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Economic Analysis of the North Atlantic Right Whale Vessel Speed Restriction Rule

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Prepared for:

Office of Protected Resources
National Marine Fisheries Service
1315 East-West Highway, SSMC III
Silver Spring, MD 20910

Prepared by:

Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, MA 02140
617/354-0074

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EXECUTIVE SUMMARY

In accordance with the requirements of 50 CFR § 224.105(d), the National Oceanic and Atmospheric Administration (NOAA) has initiated an assessment of the costs and benefits of the vessel speed limitations set forth in the Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales. In support of this effort, Industrial Economics, Incorporated (IEc) is working with the Office of Protected Resources of the National Marine Fisheries Service (NMFS) to analyze the Rule's costs. This report presents our findings. It begins with an analysis of vessel transit data to assess the marginal effect of the Rule on transit times, *i.e.*, the extent to which transits through areas subject to the Rule are delayed when vessels reduce their speed to comply with its requirements. It then applies available data on hourly operating costs for various types of vessels to estimate the direct costs attributable to these delays.

Depending on the method employed to characterize the Rule's impact on transit times, we estimate its direct costs at approximately $28.3 million to $39.4 million annually. The analysis indicates that the commercial shipping industry bears between 74 to 87 percent of these costs. This result is not surprising. Of the wide range of vessels the Rule affects, commercial shipping accounts for the greatest number of affected transits. These vessels also have high hourly operating costs and ordinarily operate at relatively high speeds; thus, the impact of the speed restrictions on their operations accounts for a large share of the costs attributable to the Rule. In comparison, other types of vessels account for a substantially smaller share of the Rule's estimated costs, either because their hourly operating costs and/or routine operating speeds are much lower – as is the case with commercial fishing vessels – or because they account for a smaller share of affected transits.

Our analysis is subject to several important limitations. Most notably, the data available on vessel operating costs are limited, and the characterization of the counterfactual scenario upon which our estimates are based – *i.e.*, our estimate of the speed at which vessels would operate in the absence of the Rule – involves some degree of professional judgment. Additionally, our analysis considers only the direct costs of the Rule; we do not attempt to evaluate the extent to which these costs may be passed on to consumers in the form of higher prices, nor do we attempt to analyze the potential effect of changes in operating costs on overall levels of commercial shipping activity. We do, however, briefly review the available data on commercial shipping activity since the Rule took effect. This review provides no *prima facie* evidence that the Rule has had an adverse effect on the volume or value of economic activity at ports along the eastern seaboard.

CHAPTER 1 | INTRODUCTION

OVERVIEW OF RULE

The North Atlantic right whale (*Eubalaena glacialis*) is one of the world's most endangered large whale species, having been hunted by commercial whalers over many decades to the brink of extinction. The species has been protected from whaling since 1935, and in 1970 was listed as endangered under the U.S. Endangered Species Act. Despite these and other efforts to protect right whales, the species has failed to recover. Current estimates place the remaining population at approximately 400 individuals.[1]

Recent efforts to restore the population of the North Atlantic right whale have focused on reducing the number of deaths and injuries attributable to anthropogenic causes. This includes reducing the likelihood and severity of vessel strikes – collisions between vessels and whales – which have been identified as one of the leading causes of right whale mortality. The potential for a vessel strike is likely to be higher where busy transit corridors intersect with important right whale habitat.

Research on vessel strikes has shown that both their likelihood and severity increase with vessel speed. Guided by these findings, NMFS aims to protect right whales from vessel strikes by restricting vessel operating speeds in areas where right whales are likely to be found. These restrictions first took effect in 2008, when NMFS published a "Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales" (we refer to the 2008 Final Rule, collectively with its modifications, as the "Rule").[2] The objective of the Rule is to facilitate the recovery of the right whale by requiring certain oceangoing vessels to travel at speeds of 10 knots or less at specific times and locations, known as Seasonal Management Areas (SMAs), where right whales are likely to be found. In addition to establishing SMAs, the Rule provides for the establishment of Dynamic Management Areas (DMAs) at locations and times in which aggregations of right whales outside SMAs are detected. DMAs are established as needed, generally for a period of 15 days, though they can be extended if whales remain in the area. Vessel operators are requested, but not required, to avoid DMAs or to transit DMAs at speeds no greater than 10 knots.

With certain exceptions, all vessels greater than or equal to 65 feet in overall length and subject to the jurisdiction of the United States, as well as all vessels greater than 65 feet entering or departing a U.S. port or place, are subject to the speed restrictions while traveling through SMAs.[3] Vessels greater than or equal to 65 feet in length that are not subject to the Rule include vessels owned or operated by the Federal

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[1] https://www.fisheries.noaa.gov/species/north-atlantic-right-whale.

[2] "Endangered Fish and Wildlife; Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales," 73 *Federal Register* 60173 (December 9, 2008), 50 CFR Part 224.

[3] Compliance Guide for Right Whale Ship Strike Reduction Rule 950 CFR 224.105), National Marine Fisheries Service.

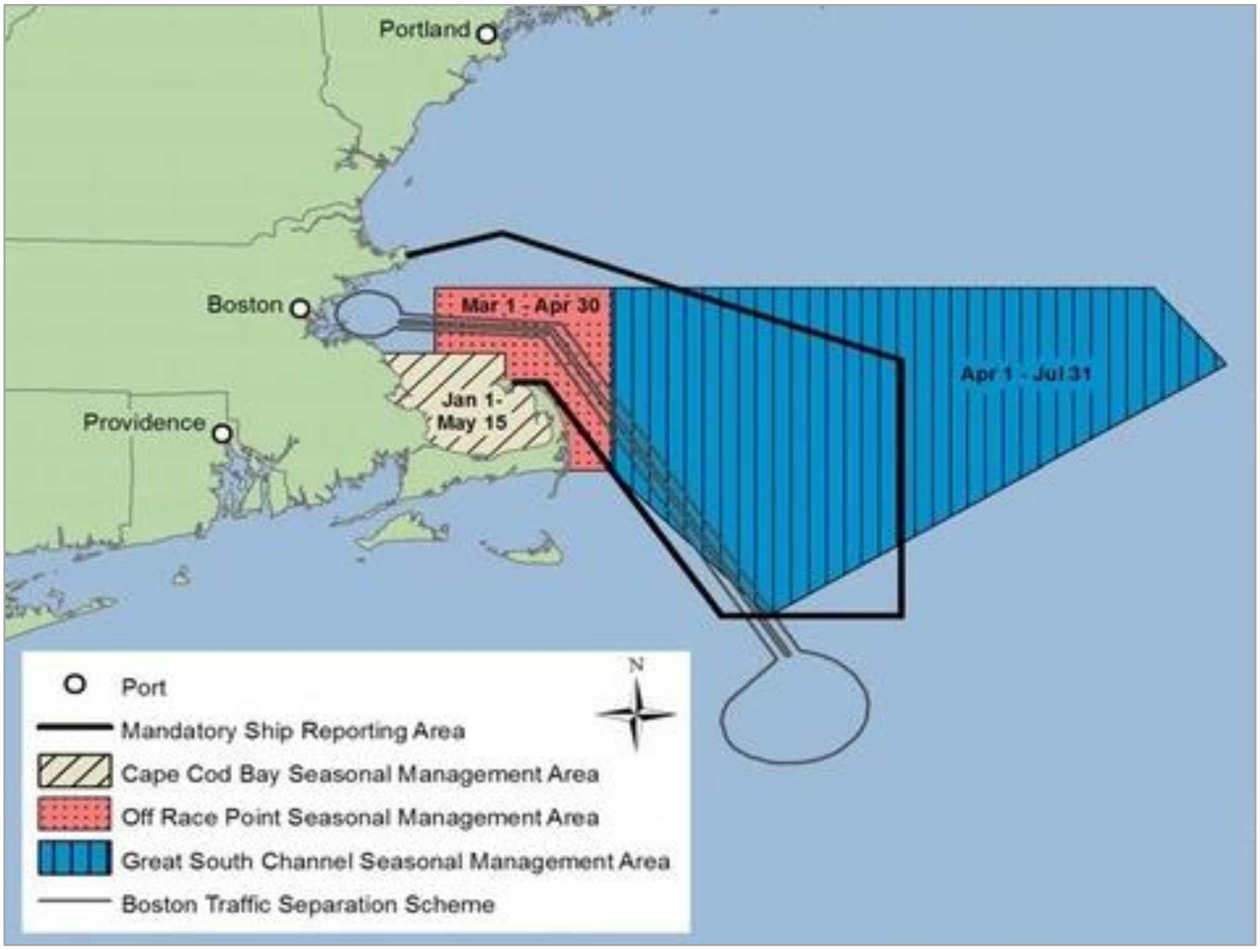
government; U.S. military vessels; foreign military vessels while engaged in exercises with the U.S. Navy; and active state law enforcement/rescue vehicles.

Table 1-1 identifies the 10 SMAs established under the Rule and the dates the speed restrictions are in effect. Figure 1-1, Figure 1-2, and Figure 1-3 show the location of the SMAs in the Northeast, Mid-Atlantic, and Southeast regions.

TABLE 1-1. SEASONAL MANAGEMENT AREAS

REGION	NAME	SHORTHAND NAME	EFFECTIVE DATES	PERCENT OF YEAR IN EFFECT
Northeast	Cape Cod Bay	Cape Cod Bay	January 1 - May 15	37%
	Off Race Point	Off Race Point	March 1 - April 30	17%
	Great South Channel	Great South Channel	April 1 - July 31	33%
Mid-Atlantic	Block Island Sound	Block Island	November 1 - April 30	50%
	Ports of New York/New Jersey	New York		
	Entrance to the Delaware Bay (Ports of Philadelphia and Wilmington)	Philadelphia		
	Entrance to the Chesapeake Bay (Ports of Hampton Roads and Baltimore)	Norfolk		
	Ports of Morehead City and Beaufort, NC	Morehead City		
	Wilmington, NC, to Brunswick, GA	North Carolina to Georgia		
Southeast	Calving and Nursery Grounds	Southeast	November 15 - April 15	42%

FIGURE 1-1. NORTHEAST SEASONAL MANAGEMENT AREAS[4]



[4] "Reducing Ship Strikes to North Atlantic Right Whales," NOAA Fisheries, accessed at https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales.

FIGURE 1-2. MID-ATLANTIC SEASONAL MANAGEMENT AREAS[5]

[5] "Reducing Ship Strikes to North Atlantic Right Whales," NOAA Fisheries, accessed at https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales.

FIGURE 1-3. SOUTHEAST SEASONAL MANAGEMENT AREAS[6]

[6] "Reducing Ship Strikes to North Atlantic Right Whales," NOAA Fisheries, accessed at https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-ship-strikes-north-atlantic-right-whales.

PREVIOUS ECONOMIC ANALYSES

2008 ANALYSIS

In support of the 2008 Rule, Nathan Associates Inc. prepared a prospective analysis of its potential economic impacts.[7] In its analysis, Nathan Associates estimated the potential economic impacts associated with six different combinations of four operational measures (recommended routes; SMAs; DMAs; and speed restrictions) designed to reduce the frequency and severity of vessel strikes to right whales. The preferred alternative in this analysis closely aligns with – but is not identical to – the final Rule.[8]

Nathan Associates' economic impact assessment was based on estimates of the delay vessels would experience by complying with the proposed speed restrictions, coupled with information on typical vessel operating costs.[9] Notably, Nathan Associates estimated delays under an assumption of full compliance with the Rule; *i.e.*, an assumption that all vessels subject to the rule would reduce their speeds to the proposed statutory limit. Nathan Associates estimated delays using Mandatory Ship Reporting System data (which provides actual operating speeds reported by ship captains) and U.S. Army Corps of Engineers (USACE) operating cost data (which include annualized capital costs, estimates of fixed operating costs, and fuel costs at sea and in port).[10]

Nathan Associates estimated a wide range of economic impacts to the commercial shipping industry, with annual impacts under the preferred alternative of approximately $53 million.[11] Nathan Associates estimated substantially lower impacts to commercial fishing, charter fishing, passenger ferry, and whale watching vessels.[12]

2012 ANALYSIS

Nathan Associates conducted a retrospective economic analysis of the Rule in 2012.[13] The methodology employed in this analysis was similar to that used in Nathan Associates' 2008 analysis; *i.e.*, calculating the impact of the Rule on travel time, then estimating the associated increase in operating costs. In this case, however, the estimate of impacts on the commercial shipping industry was based on observations of vessel operations within the SMAs, as recorded by the U.S. Coast Guard Automatic Identification System (AIS). AIS uses transmitters to relay a vessel's location as well as other information (such as vessel type,

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[7] Nathan Associates Inc., "Economic Analysis for the Final Environmental Impact Statement of the North Atlantic Right Whale Ship Strike Reduction Strategy," submitted to the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources, August 2008.

[8] Nathan Associates Inc., 2008, pp. 3-6.

[9] Nathan Associates Inc., 2008, p. 53.

[10] Nathan Associates Inc., 2008, pp. 53-56.

[11] Nathan Associates Inc., 2008, p. 112. This estimate is based on reports of vessel arrivals by port in 2003 and 2004, coupled with hourly operating cost data for 2004, updated to reflect average bunker fuel prices for New York as of June 13, 2008.

[12] Nathan Associates Inc., 2008, p. 156.

[13] Nathan Associates Inc., "Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule," submitted to the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources, December 2012.

size, speed, and heading). As Table 1-2 indicates, AIS carriage requirements apply to all commercial vessels subject to the Rule; thus, the AIS data provide a reasonable foundation for analyzing the effects of the Rule on commercial vessels.

In its 2012 analysis, Nathan Associates estimated the delay associated with the Rule by calculating the difference between the average operating speed and time required to transit an SMA when the Rule was *not* in effect, as reflected in the AIS data, and the time required to transit this area at a speed of 10 knots.[14] Thus, Nathan Associates' analysis modeled the effects of full compliance with the Rule, rather than impacts based on observed operating speeds. The analysis relied on a USACE model of vessel operating costs to calculate impacts on the commercial shipping industry. It estimated a total annual cost to commercial shipping vessels of $19.6 million.[15]

Nathan Associates' 2012 analysis presented separate analyses of economic impacts to commercial fishing, passenger ferry, and whale watching vessels; these analyses were not based on AIS data. Nathan Associates estimated impacts of approximately $0.9 million to the commercial fishing industry. The report found no impact on passenger ferries or whale watching vessels, as speed restrictions where these vessels operate were not in effect during their peak operating periods.[16]

SCOPE OF THIS ANALYSIS

This report presents a retrospective analysis of the annual economic impact of the Rule to marine vessel operators. The analysis considers impacts to the commercial shipping sector (*e.g.*, cargo vessels, tankers, and container ships), as well as to commercial fishing vessels, passenger vessels, and other commercial vessels. We estimate the economic impacts associated with the mandatory speed restrictions that apply to vessels transiting SMAs. We do not analyze impacts associated with DMAs, for which reductions in operating speed are suggested but not required.

Like Nathan Associates' 2012 analysis, we base our assessment of the Rule's impacts on AIS data. Specifically, we rely on AIS data for 2017, the most recent year for which a complete dataset was available when the analysis began. In the absence of data to the contrary, we assume this year is reasonably representative of vessel activity in recent years. In one important respect, however, our approach differs from that taken by Nathan Associates: we do not base our assessment of the Rule's impacts on the assumption of full compliance. Instead, our primary estimates of the impacts of the Rule are based on *observed* vessel transits and operating speeds, both for the period when the speed restrictions were in effect and when they were not. Thus, to the extent that vessels do not comply with the Rule, our assessment of cost impacts takes this into account. An analysis of the cost impacts of full compliance is presented separately.[17]

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[14] Nathan Associates' calculation of average operating speeds during the period the speed restrictions were not in effect included only transits where the average speed was greater than 10 knots. Nathan Associates Inc., 2012, pp. 4-5.

[15] Nathan Associates Inc., 2012, pp. 8-9.

[16] Nathan Associates Inc., 2012, pp. 20-27.

[17] See Appendix B.

TABLE 1-2. RULE AND AIS CARRIAGE REQUIREMENTS BY VESSEL TYPE

CATEGORY	SUBCATEGORY	SUBJECT TO RULE AND AIS CARRIAGE REQUIREMENTS	SUBJECT TO RULE, BUT NOT AIS	SUBJECT TO AIS, BUT NOT RULE	SUBJECT TO NEITHER RULE NOR AIS
Commercial Vessels	Vessels "in commercial service" (including fishing vessels)	≥65 feet			<65 feet
	Passenger vessels	≥65 feet (regardless of passenger count)		<65 feet; certificated to carry >150 passengers	<65 feet; certificated to carry <150 passengers
	Towing vessels	≥65 feet		≥26 feet but <65 feet	<26 feet
Commercial Vessels with Special Considerations	Dredging vessels			<65 feet obstructing navigation	
	Vessels with dangerous cargo			<65 feet	
Non-Commercial Vessels	Research, academic, & non-profit vessels	≥65 feet; >150 passenger certification	≥65 feet; <150 passenger certification	<65 feet; carrying >150 passengers	<65 feet; carrying <150 passengers
	Recreational vessels		≥65 feet		<65 feet
Government / Military Vessels	State government-owned/operated vessels (non-military)		≥65 feet not engaged in law enforcement / search and rescue		≥65 feet engaged in law enforcement / search and rescue
	Federally owned/operated vessels				All vessels

The remainder of this report presents additional detail on our approach and findings. Specifically:

- Chapter 2 describes our analysis of the effect of the Rule on transit times for vessels that operate within the SMAs.
- Chapter 3 presents our assessment of the costs associated with increases in travel time.
- Chapter 4 provides a high-level analysis of the Rule's potential impact on economic activity at ports along the East Coast.
- Chapter 5 summarizes the results and implications of our analysis.

CHAPTER 2 | IMPACTS ON TRANSIT TIME

INTRODUCTION

The discussion that follows presents our analysis of the impact of the Rule's vessel speed restrictions on transit times through Seasonal Management Areas (SMAs). We first describe the data sources we rely upon to analyze these impacts. Next, we present a high-level analysis of vessel operating speeds through the SMAs, comparing the speeds at which transits occur when the speed restrictions are in effect and when they are not; this comparison motivates the selection of the methods we employ to estimate the effect of the speed restrictions on transit times. We then provide detailed information on these methods and summarize our findings.

DATA SOURCES

AIS DATA

The primary source of vessel transit information we rely upon is Automatic Identification System (AIS) data. AIS is a maritime navigation safety communications system adopted by the International Maritime Organization (IMO) that provides vessel information automatically to appropriately equipped shore stations and similarly equipped ships.[18] AIS uses transmitters installed on a vessel to relay the vessel's precise location, as well as other information such as its size, speed, and heading. Vessel traffic operators use AIS in ports to coordinate docking and ensure safety. For navigators at sea, AIS supplements radar as the primary means of detecting other vessels and avoiding collisions.

DATA PROCESSING AND SCREENING

We obtained the AIS data we use in our analysis from NMFS. At our request, NMFS provided data on vessel activity in each SMA from January 1 to December 31, 2017, the most recent year for which a complete dataset was available. To develop the dataset, NMFS aggregated individual records (which are often transmitted multiple times per minute) into "transit segments" and calculated transit-level characteristics (for example, total distance, total operating hours, average speed over ground).[19] We worked with NMFS to screen the data, excluding records with an invalid vessel identification number as

[18] United States Coast Guard. AIS Frequently Asked Questions. Accessed May 27, 2019. https://www.navcen.uscg.gov/?pageName=AISFAQ.

[19] NMFS separates "transits" into individual "transit segments" specified by NMFS as a unique transit when the vessel passes into or out of an SMA, or when the status of the SMA changes from inactive to active (or vice versa). For additional information on AIS transmissions, see, *e.g.*, https://help.marinetraffic.com/hc/en-us/articles/217631867-How-often-do-the-positions-of-the-vessels-get-updated-on-MarineTraffic-. For analytical purposes, we consider each "transit segment" as a unique "transit." For simplicity, we refer to transit segments as "transits."

well as records for vessels that, based on reported type or length, are not subject to the Rule. As detailed below, this process required some degree of judgment. Specifically:

- AIS records contain a unique identification number for each vessel, but sometimes provide inconsistent data on vessel length, which is an important consideration in identifying vessels that are subject to the Rule. To address any inconsistencies, NMFS evaluated the AIS data – along with vessel characteristic data from a separate database maintained by IHS Markit, a commercial information services provider – to determine the most appropriate length to assign to a vessel. In cases where IHS information was not available, NMFS assigned the vessel the maximum length reported in the vessel's AIS signals. This may lead the dataset to include records for some vessels that are less than 65 feet in length, and thus not subject to the Rule. The approach, however, avoids inadvertently excluding from the analysis transits made by vessels that are in fact subject to the Rule, and thus errs on the side of potentially overstating the Rule's costs.
- AIS records also provide information on vessel type. NMFS classified commercial shipping vessels into five categories: container ships; tankers; "ro-ro" (*i.e.*, "roll-on, roll-off") cargo vessels; bulk carriers; and general cargo vessels. The dataset also includes vessels of the following types: fishing; towing/pushing; passenger cruise ships; other passenger vessels; dredging; sailing; and pleasure craft (*e.g.*, motorized recreational vessels). If the information provided on this parameter was inconsistent, NMFS identified the type as "Undetermined" but retained the record in the dataset. Similarly, NMFS retained in the dataset records for vessels that reported their type as "Other." In our analysis, we aggregate the latter two sets of records into a broader "Other/Undetermined" category.[20] Again, this approach avoids inadvertently excluding from the analysis transits made by vessels that may be subject to the Rule.

In addition to the steps described above, we reviewed the AIS records provided by NMFS for information on transit speed, transit distance, and operating hours.[21] We excluded from the dataset transits that report speed, distance, or operating hours of zero, as well as portions of a transit that occurred at speeds below one knot. We excluded these records to reduce the potential that our analysis would be biased by data points representing vessels that are momentarily adrift, moored and swinging at anchor, or otherwise not actively under way. Similarly, we excluded transits of less than one nautical mile in length out of concern that ships that venture into an SMA only briefly may not adjust their speeds, and that inclusion of these transits would thus bias our assessment of the impact of the Rule.[22]

As a final step in the data screening process, we tested the statistical significance of the difference in mean operating speeds within each SMA when the speed restrictions are in effect (the "restricted period") and when they are not (the "unrestricted period"). In most cases, these tests indicated with a high degree

[20] NMFS identified fewer than 25 transits as "Other Cargo" vessels. In our analysis, we aggregate these transits into the "General Cargo" category. NMFS identified fewer than 20 transits as pollution control vessels, fewer than 250 transits as pilot vessels, and fewer than 900 transits as port tenders and offshore work vessels. In our analysis, we aggregate these vessels into the "Other/Undetermined" category.

[21] We define transit speed as *avg_sog_dw_sog_gt01*, transit distance as *seg_dist_nm_sog_gt01*, and operating hours as *op_hrs_sog_gt01*.

[22] In addition to the factors listed above, NMFS identified transit records of poor or suspect quality based on the time elapsed or distance between the successive AIS data points used to create the record. Our analysis retains these records, thereby increasing our estimate of the impact of the Rule on vessel transit times.

of confidence that the means are significantly different. This was not true, however, for sailing vessels, largely because these transits typically occur at speeds below 10 knots, regardless of whether the speed restrictions are in effect. Based on this review, we excluded transits of sailing vessels from further analysis.

OVERVIEW OF ANALYSIS DATA SET

The dataset that resulted from the screening process described above includes 101,547 transits made by approximately 6,000 different vessels. Table 2-1 displays the distribution of transits by vessel type and SMA. As the table indicates, commercial shipping vessels (bulk carriers, container ships, ro-ro cargo ships, tankers, and general cargo vessels) account for the largest number of transits – approximately 37,400 (36.8 percent). Fishing vessels (24,800 transits; 24.5 percent); towing/pushing vessels (14,800 transits; 14.6 percent); non-cruise passenger vessels (7,600 transits; 7.5 percent); and pleasure vessels (6,600 transits; 6.5 percent) also account for a substantial portion of transits.

It is important to note that the dataset includes many transits by fishing vessels. We are aware of concern that fishing vessels may be underrepresented in the AIS data in waters where AIS coverage is not mandatory; *i.e.*, that fishermen may choose not to operate their AIS transmitters in order to avoid disclosing to potential competitors the areas in which they fish. It is difficult to estimate the degree to which fishing vessel transits may be underrepresented; however, we observe a general concordance between vessel counts in the AIS data and the available data on commercial fishing permits. We also note that the average number of trips per vessel recorded within SMAs does not appear to be unreasonably low. We therefore have not adjusted the analysis of fishing vessel transits to account for underreporting. We acknowledge, however, the possibility that underreporting may lead us to understate impacts on commercial fishing vessels, as well as any other category of vessel that for unknown reasons might be underrepresented in the AIS data.

Additionally, we note that the dataset used in our analysis includes transits for seasonally operated high-speed ferries. The operation of at least some of these vessels, particularly in New England waters, is limited to periods when the speed restrictions are not in effect. Inclusion of these transits in our analysis may lead us to overstate the impacts of the Rule on passenger vessels. It is arguable, however, that the Rule has led operators of at least some high-speed ferries to curtail their schedules in order to avoid operating when the speed restrictions are in effect. Given this possibility, we have chosen to err conservatively and include transits for seasonally operated ferries in our analysis.

ANALYSIS OF TRANSIT SPEEDS

Our analysis of the potential impacts of the Rule begins by comparing vessel transit speeds when SMA speed restrictions are in effect and when they are not. As explained later in this chapter, differences in the distribution of transit speeds between the restricted and unrestricted periods are one factor motivating our use of two different methods to estimate the impact of the Rule.

TABLE 2-1. NUMBER OF TRANSITS BY VESSEL TYPE AND SMA

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILA-DELPHIA	NORFOLK	MORE-HEAD CITY	NORTH CAROLINA TO GEORGIA	SOUTH-EAST	TOTAL
Bulk Carrier	1	141	178	247	413	456	1,845	55	751	328	**4,415**
Container		381	397	4	3,905	1,275	3,444	1	6,996	1,026	**17,429**
Ro-Ro	47	112	108	379	1,058	382	1,342		853	1,986	**6,267**
Tanker	49	268	377	329	2,457	1,344	341	62	880	321	**6,428**
General Cargo	1	26	53	124	214	559	507	148	706	490	**2,828**
Passenger (Cruise)	55	176	186	79	583	10	239	15	241	196	**1,780**
Fishing	928	2,128	6,023	6,388	1045	2,878	2,356	977	1,137	980	**24,840**
Towing/Pushing	1,564	251	22	592	3,053	2,814	1,198	310	2,884	2,143	**14,831**
Dredging	8	6	2	4	112	133	419	19	701	488	**1,892**
Passenger (Other)	2,550	1,528	2	197	625	864	548	40	892	399	**7,645**
Pleasure	432	276	109	428	577	634	584	791	1,852	901	**6,584**
Other/Undetermined	841	496	248	1,133	1,098	431	612	283	900	566	**6,608**
Total	**6,476**	**5,789**	**7,705**	**9,904**	**15,140**	**11,780**	**13,435**	**2,701**	**18,793**	**9,824**	**101,547**

The analysis indicates that transit speeds are generally lower in the restricted period than in the unrestricted period, with the difference varying by vessel type. Table 2-2 presents mean transit speeds by vessel type across all SMAs.[23] As the table indicates, the mean transit speed for all categories is lower during the restricted period than during the unrestricted period. In some cases (fishing, towing/pushing, and dredging vessels), the mean transit speed during the *unrestricted* period is well under 10 knots; not surprisingly, the introduction of a 10-knot speed limit during the restricted period has relatively modest impacts on mean transit speeds for vessels in these categories. In contrast, mean transit speeds for commercial shipping vessels range from 10.7 to 13.0 knots during the unrestricted period but fall below 10 knots during the restricted period. In all other cases, mean transit speeds during the unrestricted period are above 10 knots and, although lower, remain at or above 10 knots during the restricted period. Notably, the mean operating speed of pleasure craft during the restricted period is 16.0 knots, close to the mean calculated for the unrestricted period (16.7 knots) and well above the Rule's 10-knot limit. The mean transit speed for vessels in the passenger (cruise) and passenger (other) categories during the restricted period is much lower than during the unrestricted period, but also remains above 10 knots.

TABLE 2-2. MEAN TRANSIT SPEEDS (KNOTS) BY PERIOD

VESSEL TYPE	UNRESTRICTED PERIOD	RESTRICTED PERIOD
Bulk Carrier	10.7	9.8
Container	13.0	9.8
Ro-Ro	13.0	9.5
Tanker	11.2	9.5
General Cargo	11.9	9.8
Passenger (Cruise)	14.3	10.5
Fishing	7.5	7.2
Towing/Pushing	8.1	7.7
Dredging	8.5	6.4
Passenger (Other)	18.2	10.3
Pleasure	16.7	16.0
Other/Undetermined	11.5	10.0

Comparing the distribution of transit speeds during the restricted and unrestricted periods further illustrates the apparent effects of the Rule. Figure 2-1 shows the distribution of transit speeds for general cargo vessels within the Philadelphia SMA. As the figure indicates, transit speeds are clearly lower during the restricted period (November 1 to April 30), when most transits occur at speeds less than 10 knots; the highest speed reported during the restricted period is approximately 12 knots. In contrast, speeds during the unrestricted period tend to be much higher, with some vessels transiting the SMA at

[23] See Appendix A for data on mean transit speeds by vessel type within each SMA, as well as figures illustrating the distribution of transit speeds by vessel type within each SMA during the restricted and unrestricted periods.

speeds exceeding 18 knots. The difference between the distributions suggests that the Rule has a substantial impact on the speeds at which general cargo vessels operate in this area.

FIGURE 2-1. TRANSIT SPEEDS: GENERAL CARGO VESSELS, PHILADELPHIA SMA (RESTRICTED PERIOD NOVEMBER 1 – APRIL 30)

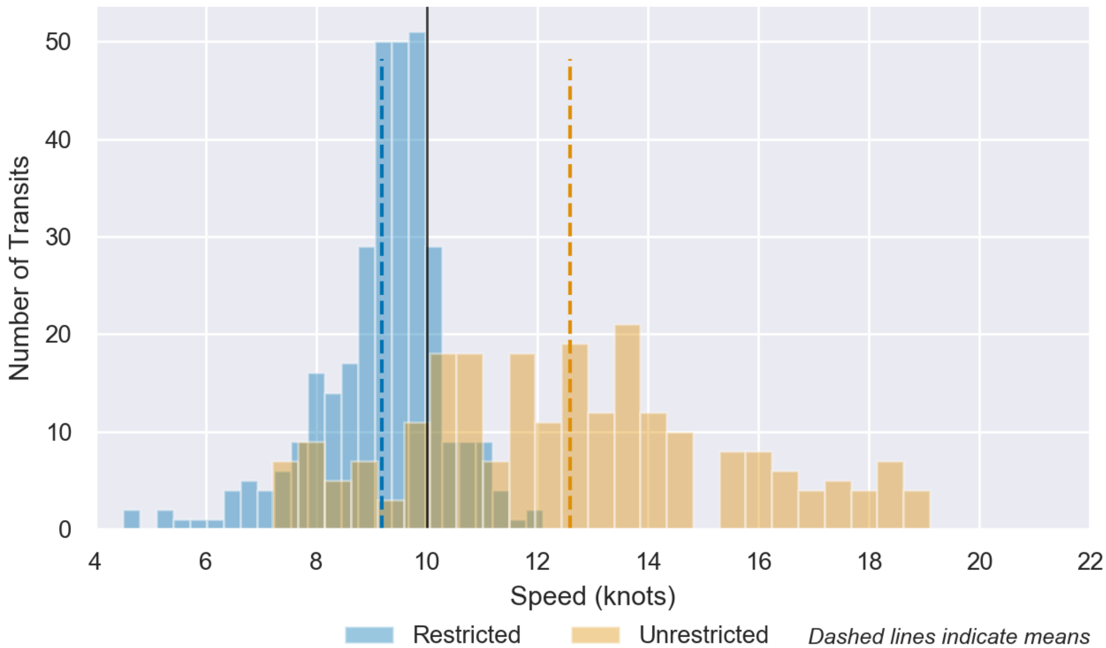


Figure 2-2 provides a similar illustration, showing the distribution of transit speeds for fishing vessels in the Off Race Point SMA, north and east of Cape Cod. In this case the effect of the Rule appears to be much more limited. The distribution of transit speeds clearly shifts to the left during the restricted period (March 1 to April 30), suggesting that fishing vessels generally operate at lower speeds when the 10-knot limit is in effect. The shift is slight, however, and during both periods most transits within this SMA occur at speeds well under 10 knots.

Figure 2-3 offers a third example, illustrating the distribution of mean transit speeds for pleasure craft in the Norfolk SMA. In this case, the number of transits that occur during the restricted period (November 1 to April 30) is much lower than the number that occur during the unrestricted period, reflecting the seasonal nature of pleasure craft use. In general, however, the distribution of vessel speeds during the two periods is similar, with most transits made at speeds greater than 10 knots. This similarity indicates that the Rule has had little practical impact on the operation of pleasure craft within the Norfolk SMA, with many vessels operating at speeds during the restricted period that violate the Rule.

FIGURE 2-2. MEAN TRANSIT SPEEDS: FISHING VESSELS, OFF RACE POINT SMA (RESTRICTED PERIOD MARCH 1 – APRIL 30)

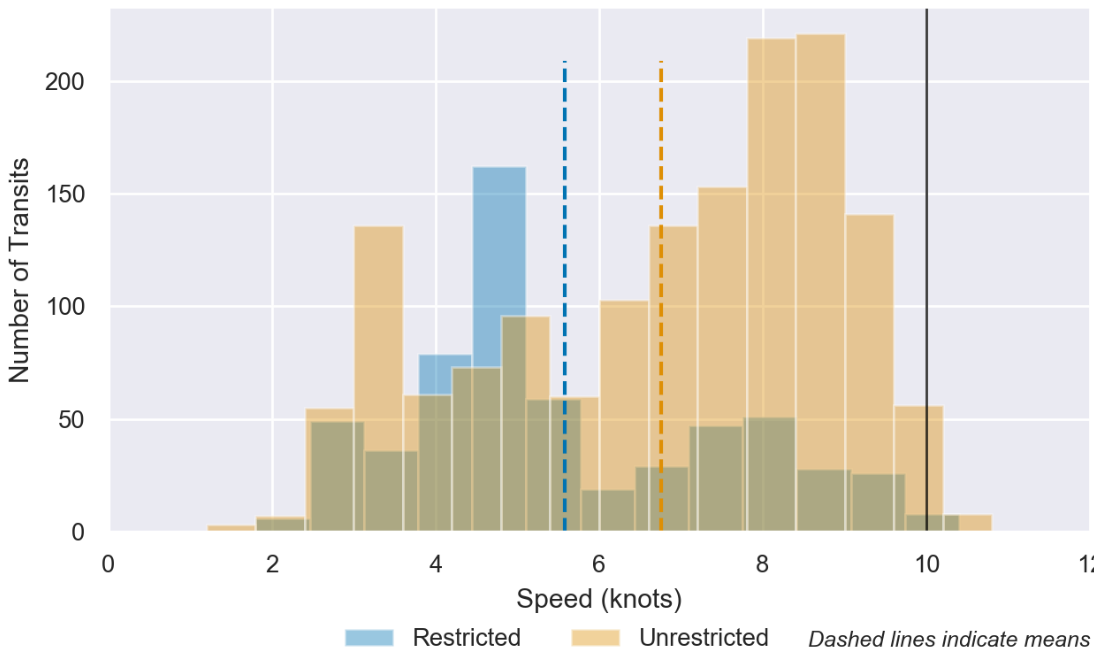
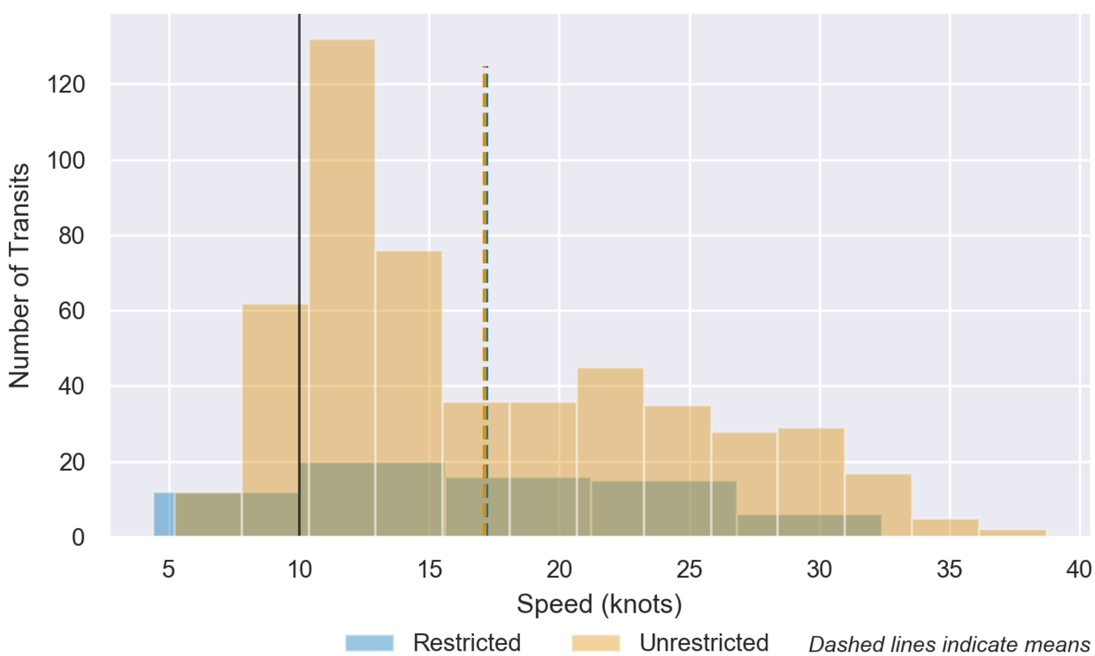


FIGURE 2-3. MEAN TRANSIT SPEEDS: PLEASURE VESSELS, NORFOLK SMA (RESTRICTED PERIOD NOVEMBER 1 – APRIL 30)



CALCULATION OF IMPACTS ON TRANSIT TIMES

OVERVIEW OF METHODS

In order to estimate the economic impact of the Rule's speed restrictions on vessel operations, we calculate the effect of the Rule on transit times, *i.e.*, the additional time required to complete a transit during the restricted period as a result of the Rule. We calculate the delay the Rule causes by comparing observed transit speeds during the restricted period to "counterfactual" speeds – *i.e.*, the speeds at which we assume transits would have occurred but for the Rule. To control for variations in vessel transit characteristics, we calculate counterfactual speeds separately by vessel type and SMA.[24] For each vessel category within each SMA, we calculate the time required to complete the restricted-period transits at the observed distance-weighted average speed, as well as the time these transits would have taken at the counterfactual transit speed.[25] We estimate the delay experienced for each individual transit as the difference in the transit time at the observed speed and the transit time at the counterfactual speed. Mathematically, our approach can be expressed as:

$$delay = time_{observed} - time_{cf} = \frac{distance_{observed}}{speed_{observed}} - \frac{distance_{observed}}{speed_{cf}}$$

As described below, we use this approach to estimate delays in two ways.

- **Method 1: Comparison of Means –** The first option we consider is to examine the difference in mean speeds between the restricted and unrestricted periods, and to assume that in the absence of the Rule, the average speed during the restricted period would equal the average speed observed during the unrestricted period. This approach makes no attempt to differentiate between transits that may or may not have been affected by the Rule; it treats all transits as potentially affected and bases the calculation of operating delays on the difference in mean speeds during the two periods.
- **Method 2: Comparison of High-Speed Transits –** A second option is to focus the analysis on a subset of "affected" transits, *i.e.*, the share of transits that arguably, but for the Rule, would have occurred at speeds greater than 10 knots. To apply this method, we first calculate the percentage of observed vessel transits during the unrestricted period that occurred at distance-weighted average speeds of greater than 10 knots.[26] We assume, but for the Rule, that the same percentage of transits during the restricted period would have occurred at speeds greater than 10 knots. We identify the "affected" transits during the restricted period by beginning with the highest speed

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[24] We do not distinguish between vessel length, deadweight tonnage, gross tonnage, etc. in calculating counterfactual transit speeds.

[25] For each transit, the "observed transit speed" is the distance-weighted average speed for the portion(s) of the transit with speeds greater than one knot. We note that while the actual distance-weighted average speed and operating hours reflect real-world variations in speed over the duration of the transit, the counterfactual speed is a single value: an across-transit mean of transit-level mean speeds. We can only estimate how long a transit would have taken at the counterfactual speed by dividing the transit distance by the counterfactual speed. Thus, in order to make as equal a comparison as possible in our calculation of delay, we also re-calculate the observed transit time by dividing the total transit distance by the average speed across the entire transit.

[26] As noted above, we define the "observed transit speed" as the distance-weighted average speed for the portion(s) of the transit with speeds greater than one knot. A transit that occurred at a distance-weighted average speed of greater than 10 knots may be composed of some segments that occurred at speeds less than 10 knots. Similarly, a transit that occurred at a distance-weighted average speed of less than 10 knots may be composed of some segments that occurred at speeds greater than 10 knots.

transit, expanding the dataset to include progressively slower transits until the target percentage is reached. We calculate the delays attributable to the Rule by assuming that in its absence, these transits would have occurred at the mean speed of the transits during the unrestricted period that occurred at speeds greater than 10 knots.

The discussion that follows describes the application of these methods in greater detail and presents their results.

An important consideration in evaluating the effect of the Rule is the treatment of non-compliant transits. For purposes of a retrospective assessment like that presented here, it is appropriate to take non-compliance into account; only by doing so can we characterize the effects of the Rule as implemented. At the same time, it is important to consider what the impact of the Rule would be if full compliance were achieved. For this reason, Appendix B presents an analysis that assumes full compliance. The analysis presented in Appendix B employs methods identical to those described above with one modification: average operating speeds during the restricted period are calculated after setting all transits that occurred at non-compliant speeds to the maximum compliant speed – 10 knots. This adjustment provides some perspective on the implications of full compliance for various types of vessels, particularly those that show relatively high rates of non-compliance.

METHOD 1: COMPARISON OF MEANS

Under Method 1, we assume that each transit in the restricted period would have – but for the Rule – occurred at the average speed in the unrestricted period. To estimate delays under this method, we calculate the mean unrestricted-period transit speed, by vessel type and SMA. We calculate transit times for each restricted-period transit based on the observed transit distance, observed transit speed, and counterfactual speed, and estimate the delay as the observed transit time minus the counterfactual transit time.[27]

Figure 2-4 presents a graphical example of this method. On average, tankers transit the Norfolk SMA at slightly less than 12 knots during the unrestricted period, and slightly less than 10 knots when the speed restriction is in effect. The impact of the speed restriction on aggregate travel times is calculated by assuming, but for the Rule, that all transits during the restricted period would have occurred at the mean speed observed for all transits during the unrestricted period; *i.e.*, slightly less than 12 knots.[28]

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[27] At an aggregate level, this method estimates delays by assuming the average restricted-period transit instead occurred at the average unrestricted-period speed, multiplied by the number of restricted-period transits.

[28] It is important to note that for some transits during the restricted period – *i.e.*, those that occurred at speeds *greater* than the mean speed during the unrestricted period – application of the counterfactual speed leads to a projected *increase* in transit times, and thus to the calculation of a *negative* delay. While this is simply an artifact of the methodology, it can, in a limited number of cases, lead to projections of *negative* costs (*i.e.*, cost savings) attributable to the Rule. The same is true in applying Method 2 to transits during the restricted period that occurred at speeds greater than the counterfactual speed. Whenever the counterfactual leads to a projected *increase* in transit time, it yields a *negative* delay. If enough transits in an SMA fall into this category, the estimated impact of the Rule could be a *reduction* in aggregate transit times.

One possible explanation for these types of counterintuitive results is that conditions *other than* the vessel speed restrictions account for changes in operating speeds at different times of year. This might be the case, for example, if weather and sea conditions during the restricted period are generally more favorable than during the unrestricted period, allowing vessels to transit the SMA at greater speeds. The opposite might also be true, leading us to *overestimate* the Rule's impacts. Unfortunately, the information required to control for these types of confounding factors is

FIGURE 2-4. TANKER VESSELS, NORFOLK SMA (NOVEMBER 1 – APRIL 30)

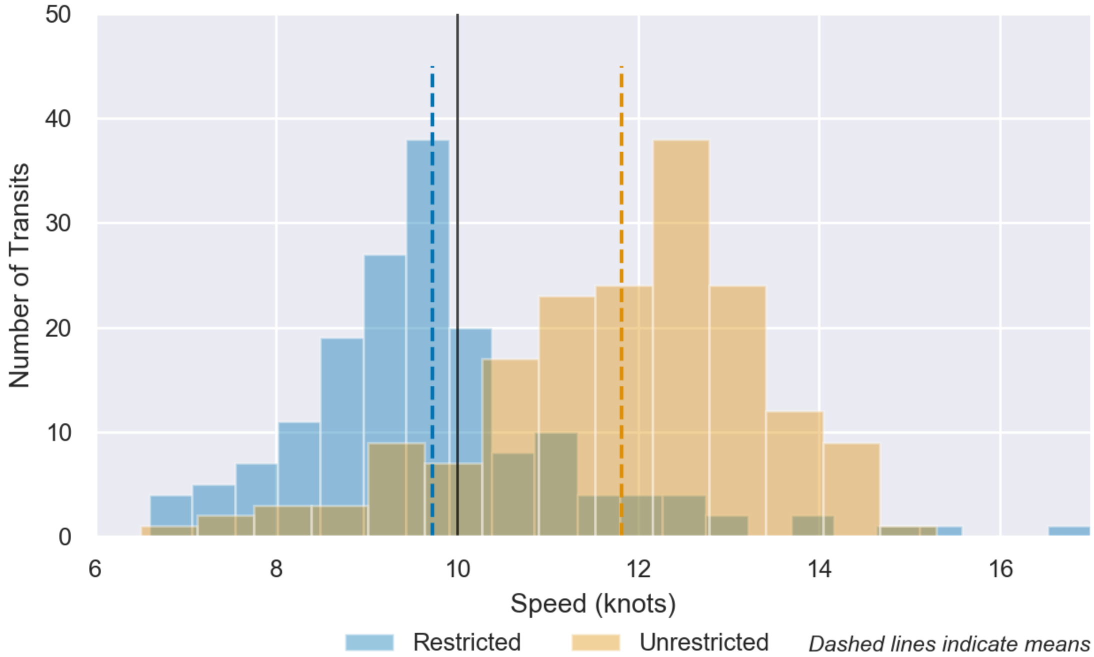

Table 2-3 presents estimates of the aggregate delay imposed by the Rule developed in accordance with Method 1. The estimates are disaggregated by vessel type and SMA.

METHOD 2: COMPARISON OF HIGH-SPEED TRANSITS

Under Method 2, we assume that – but for the Rule – the same percentage of transits would have occurred at speeds greater than 10 knots in both the restricted and unrestricted periods, and that the average speed of these transits in the restricted period would be equal to the average speed of the transits in the unrestricted period. This method focuses the analysis on transits that are likely to have been delayed by the speed restrictions, on the rationale that the 10-knot limit would have no effect on transits that ordinarily would occur at speeds of 10 knots or less.

In applying this methodology, we estimate the impact of the rule on transit times as follows:

- **Step 1 –** We calculate the proportion of transits that occurred at speeds of greater than 10 knots in the unrestricted period.
- **Step 2 –** We calculate the mean transit speed for this sample of unrestricted period transits.

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not available. We can only acknowledge that the absence of such controls could have an impact on our estimate of the Rule's effects; whether this impact is significant and leads us to over- or underestimate the Rule's costs is unclear.

TABLE 2-3. TOTAL DELAY (HOURS) BY VESSEL TYPE AND SMA, METHOD 1

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILA-DELPHIA	NORFOLK	MORE-HEAD CITY	NORTH CAROLINA TO GEORGIA	SOUTH-EAST	TOTAL
Bulk Carrier		4	5	48	87	61	185	9	77	83	**559**
Container		87	275	-0.3	1,511	366	1,275		1,390	458	**5,363**
Ro-Ro	14	28	64	234	354	119	471		193	770	**2,247**
Tanker	4	37	136	85	517	197	72	8	163	113	**1,332**
General Cargo		4	11	30	56	162	109	31	80	144	**628**
Passenger (Cruise)	2	1	77	3	145	0.3	54	6	91	78	**458**
Fishing	161	1,238	-117	456	9	183	375	1,243	2,575	642	**6,764**
Towing / Pushing	203	10	11	40	418	257	63	46	1,160	172	**2,379**
Dredging	-0.5	1	0.3		-1	53	77	3	953	-11	**1,076**
Passenger (Other)	69	18		7	10	5	-6	-2	116	13	**231**
Pleasure	1	-1	-9	27	8	14	10	50	368	142	**611**
Other / Undetermined	85	188	-46	228	1,693	52	79	175	53	99	**2,606**
Total	**538**	**1,615**	**407**	**1,159**	**4,809**	**1,468**	**2,765**	**1,568**	**7,221**	**2,705**	**24,254**

- **Step 3 –** We identify the transits during the restricted period that constitute the same proportion of transits calculated in Step 1. We begin with the transit that occurred at the highest speed (*i.e.*, at the far right of the distribution) and continue to select transits in order of diminishing speed until we reach the proportion desired. We designate these transits as the "affected" set.
- **Step 4** – We calculate the delay experienced by the affected set of transits by calculating the difference between their actual transit times and their transit times had they traveled at the mean speed calculated in Step 2.

Figure 2-5 helps to illustrate the rationale for employing Method 2, depicting the speeds for transits of the Morehead City SMA by fishing vessels during the restricted and unrestricted periods. As this figure shows, the mean transit speed during the unrestricted period was approximately 10.2 knots, while the mean during the restricted period was approximately 7.2 knots. During the unrestricted period, however, a substantial number of transits occurred at speeds below 10 knots; because no speed restrictions were in effect during this period, it is reasonable to assume that the vessels operating at these speeds did so for other reasons. Method 2 takes this into account, focusing the analysis on the subset of transits likely to have been delayed by the Rule. Specifically, Method 2 identifies the proportion of transits that occurred at speeds greater than 10 knots when the speed restriction *was not* in effect – in this case, approximately 53 percent. It takes this percentage as an indicator of the share of transits *during the restricted period* that are likely to have been affected by the Rule. It assumes, but for the Rule, that the fastest 53 percent of transits when the speed restriction *was* in effect would have occurred at the average speed of the fastest 53 percent of transits when the speed restriction *was not* in effect. As Figure 2-6 shows, the counterfactual speed for affected transits under this method is approximately 13 knots, compared to a mean of 8.6 knots during the restricted period.

FIGURE 2-5. FISHING VESSELS, MOREHEAD CITY SMA (NOVEMBER 1 – APRIL 30)

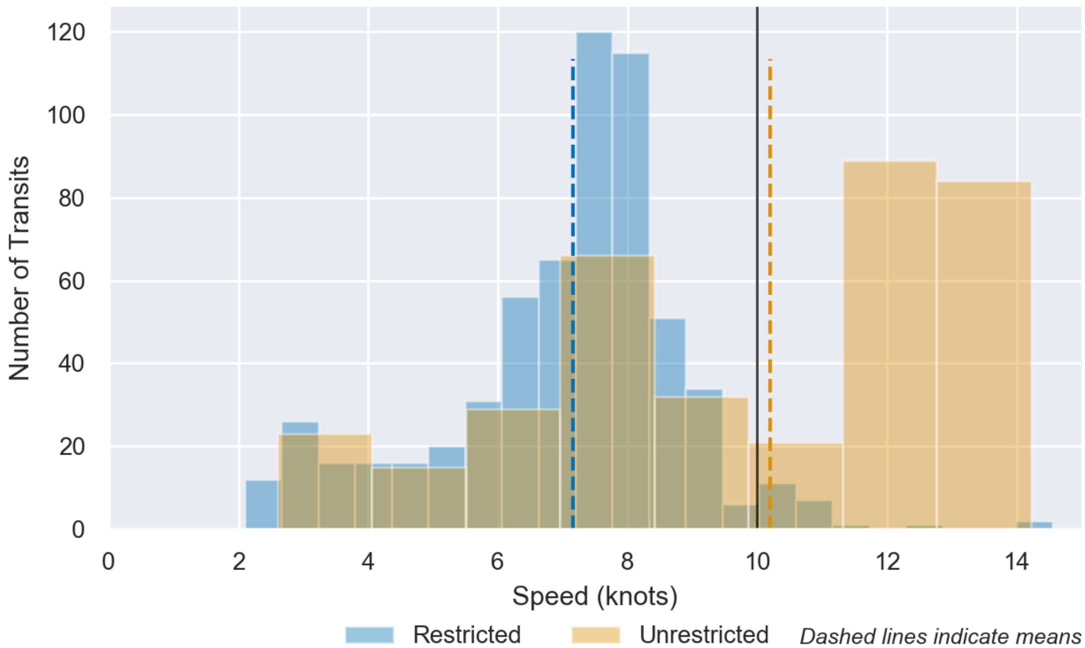

FIGURE 2-6. FISHING VESSELS, TOP 53 PERCENT OF TRANSITS BY SPEED, MOREHEAD CITY SMA (NOVEMBER 1 – APRIL 30)

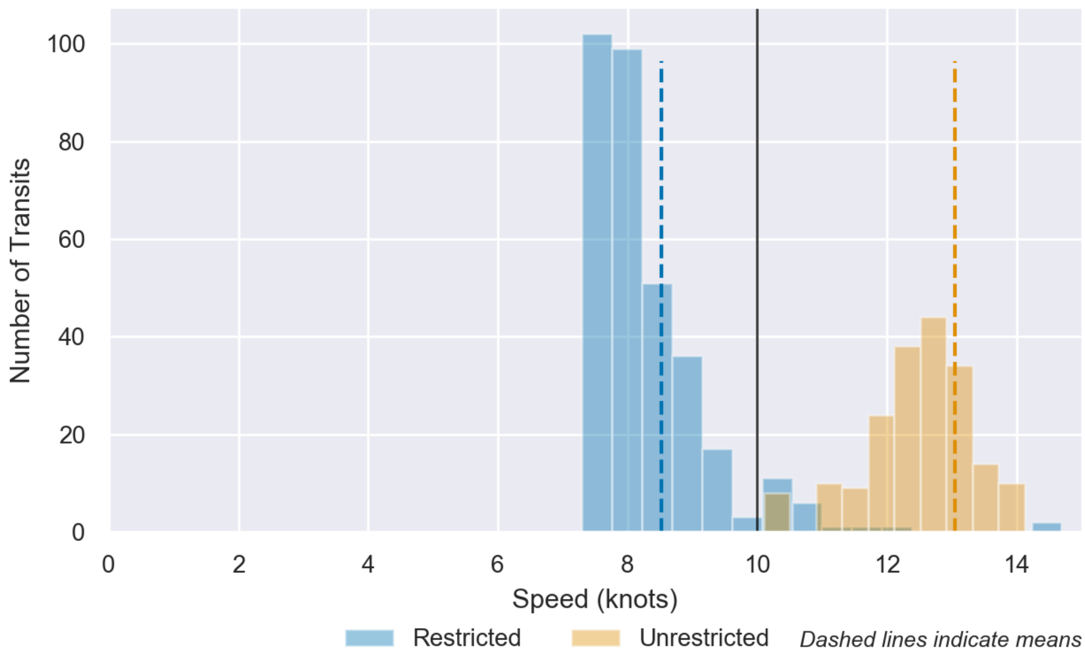

Table 2-4 presents estimates of the aggregate delay imposed by the Rule developed in accordance with Method 2. The estimates are disaggregated by vessel type and SMA. Overall, this method leads to a substantially lower estimate of the impact of the Rule, with estimated total operating delays of approximately 10,800 hours, compared to 24,300 under Method 1.

TABLE 2-4. TOTAL DELAY (HOURS) BY VESSEL TYPE AND SMA, METHOD 2

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILA-DELPHIA	NORFOLK	MORE-HEAD CITY	NC TO GA	SOUTH-EAST	TOTAL
Bulk Carrier		3	5	20	29	43	111	4	50	55	**320**
Container		78	245	-1	1,246	297	1,100		1,243	405	**4,615**
Ro-Ro	4	26	55	180	265	100	424		169	641	**1,863**
Tanker	5	32	127	66	233	128	60	5	127	91	**874**
General Cargo		5	9	20	35	132	96	21	67	112	**496**
Passenger (Cruise)	2	1	74	3	145	0.4	53	2	83	80	**444**
Fishing	3	1	8	8	5	10	147	415	156	-1	**751**
Towing / Pushing	18	2	0.2	7	33	15	6	-1	133	9	**222**
Dredging					6	25	5		30	0.1	**66**
Passenger (Other)	69	18		6	4	4	-5	-0.3	38	2	**135**
Pleasure	-0.2	-1	4	19	6	11	7	31	274	87	**438**
Other / Undetermined	84	152	2	-1	219	10	25	53	-13	3	**534**
Total	**184**	**316**	**529**	**327**	**2,225**	**775**	**2,030**	**531**	**2,357**	**1,485**	**10,758**

SUMMARY

Table 2-5 summarizes the estimated delay across all SMAs by vessel type and methodology. As the table indicates, the two methods lead to substantially different estimates of the Rule's impact. Total delays range from approximately 10,800 hours under Method 2 to approximately 24,300 hours under Method 1.

TABLE 2-5. TOTAL DELAY (HOURS) BY METHOD AND VESSEL TYPE

VESSEL TYPE	METHOD 1	METHOD 2
Bulk Carrier	559	320
Container	5,363	4,615
Ro-Ro	2,247	1,863
Tanker	1,332	874
General Cargo	628	496
Passenger (Cruise)	458	444
Fishing	6,764	751
Towing / Pushing	2,379	222
Dredging	1,076	66
Passenger (Other)	231	135
Pleasure	611	438
Other / Undetermined	2,606	534
Total	**24,254**	**10,758**

Across all vessel categories, the estimated impact of the Rule is greater under Method 1 than under Method 2. The choice of methodology, however, affects estimated delays for certain types of vessels more than others. The estimated delays for commercial shipping vessels – container, tanker, ro-ro, bulk carrier, and general cargo vessels – are generally similar regardless of method because these vessels tend to transit SMAs at speeds greater than 10 knots when the speed restriction is not in effect; thus, there is greater similarity between Method 1 and Method 2, both in the number of transits analyzed and in the calculation of observed and counterfactual vessel speeds. In contrast, estimates of delays for vessels that frequently transit SMAs during unrestricted periods at speeds below 10 knots – e.g., fishing, towing/pushing, and dredging vessels – are more sensitive to the methodology employed, since the selection of method has a more pronounced effect on the number of transits analyzed and the calculation of observed and counterfactual speeds. When differences in average restricted and unrestricted-period transits are applied to *every* transit (Method 1), estimated delays for these vessel types increase substantially.[29] Given these substantial differences, our analysis of the costs of the Rule considers both methods.

[29] Other vessels are not as sensitive to the set of transits used to estimate delays but are sensitive to the assumption of full compliance. See Appendix B.

CHAPTER 3 | ANNUAL COST IMPACTS

INTRODUCTION

The analysis of the costs directly attributable to the Rule is driven by two factors: our assessment of the Rule's effect in increasing the time required to transit SMAs, as described in Chapter 2; and estimates of hourly operating costs for the various types of vessels the Rule affects. The discussion that follows outlines the derivation of these hourly operating cost estimates and applies them to calculate the Rule's direct costs. The discussion is organized by vessel type, as follows:

- Commercial shipping vessels;
- Passenger cruise ships;
- Fishing vessels;
- Towing/pushing vessels;
- Dredging vessels;
- Other passenger vessels;
- Pleasure craft;
- Other vessels.

As discussed in Chapter 2, we present results for two methods that characterize the impact of the Rule on transit times (Method 1 and Method 2); these results reflect the impact of the rule as implemented, including observed levels of non-compliance. Appendix B presents an analysis that assumes full compliance with the Rule's requirements.

HOURLY VESSEL OPERATING COSTS: CAVEATS AND LIMITATIONS

In assessing the cost of a regulation, the appropriate measure is its social cost, *i.e.*, the total burden the regulation places on the economy. In this context, social cost is defined as the sum of all opportunity costs incurred as the result of a regulation. Opportunity costs represent the value of goods and services that will not be available as a result of the reallocation of resources the regulation requires.

The vessel speed restrictions established by the Rule may impose a variety of opportunity costs. This is most clearly the case with respect to what are generally considered to be a vessel's variable operating costs, *i.e.*, operating costs that are likely to increase with time at sea, such as labor costs. Even if direct expenditures on labor do not increase with time at sea – e.g., if the crew of a fishing vessel is paid the same amount regardless of a marginal increase in the duration of a trip – there is an opportunity cost in the form of the time lost, time which the crew could have spent in other productive endeavors or in leisure. Similarly, there is an opportunity cost if the additional time at sea leads to the consumption of more fuel or other supplies and materials to complete the trip. In this case, the value of the additional resources consumed reflects their opportunity cost.

Whether the Rule imposes other types of costs is less clear. For example, the U.S. Army Corps of Engineers (USACE) guide to deep-draft vessel operating costs characterizes vessel maintenance as a "quasi-fixed/variable" cost.[30] As the guide explains, maintenance costs are likely to increase with time at sea, but even vessels that are not in use require some degree of maintenance. Thus, the Rule likely leads to some increase in vessel maintenance costs, but the increase may not be directly proportional to the increase in operating time.

The most difficult question comes with respect to the treatment of vessel capital costs (sometimes referred to as "hull" costs), which are generally recognized as fixed. Marginal increases in transit time through an SMA will have no effect on the initial cost of a vessel, nor are they likely to have a material effect on a vessel's useful life. Nonetheless, one could argue that a vessel's capital cost should be accounted for in evaluating the costs of the Rule because an increase in transit times imposes an opportunity cost. In this case, the opportunity cost would be in the form of vessel capacity that is not available for other uses during the additional time required to transit an SMA. This is the logic that underlies the USACE's development of hourly operating cost estimates that include annualized capital costs (*i.e.*, the cost of replacing the vessel, adjusted for its scrap value and amortized over the vessel's operating life).[31] In analyzing the effects of the Rule, however, the application of hourly operating cost estimates that incorporate vessel capital costs would be appropriate only if the Rule's impact on available vessel capacity *imposes an opportunity cost*; *i.e.*, only if additional capacity is not available. If additional capacity is available there would be no opportunity cost and the application of hourly operating cost estimates that incorporate vessel capital costs would lead to an overestimate of the Rule's impact.

As a practical matter, the question of whether to include vessel capital costs in our calculation of hourly operating costs and our assessment of the Rule's impact is moot. Confidentiality concerns prevented USACE from sharing its deep draft vessel operating cost data with us, and other reliable sources of information on vessel capital costs in the commercial shipping sector are not readily available. In the absence of reliable data on vessel capital costs, we limit our analysis of the Rule's effects on the commercial shipping sector to impacts on variable and quasi-fixed/variable costs. For consistency – when available data permit – we follow a similar approach in other sectors. To the extent that additional capacity is available in each sector, this approach is appropriate; if it is not, it will lead us to underestimate the opportunity costs attributable to the Rule.

In addition to the caveats noted above, it is important to emphasize that we lack data on hourly operating costs for several types of vessels (*e.g.*, cruise ships, towing/pushing vessels, dredging vessels). In the interest of providing an estimate of the Rule's costs that is as complete as possible, we have relied on other types of data *(e.g.*, hourly rate information) to characterize hourly operating costs. The resulting

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[30] U.S. Army Corps of Engineers. Institute for Water Resources. Appendix H: Guide to Deep-Draft Vessel Operating Costs. 2010.

[31] *ibid*.

estimates are subject to substantial uncertainty and should be considered only rough approximations of actual costs.

Lastly, as the above discussion indicates, we rely out of necessity on a variety of data sources to develop hourly operating cost estimates for different types of vessels. These sources express costs in different nominal dollar years. For consistency, we adjust for inflation and present estimates of the Rule's cost impacts in 2019 dollars, adjusting all costs using the Gross Domestic Product Implicit Price Deflator published by the U.S. Bureau of Economic Analysis.[32]

COMMERCIAL SHIPPING VESSELS

Commercial shipping firms operate a variety of vessels, including bulk carriers, container ships, ro-ro vessels, tankers, and general cargo ships. These vessels serve a variety of industries and are among those whose operations are substantially affected by the Rule. Our analysis of the AIS data indicates that in 2017, the Rule imposed aggregate operating delays of from 8,200 hours to 10,100 hours on commercial shipping vessels. Impacts on container ships (an aggregate delay of 4,600 to 5,400 hours) accounted for the greatest share of this total.

HOURLY OPERATING COSTS

To characterize hourly operating costs for commercial shipping vessels, we rely on data provided in an annual report produced by Drewry Shipping Consultants Ltd., an international maritime research and consulting firm.[33] Drewry's report provides estimates of daily operating costs for a variety of vessels, based on reports from officers representing 65 maritime shipping companies. We convert Drewry's estimates of daily operating costs to hourly costs based on the assumption of a 24-hour working day. For purposes of this analysis we rely on Drewry's 2017 daily operating cost estimates, the most recent "final" cost estimates available when the analysis began.

Drewy's estimates of operating costs include the following cost elements:

- **Manning –** all crew-related costs, including wages, subsistence, training and any crew travel and other costs.
- **Insurance –** premiums and insurance coverage for the vessel itself as well as all cargo and any additional risks (war risk, kidnap risk etc.).
- **Stores, spares and lubes** – lubricating oils, materials, supplies and tools required for the efficient operation of the vessel.
- **Repairs and maintenance** – contracts and parts for vessel engines and system repairs as well as maintenance to equipment such as navigation or communication technology.

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[32] U.S. Bureau of Economic Analysis, Gross Domestic Product: Implicit Price Deflator [GDPDEF], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPDEF, October 9, 2019.

[33] Drewry Maritime Research. *Ship Operating Costs: Annual Review and Forecast 2018/2019*. November 2018. https://www.drewry.co.uk/maritime-research-products/maritime-research-products/ship-operating-cost-annual-review-and-forecast-201819. Due to the confidentiality of the data, we do not present the operating cost estimates directly provided in the Drewry report.

- **Management and administration** – business operations costs for the registration and management of the vessel, as well as compliance costs, such as costs related to vessel inspections or waste disposal.

These cost categories are consistent with those the U.S. Maritime Administration employs and, except for fuel, capture all major elements of vessel operating costs.[34] As described in greater detail below, we rely on other sources to estimate fuel costs.

As Table 3-1 shows, Drewry presents estimates of operating costs for nine types of oceangoing vessels. Within seven of these categories, estimates of operating costs vary with vessel size, as expressed with respect to the standard measure of carrying capacity for that type of vessel: deadweight tons (DWT); twenty-foot equivalent units (TEUs); cubic meters (CBM); or cubic feet (CBF). In total, Drewry provides operating cost models for 43 unique vessel type-size categories.

TABLE 3-1. SIZES AND TYPES OF COMMERCIAL SHIPPING VESSELS ADDRESSED BY DREWRY'S OPERATING COST DATA

VESSEL CATEGORY	NUMBER OF SIZE CATEGORIES	SIZE RANGE OR INDICATIVE SIZE
Bulk Carrier	8	30,000 to 400,000 DWT
Chemical Tanker	7	5,000 to 50,000 DWT
Oil Tanker	6	30,000 to 320,000 DWT
Roll-On/Roll-Off Cargo ("Ro-Ro")	1	10,000 DWT
General Cargo	2	7,000 to 20,000 DWT
Container	9	<1,000 to 18,000+ TEU
Liquid Natural Gas (LNG) Tanker	3	140,000 to 180,000 CBM
Liquid Petroleum Gas (LPG) Tanker	6	3,000 to 80,000+ CBM
Refrigerated Cargo ("Reefer")	1	550,000 CBF

To calculate the impact of the Rule on operating costs, we match the commercial shipping vessels identified in the AIS data to the Drewry operating cost model that is most appropriate for each vessel. This matching process is based on the nature of the vessel, as indicated by its StatCode 5 classification, and by its size.[35] NMFS obtained data on StatCode 5 classifications from IHS Markit, linking this information to the AIS dataset using standard vessel identifiers. In a very small number of cases, the AIS records did not provide vessel type or size information. In these cases, we used publicly available marine vessel information to determine the appropriate operating cost model to assign.

[34] See: Stopford, M. 2003. Maritime Economics: Second Edition. U.S. Department of Transportation Maritime Administration. 2011. Comparison of U.S. and Foreign-Flag Operating Costs. September 2011.

[35] StatCode 5 is a five-level hierarchical ship type coding system used to categorize vessels by type. The first level is a very broad category; each subsequent level is progressively more detailed.

A limitation of the Drewry data is that it is based primarily on operating costs for foreign-flagged vessels. The operating costs of U.S.-flagged vessels are substantially higher than those of foreign-flagged vessels – 2.7 times higher, on average, according to the U.S. Department of Transportation.[36] This difference is due primarily to higher manning costs. According to the AIS data we analyzed, U.S.-flagged vessels account for only 7 percent of SMA transits made by vessels in the commercial shipping category. Nonetheless, the difference in operating costs is high enough that an adjustment is warranted. Accordingly, our calculation of the impact of the rule on vessel operating costs increases Drewry's base estimates by a factor of 2.7 for all transits made by U.S.-flagged commercial ships.

Due to the confidentiality of the data, we cannot present operating cost estimates for each of Drewry's vessel type-size categories. To provide a sense of the costs' magnitude, Table 3-2 presents the mean operating costs for the vessels identified in the AIS dataset by vessel category, based on the distribution of vessel sizes and U.S.- vs. foreign-flagged vessels in each category.

TABLE 3-2. ESTIMATED MEAN HOURLY OPERATING COSTS: COMMERCIAL SHIPPING VESSELS

AIS VESSEL CATEGORY	DREWRY VESSEL CATEGORIES	NUMBER OF UNIQUE VESSELS	MEAN HOURLY OPERATING COST (2019 $)
Bulk Carrier	Bulk Carrier	1,168	$224
Container	Container	788	$287
General Cargo	General Cargo; Refrigerated Cargo ("Reefer")	524	$200
Ro-Ro	Roll-On/Roll-Off Cargo ("Ro-Ro")	431	$218
Tanker	Chemical Tanker; Liquid Natural Gas (LNG) Tanker; Liquid Petroleum Gas (LPG) Tanker; Oil Tanker	1,185	$322

FUEL COSTS

Fuel Consumption

As previously noted, Drewry's vessel operating cost estimates do not include fuel costs. To estimate these costs we rely on a set of fuel consumption equations for commercial shipping vessels developed by the USACE's Institute for Water Resources.[37] These equations estimate daily fuel consumption for four types of vessels: tankers; bulk carriers ("bulkers"); container ships; and general cargo ships. The equations

[36] U.S. Department of Transportation: Maritime Administration. Comparison of U.S. and Foreign-Flag Operating Costs. September 2011.

U.S. Government Accountability Office. Before the Subcommittee on Coast Guard and Maritime Transportation, Committee on Transportation and Infrastructure, House of Representatives: DOT is Still Finalizing Strategy to Address Challenges to Sustaining U.S.-Flag Fleet. November 29, 2018. https://www.gao.gov/assets/700/695722.pdf

[37] U.S. Army Corps of Engineers. Institute for Water Resources. Appendix H: Guide to Deep-Draft Vessel Operating Costs. 2010.

developed by USACE are based on a regression analysis of vessel data from Lloyd's Register Fairplay database (now owned by IHS Markit), as well as data from Clarksons and Fearnleys.[38]

The database that USACE employed to develop its fuel consumption equations includes data on reported fuel consumption, horsepower, beam, length, and service speed, among other variables; however, the regression models for fuel consumption include horsepower as the only explanatory variable. The documentation indicates that vessel horsepower explains between 78 and 96 percent of the variation in fuel consumption for the vessels USACE analyzed. Table 3-3 presents the four fuel consumption equations that we apply in this analysis.

TABLE 3-3. DAILY FUEL CONSUMPTION AS A FUNCTION OF VESSEL HORSEPOWER

VESSEL TYPE	DAILY FUEL CONSUMPTION (METRIC TONS)
Tankers	$Fuel\ consumption = 0.007035 \times HP^{0.903943}$
Bulkers	$Fuel\ consumption = 0.00466 \times HP^{0.954379}$
Containerships	$Fuel\ consumption = 0.005775 \times HP^{0.932771}$
General Cargo Ships	$Fuel\ consumption = 0.008882 \times HP^{0.880101}$

Source: U.S. Army Corps of Engineers. Institute for Water Resources. Appendix H: Guide to Deep-Draft Vessel Operating Costs. 2010, p. H-17.
Note: We add an additional 0 to the coefficient the source document reports for the containership equation, changing it from 0.05775 to 0.005775. We assume the coefficient as published is erroneous, as it produces fuel consumption estimates 10 to 60 times that of the other vessels.

USACE's equations reflect the relationship between horsepower and fuel consumption at a vessel's service speed, which USACE defines as the fastest speed the vessel could reasonably operate under ideal conditions. A vessel's service speed is typically higher than the speed at which it normally operates. For example, the average service speed for the commercial shipping vessels included in the 2017 AIS dataset is approximately 20 knots, well above the average speed at which these vessels operate when transiting SMAs, even during unrestricted periods (see Appendix A). The available research shows that fuel consumption increases exponentially with vessel speed.[39] This raises the likelihood that use of USACE's equations will overstate fuel consumption rates for vessels operating at the speeds observed within SMAs; it also raises the possibility that complying with the vessel speed restrictions reduces fuel consumption. An offsetting consideration, however, is that vessels may attempt to compensate for the delay imposed by the vessel speed restrictions within an SMA by operating at higher than ordinary speeds outside these areas, thus increasing their overall fuel consumption. Moreover, the research on the relationship between a commercial shipping vessel's speed and its fuel consumption suggests that at speeds below 14 knots – *i.e.*, at speeds closer to those at which most vessels transit SMAs, even during unrestricted periods – fuel

[38] Clarksons (https://www.clarksons.com/) is the world's leading provider of integrated shipping services including broking, financial services, and market research. Fearnleys provides industry research services as well as support for offshore energy development and commercial shipping.

[39] Fagerholt, Kjetil, Gilbert Laporte, and Inge Norstad. "Reducing fuel emissions by optimizing speed on shipping routes." Journal of the Operational Research Society 61, no. 3 (2010): 523-529.

consumption remains relatively constant.[40] Given these considerations, and in the absence of data that would allow us to develop more refined fuel consumption estimates, we rely on the equations specified above, noting that they likely lead us to overstate fuel consumption rates for the speeds at which vessels typically transit SMAs. All else equal, overstating fuel consumption rates will bias our estimates of hourly operating costs upward. It will have a similar effect on our estimates of the costs imposed by the Rule.

Application of Fuel Consumption Equations

We apply the fuel consumption equations specified above to the AIS transit data based on the vessel classification provided in the AIS dataset (tanker, bulk carrier, general cargo, and container). In the absence of a fuel consumption equation for ro-ro vessels, we apply the equation for general cargo vessels. This assumption is based on similarities in the size and design of ro-ro vessels and general cargo vessels, which share the same StatCode 5 level two designation (Dry/Cargo/Passenger).

Application of USACE's fuel consumption equations requires information on vessel horsepower, which the AIS dataset does not provide. NMFS obtained this information from IHS Markit, linking the two datasets via vessel identification numbers. For the relatively few vessels for which horsepower data are unavailable, we calculate fuel consumption based on the mean horsepower for other vessels in that category. We convert the daily fuel consumption rate provided by each equation to an hourly rate by assuming the daily rate reflects 24 hours of operation. Table 3-4 illustrates the results of these calculations, presenting the daily and hourly fuel consumption estimates obtained by applying USACE's equations to vessels in each AIS category, based on the mean horsepower reported for the vessels in that category.

TABLE 3-4. FUEL CONSUMPTION ESTIMATES AT MEAN REPORTED HORSEPOWER

AIS VESSEL CATEGORY	MEAN HORSEPOWER	DAILY FUEL CONSUMPTION (METRIC TONS)	HOURLY FUEL CONSUMPTION (METRIC TONS)
Bulk Carrier	11,610	35.30	1.47
Container	59,321	163.63	6.82
General Cargo	9,979	29.38	1.22
Tanker	13,211	37.36	1.56
Ro-Ro	19,288	52.48	2.19

[40] *ibid.*

Fuel Prices

To estimate the costs associated with the change in fuel consumption resulting from the vessel speed restrictions, we apply an average fuel price to the estimates of total fuel consumption. To better capture the potential range of fuel prices paid by commercial shipping vessels transiting the SMAs, we average monthly 2019 prices from two major Atlantic ports: New York and Rotterdam.

We obtained average monthly marine gas oil (MGO) prices (USD/metric ton) for New York and Rotterdam from *Ship & Bunker*.[41] While *Ship & Bunker* also reports prices for intermediate fuel oil 380 (IFO 380) and intermediate fuel oil 180 (IFO 180), we rely solely on MGO prices, assuming that most vessels will utilize MGO when transiting SMAs. This assumption is based on our understanding of the effect of emission control requirements on the choice of fuel vessels employ. All the SMAs are located within the Emissions Control Areas (ECAs) for marine engines that the U.S. Environmental Protection Agency has established off the U.S. coast.[42] Within the ECAs, vessels are required to limit their emissions of SO_x, NO_x, and $PM_{2.5}$. To comply with the SO_x limitations, many commercial shipping vessels switch to low sulfur fuels upon entering an ECA.[43] MGO has a lower sulfur content than both IFO 380 and IFO 180.[44] We therefore assume that the average price of MGO most accurately characterizes the price of fuel being used by commercial shipping vessels when transiting the SMAs.

Table 3-5 presents the fuel price data we use in our analysis, including the average monthly price from January through September 2019 for MGO at the ports of New York and Rotterdam. We employ the overall average for both ports – approximately $598 per metric ton – to calculate fuel costs for commercial shipping vessels that transit SMAs during both restricted and unrestricted periods.

[41] World Bunker Prices. Accessed at: https://shipandbunker.com/prices

[42] Environmental Protection Agency. Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder. Federal Register Vol. 75 No. 83. April 30, 2010.

[43] Environmental Protection Agency. Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines. EPA-420-R-09-019. December 2009.

[44] Marine Gas Oil (MGO) is a pure distillate oil mainly used by harbor craft (*e.g.*, towing vessels) and fishing vessels. MGO has the lowest sulfur content of the commonly used marine fuel oils. IFO 180 and 380 are mixtures of residual oil and distillate oil with higher sulfur contents than MGO and Marine Diesel Oil (MDO). Low sulfur versions (LSMGO, LS 180, and LS 380) of all these fuel oils are commercially available; however, *Ship & Bunker* only lists market prices for the full-sulfur varieties of these fuels. Additionally, IFO 180 and IFO 380 typically have the same sulfur content; the numbers 180 and 380 refer to the maximum viscosity.

TABLE 3-5. SHIP & BUNKER FUEL PRICE CALCULATION (2019)

DATE	MGO		AVERAGE (BOTH PORTS)
	NEW YORK (2019 $/METRIC TON)	ROTTERDAM (2019 $/METRIC TON)	
1/1/2019	$626.00	$512.50	$569.25
2/1/2019	$639.00	$554.50	$596.75
3/1/2019	$643.50	$581.00	$612.25
4/1/2019	$654.00	$599.50	$626.75
5/1/2019	$656.00	$616.00	$636.00
6/1/2019	$611.50	$553.50	$582.50
7/1/2019	$616.50	$575.00	$595.75
8/1/2019	$584.50	$547.00	$565.75
9/1/2019	$613.00	$576.00	$594.50
January-September 2019 Average MGO Price			**$597.72**

Limitations

It is important to note that fuel costs represent a substantial share of vessel operating costs, and that the analysis of vessel operating costs can therefore be quite sensitive to changes in fuel prices. As the data above indicate, fuel prices can vary substantially by port. They also can vary substantially over time. While an average of 2019 New York and Rotterdam prices is likely to be reasonably representative of the fuel prices commercial shipping vessels operating in Atlantic waters have recently faced, they may not be representative of prices in the future. Substantial changes in these prices could thus have an important effect on vessel operating costs and, by extension, the costs attributable to the vessel speed restrictions within SMAs.

In addition, while our analysis is based on the average price of MGO fuel, research on commercial shipping vessel fuel consumption indicates that different types of fuel are used during different legs of a voyage and when operating at different speeds.[45] While MGO has the lowest sulfur content of the three fuels for which *Ship & Bunker* reports prices, it is possible that commercial shipping vessels employ low-sulfur versions of other commonly-used marine fuel oils within the SMAs. To the extent this is true for the vessels and transits we analyze, applying the MGO price to our estimates of fuel consumption will lead to inaccuracies in our estimate of fuel costs.

ANNUAL COST IMPACTS

To calculate annual costs to commercial shipping vessels attributable to the Rule, we multiply our estimates of the impact of the Rule on SMA transit times by the sum of hourly operating costs and hourly fuel costs for each vessel category. Table 3-6 presents our estimates of annual costs under Method 1, by

[45] Environmental Protection Agency. Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines. EPA-420-R-09-019. December 2009.

SMA and vessel type; Table 3-7 presents our estimates of costs under Method 2. As these tables show, we estimate that the annual cost of the Rule to commercial shipping vessels ranges from $24.8 million to $29.2 million. The cost to container ships accounts for most of the estimated impact, reflecting the large number of container ship transits that are affected by the Rule, the magnitude of the delays imposed by the vessel speed restrictions, and the higher hourly cost of operating these types of vessels, due primarily to their higher rates of fuel consumption.

PASSENGER CRUISE SHIPS

The 2017 AIS dataset identifies 1,780 transits of SMAs by cruise ships. Our assessment of the effect of the Rule on these transits is relatively insensitive to the method we employ to calculate impacts on transit time; we estimate an aggregate delay of 458 hours under Method 1 and 444 hours under Method 2. To estimate the cost imposed by these delays, we rely on an estimate of hourly operating costs derived from publicly available financial reports filed by three major cruise lines. The discussion that follows describes the derivation of this estimate and our assessment of the impact of the Rule on cruise ship operating costs.

HOURLY OPERATING COSTS

We estimate cruise ship operating costs based on information provided in publicly available Security and Exchange Commission (SEC) Form 10-K filings from the three largest global cruise lines: Carnival Corporation & PLC; Royal Caribbean Cruises Ltd.; and Norwegian Cruise Line Holdings. These cruise lines currently account for approximately 75 percent of passenger cruise trips worldwide.[46] Table 3-8 summarizes the costs reported in their Form 10-K filings for fiscal year 2018. For purposes of our analysis we focus on costs that are likely to vary with changes in travel time, *i.e.*, payroll and related costs, as well as costs for food and fuel. We also include 10 percent of "other" operating costs on the assumption that a portion of these costs – specifically, repair and maintenance costs – also vary with time at sea. We exclude from the analysis costs that are unlikely to vary with changes in travel time, such as travel agent commissions, entertainment costs, and the cost of products sold onboard. The costs we identify as variable with travel time range from $1.5 billion per year for Norwegian to $5.2 billion per year for Carnival.

The costs reported above represent costs fleetwide. As Appendix C describes in greater detail, we convert these costs to an estimate of daily operating costs for the vessels in each fleet using the following equation:

$$Operating\ Costs\ per\ Vessel\ per\ Day = \frac{\left(\frac{Fleetwide\ Annual\ Operating\ Costs}{Number\ of\ Vessels}\right)}{Annual\ Operating\ Days\ per\ Vessel}$$

[46] According to their annual filings, Carnival, Royal Caribbean, and Norwegian serviced 21.3 million passengers in their 2018 fiscal years – approximately 75 percent of the 28.5 million cruise passengers served by all cruise lines in the 2018 calendar year. See Cruise Lines International Association. 2018 Year in Review. April 9, 2019. Accessed at: https://cruising.org/news-and-research/press-room/2019/april/clia-reveals-growth.

TABLE 3-6. ANNUAL COST IMPACTS: COMMERCIAL SHIPPING VESSELS, METHOD 1 (2019 $, THOUSANDS)

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILA-DELPHIA	NORFOLK	MORE-HEAD CITY	NC TO GA	SOUTH-EAST	TOTAL
Bulk Carrier		$3	$4	$50	$91	$62	$235	$9	$74	$90	$619
Container		$434	$1,473	-$0.3	$6,603	$906	$5,954		$6,043	$1,541	$22,953
Ro-Ro	$13	$33	$91	$336	$547	$175	$741		$316	$1,128	$3,381
Tanker	$4	$60	$189	$92	$665	$283	$72	$9	$170	$149	$1,693
General Cargo		$3	$11	$22	$46	$175	$100	$27	$67	$127	$578
Total	**$17**	**$534**	**$1,768**	**$500**	**$7,953**	**$1,601**	**$7,101**	**$45**	**$6,670**	**$3,035**	**$29,224**

TABLE 3-7. ANNUAL COST IMPACTS: COMMERCIAL SHIPPING VESSELS, METHOD 2 (2019 $, THOUSANDS)

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILA-DELPHIA	NORFOLK	MORE-HEAD CITY	NC TO GA	SOUTH-EAST	TOTAL
Bulk Carrier		$3	$3	$20	$30	$42	$139	$4	$48	$56	$346
Container		$391	$1,313	-$2	$5,520	$732	$5,210		$5,474	$1,387	$20,025
Ro-Ro	$6	$33	$79	$260	$409	$146	$670		$276	$944	$2,825
Tanker	$5	$51	$185	$72	$291	$181	$61	$6	$133	$126	$1,110
General Cargo		$3	$7	$20	$26	$143	$89	$17	$58	$96	$461
Total	**$11**	**$482**	**$1,588**	**$369**	**$6,277**	**$1,244**	**$6,170**	**$27**	**$5,989**	**$2,608**	**$24,767**

TABLE 3-8. FLEETWIDE CRUISE SHIP OPERATING COSTS

COST CATEGORY	AFFECTED BY CHANGES IN TRAVEL TIME	COST ($ BILLIONS 2018)		
		CARNIVAL	ROYAL CARIBBEAN	NORWEGIAN
Commissions, transportation, and other	No	$2.6	$1.4	$1.0
Onboard and other	No	$0.6	$0.5	$0.3
Payroll and related	Yes	$2.2	$0.9	$0.9
Food	Yes	$1.6	$0.5	$0.4
Fuel	Yes	$1.1	$0.7	$0.2
Other operating	No*	$2.8	$1.1	$0.5
Total		**$10.9**	**$5.3**	**$3.4**
Total variable operating costs		**$5.2**	**$2.3**	**$1.5**

*The “Other operating” cost category includes repair and maintenance costs, which may increase as travel times increase. We assume 10 percent of “Other operating” expenses are attributable to repairs and maintenance and add this to the other costs that are affected by changes in travel time.

Sources:
U.S. Securities and Exchange Commission. Form 10-K; Carnival Corporation & PLC, FY 2018.
U.S. Securities and Exchange Commission. Form 10-K; Royal Caribbean Cruises Ltd., FY 2018.
U.S. Securities and Exchange Commission. Form 10-K; Norwegian Cruise Line Holdings, FY 2018.

We convert our estimates of daily operating costs to hourly operating costs based on a 24-hour operating day, then calculate a weighted average hourly operating cost across the three fleets. Table 3-9 summarizes the results of these calculations, which yield an estimated operating cost of approximately $6,000 per hour.

TABLE 3-9. ESTIMATED HOURLY OPERATING COSTS: CRUISE SHIPS

CRUISE LINE	FLEETWIDE ANNUAL OPERATING COSTS ($ BILLIONS 2018)	VESSELS	OPERATING DAYS PER VESSEL	HOURLY OPERATING COSTS PER VESSEL ($ 2018)
Carnival	$5.2	104	354	$5,835
Royal Caribbean	$2.3	50	339	$5,578
Norwegian	$1.5	26	346	$7,174
Weighted Average (by number of vessels)				**$5,952**
Weighted Average (2019 dollars)				**$6,029**

ANNUAL COST IMPACTS

To assess the annual economic impact of the Rule on cruise ships, we multiply our estimate of the hourly operating cost per vessel by the estimated impact of the Rule on transit times. Table 3-10 presents our findings. As the table shows, we estimate that the Rule increases operating costs in the cruise ship sector by approximately $2.7 million (Method 2) to $2.8 million (Method 1) per year. The effect of the New York SMA on cruise ship transits accounts for nearly a third of the total estimated cost.

TABLE 3-10. ANNUAL COST IMPACTS: CRUISE SHIPS (2019 $, THOUSANDS)

DELAY METHOD											
Method 1	$13	$5	$464	$16	$877	$2	$326	$34	$549	$472	**$2,759**
Method 2	$11	$6	$446	$17	$875	$2	$322	$15	$499	$483	**$2,677**

FISHING VESSELS

The 2017 AIS dataset identifies 24,840 transits of SMAs by fishing vessels. Our assessment of the effect of the Rule on these transits is highly sensitive to the method we employ to calculate impacts on transit times. Applying Method 1, we estimate an aggregate increase in transit time of approximately 6,800 hours per year. Applying Method 2, our estimate of the aggregate increase in transit time is approximately 750 hours per year.

To estimate the costs imposed by Rule, we rely on an estimate of hourly operating costs for commercial fishing vessels derived from data provided by NMFS. The discussion that follows describes the derivation of this estimate and our assessment of the impact of the Rule on fishing vessel's operating costs.

HOURLY OPERATING COSTS

We base our estimate of fishing vessel operating costs on data obtained from the Northeast Fisheries Science Center's Social Sciences Branch (NEFSC). NEFSC collects information on what it refers to as "trip costs" – *i.e.*, costs that are incurred when a vessel takes a fishing trip – via the Northeast Fishery Observer Program (NEFOP).[47] NEFOP places trained personnel (officially known as observers) aboard commercial fishing vessels to gather biological and economic data for fisheries management purposes. Among the data collected is information on vessel operating costs, trip duration, and the number of crew aboard, as well as the region in which the vessel landed its catch (broadly categorized as New England or Mid-Atlantic) and other vessel characteristics (length, gross tonnage, horsepower, and gear type). NEFSC provided us with records of trips taken by federally permitted fishing vessels, 65 feet or greater in length, which carried an observer for trips taken during the 2017 and 2018 calendar years, as determined

[47] NEFSC differentiates trip costs from what it refers to as annual costs. Annual costs include all costs vessel owners bear irrespective of the number of trips taken. For purposes of this analysis we treat trip costs as variable costs and annual costs as fixed.

by the year the trip was completed.[48] The data provided included records for 2,870 trips. As described below, we employed the data NEFSC provided to develop two simple econometric models that characterize average hourly vessel operating costs as a function of vessel length.

Non-Labor Costs

Each record in NEFSC's database provides information on a single fishing trip. The information on operating costs includes the following:

- **Ice –** The quantity of ice used (in tons, to the nearest hundredth of a ton) and the price paid ($/ton);
- **Fuel –** The quantity of fuel consumed (in gallons, to the nearest gallon) and the price paid ($/gallon);
- **Supplies –** The cost of commonly used supplies purchased for the trip;
- **Food –** The cost to the crew and captain of food purchased for the trip;
- **Water –** The cost of fresh water purchased for the trip;
- **Oil –** The cost of lubricating oil purchased for the trip;
- **Bait –** The cost of bait purchased for the trip.

We employ the data on the quantity of fuel and ice used and the price paid for these commodities to calculate the cost of fuel and ice for each trip. To provide an estimate of hourly operating costs, we sum the costs reported across categories and divide by the trip's duration (in hours). We apply the GDP implicit price deflator to adjust the resulting estimate to 2019 dollars.

Labor Costs

With respect to the vessel's crew, the records in NEFSC's database do not provide a direct estimate of costs; they simply indicate the crew's size (including the captain). This is in part because the compensation of the crew is commonly based on a share of the catch rather than a predetermined hourly wage. In the absence of a standard wage, we must rely on alternative methods to estimate labor costs. The method we employ applies an implicit value to fishermen's time based on labor rates in professions they would pursue if not involved in fishing. Economists refer to this concept as the opportunity cost of time.

To identify the professions to be considered in gauging fishermen's opportunity costs, we rely on responses provided to a survey administered by the Gulf of Maine Research Institute (GMRI) in 2005.[49] This survey asked fishermen to identify the occupations they would pursue if they could not work in commercial fishing. We then match the alternative occupations with Bureau of Labor Statistics (BLS)

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[48] The duration of a trip is defined as the moment a vessel leaves the dock until the vessel lands to offload its catch (either at the same port or a different port).

[49] Gulf of Maine Research Institute, Lobster Socioeconomic Impact Survey, prepared by Market Decisions, prepared for Laura Taylor Singer and Daniel S. Holland, November 16, 2006.

occupational categories, developing a simple average wage rate for each occupation (or group of occupations) based on the 2018 mean hourly wage rate reported by BLS. For instance, the survey response "carpentry/trades/mechanic" is assigned an average wage rate based on the rates that BLS reports for "Carpenters" and for "Automotive Service Technicians and Mechanics." Finally, we weight the wage rates by the distribution of survey responses and inflate to 2019 dollars to estimate an average opportunity cost of $27.03 per hour.[50] Appendix C provides additional detail on the calculation of this rate.

Total Hourly Costs

To develop an estimate of total hourly operating costs for each trip, we sum the estimates of hourly labor and non-labor costs. We then reviewed each record for completeness. For more than 500 records, data on one or both of two critical cost factors – fuel consumption and/or crew size – are not available. We exclude these records from further analysis, leaving us with a dataset of 2,349 records.

ESTIMATION OF OPERATING COST MODELS

While it would be preferable to develop operating cost models for fishing vessels that take into account a number of potentially important explanatory variables (e.g., the type of gear deployed, the species targeted, or other fisheries-related data), the information needed to link these variables to the data on vessel transits is not available. In the absence of more complete information, we conducted a regression analysis that characterizes hourly operating costs as a function of the natural log of the single explanatory variable that we can reliably link to the AIS data: vessel length.[51] Table 3-11 presents the regression models we estimate. As the table shows, we develop separate models for the New England and Mid-Atlantic regions, based on the region in which the vessel offloaded its catch.[52] Not surprisingly, the R-squared values for both models are relatively low, suggesting that length provides only a partial explanation of the observed variation in hourly operating costs. Despite this limitation, the coefficients on the natural log of length in both cases are statistically significant ($p \leq 0.01$), suggesting that vessel length is an important factor in characterizing hourly operating costs.

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[50] We normalize the distribution by eliminating responses that failed to indicate an alternative profession ("other," "don't know," and "retire").

[51] While the NEFSC cost data contain information on horsepower, the records on fishing vessels in the AIS dataset often lack horsepower information. We therefore use length as the sole explanatory variable (other than region), as it is the only well-populated explanatory variable present in both the NEFSC and AIS data.

[52] Ports in states from Maine to Rhode Island constitute the New England region, and ports in states from Connecticut to North Carolina constitute the Mid-Atlantic region. We apply the regression model for the Mid-Atlantic region to estimate operating costs for fishing vessels transiting SMAs in the Southeast (North Carolina to Florida).

TABLE 3-11. FISHING VESSEL HOURLY OPERATING COST MODELS

REGION	EQUATION	95% CONFIDENCE INTERVAL		R^2	OBSERVATIONS
New England	$-901.3431 + 349.0782 * \ln(length)$	330.8857	367.2707	0.5059	1,386
Mid-Atlantic	$-605.8238 + 244.2857 * \ln(length)$	218.7942	269.7771	0.2683	963

ANNUAL COST IMPACTS

To estimate the costs incurred by fishing vessels subject to the vessel speed restrictions, we apply the cost equations derived above to the fishing vessels that transited an SMA during the SMA's restricted period, based on vessel length and region. As the NEFSC data cover only the New England and Mid-Atlantic regions, we apply the Mid-Atlantic cost model to the fishing vessels identified in transits of SMAs in the Southeast (North Carolina to Florida). The application of these models provides an hourly operating cost estimate for each vessel.[53] We then multiply this estimate by the estimated impact of the vessel speed restrictions on each vessel's transit time and sum the results across all vessels. Table 3-12 presents our findings. As the table shows, we estimate that the Rule increases the operating costs of fishing vessels by approximately $147 thousand (Method 2) to $1.3 million (Method 1) per year. Under Method 1, the effect of the speed restrictions on vessels transiting the North Carolina to Georgia SMA accounts for the greatest cost increase, followed by the effects of the Rule on vessels transiting the Off Race Point SMA and the Morehead City SMA. Under Method 2, the effect of the speed restrictions on vessels transiting the Morehead City SMA accounts for the greatest increase in operating costs, followed by the estimate of impacts on vessels transiting the North Carolina to Georgia SMA and the Norfolk SMA.

[53] As an example, based on the equations specified, we would assign a 30-meter fishing vessel operating in New England waters an estimated hourly operating cost of approximately $278.

TABLE 3-12. ANNUAL COST IMPACTS: FISHING VESSELS ($ THOUSANDS)

DELAY METHOD	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MOREHEAD CITY	NC TO GA	SOUTEAST	TOTAL
Method 1	$35	$324	-$94	$114	$2	$33	$71	$209	$496	$128	**$1,318**
Method 2	$1	$0.2	$2	$3	$1	$2	$30	$76	$32	-$0.3	**$147**

TOWING/PUSHING VESSELS

The 2017 AIS dataset identifies 14,831 transits of SMAs by towing/pushing vessels. As with fishing vessels, our assessment of the effect of the Rule on the transits these vessels made during restricted periods is highly sensitive to the method we employ to calculate impacts on transit times. Applying Method 1, we estimate an aggregate increase in transit time of approximately 2,400 hours per year. Applying Method 2, our estimate of the aggregate increase in transit time is approximately 200 hours per year.

We were unable to identify a reliable source of information on hourly operating costs for towing/pushing vessels. In the absence of cost data, we rely on publicly available sources of information on the hourly rates these vessels charge for their services. The discussion that follows describes the data we employ and the application of the data to develop an estimate of the Rule's costs.

HOURLY OPERATING COSTS

As noted above, the analysis of the impact of the Rule on towing/pushing vessels relies on information on the rates that vessel operators charge for their services. A review of publicly available information indicates that commercial rate schedules generally include several components:

- A flat charge based on the size of the vessel that requires towing/pushing services (typically measured in deadweight tons);
- A flat charge based on the vessel's location relative to its destination (e.g., distance from port);
- An hourly charge.

For purposes of this analysis we focus on the hourly rate, which we assume most closely approximates the marginal hourly operating cost of a towing/pushing vessel.

To obtain rate data we consulted the websites of three firms that provide towing/pushing services at one or more major ports along the eastern seaboard: Moran Towing Corporation; Boston Towing and Transportation Company; and McCallister Towing and Transportation. Table 3-13 summarizes the data we were able to obtain, reporting each company's median hourly rate by port. As the table indicates, the nine hourly rates quoted range from $941 to $1,435 per hour. For purposes of our analysis we rely on the median value: $1,101 per hour, the rate quoted by McCallister Towing and Transportation for services in Norfolk.

TABLE 3-13. TOWING/PUSHING VESSEL HOURLY RATES

PORT	HOURLY RATE (2019 DOLLARS)	SOURCE
New York/New Jersey	$1,045	Moran Towing Corporation
Norfolk	$1,434	Moran Towing Corporation
Boston	$941	Boston Towing & Transportation Company
Baltimore	$1,435	McCallister Towing & Transportation
Charleston	$1,133	McCallister Towing & Transportation
Jacksonville	$1,200	McCallister Towing & Transportation
Norfolk	$1,101	McCallister Towing & Transportation
New York	$1,060	McCallister Towing & Transportation
Philadelphia	$1,015	McCallister Towing & Transportation
Median Hourly Rate	**$1,101**	

Sources:
Port Information and Rates. Moran Towing Corporation. Accessed at: https://www.morantug.com/site/#/port_information.
Schedule of Tug Service Rates, Terms and Conditions - Effective January 1, 2016. Boston Towing & Transportation Company. Accessed at: http://bostontowboat.com/siteimages/2016%20Schedule%20of%20Tug%20Service%20Rates%20Terms%20and%20Conditions.pdf
Towing Contracts. McAllister Towing & Transportation. Accessed at: https://www.mcallistertowing.com

ANNUAL COST IMPACTS

To assess the annual economic impact of the Rule on towing/pushing vessels, we multiply the median hourly rate cited above – which we treat as a proxy measure of hourly operating costs – by the estimated impact of the Rule on transit times. Table 3-14 presents our findings. As the table shows, we estimate that the Rule increases operating costs for towing/pushing vessels by approximately $244 thousand to $2.6 million per year, depending on the method employed to estimate the impact of the Rule on vessel transit times.

TABLE 3-14. ANNUAL COST IMPACTS: TOWING/PUSHING VESSELS ($ THOUSANDS)

DELAY METHOD											
Method 1	$223	$11	$12	$43	$460	$283	$70	$51	$1,277	$190	**$2,619**
Method 2	$19	$2	$0.2	$7	$36	$17	$7	-$1	$147	$10	**$244**

DREDGING VESSELS

The 2017 AIS dataset identifies 1,892 transits of SMAs by dredging vessels. As with towing/pushing vessels, our assessment of the effect of the Rule on the transits these vessels made during restricted periods is highly sensitive to the method we employ to calculate impacts on transit times. Applying Method 1, we estimate an aggregate increase in transit time of approximately 1,100 hours per year. Applying Method 2, our estimate of the aggregate increase in transit time is less than 70 hours per year.

We were unable to identify direct estimates of hourly operating costs for dredging vessels. In the absence of a direct estimate, we present information from a USACE database on the cost of dredging projects and rely on this information to derive what we believe is an upper bound estimate of hourly operating costs. The discussion that follows describes the information we employ and its application in estimating the costs imposed by the Rule.

HOURLY OPERATING COSTS

As the Federal agency charged with maintaining and improving the nation's harbors and inland waterways, USACE regularly undertakes dredging projects and issues contracts for dredging services. The Institute for Water Resources maintains a database of information on USACE dredging operations, which is available online.[54] The most recent dataset includes records for approximately 2,500 projects undertaken in USACE Districts along the Atlantic seaboard from fiscal year 1990 to 2019. The dataset includes the following fields: start date; stop date; job duration; and total expenditures. The expenditures reported presumably cover all aspects of the project, including the cost of steaming to and from the job site, engaging in dredging operations, and disposing of the dredged material. The dataset includes records for vessels owned and operated by the USACE and those operated by 129 private entities.

Vessel speed restrictions are likely to have an impact on the operation of dredging vessels primarily when such vessels are steaming to and from a job site or dredged material disposal site. As noted above, the expenditures reported in USACE's database likely cover a variety of costs that would not be affected by vessel speed restrictions, such as costs incurred when the vessel is stationary and actively engaged in dredging. The information available does not provide a basis for isolating steaming costs. In the absence of better data, we draw on USACE's dataset to develop an estimate of hourly operating costs that likely overstates steaming costs but provides at least some basis for quantifying the Rule's impacts. Specifically:

1) We inflate the information on each project's costs to 2019 dollars.

2) We calculate the average daily cost of each project, based on the duration of the project (in workdays) each record specifies.

[54] 1991-2019 USACE Dredge Schedule. United States Army Corps of Engineers: Institute for Water Resources. Accessed at: https://www.iwr.usace.army.mil/About/Technical-Centers/NDC-Navigation-and-Civil-Works-Decision-Support/.

3) We convert the average daily cost to an average hourly cost, assuming dredging vessels typically operate 14 hours per day. This assumption is based on an estimate obtained from the literature on emissions of air pollutants from working vessels.[55]

4) We identify the *minimum* hourly cost we derive for each vessel across all projects. Because the hourly values are based on *total* project expenditures, we assume that the minimum hourly cost figure for each vessel would be high enough to equal or exceed the vessel's hourly steaming costs.

Table 3-15 provides an illustration of these steps for a subset of records from the USACE dataset. We rely on the median of the cost figures we identify in Step 4 - $1,695 per hour – to assess the impacts of the Rule, acknowledging that this figure may substantially overstate the hourly operating costs dredging vessels incur while steaming through an SMA.

TABLE 3-15. ILLUSTRATION OF USACE DREDGING COST DATA APPLIED IN THE COST ANALYSIS

VESSEL / OPERATOR	START DATE	STOP DATE	COST	WORK-DAYS	DAILY COST	HOURLY COST	MINIMUM HOURLY COST (BY VESSEL / OPERATOR)
1	6/7/2017	6/16/2017	$243,000	10	$24,300	$1,736	$487
1	12/12/2016	1/6/2017	$353,700	24	$14,738	$1,053	$487
1	7/8/2017	8/16/2017	$265,950	39	$6,819	$487	$487
2	6/30/2017	8/1/2017	$2,670,000	30	$89,000	$6,357	$6,357
2	3/20/2017	5/3/2017	$3,560,000	40	$89,000	$6,357	$6,357
3	8/12/2017	8/16/2017	$35,000	5	$7,000	$500	$454
3	2/5/2017	2/9/2017	$70,000	4	$17,500	$1,250	$454
3	10/1/2016	10/25/2016	$158,750	25	$6,350	$454	$454
3	6/23/2017	7/13/2017	$420,000	21	$20,000	$1,429	$454
4	4/19/2017	12/17/2017	$3,998,170	242	$16,521	$1,180	$1,180
4	12/29/2016	1/29/2017	$1,742,804	31	$56,219	$4,016	$1,180
4	7/28/2017	9/12/2017	$3,238,087	46	$70,393	$5,028	$1,180

ANNUAL COST IMPACTS

To assess the annual economic impact of the Rule on dredging vessels, we multiply the hourly cost figure cited above by the estimated impact of the Rule on transit times. Table 3-16 presents our findings. As the table shows, we estimate that the Rule increases operating costs for dredging vessels by approximately $112 thousand to $1.8 million per year, depending on the method employed to estimate the impact of the Rule on vessel transit times.

[55] The California Air Resources Board (CARB) estimates an average of 14 operating hours per day for tugs and towboats, dredging vessels, and other vessels. "Source Inventory: Tugs & towboats, Dredge Vessels and Other Emissions." California Air Resources Board (CARB). 1999.

TABLE 3-16. ANNUAL COST IMPACTS: DREDGING VESSELS ($ THOUSANDS)

DELAY METHOD	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MORE-HEAD CITY	NC TO GA	SOUTEAST	TOTAL
Method 1	-$1	$2	$1		-$1	$89	$131	$5	$1,616	-$19	**$1,824**
Method 2					$9	$43	$9		$51	$0.2	**$112**

OTHER (NON-CRUISE) PASSENGER VESSELS

The 2017 AIS dataset identifies 7,645 transits of SMAs by passenger vessels other than cruise ships. Most of these transits were made by ferries, but the figure also includes transits by whale watching vessels, charter fishing vessels, and other commercial passenger craft. Our assessment of the effect of the Rule on these vessels is relatively insensitive to the method we employ to calculate impacts on transit times. Applying Method 1, we estimate an aggregate increase in transit time of approximately 230 hours per year. Applying Method 2, our estimate of the aggregate increase in transit time is only 135 hours per year.

To estimate the costs the Rule imposes on vessels in the passenger (non-cruise) category, we rely on a U.S. Department of Transportation (DOT) model that characterizes operating costs for ferries. [56] The discussion that follows describes our application of this model.

HOURLY OPERATING COSTS

DOT's cost model estimates a high and low range of hourly operating costs for 12 different classes of passenger vessels based on passenger capacity, hull type, roll-on/roll-off functionality, and maximum speed. The operating cost estimates include fuel and lubricant costs, labor costs for captains and deck hands, vehicle maintenance, and passenger insurance.

The DOT model allows users to specify values for certain variables that affect operating costs. In most cases we use the default assumptions DOT suggests, varying from these assumptions only when necessary to improve the applicability of the resulting cost estimates to our analysis. For example, the fuel consumption rate is partially determined by the number of stops along the route; we specify zero stops to best approximate an uninterrupted trip through an SMA. Similarly, to ensure the model's estimates of operating costs reflect current conditions, we employ 2019 data on labor rates and fuel prices. In addition, we exclude passenger insurance costs from our analysis, on the assumption that these costs are unlikely to be affected by the marginal increases in transit times attributable to the Rule. Appendix C provides additional detail on our application of the model.

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[56] U.S. Department of Transportation, Volpe Center: Ferry Lifecycle Cost Model. December 2011. https://www.volpe.dot.gov/transportation-planning/public-lands/department-interior-bus-and-ferry-lifecycle-cost-modeling.

DOT's model generates estimates of hourly operating costs for 12 types of vessels (see Appendix C). For purposes of our analysis we calculate a weighted average operating cost, based on the distribution of vessels represented in the 2017 AIS dataset and information on vessel characteristics obtained from the National Census of Ferry Operators (NCFO).[57] This calculation yields a weighted-average operating cost of approximately $484 per hour.

ANNUAL COST IMPACTS

To assess the annual economic impact of the Rule on passenger (non-cruise) vessels, we multiply the hourly cost figure cited above by the estimated impact of the Rule on transit times. Table 3-17 presents our findings. As the table shows, we estimate that the Rule increases operating costs for passenger (non-cruise) vessels by approximately $65 thousand to $112 thousand per year, depending on the method employed to estimate the impact of the Rule on vessel transit times.

TABLE 3-17. ANNUAL COST IMPACTS: OTHER (NON-CRUISE) PASSENGER VESSELS ($ THOUSANDS)

DELAY METHOD	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MORE-HEAD CITY	NC TO GA	SOUTEAST	TOTAL
Method 1	$33	$9		$4	$5	$2	-$3	-$1	$56	$6	**$112**
Method 2	$33	$9		$3	$2	$2	-$3	-$0.1	$18	$1	**$65**

LIMITATIONS

The analysis presented above does not consider the potential impact of the Rule on the seasonal operation of high-speed ferries. The imposition of speed restrictions within an SMA may lead the operators of high-speed ferries that transit SMAs to curtail service when the speed restrictions are in effect. This could have an adverse effect on the profitability of such operations.[58]

A review of the ferry routes identified in the NCFO suggests that speed restrictions within SMAs likely affect two high-speed ferry operators in Massachusetts: Bay State Cruise Company and Boston Harbor Cruises. The Cape Cod Bay SMA's restricted period ends May 15th; both companies resume the seasonal operation of high-speed ferries from Boston to Provincetown on May 16th. NCFO records from years prior to the Rule indicate that at that time, the seasonal operation of high-speed ferries from Boston to Provincetown began May 1st. It is likely that the Rule directly affected the change in operating schedules.

[57] The NCFO is a national survey of ferry owners and operators conducted every 2-4 years by the United States Bureau of Transportation Statistics. Data are self-reported by ferry operators, and report characteristics of ferry operators and the vessels in their fleets, as well as ferry routes and the terminals serviced by them. The most recent census was conducted in 2016.

[58] Fast ferries typically operate at speeds in excess of 30 knots. Fast ferry operators' business relies on the ability to travel at these high speeds to deliver passengers between ports as efficiently as possible.

Whether the Rule has in fact had an adverse impact on the profitability of high-speed ferry operators is unclear. Evaluating this impact would require estimates of the increase in annual revenue that might be realized if the ferries were able to operate in the first half of May, as well as information on the associated increase in operating costs. In the absence of reliable data on the effect of an expanded operating schedule on annual ridership, we have not attempted to develop such estimates. We note, however, the possibility of an adverse impact on profits and the relevance of such impacts in characterizing the costs of the Rule.

PLEASURE CRAFT

Vessels classified in the AIS data as pleasure craft consist primarily of motorized, personal recreational vessels. Pleasure craft subject to the Rule (*i.e.*, those greater than 65 feet in length) consist primarily of motor yachts (*i.e.*, large motorboats) or large recreational fishing boats. Due to inconsistencies in the AIS data, some sailing vessels equipped with auxiliary engines may also be included in the "pleasure vessel" category.

The 2017 AIS dataset identifies approximately 6,600 transits of SMAs by pleasure craft. Our assessment of the effect of the Rule on these vessels is relatively insensitive to the method we employ to calculate impacts on transit times. Applying Method 1, we estimate an aggregate increase in transit time of approximately 610 hours per year. Applying Method 2, our estimate of the aggregate increase in transit time is approximately 440 hours per year.

Given that pleasure craft are designed primarily for recreational use, we have not attempted to quantify a cost associated with the delays we estimate for these vessels. Their operators or passengers may experience a loss in economic welfare if the vessel speed restrictions reduce their enjoyment of their time on the water or delay them from reaching their destination as rapidly as they would otherwise. For others, the vessel speed restrictions may have no effect on the quality of their recreational experience, and thus no effect on economic welfare. Analysis of these impacts would require primary research, such as a stated preference survey designed to quantify recreational boaters' willingness to pay to operate at speeds above 10 knots within each SMA during the restricted period. In the absence of such research we simply note that vessel speed restrictions could adversely affect the quality of the recreational experience for some boaters. The effect of such impacts on economic welfare, however, is unclear.

OTHER VESSELS

As noted in Chapter 2, approximately 6,600 transits included in the 2017 AIS dataset were made by vessels in the "Other/Undetermined" vessel category. This category includes vessels that reported multiple, conflicting vessel types in their AIS signals as well as vessels in categories with too few transits to warrant independent analysis (*e.g.*, pollution control vessels, pilot vessels, or port tenders and offshore work vessels).

HOURLY OPERATING COSTS

We estimate the impacts of the Rule on vessels in the "Other/Undetermined" category by using a weighted average hourly cost figure for dredging, fishing, passenger (other), and towing/pushing vessels, based on the distribution of transits in the AIS dataset. We exclude estimates of operating costs for commercial shipping vessels and cruise ships from the calculation of the weighted average because the availability of IHS data on these types of vessels makes it unlikely that any are included in the "Other/Undetermined" category. As Table 3-18 illustrates, our calculation yields a weighted average hourly operating cost estimate of approximately $589.

TABLE 3-18. CALCULATION OF HOURLY OPERATING COST FOR OTHER/UNDETERMINED VESSELS

VESSEL TYPE	PERCENT OF TRANSITS	AVERAGE HOURLY OPERATING COST	WEIGHTED AVERAGE HOURLY OPERATING COST
Dredging	3.8%	$1,695.00	$65.17
Fishing	50.5%	$231.18	$116.70
Passenger (Other)	15.5%	$484.45	$75.26
Towing/Pushing	30.1%	$1,101.00	$331.83
Total	**100%**		**$588.97**

ANNUAL COST IMPACTS

To assess the annual economic impact of the Rule on vessels in the "Other/Undetermined" category, we multiply the hourly cost figure cited above by the estimated impact of the Rule on the transits of these vessels. Table 3-19 presents our findings. As the table shows, we estimate that the Rule increases operating costs for vessels in the "Other/Undetermined" category by approximately $314 thousand to $1.5 million per year, depending on the method employed to estimate the impact of the Rule on vessel transit times.

TABLE 3-19. ANNUAL COST IMPACTS: OTHER/UNDETERMINED VESSELS ($ THOUSANDS)

DELAY METHOD	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MORE-HEAD CITY	NC TO GA	SOUTEAST	TOTAL
Method 1	$50	$111	-$27	$134	$997	$31	$46	$103	$31	$58	**$1,535**
Method 2	$50	$89	$1	-$0.5	$129	$6	$15	$31	-$8	$2	**$314**

SUMMARY

Table 3-20 summarizes our estimates of the Rule's impact on annual operating costs. As the table indicates, we estimate an annual impact of $28.3 million to $39.4 million, depending on the method employed to estimate the impact of the Rule on transit times. Most of these costs are attributable to impacts on container ships, and more generally to vessels operated by the commercial shipping industry (bulk carriers, container ships, ro-ro vessels, tankers, and general cargo ships).

TABLE 3-20. SUMMARY OF ANNUAL COST IMPACTS ($ THOUSANDS)

VESSEL TYPE	DELAY METHOD 1	DELAY METHOD 2
Bulk Carrier	$619	$346
Container	$22,953	$20,025
Ro-Ro	$3,381	$2,825
Tanker	$1,693	$1,110
General Cargo	$578	$461
Passenger (Cruise)	$2,759	$2,677
Fishing	$1,318	$147
Towing/Pushing	$2,619	$244
Dredging	$1,824	$112
Passenger (Other)	$112	$65
Pleasure	$0	$0
Other/Undetermined	$1,535	$314
Total	**$39,391**	**$28,327**

CHAPTER 4 | CONSIDERATION OF BROADER ECONOMIC IMPACTS

INTRODUCTION

Previous analyses have noted the possibility that the costs associated with the Rule could lead to changes in the overall level or distribution of shipping activity along the Atlantic coast. These concerns were likely heightened by economic conditions at the time the Rule was promulgated. At that time, the U.S. was experiencing a significant recession, which began in December 2007 and continued until June 2009.[59] When the Rule was promulgated in 2008, the effects of the recession were still unfolding.

An in-depth investigation of the potential impacts of the Rule on the level or distribution of economic activity at U.S. ports would require a detailed analysis that is beyond the scope of this report. Nonetheless, we can provide some insights on this issue by presenting a limited review of data on shipping activity since implementation of the Rule. The discussion that follows summarizes our findings.

PORT CALLS

As a measure of potential impacts on the general level of economic activity at U.S. ports along the Atlantic seaboard, we first assess the number of port calls reported in the period before and after the Rule. To conduct this analysis, we rely upon data provided by the U.S. Maritime Administration (MARAD), which reports the number of port calls by privately-owned, oceangoing merchant vessels of greater than 10,000 deadweight tons from 2002 to 2015.[60] The MARAD data include port calls by oil, liquefied natural gas (LNG), liquefied petroleum gas (LPG), and chemical tankers; container ships; dry bulk carriers; ro-ro vessels; and other general cargo vessels. MARAD defines "calls" as the number of times a vessel arrived at a port, facility, or terminal. The number of calls may include berth shifts, movements to and from anchorage, or other activities related to vessel, port, or terminal operations.

Figure 4-1 presents the number of port calls by East Coast port from 2002 to 2015. Figure 4-2 presents the aggregate number of port calls at these ports over the same period (excluding ports with fewer than 200 port calls in each year). We observe that the number of vessels entering ports on the East Coast has remained relatively constant over time, both by port and in aggregate.

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[59] US Business Cycle Expansions and Contractions, National Bureau of Economic Research, accessed at https://www.nber.org/cycles/.

[60] "Vessel Calls in U.S. Ports, Selected Terminals and Lightering Areas (2015)." U.S. Maritime Administration. Accessed at https://www.maritime.dot.gov/data-reports/data-statistics/data-statistics.

FIGURE 4-1. PORT CALLS AT EAST COAST PORTS, 2002-2015

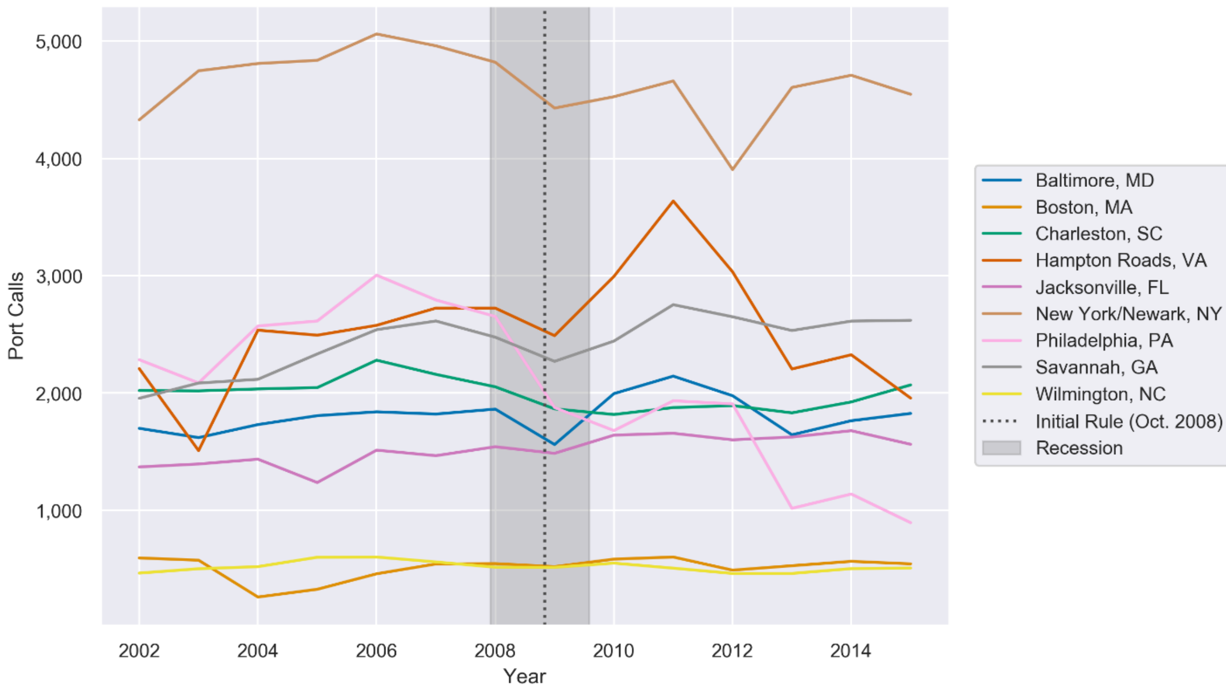
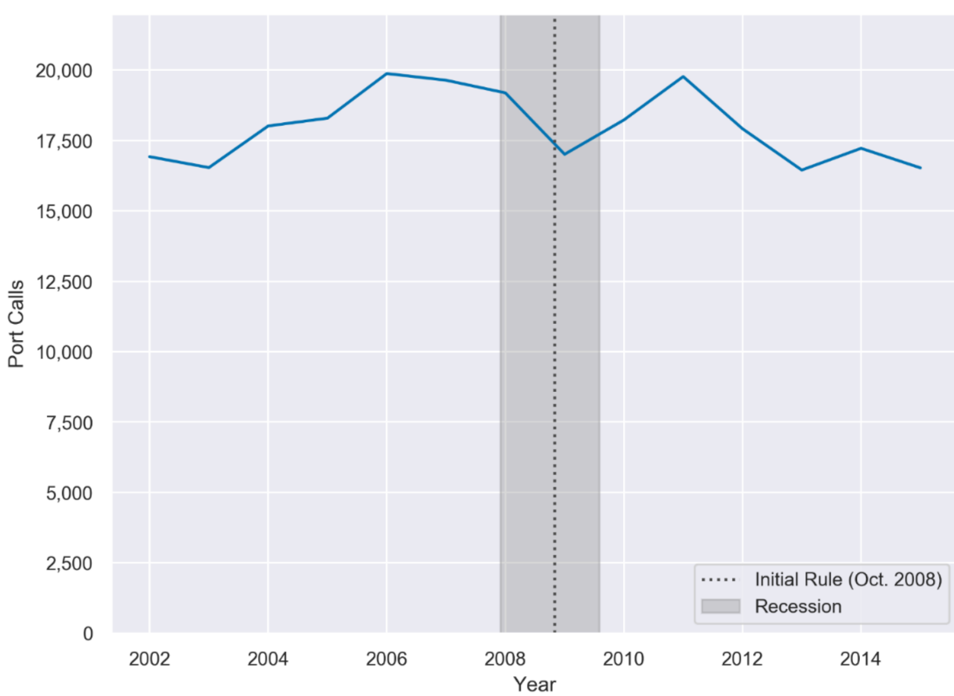


FIGURE 4-2. TOTAL PORT CALLS AT EAST COAST PORTS, 2002-2015

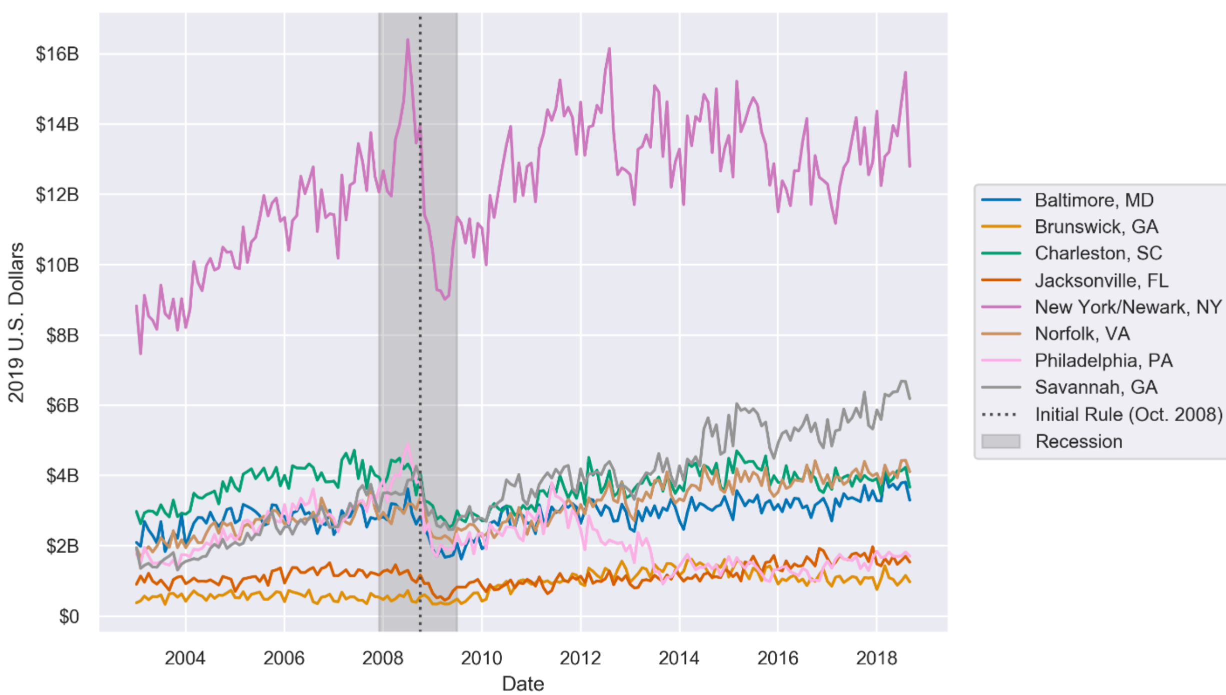


IMPORT/EXPORT VALUES

As an additional indicator of shipping activity, we examine the value of goods traveling through East Coast ports, either as imports into the U.S. or as exports out of the U.S. For this analysis, we rely upon port-level import and export data from the U.S. Census Bureau's Economic Indicators Division.[61] We reviewed monthly import and export data from 2003 to September 2019, compiled from electronic records related to goods entering or leaving the U.S. The value of imports is based on the appraised value, as estimated by U.S. Customs and Border Protection, while the value of exports is based on the "free alongside ship" price – *i.e.*, the value of exports at the U.S. port of export, based on transaction prices, inland freight prices, and other charges in placing merchandise alongside the carrier at the port of exportation.[62]

As shown in Figure 4-3, Figure 4-4, and Figure 4-5, the value of imports and exports from January 2003 to September 2019 decreased noticeably during the recession, but does not appear to have been adversely affected in the long term, either for a particular port or in aggregate.

FIGURE 4-3. VALUE OF IMPORTS BY PORT, 2003-2019



[61] "U.S. Import and Export Merchandise Trade Statistics." U.S. Census Bureau: Economic Indicators Division. Accessed at https://usatrade.census.gov/data/Perspective60/Browse/BrowseTables.aspx.

[62] "Guide to Foreign Trade Statistics." U.S. Census Bureau. Accessed at https://www.census.gov/foreign-trade/guide/sec2.html.

FIGURE 4-4. VALUE OF EXPORTS BY PORT, 2003-2019

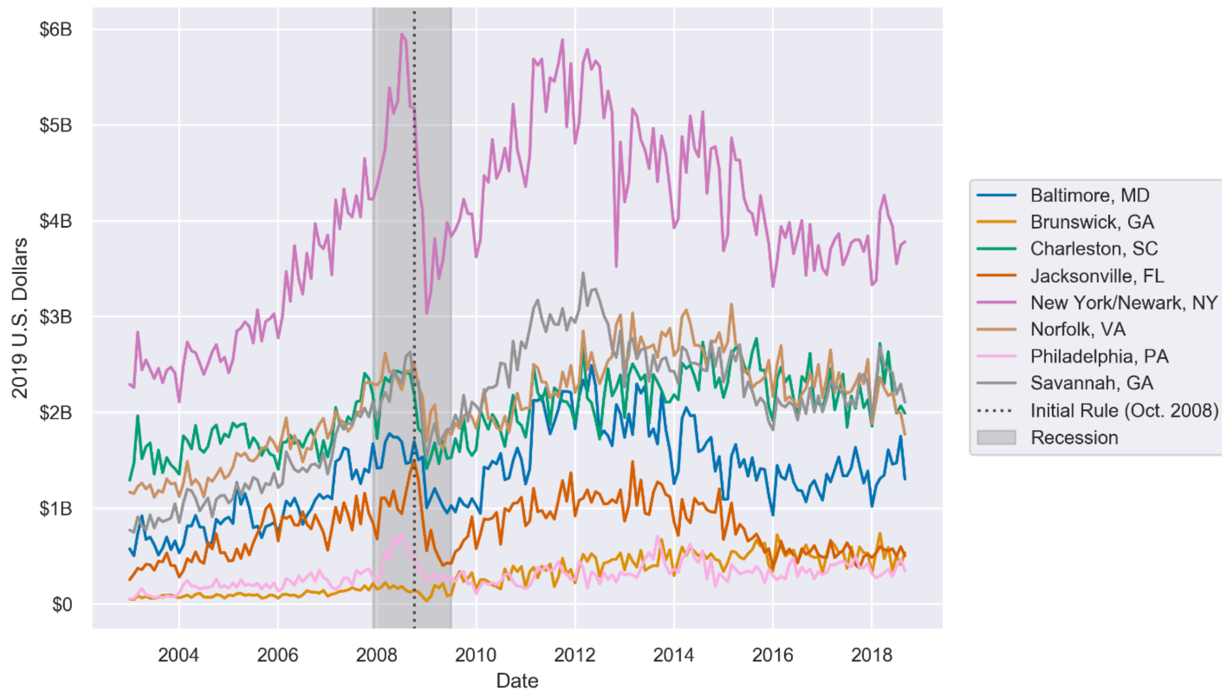
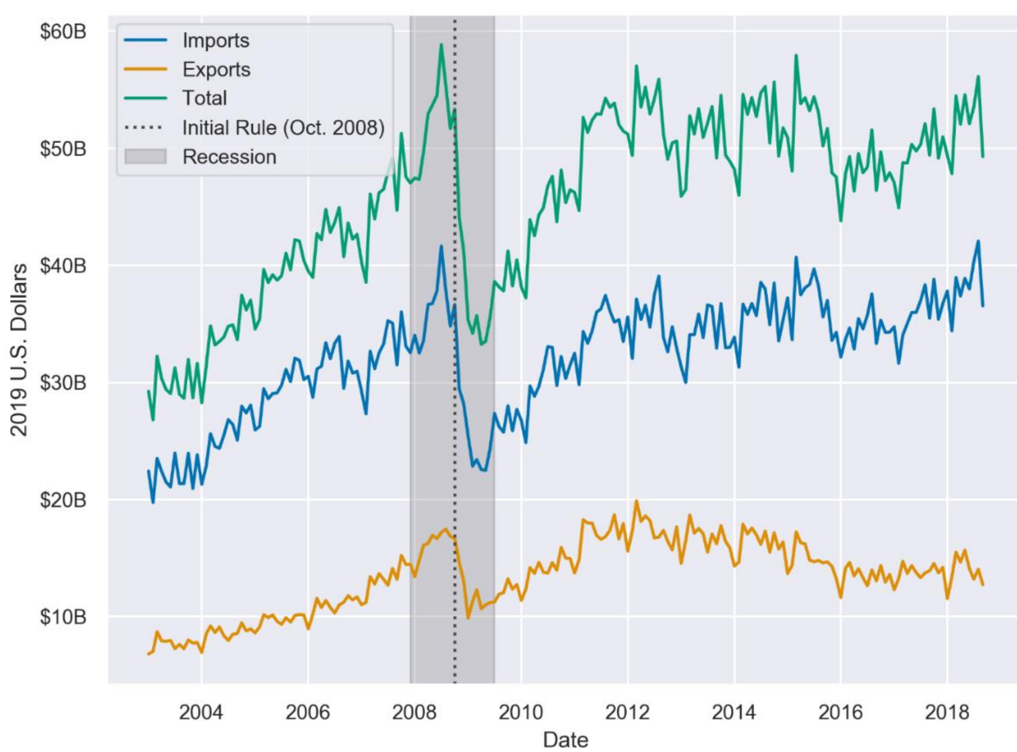


FIGURE 4-5. TOTAL VALUE OF IMPORTS AND EXPORTS, 2003-2019



SUMMARY

Shipping activity at U.S. ports is influenced by many factors, including global economic conditions. Given these considerations, a cursory review of the type presented here is insufficient to support definitive conclusions concerning the potential impacts of the Rule on shipping activity. Nonetheless, this review provides no *prima facie* evidence that the promulgation of the Rule has led to substantial impacts on shipping activity. Overall, the value of goods entering and leaving East Coast ports recovered following the recession and has remained relatively constant over the past decade. Similarly, the number of vessels entering ports on the East Coast has remained relatively constant over time, both by port and in aggregate. Thus, a high-level review of the data suggests the Rule has not had a readily observable effect on the volume or value of economic activity at potentially affected ports.

CHAPTER 5 | CONCLUSIONS

PRINCIPAL FINDINGS

The analysis presented in this report estimates the direct costs attributable to the Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales. The analysis is based on AIS data that allow us to estimate the speed with which vessels that are subject to the Rule transit the Seasonal Management Areas where the vessel speed restrictions apply. We estimate the impact of the Rule on transit times for various types of vessels by comparing vessel operations during restricted periods – *i.e.*, the seasonal periods when the speed restrictions are in effect – to counterfactual scenarios that are based on the speeds at which vessels operate when the speed restrictions are not in effect. We calculate the cost of the estimated increase in transit times by applying estimates of hourly operating costs for each type of vessel.

Depending on the method employed to characterize the Rule's impact on transit times, we estimate its direct costs at approximately $28.3 million to $39.4 million annually. The analysis indicates that the cost to commercial shipping operations alone ranges from $24.8 million to $29.2 million per year. Most of these costs are associated with the operation of container ships, reflecting the large number of container ship transits that are affected by the Rule, the magnitude of the delays imposed by the vessel speed restrictions, and the high hourly cost of operating these types of vessels.

LIMITATIONS AND UNCERTAINTIES

Our analysis is subject to number of limitations and uncertainties. Notably, the AIS data we use to estimate the impact of the Rule on SMA transits are subject to a number of data quality concerns, including records that report questionable average speeds, distances traveled, or elapsed operating times, as well as records that are unsuitable for our specific analytic needs (*e.g.*, transits which appear to have "clipped" the bounds of an SMA rather than traveled through it for a significant length of time). Additionally, the vessel type and length designations reported in AIS records are often ambiguous, complicating the classification of transits by vessel type and perhaps leading us to include in the analysis transits made by vessels that are not subject to the Rule.[63]

Another important limitation of our analysis is that our methods treat observed differences in transit speeds during an SMA's restricted and unrestricted periods as entirely attributable to the Rule. It is quite possible – and in fact likely – that at least some of the observed differences are due to other factors, such as seasonal differences in weather and sea conditions, seasonal fluctuations in the activity of commercial

[63] As explained in Chapter 2, Data Sources, AIS Data, when the vessel length is ambiguous, we err on the side of over-including vessels in our analysis by using the maximum length reported in the vessel's AIS signal.

fishing fleets, seasonal variation in the use of pleasure craft, or other factors. Failure to control for these factors may bias our assessment of the Rule's costs. The potential magnitude and direction of any such bias, however, is unknown.

Our estimates of vessel operating costs are also subject to considerable uncertainty. In the absence of reliable data on vessel capital costs, we limit our analysis of the Rule's effects on the commercial shipping sector to impacts on variable and quasi-fixed/variable costs. For consistency – when available data permit – we follow a similar approach in other sectors. As discussed in greater detail in Chapter 3, this approach is appropriate if the Rule has no impact on capital costs; *i.e.*, if marginal changes in operating speeds do not lead to additional demand for shipping capacity or for vessels of a specific type (*e.g.*, dredging or fishing vessels). If this is not the case, failure to account for the need for additional vessel capacity will lead us to underestimate the costs attributable to the Rule.

In addition to the caveats noted above, it is important to emphasize that we lack data on hourly operating costs for several types of vessels (*e.g.*, cruise ships, towing/pushing vessels, dredging vessels). In the interest of providing an estimate of the Rule's costs that is as complete as possible, we have relied on other types of data *(e.g.*, hourly rate information) to characterize hourly operating costs. The resulting estimates are subject to substantial uncertainty and should be considered only rough approximations of actual costs.

POTENTIAL REFINEMENTS AND ADDITIONAL APPLICATIONS

The analysis presented in this report is based entirely on AIS data and estimates of vessel operating costs derived from secondary sources. Direct outreach to the commercial shipping industry or to representatives of the other sectors the Rule affects would offer an opportunity to ground truth our findings and develop a clearer understanding of the Rule's impact on vessel operations. It might also provide an opportunity to refine our estimates of vessel operating costs.

In addition to improving our understanding of the Rule's current impacts, the data and methods employed in this report could be applied to evaluate modifications to the Rule designed to improve its cost-effectiveness or provide additional protections to right whales. These modifications might include, for example:

- Designating new SMAs;
- Changing the spatial or temporal extent of established SMAs;
- Revising the Rule's specification of vessels that are subject to speed restrictions;
- Changing the maximum permissible speed within SMAs; or
- Establishing mandatory limits on vessel speed within DMAs.

Should NMFS wish to consider potential revisions to the Rule, we could expand our analysis to evaluate any of these alternatives.

APPENDIX A | ADDITIONAL STATISTICS ON SMA TRANSITS

TABLE A-1. TRANSITS BY VESSEL TYPE, SMA, AND PERIOD

VESSEL TYPE	CAPE COD BAY		OFF RACE POINT		GREAT SOUTH CHANNEL		BLOCK ISLAND		NEW YORK	
	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.
Bulk Carrier		1	20	121	36	142	122	125	192	221
Container			55	326	140	257	3	1	1,976	1,929
Ro-Ro	17	30	18	94	35	73	178	201	515	543
Tanker	14	35	44	224	139	238	146	183	1,139	1,318
General Cargo		1	7	19	19	34	64	60	117	97
Passenger (Cruise)	3	52	2	174	57	129	3	76	172	411
Fishing	545	383	599	1,529	2,230	3,793	2,560	3,828	290	755
Towing/Pushing	596	968	32	219	7	15	281	311	1,659	1,394
Dredging	3	5	2	4	1	1	4		40	72
Passenger (Other)	60	2,490	35	1,493		2	69	128	128	497
Pleasure	7	425	1	275	28	81	35	393	45	532
Other/Undetermined	102	739	75	421	42	206	417	716	375	723
Total	1,347	5,129	890	4,899	2,734	4,971	3,882	6,022	6,648	8,492

VESSEL TYPE	PHILADELPHIA		NORFOLK		MOREHEAD CITY		NORTH CAROLINA TO GEORGIA		SOUTHEAST		TOTAL
	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	
Bulk Carrier	223	233	942	903	28	27	351	400	130	198	4,415
Container	628	647	1,701	1,743		1	3,426	3,570	433	593	17,429
Ro-Ro	188	194	642	700			405	448	842	1,144	6,267
Tanker	620	724	168	173	27	35	432	448	142	179	6,428
General Cargo	325	234	236	271	74	74	370	336	210	280	2,828
Passenger (Cruise)	2	8	76	163	8	7	130	111	103	93	1,780
Fishing	1,310	1,568	813	1,543	611	366	396	741	388	592	24,840
Towing/Pushing	1,505	1,309	530	668	173	137	1,872	1,012	789	1,354	14,831
Dredging	107	26	94	325	10	9	640	61	415	73	1,892
Passenger (Other)	43	821	98	450	6	34	430	462	160	239	7,645
Pleasure	49	585	69	515	163	628	510	1,342	198	703	6,584
Other/Undetermined	123	308	219	393	109	174	519	381	245	321	6,608
Total	**5,123**	**6,657**	**5,588**	**7,847**	**1,209**	**1,492**	**9,481**	**9,312**	**4,055**	**5,769**	**101,547**

TABLE A-2. MEAN VESSEL SPEED (KNOTS) BY VESSEL TYPE, SMA, AND PERIOD

VESSEL TYPE	CAPE COD BAY		OFF RACE POINT		GREAT SOUTH CHANNEL		BLOCK ISLAND		NEW YORK	
	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.
Bulk Carrier		13.0	10.9	11.0	11.0	11.1	10.8	11.6	9.2	10.2
Container			9.8	13.9	9.5	14.2	11.9	11.8	9.1	12.6
Ro-Ro	7.3	8.8	8.4	13.3	9.1	14.0	8.9	13.5	9.2	12.0
Tanker	9.7	11.0	9.6	11.8	10.0	11.9	10.4	12.4	9.2	10.5
General Cargo		8.6	9.6	12.8	11.3	12.5	10.5	11.9	9.7	11.5
Passenger (Cruise)	9.3	12.0	12.6	15.1	10.8	14.5	9.7	14.4	10.3	14.5
Fishing	7.2	7.8	5.6	6.8	6.3	5.8	7.7	7.8	8.9	8.2
Towing/Pushing	8.3	8.6	8.8	9.4	9.3	14.2	9.0	9.2	7.8	8.3
Dredging	7.2	7.0	6.8	8.6	8.4	8.8	8.9		5.5	6.9
Passenger (Other)	12.2	23.3	8.4	21.1		17.2	11.6	11.8	14.6	14.5
Pleasure	15.8	13.4	31.3	13.0	11.0	10.2	10.1	15.3	15.7	16.2
Other/Undetermined	8.4	15.8	5.1	13.4	6.8	5.8	12.0	10.9	10.1	11.9

VESSEL TYPE	PHILADELPHIA		NORFOLK		MOREHEAD CITY		NORTH CAROLINA TO GEORGIA		SOUTHEAST	
	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.	RESTR.	UNRESTR.
Bulk Carrier	9.5	11.0	9.7	10.5	9.5	10.8	10.2	10.9	9.2	10.9
Container	9.1	13.1	9.0	13.1		13.1	10.9	13.0	9.5	13.8
Ro-Ro	9.0	13.0	9.2	13.7			11.0	13.6	9.6	12.9
Tanker	9.2	10.9	9.7	11.8	9.2	10.1	10.2	11.8	9.4	12.0
General Cargo	9.2	12.6	9.7	12.2	9.4	11.1	10.5	11.5	9.6	11.9
Passenger (Cruise)	10.5	11.3	10.1	15.4	9.6	12.1	11.6	13.6	9.7	12.6
Fishing	7.7	8.1	8.7	10.2	7.2	10.2	7.4	10.1	5.2	5.1
Towing/Pushing	7.4	7.6	7.9	7.7	6.8	6.8	7.1	7.7	7.9	7.8
Dredging	7.6	8.1	8.3	9.7	7.2	7.0	5.8	7.1	6.5	6.1
Passenger (Other)	11.8	12.7	11.2	10.5	23.4	16.4	8.6	9.1	8.8	9.1
Pleasure	16.4	18.5	17.2	17.1	18.4	18.9	16.0	17.3	15.2	17.0
Other/Undetermined	7.9	8.8	10.2	10.4	9.1	13.2	10.7	9.0	9.1	9.2

FIGURE A-1. DISTRIBUTION OF CONTAINER VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

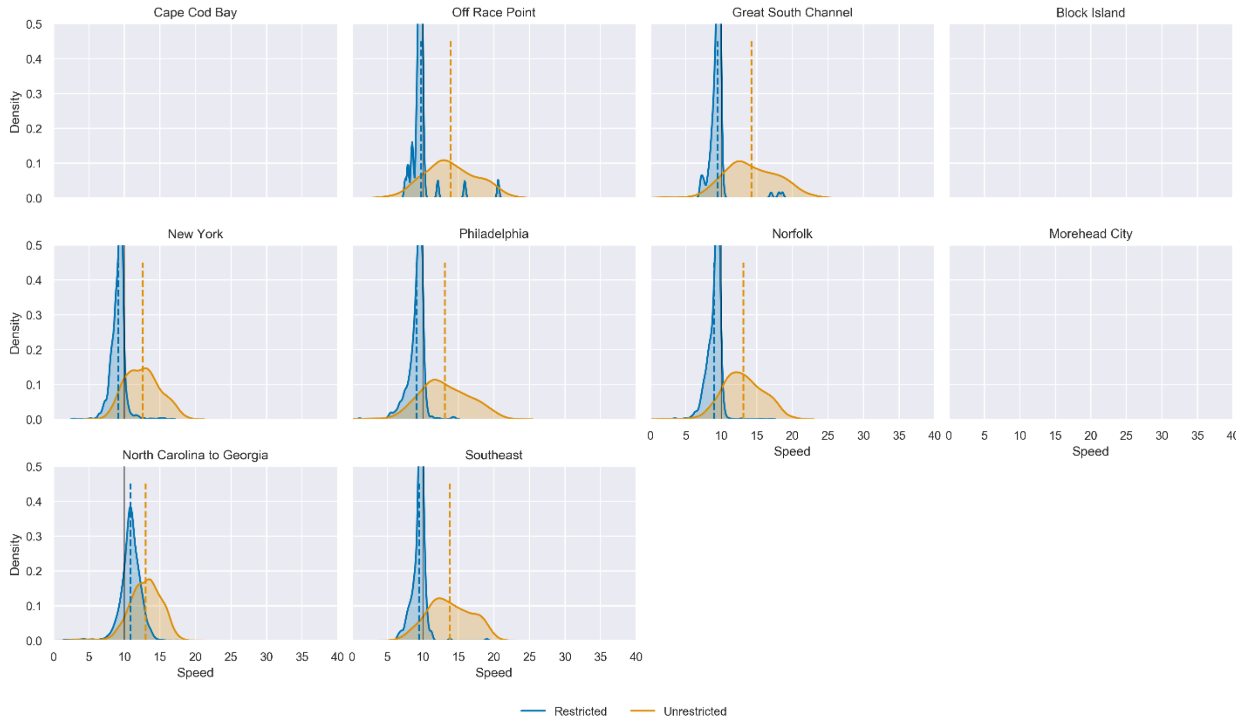


FIGURE A-2. DISTRIBUTION OF TANKER VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

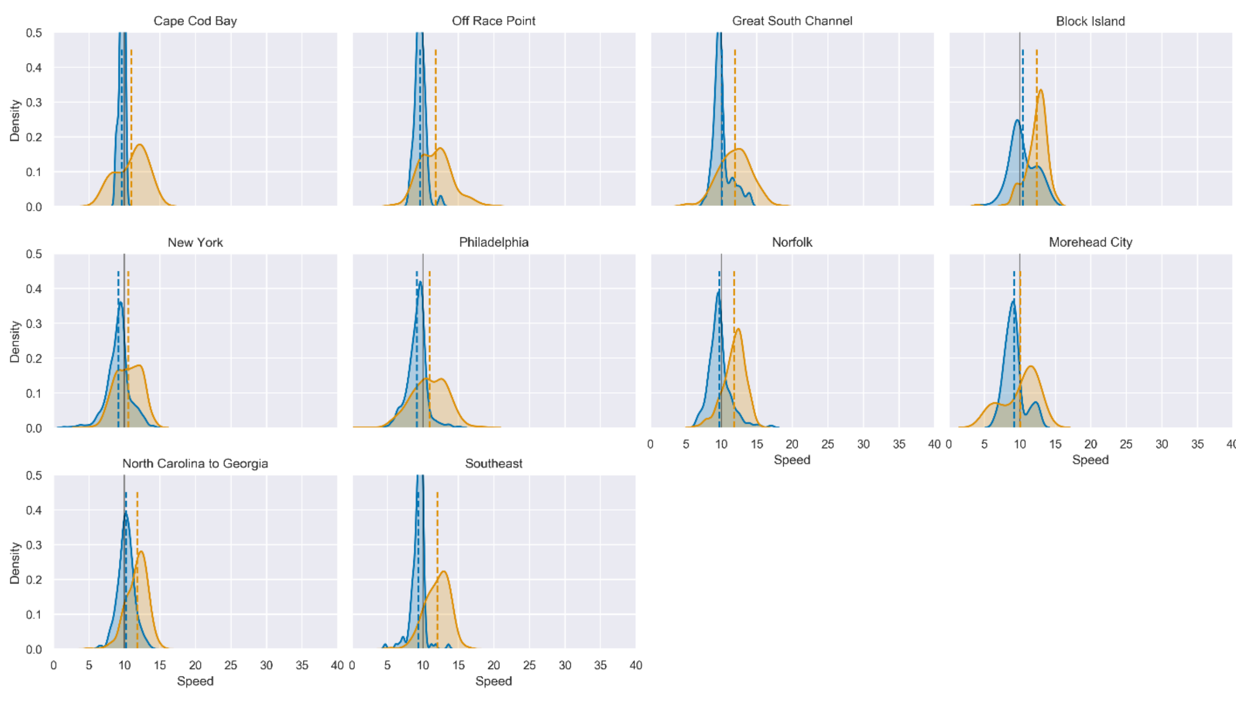


FIGURE A-3. DISTRIBUTION OF RO-RO VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

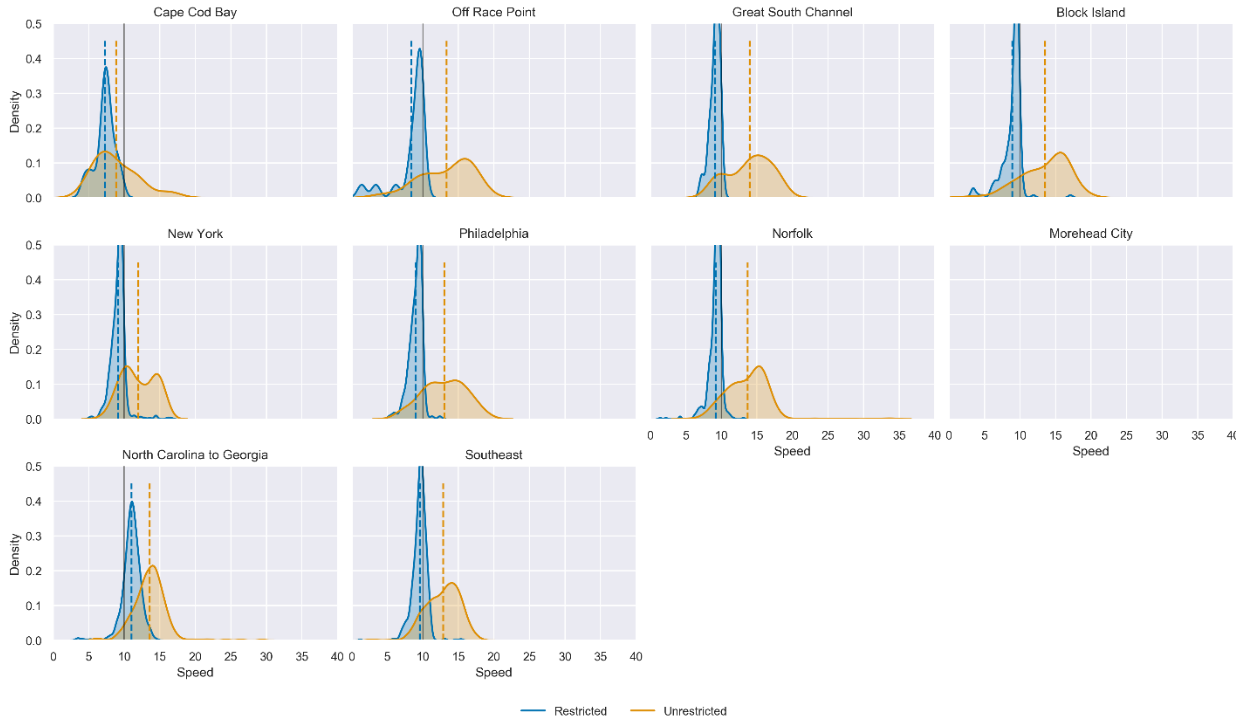


FIGURE A-4. DISTRIBUTION OF BULK CARRIER VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

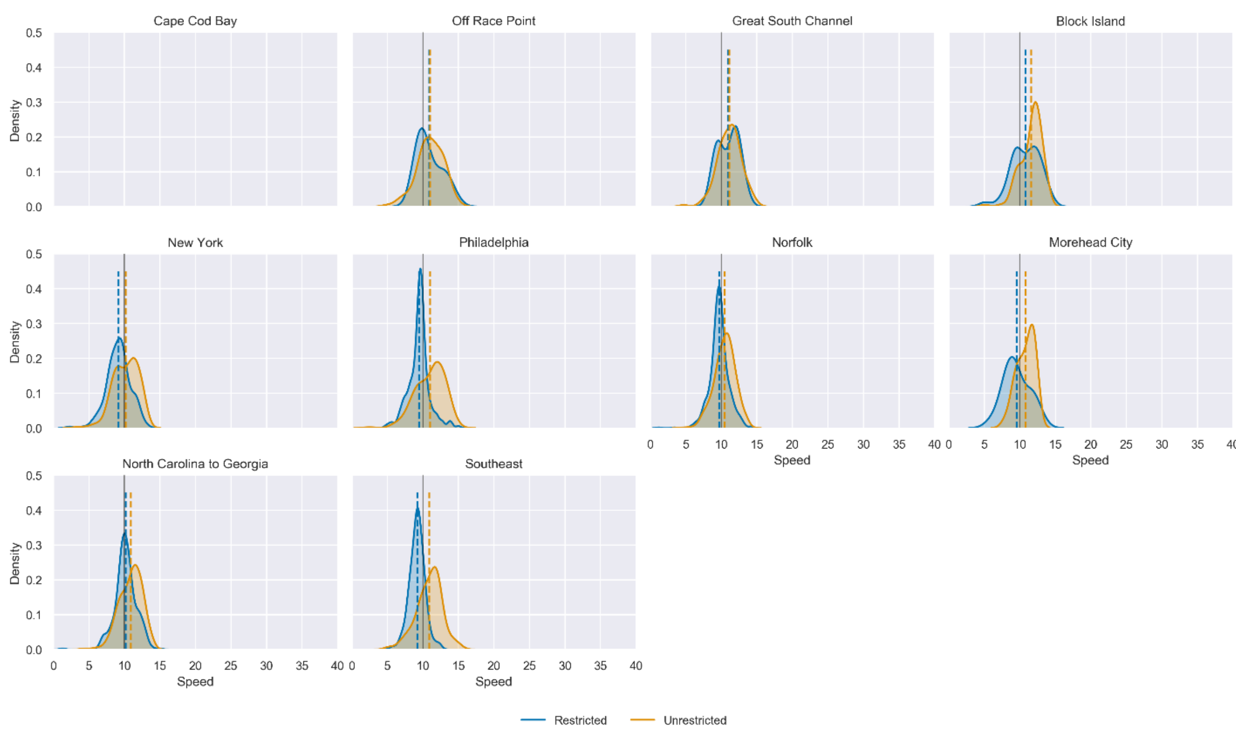


FIGURE A-5. DISTRIBUTION OF GENERAL CARGO VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

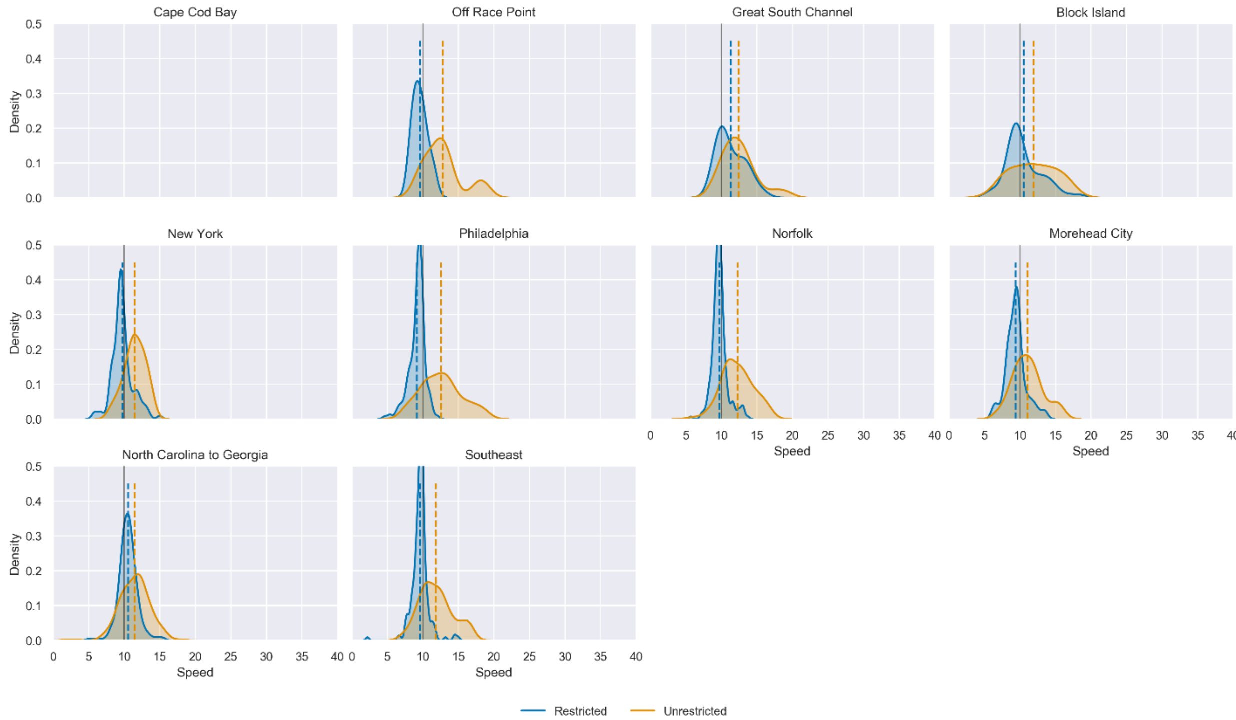


FIGURE A-6. DISTRIBUTION OF FISHING VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

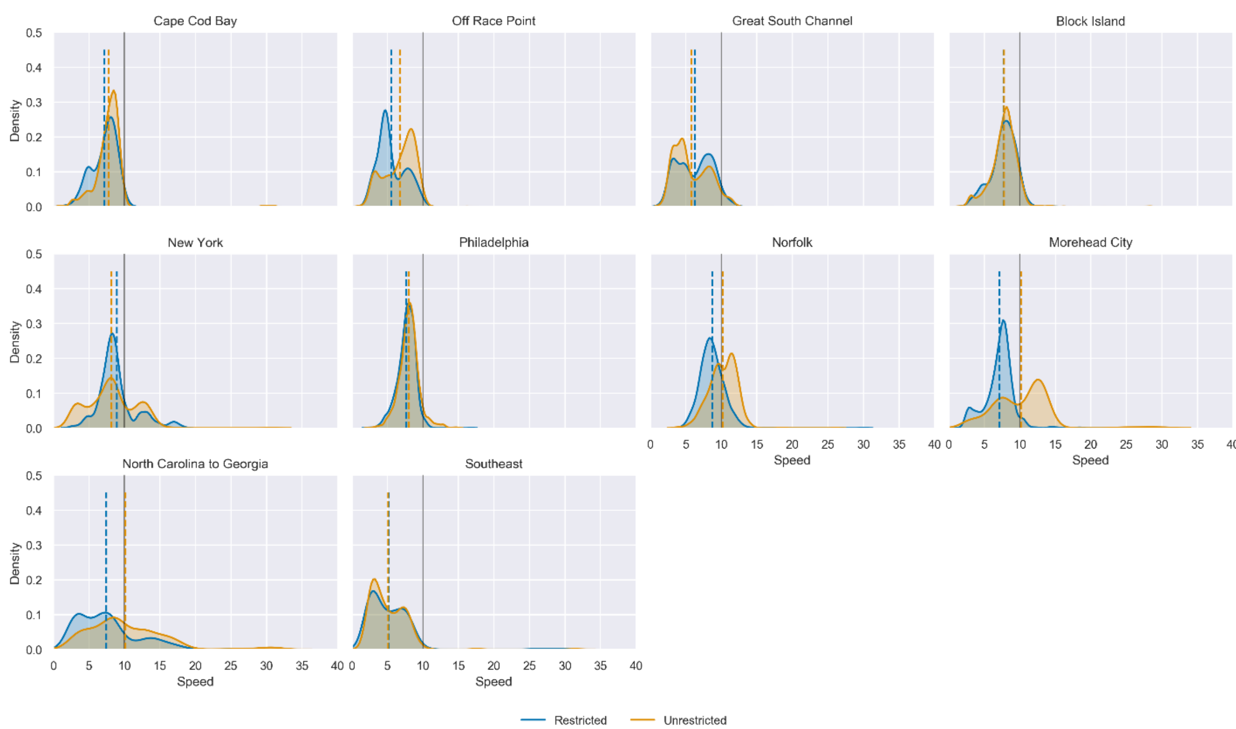


FIGURE A-7. DISTRIBUTION OF TOWING/PUSHING VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

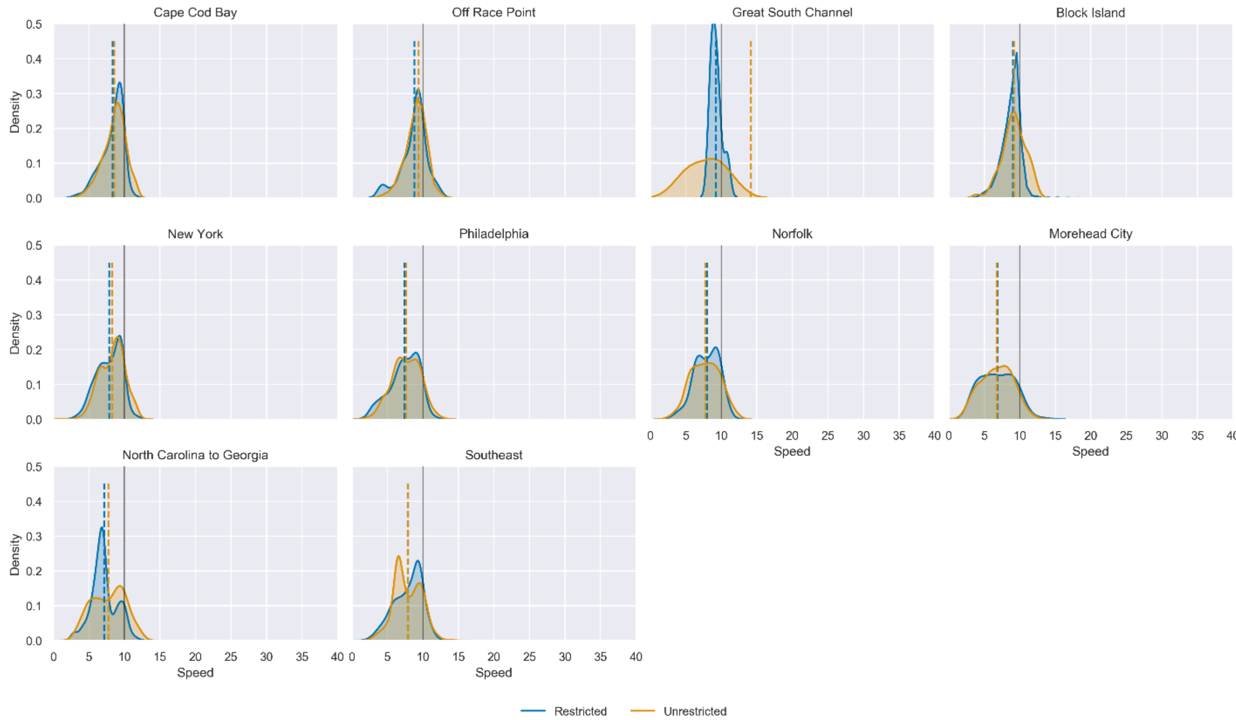


FIGURE A-8. DISTRIBUTION OF CRUISE PASSENGER VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

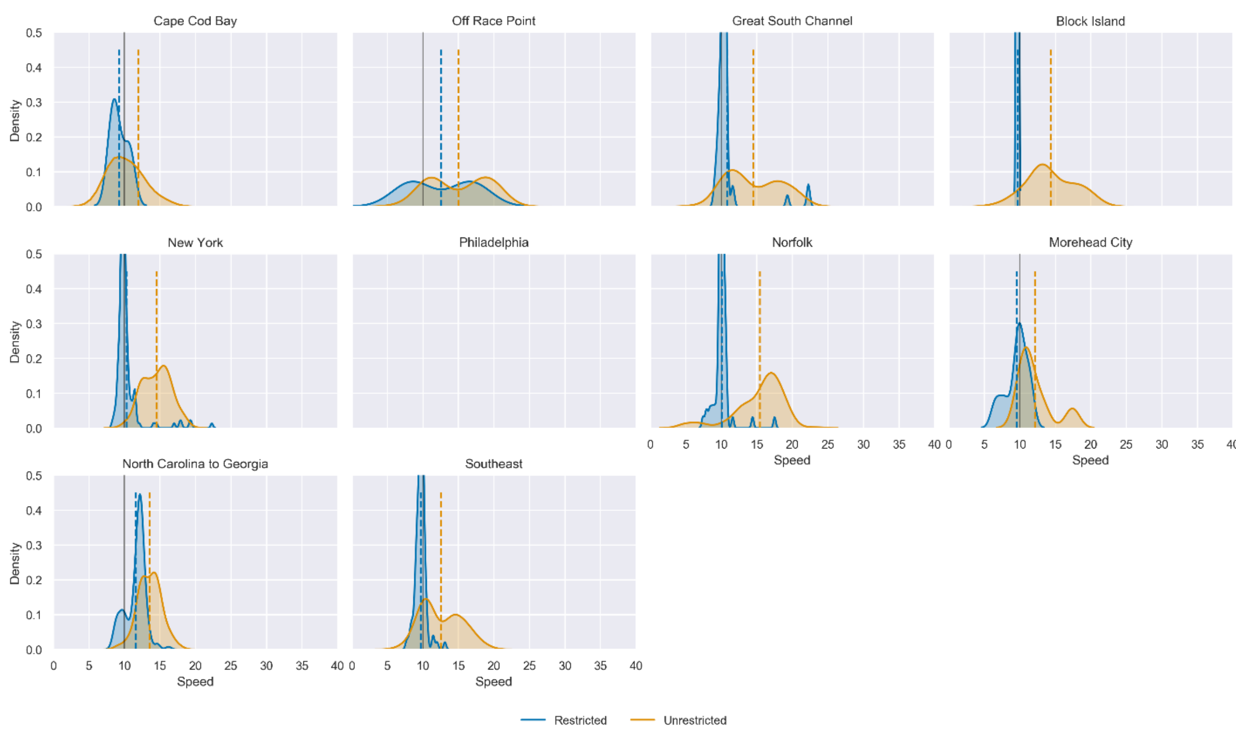


FIGURE A-9. DISTRIBUTION OF OTHER PASSENGER VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

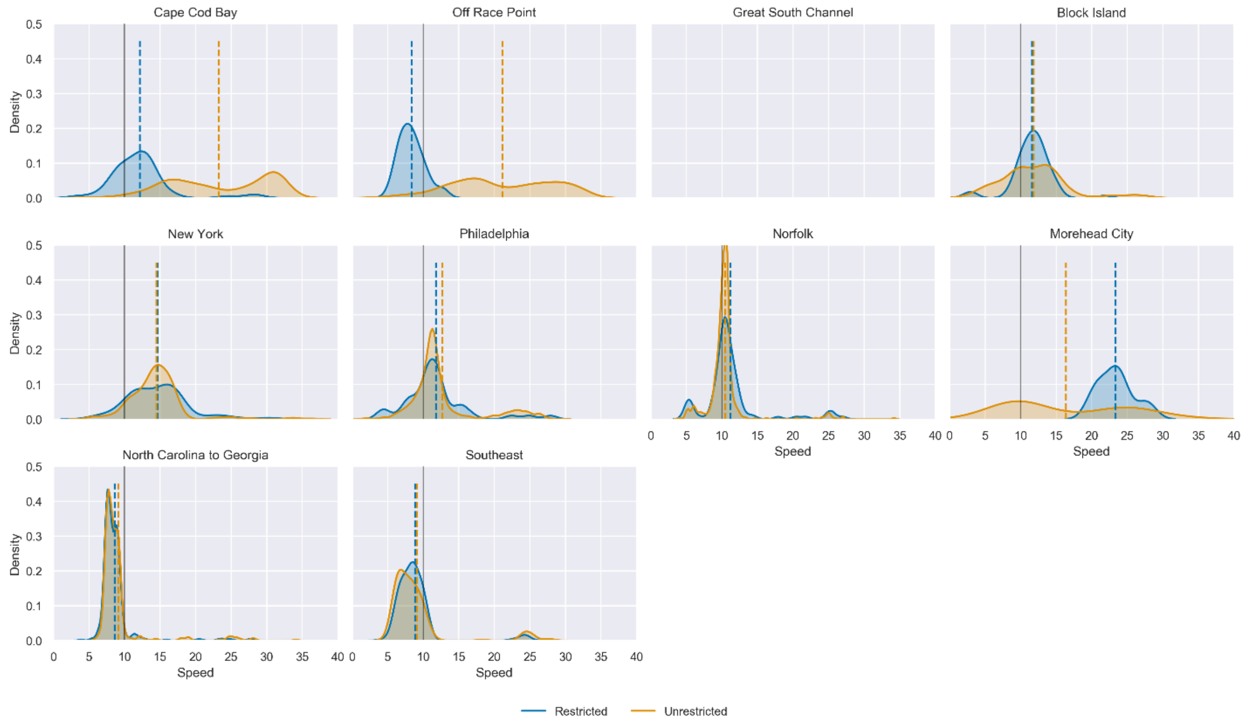


FIGURE A-10. DISTRIBUTION OF PLEASURE VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

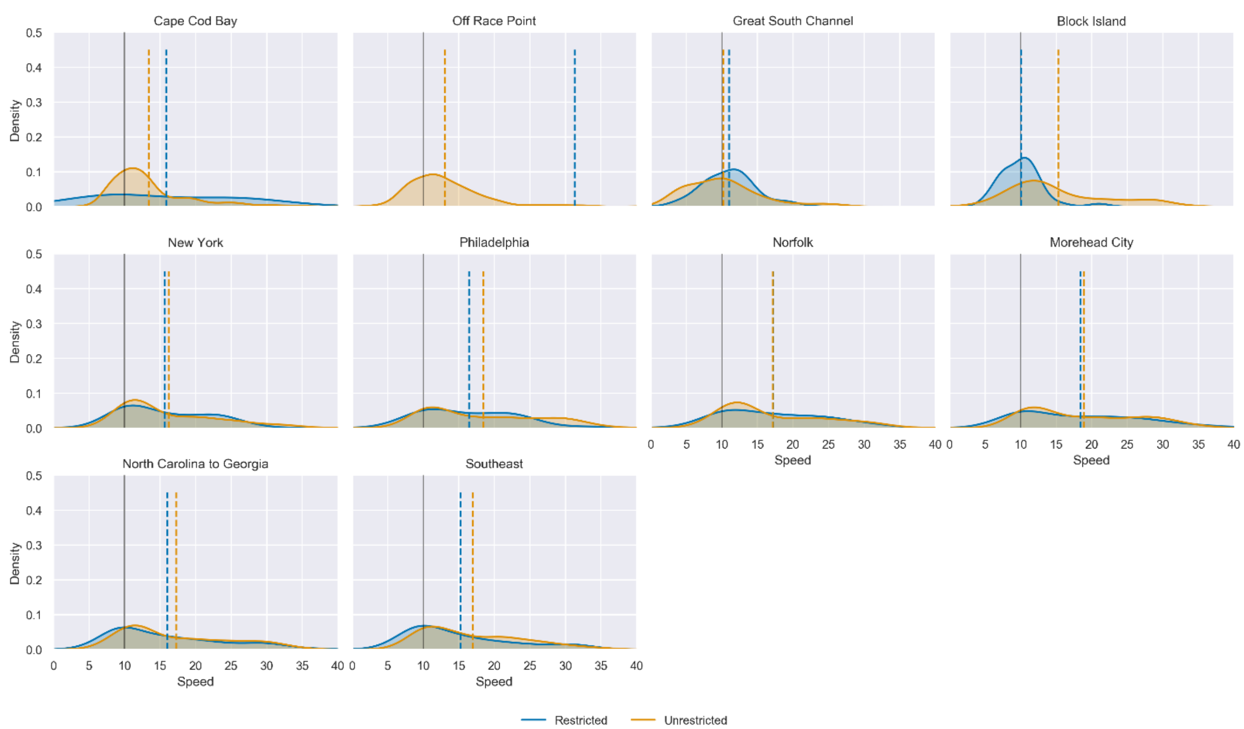


FIGURE A-11. DISTRIBUTION OF DREDGING VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD

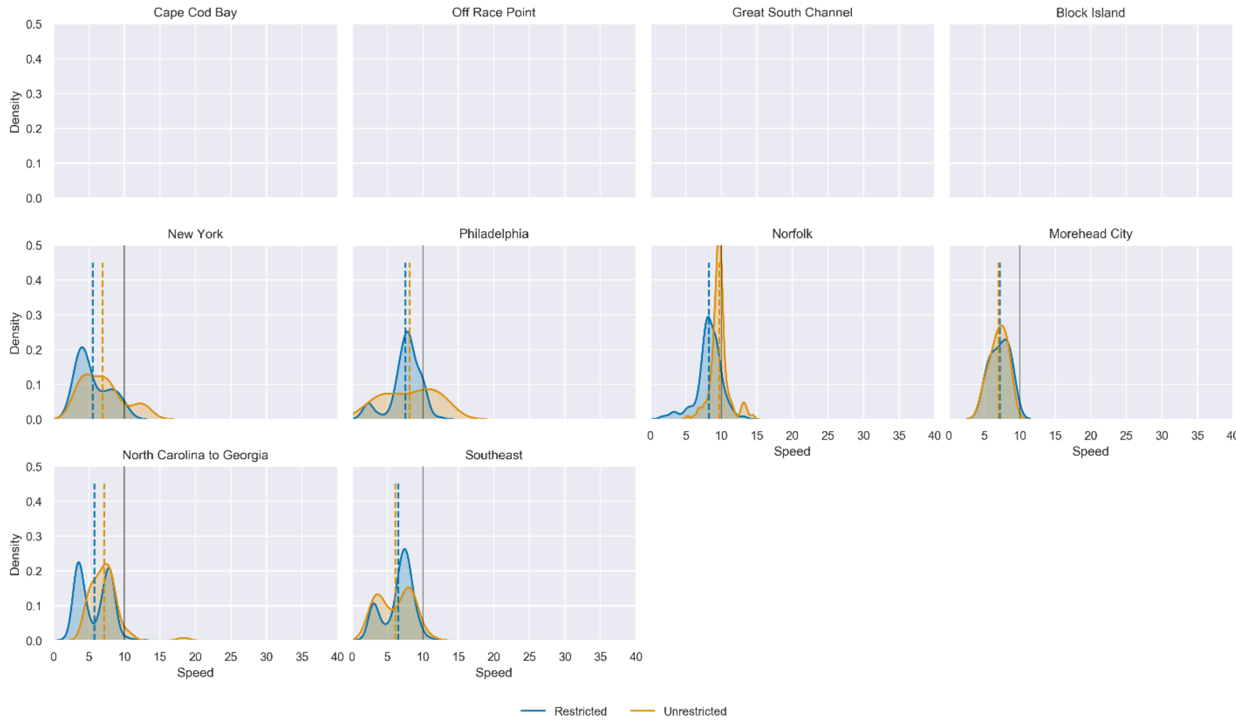
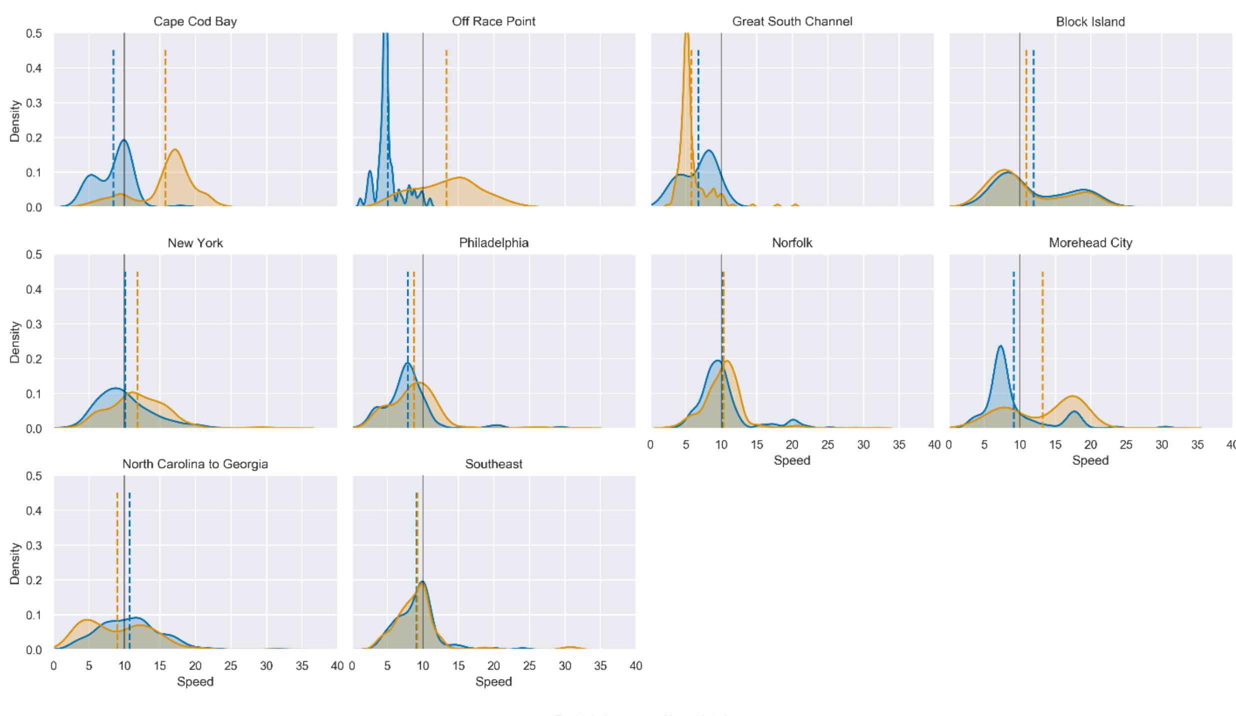


FIGURE A-12. DISTRIBUTION OF OTHER / UNDETERMINED VESSEL SPEEDS (KNOTS) BY SMA AND PERIOD



APPENDIX B | IMPACTS ASSUMING FULL COMPLIANCE

INTRODUCTION

An important consideration in evaluating the effect of the Rule is the treatment of non-compliant transits. The main body of this report characterizes the effects of the Rule as implemented, including transits of SMAs that violate the Rule. This approach is appropriate for a retrospective analysis. At the same time, it is important to consider what the impact of the Rule would be if full compliance were achieved. This appendix presents an analysis that assumes full compliance. It employs methods identical to those described in the main body of the report, with one modification: average operating speeds during the restricted period are calculated after setting all transits that occurred at non-compliant speeds to the maximum compliant speed – 10 knots.[64] Mathematically, this methodology may be written as:

$$delay = time^{*}_{observed} - time_{cf} = \frac{distance_{observed}}{speed^{*}_{observed}} - \frac{distance_{observed}}{speed_{cf}}$$

where

$$speed^{*}_{observed} = \begin{cases} speed_{observed} \; if \; speed_{observed} \leq 10 \\ 10 \; if \; speed_{observed} > 10 \end{cases}$$

This adjustment provides some perspective on the implications of full compliance for various types of vessels, particularly those that show relatively high rates of non-compliance. We refer to the methods that employ this adjustment as Method 1A and Method 2A.

METHOD 1A: COMPARISON OF MEANS WITH ASSUMPTION OF FULL COMPLIANCE

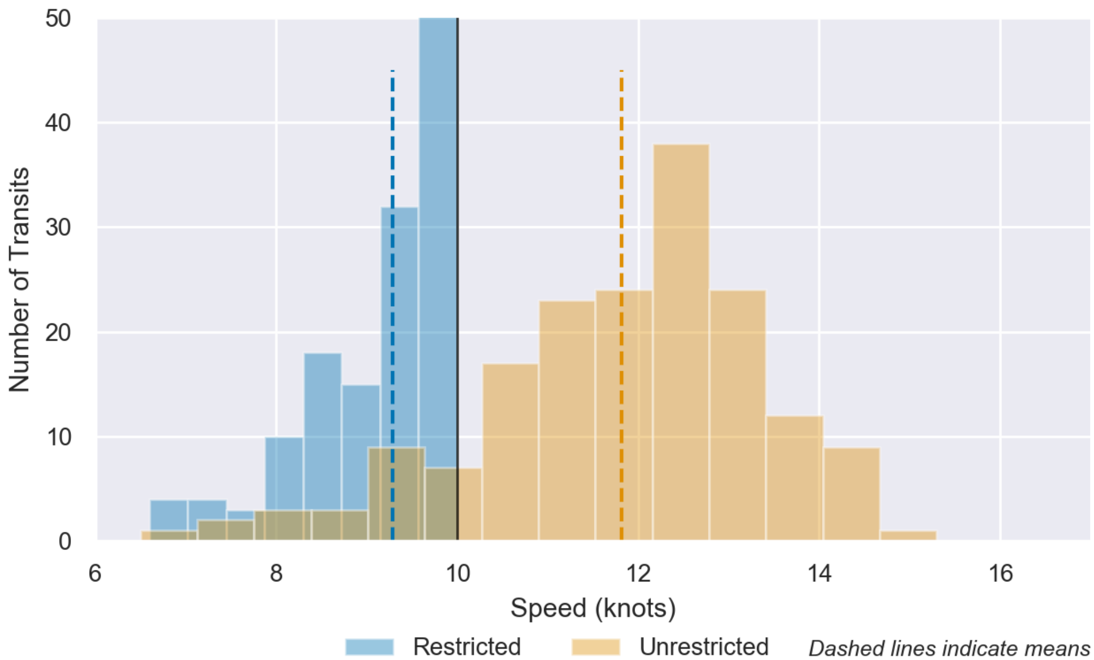
Under Method 1A, as was the case under Method 1, we assume that each transit in the restricted period would have – but for the Rule – occurred at the average speed in the unrestricted period. To reflect the impact of full compliance, however, we modify observed transit speeds during the restricted period as described above. This modification increases the estimated impact of the rule on transit times.

Figure B-1 illustrates the impact of the assumption of full compliance on the analysis, focusing on the same set of transits presented in Figure 2-4. Under Method 1A, we modify the distribution of restricted-period transits, resetting the speed of all transits that occurred at non-compliant speeds to 10 knots. This modification reduces the average speed of restricted-period transits (albeit only slightly in this case, as most transits occurred at less than 10 knots). There is no difference in the counterfactual speed employed in the analysis, which remains at approximately 12 knots. Thus, the assumption of full compliance

[64] For example, if a restricted-period transit of 18 nautical miles occurred at an average speed of 14 knots, taking an estimated 1.29 hours, we assume that this transit would have occurred at 10 knots, taking an estimated 1.8 hours.

increases the estimated impact of the Rule on transit times. Table B-1 presents the total estimated delay under Method 1A by vessel type and SMA. Table B-2 presents our estimate of the associated costs.

FIGURE B-1. TANKER VESSELS, NORFOLK SMA (NOVEMBER 1 – APRIL 30): FULL COMPLIANCE SCENARIO



Notes: y-axis truncated to preserve readability of graph; restricted-period histogram bins change slightly even for unaffected transits.

TABLE B-1. TOTAL DELAY (HOURS) BY VESSEL TYPE AND SMA, METHOD 1A

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MOREHEAD CITY	NC TO GA	SOUTHEAST	TOTAL
Bulk Carrier		11	25	85	99	68	244	13	123	88	**756**
Container		92	280	1	1,538	370	1,280		2,156	467	**6,184**
Ro-Ro	14	28	64	237	362	119	474		292	809	**2,399**
Tanker	4	39	168	120	572	208	87	10	214	115	**1,536**
General Cargo		5	22	46	65	166	120	34	143	153	**754**
Passenger (Cruise)	2	3	94	3	159	0.4	58	6	136	82	**543**
Fishing	161	1,238	-97	470	29	185	407	1,253	2,643	652	**6,942**
Towing / Pushing	206	11	11	56	432	265	69	48	1,183	185	**2,466**
Dredging	-0.5	1	0.3		-1	54	79	3	957	-10	**1,083**
Passenger (Other)	93	19		21	62	11	8	4	156	30	**403**
Pleasure	4	1	12	30	35	46	56	163	1,113	360	**1,820**
Other / Undetermined	88	188	-45	274	1,770	59	112	191	211	128	**2,976**
Total	**572**	**1,635**	**533**	**1,342**	**5,122**	**1,553**	**2,995**	**1,724**	**9,327**	**3,060**	**27,861**

TABLE B-2. TOTAL COSTS BY VESSEL TYPE AND SMA, METHOD 1A ($ THOUSANDS)

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MOREHEAD CITY	NC TO GA	SOUTEAST	TOTAL
Bulk Carrier		$11	$24	$84	$104	$70	$306	$11	$119	$94	$823
Container		$459	$1,497	$3	$6,686	$916	$5,979		$9,648	$1,574	$26,762
Ro-Ro	$13	$33	$91	$339	$559	$176	$748		$475	$1,186	$3,621
Tanker	$5	$62	$231	$133	$731	$300	$90	$10	$226	$151	$1,940
General Cargo		$4	$20	$39	$53	$179	$109	$31	$125	$136	$695
Passenger (Cruise)	$14	$16	$565	$16	$959	$2	$348	$37	$817	$497	$3,272
Fishing	$35	$324	-$87	$119	$6	$34	$79	$211	$512	$130	$1,364
Towing / Pushing	$227	$12	$12	$62	$476	$292	$76	$53	$1,303	$204	$2,715
Dredging	-$1	$2	$1		-$1	$91	$135	$5	$1,621	-$17	$1,835
Passenger (Other)	$45	$9		$10	$30	$5	$4	$2	$76	$14	$195
Pleasure											
Other / Undetermined	$52	$111	-$27	$161	$1,042	$35	$66	$112	$124	$75	$1,753
Total	**$389**	**$1,044**	**$2,327**	**$966**	**$10,645**	**$2,099**	**$7,940**	**$473**	**$15,047**	**$4,046**	$44,975

METHOD 2A: COMPARISON OF HIGH-SPEED TRANSITS WITH ASSUMPTION OF FULL COMPLIANCE

Under Method 2A, as was the case under Method 2, we assume that – but for the Rule – the same percentage of transits would have occurred at speeds of greater than 10 knots in both the restricted and unrestricted periods, and that the average speed of these transits in the restricted period would be equal to the average speed of the transits in the unrestricted period. To reflect the impact of full compliance, however, we modify observed transit speeds during the restricted period as described above. This modification increases the estimated impact of the rule on transit times. Table B-3 presents the total estimated delay under Method 2A by vessel type and SMA. Table B-4 presents our estimate of the associated costs.

TABLE B-3. TOTAL DELAY (HOURS) BY VESSEL TYPE AND SMA, METHOD 2A

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MOREHEAD CITY	NC TO GA	SOUTHEAST	TOTAL
Bulk Carrier		11	25	58	41	50	170	7	96	61	**517**
Container		83	250	0.3	1,273	301	1,105		2,009	415	**5,435**
Ro-Ro	4	26	55	182	272	100	428		269	680	**2,015**
Tanker	5	34	160	101	287	140	74	7	178	93	**1,078**
General Cargo		5	20	35	43	136	107	24	131	120	**622**
Passenger (Cruise)	2	3	91	3	159	0.4	57	3	127	84	**529**
Fishing	3	1	29	22	25	12	179	425	224	7	**927**
Towing / Pushing	21	2	0.2	23	47	24	12	1	156	22	**309**
Dredging					6	26	7		33	1	**73**
Passenger (Other)	92	18		17	56	10	9	3	78	19	**303**
Pleasure	3	1	22	22	32	43	53	145	1,018	304	**1,644**
Other / Undetermined	87	152	2	42	296	17	59	69	135	32	**892**
Total	**217**	**336**	**652**	**506**	**2,537**	**859**	**2,260**	**684**	**4,454**	**1,838**	**14,343**

TABLE B-4. TOTAL COSTS BY VESSEL TYPE AND SMA, METHOD 2A ($ THOUSANDS)

VESSEL TYPE	CAPE COD BAY	OFF RACE POINT	GREAT SOUTH CHANNEL	BLOCK ISLAND	NEW YORK	PHILADELPHIA	NORFOLK	MOREHEAD CITY	NC TO GA	SOUTHEAST	TOTAL
Bulk Carrier		$11	$23	$54	$42	$50	$210	$6	$93	$60	**$550**
Container		$416	$1,338	$1	$5,604	$742	$5,235		$9,079	$1,420	**$23,834**
Ro-Ro	$6	$33	$79	$263	$421	$147	$677		$435	$1,002	**$3,064**
Tanker	$5	$53	$227	$114	$356	$198	$80	$7	$189	$128	**$1,357**
General Cargo		$4	$17	$36	$33	$147	$98	$21	$117	$105	**$577**
Passenger (Cruise)	$12	$18	$547	$17	$957	$2	$345	$17	$767	$508	**$3,191**
Fishing	$1	$0.2	$10	$8	$5	$2	$38	$78	$48	$2	**$192**
Towing / Pushing	$23	$2	$0.3	$25	$52	$26	$13	$1	$172	$24	**$340**
Dredging					$9	$44	$12		$56	$1	**$123**
Passenger (Other)	$45	$9		$8	$27	$5	$4	$2	$38	$9	**$147**
Pleasure											
Other / Undetermined	$51	$90	$1	$25	$174	$10	$35	$41	$80	$19	**$525**
Total	**$144**	**$636**	**$2,242**	**$551**	**$7,682**	**$1,374**	**$6,747**	**$173**	**$11,073**	**$3,279**	**$33,901**

SUMMARY

Table B-5 compares the results of the full-compliance analysis to the results of the analysis presented with no adjustment for non-compliance. As the table indicates, the assumption of full compliance with the Rule increases our estimate of the costs associated with the vessel speed restrictions by approximately $5.6 million per year, regardless of whether we employ Method 1 or Method 2 to calculate the Rule's effect. Approximately 68 percent of this increase is attributable to the additional cost container ships would incur to achieve full compliance. As the charts presented in Appendix A indicate, this finding is not a result of a disproportionately high degree of non-compliance among container ships. Rather, it reflects the relatively high hourly operating costs of these vessels, coupled with the large share of affected transits that container ships represent.

TABLE B-5. ESTIMATED COSTS BY VESSEL TYPE AND METHOD ($ THOUSANDS)

VESSEL TYPE	METHOD 1	METHOD 1A	METHOD 2	METHOD 2A
Bulk Carrier	$619	$823	$346	$550
Container	$22,953	$26,762	$20,025	$23,834
Ro-Ro	$3,381	$3,621	$2,825	$3,064
Tanker	$1,693	$1,940	$1,110	$1,357
General Cargo	$578	$695	$461	$577
Passenger (Cruise)	$2,759	$3,272	$2,677	$3,191
Fishing	$1,318	$1,364	$147	$192
Towing / Pushing	$2,619	$2,715	$244	$340
Dredging	$1,824	$1,835	$112	$123
Passenger (Other)	$112	$195	$65	$147
Pleasure	NA	NA	NA	NA
Other / Undetermined	$1,535	$1,753	$314	$525
Total	$39,391	$44,975	$28,327	$33,901

APPENDIX C | NOTES ON ESTIMATES OF VESSEL OPERATING COSTS

FISHING VESSEL COSTS

Table C-1 summarizes the responses to the GMRI survey on alternative occupations for commercial fishermen and illustrates the calculations used to estimate the implicit hourly value of fishermen's time.

TABLE C-1. CALCULATION OF IMPLICIT VALUE OF FISHERMEN'S TIME

ALTERNATIVE OCCUPATION	PERCENT OF RESPONDENTS THAT IDENTIFIED ALTERNATIVE*	NORMALIZED DISTRIBUTION OF RESPONSES	AVERAGE 2018 BLS WAGE RATE	BLS OCCUPATIONAL CATEGORIES INCORPORATED INTO AVERAGE WAGE RATE
Carpentry/Trades/ Mechanic	28%	41%	$22.80	Carpenters; Automotive Service Technicians and Mechanics
Other Commercial Fishing/Merchant Marine/Boat Building and Maintenance	26%	38%	$27.39	Fishers and Related Fishing Workers; Motorboat Mechanics; Sailors and Marine Oilers; Captains, Mates, and Pilots of Water Vessels
Other Business	8%	12%	$36.98	Business and Financial Operations Occupations
Truck Driver/Equipment Operator	3%	4%	$23.71	Heavy and Tractor-Trailer Truck Drivers; Operating Engineers and Other Construction Equipment Operators
Education	2%	3%	$27.22	Education, Training, and Library Occupations
Police/Firefighter/ EMT/Military	1%	1%	$25.06	Police and Sheriff's Patrol Officers; Firefighters; Emergency Medical Technicians and Paramedics
Engineering	1%	1%	$44.62	Mechanical Engineers
Other	10%	N/A		
Retire	2%	N/A		
Don't Know	16%	N/A		
Weighted Average			**$26.69**	
Weighted Average (Inflated to 2019 Dollars)			**$27.03**	
*Because the survey permitted multiple responses, these figures do not sum to 100 percent.				

OTHER PASSENGER VESSEL COSTS

Table C-2 presents the inputs specified in applying DOT's ferry cost model to obtain hourly operating costs for passenger vessels other than cruise ships.

TABLE C-2. FERRY COST MODEL INPUTS

COST CATEGORY	INPUT	VALUE
Fuel/Lubricant	How many stops will there be?	**None**
	Service Speed/Max Speed	0.8
	Stop Time (min)	5
	Lubricant Cost/Gallon (2019 $)	$8.00
	Diesel Fuel Cost/Gallon (2019 $)	**$3.09**[1]
Wages	Captain Hourly Wage Rate (2019 $)	**$31.89**[2]
	Deckhand Hourly Wage Rate (2019 $)	**$16.36**[3]
	Labor Overhead Rate	15%

Notes:

1. Diesel price is taken from the average diesel price for East Coast ports in 2019. This figure was obtained from the U.S. Energy Information Administration's Petroleum price tool, accessed at: https://www.eia.gov/dnav/pet/pet_pri_gnd_a_epd2d_pte_dpgal_a.htm.
2. Estimated using U.S. Bureau of Labor Statistics recorded median hourly rate for a captain, mate, or pilot of a water vessel within NAICS code 483100 (Deep Sea, Coastal, and Great Lakes Water Transportation). Accessed at: https://www.bls.gov/oes/current/naics4_483100.htm. Accessed October 3, 2019.
3. Estimated using U.S. Bureau of Labor Statistics recorded median hourly rate for a laborer/material mover within NAICS code 483100 (Deep Sea, Coastal, and Great Lakes Water Transportation). Accessed at: https://www.bls.gov/oes/current/naics4_483100.htm. Accessed October 3, 2019.

We assume no stops along the ferry route, so that the model best represents an uninterrupted transit through an SMA.[65] The model also adds hourly costs for insurance, which is calculated by dividing the total estimated number of passengers serviced each year by the total estimated operating hours, then multiplying the result by a fixed cost per passenger. We do not expect delays resulting from the Rule to affect the number of passengers serviced in a year, so we exclude these insurance costs from the total hourly cost calculation. Table C-3 presents the resulting cost estimates for each type of vessel specified in the model.

[65] When the number of stops is greater than zero, the estimated hourly operating costs are also affected by the user's input regarding round trip distance. As we assume zero stops, this parameter is not relevant to our analysis.

TABLE C-3. PASSENGER VESSEL COST MODEL OUTPUTS BY VESSEL CLASS

PASSENGER CAPACITY	MAXIMUM SPEED (KNOTS)	ROLL-ON / ROLL-OFF	VEHICLE CAPACITY	HOURLY OPERATING COST (2019 $)		
				LOW	HIGH	AVERAGE
1-30		No		$64.28	$84.68	$74.48
31-50 (pontoon)		No		$117.70	$136.13	$126.91
31-50 (monohull or catamaran)		No		$116.93	$157.89	$137.41
51-100	<20	No		$126.15	$156.03	$141.09
51-100	>20	No		$153.66	$293.17	$223.41
101-150	<20	No		$117.70	$304.32	$211.01
101-150	>20	No		$239.81	$547.02	$393.41
151-300		No		$292.79	$870.25	$581.52
<100		Yes	<10	$105.02	$176.70	$140.86
<500		Yes	<10	$214.32	$480.57	$347.44
<500		Yes	<50	$189.10	$683.70	$436.40
250-500		Yes	45-100	$3,246.90	$3,515.79	$3,381.34

Source: United States Department of Transportation, Volpe Center. Department of the Interior - Bus and Ferry Lifecycle Cost Modeling. December 2011.

CRUISE SHIP OPERATING COSTS

This section provides details underlying the calculation of cruise ship operating costs presented in Chapter 3. We develop these estimates using SEC Form 10-K annual filings for three large cruise companies: Carnival Corporation & PLC; Royal Caribbean Cruises Ltd.; and Norwegian Cruise Line Holdings.

As noted in Chapter 3, we estimate hourly cruise ship operating costs using the following equation:

$$Operating\ Costs\ per\ Vessel\ per\ Day = \frac{\left(\frac{Fleetwide\ Annual\ Operating\ Costs}{Number\ of\ Vessels}\right)}{Annual\ Operating\ Days\ per\ Vessel}$$

We divide operating costs per vessel per day by 24 to estimate hourly operating costs per vessel. The discussion below describes the steps taken to calculate the number of vessels in each company's fleet and the annual operating days of the average vessel in each fleet.

DETERMINING FLEET SIZE

The 10-K filings for Carnival, Royal Caribbean, and Norwegian disclose the number of vessels each company operates. In tabulating the size of each fleet, we consider only those vessels whose operating costs are captured in the 10-K filings. We exclude, for example, vessels operated under Royal Caribbean's *Pullmantur* brand, as Royal Caribbean owns only a 49 percent share of the brand, and therefore is not required to include financial information for this cruise line in its Form 10-K filings. The filings information does not disaggregate costs by region; therefore, our tabulation of the size of each fleet includes vessels regardless of the region(s) in which they operate. Table C-4 lists the resulting estimate of the number of vessels in each fleet.

TABLE C-4. CRUISE FLEET SIZE

COMPANY	CRUISE LINE	VESSELS IN CRUISE LINE FLEET	VESSELS IN COMPANY FLEET
Carnival	Carnival Cruise Line	26	104
	Princess Cruises	17	
	Holland America Line	15	
	P&O Cruises	12	
	Seabourn	5	
	Costa Cruises	14	
	AIDA Cruises	12	
	Cunard	3	
Royal Caribbean	Royal Caribbean International	25	50
	Celebrity Cruises	13	
	Azamara Club Cruises	3	
	Silversea Cruises	9	
Norwegian	Norwegian	16	26
	Oceania Cruises	6	
	Regent	4	

CALCULATING AVERAGE OPERATING DAYS PER VESSEL

We derive an estimate of annual operating days per vessel for each company based on the total number of passengers the company reports it carried, total fleetwide passenger capacity, total passenger cruise days, and the fleetwide occupancy ratio (*i.e.*, the ratio between the number of passengers a company carried and the capacity of its fleet).[66] Occupancy ratios of 100 percent indicate the fleet is operating at capacity. Ratios above 100 percent indicate that some rooms are filled with more than two passengers. Passenger cruise days are a standard measure of passenger capacity, calculated by multiplying passenger capacity by the number of revenue-producing ship operating days in the period. Some companies report this figure directly. Other companies report available lower berth days (ALBDs), the product of total passenger capacity and total fleetwide operating days. ALBDs assume full capacity. For companies reporting ALBDs, we calculate passenger cruise days by multiplying ALBDs by the company's occupancy ratio.

Dividing each company's passenger cruise days by total passengers carried determines the average number of operating days that a passenger spends aboard a cruise ship (a "trip"). As shown in Table C-5, the average trip length for each company is approximately seven days.

[66] In the Form 10-K filings, full capacity assumes every passenger cabin aboard the vessel is occupied by two passengers.

TABLE C-5. AVERAGE CRUISE TRIP LENGTH

COMPANY	PASSENGER CRUISE DAYS	PASSENGERS CARRIED	AVERAGE TRIP LENGTH (DAYS)
Carnival	89,659,168	12,407,000	7.23
Royal Caribbean	41,853,052	6,078,201	6.89
Norwegian	20,276,568	2,795,101	7.25

We calculate the number of trips the average vessel takes per year by determining how many trips the entire fleet would need to take ("fleet trips") to serve every passenger carried for the year. We first multiply the total fleetwide capacity by the occupancy ratio to determine the total passengers serviced if every vessel in the fleet were to embark on one trip. The total number of passengers carried for the entire year is divided by this figure to determine the average number of trips each vessel takes per year. We present these calculations in Table C-6.

TABLE C-6. ANNUAL CRUISE SHIP FLEET TRIPS

COMPANY	FLEETWIDE CAPACITY (BERTHS)	OCCUPANCY RATIO	PASSENGERS PER FLEET TRIP	PASSENGERS CARRIED	ANNUAL FLEET TRIPS
Carnival	236,910	106.9%	253,257	12,407,000	49.0
Royal Caribbean	113,320	108.9%	123,405	6,078,201	49.3
Norwegian	54,400	107.6%	58,534	2,795,101	47.8

These calculations indicate that the average cruise vessel annually conducts approximately 48-49 trips of approximately 7 days. Multiplying these two factors results in the total number of operating days for the average vessel in each company's fleet. On average, each vessel operates most days of the year. We present these calculations in Table C-7.

TABLE C-7. ANNUAL OPERATING DAYS PER CRUISE SHIP

COMPANY	AVERAGE TRIP LENGTH (DAYS)	ANNUAL FLEET TRIPS	OPERATING DAYS PER VESSEL
Carnival	7.23	49.0	354
Royal Caribbean	6.89	49.3	339
Norwegian	7.25	47.8	346

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