from the State would reflect future needs.	Disaster-related damages to critical infrastructure by Hurricane Katrina on 8/29/2005 rendered parts of the city inoperable and uninhabitable. The city could not adequately support reconstruction and repopulation.	DHS / FEMA	Initial contact: November 2005 CEQ Response: 12/6/2005	CEQ approved alternative arrangements to expedite the processing of grant applications. The measures included: regular public outreach including special efforts to involve NOMA residents, including those relocated outside of NOMA; developing an internet page for environmental related public notices and environmental related information specific to the proposed actions in NOMA that would also track other projects in NOMA in order to provide the public with information on the individual and cumulative nature of impacts of the FEMA funded actions; establishing criteria for each type of critical physical infrastructure reconstruction project to mitigate or avoid significant environmental impacts whenever possible; and using the website to document agency actions (receiving, approving, conditioning, or denying critical infrastructure grant applications) as well as their environmental effects. See: https://www.fema.gov/new-orleans-metropolitan-area-infrastructure-projects-6

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
38. The Secretary of Energy issued an emergency order on 12/20/2005 directing Mirant to generate electricity at the coal-fired Potomac River Generating Station in Alexandria, VA, under certain limited circumstances.	Plant's operations were exceeding the National Ambient Air Quality Standards of the Clean Air Act and closure of the plant reduced the reliability of the electrical supply to much of the central business district of the District of Columbia and other portions of Northwest DC, and the District of Columbia Water and Sewer Authority's Blue Plains Advanced Water Treatment Plant, placing these electrical customers in risk of a blackout.	DOE	Consulted 12/20/2005 through 1/17/2006 Request and CEQ response: 1/18/2006	CEQ approved the following alternative arrangements: (1) prepare a Special Environmental Analysis (SEA) that will examine the potential impacts from issuance of the order, and identify potential mitigation measures; (2) provide opportunities for public involvement by disseminating information related to the environmental effects of Mirant's operations and by accepting public comment on this notice, the compliance plan Mirant submitted to DOE, and the SEA; (3) continue consultations with appropriate agencies with regard to relevant environmental issues; and (4) identify in the SEA any steps that DOE believes can be taken to mitigate the impacts from its Order. See: 71 FR 69102 (Nov. 29, 2006)
39. Lower Lake Cumberland behind Wolf Creek Dam to an elevation 680 feet above mean sea level for an indefinite period and accelerate a grouting program in the most crucial areas of the Wolf Creek Dam embankment to further reduce seepage under the dam.	Dam in danger of breaking and flooding down river through Kentucky and into Nashville, Tennessee.	USACE	Contacted: 1/9/2007 Request and CEQ response: 1/18/2007	CEQ approved alternative arrangements requiring USACE to: (1) issue an interim emergency measures decision document including discussion of alternatives and likely environmental effects as they are currently known, coordination with the U.S. Fish and Wildlife Service pursuant to the Endangered Species Act (ESA), the Fish and Wildlife Coordination Act, and other relevant authorities, and with the EPA and other appropriate Federal, state, and local leaders and agencies, and a communication plan for the public and stakeholders; and (2) issue a Notice of Intent to prepare a NEPA document would addresses the Corps' existing and future efforts to preserve, repair, strengthen, and operate the Wolf Creek Dam and Lake Cumberland, including mitigation measures that can be implemented to minimize adverse effects from lowered lake levels and other measures.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
40. New Orleans flood protection.	Reconstruction of levies damaged in Hurricane Katrina for 100-year flood protection.	USACE		See: https://www.mvn.usace.army.mil/Missions/Environmental/NEPA-Compliance-Rebuilding/
41. Navy MFA-sonar training in waters off southern California.	Naval training necessary for deployment.	DOD / US Navy	Request submitted: 1/10-11/2008 CEQ response: 1/15/2008	CEQ granted alternative arrangements calling for the Navy to prepare an environmental assessment an implement a suite of mitigation measures for training proposed during the period necessary to complete an EIS evaluating the environmental impact of establishing mid-frequency active sonar training exercises at the Navy's Southern California Range Complex. See: 73 FR 4189 (Jan. 24, 2008)
42. Temporary suspension of certain NEPA requirements for the Emergency Temporary Interim Rule (ETIR) to support Deepwater Horizon Oil Spill of National Significance Response.	Spill of National Significance (SONS) from the *Macondo* well in the Gulf of Mexico.	DHS / USCG	Request submitted: 7/6/2010 CEQ response: 7/12/2010	CEQ approved alternative arrangements which take the place of an EIS and provide that DHS and the USCG will consider the potential for significant impacts to the human environment as they implemented the ETIR and shift additional response resources from around the country to the Gulf of Mexico to assist in the cleanup of the SONS.
43. Emergency evacuation route along the lava-covered section of Chain Craters Kalapana Road in the Hawai'i Volcanoes National Park.	Established a new evacuation route as existing routes were anticipated to be covered by lava within 45 days.	DOI / NPS	Request submitted: 10/27/2014 CEQ response: 10/30/2014	CEQ approved alternative arrangements requiring the NPS to: (1) continue to enhance public and stakeholder engagement during the implementation of the proposed action; (2) provide responses to public comments received and periodic reports on the results of the monitoring commitments; (3) prepare the NEPA review for the future of the emergency access road after the emergency ends; and (4) continue consulting with affected agencies and stakeholders, adhere to mitigation and monitoring requirements committed to during consultations, and address future consultation or compliance actions as required.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
44. For the Rim Fire Recovery Project in the Stanislaus National Forest, to shorten the draft EIS comment period and eliminate the waiting period before publication of the ROD.	The Rim Fire burned 154,430 acres of National Forest System lands. Immediate action was required to restore the affected lands and mitigate future risks of wildfire.	USDA / Forest Service	Request submitted: 12/5/2013 CEQ response: 12/9/2013	CEQ approved alternative arrangements: continue to enhance public and stakeholder engagement during the scoping initiated by the 12/6/2013 NOI to prepare an EIS; continue engagement of interested parties throughout EIS preparation; continue communication with the Yosemite Stanislaus Solutions collaborative group; continue communication with the Sierra Nevada Conservancy and parties participating in the Rim Fire Landscape Restoration Technical Workshop on 12/18/2013; and post the Final EIS and proposed ROD on the Forest Service website for public review for 5-10 business days prior to publishing the Notice of Availability in the *Federal Register*.
45. Alternative arrangement to shorten the comment period for the draft EIS and eliminate the waiting period before publication of the ROD for fire restoration efforts in the Eldorado National Forest.	The King Fire burned 63,000 acres in California's Eldorado National Forest in 2014. Restoration efforts were needed to prepare for the subsequent wildfire season, especially in light of an ongoing drought.	USDA / Forest Service	Request: 5/7/2015 First CEQ response: 5/14/2015 Second CEQ response: 8/17/2015	CEQ approval based on Forest Service commitments to: (1) enhance collaborative engagement during development of the Draft EIS; (2) provide the interested members of the public with an opportunity to comment on the preferred alternative as it has evolved since the DEIS before finalizing the EIS and ROD and (3) posting the final EIS on the Eldorado National Forest website for public review prior to publishing Notice of Availability in the *Federal Register*.
46. Alternative arrangement to shorten the draft EIS comment period and eliminate the waiting period before publication of the ROD for fire restoration efforts in the Klamath National Forest.	Approximately 183,000 acres of public lands in the Klamath National Forest burned by the Beaver, Happy Camp Complex, and Whites fires in 2014. They were identified as requiring critical treatments to address post-fire conditions.	USDA / Forest Service	Request: 3/6/2015 CEQ Response: 3/6/2015 Remaining Request withdrawn: 8/15/2015	CEQ approved alternative arrangements to shorten the comment period on the Draft EIS based on commitments by the Forest Service to enhance collaborative engagement during development of the Draft EIS. The remaining request was withdrawn in light of ongoing consultation and regulatory processes.

PROPOSED ACTION	NATURE OF EMERGENCY	AGENCY	DATES	RESOLUTION
47. Alternative arrangements for the relocation of the F-22 Formal Training Unit (FTU) to Eglin Air Force Base (AFB).	In October 2018, Hurricane Michael (Category 5) displaced the USAF's only F-22 FTU from Tyndall AFB, Florida, to Joint Base Langley-Eustis in Virginia. Hurricane Michael rendered many of the FTU's facilities unusable for the foreseeable future. The Air Force needed to temporarily relocate the FTU to resume production of trained and qualified F-22 pilots by January 31, 2019.	DOD/Air Force	Request: 12/21/2018 CEQ Response: 12/21/2018 SEA: April 2019 ROD: 4/25/2019	The alternative arrangements required DOD/Air Force immediately to implement five conditions: develop and complete, within 30 days, an EA tiered to a 2014 Eglin AFB EIS documenting the environmental impacts of operations which exceeded the nature and number of flights occurring prior to relocation of the F-22 FTU; provide for distribution, notice of availability, and a 30-day public comment period; provide Air Force responses to substantive comments; and continue efforts to remain alert to opportunities to lessen noise impacts to neighboring communities. The Air Force committed to monitoring and publishing the results, and to preparing an EIS for the permanent beddown of the F-22 FTU.

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL ON ENVIRONMENTAL QUALITY
WASHINGTON, D.C. 20503

September 14, 2020

CEQ–NEPA–2020–01

MEMORANDUM FOR HEADS OF FEDERAL DEPARTMENTS AND AGENCIES

FROM: Mary B. Neumayr *Mary B. Neumayr*
Chairman

SUBJECT: Emergencies and the National Environmental Policy Act Guidance

This guidance[1] updates and replaces previous guidance from the Council on Environmental Quality (CEQ) on the environmental review of proposed emergency response actions under the National Environmental Policy Act, 42 U.S.C. 4321–4347 (NEPA).[2] Federal departments and agencies (agencies) should distribute this guidance as part of their general guidance on emergency actions to agency offices that are or may become involved in developing and taking actions in response to emergencies.

As agencies respond to situations involving immediate threats to human health or safety, or immediate threats to valuable natural resources, they must consider whether there is sufficient time to follow the procedures for environmental review established in the CEQ National Environmental Policy Act Implementing Regulations, 40 CFR parts 1500–1508 (CEQ NEPA regulations),[3] and their agency NEPA procedures.

This guidance does not establish new requirements. CEQ established the regulation addressing alternative arrangements in emergency circumstances in 1978,[4] and amended it in 2020 to clarify that it provides for alternative arrangements for compliance with NEPA section 102(2)(C) (42 U.S.C. 4332(C)).[5] 40 CFR 1506.12. CEQ has approved, and agencies have applied successfully, numerous alternative arrangements to allow a wide range of proposed actions in emergency circumstances including natural disasters, catastrophic wildfires, threats to species and their habitat, economic crisis, infectious disease outbreaks, potential dam failures, and insect infestations.[6]

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[1] The contents of this guidance do not have the force and effect of law and are not meant to bind the public in any way. This memorandum is intended only to provide clarity to the public regarding existing requirements under the law or agency policies.
[2] This guidance replaces guidance issued by CEQ on September 29, 2016, May 12, 2010, and September 8, 2005. CEQ rescinds the prior guidance.
[3] https://ceq.doe.gov/laws-regulations/regulations.html.
[4] 43 FR 55977, Nov. 29, 1978.
[5] 85 FR 43304, July 16, 2020.
[6] A synopsis of previous alternative arrangements is available at https://ceq.doe.gov/nepa-practice/alternative_arrangements.html.

Attachment 1 provides agencies with a step-by-step process for determining the appropriate path forward for the NEPA environmental review of all actions proposed in response to an emergency situation.

Environmental Impact Statements:

The CEQ regulations, at 40 CFR 1506.12, provide for alternative arrangements for NEPA compliance in emergency situations when the agency proposal has the potential for significant environmental impacts and would require an environmental impact statement (EIS) if the situation were not an emergency:

> Where emergency circumstances make it necessary to take an action with significant environmental impact without observing the provisions of the regulations in [parts 1500–1508], the Federal agency taking the action should consult with the Council about alternative arrangements for compliance with section 102(2)(C) of NEPA. Agencies and the Council will limit such arrangements to actions necessary to control the immediate impacts of the emergency. Other actions remain subject to NEPA review.

Agencies develop these alternative arrangements, based on emergency-specific facts and circumstances, during consultation with CEQ. The alternative arrangements developed by an agency address the actions necessary to respond immediately to the impacts of an emergency. The long-term response to the emergency, including recovery actions, remains subject to the regular NEPA process set forth in the CEQ NEPA regulations.

Alternative arrangements do not waive the requirement to comply with the statute, but establish an alternative means for NEPA compliance. Alternative arrangements also do not complete or alter other environmental requirements (except as provided by other environmental statutes or regulations); however, engaging other resource and regulatory agencies about other environmental requirements during development and implementation of alternative arrangements can facilitate meeting other compliance requirements. Final agency action taken pursuant to alternative arrangements for compliance with NEPA under 40 CFR 1506.12 may be subject to judicial review if a statute, such as the Administrative Procedure Act, provides for such review.

Attachment 1 describes the factors for an agency to address when requesting and designing alternative arrangements. Once the agency develops the alternative arrangements, CEQ will provide documentation detailing the alternative arrangements and the considerations on which they are based.

Environmental Assessments:

When agencies are considering proposals with less than significant impacts or are uncertain about the significance of impacts, the agency can prepare a concise, focused environmental assessment (EA). Attachment 2 of this memorandum provides guidance for preparing an EA. Some agency

NEPA procedures provide processes for preparing EAs for emergency actions.[7] Agencies must continue their efforts to notify and inform the affected public and relevant Federal, State, Tribal, and local agency representatives of the Federal agency activities and proposed actions. Agencies must comply with the CEQ NEPA regulatory requirements for content, interagency coordination, and public involvement to the extent practicable.[8]

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[7] *See* Agency NEPA procedures, for example: Department of Homeland Security Instruction Manual 023-01-001-01, Revision 01 at VI–1, https://www.dhs.gov/sites/default/files/publications/DHS_Instruction%20Manual%20023-01-001-01%20Rev%2001_508%20Admin%20Rev.pdf; U.S. Forest Service, 36 CFR 220.4(b), http://www.fs.fed.us/emc/nepa/nepa_procedures/includes/fr_nepa_procedures_2008_07_24.pdf; and Department of the Interior, 43 CFR 46.150, https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=2a2ce144c79da6f3e773bfa9cdf17bcf&mc=true&n=sp43.1.46.b&r=SUBPART&ty=HTML#se43.1.46_1150.

[8] 40 CFR 1501.5, 1501.6, and 1506.6 (these regulations address required content and public involvement for preparing EAs and Findings of No Significant Impact).

ATTACHMENT 1

Emergency Actions Under the National Environmental Policy Act (NEPA)

In the case of an emergency:

1. Do not delay immediate actions necessary to secure lives and safety of citizens or to protect valuable resources. Consult with CEQ as soon as feasible. Please coordinate any communications with your Federal agency NEPA contacts. *See* https://ceq.doe.gov/nepa-practice/agency-nepa-contacts.html.

2. Determine if NEPA applies and the appropriate level of NEPA analysis:

    - Determine if a Federal agency is taking the proposed action (e.g., city or State action does not trigger NEPA; Federal decisions to fund city or State action may trigger NEPA, depending on the nature of the funding arrangements) or is exempt from NEPA (e.g., certain Federal Emergency Management Agency response actions under the Stafford Act are statutorily exempt from NEPA; additional information is available at https://www.fema.gov/media-library-data/20130726-1748-25045-1063/stafford_act_nepa_fact_sheet_072409.pdf.).

    - If the Federal agency's proposed emergency response activity is not statutorily exempt from NEPA, and the agency has a categorical exclusion (CE) that includes that type of activity, then apply the CE unless there are extraordinary circumstances that indicate using the CE in this particular case is not appropriate. Agency NEPA personnel can assist in identifying agency-specific actions that are categorically excluded.

    - If the proposed Federal agency emergency response activity is not statutorily exempt from NEPA, a CE is not available, and the agency does not expect the potential environmental impacts of the proposed response activity to be significant, then an environmental assessment (EA) is appropriate. Prepare a focused, concise EA as described in Attachment 2. Alternative arrangements, as outlined at 40 CFR 1506.12, do not apply because the environmental impacts are not expected to be significant. Agency NEPA personnel can assist in identifying agency-specific actions that typically require an EA.

    - If the proposed Federal emergency response activity is not statutorily exempt from NEPA, and the agency expects it would have significant environmental impacts, the agency should determine whether an existing NEPA analysis covers the activity (e.g., implementing pre-existing spill response plans). If so, the agency may rely upon its existing analysis or adopt the analysis of another agency consistent with 40 CFR 1506.3.

    - If the proposed Federal emergency response activity is not statutorily exempt from NEPA, the agency expects it to have significant environmental impacts, and an existing NEPA analysis does not cover the activity, then the agency should consult with CEQ to determine whether alternative arrangements can take the place of an EIS. Contact CEQ to develop alternative arrangements under 40 CFR 1506.12. CEQ's main phone number is (202) 395–5750.

3. Factors to address when requesting and designing alternative arrangements include the:

   - Nature and scope of the emergency;
   - Actions necessary to control the immediate impacts of the emergency;
   - Potential adverse effects of the proposed action;
   - Components of the NEPA process that the agency can follow and provide value to decision making (e.g., coordination with affected agencies and the public);
   - Duration of the emergency; and
   - Potential mitigation measures.

ATTACHMENT 2

Preparing Focused, Concise and Timely Environmental Assessments

An agency can prepare a concise and focused EA in a short time in those situations where:

- There is no statutory exemption from NEPA requirements;
- There is no CE available, either because the agency has none that cover the activity or there are extraordinary circumstances;
- An existing NEPA analysis (EA or EIS) does not cover the proposed recovery or response actions; and
- The environmental impacts of the proposed recovery or response actions are not likely to be significant.

The following outline with notations addresses the core elements of an EA as required by 40 CFR 1501.5:

- The purpose and need for the proposed action;
- Alternatives as required by NEPA section 102(2)(E);
- The description of environmental impacts of the proposed action and the alternatives; and
- The list of agencies and persons consulted.

Purpose and Need for the Proposed Action

The agency should briefly describe information that substantiates the purpose and need for the action and incorporate by reference information that is reasonably available to the public. For example, "This agency is preparing to erect a temporary emergency response facility to replace facilities disrupted or destroyed by the [hurricane/flooding/contamination/etc.] to facilitate rescue or relief efforts in an effort to [minimize further adverse health conditions/restore communications/restore power]."

The agency should briefly describe the existing conditions and the projected future conditions of the area impacted by the action. For example, "The area(s) in which the temporary facility will be located or relocated is identified in the attached map. This area consists of [add brief description of the environmental state of the area that will be affected by the location and operation of the facility, focusing on those areas that are potentially sensitive. The goal is to show that environmental effects have been considered and the facts found indicate no significant impact (for example, refueling sites are not on top of aquifers, nesting areas, graves, sacred sites, etc.). These are examples to show the utility of and need to identify actual place-based environmental issues rather than compiling lists of environmental resources not at issue]."

Proposed Action and Alternatives

The agency should list and briefly describe its proposed action and reasonable alternatives that meet the purpose and need. The agency must use its discretion to ensure the number and range of reasonable alternatives is reasoned and not arbitrary or capricious. The purpose and need for the proposed action and its environmental impacts should focus the alternatives. For example, the need to use existing infrastructure necessary to support the facility is a reasoned basis for focusing on a discrete number of alternatives.

When there is no conflict over the resource effects of the proposed action based on input from interested parties, the agency can consider the proposed action and proceed without consideration of additional alternatives. Otherwise, the agency must identify reasonable alternatives that meet the action's purpose and need, consistent with section 102(2)(E) of NEPA.

Environmental Impacts of the Proposed Action and Alternatives

The agency should describe the environmental impacts of its proposed action and each alternative. The description should provide enough information to support a determination to either prepare an EIS or a finding of no significant impact.

The agency should focus on whether the action would significantly affect the quality of the human environment. The agency should follow CEQ's NEPA regulations in considering whether the effects of a proposed action are significant. 40 CFR 1501.3. Agency NEPA contacts and contacts at resource agencies can assist in this effort.

Tailor the length of the discussion to the complexity of each issue. Focus on those human and natural environment issues where impacts are a concern. Telephone or email discussions with State, Tribal, and local governments and agencies, and other Federal agencies that operate in the area, will help focus those issues.

The agency must discuss the impacts of each alternative and may discuss those impacts together in a comparative description, or discuss each alternative separately. The agency should use the approach that will be most effective in the time available. The agency may contrast the impacts of the proposed action and alternatives with the current condition and expected future condition in the absence of the action. This constitutes consideration of a no action alternative as well as demonstrating the need for the action.

The agency should incorporate by reference data, inventories, other information, and analyses relied on in the EA. CEQ encourages the use of hyperlinks in web-based documents. This information must be reasonably available to the public. For example, include relevant existing programmatic agreements and generally accepted best management practices.

The agency should be clear and concise about its conclusions and their bases.

List of Agencies and Persons Consulted

The agency must involve the public, relevant agencies, and any applicants, to the extent practicable in preparing EAs, and list the agencies and persons consulted. For example, include the people, offices, and agencies that the agency coordinated with to ensure that the location of the action did not cause unintentionally an adverse impact. Also include information about individuals consulted to comply with substantive environmental requirements and regulations, for example: the Clean Water Act, the National Historic Preservation Act, and the Endangered Species Act (ESA). [Note that the ESA emergency provisions at 50 CFR 402.05 may be applicable to the proposed action.]

code_

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FWC documents shed new light on boat strike that killed right whale calf

Mar. 12th, 2021

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JACKSONVILLE, Fla. – Documents obtained Friday by News4Jax uncover that the captain of a boat that struck a right whale calf in St. Augustine was on the phone with the U.S. Coast Guard for about 12 minutes as the vessel was sinking.

The calf was hit and killed in February and washed up on the shore of Anastasia State Park. The calf's mother was found alive days later with similar wounds.

According to investigators with the Florida Fish and Wildlife Conservation Commission, seven people had just finished a day of fishing when the 54-foot boat called "About Time" struck the calf.

"Coast Guard, this is About Time. We're outside St Augustine Marina, taking on water. We hit an object in the inlet here," the captain is heard saying in the call to the Coast Guard.

FWC documents state that the boat lost all engine power. The captain said the passengers heard a loud thud at the stern of the vessel.

The FWC determined the boat was traveling at 21 knots, which is about 24 mph. The incident was reported around 6:20 p.m.

According to the documents, a passenger told the FWC: "Once we realized we hit an object, we looked back to see a floating object we think might have been a whale, but it was dark so unsure."

The report shows the captain was able to get the port engine started.

"We're going to beach it right here by the Conch House and see how shallow we can get," the captain tells the Coast Guard.

The St. Augustine Fire Department and the FWC helped rescue the men from the boat. The FWC report states that there were no injuries, however, About Time did suffer damage.

An investigator states in the report, “Based on my interviews with occupants and evidence, I find no evidence of violation of navigation rules of state statutes.”

Mariners are reminded to stay 500 yards away from right whales, when spotted. The captain said he never saw the two whales that his boat hit.

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https://www.news4jax.com/news/local/2021/03/12/fwc-documents-shed-new-light-on-boat-strike-that-killed-right-whale-calf/?__vfz=medium%3Dsharebar

FWC documents shed new light on boat strike that killed right whale calf

Calf was struck by propeller and washed up on shore of Anastasia State Park

Brie Isom
, Reporter

Published: **March 12, 2021, 5:46 pm**
Updated: **March 12, 2021, 10:41 pm**

Tags: **News, Jacksonville**

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- Federal Source Code CoP Meeting Minutes: This folder contains the notes from our monthly Community of Practice meetings.
- Federal Source Code Study: This folder contains the Federal Source Code Study (FSCS) and summary documents to be used for upcoming blog posts.
- Metadata Schema: This folder contains the notes from our metadata schema workgroup meetings.
- UX: This folder contains Code.gov UX personas.
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- data_quality_scoring.md: Info on how the Code.gov data quality scores are determined.
- front_end_guidelines.md: General guidance to follow when developing on the front end.

- help_wanted.md: Detailed info on our Open Tasks (formerly Help Wanted) and the labels projects need to use in order to display these on code.gov.
- infrastructure.md: Description of the infrastructure, server space and memory, required to run code.gov. It breaks down the server requirements by front-end and different back-end processes.
- labor_hour_calc.md: Guidance on how agencies can calculate labor hours on open source projects.
- metadata_examples.md: A showcase of good examples of metadata in current agency code.json files.
- procedures.md: Administrative procedures for the Code.gov team
- repo-labels.json: A json file that can be used to add the specific GitHub issue labels code.gov uses on their projects.
- repository_management.md: This living document explains how we collaboratively manage the Code.gov platform repositories.

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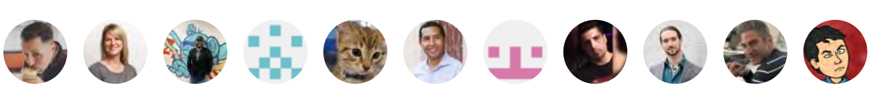

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Interactive Monthly DMA Analyses
An Analysis of Dynamic Management Areas, January 2010- August 2019,
in Support of the U.S. Take Reduction Team
Links to Interactive Analyses by Month

January Interactive TRT »

February Interactive TRT »

March Interactive TRT »

April Interactive TRT »

May Interactive TRT »

June Interactive TRT »

July Interactive TRT »

August Interactive TRT »

September Interactive TRT »

October Interactive TRT »

November Interactive TRT »

December Interactive TRT »

▼ Download Seasonal Proposed Closure Maps

▼ Download Monthly Analysis Maps

April 2019

Updated September 2019

Tim Cole and Leah Crowe

Introduction

We used the Dynamic Management Area (DMA) dataset housed at the NOAA NEFSC to generate maps that are roughly analogous to analyses used to create Seasonal Area Management zones (SAMs) for fisheries management (Merrick et al. 2001) and Seasonal Management Areas (SMAs) for vessel speed restrictions (Merrick 2005) to protect right whales. These seasonal areas were drawn to contain areas where sightings of three of more right whales occurred over multiple years. In Merrick et al. (2001), only NOAA aerial survey sightings 1999-2001 were used, and SAMs were drawn around areas where sightings of three of more right whales occurred seasonally over at least two years. In Merrick (2005), survey sightings from the North Atlantic Right Whale database (NARW) 1999-2003 were used, and SMAs were drawn around areas where sightings of three of more right whales occurred seasonally over at least three years. This analysis provides the most recent 9+ years of verified sightings of three of more right whales for Take Reduction Team (TRT) members. An interactive interface is provided for members to facilitate their review of right whale distribution and potential persistence relative to fisheries.

Dynamic Management Areas (DMAs)

DMAs are a component of the 2008 NOAA Ship Strike Rule to minimize lethal ship strikes of North Atlantic right whales. DMAs are temporary protection zones that are triggered when three or more whales are sighted within 2-3 miles of each other outside of active Seasonal Management Areas (SMAs). The size of a DMA is larger if more whales are present. A DMA is a rectangular area centered over whale sighting locations and encompasses a 15-nautical mile buffer surrounding the sightings' core area to accommodate the whales' movements over the DMA's 15-day lifespan. The DMA lifespan is extended if three or more whales are sighted within 2-3 miles of each other within its bounds during the second week the DMA is active. Only verified sightings are used to trigger or extend DMAs. The trigger of three or more whales is taken from a NOAA NEFSC analysis of sightings data from Cape Cod Bay and Stellwagen Bank from 1980 to 1996 (Clapham & Pace 2001). This analysis found that an initial sighting of three or more right whales was a reasonably good indicator that whales would persist in the area, and the average duration of the whale's presence based on these sightings data was two weeks.

Analysis

DMAs issued since January 2010 that occurred north of 36° North were used in this analysis. For the winter seasonal analysis, November and December 2009 were additionally included. An overall analysis was done that included all DMAs to show density within 1nm^2 grid cells of management areas issued similar to methods in Asaro (2012). Additionally, maps were compiled grouped by months as well as by seasons and included iterative, consecutive 3-year periods to compare to the methods of Merrick et al. (2001) and Merrick (2005). Within each year, one layer was created so that overlapping DMAs within a year were flattened so that each zone was only represented once. Shading indicates the number of consecutive years an area had overlapping DMAs by month or season.

The trigger date, defined here as the date of observed right whale sightings that triggered a DMA or DMA extension, was used for monthly/seasonal binning. Please note that instances where a DMA's 15-day lifespan went into the following month are not reflected in these maps, e.g., a DMA that is triggered by sightings on 17 February and expires on 05 March will only be included in the February map. A DMA would be reflected the following month if the extension was made in the following month, e.g., sightings on 03 March would extend the DMA example above through March 17 and would be reflected in maps within the month of March. We decided to use the trigger date, rather than the span of the DMA, because the trigger month is reflective of whale sightings, and this analysis did not aim to quantify the effectiveness of the DMA process.

For the seasonal analysis, seasons were divided in three 4-month groups as follows:

Winter = November through February

Spring (primavera) = March through June

Summer = July through October

The spring season grouping was chosen to coincide with the spring bloom (generally Feb/Mar south of the islands, April on George's and the GOM), and the summer period ending in October to coincide with fall turnover (generally October in the Mid-Atlantic).

Proposed Area Closures

The following proposed area closures were included with the DMA analysis:

Georges Bank 100m - 600m: all months

Gulf of Maine 100m - EEZ: all months

Statistical Area 537: January through May 14, November, and December

Massachusetts Restricted Area: February through April

Massachusetts Restricted Area -- Northern expansion: February through May 14

Rectangle south of Nantucket: February through May

Great South Channel Restricted Area: April through June

Western Gulf of Maine: April

Caveats

This analysis used DMAs rather than sighting locations as in Merrick et al. (2001), and therefore the results are analogous but not directly comparable. More importantly, however, DMAs are not triggered if a right whale aggregation is sighted within an active SMA. Therefore, this analysis does not assess the recurrence of right whales in the existing SMAs. The boundaries of SMAs are shown on the maps as blue polygons, and any grey shading indicates DMAs that were triggered either outside an SMA or were triggered during periods when an SMA was not active (see SMA regulations).

Interpretive Value

Perhaps the most important result of this analysis is the apparent changes as well as consistency in the distribution of DMAs over the years. There are areas where right whales have been consistently sighted that are outside of SMAs, but there has also been an increase in the persistence of right whale occupancy south of the Cape and Islands.

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Acoustic Indicators of Right Whale Occurrence

April 2019

Danielle Cholewiak, Genevieve Davis, Josh Hatch

Purpose

An indicator of the spatial and temporal occurrence of North Atlantic right whales is presented based on passive acoustic monitoring conducted along the US eastern seaboard from 2010-2018. These results are intended to complement the DMA analyses and additional analyses in support of the ALWTRT.

Indicator of Occurrence based on Passive Acoustics

Passive acoustic data collected by the NEFSC and multiple collaborators along the U.S. eastern seaboard from 2010-2018 were used to acoustically assess right whale presence on a monthly basis (i.e. Davis et al. 2017). Acoustic receivers were deployed at varying times and locations depending on project-specific goals. Acoustic data were analyzed using the Low-Frequency Detection Classification System (LFDCS, Baumgartner & Mussoline 2011), and detections of right whale up-calls were verified by an experienced analyst. Right whales were considered "present" at a site on any given day if at least three verified up-calls were detected that day. For more information, see Davis et al. 2017.

An indicator of right whale occurrence was developed using the percentage of days within a month in which right whales were present on any given acoustic receiver. The number of days with right whale detections, as well as the number of recording days, were aggregated by month across years for each acoustic receiver to provide the percentage of days within a month that had right whale detections. The acoustic indicator of occurrence was then calculated as,

$$Indicator_{i,j} = \frac{\sum_k number\ of days with NARW detections_{i,j,k}}{\sum_k total\ number of recording days_{i,j,k}}$$

where *i* denotes the acoustic receiver, *j* denotes the month, and *k* denotes the year. The acoustic indicator was then divided into three categories to reflect levels of occurrence:

Category	% Days/month with Acoustic Detections
Low	< 10%
Medium	10 - <50%
High	>= 50%

Caveats

Passive acoustic monitoring can only detect vocally-active animals; silent animals are not detectable. Additionally, automated detectors may miss some calls, leading to an underestimation of vocal activity. Therefore, these results represent a minimum number of days in which right whales were present, but there may be additional days in which animals were present but not detected.

Acknowledgments and Funding

The passive acoustic data summarized here are the result of contributions from many collaborators and funding streams. The compilation of these data and subsequent analyses were conducted under the direction of Dr. Sofie Van Parijs, NEFSC. For data from 2010-2014, please see Davis et al. 2017 for a complete list of collaborators and acknowledgements. For data from 2015-2018, data collection and analyses by the NEFSC Passive Acoustics Group were supported by NOAA Fisheries, BOEM and the US Navy, and were conducted in collaboration with Cornell University and Scripps Institution of Oceanography Whale Acoustics Lab. We thank Alyssa Scott and Sarah Weiss for analysis assistance.

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Largest Container Ship Ignores Slow Zone Established to Protect North Atlantic Right Whales

Oceana Calls for Mandatory Speed Zones to Help Save Whales from Extinction

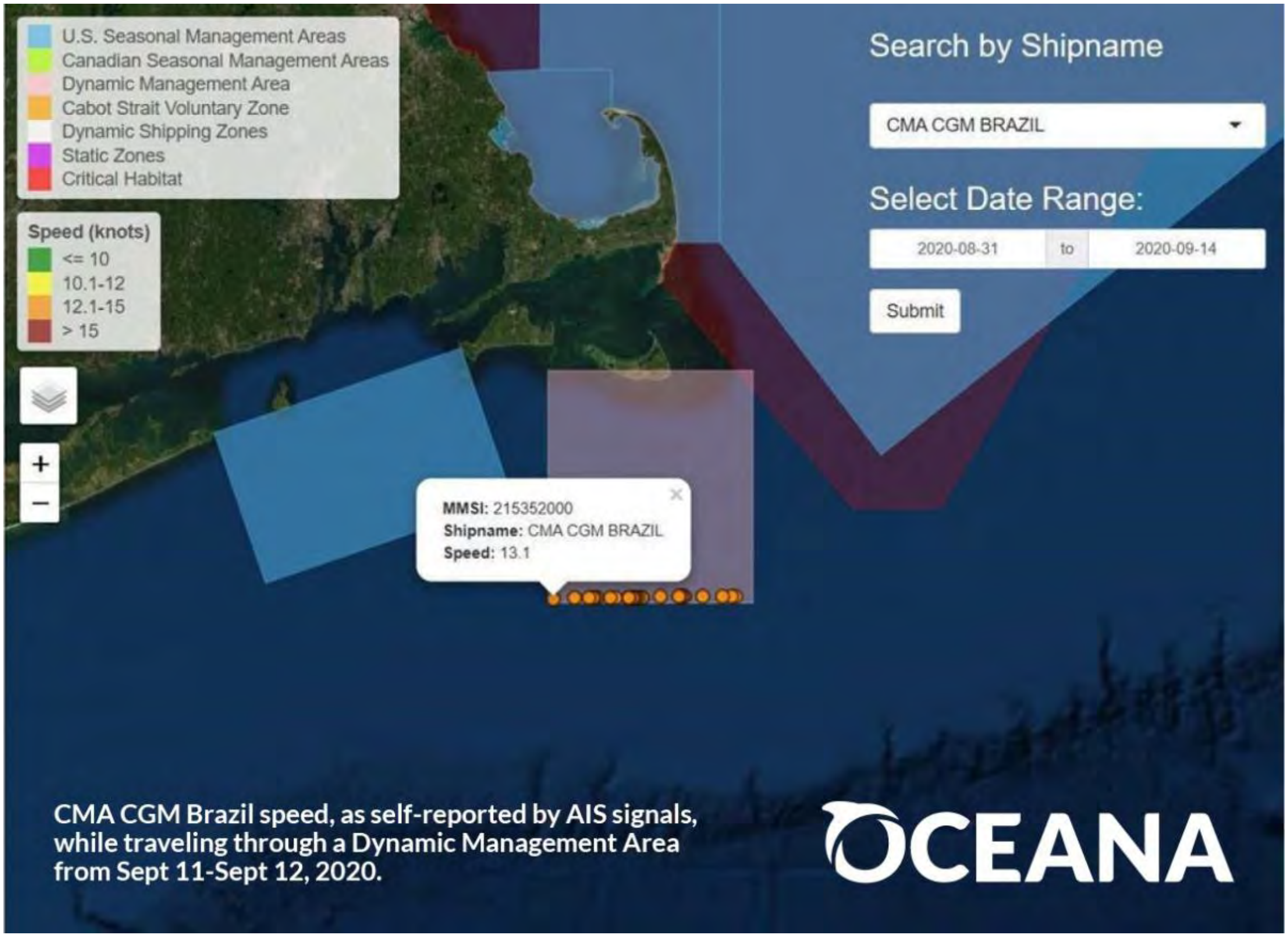
Press Release Date
Tuesday, September 22, 2020
Location: Washington, DC
Contact: Dustin Cranor, APR: dcranor@Oceana.org 954.348.1314

A new analysis from Oceana today finds that the largest container ship to ever visit the East Coast of the United States sped through waters critical to endangered North Atlantic right whales on its way from Nova Scotia to New Jersey this month.

Using Ship Speed Watch, an innovative tool launched by Oceana in July to monitor ship speeds in slow zones established to protect North Atlantic right whales, Oceana documented the CMA CGM Brazil, a 15,000-container ship that is 1,200 feet long, exceeding the 10-knot voluntary speed limit in a right whale conservation zone.* This Dynamic Management Area south of Nantucket was established to protect an aggregation of North Atlantic right whales. In self-reported data, the Malta-flagged vessel owned by a French transportation and shipping company transited through the area on Sept. 11 and 12 at a speed of up to 13.4 knots, which Oceana says is reason for grave concern considering its massive size. Oceana reached out to the company for comment but has not received a response.

"By ignoring the slow zone, this ship, longer than two Washington monuments and wider than a football field, sped through an area with a known aggregation of North Atlantic right whales. While any size vessel can be lethal to these whales, the sheer size of this one requires an added level of caution," said Whitney Webber, campaign director at Oceana. "Oceana's analysis earlier this year showed that many ships are ignoring these voluntary slow zones. To protect North Atlantic right whales, we must shift to expanded mandatory slow zones that require ships to reduce their speed when whales are present along their migratory routes. When ships slow down, it will help save whales."

Collisions with ships is one of the leading causes of North Atlantic right whale deaths. Research suggests that if ships slow down to 10 knots or less, they can reduce the risk of death by up to 86%. The U.S. government created the Dynamic Management Area south of Nantucket earlier this month to protect an aggregation of North Atlantic right whales. This zone was recently extended through Sept. 29.



About Ship Speed Watch:

Oceana's *Ship Speed Watch* allows users to monitor ship speeds and positions in areas frequented by North Atlantic right whales along the East Coast of Canada and the U.S. in near real-time. The tool uses self-reported data to show ship locations, ship speeds and active voluntary and mandatory speed restriction zones. The tool also provides additional information about speed restrictions in place to protect this endangered species. When mandatory and enforced, speed restriction zones can help prevent deadly collisions with ships, one of two leading causes of North Atlantic right whale injury and death. *Ship Speed Watch* was created based on Automatic Identification System (AIS) data from Global Fishing Watch, an independent non-profit founded by Oceana in partnership with Google and SkyTruth, which uses cutting-edge technology to interpret data from various ship tracking resources.

Background:

North Atlantic right whales were named for being the "right" whale to hunt because they were often found near shore, swim slowly and tend to float when killed. They were aggressively hunted, and their population dropped from peak estimates of up to 21,000 to perhaps fewer than 100 by the 1920s. After whaling of North Atlantic right whales was banned in 1935, their population increased to as many as 483 individuals in 2010. Unfortunately, that progress has been reversed.

Collisions with vessels is one of two leading causes of North Atlantic right whale injury and death. North Atlantic right whales are slow, swimming around 6 miles per hour, usually near the water's surface. They are also dark in color and lack a dorsal fin, making them very difficult to spot. Studies have found that the speed of a vessel is a major factor in collisions with North Atlantic right whales. At normal operating speeds, many vessels cannot maneuver to avoid them, and North Atlantic right whales swim too slowly to be able to move out of the way. This puts them at great risk of being struck, which can cause deadly injuries from blunt-force trauma or cuts from propellers.

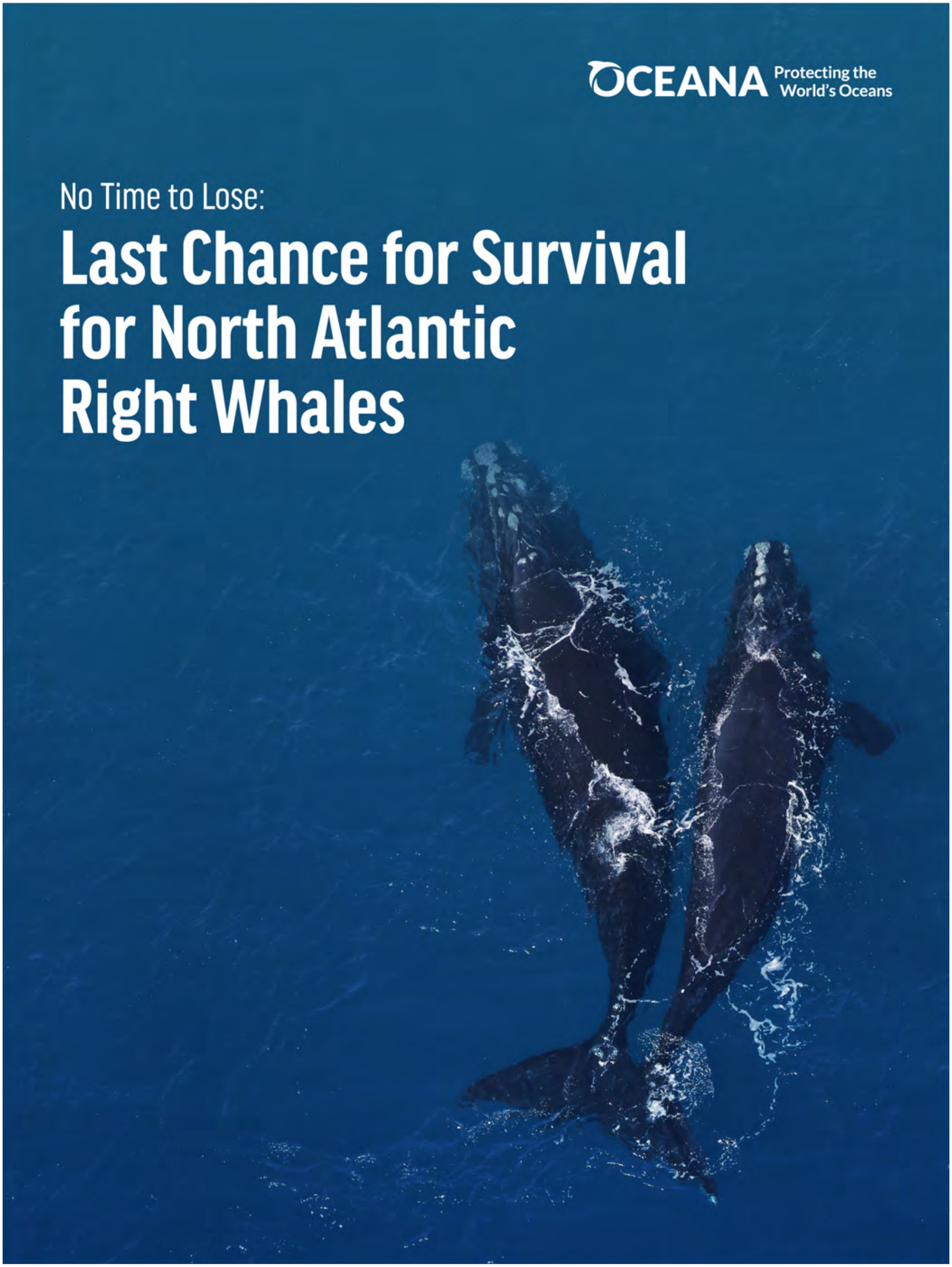
Entanglement in fishing gear used to catch lobster, snow crab and bottom-dwelling fish like halibut, flounder and cod is the other leading cause of North Atlantic right whale deaths. Fishing gear from the U.S. and Canada entangles an estimated 100 North Atlantic right whales each year, and about 83% of all North Atlantic right whales have been entangled at least once. Ropes have been seen wrapped around North Atlantic right whales' mouths, fins, tails and bodies, which slows them down, making it difficult to swim, reproduce and feed, and can kill them. The lines cut into the whales' flesh, leading to life-threatening infections, and are so strong that they have severed fins and tails, and cut into bone.

To learn more about Oceana's campaign to save North Atlantic right whales from extinction, please **click here**.

*Ship Speed Watch uses vessel information in the Global Fishing Watch database. This information is transmitted from a vessel's Automatic Identification System (AIS) device, which is collected via satellites and terrestrial receivers. Faulty AIS devices, user error, intentional manipulation, crowded areas, poor satellite reception, and transmission flaws are factors that contribute to noise and errors in AIS data, and sometimes those inaccuracies can be reflected in the speed and location of a vessel. Vessel operators can accidentally or purposefully enter false information into their ship's AIS thus concealing their identity or location. In crowded areas, such as ports, the massive number of radio transmissions can crowd the bandwidth of satellite and terrestrial receivers, leading to inaccuracies as well. For these reasons, Ship Speed Watch information must be relied upon solely at your own risk.

REPORT | SEPTEMBER, 2019

Last Chance for Survival for North Atlantic Right Whales


OCEANA Protecting the World's Oceans
No Time to Lose:
Last Chance for Survival for North Atlantic Right Whales

The North Atlantic right whale is one of the most endangered large whales on the planet. They were named for being the "right" whale to hunt because they were often found near shore, swim slowly and tend to float when killed.

Right whale populations first crashed due to whaling until hunting this species was banned in 1935. Now the right whale is on the brink of extinction mostly due to threats from commercial shipping and fishing. At normal operating speeds, ships cannot maneuver to avoid right whales, putting the whales at great risk of strikes, which can cause deadly injuries from blunt force trauma or cuts from the propellers. Additionally, a jungle of roughly one million fishing lines sprawls across right whale migration routes and feeding areas in the U.S. and Canada. These ropes have been seen wrapped around right whales' mouths, fins, tails and bodies, and cut into the whales' flesh, which can lead to life-threatening infections. Emerging threats like seismic airgun blasting, a process used to search for oil and gas deep below the seafloor, put the species at even greater risk.

Today, only about 400 North Atlantic right whales remain, including fewer than 100 breeding females. To reverse course, North Atlantic right whales must be protected from fishing gear entanglements and ship strikes.

Reducing the amount of vertical lines from fishing gear in the water and requiring ships to slow down can help save North Atlantic right whales.

- **Press Release**
- **Fact Sheet**
- **Launch Video**

- **Sam Waterston PSA**

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OCEAN POLICY • Marine Species Range Shifts Necessitate Advanced Policy Planning: The Case of the North Atlantic Right Whale

Erin L. Meyer-Gutbrod ✉, Charles H. Greene, Kimberley T.A. Davies

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ARTICLE ABSTRACT

Rising global temperatures are causing a poleward shift in species distribution. Range shift velocities are higher in the marine environment, with observed rates of 30–130 km per decade. Both protected and exploited species will be at risk if marine species management policies are not structured to anticipate these range shifts. The 2017 mass mortality event of the North Atlantic right whale showcases the detrimental impact of unanticipated climate-mediated behavior in a species protected by geographically and seasonally fixed policies. Based on the results of a demographic capture-recapture model, right whales may face extinction in fewer than 30 years unless protective

policies are expanded to cover their shifting distribution. Increased support of long-term monitoring programs paired with environmental modeling research is critical to developing more proactive conservation management strategies and preventing further ecological crises.

FULL TEXT

RIGHT WHALES THREATENED BY HUMANS AND CLIMATE

The North Atlantic right whale is one of the world's most endangered cetacean species, with estimates of fewer than 500 animals remaining in the population (Pace et al., 2017; Pettis et al., 2017). Evolving interactions with humans have greatly influenced the history of this species. Following centuries of intense whaling pressure, population growth is now stifled by high mortality rates attributed to ship strikes and entanglement in fishing gear (Kraus et al., 2005, 2016; Figure 1). NOAA Fisheries and Fisheries and Oceans Canada have designated critical habitats throughout the right whale's traditional range, including portions of the Gulf of Maine and the Scotian Shelf where right whales typically forage for zooplankton (NMFS, 2016; Fisheries and Oceans Canada, 2014; Figure 2). These critical habitats guide the development of protective policies to reduce anthropogenic mortalities, such as vessel speed reductions, vessel rerouting zones, and fishery modifications.

(https://tos.org/oceanography/assets/images/content/31-2_meyer-gutbrod_f1.jpg)

Figure 1. Right whale "Mayport" entangled in fishing gear in the Gulf of St. Lawrence. Image collected on July 19, 2017, under SARA permit DFO-MAR2016-2. *Photo credit: NOAA/NEFSC/Peter Duley.* > High res figure (https://tos.org/oceanography/assets/images/content/31-2_meyer-gutbrod_f1.jpg)

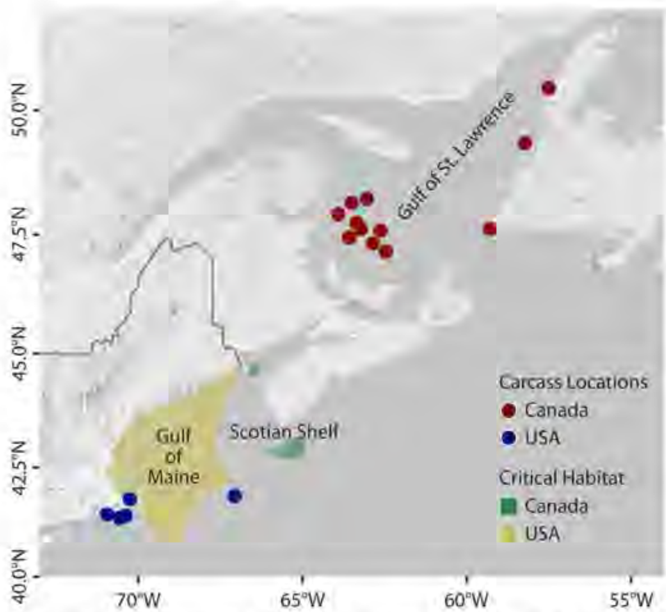

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Figure 2. Map of NOAA Fisheries (yellow) and Fisheries and Oceans Canada (green) right whale northern critical habitat designations and locations of right whale carcasses found in US (blue) and Canadian (red) waters and beaches in 2017. > High res figure (https://tos.org/oceanography/assets/images/content/31-2_meyer-gutbrod_f2.jpg)

While scientists and managers have focused much of their effort on limiting mortalities in these feeding grounds, little consideration has been given to the effect of shifting prey distribution. In the 1990s, declines in the copepod species *Calanus finmarchicus*, the right whale's primary source of nutrition, were attributed to a regime shift in the Gulf of Maine ecosystem associated with climate forcing from the Arctic (Greene et al., 2013). These declines drove a shift in right whale habitat use among several important feeding grounds (Hamilton et al., 2007; Patrician and Kenney, 2010; Davies et al., 2015). Low prey abundances reduced calving rates, demonstrating the significant impact prey availability can have on right whale demography (Meyer-Gutbrod et al., 2015; Meyer-Gutbrod and Greene, 2018). Although previous observations of *C. finmarchicus* declines in the Gulf of Maine have been related to natural climate oscillations and variability in water mass advection (Pershing et al., 2010; Greene et al., 2013; Davies et al., 2014), anthropogenic warming will also play a role in right whale prey availability. Because the Gulf of Maine constitutes the southern edge of suitable habitat for this subarctic copepod species, forecasts of future warming predict significant declines in *C. finmarchicus* in the Gulf of Maine within this century (Reygondeau and Beaugrand, 2011; Grieve et al., 2017).

Starting in 2012, right whale sightings in several traditional feeding habitats began to decline, causing speculation that a shift in right whale habitat usage was occurring (Pettis et al., 2017). Passive acoustic monitoring efforts indicated a decrease in summertime occupation of the northern Gulf of Maine, supporting this theory (Davis et al., 2017). With fewer animals sighted, scientists and managers were unable to distinguish between a decline in population size and a change in spatial distribution. Using knowledge of summer right whale feeding habitat history to guide exploratory surveys of candidate habitats (e.g., Michaud and Taggart, 2011; Davies et al., 2014), a collaborative effort between the United States and Canada to search for the animals in 2015 revealed an aggregation in the southern Gulf of St. Lawrence (GoSL), well north of the known and protected critical feeding habitats. In 2017, the discovery of 17 right whale carcasses triggered the declaration of an unusual mortality event (Table 1; NOAA Fisheries, 2018). Twelve of these carcasses were located in the GoSL and five in the Gulf of Maine

(Figure 2; Daoust et al., 2017). Necropsies of seven of the 12 GoSL carcasses found the causes of death to be blunt force trauma indicative of ship strike in four cases (57%), entanglement in snow crab gear in two cases (29%), and undetermined due to advanced decomposition in one case (14%; Daoust et al., 2017). In addition, five live right whales were seen entangled in snow crab gear in the GoSL (Daoust et al., 2017). When a portion of the right whale population shifted north, likely in search of better feeding grounds, the spatial and temporal mismatch between protective policies and habitat occupancy led to a confirmed loss of over 3% of the estimated population size.

Table 1. Annual counts of confirmed North Atlantic right whale mortalities. Counts are listed by the country where the carcasses were discovered, which is not necessarily the original location of the injury or death of the animal (Pettis and Hamilton, 2010, 2011; Pettis, 2012; NOAA Fisheries, 2018). > High res table (https://tos.org/oceanography/assets/images/content/31-2_meyer-gutbrod_t1.jpg)

	2010	2011	2012	2013	2014	2015	2016	2017
United States	3	4	3	1	3	0	3	5
Canada	1	0	1	0	1	3	1	12

(https://tos.org/oceanography/assets/images/content/31-2_meyer-gutbrod_t1.jpg)

FORECASTING CHANGES TO THE POPULATION

The eventual fate of the North Atlantic right whale depends on both the timeliness and efficacy of new policies, which drive anthropogenic mortality rates, and the future prey environment, which drives reproduction. Prey-dependent demographic modeling studies spanning the period 1980 to 2012 demonstrate that the population has exhibited periods of growth and stasis, but no significant period of decline (Meyer-Gutbrod and Greene, 2018). However, models that include demographic data through 2015 indicate that the species has recently entered a period of decline (Pace et al., 2017). The discovery of 17 carcasses in 2017 constitutes a confirmed annual mortality count unprecedented since the cessation of whaling. Compared to the average of 3.1 confirmed mortalities per year from 1970 to 2009 (van der Hoop et al., 2013), 2017 represented more than a fivefold increase in confirmed mortalities.

Probability of species extinction and time to extinction can be derived from a 1980–2012 prey-dependent capture-recapture model (Meyer-Gutbrod and Greene, 2018) using the relative increase in mortality rates between that time period and 2017. For this analysis, the species is considered functionally extinct when fewer than 10 females remain. Given historical prey conditions, if the 500% relative increase in mortality rates observed in 2017 persists, the population will decline to extinction in just 34 years. Additionally, if reduced *C. finmarchicus* abundance results in a decrease in reproduction similar to that observed in the late 1990s, which we hypothesize has occurred during the past five years, then extinction could take place in just 27 years (Figure 3). Even with a mortality rate increase of 200%–250%, extinction risk remains high. Under these more moderate increases in mortality, prey availability strongly influences the population's future (Figure 3).

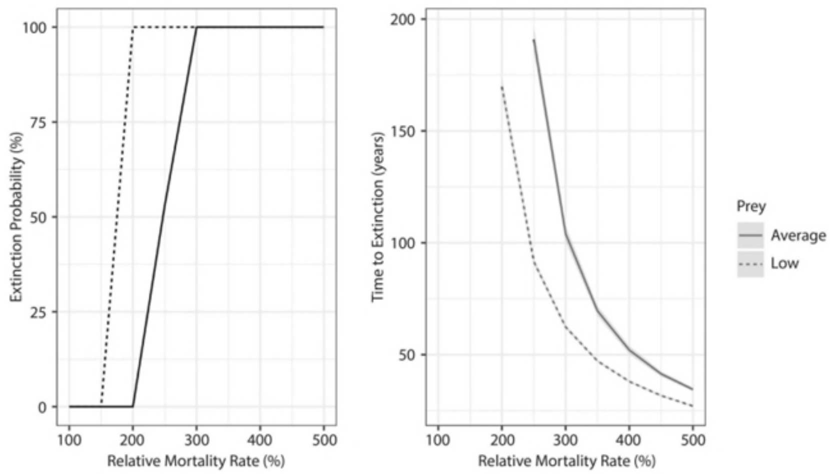

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Figure 3. Probability of right whale population extinction (left) and estimated time until extinction (right) derived from a capture-recapture model given a range of mortality rates and prey scenarios. Mortality rates are relative to those observed historically, where 100% indicates the rates observed from 1980 to 2012 (Meyer-Gutbrod and Greene, 2018) and 500% indicates a fivefold increase from those historical mortality rates. Modeled reproduction rates depend on *Calanus finmarchicus* anomalies resampled from annually averaged Continuous Plankton Recorder time series 1979–2011 (solid lines) or the lowest five annual anomalies observed in that same period (dashed lines). > High res figure (https://tos.org/oceanography/assets/images/content/31-2_meyer-gutbrod_f3.jpg)

Unfortunately, there have been signals that the right whale prey environment is worsening. The reduced use of most traditional foraging grounds combined with the recent decline in calving rates indicate that the population has been facing prey limitation during the last few years (Pettis et al., 2017). *C. finmarchicus* abundance has been anomalously low in Gulf of Maine and Scotian Shelf waters since 2011 (Johnson et al., 2017). Concurrent declines in *Calanus* spp. in the Gulf of St. Lawrence suggest that the whales' northward range shift may not be a successful adaptation to declines in Gulf of Maine prey (Devine et al., 2017). This decline in prey has been reflected in the low calving rates since 2012 (Pettis et al., 2017). Only five calves were born in 2017, and no newborn calves have been sighted thus far in 2018.

EXPANDING PROTECTIVE POLICIES

These population projections demonstrate the extent of human involvement in the viability of the North Atlantic right whale population. Prior to the distributional shift, vessel speed reductions and rerouting zones in the United States and Canada resulted in a significant reduction in right whale deaths attributed to ship strikes (Vanderlaan and Taggart, 2009; Laist et al., 2014). Fishery modifications have been less successful in reducing mortalities, with increasing entanglement severity over the last three decades, potentially attributable to increasing rope strength (Knowlton et al., 2012, 2016). However, these government and industry efforts should inspire cautious optimism that conservation of this highly endangered species remains within our grasp. In an impressive display of rapid response during the GoSL mortality crisis, policymakers and industry leaders were able to draw upon decades of research and experience to introduce emergency protection measures within weeks. These policies included a massive search for right whales using aerial, vessel, and autonomous vehicle platforms in the GoSL; a mandatory 10-knot speed limit for all large vessels; and snow crab fishery closures (Daoust et al., 2017).

The 2017 GoSL emergency management action was informed by the temporary, near-real-time right whale search effort, but these rapid-response measures were arduous and expensive. We are now challenged to develop a program that combines scientific effort and conservation policy that is sustainable and adaptive. It is essential that future management efforts continue to draw upon previous policy outcomes and scientific best practices while also considering the present and potential future distributional shifts in right whales.

The 2018 plan for protecting right whales in the Gulf of St. Lawrence announced by Fisheries and Oceans Canada includes a number of risk mitigation strategies, notably mandatory speed reductions for vessels >20 m, an early closure of the snow crab fishery, a large fixed closed area where no snow crab or lobster gear is permitted, and dynamic management areas (Fisheries and Oceans Canada, 2018). In addition to these efforts, we recommend the following strategies, some of which are under development:

1. Establish a robust and sustainable program for monitoring North Atlantic right whale occupation in the GoSL using a combination of vessel-based, aerial, and passive-acoustic monitoring methods. Monitoring efforts should be balanced to optimize the trade-off between monitoring known aggregation areas and searching for unknown habitats. These long-term data are essential for the creation and assessment of conservation policy.

2. Reinstitute the Continuous Plankton Recorder (CPR) program in the Gulf of Maine to monitor prey conditions in the traditional feeding grounds of right whales. Overseen by the Sir Alister Hardy Foundation for Ocean Science, this plankton monitoring program began in 1961 (Jossi and Kane, 2013), but due to funding limitations, samples have not been processed since 2011 and data collection ceased in spring 2017. Plankton data from the CPR survey are critical to predicting right whale reproductive potential and evaluating the likelihood of these feeding grounds being abandoned in any given year.

3. Conduct a robust study of the effectiveness of the mandatory dynamic management area strategies for fisheries and shipping implemented in the GoSL in 2018.

4. Continue to evaluate and enhance current efforts to minimize the spatial and temporal overlap between snow crab fishery gear and right whales through trap limits, quota limits, and changes to the seasonal timing of the fishery. Consider expanding these policies to other Canadian critical habitats according to observed habitat use.

5. Pilot test and implement appropriate fishing gear modifications to reduce risk of entanglements. Options currently under consideration include ropeless fishing and whale release ropes.

6. With the help of expanded routine and exploratory monitoring, establish and legislate new critical habitat(s) for right whales in the GoSL.

The GoSL crisis demonstrated that mismatches between localized policy implementation and habitat occupancy can rapidly and severely impact right whale recovery potential. A robust monitoring program forms the backbone of right whale science and policy development. Manned aerial and vessel-based surveys that collect photo-identification data will continue to be essential for population and health assessments. However, acoustic technologies on autonomous gliders and buoys can efficiently and inexpensively identify right whale presence over large areas in near-real time while operating in remote habitats or bad weather (Baumgartner et al., 2013). Extended support of environmental monitoring, including collection of oceanographic and climatic data and ecological monitoring programs such as the CPR survey, can help alert scientists to impending distributional shifts. It should be noted that while recent efforts to update right whale protections focus on the GoSL, continued survey support and progress in fishery modifications remain critical in US waters and other areas of Canada.

The need for expanded monitoring efforts and adaptive management strategies is not unique to right whale conservation. Evidence of impending distributional shifts is mounting for marine top predators whose well-being relies on protective policies (Cheung et al., 2010; Hazen et al., 2013). Lagged policy responses pertaining to commercially exploited species threaten fishery sustainability and disproportionately impact the world's least developed nations (Allison et al., 2009; Pinsky and Fogarty, 2012). Because not all climate change interactions can be predicted, harvest control rules and conservation policies must be structured dynamically, allowing for rapid expansion following unexpected events. In the long term, effective policies should be expanded globally to encourage management that is proactive instead of just reactive. Under mounting pressure from increased anthropogenic stressors to marine ecosystems, the timely implementation and adaptation of conservation and management policies is critical to the health of the global ocean and its living inhabitants (Greene, 2016). As it has in the past, the future fate of iconic species such as the North Atlantic right whale, and the ecosystem that it depends upon and contributes to, will be determined by these policy decisions.

CITATION

Meyer-Gutbrod, E.L., C.H. Greene, and K.T.A. Davies. 2018. Marine species range shifts necessitate advanced policy planning: The case of the North Atlantic right whale. *Oceanography* 31(2):19–23, https://doi.org/10.5670/oceanog.2018.209 (https://doi.org/10.5670/oceanog.2018.209).

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New Estimate Finds North Atlantic Right Whale Population Plummeting

Oceana Calls on NOAA Fisheries for Immediate Action to Save Whales from Extinction

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A new estimate from NOAA Fisheries finds the North Atlantic right whale population plummeting. With only about 360 North Atlantic right whales remaining, Oceana is calling on NOAA Fisheries to take immediate action to save the species from extinction.

Below is a statement from Whitney Webber, campaign director at Oceana in the United States, and Kim Elmslie, campaign director at Oceana Canada:

"The new estimates that only about 360 North Atlantic right whales remain underscores the need for immediate action to protect this critically endangered species. The time to act is now. We know that North Atlantic right whales are getting entangled in fishing gear and hit by vessels. We must reduce the number of fishing lines in the water and require vessels to slow down when right whales are present. Oceana calls on the U.S. and Canadian governments to act now to strengthen protections for these whales before it's too late."

Background:
North Atlantic right whales were named for being the "right" whale to hunt because they were often found near shore, swim slowly and tend to float when killed. They were aggressively hunted, and their population dropped from peak estimates of up to 21,000 to perhaps fewer than 100 by the 1920s. After whaling of North Atlantic right whales was banned in 1935, their population increased to as many as 483 individuals in 2010. Unfortunately, that progress has been reversed.

Collisions with vessels is one of two leading causes of North Atlantic right whale injury and death. North Atlantic right whales are slow, swimming around 6 miles per hour, usually near the water's surface. They are also dark in color and lack a dorsal fin, making them very difficult to spot. Studies have found that the speed of a vessel is a major factor in collisions with North Atlantic right whales. At normal operating speeds, many vessels cannot maneuver to avoid them, and North Atlantic right whales swim too slowly to be able to move out of the way. This puts them at great risk of being struck, which can cause deadly injuries from blunt-force trauma or cuts from propellers.

Entanglement in fishing gear used to catch lobster, snow crab and bottom-dwelling fish like halibut, flounder and cod is the other leading cause of North Atlantic right whale deaths. Fishing gear from the U.S. and Canada entangles an estimated 100 North Atlantic right whales each year, and about 83% of all North Atlantic right whales have been entangled at least once. Ropes have been seen wrapped around North Atlantic right whales' mouths, fins, tails and bodies, which slows them down, making it difficult to swim, reproduce and feed, and can kill them. The lines cut into the whales' flesh, leading to life-threatening infections, and are so strong that they have severed fins and tails, and cut into bone.

To learn more about Oceana's campaign to save North Atlantic right whales from extinction, please **click here**.

NOAA Technical Memorandum NMFS-NE-247

North Atlantic Right Whales- Evaluating Their Recovery Challenges in 2018

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
September 2018

NOAA Technical Memorandum NMFS-NE-247

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North Atlantic Right Whales - Evaluating Their Recovery Challenges in 2018

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US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
September 2018

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ABSTRACT

The North Atlantic right whale (*Eubalaena glacialis*) population has been in decline for 8 years due to increased mortality and sublethal effects from multiple factors. Together these have contributed to a decrease in calving. Shifting ecosystem conditions have also changed North Atlantic right whale behavior and fishing patterns. For example:

- North Atlantic right whales have expanded their distribution farther into northern waters, and are visiting different foraging areas.
- Calanoid copepod distributions appear to be in a similar state of change and this may be affecting available forage for North Atlantic right whales
- The whales' range expansion has exposed them to vessel traffic and fisheries in Canadian waters, which did not have protections for right whales in place until late last summer (2017).
- American lobster (*Homarus americanus)* populations are also changing distribution, moving north and into deeper, cooler waters of the Gulf of Maine. The US fisheries are moving farther offshore to capitalize on this, increasing the overlap between their fishing activity and North Atlantic right whale foraging areas and migration corridors.

The net result of these events is that severe entanglements have increased among North Atlantic right whales. Animals are in poor body condition likely from a combination of repeated entanglement stress, potentially limited forage and increased migratory costs- all contributing to a decrease in female calving rate. Ship strikes are still a real threat to the population. At the current rate of decline, all recovery achieved in the population over the past three decades will be lost by 2029.

INTRODUCTION

Signs of Trouble

After several decades of recovery and years of collaboration among stakeholders, the North Atlantic right whale (*Eubalaena glacialis*), hereafter referred to as the right whale, began to decline (Pace et al. 2017). This trend was subtle at first, initially signaled by fewer sightings in traditional survey areas, but other warning signs began to emerge (Kraus et al. 2016). The number of documented mortalities increased markedly in 2016 and 2017 (Hayes et al. 2018; Hayes et al. 2017) and an improved way of modeling the population's numbers (Pace et al. 2017) revealed a clearer picture of the population size and decline in numbers. Concern further escalated throughout 2017 and 2018 when only 5 calves were born and there were 19 confirmed mortalities through August.

Taken together these signs meant that risks posed to right whales and associated management measures needed to be revisited for multiple US fisheries on the Atlantic coast. This occurs through the biological opinion process under the federal Endangered Species Act, which was reinitiated in October 2017, and through the take reduction team process under the federal Marine Mammal Protection Act.

Demographic Effects

Increased mortality rates and decreased calving have moved the population into a decline that has continued for at least the last 8 years. At present, right whale deaths attributable to human activity are mostly caused by ship strikes and entanglement in pot/trap and anchored gillnet fishing gear. An encounter with fishing gear is the most frequent cause of documented right whale serious injuries and deaths in recent years. The odds of an entanglement event are now increasing by 6.3% per year, while ship strikes events remain flat (Fig. 1). At the current rate of decline, the population will have returned to its 1990 numbers, likely with comparatively reduced genetic diversity, and could decline past a point of no return in just a few decades.

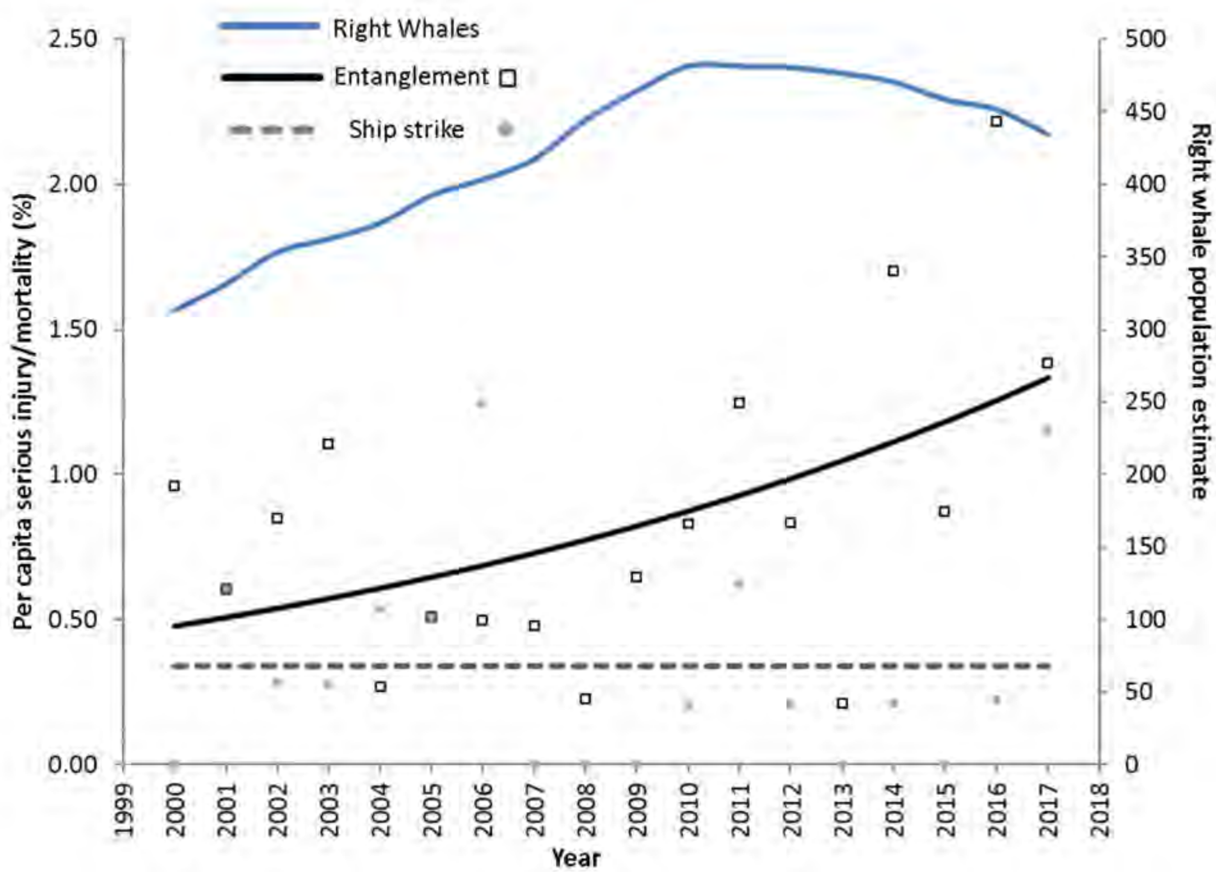

Fig. 1 North Atlantic right whale serious injury/mortality rates from known sources 2000-2017 (Henry et al 2017; 2016 & 2017 values preliminary). Models are simple logistic regressions fit using maximum likelihood-based estimation procedures available in R. The right whale population trend is overlaid and referenced to right y-axis (Hayes et al, 2018).

Distribution Change

Historically, right whales have returned to habitats in specific geographic locations annually, ensuring that a large portion of the population could be seen in each year. Therefore annual population estimates were conducted by simply sighting and counting as many animals as possible each year. Resulting estimates also assumed that an animal had died if it were not seen for 6 consecutive years.

Changes in this distribution pattern began around 2010 when the population peaked at 481 individuals. The whales were no longer using some of their established habitat areas in as great a number, and not staying within them for as long. This meant a new method was needed to account for animals, even those not sighted in a year. Once developed, this more advanced assessment tool, based upon mark recapture methods, enabled rapid assessment of the population with increased precision within one calendar year, much faster than the five or so years required to get good confidence on an annual estimate using the previous method. It also provided precise population estimates with greater resolution on the number of whales that likely died in any given year. Estimates made using the new method confirmed that in recent years, many deaths (around 10 to 20/yr) were going undetected annually and that by the end of 2016, the right whale population had declined to 451 individuals. A revised population estimate accounting for the many deaths and few births of 2017 is being developed and will be available later this year.

Increased Mortality

The large number of observed right whale mortalities in 2017 triggered an unusual mortality event (UME) to investigate the causes. The National Marine Fisheries Service (NMFS) is authorized to declare UMEs under the federal Marine Mammal Protection Act when an unanticipated significant die-off occurs in a marine mammal population, requiring an immediate response. Two other UMEs were declared that year due to 80 humpback whale and 40 minke whale deaths. Ongoing investigations for these two species have preliminarily identified causes of death that include entanglements, ship strikes, and disease.

In contrast to other large whale species, the problems of right whales are often more apparent because they are monitored more intensely and their coastal distribution means more opportunity for overlap with human activities, leading to it being nicknamed ‘the Urban Whale’ (Kraus et al. 2007).

While perhaps more attention is paid to the right whale given their more dire population status, it can be an indicator of more chronic problems that need addressing, not just for the sake of right whales but also for other populations of large whales. By example, although Gulf of Maine humpback whale status has improved, entanglement mortalities still remain high for this stock (Hayes et al. 2018).

There is considerable urgency to address the issues of mortalities that stem from human activities. Large whales, including right whales, are long-lived and can breed multiple times during their lives. This means these species can be resilient and able to recover after periods of poor reproduction. However, recovery for any species cannot take place if the number of deaths is more than the number of births in the population.

POTENTIAL CAUSES OF THE DECLINE

Ecosystem Dynamics

One of the constant challenges of resource management is that things change. While it is much easier to make management decisions if conditions are static, ecosystems are inherently dynamic and will change over time in response to a variety of influences. This is the case for the emerging story for right whales.

Sometime around 2010, ecosystem shifts occurred within their habitat that changed right whale movements and fishing practices in a way that has increased interaction between whales and fishing gear, and that potentially presents other environmental challenges.

Currently the Gulf of Maine is warming faster than 99.9% of all other ocean regions on the planet (Pershing et al. 2015). This is having dramatic impacts across the food web, from the middle and upper trophic level organisms such as American lobster (*Homarus americanus)*, Atlantic cod (*Gadus morhua)* and right whales (Greene 2016); to the zooplankton at the base of the food web such as calanoid copepods (Grieve et al. 2017; NEFSC 2018).

Whales and Fisheries Are On the Move

American lobster are experiencing strong population fluxes and redistributions with temperature warming. The southern New England lobster fishery has been severely limited by epizootic shell disease, which lobsters become susceptible to at warmer temperatures. In the Gulf of Maine, coastal waters remain cool enough and offshore, deeper waters have warmed enough for lobsters, and lobster fishing, to expand farther offshore. As a result, Maine lobster landings have increased steadily for the past 30 years, with an increasing portion of this caught 3 or more miles offshore over the past 10 years (Fig. 2). Note that Maine lobster landings did downturn sharply in 2017, and future trends are uncertain.

Prey Availability Drives Reproductive Success

It is essential to also recognize that environmental factors and lower trophic level dynamics also contribute to right whale birth and mortality rates. Changes in prey availability influence right whale health and reproduction. In particular, abundance of the copepod *Calanus finmarchicus* in the Gulf of Maine is a strong predictor of right whale reproductive success (Greene and Pershing 2004; Meyer-Gutbrod and Greene 2014; Meyer-Gutbrod et al. 2015).

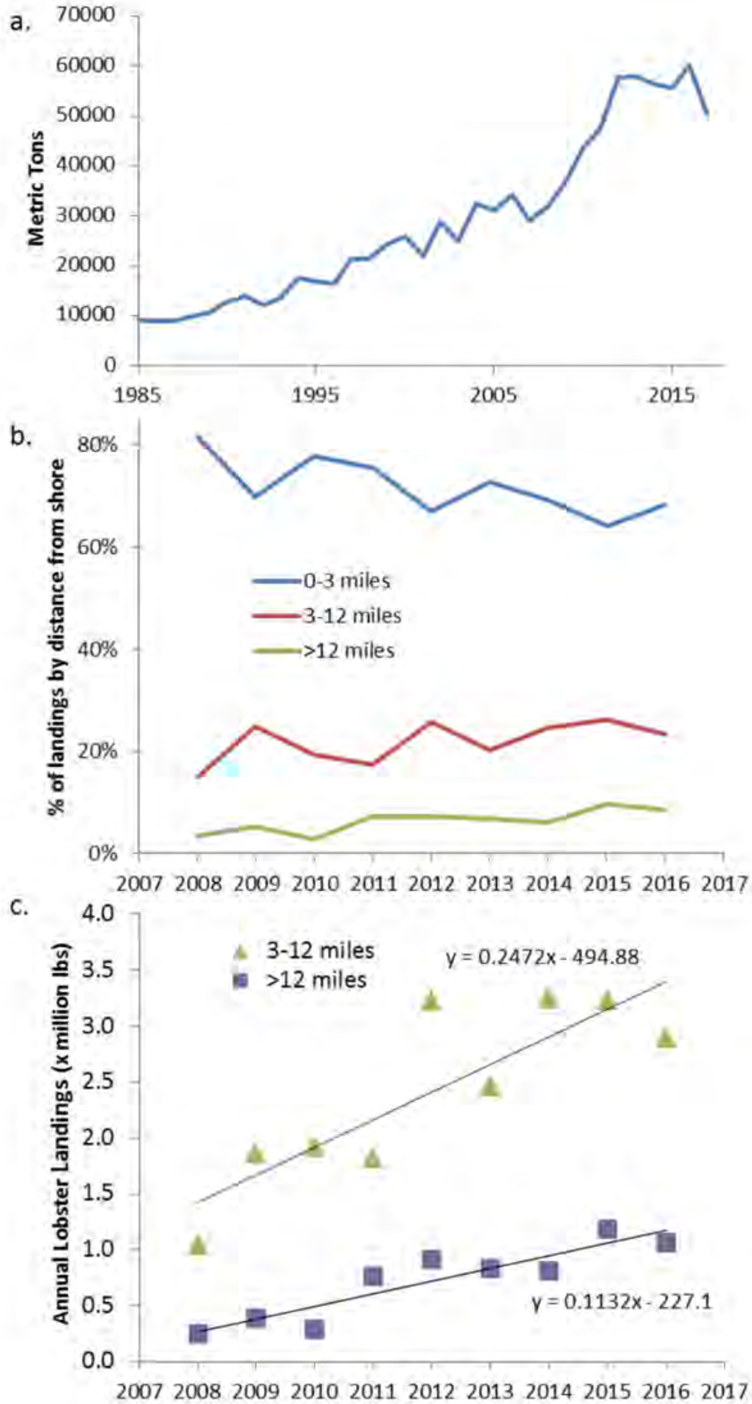

Fig 2. American lobster landings in Maine: a) total annual landings b) relative proportion of landing by distance from shore c) increase in landings from 3-12 and >12 miles offshore from Maine's 10% harvester reporting, no VTR data included. https://www.maine.gov/dmr/commercial-fishing/landings/

Meyer-Gutbrod and Greene (2018) followed individual whales over the past three decades to evaluate the relationship of calving and mortality rates to prey availability. They found that prey availability is a driver of decadal differences in the right whale population's recovery. Periods of low prey availability coincided with reduced birth rates (Meyer-Gutbrod and Greene 2018) and the interval between births has been observed to lengthen during periods when prey availability is low (Meyer-Gutbrod et al. 2015).

Similarly, years with few births contribute to years of decline or stagnation in population growth, indicating the pronounced effect of reproductive variability on species viability (Pace et al. 2017). That said, Meyer-Gutbrod and Greene (2018) modeled population growth rates under scenarios of high and low prey availability and found that the population should continue to grow even with poor prey availability and only fails to do so when whale mortalities reach 8 to 10 per year. It is worth noting natural mortality seems to be very rare in adult right whales: there has been no confirmed case of natural mortality in adult right whales in the past several decades (Corkeron et al. *Accepted with revision;* Henry et al. 2017; van der Hoop et al. 2013).

Right Whales Follow Prey in a Changing Ocean

The copepod *C. finmarchicus* has shifted in distribution and abundance in recent years due to unprecedented warming in the Gulf of Maine, and this is likely to impact the right whale population (Greene 2016; Mills et al. 2013; Reygondeau and Beaugrand 2011). It appears that in the last decade (~2005-2015), that there has been a general decline in *C. finmarchicus* in the Gulf of Maine (2009-2014, but 2015 was average abundance) and on Georges Bank (below average abundance since 2008) (NEFSC 2018) as well as the Scotian Shelf (Johnson et al. 2017).

Changes in plankton forage species abundance likely played a role in the changing movement patterns of right whales that began sometime in the past 10 years. There have been decreases in both acoustic detections and physical observations of right whales in the northern Gulf of Maine and the Bay of Fundy, and a concurrent increase in sightings of many of the same animals in the Canadian Gulf of St. Lawrence (Daoust et al. 2018; Davis et al. 2017; Meyer-Gutbrod et al. 2018; Meyer-Gutbrod and Greene 2018).

During winter, whales are spending more time offshore in the mid-Atlantic, and less time on the coastal calving grounds just off the southeastern U.S., where in 2017 and 2018 calving has been quite poor.

Reproduction Requires Robust Females

Reproduction depends on adequate adult female health and body condition. Reproductive females are particularly vulnerable to prey reductions because pregnancy and lactation increases caloric demand and they have less access to prey during migration to calving grounds (Fortune et al. 2013; Miller et al. 2012; Rolland et al. 2016).

Several of the ecosystem shifts mentioned earlier are likely to have negative consequences for reproduction in right whales. First, a reduction in prey will have energetics costs for females. Northward shifts in the right whales' feeding grounds, as a result of changes in prey availability, will increase energetic cost of the calving migrations from the southern calving grounds off the coast of Florida and Georgia, particularly if animals do not adapt to also calve farther north.

The cost of entanglement has also been shown to have direct and indirect consequences for right whales (van der Hoop et al. 2017b; van der Hoop et al. 2017c). This will be detailed next, but in the Gulf of Maine where ecosystem shifts are occurring more trap fishing is also occurring offshore, increasing the overlap with right whale foraging areas.

Whales have also expanded their range, foraging into the Gulf of St. Lawrence. This increased the whales' exposure to risk from fixed gear fisheries. Some of this risk has reduced by strong protections put in place by the Canadian government during the spring of 2018 (DFO/TC Canada 2018; DFO Canada 2018).

Anthropogenic Stressors

In a review of mortality sources for all large whales, entanglement in fishing gear was the number one cause, followed by natural causes and then vessel strikes. An exception to this is the right whale for which there is very little evidence of natural mortality in adult whales, likely due to shortened life spans associated with anthropogenic causes (Corkeron et al. *Accepted with revision*), as all confirmed causes of adult mortality and serious injury since 1970 have been due to fishing gear and vessel strike (Henry et al. 2017; van der Hoop et al. 2013).

The relative contribution from these two causes was approximately equal through the year 2000 (van der Hoop et al. 2013), but entanglement events resulting in death or serious injury have increased steadily since then, while ship strike frequency has remained lower with no specific trend (Fig. 1). For the recent 19 known right whale mortalities (17 in 2017 and 2 to date in 2018), the cause of death could be determined for 10. Ship strikes are implicated in five blunt force trauma cases and entanglement in the remaining five. In 2017, seven other entangled whales were observed: three were disentangled, three shed the gear, and one was not seen again.

Ship Strikes

Reducing Risk

Ship strikes are currently the second most frequently documented cause of mortality in right whales. The per capita mortality frequency has not varied much, hovering around 0.34% deaths or serious injury events per year (Fig. 1). Several management actions were implemented in U.S. and Canadian waters beginning in 2008 to reduce the risk of collisions between right whales and large vessels. Major actions include:

- Voluntary two-way routes for commercial vessels off the Southeast U.S. and in Cape Cod Bay
- Modification of the Boston, Massachusetts Traffic Separation Scheme
- Canada and the International Maritime Organization established the voluntary Area To Be Avoided concept in the Roseway Basin
- Seasonal Management Areas in habitats off of Massachusetts, ports along the Mid-Atlantic coast, and the southeastern U.S. where vessels are required to slow to speeds less than 10 knots during transits for vessels 65 ft in length or longer

- Intermittent implementation of voluntary speed restrictions in Dynamic Management Areas within which right whale aggregations are observed outside the boundaries of the Seasonal Management Areas

Several analyses have been conducted to evaluate the effectiveness of these management efforts (Conn and Silber 2013; Lagueux et al. 2011; Silber et al. 2014; van der Hoop et al. 2012). In general, while these analyses were based on a short time-series of available data, collectively they suggest that after ship-strike rules put in place, a reduction in right whale mortality from ship strikes followed, and in general were at the lowest on record per capita from 2010 through 2016.

Responding to Changing Risk

In 2017, right whale deaths by ship strike increased when 5 ship-strike mortalities were confirmed, 1 in U.S. and 4 in Canadian waters (Fig. 1), likely caused in part when right whales began to spend more time in new areas with high vessel traffic and no speed restrictions. Increased survey effort in these areas also made it more likely that these events would be observed and reported.

Entanglement

Reducing Risk

Management efforts to reduce entanglement risks in U.S. waters have focused on gear technology to make entanglements less likely to harm or kill whales, restricting where and when gear that poses a threat can be used when whales are likely to be present, and reducing the amount of gear in the water column (Fig 3). Measures are recommended through a take reduction team, as mandated under the federal Marine Mammal Protection Act. Each team comprises a variety of experts and stakeholders, who assist NOAA Fisheries in developing a take reduction plan when necessary.

Since 1997, a series of rules have been implemented based on the take reduction plan (Fig. 3). These include the sinking groundline (2009) and vertical line (2015) rules. While there appears to have been a subsequent reduction in entanglements caused by groundline (Morin et al. 2018), which moved 27,000 miles of line from the water column to the bottom (NMFS, 2014), absolute entanglement rates appear to be on the rise (Fig 1).

Increase in Entanglement Risk

Fewer but Stronger Lines in US Waters

There may also have been unintended consequences of the 2015 vertical line rule. The rule required ‘trawling up’ (using more traps per trawl) in some regions. While this reduced the number of lines, it also meant that lines had to be stronger to accommodate the increased load of multiple traps. This natural adaptation, and the fact that stronger rope was available, contributed to an increase in the severity of entanglements as found by Knowlton et al. (2016), who observed very little evidence of entanglement with ropes weaker than 7.56 kN (1700 lbsf).

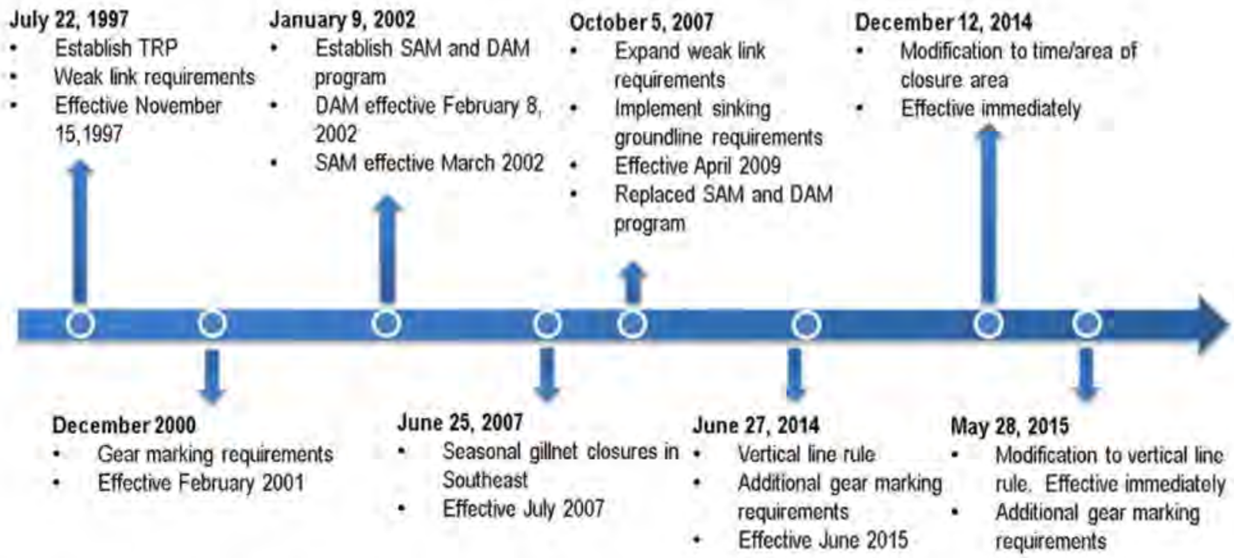

Fig 3. Timeline of significant management actions focused on reducing fishing entanglement

Entanglement Trends Upward

Knowlton et al.(2012) showed that nearly 85% of right whales have been entangled in fishing gear at least once, 59% at least twice, and 26% of the regularly seen animals are entangled annually. These findings represent a continued increase in the percentage of whales encountering and entangling in gear, which grew from to 61.5% in 1995 (Hamilton et al. 1998), to 75.6% in 2002 (Knowlton et al. 2005), confirming further the growing severity of the problem.

More Vertical Line in Right Whale Habitat

Rough estimates are that approximately 622,000 vertical lines are deployed from fishing gear in U.S. waters from Georgia to the Gulf of Maine. Notably until spring of 2018, very few protections for right whales were in place in Canadian waters. In comparison to recent decades, more right whales now spend significantly more time in more northern waters and swim through extensive pot fishery zones around Nova Scotia and into the Canadian Gulf of St. Lawrence *(Daoust et al. 2018).*

Taken together, these fisheries exceed an estimated 1 million vertical lines (100,000 km) deployed throughout right whale migratory routes, calving, and foraging areas. Figure 4 illustrates the scale of the challenge by providing fishery statistics for the various regions (data sources provided in Appendix 1).

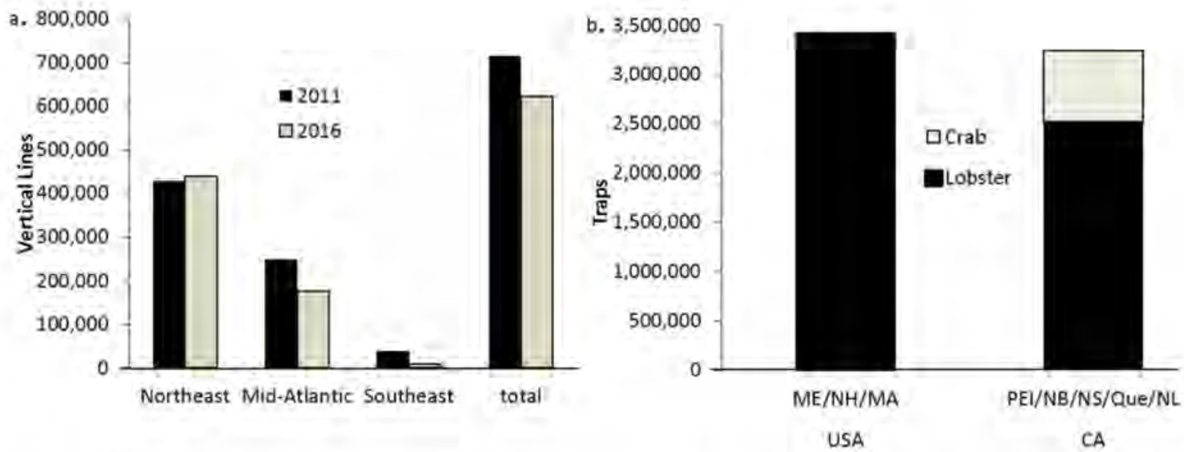

Fig 4. Index of fishing effort. a) The change in number of vertical lines in US waters from 2011 to 2016, b.) The approximate number of traps in USA Northeastern states and Canadian provinces. Data sources in Appendix 1.

Closures Are Effective, But May Not be Enough

A great deal of effort has been put into identifying entanglement 'hot-spots': relatively small areas where focused management measures can have minimal impact to fishing while providing great benefit to whales. Clear examples of this approach include the seasonal closure of Cape Cod Bay, and now the static closure within the Area 12 fishing zone of the Canadian Gulf of St. Lawrence. Both are relatively small areas where a significant portion (30 to 50+ %) of the right whale population has reliably occurred for several weeks to months over the past few years. Management actions have a population level benefit with impacts restricted to very local portions of fisheries. While still difficult choices, this has been the preferred management approach.

However, these closures, while likely very effective regionally, may not be enough. Each vertical line out there has some potential to cause an entanglement. With a 26% annual entanglement rate in a population of just over 400 animals, this translates to about 100 entanglements per year, which is significant for such a small population. But from the perspective of an individual fixed gear fisherman, they may never encounter a right whale. With more than 1 million lines out there, any single line has perhaps a 1 in 10,000 chance of entangling a whale in any one-year period. This can vary somewhat from regions with high to low densities of lines and/or whales.

However, in general, this means a fisherman and his or her descendants could go several generations without ever entangling of a right whale. Given this, it's easy to believe that *'all these entanglements are happening somewhere else'* regardless of where one fishes. Being able to directly link an entanglement with specific gear deployed at a specific place in time is rare, but by mapping known locations of gear that led to the entanglement of a right whale, one can see that there is no place within the fished area along the East Coast of North America for which entanglement risk is zero (Fig 5).

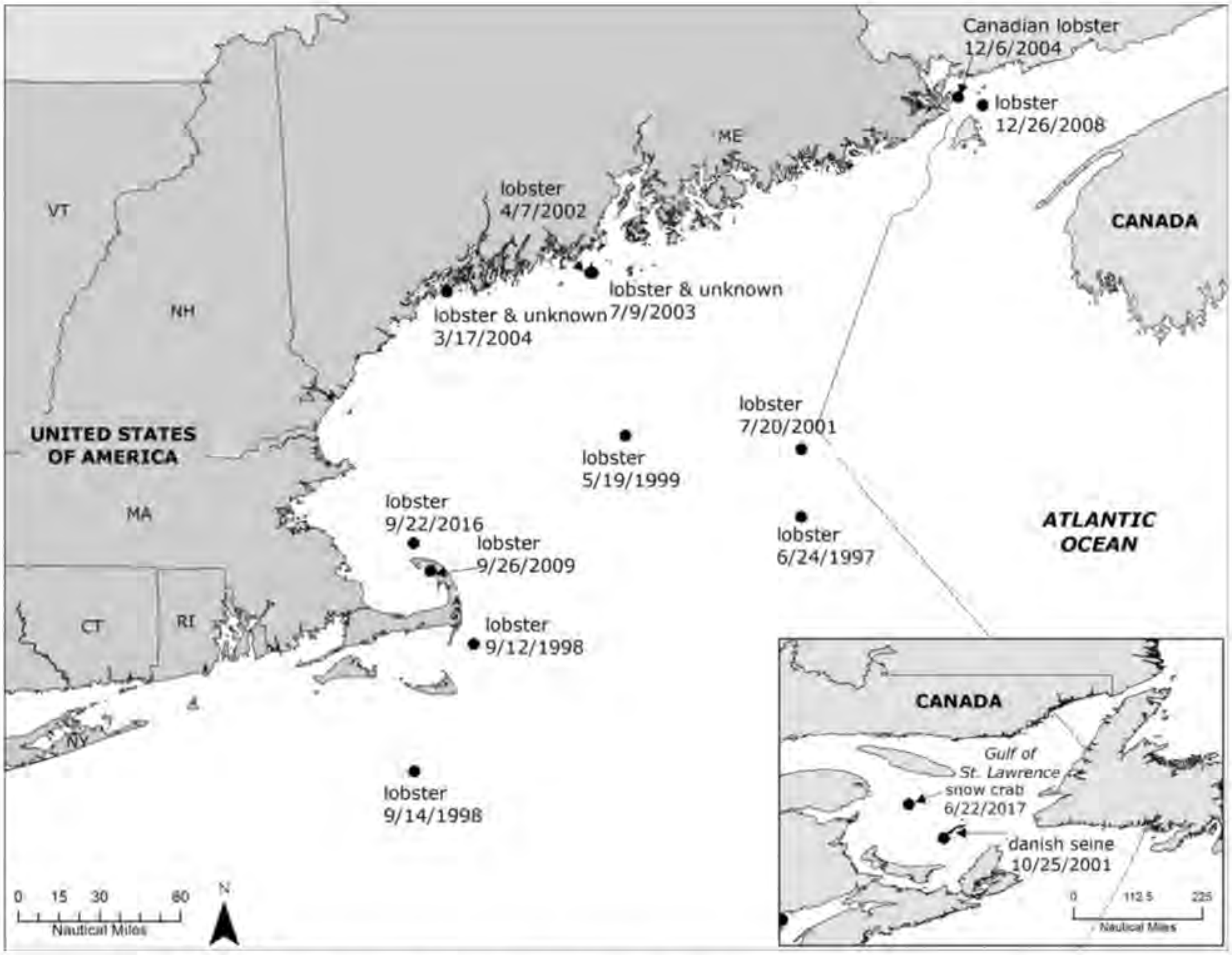

Fig 5. Right whale entanglements from 1997 through 2017 for which the set location and type of gear are known, and gear was recovered from a whale.

Sublethal Challenges- Skinny Whales and Few Calves

Fundamentally, a population increases when there are more births than deaths. Much attention has been paid to direct mortality caused by ship strikes and entanglement, but less focus has been put on the secondary effects of these and other variables where animals survive but fail to thrive because of the harm done. This is particularly evident in calving among mature females.

Biological Cost of Stressors

The abundance of photographs of known individual right whales taken over several decades have been used to develop health indicators associated with natural and human-caused stressors (Schick et al. 2013). This has been refined into a quantitative health score, including a predictive threshold below which females seem incapable of having a calf (Miller et al. 2012; Rolland et al. 2016).

We understand that right whales are exposed to numerous sublethal stressors, including fluctuating food resources (Meyer-Gutbrod and Greene 2014) and even underwater noise (Rolland et al. 2012). Several recent studies have also focused on sublethal effects of entanglement, the first of which includes increased swimming energy costs from dragging gear (van der Hoop et al. 2016). Even if disentangled, there are several injuries that can have costs lasting long after disentanglement. These include trauma wounds from rope cuts that may or may not eventually heal, and damage to baleen plates that can prevent efficient filter feeding for many years since these plates grow slowly.

Recent studies have also shown that even without accounting for injury, the drag from carrying rope and other gear for long periods of time can be energetically more expensive for a female than the migratory and developmental costs of a pregnancy (van der Hoop et al. 2017a; van der Hoop et al. 2017b; van der Hoop et al. 2017c).

Biological Demands of Right Whale Pregnancy

While serious injuries represent 1.2% of all entanglements, there are often sublethal costs to less severe entanglements. Should an entanglement occur but the female somehow disentangles and recovers, it still has the potential to reset the clock for this "capital" breeder. She now has to spend several years acquiring sufficient resources to get pregnant and carry a calf to term, the probability of a subsequent entanglement is fairly high, and this will create a negative feedback loop over time, where the interval between calving becomes longer. This is certainly a contributing factor in the longer calving interval for females, which has now grown from 4 to 10 years (Pettis et al. 2017).

Figure 6 demonstrates a simple model for estimating the probability that an animal will NOT become entangled over time. Similar to asking what are the odds of NOT getting 'heads' in 10 coin tosses, this model simply asks what are the odds of not getting entangled over time if there is a 74% chance of not getting entangled each year (Knowlton et al. 2012). Historically the median calving interval of a female right whale is 3 to 4 years (Pettis et al. 2017). The model estimates that animals have a about a 30 to 40% chance of not getting entangled during that period, or, conversely, a 60 to 70% chance of getting entangled.

With the calving interval now nearly twice as long as in the past, half as many calves are being born. So while entanglements often do not kill an animal, they may have a large impact by reducing or preventing births in the population. There is an additional variable, stress, which is much harder to quantify but known to have costs in mammals that are foraging in an environment with some mortality threat (Hernández and Laundré 2005).

It is difficult to tease out the relative effects of poor foraging conditions and the energetic costs of entanglement on the increased frequency of thin whales and the subsequent decrease in calving. Both are likely having some influence. While there are dozens of documented cases of ship strikes and entanglement linked to right whale mortality, to date there is no confirmed observation of a right whale starving to death from poor forage.

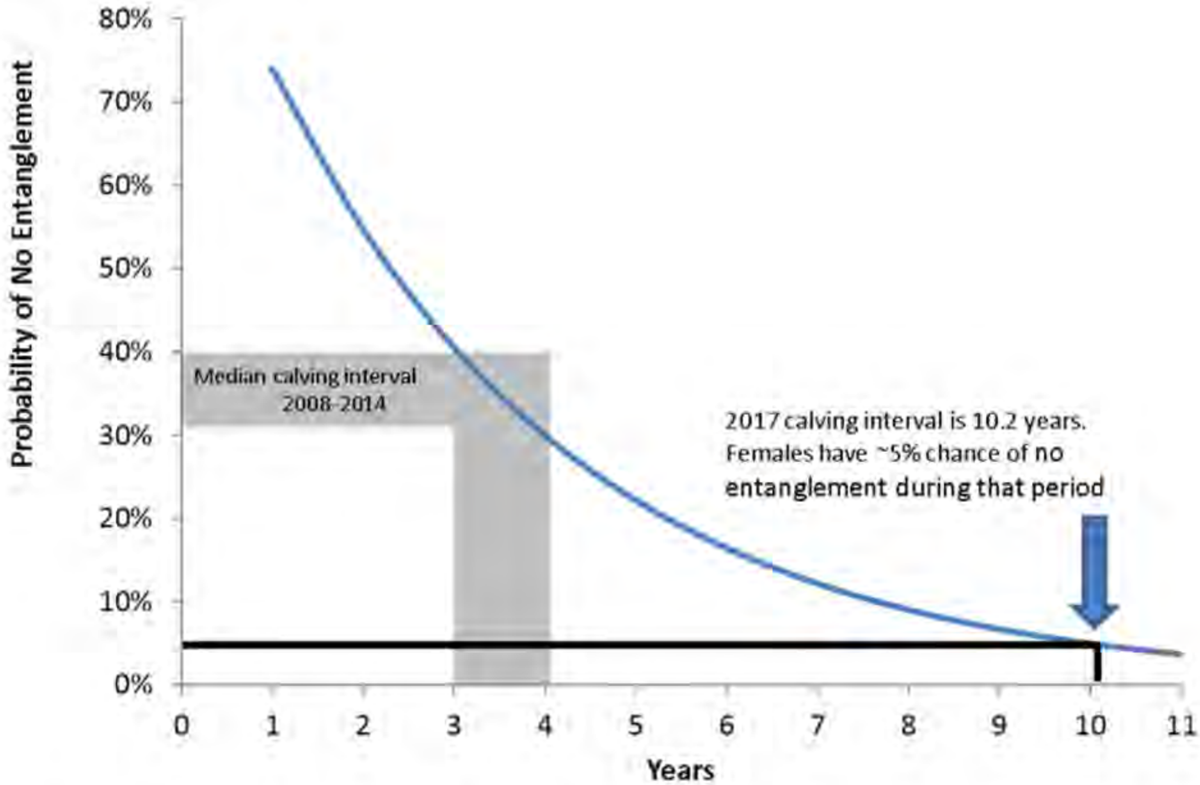

Fig 6. Cumulative annual probability of no entanglement (annual rate = 74%)

HOW LONG DO NORTH ATLANTIC RIGHT WHALES HAVE?

A Long-Lived Animal

Right whales have the potential to be a very long-lived species. In the southern hemisphere where shipping and fishing pressures are much lower, there is little evidence of human activities causing right whale mortality. There is also little evidence of natural mortality in adult animals (Corkeron et al. *Accepted with revision*). Since the ban on commercial whaling of Southern right whales in 1935 (Gambell 1993) these animals have not yet lived long enough to die of natural causes.

Meyer-Gutbrod and Greene (2018) demonstrated that even under poor foraging conditions, right whales should be able to recover if annual human-caused mortality is kept somewhere below 8-10 deaths per year. This means that in the absence of human-caused mortalities, right whales could potentially endure several decades under poor foraging conditions and still recover once environmental conditions improve. However, in the current situation in the northern hemisphere, where animals are living much shorter lives, there is great cause for concern that the risk of extinction is much higher than in the southern hemisphere, where animals are not regularly subject to human caused mortality.

An Illustration of Potential Decline, 2017-2067

A Matrix Model

In order to measure current population trends, we used a three-stage (calf, juvenile, adult) matrix population projection model (Caswell 2006) for female right whales, derived from Corkeron et al. (*Accepted with revision*), to project the future abundance of right whales. Survival values used for input into the population projection model were calculated using a Cormack-Jolly-Seber (Pace et al. 2017) variant of a mark-resight model (see Appendix 2 for details) and determined the population is declining at 2.33% per year.

We started the model estimating an abundance of 160 females alive at the end of 2017. With approximately 1.5 males per female (Pace et al. 2017), 160 females would result in an overall species abundance of about 400. It is possible that this abundance estimate may be marginally low, but since the model overestimates calving success, we assumed that these biases should cancel each other out.

Using the stage derived from the matrix model, we assumed that the 2017 starting population of 160 females was composed of 10 calves, 60 juveniles, and 90 adults. We ran 1000 stochastic projections forward 50 years (Fig. 7).We then extracted median and 95% quantile estimates of projected abundance from those projections, and estimates of the number of adult females remaining, for 5, 10, 15, 20, 25 and 50 years. Results are shown in the Table.

Results

The model projects that in 2067, 50 years from 2017, there would be 49 female North Atlantic right whales remaining, of which only 32 would be adults. In 20 to 25 years (2037-2042) there would be fewer than 50 adult females. In the near term, at the current rate of decline, all recovery in the population over the past 3 decades will be lost by 2029, with the population returning to the 1990 estimate of 123 females.

Notably, the model does not adjust for varying environmental conditions, which are known to fluctuate on a decadal time scale for North Atlantic Ecosystems (Nye et al. 2014) and are presently unfavorable. This approach may overestimate the rate of population decline but not the overall trajectory.

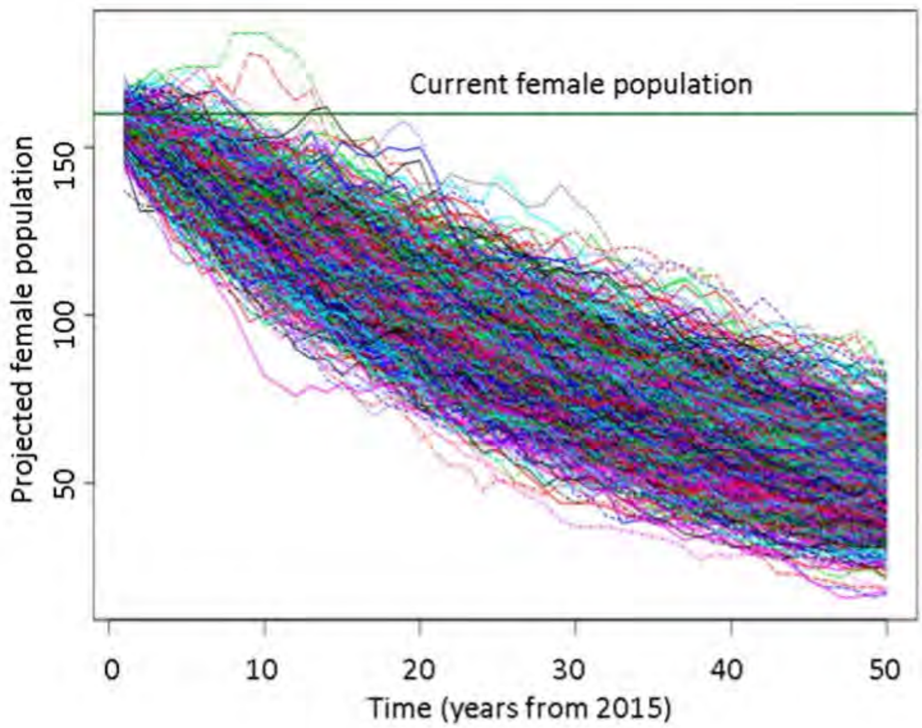

Fig. 7 Matrix population projection model output of North Atlantic right whale female population trend under current population conditions.

Table of matrix projection model output of female North Atlantic population trends for 5-year intervals, 2017-2067

Years from 2017	Number of females	Cis	Number of adult females
5	144	126 to 161	75
10	129	107 to 150	67
15	114	91 to 141	59
20	102	77 to 130	53
25	90	66 to 119	47
50	49	27 to 76	32

The threshold for functional extinction is very hard to define and likely varies by species. If the population declines to the 1990 level, there is a new threat: a repeated genetic bottleneck. Genetic bottlenecks happen when a population is so small that the genetic make-up of remaining group is not the same as that of the initial population. The effect of repeated bottlenecks is likely to mean that if the population returned to the 1990 level, that group would have less genetic diversity than the group that existed in1990. This can lead to reduced resilience and contribute to increased risk of extinction (Amos and Harwood 1998; Melbourne and Hastings 2008).

INDICATORS OF SUCCESSFUL MANAGEMENT MEASURES

Determining the management actions necessary to reverse the current population trend is beyond the scope of this document. However, the scale of the actions will need to be quite significant to be successful. Entanglement has increased dramatically and ship strikes continue to occur.

The population decline began in 2010 (Fig. 1), when entanglement was occurring at a rate of 26% among sited animals per year (Knowlton et al. 2012). Since then, the right whale range expansion has put them in the path of more shipping and more fishing gear – encountering almost twice the amount of gear owing to expansion of more fishing farther offshore in US waters and northward into Canadian waters (Fig. 4).

It is logical to conclude that to reverse the right whale decline, it may be necessary to reduce the impacts of entanglements and other harmful human interactions with right whales across their expanded range to pre-2010 levels. For recovery it may be necessary to go further, considering more modifications to fishing and shipping practices to compensate for potentially reduced forage opportunity and increased migratory costs.

Several biological indicators can be recommended for monitoring the short- and long-term effectiveness of any management actions that might be put in place to reduce the rate of both ship strikes and fishing gear entanglement.

Short-term indicators include fewer observed numbers of ship strikes and entanglements. These could be noticeable within 6 months to 1 year, but there is considerable variation around detectability of these events and the results will initially have a great deal of uncertainty. It takes approximately 1 year to conduct a population assessment and determine any changes in abundance. The assessment will alleviate some the uncertainty in detecting mortality risks that that might be mitigated by management actions. It should be noted that number of mortalities is the bluntest indicator of management success.

However, teasing the relative effects of management actions and natural variability on population size and condition will take several years of data and analysis. Metrics such as the frequency of scarring, improvements in body condition, and overall health scores could be detectable under stable environmental conditions in 2 to 3 years. Similarly, if environmental conditions are adequate for females to accumulate enough resources to calve, it will likely take at least 2 to 4 years to separate the impact of management action that reduced the frequency of, say, costly entanglements from the impact of natural variability. Ultimately, confidence in any estimate of population trajectory will emerge over 5 to 10 years.

In an ideal situation, evidence of human-caused injuries and mortality decreases, body condition improves, and the birth rate exceeds the death rate, resulting in more North Atlantic right whales.

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APPENDIX 1 Data Sources for Figure 4

Several data sources were used to construct Fig 4. All vertical line estimates in 4A were provided by Industrial Economics. Trap counts provided in 4B were acquired from a variety of sources. Raw trap counts were provided for Maine and Massachusetts. Trap counts for New Hampshire and all Canadian provinces were generated by multiplying license counts by trap limits. These were quite variable across regions, in which case the multiplier used is reported in the Table in the report.

Table 2. Data sources for trap counts and license numbers by country and regions.

Location	species	# traps	data year	Source
Maine	Lobster	2,901,000	2016	https://www.maine.gov/dmr/commercial-fishing/landings/documents/lobster.table.pdf
New Hampshire	Lobster	133,700	2010	https://www.greateratlantic.fisheries.noaa.gov/protected/whaletrp/trt/meetings/2012 meeting/Day%202/day_2_1c_new_hampshire_alwtrp_proposal.pdf
Massachussetts	Lobster	383,447	2011	http://www.lobstermen.com/wp-content/uploads/2009/10/MASS-LOBSTER-INDUSTRY-2012.pdf
Canada	**species**	**# license**	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Nova Scotia	lobster	3,249	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	748	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
New Brunswick	lobster	1,460	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	123	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Prince Edward Island	lobster	1,245	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	39	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Quebec	lobster	591	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	382	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Newfoundland	lobster	2,353	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	3,379	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Canada	**species**	trap limit range	trap multiplier used	**Source**
Nova Scotia- GOSL	lobster	225-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
Nova Scotia- GOSL	crab	75-150	150	neiges-en.html
Nova Scotia- east	crab	30-60		http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/snow-crab-neige/snow-crab-neiges2013-eng.htm
New Brunswick	lobster	240-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
	crab	75-150	150	neiges-en.html
Prince Edward Island	lobster	240-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
	crab	75-150	150	neiges-en.html
Quebec	lobster	235	235	http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/lobster-homard/index-eng.htm
	crab		200	
Newfoundland	lobster	185	235	https://thisfish.info/fishery/atlantic-lobster-canada-lfa11/
		100-425		http://waves-vagues.dfo-mpo.gc.ca/Library/282426.pdf
	crab	200	200	http://dfo-mpo.gc.ca/decisions/fm-2018-gp/atl-07-eng.htm

APPENDIX 2 Model Inputs and Methods used for Population Projection

In order to determine current rate of population decline we used a simple, three-stage matrix population projection model (Caswell 2006) for female right whales, derived from Corkeron et al. (*Accepted with revision*), to project the future abundance of North Atlantic right whales. The model's three stages are: calf, juvenile and adult. Survival values used for input into the population projection model are derived from survival estimates calculated using a Cormack-Jolly-Seber (as opposed to the published Jolly-Seber, Pace et al 2017) variant of a mark-resight model (see Appendix 1 for details). We used the lower 95% credibility intervals of the median estimates of survival for 2011-2015 from the model. These were: calves: 0.86137, juveniles: 0.92684, and adult females: 0.92684. The matrix projections also assume: a calving interval of 4.75 years (the mean of median inter-calf intervals for calving females 2011-2017, from the 2017 North Atlantic Right Whale Report Card (Pettis et al. 2017), ; females maturing at 11; and a current maximum longevity of 50. With no calves born this year, this calving estimate is arguably optimistic, but the inter-calf interval estimate for 2018 would be undefined, and so is unusable. Survival and transition probabilities for stages were calculated as described in Corkeron et al. (*Accepted with revision*).The model was run in R 3.4.3 (R_Core_Team 2017), using the libraries *diagram* (Soetaert 2017), *popbio* (Stubben and Milligan 2007) and *popdemo* (Stott et al. 2016).

The matrix used for analyses is:

	calf	immat	adlt
calf	0.00000	0.00000	0.10526
immat	0.86137	0.86254	0.00000
adlt	0.00000	0.06430	0.92443

This gives an intrinsic rate of increase of 0.9767, or a decline of 2.33% per year.

To develop a stochastic projection from this model, we took a starting abundance estimate of 160 females alive at the end of 2017, as the unusually high observed mortality of right whales that year (Meyer-Gutbrod and Greene 2018) meant that starting earlier would not capture one important recent anthropogenic impact on this species. With approximately 1.5 males per female North Atlantic right whale now (Pace et al. 2017), 160 females would give an overall species abundance of ~400. It is possible that this abundance estimate may prove to be marginally low, but as the model overestimates calving success, we assume that these biases should cancel each other out. When an abundance estimate for 2017 is available (by October-November 2018) the model can be revised.

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Organization: Manuscripts must have an abstract, table of contents, and -- if applicable -- lists of tables, figures, and acronyms. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area," "Methods & Materials," "Results," "Discussion" and/or "Conclusions," "Acknowledgments," and "References Cited."

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Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

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North Atlantic Right Whale Monitoring and Surveillance: Report and Recommendations of the National Marine Fisheries Service's Expert Working Group

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-64
June 2020

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June 2020

U.S. Department of Commerce
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National Oceanic and Atmospheric Administration
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List of Acronyms

BOEM – Bureau of Ocean Energy Management
CCB – Cape Cod Bay (CCB)
CCS – Provincetown Center for Coastal Studies (CCS),
DFO – Department of Fisheries and Oceans Canada
GOM – Gulf of Maine
GoSL – Gulf of St. Lawrence
GSC – Great South Channel
LIMPET – Low Impact Minimally Percutaneous Electronic Transmitter
NARW – North Atlantic right whale
NEAq – the New England Aquarium
NEFSC – Northeast Fisheries Science Center
NMFS – National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
PAM – Passive Acoustic Monitoring
RNA – Ribonucleic Acid
SEFSC – Southeast Fisheries Science Center
SERO – Southeast Regional Office
SEUS – Southeastern United States
U.S. – United States
UAS – Unmanned Aerial Systems
VHR – Very High Resolution

EXECUTIVE SUMMARY

The National Marine Fisheries Service (NMFS) North Atlantic right whale (NARW) Steering Committee convened an expert Working Group to address two objectives related to monitoring NARWs: (1) improving our understanding of population status by identifying and tracking essential population metrics, and (2) improving our understanding of distribution and habitat use. The Working Group consisted of five NMFS researchers (the authors of this report) with expertise in marine mammal monitoring, but not directly involved in current NARW monitoring efforts. The Working Group was convened during a three-day workshop (held at NMFS Southwest Fisheries Science Center in La Jolla, California, from October 22-24, 2019, with remote participants on Day 1), and on a series of follow up conference calls. This report provides a brief summary of the information provided to the Working Group, including historic and current NARW monitoring efforts conducted by NMFS and partner institutions, information on the status and trends of NARWs, and analyses conducted during the workshop or at the Working Group's request. Moreover, the report primarily presents the Working Group's recommendations for a comprehensive monitoring strategy to guide future analyses and data collection on (1) NARW demographics and population status, (2) distribution shifts and habitat use range-wide, and (3) the health of individuals and the population. The Working Group's recommendations are intended to improve NMFS' overall monitoring strategy for NARW, with recognition of the significant contribution to NARW research and monitoring carried out by NMFS and partner institutions and agencies.

The Working Group's recommendations address several overarching themes. These include (1) identifying the essential population and individual metrics to be monitored, (2) characterizing analyses that may be conducted with existing data that are critical to fine-tuning and efficiently executing an effective monitoring plan, (3) expanding the NARW species distribution model through data standardization and coordination, (4) establishing an integrated visual and passive acoustic monitoring (PAM) scheme, and (5) evaluating the utility of other research tools including satellite imagery and telemetry tagging for NARWs.

The Working Group agreed that the most important population and individual metrics to be monitored include adult survival, calf to subadult survival, abundance, calf production, population age-sex structure, number or reproductive females, and the visual health index. At present, adult survival, abundance, and calf survival are estimated with high precision and low bias through the intensive aerial photo-identification efforts of NMFS and its partners. In contrast, calf to subadult survival is estimated with low precision owing to small sample size, and the number of reproductive females is not estimated annually. The age-sex structure of NARWs has not been estimated, though given the extensive data available on individual whales, could be generated and would provide valuable insight into the current demographics of the population and its future trajectory. Finally, a visual health assessment has been developed that provides information on individual health and body condition. A 2019 workshop on NARW

health assessment provided insights into expanding and improving this assessment. The Working Group recommends that once the utility of those metrics has been established, their estimation should be considered for integration in the monitoring program.

The NARW data that have been amassed to date are an invaluable resource that could be further analyzed to inform a future, more optimized monitoring plan. The Working Group identified and described 11 retrospective analyses within four overarching objectives: (1) optimizing aerial and vessel-based survey effort to ensure high precision and low bias in the estimation of population and individual metrics identified above, (2) maintaining sufficient effort to detect entangled, injured, and dead NARWs, (3) improving characterization of the overall risk seascape, and (4) improving understanding of the relative detection by visual versus passive acoustic platforms. Many of the analyses identified will be critically important to designing and executing an efficient monitoring plan.

The current NARW habitat model is a valuable resource for examining habitat hotspots and historical distribution shifts. A robust quantitative habitat-based density model requires specific data inputs, and the variability in data collection approaches across all NARW partners has slowed progress toward the next generation model. Increased standardization in the collection of a small subset of survey effort metrics and sighting parameters would facilitate much broader integration of the vast network of spatial data collected on NARWs and, together with cooperation with Canadian modeling efforts, provide a more robust model for future predictions of habitat shifts and risk assessments.

Based on review of past and current NMFS and partner survey efforts, the relative contribution of unique photographic identifications from various regions and contributors, and the ongoing PAM work along the U.S. and Canadian east coasts, the Working Group provides specific recommendations for developing an integrated visual (aerial and vessel-based) and PAM plan that attempts to maintain appropriate survey effort to estimate essential population demographic metrics, track individual health status, and capture habitat hotspots and shifts, in an efficient and cost-effective manner while reducing cost and risk to humans of significant and sustained use of survey aircraft. This plan envisions:

- Establishing a network of 16 long-term passive acoustic listening stations to monitor distribution and habitat use
- Conducting targeted aerial surveys (i.e., at aggregations of whales) to collect photo-identifications of ~90% of the population within a given year
- Coordinating efficient, and timely identification of individuals across all data collectors within a survey year
- Conducting periodic broad-scale systematic aerial surveys of the entire Gulf of Maine and Southern New England area, alternating with a systematic rotation through all historical NARW hotspots

- Maintaining or increasing vessel survey effort to collect individual health data and replace aerial surveys for collecting individual identification photos whenever possible

The Working Group puts forward these recommendations acknowledging the significant efforts of NMFS and its partners over several decades. The recommendations in this report are intended to capture the best and most effective elements of those past and ongoing efforts and provide a roadmap for a systematic, efficient, and effective monitoring strategy for the future.

I. Workshop Objectives

The National Marine Fisheries Service (NMFS) North Atlantic right whale (NARW) Steering Committee convened an expert Working Group to address two broad objectives related to monitoring NARWs: (1) improving our understanding of population status by identifying and tracking essential population metrics, and (2) improving our understanding of distribution and habitat use. The expert Working Group consisted of five staff with expertise in marine mammal monitoring and quantitative assessments, but not directly involved with current NARW monitoring efforts, who were asked to develop options for a comprehensive strategy to:

1. Monitor population status, including estimates of abundance, trends, survival and birth rates, and other demographic metrics
2. Monitor distribution shifts and habitat use range-wide
3. Assess health of individuals and the population (e.g., identify causation/threats, assess sublethal effects) through biological sampling

The Working Group's specific tasks were to provide expert guidance to the Steering Committee on how best to achieve the following more specific objectives:

Population Status

- Identify the essential population demographic metrics (e.g., survival rate, birth rate, age at calving, calving rate, age structure, life span) the agency should use to track recovery of this species, including a description of why each metric is essential for monitoring the population status.
- Develop a monitoring/surveillance plan for each essential population metric identified above, including options for:
    - Sampling methods
    - Data types
    - Sampling locations (e.g., region and/or range-wide)
    - Monitoring/survey frequencies

Distribution and Habitat

- Determine approach for identifying:
    - Distribution, occurrence, and habitat use in the mid-Atlantic region (i.e., west of 72° 30' West, south of 40° 00' North through 35° 30' North (North Carolina))
    - Migratory corridor and associated physical and biological features in the mid-Atlantic
    - The unobserved portion of the population in time/space (i.e., "missing whales" not detected during aerial surveys in northeast and southeast)
    - Where animals die

- Determine best methods for quantifying changes in occurrence and distribution (e.g., relative to a changing climate)
- Determine whether, and if so how, historic and current visual sightings data can be combined with passive acoustic detection data to assess past and current occurrence and distribution, and decadal-scale changes in distribution

Health Status

- Determine approach for identifying cause(s) or contributing factors for dead, injured, entangled animals and poor reproduction and poor health
- Determine approach for collecting:
    - Health assessment data, such as body condition and skin condition including scarring
    - Hormones for assessing reproductive state, stress, metabolism/energetics, nutritional state
    - Injury state (e.g., wounds, entanglements, skin lesions, etc.)

The Working Group met October 22-24, 2019 at the NMFS Southwest Fisheries Science Center in La Jolla, California (see Appendix II). The group received presentations on management needs for monitoring data, using mark-recapture analysis to estimate abundance and evaluate trends, current monitoring efforts in the U.S. and Canada using planes, vessels, and passive acoustics, and current funding levels (see Appendix III). The following report describes recommended options for comprehensively monitoring the NARW population throughout its range using various platforms and the rationale associated with each element.

II. DESCRIPTION OF CURRENT EFFORTS

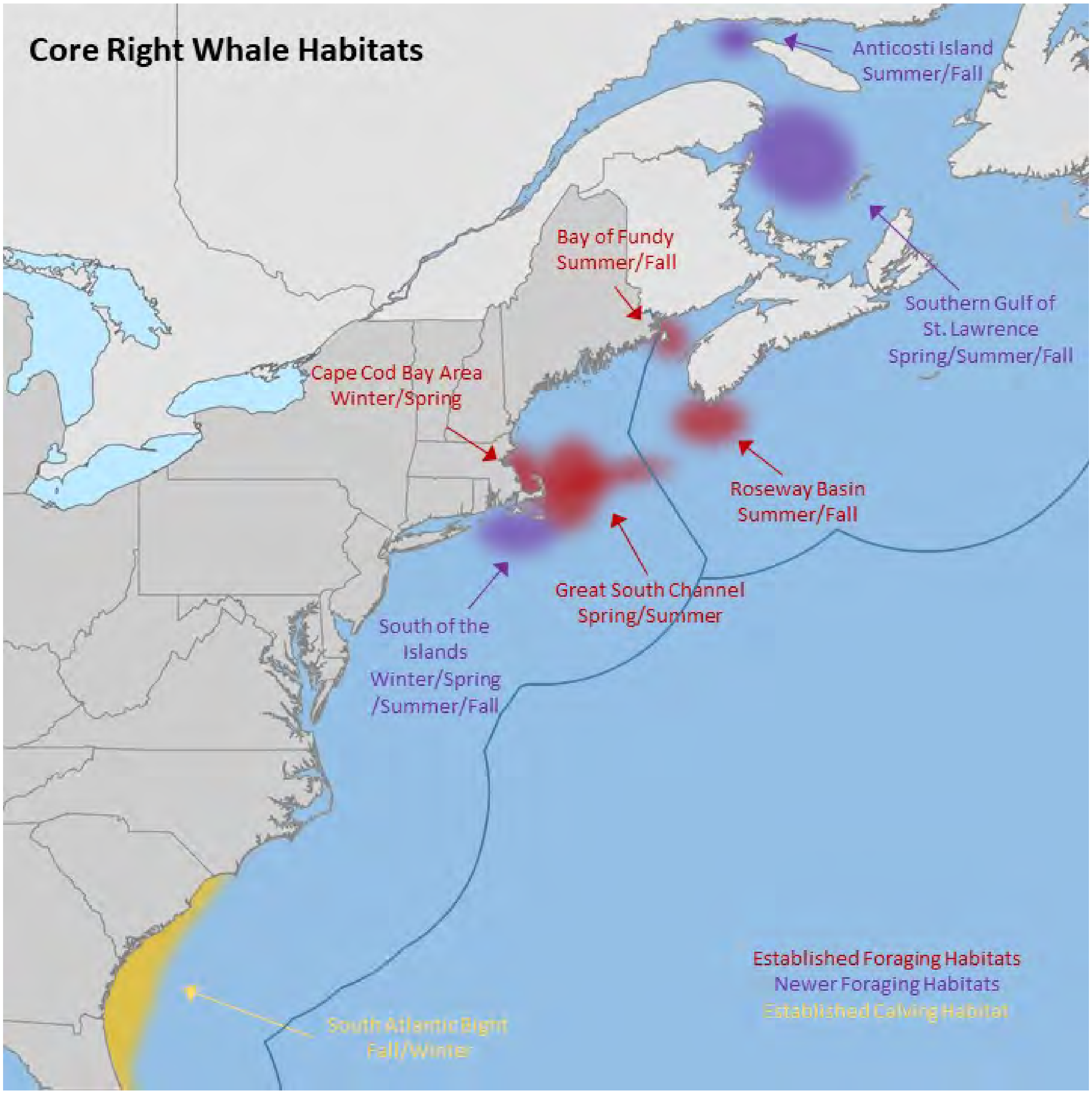

Figure 1. Known primary North Atlantic right whale habitats.

Primary Data Collection Efforts in Support of Population Assessment

The primary data collected for monitoring population status (population size, trends in abundance, survival rates, and recruitment) come from the photo-identification studies in known NARW habitats (Figure 1) conducted from multiple platforms (aircraft and surface vessels) by multiple governmental and non-governmental programs. Most of the current data are provided by the Provincetown Center for Coastal Studies (CCS), NMFS Northeast Fisheries Science Center (NEFSC), Department of Fisheries and Oceans (DFO) Canada and Transport Canada, the

New England Aquarium (NEAq), and combined efforts of the NMFS Southeast Fisheries Science Center (SEFSC), NMFS Southeast Regional Office (SERO), and the states of Florida and Georgia, as well as a variety of other contributors. Major funders of this data collection include NMFS, the Bureau of Ocean Energy Management (BOEM), U.S. Navy, Transport Canada, DFO and the State of Massachusetts. All sighting and survey effort records are submitted to the NARW Consortium Database maintained by the University of Rhode Island for inclusion in the sightings database and those with photographs are also submitted to the NEAq for integration into a unified photo-identification catalog[1]. Most field research teams match their photographs to this catalog during their field efforts.

The number of NARW identifications collected by each cooperating institution and platform (aerial or vessel) has varied from 2001 to 2017 (Appendix I, Tables 1 and 2), with contributions from Canada increasing dramatically in recent years as the distribution of NARWs has shifted and the efforts of Canadian Government agencies have increased. Similarly, the number of NARW identifications has varied by region from 2001 to 2017 (Appendix I, Tables 3 and 4), most notably with recent increases in sampling in the Gulf of St. Lawrence. Many individual NARWs are seen by multiple institutions and in multiple areas within a single year, such that the number of NARWs seen uniquely by a single institution/platform (Appendix I, Table 2) or in a single area (Appendix I, Table 4) is typically less than ⅓ of the total number of NARWs seen in a year. Each year, surface vessels provide a few identifications that are not obtained from any other source (Appendix I, Table 2), but the majority of identifications now come from aircraft (Appendix I, Table 1).

Photo-Identification Data Contributed by Partners

1. Provincetown Center for Coastal Studies aerial surveys in Cape Cod Bay[2]

CCS flies a fixed survey grid over the entirety of Cape Cod Bay and the eastern Cape several days per month during winter and early spring until NARWs leave this foraging ground for other regions. These surveys provide a large number of photo identifications (Appendix I, Tables 1 and 3), including a large proportion of the unique identifications provided to the catalog each year (Appendix I, Tables 2 and 4). CCS also conducts small boat habitat surveys along predetermined tracklines to visit 8-9 sampling stations, as well as foraging surveys directed by aerial sightings of NARWs, both of which may provide additional photo identifications.

[1] http://rwcatalog.neaq.org/Terms.aspx
[2] https://coastalstudies.org/right-whale-research/population-monitoring/

2. DFO Canada[3] and Transport Canada[4] aerial surveys in the Gulf of St. Lawrence

In response to apparent recent increases in NARW abundance and observed deaths in the Gulf of St. Lawrence, DFO and Transport Canada now conduct substantial aerial survey effort from spring through fall to locate NARWs. The survey effort has been focused primarily on the main shipping routes within the Gulf of St. Lawrence, as well as over primary fishing regions, but includes some flights into other regions of likely NARW habitat. Oblique identification photographs are collected from the planes, though information on regions with large aggregations of whales is generally passed to NMFS to conduct flights for additional photo-identification efforts. DFO survey efforts account for most of the unique identifications in Canada (Appendix I, Tables 2 and 4).

3. New England Aquarium[5] small boat surveys in the Bay of Fundy, Roseway Basin/Scotian Shelf, and Gulf of St. Lawrence

The NEAq began annual small boat surveys in the Bay of Fundy in 1980 and in the Roseway Basin/Scotia Shelf regions more recently. Traditionally, both surveys provided a reasonable number of unique identifications (Appendix I, Table 2), but the number of NARWs using these areas has declined in recent years. The NEAq has recently been conducting small boat surveys in the Gulf of St. Lawrence in response to an increase in NARW sightings in that region. Many of the NEAq photo-identification efforts are focused on collecting data for individual whale health assessments, requiring more detailed photographs from a variety of angles to provide a robust examination of current health status (e.g., Pettis et al. 2004). The NEAq has been conducting aerial surveys in the offshore waters south of Nantucket and Martha's Vineyard since 2011, though the steering committee did not have access to these data so they are not discussed specifically in this report.

4. Southeastern U.S. (SEUS) small boat surveys

The states of Georgia and Florida conduct small boat surveys of the winter calving areas, directed by NARW detections from the aerial surveys. This effort serves primarily to collect biopsy samples of calves for genotyping and later identification.

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[3] https://www.dfo-mpo.gc.ca/species-especes/mammals-mammiferes/narightwhale-baleinenoirean/alert-alerte/index-eng.html

[4] https://www.tc.gc.ca/en/services/marine/navigation-marine-conditions/protecting-north-atlantic-right-whales-collisions-ships-gulf-st-lawrence.html

[5] https://www.andersoncabotcenterforoceanlife.org/category/right-whale-research/

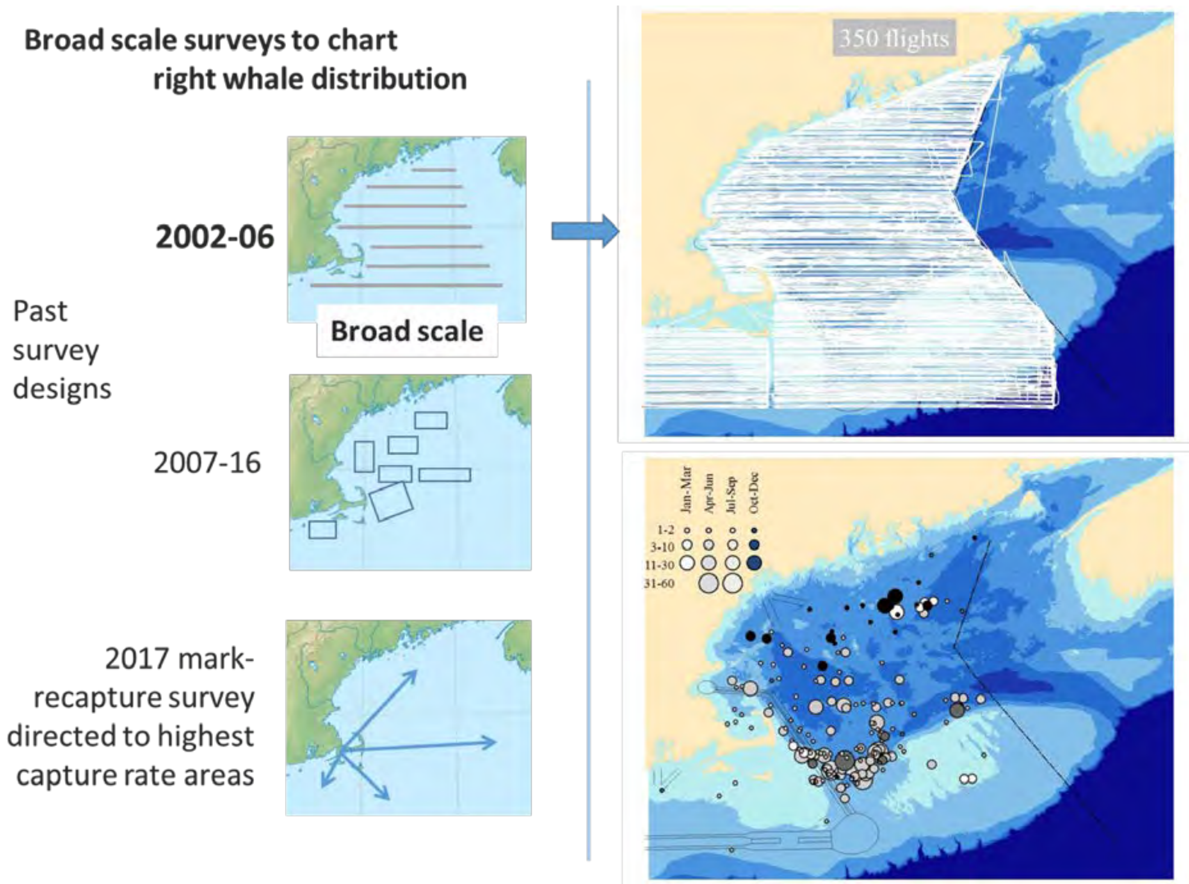

Figure 2. Summary of NEFSC aerial survey approaches since 2002 (left panels), and overall survey effort and combined NARW sightings resulting from broad-scale surveys form 2002-2006 (right panel). Provided to Working Group by NEFSC.

Photo-Identification Data Collected by NMFS Aerial Surveys

The NEFSC conducts aerial surveys in a National Oceanic and Atmospheric Administration (NOAA) Twin Otter for much of the year. These include surveys of designated geographic areas as well as other Gulf of Maine sites in spring, summer, and fall, South of the Islands (i.e., Nantucket and Martha's Vineyard) in fall, winter, and spring, and most recently in the Gulf of St. Lawrence in spring, summer, and fall. Much of the survey effort in the Gulf of St. Lawrence is dedicated to areas of NARW concentration identified from DFO surveys and also to locate dead or entangled NARWs for recovery efforts.

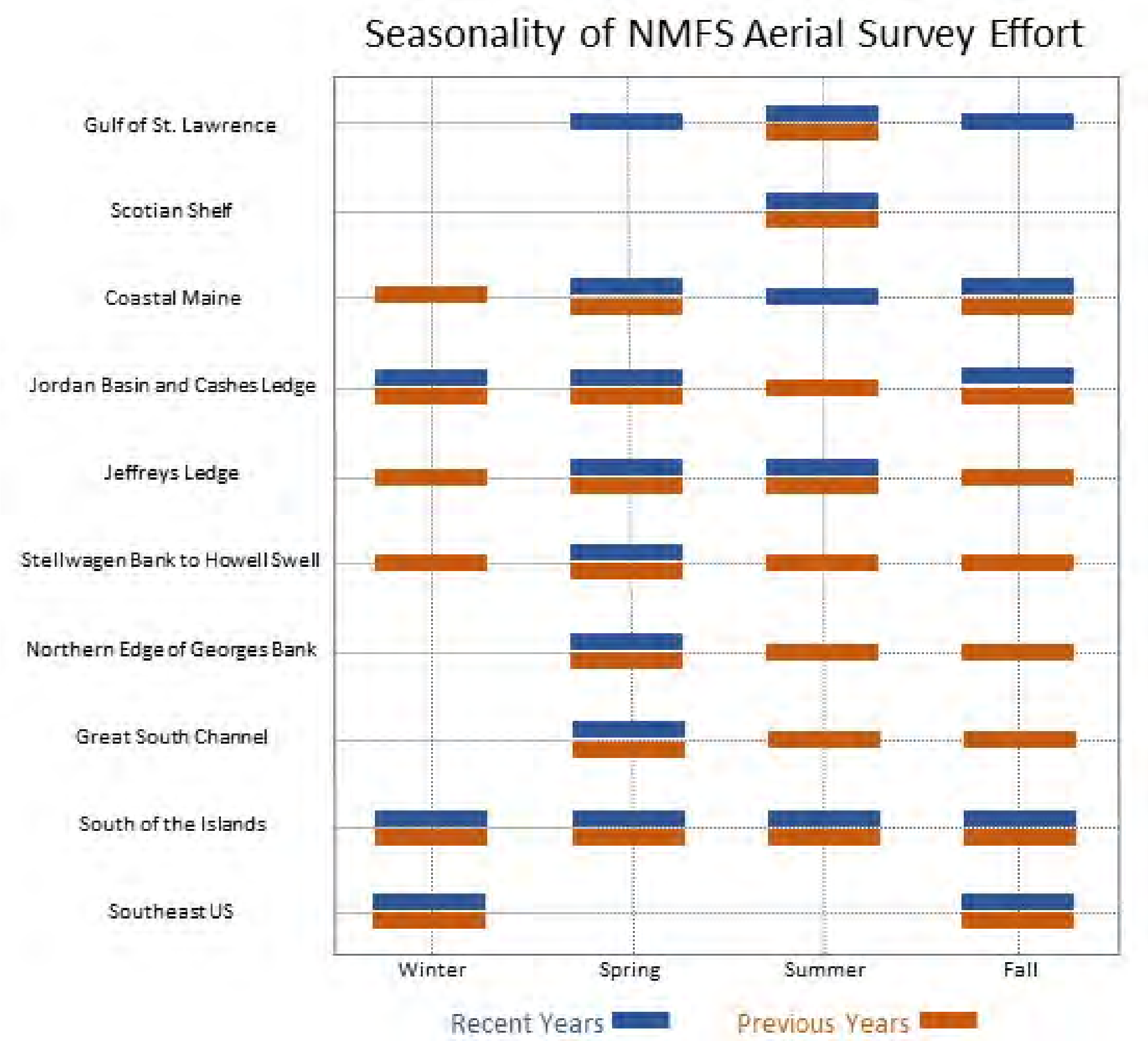

Figure 3. Seasonal distribution of NMFS aerial survey effort in recent years (2016-2019), and previous years (2010 through 2015). Actual effort may vary considerably between locations.

Photo-identification surveys conducted by the NEFSC have evolved substantially over time. These surveys initially flew over the Great South Channel (1998-2001), and then evolved to broad-scale systematic surveys (2002-2006) throughout U.S. waters in the Gulf of Maine and Southern New England (Figure 2 and Figure 3). The results of those broad-scale surveys led to more targeted surveys in designated "boxes" from 2007-2016 in order to maximize survey effort in locations that consistently contained aggregations of NARWs. This was modified starting in 2017 to direct survey efforts to areas with the highest capture rates, to maximize detections of unique individuals. Surveys are flown repeatedly to the same area until the discovery curve for new individuals levels off and few or no new individuals are detected.

SERO, in collaboration with the states of Georgia and Florida, conduct aerial surveys of the winter calving areas. These have been very successful, and not long ago were providing as many as 120 unique identifications per year. However, NARWs' usage of the area has dramatically declined, and as few as seven NARWs, including accompanied calves, have been identified in recent years.

Analysis Efforts to Assess Population Status

The primary tool for integrating and interpreting the photo-identification data into population assessments is the Bayesian integrated population model developed by Pace et al. (2017). Analyses of data collected through 2018 presented at the workshop show relatively constant non-calf (ages 5+) survival rates of ~0.98 and 0.97 (for males and females, respectively) from 1990 to 2014 and a decrease to ~0.96 and 0.95 (respectively) for 2015-2016. Survival rates of calves (0-5 years) were about 2% less than for females ages 5+, and changes in both adult and calf survival rates over time are constrained in the model to follow an identical trend (i.e., the age-sex class effect is additive on the logit scale). Survival rate estimates of NARWs younger than adults have low precision, owing to small sample sizes. Consequently, it remains uncertain whether juvenile survival has changed in recent years. The model estimates an increasing population trend from ~260 in 1990 to a maximum of ~483 in 2011 followed by a decrease to ~410 in 2018.

A calf production index (the proportion of calves in the population) can be estimated from the number of calves observed in a given year and the model-based estimates of population size. Results show that calf production has been very low since 2010 (compared to values in 2001-2009) and is below the level required for replacement of adults. It appears that this recent decline in calf production is largely responsible for the observed decline in population size in recent years. The potential contribution of reduced survival of both young and adult NARWs to the population trend remains uncertain.

The estimated proportion of the population sampled by photo-identification each year (capture probability) has been very high, roughly 90% in the years 2000 to 2010. Capture probabilities began to drop starting in 2011 likely because of changes in NARW distributions (Davis et al. 2017), reaching levels of approximately 50-60% in 2014. With subsequent changes in survey effort, values for the most recent years (2016-17) are again approaching 90%. A high capture probability not only reduces the variance in estimated parameters, it also reduces the likelihood of bias caused by violations in model assumptions.

The higher male survival rate than female survival rate will result in a population with an increasingly biased sex ratio in older individuals, which reduces the reproductive potential for a given total population size. In the published model of NARW population dynamics, Pace et al. (2017) estimate that the ratio of females to males increased from 1:1.15 in 1990 to 1:1.46 in 2015. If this apparent pattern continues, there is concern that population productivity may continue to decrease.

Efforts to Describe Distribution and Habitat

There have been many efforts to describe NARW foraging and mating habitat, drivers of habitat preferences, and habitat quality and variability. The same aerial and vessel surveys that provide identification photographs also provide much of the data used to study distribution and habitat. Opportunistic sightings also provide new insights in areas that are not covered by existing survey effort. Quantitative descriptions of NARW habitat typically require design-based surveys and data from targeted surveys cannot be used for these analyses. Diverse PAM efforts have also been ongoing for almost two decades and collectively provide a rich dataset for examining distribution. However, most passive acoustic recorder deployments have been short-term or funded by partners interested in specific questions or regions, requiring researchers to piece together datasets that do not overlap in time, do not consistently sample the same sites, and may not be recording in optimal seasons or locations.

Several decades of research have shown that NARWs use discrete habitats at specific times of the year (Figure 1), and researchers have taken advantage of this to target data collection. Well documented NARW foraging habitats include Cape Cod Bay, the Great South Channel and edge of Georges Bank, an area to the south of Martha's Vineyard and Nantucket, the waters around the Bay of Fundy, Roseway Basin, the southern Gulf of St. Lawrence and the western end of Anticosti Island (Davies et al. 2019; Davis et al. 2017; Durette-Morin et al. 2019; Leiter et al. 2017; Mayo et al. 2018; Simard et al. 2019). Additionally, the whales' only known calving ground extends along the coast of the South Atlantic Bight (Gowan and Ortega-Ortiz 2014; Keller et al. 2012). NARWs respond to environmental changes and may use habitat intermittently over time. The whales have been known to nearly abandon a frequently used foraging habitat only to come back in future years in large numbers. In recent years, the whales have demonstrated actual shifts in distribution, frequenting previously unrecognized foraging habitats. However, sightings data indicate that NARWs may investigate a previously preferred habitat, but not stay if the prey resource is insufficient, so some habitats previously used no longer have high densities of NARWs (Davies et al. 2019; Davis et al. 2017).

A recent effort to aggregate all available and appropriate survey data resulted in monthly predictive habitat models along the U.S. east coast for NARWs and several other cetacean species (Roberts et al. 2016). These habitat-informed density models offer the most comprehensive evaluation of NARW density along the east coast to date and include relevant data through 2016. The Duke University team is currently funded under a cooperative agreement with NMFS to update the models using 2017 and 2018 data as well as create separate models for the periods before and after 2010 when NARW distribution began to shift. It is worth noting that not all NARW surveys or datasets are appropriate for use in this type of quantitative model. This density modeling effort requires survey data collected using line-transect survey protocols. The Roberts et al. models are not able to incorporate opportunistic NARW sightings, non-line transect survey data, or data from directed survey efforts (i.e., those directed at known aggregations of NARWs).

There have been many PAM efforts throughout the northwest Atlantic over the past decade, including efforts by NEFSC to maintain collaborative long-term monitoring of species occurrence from the northern Gulf of Maine south through the New York Bight as part of the Northeast Passive Acoustic sensing Network (Van Parijs et al. 2015). Acoustic data provide insights into the occurrence of NARWs at times of the year when poor weather and lack of light make visual surveys highly restricted (i.e., late fall to early spring). A recent analysis of NARW seasonal and annual occurrence throughout the Northwest Atlantic using a diverse set of PAM data collected by a large number of collaborators resulted in an impressive assessment of changes in NARW distribution over 11 geographic regions from 2004 through 2014 (Davis et al. 2017). Although the aggregated dataset provides great insights into NARW occurrence and changes in distribution over the decade, the lack of concurrent and continuous monitoring at many locations hinders detailed examination of the movements of NARWs between regions and the changes in distribution over time (see Figure 4).

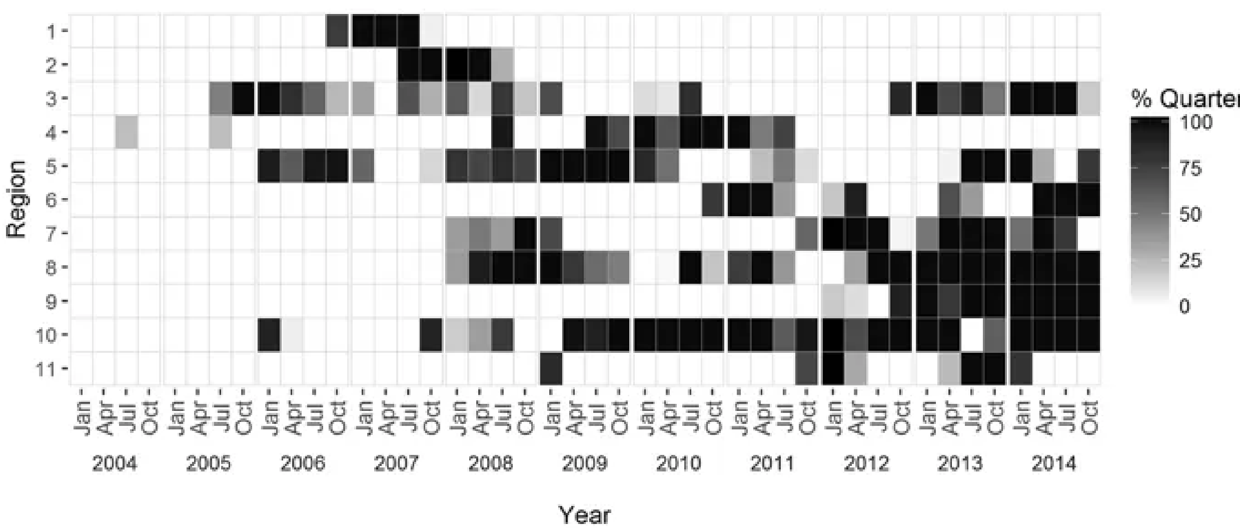

Figure 4. (Reprinted from Davis et al. 2017, Figure 5). The proportion of year with available passive acoustic recordings in each monitored region (see Davis et al. 2017, Fig. 1). Years are split into quarters from January 2004 to December 2014. Black indicates at least one recorder present for the entire quarter year for that region, lighter gray indicates a portion of that time period with recordings, and white indicates no available acoustic data for that region and time period.

Recent NARW sightings and acoustic detections in the Northeast Atlantic, coupled with historic records of NARW presence, are intriguing and suggest monitoring efforts should expand to targeted surveys in these more eastern areas, at least on a sporadic basis. For example, within the last decade one NARW has been sighted and detected in Icelandic waters during the summer months. Historic whaling records also indicate NARWs used this area in the summer.

Efforts to Assess Population Health

Health status has largely been assessed using photographs from the aerial and vessel surveys using a well-established NEAq protocol. These visual health assessments have been shown to be correlated with survival and birth rates for NARWs (Pettis et al. 2004). Additional biological samples taken during small boat efforts also contribute information on hormone levels and other metrics. Photogrammetric measurements of NARWs have been made from unmanned aerial systems (UAS) deployed from surface vessels and may also contribute useful information on health status. To date, only the visual health assessments are routinely done and other efforts are largely in the research and development phase. Additional research is needed to determine whether other metrics are correlated with survival and birth rates.

In June of 2019, NMFS convened a workshop related to assessing NARW health. The goals of the workshop were to (1) assess current NARW health information data, including associated data gaps, and (2) identify appropriate available and needed tools and techniques for collecting standardized health data that can be used to understand health effects of environmental and human impacts (e.g., entanglement), and inform fecundity and survivorship models to ultimately guide population recovery. A forthcoming report further details this workshop and efforts to assess NARW population health. An important result of the workshop was the recognition that the vast majority of data used to assess NARW health are collected during vessel surveys. Accordingly, in developing recommendations for vessel surveys, the Working Group considered health assessment data needs.

III. Data Gaps and Limits to Inference

Need for Spatially-Temporally Standardized Survey Design

As NARW distribution has varied over time, so has the spatial distribution of survey effort, as ‘following’ larger aggregations of animals maximizes collection of photo identifications and other datasets. Indeed, the collection of identification photographs of NARWs has been spectacularly successful, providing for precise estimates of population size and survival rate by year (Pace et al. 2017).

However, there are trade-offs to this adaptive sampling approach. As noted above, such opportunistic (in contrast with design-based) datasets are less amenable to spatial habitat and density-surface modeling. They also make it difficult to assess longitudinal changes in population distributions because the locations of animals are confounded with the locations of effort and new aggregation sites can be difficult to detect (e.g., if NARWs start using un-surveyed areas). In addition, the estimation of certain demographic metrics can be prone to bias under this adaptive sampling approach. In particular, obtaining an unbiased estimate of population size requires that all animals in the population are available to be sampled, meaning that all individuals are at least occasionally present in areas where photo-identification efforts are occurring. If a segment of the population is, or becomes, unavailable to the survey efforts (by permanently moving to new areas), the population size will be under-estimated. Less obviously, estimates may also be biased if capture heterogeneity (across years or individuals) is extreme. Extreme heterogeneity can occur if, for example, some animals temporarily (for a period of years) emigrate to un-sampled areas, or if individuals are site-faithful to areas sampled more- or less-often. Heterogeneity can be modeled with random effect parameters, but this does not provide a guarantee of eliminating bias (e.g., if heterogeneity is not logit-normal distributed) and does not improve precision. These issues can affect survival-rate estimation as well, although survival estimation is more robust to capture heterogeneity than is abundance estimation. Finally, this adaptive sampling approach means that only a fraction of the population's distribution is known, with the remainder of the population being distributed in un-surveyed areas. A potential concern is that these 'missing' animals could be incurring mortality risk (e.g., from vessel strike or gear entanglement) that is not being managed or assessed. Systematic annual survey area throughout the NARW range, including new areas that may have a relatively high likelihood of being occupied, would provide a more complete picture of whether the population is incurring risks throughout the year.

A coordinated range-wide monitoring plan should achieve a balance between maximizing photo-identification data collection (i.e., targeted effort on aggregations) and obtaining broad-scale, spatially and temporally representative distribution data throughout the range that allows for valid spatial modeling and detecting changes in animal use and movement patterns. There should be continuous monitoring in potential high-risk areas should NARWs start using those areas (e.g., in areas of high fishing vertical line density or vessel traffic), as well as periodic monitoring of some sort (acoustic or visual survey) in areas of potential but previously undocumented use, so that potential colonization of these areas is detectable. Areas of potential use could be identified, for example, by spatial density or occupancy modeling efforts, fit to visual survey or PAM data (cf., Monsarrat et al. 2015; Roberts et al. 2016). The viability of using satellite image data to identify new aggregation areas could also be explored.

Collection of Consistent Data Elements by All Data Contributors

There are many researchers and institutions contributing to NARW research and recovery efforts. Many of these institutions have been conducting NARW research for decades and use their own established protocols for various types of data collection. The NARW Consortium has done a tremendous job of aggregating the various data sources to make all data maximally usable to the collective; however, some quantitative analysis efforts have been hindered by differences in data collection approach among data contributors. In particular, NARW spatial density models require standard measures of search effort and perpendicular detection distance, which have not been readily available from all surveys. Although there have been significant post-hoc efforts to standardize data for analyses, this has been a large task that could be mitigated through developing standards for collecting a common data subset across the various data contributors.

Leveraging Existing Data to Address Key Management Questions

The impressive photo-identification catalog and analyses of these data have generated precise inferences about trends in population size, survival, and reproductive rates. However, the full potential of the catalog in addressing additional management questions has yet to be fully explored. Additional, key management questions such as those related to quantifying unobserved human-caused mortality and understanding anthropogenic influences on survival and reproduction may be addressed through additional analyses of the catalog, modifying or extending existing models, and in some cases, through modifying survey efforts to obtain additional necessary data. Below, the Working Group makes several related recommendations on this point.

IV. RECOMMENDATIONS

Essential Population and Individual Metrics

Several key demographic metrics and individual-level metrics have been and continue to be estimated for this population. Some of these, including adult survival and abundance, are estimated with high precision and apparently with little bias. It would be informative to improve estimates of some other metrics and population metrics that are currently either estimated with low precision or not available. Below, the Working Group provides a list of high priority metrics and recommendations regarding their relative need for improvement.

Adult Survival

Adult survival is currently estimated annually with sufficient precision and low bias. This should be continued. The Working Group suggests that survival modeling be further investigated to evaluate support for any change in the disparity between adult male and female survival rates over time. The estimated survival rates in Pace et al. (2017) and updated output shared at the workshop were based on a model with an additive survival effect, which constrains the sex difference to be constant over time. A model with a *sex x time* interaction might indicate whether adult female survival has become relatively lower than male survival in recent years. The initial sex state of individuals of unknown sex (assumed to be at parity) may also affect the change in sex ratio in the model. The Working Group also recommends exploration of alternative assumptions on initial sex ratios.

Calf to Subadult Survival (Roughly Ages 0 to 5 Years)

Calf to subadult survival is currently estimated annually but with relatively low precision owing to low sample sizes. The Working Group recommends exploring alternative capture-recapture model formulations to determine whether any change in survival of young animals has occurred in recent years. One such potential formulation might allow young NARW survival to be estimated independently from adults (i.e., an interaction rather than additive age effect) and with years grouped appropriately (i.e., before and after some potential change-point year) for young animals in order to increase the precision of estimates for this age class. A proportion of young NARWs are of uncertain age. Precision in age-specific estimates of young NARW survival could be improved by increased effort to determine their ages through genetic sampling and matching with biopsy samples obtained from neonates.

Abundance

Population size is estimated annually and with high precision and low bias. This should be continued.

Calf Production

The number of calves born annually is determined through total enumeration during intensive aerial surveys in the calving area. It is rare to find a new calf on the foraging grounds not previously identified on the southeast calving grounds. Calf production combined with other relevant information can be used to derive other reproductive metrics of interest, including gross reproductive rate (calves per mature female), calves per female (without regard to age), a calving index (calves divided by total abundance), and inter-birth interval. Estimation of calf production should continue, with effort adjusted appropriately to achieve total enumeration without excessive expenditure of survey resources.

Population Age-Sex Structure

The age-sex structure of the NARW population is not currently available. The age-sex structure is a product of the annual survival and reproductive output of a population for a generation. As such, it is a convenient graphical integration of a population's history. Gaps in one or more ages reflect either a deficit in births or high historic mortality. Furthermore, future population trends are determined by both prevailing vital rates (survival and reproductive rates) and current age-sex structure. If an age-sex structure is significantly perturbed relative to the theoretical stable age distribution associated with the lifetable (matrix of survival and reproductive rates), the future realized population trend may be dominated by the age-sex structure. Currently, the NARW age-sex structure is not estimated, but it could be based on the known individuals in the population and information on their known, estimated, or minimum ages. There will be error in the estimated age-sex structure owing to uncertainty in observed individuals' ages and sexes, as well as uncertainty in the estimated unobserved portion of the population in a given year. However, given the wealth of data available for this population, it is anticipated that the uncertainty in the age-sex structure will be relatively low. A variety of statistical approaches could be used to incorporate uncertainty in age and sex into the estimated structure. Again, additional effort to biopsy young animals and match them via genetic analysis to already sampled neonates would reduce uncertainty in the calf to subadult ages.

Number of Reproductive Females

This metric is easy to understand and conveys the current dire status of the NARW. It has been estimated in the past but apparently is not updated regularly. This could be readily achieved using reproductive histories of individual females combined with the female population age structure.

Visual Health Index (and Potentially Other Health Metrics)

The preceding metrics are all population-level metrics in that they apply to demographic groups of animals or the entire population. Here the Working Group highlights the priority to measure relevant health metrics at the *individual* level. An existing visual health assessment index is derived from photographs and incorporates information on qualitative body condition, skin condition, rake marks, cyamid loads, and lesions. These body and skin condition metrics have proven to be a significant predictor of individuals' survival. A suite of additional individual health associated metrics was identified during the 2019 NARW Health Workshop as potentially informative for health status, future survival, and future reproductive performance. Once the utility of such metrics has been established, their estimation should be considered for integration in the monitoring program.

Interrogating Existing Data to Inform Future Monitoring Schemes

The NARW data that have been amassed to date are an invaluable resource that could be further analyzed to inform a future, more optimized monitoring plan. The Working Group was provided an extensive overview of the data collection and monitoring efforts that have been ongoing by NMFS and other organizations; however, the Working Group did not have an opportunity to analyze existing data to inform monitoring plan recommendations. Although the Working Group presents a monitoring plan below, it acknowledges that aspects of this proposed plan may be refined through additional analyses of existing datasets. **The Working Group recommends several analyses of the photo-identification, survey, and other data prior to finalizing a monitoring plan**. Below the Working Group outlines desired objectives and a suite of analyses that could be conducted on existing data to help achieve those objectives through the design of an improved monitoring plan.

Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner

Achieving this objective depends upon maintaining high (approximately ≥ 0.90) annual capture probabilities for all age and sex classes, minimizing heterogeneity in capture probabilities among individuals, and re-distributing effort in such a way as to reduce oversampling or undersampling of certain areas (and thereby certain segments of the population).

Proposed retrospective analyses:

A. Enumerate and track number of overall and unique identifications by source, platform, and region. During the workshop, the number of individuals documented per year by platform and organization (Appendix I, Table 1) and geographic area (Appendix I, Table 3) was provided for review, together with the number of individual NARWs seen only by a single platform or source (Appendix I, Table 2) and in a single area (Appendix I, Table 4). This information is extremely informative for determining where effort may be adjusted to maximize the number of individuals identified each year. The 2018-2019 data could not yet be evaluated in this way, but should be added when it becomes available to reflect the most current information for planning future survey effort. Further, while the Working Group aimed to identify the most significant data contributors based on the provided presentations, some significant sources may have been omitted such that the organizations and platforms should be reviewed for completeness.

B. Investigate drivers of individual capture heterogeneity. Heterogeneity can be attributed to both sampling methods and intrinsic biology of animals. It may be possible to discern from existing capture histories if the variability in re-sightability among individuals is mostly due to distribution of survey effort in space and time, variability in animal behavior affecting detection and identification, or variability in mark distinctiveness among individuals. Such information could be used to adjust survey design to reduce heterogeneity.

C. Related to (B), investigate temporal and spatial patterns of occurrence for those NARWs seen only once per year, or which go undetected for one or more years. These NARWs, by definition, have relatively low sighting probabilities. This analysis may suggest strategies for increasing the probability of detecting these NARWs, thereby reducing potential bias in estimates of survival and abundance.

D. Subsample existing sightings histories to simulate how reduced effort (temporally/spatially) might affect the precision and bias of the metrics used to monitor population status. This will help inform whether reducing effort in specific areas, times, or from specific platforms will result in undue bias or unacceptable uncertainty. This will also help evaluate whether the overall capture probability goal could be reduced to less than 90% of the population per year.

E. Determine level of effort required to identify new calves. With the reduced number of calves seen in the southeast area in recent years, a post-hoc re-sampling analysis could be used to determine the level of aerial effort that is needed to find and photograph all calves born in a given year (recognizing that this effort is likely to change as the number of births changes). In addition, the integrated mark-recapture model provides estimates of calf production. These estimates should be compared to independent estimates of calf production (e.g., from the southeast surveys). If the model approach indeed provides good estimates of calf production, this could potentially reduce the need to collect as much winter survey data from the southeast region.

Objective 2. Maintain Sufficient Effort to Detect Entangled, Injured, and Dead North Atlantic Right Whales

Achieving this objective is critical for assessing threats, assigning cause of death, designing mitigation strategies, and evaluating the efficacy of those strategies. Between 2010 and 2017, approximately 50% of the estimated NARWs that were killed or seriously injured were detected. Live, entangled NARWs may be disentangled and thereby relieved of suffering, injury, and death. Any adjustment in surveillance for optimizing estimation of demographic metric must be balanced with potential degradation in the likelihood of detecting entangled, injured, and dead NARWs.

Proposed retrospective analyses:

A. Map when, where, and by what platform entangled, injured and dead NARWs have been first detected to date.

B. Subsample existing sightings data to simulate how dead, injured, and entangled NARW detections would have been affected by reduced effort. Determine the level of aerial survey effort needed to detect dead, injured, or entangled NARWs.

C. Estimate unobserved human-caused mortality. Integrating information on human-caused injury and mortality (e.g., entanglements, vessel strikes) into the mark-recapture model may help build on previous efforts to estimate unobserved human-caused mortality (Pace et al. in prep.). For example, for entanglements this would take the form of a multi-state model, where sighting information is used to classify individuals as entangled or not, and this information is used to estimate the probability of transitioning from an un-entangled to an entangled state (taking resight probability into account) and the associated mortality rate. It would also provide estimates of the annual likelihood of animals becoming entangled in a year. Surveys designed to maximize detection of entangled, injured, or dead NARWs, and to identify the location of entanglement, injury, and mortality, would provide more robust data to inform this effort.

Objective 3. Improve Characterization of Risk Seascape

Understanding the spatial and temporal distribution of threats is key to designing mitigation measures.

Proposed retrospective analyses:

A. The Working Group recommends increased modeling effort to better understand drivers of variation in calf production, the correlation between calf production and survival (for various age classes), and the relative contribution of environmental versus anthropogenic impacts to survival and reproduction. An effort should be made to investigate correlates of survival and reproduction in sighting histories (cf., Wade and Clapham 2000) to determine whether individuals' distribution patterns have been predictive of subsequent survival, health status, reproductive success, or observation as injured or entangled. Calf production may be reduced by nutritional stress, injury-related stress (vessel strike or entanglement), or the additive or synergistic effect of these. An analysis of an individual's reproductive success and sighting histories as they relate to these factors may help to tease apart the influence of these factors on calf production.

As with calf production, adult survival may similarly be reduced by nutritional stress and human-caused factors (entanglements and vessel strikes). In general, adult survival is expected to be more robust to environmental conditions than reproduction, but whether the environment is playing a role in reducing adult survival may be detectable by correlation with calf production, annual oceanographic or prey metrics that should relate to the individual's ability to meet energetic needs, and independent population-health assessment data. Inferences from this effort would better inform risk assessments and the extent to which current population dynamics are within management control vs. driven by environmental conditions.

B. Some risks have been more or less well described for the areas and times where NARWs have traditionally been present. In recent years, NARWS have redistributed in ways that were not predicted nor are even yet well characterized. Given this uncertainty, formally characterizing threats (e.g., vessels/fishing) in areas where NARWs *may* be spending more time in recent years (e.g., Mid-Atlantic, Canada outside Gulf of St. Lawrence, Iceland, others) could help prioritize survey effort (including acoustic recorders) to characterize NARW use of the highest perceived risk areas.

Objective 4. Improve Understanding of Relative Detection by Acoustics Versus Visual Survey

Acoustic and visual (aerial and vessel) surveillance are used to detect presence of NARW and a future monitoring plan will continue to employ both methods. Both methods fail to detect some NARWs that are present. In particular, behavioral state and acoustic propagation conditions may have significant impact on the ability of acoustic monitoring devices to detect NARWs known to be in a given area. Understanding these factors and predicting when each method will provide the greatest surveillance pay-off is key to a cost-effective monitoring plan.

Proposed retrospective analyses:

A. Evaluate situations where acoustic recorders were present in the same times and places as aerial or boat surveys. Identify instances where acoustic monitoring indicated NARWs were present but they were not detected visually, and vice versa. This may inform strategies for deploying surveillance resources, especially in currently under-surveyed locations of interest.

Improving the North Atlantic Right Whale Habitat Model

NARW spatial density models have been developed at Duke University (e.g., Roberts et al. 2016). There have been a number of challenges associated with expanding the geographic scale of the models and the types of data that can be used to inform the density predictions. For example, it seems that some data contributors do not distinguish between periods of ‘on-effort’ vs. ‘off-effort’ survey or note the distance to sighted groups. Many of our other recommendations already address some of these challenges (need for systematic effort, need for common data types, etc.). However, the existence of a broad spatial-scale predictive modeling tool would have many uses in facilitating efficient monitoring for NARWs within and between years. Extrapolation of models using environmental covariates to presently un-surveyed areas could provide clues for targeting regions for PAM or focusing aerial surveys in the future.

Further, the Working Group was presented an overview of ongoing work by DFO with regard to developing NARW habitat-prediction models. To the extent feasible, **the Working Group recommends a coordinated and unified modeling approach to provide distribution and density predictions across the range of NARW habitat.** Such a model would require considerable collaboration among U.S. and Canadian researchers to ensure consistent data inputs, but would provide a powerful tool for examining possible distribution shifts based on future conditions or for identifying locations where future focused effort may be most efficient or effective.

Although NMFS conducts a large share of overall aerial survey efforts, there are several other research groups that regularly or intermittently conduct aerial surveys, including collection of identification photographs. Attempts to integrate and use these data are slowed by the need to standardize the data to a common framework (identifying periods of survey effort versus periods off the transect line for other purposes, measurement perpendicular sighting distance, etc.). Working with contributing research groups, **the Working Group recommends developing standards for collecting a common data subset (e.g., effort and perpendicular sighting distance) instituted by all aerial survey efforts to facilitate maximal use of collected encounter and photo-identification data.** The identification and collection of a common data subset isn’t meant to replace data collection protocols long used by various survey groups, but rather to ensure that a standard set of data required for quantitative analyses is collected in the same way by all partners, maximizing the utility for all datasets. At minimum, all teams should record whether the survey (or portion of the survey) was systematic, opportunistic, or directed at known aggregations, and for those portions that represent systematic survey effort, indicate when the plane is “on-effort” surveying along the transect line, and the distance to sighted groups.

An Integrated Passive Acoustic and Visual Survey Monitoring Plan

The Working Group thinks that a well-designed, long-term coordinated visual and PAM effort may yield the greatest benefit by providing consistent input datasets for examining occupancy, predicting (or at least retrospectively identifying) distribution shifts, and supporting abundance analyses and estimation of other vital demographic rates for this population. Passive acoustic recorders can provide continuous monitoring year-round, providing valuable information on occurrence, even in times of year with poor weather conditions. Visual surveys provide opportunity to collect identification photographs, critical for quantitative assessment. Aerial platforms also provide broad geographic sampling, better for spatial modeling of habitat use, compared to fixed-site PAM efforts.

The complementary strengths of these data collection platforms allow for efficient and cost-effective data collection across a broad area. Monitoring of high risk areas (e.g., shipping lanes, high density vertical line fishing areas) with low densities of NARWs is probably best accomplished with acoustic recorders, whereas monitoring and data collection in high density hotspots is achieved with visual survey platforms where critical identification photographs can be taken, and other biological samples can be collected. While specific regions or periods may be best suited to either passive acoustic or visual survey effort, there are several cases where the combination of monitoring approaches may provide for the greatest and most consistent data collection opportunity. For example, acoustic monitoring data may reveal the presence of NARWs in an area, allowing subsequent targeted visual surveys to that area. In specific regions, deploying near real-time auto-detection buoys may provide opportunity to rapidly deploy visual survey resources when NARWs are detected, allowing for data collection from NARWs that may not be commonly seen in core foraging areas. Conversely, if visual sighting rates fall in an area where NARWs used to occur at higher density, a switch to acoustic monitoring of the area allows for continued monitoring of the region in the event that the NARWs return as conditions change and NARW distribution shifts.

Therefore**, the Working Group recommends that NARW passive acoustic and visual surveys become more systematic**. There are many areas that should be monitored each year (continuously or seasonally as appropriate) in a similar way, and on a standard cycle. Such monitoring may be acoustic or visual depending on the density of NARWs likely to be in that area, and may switch between visual and acoustic monitoring over time, but consistent monitoring in those spaces should be maintained through some sampling platform. Some areas should continue to be sampled every year. Other areas can be sampled on a less frequent basis, but without abandoning periodic sampling altogether, despite the apparent distribution of NARWs. This will reduce the number of assumptions being made about where the NARWs are, and will let data inform the analyses of NARW distribution, and its change through time. Specific passive acoustic and visual survey recommendations addressing this need for systematic survey efforts are described in more detail in the sections below.

Acoustic Monitoring to Examine Distribution and Habitat Use

Although NARWs are not highly vocal when transiting and mom-calf pairs are often quiet, presumably to prevent detection by predators, PAM efforts have clearly identified occurrence in regions that were not otherwise being monitored. While the detection probability may vary seasonally and by behavioral state, PAM is a low cost monitoring tool, particularly when using archival recorders and analyzing data with highly efficient and accurate automatic detectors and call classifiers.

While visual surveys, both aerial and vessel-based, have been common for decades, PAM efforts specifically designed for monitoring NARW distribution and habitat shifts have not been broadly or sustainably supported. Several PAM efforts have been undertaken by a large variety of institutions, though many were not specifically designed to assess NARW distribution or occurrence. An impressive effort to consolidate these disparate data to assess NARW trends and distribution over time has resulted in valuable insights (Davis et al. 2017); however, the lack of systematic long-term sampling designs hinder the ability to derive strong conclusions from these data. **The Working Group recommends that NMFS establish and analyze long-term permanent passive acoustic stations** where recorders will be regularly maintained to ensure long-term records of NARW occurrence at those sites. Analysis of passive acoustic data from specific monitoring locations will allow for identifying shifts in distribution over time and habitat use changes. Some of our recommended monitoring locations occur in Canadian waters. The Canadian Government and some academic researchers have plans for an impressive array of PAM stations in the Gulf of St. Lawrence and surrounding waters. Effort need not be duplicated, but the long-term effort should be sustained independent of the funding streams of these individual researchers.

The Working Group recommends a large number of permanent continuous long-term monitoring sites, augmented by a smaller number of established stations that could be monitored every 2-4 years, or in response to other information such as from visual surveys. There should be a commitment to fund all stations consistently through time and all sites should be monitored with calibrated and standardized equipment to allow for robust quantitative comparisons among sites. Although the location of specific monitoring sites may need to be adjusted over time for various reasons, possible monitoring sites should be well considered in advance to allow for the greatest consistency without additional confounding variables (including differences in site-specific physical features and detection range) that may reduce the value of some datasets for various quantitative or qualitative examination of space use, population trends, or other metrics. Reductions in overall monitoring effort should be carefully considered based on proven redundancy in the results of passive acoustic efforts at neighboring monitoring stations, and the ability to monitor that region with other approaches.

The location of the permanent acoustic stations should be based on a combination of several factors, including:

- Hotspots of historical and/or current NARW distribution
- Shipping lanes where risk of vessel strike is highest
- Areas with high density of fishing gear with vertical lines
- Areas through which migration is thought to occur

- Calving areas

The Working Group recommends long-term (multi-year) continuous acoustic monitoring in the regions listed below (Figure 5). The rationale for choosing various locations is noted in parentheses. Some locations may require more than one acoustic monitoring site to adequately monitor the region. Acoustic monitoring has been conducted in several of these locations. If appropriate, use of the same monitoring sites should be considered.

1. Northern Gulf of St. Lawrence near Anacosti Island (current foraging area, high density of fishing gear)
2. Southern Gulf of St. Lawrence near Prince Edward Island (current foraging area, high density of fishing gear)
3. Roseway Basin/Scotia Shelf (historical foraging area)
4. Coast of Maine (high density of fishing gear)
5. Jordan Basin (historical foraging area, seasonally increasing density of fishing gear)
6. Boston Harbor shipping lane (exposure to vessel traffic)
7. Georges Bank (historical forging area, offshore pot fishery)
8. North of Great South Channel (current foraging area, exposure to vessel traffic)
9. Great South Channel (current foraging area, exposure to vessel traffic)
10. South of Islands (e.g., Martha's Vineyard and Nantucket) (current foraging area)
11. New York Bight (current foraging area, exposure to vessel traffic)
12. Mouth of Delaware Bay (migratory route, historical winter aggregations, exposure to vessel traffic)
13. Mouth of Chesapeake Bay (migratory route, historical winter aggregations, exposure to vessel traffic)
14. Cape Hatteras (migration pinch point)
15. Charleston Inlet (migratory route, exposure to vessel traffic)
16. Southeast US calving ground (calving area, exposure to vessel traffic)

The Bay of Fundy was identified as a high priority area for passive acoustic monitoring; however, strong tidal currents may prevent successful monitoring of this region so it is not listed above. If appropriate and cost-effective mooring options become available, monitoring in this region should be considered. Alternative approaches to monitoring the Bay of Fundy may be needed in the meantime.

In addition to the permanent monitoring areas identified above, the Working Group recommends additional year-round monitoring occur on a periodic basis (every 2-4 years) in the following regions:

- Jeffreys Ledge (historical foraging area)
- Wilkinson Basin, Gulf of Maine (historical foraging area)
- Savannah Inlet (migratory route, exposure to vessel traffic)

Finally, exploratory short-term monitoring should be carried out to investigate the occurrence of NARWs in potential foraging areas that are not being surveyed by other means. Such areas may include regions with infrequent sightings of NARWs, or regions to the northeast where foraging habitat is predicted by various modeling efforts (including that of Monsarrat et al. 2015). This list is not exhaustive, but rather provides suggestions based on the above rationale. Some regions may be better assessed with underwater gliders outfitted with PAM devices. The choice of acoustic monitoring platform can be determined based on hardware available, the size of the possible monitoring region, and the need to monitor for extended duration. After examination of the results in Monsarrat et al. (2015), the Working Group specifically recommends exploratory short-term monitoring in the following areas that have three features: (1) identified as predicted habitat from the model results, (2) historical (pre-1950) records of NARWs, and (3) post-1950 sightings of NARWs:

- Off of southeast Labrador (possible summer/fall foraging area). Labrador is approximately the same distance from the Gulf of Maine as is the foraging area in the Gulf of St. Lawrence, suggesting easy travel to this area if it becomes a productive foraging area.
- Off of southeast Greenland (possible summer/fall foraging area). Although farther, this area could be utilized once NARWs leave Cape Cod Bay after the spring.
- Off the east and west coasts of Iceland (possible summer/fall foraging area). Iceland is more distant than other proposed monitoring areas; however, at least one NARW has been seen recently in local waters.

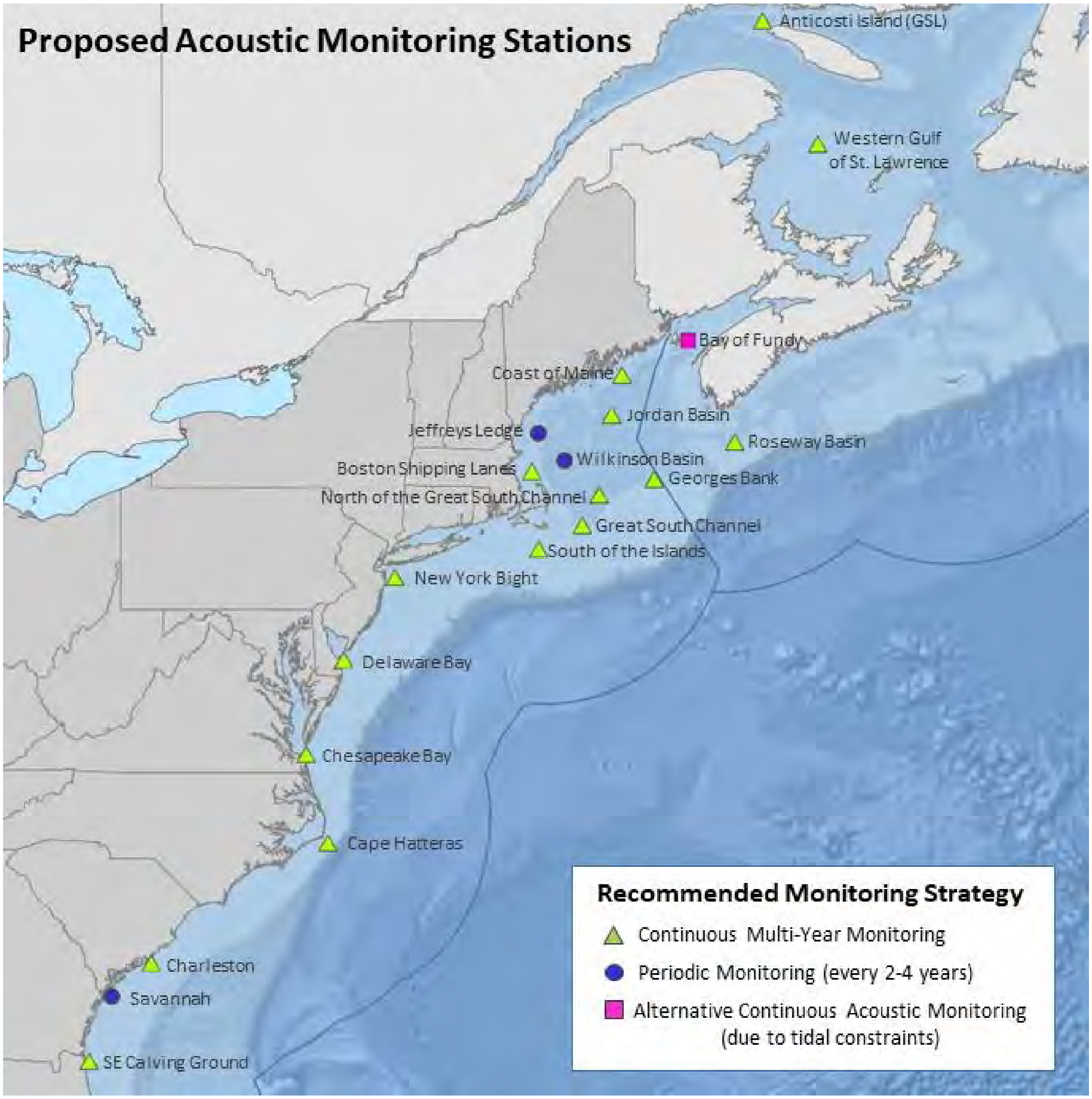

Figure 5. Proposed acoustic monitoring stations in the U.S. and Canada. Continuous year-round monitoring is recommended at the green sites and periodic monitoring (every 2-4 years) at purple sites. The red site (Bay of Fundy) is considered a priority for continuous monitoring but may require an alternate plan due to strong tidal forces. The locations are approximate and do not represent a specific monitoring site.

In addition to archival long-term monitoring, real-time acoustic monitoring in the mid-Atlantic area and in currently sparsely used foraging areas may provide opportunity for response to intermittent and infrequent aggregations of NARWs in these areas. Auto-buoys provide for near real-time detections of NARW calls that visual survey teams can then respond to for collection of identification photographs or biological samples. Real-time monitoring efforts must be well coordinated to ensure visual teams are available to respond to relatively rare detection events. If such coordination is not feasible, the cost of real-time efforts may not be worth the investment.

PAM is a powerful and efficient method for monitoring NARW distribution, though its capacity to provide insights is limited by several biological and physical factors that must be considered when designing a PAM network for the species. Calling rates vary among demographic groups and during different behaviors (Parks et al. 2014), such as quieter mother-calf pairs, which may result in lower detection probability in calving regions and along northbound migration routes. Detection probability also varies with different acoustic habitats, bathymetry, and recorders (e.g., Rice et al. 2014; Risch et al. 2014), highlighting the need to use consistent calibrated hardware and quantify detection range seasonally if aiming to use the data in quantitative analyses of NARW distribution, and especially if attempting to estimate NARW abundance using these data.

Aerial Surveys and Collection of Identification Photographs

Photo-identification studies are conducted by a number of groups independent of NMFS, including CCS, DFO, and the NEAq. These groups have consistently provided 50% or more of all photo identifications, and their efforts are essential to maintaining a high quality monitoring program for this population. Below, the Working Group provides a strawman survey plan based on the information provided to the Working Group (not informed by the analyses outlined above).

Specifically, the plan assumes continuation of the following efforts by NMFS partners:

- Vessel-based surveys in the Bay of Fundy, Roseway Basin, and in the Gulf of St. Lawrence by the NEAq
- Aerial surveys in Cape Cod Bay and areas adjacent to Cape Cod by CCS
- Aerial surveys in the Gulf of St. Lawrence by Canada DFO and Transport Canada

The evolution of the NEFSC survey effort- from broad-scale surveys, to specific survey boxes, to directed effort in areas of high capture rates- was sensible and highly successful at maximizing the collection of identification photographs. The NEFSC aerial surveys in recent years have often resulted in more than 200 identifications in a year (Appendix I, Table 1), but there is considerable overlap in identifications with other survey efforts, such as with CCS effort in Cape Cod Bay, and in 2017-2018 with DFO efforts in the Gulf of St. Lawrence (Appendix I, Table 4). The proportion of unique identifications attributable to NEFSC aerial surveys averages about 32% per year since 2002, though this identification rate has fallen by about 10% compared to the period of broad-scale surveys (~41%). There are many factors that may confound the rate of capturing unique identifications in recent years, including extent and distribution of survey effort and NARW distribution, and while the Working Group commends the significant NEFSC aerial efforts to collect identification photos, it recommends returning to broader scale surveys that would allow for identifying habitats being used by NARWs for the first time, return to historically used habitats, and presence of NARWs in high risk areas.

Underlying all of our survey recommendations is the premise that **photo-identification efforts should be designed and maintained to achieve a capture probability of approximately 90%.** A metric for measuring progress towards meeting this objective is the number of unique individuals sampled in a given year. The NEFSC endeavors to maximize the number of animals identified in a year for a given level of sampling effort by targeted sampling of high-density areas. In this way, roughly the same number of unique animals can be detected with significantly fewer flight hours. The Working Group supports this approach, though also recommends that sampling be designed to achieve a wide range of sample locations to reduce potential bias associated with geographic heterogeneity in capture probability among individuals.

The Working Group also recognizes that aerial photo-identification efforts represent a risk to survey personnel. The geographic coverage provided by aerial surveys should be weighed against the high value of data that may be collected using alternative platforms, such as surveys by surface vessels and the use of UAS launched from surface vessels. In particular, the use of UAS for collecting photographs may allow for reducing aerial survey effort for photo-identification. Mindful of the danger of aerial surveys, **the Working Group specifically does not recommend increasing aerial survey effort to achieve a higher than 90% capture probability** to monitor population abundance, trends, and vital rates. Effort reductions may be achieved by reducing the number of days allocated to return to high-density hotspots, and terminating effort there before a full plateau in the discovery curve. From discovery curves presented to the Working Group, it appears that ~1/3 to 1/4 of the survey effort in those locations results in obtaining only a few additional identifications. Of course, one cannot know when the discovery curve will plateau until it is observed. However, sufficient experience in the last few years exists to be able to make some predictions of how many days should be spent returning to a high-density area, in order to reduce the total number of flight days.

The Working Group considers this 90% metric to be cumulative across all data contributors and platforms, such that **the Working Group recommends additional efforts to coordinate identification of individuals across all data collectors** operating along the east coast throughout the survey year. This could be accomplished if survey teams were to determine NARW identities as soon as possible after detection by vessel or aerial surveys. These would ideally be entered into a shared near real-time updated list of unique NARWs identified by any survey platform during the year. When the collective effort from all surveys identifies a number of unique NARWs greater than 90% of the NARW abundance estimated for the previous year, aerial survey efforts should be reduced, or redirected to other tasks, including identifying and tracking dead or injured NARWs.

NARW distribution is likely to continue to vary in the future, and it is important that systematic surveys be conducted to recognize those changes when they occur. The Working Group approves of the current design, whereby key areas of known NARW aggregation are targeted (i.e., boxes in Figure 2) and survey effort is dynamically allocated in those areas until most or all the unique NARWs within them have been identified. However, **the Working Group recommends that this approach should be balanced by repeating broad-scale systematic surveys of the entire Gulf of Maine/Southern New England on a regular schedule**. The Working Group also notes that some boxes are no longer surveyed in some years, apparently because they have recently contained few or no NARWs (e.g., Jordan Basin in the middle of northern Gulf of Maine). The Working Group recommends that some effort continue in these areas, on an annual basis if possible. This could be accomplished by a lower density of aerial track lines or by a shift to passive acoustic recorders to, at least retrospectively, identify a return of NARWs to that habitat.

The following is an example of an aerial survey plan that accords with our recommendations.

(I) Conduct a broad-scale survey covering the Gulf of Maine and Southern New England every 3rd year.

The Working Group recommends that a broad-scale survey should be conducted every 3rd year. This timing balances detecting distributional shifts in a timely fashion with maintaining higher efficiency in obtaining NARW identifications in other years by focusing effort on high NARW density areas. The survey would be designed to provide data that could be used for modeling the spatial distribution of NARWs, by providing systematic uniform coverage of the survey area. These data would help identify and analyze major changes in NARW distribution and habitat use. This would ensure that emerging habitat hotspots have a high probability of being discovered relatively quickly so they can be included in future photo-identification surveys, and that emerging use of areas with high risk from vessel traffic or high density of fishing gear vertical lines would also be identified. At least two complete surveys should be completed, one in spring, and one in late summer/fall (September/October) to ensure surveys are not missing important areas being used by NARWs. The goal should not be to detect every single NARW in the survey area, rather to achieve a high probability of detecting areas being used by an appreciable number of NARWs.

The Working Group recognizes that conducting such broad-scale surveys could potentially consume all or a large percentage of available flight time in a year. To balance the need for information on broad-scale distribution with collecting identification photographs, a stratified design may be appropriate, where specific strata could be designated to have higher sampling intensity (e.g., more transect lines). Strata with higher sampling would be guided by those areas currently known to contain higher densities of NARWs, such as South of the Islands. The Working Group is aware that the NEAq is currently conducting aerial surveys south of Nantucket and Martha’s Vineyard, and that this effort is not captured in the present enumeration of unique identification photos by platform or area. That effort need not be replicated by NMFS to the extent that the NEAq continues to fly in that region and collect the data needed to assess overall distribution and abundance (i.e., identification photographs and effort information).

(II) In the two other years of a 3-year period, continue targeted photo-identification surveys, with modification to ensure some systematic components are maintained through time.

The Working Group is impressed by the efforts to increase the collection of identification photographs of NARWs from the NEFSC aerial surveys. It is clear that photographs from some locations are only collected from that platform, and every year these contain identifications of NARWs only seen in those areas. This especially includes the Great South Channel, the area north of the Great South Channel, north of Cape Cod Bay, the northern edge of Georges Bank, and the area South of the Islands. The Working Group encourages continuation of this work, and commend the NEFSC aerial survey team for their efforts.

The establishment (after the 2002-2006 broad-scale surveys) of designated survey boxes around hotspots was an excellent idea. The Working Group recommends maintaining consistent survey boxes through time to provide another source of long-term data to assess habitat use and NARW movements. It appears from examination of past survey efforts that the geographic boundaries of some surveyed boxes occasionally changes seasonally or annually. The Working Group recommends fixing the boundaries of the survey boxes and maintaining a single design of specified survey boxes. In particular, the Working Group recommends establishing a permanent survey box South of the Islands (Nantucket and Martha's Vineyard), to the south of Block Island, and in the New York shipping lane. This could include a partitioning into an eastern (south of Block Island) box and a western (south of Nantucket) box. The Working Group also notes that a large number of NARWs were seen in spring well to the south of the area typically surveyed (i.e., Nantucket shoal, or south of Block Island), close to the edge of the shelf break. The Working Group realizes this may be a newly discovered extension of this area, such that the 'permanent' box to be surveyed in the future may need to encompass this area, as well.

Further, as shown in Figure 3, there are several locations in the Gulf of Maine that are no longer surveyed in summer or fall because NARWs are no longer commonly seen there. The recommended broad-scale surveys will provide information from this area; however, additional effort in this historical hotspot would be worthwhile given the significant fishing effort there. Therefore, **the Working Group further recommends establishing a regular systematic rotation through all historical hotspots** and in all seasons previously detected. This could be accomplished by rotating among historical hotspots over the two years of targeted surveys between broad-scale surveys.

Finally, reiterating our recommendation related to improving the NARW habitat model, **the Working Group recommends working with all data contributors to develop standards for**

collecting a common data subset that may be instituted by all aerial survey efforts to facilitate maximal use of collected encounter and photo-identification data. Many aerial survey efforts provide identification photos that contribute to examining population demographics and distribution. With relatively little additional data recording effort, periods of survey efforts that are either systematic, opportunistic, or targeted may be identified, and the effort within each state tracked to allow for use of a border set of survey data within a robust quantitative habitat-modeling framework.

Data Collected on Vessel-Based Surveys

As much as possible, **the Working Group recommends substituting vessel-based effort for aerial effort**. The Working Group makes this recommendation for several reasons. First, for the safety of researchers, as cumulative time spent flying adds to cumulative risk. Second, genetic, some health assessment, and other biological sample data can only be collected from NARWs on the water. A monitoring plan that aims to provide appropriate data for monitoring individual and population health must include vessel-based survey and data collection efforts. Such efforts provide the only opportunity to collect biopsy samples for genetic and other tissue-based analyses, to fly UAS platforms for photogrammetry or blow sampling, and to allow for collection of fecal samples. **The Working Group recommends that vessel-based survey efforts be maintained at least at current levels, or increased to replace aerial survey effort, across all data contributors**. Expansion of boat-based UAS surveillance may be a viable replacement for some aerial survey effort though will require investment in vessel support. Vessel-based survey efforts are currently undertaken primarily by NMFS' partners. If partners are not able to continue vessel-based survey and data collection efforts, such efforts may need to be augmented by or funded by NMFS.

Work by Pettis et al. (2004) has shown that photo-identification images can be used for monitoring the health of individuals. There are also many powerful new techniques and methodologies that have become available in recent years. These include analyses of hormones, various 'Omics- including ribonucleic acid (RNA) transcriptomics for gene expression such as immune response and photogrammetry for examining body condition and identifying pregnant females. Although many of these analyses are not yet being undertaken on NARWs, every effort should be taken to accommodate the greatest range of future analytical approaches possible. **To that end, the Working Group recommends that biopsy samples be placed into small liquid nitrogen dry shippers immediately on collection**, to provide high quality genetic material that can be used for cutting edge methods such as RNA transcriptomics, but also archived for methods that have not yet been developed. Further, efforts to obtain biopsy samples from older calves should be prioritized so they can be genetically matched to samples from neonates in order to reduce age and sex uncertainty in assessment models.

At present, the majority of health assessments linked to survival are almost entirely based on photographs collected during vessel-based surveys. Through development and testing of various proxies, it may be feasible to determine overall health condition through use of aerial imagery, collected by airplane or UAS. As such, **the Working Group recommends a set of feasibility studies using imagery collected by UAS**. Lateral imagery taken from the vessel paired with aerial imagery collected by UAS for the same whale may provide for development of proxies measured from the aerial photographs for health metrics that are currently only derived from vessel-based photos. In particular, health assessments based on length and girth measurements made from aerial photographs would provide additional health data for a larger sample of NARWs than can currently be achieved by vessel-based photographs alone.

The Working Group members do not consider themselves experts in health assessment, and largely defer to input provided at the June 2019 Health Assessment Workshop. Beyond recommendations for maintaining vessel-based survey effort, the Working Group outlines two research projects it feels should be carried out to further health assessment studies on NARWs.

1. Examine whether body condition or skin condition assessments may provide an early indication of calf production. It is possible that years of low calf production would be preceded by periods of poor body of skin condition.
2. Determine appropriate and efficient biological sampling for establishing pregnancy rates.

Other Research Recommendations

In addition to the monitoring plan recommendations provided above, the Working Group identified several other research tools that could be used to assess NARW distribution and abundance.

Examination of Acoustic Records from the Northeast Atlantic and Adjacent Seas

Many researchers along the west coast of Europe and in the Mediterranean have deployed passive acoustic sensors to study a variety of cetacean and fish taxa. In addition, NARWs have been observed off the coast of France and the west coast of Europe and a portion of adjacent seas have been identified as regions of probable NARW habitat by Monsarrat et al. (2015). Although none of these sensors were deployed specifically to look for NARW calls, **the use of efficient and reliable automatic detectors could make such “needle in a haystack” analysis a relatively quick and possibly highly valuable task**.

Satellite Imagery

Recent progress has been made in using very high resolution (VHR) satellite imagery to study large whales in remote areas (e.g., Cubaynes et al. 2019) This approach could be useful for identifying new or previously undetected aggregation areas, particularly if any exist to the north of where current survey efforts exist. Spatially extrapolated areas of predicted occurrence would be a logical first area to explore with VHR imagery. **Satellite image data should be explored as a potential option for identifying NARWs and documenting distribution shifts**.

Tagging

It is clear that long-term location satellite tags could help provide valuable data about NARW habitat use, including discovery of unknown foraging areas, return to previously used forarging areas, and other shifts in distribution that might occur. It could also help estimate time spent by NARWs in high-risk areas, and could help further define important migration corridors. However, tag durations are still too short to provide the needed information without deploying deep implantation tags that embed in muscle tissue. Information presented to the Working Group indicated that Low Impact Minimally Percutaneous Electronic Transmitter (LIMPET) tags had fairly short durations and that the newly developed 'Blubber' tags, although better, in a test on eight Southern right whales, had a median duration of only 16 days, with a mean of 21 days (A. Zerbini. pers. comm.). The developers of the 'Blubber' tag are continuing research and modifications with a goal of trying to extend the median duration to 30 days.

Assuming a travel rate of ~75 nautical miles per day, it would take a NARW leaving Cape Cod Bay ~10 days to reach the Gulf of St Lawrence or southeast of Labrador, but about ~22 days to reach possible foraging areas southeast of Greenland, and even longer to reach Iceland. Migration from South of the Islands to Georgia would take ~11 days. Many of these movements cannot yet be fully documented via existing non-deep-implant tag technology. Documenting shorter distance movements, though potentially feasible, would require deployment of the tag within several days of departure to have a reasonable chance of documenting the journey, a logistical challenge for most research teams.

Given concerns about risk to these critically endangered whales from deep implantation tags, it seems reasonable to wait to evaluate whether the retention time can be increased for novel, less invasive tagging technologies (e.g., LIMPET tags, 'Blubber' tags, or other technologies) to the point where they can be used to answer the most pressing questions about NARW movement. **The Working Group recommends evaluating the results from Southern right whale tagging efforts before additional tagging of NARWs.**

V. Conclusions and Acknowledgements

The Working Group assembled by the NARW Steering Committee consisted of NMFS researchers with expertise in marine mammal monitoring and quantitative assessments, but not directly involved in current NARW monitoring efforts. The intent of assembling such a group was to provide a knowledgeable, but independent review of the past and current research efforts by NMFS and its partners, and from that, develop a comprehensive monitoring plan that was not influenced by a direct interest in the long-standing research efforts. The Working Group endeavored to consider the full range of monitoring options, while understanding funding and logistic constraints, the rationale for various research approaches, and the evolution of NARW research in the region. The Working Group did not attempt to conduct independent analyses or assessments of the vast wealth of NARW data available. The Working Group did its best to be as detailed as possible with recommendations in hopes that they will be helpful as NMFS considers how to move forward with NARW monitoring over the coming years.

The Working Group could not have accomplished their task without the direct input of several NMFS researchers from the NEFSC (Tim Cole, Lisa Conger, Richard Pace, Sofie Van Parijs), managers from NMFS' Greater Atlantic Regional Office (Diane Borggaard), NMFS Office of Protected Resources (Caroline Good), and DFO (Simon Nadeau) the NARW Steering Committee (Mike Asaro, Lance Garrison, Sean Hayes, Kristy Long, Eric Patterson, Barb Zoodsma, and see Appendix II) and other independent institutions and agencies dedicated to NARW research and conservation. NMFS and other research institutions and agencies have been working to understand many aspects of NARW biology, ecology, and the threats to the species for decades. The large and impressive collective effort and the cooperation among research groups should be applauded. It is the summary of this impressive effort and large dataset that provided the Working Group with a rich understanding of the rationale for past and current efforts, where efforts could be shifted while maintaining the high quality demographic dataset, and where new approaches or new analyses of existing data may provide new insights.

The Working Group has developed a set of recommendations that include retrospective analyses of existing datasets, expansion of the NARW habitat model, and specific recommendations for the design and execution of an integrated visual and PAM plan. Ideally, these recommendations will contribute to efficient and effective monitoring of important NARW population metrics, while also making those research efforts safer for the dedicated researchers who conduct them every year.

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APPENDIX I. TABLES

Table 1. Total number of NARWs identified by each contributing survey platform and institution from 2001 to 2017 (resights across contributors have not been removed, but resights of individuals within an institution have)[6]. Abbreviations are given in Section II. Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	NEFSC Aerial	NEFSC Vessel	CCS Aerial	SEUS Aerial	NEAq Vessel	DFO Aerial	All
2001	31	52	106	83	142	7	282
2002	206	89	96	58	115	20	303
2003	175	152	93	84	91	6	314
2004	118	21	91	76	154	1	286
2005	258	44	93	179	243	6	353
2006	188	0	121	135	225	6	347
2007	295	0	191	137	144	1	379
2008	288	115	200	188	176	0	389
2009	262	0	214	237	218	0	422
2010	267	111	182	225	102	1	422
2011	257	46	329	152	190	3	437
2012	183	169	236	59	86	8	374
2013	23	73	241	50	117	4	297
2014	134	62	262	49	83	21	371
2015	103	50	144	39	6	20	267
2016	140	31	195	30	97	49	323
2017	211	128	254	5	38	105	363

[6] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner*, Proposed retrospective analyses: A.

Table 2. Number of NARWs uniquely identified by only one survey platform and institution from 2001 to 2017 (NARWs sighted by more than one institution have been removed)[7]. Abbreviations are given in Section II. Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	NEFSC Aerial	NEFSC Vessel	CCS Aerial	SEUS Aerial	NEAq Vessel	DFO Aerial	All
2001	2	2	8	8	4	0	24
2002	40	11	5	4	6	0	66
2003	22	28	18	14	0	0	82
2004	28	5	14	16	21	1	85
2005	40	1	7	6	12	1	67
2006	38	0	9	15	22	0	84
2007	41	0	13	8	1	1	64
2008	56	3	17	5	6	0	87
2009	34	0	20	17	5	0	76
2010	43	5	10	24	2	0	84
2011	36	0	31	11	2	1	81
2012	44	19	43	5	5	1	117
2013	4	1	78	9	3	2	97
2014	27	1	74	11	1	5	119
2015	44	4	37	10	2	6	103
2016	35	0	39	5	11	14	104
2017	23	1	27	0	2	25	78

[7] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner*, Proposed retrospective analyses: A.

Table 3. Total number of NARWs identified in each survey location from 2001 to 2017 (resights across locations have not been removed, but resights of individuals within a location have)[8]. Abbreviations are for the Bay of Fundy (Fundy), Cape Cod Bay (CCB), the great south Channel (GSC), the Gulf of St. Lawrence (GoSL), the Gulf of Maine (GOM), and the southeastern United States (SEUS). Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	Fundy	CCB	GSC	GoSL	GOM	SEUS	All
2001	151	78	210	9	82	83	282
2002	145	20	207	20	98	58	303
2003	116	36	217	6	111	84	314
2004	108	61	160	1	76	76	286
2005	192	45	282	6	70	179	353
2006	113	66	99	6	190	135	347
2007	162	127	287	1	210	137	379
2008	183	180	227	0	193	188	389
2009	186	205	142	0	209	237	422
2010	86	136	178	1	243	225	422
2011	178	283	155	3	286	152	437
2012	53	192	98	8	230	59	374
2013	15	216	67	4	82	50	297
2014	108	247	111	21	98	49	371
2015	29	124	42	50	97	39	267
2016	120	180	110	50	98	30	323
2017	35	252	98	131	95	5	363

[8] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner*, Proposed retrospective analyses: A.

Table 4. Number of NARWs uniquely identified in only one survey location from 2001 to 2017 (NARWs sighted in multiple locations have been removed)[9]. Abbreviations are for the Bay of Fundy (Fundy), Cape Cod Bay (CCB), the great south Channel (GSC), the Gulf of St. Lawrence (GoSL), the Gulf of Maine (GOM), and the southeastern US (SEUS). Information provided by Richard M. Pace based on data collected by many individuals and institutions (see acknowledgements in Pace et al. 2017).

Year	Fundy	CCB	GSC	GoSL	GOM	SEUS	All
2001	13	2	55	1	5	8	84
2002	24	2	51	6	8	4	95
2003	7	4	71	3	21	14	120
2004	19	7	42	0	8	16	92
2005	10	3	44	1	8	6	72
2006	9	3	7	2	33	15	69
2007	8	1	42	0	14	8	73
2008	12	11	21	0	28	5	77
2009	4	20	11	0	23	17	75
2010	4	6	17	0	25	24	76
2011	5	19	8	0	25	11	68
2012	8	29	15	3	52	5	112
2013	3	83	16	2	9	9	122
2014	14	63	23	5	3	11	119
2015	7	33	18	17	15	10	100
2016	38	49	30	8	10	5	140
2017	2	52	7	16	1	0	78

[9] The data used to generate these tables were preliminary working datasets. The tables should be updated prior to use in future planning. Also see recommendations in *Objective 1. Optimize Aerial and Vessel Survey Effort to Ensure High Precision and Minimize Bias in Estimates of Survival, New Entrants, and Abundance in an Efficient Manner*, Proposed retrospective analyses: A.

APPENDIX II. WORKSHOP PARTICIPANTS AND CONTRIBUTORS

Table 5. List of workshop participants, contributors, affiliations, and role and contributions.

First	Last	Affiliation	Role and Contributions
Jason	Baker	Pacific Islands Fisheries Science Center	Working Group
Jay	Barlow	Southwest Fisheries Science Center	Working Group
Jeff	Moore	Southwest Fisheries Science Center	Working Group
Erin	Oleson	Pacific Island Fisheries Science Center	Working Group
Paul	Wade	Alaska Fisheries Science Center	Working Group
Mike	Asaro	Greater Atlantic Regional Fisheries Office	NARW Steering Committee, Workshop Organizer
Lance	Garrison	Southeast Fisheries Science Center	NARW Steering Committee, Workshop Organizer, Presenter, Participant, Report Editor
Sean	Hayes	Northeast Fisheries Science Center	NARW Steering Committee, Workshop Organizer, Presenter, Participant, Report Editor
Kristy	Long	Office of Protected Resources	NARW Steering Committee, Lead Workshop Organizer, Presenter, Participant, Report Editor
Eric	Patterson	Office of Protected Resources	NARW Steering Committee, Workshop Organizer, Report Editor
Barb	Zoodsma	Southeast Regional Office	NARW Steering Committee, Workshop Organizer, Participant, Report Editor
Diane	Borggaard	Greater Atlantic Regional Fisheries Office	Participant
Tim	Cole	Northeast Fisheries Science Center	Presenter
Lisa	Conger	Northeast Fisheries Science Center	Presenter
Caroline	Good	Office of Protected Resources	Presenter, Participant, Report Editor
Simon	Nadeau	Fisheries and Oceans Canada	Presenter
Richard	Pace	Northeast Fisheries Science Center	Presenter, Participant, Analytical Support
Sofie	Van Parijs	Northeast Fisheries Science Center	Presenter

APPENDIX III. WORKSHOP AGENDA

North Atlantic Right Whale Expert Working Group: Monitoring and Surveillance

October 22-24, 2019

Meeting Location:
NMFS Southwest Fisheries Science Center, Pacific Conf. Rm.
La Jolla, California

AGENDA

Meeting Goals

The primary goals of this meeting are to develop options for a comprehensive strategy to:

1. Monitor population status
    a. Estimate abundance
    b. Evaluate trends
    c. Estimate survival rates, birth rates, and other demographic parameters
2. Monitor distribution shifts and habitat use range-wide
3. Assess health of individuals and the population (e.g., identify causation/threats, assess sub-lethal effects) through biological sampling

The options should range from a minimally-acceptable effort (i.e., reduced precision) to the ideal, best case effort, while simultaneously considering cost effectiveness.

Objectives

The Working Group's specific tasks are to provide expert guidance to the North Atlantic Right Whale Steering Committee on how best to achieve the objectives below.

Population Status

- Identify the essential population demographic metrics (e.g., survival rate, birth rate, age at calving, calving rate, life span) the agency should use to track recovery of this species, including a description of why each metric is essential for monitoring the population status.
- Develop a monitoring/surveillance plan for each essential population metric identified above, including options for:

    - Sampling methods,
    - Data types,
    - Sampling locations (e.g., region and/or range-wide), and
    - Monitoring/survey frequencies.

Distribution and Habitat

- Determine approach for identifying:
    - Distribution, occurrence, habitat use in the mid-Atlantic region (i.e., west of 72° 30’ West, south of 40° 00’ North through 35° 30’ North (North Carolina))
    - Migratory corridor and associated physical and biological features in the mid-Atlantic
    - The unobserved portion of the population in time/space (i.e., “missing whales” not detected during aerial surveys in the northeast and southeast)
    - Where animals die
- Determine best methods for quantifying changes in occurrence and distribution (e.g., relative to a changing climate)
- Determine whether, and if so how, historic and current visual sightings data can be combined with passive acoustic detection data to assess past and current occurrence and distribution, and decadal-scale changes in distribution

Health Status

- Determine approach for identifying cause(s) or contributing factors for dead, injured, entangled animals and poor reproduction and poor health
- Determine approach for collecting:
    - Health assessment data, such as body condition and skin condition including scarring
    - Hormones for assessing reproductive state, stress, metabolism/energetics, nutritional state
    - Injury state (e.g., wounds, entanglements, skin lesions, etc.)

<u>DAY ONE: TUESDAY, OCTOBER 22</u>

8:30 AM **ARRIVALS AND GREETINGS**

8:45 AM **WELCOME AND INTRODUCTIONS**

9:00 AM **DESCRIBE MANAGEMENT NEEDS AND ASSOCIATED MEETING GOALS AND OBJECTIVES** (KRISTY LONG, OFFICE OF PROTECTED RESOURCES (OPR))

9:30 AM **<u>EVALUATE POPULATION STATUS</u>**

USING MARK RECAPTURE PHOTO-IDENTIFICATION DATA TO MONITOR ABUNDANCE AND EVALUATE TRENDS (RICHARD PACE, NEFSC) (15 MINUTES)

NORTHEAST - AERIAL & VESSEL SURVEYS (TIM COLE, NEFSC) (45 MINUTES)

- Describe all surveys (NMFS and partners) and purposes (e.g., mark recapture, entanglement status)
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying questions and discussion

10:30 AM **BREAK**

10:45 AM **SOUTHEAST & MID-ATLANTIC - AERIAL SURVEYS AND VESSEL-BASED EFFORTS** (LANCE GARRISON, SEFSC) (20 MINUTES)

- Describe surveys and purposes (e.g., calf production, biopsy efforts via vessels)
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying questions and discussion

INITIAL THOUGHTS AND REFLECTIONS (10 MINUTES)

11:15 AM **<u>ASSESSING HEALTH THROUGH BIOLOGICAL SAMPLING</u>**

VESSEL SURVEYS – NMFS AND PARTNERS (LISA CONGER, NEFSC) (45 MINUTES)

- Describe health-related data collection (e.g., photogrammetry, biopsies, scarring rates, etc.)
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying Questions and Discussion

12:00 pm **LUNCH (ORDER IN - CHEESE SHOP)**

1:00 PM **CANADIAN MONITORING AND SURVEILLANCE EFFORTS** (SIMON NADEAU, DFO)

1:45 PM **<u>DISTRIBUTION AND MONITORING</u>**

PASSIVE ACOUSTIC MONITORING OVERVIEW (SOFIE VAN PARIJS, NEFSC) (45 MINUTES)

- Describe projects and purposes
- Describe assets, methods, and data collected
- Describe projected Fiscal Year 2020 plans
- Clarifying Questions and Discussion

OVERVIEW OF TAGGING EFFORTS (SEAN HAYES, NEFSC) (30 MINUTES)

3:00 PM	**BREAK**
3:15 PM	**OVERVIEW OF RECENT MONITORING AND SURVEILLANCE EFFORTS** (CAROLINE GOOD, OPR)
3:45 PM	**OVERVIEW OF CURRENT FUNDING AND CAPACITY** (KRISTY LONG, OPR)
4:15 PM	**DISCUSS APPROACH FOR DEVELOPING COMPREHENSIVE MONITORING AND SURVEILLANCE PLAN(S)**
5:15 PM	**ADJOURN**
6:30 PM	**SOCIAL GATHERING** (HOSTED BY JAY BARLOW)

DAY TWO: WEDNESDAY, OCTOBER 23

8:30 AM	**ARRIVALS AND GREETINGS**
8:45 AM	**REVIEW DAY 1 AND PREVIEW DAY 2**
9:00 AM	**GROUP DISCUSSION AND DRAFTING (INCLUDING BREAK)**
12:00 PM	**LUNCH**
1:00 PM	**GROUP DISCUSSION AND DRAFTING (INCLUDING BREAK)**
5:00 PM	**REVIEW PROGRESS FROM DAY 2 AND PREVIEW DAY 3**
5:30 PM	**ADJOURN**

DAY THREE: THURSDAY, OCTOBER 24

8:30 AM	**ARRIVALS AND GREETINGS**

8:45 AM **GROUP DISCUSSION AND DRAFTING (INCLUDING BREAK)**

12:00 PM **LUNCH**

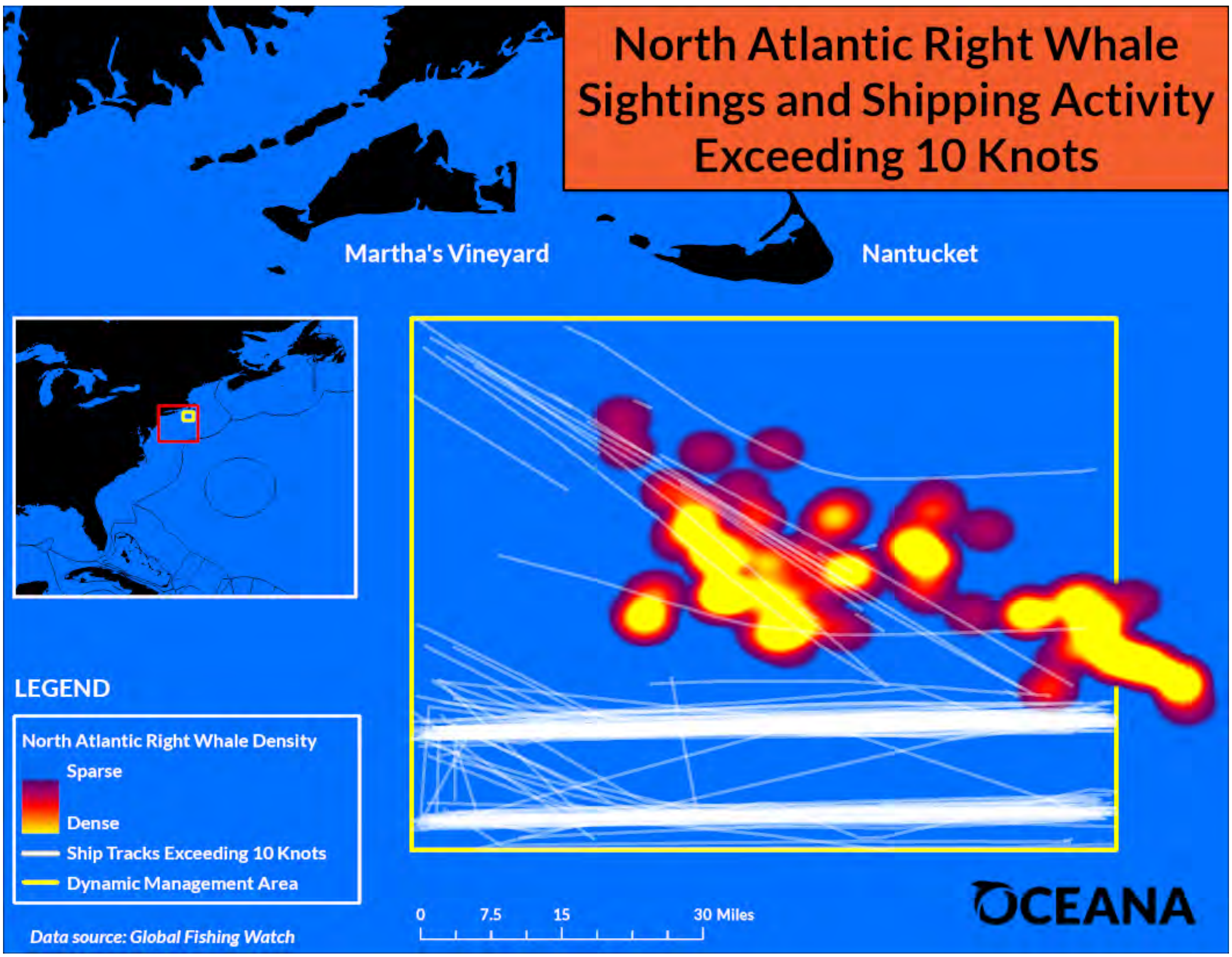
1:00 PM **REVIEW PROGRESS AND FINALIZE STRATEGY**

4:00 PM **WRAP-UP AND NEXT STEPS**

5:00 PM **ADJOURN**

REPORT | MARCH, 2020

Ships Ignore Voluntary Speed Zone Designed to Protect Endangered Right Whales



An Oceana analysis found ships ignoring a voluntary speed zone in an area south of Nantucket designed to protect endangered North Atlantic right whales, of which only about 400 remain. Between January 22 and March 6, 2020, more than 41% of the 446 ships in

400 remain. Between January 22 and March 6, 2020, more than 41% of the 446 ships in the area exceeded the voluntary speed limit of 10 knots, which was established by the National Oceanographic and Atmospheric Administration (NOAA) to reduce the risk of injury and death to these whales.

Studies have found that the speed of a ship is a major factor in ship-related collisions with North Atlantic right whales and that slowing ship speeds to less than 10 knots in areas where these whales may be encountered can reduce the risk of collisions by 86%.

- **Press Release**
- **Infographic**
- **Map** of vessel traffic over 10 knots in the Nantucket Dynamic Management Area between January 22 and March 6, 2020. North Atlantic right whale density information provided by NOAA Interactive North Atlantic Right Whale **Sightings Map**.
- **Vessel speed report in the** voluntary Dynamic Management Area
- **Vessel speed report in the** mandatory Seasonal Management Area

OCEANA

Vessel Speed Report in Voluntary DMA - United States

01/22/2020 - 03/06/2020

Along the eastern coast of the United States, there are numerous speed restriction zones for maritime vessels, known as Seasonal Management Areas (SMAs) and Dynamic Management Areas (DMAs). These are active throughout different times of the year and have been created to reduce the incidence of North Atlantic right whale ship strikes. Reduced speeds in these critical zones allows for the increased maneuverability around spotted whales, as well as increased survivability in the event of a strike. SMAs observe mandatory speed-restrictions of 10-knots when active, while DMAs observe voluntary 10-knot speed restrictions and are only activated when large aggregations of whales are spotted in a particular area.

Methods-

Using Global Fishing Watch, Oceana has compiled a list of vessels that exhibited speeds exceeding the voluntary 10-knot limit in active DMAs. The "Pings over 10 knots" column represents the number of distinct AIS signals above the 10-knot speed limit that were transmitted by a vessel inside the DMA on a given day, and the "Maximum speed" column represents the highest speed attained by that vessel on that particular day. In some cases, a vessel may have transmitted speeds in excess of 10 knots on separate days and will appear in the tables below as two entries but in the summary statistics, these are treated as one distinct vessel.

Data for the DMA/SMA report was pulled from Global Fishing Watch's (GFW) vessel database. The data was filtered to only include vessels that recorded at least two AIS signals in the timeframe of January 22, 2020 – March 6, 2020. Furthermore, the data was analyzed for erroneously high speeds, which were also removed. For example, if a ship's AIS recorded the following consecutive speeds: 11, 12, 11, 11, 38, 12, then the outlier would be removed from the data as an error. In some cases, a vessel's highest recorded AIS signal was cross-referenced with online resources and could be discounted as an error based on a large discrepancy between the AIS signal and the maximum attainable speed of that vessel.

To obtain the speed compliance value, the number of distinct vessels with at least two AIS signals and at least one AIS signal over 10 knots in the DMA was divided by the number of distinct vessels with at least five AIS signals in the DMA.

Results-

Number of distinct vessels traveling above 10 knots: **183**

Number of distinct vessels traveling through the DMA: **446**

Percent of vessels relative to all active vessels in the Nantucket DMA with a maximum speed over 10 knots: **41.03%**

Percent of U.S. vessels relative to all active vessels in the Nantucket DMA with a maximum speed over 10 knots: **4.04%**

Fastest observed vessel speed in the Nantucket DMA: **22.2**

Distinct Speed Events Over 10 Knots

Class	Length (meters)	Flag	Day	Pings over 10 knots	Maximum speed (knots)
cargo	215.48	France	2020-01-22	28	20.3
cargo	204.54	Norway	2020-01-22	36	16.7
cargo	252.68	United Kingdom	2020-01-22	7	15.4
tanker	124.34	Marshall Islands	2020-01-22	29	13.2
tanker	145.41	Denmark	2020-01-22	5	13.0
cargo or tanker	115.02	Norway	2020-01-22	25	11.6
fishing	28.06	United States	2020-01-22	2	10.3
other purse seines	33.05	United States	2020-01-22	2	10.2
cargo	166.61	Panama	2020-01-23	30	19.1
cargo	239.80	Singapore	2020-01-23	31	18.9
cargo	226.62	United Kingdom	2020-01-23	36	17.5
cargo	199.45	Panama	2020-01-23	46	17.0
tanker	183.00	Hong Kong	2020-01-23	71	14.6
cargo	282.97	Japan	2020-01-23	53	13.1

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tanker	145.41	Denmark	2020-01-23	9	12.5
tanker	178.95	The Bahamas	2020-01-23	10	11.5
pole and line	33.65	United States	2020-01-23	2	10.6
non fishing	39.96	United States	2020-01-23	13	10.6
other purse seines	33.05	United States	2020-01-23	5	10.5
tanker	158.26	Japan	2020-01-23	3	10.2
cargo	245.76	Panama	2020-01-24	25	20.2
cargo	203.82	Germany	2020-01-24	48	16.9
cargo	226.62	United Kingdom	2020-01-24	14	16.7
tanker	152.16	Liberia	2020-01-24	60	14.5
cargo	214.22	Israel	2020-01-24	16	12.7
cargo	171.16	Marshall Islands	2020-01-24	52	12.3
tanker	152.44	Singapore	2020-01-24	26	12.3
cargo	239.83	Denmark	2020-01-25	39	18.0
cargo	196.19	Malta	2020-01-25	29	17.5
cargo	213.00	China	2020-01-25	3	16.8
cargo	192.86	Panama	2020-01-25	65	16.6
cargo	136.81	Hong Kong	2020-01-25	54	12.0
cargo	120.13	Malta	2020-01-25	20	11.7
cargo	193.23	Panama	2020-01-25	73	10.9
cargo	213.03	Panama	2020-01-25	2	10.2
cargo	187.23	Panama	2020-01-26	32	22.0
cargo	270.68	Denmark	2020-01-26	22	15.1
cargo	191.55	Cyprus	2020-01-26	13	14.5
cargo	212.63	Liberia	2020-01-27	34	18.2
cargo	286.53	United States	2020-01-27	22	17.6
cargo	162.82	Italy	2020-01-27	8	16.8
cargo	227.98	Germany	2020-01-27	37	13.2
tanker	100.74	Germany	2020-01-27	42	12.3
tanker	183.06	Marshall Islands	2020-01-27	33	11.7
tanker	162.51	Marshall Islands	2020-01-27	13	11.1
cargo	214.51	Hong Kong	2020-01-27	7	10.4
cargo	190.00	Singapore	2020-01-27	31	10.4
cargo	208.17	United Kingdom	2020-01-28	10	16.8
cargo	167.84	Panama	2020-01-28	33	16.0
tanker	146.84	Marshall Islands	2020-01-28	70	15.8
cargo	186.64	Liberia	2020-01-28	24	15.3
cargo	212.20	Liberia	2020-01-28	41	12.7
cargo	179.08	Panama	2020-01-28	2	12.2
tanker	145.40	Cayman Islands	2020-01-28	4	11.7
pole and line	33.36	United States	2020-01-28	4	10.9
tanker	138.36	Marshall Islands	2020-01-29	30	14.5
tanker	162.63	Denmark	2020-01-29	3	14.2
cargo	147.21	Liberia	2020-01-29	12	13.8
cargo	179.08	Panama	2020-01-29	3	12.0
tanker	145.40	Cayman Islands	2020-01-29	32	11.8

cargo	167.35	Singapore	2020-01-30	22	15.7
cargo	192.40	Marshall Islands	2020-01-30	32	14.4
cargo	192.87	Panama	2020-01-30	34	12.4
cargo	170.28	Panama	2020-01-31	20	17.8
tanker	152.16	Liberia	2020-01-31	26	14.1
cargo	239.91	Liberia	2020-01-31	2	13.4
tanker	138.12	Marshall Islands	2020-01-31	20	13.2
cargo	217.26	Hong Kong	2020-02-01	52	16.4
cargo	161.66	Panama	2020-02-01	33	12.5
tanker	146.71	Marshall Islands	2020-02-01	40	12.3
tanker	162.51	Marshall Islands	2020-02-01	16	11.2
seismic vessel	70.00	Panama	2020-02-01	3	10.9
cargo	184.86	Liberia	2020-02-02	24	20.8
cargo	335.63	Liberia	2020-02-02	52	18.4
cargo	294.10	Marshall Islands	2020-02-02	20	17.9
tanker	104.66	Malta	2020-02-02	35	16.9
cargo	227.01	Denmark	2020-02-02	36	16.1
cargo	206.79	Liberia	2020-02-02	26	14.7
tanker	150.00	Marshall Islands	2020-02-02	33	12.4
tanker	183.06	Marshall Islands	2020-02-02	11	11.7
cargo	205.91	Taiwan	2020-02-02	67	11.6
tanker	121.18	Marshall Islands	2020-02-02	36	11.6
tanker	138.12	Marshall Islands	2020-02-02	66	11.1
seismic vessel	70.00	Panama	2020-02-02	5	10.3
cargo	214.43	Hong Kong	2020-02-03	46	19.7
cargo	199.96	The Bahamas	2020-02-03	50	11.8
pole and line	33.36	United States	2020-02-03	2	10.6
cargo	253.59	Marshall Islands	2020-02-04	4	18.6
cargo	223.99	United Kingdom	2020-02-04	34	16.6
pots and traps	26.54	United States	2020-02-04	35	12.1
tanker	142.32	Italy	2020-02-05	44	16.9
cargo	242.96	Panama	2020-02-05	65	14.6
cargo	181.73	Panama	2020-02-05	4	11.3
cargo or tanker	126.84	Canada	2020-02-06	40	12.1
tanker	144.16	Marshall Islands	2020-02-06	11	10.2
cargo	181.73	Panama	2020-02-07	62	16.4
tanker	147.72	Barbados	2020-02-07	39	13.9
tanker	178.95	The Bahamas	2020-02-07	25	13.2
cargo or tanker	103.81	Malta	2020-02-07	4	10.8
cargo	191.16	Sweden	2020-02-08	4	15.7
cargo	242.11	Liberia	2020-02-08	17	14.0
cargo or tanker	103.81	Malta	2020-02-08	3	11.3
cargo	242.11	Liberia	2020-02-09	9	17.1
tanker	152.16	Liberia	2020-02-09	8	13.8
cargo	185.71	Liberia	2020-02-09	24	13.5
cargo	293.53	United States	2020-02-09	39	13.2

cargo	115.21	Netherlands	2020-02-09	13	13.1
pole and line	33.65	United States	2020-02-09	2	10.3
cargo	195.44	United States	2020-02-10	46	16.5
tanker	152.16	Liberia	2020-02-10	15	14.0
tanker	151.84	NA	2020-02-10	41	12.9
cargo	223.99	United Kingdom	2020-02-11	20	19.2
tanker	206.21	United States	2020-02-11	41	15.7
cargo or tanker	126.84	Canada	2020-02-11	37	13.0
tanker	152.44	Singapore	2020-02-11	53	12.9
cargo	147.21	Liberia	2020-02-11	11	12.2
tanker	146.71	Marshall Islands	2020-02-11	28	11.1
cargo	214.87	Singapore	2020-02-12	10	19.4
cargo	198.14	Malta	2020-02-12	29	16.7
cargo	163.11	Germany	2020-02-13	46	18.9
cargo	164.65	Norway	2020-02-13	20	16.7
cargo	180.17	Panama	2020-02-13	24	13.0
cargo	157.55	Canada	2020-02-13	23	11.9
cargo	228.76	Malta	2020-02-14	36	17.0
cargo	181.10	United Kingdom	2020-02-14	44	16.8
tanker	146.71	Marshall Islands	2020-02-14	39	12.5
cargo	114.80	Philippines	2020-02-14	28	12.2
cargo	233.29	Hong Kong	2020-02-15	23	18.9
cargo	240.95	Marshall Islands	2020-02-15	38	15.3
cargo	170.28	Panama	2020-02-15	24	13.8
tanker	156.02	Liberia	2020-02-15	12	13.6
cargo	253.50	Denmark	2020-02-15	3	13.4
tanker	152.36	Marshall Islands	2020-02-15	9	10.4
cargo	203.73	Liberia	2020-02-16	61	20.5
cargo	204.54	Norway	2020-02-16	48	16.4
cargo	199.90	Panama	2020-02-16	5	16.1
cargo	225.74	United Kingdom	2020-02-16	17	16.1
tanker	156.02	Liberia	2020-02-16	4	13.7
cargo	216.45	Israel	2020-02-16	13	13.3
tanker	131.54	Liberia	2020-02-16	18	13.1
tanker	145.94	Denmark	2020-02-16	2	12.2
cargo	181.20	Cyprus	2020-02-16	23	12.1
cargo	293.53	United States	2020-02-17	18	17.9
cargo	185.23	Marshall Islands	2020-02-17	54	16.1
tanker	145.94	Denmark	2020-02-17	5	12.8
NA	28.00	United States	2020-02-17	3	11.3
pole and line	33.65	United States	2020-02-17	3	10.5
NA	28.00	United States	2020-02-18	2	10.1
cargo	217.77	Singapore	2020-02-19	65	19.4
cargo	116.93	Marshall Islands	2020-02-19	7	10.4
tanker	143.72	Marshall Islands	2020-02-20	11	11.0
cargo	129.15	Panama	2020-02-20	7	10.6

cargo	232.10	Hong Kong	2020-02-21	17	20.3
cargo	209.36	Malta	2020-02-21	15	15.9
cargo	163.06	Italy	2020-02-21	56	15.1
tanker	131.54	Liberia	2020-02-21	63	12.4
tanker	143.72	Marshall Islands	2020-02-21	4	10.9
pots and traps	28.00	United States	2020-02-21	4	10.5
cargo	259.87	Liberia	2020-02-21	3	10.1
cargo	174.41	Germany	2020-02-22	7	19.1
cargo	194.12	Liberia	2020-02-22	9	18.1
cargo	198.19	Malta	2020-02-22	13	17.8
cargo	228.15	Germany	2020-02-22	30	13.9
tanker	134.76	Marshall Islands	2020-02-22	19	12.9
cargo	130.79	Cyprus	2020-02-22	17	12.2
pots and traps	28.00	United States	2020-02-22	9	10.7
tanker	152.36	Marshall Islands	2020-02-22	45	10.4
cargo	194.12	Liberia	2020-02-23	43	18.7
cargo	117.09	Netherlands	2020-02-23	8	16.1
cargo	134.25	Portugal	2020-02-23	32	13.9
tanker	145.94	Denmark	2020-02-23	14	13.9
cargo	293.53	United States	2020-02-23	41	13.2
tanker	154.21	Malta	2020-02-23	48	13.0
tanker	110.45	Canada	2020-02-23	8	12.7
pots and traps	28.00	United States	2020-02-23	38	12.6
cargo	204.24	Hong Kong	2020-02-23	33	12.1
cargo	130.79	Cyprus	2020-02-23	8	11.7
tanker	145.81	Hong Kong	2020-02-23	7	10.2
cargo	196.71	Panama	2020-02-24	22	22.2
cargo	200.04	Cyprus	2020-02-24	63	14.7
cargo	293.53	United States	2020-02-24	6	13.7
tanker	110.45	Canada	2020-02-24	37	12.6
cargo	183.43	Japan	2020-02-24	6	12.6
cargo	204.24	Hong Kong	2020-02-24	52	12.3
tanker	178.95	The Bahamas	2020-02-24	40	12.2
NA	28.00	United States	2020-02-24	7	11.1
cargo	186.64	Liberia	2020-02-25	40	16.6
cargo	294.10	Marshall Islands	2020-02-25	33	15.8
cargo	293.53	United States	2020-02-25	17	14.0
cargo	147.21	Liberia	2020-02-25	3	12.2
tanker	144.80	Singapore	2020-02-25	6	11.9
NA	28.00	United States	2020-02-25	3	10.9
pole and line	33.65	United States	2020-02-25	5	10.7
tanker	156.19	Panama	2020-02-25	14	10.3
cargo	199.45	Panama	2020-02-26	45	20.8
cargo	181.64	China	2020-02-26	33	18.4
cargo	276.03	Liberia	2020-02-26	19	18.0
tanker	178.95	The Bahamas	2020-02-26	3	13.7

cargo	147.21	Liberia	2020-02-26	22	12.4
cargo	235.36	Japan	2020-02-26	20	12.0
cargo	120.31	Panama	2020-02-26	3	10.6
cargo	349.00	Liberia	2020-02-27	27	16.2
cargo	165.86	Hong Kong	2020-02-27	36	15.1
tanker	178.95	The Bahamas	2020-02-27	13	13.5
tanker	110.45	Canada	2020-02-27	31	12.6
cargo	124.26	Marshall Islands	2020-02-27	54	11.3
cargo	215.48	France	2020-02-28	20	18.3
tanker	145.22	Singapore	2020-02-28	50	13.4
tanker	145.40	Cayman Islands	2020-02-28	39	13.3
cargo	186.11	Singapore	2020-02-28	21	11.6
drifting longlines	23.97	United States	2020-02-28	2	11.2
cargo	227.28	United Kingdom	2020-02-29	4	15.7
cargo	223.69	France	2020-02-29	34	15.7
non fishing	135.65	Malta	2020-02-29	22	13.5
tanker	183.06	Panama	2020-02-29	17	13.1
tanker	143.10	Denmark	2020-02-29	47	13.0
cargo	138.10	Germany	2020-02-29	27	11.9
cargo	123.42	Netherlands	2020-02-29	22	11.7
cargo	230.54	Singapore	2020-03-01	37	17.1
cargo	151.75	Singapore	2020-03-01	38	15.8
cargo	234.28	Hong Kong	2020-03-01	44	13.4
non fishing	135.65	Malta	2020-03-01	21	13.3
tanker	134.39	Marshall Islands	2020-03-01	23	13.1
cargo	293.53	United States	2020-03-01	28	13.0
cargo	142.54	Germany	2020-03-01	16	11.7
tanker	135.99	Liberia	2020-03-01	22	11.2
cargo	191.10	Liberia	2020-03-01	17	11.2
cargo	232.73	Malta	2020-03-02	39	18.8
cargo	161.66	Panama	2020-03-02	24	17.4
tanker	178.95	The Bahamas	2020-03-02	25	14.7
tanker	145.94	Denmark	2020-03-02	11	14.1
tanker	120.87	Malta	2020-03-02	30	12.8
cargo	169.84	Germany	2020-03-02	13	12.1
NA	28.00	United States	2020-03-02	7	10.8
cargo	213.68	Panama	2020-03-03	52	18.0
tanker	145.94	Denmark	2020-03-03	23	13.7
tanker	150.92	Liberia	2020-03-03	36	12.8
cargo	166.26	Panama	2020-03-03	21	12.7
non fishing	69.31	United States	2020-03-03	2	10.2
cargo	206.28	Taiwan	2020-03-04	13	18.4
cargo	238.95	Liberia	2020-03-04	40	16.5
cargo	208.17	United Kingdom	2020-03-04	2	13.1
cargo	166.26	Panama	2020-03-04	6	12.6
cargo	208.17	United Kingdom	2020-03-05	27	13.9

cargo	184.43	Denmark	2020-03-05	8	13.5
tanker	134.39	Marshall Islands	2020-03-05	60	11.5
tanker	103.84	Denmark	2020-03-05	62	11.0
cargo or tanker	126.84	Canada	2020-03-05	8	10.4
tanker	152.44	Singapore	2020-03-06	74	14.7
tanker	147.72	Barbados	2020-03-06	38	13.0
tanker	159.11	Liberia	2020-03-06	32	11.5

Vessels with Maximum Speeds Between 10-11.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
cargo	157.55	Canada	11.9
tanker	144.80	Singapore	11.9
cargo	138.10	Germany	11.9
cargo	199.96	The Bahamas	11.8
cargo	120.13	Malta	11.7
tanker	183.06	Marshall Islands	11.7
cargo	123.42	Netherlands	11.7
cargo	142.54	Germany	11.7
cargo or tanker	115.02	Norway	11.6
cargo	205.91	Taiwan	11.6
tanker	121.18	Marshall Islands	11.6
cargo	186.11	Singapore	11.6
tanker	159.11	Liberia	11.5
cargo or tanker	103.81	Malta	11.3
NA	28.00	United States	11.3
cargo	124.26	Marshall Islands	11.3
tanker	162.51	Marshall Islands	11.2
drifting longlines	23.97	United States	11.2
tanker	135.99	Liberia	11.2
cargo	191.10	Liberia	11.2
tanker	143.72	Marshall Islands	11.0
tanker	103.84	Denmark	11.0
cargo	193.23	Panama	10.9
pole and line	33.36	United States	10.9
seismic vessel	70.00	Panama	10.9
pole and line	33.65	United States	10.7
non fishing	39.96	United States	10.6
cargo	129.15	Panama	10.6
cargo	120.31	Panama	10.6
other purse seines	33.05	United States	10.5
cargo	214.51	Hong Kong	10.4
cargo	190.00	Singapore	10.4
tanker	152.36	Marshall Islands	10.4
cargo	116.93	Marshall Islands	10.4

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fishing	28.06	United States	10.3
tanker	156.19	Panama	10.3
tanker	158.26	Japan	10.2
cargo	213.03	Panama	10.2
tanker	144.16	Marshall Islands	10.2
tanker	145.81	Hong Kong	10.2
non fishing	69.31	United States	10.2
cargo	259.87	Liberia	10.1

Vessels with Maximum Speeds Between 12-13.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
tanker	147.72	Barbados	13.9
cargo	228.15	Germany	13.9
cargo	134.25	Portugal	13.9
cargo	147.21	Liberia	13.8
tanker	156.02	Liberia	13.7
cargo	185.71	Liberia	13.5
non fishing	135.65	Malta	13.5
cargo	184.43	Denmark	13.5
cargo	239.91	Liberia	13.4
cargo	253.50	Denmark	13.4
tanker	145.22	Singapore	13.4
cargo	234.28	Hong Kong	13.4
cargo	216.45	Israel	13.3
tanker	145.40	Cayman Islands	13.3
tanker	124.34	Marshall Islands	13.2
cargo	227.98	Germany	13.2
tanker	138.12	Marshall Islands	13.2
cargo	293.53	United States	13.2
cargo	293.53	United States	13.2
cargo	282.97	Japan	13.1
cargo	115.21	Netherlands	13.1
tanker	131.54	Liberia	13.1
tanker	183.06	Panama	13.1
tanker	134.39	Marshall Islands	13.1
tanker	145.41	Denmark	13.0
cargo or tanker	126.84	Canada	13.0
cargo	180.17	Panama	13.0
tanker	154.21	Malta	13.0
tanker	143.10	Denmark	13.0
cargo	293.53	United States	13.0
tanker	151.84	NA	12.9
tanker	134.76	Marshall Islands	12.9
tanker	120.87	Malta	12.8

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tanker	150.92	Liberia	12.8
cargo	214.22	Israel	12.7
cargo	212.20	Liberia	12.7
tanker	110.45	Canada	12.7
cargo	166.26	Panama	12.7
pots and traps	28.00	United States	12.6
cargo	183.43	Japan	12.6
tanker	146.71	Marshall Islands	12.5
cargo	192.87	Panama	12.4
tanker	150.00	Marshall Islands	12.4
cargo	171.16	Marshall Islands	12.3
tanker	100.74	Germany	12.3
cargo	204.24	Hong Kong	12.3
cargo	179.08	Panama	12.2
cargo	114.80	Philippines	12.2
cargo	130.79	Cyprus	12.2
pots and traps	26.54	United States	12.1
cargo	181.20	Cyprus	12.1
cargo	169.84	Germany	12.1
cargo	136.81	Hong Kong	12.0
cargo	235.36	Japan	12.0

Vessels with Maximum Speeds Between 14-15.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
cargo	209.36	Malta	15.9
tanker	146.84	Marshall Islands	15.8
cargo	151.75	Singapore	15.8
cargo	167.35	Singapore	15.7
cargo	191.16	Sweden	15.7
tanker	206.21	United States	15.7
cargo	227.28	United Kingdom	15.7
cargo	223.69	France	15.7
cargo	252.68	United Kingdom	15.4
cargo	240.95	Marshall Islands	15.3
cargo	270.68	Denmark	15.1
cargo	163.06	Italy	15.1
cargo	165.86	Hong Kong	15.1
cargo	206.79	Liberia	14.7
cargo	200.04	Cyprus	14.7
tanker	178.95	The Bahamas	14.7
tanker	152.44	Singapore	14.7
tanker	183.00	Hong Kong	14.6
cargo	242.96	Panama	14.6

tanker	152.16	Liberia	14.5
cargo	191.55	Cyprus	14.5
tanker	138.36	Marshall Islands	14.5
cargo	192.40	Marshall Islands	14.4
tanker	162.63	Denmark	14.2
tanker	145.94	Denmark	14.1
cargo	293.53	United States	14.0

Vessels with Maximum Speeds Between 16-17.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
cargo	294.10	Marshall Islands	17.9
cargo	293.53	United States	17.9
cargo	170.28	Panama	17.8
cargo	198.19	Malta	17.8
cargo	286.53	United States	17.6
cargo	226.62	United Kingdom	17.5
cargo	196.19	Malta	17.5
cargo	161.66	Panama	17.4
cargo	242.11	Liberia	17.1
cargo	230.54	Singapore	17.1
cargo	228.76	Malta	17.0
cargo	203.82	Germany	16.9
tanker	104.66	Malta	16.9
tanker	142.32	Italy	16.9
cargo	213.00	China	16.8
cargo	162.82	Italy	16.8
cargo	208.17	United Kingdom	16.8
cargo	181.10	United Kingdom	16.8
cargo	204.54	Norway	16.7
cargo	198.14	Malta	16.7
cargo	164.65	Norway	16.7
cargo	192.86	Panama	16.6
cargo	186.64	Liberia	16.6
cargo	195.44	United States	16.5
cargo	238.95	Liberia	16.5
cargo	217.26	Hong Kong	16.4
cargo	181.73	Panama	16.4

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cargo	349.00	Liberia	16.2
cargo	227.01	Denmark	16.1
cargo	199.90	Panama	16.1
cargo	225.74	United Kingdom	16.1
cargo	185.23	Marshall Islands	16.1
cargo	117.09	Netherlands	16.1
cargo	167.84	Panama	16.0

Vessels with Maximum Speeds Between 18-19.99 knots

Class	Length (meters)	Flag	Maximum speed (knots)
cargo	214.43	Hong Kong	19.7
cargo	214.87	Singapore	19.4
cargo	217.77	Singapore	19.4
cargo	223.99	United Kingdom	19.2
cargo	166.61	Panama	19.1
cargo	174.41	Germany	19.1
cargo	239.80	Singapore	18.9
cargo	163.11	Germany	18.9
cargo	233.29	Hong Kong	18.9
cargo	232.73	Malta	18.8
cargo	194.12	Liberia	18.7
cargo	253.59	Marshall Islands	18.6
cargo	335.63	Liberia	18.4
cargo	181.64	China	18.4
cargo	206.28	Taiwan	18.4
cargo	212.63	Liberia	18.2
cargo	239.83	Denmark	18.0
cargo	276.03	Liberia	18.0
cargo	213.68	Panama	18.0

Vessels with Maximum Speeds Greater Than or Equal to 20 knots

Class	Length (meters)	Flag	Maximum speed (knots)
cargo	196.71	Panama	22.2
cargo	187.23	Panama	22.0
cargo	184.86	Liberia	20.8
cargo	199.45	Panama	20.8
cargo	203.73	Liberia	20.5
cargo	215.48	France	20.3

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cargo	232.10	Hong Kong	20.3
cargo	245.76	Panama	20.2

Vessel Classification with Speed Events over 10 Knots

Vessel class	10-11.99 knots	12-13.99 knots	14-15.99 knots	16-17.99 knots	18-19.99 knots	Greater than or equal to 20 knots	Total	Percentage of Vessels
Cargo	18	30	17	32	19	8	124	67.76
Tanker	13	20	9	2	0	0	44	24.04
Fishing	2	1	0	0	0	0	3	3.83
Cargo or tanker	2	1	0	0	0	0	3	1.64
Non fishing	2	1	0	0	0	0	3	1.64
Seismic vessel	1	0	0	0	0	0	1	0.55
N/A	1	0	0	0	0	0	1	0.55

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Vessel Speed Report in Mandatory SMA - United States

01/22/2020 - 03/06/2020

Along the eastern coast of the United States, there are numerous speed restriction zones for maritime vessels, known as Seasonal Management Areas (SMAs) and Dynamic Management Areas (DMAs). These are active throughout different times of the year and have been created to reduce the incidence of North Atlantic right whale ship strikes. Reduced speeds in these critical zones allows for the increased maneuverability around spotted whales, as well as increased survivability in the event of a strike. SMAs observe mandatory speed-restrictions of 10-knots when active, while DMAs observe voluntary 10-knot speed restrictions and are only activated when large aggregations of whales are spotted in a particular area.

Methods-

Using Global Fishing Watch, Oceana has compiled a list of vessels that exhibited speeds exceeding the voluntary 10-knot limit in active DMAs. The "Pings over 10 knots" column represents the number of distinct AIS signals above the 10-knot speed limit that were transmitted by a vessel inside the DMA on a given day, and the "Maximum Speed" column represents the highest speed attained by that vessel on that particular day. In some cases, a vessel may have transmitted speeds in excess of 10 knots on separate days and will appear in the tables below as two entries but in the summary statistics, these are treated as one distinct vessel.

Data for the DMA/SMA report was pulled from Global Fishing Watch's (GFW) vessel database. The data was filtered to only include vessels that recorded at least two AIS signals in the timeframe of January 22, 2020 – March 6, 2020. Furthermore, the data was analyzed for erroneously high speeds, which were also removed. For example, if a ship's AIS recorded the following consecutive speeds: 11, 12, 11, 11, 38, 12, then the outlier would be removed from the data as an error. In some cases, a vessel's highest recorded AIS signal was cross-referenced with online resources and could be discounted as an error based on a large discrepancy between the AIS signal and the maximum attainable speed of that vessel.

To obtain the speed compliance value, the number of distinct vessels with at least two AIS signals and at least one AIS signal over 10 knots in the DMA was divided by the number of distinct vessels with at least five AIS signals in the DMA.

Results-

Number of distinct vessels traveling above 10 knots: **60**

Number of distinct vessels traveling through the SMA: **516**

Percent of vessels relative to all active vessels in the Block Island SMA with a maximum speed over 10 knots: **11.63%**

Percent of U.S. vessels relative to all active vessels in the Block Island SMA with a maximum speed over 10 knots: **5.04%**

Fastest observed vessel speed in the Block Island SMA: **20.9**

Distinct Speed Events Over 10 Knots

Class	Length (meters)	Flag	Day	Pings over 10 knots	Maximum speed (knots)
pots and traps	44.18	United States	2020-01-19	35	12.6
tanker	150.46	Singapore	2020-01-20	5	10.4
seismic vessel	70.00	Panama	2020-01-20	10	10.3
tug	34.46	United States	2020-01-20	2	10.6
non fishing	67.08	United States	2020-01-21	3	10.2
tanker	150.46	Singapore	2020-01-21	8	10.3
cargo	111.23	Marshall Islands	2020-01-21	7	11.4
cargo	113.46	Marshall Islands	2020-01-22	3	10.2
tanker	138.36	Marshall Islands	2020-01-22	7	10.2
non fishing	39.96	United States	2020-01-22	5	10.2
non fishing	39.96	United States	2020-01-23	7	10.4
tanker	124.34	Marshall Islands	2020-01-23	3	10.4
tanker	183.00	Hong Kong	2020-01-23	9	10.4
non fishing	39.96	United States	2020-01-24	22	10.6
passenger	27.43	United States	2020-01-24	4	10.4

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NA	28.00	United States	2020-01-24	2	10.5
patrol vessel	30.92	United States	2020-01-25	6	12.0
non fishing	43.00	United States	2020-01-25	4	10.2
cargo	193.23	Panama	2020-01-25	2	10.1
passenger	30.61	United States	2020-01-25	7	14.1
cargo	162.82	Italy	2020-01-27	5	10.2
patrol vessel	73.56	United States	2020-01-27	8	17.0
cargo	190.00	Singapore	2020-01-28	12	10.7
supply vessel	58.02	United Kingdom	2020-01-28	3	11.3
passenger	38.46	United States	2020-01-28	3	19.7
tanker	135.49	Marshall Islands	2020-01-28	9	10.2
NA	21.97	United States	2020-01-28	4	10.4
other purse seines	33.05	United States	2020-01-29	2	10.4
fishing	31.64	United States	2020-01-29	3	10.7
other purse seines	33.05	United States	2020-01-30	4	10.5
fishing	31.64	United States	2020-01-30	4	11.0
cargo	111.23	Marshall Islands	2020-01-30	26	12.7
cargo	136.81	Hong Kong	2020-01-31	2	10.2
cargo	136.81	Hong Kong	2020-02-01	2	11.5
seismic vessel	70.00	Panama	2020-02-01	27	10.8
passenger	38.46	United States	2020-02-01	8	20.9
non fishing	56.00	United States	2020-02-02	9	11.2
NA	21.97	United States	2020-02-02	9	10.6
cargo	103.94	Netherlands	2020-02-03	12	11.0
NA	21.97	United States	2020-02-03	7	10.7
supply vessel	58.02	United Kingdom	2020-02-04	3	10.1
pots and traps	26.54	United States	2020-02-04	5	10.3
tanker	142.32	Italy	2020-02-05	2	10.2
cargo	134.72	China	2020-02-05	4	11.7
non fishing	56.00	United States	2020-02-06	2	10.6
passenger	42.49	Cayman Islands	2020-02-08	11	11.0
cargo	103.94	Netherlands	2020-02-08	7	11.9
tanker	179.34	United States	2020-02-11	2	10.2
cargo	134.72	China	2020-02-14	15	13.4
tanker	146.71	Marshall Islands	2020-02-14	13	13.0
tug	27.51	United States	2020-02-14	2	10.4
cargo	172.89	Croatia	2020-02-17	6	10.2
NA	21.97	United States	2020-02-17	2	10.3
cargo	183.48	Japan	2020-02-19	15	10.3
cargo	129.15	Panama	2020-02-21	3	10.5
pots and traps	28.00	United States	2020-02-21	3	10.5
cargo	130.79	Cyprus	2020-02-23	31	11.8
cargo	136.96	Panama	2020-02-23	36	11.6
pots and traps	28.00	United States	2020-02-24	6	12.1
tanker	145.81	Hong Kong	2020-02-24	3	10.1
cargo	127.94	Singapore	2020-02-24	81	14.4
fixed gear	26.25	United States	2020-02-24	4	10.2

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NA	21.97	United States	2020-02-24	3	11.5
cargo	186.64	Liberia	2020-02-24	2	10.6
tanker	145.40	Cayman Islands	2020-02-26	3	10.3
tanker	145.81	Hong Kong	2020-02-26	4	10.3
cargo	129.15	Panama	2020-02-26	4	10.7
non fishing	59.16	United States	2020-02-26	27	11.2
tanker	145.40	Cayman Islands	2020-02-27	3	10.3
tanker	145.40	Cayman Islands	2020-02-28	10	10.7
fishing	24.55	United States	2020-02-29	3	10.9
cargo	131.62	Marshall Islands	2020-02-29	2	13.0
cargo	127.94	Singapore	2020-02-29	26	13.4
tanker	134.39	Marshall Islands	2020-03-01	27	10.5
tanker	145.94	Denmark	2020-03-03	7	10.8
cargo	136.96	Panama	2020-03-03	35	13.6
non fishing	69.31	United States	2020-03-04	14	10.5
cargo	120.31	Panama	2020-03-04	3	10.7
tanker	121.17	Norway	2020-03-04	3	10.3
tanker	134.39	Marshall Islands	2020-03-04	6	12.4
cargo	166.26	Panama	2020-03-05	21	10.7
pots and traps	30.09	United States	2020-03-05	8	11.5
tanker	121.17	Norway	2020-03-06	6	12.7
fishing	25.60	United States	2020-03-06	4	10.5
non fishing	64.41	United States	2020-03-06	16	14.0
tanker	159.11	Liberia	2020-03-06	3	10.3

Vessels with Maximum Speeds Between 10-11.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
tanker	150.46	Singapore	10.4
seismic vessel	70.00	Panama	10.8
tug	34.46	United States	10.6
non fishing	67.08	United States	10.2
cargo	113.46	Marshall Islands	10.2
tanker	138.36	Marshall Islands	10.2
non fishing	39.96	United States	10.6
tanker	124.34	Marshall Islands	10.4
tanker	183.00	Hong Kong	10.4
passenger	27.43	United States	10.4
NA	28.00	United States	10.5
non fishing	43.00	United States	10.2
cargo	193.23	Panama	10.1
cargo	162.82	Italy	10.2
cargo	190.00	Singapore	10.7
supply vessel	58.02	United Kingdom	11.3
tanker	135.49	Marshall Islands	10.2
NA	21.97	United States	11.5
other purse seines	33.05	United States	10.5
fishing	31.64	United States	11.0

cargo	136.81	Hong Kong	11.5
non fishing	56.00	United States	11.2
cargo	103.94	Netherlands	11.9
pots and traps	26.54	United States	10.3
tanker	142.32	Italy	10.2
passenger	42.49	Cayman Islands	11.0
tanker	179.34	United States	10.2
tug	27.51	United States	10.4
cargo	172.89	Croatia	10.2
cargo	183.48	Japan	10.3
cargo	129.15	Panama	10.7
cargo	130.79	Cyprus	11.8
tanker	145.81	Hong Kong	10.3
fixed gear	26.25	United States	10.2
cargo	186.64	Liberia	10.6
tanker	145.40	Cayman Islands	10.7
non fishing	59.16	United States	11.2
fishing	24.55	United States	10.9
tanker	145.94	Denmark	10.8
non fishing	69.31	United States	10.5
cargo	120.31	Panama	10.7
cargo	166.26	Panama	10.7
pots and traps	30.09	United States	11.5
fishing	25.60	United States	10.5
tanker	159.11	Liberia	10.3

Vessels with Maximum Speeds Between 12-13.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
pots and traps	44.18	United States	12.6
patrol vessel	30.92	United States	12.0
cargo	111.23	Marshall Islands	12.7
cargo	134.72	China	13.4
tanker	146.71	Marshall Islands	13.0
pots and traps	28.00	United States	12.1
cargo	131.62	Marshall Islands	13.0
cargo	136.96	Panama	13.6
tanker	134.39	Marshall Islands	12.4
tanker	121.17	Norway	12.7

Vessels with Maximum Speeds Between 14-15.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
passenger	30.61	United States	14.1
cargo	127.94	Singapore	14.4
non fishing	64.41	United States	14.0

OCEANA

Vessels with Maximum Speeds Between 16-17.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
patrol vessel	73.56	United States	17

Vessels with Maximum Speeds Between 18-19.99 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
N/A			

Vessels with Maximum Speeds Greater than or Equal to 20 Knots

Class	Length (meters)	Flag	Maximum speed (knots)
Passenger	38.46	United States	20.9

Violators Count Based on Vessel Classification with Speeding Events over 10 knots

Vessel class	10-11.99 knots	12-13.99 knots	14-15.99 knots	16-17.99 knots	18-19.99 knots	Greater than or equal to 20 knots	Total	Percentage of Vessels
Cargo	13	4	1	0	0	0	18	30
Tanker	11	3	0	0	0	0	14	23.33
Fishing	7	2	0	0	0	0	9	15
Non fishing or N/A	8	0	1	0	0	0	9	15
Passenger	2	0	1	0	0	1	4	6.67
Patrol vessel	0	1	0	1	0	0	2	3.33
Tug/Supply	3	0	0	0	0	0	3	5
Seismic vessel	1	0	0	0	0	0	1	1.67

Ship Speed Watch Methodology

Data for Ship Speed Watch* was obtained from Global Fishing Watch's (GFW) database via Google's BigQuery platform. The GFW database contains information from AIS transmissions such as the vessel Maritime Mobile Service Identity (MMSI), location, speed, class, length, flag state, timestamp, and date. The locational coordinates for the speed restriction zones and the time periods when they were active were obtained from the U.S. National Oceanic and Atmospheric Administration (NOAA) and Fisheries and Oceans Canada (DFO)'s respective websites:

NOAA - https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales

DFO - https://www.dfo-mpo.gc.ca/fisheries-peches/commercial-commerciale/atl-arc/narw-bnan/2020/right-whale-baleine-noires-0429-eng.html#restricted-area

In all active U.S. and Canadian speed restriction zones, the mandatory speed limit is 10-knots. These speed limits apply to vessels 13-meters (43 feet) or greater in Canadian zones, and 19.8-meters (65 feet) or greater in U.S. zones – which is reflected in the data displayed in Ship Speed Watch. The only exceptions are U.S. Dynamic Management Areas and the Canadian Cabot Strait Voluntary Area where the 10-knot speed limit is voluntary. Faulty AIS devices, user error, intentional manipulation, crowded areas, poor satellite reception, and transmission flaws are factors that contribute to noise and errors in AIS data, and sometimes those inaccuracies can be reflected in the speed and location of a vessel. Speeds greater than 40-knots were filtered out of the dataset as the majority of vessels cannot travel that fast, and many signals over 40-knots can be attributed to AIS or satellite errors.

The GFW data is then moved to the R-Shiny programming software, which displays the data on an interactive map. The Data tab includes the vessel's MMSI, name, flag state, class, length, speed, zone, timestamp, and date.

Detailed information about the locational coordinates and active time periods of the speed restriction zones can be found on the Information tab, with links to both the NOAA and DFO Canada regulations. Additionally, the Information tab contains an overview of NOAA's North Atlantic right whale sightings map and the associated link to that map. The EEZ boundaries on the Ship Speed Watch map were downloaded from MarineRegions.org (Flanders Marine Institute (2019). Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM), version 11. Available online at https://www.marineregions.org/. https://doi.org/10.14284/386):

MarineRegions - https://www.marineregions.org/eezsearch.php

The ShinyApp is then published onto a remote server via shinyapps.io. This makes the app available to anyone with internet access.

*Ship Speed Watch uses vessel information in the Global Fishing Watch database. This information is transmitted from a vessel's Automatic Identification System (AIS) device, which is collected via satellites and terrestrial receivers. Faulty AIS devices, user error, intentional manipulation, crowded areas, poor satellite reception, and transmission flaws are factors that contribute to noise and errors in AIS data, and sometimes those inaccuracies can be reflected in the speed and location of a vessel. Vessel operators can accidentally or purposefully enter false information into their ship's AIS thus concealing their identity or location. In crowded areas, such as ports, the massive number of radio transmissions can crowd the bandwidth of satellite and terrestrial receivers, leading to inaccuracies as well. For these reasons, Ship Speed Watch information must be relied upon solely at your own risk.

FINAL DRAFT

Ship Strike Committee Report on Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales

1 August 2001

Submitted to: National Marine Fisheries Service

Via: Northeast and Southeast Implementation Teams for the Recovery of the North Atlantic Right Whale

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Background/Premises

Essentially, three basic management measures, derivatives and combinations thereof are proposed to address commercial ships:

- Routing vessels around high-risk areas.
- Routing ships through a high-risk area to minimize travel distances of vessels and risks of whale-vessel interactions through the area.
- Restricting vessel speed through high-risk areas.

Imposition of these measures could be seasonal, or year-round and limited to a specific high-risk area based on historical occurrence. Imposition of measures could also be initiated upon the detection and / or prediction of right whales in a high-risk area, and might remain in force until right whales are no longer detected or have a low probability of remaining in the area. One or more options could be imposed in an overall management scheme for a given area.

We define a high-risk area as the convergence of either areas of high volume of shipping and right whales, or high numbers of whales and shipping. Areas of high volumes of shipping include designated shipping lanes, historic shipping routes and port approaches. Areas of high numbers of right whales include areas where right whales are aggregating, right whales are known to return in numbers on a regular basis, or critical population areas or habitats (e.g., the calving grounds off the Southeast U.S. coast).

The success of the recommended right whale protection strategy is predicated on the mariner being educated on the seasonal distribution and occasional occurrence of right whales through education programs; licensing and personnel qualifications (e.g., trained but not necessarily additional lookouts); inclusion of right whale information in key required nautical publications; voyage planning requirements; and planning for emergency maneuvering by testing steering gear, and ensuring that engines are ready for maneuvering prior to entering right whale habitat. Several of our recommendations address these matters.

Recommended long-term routing measures conform to the International Maritime Organization's *General Provisions for Ship Routing*. The measures must not inadvertently lead to any situation that endangers a vessel or other vessels or the marine environment. For example, if a vessel is operating in a designated shipping lane, we are not recommending measures that would divert a vessel out of the lane. We do however, recommend that NMFS establish a speed restriction of 10 knots in certain situations or in areas at certain times of year. This speed limit would be imposed with the explicit understanding so as not to endanger the vessel or create a navigation safety or marine pollution hazard.

Slowing vessels down is a measure that was initially considered as a measure of last resort because of the inherent uncertainty in the effectiveness and the potential for unwarranted economic impacts. A primary focus was on routing measures and detection of whales so that a mariner could steer clear with advance notice. The technology to provide adequate advance warning does not yet exist, and it likely will never prove one hundred percent effective. Right whales will occur in a specific area unpredictably, in other areas within a particular time window. They occur along shipping routes or lanes and cross port approaches during migrations. In many cases, routing vessels around known or predicted right whale locations is impossible, for example at port entrances. The only viable option, then, is for a vessel to slow. The question then become how slow and what discretion should be left to the mariner. The conventional way mariners are advised to proceed slowly is found in Rule 6 of the international collision avoidance regulations (COLREGS). Mariners are required to proceed at "safe speed" in uncertain conditions, the discretion left to the mariner to decide what is safe. The measure of "safe" is whether a collision is avoided.

The mariner does not know what safe speed is to avoid a whale, but more importantly to let the whale avoid the vessel or to minimize the impact of a collision. It is up to the resource agency, NMFS, to make this call based on available information. This does not however imply that the mariner gives up the discretion to drive his/her vessel safely.

There are three studies on right whales and vessel speed, none of which is definitive; all are lacking in many respects. Nonetheless, these studies do point to slower vessel speeds being a factor in reducing whale-ship interactions. As lead author of this report, I find that I must choose among options: 8 knots, 10 knots, 13 knots, or leave speed to the mariners' discretion. I do not believe the latter option is prudent. I would defer if I thought additional studies on vessel speed and whales would shed more light, but I do not. There are too few records of ship strikes to study. The uncertainty and unknowns of how an individual right whale will react to or be drawn into a ship suggests that an answer to what precisely is a safe speed for each vessel type is very, very far off.

After listening to all the arguments, pros and cons, ***I am recommending that NMFS determine that safe speed is 10 knots.*** A speed restriction could be imposed as follows: mariners limit vessel speed over ground to 10 knots or less, so as not to endanger the vessel or create a navigation safety or marine pollution hazard. Other factors should be established: a mariner could exceed the slow speed, 10 knots, for suitable reasons such as search and rescue, medical emergencies, storm avoidance, and weather/sea conditions.

Finally, I considered the impact of such a speed restriction on vessels entering East Coast ports. After a fairly detailed analysis, documented in previous reports, I find that the typical worst case scenario would mean a delay of one hour for an inbound vessel

Several "short-hand" phrases used in the recommendations follow:

> *Vessel:* all vessels engaged in commerce, with length greater than or equal to 65 feet or 20 meters, all commercial tugs and tows regardless of length, and all recreational vessels, with length greater than or equal to 65 feet or 20 meters. Note: we propose to define a ship as any vessel greater than or equal to 65 feet or 20 meters. Some tugs are less than 65 feet, and tow larger barges or vessels and

therefore are included in this definition. The one ship strike resulting in a fatal blow to a right whale where the vessel is identified was 82 feet. In this case, the fatal blow was not from the hull rather it was from the propeller. There is evidence of vessel strikes by smaller vessels (scarring on whales back) that could have been fatal if this happened to a calf. There is an argument that large planing vessels be exempt because of their operating at a shallower draft, but this does not address the problem of large propellers.

Geographically-targeted re-routing:
Routing measures implemented and adjusted on a short-term basis in response to continually updated data and analyses of right whale occurrences or aggregations.

Regional/seasonal re-routing:
Routing measures implemented based on long-term (several years) analyses of right whale distribution.

Speed restrictions:
Requirement that mariners limit their vessel speed over ground to 10 knots or less, so as not to endanger the vessel or create a navigation safety or marine pollution hazard. Other factors should be established so that a mariner could exceed the slow speed, 10 knots, for suitable reasons such as search and rescue, medical emergencies, storm avoidance, and weather/sea conditions.

Geographically-targeted vessel speed restrictions:
Restrictions implemented and adjusted on a short-term basis in response to continually updated data and analyses of right whale occurrences or aggregations.

Regional/seasonal speed restrictions:
Restrictions implemented on a longer-term basis based on analyses several year of right whale survey / detection data.

We assume that that the U.S. has the ability to institute vessel-operating measures within the exclusive economic zone, enforced consistent with international law. The question is not whether the U.S has the ability to protect right whales from ship strikes: NMFS, working with the U.S. Coast Guard has demonstrated or indicated that they have or will seek authority both internationally and through Congress to protect right whales with due consideration of the interests of the shipping industry, freedom of navigation and international law. Some of our recommendations may require specific authorizing legislation. An interpretation of the Endangered Species Act provides authority for imposing operating restrictions on all U.S. flagged vessels. This authority would extend to foreign flagged vessels that are calling at a U.S. port (not necessarily within right whale habitat), as a condition of entry into U.S. ports. Enforcement must be consistent with international law. Several of the recommendations require approval by IMO. ***We strongly encourage responsible agencies to start working on matters of domestic and international authority as soon as possible***.

Some of the measures we recommend require additional studies. We will so note and elaborate further in other sections of this report. For example, we are proposing the establishment of designated mandatory or recommended shipping lane(s) through critical habitat. These recommendations are predicated on the conduct of a detailed risk assessment to ensure actual risk reduction and to examine alignments that would minimize risk to right whales. In turn, any proposal that affects ship routing requires that the Coast Guard conduct a Port Access Route Study (PARS) in accordance with 33 USC 1223; navigation safety is the primary concern in these studies.

There are several recommended measures that could be enhanced by new technology or improved methodologies. For example, real-time passive acoustic detection may serve as a viable resource in alerting vessels to the occurrence of right whales along a vessel's route.

We make recommendations to examine unproven technology that may or may not hold promise and that may pose environmental safety problems, for example active acoustic (sonar) detection and acoustics deterrence.

Recreational vessels, yachts and small passenger vessels for hire whose propellers turn at high rpm can tear apart and kill a young right whale. We recommend that the Implementation Teams, NMFS, working with the boating, recreational fishing and conservation community, develop collaborative education and outreach programs, and regulations for targeted speed restrictions.

Finally, we include recommendations to address U.S. Naval operations in the Northeast U.S. (Hampton Roads area and north) and other maritime operating agencies, specifically the U.S. Maritime Administration of the Department of Transportation and the U.S. Military Sealift Command. Naval operations represent 5% of the total traffic moving in and out of the Chesapeake Bay. The U.S. Maritime Administration (MARAD) bases part of its fleet in the mid-Atlantic area. The U.S. Military Sealift Command operates 28 vessels in the Atlantic area. This represents a significant volume of traffic. Our industry sources advise us that the Hampton Roads maritime community will follow the Navy's lead and to a lesser degree MARAD's support on this issue. Thus far the Hampton Roads Maritime community has not engaged on this issue, and has objected to measures proposed by the ship strike committee in earlier Discussion Drafts. Neither the Navy nor MARAD have engaged despite repeated overtures by the ship strike committee.

Summary of recommendations*

*See Appendices for rationale and amplifying information, and detailed discussions.

Vessel operating restrictions

Dynamic Management Areas: Establish a regulatory mechanism applicable to vessels operating anywhere along the U.S. East coast which would enable the agencies to impose measures, including geographically-targeted re-routing and / or geographically-targeted vessel speed restrictions. This measure could be used in conjunction with other recommended vessel operating restrictions. Enhanced aerial surveillance techniques, expanded surveys, and other means of detection, for example real-time passive acoustics, will increase the effectiveness of this measure. Legislative authority may be required. See Appendix I for rationale and amplifying information and the recommendations on *Research, Studies and Projects***.**

Designate the Cape Cod Bay critical habitat as seasonal area to be avoided. Effective dates could be determined based on historical data. Exceptions could include vessels providing fuel oil and ferry service subject to operating restrictions for example daytime transit, posting of lookouts, or speed restrictions. Designation may require a PARS.

Designate the Boston Approach shipping lane as a mandatory route, and *designate the Great South Channel right whale critical habitat east of the shipping lane as an area to be avoided.* Both designations will be subject to a risk assessment, a PARS, and approval by the International Maritime Organization. The risk assessment is already funded.

Establish a seasonal management area to encompass parts of the Boston Approach Sea Lane to the west, east and south of Race Point, Cape Cod, MA. This is a high-risk area during the departure of right whales from Cape Cod Bay after their winter-feeding in the Bay and the subsequent dispersal of right whales to the Gulf of Maine, including the Great South Channel. Vessels would be required to avoid this area or transit this area at no more than 10 knots. Legislative authority may be required. Designation may require a PARS. Implementation and enforcement would be a condition of port entry. See Appendix II for rationale and amplifying information

Establish seasonal management areas at major port entrances from Block Island, RI, south to and including Savannah, GA. Port entrances are high-risk areas during the northern and southern migrations of right whalesfrom/to the Southeast critical habitat when right whales cross port entrances. Vessels would be required to approach ports from approximately 20 nautical miles to the harbor entrance at no more than 10 knots. Legislative authority may be required. Designation may require a PARS. Implementation and enforcement for would be a condition of port entry. See Appendix II for rationale and amplifying information

Establish mandatory or designated recommended routes for the ports of Brunswick, GA, Jacksonville, FL and Fernandina Beach, FL. North-south traffic would be required to stay east of the critical habitat and areas of high right whale occurrences. Each route would be conditional on a risk assessment to determine impact and recommended alignment and a PARS. Legislative authority may be required. See Appendix III for rationale and amplifying information.

Establish a seasonal 10-knot speed restriction for vessels calling at the ports of Brunswick, GA, Jacksonville, FL and Fernandina Beach, FL. Legislative authority may be required. See Appendix III for rationale and amplifying information.

Require for each recommended measure above that each vessel, prior to entering critical habitat or dynamic or seasonal management area, check steering, ensure engines are ready for maneuvering, and post trained lookouts (not necessarily additional lookouts). Implementation and enforcement would be a condition of port entry.

Should acoustic/sonar-detection *technology prove effective and environmentally safe and become available, NMFS should offer use of this equipment subject to certain conditions as an option, instead of routing around or slowing.* An unproven technology that is currently under research and development is a vessel-mounted forward-looking active-sonar device. Port authorities and the shipping industry have embraced the concept as a technologic solution instead of or in addition to other management options. Government acoustic experts have examined the use of active sonar and have dismissed the approach as unworkable. However, before additional funds are expended on this R&D, an evaluation of concept review should be conducted. See research recommendations and Appendix IV.

Voyage planning, personnel qualifications, merchant mariner education

Develop voyage planning guidelines for domestic and foreign flagged vessels calling at U.S. east coast ports for inclusion in required voyage planning documentation, and manning standards and qualifications as appropriate. The International Chamber of Shipping publishes a bridge manual, which may be a good vehicle, in addition to other means.

Work with the U.S. Coast Guard and IMO on merchant personnel qualifications to address protection of the environment and endangered / protected species, including the North Atlantic right whale.

Ensure that relevant information and requirements are included in equivalent required charts and nautical publications, including British Admiralty publications. The Coast Guard and NMFS have been slow in ensuring that MSR requirements are in the British Admiralty equivalent to the U.S. Coast pilot in particular, which may be contributing to the low MSR compliance rate.

Develop a merchant mariner education program as part of the ship strike program. Merchant mariner education must be an integral part of the implementation strategy and program management plan.

<u>Recreational vessels, yachts and small passenger vessels for hire</u> **(**Vessel propellers turning at high rpm can tear apart a young right whale.)

Develop an education and outreach program targeted at large recreational vessels, yachts and small passenger vessels for hire. It is essential that owners and operators be made aware of the occasional aggregations and seasonal occurrence of rights whales in coastal areas, in particular those operating from the smaller coastal inlets. Vessel propellers turning at high rpm can tear apart a young right whale. Develop of right whale education programs in collaboration with one or more regional or national conservation groups, the Coast Guard Auxiliary, the US Power Squadron, and sport fishing associations.

The Implementation Teams, NMFS and the Coast Guard should work with state boating safety law administrators to develop and institute program(s) of geographically and seasonally targeted speed restrictions.

<u>U.S. Navy operations</u>

The U.S. Navy should conduct a Section 7 consultation on naval operations (air and sea) for areas under the jurisdiction of NMFS Northeast Region. DoD's Atlantic fleet maritime operations pose potential adverse impact on right whales and humpback whales off the mid-Atlantic coast. Recent ship-strike data compiled from a variety of sources including the New England Aquarium, the marine mammal stranding networks, and the Smithsonian Institution's Marine Mammal Events Program (MMEP), identify as many as nine fatal humpback whale ship-strikes and five fatal right whale ship-strikes in the Virginia Capes area in recent years. The case records substantiate the requirements for immediate fleet-wide remedial actions, and consultation with the National Marine Fisheries Service. Recent studies have identified the Virginia Capes area as a winter feeding ground for juvenile humpback whales, an endangered species. We note that the remit of the Northeast Implementation Team includes humpback whales.

We believe that the Navy's policy *not to* conduct generic consultations, rather to approach "these matters on a case-by-case basis" does not work, nor is it consistent with the intent of the ESA. In spite of written assurances by DoD leadership on behalf of the Navy that the Navy would assess Naval operations and institute "appropriate remedial actions," there is no obvious record of an assessment of impacts of Naval operations in the Norfolk / Hampton Roads area and certainly no record of resulting remedial actions.

The Navy should issue specific operating procedures for vessel operations in the Norfolk / Hampton Roads area similar to those issued for operations off the Southeast U.S. Naval operations represent 5% of the total traffic moving in and out of the Chesapeake Bay. The U.S. Military Sealift Command operates 28 vessels in the Atlantic area. This represents a significant volume of traffic. Our industry sources advise us that the Hampton Roads maritime community will follow the Navy's lead on this issue. Thus far the Hampton Roads Maritime community has not engaged on this issue and has objected to measures proposed by the ship strike committee in earlier Discussion Drafts.

The Navy should issue specific operating procedures for air operations for its Brunswick, ME Naval Air Station similar to those issued for operations off the Southeast U.S. This recommendation should address practice bombing in the Gulf of Maine, pre-bombing surveys, education of regular and reserve personnel in nautical references. Written procedures and education should include at a minimum: consulting the Coast Pilot and Notice to Mariners on seasonal distributions and real-time occurrences of right whales, aerial survey techniques at proper altitude and speed). Alternative bombing ranges should be examined.

U.S. Department of Transportation, Maritime Administration (MARAD)

MARAD should conduct a section 7 consultation for the operation of its inactive National Defense Reserve Fleet located at Ft. Eustis, Virginia (conducting periodic sea trials off the mouth of Chesapeake Bay), and its eighty six domestically-stationed ships operating off the U.S. east coast. This agency should participate on the Implementation Teams.

The U.S. Military Sealift Command (MSC)

MSC should conduct a section 7 consultation for the operation of 28 it operates in the Atlantic area. This agency should participate on the Implementation Teams

Research, Studies and Projects (See Appendix IV for detailed discussions)

Regional risk assessments: Conduct risk assessments off the Southeast US, in the Great South Channel and Gulf of Maine to determine how many vessel miles can be removed from the high density whale areas by safely routing ships into and out of whale areas using the shortest route possible.

Economic impact analysis. Conduct more detailed treatments of port-specific economic effects by enhancing and providing more accurate data into a model currently under development.

Assess temporal and spatial extent of the mid Atlantic migratory corridor. Analyze existing data and survey data from targeted surveys and other surveillance techniques to determine statistical probabilities of occurrence (time and location) of right whales during migrations off port approaches from Block Island, RI to Savannah, GA. Additional aerial surveys may be necessary.

Integrate all available information into a management system. Continue and expand the ongoing development of a comprehensive information management system using Global Information Systems (GIS) software. This system will be used to monitor the health of the population and the efficacy of and effectiveness of management measures designed to reduce human impacts on whales.

Merchant mariner education. Continue, enhance and accelerate the development of a program and outreach strategy to assist mariners, worldwide, in voyage planning, qualifications and licensing programs, and in shipboard safety management planning.

Right whale detection research/monitoring.

- Expand aerial surveys to cover port approaches from Block Island sound, RI to Savannah, GA.
- Evaluate and improve the effectiveness of aerial survey techniques.
- Continue passive acoustics detection research and investigate automation of a real-time system suitable for deployment offshore.
- Continue research into the biological and oceanographic ‘predictors’ of right whale distribution on suitable scales in support of an "expert system" to predict right whale occurrences in high-risk areas.
- Evaluate the effectiveness, methods and safety (to the animal) of satellite tagging and if appropriate develop and implement a program to address specific information gaps on the occurrence of right whales in high-risk areas.

Right whale behavior in relation to ships. Develop a research program to improve the understanding of how right whales react to approaching vessels. Characteristics of changes in a vessel's sounds may enable a whale to hear an approaching vessel to realize that there is a threat of a collision. From reviewing anecdotal evidence about right whale reactions to approaching vessels, it seems that some right whales may be reacting to changes in the sound emanating form the vessel. For example, small changes in propeller speed or pitch (for variable pitch propellers) or small changes in the rudder angle.

Active sonar detection; evaluation of concept proof. Before further discussion on the potential use of this technology, the practical application of active sonar detection needs to be realistically presented, including, for example, realistic time frames for the required technological development and careful consideration of possible environmental impacts. Several researchers have advertised an unproven technology that *could* detect right whales ahead of ship using active sonar. Port authorities and the shipping industry have embraced the concept as a technologic solution instead of or in addition to other management options. In contrast, acoustic experts have examined the use of active sonar and have dismissed the approach as unworkable.

Mortality data. Review right whale mortality data to better estimate the number of whales killed by ships and other sources.

Appendix I
Dynamic Management Areas

Rationale and amplifying information for recommendations on vessel operations: aggregations of right whales

A. <u>Objective</u>: To reduce the risk of harmful whale-ship interactions when right whale(s) are found aggregating in an area by:

- Reducing the probability of whale-ship interactions (by i.e. routing ships away from whales[1])
- Increase the probability that a whale-ship interaction (by slowing ships down to 10 knots) that will:
  a) not harm the whale, or
  b) provide the whale the opportunity to react with sufficient time to avoid the ship, or
  c) provide the ship the opportunity to sight whales and react with sufficient time to avoid a whale or group of whales.

B. <u>Trigger</u>: Right whale(s) are determined to be in an area with vessel traffic. Right whales are known to aggregate when foraging and / or feeding, and in courtship groups. These aggregations have been seen as far south as New Jersey, Block Island Sound and in throughout the Gulf of Maine, including the Great South Channel. Courtship aggregations are occasionally seen in the southeast U.S. Resident mother /calf (new born) pairs of right whales have been found north and east of the designated critical habitat in the Southeast U.S.; for example off the approaches to the ports of Savannah, GA and Charleston, SC

NMFS has established criteria for dynamic area management for fisheries closures to prevent entanglements when feeding or foraging whales are detected in the Northeast U.S. in an April 2001 report "*Defining Triggers for Temporary Area Closures to Protect Right Whales from Entanglements: Issues and Options,*" (Northeast Fisheries Science Reference Document 01-06). We propose that aspects of this approach may be appropriate to prevent ship strikes and have adapted parallel language with several exceptions as noted. This study is based on right whales in the Gulf of Maine area, and its applicability to other areas should be used only as a guide to assist in determining residency of right whales in an area.

Vessel operating restrictions shall be imposed in an area when three or more right whales are observed resident in an area of size such that the right whale density in this area is 0.04 right whales per nm^2. This equals four right whales observed in a 10x10 nm square. Operationally, this may be applied as follows:

1. A resident right whale is defined as a right whales determined to be actively feeding or in a courtship group. Observation of a dense patch of right whales' primary food, the copepod *calanus,* is good indication that right whales are

[1] Routing vessels around areas where whales are known or determined to be located in aggregation or densities to areas of no known whale aggregations or lower densities will reduce the probability of whale-vessel interactions. There are many circumstances however that routing vessels is not an option. The only other option currently available is the reduction in vessel speed.

resident in an area. Successive observations obviously indicate residence. As we understand, residence is not explicitly defined in the trigger mechanism for fisheries. It is our belief that a foraging whale, that is a whale searching for food, will not necessarily remain in a specific area, whereas a feeding whale is likely to remain in a management area. The concern is that the basis for the science center's analysis should be used only as an indicator of residence. Other factors should be considered, if available.

2. A circle of a radius equal to three nautical (nm) per animal shall be drawn around each individual sighting. This radius will be adjusted to account for the number of animals seen in the sighting, so that the density of 0.04 animals per nm^2 is maintained. This is a nonlinear relationship (the area is circular) so that to maintain this density, the radius of the circle for a sighting of a single animal would be 2.77 nm, for 2 whales in the sighting the radius would be 3.99 nm, for 3 whales the radius would be 4.89 nm, and so on….
3. If any circle or group of contiguous circles includes three or more animals, the area shall be a candidate for dynamic management.

Having identified a group of 3 or more resident right whales as candidates for protection to adequately protect these animals for the duration of the event, it is necessary to expand the original area of sighting to provide a buffer for movement within the DMA. Determination of residency is of course subjective. This will define the actual DMA, and operationally could be applied as follows:

1) A **buffer zone** of radius of up to 15 nm, shall be drawn from the boundary of the individual sighting area triggering a DMA.
2) The DMA shall then be defined by east-west (latitude) and north-south (longitude) lines, which demarcate the outer periphery of the defined circles.

Exceptions:

1) When two or more animals are seen actively feeding on a patch of food in a designated shipping lane a DMA shall be imposed. Rationale: Actively feeding right whales are believed to be the most vulnerable. Designated shipping lanes carry more shipping traffic and therefore the probability of whale-ship interaction is higher than other areas.
2) When a non-migrating mother/calf pair is sighted within 15 nm of shipping lanes, and no other operating restrictions apply, a DMA shall be imposed. Mother / calf pairs are the most vulnerable (they are restricted in their abilities to maneuver) and mature breeding females are the most critical to survival of the species. Non-migration could be defined as any time after the northern migration from the Southeast calving grounds to the Great South Channel area.
3) A single right whale when in the immediate vicinity of a port entrance or a port area, or in or near the entrances to Cape Cod Canal, may trigger a DMA or imposition of operating restriction by the US Army Corps of Engineers (e.g., the Cape Cod Canal) or by the Coast Guard. Compliance by a vessel with the 500 yard no approach rule 50 CFR.224.103 can create a navigation safety hazard.

C. <u>Proposed vessel operating restrictions in a DMA</u>: The responsible agency would impose one or more measures that could include, for example: 1) establishment a temporary area to be avoided, and / or 2) impose a speed restrictions to 10 knots speed for vessels unable to avoid the area; or 3) provide the option to the mariner proceed at 10 knots through the area in lieu of avoiding the area. Mariners would also be required to check their steering, ensure that their engines are ready for maneuvering and to post look-out(s) (not necessarily additional persons) familiar with spotting whales.

D. <u>Regulatory Approach and Notification of Mariners:</u> As the lead Federal agency that regulates ship operations, we propose that the Coast Guard be the regulating agency. In our view, NMFS would make a determination that a DMA is necessary and request that the Coast Guard impose and enforce these restrictions. We also suggest that NMFS establish a discretionary consultation process with the purpose to coordinate advice on geographic extent, estimated time limit and specific measures. We propose that NMFS and the Coast Guard model the regulatory approach to that already used by the Coast Guard to impose operating restrictions on vessels on an emergency basis, an emergency safety zone, see 33 CFR Part 165. This general authority extends through the contiguous zone and is somewhat limited in its scope, unless specifically amended. (An interpretation suggests that this authority, under the Ports and Waters Safety Act, does not apply to the protection of right whales. This authority was specifically amended to implement the MSR, and in this case in waters beyond the contiguous zone.) Detailed establishment procedures, geographic coordinates, seasonal occurrence, vessel operating requirements and general regulation, notification, shipboard log keeping could all be specified.

E. <u>Implementation and enforcement:</u> Unlike NMFS' Dynamic Area management program for fisheries, direction of shipping can be accomplished relatively quickly--there is no gear in the water, no gear to reset. A vessel can still move cargo or get from point A to point B. Existing communications systems can be used to relay the order or rule. If used in combination with other measures, for example mandatory shipping lanes and areas to be avoided, detection and emergency actions need only focus on/adjacent to the lanes. Port authorities, ships' agents, national and international industry associations, and pilots associations should be partners in this education. Coast Pilots, British Admiralty publications, and Port Guides to Entry should include information on the need for mariners to be alert to emergency Dynamic Management Areas. Regular Coast Guard port-state control boardings could include examination of ship's logs and random checks of these logs by NMFS and NOAA personnel should suffice. (Mariners are required to log course and speed changes). Sovereign immune vessels, and foreign flagged transiting and not calling at any U.S. port would not be subject to this measure.

E. <u>Note:</u> There may be circumstances when vessels will be unable to avoid an area or, reduce speed: for example, a deep-draft vessel in harbor approaches when other vessels are in proximity, or the channel is restricted (e.g., depth), the seas, current and winds are unfavorable and pose a navigation safety risk. The ultimate decision on the handling of a vessel, is always that of the master or mate on watch. Another example is when a vessel is in a designated shipping lane; in this case a mariner's only option would be to slow.

Appendix II
Seasonal Management Areas

Rationale and amplifying information for recommendations on vessel operations: predictable seasonal occurrences of right whales during migrations

A. Objective: To reduce the risk of harmful whale-ship interactions when right whale(s) are predicted to seasonally occur (e.g., when migrating) in a specific geographic area by:

1. increasing the probability that a whale-ship interaction by slowing ships down to 10 knots or less.
2. providing the whale the opportunity to react with sufficient time to avoid the ship, and / or
3. providing the ship the opportunity to sight whales and react with sufficient time to avoid a whale or group of whales.

B. Triggers: Right whale(s) are predicted to occur seasonally when migrating across or through designated shipping lanes or port approaches. Rather than the density of right whales in an area determining the need to impose vessel- operating restrictions, the motivation is the relative high density of shipping coincidental with known migrations of right whales. We have identified three migrations of concern:

1) The departure of right whales from Cape Cod Bay after their winter feedings in this area and the subsequent dispersal of right whales to the Gulf of Maine, including the Great South Channel. This departure of many animals often occurs abruptly over several days in mid to late April. In leaving Cape Cod Bay, right whales cross the Boston Approach Sea Lane. A GIS study is currently underway to study/map this departure. We expect to be able to determine a probable geographic range through the sea lanes, approximate duration of the dispersal and mean date and duration for the dispersal with a high confidence level for each.
2) The northern migration of right whales from the Southeast critical habitat when right whales cross port entrances. As many as 90 individual right whales were seen in the Southeast calving grounds in the winter of 1996 migrating northward in late winter/early spring. Good information exists on the dates whales depart the southeast and arrive in the northeast. Tagged whale data and opportunistic sightings provide information on speed and some information on path. Vessel sighting data in the mid-Atlantic area from Block Island Sound to and including Savannah, GA is sparse or absent. We reviewed the information available and consulted with statisticians, GIS experts and others and believe that a model can be constructed that can predict the mean date of the peak occurrence of right whales at port entrances. The peak date in any given year could be estimated with a high degree of confidence based on real-time observations as long as surveillance levels in the northeast and southeast are maintained. We would propose then that seasonal vessel operating restrictions could be imposed for port approaches around the peak date of migration past each port. The geographic extent is more problematic. Survey data for the mid-Atlantic is virtually absent. However, records of opportunistic sightings and tracks of tagged whales may

provide sufficient information to establish a zone; we estimate that 85% of migrating whales are within 20 nm from the coast. We are working with statisticians and others to determine the confidence level we can attribute to an analysis of these data.

3) The southern migration of right whales to the calving grounds will include pregnant females, as well as other adults and juveniles. The departure time for animals leaving the northern area is not as well identified, however arrival time in the southeast is fairly well documented. A calculation based on travel speed might allow for a peak probability of migration past mid Atlantic ports. A similar calculation for the geographic extent can be made, and it is not expected to be different than for the southern migration.

C. Proposed vessel operating restrictions: The responsible agency would notify mariners that on or about a certain date, for a specified period and in accordance with published regulations that a speed restriction to 10 knots is in force. The exact dates could be linked to real-time sightings. Mariners would also be required check their steering, to ensure that their engines are ready for maneuvering, and to post look-out(s) familiar with spotting whales (not necessarily additional persons). This process is akin to the Coast Guard's regulated navigation area

D. Regulatory Approach and Notification of Mariners: As the lead Federal agency that regulates ship operations, we propose that the Coast Guard be the regulating agency. In our view, NMFS would make a determination that a SMA is necessary in an area and request that the Coast Guard impose and enforce these restrictions. We also suggest that NMFS establish a discretionary consultation process with the purpose to coordinate advice on the date of implementation, estimated duration and estimated limit and specific measures. The geographic coordinates and approximate imposition dates would be published in advance in regulation(s), with specific imposition subject to determination by NMFS and the Coast Guard, with subsequent notification through regular notice to mariners and NAVTEX. We propose that NMFS and the Coast Guard model the regulatory approach to that already used by the Coast Guard to impose operating restrictions on vessels in a specific area on a regular or permanent basis, a regulated navigation area (RNA), see 33 CFR Part 165. This general authority extends through the contiguous zone and is somewhat limited in its scope, unless specifically amended. (An interpretation suggests that this authority, under the Ports and Waters Safety Act, does not apply to the protection of right whales. This authority was specifically amended to implement the MSR, and in this case in waters beyond the contiguous zone.) Detailed establishment procedures, geographic coordinates, seasonal occurrence, vessel operating requirements and general regulations, notification, and shipboard log keeping could all be specified.

A comprehensive merchant mariner education program will be essential. Port authorities, ships' agents, national and international industry associations, and pilots associations should be partners in this education. Coast Pilots and Port Guides to Entry, and equivalent foreign publications and charts should include information on the need for mariners to be alert seasonal management areas. Regular Coast Guard port-state control boardings could include examination of ship's logs and random checks of these logs by NMFS and NOAA personnel should suffice. (Mariners are required to log course and speed changes.)

Appendix III
Southeast U.S. Calving Area

Rationale and amplifying information for recommendations on vessel operations: management measures off the Southeast U.S. coast from Port Canaveral, Florida to just north of Brunswick, GA

We compiled 10 seasons of sighting data and superposed these on nautical charts. The data we used are not corrected for effort (sightings per unit effort, SPUE), as the SPUE analysis is not yet complete. For our purposes, we chose a conservative approach to determine the approximate geographic extent of operating restrictions. These of course should be reviewed as the SPUE analysis is completed later this year.

We found that, based on the occurrence of whales to the east of the critical habitat, operating restrictions could extend to 80°55' W off Brunswick, 8.3 miles east of the critical habitat near buoy "28"; to 80° 57' W off Fernandina, 7 miles east of the critical habitat off the St Mays Entrance; to 80° 57' W off Jacksonville 7 miles east of the eastern approach to the St Johns River; and extending five miles south of the "jog" or the existing southern limit of the "15 miles from the coast extension" of the critical habitat (at 30°15'N) to 30° 10'N.

In order to determine the time delays imposed by any routing and/or speed limits, we spoke to the Brunswick Bar, Cumberland Sound and St. Johns Bar pilots association to understand vessel approaches, pilot boarding points and vessel speed (8-10 knots) for boarding pilots. We also reviewed an extract of data from the mandatory ship reporting system and found average speed (15.9 knots) and median speed (16.5) and the range of speeds (7-22.8 knots) for vessels entering the MSR area. The MSR area is bounded to the east at 81°51.6'W.

We then laid track lines to the pilot boarding points for a NE, E and SE approach to each port. We defined a "maximum" delay using Jacksonville as an example. The worst case was the imposition of a single eastern approach to minimize travel distance in the critical habitat (and taking into account fish havens) and a seasonal speed restriction of 10 knots (so as not to endanger the vessel) to the pilot boarding point. We assumed the vessel would ordinarily travel at 20 knots right to the pilot boarding point (note that the average and median speed is about 16 knots, and that vessels take a mile or so to slow their speed). The maximum delay time is about an hour for an inbound vessel.

Appendix IV
Research, Studies and Projects

Detailed discussions

Regional risk assessments. Risk assessments off the Florida and Southern Georgia coast, in the Great South Channel and north of Cape Cod, Massachusetts will be used to determine the probability of interactions between whales and ships for each area by whale behavior, season, and shipping traffic characteristics and to determine how many vessel miles can be removed from the high density whale areas by routing ships into and out of whale areas using the shortest route possible, or routes in general. Navigation safety, port access concerns and competition with other ocean users (e.g. fisherman) must be assessed as part of or in support of each assessment. If for example, a risk assessment finds that a particular route would reduce risk, the Coast Guard would be required to conduct a port access route study, in order to ensure safe access routes for the movement of vessels...navigation safety is the primary concern in these studies. This is partially funded by the Northeast Consortium.

Assess temporal and spatial extent of mid Atlantic migratory corridor. Analyze existing data and survey data from targeted surveys and other surveillance techniques to determine statistical probabilities of occurrence (time and location) of right whales during migrations off port approaches from Block Island, RI to Savannah, GA. Survey effort and photo-id data from the mid Atlantic are sparse; however, animals are often sighted within the same year in the southeast in the winter/early spring and in Cape Cod Bay or Great South Channel in the spring. By looking at these two data endpoints and factoring in speed of travel long the coast and distances to major port entrances, it will be possible to assess the time frame that the majority of these animals would be passing by the major port entrances along the mid Atlantic and to see how much this time frame could vary on an annual basis. An assessment of available survey effort, satellite tagging data, and photo id records from the mid Atlantic should also be made to determine whether the geographic extent of this migratory corridor can be well defined.

Economic impact analysis. Conduct more detailed treatments of port-specific economic effects by enhancing and providing more accurate data into a model currently under development. An ongoing project is examining economic impacts of risk reduction strategies on the regulated industries. These economic impacts may ultimately extend down the supply chain to consumers. It is therefore important for regulators and others to understand the complexity of the shipping industry and to consider the potential economic impact before implementing management options. For example, many shipping companies are foreign owned, port authorities have limited management control over vessel and waterfront activities (except those managed directly by the port authority), management practices and labor contracts put pressure on schedules and on masters that have ripple effects. The effects may translate across transportation modes, may affect the entire East Coast and may extend to inland distributors and manufacturers. The shipping industry and associated inter-modal transportation (truck, rail and pipeline) could incur additional costs due to the management measures under consideration. This is particularly important to address, as long-term viability of some ports may be further threatened if there is a perception of higher transaction costs and /or real significant costs to trade at one port over another competitor port. This was partially funded by NMFS.

Integrate all available information into a management system
Continue and expand the ongoing development of an effective information management system using GIS. Survey data, ship routing data, data from the right whale catalogue on individual whales, for example scarring and lesions, could be used to monitor the health of the population and the effectiveness of management measures designed to reduce human impacts on whales. Maps, graphs, and tables generated from these management systems must be backed up by proper analysis of the data

Merchant mariner education
- Continue, enhance and accelerate the development of a program and outreach strategy to assist mariners, worldwide, in voyage planning, qualifications and licensing programs, and in their shipboard safety management planning. The focus should be on understanding: existing and new regulations on right whale protection; the seasonal occurrence of right whales on their routes; and prudent measures to avoid high-risk areas or other means (e.g. speed reduction) to reduce their risk of collision.
- Develop a right whale ship strike curriculum module for mariners in training (i.e., service and maritime academies, pilots programs), continuing education, and licensing upgrades.

Right whale detection research/monitoring. At present, right whale detection relies heavily upon visual sightings. Whales can only be seen when they are at the surface during daylight hours, detecting them is highly dependant on weather conditions. Aerial surveys are currently an important method for detecting the presence of right whales in many circumstances, but there are additional ways of monitoring for right whales that are presently under consideration and require further development. The information gaps on right whale distribution are particularly acute in certain regions where ship strikes are concentrated. In addition, in certain port areas, there is very little or no data on right whale occurrence, distribution and movements (e.g. the Mid Atlantic). This is a priority for future research effort.

Detection will likely require an integrated surveillance system with a combination of aerial surveys, acoustic detection, and predictive modeling**.** Elements of an integrated surveillance system will rely on real-time information on the known or predicted location of right whales through a surveillance and predictive modeling program. Such a system may include aerial surveillance, vessel platform observations, acoustic detection arrays, GIS (historical data) and predictive modeling. Passive acoustic methods may contribute to a surveillance system. Like most marine mammals, right whales are difficult to see, and they cannot be seen at all at night or in fog. Some of the regions from which information on right whale distributions are critical are particularly difficult areas to detect right whales visually. The Great South Channel (GSC) for example, is some 50 miles offshore and right whales are found here in the spring when the weather is poor, fog is frequent and days are short. Currently, although aerial surveys are flown over the GSC, these are expensive and can only provide intermittent coverage. These considerations have encouraged several research groups to investigate passive acoustic techniques for detecting right whales in such areas. Some of this passive-acoustic research has proceeded on two fronts. Developing an effective detector for right whale vocalizations, and assessing vocalization rates and detection ranges. In addition, simulations to explore the effectiveness of potential acoustic systems are planned. These studies will simulate detection rates and risk reduction given assumptions (and increasingly data) on vocalization rates, source levels, background noise, and right whale and vessel distributions. Due to the low and intermittent vocalization rates in the GSC, it is already clear that it will never be possible to give accurate up to the minute information on the locations of right whales. On the other hand, it may still be possible to provide useful information on a larger temporal and spatial scale. For instance, if whales were heard predominantly in one particular area one day, it is likely that they would still be in the same area the next day and diverting ships away from that area on subsequent days may significantly reduce the probability of a strike. In situations where there are a large number of unknown parameters, a common practice is to develop a simulation, which can be easily (and relatively cheaply) manipulated to study the effects of different detection systems and management strategies on the numbers of vessel strikes. Simulations can also be helpful in prioritizing future data collection effort. For example, developing a better understanding of day to day movements of groups of animals may be as important as improving our knowledge of their vocalization rates and detection ranges. As improved information on right whale behavior becomes available, it can then be fed back into the model to improve its effectiveness. Such a simulation need not necessarily be confined to acoustic monitoring, but could also be used to study relative merits of aerial surveys, and other methods.

Aerial surveillance

- *Systematic surveys of port approaches:* There are major gaps in knowledge of the occurrence of right whales in the mid-Atlantic and northern parts of Southeast U.S. from Block Island Sound to Savannah, GA. Survey data for these areas is virtually absent. Yet, we do know that as many as 90 whales migrate through these areas, crossing major port approaches. Predictive modeling can provide estimates of the occurrence of right whales in the port approaches. The degree of confidence in these estimates, both temporal (e.g. do the whales lead or lag the estimates, are the peak times at port approaches narrowly or broadly defined?) and geographic extent (i.e. how far offshore?), will be problematic for both right whale protection and shipping.

- *Evaluation of the effectiveness of aerial survey techniques:* Work should be conducted to evaluate the effectiveness of aerial survey techniques in providing data on which management actions can be based. Preliminary work has indicated that air surveys are detecting only a low percentage of whales that are in a given survey area. Further studies are needed to determine with statistical confidence if increased effort and or changes in techniques would result in significantly more sightings for an area. Data on detection probabilities could be obtained directly from replicate aerial surveys using similar methods to those used for abundance estimation of other cetacean species. However, there is a trade-off between flying replicate surveys covering a smaller area and effective surveillance of a larger area. Coincidental with this work, studies of right whale behavior, including blow rates and the proportion of time spent underwater in each unique right whale habitat will affect the probability of detection. Studies of right whale diving behavior to understand the amount of time whales spend at the surface and can be seen during aerial surveys) would also contribute to estimating detection probabilities. Right whale behavior is likely to vary between habitats and according to oceanographic conditions. Data on sightings probabilities are required for various demographic components of population (e.g. mother/calf pairs, vs. single adults, juveniles, etc.) by season and by area. Research to ascertain the time spent underwater and at the surface, over defined time intervals has been conducted, but not in all areas.

- *Aerial surveys in the Southeast U.S (SEUS):* These surveys are flown to detect right whales and alert mariners so that they may avoid or use caution when transiting those areas. Four areas in the SEUS are surveyed at varying effort levels. The Early Warning System (EWS) surveys are flown daily (weather permitting) from 10 nautical miles (nm) north of Brunswick to 10 nm south of Jacksonville from the beaches out approximately 18 nm. Surveys are flown offshore of this area with nearly the same level of effort. Surveys are also flown just north and south of the EWS survey area with somewhat less frequency. Three aerial survey efforts in the SEUS use east-west transects flown three nm apart. The mean sighting distance for EWS surveys flown by New England Aquarium from 1994-2000 was 0.74nm. Over the past 5 years, surveys have revealed right whale distribution patterns. For instance, right whales appear to be found most often in the EWS area and ~5-10 miles just north, south, and east of the EWS area. Existing data should be analyzed to determine where most sightings occur relative to survey effort. Management goals may be better addressed by using transects that are closer together (e.g., 1-1.5 nm apart) and redistributing survey effort to concentrate on areas where most whales are likely to be observed. If the condensed survey area and refined survey methodology (transects closer together) are concentrated around port entrances and include those areas where close encounters between ships and whales have been observed, managers could be relatively confident that they are achieving their management goals for these aerial surveys in the most efficient manner possible.

Passive acoustics: Recent ongoing research on the detection of right whale vocalizations using passive acoustics has demonstrated that this technique has potential for detection of vocalizing right whales in certain offshore areas, at ranges of 10 miles or so. Research into further automation of the detection process and the implementation of a fully automatic, real-time detection system suitable for deployment offshore is underway but with limited. This is potentially an important additional technique for real-time detection of right whales and if implemented on a wide scale, will require investment in technological developments. This has been partially funded by the Northeast Consortium and the International Fund for Animal Welfare.

Predictive modeling. Continued research into the biological and oceanographic ‘predictors' of right whale distribution on suitable scales is needed. These predictors include variables such as sea surface temperature, biological-ocean productivity, and copepod (prey) distribution. This could include for example, the development of quantitative methods to identify and assess samples collected by a small fleet of vessels under contract (e.g. whale watch vessels, charter boats, ferries, ships on dedicated runs, fishing vessels) to identify densities of calanoid copepods, followed up by aerial surveys. Reviews of historical data should be useful in this context.

Satellite tagging. Tagging and long term tracking of right whales could also be used to understand the occurrence of right whales in high-risk areas. However, some analysis needs to be done before considering whether satellite tagging or aerial surveillance will be more effective for this. Existing data from satellite tagging of a few individuals indicates highly variable behaviors. Satellite tagging provides a potentially long time series of data on movement patterns for a single individual but tagged individuals might not go to the areas where risk assessments are being considered or be truly representative of the whales in that area. In contrast, aerial surveillance can be targeted at essential areas and results are less sensitive to individual variation, but observations are limited to a short time period. However, concerns have been raised by several conservation groups and research institutions regarding the threat that these implantable tags pose to the health of the subjects. We recommended that, before a program of satellite tagging of right whales, the long-term safety of tags be demonstrated on non-endangered species before issuing further permits for their use on endangered North Atlantic right whales. As well, that the relative merits of satellite tagging over research techniques be evaluated in light of the need to close information gaps for the explicit purpose of reducing ship strikes.

Active sonar detection; evaluation of concept. Several researchers have advertised an unproven technology that *could* detect right whales ahead of ship using active sonar. Port authorities and the shipping industry have embraced the concept as a technologic solution instead of or in addition to other management options. In contrast, acoustic experts have examined the use of active sonar and have dismissed the approach as unworkable. The use of bow-mounted active sonar to detect whales underwater ahead of vessels might enable vessels to detect and avoid whales. However, active sonar detection systems have actually only been tested and proven at short ranges of up to about 50 m, for scientific purposes. Further trials are planned in the hope that future technological developments could improve this range, such that it might improve the ability of some types of vessel to avoid whales. These systems are currently not able to differentiate between species of whale. Concerns have also been raised about the environmental impacts of increasing noise levels in the ocean, particularly disturbance to dolphin and porpoise species that are known to have sensitive hearing in the same sound frequencies. Prior to further discussion on the potential use of this technology in ship strike mitigation, the practical, commercial application of active sonar in the context of ship/whale strike mitigation needs to be realistically presented, including, for example, realistic time frames for the required technological development and careful consideration of possible environmental impacts. We are also concerned that detection by itself does not mean avoidance. Even if the technology were proven an effective detector for more than a few hundred yards, such a system much demonstrate its effectiveness in assisting the mariner in avoiding as ship strikes.

Right whale behavior in relation to ships. Little is known about how right whales react to approaching vessels, and what characteristics of a vessel sounds enable a whale to hear an approaching vessel and realize that there is a threat of a collision. Models and simulations of right whale motion relative to vessels should be developed, to include components of behavior, ship speed, hydrodynamics of different vessels. The collection of data on ‘near-misses’ and close approaches between whales and ships is important to determine whale behavior near vessels. The behavior of the ship should also be examined as there is some indication that changes in vessel speed or course may signal to the whale that avoidance actions are necessary.

Mortality data. It is necessary to better estimate the number of whales killed by ships. The question of the few number of confirmed ships strike mortalities is a consistent concern expressed by the shipping industry –it is possible that many more right whales are affected, but the deaths go undetected or unconfirmed. It has also been demonstrated that ship strikes are a major source of right whale mortality. It would be useful however to assess whether the cause of death determined from strandings and necropsied animals accurately represents the mortalities that occur in offshore and “presumed” mortalities in the catalog. It would also be useful to compare beached animal necropsy data with data from animals retrieved by boat from offshore locations for necropsy.

Port Access Route Studies (PARS)

The Ports and Waterways Safety Act (PWSA)(P.L. 95-474, 33 U.S.C. 1223(c)) requires the Coast Guard to conduct a Port Access Route Study (PARS) before establishing new or adjusting existing fairways or traffic separation schemes (TSS's). A primary purpose of a PARS is, to the extent practicable, to reconcile the need for safe access routes with other reasonable waterway uses such as renewable energy sites. A PARS also seeks to reduce the risk of marine casualties and increase the efficiency of vessel traffic in the study area. Recommendations from a PARS may lead to future rulemaking action or appropriate international agreements.

In addition to aiding us in establishing new or adjusting existing fairways or Traffic Separation Schemes (TSS), the PARS process may be used to determine and justify if safety zones, security zones, recommended routes, regulated navigation areas, and other ships' routing measures should be created.

PARS overall objectives include, but are not limited to, the following:

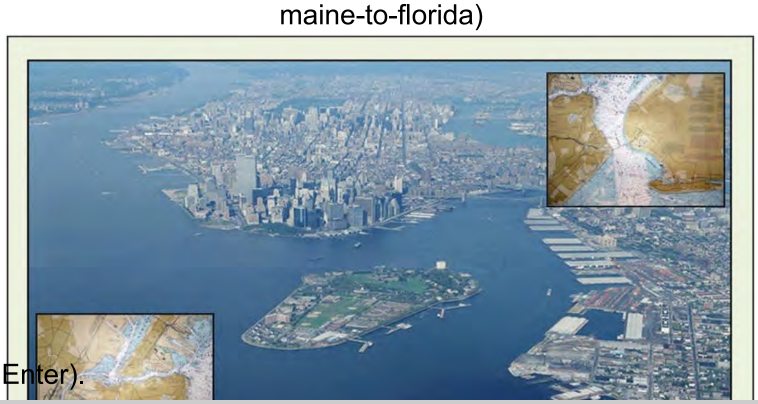
1) Determine present vessel traffic density.
2) Determine present vessel traffic movement.
3) Determine potential vessel traffic density.
4) Determine if existing vessel routing measures are adequate.
5) Determine if existing vessel routing measures require modifications.
6) Determine the type of modifications.
7) Define and justify the needs for new vessel routing measures.
8) Determine the type of new vessel routing measures.
9) Determine if the usage of the vessel routing measures must be mandatory for specific classes of vessels.

PARS Websites:

PARS for Bering Strait, Alaska
(http://www.federalregister.gov/articles/2010/11/08/2010-28115/port-access-route-study-in-the-bering-strait#p-3)

PARS for San Francisco, California
(http://www.federalregister.gov/articles/2009/12/10/E9-29415/port-access-route-study-off-san-francisco-ca)

PARS for Atlantic Coast from Maine to Florida
(http://www.federalregister.gov/articles/2011/12/09/2011-31594/port-access-route-study-the-atlantic-coast-from-maine-to-florida)



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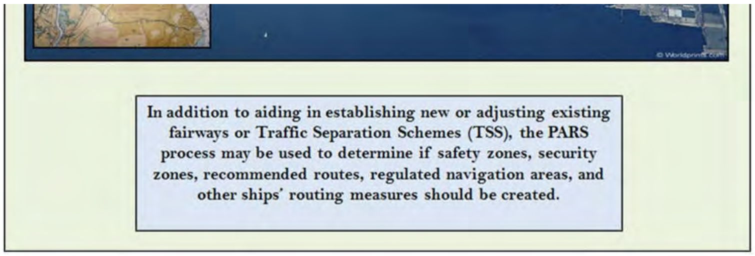

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