Marine Mammal Commission

An independent agency of the U.S. Government

North Atlantic Right Whale Tagging Workshop Report

February 2024

North Atlantic Right Whale Tagging Workshop Report

Marine Mammal Commission

An independent agency of the U.S. Government

4340 East-West Highway, Room 700

Bethesda, Maryland 20814

www.mmc.gov

Photo Credits:
Cover page: Tim Cole/NMFS/NEFSC, NMFS permit #17355
Pages 5,12: Georgia DNR, NMFS permit #15488
Page 13: Florida Fish and Wildlife Conservation Commission, NMFS permit #775-1875

Suggested Citation: Marine Mammal Commission. 2024. North Atlantic right whale tagging workshop report. Final report, Marine Mammal Commission. Bethesda, MD. 37 pages.

Table of Contents

North Atlantic Right Whale Tagging Workshop Report

Herndon, Virginia

September 12-14, 2023

Workshop Overview

The workshop convened 52 experts in diverse fields including marine mammal biological and ecological research, veterinary medicine, whale tagging technology, and management and policy with some participants joining in person and others remotely. Experts were invited to review and summarize current knowledge of the effects of telemetry tags on the survival, reproduction, and health of North Atlantic right whales (*Eubalaena glacialis*) and other baleen whales, as well as to assess the capabilities of telemetry devices currently available to address knowledge gaps relevant to North Atlantic right whale behavior, distribution, and movements.

The **goals** of the workshop were to:

- Review key knowledge gaps and data needs regarding the movements and ecology of North Atlantic right whales;
- Review the history of satellite telemetry and evaluate progress in tag attachment technologies and follow-up studies;
- Generate knowledge to inform planning and permitting decisions regarding potential tagging of North Atlantic right whales, as well as other endangered baleen whales.

The first day was open to the public, with a series of presentations by scientists that reviewed current tagging technologies and their uses on northern and southern right whales and other baleen whales. Government officials provided an overview of the permitting environments under their respective legislative frameworks. The second and third days were a closed workshop for invited experts with focused discussion on the status and performance of current tag technologies for tagging North Atlantic right whales to address management questions vital to conservation, and on follow-up studies undertaken with other species to assess potential effects of tags on individual whales. Participants provided summaries of the different tag types that are currently used on baleen whales and discussed the evolution of their design, capabilities, limitations, and effects on health and survival, with examples of use in other species. Management and research data gaps for endangered North Atlantic right whales were identified, and the potential value of different tag types to fill these data gaps was discussed. The utility of technologies other than tagging in fulfilling these needs was beyond the scope of the tagging workshop and is expected to be addressed in other workshops, and therefore, was not discussed in depth. The participants identified several action items that should inform future management and permitting decisions regarding tagging North Atlantic right whales. The workshop invitees were specifically told that consensus was not being sought but rather they were expected to provide individual expert opinions regarding steps to consider when contemplating North Atlantic right whale tagging projects.

About the Host Agencies

The Marine Mammal Commission is an independent, federal agency charged by the Marine Mammal Protection Act to further the conservation of marine mammals and their ecosystems. The Commission provides science-based oversight of all science, policy, and management actions affecting marine mammals.

The Marine Mammals and Biology program within the Office of Naval Research supports basic and applied research and technology development related to understanding the effects of sound on marine mammals, including physiological, behavioral, ecological, and population-level effects.

NOAA Fisheries is responsible for the stewardship of U.S. ocean resources and their habitat. They provide vital services for the U.S.: productive and sustainable fisheries, safe sources of seafood, the recovery and conservation of protected resources, and healthy ecosystems—all backed by sound science and an ecosystem-based approach to management.

Fisheries and Oceans Canada helps to ensure healthy and sustainable aquatic ecosystems through habitat protection and sound science. Their work supports economic growth in the marine and fisheries sectors, and innovation in areas such as aquaculture and biotechnology.

Background

The North Atlantic right whale (*Eubalaena glacialis*) (NARW) is listed as endangered in the U.S. and Canada, with approximately 360 individuals and approximately 70 reproductively active females remaining (Pace et al. 2017, Pettis et al. 2022, Linden 2023). The recent decline caused in part by high mortality that was declared an Unusual Mortality Event in 2017 has included, at January 2024, 122 deaths, serious injuries, and cases of morbidity (sublethal injury/illness). Undetected deaths (cryptic mortality) also occur, as some individually identified animals have not been resighted (Pace et al. 2021). Vessel strikes and entanglement in fishing gear are recognized as the two primary causes of death. NARWs are at high risk for vessel strikes due to their slow movement and the amount of time they spend at the surface. Additionally, fishing gear, such as vertical lines in the water column, entangle whales, and cause serious injury and death. Non-lethal entanglement has been shown to lead to increased stress, reduced energy balance, and impaired movement, feeding, growth, and reproduction (Stewart et al. 2021, Knowlton et al. 2022). Additional threats to NARWs include changes in prey distribution and quality due to climate change, exposure to anthropogenic noise and biotoxins, and the cumulative effects of multiple stressors, with body lengths of whales having decreased over the past four decades (Stewart et al. 2021 & 2022, Meyer-Gutbrod et al. 2022, Pirotta et al. 2023).

Extensive research on NARWs has provided valuable information necessary for implementing more effective management measures. Knowledge gaps do still exist that, if filled, could potentially serve to refine or expand present and proposed management measures. These gaps include details on seasonal migration and distribution, use of unknown habitats, persistence in areas of threats, and behavior within the water column. Due to their endangered status, it is essential that all scientific research on NARWs be conducted in a way that minimizes effects on individuals to ensure population recovery.

A variety of methods are available or under development to detect and monitor whales, with varying potential impacts on whales, including passive acoustic monitoring (PAM), aerial and boat-based visual surveys, and the use of telemetry devices attached to the animals; research is ongoing to develop new detection technologies such as those based on satellite imagery and infra-red imaging techniques. Additionally, biologging tags are commonly used in wildlife research and conservation, including on marine mammals. For large cetaceans, both tag technology and monitoring for health effects have improved over the years, yet concerns remain over the potential effects of tags on individual health, reproduction, and survival.

This workshop was convened to review the most recent capabilities, limitations, and potential effects of biologging tags designed for use on baleen whales in order to inform decisions on why, whether, when, and how to tag NARWs. NOAA Fisheries (NMFS), the Marine Mammal Commission (MMC), and the Office of Naval Research (ONR) in coordination with Fisheries and Oceans Canada (DFO) convened this workshop to discuss methods to increase knowledge and address data gaps for the conservation of NARWs and provide NOAA Fisheries and DFO summarized scientific and technical information to evaluate when considering permitting the use of tags on NARWs.

Workshop Activities

Day 1 was an **open meeting**, with presentations and panel discussions by invited experts (Appendix A) who reviewed progress in tag development and use with baleen whales, the capabilities and limitations of current tag types, management questions that such tags could help address, and the permitting requirements for tagging whales in the United States and Canada. The first day set the stage for this tagging workshop in the context of previous workshops and existing Best Practice Guidelines for Cetacean Tagging (Andrews et al. 2019), which should be considered for all cetacean tagging projects. The agenda is included as Appendix B, and the presentations are available at https://www.mmc.gov/events-meetings-and-workshops/other-events/narw-tagging-workshop/

Frances Gulland and Michael Weise introduced the goals for the workshop, which were to review key knowledge gaps and data needs regarding the movements and ecology of North Atlantic right whales and evaluate progress in tagging technologies for baleen whales to provide updated information to NOAA Fisheries and DFO to consider in their decision-making on telemetry studies for NARWs. Greg Donovan next emphasized the need for tagging programs to be question-driven and for tagging to be considered in the context of cumulative effects. He mentioned the value of cost-benefit analyses to assess population-level consequences with respect to survival and reproduction, the need to consider limitations of sample size, and the importance of ensuring the resulting data inform and improve mitigation and management efforts. He emphasized that if tagging is deemed necessary and appropriate, experienced personnel, detailed tagging protocols, follow-up studies, and prompt analysis of data are all essential.

The first panel discussed gaps in knowledge of NARW ecology and movements pertinent to management needs, with emphasis on information that can be provided by tag data. Véronique Lesage described how a tagging study of NARW dive behavior in the Gulf of St. Lawrence contributed to understanding threat exposure, by revealing that whales had interannual variability in dive behavior, and often dove to the seafloor with a higher risk of entanglement during the day, whereas they tended to stay near the surface and be at greater risk of vessel strike at night.

Colleen Coogan discussed information needs of the Atlantic Large Whale Take Reduction Team, including the need to know where NARWs are between October and December, where unobserved deaths are occurring, and what is causing them. She also cited current stakeholder requests for tagging data to support proposed management measures.

Clay George described current threats in the NARW calving grounds, including military training and vessel traffic. He discussed how tagging could help to determine where whales go when they leave the standard aerial and boat-based survey areas. He emphasized that a tagging program should include accurate identification of the demographic groups being targeted, a robust pre-tagging health assessment, improved tag attachment methods, and a requirement for all health assessment images to be submitted promptly for integration into the NARW catalog curated by the New England Aquarium.

Sean Hayes illustrated the current situation for NARWs with a series of statistics (see Appendix C). He emphasized knowledge gaps regarding NARW presence, distribution, and migration throughout the year, despite increased survey efforts since 2016, and reported on Congressional and constituent inquiries in recent years expressing concern that NOAA Fisheries does not have enough data to support and implement proposed mitigation measures. He stated that such concerns likely led to the six year pause to further regulation of the lobster fishery, demonstrating that there is a limit to how much protection can be implemented without greater scientific certainty about human activities and impacts on the whales. Hayes suggested that tagging is a method that could provide that increased certainty. Scott Kraus gave another series of statistics stressing the vulnerability of NARWs to extinction (see Appendix C).

Amy Knowlton suggested that the potential benefits of tagging were outweighed by the potential health impacts and questioned whether tagging data would substantially improve management. She recommended a retrospective analysis of tagging efforts to understand any health impacts and whether management measures were better informed as a result. Knowlton also expressed concerns about the selection of individual whales to tag and the need for follow-up surveys to evaluate potential health impacts and to also learn more from tagged whales and where they go (e.g., are there other whales in the vicinity of tagged animals). She asked whether lessons learned from other species are applicable to a species such as the NARW that is already health-compromised and faces multiple stressors. Michael Moore reinforced these concerns over the health of the NARWs facing multiple stressors.

Erin Meyer-Gutbrod noted that NARW conservation is difficult because the whales' habitat use and distribution are unpredictable. Their distribution is often a function of where prey is, but prey distribution is dynamic in part due to ongoing effects of climate change. She identified several key questions to improve our understanding of current and future NARW distribution, including what the whales are feeding on, where their prey is in the water column, what regions and seasons they feed in, and whether their foraging environment is sufficient to support growth and reproduction. She suggested that declining reproduction can be associated with poor foraging conditions, and that periods of poor foraging and reproduction may, therefore, lead to a shift in habitat selections.

The regulations in the U.S. and Canada pertinent to tagging NARWs were reviewed by Amy Sloan and Laurence Deneault-Tremblay. In the U.S., NOAA Fisheries issues research and enhancement permits under the Endangered Species Act and Marine Mammal Protection Act (MMPA). All research must be *bona fide* and humane, such that it involves the least practicable degree of pain and suffering, does not present unnecessary risks to health and welfare, and is unlikely to have an adverse impact on the species. Where applicable under the Animal Welfare Act, research must be approved by an Institutional Animal Care and Use Committee. Annual reports, including information on successful and unsuccessful invasive tag deployments and post-tagging monitoring, are required by NMFS permits. Currently, five NMFS permits authorize NARW suction-cup and/or Type A (LIMPET-style dart) tagging in the U.S. For invasive tags (tags that pierce the skin), these permits require post-tagging monitoring of all individual whales, prohibit tagging reproductive aged females, calves less than six months old, and animals in poor health, and stipulate that tags must not penetrate deeper than the blubber layer. Researchers must take reasonable measures to identify individual whales before invasive tagging and report the tagging event within 24 hours to the NOAA Fisheries Permits and Conservation Division and the Marine Mammal Health and Stranding Response Program.

In Canada, tagging of endangered or threatened species such as NARWs is permitted under the Species at Risk Act (SARA). The use of a Remotely Piloted Aircraft System (RPAS) over a marine mammal in order to facilitate tagging activities also requires an authorization under the Marine Mammal Regulations of the Fisheries Act. Under SARA, permits are delivered for research activities, for activities that will benefit the species or enhance its chance of survival in the wild, and for any activities that may affect a species incidentally. Certain pre-conditions must be met, including that all reasonable alternatives that would have a lesser impact on the species have been considered and the best solution has been adopted, all feasible measures have been taken to minimize the impact on the species or critical habitat, and the activity will not jeopardize survival or recovery of the species. In 2023, two permits authorized NARW tagging in Canada, one for suction-cup and one for Type A (LIMPET-style dart) tags. SARA permits issued for tagging have associated conditions to address items such as, but not limited to: vessel approach distances and speed limit, interaction time with the animals, photo-identification and visual health assessment prior to tagging individuals, prohibitions of tagging animals in poor health or mother-calf pairs, etc. The Canadian framework also requires that a report be submitted after completion of field activities including details such as, but not limited to, sightings, interactions, activities carried out and methods, as well as highlighting any mitigation measures implemented.

Michael Weise presented the "Best practice guidelines for cetacean tagging" (Andrews et al. 2019; Appendix D). These guidelines provide internationally recognized standards for tagging programs, with standardized terminology and protocols for tag deployment and follow-up studies, and are a resource for tag users, veterinarians, ethics committees, and regulatory agency staff.

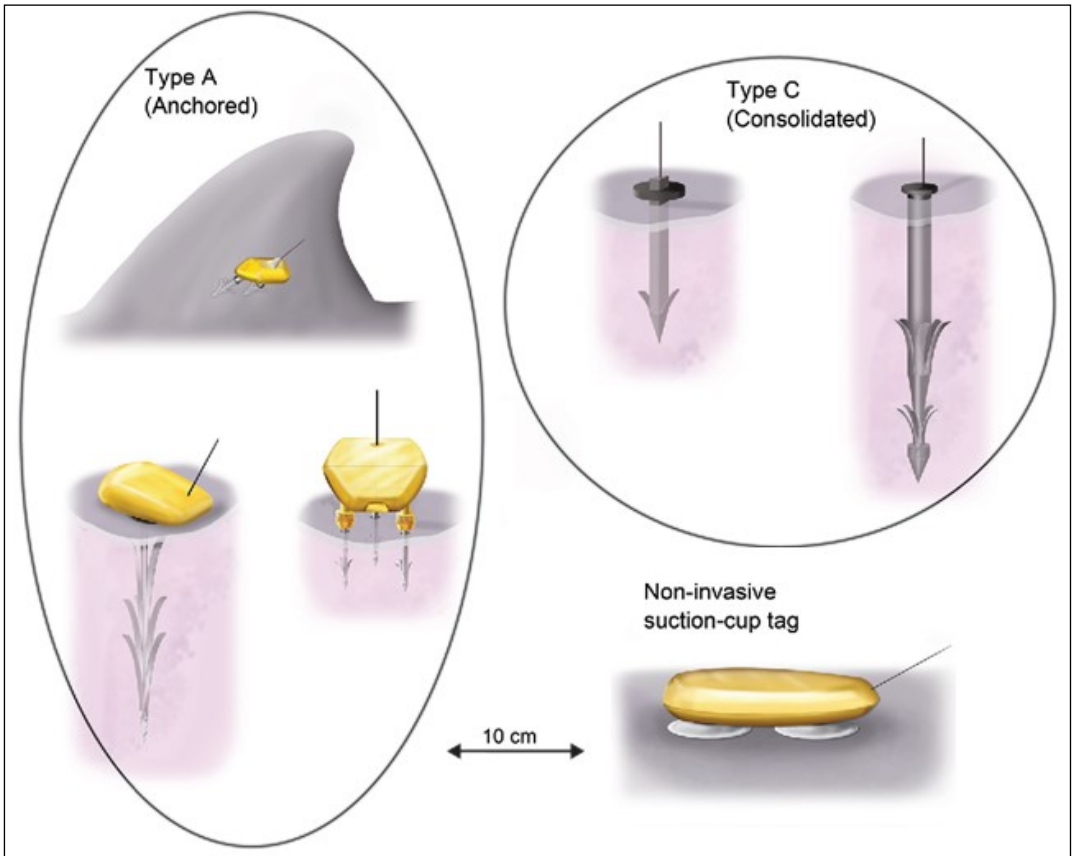


Figure 1. Tags that could be applied to North Atlantic right whales include non-invasive suction-cup, Type A (Anchored), and Type C (Consolidated). Image modified from Andrews et al. 2019, illustrations by Michael Ortiz.

Dave Weller reviewed the history of NARW tagging and previous workshops on this subject. He stated that approximately 90 invasive tagging events of 85 individual NARWs occurred from 1988 to 2023, and 214 suction-cup tagging events of 160 individuals occurred from 1999 to 2021 (Fisheries and Oceans Canada 2023; North Atlantic Right Whale Consortium 2023). Reviewing these data should improve understanding of what information was gained and whether management improved as a result, yet such an analysis has not been conducted.

Experts in tagging and tag development provided overviews of different telemetry tag types (see Figure 1) and anchor designs, the species on which they have been deployed, tag locations and deployment durations, and data gathered from the tags. They discussed known or suspected effects of tags on individuals based on follow-up studies, and overall challenges and opportunities.

Alex Shorter and Susan Parks reviewed the use of suction cup Dtags which are often used to evaluate baleen whale behavioral responses to disturbance. These short duration (hours, occasionally days) attachment tags offer high resolution data on how whales use habitat, including depth, movements, and location in the water column, often using audio and video data and GPS position, that have contributed to conservation. Tag effects noted were modifications to dive behavior in the first and second dives after tagging, and noise disturbance from vessel or drone deployment. Suction-cup tags must be retrieved to allow data download once they detach from the whale.

Russ Andrews presented an overview of Type A LIMPET satellite tags, consisting of an external electronics package and two or more short retention elements that insert into the blubber. He described a project where seven right whales were tagged with LIMPET tags in the southeastern U.S. during 2015-2016. The duration of attachment of these tags, with up to 7 cm of dart penetration, ranged from 2 hours to 50 days, with a mean of 10.8 days and a median of 3.1 days. He noted that all tagged whales were re-sighted at least once after tag loss,

and in all seven, tag wounds appeared to have healed well. One whale tagged during the study was later entangled in fishing gear in 2017 and is now presumed dead as a result of the entanglement.

John Calambokidis contributed his experience with Type A- archival tags on baleen whales other than NARWs, highlighting the choice of these longer duration (days) tags attached with darts over suction-cup tags as dictated by the goals of a particular study. These tags have provided critical data on whale-human interactions, including whale responses to sound, and whale movement and behavior around ships and fishing gear. Duration of attachment varies by species and the type of tags used, with Type A tags providing high resolution behavior and movement data over varying periods. Limitations to Type A tags include damage or loss of the tag caused by animal-to-animal contact, breakage of dart attachments that can lead to retained fragments in whales, and the difficulty of recovering some types of sensors on archival tags in order to download data.

Alex Zerbini and Daniel Palacios presented an overview of Type C tag use with baleen whales and major findings. The electronics package and attachment systems of these tags are designed to be embedded in the body of the animals to reduce drag and minimize risks of premature detachment due to contact with conspecifics or the ocean floor. Most Type C tags are designed to anchor below the blubber muscle interface and are, therefore, long duration. These tags last weeks to months and for some species (e.g., southern right whales (*Eubalaena australis*), bowhead whales (*Balaena mysticetus*)) transmission durations longer than a year have been documented. Shorter tags that are attached in the blubber layer have been deployed and evaluated successfully in southern right whales. Type C tags are less vulnerable than other tag types to loss due to contact with other animals or the seafloor. Data collected from past Type C tag deployments on NARW have been limited because the specific tags chosen had fewer sensors than Type A tags, (see Table 1), yet their long duration has contributed to major findings on migratory routes and destinations, novel habitats, and ecology, all of potential value to management applications.

Zerbini described the evolution of Type C tags since 2014. By fixing design flaws, incremental improvements have been made on observed health effects on individual North Atlantic humpback whales (*Megaptera novaeangliae*) and in deployment durations on both North Atlantic humpback and southern right whales. Early Type C tags had articulated anchors and/or screw-on anchors at the anchor/transmitter interface, which led to a relatively large number of tag breakages and caused premature detachment of the tag (average duration of early tags on southern right whales was 47 days). In some cases these early Type C tags also caused swellings that persisted for some years. Welding of the anchor articulation and the anchor/ transmitter interface resulted in increased deployment durations (average of 112 days on southern right whales). Further modifications have led to the latest design, an integrated 3D printed Type C tag, resulting in even longer deployment durations (average of 211 days on southern right whales) and few to no observed effects on the health of tagged individuals.

Type C tags were deemed necessary for research on southern right whales, specifically to help determine changes in migratory destinations and foraging habitat use in response to ongoing climate change effects, and overlap of habitat use by whales and human activities such as fisheries, shipping, and oil and gas exploration. In reviewing several years of southern right whale tagging, Zerbini highlighted the importance of following tagging best practices, including predetermining tagging candidates, carrying out behavioral and health assessments both pre- and post-tagging, and requiring a local whale expert on board the tagging boat. The tagging program ultimately provided new information on the movements and habitat use of southern right whales at local, regional, and global scales.

Days 2 and 3 were **closed sessions** where invited experts discussed key information that can be gained from tagging, the evolution of tag technology and design, and the effects of tagging on baleen whales, using case studies from non-NARW populations of baleen whales. Diverse perspectives were expressed throughout the workshop regarding the value of tagging NARWs, but as mentioned earlier, no consensus was sought. Key elements of the discussions are summarized below.

Specific Discussion Topics

Stakeholder and Management Needs

Improved communication between and among scientists, managers, and stakeholders is needed in order to build a collaborative environment where the science is more clearly understood by non-scientists, and the management options are considered in the context of NARW population recovery. Communication about the strengths and limitations of tagging as a tool for research into NARW biology is needed amongst scientists, stakeholders, managers, and the public. The following science and management needs were discussed:

1. Better knowledge of current and climate-induced changes in temporal and spatial distribution of NARWs (ideally with age/sex class information) including consideration of breeding grounds, migration routes, and foraging grounds and especially with respect to human threats. More specifically, the following gaps were discussed:

- timing of migration and migratory routes (e.g., out of Cape Cod Bay in spring),
- Late summer/early fall distribution in Canadian waters after the main aggregation in the southern Gulf disperses,
- determining when and to what extent NARWs co-occur with threats including fishing, shipping, wind energy, etc. (e.g., Lobster Management Area 3 in the Gulf of Maine),
- location of presently unknown habitats and future potential habitats,
- summer distribution of the large portion of the population that is not in the Gulf of St. Lawrence,
- identification of areas to target with aerial or vessel-based surveys, and
- locations of entanglements, vessel strikes, and deaths.

2. A better understanding of fine scale dive behavior and bioenergetics including time at depth and position in water column in relation to threats of fishing gear and vessel traffic.

3. A need for region-specific detection functions (correction factors applied to survey data account for missed animals) to inform analyses of aerial surveys and passive acoustic monitoring data.

4. Continuous movement data to integrate with environmental information, such as ocean conditions and prey distribution, at a variety of scales, to increase understanding of habitat use and more reliably predict potential changes in distribution.

5. Better data and information to support management decisions and more effective communication among stakeholders and Congress, including the consideration of how different management scenarios may contribute to population recovery (Runge et al. 2023).

Ongoing NARW Tagging Projects

Véronique Lesage and Russ Andrews presented an overview of a current project using Type A (LIMPET) satellite tags on NARWs in Canada which follows the guidelines and protocols set in the published “Best practice guidelines for cetacean tagging” (Andrews et al., 2019). The project

objectives include obtaining data on NARW diving behavior and movement patterns in relation to prey distribution to assess vulnerability to entanglement and vessel strikes in the Gulf of St. Lawrence. Data collection occurred over the span of four field seasons with the deployment of 27 tags in the Gulf of St. Lawrence. Preliminary results indicate variability in deployment duration across years (median range of 0.5 days to 11.3 days), as well as inter-annual and seasonal variability in dive behavior. The study is intended to inform management and policy decisions, and has reinforced existing management measures such as fishery closures in shallow waters. For example, movement patterns revealed that NARWs frequent shallow waters in the Gulf of St. Lawrence, which many suspected was not the case. Further, the presenters shared details of a recently tagged whale which has been flagged for monitoring due to it being re-sighted with swelling and lesions at the likely tag attachment site on the body. The study is ongoing including post-tagging visual health assessments using serial photographs.

Deciding Whether to Tag Whales: Case Studies

In deciding whether or not to tag whales, full consideration of alternative less invasive methods to obtain the information is required by the U.S. and Canadian permitting agencies. These methods, such as aerial surveillance, were only briefly discussed during the workshop, as the intent was to discuss them at future workshops. A table summarizing alternative methods to tagging and a decision matrix were drafted by Michael Moore and Roxanne Gillett, see Appendices E and F, but were not reviewed by all workshop participants.

Several case studies of tagging endangered baleen whales, including southern right whales, with Type C tags were discussed. These case studies highlighted both the decision-making processes and the management applications and implications that resulted from the increased and sometimes novel data that the tags provided.

Western gray whales

Dave Weller presented an overview of the Type C tagging program for western gray whales (*Eschrichtius robustus*). The goal of this work was to determine where whales went in winter after leaving their summer/autumn feeding area near Sakhalin Island, Russia. It was generally understood by the international expert panel working on these whales that no other technology or approach could address this question. The first whale tagged migrated east and south from the Russian Far East to the eastern North Pacific and U.S. waters instead of south to Asian waters as predicted. The program followed strict protocols for tagging and candidate whale selection, with experts present in the field to identify individual animals. For transparency, tracking data were shared with stakeholders and the public in near real-time which incorporated a two-day delay given the sensitivity of the data. Despite the small sample size, the results of this study (three whales tracked to the coast of Canada, the U.S. and/or Mexico) revealed unexpected migration routes within this endangered population and highlighted a possibly even more critical conservation status of the few western gray whales that migrate south from Sakhalin and remain in Asian waters.

Arabian Sea humpback whales

Andy Willson presented work on Type C tagging of Arabian Sea humpback whales. Limited temporal and spatial coverage by vessel surveys and acoustic deployments hindered the design of urgent efforts to mitigate the threats of vessel strike and entanglement to Arabian Sea humpback whales. These

known threats were evaluated relative to the risks and benefits of tagging prior to the decision to initiate a tagging program. The program was implemented following the "Best Practices Guidelines" (Andrews et al. 2019) and with an expert in individual whale identification in the field with the tagging team. The use of Type C tags was deemed necessary to identify hot spots for this population outside of its known core range. Results have informed risk assessment work and informed proposals for vessel management to minimize risks of vessel strikes to whales. The study highlighted the importance of integrating movement and behavior data into species distribution models and mapping. It also indicated the need for distribution, or habitat, models to consider the changing climate, and in turn environmental variables that may be driving distribution.

For the case studies of the western gray whales and Arabian Sea humpback whales, the ethics and cost/benefit of tagging critically endangered animals where the survival of each individual is potentially important to the population were evaluated. In these cases, the potential benefits of Type C tagging were deemed to outweigh the risks, and the projects went forward.

Southern right whales in Argentina, South Africa, New Zealand, and Australia

Alex Zerbini presented work on Type C tagging of southern right whales at coastal breeding and foraging locations around the southern hemisphere. The tags transmitted for several months to well over a year and revealed migratory destinations, foraging areas, and habitat use. Re-sighting of whales tagged in Argentina was used to evaluate health effects of tagging (see below).

Themes common across all three case studies included:

- the importance of having a clear research question and management applications in mind and using this to guide tag type selection with the goal of minimizing risk;
- having a protocol established before tagging as well as a person in the field with the tagging team who is familiar with the whales (demographic group, condition) and will help make final decisions on whether or not to tag;
- follow-up studies and ongoing review to document and assess tag effects and make changes as necessary;
- communication with the public to explain why certain tag types were chosen; and
- promoting the public sharing of data whenever possible.

U.S. Regulations Pertinent to Animal Welfare

The Animal Welfare Act constitutes the legal authority for ensuring the welfare of animals used in research, although exemptions exist. It requires review by an Institutional Animal Care and Use Committee (IACUC) that consists of at least three members, one of whom is the attending veterinarian of the facility undertaking the research and one of whom is not affiliated in any way with the facility other than as a member of the committee. Amongst other duties, the IACUC must determine that the proposed activities or significant changes in ongoing activities meet the following requirements:

i. Procedures involving animals will avoid or minimize discomfort, distress, and pain to the animals;

ii. The principal investigator has considered alternatives to procedures that may cause more than momentary or slight pain or distress to the animals, and has provided a written narrative description of the methods and sources.

https://www.aphis.usda.gov/animal_welfare/downloads/AC_BlueBook_AWA_508_comp_version.pdf

Canadian Regulations Pertinent to Animal Welfare

The Canadian Council on Animal Care (CCAC) is the national peer-review organization responsible for setting, maintaining, and overseeing the implementation of standards for animal ethics and care in science throughout Canada. Created in 1968, the CCAC is an independent, non-profit organization, acting in the interests of the Canadian people. The CCAC has developed a Certificate of Good Animal Practice® (GAP) for institutions with animal-based programs. To become GAP certified, an institution must, among other things, develop an animal ethics and care program including the establishment of an animal care committee as set out in CCAC guidelines. The animal care committee is responsible for reviewing all proposed research projects that involve animals and ensuring they are undertaken in accordance with the best available procedures and practices. Maintaining a Certificate of GAP requires regular reviews by the CCAC, which involves an assessment of the institution's animal ethics and care program, the effectiveness of the animal care committee to oversee the program, and the appropriateness of their animal facilities, practices, and procedures (CCAC 2023). Built within this framework is the necessity of animal care committees to consider the three Rs: replacement, reduction and refinement, which are a framework for examining how decisions should be made about animals in science. For more information, please visit the CCAC's website.

The movements of a few tagged individuals may or may not provide definitive answers regarding overall seasonal movements or consistent habitat use. The desired sample size will depend upon the questions to be answered. In the example of western Pacific gray whales, the tagging of three individual whales dramatically altered understanding of the population's range, seasonal distribution, and discreteness. The larger sample of southern right whales provided new information on their movements and habitat use at local, regional, and global scales. Knowledge gained may guide deployment of other survey or monitoring technologies or inform further tag studies.

Tag Type Choice

Participants discussed tag types (Figure 1; Table 1) that could address particular management questions within meaningful and reasonable timeframes (see Appendix G). When multiple different tag types could be used to answer a specific management question, experts urged that the least-invasive methods and/or tag types be used, which aligns with the ethical considerations in animal care and use protocols overseen by animal care committees. Due to time constraints and the narrow focus of this workshop, alternatives to tagging (e.g., Baumgartner et al. 2020, Crowe et al. 2021, Hodul et al. 2022) were not discussed in depth.

Follow-up Studies/Health Assessments

Follow-up case studies were presented in which visual health assessment methods were used to evaluate tissue responses to tags. The presentations described the current versions of the Type C tags that are integrated and either welded as a single unit or 3D printed as a single unit. Studies of southern right whales, presented by Marcela Uhart, have allowed for visual evaluation of tag site healing following tagging with 3D printed tags through serial photography of the tag site. Features of the earlier non-integrated tag sites evaluated in 42 whales included swelling, divots, loss of skin, blubber extrusion, skin color change, and presence of cyamids in the immediate vicinity of tag placement. With the use of the latest Type C integrated 3D tag design over the last few years few to no health effects have been observed in southern right whales. The position on the body where the tag was placed and the angle of penetration of the tag significantly influenced the effects observed: less swelling was observed when tags were placed high on the back and closer to the midline.

Table 1. Summary of tag types deployed on cetaceans, including attachment duration categories, sensors used and data generated, and advantages and disadvantages in the context of how they may be used in North Atlantic right whale conservation science and management.

Tag type (attachment type)	Species used in	Attachment duration	Information generated	Advantages	Disadvantages	Comments
Suction cup	Wide range of marine mammals including most mysticetes, odontocetes ranging from porpoise to sperm whales, several pinniped species, and manatees, including NARWs.	Hours (to a few days).	Location (GPS option), dive depth and profile, animal movement (3 dimensional reconstruction of subsurface movement with pitch, roll and heading), acceleration, water temperature, acoustics. Some include video to provide direct observation of behavior/prey/ proximity to hazards.	Multiple sensors can be included in the tag. Suction to skin causes minimal trauma. Can provide detailed data on behavioral responses to stressors (e.g. ships, sonar). Increasingly applied by drone.	Short duration. Need to recover tag to obtain data. External tag is vulnerable to rubbing on sea bed or other animals resulting in damage or detachment.	Reviewed in the workshop by Shorter, Parks, & Calambokidis.
Type A	38 species total, including killer, blue, gray, & humpback whales; NARWs since 2015.	Days to weeks.	Location (GPS option), dive depth, water temperature. The archival tags often attached with suction cups can also be attached to Type A tags but need recovery for data downloading.	Longer duration, including dive data. Hybrid tags can provide data on behavioral responses to stressors (i.e. ships, sonar).	External tag is vulnerable to rubbing on sea bed or other animals resulting in dis-attachment and possible barb breakage. Penetration of the skin and underlying tissue may have health effects.	Use in 2023 on NARWs in Canada reviewed in workshop by Andrews & Lesage.
Type C	Blue, gray (including western Pacific), humpback (including Arabian Sea), fin, Bryde's, bowhead, sei, minke, sperm, southern right, North Pacific right, & North Atlantic right whales.	Weeks to many months, occasionally years.	Location; some include dive monitoring, accelerometry, fine scale movements, light levels, water temperature.	Long duration to track large-scale movements, migration routes, habitat use. Minimal risk of tag being rubbed off on seabed or by other animals. Long-term health effects not detected in recent southern right whale deployments.	Penetration of tissue deeper than blubber into the subfascial layer may pose a greater risk to health than other tags.	Reviewed in the workshop by Zerbini & Palacios. Design has evolved over the last 5 years, with most recent tags being consolidated, welded or 3-D printed, reducing breakage risk to a minimum. Tag length determines extent of tissue penetration, in some species into blubber, others into fascia and muscle internal to the blubber layer.

Such visual assessments as described above were developed as part of a dedicated, long-term study of Type C tag effects on North Atlantic humpback whales in the Gulf of Maine (presented by Jooke Robbins) (publication in review see Gulland et al. 2024). That on-going study involves regular monitoring of 79 well-studied, tagged individuals to evaluate behavioral responses, tag site effects, and eventually female reproduction and survival. The non-integrated Type C tags initially deployed in that study exhibited breakage (as described on Day 1 by Zerbini) and were associated with more severe tag site tissue responses than later deployments involving more robust, integrated tags. Tag placement was important in this study as well; tags placed higher on the body, especially in the vicinity of the dorsal fin, resulted in less severe tissue responses. Tag site effects diminished over time in most individuals.

Outstanding questions about the potential impacts of Type C tags on the health, reproduction, and survival of baleen whales were discussed, including the design of robust long-term follow-up studies. In many populations, individual and annual variability in reproductive and survival rates can make evaluating effects of tagging difficult (see Best et al. 2015). The relevance of studies on other species to predicting effects on NARWs was questioned during the workshop in light of the poor body condition of some NARWs, the reduced growth rate of some animals, and the exposure of individual whales to multiple stressors.

Some participants noted that visual health assessments have limited sensitivity to detect changes in deeper tissues, and do not allow assessment of pain. Although the potential welfare impacts of tagging, including pain, were not discussed in any depth during the workshop, it was noted that these issues are considered by veterinarians during the permitting and animal care and use protocol review processes in the U.S. and Canada. After a brief discussion, participants recommended that a subgroup of veterinarians meet after the workshop to further discuss health and welfare concerns (see Appendix H).

Highlighted themes common across all of the health assessment follow-up case studies included:

- the importance of tag placement and indices of blubber depth at the attachment sites;
- the need for long-term monitoring of tag effects through focused follow-up studies;
- the benefits of complementary methods (including some in development) such as photogrammetry, behavioral follows, and developing hormonal analyses and ‘omics to examine stressors and physiological responses, all in addition to visual health assessments;
- the value of using a suite of techniques and technologies to provide the best available science for management decision making; and
- the necessity of having a knowledgeable expert with familiarity with individual whales in the field to help the tagging team decide on actions.

Potential Elements of a Tagging Program

The following best practices were discussed:

1. Understand and identify in advance the questions to be answered using tag data as well as determining whether there is a need for tagging rather than other less invasive ways of obtaining the information needed for management (animal care and use considerations).

2. Determine the number of animals and representation of age and sex classes proposed to be tagged in order to address identified research questions.
   A. Develop criteria for candidate selection as a core component of research design.
   B. Determine the appropriate number of tag deployments to be used according to the goals of the research and tag type and expected tag duration.

3. Establish protocols before starting to tag animals (the "Best practice guidelines for tagging" provide detail on these elements; see Appendix D).
   A. Identify tag types to be used and the established protocols for their deployment.
   B. Establish a team with experienced taggers with personnel support required to identify individual whales in the field, support decisions on whether to tag, and collect additional information, especially with respect to health assessment and follow-up.

4. Ensure established tagging candidate criteria are followed in the field.
   A. Include a team member who is familiar with the criteria and an expert at identifying and evaluating individual whales in the field to ensure that candidate whales are identified and their body condition assessed prior to the decision to tag.

5. Incorporate a post tagging health assessment follow-up study as part of the tagging project.
   A. Include repeated photographic documentation of the tag site, photogrammetry to assess body condition, and long-term assessment of reproductive success and survival.
   B. In the event of strandings involving a previously tagged individual, make all efforts to access the carcass and examine tag sites.

6. Use a shared common database to prevent multiple impacts on individual animals and to ensure observations for health impacts are shared across the range.

7. Review the program in real-time to monitor impacts and assess the value of information being generated.

8. Promote communication among scientists, managers, stakeholders, and the public, including the sharing of data whenever possible in publicly accessible databases.

Workshop Outcomes

Key Messages

The workshop did not seek consensus on whether or not to use specific tagging technologies on NARWs, yet through the discussions, several key points were stressed, and are listed below.

- There are outstanding questions about NARW distribution, movements, habitat use, and behavior that, if addressed, would better position managers and policy makers to implement efficient and effective conservation measures. In addition, there is a sense of urgency around the need to fill these gaps where possible, as the population has been declining significantly since 2010, there are approximately 70 reproductive females remaining, with reduced calving, increasingly poor health, and an ongoing Unusual Mortality Event.
- All existing data on NARW distribution, migration, movements, and behavior should be compiled to ensure perceived data gaps cannot be answered with existing data. These existing data could provide information to managers that could be used to increase whale protection if there was

greater stakeholder support. To date, gaining buy-in from stakeholders on protection measures continues to be challenged due to information gaps. However, filling these information gaps cannot further compromise the health of NARWs.

- NARWs are subject to a variety of anthropogenic threats and environmental stressors, which in addition to direct mortality, have led to reduced body condition and health concerns for many individuals in the population. The endangered status of NARWs and reduced body condition heightens the concern over tagging of NARWs relative to other species. Improved communication regarding what is known about NARWs and what gaps exist relative to management needs will build a more collaborative environment among all stakeholders.
- Addressing data and information gaps requires integrating information from a range of technologies and research methods.
- Telemetry is a viable technique that can provide continuous movement data for the individuals tagged, show individual animals' movements among known and unknown habitats, and increase our understanding of whale behavior and habitat use (various durations and information, depending on the type of tag).
- The "Best practice guidelines for cetacean tagging" (Andrews et al. 2019) remains the best available resource to guide the development and implementation of tagging studies.
- Type C tags have been successfully used with western gray whales, Arabian Sea humpback whales, and southern right whales to address critical management needs to elucidate longer-term movement patterns, habitat use, and migration routes.
- Type C tag designs have been modified based on observations from follow-up studies, producing more durable welded and 3-D printed versions with significantly longer deployment durations and fewer to no observed health effects on tagged individual humpback and southern right whales.
- Any research on live animals must use techniques that cause the fewest possible effects on individual animals and that are the least invasive to answer the specific question according to U.S. and Canadian laws and policies regarding marine mammal protection and welfare.

Next Steps Identified by Workshop Participants

1. Discuss possible criteria for selecting candidate whales for tagging

During the workshop, a list of tagging candidate selection criteria based on tag type and implications for individual whales was suggested by Heather Pettis and Amy Knowlton (see Appendix I). Due to time constraints, it was determined that this topic needs further discussion. A working group was established (with members Shasta McClenahan, Dave Weller, Emilie Couture, Christian Ramp, Ruth Ewing, Courtney Druce, and Clay George) to develop these criteria. The group's charge was to identify individuals or demographic groups that should (or should not) be tagged with invasive tags, to ensure that important data can be collected to address management questions, while minimizing risk to the species as a whole.

2. Conduct a retrospective analysis of the effects of pre-2010 tagging with Type C tags on NARW health, reproduction, and survival.

A working group led by Heather Pettis and Amy Knowlton was established to conduct this analysis. Available data on NARW whale tagging events and subsequent sightings will be used in an existing model for assessing the cumulative stressors on NARWs (see Pirotta et al. 2023). The

results may not be applicable to current tag designs, as tagging technology has advanced significantly in recent years, and the analysis will only include whales tagged before 2010. The analysis could nonetheless provide useful information.

3. Synthesize data and information obtained from previous NARW tagging studies.

   Not all NARW tag data are published and shared in publicly accessible databases. The goal identified at the workshop is to review and synthesize all satellite and suction-cup tag data from the 1990's to the present, to improve understanding of what information was gained from the tagging efforts in aggregate relative to current management measures and needs. As of January 2024, data were identified from 90 invasive tagging events of 85 individual NARWs from 1988 to 2023, and 214 suction-cup tagging events of 160 individuals from 1999 to 2021. Data will be submitted to the interagency U.S. IOOS Animal Telemetry Network (ATN) Data Assembly Center and shared publicly and with transboundary management agencies to make informed decisions. Daniel Palacios and Michael Weise will lead this effort.

4. Enhance methods for whale health assessments post tagging.

   A veterinary working group had a follow-up call to discuss this, see Appendix H.

   If a previously tagged animal were to be found dead, a full necropsy should be conducted, if feasible, to determine cause of death and investigate any health effects that might be associated with the tag. A recommended protocol for the necropsy and dissection of the tag implant site is included in Appendix A of Andrews et al. (2019).

5. Compile data on blubber thicknesses of recently stranded NARWs to inform tag design.

6. Consider publishing reports on health effects of tags on baleen whales in a special edition of the Journal of Cetacean Research and Management.

Summary

The workshop brought together experts to share knowledge about tagging technologies relative to NARWs and engage in discussion on what concerns should be at the forefront when considering tagging NARWs. Participants provided summaries of the different tag types currently used with baleen whales, including their design evolution, capabilities, limitations, health effects, and examples of use with other species. Data gaps for management for NARW conservation and the value of using different tag types to fill these data gaps were discussed. The utility of technologies other than tagging in fulfilling these needs was not discussed in depth as this was beyond the scope of the tagging workshop. Concerns about the potential impacts of tagging were discussed as well as ways those impacts could be mitigated and evaluated over time. The participants identified several action items that could inform future management and permitting decisions regarding tagging NARWs.

Acknowledgments

The workshop steering committee was composed of Kim Damon-Randall, Frances Gulland, Adèle Labbé, Peter Thomas, and Michael Weise. Their sincere thanks go to Randy Reeves and Greg Donovan for their patient and able chairing of the workshop, to the presenters and participants for sharing their expertise and contribution to a successful workshop, and to workshop rapporteurs Sarah Weiss, Lauri Leach, and Lindsey Stadler for their hard, careful, and extensive work in recording the presentations and discussions and assistance in compiling and drafting this report.

Appendix A: Participants

Final list of invited participants for the North Atlantic right whale tagging workshop in Herndon, Virginia from September 12-14, 2023.

Deborah Austin	DFO	Virtual
Russ Andrews	MarEcoTel	In person
Shannon Bettridge	NMFS	Virtual
Simon Blanchette	DFO	Virtual
Laura Bourque	University of Prince Edward Island	Virtual
Moira Brown	Canadian Whale Institute	Virtual
Danielle Cholewiak	NMFS	In person
John Calambokidis	Cascadia Research	In person
Lisa Conger	NMFS	Virtual
Colleen Coogan	NMFS	Virtual
Emilie Couture	University of Montréal	In person
Laurence Deneault-Tremblay	DFO	Virtual
Greg Donovan	International Whaling Commission retired	In person
Laura Engleby	NMFS	Virtual
Dan Engelhaupt	HDR	Virtual
Ruth Ewing	NMFS	In person
Deborah Fauquier	NMFS	Virtual
Sarah Fortune	Dalhousie University	Virtual
Lance Garrison	NMFS	In person
Clay George	NMFS	Virtual
Roxanne Gillett	DFO	Virtual
Amy Hapeman	NMFS	Virtual
Valerie Harvey	DFO	In person
Sean Hayes	NMFS	Virtual
Amy Knowlton	New England Aquarium	In person
Scott Kraus	New England Aquarium	In person
Melissa Landry	DFO	Virtual
Véronique Lesage	DFO	In person
Anthony Martinez	NMFS	Virtual
Shasta McClenahan	NMFS	Virtual

Erin Meyer-Gutbrod	University of South Carolina	In person
Michael Moore	Woods Hole Oceanographic Institution	In person
Daniel Palacios	Oregon State University	In person
Susan Parks	Syracuse University	Virtual
Eric Patterson	NMFS	In person
Heather Pettis	New England Aquarium	In person
Christian Ramp	DFO	Virtual
Stephanie Ratelle	DFO	Virtual
Stephen Raverty	University of British Columbia	In person
Randy Reeves	MMC	In person
Jooke Robbins	Center for Coastal Studies	In person
Teri Rowles	NMFS	Virtual
Alex Shorter	University of Michigan	Virtual
Greg Schorr	MarEcoTel	Virtual
Amy Sloan	NMFS	In person
Erin Summers	Maine Department of Marine Resources	In person
Marcela Uhart	University of California Davis	In person
Angelia Vanderlaan	DFO	Virtual
Andrew Willson	Future Seas Global SPC	Virtual
Sarah Wilkin	NMFS	Virtual
Dave Weller	NMFS	In person
Alex Zerbini	CICOES - University of Washington	In person

Steering Committee and Meeting Support

Kimberly Damon-Randall	NMFS	In person
Frances Gulland	MMC	In person
Adèle Labbé	DFO	In person
Lauri Leach	MMC	In person
Lindsey Stadler	NMFS	In person
Peter Thomas	MMC	In person
Michael Weise	ONR	In person
Sarah Weiss	ONR	In person

Appendix B: Agenda

Final agenda for the North Atlantic right whale tagging workshop in Herndon, Virginia from September 12-14, 2023.

North Atlantic Right Whale Tagging Workshop

OVERVIEW

Hosted by the Marine Mammal Commission, NOAA Fisheries, and the Office of Naval Research in coordination with Fisheries and Oceans Canada

September 12–14, 2023 in Herndon, VA and virtually

The goals of this expert workshop are to:

1. review key knowledge gaps and data needs regarding the movements, life history, and ecology of North Atlantic right whales (NARWs);
2. review the history of satellite telemetry and evaluate progress in tag attachment technologies and follow-up studies; and
3. generate knowledge to inform planning and permitting decisions regarding potential tagging of NARWs, as well as other endangered baleen whales.

The workshop will occur over 2 ½ days and will include:

- Day 1 Open session: Presentations to the assembled experts and virtual attendees, on research needs for NARWs, the history of telemetry tag development and use for large whales, the permitting environment in the United States and Canada, and tagging best practices.
- Day 2 Closed session: Invited experts will engage in-depth on key information that can be gained from tagging, on their experience with different tag types applied to large whales with a particular focus on Type C consolidated tags, review follow-up studies to examine the effects of tagging on baleen whales, and discuss the utility of different tag types with respect to identified research questions.
- Day 3 Closed session: During this half-day concluding session, invited experts will consider data management and sharing, the evolution of tag technology and design, and potential future NARW tagging, and follow-up monitoring to address important data deficiencies.

Expected outputs/deliverables:

- Workshop report highlighting issues and information discussed at the workshop
- Verbally presented technical information, opinions, and feedback from all participants during the workshop is welcomed, but a consensus is not expected nor will any be solicited.

Select reading materials from previous relevant tagging workshops:

- Report on the 24-26 February 1987 Workshop to Assess Possible Systems for Tracking Large Cetaceans (Montgomery 1987)
- A workshop on effects of tagging NARW and related report (Kraus et al. 2000)
- Report of the Large Whale Tagging Workshop (Weller 2008)
- Report of the Joint ONR IWC NOAA Workshop on Cetacean Tag Development, Tag Follow-up and Tagging Best Practices (ONR/NOAA/IWC 2020) and Workshop Proceedings (ONR 2009)
- Best practice guidelines for cetacean tagging (Andrews et al. 2019)

North Atlantic Right Whale Tagging Workshop

AGENDA

Day 1: Tuesday September 12, 2023

9:00 – 9:15 Welcome and introduction

Frances Gulland (MMC) and Mike Weise (ONR)

9:15 – 9:45 Introductory talk: Telemetry data and the conservation and management of North Atlantic right whales (NARW)

Greg Donovan (IWC retired)

9:45 – 10:30 Facilitated panel discussion on gaps in knowledge of NARW ecology and movements pertinent to management needs, with emphasis on information that could be provided by telemetry data

Panelists: Véronique Lesage (DFO), Colleen Coogan (NMFSGARFO), Clay George (NMFS-SERO), Sean Hayes (NMFS-NEFSC), Amy Knowlton (New England Aquarium), Erin Meyer-Gutbrod (University of South Carolina)
Facilitator: Kim Damon-Randall (NMFS)

10:30 – 10:45 **BREAK**

10:45 – 11:30 Permitting Environment: Government officials will summarize the U.S. and Canadian regulatory context when contemplating tagging endangered large whales

Amy Sloan (NMFS-OPR), Laurence Denault-Tremblay (DFO)

11:30 – 11:45 Brief Overview of Best Practice Guidelines for Cetacean Tagging

Mike Weise (ONR)

11:45 – 12:15 History of NARW tagging

Dave Weller (NMFS - SWFSC)

12:15 – 1:15 **LUNCH**

1:15 – 2:30 Review of types of tags used to date on baleen whales: Experts in tagging and tag development will provide an overview of different telemetry tag types and on which species they have been deployed, deployment durations, anchor design, target location on animals, any known and/or suspected effects based on follow-up studies, data to be gathered from the tags, overall challenges and opportunities.

Suction cup: Alex Shorter (University of Michigan) and Susan Parks (Syracuse University)

Type A Anchored: Russ Andrews (MarEcoTel) and John Calambokidis (Cascadia Research)

Type C Consolidated: Alex Zerbini (CICOES-UW) and Daniel Palacios (Oregon State University)

2:30 – 3:15 Discussion and Q&A session

Peter Thomas (MMC)

3:15 – 3:30 Wrap-up public session

Adèle Labbé (DFO)

3:30 – 4:00 **BREAK**

4:00 – 5:00 Preparation for Day 2 (closed session)

North Atlantic Right Whale Tagging Workshop

AGENDA

Day 2: Wednesday September 13, 2023
Discussions led by Randy Reeves (MMC) and Greg Donovan (IWC retired)

9:00 – 9:15 Opening remarks

Kim Damon-Randall (NOAA) and Adèle Labbé (DFO)

9:15 – 10:15

Information gaps that could be addressed using suction cup and Type A anchored tags on NARW and discussion on any known/suspected effects

Suction cup: Susan Parks and Alex Shorter

Type A anchored: Véronique Lesage, Christian Ramp, John Calambokidis, Russ Andrews

10:15 – 10:30 **BREAK**

10:30 – 11:30

Review of decision-making criteria and deployment of Type C tags with endangered whale populations including Western gray whales, Arabian Sea humpback whales, Southern right whales

Dave Weller, Marcela Uhart, Alex Zerbini, Andrew Willson

11:30– 12:30

Follow-up studies: The evolution of Type C tags and the effects on survival, reproduction, and tissue healing

Alex Zerbini, Jooke Robbins, Marcela Uhart, Frances Gulland, Daniel Palacios, John Calambokidis

12:30 – 1:30 **LUNCH**

1:30 -3:00

Follow-up studies continued: The evolution of Type C tags and the effects on survival, reproduction, and tissue healing

3:00 – 4:30

Key information needed to inform potential future NARW tagging

Management questions addressed by different tag types
Selection criteria for candidate whales to be tagged
Protocols to be considered (pre-, during and post-tagging)
Follow-up monitoring studies
Additional considerations and practicalities

4:30 – 5:15 General Discussion and Wrap-up

North Atlantic Right Whale Tagging Workshop

Day 3: Thursday September 14, 2023

9:00 – 9:15	Opening remarks Kim Damon-Randall (NOAA) and Adèle Labbé (DFO)
9:15 – 10:15	Key information needed to inform potential future NARW tagging Randy Reeves (MMC) and Greg Donovan (IWC retired)
10:15 - 10:30	**BREAK**
10:30 - 11:00	Key information needed to inform potential future NARW tagging (cont) Randy Reeves (MMC) and Greg Donovan (IWC retired)
11:00 - 11:30	Data Management Considerations: Overview of Animal Telemetry Network and Data Assembly Center and discussion on data management, and sharing Mike Weise (ONR)
11:30 – 12:00	Aspects to contemplate in the evolution of tag technology and design Mike Weise (ONR)
12:00 – 12:15	Next Steps and Closing remarks Steering Committee

Appendix C: Whales by the Numbers

Excerpts from presentations by Sean Hayes and Scott Kraus

By the numbers: Hayes

"**131** the number of right whales we estimated died between 2010 and 2016 before we were able to confirm new foraging habitats and partial sources and locations of new mortality in 2017.

110 the number of whales that have died between 2017 and 2020 while we started to figure out what to do about it. At least 74 of those 110 just disappeared.

50 the percent of the population that has died since its peak while we relied solely on planes, boats, and hydrophones to identify where whales were.

400,000 the number of square kilometers of marine habitat that right whales are likely to occupy.

50 million to 1 billion dollars the potential annual cost to actually survey the amount of area with the necessary rigor to understand where the animals are and their threats by using visual and passive acoustic methods.

5 the number of human lives in a typical NOAA survey plane that could be lost if we attempted to significantly increase our aerial effort to understand where the animals are.

50 the approximate number of written high level congressional and political inquiries in recent years expressing concerns that NMFS doesn't know where the problem is and is unfairly regulating their citizens and local economies.

6 the number of years Congress paused further regulation on the lobster fishery until better certainty on the distributions and innovative gear technologies could be developed.

This and the previous point indicate that there's a limit to just how far society will allow protections of right whales to go without better certainty."

By the numbers: Kraus

"**340** animals left, **70** reproductive females.

86% have been entangled at least once, more than **50**% have been entangled at least twice, some as many as nine times.

73 whales are alive that were hit by ships.

90 living whales have been tagged with Type A or C tags.

67 whales are considered at risk because of health problems, entanglements, or injuries.

In 2010 the population declined, whale size and whale health have declined since then.

Calving is about **1/2** to **1/3** of what would be expected for a population of right whales that elsewhere give birth every 3 years.

Mortality is up, stock assessment reports estimate that over **30** whales die per year…which gives them only **12** years if mortality and calving continue at the current rates."

Appendix D: Tagging Guidelines

Best practice guidelines by Andrews et al. 2019 that were referenced throughout the workshop. Click the image below to open the full publication.

Best practice guidelines for cetacean tagging

Russel D. Andrews[1], Robin W. Baird[2], John Calambokidis[2], Caroline E.C. Goertz[3], Frances M.D. Gulland[4], Mads Peter Heide-Jørgensen[5], Sascha K. Hooker[6], Mark Johnson[6], Bruce Mate[7], Yoko Mitani[8], Douglas P. Nowacek[9], Kylie Owen[10], Lori T. Quakenbush[11], Stephen Raverty[12], Jooke Robbins[13], Gregory S. Schorr[1], Olga V. Shpak[14], Forrest I. Townsend, Jr.[15], Marcela Uhart[4,16], Randall S. Wells[17] and Alexandre N. Zerbini[1,2,18]

Contact e-mail: russ@marecotel.org

ABSTRACT

Animal-borne electronic instruments (tags) are valuable tools for collecting information on cetacean physiology, behaviour and ecology, and for enhancing conservation and management policies for cetacean populations. Tags allow researchers to track the movement patterns, habitat use and other aspects of the behaviour of animals that are otherwise difficult to observe. They can even be used to monitor the physiology of a tagged animal within its changing environment. Such tags are ideal for identifying and predicting responses to anthropogenic threats, thus facilitating the development of robust mitigation measures. With the increasing need for data best provided by tagging and the increasing availability of tags, such research is becoming more common. Tagging can, however, pose risks to the health and welfare of cetaceans and to personnel involved in tagging operations. Here we provide 'best practice' recommendations for cetacean tag design, deployment and follow-up assessment of tagged individuals, compiled by biologists and veterinarians with significant experience in cetacean tagging. This paper is intended to serve as a resource to assist tag users, veterinarians, ethics committees and regulatory agency staff in the implementation of high standards of practice, and to promote the training of specialists in this area. Standardised terminology for describing tag design and illustrations of tag types and attachment sites are provided, along with protocols for tag testing and deployment (both remote and through capture-release), including training of operators. The recommendations emphasise the importance of ensuring that tagging is ethically and scientifically justified for a particular project and that tagging only be used to address *bona fide* research or conservation questions that are best addressed with tagging, as supported by an exploration of alternative methods. Recommendations are provided for minimising effects on individual animals (e.g. through careful selection of the individual, tag design and implant sterilisation) and for improving knowledge of tagging effects on cetaceans through increased post-tagging monitoring.

KEYWORDS: BIO-LOGGING; RADIO-TAGGING; SATELLITE TAGGING; TELEMETRY

1. INTRODUCTION*

The understanding of the biology of cetaceans and their habitat requirements, and our ability to mitigate threats to them, are challenged by the difficulty of observing animals that spend most of their time beneath the water surface, often in remote areas. This challenge can be at least partly overcome by using animal-borne monitoring instruments (bio-logging tags; hereafter referred to as 'tags'). Depending on the design, these tags can provide a variety of data, such as environmental (e.g. water temperature, salinity), physiological (e.g. heart rate, body temperature) and behavioural (e.g. dive depth and duration, acceleration, geographic position). Although the first time a tag of this type was applied to a cetacean was as early as the 1930s (Scholander, 1940), it took several decades and the advent of VHF transmitters, digital time-depth-recorders and eventually satellite-linked transmitters, for these tags to be regularly used in the study of wild cetaceans. Modern tags can archive data for eventual recovery and downloading, or they can transmit data via electromagnetic and/or sound waves. Tags are now a critical component in advancing cetacean science. Compared with other types of observations, tags can provide nearly continuous data as opposed to snapshots in time and are observer-independent. They have yielded data important for answering basic science and life history questions and for the management and conservation of cetaceans, including data on population

*Note: In-text references have been used sparingly here as we aim to offer recommendations broad enough to be relevant to all those interested in cetacean tagging, to be as concise as possible, and also to aid readability. An exhaustive list of references (over 500) related to cetacean tagging is provided in the Supplementary Bibliography (see Appendix B).

[1] *Marine Ecology and Telemetry Research, 2468 Camp McKenzie Tr NW, Seabeck, WA 98380, USA.*
[2] *Cascadia Research Collective, 218 1/2 W 4th Avenue; Olympia, WA 98501, USA.*
[3] *Alaska SeaLife Center, P.O. Box 1329, Seward, AK 99664, USA.*
[4] *Wildlife Health Center, UC Davis School of Veterinary Medicine, Davis, CA 95616, USA.*
[5] *Greenland Institute of Natural Resources, Strandgade 91,2, DK-1401 Copenhagen K, Denmark.*
[6] *Sea Mammal Research Unit, Scottish Oceans Institute, School of Biology, University of St Andrews, St Andrews, Fife, KY16 8LB, UK.*
[7] *Oregon State University Marine Mammal Institute, Hatfield Marine Science Center, 2030 SE Marine Science Dr, Newport, OR 97365, USA.*
[8] *Field Science Center for Northern Biosphere, Hokkaido University, Hakodate Research Center for Fisheries and Oceans, 20-5 Benten-cho, Hakodate, Hokkaido 040-0051, Japan.*
[9] *Duke University Marine Lab, Nicholas School of the Environment, 135 Duke Marine Lab Rd, Beaufort, NC 28516, USA.*
[10] *Cetacean Research Unit, School of Veterinary and Life Sciences, Murdoch University, Murdoch, WA, 6150, Australia.*
[11] *Arctic Marine Mammal Program, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701, USA.*
[12] *Animal Health Center, British Columbia Ministry of Agriculture and Lands, 1767 Angus Campbell Rd, Abbotsford, BC, V3G 2M9, Canada.*
[13] *Center for Coastal Studies, 5 Holway Avenue, Provincetown, MA 02657, USA.*
[14] *Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia.*
[15] *Bayside Hospital for Animals, 251 Racetrack Road, NE, Fort Walton Beach, FL 32547, USA.*
[16] *Programa de Monitoreo Sanitario Ballena Franca Austral, Puerto Madryn, Chubut, Argentina.*
[17] *Chicago Zoological Society, Sarasota Dolphin Research Program, c/o Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, USA.*
[18] *Marine Mammal Laboratory, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA.*

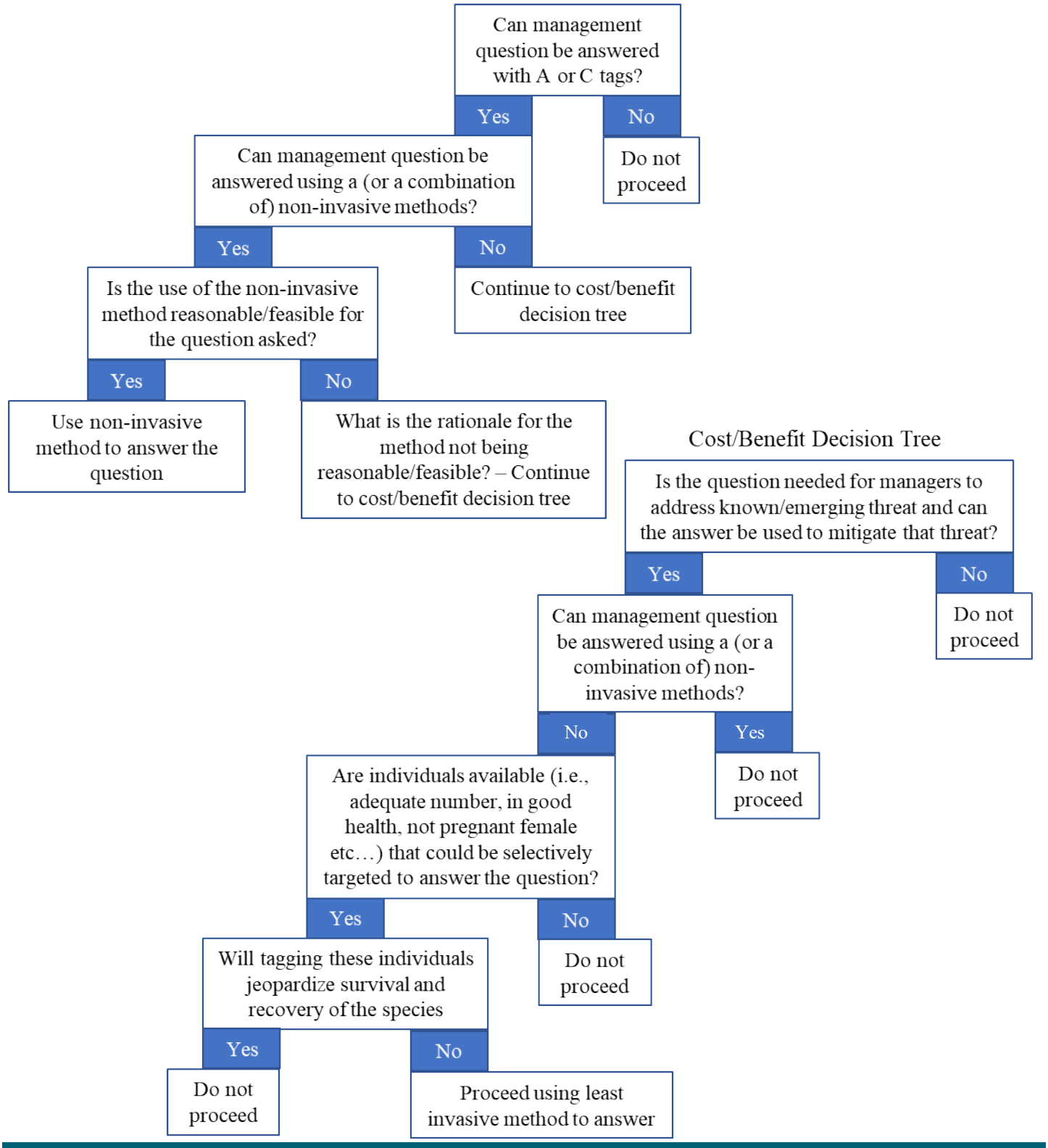
Appendix E: Alternative Tools to Tagging

Voluntary feedback shared from participant Michael Moore. This table was shared with all invited meeting participants via email during the workshop but was not discussed. 0 = bad, 3 = good

Method	First use	Range	Data Product	Limitations	Impact on Target animal	Behavioral disturbance to individual (0-3)	Tag trauma (0-3)	Sample size limited (0-3)	Actively find new habitat? (0-3)	Ready now? (0-3)	Sum Conservation value (0-15)
Land visual	Subsistence hunts - millennia	A few miles depending on eye height	Sightings	Range, sea state, daylight	None	3	3	3	0	3	12
Vessel visual			Sightings	Sea state, daylight	Potential disturbance	2	3	3	0	3	11
Aircraft visual	1920		Sightings	Sea state, daylight		3	3	3	0	3	12
Implantable Discovery Tag	1932	Tagging & kill locations	Two positions	History	Death	0	0	0	1	0	1
Photo ID Land	?	Capture to recapture locations	ID Catalog	Range, sea state, daylight	None	3	3	3	0	3	12
Photo ID Vessel/ aircraft	?	Capture to recapture locations	ID Catalog	Sea state, daylight	Potential disturbance from vessel or aircraft	2	3	3	0	3	11
Radio tag	?	10-20 km		Short term	Invasive attachment	0	0	1	2	2	5
Satellite tag		Tag life dependent	2 or 3D Track for months	Trauma +++		0	0	1	3	3	7
Suction cup archival tag		A few km	3D track, sounds, energetics	Short term	Potential disturbance - drone delivery minimizes	2	3	1	0	3	9
Passive Acoustic - anchor, glider or towed array	?	Frequency dependent up to ocean basin	Detection of vocalization	Range	None	3	3	3	2	3	14
Satellite visual	?	?	Sightings	Not yet functional	None	3	3	3	3	1	13

Appendix F: Decision-Making Matrix

Voluntary feedback shared from participant Roxanne Gillett. This graphic was shared with all invited meeting participants via email during the workshop but was not discussed.



Appendix G: Comparison of Tag Capabilities Relative to Research Questions and Management Needs

A decision-making matrix was created during Day 3 of the workshop. Some participants discussed tag types that could address each proposed management question within a reasonable timeframe. Management questions were struck out when the reviewing participants felt they were previously captured or better addressed by other tools. This matrix does not represent consensus from the workshop attendees, and is presented as it was last discussed in the workshop (not edited, altered, nor further completed).

	Tools that could address the management question within a meaningful/ reasonable timeframe				
	Suction cup tag	**Type A (Limpet tag)**	**Type C blubber tag (max. 13 cm penetration)**	**Type C subfascial tag (max. 29 cm penetration)**	**Other Tools (PAM, visual, etc)**
tag duration	Short (hours, occasionally days)	Medium (weeks, occasionally months)	Medium (weeks, occasionally months)	Long (months, occasionally years)	
sensor assumptions	behavior, acoustics, position	ARGOS and GPS position, dive behavior, other	ARGOS position only	ARGOS position, depth, dive behavior, water temperature, light	
MANAGEMENT QUESTIONS (NOT EXHAUSTIVE)					
Temporal-Spatial Distribution Data Gaps					
GOM- GSL migratory paths, Scotian Shelf, Cabot strait	no	no	maybe	yes	
Identify Unknown summer foraging habitats (Labrador Sea, Scotian Shelf, other regions)	no	no	no	yes	
Occurrence (i.e., in the GOM, U.S. mid-Atlantic, Scotian Shelf)	no	maybe	maybe	yes	U.S. mid-Atlantic doable with other methods
Offshore distribution/behavior (priority for fisheries management)	no	maybe	maybe	yes	
Southeast U.S. calving grounds - reproductive female habitat use and movement	no	no	maybe	yes	
Persistence (i.e., in the GOM, U.S. mid-Atlantic, Scotian Shelf) and individual behavior	no	no	no	yes	need aerial surveys and photo-ID
Frequency of travel between habitats & management areas	no	maybe	maybe	yes	
Identify Unknown winter habitat(s)	no	no	no	yes	
Use of shallow water habitats	maybe	yes	yes	yes	

	Suction cup tag	Type A (Limpet tag)	Type C blubber tag (max. 13 cm penetration)	Type C subfascial tag (max. 29 cm penetration)	Other Tools (PAM, visual, etc)
Demographic differences in broad scale habitat use (e.g., reproductive females) (temporal and spatial)	no	no	no	yes *but tagging candidates?	can be addressed with photo-ID data in areas where we are surveying?
Phenology					
~~Arrival/departure times in GSL~~	~~no~~	~~no~~	~~no~~	~~maybe~~	better addressed with other survey methods (aerial, real-time acoustics)
~~Arrival/departure times in NE/SE US~~	~~no~~	~~no~~	~~no~~	~~maybe~~	better addressed with other survey methods (aerial, real-time acoustics)
Threats & behavior					
Movement & persistence & behavior around areas of threats (vessel traffic, wind energy areas, etc)	yes	yes	maybe	yes	
Fishing: behavior relative to risk encounter for line/gillnets and vessel traffic (i.e. time at depth, position in water column)	yes	yes	no	yes	
~~Dive/surface behavior (with respect to vessels, gear, etc) when feeding, resting, socializing etc. vs transiting, by demographic groups, etc.~~	yes	maybe	no	maybe	
~~Relative risk between vertical lines and groundlines and gillnets~~					
Availability bias (time at surface)	yes	yes	no	yes	
~~Better assess cryptic mortality (where is it occuring, what are the causes, etc.) Captured in all other rows~~					
Assess fine scale energetic requirements to inform modeling (gaining and expending energy)	yes	no	no	no	
Climate change impacts - relate to broad scale distribution questions above					
~~Matching protective measures to shifting distributions~~					
~~Predictive habitat/movement models to support better (dynamic) management~~					
~~Track distribution shifts as they change vs. retrospectively (e.g., catch 2010/201 shift earlier)~~					
~~Inform and validate predictive tools (e.g., forecast models (prey and NARW), DMS, etc.)~~					

Appendix H: Veterinary Follow-up Call

Summary of November 3, 2023 Zoom "Vet Meeting" of some workshop attendees to capture some concerns that were not fully addressed within the workshop.

Attendees: Frances Gulland, Teri Rowles, Ruth Ewing, Sarah Sharp, Laura Bourque, Émilie Couture, Michael Moore. Unable to attend: Marcy Uhart, Deb Fauquier

Alternatives to tagging approaches and welfare concerns were raised at the workshop. However, the organizers did not allow time on this topic, beyond the excellent presentations of field studies of implantable tag impacts. Therefore, veterinarians sought a further meeting to discuss them. Topics discussed by the veterinarians on the zoom call that were not explored at the workshop included:

1) The risks to whale health of different tags and the information gained from them compared to non-invasive tracking tools that could be used to answer certain management or research questions. This is an essential aspect of any discussion about the potential future tagging of NARWs. Details of advantages and limitations of alternative technologies such as passive acoustics and satellite imagery were not discussed as this was beyond the scope of the workshop. This comparison is a core tenet of any Institutional Animal Care and Use Committee's (IACUC) work under the Animal Welfare Act in the U.S, or of any Animal Care Committee's (ACC) in the Canadian context. The veterinary group discussed the role of IACUCs and/or ACCs in evaluating the need for a specific technique if less impactful alternatives exist.

2) The question of whether trauma from implantable tags was acceptable at all, given the legal acceptable mortality in fisheries in the U.S. under the MMPA (Potential Biological Removal) in fisheries in the U.S. is less than 1, was raised. As this is a management question rather than a clinical veterinary one, the topic was not discussed further.

3) Limitations of current methods to evaluate whale health at sea were acknowledged, reflecting that mortality and reproductive rates are insensitive metrics to assess tag impacts. Methods to evaluate impacts of tags on whale health beyond photography were discussed.

- NOAA Fisheries has established a working group on NARW health assessment that can include assessment of tag effects among other factors influencing whale health.
- Technologies to consider that have not been used significantly to date that could prove to be clinically useful include aerial thermography and remote ultrasound.
- Ethograms (catalog of animal behavior) could help investigate behavioral modification associated with invasive tag placement, which could provide insight into the ability to detect nociception/pain associated with the procedure in baleen whales. The added use of suction cup tags would allow a case -controlled study, albeit of a limited duration associated with tag retention times (approximately 24 hours).

4) Concerns pertaining to the different types of implantable Type C tags and their potential use with NARWs include different morphology between NARWs and southern right whales, specifically concerning blubber depth and structure. Carcass testing of implantable Type C tags on NARWs could clarify depth of penetration of various tag types, and would inform the risk assessment of using these tags on live animals.

Appendix I: Draft Tagging Candidate Selection Criteria

Suggested selection criteria for North Atlantic right whale tagging candidates for Type C tags proposed by Heather Pettis and Amy Knowlton during the workshop. Due to the time constraints of the workshop, it was determined that this topic needs further discussion, with a working group established to finalize these suggested criteria. This list is NOT the final list, but a draft at November 2023.

- No adult females (>9 years of age – though several whales have calved at 5/6 years)
- No whale on NOAA Fisheries Unusual Mortality Event or New England Aquarium injury monitoring list
- No whale with fresh injuries that may not yet be included in the monitoring lists above
- No whale previously tagged with a Type C tag (or LIMPET tagged within year)
- No signs of compromised condition detected by visual health assessment
- IDs for specific objectives/targeted whales
- Observer on board who can determine all of the above
- If the candidate whale cannot be confirmed to meet all of the above criteria, it's a no-go (Current NMFS permit language that says "best efforts to ID" but there isn't no-go language)

Appendix J: Citations and Useful Literature

Andrews, R.D., R.W. Baird, J. Calambokidis, C.E.C. Goertz, F.M.D. Gulland, M.P. Heide-Jorgensen, S.K. Hooker, M. Johnson, B. Mate, Y. Mitani, D.P. Nowacek, K. Owen, L.T. Quakenbush, S. Raverty, J. Robbins, G.S. Schorr, O.V. Shpak, F.I. Townsend Jr., M. Uhart, R.S. Wells, and A.N. Zerbini. 2019. Best practice guidelines for cetacean tagging. Journal of Cetacean Research and Management 20: 27-66. https://doi.org/10.47536/jcrm.v20i1.237

Baumgartner, M.F., J. Bonnell, P.J. Corkeron, S.M. Van Parijs, C. Hotchkin, B.A. Hodges, J.B. Thornton, B.L. Mensi, and S.M. Bruner. 2020. Slocum gliders provide accurate near real-time estimates of baleen whale presence from human reviewed passive acoustic detection information. Frontiers in Marine Science, 7, Article 100. https://doi.org/10.3389/fmars.2020.00100

Best P.B., B. Mate, and B. Lagerquist. 2015. Tag retention, wound healing, and subsequent reproductive history of southern right whales following satellite-tagging. Marine Mammal Science 31(2): 520-539. https://doi.org/10.1111/mms.12168

Burgess, E.A., K.E. Hunt, S.D. Kraus, and R.M. Rolland. 2018. Quantifying hormones in exhaled breath for physiological assessment of large whales at sea. Scientific Reports 8: 10031. https://doi.org/10.1038/s41598-018-28200-8

Calambokidis J., J.A. Fahlbusch, A.R. Szesciorka, B.L. Southall, D.E. Cade, A.S. Friedlaender and J.A. Goldbogen. 2019. Differential vulnerability to ship strikes between day and night for blue, fin, and humpback whales based on dive and movement data from medium duration archival tags. Frontiers in Marine Science 6: 543. https://doi.org/10.3389/fmars.2019.00543

CCAC. 2023. “CCAC - Canadian Council on Animal Care”. https://ccac.ca/. Accessed 22 December 2023.

Crowe, L.M., M.W. Brown, P.J. Corkeron, P.K. Hamilton, C. Ramp, S. Ratelle, A.S.M. Vanderlaan, and T.V.N. Cole. 2021. In plane sight: a mark-recapture analysis of North Atlantic right whales in the Gulf of St. Lawrence. Endangered Species Research, 46: 227–251. https://doi.org/10.3354/esr01156

Fisheries and Oceans Canada. 2023. North Atlantic right whale tagging data. [Unpublished data]

Gulland, F.M.D., J. Robbins, A.N. Zerbini, V. Andrews-Goff, M. Berube, P.J. Clapham, M. Double, N. Gales, A.S. Kennedy, S. Landry, D.K. Mattila, D. Sandilands, J.E. Tackaberry, M. Uhart, and R.E.T. Vanstreels. In Review. Effects of satellite-linked telemetry tags on humpback whales in the Gulf of Maine: Photographic assessment of tag sites. Journal of Cetacean Research and Management. https://doi.org/10.1101/2024.02.07.579298

Hodul, M., A. Knudby, B. McKenna, A. James, C. Mayo, M. Brown, D. Durette-Morin and S. Bird. 2023. Individual North Atlantic right whales identified from space. Marine Mammal Science, 39(1). https://doi.org/10.1111/mms.12971

International Whaling Commission. 2020. Report of the joint US Office of Naval Research, International Whaling Commission and US National Oceanic and Atmospheric Administration workshop on cetacean tag development, tag follow-up and tagging best practices. Journal of Cetacean Research and Management, 21(Supplement): 349-372. http://dx.doi.org/10.25607/OBP-858

Knowlton, A.R., J.S. Clark, P.K. Hamilton, S.D. Kraus, H.M. Pettis, R.M. Rolland, and R.S. Schick. 2022. Fishing gear entanglement threatens recovery of critically endangered North Atlantic right whales. Conservation Science and Practice 4(8): e12736. https://doi.org/10.1111/csp2.12736

Kraus, S., C. Quinn, and C. Slay. 2000. A workshop on the effects of tagging on North Atlantic right whales. New England Aquarium. Boston, Massachusetts. 16 p. https://darchive.mblwhoilibrary.org/entities/publication/daf62c64-4721-5315-bdcb-99ef5d37b544

Linden, D.W. 2023. Population size estimation of North Atlantic right whales from 1990-2022. US Dept Commer Northeast Fish Sci Cent Tech Memo 314. 14 p. https://www.fisheries.noaa.gov/s3/2023-10/TM314-508-0.pdf

Meyer-Gutbrod, E.L., K.T.A. Davies, C.L. Johnson, S. Plourde, K.A. Sorochan, R.D. Kenney, C. Ramp, J.-F. Gosselin, J.W. Lawson, and C.H. Greene. 2022. Redefining North Atlantic right whale habitat-use patterns under climate change. Limnology and Oceanography 68(S1): S71-S86.

Miller, C.A., D. Reeb, P.B. Best, A.R. Knowlton, M.W. Brown, and M.J. Moore. 2011. Blubber thickness in right whales *Eubalaena glacialis* and *Eubalaena australis* related with reproduction, life history status and prey abundance. Marine Ecology Progress Series 438: 267-283. http://dx.doi.org/10.3354/meps09174

Montgomery, S. 1987. Report on the 24-26 February 1987 Workshop to Assess Possible Systems for Tracking Large Cetaceans. Northwest and Alaska Fisheries Science Center. Seattle, Washington. 62 p. https://www.mmc.gov/wp-content/uploads/Commission_Report_Montgomery_1987.pdf

Moore, M., R. Andrews, T. Austin, J. Bailey, A. Costidis, C. George, K. Jackson, T. Pitchford, S. Landry, A. Ligon, W. McLellan, D. Morin, J. Smith, D. Rotstein, T. Rowles, C. Slay, and M. Walsh. 2012. Rope trauma, sedation, disentanglement, and monitoring-tag associated lesions in a terminally entangled North Atlantic right whale (*Eubalaena glacialis*). Marine Mammal Science, 29(2): E98–E113. https://doi.org/10.1111/j.1748-7692.2012.00591.x

Moore, M.J. and A.N. Zerbini. 2017. Dolphin blubber/axial muscle shear: Implications for rigid transdermal intramuscular tracking tag trauma in whales. Journal of Experimental Biology, 220(20): 3717-3723. https://doi.org/10.1242/jeb.165282

North Atlantic Right Whale Consortium. 2023. North Atlantic Right Whale Consortium Identification Database 09/07/2023 (Anderson Cabot Center for Ocean Life at the New England Aquarium, Boston, MA, U.S.A.).

ONR. 2009. Final workshop proceedings for cetacean tag design workshop. Office of Naval Research. Arlington, Virginia. 18p. https://www.nre.navy.mil/media/document/final-workshop-proceedings-cetacean-tag-design-workshop-16-17-march-2009

Pace, R.M., R. Williams, S.D. Kraus, A.R. Knowlton, and H. Pettis. 2021. Cryptic mortality of North Atlantic right whales. Conservation Science and Practice, 3(2): e346. https://doi.org/10.1111/csp2.346

Pace, R.M., P.J. Corkeron, and S.D. Kraus. 2017. State-space mark-recapture estimates reveal a recent decline in abundance of North Atlantic right whales. Ecology and Evolution 7(21): 8730-8741. https://doi.org/10.1002/ece3.3406

Pettis, H.M., R.M. Pace III, and P.K. Hamilton. 2023. North Atlantic Right Whale Consortium 2022 Annual Report Card. Report to the North Atlantic Right Whale Consortium. www.narwc.org

Pettis, H.M., R.M. Rolland, P.K. Hamilton, S. Brault, A.R. Knowlton, and S.D. Kraus. 2004. Visual health assessment of North Atlantic right whales (*Eubalaena glacialis*) using photographs. Canadian Journal of Zoology 82(1): 8-19. https://doi.org/10.1139/z03-207

Pirotta, E., R.S. Schick, P.K. Hamilton, C.M. Harris, J. Hewitt, A.R. Knowlton, S.D. Kraus, E. Meyer-Gutbrod, M.J. Moore, H.M. Pettis, T. Photopoulou, R.M. Rolland, P.L. Tyack, and L. Thomas. 2023. Estimating the effects of stressors on the health, survival, and reproduction of a critically endangered, long-lived species. Oikos 2023(5): e09801. https://doi.org/10.1111/oik.09801

Quinn, C.A., P.K. Hamilton, S.D. Kraus, and C.K. Slay. 1999. An assessment of wounds caused by the attachment of remote sensing tags to North Atlantic right whales (*Eubalaena glacialis*): 1988-1997. New England Aquarium. Boston, Massachusetts. 33 p. https://darchive.mblwhoilibrary.org/entities/publication/84a003e4-7b76-51ef-98d6-1b13aeef6f74

Rolland, R.M., R. S. Schick, H. M. Pettis, A. R. Knowlton, P. K. Hamilton, J. S. Clark, and S. D. Kraus. 2016. Health of North Atlantic right whales, *Eubalaena glacialis,* over three decades: from individual health to demographic and population health trends. Marine Ecology Progress Series 542: 265–282. https://doi.org/10.3354/meps11547

Runge M.C., D.W. Linden, J.A. Hostetler, D.L. Borggaard, L.P. Garrison, A.R. Knowlton, V. Lesage, R. Williams, R.M. Pace III. 2023. A management-focused population viability analysis for North Atlantic right whales. US Department of Commerce Northeast Fisheries Science Center Technical Memorandum 307. 93 p. https://www.fisheries.noaa.gov/s3/2023-10/TM307-508-1-.pdf

Sequeira, A.M., M.R. Heupel, M.A. Lea, V.M. Eguíluz, C.M. Duarte, M.G. Meekan, M. Thums, H.J. Calich, R.H. Carmichael, D.P. Costa, and L.C. Ferreira. 2019. The importance of sample size in marine megafauna tagging studies. Ecological Applications, 29(6): p.e01947. https://doi.org/10.1002/eap.1947

Sharp, S. M., W.A. McLellan, D.S. Rotstein, A.M. Costidis, S.G. Barco, K. Durham, T.D. Pitchford, K.A. Jackson, P.-Y. Daoust, T. Wimmer, E.L. Couture, L. Bourque, T. Frasier, B. Frasier, D. Fauquier, T.K. Rowles, P.K. Hamilton, H. Pettis, and M.J. Moore. 2019. Gross and histopathologic diagnoses from North Atlantic right whale *Eubalaena glacialis* mortalities between 2003 and 2018. Diseases of Aquatic Organisms, 135: 1–31. https://doi.org/10.3354/dao03376

Stewart, J.D., J.W. Durban, A.R. Knowlton, M.S. Lynn, H. Fearnbach, J. Barbaro, W.L. Perryman, C.A. Miller, and M.J. Moore. 2021. Decreasing body lengths in North Atlantic right whales. Current Biology. https://doi.org/10.1016/j.cub.2021.04.067

Stewart, J.D., J. Durban, E. Europe, H. Fearnbach, P. Hamilton, A. Knowlton, M. Lynn, C. Miller, W. Perryman, B. Tao, and M. Moore. 2022. Larger females have more calves: influence of maternal body length on fecundity in North Atlantic right whales. Marine Ecology Progress Series 689: 179–189. https://doi.org/10.3354/meps14040

Weller, D. 2008. Report of the Large Whale Tagging Workshop. U.S. Marine Mammal Commission and U.S. National Marine Fisheries Service. San Diego, California. 32 p. https://swfsc-publications.fisheries.noaa.gov/publications/CR/2008/2008Weller4.pdf

Marine Mammal Commission

An independent agency of the U.S. Government

4340 East-West Highway | Room 700 | Bethesda, Maryland 20814

www.mmc.gov