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The right whale mandatory ship reporting system: a retrospective

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ABSTRACT

In 1998, the United States sought and received International Maritime Organization-endorsement of two Mandatory Ship Reporting (MSR) systems designed to improve mariner awareness about averting ship collisions with the endangered North Atlantic right whale (*Eubalaena glacialis*). Vessel collisions are a serious threat to the right whale and the program was among the first formal attempts to reduce this threat. Under the provisions of the MSR, all ships >300 gross tons are required to report their location, speed, and destination to a shore-based station when entering two key right whale habitats: one in waters off New England and one off coastal Georgia and Florida. In return, reporting ships receive an automatically-generated message, delivered directly to the ship's bridge, that provides information about right whale vulnerability to vessel collisions and actions mariners can take to avoid collisions. The MSR has been in operation continuously from July 1999 to the present. Archived incoming reports provided a 15-plus year history of ship operations in these two locations. We analyzed a total of 26,772 incoming MSR messages logged between July 1999 and December 2013. Most ships that were required to report did so, and compliance rates were generally constant throughout the study period. Self-reported vessel speeds when entering the systems indicated that most ships travelled between 10 and 16 (range = 5–20+) knots. Ship speeds generally decreased in 2009 to 2013 following implementation of vessel speed restrictions. The number of reports into the southern system remained relatively constant following a steady increase through 2007, but numbers in the northern system decreased annually beginning in 2008. If reporting is indicative of long-term patterns in shipping operations, it reflects noteworthy changes in marine transportation. Observed declines in ship traffic are likely attributable to the 2008–2009 economic recession, the containerized shipping

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industry making increased use of larger ships that made fewer trips, and diminished oil/gas US imports as previously inaccessible domestic deposits were exploited. Recent declines in shipping activity likely resulted in lowered collision risks for right whales and reduced their exposure to underwater noise from ships.

Subjects Conservation Biology, Marine Biology, Legal Issues, Science Policy
Keywords Endangered whale, US energy imports, North Atlantic right whale, Ship collisions, International Maritime Organization, Shipping industry, Endangered whale, Underwater noise, Economic recession

INTRODUCTION

By the mid-18th century, the North Atlantic right whale (*Eubalaena glacialis*) (hereafter "right whale") was depleted to near extinction by commercial whaling. Consequently, right whales were among the first of the baleen whales to receive international protection. After whaling for this species ended, attention turned to different threats: serious injury and deaths caused by entanglement in commercial fishing gear and collisions with large ships (*Clapham, Young & Brownell, 1999*; *Kraus et al., 2005*). Vessel collisions involving a number of endangered large whale species are relatively common in US waters (*Henry et al., 2012*; *Laist et al., 2001*; *van der Hoop et al., 2014*) and are regarded as a significant impediment to the recovery of right whales (*NMFS, 2005*). In general, individuals of this species migrate in coastal waters along the US eastern seaboard between feeding/socializing areas in waters off New England and eastern Canada to/from nursery areas off the South Carolina to Florida coasts. The right whale is vulnerable to collisions with vessels throughout its range, but the threat may be particularly high in these aggregation areas where vessel traffic is also concentrated (*NMFS, 2005*).

As one of the first efforts to reduce the threat of ship collisions with right whales, the United States submitted a proposal to the International Maritime Organization (IMO) in June 1998 to establish two Mandatory Ship Reporting systems (MSR) (*USG, 1998*). The goal of the MSR is to provide timely information about right whales and their vulnerability to vessel strikes directly to individual vessels as they enter key right whale feeding and nursery habitats.

The MSR proposal was approved by the IMO's Subcommittee on Navigation in July 1998 and its Marine Safety Commmittee in December 1998 (*Silber et al., 2012*), becoming the first time an IMO-endorsed measure was used to protect a particular marine species (*Johnson, 2004*; *Luster, 1999*) and one of the first formal actions to reduce ship collisions with the right whale. To implement the MSR, the US Coast Guard (USCG) issued a Final Rule in the US Federal Register (*USCG, 2001*) that codified the systems by amending the *US Code of Federal Regulations* (33 CFR 169). The US National Oceanic and Atmospheric Administration (NOAA) then added the MSR areas to relevant nautical charts and incorporated the new requirements into various navigational aids such as the US Coast Pilot and elsewhere. As prescribed by the IMO, the two MSR systems became effective in

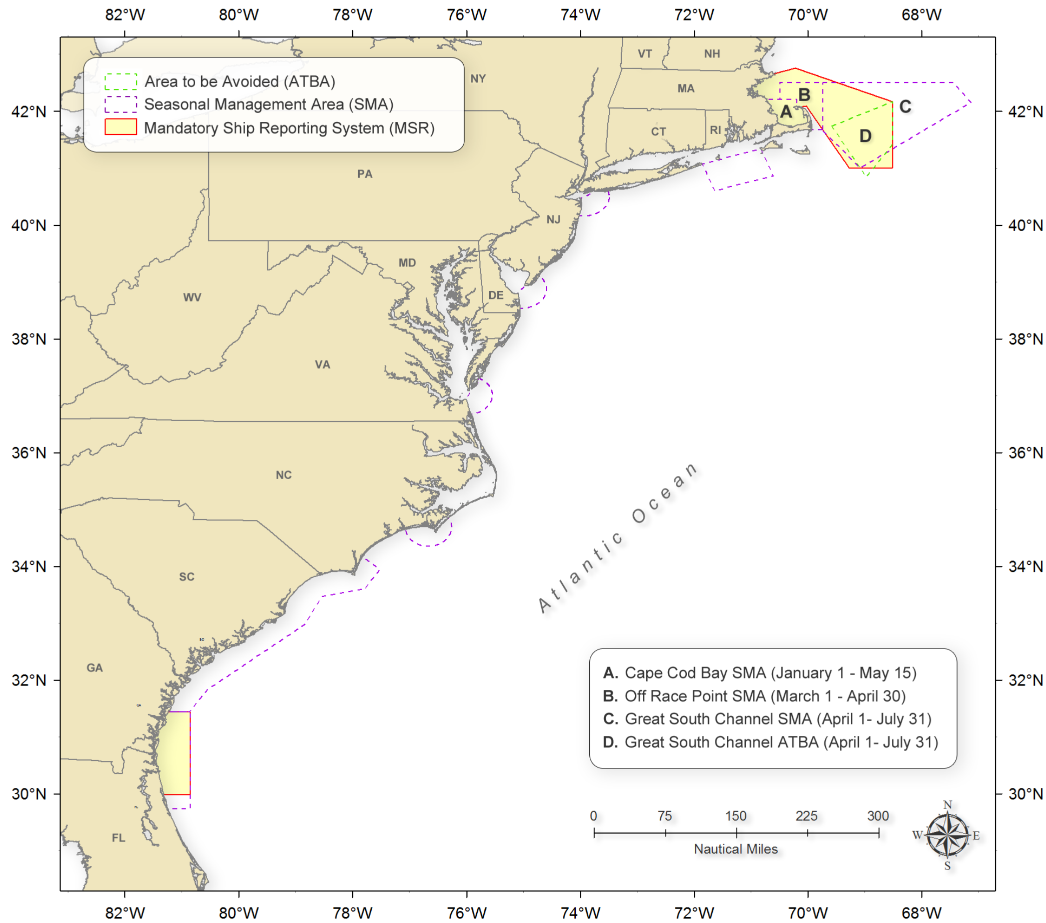

Figure 1 **Locations of the Mandatory Ship Reporting systems, Area To Be Avoided, and speed restriction seasonal management areas.**

1 July 1999, and have been in operation continuously since that time. From July 1999 to present, operation and administration of this program have been co-funded and -operated by the USCG and NOAA's National Marine Fisheries Service (NMFS). All ship-to-shore and shore-to-ship communication costs are borne by these two agencies (including a government contract to the communications provider).

Under the rule, self-propelled commercial ships ≥300 gross tons (gt) are required to report to shore-based stations when they enter either of two regions off the eastern US coast where and when right whales are known to occur: one off the state of Massachusetts operating year-round (a total area of approx. 2,200 km^2); the other, off the states of Georgia and Florida, is operational annually from 15 November through 15 April (ca. 800 km^2) (*Silber et al., 2012*) (Fig. 1). Reports are typically sent as text messages via INMARSAT-C Internet (International Maritime Satellite) and include ship name, course, speed, and destination among other things. Only reporting is required; no other aspect of vessel operations is affected. Incoming reports were parsed and stored on a server for subsequent analysis. An automatically-generated message is returned to the reporting vessel that includes information on locations of recently-sighted right whales; procedural guidance to help prevent vessel/whale collisions; and information concerning additional regulations (e.g., vessel speed restrictions) in place to protect whales from vessel strikes.

The dataset of incoming MSR reports represents a unique long-term record of vessel activities in the areas, in that the system predates similar technologies (e.g., the Automatic Identification System (AIS) and Long-Range Identification and Tracking) that are now used for detailed monitoring of ship locations and operations. When the MSR was established, minimal systematic data regarding vessels entering US ports existed—ships were required only to establish radio contact with the captain of the port at least 24 h prior to arrival. Following the 11 September 2001 terrorist attacks on the United States, systems were developed to more closely monitor vessels making US port calls. Among these, the USCG issued regulations requiring 96-hour notification from vessels (33 CFR 160) (*CFR, 2003*), known as the Ship Arrival Notification System (SANS). Our study utilized SANS data to assess vessel compliance with the MSR, as discussed below.

Here, we provide a cumulative summary of self-reported vessel activity entering key right whale habitats from July 1999 through December 2013 derived from incoming MSR reports. Our objectives in analyzing and presenting these data, while also recognizing their limitations, were to (a) provide basic summary statistics and a general characterization of vessel traffic in MSR areas since its inception; (b) indicate how trends in vessel activity may reflect changes in various aspects of international shipping operations; and (c) describe how changes in commercial shipping practices may have had unintended implications for right whale conservation.

MATERIALS AND METHODS

Mandatory reporting information included the following: system location name (i.e., WHALESNORTH or WHALESSOUTH), vessel name, INMARSAT (satellite communication identification) number, vessel call sign, report date and time, entry date and time, point of entry into these systems, vessel course (heading), vessel speed, destination port, estimated time of arrival at destination, and routing information (e.g., waypoints) (http://www.nmfs.noaa.gov/pr/shipstrike/msr.htm). At a minimum, routing information was provided as a system entry location and a destination. Routing information could also be provided as, or supplemented with, a series of waypoints. Because the data are self-reported and manually entered, these data are not error-free. As such, relevant data fields (entry date and time, entry location, vessel speed, destination port, and routing information) from the MSR reports were vetted before conducting analyses.

Data quality control

A number of data quality issues were identified when reviewing the incoming reports. Determining whether these issues resulted from misinterpretations of the reporting requirements or data entry issues was beyond the scope of this study. However, a number of actions were taken to address reporting errors. Some reports were sent multiple times; when duplicates were encountered only the most recently logged report was retained.

Other reports contained missing entry date and time data or had entry date and time values beyond the temporal bounds of the study period (July 1999 to December 2013). These were removed from our analysis, as were messages that lacked entry latitude and longitude values, had a value of 0 in the entry latitude and/or longitude field, or had invalid entry latitude/longitude values (not between −90 to 90 or −180 to 180, respectively). Reports with entry locations that were more than 5 nautical miles (nm) from a MSR boundary were not included. Some messages contained entry locations that were within 5 nm of a MSR system, but had identified the opposite system in their report (e.g., WHALESNORTH vs. WHALESSOUTH). In these cases, the identified MSR systems for these reports were changed to reflect the system corresponding to the provided entry location. Review of destination port data revealed a number of typographic errors and destination port name variants (e.g., BOSTON, BOSTONPILOT, BOSTOXN, BOSTONMA, BOSTOON). Reasonable efforts were made to resolve these typographic errors and variations.

To test whether transits associated with reported entry locations traveled through the MSR, at least one additional valid location (destination port or waypoint) was required so line features could be created and a spatial overlay performed (this was for validation purposes only and are not presented here). For trips with destination ports located within US waters, Morse Code Alpha (MoA) buoys associated with the port were used as destination locations; the Bureau of Transportation Statistics, National Transportation Atlas Database (NTAD) was used to determine coordinates for destination ports outside the United States. Reports that did not include a valid entry location and at least one additional valid location were removed from our analysis.

Line features were created for those reports containing a valid entry location and at least one additional valid location. For simple transits (those reports that included only an entry location and a destination port), line features were created by connecting a rhumb line from the entry location directly to the destination location. Line features for complex transits (those indicating an entry location and one or more waypoints) were created by connecting rhumb lines between the entry location, provided waypoints, and destination location (when available). For complex transits, initial waypoints that were coincident with the entry location were removed. Similarly, final waypoints coincident to provided destination locations were also removed. A spatial overlay was performed with the resulting transits to determine if they intersected the MSR system associated with their corresponding entry locations. Transits that did not intersect their corresponding MSR system were removed from the analyses. In addition, a visual examination of the transit line features indicated that some mariners submitted reports as they exited MSR systems (reporting that is not required). To remove reports of outbound trips, we included only those with at least 10 nm of travel within its corresponding MSR system.

Operators are also required to report vessel speed when entering the system. Some ships that provided waypoints also indicated speeds for a subset or all of the waypoints; however, for consistency purposes, only the entry speed (as required) was included in our analysis.

Transits that met all of the previously described criteria for inclusion, but reported initial speeds $\geq$50 knots were also excluded.

For the years 1999–2001, compliance requirements with the MSR were documented by the USCG during routine vessel boarding inspections after a vessel arrived in port and were conducted primarily in conjunction with safety and other vessel inspections. In these cases, mariners were asked to provide a 'hard-copy' of the return message sent to the vessel via the MSR. Since 2001, the USCG issued 106 civil penalties including warnings and financial penalties to non-compliant mariners. From 2003 to present, SANS data were incorporated into the MSR data base and compliance levels (i.e., each MSR vessel report as directly compared to SANS reports) were computed automatically. Therefore, for compliance rate information reported here, we used only 2003 to present data derived from these SANS-MSR incoming reports comparisons, which we regard as an accurate measure of compliance with the system.

From the vetted incoming reports, we analyzed the spatial and temporal distribution of vessel activity, including: the number of reports, compliance, reported destinations, and vessel entry speeds.

RESULTS

A total of 46,477 incoming MSR reports were logged between July 1999 and December 2013. Our data quality control eliminated 19,705 of these reports from analysis. We removed 6,505 reports that were either duplicate reports, lacked date information or indicated dates outside of the study period (July 1999 to January 2014), or whose entry latitude and/or longitudes were either missing or invalid (Fig. 2 provides examples of reports with erroneously indicated locations). As noted above, we restricted analyses to reports that included at least one valid location (e.g., a destination or waypoint) other than the entry location, provided an entry location within 5 nm of the MSR boundary, was associated with an currently active MSR area (applies to WHALESSOUTH only), and in which the ship made a trip that passed through the same MSR area as the area indicated in the incoming report. Based on these criteria, 2,091 reports were removed because they did not contain at least one valid location in addition to the entry location; 8,243 were excluded because they did not have entry locations within 5 nm of the closest MSR boundary; and 2,032 were removed because they were reported for WHALESSOUTH when this system was not active. We also eliminated 189 records because the trip did not intersect the MSR area as indicated in the report. Another 487 records were removed because they contained vessel speed values that were not between 0 and 50 knots; and 158 were excluded because they represented outbound transits. In sum, a total of 26,772 reports were used in the subsequent analyses.

Simple operator error appears to be responsible for a relatively large number of incorrectly formatted reports. For example, the grid of reports that surrounds the WHALESSOUTH reporting area, in which locations are offset by one latitude or longitude digit from the reporting area boundary (Fig. 2) suggests that operators inadvertently entered incorrect location information. In addition, a number of reports were submitted

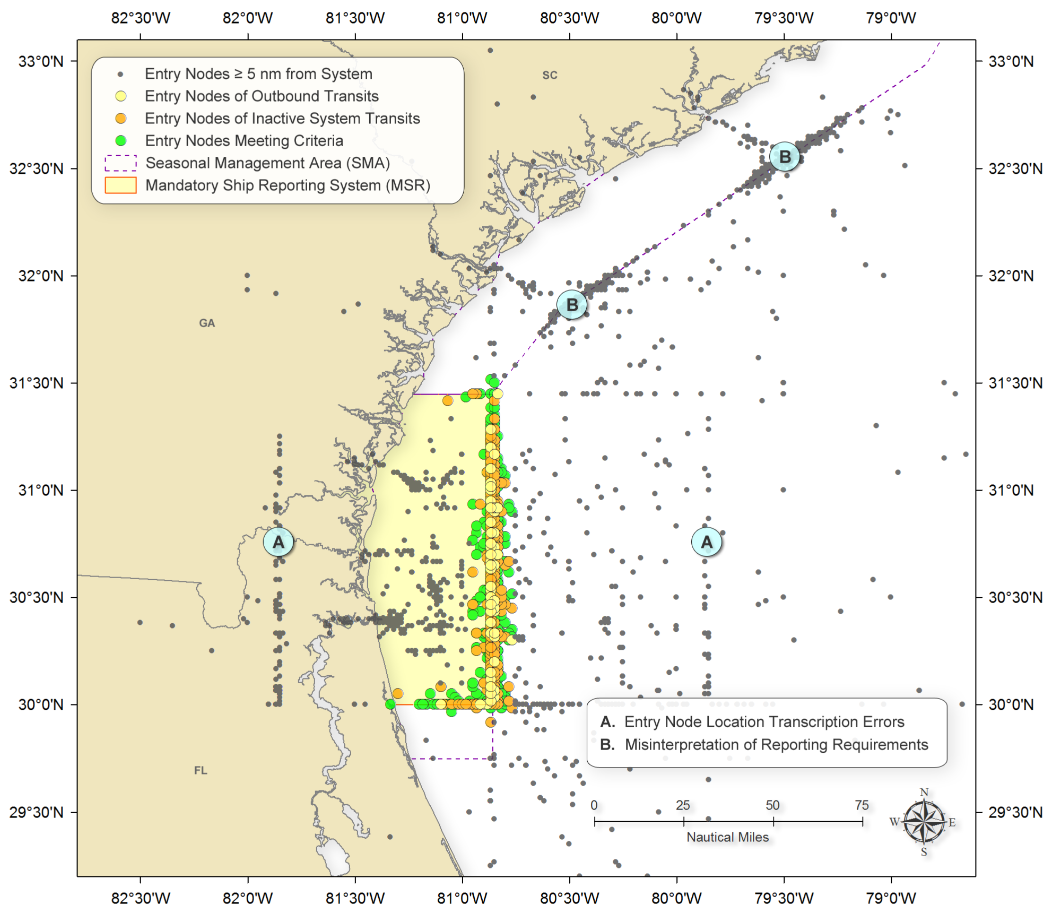

Figure 2 Locations of vessels reporting into WHALESSOUTH. Reports included in the analyses are depicted by green circles. Reports were excluded from analysis if they described outbound trips (yellow circles), were sent outside of the date ranges in which reporting was required (orange squares), or contained starting locations that were >5 nm from the system boundary (blue circles). Of those reports containing starting locations that were >5 nm from the system boundary, many appear to be the result of (A) location data entry errors or (B) reports that were mistakenly provided when entering a North Atlantic Right Whale Vessel Speed Restriction Seasonal Management Areas boundaries (B). Reports used in this study are depicted by green circles. Criteria for selecting these reports are described in Methods.

by vessels when entering vessel speed seasonal management areas instead of MSR reporting areas (Fig. 2).

Compliance with the south reporting system was below 70% for a number of years at the outset of our study, but after 2006 compliance in both systems remained generally constant, between 70% and 80%, each year thereafter (Fig. 3). With the exception of years 1999–2002, the total number of vetted incoming reports was greater in the WHALESSOUTH system than in the WHALESNORTH system (Fig. 4). The number of reports for WHALESSOUTH (excluding 1999 which was a partial year of data collection) ranged from 354 (in 2000) to 1,057 (in 2010) and averaged 791 reports per year. In WHALESNORTH, the number of reports (excluding 1999) ranged from 724 (in 2013) to 1,446 (in 2007) and averaged 1,084 reports per year. Monthly counts for WHALESSOUTH

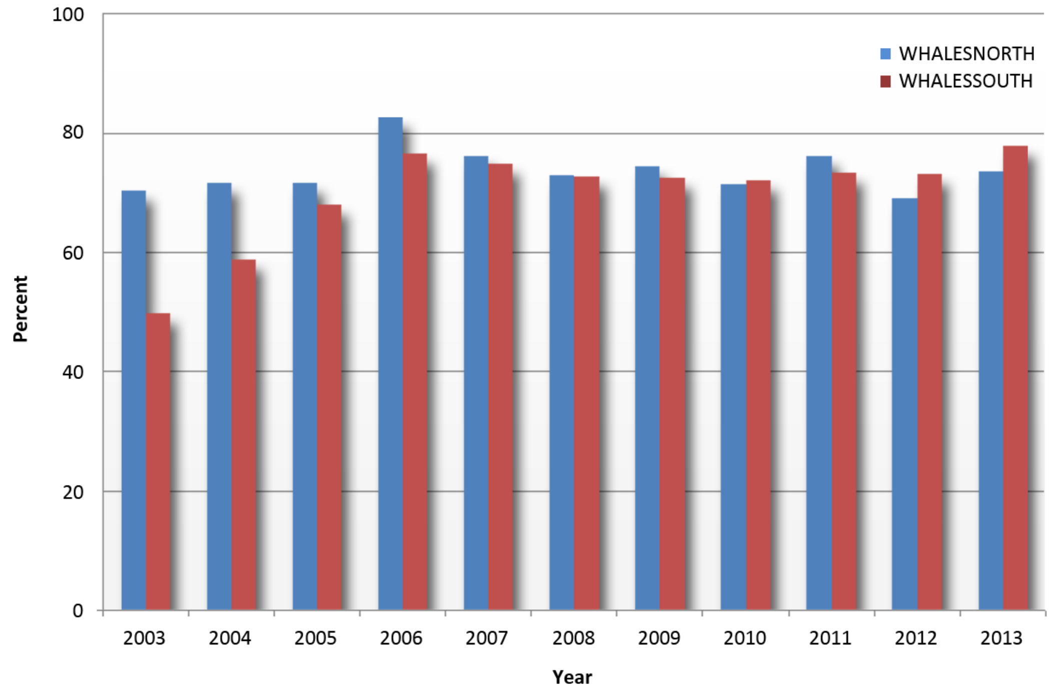

Figure 3 **Compliance rates for WHALESNORTH and WHALESSOUTH using MSR reports as compared to USCG SANS data (see text for explanations).**

averaged 156 reports with a range of 61 (in March 2001) to 216 (in December 2006) (partial months of April and November not included). In WHALESNORTH, the average number of reports monthly was 90 and ranged from 39 (in December 2013) to 174 (in September 2007).

The city of Boston and its associated suite of terminals and ports were listed as the destination for a total of 8,823 vetted reports (Table 1). Jacksonville, Florida and Brunswick, Georgia accounted for a combined total of 9,965 reported destinations in WHALESSOUTH, and constituted the second and third highest, respectively, of all reported destination ports (Table 1). Nearly all ships entering WHALESSOUTH were bound directly for southeast US ports (Table 2), while many vessels entering WHALESNORTH were traversing the area in route to locations outside the reporting area, such as ports in Maine, Canada, mid-Atlantic US states, South and Central America, and the Caribbean (Table 3).

The number of reports annually into WHALESSOUTH generally increased through 2007 and remained relatively constant thereafter (Fig. 4). Following a steady increase in the number of reports that peaked in 2007, the number of WHALESNORTH reports decreased annually beginning in 2008 (Fig. 4). A 2007–2013 annual decline in reports into WHALESNORTH appears to be driven both by the number of ships bound for Boston and, more strongly, by vessels traversing this system in route to locations outside of the area (Fig. 4). A modest seasonal signal is evident for WHALESNORTH for all years,

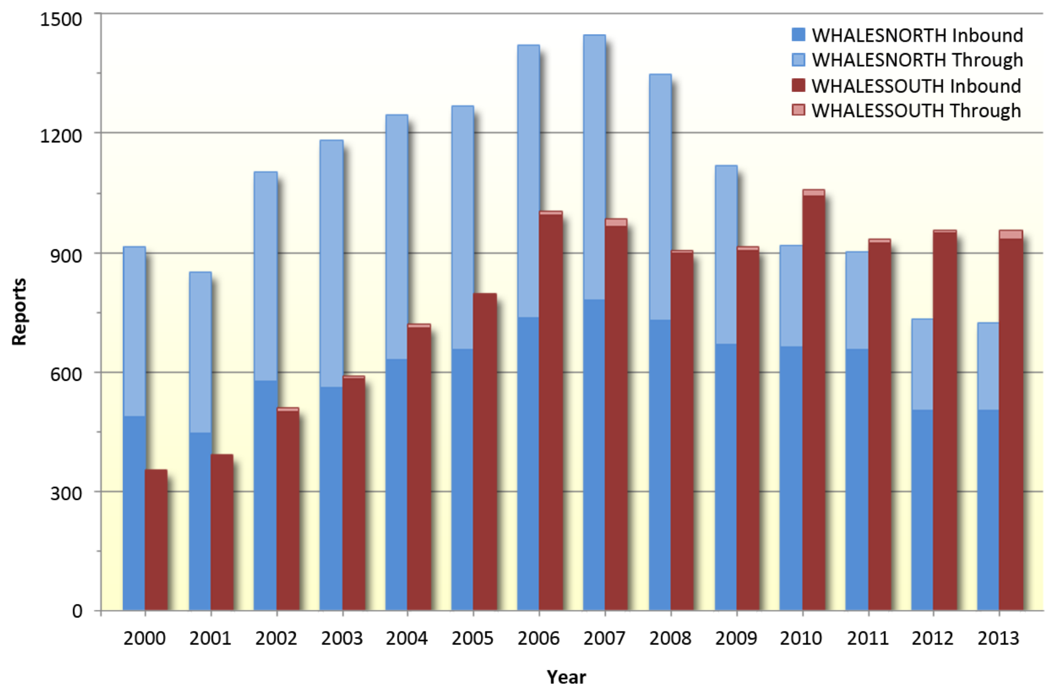

Figure 4 Number of reports into the MSR (meeting data quality criteria described in Methods) for WHALESNORTH and WHALESSOUTH, 1999–2013. Indicated are trips with reported destinations within the reporting area and those that indicated the vessel was traveling through the system to a destination outside the reporting area.

Table 1 Number of reports into the MSR (meeting data quality criteria described in Methods) associated with destinations within WHALESNORTH and WHALESOUTH.

Destination	MSR	Reports
Boston and related ports[a]	WHALESNORTH	8823
Jacksonville, FL	WHALESOUTH	7803
Brunswick, GA	WHALESOUTH	2162
Fernandina Beach, FL	WHALESOUTH	835
Kings Bay, GA	WHALESOUTH	258

Notes.
[a] This includes a relatively small number of reports that indicated destinations within or in areas adjacent to the Boston Harbor, including for example, Braintree, Salem, Gloucester, Rockland, Buzzards Bay, Cape Cod Canal, and Provincetown.

whereby the number of reports tended to be consistently higher July–October, and in December–January than in other months (Fig. 5).

Reported ship speeds ranged from 5 to over 20 knots, with the majority between 10 and 16 knots (Figs. 6 and 7). The distribution of ship speeds reported for WHALESSOUTH differed from WHALESNORTH, with the former appearing to be roughly bimodal around 10–12 and 14–18 knots and the latter more closely approximating a bell-shaped distribution. Reported ship speeds shifted lower in both locations in 2009 to 2013 following implementation of required vessel speed restrictions (Figs. 7A and 7B).

Table 2 **Number of reports into the MSR (meeting data quality criteria described in Methods) associated with destinations outside of WHALESNORTH and WHALESOUTH, summarized by region.**

	WHALESNORTH		WHALESSOUTH	
Destination	**Reports**	**% of Total**	**Reports**	**% of Total**
US Ports	4480	66.4	94	68.3
Canada	1406	20.8	1	0.7
Central/South America	252	3.7	3	2.2
Caribbean	157	2.3	1	0.7
Europe	49	0.7	0	–
Middle East	1	–	0	–
Africa	1	–	0	–
Asia	1	–	0	–
Not reported	396	5.9	39	28.3

Table 3 **Number of reports into the MSR (meeting data quality criteria described in Methods) associated with domestic destinations outside of WHALESNORTH and WHALESOUTH, summarized by region.**

	WHALESNORTH		WHALESSOUTH	
Destination	**Reports**	**% of Total**	**Reports**	**% of Total**
New England	1882	42.0	0	–
Mid-Atlantic States	1839	41.1	15	16.0
Florida/Georgia	671	15.0	74	78.7
Gulf of Mexico	88	2.0	5	5.3

DISCUSSION

Value of the MSR

The MSR was established to reduce the threat of vessel collisions with right whales and has provided a means to alert mariners to this threat for over 15 years. While reporting is required for vessels entering the prescribed MSR area, our analysis relies on accurate self-reporting. We did not analyze those records that contained information falling outside the reasonable range of values for the reporting variables. Aside from this, no attempts were made to confirm the veracity of the information contained in the messages; and, prior to the emergence of vessel tracking technologies, there were little or no means to do so. In sum, only about 60% of the total incoming reports were used for the purposes of this study. These limitations notwithstanding, we believe these data represent a reasonable characterization, in relative numbers, of vessel operations in these areas over the 15-year study period.

Regardless of reporting issues or data entry accuracy, reporting vessels received a return message containing right whale conservation information. Thus, the MSR has provided an important function: vessels associated with the over 46,000 incoming reports

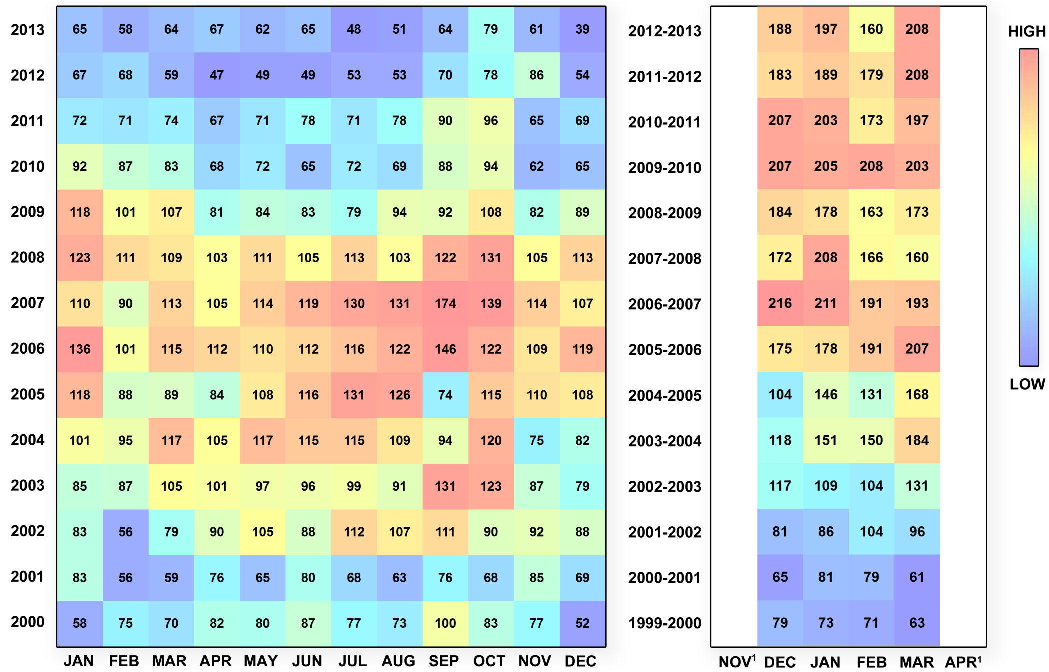

Figure 5 Temporal heatmap depicting the number of reports into the MSR (meeting data quality criteria described in 'Methods') for WHALESNORTH and WHALESSOUTH, by month/year.

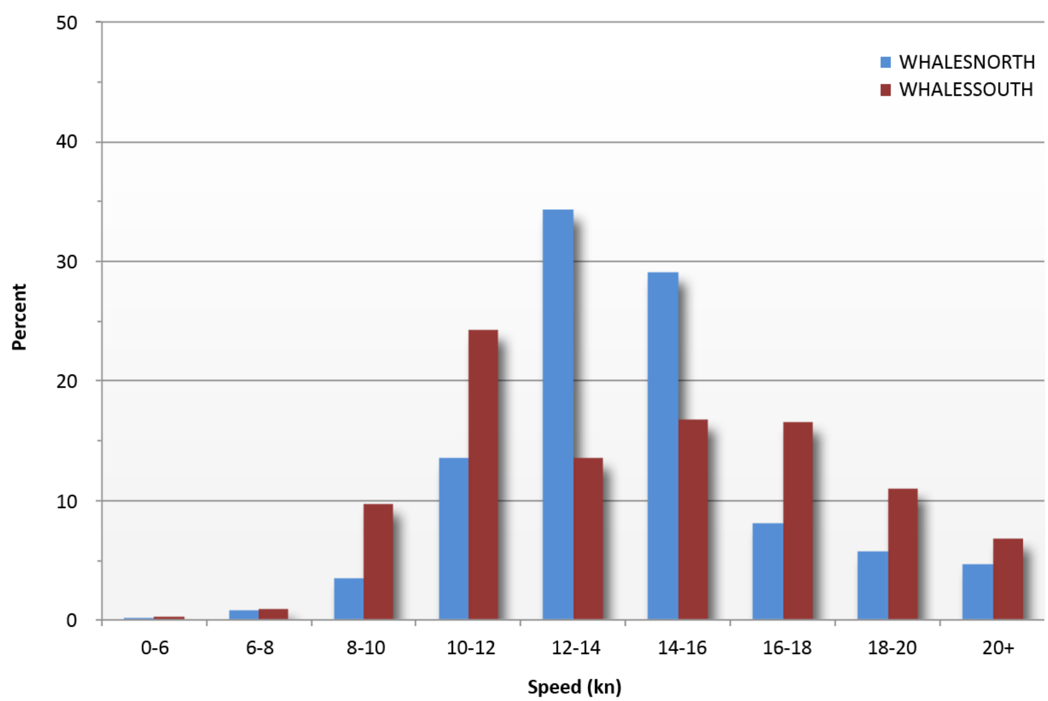

Figure 6 Reported vessel speeds for WHALESNORTH and WHALESSOUTH, 2000–2013.

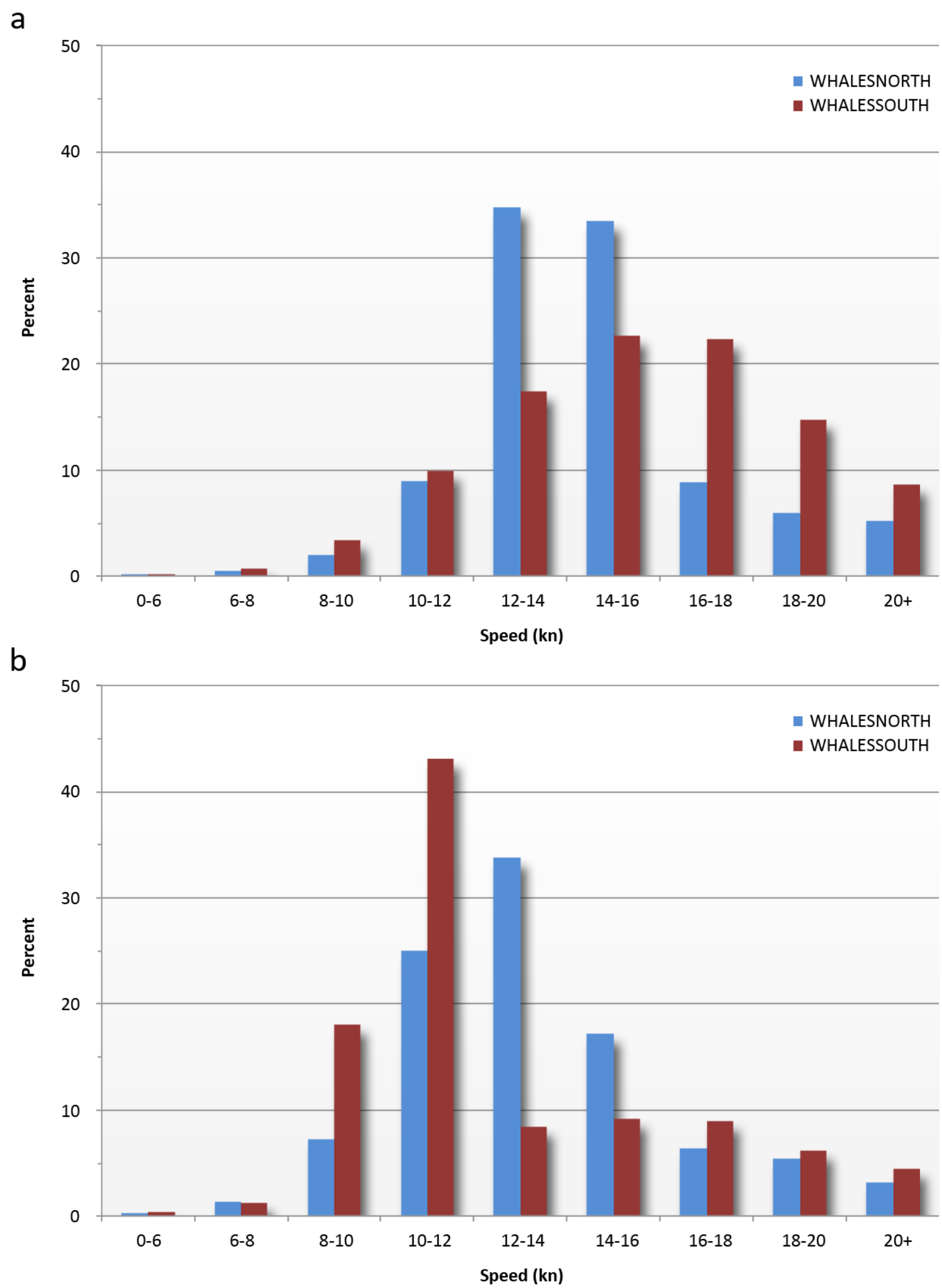

Figure 7 **Reported vessel speeds for WHALESNORTH and WHALESSOUTH in (A) 2000–2009 and (B) 2009–2013.**

received messages delivered directly to the ship's bridge—hundreds of messages each year—regarding right whale vulnerability to collisions by ships.

Reporting compliance rates have been generally constant throughout the 15-year period, with a majority of the required vessels reporting. Due to finite resources and the need to focus on multiple priorities, the USCG has not fined non-reporting vessels since 2006—it has also relied on outreach/education and non-financial civil penalties to encourage compliance. While it is important to enforce any requirement, the MSR program was not intended to be punitive. Instead, the goal of the program was to communicate information and raise awareness.

Clearly, there is some confusion for some mariners about where the MSR reporting areas are located (relative to vessel speed restriction areas, for example) and what is required of them when reporting (Fig. 2). For example, we are told, anecdotally, that ocean-going tug boat operators may report on occasion but not always, when their tug/barge combinations exceed 300gt, but the tug itself does not—representing another example of a lack of clarification about reporting. Improved information and outreach about MSR locations and requirements would improve this situation and would likely enhance the conservation value of the system. In addition, simplifying the reporting format might help reduce transcription errors observed in the data.

WHALESNORTH vs. WHALESSOUTH

The two reporting areas differed in overall size and the times/duration that they were in effect; and their proximity to various ports had an influence on the character of the trips through each area. When compared to WHALESOUTH, a far greater number of reports for WHALESNORTH indicated trips destined for locations outside the system, including ships bound for various New England ports as well as those that may have been engaged in trade with a variety of US ports, the Caribbean, and European nations (e.g., those inbound for New York from across the Atlantic Ocean) and other trading partner countries (Tables 2 and 3). For these reasons, aggregated vessel operation information for this area (particularly those on voyages through the area) may provide a unique glimpse into patterns regarding commercial shipping activities and international trade, and provide information relative to right whale feeding and socializing aggregations subjected to this ship traffic. It is noteworthy that the overall (and, in some years, the annual) number of reports into WHALESOUTH exceeded those in WHALESNORTH considering the former is operational for only a portion of the year and is smaller in size than the latter, reflecting the importance of the volume of port calls in this region and its implications for key right whale nursery areas. A steady increase (in years 2000–2006) and then a leveling (2007–2013) in the number of reports by vessels entering WHALESSOUTH may reflect the steady or sustained growth of demand for products and services (which includes, for example, popular cruise ship destinations (*MARAD, 2012*), and containerized, "break bulk" and automobile cargos (*Martin Associates, 2013*) and the importance of these commodities to the economy of this region and adjoining in-land areas.

Ward-Geiger et al. (2005) provided an analysis of MSR reports, ship tracks, and vessel speeds for July 1999 to June 2002. The distribution of reported ship speeds in our study is generally similar to those presented by these authors, although we found somewhat differing distributions in average speeds in the south versus the north reporting areas. It is not clear why speed distributions differed in the two areas, although adherence with the 2008 vessel speed restrictions (NMFS, 2008) was almost certainly a factor, particularly as compliance with these regulations improved (Silber et al., 2014). Virtually all ships entering the south reporting area were subject to required speed limits after 2008; however, because the north reporting area is not completely concurrent in time and space with speed restriction areas, not all vessels reporting into the north system were subject to the restrictions. Other factors may also contribute to differences in speed distributions, including possible differences in the composition of shipping in the two areas, but assessing additional factors is beyond the scope of our analysis.

Trends in shipping

Various authors have indicated that the number of large vessels and volume of maritime transport have steadily increased for decades and that continued growth is expected for the foreseeable future (e.g., Corbett, 2004; Dalsøren et al., 2007; Vanderlaan et al., 2009). While these observations may be generally true, they are not borne out in the MSR data, which indicate little or no growth (in the south reporting area) or a decline (in the north) in the number of reporting vessels from 2008 to the end of the study period, presumably reflecting the amount of east coast ship passages and commerce. Thus, the expected trend in traffic volume may be reversing.

The decrease in the number of reports for vessels entering, and in some cases travelling through, the WHALESNORTH area (Figs. 4 and 5) coincides with the "great recession" of 2008–2009 and related global economic dynamics. In 2009, Gross Domestic Product growth dropped 0.6% throughout the world (Labonte, 2010). Between 2008 and 2009, the volume of merchandise trade in the United States declined by 14.0% and 16.4% for exports and imports, respectively; global import and export merchandise trade values likewise fell (UNCTAD, 2013). As global demand for goods declined, the entire supply and delivery chain slowed. The effects of the 2009 recession were largely reversed in 2010 with modest but steady growth in subsequent years, whereby port calls in most locations (MARAD, 2013) and maritime trade and shipping activities returned to or exceeded pre-2007 levels by 2011 (Ex-Im Bank, 2014). The port of Boston was an exception, where imports, as measured by total shipping weight, exhibited a steady decline from a peak in 2004 (NOEP, 2014).

Several factors may be involved in the sustained 2009–2013 annual decline in MSR reports, although determining with certainty the role, if any, of these factors is beyond the scope of this study. The decrease in reports may reflect a continued eroding of commercial shipping activities. However, this seems unlikely as many shipping activities (MARAD, 2013) and most international economies had begun to rebound to pre-recession levels by mid-2010.

Two additional right whale conservation measures, vessel speed restrictions in waters along the US eastern seaboard in December 2008 (*NMFS, 2008*) and establishment of an Area To Be Avoided (ATBA) in Great South Channel in July 2009 (*Silber et al., 2012*), may have resulted in modifications of vessel operations or diminished reporting into the MSR. Speed limits may have caused some ship operators to refrain from reporting (perhaps for fear of retribution for reported ship speeds); however, MSR compliance information (as a function of the rather rigorous USCG-SANS 96-hour call-in requirements) (Fig. 3) suggests that the number of reporting ships, relative to those actually making port calls, remained relatively constant after these regulations were established. No strong declines in numbers of trips or vessels in the seasonal management areas were apparent (although modest declines may have occurred in 2012 and 2013) after speed restrictions took effect (*Silber et al., 2014*), suggesting that operators did not avoid these areas. In addition, we made a cursory examination of vessel AIS data to examine traffic movement in and around the ATBA and found no obvious modifications of routes that would have taken vessels outside MSR reporting areas.

Instead, we believe the MSR reporting data were influenced, at least in part, by significant changes in the composition of the industrial fleet and trade in energy-related commodities. For example, in anticipation of the expansion of a number lock chambers in the Panama Canal, the use of "Post-Panamax" vessels has expanded in recent years. Capable of carrying up to three times the amount of bulk and containerized cargo as most ships currently in use (*Rodrigue & Notteboom, 2012*), increased use of Post-Panamax vessels is a harbinger of an era in which the transoceanic involves transport of enormous amounts of goods. This will reduce the number of required trips. Post-Panamax ships accounted for 17% of all containership calls at US ports in 2006 and 27% of all US calls in 2011 (*MARAD, 2013*). From 2006 to 2011, the average vessel size per US port call increased (and the average age of ships in the world's fleet dropped as new large ships are built and put into service) (*DOT, 2013*), while calls by smaller vessel classes decreased (*UNCTAD, 2013*). Therefore, an increased use of large ships may account, at least in part, for the reduction of reports into the MSR. Ports in New York and New Jersey, Baltimore, Maryland, and Mobile, Alabama have already dredged their harbors to accommodate these large ships, while Savannah, Georgia, Charleston, South Carolina, and Jacksonville, Florida either have channel modifications underway or planned for this purpose.

Another large scale shift in US imports/exports took place in this same period. Natural gas and crude oil production in the United States has steadily increased in the last five years with the development of new (primarily shale gas) sites and with increased use of hydraulic fracturing and horizontal drilling technologies (*EIA, 2014a*; *Humphries, 2014*). As a result, US natural gas imports have declined annually since 2007; in 2009, for the first time, the country's domestic gas and oil production outpaced its imports (*EIA, 2014b*). The Marcellus shale gas field of Pennsylvania and West Virginia, alone, yielded virtually no natural gas in 2007, but is projected to provide nearly one-quarter of the United States' gas in 2015. As sources and destinations for oil have rapidly evolved (*PIRA, 2014*) the complexion of water-borne shipment of these commodities has shifted in the areas we studied and elsewhere. As one example, liquefied natural gas (LNG) imports from Trinidad/Tobago (the largest LNG exporter to the United States (*EIA, 2014b*)) to Everett, Massachusetts (a destination port in our data) declined each year from over 180 million cubic feet in 2007 to 52 million cubic feet in 2013 (*EIA, 2014b*). In addition, a number of locations, including the ports of Saint John, New Brunswick, Canada (which hosts Canada's largest crude oil refinery; *Tremblay , 2013*) and those in Trinidad/Tobago and Venezuela (crude oil) MSR reported destinations for ships passing through WHALESNORTH. Although our data lack sufficient specificity (e.g., vessel type designations) to allow definitive statements regarding shifts in oil/gas trade, we believe the observed 2009–2013 declines in vessel reports reflect the profound, ongoing changes in the transport of these materials.

Considerable variation becomes clear when numbers of reports are considered on a monthly basis (Fig. 5). In some years, certain seasonal fluctuations also appear to be occurring which may reflect influxes of passenger, cruise, and large recreational vessels in summer; or the movement of heating oil or other seasonally-important commodities through WHALESNORTH.

In addition, several months exhibited atypically low numbers of reports relative to months that preceded or followed it—or in the same month in other years. This pattern may be attributed to hurricane activities and other significant large scale events that limited maritime commerce. For example, one of the lightest reporting months (relative to the same month in other years) occurred in September 2005 (Fig. 5) when hurricanes Katrina (making landfall 30 August 2005) and Rita (landfall on 25 September 2005) battered Gulf of Mexico coasts, keeping ships in port or at sea to avoid the storm and slowed or stopped production of Gulf coast oil refinery facilities. August and September 2004 were also relatively light reporting months relative to those same months in other years coincident with four Category 2 or greater hurricanes that struck the Gulf of Mexico, Florida, and mid-Atlantic state coastlines. In contrast, we see no particularly strong signal in the number of reports from hurricane Sandy (October 2012) and other storms that brought destruction on large geographic scales. The Gulf of Mexico's Deepwater Horizon oil spill beginning in late April 2010, and related activities to rescue lives and contain oil, likely disrupted supply chains and contributed to reduced vessel activities in the Gulf and elsewhere and may account for relatively fewer MSR reporting in May and June of that year relative to the same months in other years.

Shipping activities and right whales

Regardless of reasons for shifts in composition and evolving practices in international shipping fleets, reductions in the relative amount of ship traffic in the last five years likely resulted in important consequences for right whales and other large whale species. Several authors have reported that the economic downturn of 2008–2009 resulted in reduced ship traffic and, consequently, a corresponding decrease in the amount of oceanic noise as introduced by large ships (*Andrew, Howe & Mercer, 2011*; *McKenna et al., 2012*; *Miksis-Olds & Bradley, 2013*).

And related to this, *Rolland et al. (2012)* reported that the absence of ships following the terrorist attacks in the United States on 11 September 2001 resulted in less underwater noise and lowered baseline levels of stress-related hormone metabolites (glucocorticoids) in right whales in the Bay of Fundy, Canada. These and other authors noted the strong link between chronic elevations of glucocorticoids and suppressed immune systems, impaired individual health, and population declines in a number of vertebrate populations (e.g., *von der Ohe & Servheen, 2002*; *Romero, 2004*). However, unlike the Bay of Fundy study, when comparing (a) two-week periods before and after the 11 September 2001 terrorist attacks, and (b) September 2001 to that month across all years, we found no change in the number of ship reports including those reporting northbound transits into Canadian waters.

More generally, assuming that (a) the MSR data are truly indicative of relative levels of (and declines in) shipping activity in US northeast ports, and (b) these declines are accompanied by a decrease in radiated ship noise in waters in and around New England, the Canadian maritime provinces and perhaps elsewhere throughout range of right whales, then the species may have been exposed to a soundscape and disturbance from noise that the species has not experienced for nearly two decades. Therefore, declines in supply and demand for certain goods may have resulted in increasingly hospitable right whale habitat.

A decrease in the number of ship transits would also suggest that right whales and other large whale species have experienced lowered exposure rates to the potential for fatal collisions with large vessels. Recent decreases in both the number (*Laist, Knowlton & Pendleton, 2014*) and probability (*Conn & Silber, 2013*) of fatal ship strikes of right whales has been attributed to the 2008 creation of vessel speed restrictions in right whale habitat. However, a reduction in the actual number of trips in these areas may also have had a role in reducing strikes. Known fatal right whale/vessel collisions occurred at an average rate of 1.0 per year in 1996 to 2001; increased to 1.7 per year 2002 to 2007; and fell to 0.5 per year 2008 to 2013 (*MMC, 2014*).

SUMMARY AND CONCLUSIONS

Submitting a message into the MSR is required for certain vessel classes, but the content and accuracy of these messages rely on "good faith" self-reporting. Numerous reports contained mistakes such as transcription errors. Errors in incoming messages notwithstanding, all reporting ships received a return message; and hundreds of messages were sent to reporting ships each year since the MSR's inception. For this reason alone—and because it was one of the first formal measures aimed at reducing the threat of ship collisions with right whales—the MSR has probably provided an important function in notifying a broad international community about vessel/whale collisions. Steps should probably be taken to better equip ships' captains and mates about reporting requirements and to further enhance the overall conservation value of the information provided through the program.

The MSR has also provided a relatively long time series characterization of shipping operations that, in part, pre-dates more rigorous vessel monitoring programs and technologies. We believe the data set of accurately entered and transmitted reports provides a reasonable15-year representation of maritime transportation activities in these areas.

Among other things, reported speeds were largely consistent with those determined from remote monitoring programs and reflect the maritime community's response to additional measures to minimize right whale ship-strike rates.

If the number of incoming reports is truly indicative of shipping practices, a number of economically-driven changes in marine transportation activities, as well as large scale meteorological events, appear to be reflected in the data. Although we are not able to determine their role with certainty, it appears that global and industry-wide events may have had unanticipated benefits in reducing shipping-related impacts to right whales. Among these, a troubled worldwide economy in the late 2000's and slowed or diminished supply chains that move various commodities such as oil and gas resources likely reduced the overall amount of ship traffic. Industry-wide shifts toward larger ships conveying containerized goods have also altered the complexion of maritime transport during our study period. As a result, right whales may have been exposed to a lowered risk of collisions with ships and levels of anthropogenic underwater noise disturbance that the species has not experienced for nearly two decades.

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Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Gregory K. Silber conceived and designed the experiments, performed the experiments, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Jeffrey D. Adams performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Michael J. Asaro, Timothy V.N. Cole, Katie S. Moore, Leslie I. Ward-Geiger and Barbara J. Zoodsma wrote the paper, reviewed drafts of the paper.

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RIGHT WHALES

North Atlantic Right Whale off the Coast of France

Friday, July 5, 2019 by Heather Pettis

While the last few weeks have been consumed with the devastating news of six right whale deaths in the Gulf of St. Lawrence, our hearts were lifted by the discovery of a very exciting and unusual sighting last week. While four of us were attending a workshop on right whale health in Washington, D.C., we received an email suggesting that there was a recent video posted on social media of a right whale feeding off the coast of FRANCE! We were a bit skeptical at first. It's not unusual to come across images and videos misidentified as right whales or attributed to incorrect locations.

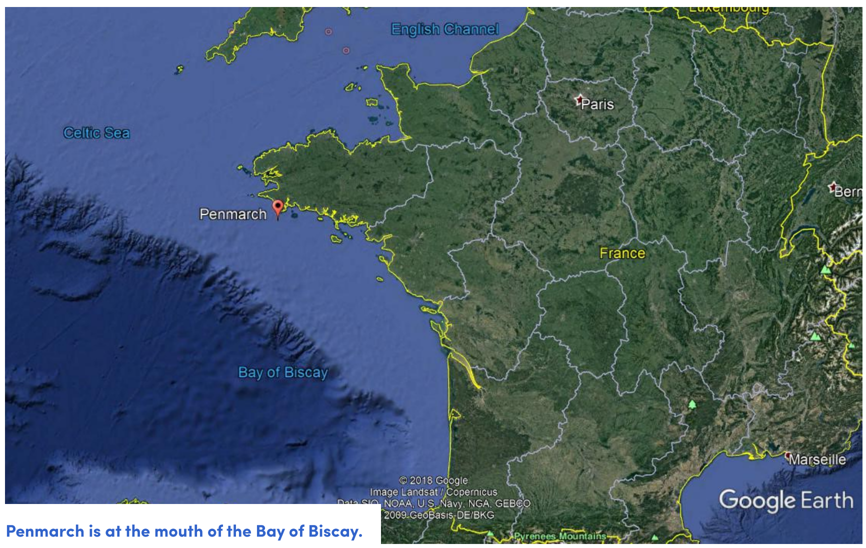
After a bit of sleuthing and enlisting the assistance of a French translator, we were able to connect with the person who had posted the video and confirm that yes, they had in fact observed a right whale feeding off Penmarch on the northwest coast of France on Friday, June 21. The video quality was excellent and as such, we were able to identify the right whale as **Catalog #3845** (**Mogul),** an 11-year-old male.

Mogul in the Bay of Fundy. Credit: Monica Zani, Anderson Cabot Center-NEAQ.

Mogul is a whale we know well. Born in 2008 to #1245 (Slalom), Mogul has been sighted in many of the "typical" right whale habitats throughout his life, including the southeast U.S., Cape Cod Bay, Great South Channel, and the Bay of Fundy. However, he threw us all for a bit of a loop when in July 2018 he was sighted by a whale watch boat off the coast of Iceland! With this recent sighting off the coast of

France, we initially assumed that Mogul had taken an extended long-distance walkabout. However, we just confirmed that he was seen repeatedly in Cape Cod Bay in March, just three months ago and nearly 3,200 miles away, so this in fact is his second trans-Atlantic walkabout in a year!

Mogul in Iceland! Credit: Guðlaugur Ottesen Karlsson, Elding Adventure at Sea.



Penmarch is at the mouth of the Bay of Biscay.

While this is the first contemporary sighting of a right whale off the coast of France, Penmarch sits at the northern part of the Bay of Biscay, where the Basque whalers were the first to hunt North Atlantic right whales beginning in the 11th century. Prior to these whaling efforts, North Atlantic right whales existed in large numbers in the eastern North Atlantic, ranging from the northern coast of Spain to Norway, including the Bay of Biscay. However, after several hundreds of years of intense activity, whalers effectively eliminated the eastern population.

There have been a handful of right whale sightings in the eastern North Atlantic over the last few decades, but these are primarily whales from the western stock taking long walkabouts like Mogul. Thankfully, Mogul is safe from whaling, but we do worry about other threats he may face on his journey, including entanglement in fishing gear and vessel strike. We are keeping our fingers crossed for a safe journey for Mogul and look forward with great curiosity to seeing where he is sighted next!

Learn more about our Right Whale Research.

Tags: right whales, unusual sighting location

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News | Iceland Monitor | Wed 25 Jul 2018 | 10.04 GMT

Rare Right Whale Spotted in Iceland

Right whales are rarely spotted in Icelandic waters. *AFP*

A North Atlantic right whale was spotted by whale watchers onboard a boat from Elding Whale Watching on Monday. On the company's website, photos of the whale were posted yesterday, along with information about this rare, protected species.

The whale has since been identified by experts. "We now know which right whale was spotted off Reykjanes peninsula and near Reykjavík [Monday morning]," Gísli Víkingsson, a whale expert at the Icelandic Marine and Freshwater Research Institute, told *Morgunblaðið*. "My colleagues in the US recognized it from a picture as a ten-year-old male, on his first trip to Iceland, but who has previously always traveled to Canada in the summer." Gísli reports that the whale comes all the way from the waters of Massachusetts in the US.

The skipper, Guðmundur Falk, who spotted the whale, describes it this way: "I had brought tourists out by Hrafnkelsstaðir when I spotted the whale, and I had no idea what species it was. I had no time to take a picture, but notified others right away and told them where I thought it would swim."

His calculations were right, and about 2 pm the same day, Guðlaugur Ottesen Karlsson, who also is a skipper for Elding, caught a picture of it just off Akranes. The whale was spotted again in Faxaflói bay and appeared to be healthy.

North Atlantic right whales are an endangered species, protected since the 1930s, and rarely seen elsewhere than off the east coast of North America. Despite being protected, they are the rarest of all whales, counting only 300-500 animals.

The whale derived its name from being regarded by whalers as the “right” whale to kill on a hunt. It was an easy prey, for it swims slowly and, moreover, it was easy to transport to port after being killed, since its thick blubber made it float.

Whales Whale Watching

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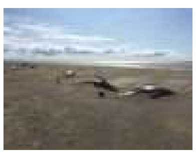
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FINAL REPORT

Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule

Update of Economic Impact and Scoping Assessment for Study of Potential Modifications

SUBMITTED TO
National Oceanic & Atmospheric Administration (NOAA)
National Marine Fisheries (NMFS)
Office of Protected Resources

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1. Introduction

Background

On December 9, 2008, the Right Whale Ship Strike Reduction Rule (Rule) issued by the U.S. National Marine Fisheries Service (NMFS) went into effect. The rule requires certain vessels to travel at 10 knots or less in certain areas of right whale aggregation and near several key port entrances along the U.S. eastern seaboard.

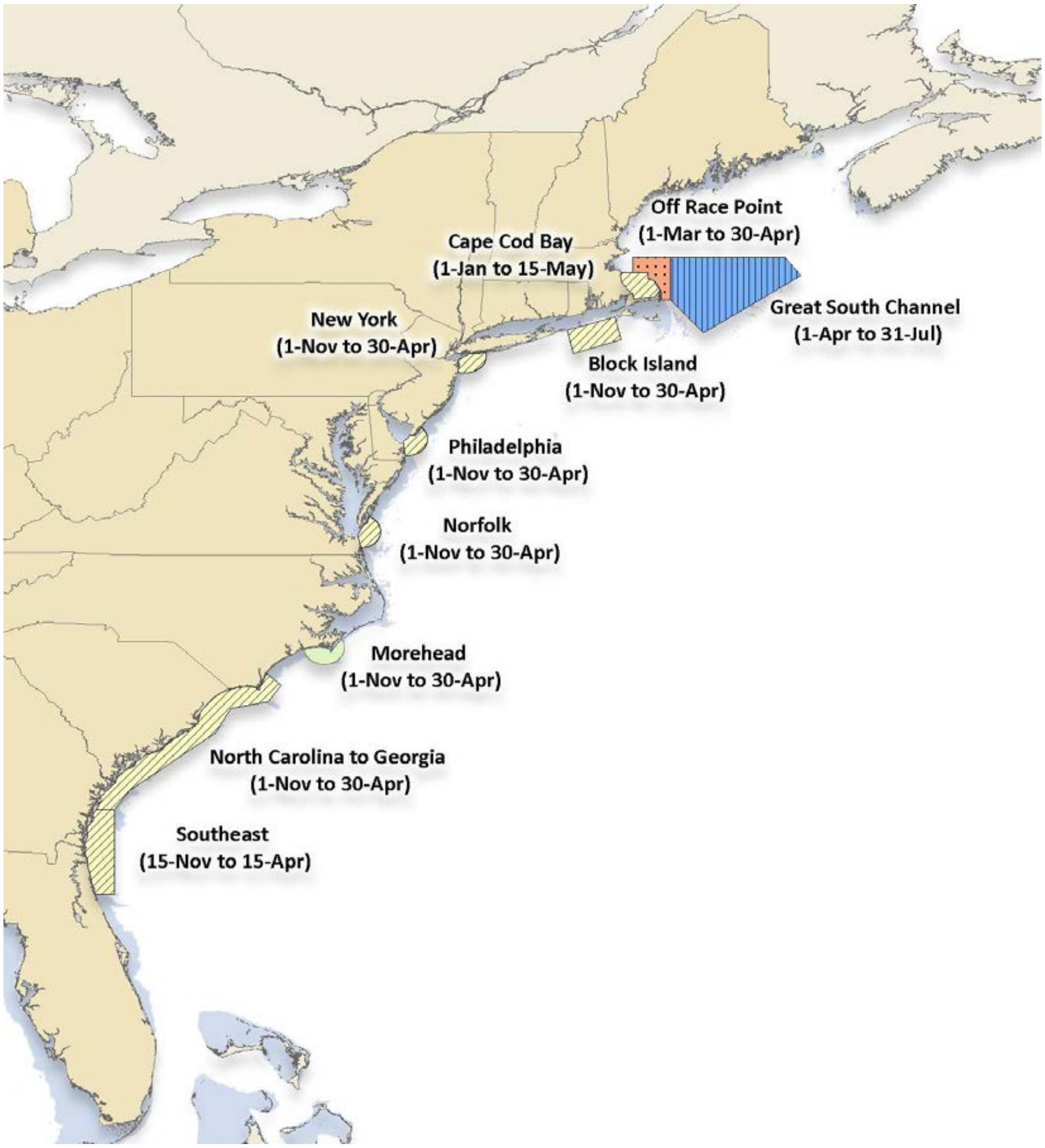
The U.S. National Marine Fisheries Service's (NMFS) Final Rule to reduce the severity and likelihood of vessel strikes to North Atlantic right whales went into effect on 9 December 2008 (73 FR 60173; 10 October 2008). The stated goal of the rule was "*to reduce or eliminate the threat of ship strikes [of North Atlantic right whales] - the primary source of mortality in the endangered population*." It requires that vessels 65 feet and greater in length travel at speeds of 10 knots or less near several key port entrances and in certain areas of right whale aggregation and along the U.S. eastern seaboard, known as "Seasonal Management Areas" (SMA) (Figure 1- 1).

As indicated in the preamble to the rule, a program of "Dynamic Management Areas" (DMA) was also established whereby temporary zones (15 days in duration, generally) are created around aggregations of right whales occurring outside of SMAs. Mariners are asked, but not required, to either avoid established DMAs altogether or travel through them at speeds of 10 knots or less.

The rule is set to expire five years from the date of its publication. NMFS indicated that it would develop ways to monitor the effectiveness of the rule. This report presents an updated assessment of the estimated economic impact of the Rule. In large measure, the economic impact assessment is based on the approach and analysis presented in the FEIS Report, Economic Analysis for the Final Environmental Impact Statement of the North Atlantic Right Whale Ship Strike Reduction Strategy prepared by Nathan Associates Inc. for NMFS in August 2008.

Whereas the economic analysis included in the FEIS report were based on assumptions regarding the impact on vessel operations, this updated assessment is based on actual vessel operations recorded during periods when the rule was in effect and not in effect. There are also several important data and analytical improvements that are incorporated in the present assessment that are further described herein.

Figure 1-1. Locations of Vessel Speed Restriction Seasonal Management Areas



General Approach

Our approach for the estimation of the potential economic impact of the proposed operational measures of the Rule has been designed so that results can be identified and analyzed at a summary level or disaggregated by port area, vessel type, vessel size, and vessel flag. An ancillary benefit of this approach is that it also enhances the accuracy and rigor of the analysis. Key factors such as vessel operating speed vary significantly by vessel type and size; vessel operating costs vary by those vessel characteristics as well as flag of registry. For this study, we have used 10 knots as the base case.

As depicted in Figure 1-2, our general approach is organized into the following four principal tasks:

Task A. Identify and analyze vessels affected by the final rule. Detailed information regarding vessels transiting SMAs during 2009 was obtained from the U.S. Coast Guard's Automatic Identification System (AIS) database. Vessel transits were analyzed for 10 SMAs on the U.S. East Coast, 12 vessel types, 18 vessel DWT size ranges and U.S. and foreign flag registration.

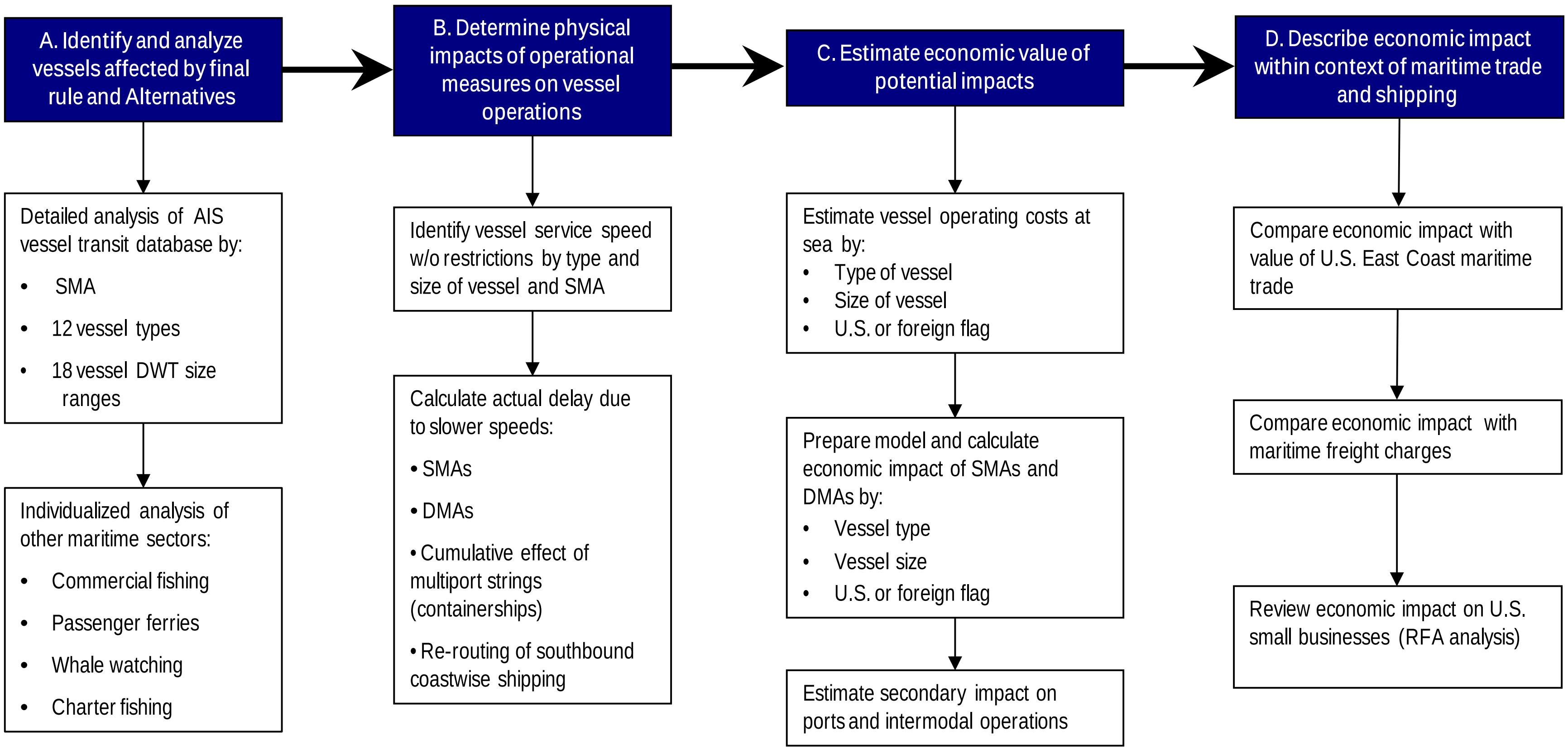
Task B. Determine physical impacts of operational measures on vessel operations. Key information include vessel service speed by type and size of vessel for periods when the SMAs were not in effect as compared to when they were in effect. Similar information was analyzed for DMAs. Results of this task include estimate of minutes of delay per vessel transit for SMAs and DMAs.

Task C. Estimate economic value of potential impacts. Key data include vessel operating costs at sea by type and size of vessel and whether U.S. or foreign flag registry. Results include detailed estimates of economic impact of speed restrictions by SMA, vessel type, vessel DWT size range, and flag of registration.

Task D. Describe economic impact within context of U.S. East Coast maritime trade and shipping. The estimated economic impact is assessed relative to the value of maritime trade and relative to maritime freight charges. We also conducted separate economic impact analyses for sectors not sufficiently included in the AIS database such as whale watching vessels, passenger ferries, commercial fishing and charter fishing.

Chapter 2 provides a detailed assessment of the impact of the rule on the shipping industry, while Chapter 3 presents the assessment on other maritime sectors. Chapter 4 presents a summary of the total direct and indirect economic impact. Chapter 5 presents the updated analysis of the impact of the rule on small business entities, consistent with a Regulatory Flexibility Act (RFA) threshold assessment. Chapter 6 provides a scoping analysis of the approach, data requirements and issues for the conduct of an economic analysis of potential modifications of the current rule.

Figure 1-2. General Approach



2. Economic Impact on Shipping Industry

Direct Economic Impact

AIS Data and Approach

A key data improvement is the availability of Automatic Identification System (AIS) that uses a Global Positioning System-linked, very high frequency radio signal that provides for ship-to-ship and ship-to-shore information transfer. It transmits the ship's name, call sign, position, dimensions, speed, heading and other information multiple times each minute. The AIS signal provides a suite of information, both dynamic (that is unique to a particular voyage) and static (that is consistent for a given vessel). Dynamic information includes the vessel's position, speed over ground, course over ground, heading, rate of turn, and position accuracy (< or > 10 m) which are determined by continuous GPS linked updates. Static information includes the vessel name, call sign, type, cargo, and its Maritime Mobile Service Identity (MMSI) number. Given the rate at which it provides this information, AIS is a precise means to remotely track vessel speeds and other vessel operations.

AIS transponders are required on certain vessel types that transit U.S. waters. These include: 1) all commercial tugs, barges, tow and similar vessels that are 26 feet in length or greater; 2) all passenger vessels (such as ferries and cruise ships) 150 gross tonnage or more; and 3) any commercial self-propelled vessel that is 65 feet in length or greater, which consists of commercial fishing vessels, tankers, cargo ships, etc.

The goal of the economic impact analysis is to estimate the impact on the shipping industry and overall economy from the actual implementation of the Rule. For these reasons, the economic impact analysis uses actual speeds of vessel transiting areas when the rule is not in effect by vessel type, size and flag compares those speeds with those from transits when the rule is in effect

We obtained access to the AIS for the areas relevant to the Rule for the full year of 2009 from the NOAA Office of Protected Resources. We then spent a significant effort to review the data and fill-in critical missing information for the economic analysis on vessel type and size. This was accomplished by matching various vessel identifiers such as the Maritime Mobile Service Identity (MMSI) number, call sign, and IMO number. In some instances, information on the type and size of vessel were confirmed based on the name of the vessel, length and cargo type. For vessels that the vessel type was known as well as the gross registered tonnage, the deadweight tonnage was estimated using the regression analysis described in the 2008 FEIS Report, Appendix A, Attachment 5.

As a result of the AIS data review and analysis, we were able to obtain for 2009, operating information for 62,765 vessel transits through areas affected by the Rule[1]. Table 2-1 presents the distribution of the total vessel transits through SMA areas by type and size of vessel. Containerships accounted for 18,540 transits followed by towing vessels with 14,425 transits and tank ships with 10,002 transits.

Table 2-1. Total Vessel Transits through SMAs by Type and Size of Vessel, 2009 (includes periods when Rule is in effect and not in effect)

	DWT Size Range																	
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	0-100	00-120	0-150	150+	Total
Bulk Carrier	1	276	257	206	134	312	239	565	258	297	380	251	767	177	3		22	20	4,165
Combination Carrier (e.g. OBO)		6						44					6	13		2			71
Container Ship	139	610	964	352	712	506	1,221	888	1,450	1,078	3,704	6,616	79	221					18,540
General Dry Cargo Ship	371	559	510	322	347	311	116	123	258	100	8	1							3,026
Industrial Vessel	1,270	125	13				6												1,414
Passenger Ship a/	3,143	933	159																4,235
Refrigerated Cargo Ship	4	225	265	54	1	2	96		5		26								678
Ro-Ro Cargo Ship	138	201	962	1,627	988	804	176	79	211	24	317	22							5,549
Tank Barge										2									2
Tank Ship	13	389	403	501	116	193	317	891	786	2,284	695	567	774	282	525	531	448	287	10,002
Towing Vessel	14,425																		14,425
Other b/	1,900	148	18	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	2,072
Total	20,134	3,347	3,538	3,062	2,298	2,128	2,171	2,590	2,968	3,785	5,130	7,457	1,626	693	528	533	470	307	62,765

a/ Includes recreational vessels.
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.
Source: Nathan Associates Inc.

Of total 62,765 transits, 28,543 vessel transits (45.5%) occurred during periods when the Rule was in effect and 34,222 vessel transits (54.5%) occurred during periods when the Rule was not in effect (Table 2-2).

[1] The data file received from NOA had a total of 78,757 transit records. However, we excluded 15,992 records due to vessels less than 65 feet LOA, non-commercial shipping vessels and where the vessel type or size could not be determined.

Table 2-2. Percent of Vessel Transits through SMAs during Effected Periods by Type of Vessel, 2009

Vessel Type	Rule in Effect	Rule Not in Effect	Total	% Rule in Effect
Bulk Carrier	2,193	1,972	4,165	52.7
Combination Carrier (e.g. OBO)	46	25	71	64.8
Container Ship	8,634	9,906	18,540	46.6
General Dry Cargo Ship	1,310	1,716	3,026	43.3
Passenger Ship	1,244	2,991	4,235	29.4
Refrigerated Cargo Ship	390	288	678	57.5
Ro-Ro Cargo Ship	2,648	2,901	5,549	47.7
Tank Barge	2		2	100.0
Tank Ship	4,494	5,508	10,002	44.9
Towing Vessel	6,751	7,674	14,425	46.8
Other b/	831	1,241	2,072	40.1
Grand Total	28,543	34,222	62,765	45.5
a/ Includes recreational vessels.				
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.				
Source: Nathan Associates Inc.				

Table 2-3 presents the number of transits through SMA areas in 2009 by SMA and type of vessel. The New York SMA had the largest number of transits at 15,180 transits followed by the SMA from North Carolina to Georgia with 13,437 transits and Norfolk with 9,549 transits. Each of these areas had a large number of containership transits.

Table 2-3. Total Vessel Transits through SMAs by Type of Vessel, 2009 (includes periods when Rule is in effect and not in effect)

SMA	Bulk Carrier	Combination Carrier (e.g. OBO)	Container Ship	General Dry Cargo Ship	Passenger Ship a/	Refrigerated Cargo Ship	Ro-Ro Cargo Ship	Tank Barge	Tank Ship	Towing Vessel	Other b/	Total
Off Race Point	177		341	51	192	2	92		672	446	53	2,026
Cape Cod Bay	44		17	27	69		21		166	1,633	107	2,084
Great South Channel	246		353	78	173	2	89		618	24	32	1,615
Block Island	326	4	55	138	109	25	237		605	826	141	2,466
New York	592	27	4,850	266	478	20	1,056	2	3,173	4,294	422	15,180
Philadelphia	430	5	870	532	1,308	567	333		1,779	2,687	189	8,700
Norfolk	1,424	27	3,988	632	235	10	1,198		622	1,130	283	9,549
Morehead City	50		15	49	40		8		72	429	54	717
North Carolina to Georgi	533	6	6,668	735	981	14	843		1,707	1,338	612	13,437
Southeast	343	2	1,383	518	650	38	1,672		588	1,618	179	6,991
Grand Total	4,165	71	18,540	3,026	4,235	678	5,549	2	10,002	14,425	2,072	62,765
a/ Includes recreational vessels.												
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.												
Source: Nathan Associates Inc.												

In terms of transits during periods when the SMAs were in effect, the Mid-Atlantic region registered the highest percentage of transits, generally between 45-50 percent of total transits (Table2-4). This is consistent with the 181-day period that the SMAs were in effect in these areas from November 1 through April 30. Other areas also generally had the percentage of transits through active SMAs matching the percent of the days of the year that they were in effect.

Table 2-4. Percent of Vessel Transits through SMAs by Type of Vessel during Effected Periods, 2009

SMA	Rule in Effect	Rule Not in Effect	Total	% Rule in Effect
Off Race Point	316	1,710	2,026	15.6
Cape Cod Bay	882	1,202	2,084	42.3
Great South Channel	477	1,138	1,615	29.5
Block Island	1,121	1,345	2,466	45.5
New York	7,520	7,660	15,180	49.5
Philadelphia	3,979	4,721	8,700	45.7
Norfolk	4,652	4,897	9,549	48.7
Morehead City	182	535	717	25.4
North Carolina to Georgia	6,499	6,938	13,437	48.4
Southeast	2,915	4,076	6,991	41.7
Grand Total	28,543	34,222	62,765	45.5
Source: Nathan Associates Inc.				

AVERAGE OPERATING SPEEDS BY VESSEL TYPE AND SIZE

Accurate information on current vessel operating speeds is clearly an important element for the determination of the economic impact of the speed restriction required by the Rule. The AIS information provides the most detailed and accurate information of vessels operating speeds for the areas subject to the Rule. For each area subject to the Rule, we have computed the average operating speeds by type and size of vessel for periods in 2009 when the Rule was not in effect. This provides the most robust estimate for actual vessel operations and average operating speeds without the influence of the Rule. In Table 2-5 below, we present the data by vessel type and size but summarized across all of the areas affected by the Rule. The fastest average vessel operating speed in these areas observed in 2009 was 14.0 knots for containerships and 13.9 knots for refrigerated cargo ships. The overall weighted average speed was 11.9 knots.

Table 2-5. Average Vessel Operating Speed through SMAs by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule Is Not in Effect, 2009 (knots)

	DWT Size Range																	
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	4.6	11.1	11.2	11.9	9.6	11.4	11.1	10.7	11.2	11.9	12.3	11.3	11.4	10.8			12.6	10.6	11.3
Combination Carrier (e.g. OBO)		13.9						10.1					9.8			12.7			10.6
Container Ship	12.4	12.9	14.1	13.7	13.2	14.9	14.5	13.9	14.0	13.9	14.4	13.9	13.6	14.1					14.0
General Dry Cargo Ship	11.4	11.6	13.5	12.3	12.4	11.5	12.3	11.2	11.8	12.9	12.8								12.1
Passenger Ship	10.7	15.7	14.8																12.4
Refrigerated Cargo Ship	11.0	14.4	14.6	15.0			11.3		13.4		13.7								13.9
Ro-Ro Cargo Ship	8.4	13.3	13.6	14.2	13.7	13.2	13.9	15.3	13.4	14.3	13.6	13.4							13.6
Tank Ship	9.6	12.3	11.6	12.7	11.0	12.4	12.1	12.3	11.9	11.9	11.8	11.8	11.3	11.1	10.9	11.3	10.3	11.2	11.7
Towing Vessel	8.2																		8.2
Total	9.3	13.7	13.4	13.6	12.9	13.0	13.5	12.5	13.0	12.6	13.9	13.7	11.5	12.0	10.9	11.3	10.3	11.2	11.9
Source: Nathan Associates Inc.																			

Average vessel operating speeds through SMAs in 2009 during period when the Rule was in effect declined to an overall average of 10.0 knots (Table 2-6). Containerships slowed from an average of 14 knots to 10.6 knots. Ro-ro vessels slowed from 13.6 knots to 10.5 knots. The fastest average vessel speed through SMA active areas was by refrigerated cargo ships at 13.1 knots just slightly slower than the 13.9 knots recorded during non-active SMA periods.

Table 2-6. Average Vessel Operating Speed through SMAs by Type and Size of Vessel for Areas Subject to Rule During Periods When Rule Is in Effect, 2009 (knots)

	DWT Size Range																	
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier		10.5	10.4	11.4	9.1	10.6	10.3	9.9	10.3	10.3	10.7	9.6	10.4	10.8	9.6		10.6	9.2	10.3
Combination Carrier (e.g. OBO)		10.6						6.8					8.5	10.0					8.2
Container Ship	12.3	11.1	10.7	10.6	10.3	10.2	11.1	11.1	11.0	10.1	10.6	10.5	10.7	10.4					10.6
General Dry Cargo Ship	10.5	11.4	11.6	11.1	11.5	10.6	11.2	10.8	11.0	10.5	9.2	9.9							11.2
Passenger Ship	9.1	10.7	11.5																9.7
Refrigerated Cargo Ship		13.4	13.8	11.8	12.9	9.4	11.7		9.9		9.9								13.1
Ro-Ro Cargo Ship	9.3	10.8	10.3	10.5	10.7	10.6	10.3	10.4	11.1	10.9	10.2	10.8							10.5
Tank Barge										10.6									10.6
Tank Ship	9.2	10.1	10.5	10.8	10.3	10.9	10.3	10.4	10.5	10.3	10.5	10.0	9.9	9.8	9.6	10.6	9.7	10.9	10.3
Towing Vessel	8.2																		8.2
Total	8.6	10.9	11.0	10.7	10.5	10.5	10.9	10.5	10.8	10.2	10.6	10.4	10.2	10.4	9.6	10.6	9.8	10.7	10.0
Source: Nathan Associates Inc.																			

AVERAGE DELAYS DUE TO RULE BY TYPE AND SIZE OF VESSEL

The primary operational impact of the Rule on the shipping industry is the extra sailing time incurred caused by vessels having to slow down within the restricted areas. Estimates of the extra sailing time were calculated by subtracting the time required to sail through each restricted area using the detailed average vessel operating speeds for that restricted area during periods when the Rule was not in effect from the time required at a sailing speed of 10 knots. Only average vessel speeds of greater than 10 knots during non-Rule periods were used for these calculations. A summary across all restricted areas of the average extra time per vessel transit by vessel type and size is presented in Table 2-7. The average delay for all vessels is 0.37 of an hour or 22 minutes. The highest average delay by vessel type is 37minutes (0.62 hours) for combination carriers followed by 34 minutes for Ro-Ro carriers and 32 minutes for containerships. Refrigerated cargo ships only experienced an average delay of 5 minutes.

Table 2-7. Average Delays per Vessel Transit through SMAs due to Rule by Type and Size of Vessel, 2009 (hours)

	DWT Size Range																		
Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	.00-12(	.20-15(	150+	Total
Bulk Carrier		0.12	0.17	0.08	0.12	0.16	0.18	0.16	0.21	0.37	0.33	0.39	0.19	0.00			0.34	0.31	0.20
Combination Carrier (e.g. OBO)		0.75						0.93					0.50						0.62
Container Ship	0.02	0.36	0.61	0.46	0.47	0.78	0.49	0.45	0.45	0.64	0.59	0.55	0.53	0.59					0.54
General Dry Cargo Ship	0.19	0.04	0.29	0.20	0.17	0.16	0.19	0.08	0.16	0.44	0.62								0.17
Passenger Ship	0.17	0.84	0.42																0.35
Refrigerated Cargo Ship		0.11	0.08	0.32			-0.06		0.54		0.62								0.08
Ro-Ro Cargo Ship	0.00	0.46	0.64	0.66	0.51	0.48	0.60	0.72	0.35	0.43	0.54	0.49							0.56
Tank Ship	0.14	0.45	0.23	0.33	0.12	0.28	0.30	0.36	0.29	0.36	0.27	0.38	0.29	0.27	0.27	0.13	0.12	0.07	0.29
Total	0.19	0.55	0.42	0.49	0.42	0.45	0.41	0.36	0.37	0.46	0.54	0.54	0.25	0.29	0.27	0.13	0.12	0.09	0.37
Source: Nathan Associates Inc.																			

VESSEL OPERATING COSTS AT SEA BY TYPE AND SIZE OF VESSEL

The U.S. Army Corps of Engineers (USACE) prepares estimates of vessel operating costs to be used by planners in studies to determine the potential benefits of harbor improvement projects. Vessel operating costs include annual capital costs as determined by the replacement cost of the vessels and application of capital recovery factors; estimates of fixed annual operating costs such as for crew, lubricating materials and stores (supplies), maintenance and repair, insurance and administration; the number of operational days per year; and fuel costs at sea and in port.

The type and DWT size of vessels for which operating costs are reported by the USACE is shown in Table 2-8 below. Vessel operating costs are presented separately for U.S. flag and foreign flag vessels, for five vessel types, and up to 14 vessel DWT sizes within a vessel type.

Table 2-8. Type and Size of Vessels for which USACE Reports Vessel Operating Costs (DWT)

Foreign flag					U.S. flag				
General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull	General cargo vessel	Container ship	Bulk carrier	Tanker (double hull)	Tanker (single hull
11,000	9,000	15,000	20,000	20,000	11,000	9,000	15,000	20,000	20,000
14,000	14,000	25,000	25,000	25,000	14,000	14,000	25,000	25,000	25,000
16,000	17,000	35,000	35,000	35,000	16,000	17,000	35,000	35,000	35,000
20,000	20,000	40,000	50,000	50,000	20,000	20,000	40,000	50,000	50,000
24,000	23,000	50,000	60,000	60,000	24,000	23,000	50,000	60,000	60,000
30,000	28,000	60,000	70,000	70,000	30,000	28,000	60,000	70,000	70,000
	31,000	80,000	80,000	80,000		31,000	80,000	80,000	80,000
	35,000	100,000	90,000	90,000		35,000	100,000	90,000	90,000
	39,000	120,000	120,000	120,000		39,000	120,000	120,000	120,000
	42,000	150,000	150,000	150,000		42,000	130,000	150,000	150,000
	49,000	175,000	175,000	175,000		49,000		175,000	175,000
	55,000	200,000	200,000	200,000		55,000		200,000	200,000
	66,000		265,000	265,000		66,000		265,000	265,000
	82,000		325,000	325,000					

Source: U.S. Army Corps of Engineers, Economic Guidance Memorandum 02-06, Deep Draft Vessel Operating Costs

As the USACE data includes more vessel size ranges than necessary for this economic impact analysis We applied regression techniques to the USACE vessel operating cost data in order to match with the vessel size categories with thoase used in this analysis of U.S. East Coast vessel arrivals. A logarithmic equation was specified relating hourly operating costs at sea with vessel DWT for each of the vessel types used in this economic impact analysis.

A concern over the use of the USACE operating cost estimates is the variability of actual vessel operating costs due to the fluctuations in the price of bunker fuel. The USACE estimates include the assumed fuel consumption per day at sea for the primary propulsion and auxiliary propulsion for each vessel type and DWT size. The primary propulsion is assumed to use heavy viscosity oil while the auxiliary propulsion is assumed to use marine diesel oil. We updated the USACE vessel operating costs to reflect the average bunker fuel prices per ton for New York for using an annual average 2009 calculated from data reported by Bunkerworld. The average price for heavy viscosity oil for 2009 was $347 per metric ton and marine diesel oil was $685 per metric ton. The resulting estimates of vessel operating costs by type and size of vessel for 2009 are presented for foreign flag and U.ZS.-flag vessels in Table 2-9 and Table 2-10, respectively. These estimated vessel operating costs for 2009 represent the best method to value the actual impact on the shipping industry of the Rule that year.

It is important to distinguish between foreign flag and U.S. flag vessels as their costs structures differ considerably. Overall, U.S.-flag vessels have operating costs 40-70 percent higher than foreign flag vessels. This is principally due to higher costs for U.S. crews, vessel maintenance and insurance requirements that U.S.-flag vessels have to satisfy[2].

Table 2-9. Hourly Vessel Operating Costs at Sea for Foreign Flag Vessels by Type Size of Vessel Using Average 2009 ($000s)

	DWT Size Range (000s)																	
Vessel type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+
Bulk Carrier	786	805	825	845	865	886	907	929	951	974	1,010	1,059	1,110	1,164	1,221	1,311	1,477	1,703
Combination Carrier (e.g. OBO)	826	846	866	887	908	930	952	975	999	1,023	1,060	1,112	1,166	1,223	1,282	1,377	1,551	1,789
Container Ship	788	888	1,000	1,126	1,267	1,427	1,607	1,809	2,037	2,294	2,740	3,474	4,405	5,584	7,080	10,107	-	-
Freight Barge	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
General Dry Cargo Ship	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-
Passenger Ship a/	3,551	5,069	7,237	10,962	13,897	-	-	-	-	-	-	-	-	-	-		-	-
Refrigerated Cargo Ship	1,774	1,997	2,249	2,532	2,851	3,211	3,615	4,071	4,583	5,161	6,166	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	867	977	1,100	1,238	1,394	1,570	1,767	1,990	2,241	2,523	3,014	3,822	4,845	-	-	-	-	-
Tank Ship	960	978	996	1,015	1,034	1,053	1,073	1,093	1,113	1,134	1,166	1,210	1,256	1,304	1,353	1,431	1,570	1,755
Towing Vessel	960	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	485	594	728	892	1,093	1,339	1,641	2,010	2,463	3,017	-	-	-	-	-	-	-	-

a/ Includes recreational vessels.
b/ Includes fishing vessels, industrial vessels, research vessels, and school ships.
Source: Prepared by Nathan Associates Inc. as decribed in text from data provided in U.S. Army Corps of Engineers, Economic Guidance Memorandum 05-01, Deep Draft Vessel Operating Costs and adjusted for bunker fuel prices reported by Bunkerworld for IFO380 and MDO for New York.

Table 2-10. Hourly Vessel Operating Costs at Sea for U.S. Flag Vessels by Type Size of Vessel Using Average 2009 ($000s)

	DWT (000s)																	
Vessel type anf flag	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+
Bulk Carrier	1,321	1,358	1,396	1,435	1,476	1,517	1,559	1,603	1,648	1,694	1,766	1,866	1,972	2,084	2,203	2,393	2,748	3,243
Combination Carrier (e.g. OBO)	1,387	1,426	1,466	1,507	1,549	1,593	1,637	1,683	1,730	1,779	1,854	1,960	2,071	2,189	2,313	2,513	2,885	3,405
Container Ship	1,064	1,194	1,340	1,503	1,687	1,894	2,125	2,385	2,676	3,003	3,571	4,497	5,664	7,133	8,984	12,698	-	-
Freight Barge	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-
General Dry Cargo Ship	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-
Passenger Ship a/	4,775	6,749	9,539	14,283	17,989	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigerated Cargo Ship	2,393	2,686	3,014	3,383	3,796	4,260	4,781	5,366	6,022	6,758	8,034	-	-	-	-	-	-	-
Ro-Ro Cargo Ship	1,170	1,313	1,474	1,654	1,856	2,083	2,337	2,623	2,944	3,304	3,928	4,947	6,230					
Tank Barge	1,784	1,818	1,853	1,888	1,924	1,960	1,998	2,036	2,074	2,114	2,174	-	-	-	-	-	-	-
Tank Ship	1,784	1,818	1,853	1,888	1,924	1,960	1,998	2,036	2,074	2,114	2,174	2,258	2,344	2,434	2,528	2,675	2,939	3,291
Towing Vessel	1,784	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other b/	932	1,113	1,331	1,590	1,901	2,272	2,715	3,245	3,878	4,634	6,055	-	-	-	-	-	-	-

Source: Prepared by Nathan Associates Inc. as decribed in text from data provided in U.S. Army Corps of Engineers, Economic Guidance Memorandum 05-01, Deep Draft Vessel Operating Costs an
adjusated for bunker fuel prices reported by Bunkerworld for IFO380 and MDO for New York.

DIRECT ECONOMIC IMPACT OF SMAS

The estimated direct economic impact on the shipping industry of the Rule in 2009 is presented in Table 2-11. Across all SMAs, the total direct economic impact is estimated $19.6 million. More than 63 percent of the total direct impact incurred by containerships at $12.4 million followed distantly by Ro-Ro cargo ships at $2.2 million, tank ships at $1.6 million and passenger at $1.5 million.

[2] Some studies report a much higher differential (up to 2.7 times) between U.S.-flag and foreign flag vessel operating costs. However, those studies do not include fuel and capital costs in their comparisons.

Table 2-11. Direct Economic Impact of SMAs on Shipping Industry by Type and Size of Vessel, 2009 ($000s)

Vessel Type	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100	100-120	120-150	150+	Total
Bulk Carrier	-	17	21	7	9	27	24	81	25	49	62	60	82	-	-	-	7	6	476
Combination Carrier (e.g. OBO)	-	3	-	-	-	-	-	16	-	-	-	-	2	-	-	-	-	-	21
Container Ship	1	90	267	78	203	286	446	353	625	668	2,881	6,128	70	295	-	-	-	-	12,392
General Dry Cargo Ship	24	3	53	27	19	14	19	9	42	60	-	-	-	-	-	-	-	-	271
Passenger Ship a/	405	806	245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,455
Refrigerated Cargo Ship	-	28	28	28	-	-	-	-	7	-	23	-	-	-	-	-	-	-	114
Ro-Ro Cargo Ship	-	54	352	665	355	303	95	61	86	12	244	11	-	-	-	-	-	-	2,239
Tank Ship	0	73	39	85	7	22	51	227	116	438	127	118	122	24	68	49	32	19	1,616
Towing Vessel	194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194
Other b/	563	263	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	826
Total	1,187	1,336	1,005	889	594	651	634	746	902	1,227	3,338	6,318	277	319	68	49	39	26	19,604

a/ Includes recreational vessels.
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.
Source: Nathan Associates Inc.

The direct economic impact on the shipping industry by SMA is presented in Table 2-12. The largest impact is recorded for the SMA from North Carolina to Georgia at $5.9 million followed by New York at $5.5 million and Norfolk at $4.2 million. As previously mentioned these areas have the majority of containership transits along the U.S. East Coast. These three SMAs account for nearly 80 percent of the direct econom,ic impact of the Rule on the the shipping industry.

Table 2-12. Direct Economic Impact of SMAs on Shipping Industry by SMA and Type of Vessel, 2009 ($000s)

SMA	Bulk Carrier	Combination Carrier (e.g. OBO)	Container Ship	General Dry Cargo Ship	Passenger Ship a/	Refrigerated Cargo Ship	Ro-Ro Cargo Ship	Tank Ship	Towing Vessel	Other b/	Total
Off Race Point	9	-	74	2	4	-	7	37	3	0	136
Cape Cod Bay	7	-	2	1	1	-	3	25	20	6	65
Great South Channel	15	-	139	4	185	0	12	60	0	0	416
Block Island	55	1	37	11	27	5	84	129	10	4	362
New York	73	11	3,631	27	349	16	473	593	62	271	5,506
Philadelphia	48	-	375	43	169	73	137	229	38	26	1,138
Norfolk	174	8	2,830	61	187	8	505	111	16	267	4,166
Morehead City	5	-	8	2	4	-	2	7	2	87	117
North Carolina to Georgi	55	1	4,805	79	123	8	382	321	24	101	5,897
Southeast	37	-	490	41	406	5	634	103	20	64	1,800
Total	476	21	12,392	271	1,455	114	2,239	1,616	194	826	19,604

a/ Includes recreational vessels.
b/ Includes freight barges, fishing vessels, industrial vessels, research vessels, and school ships.
Source: Nathan Associates Inc.

DIRECT ECONOMIC IMPACT OF DMAS

The Rule specifies that voluntary dynamic management areas would be implemented along the U.S. Exclusive Economic Zone when right whale sightings occur. Triggers for implementing a DMA are based on those specified for the Atlantic Large Whale Take

Reduction Plan (ALWTRP) Dynamic Area Management fishing restrictions.[3] A DMA action would be triggered by a single reliable report from a qualified individual of an aggregation of three or more right whales within 75 square nautical miles (nm^2) (257 km^2), such that right whale density is equal to or greater than 0.04 right whales per nm^2 (3.43 km^2), equivalent to four right whales per 100 nm^2 (343 km^2). Once a DMA is triggered, NMFS would use the following procedures and criteria to establish a DMA:

- A circle with a radius of at least 2.8 nm (5.2 km) would be drawn around the location of each individual sighting. This radius would be adjusted for the number of observed whales, so as to size the DMA to maintain a density of four right whales per 100 nm^2 (343 km^2). Information on how to calculate the length of the radius can be found in the Proposed Rule to amend the regulations that implement the ALWTRP (67 FR 1133). For a group of three whales the DMA would consist of a core area with a radius of 4.8 nm (8.9 km).

- If any circle or group of contiguous circles includes three or more right whales, this core area and its surrounding waters would be a candidate DMA zone.

Once NMFS identifies a core area containing three or more whales, the agency would expand this initial core area to provide a buffer in which the whales could move and still be protected. NMFS will determine the extent to the DMA zones as follows:

- A large circular zone would be drawn extending 15 nm (27.8 km) from the perimeter of a circle around each core area.

- The DMA would be a polygon drawn outside, but tangential to, the circular buffer zone(s), defined by the latitudinal and longitudinal coordinates of its corners.

Hence each DMA consists of the core area with a radius of 4.8 nm (for a group of three whales) plus the buffer with a radius of 15 nm for a total radius of 19.8 nm. The diameter of the DMA is thus 39.6 nm. The DMA zone would automatically expire after 15 days from the day of the original sighting, unless subsequent surveys within the 15-day period demonstrated (a) whales are present in the zone, or (b) the aggregation had persisted, in which case the period would be extended 15 days from the date of any subsequent sightings in the zone.

Impact on Vessel Operations

In all regions, mariners have the option of either routing around the DMA or proceeding through it at a restricted speed. The measures are voluntary and vessel operators are not

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[3] See the January 9, 2002 Federal Register Proposed Rule (as amended by the October 28, 2002 technical amendment to the final rule) for the definition of Procedures and Criteria to Establish a DAM Zone, Criteria to Determine the Extent of the DAM Zone, and Duration of DAM Zones.

currently required to take either measure. For this analysis we have compared the average speeds for each vessel type passing through areas where DMAs were implemented in 2009 with speeds for same types of vessel through those same areas when the DMA was not in effect. The direct impact of a DMA on vessel operations is the increased time required to transit through the DMA when it is in effect.

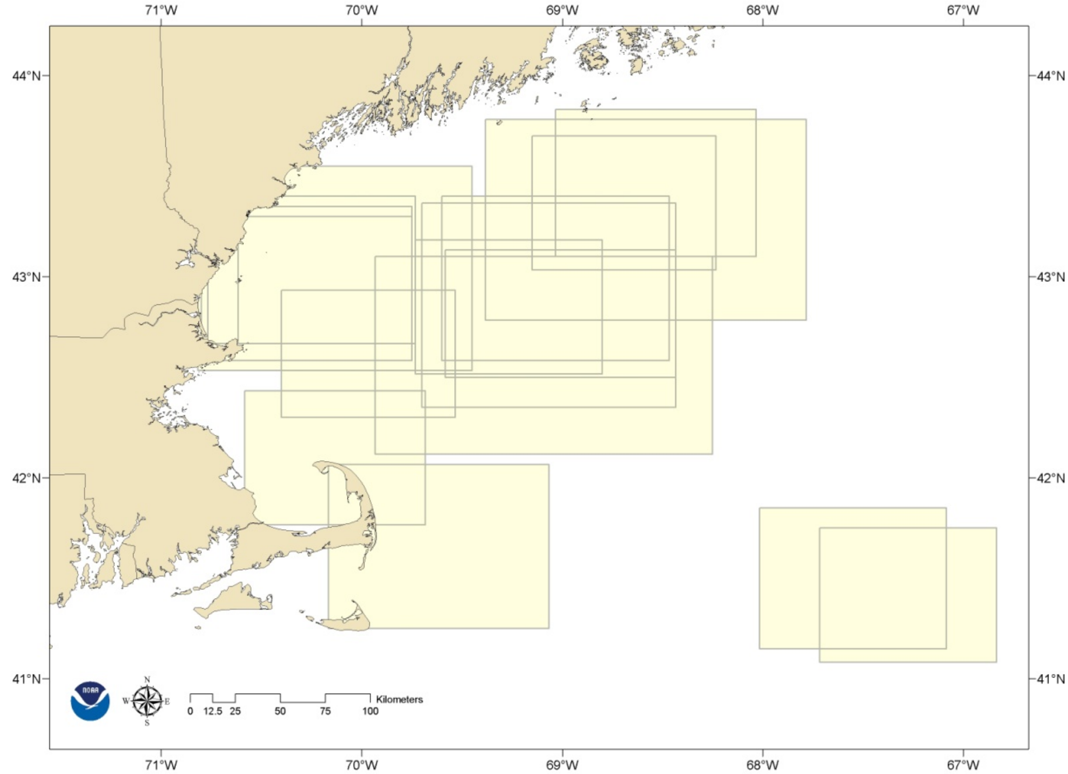
In 2009, there were18 DMAs implemented based on the sightings of right whales. Information on each of these DMAs is presented in Table 2-11 and the locations of the DMAs are shown in Figure 2-1. The average duration of the DMAs in 2009 was 18.6 days. The DMAs range in size from 1448 nm^2 to 4391 nm^2.

Table 2-13. DMAs Implemented in 2009

DMA No.	No. of Whales	Area (nm^2)	Start date	End date	Duration Days
NE_04	28	1997	1/13/2009	2/10/2009	28
NE_05	3	1605	1/16/2009	1/29/2009	13
NE_06	6	1448	2/11/2009	2/25/2009	14
NE_07	5	1456	2/11/2009	2/25/2009	14
NE_08	12	2419	2/11/2009	2/25/2009	14
NE_09	3	1592	3/17/2009	3/28/2009	11
NE_10	5	1764	4/13/2009	4/25/2009	12
NE_11	15	1926	5/12/2009	5/27/2009	15
NE_12	3	1602	5/13/2009	5/27/2009	14
NE_13	44	4391	6/2/2009	6/29/2009	27
NE_14	3	4391	7/9/2009	7/21/2009	12
NE_15	5	1644	9/2/2009	9/16/2009	14
NE_16	26	2124	10/15/2009	11/11/2009	27
NE_17	24	1918	10/22/2009	12/1/2009	40
NE_18	16	2441	10/27/2009	11/10/2009	14
NE_19	41	3661	11/10/2009	12/17/2009	37
NE_20	47	3403	11/10/2009	11/24/2009	14
NE_21	27	4198	12/4/2009	12/19/2009	15

Source: NOAA, Office of Protected Resources, National Marine Fisheries Service.

Figure 2-1. Locations of DMAs in 2009



The average vessel operating speeds by vessel type during periods when DMA were in effect and not in effect in 2009 are presented in Table 2-14. There were 11,924 transits recorded in the DMA areas at times when the DMAS were not in effect and 1,937 transits during the DMAs. The overall weighted average speed during the non-active periods was 8.0 knots whereas an average of 8.5 knots was recorded for the period when DMAs were in effect. Interestingly, only six vessel types had average speeds greater than 10 knots through the DMA areas, and of these only two vessel types, bulk carriers and passenger ships actually recorded a reduction in speed during active DMAs. For bulk carriers the reduction was minor from 10.1 knots to 9.8 knots and for passenger vessels the speed reduction was from 12.0 knots to 9.0 knots.

Table 2-14. Average Vessel Operating Speed through DMAs by Type of Vessel, 2009 (knots)

Vessel type	Number of transits: Not in effect	In effect	Total	Average speed: Not in effect	In effect	Speed reduction
Bulk Carrier	396	97	493	10.10	9.80	0.29
Container Ship	528	91	619	14.90	15.00	
Freight Barge	86	9	95	8.90	9.54	
General Dry Cargo Ship	163	26	189	11.36	11.67	
Industrial Vessel	42	7	49	6.09	9.23	
Passenger Ship	544	72	616	12.00	9.00	3.00
Recreational	120	6	126	6.88	9.77	
Research Vessel	44	14	58	9.88	11.18	
Ro-Ro Cargo Ship	155	19	174	13.52	13.60	
School Ship	62	15	77	5.66	7.31	
Tank Ship	1,697	431	2,128	11.34	11.53	
Towing Vessel	2,075	310	2,385	7.53	7.60	
#N/A	5,995	840	6,835	5.93	6.10	
Total	11,924	1,937	13,861	8.01	8.49	

Source: Nathan Associates Inc.

As previously mentioned, the speed restrictions under DMAs are voluntary. As such, a large segment of the shipping industry did not reduce speeds through active DMAs in 2009. For this reason, there was no or minimal economic impact of DMAs on the shipping industry in 2009.

OTHER DIRECT IMPACTS ON SHIPPING INDUSTRY

Cumulative Effect of Multi-Port Strings for Containerships

Many of the vessels calling at U.S. East Coast ports occur as part of a "string" of port calls by the vessel. For containerships, Ro-Ro cargo ships and some specialty tankers these multi-port calls constitute a scheduled cargo service offered by the shipping lines. Other types of vessels may have multiple U.S. East Coast port calls as part of a coastwise cabotage service, for delivery of specialty chemicals or other products, or to lighten or top off in order to maximize vessel utilization. There are several reasons why the cumulative effect of multiple port calls at restricted ports could impact a vessel more than the sum of the individual direct impacts presented in the prior sections. First, the delays incurred from speed restrictions at one port when combined with speed restrictions at a subsequent port may diminish the ability of the vessel to maintain its schedule and could result in missed tidal windows. Second, even brief delays at arrival at the second port could result in increased costs for scheduled, but unused, port labor. Third, some shipping lines felt that the cumulative impact of three or four port calls at port areas with restrictions could cause them to rework vessel itineraries and could result in dropping of one of the port calls in order to maintain a weekly service without having to add an additional vessel to the service.

However, these cumulative factors will not affect every vessel making multiple port calls at restricted ports. Also the impact may vary from an 8-hour delay due to a missed tidal window to incurring charges for unused labor if a vessel is late arriving at the port.[4] It is realistic to assume that the shipping industry will revise their itineraries to account for the delays imposed by the speed restrictions and that occurrences of missed tidal widows will be rare. From the calculations described in detail in the 2008 FEIS Report, we have used the same average additional delay of 11 minutes for each containership transit that is part of a multi-port string to account for this cumulative impact.[5] The economic value of this additional time has been calculated based on the average 2009 vessel operating and the 2009 vessel operating costs for containerships. The estimated impact for 2009 is $3.1 million.

Re-routing of Southbound Coastwise Shipping

Coastwise shipping or cabotage trade along the U.S. East Coast has always been an important segment of our nation's maritime heritage. In recent years, attention has been focused on the further development of coastwise shipping (also referred to as short-sea shipping) as a means of reducing highway congestion on the Eastern Seaboard. Benefits of coastwise shipping also include lowering transport and environmental costs and reducing our demand for imported fuel. For these reasons, it is important that the speed restrictions not unduly affect the development of increased coastwise shipping.

However, for commercial and navigation purposes, it appears unlikely that the speed restriction would significantly affect coastwise shipping. Northbound vessels prefer to use Gulf Stream further offshore and benefit from the enhanced operating speed and fuel efficiency. Southbound traffic routes closer to the U.S. East Coast; generally within 7-10 nautical miles of the shoreline. However, during the proposed seasonal management periods, masters of southbound vessels would likely route outside of seasonal speed restricted areas incurring an overall increase in distance. This affects southbound vessels between the entrance to the Chesapeake Bay and Port Canaveral.

The speed restrictions in the mid-Atlantic region are implemented for a radius of 20 nautical mile buffer around each port area for port areas north of Wilmington, NC.[6] A continuous 20-mile buffer was implemented from Wilmington, NC through Savannah to the northern boundary of the Southeastern SMA. The additional distance incurred by southbound vessels would be 56 nautical miles. The economic impact for this extra sailing distance is estimated at $1.1 million using 2009 vessel operating costs.

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[4] While tides occur on 12-hour cycle, it is assumed that a tidal window is open for 2 hours before and after high tide. This results in an 8-hour waiting period between tidal windows.

[5] Only a small portion of vessel arrivals should be affected by this additional delay. It is assumed that 7.5 percent of vessels could be affected by as much as an additional 8-hour delay due to missing the tidal window. This results in an average additional delay per vessel of 36 minutes.

[6] The exception is the Block Island Sound speed restriction area that is configured as a rectangle with a width of 30 nautical miles.

TOTAL DIRECT ECONOMIC IMPACT ON SHIPPING INDUSTRY

The total direct economic impact on the shipping industry consists of the various impacts analyzed above. These are the SMAs, DMAs, cumulative effect of multi-port strings and the re-routing of southbound coastwise shipping. The total direct economic impact on the shipping industry in 2009 is estimated at $23.8 million as shown in Table 2-15.

Table 2-15. Direct Economic Impact on Shipping Industry, 2009 ($millions)

Impact	Amount
Seasonal Management Areas (SMAs)	19.6
Dynamic Management Areas(DMAs)	-
Cumulative Effect of multi-port strings	3.1
Re-routing of southbound coastwise shipping	1.1
Total	23.8

Source: Prepared by Nathan Associates as described in text.

Direct Economic Impact Relative to Trade Value and Freight Costs

The U.S. Census Bureau data on U.S. imports of merchandise is compiled primarily from automated data submitted through the U.S. Customs' Automated Commercial System.[7] Data are compiled also from import entry summary forms, warehouse withdrawal forms and Foreign Trade Zone documents as required by law to be filed with the U.S. Customs Service. Information on U.S. exports of merchandise is compiled from copies of Shipper's Export Declarations (SEDs) and data from qualified exporters, forwarders or carriers. Copies of SEDs are required to be filed with Customs officials at the port of export.

For this study, the following data items have been used from the U.S. Census Bureau Foreign Trade Statistics:

- **Customs import value –** the value of imports appraised by the U.S. Customs Services in accordance with the legal requirements of the Tariff Act of 1930, as amended. This value is generally defined as the price actually paid or payable for merchandise when sold for exportation to the U.S. excluding U.S. import duties, freight, insurance and other charges incurred in bringing the merchandise to the U.S.

- **Import charges** – the aggregate cost of all freight, insurance and other charges (excluding U.S. import duties) incurred in bringing the merchandise from alongside the carrier at the port of exportation and placing it alongside the carrier at the first port of entry in the U.S.

- **F.A.S. export value** – the free alongside ship value of exports at the U.S. seaport based on the transaction price, including inland freight, insurance and other

[7] The description and definition of information from the U.S Census Bureau Foreign Trade Statistics is based on the Guide to Foreign Trade Statistics: Description of the Foreign Trade Statistical Program available on the U.S. census Bureau website.

charges incurred in placing the merchandise alongside the carrier at the U.S. port of exportation. The value, as defined, excludes the cost of loading the merchandise aboard the exporting carrier and also excludes freight, insurance and any other charges or transportation costs beyond the port of exportation.

- **Shipping weight** – the gross weight in metric tons including the weight of moisture content, wrappings, crates, boxes and containers.

- **District of exportation** – the customs district in which the merchandise is loaded on the vessel which takes the merchandise out of the country.

- **Import district of unlading**- the district where merchandise is unloaded from the importing vessel.

Table 2-18 presents data collected by the U.S. Census Bureau on volume and value of goods carried by vessels calling at U.S. East Coast ports.

Table 2-16. U.S. East Coast Maritime Trade, 2005-2011 Value ($ millions)

Year	Vessel Import Custom Value	Vessel Export Value	Total
2005	296,478	96,861	393,339
2006	327,804	113,955	441,759
2007	347,337	140,728	488,065
2008	381,869	173,475	555,344
2009	272,445	126,884	399,329
2010	329,035	153,977	483,012
2011	390,148	190,803	580,952

Note: Includes Custom districts 1,4,5,10,11 and 13 through 18

Source: Prepared by Nathan Associates Inc. from U.S. Census Bureau, Foreign Trade Statistics for 2005 to 2011.

To measure the significance of the operational measures on the shipping industry, it is interesting to compare the estimated direct economic impact with ocean freight costs associated with U.S. East Coast trade. Ocean freight costs are considered as a conservative proxy for shipping industry revenues. In 2009, ocean freight charges averaged 4.6 percent of the value of imports. Given the composition of our trade, it is reasonable to assume that ocean freight charges would represent no less than the same percentage of the value of our exports.

Table 2-17 US. East Coast Vessel Import Charges as Percent of Vessel Import Customs Value ($ millions)

Year	Vessel Import Custom Value	Vessel Import Charges	Percent
2005	293,065	14,921	5.1%
2006	324,220	16,509	5.1%
2007	344,068	16,558	4.8%
2008	378,250	17,745	4.7%
2009	269,814	12,418	4.6%
2010	326,126	14,242	4.4%
2011	386,358	15,171	3.9%

Note: Includes Custom districts 4,5,10,11 and 13 through 18. The Customs District of Portland has been excluded due to incongruences between the customs and the CIF value.
Source: Prepared by Nathan Associates Inc. from U.S.

Table 2-18 presents the significance of the estimated economic impact of the operational measures relative to the value of U.S. East Coast trade in 2009. This comparison is useful to determine whether increased shipping costs associated with the proposed operational measures would significantly affect the price and volume of traded goods via U.S. East Coast ports. In 2009, the total annual direct economic impact on the shipping industry is $23.8 million while the value of U.S. East Coast trade is $399.3 billion. Thus the direct economic impact represents six thousandth of one percent of the value of traded merchandise in 2009.

Table 2-18 also shows the direct economic impact on the shipping industry represents less than two-tenths of one percent of the ocean freight costs for U.S. East Coast trade. These results indicate that the implementation of the proposed operational measures had a minimal impact on the financial revenues and hence the financial performance of the vessel operators calling at U.S. East Coast ports.

Table 2-18. Economic Impact as a Percent of Value of U.S. East Coast Maritime Trade and Ocean Freight Costs, 2009

Item	Amount
Direct economic impact ($millions)	23.6
East Coast trade merchandise value ($ millions)	399,329
Direct economic impact as a percent of trade value (%)	0.0059
Ocean freight costs ($ millions)	15,973
Direct economic impact as a percent ofocean freight costs (%)	0.148

Source: Prepared by Nathan Associates as described in text.

Estimated Indirect Economic Impact

Depending on the nature and significance of the direct economic impact, it is possible that implementation of the proposed operational measures could have indirect economic impacts. Potential indirect economic impacts include:

- Increased intermodal costs due to missed rail and truck connections
- Diversion of traffic to other ports
- Impact on local economies of decreased income from jobs lost due to traffic diversions

There are many factors that influence a shipping line's decision to call at specific ports. These include the adequacy and suitability of port facilities and equipment, the ability of the terminal operator to quickly turnaround the vessel, overall cargo demand, efficiency of intermodal transportation, port charges, and the port location relative to other ports and cargo markets. If cargo is to divert to other ports this would be because the total additional costs associated with those routes are less than the cost of vessel time due to delays at the current port. Hence it would be double-counting to also include any additional overland transport costs to the estimated impact already presented.

A good portion of a port's traffic is often considered captive to that port. For cargoes that are destined for the port's immediate hinterland, it does not make economic sense to call at a distant port and then to ship back to the port via expensive land transport. However, most ports also accommodate traffic that is not destined for its immediate hinterland but is through traffic that may have economically attractive routing alternatives. Port areas in the Northeast and northern parts of the mid-Atlantic region serve as gateways to the inland population centers and industrial areas such as western New York, western Pennsylvania, Ohio, Indiana, Illinois and Michigan. These areas may be served via the Canadian ports of Halifax and Montreal without incurring delays caused by the right whale ship strike reduction measures.[8] These Canadian ports currently compete with Northeast U.S. ports for cargo destined for the mid-eastern U.S. and the speed restrictions implemented in the U.S. and not in Canada could shift the current competitive balance to the advantage of Canadian ports.

The Maritime Administration (MARAD), an agency of the U.S. Department of Transportation has developed a Port Economic Impact Kit that allows users to assess the economic impact of port activity on a region's economy. The MARAD Port Economic Impact Kit uses an adaptation of input-output analysis that is a widely established tool for undertaking economic impact assessments. The model calculates the total economic impacts or multiplier effect of

[8] Vessels may divert to other U.S. ports in addition to those diverting to Canada. While this is possible, for the total economic impact analysis only diversions to non-U.S. ports are included. For diversion to ports within the U.S. the negative economic impact for one U.S. port are offset by gains in another U.S. port.

deep-draft port industry and includes an indirect effect that reflects expenditures made by the supplying firms to meet the requirements of the deep-draft port industry as well as expenditures by firms stocking the supplying firms. The model also includes an induced effect that corresponds to the change in consumer spending that is generated by changes in labor income accruing to the workers in the deep-draft port industry as well as employment in the supplying businesses.

We have estimated the indirect economic of port diversions based on the detailed methodology described in the 2008 FEIS adjusted for the actual observed delays incurred in 2009 from the AIS data analysis and using the updated vessel operating costs for 2009. The estimated indirect economic impact of port diversion for 2009 is $15.8million.

3. Economic Impact of Rule on Other Market Segments

The AIS data captures the vast preponderance of commercial maritime activity that would be subject to the speed restrictions and other operational measures. However, there are some market segments that may be impacted by the speed restrictions and other operational measures whose maritime activities are not adequately captured in the AISA data. In this section, we identify the most relevant of these market segments and discuss the potential economic impact. Those market segments or potential impacts include:

- Commercial fishing
- Charter fishing
- Passenger ferries
- Whale watching

The economic impact for each of these elements is presented below.

Commercial Fishing

Commercial fishing is a multimillion dollar industry along the U.S. East Coast. In 2011, commercial fish landings at U.S. East Coast ports totaled $934 million (Table 3-1). The port of New Bedford, MA is the leading U.S. port in terms of value of commercial fish landings with $369.0 million in 2011.

Table 3-1. U.S. East Coast Commercial Fishery Landings by Port, 2002 through 2011 (millions of dollars)

Port	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
New Bedford, MA	168.6	176.2	207.7	282.5	281.4	268.0	241.3	249.2	306.0	369.0
Cape May-Wildwood, NJ	35.3	42.8	60.2	68.4	37.6	58.8	73.7	73.4	81.0	103.0
Hampton Roads Area, VA	69.5	79.6	100.8	85.2	51.0	70.2	12.3	68.1	75.0	88.0
Gloucetser, MA	41.2	37.8	42.8	45.9	47.3	46.8	54.2	50.4	57.0	59.0
Stonington, ME	21.7	20.5	22.4	32.3	34.3	23.5	15.4	26.5	45.0	48.0
Point Judith, RI	31.3	32.4	36.0	38.3	46.8	36.7	36.9	32.4	32.0	40.0
Point Pleasnat, NJ	19.7	22.8	19.2	21.6	22.6	23.1	22.1	20.2	23.0	37.0
Reedville, VA	24.2	24.2	26.1	27.1	23.7	27.3	23.9	25.9	34.0	36.0
Long Beach-Barnegat, NJ	14.6	16.4	20.6	26.7	24.5	23.1	22.9	21.7	26.0	34.0
Portland,ME	40.4	28.7	34.6	34.6	27.8	24.1	22.6	16.6	19.0	28.0
Provincetown-Chatham, MA	15.2	13.5	14.2	19.8	20.6	18.3	18.3	20.0	20.0	27.0
Rockland, ME	4.3	4.1	2.7	7.4	n.a.	n.a.	n.a.	n.a.	11.0	24.0
Wanchese-Stumpy Point, NC	23.2	21.0	20.6	19.6	21.7	20.6	22.4	23.1	22.0	22.0
Montauk, NY	11.1	11.0	13.1	16.5	16.8	15.7	14.3	14.6	18.0	19.0
Newport, RI	n.a.	n.a.	n.a.	n.a.	20.8	12.4	n.a.	n.a.	n.a.	n.a.
Boston, MA	8.6	8.9	8.8	10.6	n.a.	n.a.	n.a.	11.9	15.1	n.a.
Beaufort- Morehead City, NC	19.1	15.0	16.9	9.7	n.a.	n.a.	11.1	23.1	n.a.	n.a.
Atlantic City, NJ	22.4	20.8	17.7	18.5	24.2	27.5	24.1	22.2	17.3	n.a.
Other	76.2	74.9	55.2	51.1	-	-	-	-	-	-
Total	646.6	650.6	719.6	815.8	701.1	696.1	615.5	699.3	801.4	934.0
Source: NOAA Fisheries.										

The right whale ship strike reduction operational measures apply to vessels with a length of 65 feet and above. Because the AIS data lacks adequate records on commercial fishing vessels[9], we also evaluated data which included fishing vessels which are over 65 feet in length and weigh less than 150 tons, using information provided by NMFS' database of commercial fishing permits.

Table 3-2 shows that for the Southeast region nearly 80 percent of the fishing vessels over 65 feet are less than 150 tons. For the Northeast region, 63 percent of the fishing vessels over 65 feet are less than 150 tons.

[9] Commercial fishing vessels greater than 65 are required to have AIS transponders. However, the data set we received only included 147 transits of fishing vessels on the entire US East Coast during 2009 which was felt to be too small to be accurate.

Table 3-2. Fishing Vessel Permits Issued to Vessels 65 Feet and Above in LOA by Region, 2009-2011

		2009		2010		2011	
Region	Vessel size	Fishing permits	%	Fishing permits	%	Fishing permits	%
Southeast Region	All vessels	279	100%	260	100%	247	100%
	Vessels less than 150 GRT	220	79%	204	78%	195	79%
Northeast Region	All vessels	807	100%	773	100%	722	100%
	Vessels less than 150 GRT	523	65%	496	64%	453	63%

Source: Prepared by Nathan Associates Inc. from data provided by NOAA Fisheries Service, Southeast Regional Office (SERO) and Northeast Regional Office (NERO).

The estimated economic impact of the operational measures on commercial fishing vessels in 2003 is presented in Table 3-3. The analysis assumes that the commercial fishing vessels are affected for an effective distance of 20 nautical miles each way as they steam to and from fishing areas.

Many commercial fishing vessels steam at 10 knots or below and will not be affected by the operational measures if they were implemented at the 10-knot speed restriction. The typical steaming speed for other commercial fishing vessels is assumed at 12 knots. Average operating costs per hour of $400 includes fuel costs of June 2009. The duration of the speed restrictions vary from 181 days per year for the mid-Atlantic to 61 days per year for the Northeastern US. For purposes of the economic analysis, we have assumed that the speed restrictions were in effect for 181 days for commercial fishing..

Table 3-3. Estimated Economic Impact on Commercial Fishing Vessels by Region, 2009

Item	Northeast Region	Southeast Region	Total
Commercial fishing permits for vessels over 65 ft LOA and under 150	523	220	743
Percent with steaming speed over 10 knots	40%	40%	40%
Vessels potentially affected by speed restrictions	209	88	297
Typical steaming speed of affected vessels (knots)	12	12	12
Number of trips per year per vessel	25	25	25
Minutes of delay per trip with restricted speed of 10 knots	38.0	38.0	38.0
Operating cost per hour of steaming (dollars)	400	400	400
Estimated impact per year (dollars)	657,022	276,376	933,398

Source: Prepared by Nathan Associates Inc.

The estimated impact in 2009 on commercial fishing vessels is estimated at $0.7 million for the Northeast Region and $0.3 million for the Southeast Region. The combined Northeast and Southeast regional economic impact of $0.9 million is only one-tenth of one percent of the value of U.S. East Coast commercial fishery landings of $699 million in 2009.

These results indicate that the implementation of the operational measures will not have an undue adverse impact on the commercial fishing industry along the U.S. East Coast.

Charter Fishing

In some areas, charter vessels travel up to 50 nautical miles offshore to reach prime fishing areas. At vessel speeds of up to 17 knots they can reach their fishing areas in less than 3 hours. Under the Rule, speed restrictions of 10 knots for 20 nautical miles add about 100 minutes to the roundtrip steaming time, and could severely affect client demand.

The charter fishing industry is active along the U.S. East Coast with concentration in the Carolinas, Virginia, Florida, New Jersey and Massachusetts. The industry consists of half-day charters of about 6 hours that typically go up to 20 nautical miles offshore; full-day charters of 11-12 hours that can go up to 40 nautical miles offshore; and extended full day charters that can be from 18-24 hours and go up to 50 miles offshore. The vast majority of the charter fishing industry consists of modern and well-equipped fishing boats of less than 65 feet LOA and thus would not be subject to the speed restrictions and other operational measures.

A small segment of the industry referred to as head boats often uses vessels of 80 feet LOA and above that can accommodate 60 to 100 passengers. These vessels go up to 50 miles offshore stop and anchor over wreck and rock formations for fishing species as red snapper, grouper, trigger fish, amberjack. The charter fee for a head boat is typically $50- $80 per person.

As described above an increase of 100 minutes roundtrip steaming time would reduce the competitiveness of the larger head boats (more than 65 foot LOA) particularly for the half-day and full-day charters. It is likely that vessels of less than 65 foot LOA would increase their share of those market segments, partially offsetting the economic impact incurred by the larger head boats. For extended full-day charters, head boats of LOA in excess of 65 feet would incur additional costs associated with the 100 minutes increase in roundtrip steaming time. It is estimated that annual economic impact of the speed restriction of 10 knots for these vessels over 20 nautical miles is approximately $1.0 million.[10]

Passenger Ferries

The vast majority of passenger vessels operating along the U.S. East Coast sail within the COLREGS line and as such will not be affected by the Rule. However, in the southern New England area, there is a well-developed passenger ferry sector that operates beyond the COLREGS line and hence is subject to the Rule's operational measures. A list of major New

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[10] This calculation assumes 50 head boat vessels with 30 roundtrips during the off-season months of November through April and an hourly steaming operating cost of $400. These calculations do not include any offsetting impact of revenue gains by operators of smaller charter fishing vessels.

England passenger ferry operators, routes served and service characteristics are presented in Table 3-4.

Table 3-4. New England Ferry Operators, 2011

Operator	Route	Max Vessel Speed (knots)	Distance (nm)	Summer Schedule	Non-summer schedule	Travel Time (minutes)	Summer Season Adult Fare ($) Round trip
SOUTHERN NEW ENGLAND							
Fast Ferries							
Bay State Cruise Company	Boston, MA-Provincetown, MA	30	50	6 trips daily	none	90	85
Boston Harbor Cruises	Boston, MA-Provincetown, MA	40	50	4 trips daily	none	90	83
Boston Harbor Cruises	Boston, MA-Salem, MA	33	25	8 trips daily	none	60	27
Cross Sound Ferry Sevices	New London, CT-Orient Point LI, NY	30	16	12 trips daily	All year long	45	34.25
Block Island Express	New London, CT-Block Island, RI	35	30	6 - 8 daily trips	none	75	45
Freedom Cruise Line	Harwich, MA-Nantucket, MA	24	30	6 trips daily	Spring, Fall	80	74
Hy-Line Cruises	Hyannis, MA- Nantucket, MA	30	27	12 trips daily	10 trips daily	60	77
Hy-Line Cruises	Hyannis, MA-Martha's Vineyard, MA	24	20	10 trips daily	4-6 trips daily	55	71
Block Island Ferry	Point Judith, RI-Block Island, RI	30	11	12 trips daily	Spring, Fall 8-10 trips daily	30	36
Seastreak	New Bedford, MA- Martha's Vineyard, MA	30	30	12 trips daily	Spring, Fall 4-10 trips daily	60	68
Seastreak	New York City, NY- Martha's Vineyard, MA	42	150	2 trips per weekend	Holidays	315	155
The Steamship Authority	Hyannis, MA- Nantucket, MA	35	26	10 trips daily	8 trips daily	60	67
Vineyard Fast Ferry	Quonset Point, RI-Martha's Vineyard, MA	33	50	6 trips daily	Srping, fall 4 daily trips	95	79
Regular Ferries							
Bay State Cruise Company	Boston, MA-Provincetown, MA	16	50	2 trips Sat and Sun	none	180	46
Express Ferry	Plymouth, MA-Provincetown, MA	16	25	2 trips daily	none	100	43
Cross Sound Ferry Service	New London, CT-Orient Point LI, NY	15	16	30 trips daily	All year long	80	27
Hy-Line Cruises	Hyannis, MA- Nantucket, MA	15	26	6 trips daily	1-2 trips daily	110	45
Hy-Line Cruises	Hyannis, MA-Martha's Vineyard (Oak Bluffs), MA	12	20	2 trips daily	2 trips daily	100	45
Hy-Line Cruises	Nantucket, MA-Martha's Vineyard (Oak Bluffs), MA	16	20	2 trips daily	2 trips daily	70	70
Block Island Ferry	Point Judith, RI-Block Island, RI	16.5	11	18 trips daily	All year long	55	19
Block Island Ferry	Point Judith, RI- Newport, RI	13	10	2 trips daily	none	60	13
Block Island Ferry	Newport, RI-Block Island, RI	13	22	2 trips daily	none	120	17
Patriot Party Boats	Falmouth, MA- Martha's Vineyard (Oak Bluffs), MA	15	5	16 trips daily	All year long	20	20
Falmouth Ferry	Falmouth, MA-Martha's Vineyard (Edgadtown), M	12	9	8 trips daily	Spring 6 daily trips each weekend	60	50
Island Queen	Falmouth, MA-Martha's Vineyard (Oak Bluffs), MA	12	5	14 trips daily	Spring, Fall 4-10 daily trips	35	20
The Steamship Authority	Woods Hole-Martha's Vineyard	16	7	32 trips daily	28 trips daily	35-45	16
The Steamship Authority	Hyannis, MA- Nantucket, MA	14	26	12 trips daily	6 trips daily	135	33
MAINE							
Casco Bay Lines	Portland, ME - Peaks Island, ME	12.5	3	14 trips daily	All year long	20	8
Casco Bay Lines	Portland, ME - Little Diamond Island, ME	12.5	3	18 trips daily	All year long	20	8
Casco Bay Lines	Portland, ME - Great Diamond Island, ME	12.5	4	18 trips daily	All year long	25	9
Casco Bay Lines	Portland, ME - Diamond Cove, ME	12.5	5	22 trips daily	All year long	30	10
Casco Bay Lines	Portland, ME - Long Island, ME	12.5	6	24 trips daily	All year long	35	10
Casco Bay Lines	Portland, ME - Chebeague Island, ME	12.5	12	12 trips daily	All year long	70	11
Casco Bay Lines	Portland, ME - Cliff Island, ME	12.5	10	10 trips daily	All year long	60	12
Casco Bay Lines	Portland, ME - Bailey Island, ME	12.5	20	2 trips daily	none	105	25

Source: Prepared By Nathan Associates Inc. from data on operator websites and selected interviews.

Passenger ferry operations in southern New England generally fall into two categories - fast ferry service with vessel speeds ranging from 24-39 knots and regular ferry service with vessel speeds from 12-16 knots. As shown in Table 3-4 there are ten operators providing fast ferry service on 12 routes. Key destinations include Provincetown, Block Island, Nantucket, and Martha's Vineyard, while important origins include Boston, New London, Hyannis, Harwich, Point Judith and Quonset Point.

Regular ferry service in southern New England is provided by nine operators on eleven routes. Vessel speeds range from 12-16 knots and serve many of the same origins and destinations as the fast ferry service. Additional origins served by regular ferries include Plymouth, Falmouth and Woods Hole.

Regular ferry service also operates in Southern Maine with 120 trips daily to eight destinations served by Casco Bay Lines from Portland. Service is provided to local islands including Peaks Island, Great Diamond Island, Cliff Island and Bailey Island.

IMPACT ON FERRY OPERATORS

Passenger ferry service generally is not impacted by the SMAs as they are not effective during the summer season. Speed restrictions for Cape Cod Bay are implemented from January 1 through May 15. Speed restrictions for Block Island Sound are from November 1 through April 30. In addition, the speed restricted area for Block Island Sound does not extend to the shoreline and hence does not impact fast ferry operations.[11]

However, voluntary DMAs established during the summer season could have an impact, especially if they became mandatory. Interviews with passenger ferry operators identified their particular concern of the situation where a DMA were to be implemented during the peak summer season. For a fast ferry operator, a DMA implemented directly along their route would result in the suspension of service for the entire period that the DMA is in effect[12]. There are several reasons for this conclusion. First, the demand for fast ferries that normally operate between 24-39 knots would virtually disappear if the ferries were restricted to a speed of 10 knots. Second, any remaining demand would not be sufficient to cover vessel operating costs, and third, many of the handling and comfort characteristics of fast ferries would suffer at these reduced speeds.

As reported in earlier in Table 2-11, there were 18 DMAs established in 2009. Figure 3-1 below shows the seven DMAs in 2009 that are in locations relevant for ferry operations. However

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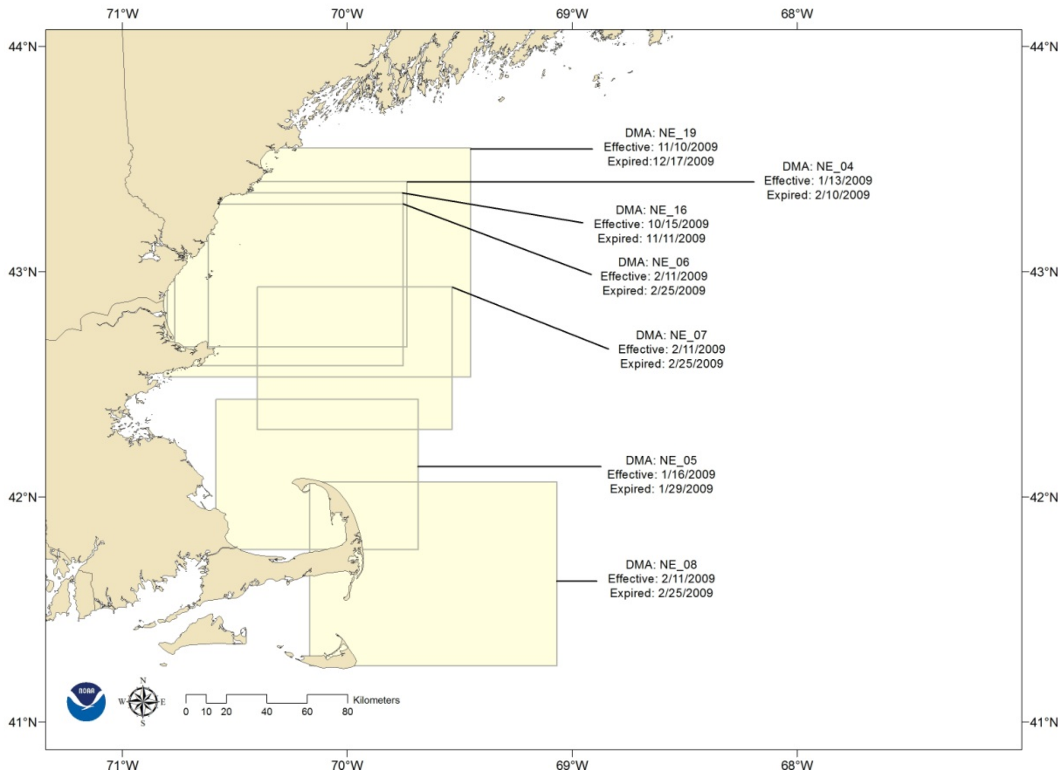
[11] The rectangular area proposed has its northern limits running approximately in a line from Montauk to the southwestern coast of Block Island.

[12] If a DMA were to be implemented say over a 15-day summer period, the two fast ferry operators on the Boston-Provincetown route would lose net revenues of over $500,000, nearly 10 percent of their annual sales and wipe out their annual profit. Multiple DMAs in one year or in consecutive years could force the shutdown of these services.

each of these DMAs occurred in the winter months and did not affect ferry operations. Hence, in 2009 there was no or minimal economic impact of DMAs on fast ferry operators.

Figure 3-1 DMAs in Areas Relevant for Passenger Ferry Operators



New England Whale Watching Industry

The New England whale watching industry also can be categorized into operations that deploy high-speed vessels with speeds ranging from 25-38 knots; and operations that deploy regular speed vessels with speeds from 16-20 knots. Table 3-5 presents information for the major whale watching operators in Massachusetts Bay. There are nine operators of high-speed vessels; three are based in Gloucester, three in Boston, one in Barnstable, one in Bar Harbor and one in Boothbay Harbor. These operators make 18 daily trips during the summer months. There are fifteen operators of regular speed vessels that have operations based in Massachusetts (eight operators), New Hampshire (four), Maine (two) and Rhode Island (one). Altogether these operators make 21 daily whale watching trips during the summer months.

Table 3-5. Massachusetts Bay Whale Watching Operators, 2012

Operator	Location	# Daily Trips (per Vessel)	Trip Duration (hr)	Adult Fare per Trip ($)	Max Vessel Speed (knots)	Number of Vessels
Regular-Speed Vessel						
Yankee Fleet	Gloucester, MA	1	4	n.a.	20	2
Coastal Fishing Charters	Gloucester, MA	1	4-5	100	20	1
Newburyport Whale Watch	Newburtyport, MA	2	4 - 4 1/2	48	20	1
Captian John Whale Watching and Fishing Tours	Plymouth, MA	4	3 1/2-4 1/2	45	17	4
Provincetown Whale Watches	Provincetown, MA	1	n.a.	37	20	1
The Dolphin Fleet of Provincetown	Provincetown, MA	8	3-4	44	16	4
Shearwater Excursions	Nantucket Island, MA	1	6	115	20	1
Al Gauron Whale Watching	Hapton Beach, NH	1	5	36	20	3
Atlantic Whale Watch	Rye Harbor, NH	1	4 - 4 1/2	36	20	1
Eastman's Docks	Seabrook Beach, NH	1	4 1/2	33	20	4
First Chance WhaleWatch	Kennebunk, ME	1	4 1/2	48	18	1
Odyssey Whale Watch	Portland, ME	2	4	48	20	1
Capt. Bill & Sons Whale Watch	Gloucester, MA	2	3 1/2	48	20	1
Granite State Whale Watch	Rye Harbor, NH	2	4-5	36	18	1
Frances Fleet Whale Watching	Narragansett, RI	1	4 1/2	n.a.	18	2
Subtotal		21				28
High-Speed Vessels						
Capt'n Fish's Whale Watch	Boothbay Harbor, ME	2	3-3 1/2	48	33	3
Boston Best Cruises	Boston, MA	2	4	45	33	2
Bar Harbor Whale Watch Company	Bar Harbor, ME	3	3-3 1/2	59-56	33	3
New England Aquarium Whale Watch	Boston, MA	1	3-4	45	30	1
Boston Harbor Cruises	Boston, MA	4	3	45	35	2
7 Seas Whale Watch	Gloucester, MA	2	3 1/2-4	48	35	1
Cape Ann Whale Watch	Gloucester, MA	2	3-4	48	25	1
Yankee Fleet	Gloucester, MA	1	4	n.a.	33	1
Hyannis Whale Watcher Cruises	Barnstable, MA	1	3 1/2-4	47	38	1
Subtotal		18				15

Source: Prepared by Nathan Associates from data on operator websites and selected interviews.

Speed restrictions for Cape Cod Bay are implemented from January 1 through May 15. Hence, the peak summer whale watching season are not affected for high-speed or regular speed vessels. Similarly, the speed restrictions for an extended Off Race Point from March through April would not impact the whale watching season.

As shown earlier in Figure 3-1, there were no DMAs implemented in 2009 that were during periods that affected whale watching operations. Further, if a DMA were to be established, a whale watching operator will select an alternative location where humpback whales are present and not right whales. The whale watching community has developed an informal communications network to advise them of whale sightings. As State and Federal regulations restrict any vessel from approaching closer than 500 yards to a right whale, they would avoid right whale as a matter of course.

4. Total Direct and Indirect Economic Impact

In the sections above we have presented the analysis of individual components of the economic impact analysis of the Rule in 2009. The total direct and indirect economic impact of is $44.7 million in 2009 (Table 4-1). This cosists of $23.8 million of direct impact on the shipping industry, 1.9 million on commercial fishing and charter fishing combined, and $19.0 million of indirect impacts.

Table 4-1 Total Direct and Indirect Economic Impact, 2009 ($ millions)

Impact	Amount
Direct iimpact on shipping industry	
Seasonal Management Areas (SMAs)	19.6
Dynamic Management Areas(DMAs)	-
Cumulative Effect of multi-port strings	3.1
Re-routing of southbound coastwise shipping	1.1
Subtotal	23.8
Direct impact on other other market segments	
Commercial fishing	1.0
Charter fishing	0.9
Passenger ferries	-
Whale watching	-
Subtotal	1.9
Indirect impact	19.0
Total impact	44.7

Source: Prepared by Nathan Associates as described in text.

5.Impact on Small Business

Size Standards for Small Entities

According to the U.S. Small Business Administration[13], a small business is a concern that is organized for profit, with a place of business in the United States, and which operates primarily within the United States or makes a significant contribution to the U.S. economy through payment of taxes or use of American products, materials or labor. Further, the concern cannot be dominant in its field, on a national basis. Finally, the concern must meet the numerical small business size standard for its industry. SBA has established a size standard for most industries in the U.S. economy.

Size standards for the industries potentially affected by the final rule are presented in Table 5-1. For international and domestic commercial shipping operators, the SBA size standard for a small business is 500 employees or less. The same threshold applies for international cruise operators and domestic ferry service operators. For whale watching operators and charter fishing operators the SBA threshold is $7.0 million of average annual receipts. For commercial fishing operators, the SBA threshold is $4.0 million of average annual receipts.

[13] United States Small Business Administration, Frequently Asked Questions About Small Business Size Standards, www.sba.gov/size/indexfaqs.html

Table 5-1. Small Business Size Standards and Firms by Employment Size and NAICS Code, 2008

Type of entity	NAICS Code	NAICS U.S. Industry Title	Size Standard ($ millions)	Size Standard Employees	Firms Employment size Total	< 20	< 500	500+
International commercial shipping operator	483111	Deep Sea Freight Transportation	n.a.	500	230	120	96	14
International cruise operator	483112	Deep Sea Passenger Transportation	n.a.	500	64	29	30	6
Domestic commercial shipping operator	483113	Coastal and Great Lakes Freight Transportation	n.a.	500	379	207	136	36
Domestic ferry service operator	483114	Coastal and Great Lakes Passenger Transportation	n.a.	500	155	103	48	4
Whale watching operators	487210	Scenic & sightseeing transportation, water	7	n.a.	1,704	1,540	152	12
Charter fishing operators	487210	Scenic & sightseeing transportation, water	7	n.a.	1,704	1,540	152	12
Commerical fishing	114111	Finfish Fishing	4	n.a.	1,060	1,017	41	2
	114112	Shellfish Fishing	4	n.a.	877	858	19	-
	114119	Other Marine Fishing	4	n.a.	34	31	3	-

Source: U.S. Small Business Administration,Table of Small Business Size Standards matched to North American Industry Classification System Codes, October 24, 2012 and SBA Office of Advocacy, Firm Size Data provided by U.S. Census Bureau on Employer Firms and Employment by Employment Size of Firm by NAICS Codes, 2008.

Table 5-1 also presents information on the total number of firms in the U.S. in 2008 by employment size ranges for these industries. The preponderance of firms involved in these industries is considered as small entities by the SBA size standards. In 2008, there were 230 firms involved in deep sea freight transportation industry of which 216 firms had 500 employees or less. In the deep sea passenger transport industry, 58 firms of the total 64 firms had 500 or fewer employees. In the Coastal and Great Lakes freight transportation industry, 343 firms of the total 379 firms had 500 or fewer employees. In the Coastal and Great Lakes passenger transportation industry, all but four firms of the 155 total firms had 500 or fewer employees.

There were 1,704 firms providing scenic and sightseeing water transportation in 2008 of which 1,692 firms had 500 or fewer employees. For the finfish fishing industry 1,058 firms of the total 1,060 firms had 500 or fewer employees; while all 877 firms involved in shellfish fishing had 500 or fewer employees.

Number of Small Entities Affected

For the FEIS Report of 2008, Nathan Associates conducted a detail analysis to determine the number of small entities involved in commercial shipping along the U.S. East Coast. Many of the firms operating within the international commercial shipping industry and international cruise industry have foreign ownership and have their primary place of business outside the U.S. and hence would not qualify as a U.S. small entity.

To identify vessel owned by U.S. entities, we analyzed information provided by the U.S. Coast Guard regarding parties owning vessels that had arrivals at the U.S. East Coast in 2004.

We were able to identify the vessel owner and/or managing owner for 99.6 percent of the vessels that had U.S. East Coast vessel arrivals in 2004.[14] The USCG data provides information on the address of the vessel owner and/or managing owner in terms of zip code, state and country. Using that information we identified vessels with U.S. East Coast arrivals in 2004 that were owned by U.S. entities or foreign entities.

Of the 27,385 U.S. East Coast vessel arrivals in 2004, 6,540 arrivals or 23.9 percent were recorded by vessels owned by parties with U.S. address (Table 5-2). The U.S. East Coast arrivals were made by 4,114 vessels of which 620 or 15.1 percent were by vessels owned by parties with a U.S. address. In terms of number of parties, the 2004 vessel arrivals were made by 3,505 parties of which 432 or 12.3 percent had a U.S. address.

Table 5-2. U.S. East Coast Vessel Arrivals by Vessels with U.S. or Foreign Parties, 2004

Item	Party address		Total
	U.S	Foreign	
Number of vessel arrivals	6,540	20,845	27,385
Percent	23.9%	76.1%	100.0%
Number of vessels	620	3,494	4,114
Percent	15.1%	84.9%	100.0%
Number of parties	432	3,073	3,505
Percent	12.3%	87.7%	100.0%

Source: Prepared by Nathan Associates Inc. from analysis of U.S. Coast Guard as described in text.

We then conducted an analysis of the entire U.S. Coast Guard vessel characteristics database to identify the number and type of vessels owned by the U.S. parties with U.S. East Coast arrivals in 2004.[15] Approximately 71 percent of the U.S.-based parties owned only one vessel and 90.7 percent owned 4 or less vessels (Table 5-3).

[14] We were not able to match party information for 198 vessels of the 4,114 vessels that had U.S. East Coast arrivals in 2004. These vessels accounted for 3.8 percent of 2004 U.S. East Coast arrivals (1,004 of the 27,385 arrivals). However using information on U.S. or foreign flag of registry, we assigned these vessels by country of ownership.

[15] For this analysis, we included all vessels owned by the party, not just those with vessel arrivals at U.S. East Coast ports in 2004.

Table 5-3. U.S-Based Parties with U.S. East Coast Arrivals by Number of Vessels Owned, 2004

Number of Vessels Owned	Number of Parties	Percentage of Parties	Number of Vessels	Percentage of Vessels
1	306	70.8	306	30.6
2	49	11.3	98	9.8
3	24	5.6	72	7.2
4	13	3.0	52	5.2
5	6	1.4	30	3.0
6	7	1.6	42	4.2
7	6	1.4	42	4.2
8	3	0.7	24	2.4
9	4	0.9	36	3.6
10	1	0.2	10	1.0
11	3	0.7	33	3.3
12	1	0.2	12	1.2
15	1	0.2	15	1.5
16	1	0.2	16	1.6
17	2	0.5	34	3.4
20	1	0.2	20	2.0
24	1	0.2	24	2.4
35	1	0.2	35	3.5
38	1	0.2	38	3.8
61	1	0.2	61	6.1
Total:	432	100	1,000	100

Source: Prepared by Nathan Associates inc. from U.S. Coast Guard data as described in text.

The next step was to determine which of these U.S. based parties should be considered a small-business for the RFA analysis. Information on the number of employees is not readily available for U.S.-based parties that own vessels with arrivals at the U.S. East Coast. However, we reviewed the list of U.S-based parties and removed the 53 parties that obviously do not qualify as a small business such as Carnival Cruise Lines, Chevron, Maersk, Holland America Line, BP Oil Shipping, etc. A further classification was made to exclude an additional 17 parties that own 5 or more vessels from the set of small businesses on the assumption that a business with 5 or more capital intensive commercial cargo vessels would employ at least 500 employees throughout its organization. We assume that the remaining set of 362 US-based parties that own vessels that had U.S. East Coast arrivals in 2004 be assumed to be small businesses for the purposes of the RFA analysis. Table 5-4 presents information on vessels and vessel arrivals for this set of vessels assumed to be operated by U.S.-based small entities.

Table 5-4. U.S. East Coast Vessel Arrivals by U.S.-Based Small Entities, 2004

Vessel Type	Number of 2004 Vessel Arrivals	Number of vessels	Number of parties
Bulk Carrier	142	25	24
Container Ship	502	30	28
Freight Barge	77	13	12
General Dry Cargo Ship	99	24	22
Multiple	435	49	31
Passenger Ship	463	33	31
Refrigerated Cargo Ship	51	6	6
Ro-Ro Cargo Ship	433	25	22
Tank Barge	702	61	51
Tank Ship	784	83	79
Towing Vessel	209	44	43
Other a/	65	14	13
Total:	3,962	407	362

a/ Other includes fishing vessels, industrial vessels, and research vessels.
Source: Prepared by Nathan Associates Inc. from U.S. Coast Guard data as described in text.

The 362 parties assumed to be small businesses operated 407 vessels that had 3,962 vessel arrivals at U.S. East Coast ports in 2004. Tank ships and tank barges are the vessel types with the most parties, vessels and vessel arrivals for the set of vessels assumed to be owned by U.S. based small businesses.

Other Industries

In Chapter 3, we presented information on entities involved in other maritime industries that would potentially be affected by the operational measures of the final rule. For purposes of this RFA analysis we have assumed that all U.S. East Coast entities involved in commercial fishing industry, domestic ferry service industry, and charting fishing industry are considered as small entities. In the whale watching industry all entities (except the New England Aquarium) are considered as small entities.

Thus as shown in Table 5-5, we estimate that there are 373 small entities potentially affected Rule. Of these, 209 entities are involved in commercial fishing in the Northeast Region and 88 entities in the Southeast region. There are 14 entities identified involved in Southern New England passenger ferry service[16], 8 entities providing whale watching services in Massachusetts Bay and 40 entities providing charter fishing service along the U.S. East Coast. Note that only the subset of charter fishing entities operating larger head boats that accommodate 60 to 100 passengers is included in this analysis. The majority of charter fishing

[16] In Table 3-4, ten entities are listed as operating fast ferries in Southern New England and eight entities that operate regular ferries. However, four of the entities operate both fast ferries and regular ferries and hence, there are only 14 entities involved in Southern New England passenger ferry service.

entities operates fishing boats of less than 65 LOA and thus are not subject to the operational measures of the Rule.

Table 5-5. Number of Small Entities in Other Industries Potentially Affected, 2009

Industry	Number of Small Entities Potentially Affected
Commercial Fishing	
Northeast Region	209
Southeast Region	88
Southern New England Passenger Ferries	14
Massachusetts Bay Whale Watching	22
Charter Fishing	40
Total	373

Source: Prepared by Nathan Associates Inc. as described in Section 3, and presented in Table 3-2, Table 3-4 and Table 3-7.

Economic Impact on Small Entities

In this section, we first present the economic impact on the small entities involved in the commercial shipping industry[17] followed the estimated impact on small entities in other maritime industries.

COMMERCIAL SHIPPING

All of the operational measures of the final rule described in Section 3 are assumed to apply to commercial shipping vessel operated by small entities. Table 5-6 presents the number of vessel arrivals by U.S. small entities in 2004 and total vessel arrivals by all U.S. entities. Those figures are used to calculate the percent of U.S. vessel in 2004 that were made by small entities. The resulting percentages are then applied to the current analysis of the 2009 economic impact on all U.S.- flagged vessels to determine the economic impact on U.S. small entities[18].

The economic impact of the Rule on U.S. small entities in the commercial shipping industry is estimated at $2.2 million in 2009. This estimate includes the direct economic impact of speed restrictions during seasonal management periods and dynamic management periods plus the cumulative effect of multi-port strings and the re-routing of southbound coastwise shipping. Containerships ($0.8 million) ro-ro cargo ships ($0.4 million) and passenger ships ($0.3 million) together account for 68 percent of the economic impact on small entities in the commercial shipping industry.

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[17] Passenger cruise vessels are included in this section as the data sources, approach and methodology applied for this market segment is same as those of the commercial shipping industry.

[18] The 2004 data and relationships were used because there wass no information on the transits in 2009 by U.S. small entities within the shipping industry.

Table 5-6. Economic Impact on U.S. Small Entities by Vessel Type, 2009

	2004 Vessel Arrivals			2009 Economic Impact		
Vessel type	Arrivals by U.S. Small Entities	Arrivals by All U.S. Entities	Percent by US Small Entities	On all U.S. Entities ($000s)	On U.S. Small Entities ($000s)	As a % of Annual Revenues
Bulk Carrier	142	150	94.7	99.1	93.8	0.044%
Container Ship	502	874	57.4	1,449.6	832.6	0.106%
Freight Barge	77	270	28.5	398.4	113.6	0.307%
General Dry Cargo Ship	99	124	79.8	18.1	14.5	0.008%
Passenger Ship	272	310	87.7	319.7	280.6	0.037%
Refrigerated Cargo Ship	51	51	100.0	-	-	0.000%
Ro-Ro Cargo Ship	433	450	96.2	404.3	389.0	0.063%
Tank Barge	702	1,474	47.6	199.2	94.9	0.010%
Tanker	731	784	93.2	220.5	205.6	0.021%
Towing Vessel	209	691	30.2	194.2	58.8	0.012%
Other a/	65	65	100.0	199.2	199.2	0.267%
Total	3,283	5,243	62.6	3,502.4	2,193.1	0.042%

a/ Other includes fishing vessels, industrial vessels, research vessels, school ships. -

Note: Annual revenue estimated as average of daily operating cost at sea and daily operating cost in port by vesel type and size for 365 days for vessels accounting for 2009 SMA transits.

Daily operating cost in port was assumed at 60 percent of daily operating cost at sea.

Source:Nathan Associates Inc.

Table 5-6 also presents the economic impact on small entities as a percent of annual revenues by vessel type. For vessels operated by small entities it was assumed that they spend equal amounts of days at sea and in port.

Overall, the economic impact of the Rule represents about 4 one-hundredth of one percent of the annual revenues of vessels operated on the U.S. East Coast by small entities. For small entities operating containerships, the economic impact increases to up to one-tenths of one percent.

Based on these findings, we conclude that the operational measures of the final rule would not have a significant economic impact on a substantial number of small entities involved in commercial shipping along the U.S. East Coast.

Other Industries

The estimated economic impact on small entities in other maritime industries is presented in Section 3. The impact on small entities in the charter fishing industry in 2009 is estimated at $1.0 million (Table 5-7). The estimated economic impact on small entities in the commercial fishing industry is $0.9 million. There was no or minimal impact in 2009 on ferry operators and whale watching operators.

Table 5-7. Estimated Economic Impact of Rule on Small Entities in Other Industries, 2009 ($000s unless otherwise specified)

Industry	Estimated Economic Impact ($000s)	No. of Small Entities	Average Economic Impact per Small Entity ($000s)	Economic Impact as a % of Annual Revenues
Commercial fishing	933.4	307	3.0	0.4%
Charter fishing	1,000.0	40	25.0	4.3%

Source: Prepared by Nathan Associates Inc.

The economic impact on commercial fishing vessels is estimated at $3,000 per vessel per year and constitutes less than one-half of one percent of their annual revenues. This is not considered to be a significant economic impact.

The annual revenue of a small entity operating a charter fishing head boat is estimated at $504 thousand based on an average of 80 passenger paying $80 for 90 charters. The estimated economic impact of the final rule at is 4.3 percent of their estimated annual revenue and for purposes of the FRFA determination is not considered to be a significant economic impact.

6. Scoping Assessment of Economic Analysis of Potential Rule Modifications

As initially mandated, the Rule is due for renewal or modification in 2013. In this section, we assess the data requirements and level of analyses that would be needed to estimate the economic impact of some issues.

Update Analysis for 2010, 2011 and 2012

The economic impact analysis presented in this report is based on 2009 AIS data. By early 2013, it should be possible to obtain AIS data for 2010 through 2012. It is most efficient for data cleaning and review if the data for these years are provided together rather than at separate times. The key issue for using the additional years of AIS data is the matching of newly appearing vessels with our detailed twelve categories of vessel types and 18 deadweight ton ranges.

We have been provided AIS data for the first 11 months of 2010. Based on a review of that data, an additional year would require matching more than 2,000 newly appearing vessels, requiring about 7 days for an analyst and 4 days for a senior economist. If the three years of 2010 through 2012 were analyzed at the same time, this work could be completed with 14 days for an analyst and 8 days for a senior economist.

Reduce 65-Foot Vessel Length Threshold

The current Rule applies to vessels that are 65 feet and above in overall length (LOA). For 2009, we have worked with the AIS for vessels that are affected by the current Rule. If the length threshold was reduced to say 30 feet, this would require matching additional vessels with our detailed twelve categories of vessel types and 18 deadweight ton ranges. In terms of the conduct of the economic impact analysis, this modification would be difficult and costly to undertake as less information is available on smaller vessels. Lowering the length threshold will also require renewed and expanded analyses for commercial fishing, ferry boats, whale watch vessels and charter fishing vessels. It is estimated that this would require 15 days for an analyst and 10 days for a senior economist.

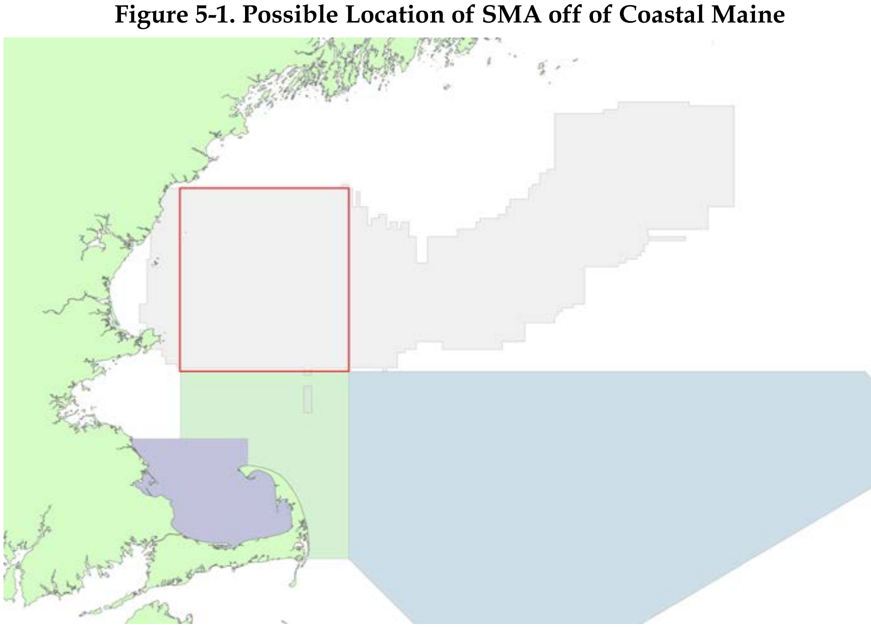
Expansion of Off-Race Point and Great South Channel SMAs

Under this modification, the existing Off-Race Point SMA and the Great South Channel SMA would be expanded to incorporate areas where DMAs regularly occur. As the vessel transits through DMAs have already been analyzed for 2009, the characteristics of those vessels have already been matched and identified. We would need to receive from NOAA a revised SMA database incorporating transits that would applicable to the newly defined geographic boundaries of the expanded SMAs. Since there would little need for matching of vessels, the economic impact for 2009 could be determined with 5 days for an analyst and 2 days for a senior economist. Other years could be conducted with the time already included for 2010-2012 update described above.

Establishment of SMAs in Waters of Coastal Maine

The current Rule does not include a SMA for waters off of Maine's coast. However, this has been an active area for right whales in recent years, as evidenced by the number of DMAs that have been implemented. The possible location of the SMA which would be effective from October 1 through February 28 is shown in Figure 5-1.

Figure 5-1. Possible Location of SMA off of Coastal Maine



We have been provided by NOAA, an AIS database that shows transits in 2009 for this possible SMA. Of the 1,734 transits made through this area in 2009 by 404 vessels, we have been able to match 1,397 transits by 305 vessels. Matching of the remaining vessels and determining the economic impact will require 3 days for an analyst and 1 days for a senior economist.

Make all DMAs Mandatory

As the vessel transits through DMAs have already been analyzed for 2009, the characteristics of those vessels have already been matched and identified. That analysis compared the amount of time needed to transit a DMA based on actual recorded speeds for the DMA areas when they were in effect and not in effect. However, since this data only corresponds to voluntary speed restrictions, it does not provide the impact for a mandatory DMA. The best estimate of the average observed speeds would be those recorded in SMAs in 2009 for each type/ size of vessel. Those speeds could b used to then calculate the impact of a mandatory DMA.

The analysis described in the paragraph above applies to the shipping industry vessels. However, making all DMAs mandatory will also require renewed and expanded analyses for commercial fishing, ferry boats, whale watch vessels and charter fishing vessels. It is estimated that this entire task would require 5 days for an analyst and 10 days for a senior economist.

North Atlantic Right Whale

North Atlantic Right Whale
Eubalaena glacialis

Protected Status

ESA ENDANGERED
Throughout Its Range

CITES APPENDIX I
Throughout Its Range

MMPA PROTECTED
Throughout Its Range

MMPA DEPLETED
Throughout Its Range

Quick Facts

WEIGHT	Up to 70 tons
LIFESPAN	Up to 70 years
LENGTH	Up to 52 feet
THREATS	Entanglement in fishing gear, Vessel strikes, Ocean noise, Climate and ecosystem change, Disturbance from whale watching activities, Small population size, Lack of food
REGION	New England/Mid-Atlantic, Southeast

About The Species

The North Atlantic right whale is one of the world's most endangered large whale species, with only about 400 whales remaining. Two other species of right whale exist in the world's oceans: the North Pacific right whale, which is found in the Pacific Ocean, and the southern right whale, which is found in the southern hemisphere. Right whales are baleen whales, feeding on shrimp-like krill and small fish by straining huge volumes of ocean water through their baleen plates, which act like a sieve.

By the early 1890s, commercial whalers had hunted right whales in the Atlantic to the brink of extinction. Whaling is no longer a threat, but human interactions still present the greatest danger to this species. Entanglement in fishing gear and vessel strikes are among the leading causes of North Atlantic right whale mortality.

NOAA Fisheries and our partners are dedicated to conserving and rebuilding the North Atlantic right whale population. We use a variety of innovative techniques to study, protect, and rescue these endangered whales. We engage our partners as we develop regulations and management plans that foster healthy fisheries and reduce the risk of entanglements, create whale-safe shipping practices, and reduce ocean noise.

Status

North Atlantic right whales have been listed as endangered under the Endangered Species Act since 1970. Today researchers estimate there are about 400 North Atlantic right whales in the population with fewer than 100 breeding females left. Only 12 births have been observed in the three calving seasons since 2017, less than one-third the previous average annual birth rate for right whales. This, together with an unprecedented 30 mortalities since 2017 (part of a declared Unusual Mortality Event), accelerates the downward trend that began around 2010, with deaths outpacing births in this population.

Protected Status

ESA Endangered

- Throughout Its Range

CITES Appendix I

- Throughout Its Range

MMPA Protected

- Throughout Its Range

MMPA Depleted

- Throughout Its Range

Appearance

North Atlantic right whales have stocky black bodies with no dorsal fin, and their spouts are shaped like a "V." Their tails are broad, deeply notched, and all black with a smooth trailing edge. Their stomachs and chests may be all black or have irregularly shaped white patches. Pectoral flippers are relatively short, broad, and paddle-shaped. Calves are about 14 feet at birth and adults can grow to lengths of up to 52 feet.

Their characteristic feature is raised patches of rough skin, called callosities, on their heads, which appear white because of whale lice (cyamids). Each right whale has a unique pattern of these callosities. Scientists use these patterns to identify individual whales, an invaluable tool in tracking population size and health. Aerial and ship-based surveys and the North Atlantic Right Whale Consortium's photo-identification database maintained by our partners at the New England Aquarium help track populations over the years using a right whale's unique pattern of callosities.

Behavior and Diet

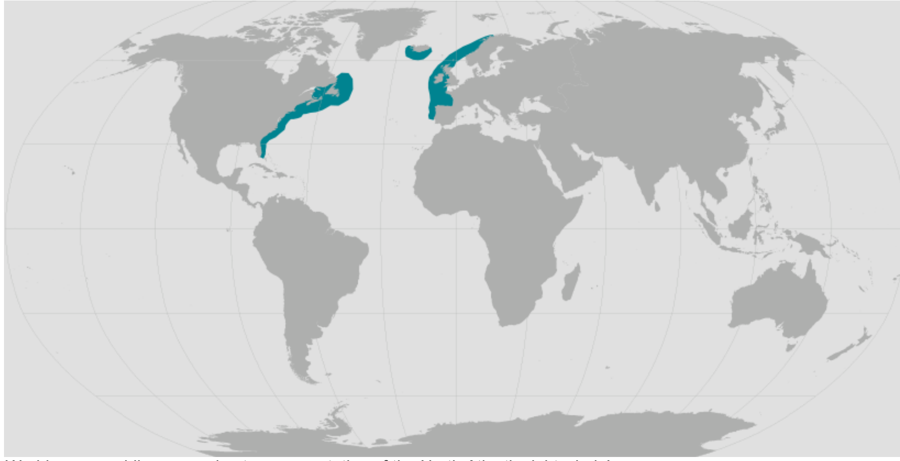
When viewing right whales, you might see these enormous creatures breaching—propelling themselves up and out of the water—and then crashing back down with a thunderous splash. You might also see them slapping their tails (lobtailing) or their flippers (flippering) on the water's surface.

Groups of right whales may be seen actively socializing at the water's surface, known as surface-active groups, or SAGs. Mating occurs in SAGs, observed during all seasons and in all habitats, but SAGs likely serve other social purposes as well.

Right whales produce low-frequency vocalizations best described as moans, groans, and pulses. Scientists suspect that these calls are used to maintain contact between individuals, communicate threats, signal aggression, or for other social reasons.

Right whales feed by opening their mouths while swimming slowly through large patches of minute zooplankton and copepods. They filter out these tiny organisms from the water through their baleen, where the copepods become trapped in a tangle of hair-like material that acts like a sieve. Right whales feed anywhere from the water's surface to the bottom of the water column.

Where They Live



World map providing approximate representation of the North Atlantic right whale's range.

North Atlantic right whales primarily occur in Atlantic coastal waters or close to the continental shelf, although movements over deep waters are known.

Right whales migrate seasonally and may travel alone or in small groups. In the spring, summer, and into fall, many of these whales can be found in waters off New England and further north into the Canadian Maritimes, where they feed and mate.

Each fall, some right whales travel more than 1,000 miles from these feeding grounds to the shallow, coastal waters of South Carolina, Georgia, and northeastern Florida. These waters in the southern United States are the only known calving area for the species—an area where females regularly give birth during winter. While this is the typical pattern, migration patterns vary for some of these whales.

NOAA Fisheries has designated two critical habitat areas to provide important feeding, nursery, and calving habitat for the North Atlantic population of right whales:

- Off the coast of New England (foraging area).
- Off the southeast U.S. coast from Cape Fear, North Carolina, to below Cape Canaveral, Florida (calving area).

Lifespan & Reproduction

Right whales can probably live at least 70 years, but data on their average lifespan is limited. Ear wax can be used to estimate age in right whales after they have died. Another way to determine life span is to look at groups of closely related species. There are indications that some species closely related to right whales may live more than 100 years. However, female North Atlantic right whales are now only living to around 45 and males only to around 65.

In recent years, we've recorded more deaths among adult females than males. There are now more males than females in the population, and that gap is widening. Females, by going through the energetic stress of reproduction, are more susceptible than males to dying from entanglement or ship strike injuries. Today, we believe there are about 95 reproductively active females.

Female right whales become sexually mature at about age 10. They give birth to a single calf after a year-long pregnancy. Three years is considered a normal or healthy interval between right whale calving events. But now, on average, females are having calves every 6 to 10 years. In the last three calving seasons (2017-2019) there were only 12 births, which is about one-third of the average annual birth rate. Biologists believe that the additional stress caused by entanglement is one of the reasons that females are calving less often.

Threats

Entanglement

Entanglement in fishing lines attached to gillnets and traps on the ocean floor is one of the greatest threats to the critically endangered North Atlantic right whale. Becoming entangled in fishing gear can severely stress and injure a whale, and lead to a painful death. Studies suggest that more than 85 percent of right whales have been entangled in fishing gear at least once, and about 60 percent have been entangled multiple times.

Vessel Strikes

Vessel strikes are a major threat to North Atlantic right whales. Their habitat and migration routes are close to major ports along the Atlantic seaboard and often overlap with shipping lanes, making the whales vulnerable to collisions with ships and other vessels.

Ocean Noise

Underwater noise pollution interrupts the normal behavior of right whales and interferes with their communication.

Scientific Classification

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Cetacea
Family	Balaenidae
Genus	*Eubalaena*
Species	*glacialis*

What We Do

Conservation & Management

We are committed to the protection and recovery of the North Atlantic right whale through implementation of various conservation, regulatory, rescue, and enforcement measures. Our work includes:

- Protecting habitat and designating critical habitat.
- Rescuing entangled right whales.
- Reducing the threat of vessel collisions.
- Reducing injury and mortality by fisheries and fishing gear.
- Minimizing the effects of vessel disturbance and noise.

Learn more about our conservation efforts ›

Science

We conduct various research activities on the biology, behavior, and ecology of the North Atlantic right whale. The results of this research are used to inform management decisions and enhance recovery efforts for this critically endangered species. Our work includes:

- Identifying habitat and when it is used by right whales.
- Investigating unusual mortality events.
- Performing stock assessments to gather population information.
- Tracking individuals over time to monitor important population traits.

Learn more about our research ›

How You Can Help

Report a Right Whale Sighting

Please report all right whale sightings from Virginia to Maine at (866) 755-6622, and from Florida to North Carolina at 877-WHALE-HELP (877) 942-5343. Right whale sightings in any location may also be reported to the U.S. Coast Guard via channel 16 or through the **WhaleAlert app**.

Stay 500 Yards Away

To protect right whales, NOAA Fisheries has regulations that prohibit approaching or remaining within 500 yards (1,500 feet) of a right whale—500 yards is the length of about four football fields. These regulations apply to vessels and aircraft (including drones), and to people using other watercraft such as surfboards, kayaks, and jet skis. Any vessel within 500 yards of a right whale must depart immediately at a safe, slow speed.

Call the NOAA Fisheries Enforcement Hotline at **(800) 853-1964** to report a federal marine resource violation. This hotline is available 24 hours a day, 7 days week for anyone in the United States.

Learn more about our marine life viewing guidelines ›

Report Marine Life in Distress

Report a sick, injured, entangled, stranded, or dead animal to make sure professional responders and scientists know about it and can take appropriate action. Numerous organizations around the country are trained and ready to respond.

Learn who you should contact when you encounter a stranded or injured marine animal ›

Be Informed and Get Involved

Stay updated on right whale take reduction and other conservation measures. For accurate information, check your sources or confirm them by reviewing our news and announcements. Participate in public meetings and share your perspectives with Take Reduction Team members who represent your constituency.

In the Spotlight

The North Atlantic right whale is NOAA Fisheries' newest Species in the Spotlight. This initiative is a concerted, agency-wide effort to spotlight and save marine species that are among the most at risk of extinction in the near future.

North Atlantic right whales, which got their name from being the “right” whales to hunt because they floated when they were killed, have never recovered to pre-whaling numbers. These whales have been listed as endangered under the Endangered Species Act since 1970 and have been experiencing a steady population decline for nearly a decade. NOAA and our partners are continuing to prioritize stabilizing and preventing extinction of this species, and this Species in the Spotlight designation will help focus federal and non-federal resources on these many efforts.

Right Whales’ Role in a Balanced Ecosystem

The natural system is balanced through food webs and nutrient transport, with every species contributing to that balance. Right whales play an important role in this balanced ocean ecosystem.

The majority of the Earth's oxygen is produced by marine phytoplankton. These tiny ocean plants also help to absorb CO2, so healthy phytoplankton levels also help to combat climate change. When they defecate at the surface, marine mammals such as right whales provide essential nitrogen and phosphorus to those phytoplankton.

When whales die, they also provide essential nutrient resources to the ocean floor ecosystems. Scavengers consume the soft tissue in a matter of months. Organic fragments, or detritus, enrich the sediments nearby for over a year, and the whale skeleton can provide habitat for invertebrate communities for decades.

Better understanding right whales’ behavior and biology also provides us with information about changing ocean conditions, giving us insight into larger environmental issues that could have implications for human health.

Sometimes we don’t know how vital a species’ role is in maintaining this balance until it’s too late, and sometimes those unforeseen impacts can have a direct effect on our own existence. The Marine Mammal Protection Act and Endangered Species Act recognize that managing species to make sure they can fulfill their role in the bigger picture is to everyone’s benefit. A diverse environment is a healthier environment. It’s part of our responsibility as stewards of the nation’s living marine resources to make sure that we protect right whales and have healthy fisheries.

NOAA’s Commitment to Right Whale Recovery

As the federal agency with the lead on recovering the North Atlantic right whale population, we believe that the right steps, people, and knowledge are in place to help us make decisions that will contribute to recovery and reduce entanglement risk significantly. Our mandate under the Marine Mammal Protection Act has provided the structure, through the Take Reduction Process, to make sure all voices on this issue are heard and that innovation comes from the people who will be most impacted by future regulatory action.

Under the Endangered Species Act, we are looking at how the threats right whales face impact their recovery and how we manage those threats to facilitate their recovery.

Learn more about NOAA’s commitment to saving North Atlantic right whales ›

Where They Live

North Atlantic right whales are found mostly along the Atlantic coast in shallower waters. Each fall, some right whales travel more than 1,000 miles from their feeding grounds along the coasts of Canada and New England to the warm coastal waters of South Carolina, Georgia, and Florida. Here they give birth and nurse their young.

Population Status

Today researchers estimate there are about 400 North Atlantic right whales in the population with fewer than 100 breeding females left. Only 12 births have been observed in the three calving seasons since 2017, less than one-third the previous average annual birth rate for right whales. This, together with an unprecedented 30 mortalities since 2017 (part of a declared Unusual Mortality Event), accelerates the downward trend that began around 2010, with deaths outpacing births in this population.

Threats

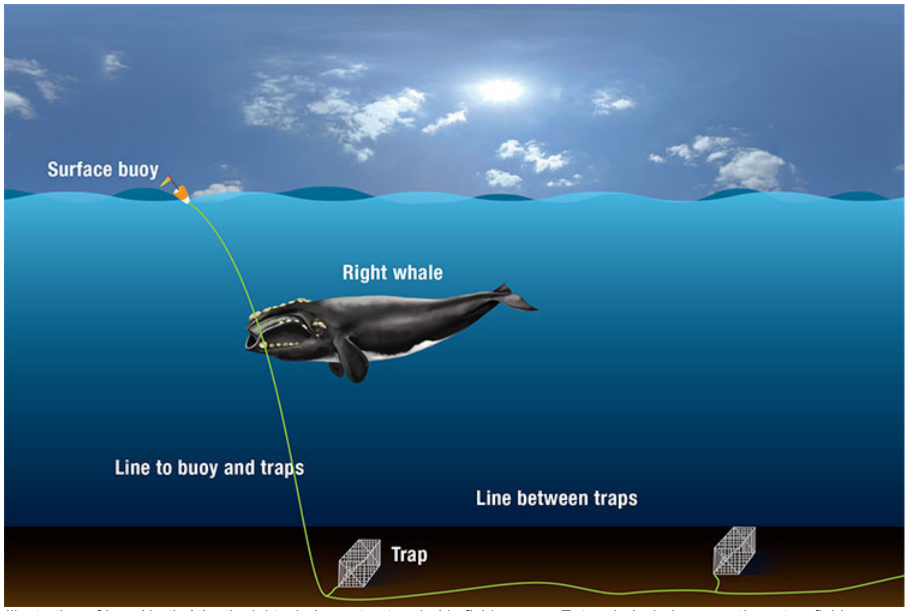


Illustration of how North Atlantic right whales get entangled in fishing gear. Entangled whales sometimes tow fishing gear for hundreds of miles. Credit: WHOI Graphic Services, Woods Hole Oceanographic Institution.

Entanglement in vertical buoy lines, or ropes, connected to fishing gillnets, traps, and pots on the ocean floor is one of the greatest threats to North Atlantic right whales. NOAA Fisheries and our partners estimate that over 85 percent of right whales have been entangled at least once. These lines can cut into a whale's body, cause serious injuries, and result in infections and mortality. Even if gear is shed or disentangled, the time spent entangled can severely stress a whale, which weakens it, prevents it from feeding, and saps the energy it needs to swim and feed. Biologists believe that this additional stress is one of the reasons that female right whales are having fewer calves; females used to have calves every 3 to 5 years, and now are having calves every 6 to 10 years.

Ship strikes are a second major threat to right whales. Their habitat and migration routes are close to major ports along the Atlantic coastline and often overlap with shipping lanes, making them vulnerable to collisions with ships. These collisions can cause broken bones and massive internal injuries or cuts from vessel propellers. As large as right whales are, most vessels are larger, and the faster a vessel is going when it hits a whale, the higher the likelihood of serious injury or death.

Underwater noise from human activities such as shipping, recreational boating, development, and energy exploration has increased along our coasts. Noise from these activities can interrupt the normal behavior of right whales and interfere with their communication with potential mates, other group members, and their offspring. Noise can also reduce their ability to avoid predators, navigate and identify physical surroundings, and find food.

Species Recovery

Recovery Plan

NOAA Fisheries formed a recovery team of scientists and stakeholders to help develop a North Atlantic right whale recovery plan, which was finalized in 2005. The recovery plan helps guide our efforts to prevent extinction of the right whale. These strategies include reducing vessel collisions and fishing gear entanglement, protecting whale habitat, maximizing efforts to free entangled right whales, and monitoring the population. NOAA Fisheries appointed a recovery team in the Northeast and a team in the Southeast to implement the recovery plan. Partnerships are a critical component of North Atlantic right whale recovery.

Critical Habitat Designation

NOAA Fisheries has designated critical habitat for the North Atlantic right whale, which includes a foraging area in the Northeast and a calving area in the Southeast. This designation means that federal agencies must ensure that any activities in these areas do not adversely modify those areas.

Reducing Vessel Strikes

The most effective way to reduce the threat of vessel collisions with North Atlantic right whales is to keep whales and traffic apart. If that is not possible, the next best option is for vessels to slow down and keep a lookout. NOAA Fisheries has taken a number of steps to reduce this threat such as:

- Requiring ships to slow down in specific areas (Seasonal Management Areas) based on right whales' migration patterns and timing.
- Asking vessels to slow down when whales are seen in an area outside of these Seasonal Management Areas.
- Modifying international shipping lanes.

- Developing right whale sighting and alert systems.
- Requiring large ships to report when they enter key right whale habitats. In return, the vessel receives a message about right whales, precautionary measures to avoid hitting a whale, and locations of recent sightings.
- Regulating how close a vessel or aircraft may get to a right whale. This reduces disturbance to the animal and the potential for negative interaction.

Reducing Entanglement in Fishing Gear

NOAA Fisheries has developed management measures to reduce whale entanglements with the help of the Atlantic Large Whale Take Reduction Team—a group of advisors consisting of fishermen, scientists, environmental organizations, and state and federal officials. The Team's Take Reduction Plan requires commercial fishermen to use certain fishing gear types that are less harmful to right whales, and specifies areas where fishing cannot take place when whales are present.

The main focus of our entanglement reduction effort has been to understand where along the East Coast the risk of entanglement is greatest and to reduce line in the water column that could pose a risk to right whales.

Because we have evidence that trap/pot and gillnet fishing gear pose the greatest risk of entanglement to large whales, we have several seasonal fishing closures during times when we know whales will be present. We've also required that fishermen use sinking groundline in between their traps and between gillnet panels and the anchoring system. Before that decision, the line would float, sometimes meters off the ocean floor, and whales traveling in between the traps or between gillnets and anchors and would get caught in the line. Sinking groundline is not in the water column, which reduces the risk of entanglement.

We've also taken steps to reduce the number of endlines. Endlines connect the first and last traps to the buoys that sit at the surface. By fishing with only one endline where safety allows it, or adding more traps to a set, we've managed to reduce the number of endlines. Again, any fishing line removed from the water column helps reduce the risk of entanglement.

All in all, our measures have helped to remove around 42,000 miles of fishing line from the water column across the entire U.S. Atlantic region. That's enough line to circle the Earth one and a half times. Removing fishing line from the water undoubtedly removes risk of entanglement for right whales and other protected species, even if statistically these benefits are hard to see.

In addition, when entangled whales are reported anywhere along the East Coast, the NOAA-funded Atlantic Large Whale Disentanglement Network is called upon to try to help. The Network is made up of emergency responders from 20 public and private organizations who have extensive training in how to disentangle large whales and increase their odds of surviving. Examining gear removed from entangled animals is one of the key ways for us to determine whether regulations are working and fishing gear modifications are effective.

Overseeing Stranding Response

We work with volunteer networks in all coastal states to respond to marine mammal strandings, including large whales. When stranded animals are found alive, NOAA Fisheries and our partners assess the animal's health. When stranded animals are found dead, our scientists work to understand and investigate the cause of death.

International Collaboration

NOAA Fisheries is actively collaborating with Canada through ongoing bilateral negotiations on the science and management gaps that are impeding the recovery of North Atlantic right whales in both Canadian and U.S. waters.

Management Overview

Right whales are protected under both the Endangered Species Act (ESA) and the Marine Mammal Protection Act. They have been listed as endangered under the ESA since 1970. This means that North Atlantic right whales are in danger of extinction throughout all or a significant portion of their range. NOAA Fisheries is working to protect this species in many ways, with the goal that its population will increase.

Recovery Planning and Implementation

Recovery Plan

Under the ESA, NOAA Fisheries is required to develop and implement recovery plans for the conservation and survival of listed species. The ultimate goal of the North Atlantic right whale plan is to recover the species, with an interim goal of down-listing its status from endangered to threatened.

The major actions recommended in the plan are:

- Reduce or eliminate injury and mortality caused by vessel collisions or by fisheries and fishing gear.
- Protect habitats essential to the survival and recovery of the species.
- Minimize effects of vessel disturbance.
- Continue international ban on hunting and other directed take.
- Monitor the population size and trends in abundance of the species.
- Maximize efforts to free entangled or stranded right whales and acquire scientific information from dead specimens.

Read the recovery plan for the North Atlantic right whale >

Implementation

The ESA authorizes NOAA Fisheries to appoint recovery teams to assist with the development and implementation of recovery plans. Two regional North Atlantic right whale recovery plan implementation teams were established to assist with issues related to the status and conservation of right whales.

Learn more about the Southeast U.S. Implementation Team >

Learn about the Northeast U.S. Implementation Team >

Critical Habitat Designation

Once a species is listed under the ESA, NOAA Fisheries evaluates and identifies whether any areas meet the definition of critical habitat. Those areas may be designated as critical habitat through a rulemaking process. The designation of an area as critical habitat does not create a closed area, marine protected area, refuge, wilderness reserve, preservation, or other conservation area; nor does the designation affect land ownership. Rather, federal agencies that undertake, fund, or permit activities that may affect these designated critical habitat areas are required to consult with NOAA Fisheries to ensure that their actions do not adversely modify or destroy designated critical habitat.

NOAA Fisheries designated critical habitat for the North Atlantic right whale in 1994 (59 FR 28805) and revised the designation in 2016 (81 FR 4838).

Critical habitat for the North Atlantic right whale includes two areas—a foraging area in the Northeast and a calving area in the Southeast:

- North Atlantic Right Whale critical habitat map and GIS data
- Final rule establishing critical habitat for North Atlantic Right whales

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Conservation Efforts

Reducing Vessel Strikes

The most common vessel-related threats to right whales are blunt force trauma and propeller cuts. Collisions between whales and large vessels often go unnoticed and unreported, even though whales can be injured or killed and ships can sustain damage.

Reducing vessel speeds where whales are present, developing recommended shipping lanes outside of specific ports, making mariners aware when whales are around, and implementing a 500-yard "no-approach" safety zone around right whales are among the measures we use to reduce these threats.

Specifically, we have taken both regulatory and non-regulatory steps to reduce the threat of vessel collisions to North Atlantic right whales, including:

- Requiring vessels to slow down in specific areas during specific times (Seasonal Management Areas).
- Advocating for voluntary speed reductions in Dynamic Management Areas.
- Recommending alternative shipping routes and areas to be avoided.
- Modifying international shipping lanes.
- Developing right whale alert systems.
- Developing mandatory vessel reporting systems.
- Increasing outreach and education.
- Improving our stranding response.

Implementing Vessel Speed Restrictions for North Atlantic Right Whales

The most effective way to reduce collision risk is to keep whales and vessels apart. If that is not possible, the next best option is for vessels to slow down and keep a lookout. There are several areas, known as seasonal management areas, along the U.S. East Coast where vessels 65 feet or longer must slow to 10 knots or less during times of the year when right whales are likely to be in the area. The idea behind the 10-knot limit is that the more slowly a vessel goes, the more time the whale has to get out of the way, and a strike at that speed is less likely to be fatal. We have fined companies for violating these speed reductions.

Outside of these areas, if three or more right whales are sighted within 75 nautical miles of each other, we implement a short-term voluntary speed reduction area around those whales and do our best to get the word out to all vessels to use extra caution in these areas. Unfortunately, studies have found that these voluntary measures are not very effective in modifying vessel speed or direction of travel, and therefore likely do little to reduce vessel collisions.

Implementing a Mandatory Vessel Reporting System for North Atlantic Right Whales

To further reduce the number of vessel strikes, NOAA Fisheries and the U.S. Coast Guard developed and implemented a mandatory vessel reporting system for North Atlantic right whales. When large vessels enter one of two key right whale habitats—one off the U.S. northeast coast and one off the U.S. southeast coast—they must report to a shore-based station. In return, the vessel receives a message about right whales, their vulnerability to ship strikes, precautionary measures to avoid hitting a whale, and locations of recent sightings.

Learn more about the mandatory ship reporting system for North Atlantic right whales ›

Implementing Right Whale Sighting and Notice Systems

To reduce collisions with right whales, mariners are urged to use caution and proceed at safe speeds in areas where right whales occur. NOAA Fisheries and our partners developed an interactive mapping application that provides up-to-date information on North Atlantic right whale sightings along the East Coast of the United States.

Learn more about reducing vessel strikes to North Atlantic right whales ›

Addressing Ocean Noise

Underwater noise threatens whale populations, interrupting their normal behavior and driving them away from areas important to their survival. Increasing evidence suggests that exposure to intense underwater sound in some settings may cause some whales to strand and ultimately die. NOAA Fisheries is investigating all aspects of acoustic communication and hearing in marine animals, as well as the effects of sound on whale behavior and hearing. In 2016, we issued technical guidance for assessing the effects of anthropogenic sound on marine mammals' hearing.

Learn more about ocean noise ›

Reducing Entanglement in Fishing Gear

Entanglement in fishing gear is a primary cause of serious injury and death for many whale species, including the North Atlantic right whale. With the help of the Atlantic Large Whale Take Reduction Team—a group of advisors consisting of fishermen, scientists, and state and federal officials—we have developed management measures to reduce whale entanglements. We require commercial fishermen to use certain gear types that are less harmful to North Atlantic right whales, and have established areas where fishing cannot take place during certain times when North Atlantic right whales are present. We are currently developing management measures to reduce the number of buoy lines in the water column in an effort to further reduce the risk of entanglement in fishing gear.

In addition, when entangled whales are reported anywhere along the East Coast, the NOAA-funded Atlantic Large Whale Disentanglement Network is called upon to try to help. The network is made up of emergency responders from 20 public and private organizations who have extensive training in how to disentangle large whales and increase their odds of surviving. The Network has successfully disentangled close to 30 North Atlantic right whales over the years. And examining gear removed from entangled animals is one of the key ways for us to determine whether regulations are working and fishing gear modifications are effective.

Learn more about the Take Reduction Team's efforts to reduce whale entanglements ›

Learn more about bycatch and fisheries interactions ›

Overseeing Marine Mammal Health and Stranding Response

We work with volunteer networks in all coastal states to respond to marine mammal strandings, including large whales. When stranded animals are found alive, NOAA Fisheries and our partners assess the animal's health. When stranded animals are found dead, our scientists work to understand and investigate the cause of death. Although the cause often remains unknown, scientists can sometimes identify strandings due to disease, harmful algal blooms, vessel strikes, fishing gear entanglements, pollution exposure, and underwater noise. Some strandings can serve as indicators of ocean health, giving insight into larger environmental issues that may also have implications for human health and welfare.

Learn more about the Marine Mammal Health and Stranding Response Program ›

Key Actions and Documents

Actions & Documents | Incidental Take

Five-Year Reviews of North Atlantic and North Pacific Right Whales

NMFS announces a 5-year review of North Atlantic right whale (Eubalaena glacialis) and North Pacific right whale (Eubalaena japonica) under the Endangered Species Act of 1973 (ESA), as amended. A 5-year review is based on the best scientific and

› Notice of Initiation (77 FR 16538, 03/21/2012)

Notice , Alaska, New England/Mid-Atlantic, West Coast, Foreign
PUBLISHED
March 21, 2012

Listing North Atlantic Right Whale Under the ESA

We, NMFS, completed a status review of right whales in the North Pacific and North Atlantic Oceans under the Endangered Species Act (ESA) in December 2006 and are listing the currently endangered northern right whale (Eubalaena spp.) as two separate

› Final Rule

Final Rule , New England/Mid-Atlantic
PUBLISHED
April 7, 2008

Regulations Governing the Approach to North Atlantic Right Whales

Disturbance is identified in the Final Recovery Plan for the Northern Right Whale (Recovery Plan) as among the principal human-induced factors impeding recovery of the northern right whale (Eubalaena glacialis) (NMFS, 1991). NMFS is issuing this interim

› Final Rule, technical amendment (69 FR 69536)
› Final Rule (62 FR 6729)

Final Rule , New England/Mid-Atlantic, Southeast
PUBLISHED
February 13, 1997

Science

NOAA Fisheries conducts various research activities on the biology, behavior, and ecology of the North Atlantic right whale. The results of this research are used to inform management decisions and enhance recovery efforts for this endangered species.

We use a variety of methods to determine where right whales are located, including aerial surveys (planes), directed shipboard surveys, underwater acoustic listening devices, habitat modeling, and anecdotal sightings reports. To better inform the public of the most recent right whale sightings, NOAA scientists maintain a Right Whale Sightings database. Our database includes more than 40 years of reliable sightings data, spanning the entire range of the species from Canada through Florida.

NOAA is working hard to develop a tracking device that will stay attached to right whales and not compromise the health of these animals. Right whales present a unique challenge to tagging efforts because they are social animals that often engage in physical contact with each other, putting tremendous stress on tags attached to their bodies.

Aerial Surveys

Scientists use small aircraft to spot North Atlantic right whales and photograph them to identify individuals and record their seasonal distribution. Understanding the whales' migration patterns helps managers establish measures to reduce vessel strikes and limit the overlap between fisheries and whales. NOAA Fisheries and our partners also use small unmanned aircraft systems—commonly called “drones”—to assess individual right whale size and body condition, as well as taking breath samples to analyze factors such as genetics and stress hormones.

North Atlantic right whale mother and calf as seen from a research drone called a hexacopter. Hexacopters allow researchers to conduct right whale photo identification and photogrammetry studies. Photogrammetry techniques allow scientists to get body measurents from aerial photographs. Photo: NOAA Northeast Fisheries Science Center/Lisa Conger and Elizabeth Josephson.

Shipboard Studies

In addition to aerial surveys, we conduct research cruises that investigate the whales’ habitat preferences and feeding ecology, as well as collect photographic and genetic identification. Information from this research can be used to inform management actions that protect the North Atlantic right whale.

The goals of many of our aerial and shipboard surveys are to photograph as many individual right whales as possible, so we concentrate on places where we are most likely to find them at the surface, aggregating to feed or engage in social behaviors. This helps us most accurately estimate the population size and monitor population trends. The photographs and other data collected when the image is made (time, date, location, behavior) are used by researchers around the region to investigate things like body condition, behavior, and life history. Over time, these data can also reflect changes in distribution.

If the whales aren’t feeding or socializing at the surface, their behavior can make them hard to spot from a plane or large research vessel (for example, if they’re engaged in deep dives or traveling while submerged). Sea state and weather also make it more complicated to spot individual right whales from a plane.

Acoustic Science

We use underwater microphones to listen for right whale calls. This is another way to learn more about where and when these whales are present in different areas (at least during times they are vocalizing) where visual surveys are not likely to be effective. For example, while we do not generally send planes up in the winter to look for right whales, acoustic detections have shown that at least some right whales can be detected year-round in locations we thought were once only seasonally used.

Other research is focused on the acoustic environment of cetaceans, including North Atlantic right whales. Acoustics is the science of how sound is transmitted. This research involves increasing our understanding of the basic acoustic behavior of whales, dolphins, and fish; mapping the acoustic environment; and developing better methods using autonomous gliders and passive acoustic arrays to locate cetaceans.

Learn more about acoustic science ›

Marine Mammal Unusual Mortality Events

To understand the health of North Atlantic right whale populations, scientists study unusual mortality events (UMEs). Understanding and investigating marine mammal UMEs is important because they can serve as indicators of ocean health, giving insight into larger environmental issues that may also have implications for human health and welfare.

Learn more about North Atlantic right whale UMEs >

Stock Assessments

Determining the size of the North Atlantic right whale population—and whether it is increasing or decreasing from year to year—helps resource managers assess the success of the conservation measures enacted. Our scientists collect population information on right whales from various sources and present the data in an annual stock assessment report.

Learn more about marine mammal stock assessments >

Documents

DOCUMENT

National Report on Large Whale Entanglements (2017)

This report provides a summary of large whale entanglements that occurred in U.S. waters in 2017…

National

DOCUMENT

Vessel Operations in Right Whale Protection Areas in 2009

NOAA Technical Memorandum NMFS-OPR-44 Published Date: 2010

New England/Mid-Atlantic, Southeast

DOCUMENT

North Atlantic Right Whale Calving Area Surveys: 2015/2016 Results

This report briefly summarizes the results of aerial surveys conducted in the Southeast United…

Southeast

DOCUMENT

North Atlantic Right Whale Recovery Plan Southeast Implementation Team Meeting Summary and Outcomes, November 2017

Meeting summary and key outcomes from the November 15-16, 2017 Southeast U.S. Implementation Team…

Southeast

More Documents >

Data & Maps

MAP

Other Southeast Gillnet Waters

New England/Mid-Atlantic

MAP

Sinking Groundline Exemption Contour

New England/Mid-Atlantic

MAP

North Atlantic Right Whale Critical Habitat Map and GIS Data

New England/Mid-Atlantic, Southeast

MAP

North Atlantic Right Whale Seasonal Management Areas (SMA) Map & GIS Data

New England/Mid-Atlantic, Southeast

More Data and Maps >

NOAA FISHERIES

Vessel Trip Reporting in the Greater Atlantic Region

All commercial and for-hire vessels fishing in federal waters (3 miles to 200 miles offshore) must report their catch.

Vessel Trip Reporting

Operators of federally permitted vessels must submit a vessel trip report (VTR) for each fishing trip. VTRs are important because they provide data that informs fishery management decisions. You may report electronically or by paper. Read the VTR Instructions.

Electronic Vessel Trip Reporting (eVTR)

Operators have the option to submit their VTRs electronically. Electronic reporting will make the collection of important data on fishing vessel activity more efficient, convenient, and timely for the fishing industry, fishery managers, and other data users. eVTR, has been authorized for all federally permitted vessels in the Greater Atlantic region.

GARFO Fish Online Web-Based Reporting

With our new NOAA Fish Online web-based reporting, you can now submit your electronic Vessel Trip Reports (eVTRs) using your tablet or computer. With web-based reporting, you can:

- Create a new eVTR
- Edit an existing report
- Print existing reports
- Be alerted to any errors made
- Auto-fill forms
- Start and complete a form at different times prior to landing

Reports submitted via web-based reporting will meet all of GARFO’s reporting requirements for both commercial (except ITQ clams) and recreational fishing.

If you have a valid federal fishing permit and would like to use NOAA Fish Online web-based reporting, contact our IT Help Desk at (978) 281-9188 or nmfs.gar.helpdesk@noaa.gov to obtain NOAA Fish Online log-in information.

In addition to our Fish Online web-based reporting, we have also approved other applications for electronic reporting.

eVTR Software Options

You may choose to use any of the following software applications to submit your eVTRs:

1. NOAA Fish Online iOS App Reporting

- NOAA Fish Online for iOS App How-To Card (provides basic assistance for using the NOAA Fish Online app)
- Search for "NOAA EVTR" in the Apple App Store
- For assistance, call (978) 281-9188 or email nmfs.gar.helpdesk@noaa.gov

2. Fisheries Logbook and Data Recording Software (Study Fleet vessels only)

- For assistance, contact Jon O’Neil, Northeast Fisheries Science Center, (508) 495-2207.

3. SAFIS Software

- For assistance, call eTrips/mobile helpdesk at (800) 984-0810 or email support@harborlightsoftware.com

4. Ecotrust Canada Elog Software

- For assistance, contact Amanda Barney, Ecotrust Canada, (250) 624-4191

eVTR app compatibility summary

App	Web-based	Windows-based Computer	Windows – based Tablet	Windows 10-based Computer	Windows 10-based Tablet	iPhone	iPad
NOAA/GARFO Fish Online iOS App Reporting **(Free)**	x	x		x		x	x
NOAA/GARFO **Fish Online** **Web Based Reporting (Free)**	x	x	x				x
NOAA/NEFSC Fisheries Logbook and Data Recording Software (FLDRS - Study Fleet vessels only) **(Free)**		x					
ACCSP SAFIS **eTrips/Mobile2** **(Free)**	x	x	x	x	x	x	x
Electric Edge (FACTS) **For purchase, contact Bryan Stevenson, 250-480-0642 or bryan@electricedgesystems.com**	**Pending Recertification**						
Olrac DDL **For purchase, contact Heidi Henninger at 603-828-9342 or heidi@olsps.com**	**Pending Recertification**						
Ecotrust Canada **(Elog)**		x	x			x	

To obtain an eVTR password

All vessel operators who will be completing an eVTR must obtain a confidential password which will serve as an electronic signature and is required to submit an eVTR. To obtain an eVTR password, please contact us at (978) 281-9188 or email us.

The only exception is for vessel operators who intend to use SAFIS eTrips as their electronic reporting application, in which case your SAFIS username and password will serve as your electronic password. To obtain a SAFIS eTrips username and password please call (800) 984-0810 or email support@harborlightsoftware.com.

Reporting assistance and resources:

- For general questions about vessel trip reporting, call (978) 281-9246 or email us.
- For questions about Fish Online, call (978) 281-9188
- To request reporting forms and logbooks, call (978) 281-9246

For additional eVTR support, contact:

- Lindsey Bergmann, (978) 281-9418
- Jim St.Cyr, (978) 281-9369

eVTR Software Developers

All eVTR software applications must meet specific technical requirements. Upon request, GARFO can test and confirm for developers whether their applications meet the technical requirements.

eVTR Technical Requirements

The eVTR Technical Requirements document provides the technical information that you need to satisfy the programming requirements for electronic reporting.

Support Tables

The eVTR Support Tables provide standard industry information that developers need to build their eVTR applications.

- Table 1 - eVTR Dealer Listing
- Table 2 - eVTR Gear Codes
- Table 3 - eVTR Location to Area
- Table 4 - eVTR Port Listing
- Table 5 - eVTR Species Codes
- Table 6 - eVTR Trip Activity Types
- Table 7 - eVTR Trip Types

Interactive Voice Response System

There are several specific situations in which fishermen fishing in federal waters in the Greater Atlantic Region must report their landings via our Interactive Voice Response System (IVR):

1) If you are not required to report via a Vessel Monitoring System

2) If you fish for quota-monitored species

3) If you land fish caught under an Exempted Fishing Permit

4) If you fish in a Research Set-Aside Program

All vessels reporting via IVR must report their trip start times 24 hours prior to leaving the dock, and report trip end times within 24 hours of returning to the dock for these types of trips:

- Handgear A trips in the Common Pool and small vessel category
- Multispecies (Common Pool and Sector) and scallop trips that fish inside and outside of the VMS demarcation line on the same trip.
- Common Pool DAS block reporting
- Herring VTR trips
- Monkfish fish only trips (and not required to use VMS given groundfish requirements)
- Monkfish RSA trips
- Tilefish trips
- VMS re-declaration trips
- Exempted Fishing Permits - participants in non-VMS fisheries have the option to report via VMS or IVR

Two ways to report via IVR:

Option 1: Report online. To access this simple system, log in to Fish Online and click the '"IVR Reporting" link to the left.

You will need a PIN number to log in to Fish Online. If you do not have one or have technical issues with the IVR system, call (978) 281-9188.

Option 2: Report via telephone. You may call (888) 284-4904 to report your landings. If you need assistance, call:

IVR and VMS reporting requirements and questions: (978) 281-9315

IVR system technical difficulties: (978) 281-9227

Additional help is available in our Current Year's Reporting Weeks.

Paper Reporting

You may still report using paper vessel trip reports. Call (978) 281-9246 or log in to Fish Online to request new logbooks.

Last updated by Greater Atlantic Regional Fisheries Office on 11/21/2019

NORTH ATLANTIC RIGHT WHALE CONSORTIUM

There are 409 North Atlantic Right Whales Left in the World

Started in 1986 as a collaborative data sharing group, the North Atlantic Right Whale Consortium (NARWC) has grown to include more than 200 individuals from various research and conservation organizations, shipping and fishing industries, technical experts, U.S. and Canadian government agencies, and state and provincial authorities, all of whom are dedicated to the conservation and recovery of the North Atlantic right whale. The Consortium is internationally recognized and has been identified as a model for establishing other species-related consortia.

MANDATE

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Tweets by @NARWC

NARWC @NARWC

NARWC: NARWC Annual Meeting Wait List, News, Right Whale Festival - https://t.co/qWZrawTA0M

Oct 29, 2019 6:50 PM

NARWC Retweets

David Abel @davabel

Federal judge requires fishing areas off Nantucket closed to protect right whales https://t.co/FxvwT5QH3u via @BostonGlobe

Oct 29, 2019 6:41 PM

NARWC @NARWC

NARWC: NARWC Board Nominations due TODAY! - https://t.co/gemiPira0R

Oct 25, 2019 1:16 PM

IN THE NEWS

North Atlantic right whales are near extinction and we can avert it

Researchers haven't found a single endangered right whale calf yet this season

To protect right whales, scientists propose major changes for lobstermen

Endangered whale found dead off of Virginia

Slow down for right whales in waters south of Nantucket, fed say

New snow crab fishery rules announced to protect North Atlantic right whales

Conservation groups sue to force greater protection for North Atlantic right whale

North Atlantic right whales spotted in Cape Cod Bay

Ships fined for speeding in Gulf of St. Lawrence

No newborns seen as calving season peaks for endangered right whales

Partners

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NORTH ATLANTIC RIGHT WHALE CONSORTIUM

NARWC
THE NORTH ATLANTIC RIGHT WHALE CONSORTIUM

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Website by NARWC

RAPID COMMUNICATION / COMMUNICATION RAPIDE

Striking the *right* balance in right whale conservation

Robert S. Schick, Patrick N. Halpin, Andrew J. Read, Christopher K. Slay, Scott D. Kraus, Bruce R. Mate, Mark F. Baumgartner, Jason J. Roberts, Benjamin D. Best, Caroline P. Good, Scott R. Loarie, and James S. Clark

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

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

[Traduit par la Rédaction]

Introduction

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

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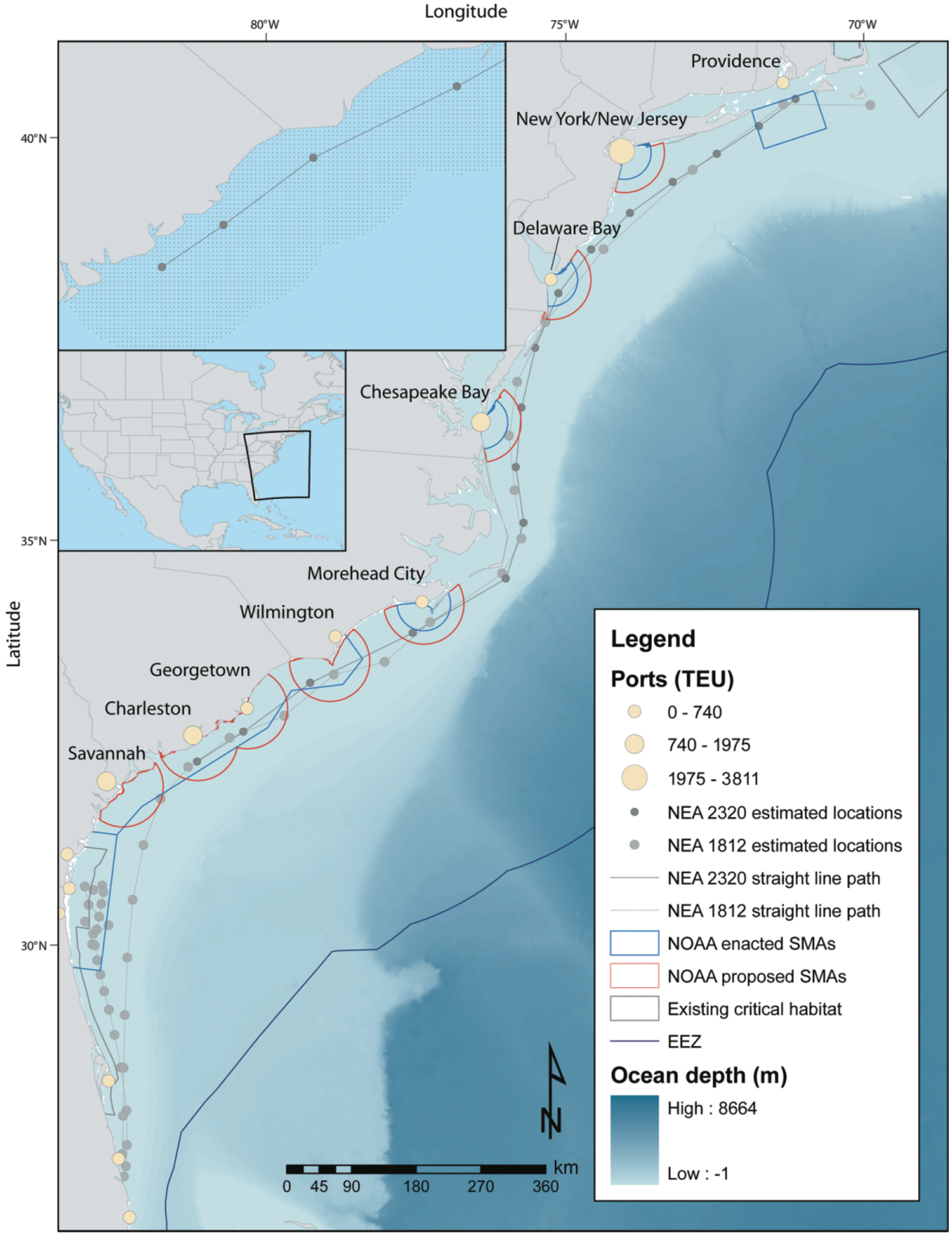
Fig. 1. The portions of two movement paths that cross the migratory corridor are depicted in relation to the proposed (red) and enacted (blue) seasonal management areas (SMA). Light grey and dark grey circles are estimated locations of NEA 1812 and NEA 2320. Major ports are in beige. The upper inset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



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

Data

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

Methods

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

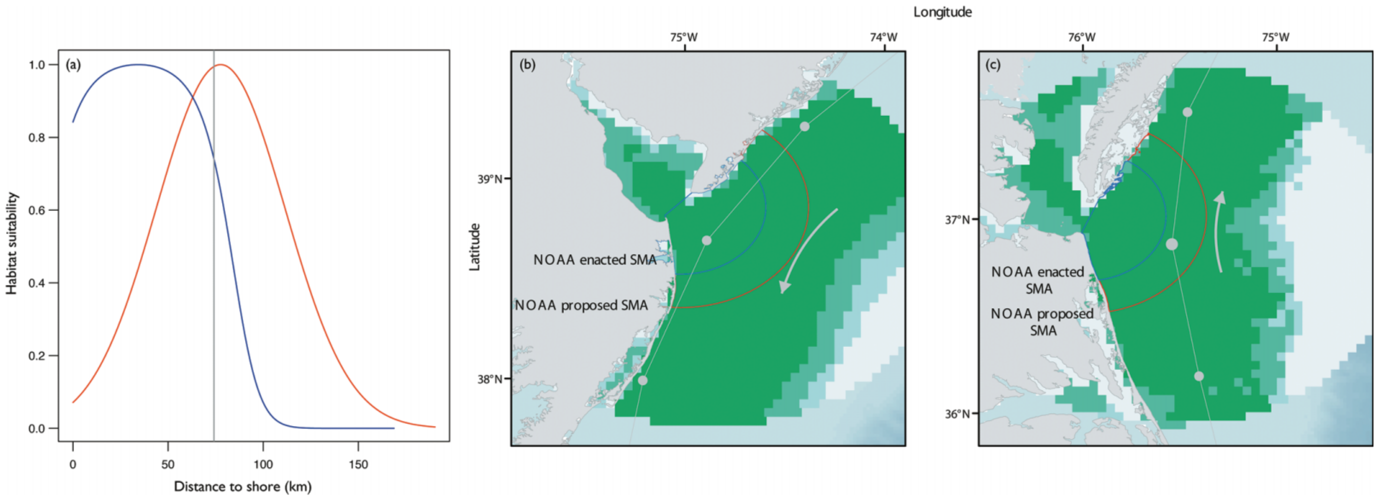
To these data, we applied the Bayesian movement model from Schick et al. (2008) that embeds a resource selection function (Manly and McDonald 2002) inside a movement model in an effort to infer the parameters governing relative habitat suitability h, where h is a function of environmental covariates.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

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

Results

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

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



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

Discussion

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

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

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

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Active Whale Avoidance by Large Ships: Components and Constraints of a Complementary Approach to Reducing Ship Strike Risk

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The recurrence of lethal ship-whale collisions ('ship strikes') has prompted management entities across the globe to seek effective ways for reducing collision risk. Here we describe 'active whale avoidance' defined as a mariner making operational decisions to reduce the chance of a collision with a sighted whale. We generated a conceptual model of active whale avoidance and, as a proof of concept, apply data to the model based on observations of humpback whales surfacing in the proximity of large cruise ships, and simulations run in a full-mission bridge simulator and commonly used pilotage software. Application of the model demonstrated that (1) the opportunities for detecting a surfacing whale are often limited and temporary, (2) the cumulative probability of detecting one of the available 'cues' of whale's presence (and direction of travel) decreases with increased ship-to-whale distances, and (3) following detection time delays occur related to avoidance operations. These delays were attributed to the mariner evaluating competing risks (e.g., risk of whale collision vs. risk to human life, the ship, or other aspects of the marine environment), deciding upon an appropriate avoidance action, and achieving a new operational state by the ship once a maneuver is commanded. We thus identify several options for enhancing whale avoidance including training Lookouts to focus search efforts on a 'Cone of Concern,' defined here as the area forward of the ship where whales are at risk of collision based on the whale and ship's transit/swimming speed and direction of travel. Standardizing protocols for rapid communication of relevant sighting information among bridge team members can also increase avoidance by sharing information on the whale that is of sufficient quality to be actionable. We also found that, for marine pilots in Alaska, a slight change in course tends to be preferable to slowing the ship in response to a single sighted whale, owing, in part, to the substantial distance required to achieve an effective speed reduction in a safe manner. However, planned, temporary speed reductions in known areas of whale aggregations, particularly in navigationally constrained areas, provide a greater range of options for avoidance, highlighting the value of real-time sharing of whale sighting data by mariners. Development and application of these concepts in modules in full mission ship simulators can be of significant value in training inexperienced mariners by replicating situations and effective avoidance maneuvers (reducing the need to 'learn on the water'), helping regulators understand the feasibility of avoidance options, and, identifying priority research threads. We conclude that application of active whale avoidance techniques by large ships is a feasible yet underdeveloped tool for reducing collision risk globally, and highlight the value of local collaboration and integration of ideas across disciplines to finding solutions to mutually desired conservation outcomes.

Keywords: vessel strike, active whale avoidance, ship operations, speed, detection probability

INTRODUCTION

Lethal collisions between large ships and large whales (ship strikes) are a recurring and common threat to whale populations across the globe (Thomas et al., 2016). In some cases, such as with the critically endangered North Atlantic right whales (Fujiwara and Caswell, 2001), and an important sub-population of sperm whales in the Canary Islands (Fais et al., 2016), ship strikes have direct implications for population persistence and biodiversity. In other cases, such as with the population of blue whales in the eastern North Pacific, ship strikes do not appear to regulate population dynamics given the frequency of (known) ship strike mortalities (Monnahan et al., 2015), although the number of detected collisions may be an underestimate of the true number that occur (Rockwood et al., 2017). Regardless, management agencies and the general public value large cetaceans and seek effective ways to reduce ship strikes, even when population persistence is not at stake (Gende et al., 2018).

To date, most management efforts aimed at reducing ship strike risk have focused either on modifying shipping lanes, which can reduce the relative and absolute risk of strikes by reducing spatial and temporal overlap between ships and whales (Knowlton and Brown, 2007; Vanderlaan et al., 2008; van der Hoop et al., 2015), and/or reducing ship speed, which may reduce the probability of a collision (Conn and Silber, 2013) or the likelihood of mortality should a collision occur (Vanderlaan and Taggart, 2007). Yet each of these approaches has limitations. Modifying shipping lanes will only be as effective as the spatial persistence of whale aggregations, can require considerable regulatory effort, or may be impractical in narrow straits or for ships arriving into ports of call (Webb and Gende, 2015; Monnahan et al., 2019). Speed restrictions can generate resistance from the shipping industry owing to economic implications of the additional at-sea time that results from lower speeds, particularly when applied over large areas, which may be one reason voluntary reductions in speeds tend to have low compliance (McKenna et al., 2012). Regardless, whales can be notably unresponsive to approaching ships (Nowacek et al., 2004; McKenna et al., 2015), and thus any action that facilitates the avoidance of whales by mariner training and active avoidance techniques (lowering the reliance on whales to avoid ships) are important to develop.

Here we describe active whale avoidance by mariners aboard large ships which serves as a complementary, but comparatively underexplored, means to reduce whale strike risk. Active whale avoidance is defined here as a mariner making operational decisions, such as a course change or speed reduction, with the goal of reducing the chance of a collision with a sighted whale. Active avoidance differs from more 'passive' regulatory approaches in that the risk- reducing action is primarily initiated by the mariner upon sighting of a whale surfacing forward of the ship as opposed, for example, to a ship entering a mandatory speed reduction area which requires a change in operational state independent of whether a whale is present in the area and/or at risk of collision.

Active whale avoidance has been developed and successfully practiced for decades by marine pilots in Alaska (and possibly elsewhere) and is not new in the maritime community. However, a more formal exploration will help clarify (1) the development and application of these techniques by other mariners, (2) the regulatory language that makes implicit or explicit assumptions about a ship's ability to avoid whales, and (3) important research questions with regard to the efficacy and effectiveness of different maneuvers under varying operational and environmental conditions. For example, the U.S. Code of Federal Regulations (50 CFR §224.103) states that it is illegal to approach [North Atlantic] right whales closer than 500 yards (457 m) with some exceptions for vessels 'restricted in her ability to maneuver.' In Alaska, federal regulation dictates that all vessels must operate at a 'slow, safe speed when near a humpback whale' (50 CFR §223.214) which assumes that the ship can take proper and effective action to avoid collision when near a humpback whale or that ship operators have advance knowledge of where whales are located. 36 CFR §13.1170 stipulates that a vessel in Glacier Bay inadvertently positioned within 1/4 nautical mile of a whale must "immediately slow the vessel to ten knots or less without shifting into reverse", and "direct or maintain the vessel on as steady a course as possible away from the whale until at least 1/4 nautical mile of separation is established" – requirements that were largely established pertaining to smaller craft and may be unattainable by large ships.

Understanding the opportunities for, and feasibility of, active whale avoidance also serves to benefit mariners by clarifying conditions and actions that may facilitate effective whale avoidance. For example, large ship operators undergo years of training, including frequent maneuver testing in full-mission bridge simulators, which are often focused on collision avoidance with objects including reefs, shoals, and other vessels. Yet we know of no simulator modules for whale avoidance, which would provide opportunities for mariners to learn from others and test new ideas for maneuvering, particularly if they incorporated state-of-the-science information pertaining to whale behavior.

Finally, clarifying research needs and models derived from active whale avoidance will help scientists prioritize and/or refine existing efforts that will have tangible conservation outcomes and assist mariners in applications of these concepts. For example, a suite of efforts currently exist to facilitate mariners sharing information on whale sightings yet it's unclear how well these sightings equate to changes in maritime operations and, ultimately, whether certain factors, such as the way the information is transmitted or when its received by the operator, equates to a reduction in ship strikes.

Our goal is to present a conceptual model of active whale avoidance derived by coupling perspectives from biologists, focused on the science of whale behavior, with the expertise of ship operators. To that end, our research team included Alaska marine pilots with over 90 years of combined experience developing and practicing active whale avoidance while piloting large ships. As proof of concept, we collected and applied data to our conceptual model focused on avoidance of humpback whales by large cruise ships transiting waters in Alaska. Data informing our conceptual model originated from (1) a study that has placed observers aboard large cruise ships in Alaska since 2006 focused on quantifying surfacing behavior of humpback whales around the ships and the ability of mariners to detect them; and (2) data collected during trial simulations in a full-mission bridge (ship) simulator to identify and quantify the practices that occur on the ship's bridge during active whale avoidance. Large ship maneuvering capabilities were further explored using SEAiq, a navigation software commonly used by marine pilots to navigate and assess maneuvering possibilities[1]. Although our work is focused on a specific type of ship (large cruise ships) and single species of whale (humpback), variations of the components of our conceptual model can be applied to whale avoidance by other types of ships and other types of whales.

We emphasize that our goal is to generate a conceptual foundation upon which specific processes, such as the relationship between whale surfacing distance and appropriate maneuver response, can be subject to more rigorous testing and replication. To that end, our findings (at this stage) are not intended to prescribe what mariners should (or shouldn't) do when in the vicinity of surfacing whales. Instead, we draw some more general but important inferences from our conceptual model and related data including the role of ship operations (e.g., speed and heading variables) in active whale avoidance. Ultimately we hope these ideas will help advance the development and application of active whale avoidance techniques on a global scale.

MATERIALS AND METHODS

Our goal for this paper was to present (1) a conceptual model of active whale avoidance, and (2) provide a proof of concept by utilizing empirical data of humpback whale surfacing behavior collected from the bow of cruise ships and from simulations of large cruise ship operations in a full-mission bridge simulator and via commonly used pilotage software. The conceptual model, generated to help deconstruct this complex and highly variable process into components that could be informed by data, was developed during a series of meetings conducted since 2013 between a team of State of Alaska marine pilots from the Southeast Alaska Pilots' Association (SEAPA), and scientists from Glacier Bay National Park, where ship strike reduction efforts have been implemented and refined since the early 1980s. The conceptual model is presented first (**Figure 1**) by describing each of the constituent processes, and factors that influence them. Components include availability and detection processes, reflecting how often and how long whales are available to be detected, and the ability of mariners to detect them once available; and command and maneuver processes, reflecting the procedures that occur on the bridge once a whale is detected, and the ability of a ship to achieve a new operational state commanded by the mariner that reduces collision risk. These components are based upon existing literature (e.g., availability and detection processes) and the collective experience of marine pilots (command and maneuver). To that end, the 'results' of the conceptual model include narrative describing how and why certain factors are important, particularly as it relates to ship operations and maneuvering, including events that transpire on the ship's bridge when a whale surfaces and is detected forward of the ship. For our proof of concept, data collection procedures are organized according to the different components of the conceptual model. While more details on the field-based methods can be found elsewhere (see Gende et al., 2011; Harris et al., 2012; Williams et al., 2016) they are described briefly below.

Availability of Whales for Detection

In the context of active whale avoidance, whales need to be available for detection in order to be avoided. Thus the availability is dictated by the type, frequency, and duration of the opportunities for perception by the mariner. In Alaska, humpback whales (and other whale species) regularly embark on a repeated cycle of a foraging dive punctuated by a surface interval. For clarification we define a *surface interval* as the time the whale first comes to the surface following a dive to the time it embarks on another dive. Therefore the surface interval encapsulates one to many *surfacing events* defined as when the whale breaks the surface of the water to respire. Surfacing events are separated by brief submergences (e.g., Dolphin, 1987; Stelle et al., 2008; Godwin et al., 2016; Garcia-Cegarra et al., 2019). During each surfacing event (surfacing) the whale may provide multiple '*cues*' that can be perceived by the mariner to infer the whale's distance from the ship and direction of travel (Hiby and Ward, 1986). Cues include spouts/blows/breaths and presentation of the head, dorsal fin, back, or tail (flukes) breaking the surface. Cues are available for only a second or two, occur in rapid succession, and often overlap in time (such as when the water vapor from a spout lingers long enough to be visible when the whale's flukes break the water's surface). In contrast, the surfacing events are separated by submergences that may

[1] http://seaiq.com/

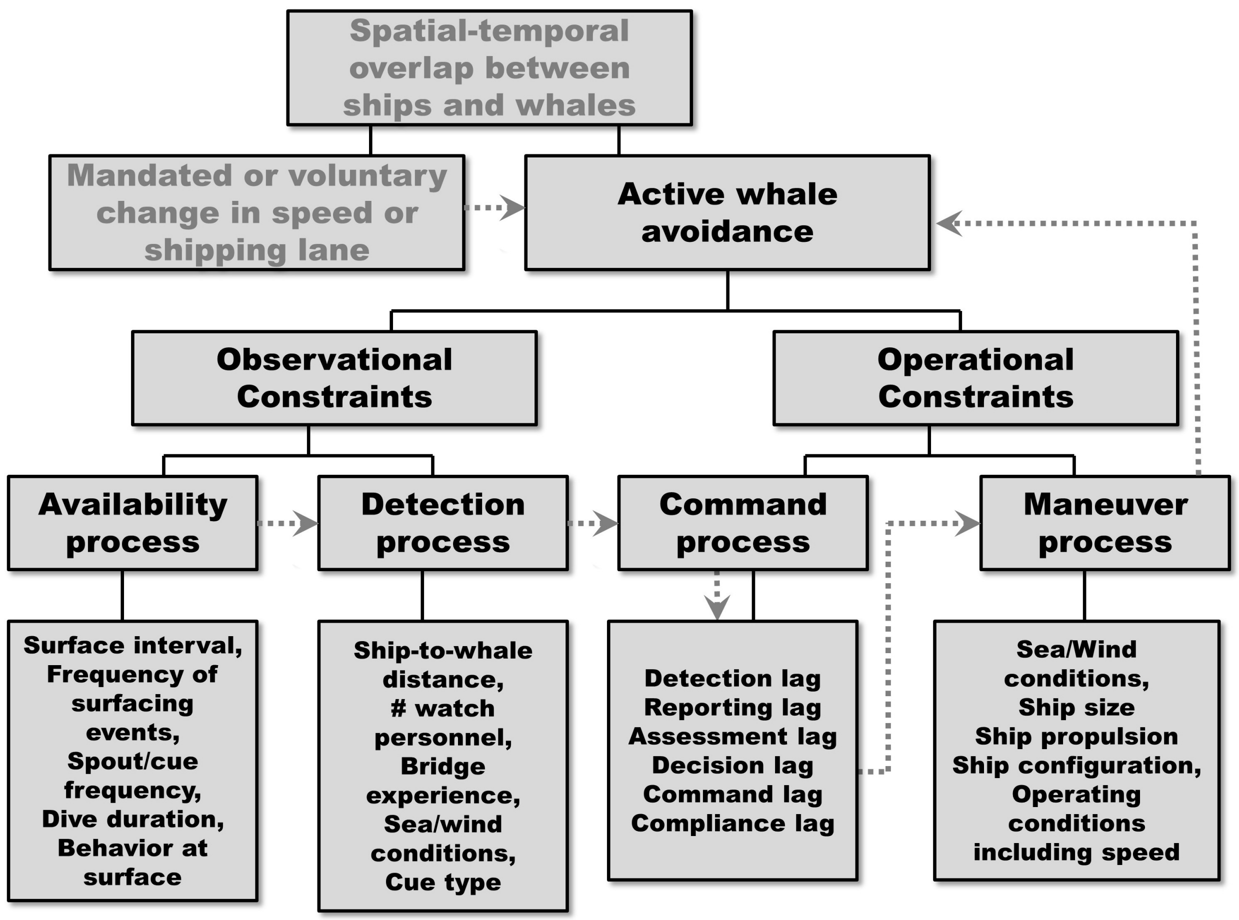

FIGURE 1 | Conceptual model depicting some components related to active whale avoidance by mariners aboard large ships. The first two rows reflect opportunity: active whale avoidance can be practiced anywhere in the world where there is overlap between large ships and large whales, including within management areas that already require (or encourage voluntary) speed reductions or within shipping lanes that have been altered to minimize ship-whale encounters. Lowermost boxes represent a sampling of important factors that may influence their related processes either singly or in concert with other factors. The arrows among the lower boxes reflect the general chronology of whale avoidance.

last 20–40 s or more, during which time the ship will move up to several hundred meters closer to the whale (depending upon speed). The change in ship-to-whale distances between cues (within a surfacing event) will thus be inconsequential (meters) whereas the change in distances between surfacing events will be sufficiently large to affect the probability of detection (see below).

To understand the nature by which humpback whales become available to be detected by mariners, we utilized data collected as part of an ongoing study that has placed an observer aboard large cruise ships in Alaska since 2006 (**Figure 2A**) to estimate (1) the frequency and duration of surfacing events throughout a surfacing interval, and (2) the probability that one or more surfacing events will be detected. We briefly summarize the relevant methods of whale detection here, but reference previously published work (Gende et al., 2011; Harris et al., 2012; Williams et al., 2016) containing more details on data collection and processing protocols.

Surfacing Behavior of Humpback Whales Near Cruise Ships

During the summers (May–September) of 2016 and 2017 a marine mammal observer embarked on $N = 67$ large cruise ship cruises (mean length = 268 m; Gende et al., 2018) while the ship transited the waters in Glacier Bay National Park, Alaska. The observer was transported out to the cruise ships just after it entered the park (only 1 or 2 ships entered per day) and boarded the ship via an NPS transport vessel. Regardless of weather, the observer proceeded to the bow (the forward-most point of the ship; **Figure 2B**) and conducted continuous naked-eye scans of the water in a 180-degree arc from directly forward to directly abeam, on both sides of the ship. Scans were assisted using Swarovski 10 × 42 binoculars and tripod-mounted laser rangefinder binoculars (Leica Viper II; accuracy + 1 m at 1 km; Leica, Charlottesville, VA, United States) to search for whales.

When the observer detected a humpback whale, the ship's position was recorded using a Global Positioning System

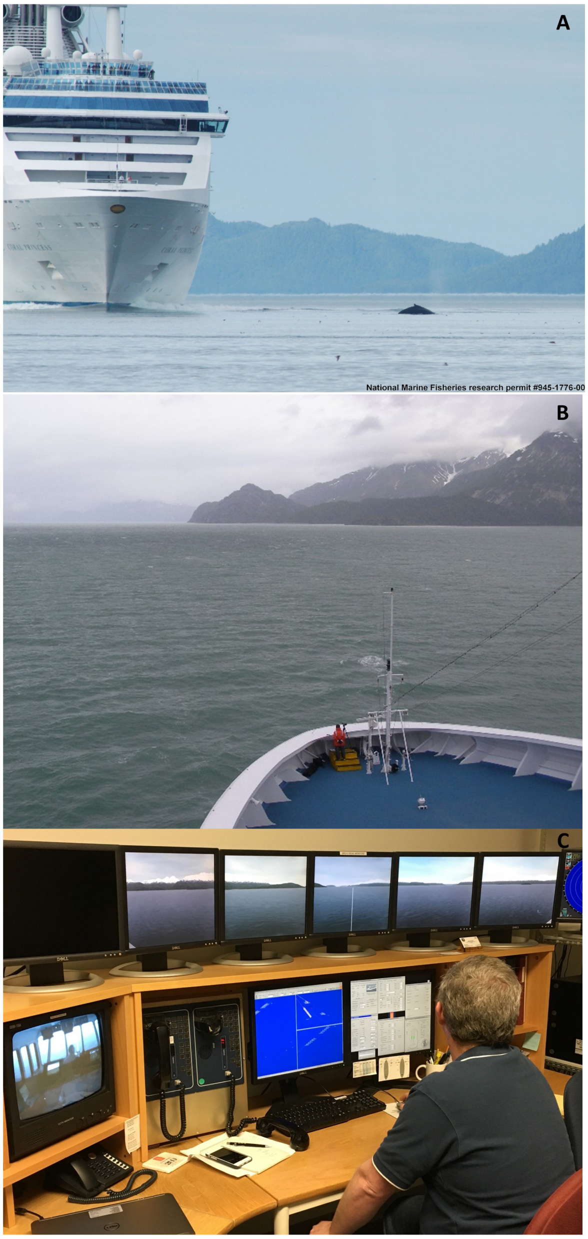

FIGURE 2 | (A) A humpback whale surfaces in front of a large cruise ship, Glacier Bay, Alaska. **(B)** An observer standing at the bow of a large cruise ship in Alaska quantifying the frequency, proximity, and behavior of humpback whales that surface forward of the ship. The Observer program has occurred since 2006 and included more than 750 cruises. **(C)** The command center at the AVTEC Full Mission Bridge simulator in Seward, Alaska, during simulations whereby marine pilots simulated whale encounters and active whale avoidance. Closed-circuit video of 2 pilots in the bridge room can be seen in lower left of the photo enacting a whale avoidance maneuver.

(Garmin 76Cx GPS, Olathe, KS, United States), and the distance between the observer and the whale was measured using tripod-mounted laser rangefinder binoculars, or estimated if the observer could not 'ping' the whale with the rangefinder. Based on training and testing throughout the study, estimated distances were deemed unbiased, and typically within 10% of the true distances (Williams et al., 2016). The relative bearing of the surfacing event was recorded using a tripod-mounted protractor along with group size, cue type (spout, fluke up, etc.), direction of travel, and sighting conditions (see Williams et al., 2016 for complete list). All data were recorded using a voice-activated recorder and transcribed following each cruise. Data were then summarized using (1) only whales with a group size of 1 (i.e., singletons) to ensure that surfacing events were not mixed in multi-whale groups (singletons constituted 91% of all groups detected in 2016 and 2017), and (2) only from a single surfacing interval per whale to insure independence. Owing to the speed of the ships (typically 14–20 kts; Webb and Gende, 2015), and foraging dives often lasting several minutes or more, only one surfacing interval was typically recorded (>90% of all sightings) before the whale passed abeam. To avoid using surface intervals that were ongoing when the whale passed abeam, the total number of surfacing events per surfacing interval was summarized across all of the surface intervals where whale flukes were displayed as the terminal cue (indicating a deep dive). In contrast, the length of submergences between surfacing events were summarized using all surface intervals, regardless of the nature of the terminal cue. Both of these parameters aid in understanding how many surfacing events are available for mariners to detect and the time elapsed between available events.

Probability of Detecting a Humpback Whale During a Surfacing Interval

Detection functions of humpback whales surfacing near cruise ships have been published previously by Williams et al. (2016) who used distance sampling applied to sighting data collected since 2008. Importantly, unlike some studies focused on estimating abundance of whales where detection functions were derived using line transects, Williams et al. (2016) derived detection functions tailored to the question of whale avoidance by using a series of instantaneous samples as point transects, with the ship-to-whale distances analyzed as radial measures from the bow. Accordingly, the proper interpretation of these detection functions is the instantaneous detection probability of a whale that becomes temporarily available at a specific ship-to-whale radial distance across the 180-degree arc forward of the ship.

In the context of active whale avoidance, the relevant inference is the probability the mariner detects at least one of the available surfacing events in a surfacing interval because whales often engage in multiple surfacing events (per surfacing interval) and mariners generally need only to detect one of the events to begin evaluating whether a whale avoidance maneuver is necessary and feasible. We thus utilized the Williams et al. (2016) estimates to calculate the *cumulative* probability of detecting one of the events in a series of surfacing events, i.e., the first or second surfacing event in a 2-surfacing interval, the first or second or third surfacing event in a 3-surfacing interval, and so on.

In this regard, the surfacing events are analogous to a series of Bernoulli trials with one of two outcomes (detected, non-detect) each of which are mutually exclusive and complementary. However, it is important to recognize two conditions when estimating cumulative probability of detection. First, once a whale is detected, it doesn't matter (for detection) how many subsequent trials (surfacings) occur because it only takes one detected surfacing for the mariner to (1) know a whale is present and forward of the ship, and (2) begin to evaluate whether an avoidance maneuver may be necessary, effective, and safe (recognizing that the first detection may be of variable quality and that subsequent surfacings may need to occur to clarify relevant information such as the whale's direction of travel). We assumed that once the mariner has detected the whale the detection probability for any subsequent surfacing events = 1 owing to the highly concentrated search efforts that ensue in the small area where the whale is likely to resurface.

Thus, if we characterize the two possible outcomes of a surfacing event as D = Detect and N = Non-detect, assume 100% detection probability for any subsequent surfacing event following detection, and that the initial surfacing is the key parameter of interest, the five possible outcomes for detecting at least one surfacing event in the series of (for example) five surfacing events simplifies from:

DDDDD, NDDDD, NNDDD, NNNDD, NNNND

to:

D, ND, NND, NNND, NNNND

Second, and perhaps more importantly, each trial (surfacing) occurs at different distances influencing the distance-specific instantaneous (radial) probability of detection. For example, if a ship is approaching a whale at 19 knots (9.77 m/s) and the time between surfacing events (duration of submergence) is 20 s, the second surfacing event can occur at a ship-to-whale distance of nearly 200 m less than the first surfacing event, the third surfacing event nearly 400 m closer than the first, etc.

To account for these conditions, we utilized the Williams et al. (2016) instantaneous detection probability estimates for the initial surfacing event, and estimated the cumulative probability of detection across the series of N surfacing events by adding the probability of detecting the second surfacing event after the first event went undetected (because if the first was detected, the second is assumed to be detected), and so on. By extension, the cumulative probability of detecting the second surfacing event will always be greater than the instantaneous probability of detecting the event at that distance because it represents the sum of two probabilities. To illustrate, for a 5-surfacing event interval, the cumulative probability of detection was calculated as:

$$\Pr[\textit{at least } 1 \textit{ detection}] = p_1 + (1-p_1)p_2 + (1-p_1)(1-p_2)p_3 + (1-p_1)(1-p_2)(1-p_3)p_4 + (1-p_1)(1-p_2)(1-p_3)(1-p_4)p_5$$

The individual, radial distance-specific detection probabilities were defined using the hazard rate function:

$$\pi = 1 - e^{(-(\frac{x}{scale})\wedge -(shape))}$$

where the scale parameter = $e^{6.73157}$ and shape parameter = $e^{0.747}$ is based on excellent sighting conditions (see Table 3 in Williams et al., 2016). R script (R Core Development Team) written for calculating the cumulative detection probabilities across any distance is provided in **Supplementary Material**.

To illustrate the *cumulative* chance that a mariner detects a whale that initially surfaces at different distances, we then plotted the cumulative probability of detecting at least one of the surfacing events for a whale engaged in an average surfacing interval of 3 surfacing events each separated by 20 s submergences (from our data below) initially surfacing at distances of 4000, 3000, 2000, or 1000 m from a ship. Note that because the speed of the ship is relevant to the changes in ship-to-whale distances among surfacings, we modeled these probabilities based on a ship traveling 19 knots.

Surfacing, Detection and Avoidance: An Example of a Ship Strike Scenario

The combined variation from ship operations (course, speed, etc.), whale behavior (swim speed, dive duration, surfacing frequency, direction of travel, etc.), and initial whale surfacing location (distance and relative bearing from the ship) produces an extremely large number of scenarios in which a ship strike can occur (final ship-to-whale distance and bearing = 0m). These scenarios range from virtually no opportunities for avoidance, such as when a whale initially surfaces from a dive just a few meters from the bulbous bow, to scenarios where mariners have an opportunity to avoid the whale, such as when it initially surfaces at a distance sufficient to allow the mariner to complete the command and maneuver processes and potentially avoid the whale.

To understand the interplay between ship operational state and whale avoidance, we chose a scenario where the mariner has the opportunity to invoke an avoidance maneuver. For our chosen scenario, we started at the point of collision, i.e., the ship and whale are in the same place and same time (horizontal distance = 0 m, time to collision = 0 s) and worked backward in time based on defined parameters of the whale's behavior (constant course traveling adjacent from, and directly perpendicular toward, the ship's path; constant swim speed = 1.23 m/s; Barendse et al., 2010; Kavanagh et al., 2017) and ship's operational state (constant course; constant speed of either 10 knots – 5.14 m/s – or 19 knots – 9.77 m/s). Thus if the collision occurred at 0 s, at 100 s prior to collision the whale will be 123 m from the point of collision and the ship will be 514 m (slow ship) or 977 m (fast ship) from the point of collision.

Whales, however, may be at the same horizontal location of the ship but owing to their dive behavior may pass safely below the ship (vertical distance > 8m which is the average large cruise ship draft from our study). To account for the vertical movements of whales (surfacing events and dive intervals), we further modeled the whale to surface 3 times during its surfacing intervals (data from this study) with 20 s submergences (this study), followed by a foraging dive of 5.4 min (324 s; a typical dive length for foraging humpback whales in Alaska; Dolphin, 1987). For simplicity, we assumed linear travel even though the whale was diving. Using these parameters we then graphed the ship-to-whale distances and time to collision through two whale surfacing intervals and a foraging dive for mariners approaching a whale that will ultimately be struck on a fast (19 knots) and slow ship (10 knots). To illustrate the trade-off between detection probability and available time for ship personnel to decide on, and achieve, an avoidance maneuver, the cumulative probability of detection for each of the surfacing events were also plotted.

Where Whales Are at Risk: A Mariner's 'Cone of Concern'

Our estimates of the cumulative probability of detection represent the probability of detecting at least one of the surfacing events for a whale initially surfacing at different distances within the entire 180-degree arc forward of the ship from beam-to-beam (Williams et al., 2016). However, throughout development of our conceptual model, marine pilots in Alaska noted that when assessing risk in active whale avoidance they often focus search on a narrower area forward of the ship where a whale strike is more probable, which they define as the 'Cone of Concern.' This is because the relative bearing of the whale influences risk; a whale initially surfacing directly forward of the ship (relative bearing: 000°) at 3000 m is at a higher risk of a collision than a whale that surfaces an order of magnitude closer (300 m), but directly abeam (relative bearing: 090°) because the closer whale is unable to swim fast enough into the ship's path to be struck.

We formalize this idea using simple vector analysis and a trigonometric representation of a whale crossing a ship's path at a 90-degree angle. We contrasted ships traveling at 10 knots (5.14 m/s) and 19 knots (9.77 m/s) with whales swimming at an average speed of 1.23 m/s (2.4 knots) and at fast swimming speeds of 2.46 m/s (4.8 knots) to explore how these parameters influence the size of the Cone of Concern.

Decision-Making During Active Whale Avoidance: Full-Mission Bridge Simulation

A ship's bridge represents a classic example of a socio-technical work environment because operational tasks, such as changing course or speed, must be achieved by a team requiring joint efforts of 'human and technological interlocutors' (Hontvedt, 2015). To that end, full-mission ship simulators are appropriate for understanding the decision-making process by coupling the human element with technology. To better understand the elements of decision-making and time lags related to active whale avoidance, we conducted familiarization and feasibility exercises during 2 days in 2016 using the Kongsberg full-mission bridge simulator (**Figure 2C**) at the Alaska Vocational Technical Center (AVTEC) in Seward, Alaska[2]. The full-mission simulator at AVTEC is regularly used for training Alaska's marine pilots in the maneuvering of large ships as part of (re)certification and continuing education, and mirrors the platforms used by marine pilots at other training centers around the United States.

Seven simulations were conducted whereby a team of two pilots, one serving as the pilot, the other as the helmsman, operated the bridge of a ship, which had operational parameters similar to that of the M/S *Diamond Princess*, a 115,875 gross tonnage, 288 m cruise ship that is representative of the large cruise ships calling in Alaska during the summer. Also on the bridge was an observer who recorded the time of events including (1) the start of simulation, (2) the first *detected* surfacing event of a simulated humpback whale spout (the first actual surfacing event – detected or not – was known only to the simulator operator and scenario coordinator who were located in a different room; **Figure 2C**), (3) the communications that occurred between the pilot and helmsman, (4) when a command was initiated and (5) the end of the simulation, once the ship had passed the whale. Following each simulation, a de-brief discussion was held to review the events and clarify the reasoning related to the decision-making process. During the de-brief, the elapsed time between first detection and the time of the ordered command was quantified, and the common elements related to the decision-making process were identified.

Our simulations were limited in number as was our bridge team size, which would normally include a dedicated Lookout and one or more deck officers. Thus, we did not draw inferences on detection probability from the simulator. Additional limitations existed due to the lack of fidelity of the simulated whale/cues which are the subject of further refinement and improvement. Nevertheless, the descriptive data on time-to-command and archive of commonalities that influenced decision-making were appropriate as full-mission simulations are regularly used to describe processes that occur on the ship's bridge, and can serve as realistic proxies for evaluating risk and commanding new operational states (Hontvedt, 2015).

Ship Maneuverability During Active Whale Avoidance

Once a decision is made on an appropriate avoidance maneuver (maintaining existing operations may also be an active decision; see section Discussion), the rapidity by which the new operational state is achieved can vary dramatically among ship types (e.g., bulk carriers vs. tankers vs. passenger vessels) and within similar-type ships based on technical features such as hull shape and maneuvering systems (e.g., Yasukawa et al., 2018; Zaky et al., 2018). Further, variation can occur based upon environmental conditions (e.g., Yasukawa et al., 2012; Rameesha and Krishnankutty, 2019) and/or the existing operational state of the ship (wave height, wind, ship's existing speed, acceleration/deceleration, whether or not the ship is already engaged in a turn, etc.; Chen et al., 2017). Consequently, determining how quickly a ship can achieve an avoidance maneuver is well beyond the scope of this paper (although our simulations were insightful for which factors should be prioritized for further development).

We utilized the navigation software SEAiq, a commonly used platform by pilots across the U.S. for understanding ship maneuverability, and to focus on a simple and achievable question: for a typical large cruise ship traveling at 10 vs. 19 knots, how far in advance must a turn be initiated to achieve a CPA of at least 100 m with a stationary whale while remaining

[2]https://www.kongsberg.com/digital/products/maritime-simulation/k-sim-navigation/

within defined safety parameters? We used a stationary whale because it simplified the vectors and isolated the focus on the maneuvering capacity of the ship. The 100 m CPA was also for simplicity purposes and should be viewed simply as a means to estimate maneuverability, not as a recommended CPA for mariners. We did not introduce confounding factors, instead simplifying the simulation to reflect 'best case scenarios' including unlimited visibility, calm water, no wind or current, deep water maneuvering, no other vessel traffic or whales, and the ship was initially traveling in straight line. Our defined safety parameters were guided by our working history of the ship's safety parameters and a generalized Pilot Card describing the ship's sensitivity to heading changes (e.g., maximum rate-of-turn; ROT) at varying speeds, as well as limitations in stopping distances. The turn, based on non-emergency safety parameters, conservatively did not exceed a 10-degree rate-of-turn and did not factor in progressively higher rates of turn.

We note that we did not use SEAiq to estimate how much time (and the total distance) it would take for the ship to slow down (e.g., from 19 to 10 knots) because during the full mission bridge simulations, pilots were found to avoid slowing speed in response to a single sighted whale, reflecting their normal practice. During de-briefings it was noted that while a moderate change in heading can be achieved in a relatively short time period (following whale detection), it takes much longer to achieve a moderate change in speed, reducing the effectiveness of speed reduction as a reactive response for whale avoidance, particularly avoidance of a single observed animal. Moreover, pilots never practice 'crash stops,' i.e., a rapid stopping of the ship to avoid a collision with a whale owing to the deleterious impacts it could have on the infrastructure of the ship. Instead, to get a general idea regarding how long it takes for a large cruise ship to reduce speed, and the distance covered during that non-emergency transitional state, we reproduce data from Nash (2009) and re-visit the role of speed reduction as a pre-emptive avoidance maneuver in the Section "Discussion."

Finally, in typical ship operations, while only one person has ultimate 'command' authority while on the bridge, the person directing the movement of the vessel may vary depending upon time and duties, and may be the pilot, captain or deck officer. For simplicity, hereafter, we refer to this person collectively as the Person Directing the Movement of the Vessel (PDMV).

RESULTS

Conceptual Model of Active Whale Avoidance by Large Ships

In its simplest terms, the process of active whale avoidance can be described as occurring in five sequential events (1) a whale surfaces somewhere forward of the ship where a collision with the vessel is possible; (2) bridge personnel tasked with ship navigational decisions detect the whale; (3) the PDMV evaluates the situation and decides that an avoidance maneuver is necessary, feasible, and safe; (3) the PDMV decides upon and commands a new operational state such as a change in course, speed or both; and (5) the ship obtains a new operational state resulting in a lower risk of a collision. Our conceptual model (**Figure 1**) includes Observational (whale surfacing behavior, detection) and Operational processes (commands and maneuvering) that are structured sequentially. Each of these components are described in more detail.

Availability and Detection Process

The first step in this process is dictated by whale behavior because whales need to be available for detection at the surface in order to be avoided. The availability and detection processes have been well studied owing to its relevance for abundance estimation (via distance sampling), and we refer to these studies for describing factors that influence cue frequency and behavior (Hiby and Ward, 1986; Zerbini et al., 2006). Gray, blue, and humpback whales (among many others) regularly embark on a cycle of surface intervals, consisting of several shallow submergences between respiration/surfacing events, punctuated by longer deep dives (e.g., Dolphin, 1987; Godwin et al., 2016; Garcia-Cegarra et al., 2019). Consequently, whales are infrequently but regularly available to be detected. In general the most frequent cue available during a surfacing event takes the form of the appearance of the whale's body in concert with a vertical spout/blow, which is composed primarily of water vapor, air, and lung mucosa, that may extend to several meters above the water and persist for several seconds.

Command Process

Our conceptual model lists a series of steps that we have termed the Command and Maneuver Processes. The Command Process consists of Detection, Reporting, Assessment, Decision, Command, and Compliance actions best described as time lags because any time that elapses after a whale is detected reduces the ship-to-whale distance (as the ship moves toward the whale in the scenarios modeled) and decreases the options for an avoidance maneuver to occur. The Maneuver Process represents the time it takes for the ship, once commands have been executed, to achieve the desired new operational state. We describe these steps in more detail below.

The Detection Lag represents the time between when a bridge team member detects an object in the water, confirms its identity, and formulates their report to the PDMV. Based on anecdotal observations from marine pilots aboard large cruise ships in Alaska, this lag was estimated to vary from 1–2 s, as when a whale spout is immediately recognizable, or as much 5–10 s if the nature of the perceived object is not readily apparent (e.g., a whale lying motionless on the surface or a floating log?). What's more, many Lookouts (personnel assigned to view the waters forward of the ship) are trained to simply make a report of an "object in the water," if they cannot readily identify what it is, and then continue to observe the object to develop clarifying information.

The Reporting Lag represents the time it takes for the person making the observation to vocalize the observation which, from our experience, may vary from 2 to 10 or more seconds depending upon: (1) the volume or quality of the initial sighting information (which may require dialogue with the PDMV); (2) the observer's ability to articulate the relative bearing, distance, direction of travel, or other relevant information;

(3) existing bridge communications; and (4) language or cultural communication issues. For example, the Lookout may spot a whale spout and report, "whale two points to starboard" with no additional information on distance, direction of travel, or speed. At that point, the PDMV will look in the indicated direction and engage the Lookout for information needed to make an assessment which may result in an additional 10–20 s depending upon the length of the submergence between surfacing events or other ongoing action by the PDMV (e.g., communicating on the radio with other traffic, establishing and monitoring navigational parameters, etc.). In the meantime, the initial cue is often no longer available. The elapsed time associated with Detection and Reporting Lags will be minimized if the PDMV makes the observation him/herself (with a high degree of certainty) and immediately articulates the observation to the bridge team. In these instances the total time elapsed may be as short as 5 s, but more frequently it will be closer to 15 s.

The Assessment Lag represents time needed for the PDMV to verify the information and subsequently assess if a collision is possible. In the determination of collision risk, mariners are trained not to make assumptions on the basis of "scanty" information (see US Coast Guard Rule 7 Risk of Collision, International Rules of the Road[3]), highlighting the need for quality information before taking action. If, for example, direction and travel speed of the whale are not available, the process may cycle back to the Detection Lag, awaiting another surfacing event upon which to formulate an avoidance decision. Consequently, a simple report of a whale at a relative bearing and distance may not provide sufficient information upon which to base an avoidance action, even for a whale sighted directly ahead. Consequently, the Assessment Lag, as with the other lags, may be relatively quick (3–5 s) for the "obvious" situations or it may take longer if inconsistent or incomplete information is reported.

The Decision Lag represents the time needed for the PDMV to consider the available safe avoidance options based on competing risks. The decision by marine pilots (serving in the capacity of PDMV) is founded on the principle of do-no-harm, firstly to people, secondly to the ship, and thirdly to the environment. In practice, this results in a rapid and dynamic calculation of the trade-offs in the risk of whale collision with the risks of harm to people, the ship, or the environment (or some combination such as a collision with another ship, a shoal, or even another whale). Consequently, critical factors in the Decision Lag are based on the situational awareness of the PDMV to the proximity to these hazards and the operational state of the ship; i.e., what is in the realm of possibility based on its speed, sea state, etc. Based on opportunistic assessments, Decision lags can vary from a few to 20 s, based on complexity and competing risks.

The Command and Compliance Lag is the time needed for the PDMV to articulate the avoidance decision into a specific command and for the bridge team to comply. For example, the PDMV may command the Helmsman to initiate a new heading. For some shipping entities, the bridge procedures require 'closed loop communication' whereby the command cannot be executed until the initial order is first acknowledged (by the Quartermaster for course changes, or by the deck officer for speed changes), and then confirmed by the PDMV. This lag is generally 5–7 s in situations where all involved understand and are in agreement, but can be longer (upwards of 60 s) if the command is misunderstood, not heard, not acknowledged, or there is disagreement on the appropriate avoidance action.

[3]https://www.navcen.uscg.gov/pdf/navRules/CG_NRHB_20151231.pdf

Maneuver Process

The Maneuver Process is the time it takes for the ship, once commands have been ordered, to achieve the desired operational state. The maneuver process is also best considered in the context of a time lag because the new commanded operational state does not occur instantaneously. The Maneuver Process can vary dramatically among ships although approximate generalizations are appropriate for estimation and/or simulation scenarios. Similar to other large ships, safe maneuvering of large cruise ships encapsulate a range of turning and slowing options based on the interaction between ship type, existing operational state, and environmental conditions. Our experience, based on informal sampling of whale avoidance maneuvers during the past several summers in best-case scenarios, has been that the maneuver process can vary from 25 to 180 s depending upon operating conditions and the type of maneuver ordered.

Proof of Concept: Large Cruise Ships Avoiding Humpback Whales

Availability

The data collected by observers stationed at the bow of cruise ships transiting waters in Alaska demonstrate that humpback whales surfacing around the ships often provide a small but variable number of opportunities for detection. For all surfacing bouts that ended with a fluke-up dive, whales embarked on an average of 2.8 surfacing events per interval (N = 156 unique intervals; range of surfacing events per interval: 1–15; **Figure 3A**). We again clarify that this average is based on the number of surfacing events per surfacing interval, not the number of cues per surfacing event. Based on the empirical cumulative density function, about 40% of all surfacing intervals included more than three events (**Figure 3A**). As we only used surface intervals that terminated in a fluke-up dive, the data on surfacing frequency was not 'right censored' in that we had confidence that the surface interval did not include unrecorded events that occurred after the fluke-up dive. However, there is a possibility that Observers may have missed a surfacing event (or two) prior to detection ('left censored' data) resulting in the true number of events likely being larger.

The time elapsed between surfacing events was also variable, although the length of most submergences were centered in groups of 10–15 and 15–20 s (**Figure 3B**). We feel confident that, once a surfacing event was observed, detection probability of subsequent events was very high as observers (and bridge teams) focus on small area where whales are likely to resurface to gain as much quality information as necessary to evaluate collision risk. Together, the data suggest that mariners engaged in active (humpback) whale avoidance in Alaska generally have about

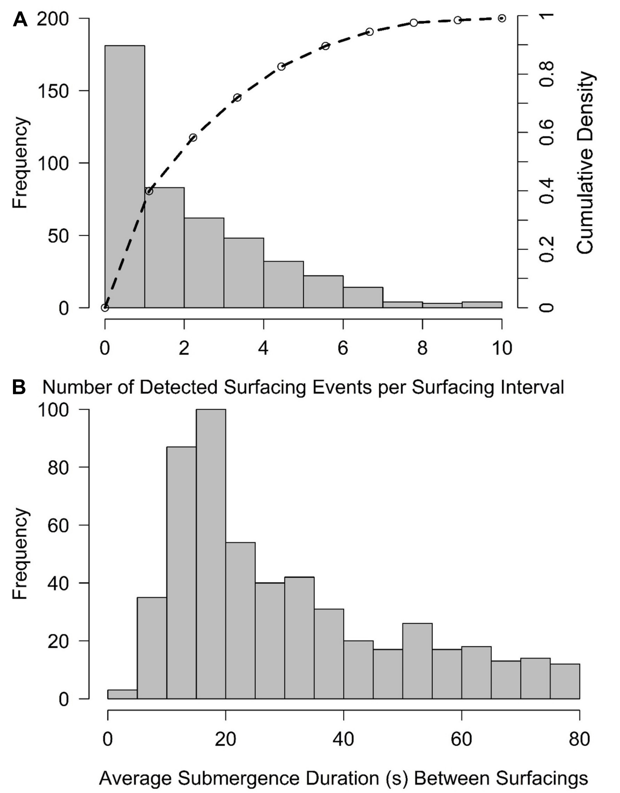

FIGURE 3 | Quantitative descriptions of whale surfacing behavior that help describe the 'availability' of humpback whales to be detected by ship personnel engaged in active whale avoidance in Alaska. **(A)** The average number of detected surfacing events per surfacing interval of humpback whales surfacing near large cruise ships, 2016–2017, with a curve representing the empirical cumulative density function. **(B)** Histogram of the average elapsed time between available surfacing events (submergence duration) during surfacing intervals of humpback whales surfacing near cruise ships, 2016–2017.

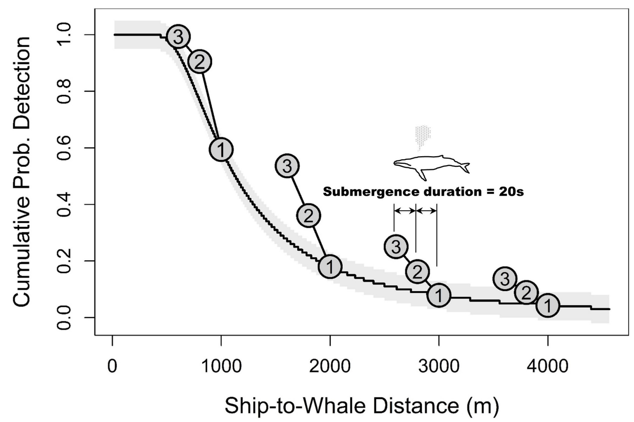

FIGURE 4 | The cumulative probability of detecting at least one of the three surfacing events for 3-event surfacing intervals that began with an initial surfacing event at 4000, 3000, 2000, or 1000 m from a ship. Circles represent the surfacing event number. The detection function used for calculating cumulative probabilities were from Williams et al. (2016) based on excellent sighting conditions.

three opportunities for detecting the whale during its surface interval, with an average of around 20 s between events.

Cumulative Probability of Detection

For a surfacing interval that included three surfacing events, the cumulative probability of detecting at least one of the events was lower at larger distances, and increased (non-linearly) with decreasing ship-to-whale distances (**Figure 4**). For example, based on detection functions for whales surfacing across the 180-degree arc in front of the ship, mariners have a nearly 60% chance of detecting at least one of the three surfacing events for a whale that initially surfaces from a dive 2000 m from the ship, but a less than 15% chance of detection for a whale that initially surfaced 4000 m from the ship (**Figure 4**). The doubling of the distance resulted in four-fold lowering probability of detection because at larger distances the cumulative increase in detection probability was more linear in nature (e.g., for a surfacing interval that begins at 4000 m) but more exponential in nature for intervals that began at mid distances (e.g., 2000 m). Whales that surface close to the ship (<1000 m) have near certainty of being detected (**Figure 4**).

Surfacing, Detection, and Avoidance: An Example of a Ship Strike Scenario

In our chosen hypothetical ship-strike scenario (ultimate CPA = 0 m) involving ships traveling at different speeds (19 or 10 knots), the whale was struck (PoC; ship-to-whale distance = 0 m, time to collision = 0 s; **Figures 5A,B**) when it surfaced to take its third respiration during its second surfacing interval (red shaded area). Working backward in time (and space) from the Point of Collision, at 40 s prior to collision the whale surfaced about 211 m from the slower ship and about 394 m from the faster ship. At both those distances, the cumulative probability of detection was near certain (>0.99). Working further backward in time, the whale embarked on a 324 s dive at 364 s prior to collision which placed it over 3500 m from the faster ship but just over 1900 m from the slower ship. At this point, which represents the last chance to detect the whale before it dives, the cumulative probability of having detected at least one of the 3 surfacing events during the first surfacing interval (green shaded area, includes fast ship-to whale distances of 3978, 3781, and 3584 m; slow ship-to-whale distances = 2135, 2029, 1924 m) was approximately 60% for the 10-knot ship but less than 15% for the 19-knot ship (red lines; **Figures 5A,B**). Owing to the near 4-fold greater (cumulative) probability of detecting at least one of the surfacing events during the first (earlier) surfacing interval, the PDMV aboard the slower ship could have an additional 324 s (post detection and during the whale's dive) to decide upon and implement an avoidance maneuver.

Note that, based on our estimates of the command and maneuver lags (see above), both the slow and fast ship would have limited (if any) opportunities to avoid the whale if it went undetected during the first surfacing interval (green shaded areas) because 40 s to collision (when the whale surfaced from its dive) exceeded the aggregate time to implement these processes.

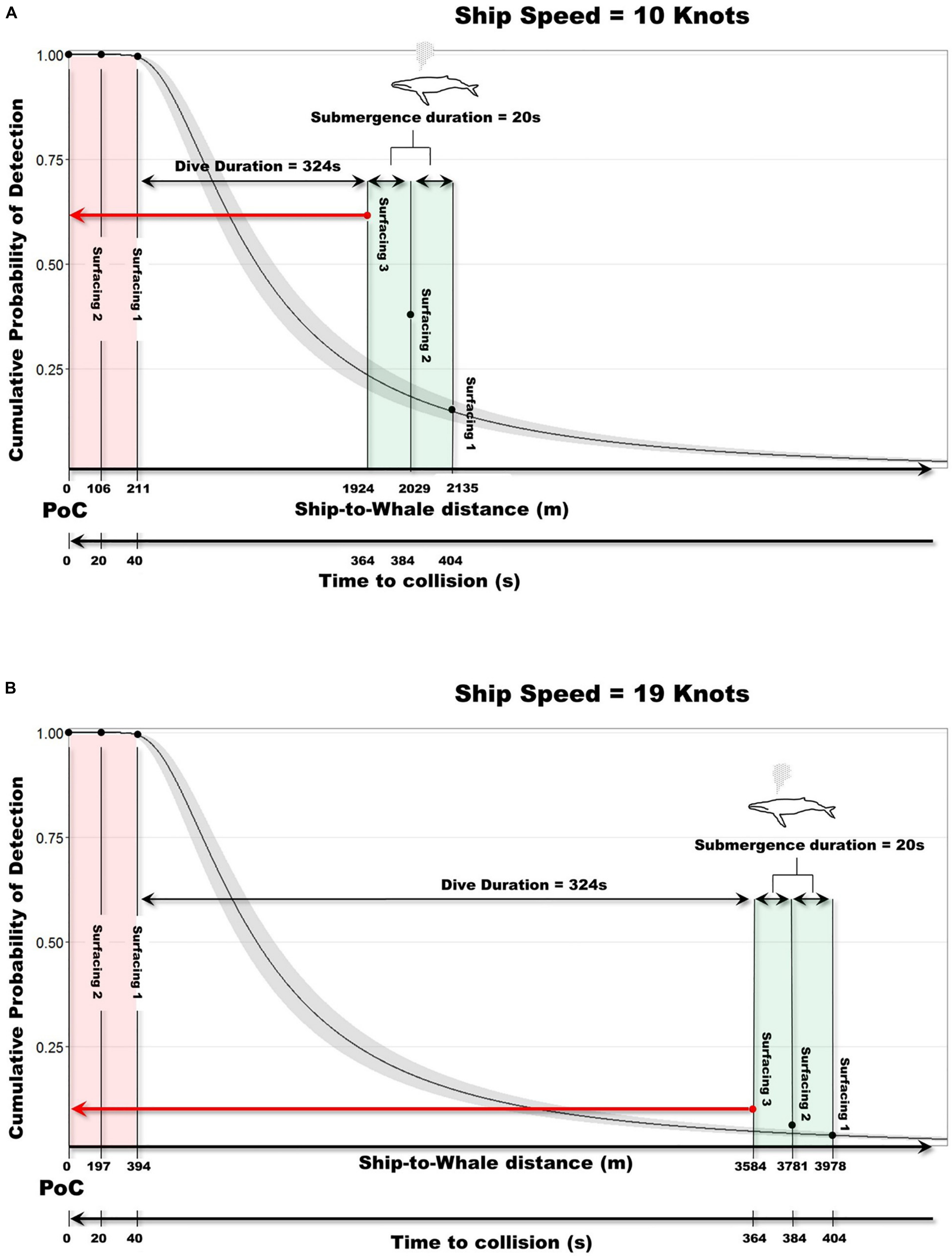

FIGURE 5 | Continued

FIGURE 5 | The cumulative probability of detecting the first, second, or third surfacing event of a 3-event surfacing interval of a humpback whale for mariners aboard a 10 knot ship **(A)** and a 19 knot ship **(B)** relative to the ship-to-whale distance and corresponding time to collision. In each scenario, the whale behavior is held constant and modeled as traveling at 1.23 m/s (2.3 knots) perpendicular to but toward the path of a ship and, following the initial surfacing interval (green shaded area) and a 5.4 min foraging dive, is struck when it surfaces a third time during the second surfacing interval (red shaded area) at the same location at same time as the ship. Surfacing events are indicated by dots and surfacing intervals by shaded areas. From the first surfacing event (Surfacing 1, green shaded area), the time to collision is held constant at 404 s for each scenario which results in an initial ship-to-whale distance of 2135 m from the slow ship **(A)** and 3978 m from the faster ship **(B)**. Curved line with gray 95% CI from Williams et al. (2016). A ship strike occurs in both scenarios unless the whale or ship deviates course or speed. Distances are approximately to scale.

Where Whales Are at Risk: A Mariner's 'Cone of Concern'

Figure 6 depicts the results of simple vector analysis demonstrating how a whale's swimming speed and a ship's transit speed influences the width of the Cone of Concern. **Figures 6A,B** depicts ships traveling at 10 knots (5.14 m/s) and 19 knots (9.77 m/s) on a collision course (toward PoC) with a humpback whale swimming at a typical speed (1.23 m/s; **6A**) or at a fast swimming speed (2.47 m/s; **6B**) perpendicular to, and toward, the ship's path. For both scenarios, the opposite angle in the right triangle (defined by the ratio of the whale's swimming speed and the ship's travel speed) is maximized because the whale is in a 'crossing' situation; i.e., it is headed directly toward the ship's path resulting in the shortest time for potential collision. For the Fast Ship/Typical Whale (6A) scenario, the Cone of Concern would be approximately 14 degrees (7.2 degrees on either side of the ship) and encapsulate a search area of nearly 0.8 km^2. For the Slow Ship/Fast Whale scenario, the Cone of Concern has a nearly equal search surface area (0.84 km^2) even though the search area is much wider (~51.2 degrees).

Command Process

As part of the simulations conducted in the full-mission ship bridge simulator at AVTEC, the average elapsed time, resulting from the aggregate of the Command time lags, i.e., from detection of the simulated whale spout to initial compliance with an ordered avoidance action, was 23 s. This compared favorably with the informal observations conducted by several pilots during opportunistic whale avoidance efforts while navigating large cruise ships in 2016 and 2017. During the debriefing meetings, we found that, following initial detection, uncertainty in the whale's direction of travel and swim speed were common factors that contributed to the delay in a command; the PDMV needed sufficient confidence in the information (making it 'actionable'), particularly on whether the whale was swimming toward or away from the ship's heading. Consequently, the PDMV regularly communicated with the Lookout and mate and, absent good information, waited for a subsequent surfacing event before deciding on an appropriate avoidance action.

During post-simulation de-briefs several common themes were discovered. First, marine pilots rarely command a speed reduction in response to a single sighted whale owing to their familiarity with the time it takes to achieve the new speed (Nash, 2009, reproduced in part in **Table 1**) and that a course change alone is most often more effective and efficient than a potential speed reduction. Second, and perhaps more importantly, the pilot's maneuvering decisions were ubiquitously based on the evaluation of competing risks. For instance, once the pilots confirmed that a whale was within the Cone of Concern, a primary consideration was how a change in course would influence other risks, such as the risk of collision with other navigation hazards including, but not limited to, other vessels, reefs, or shoals. Likewise, in all simulations where the pilot decided that a course change was needed to reduce collision risk with a whale, an evaluation occurred whereby the efficacy of the course change was considered relative to the time needed to safely 'build up' to the required rate-of-turn. The rate-of-turn required to avoid the whale was then considered relative to that particular ship's safe rate-of-turn guidelines and heel angles to mitigate the risk of deleterious impacts to the vessel and its passengers.

Maneuverability

Using SEAiq and defined safety parameters, we found that mariners aboard a ship traveling 10 knots (5.14 m/s) would require action not less than approximately 741 m from the whale to achieve a 'near-miss CPA of 100 m' (**Figure 7A**). In contrast, a CPA of 100 m aboard the 19 knot ship occurred only after it initiated a turn at least 1121 m from the confirmed sighting (**Figure 7B**; both scenarios occurred under optimal conditions). In both cases, the Command Lag was modeled as constant (based on results from the simulator), occurring in approximately 25 s, during which time the ship traveled 241 and 130 m closer to the whale for the 19 and 10 knot ship respectively. The Maneuver Lag was achieved over the course of approximately 90 s for the fast ship when it traveled 880 m, and approximately 119 s traveling just over 600 m for the 10 knot ship. Again, this was an abstract, best-case scenario, limiting the Reporting, Assessment and Decision Lags to minimums.

DISCUSSION

We coupled whale-surfacing data collected using a ship-based observer with data from simulations in a full-mission ship bridge simulator, opportunistic data collected by marine pilots aboard large cruise ships, and simulations using typical pilotage software to generate the first holistic model of active whale avoidance by large ships. While our goal was to provide a general introduction of the constituent processes such that development and more rigorous testing can build on our efforts, our results provided some insight into the opportunities and constraints for increasing the effectiveness of active whale avoidance and some priority avenues of research, which we discuss below.

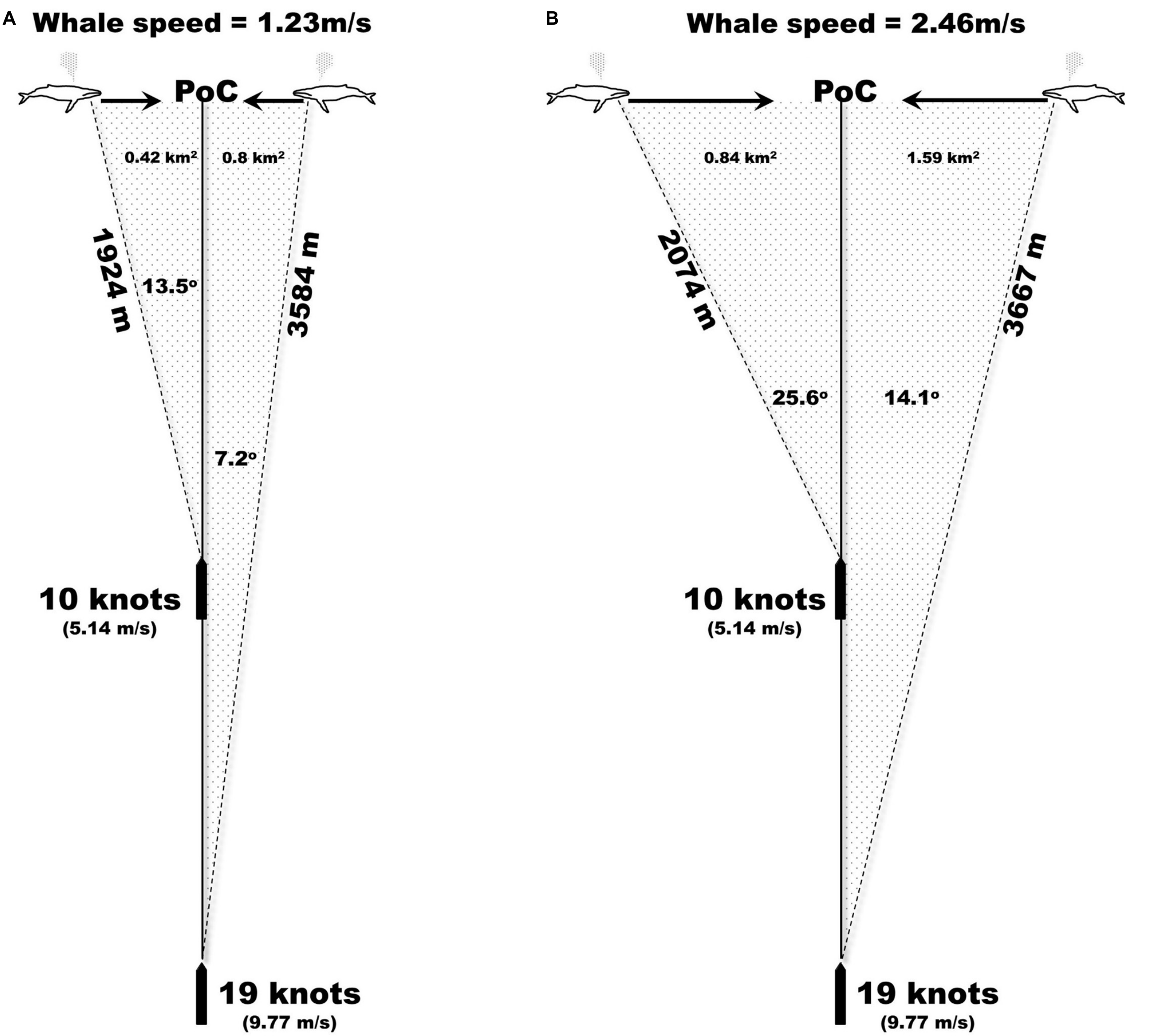

FIGURE 6 | Two scenarios encapsulating different ship transit and whale swimming speeds that define the 'Cone of Concern' (shaded area), i.e., the area searched by marine pilots to more efficiently detect surfacing whales that have the potential to be struck by the ship (at the bulbous bow). Figures depict the Cone for a 19-knot ship and 10-knot ship relative to an average swimming speed of a humpback whales (1.23 m/s; **A**) and a fast swimming whale (2.46 m/s; **B**) on a crossing pattern and on a collision course with the ship (PoC, Point of Collision; CPA = 0 m). Cones range from 14.4° (7.2° on either side of ship for fast ship and slow whale) to 51.2° (25.6° on either side of ship for a slow ship and fast whales). Distances are approximately to scale to a 284 m ship.

Availability, Detection, and a Mariner's Cone of Concern

Based on data from hundreds of surfacing events of humpback whales by observers, we demonstrate that mariners aboard large ships in Alaska typically have about three opportunities, each separated by about 20 s, to detect the whale and make a decision about whether an avoidance maneuver is necessary, possible, and safe. While these estimates were largely consistent with other studies of humpback whales in Alaska (Dolphin, 1987), we highlight that data on surfacing frequency was not corrected for any negative biases owing to the observer's chance of missing the initial (or several) surfacing events, particularly at large ship-to-whale distances or limited to the mariner's Cone-of-Concern. While we initially sought to minimize the chance for this distance bias by using only information from whales surfacing close to the ship, ultimately we decided against subsetting the data (1) because surfacing intervals that began close to the ship were often still continuing when the ship passed abeam (when observers terminated their observations of that whale) which would also underestimate the number of surfacing events per interval, and (2) to avoid biasing the inferences if, in fact, whales alter their surfacing behavior as a function of distance.

TABLE 1 | Approximate time (min) and distance (nautical miles) needed for slowing a large cruise ship with multiple engine configurations from various initial speeds to an (arbitrary) target speed of 14.7 knots using a safe slowing speed reduction of 2 RPM per minute.

# of Engines needed	Initial Speed (knots)	Propeller (RPM) at Initial Speed	Target Speed (knots)	Target Propeller RPM	Time needed (min)	Distance needed (nm)	Distance needed (m)
4 + 2	22.2	136	14.7	90	25	7.0	12,964
4 + 1	21.4	131	14.7	90	20	5.0	9,260
3 + 2	20.6	126	14.7	90	18	4.5	8,334
3 + 1	18.3	112	14.7	90	11	3.0	5,556
3	15.5	95	14.7	90	5	1.5	2,778

Note that slower (initial) speeds require less power (load) and thus fewer engines are needed to meet those power load demands for propulsion. Modified from Nash (2009).

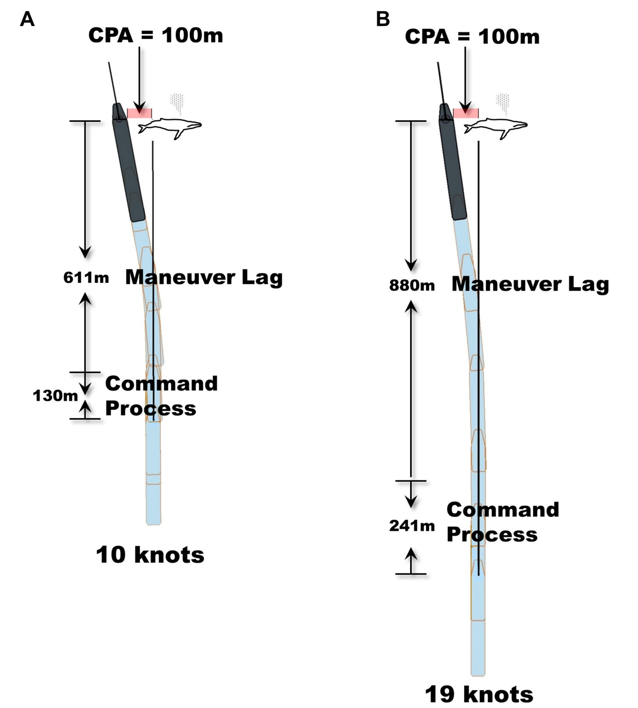

FIGURE 7 | Example of the maneuvering capability of a large cruise ship traveling at 10 knots **(A)** and 19 knots **(B)** to achieve a Closest Point of Approach (CPA) of 100 m based on defined environmental conditions and safe turning constraints and assumptions (maximum rate of turn = 10 degrees per minute; see text). These scenarios depict situations that, should a mariner want to achieve a 'near miss' of a surfacing humpback whale, the ship would have to begin its turn at 741 and 1121 m away, owing to the constant time lags (the same regardless of ship speed) related to the Command process and maneuvering capability of a large ship. This distance represents a minimum owing to uncertainty in the location, swim speed, and direction of travel for a sighted whale.

Recognizing these biases, however, helps identify possible ways in which the effectiveness of whale avoidance can be increased. For example, a key finding of our conceptual model is that processes that occur on the ship's bridge such as reporting a whale sighting, assessment of the risk, and compliance to commands, couple with maneuvering constraints to produce a variable, yet important time lag between detection and achieving a new operational state (that reduces collision risk). This aggregate lag contributes to the inverse relationship between time available to make an avoidance maneuver and the range of maneuver options available. Any activity or operation that increases the chance of detection when a whale is first available to be detected thus increases the options for avoiding the whale and the odds of successful avoidance. We identified three factors that may help PDMVs detect a whale and obtain sufficient information to actively avoid it.

First, marine pilots in Alaska, based on decades of experience encountering and avoiding (primarily humpback) whales surfacing near large cruise ships, have developed a searching pattern 'Cone of Concern' based on familiarity with approximate travel speeds of humpback whales relative to the ships' transit speeds. In doing so, pilots and other bridge personnel narrow their search efforts (by over 80% based on our simple vectors and geometry; **Figure 6**) by delineating the 'population' of surfacing whales at risk of collision vs. those that are not. This practice could easily be standardized by integrating the concept into transit planning and/or regular communications with the bridge team to focus on parameters of, and need to search within, the Cone of Concern.

Second, assigning a designated Lookout tasked solely with searching for whales in the Cone of Concern could also enhance detection probability and thus opportunities for whale avoidance. While we did not test whether different configurations of personnel (pilot, pilot + designated observer, etc.) produced different detection functions, experiments aboard large fast ferries have demonstrated that a dedicated whale 'spotter' vastly improved detection probability and the distance at which whales were detected (Weinrich et al., 2009). Research based on line transect theory and distance sampling also demonstrate that detection probability increases when additional observers are utilized (Schmidt et al., 2017) including with whales (Zerbini et al., 2006). While we recognize that transiting at night or in heavy seas may reduce or eliminate detection, we also highlight that technology continues to reduce barriers to detection in some of these conditions (Zitterbart et al., 2013) and application of the Cone of Concern may help inform development of the technology to maximize effectiveness.

The third potential way to facilitate the effectiveness of active whale avoidance is by reducing the time identified in the Command process. Pilots in Alaska are regularly conveyed unnecessary or incomplete information by members of the bridge team following a whale sighting. If the information is incomplete, the PDMV may have to wait for another surfacing event before having information of sufficient quality to be 'actionable.' This may equate to the ship traveling several hundred meters closer to the whale (based on average submergence data and typical transit speeds in Alaska) before the PDMV can confirm the whale's location and direction of travel. Training bridge personnel with regards to what information is desirable and protocols for communicating that information (e.g., 'whale approximately 2000 m three points to starboard, moving away from the ship') can make a significant difference in time available for PDMV to assess the situation and implement the maneuver without further increasing the risk of harm to the people, the ship, or other components of the marine environment. A simple suggestion of utilizing the same training used for reporting of a man-overboard to continuously point to the person (whale) promotes the effectiveness of the PDMV's detection and decision process significantly.

Ship Speed

Throughout our effort we consistently contrasted scenarios involving fast (19 knots) and slow ships (10 knots) to explore how speed may influence the constituent processes in active avoidance of a single whale surfacing near the ship. While our objectives were not to rigorously test the role of ship speed in these processes, nor were they to identify an optimal speed that balances whale avoidance vs. transit efficiency (should one exist), we highlight some insights based on our results that warrant discussion and further development.

First, when simulations of whale encounters were conducted in the full-mission ship simulator, pilots never attempted to slow the ship in response to the sighted whale, instead preferring slight changes in course. In the de-briefs that followed, pilots communicated that, while change in speed may influence the dynamics of a whale – ship encounter, the distance necessary to slow the ship to speeds necessary for effective avoidance based on speed change alone (mariner body of knowledge relative to vessel avoidance actions) tended to exceed the sighted distance to the whale owing to potential unsafe results of rapid speed changes. Given the absence of this response, we did not produce simulations that contrasted the efficacy of slowing the ship vs. slight course changes, instead reproducing some recommendations from Nash (2009) simply to provide context with regards to the magnitude of space/distance needed to slow (and recognizing that the target speeds listed in Nash were arbitrary relative to whale avoidance). However we feel a brief description as to why rapid changes in speed are not regularly practiced is necessary owing to its prominent relevance in ship strike dynamics and context for understanding the estimates in **Table 1**.

For large cruise ships (and likely other large ships) power management plays a major role in operational decision-making (e.g., Ancona et al., 2018), not just in the context of managing fuel costs and optimal fuel efficiency (and resulting levels of air pollution; Khan et al., 2012), but also for safety reasons. For large cruise ships, power needs are met using multiple engines that are variably configured for two different power loads including the propulsion load, which is typically about 80% of total load while transiting, and the hotel load, which is the electrical energy needed to power the ship's lights, heating/air conditioning, galley, etc. Rapid changes in power use can negatively affect emissions, damage the generators (engines) and, in a worst-case scenario, cause a 'blackout' (total loss of power). To help guard against these negative outcomes, large cruise ships typically have some form of power management system, such as a 'Load Control Program' that limits dramatic fluctuations in power use. Given that propulsion is the primary power requirement, and that propulsion is a function of the propeller's rotations per minute (RPM), as a general rule, when a large cruise ship is in Load Control the propeller RPMs are generally not reduced by more than 2–3 RPMs per minute. Consequently, gradual changes in speed represent best load management practices and the gradual change may not meet the more immediate change in operational state necessary for avoiding a whale.

Pre-emptive (planned) reductions in speed are, however, regularly used by pilots in Alaska as a strike risk reduction strategy. Pre-emptive speed reductions are those initiated in anticipation of, rather than in response to, a whale aggregation, and are utilized in two general scenarios. The first is when mariners are informed of a whale aggregation recently detected along the ship's route and communicated to the ship personnel. The second general scenario is when the ship is approaching a narrow navigational area that also historically has supported whale aggregations. For example, with the cooperation of cruise ship Masters, pilots regularly slow cruise ships to 14 knots in Snow Passage, Alaska, because avoidance options are limited and the area is often characterized by small to large whale aggregations. Pilots have found that these pre-emptive speed reductions tend to produce less resistance from other bridge personnel when (1) they can be accounted for in transit planning and (2) they do not adversely affect port arrival times.

We thus encourage continued development of software applications[4,5] in which mariners participate in a sighting network that helps inform others vessels that whales have been detected in their area. The type of information conveyed, its timeliness, and receiving platform is, however, critical for its utility. Receiving information via a mobile application (often with sporadic cell coverage) is a more cumbersome means than, for example, a ship's Electronic Chart Display and Information System (ECDIS) which could overlay historical (e.g., weekly) and recent (e.g., <2 h) whale sightings to assist with transit planning. Recently, the programmer for Whale Alert and the developer for SEAiq coordinated to provide the ability to import weekly whale sighting information automatically for display on the electronic chart.

Our results also demonstrate how, in some scenarios, slower ships may have increased opportunities for whale avoidance acting through both the Maneuver and Detection processes. Faster ships, by definition, travel further distances compared to slower ships during set time periods, such as when whales are submerged between surfacing events (averaged 20 s in our study), on deep dives (324 s modeled based on literature), or during

[4] www.WhaleAlert.org

[5] www.repcet.com

time lags related to decision-making and communications on the bridge following detection. For example, if the Command processes takes the same amount of time on fast and slow ships, and total time elapsed following detection to the point the ship begins to change course is approximately 115 s (**Figure 7**), we demonstrate that the faster ship achieving a 'near miss' of 100 m from a whale would need to detect the whale over 1100 m from the Point of Collision as opposed to just over 700 m for a slow ship, simply because the faster ship moves further over the same time period given the conservative safe maneuvering limitations imposed on the initial test scenarios. An alternative way of interpreting those results is that, had the slow ship and fast ship begun the Command and Maneuver process at the same distance from the whale (as opposed to the same time), the slower ship could have achieved a greater CPA because it would have had a longer time period to continue its turn.

Ship speed can also influence whale avoidance by influencing detection probability. To be clear our results do *not* indicate that mariners on slower ships are able to detect whales any better compared to mariners on faster ships – there is no logical reason why detection probability would differ for a surfacing whale at a set distance (e.g., 2000 m from the ship) for mariners aboard a fast or slow moving ship. However, if we held the *time* to a collision constant, as in the scenario in **Figure 5**, then, by definition, the faster ship will be further from the point of collision than a slower ship at the same time to collision. Thus, a surfacing event critical for detection would occur closer to the slower ship influencing the cumulative probability of detection, providing more time for a maneuver.

Future Research and Training

The conceptual model of active whale avoidance was derived primarily from the collective experience of pilots in Southeast Alaska who have 'learned by doing,' which has required significant time on the water. We thus submit a number of ideas for priority research and training development to hasten the adoption, applicability, and effectiveness of active whale avoidance.

First, ship personnel need sufficient time to make a decision related to an avoidance maneuver and achieve a new operational state, assuming one is commanded, that reduces collision risk. For example, marine pilots in Alaska are often challenged by predicting where a whale is likely to surface following its dive because, if they waited for the whale to resurface before initiating a maneuver, the options for avoidance would be significantly reduced. During simulation de-briefs pilots communicated that they will, at times, choose to 'turn behind' a whale if they ascertain it's swimming direction based on a general rule of thumb that, informed by years of encounters, humpback whales are more likely to continue their general direction of travel than they are to turn 180° following a dive. However, pilots are less likely to enact the same maneuver if humpback whales are foraging along a tidal rip, which they've found tends to produce more unpredictable movements. Thus, a priority avenue of research could be to explore the 'linearity' of whale movements, loosely defined as the degree to which whales travel in a straight line vs. turning (see also Williams et al., 2002; Barendse et al., 2010), and how it may be influenced by environmental conditions or other factors.

Refining estimates of detection probability, particularly as it applies to the area with in the Cone of Concern also represents an important research thread. The instantaneous detection estimates of the radial ship-to-whale distances we utilized (from Williams et al., 2016) were derived based on detecting whales across the 180-degree arc (beam-to-beam) forward of the ship. We assume that the probability of detection will be much higher at a given distance, or much father at a given detection probability, if similar detection functions were derived based on search effort solely in the Cone of Concern. We acknowledge that some of the 'gains' in detection from focused search in the Cone would be offset somewhat if mariners tasked with sighting whales are also tasked with other duties (e.g., monitoring radar or responding to radio communications). However, updating estimates of detection probability based on a Lookout's focused search within the Cone of Concern would provide more reliable estimates and produce a more realistic range of feasible options of avoidance maneuvers.

Another productive avenue of research is a more rigorous examination of competing risks related to whale avoidance. During our simulations, once pilots confirmed that a whale was forward of the ship at some risk of collision, a primary consideration was how to achieve a new (avoidance) heading while not increasing other risks, such as collision with other vessels, reefs, or shoals. For obvious reasons, ship operators will rarely increase the risk of deleterious impacts to passengers or damage to the electrical system that accompanies dramatic and unsafe operations [e.g., a 'crash stop' (Wirz, 2012) or rapid turn], unless those maneuvers are offset by reduction in risk to more consequential events such as a grounding (for example). The risk of negative impacts from dramatic changes in course or speed to avoid a whale will thus always be weighed against the potential benefits of whale avoidance. In all simulations where a course change was needed, the pilot evaluated the efficacy of the course change by considering the needed time to incrementally 'build up' to the desired rate-of-turn to minimize impacts to passengers, the ship, and the environment, thereby avoiding excess 'heel.' Larger heel angles aboard cruise ships increase the chance that furniture will begin to slide and passengers will be injured from falls/by falling objects, and swim pools will spill, etc. As previously discussed, the electrical or propulsions systems can be negatively impacted in extreme instances of abrupt speed changes. We note that parameters identified as "safe" often represent general guidance and can be modified depending upon the PDMV's experience and the situation (e.g., commencing an initial rate-of-turn, within defined parameters, and then after the ship has stabilized at that rate-of-turn, incrementally increasing, and stabilizing at greater rates-of-turn, while maintaining the ship within safe heel angles).

The development of a whale avoidance module in a full-mission ship simulator can also advance whale avoidance by training mariners, through repetition and experimentation, who have less experience with conditions where whale avoidance may be effective, avoidance techniques, and range of maneuvers that may be possible. Training modules can also lead to improved transit planning by scripting exercises within a specific operating area where whales are likely to be encountered while also accounting for local environmental conditions (e.g., wind, current, sea state), traffic situations, and other navigation hazards commonly experienced (e.g., ice).

Finally training can assist in communicating the value of whale avoidance to other members of the bridge team, such as the ship captain/mates. Pilots in Southeast Alaska have found that, upon boarding the ship, communicating with the bridge team that whales may be encountered, emphasizing the importance of whale avoidance, and discussion of avoidance techniques has increased situational awareness of whales while in transit (similar to communicating local knowledge of navigational hazards) and, importantly, often reduced resistance to implementing proactive avoidance maneuvers or temporary reductions in ship speed. A recent study in the St. Lawrence Estuary demonstrated the value that marine pilots can have in implementing strike-risk reduction efforts, in part, through elevating its importance for the larger bridge team (Chion et al., 2018).

An important caveat is that the development of training modules not generate a ‘recipe’ for proper maneuvers. The range of variation in avoidance maneuvers is large, based on whale swim speed, direction of travel, ship speed, and operational constraints, as are the competing risks of an avoidance maneuver. In a whale avoidance situation, mariners are often faced with making rapid decisions to prevent making an undesirable situation (e.g., risk of collision with a whale) become an even more harmful event (to the whale, the passengers, the ship itself, the environment, or all four). Marine pilots in Alaska, when asked what they do to avoid a whale, answer ubiquitously: “it depends.” In “mariner-speak” avoidance actions are based upon all factors appropriate to the prevailing circumstances and conditions, and with due regard for good seamanship. And good seamanship is a direct function of good training. To that end, we follow the reasoning of De Terssac (1992), as cited in Chauvin et al. (2009) who stated that, to achieve an overarching objective (which in this case is a reduction in collision risk) the best approach is to define “*…a space of operation within which formal rules no longer specify the solution to be implemented, but list a range of permissible solutions among which the operator will have to choose the one that seems most relevant in the context.*” Within that range of potential solutions may be a decision to maintain course or speed either because the value of the information available is insufficient or the risk of a worse outcome exceeds the risk of the ship strike (e.g., the altered course resulting in coming too close to shore, increasing the risk of grounding and catastrophic oil spill).

Based on our findings and observations, we conclude that active whale avoidance is feasible and, in most cases, can be practiced without creating an increase in competing risks. What’s more the practice can complement existing efforts that increase situational awareness of whales (e.g., Whale Alert) even in areas where other risk-reduction measures, such as operating at slower speeds, are in place. Most importantly, continuing collaboration between professional mariners, scientists, and natural resource managers is vital to reaching mutually beneficial reductions in whale strikes.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

AUTHOR CONTRIBUTIONS

SG and LV conceived the idea and initiated the collaborative efforts between the Southeast Alaska Pilots’ Association and the National Park Service. SG led the writing of the manuscript and construction of the figures including the data used for detection and availability. SG, LV, CG, RP, and AH participated in the simulator activities at AVTEC. JB and LV collaborated on generating maneuvering graphics. SG, LV, CG, and JB contributed to the writing of the manuscript and idea development.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2019.00592/full#supplementary-material

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North Atlantic Right Whales- Evaluating Their Recovery Challenges in 2018

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North Atlantic Right Whales - Evaluating Their Recovery Challenges in 2018

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US DEPARTMENT OF COMMERCE
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ABSTRACT

The North Atlantic right whale (*Eubalaena glacialis*) population has been in decline for 8 years due to increased mortality and sublethal effects from multiple factors. Together these have contributed to a decrease in calving. Shifting ecosystem conditions have also changed North Atlantic right whale behavior and fishing patterns. For example:

- North Atlantic right whales have expanded their distribution farther into northern waters, and are visiting different foraging areas.
- Calanoid copepod distributions appear to be in a similar state of change and this may be affecting available forage for North Atlantic right whales
- The whales' range expansion has exposed them to vessel traffic and fisheries in Canadian waters, which did not have protections for right whales in place until late last summer (2017).
- American lobster (*Homarus americanus)* populations are also changing distribution, moving north and into deeper, cooler waters of the Gulf of Maine. The US fisheries are moving farther offshore to capitalize on this, increasing the overlap between their fishing activity and North Atlantic right whale foraging areas and migration corridors.

The net result of these events is that severe entanglements have increased among North Atlantic right whales. Animals are in poor body condition likely from a combination of repeated entanglement stress, potentially limited forage and increased migratory costs- all contributing to a decrease in female calving rate. Ship strikes are still a real threat to the population. At the current rate of decline, all recovery achieved in the population over the past three decades will be lost by 2029.

INTRODUCTION

Signs of Trouble

After several decades of recovery and years of collaboration among stakeholders, the North Atlantic right whale (*Eubalaena glacialis*), hereafter referred to as the right whale, began to decline (Pace et al. 2017). This trend was subtle at first, initially signaled by fewer sightings in traditional survey areas, but other warning signs began to emerge (Kraus et al. 2016). The number of documented mortalities increased markedly in 2016 and 2017 (Hayes et al. 2018; Hayes et al. 2017) and an improved way of modeling the population's numbers (Pace et al. 2017) revealed a clearer picture of the population size and decline in numbers. Concern further escalated throughout 2017 and 2018 when only 5 calves were born and there were 19 confirmed mortalities through August.

Taken together these signs meant that risks posed to right whales and associated management measures needed to be revisited for multiple US fisheries on the Atlantic coast. This occurs through the biological opinion process under the federal Endangered Species Act, which was reinitiated in October 2017, and through the take reduction team process under the federal Marine Mammal Protection Act.

Demographic Effects

Increased mortality rates and decreased calving have moved the population into a decline that has continued for at least the last 8 years. At present, right whale deaths attributable to human activity are mostly caused by ship strikes and entanglement in pot/trap and anchored gillnet fishing gear. An encounter with fishing gear is the most frequent cause of documented right whale serious injuries and deaths in recent years. The odds of an entanglement event are now increasing by 6.3% per year, while ship strikes events remain flat (Fig. 1). At the current rate of decline, the population will have returned to its 1990 numbers, likely with comparatively reduced genetic diversity, and could decline past a point of no return in just a few decades.

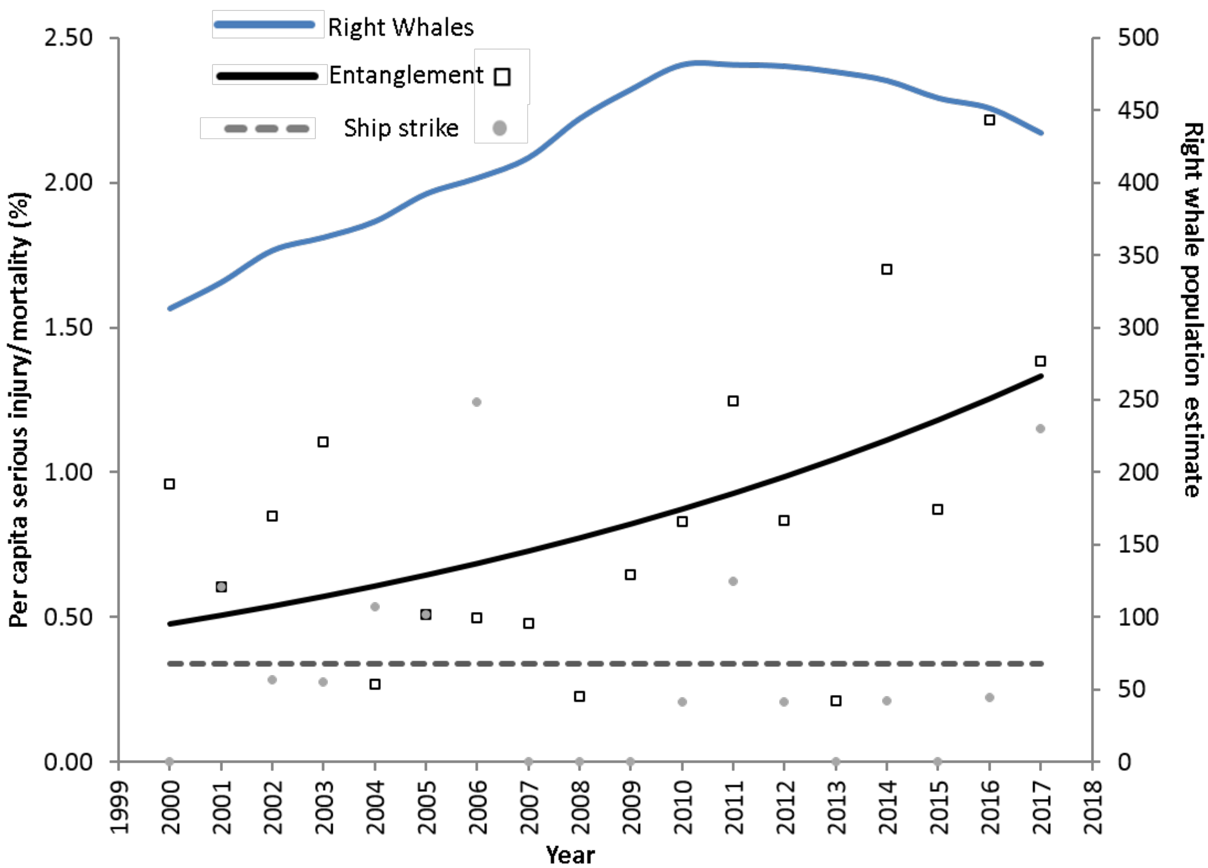

Fig. 1 **North Atlantic right whale serious injury/mortality rates from known sources 2000-2017 (Henry et al 2017; 2016 & 2017 values preliminary). Models are simple logistic regressions fit using maximum likelihood-based estimation procedures available in R. The right whale population trend is overlaid and referenced to right y-axis (Hayes et al, 2018).**

Distribution Change

Historically, right whales have returned to habitats in specific geographic locations annually, ensuring that a large portion of the population could be seen in each year. Therefore annual population estimates were conducted by simply sighting and counting as many animals as possible each year. Resulting estimates also assumed that an animal had died if it were not seen for 6 consecutive years.

Changes in this distribution pattern began around 2010 when the population peaked at 481 individuals. The whales were no longer using some of their established habitat areas in as great a number, and not staying within them for as long. This meant a new method was needed to account for animals, even those not sighted in a year. Once developed, this more advanced assessment tool, based upon mark recapture methods, enabled rapid assessment of the population with increased precision within one calendar year, much faster than the five or so years required to get good confidence on an annual estimate using the previous method. It also provided precise population estimates with greater resolution on the number of whales that likely died in any given year. Estimates made using the new method confirmed that in recent years, many deaths (around 10 to 20/yr) were going undetected annually and that by the end of 2016, the right whale population had declined to 451 individuals. A revised population estimate accounting for the many deaths and few births of 2017 is being developed and will be available later this year.

Increased Mortality

The large number of observed right whale mortalities in 2017 triggered an unusual mortality event (UME) to investigate the causes. The National Marine Fisheries Service (NMFS) is authorized to declare UMEs under the federal Marine Mammal Protection Act when an unanticipated significant die-off occurs in a marine mammal population, requiring an immediate response. Two other UMEs were declared that year due to 80 humpback whale and 40 minke whale deaths. Ongoing investigations for these two species have preliminarily identified causes of death that include entanglements, ship strikes, and disease.

In contrast to other large whale species, the problems of right whales are often more apparent because they are monitored more intensely and their coastal distribution means more opportunity for overlap with human activities, leading to it being nicknamed ‘the Urban Whale’ (Kraus et al. 2007).

While perhaps more attention is paid to the right whale given their more dire population status, it can be an indicator of more chronic problems that need addressing, not just for the sake of right whales but also for other populations of large whales. By example, although Gulf of Maine humpback whale status has improved, entanglement mortalities still remain high for this stock (Hayes et al. 2018).

There is considerable urgency to address the issues of mortalities that stem from human activities. Large whales, including right whales, are long-lived and can breed multiple times during their lives. This means these species can be resilient and able to recover after periods of poor reproduction. However, recovery for any species cannot take place if the number of deaths is more than the number of births in the population.

POTENTIAL CAUSES OF THE DECLINE

Ecosystem Dynamics

One of the constant challenges of resource management is that things change. While it is much easier to make management decisions if conditions are static, ecosystems are inherently dynamic and will change over time in response to a variety of influences. This is the case for the emerging story for right whales.

Sometime around 2010, ecosystem shifts occurred within their habitat that changed right whale movements and fishing practices in a way that has increased interaction between whales and fishing gear, and that potentially presents other environmental challenges.

Currently the Gulf of Maine is warming faster than 99.9% of all other ocean regions on the planet (Pershing et al. 2015). This is having dramatic impacts across the food web, from the middle and upper trophic level organisms such as American lobster (*Homarus americanus)*, Atlantic cod (*Gadus morhua)* and right whales (Greene 2016); to the zooplankton at the base of the food web such as calanoid copepods (Grieve et al. 2017; NEFSC 2018).

Whales and Fisheries Are On the Move

American lobster are experiencing strong population fluxes and redistributions with temperature warming. The southern New England lobster fishery has been severely limited by epizootic shell disease, which lobsters become susceptible to at warmer temperatures. In the Gulf of Maine, coastal waters remain cool enough and offshore, deeper waters have warmed enough for lobsters, and lobster fishing, to expand farther offshore. As a result, Maine lobster landings have increased steadily for the past 30 years, with an increasing portion of this caught 3 or more miles offshore over the past 10 years (Fig. 2). Note that Maine lobster landings did downturn sharply in 2017, and future trends are uncertain.

Prey Availability Drives Reproductive Success

It is essential to also recognize that environmental factors and lower trophic level dynamics also contribute to right whale birth and mortality rates. Changes in prey availability influence right whale health and reproduction. In particular, abundance of the copepod *Calanus finmarchicus* in the Gulf of Maine is a strong predictor of right whale reproductive success (Greene and Pershing 2004; Meyer-Gutbrod and Greene 2014; Meyer-Gutbrod et al. 2015).

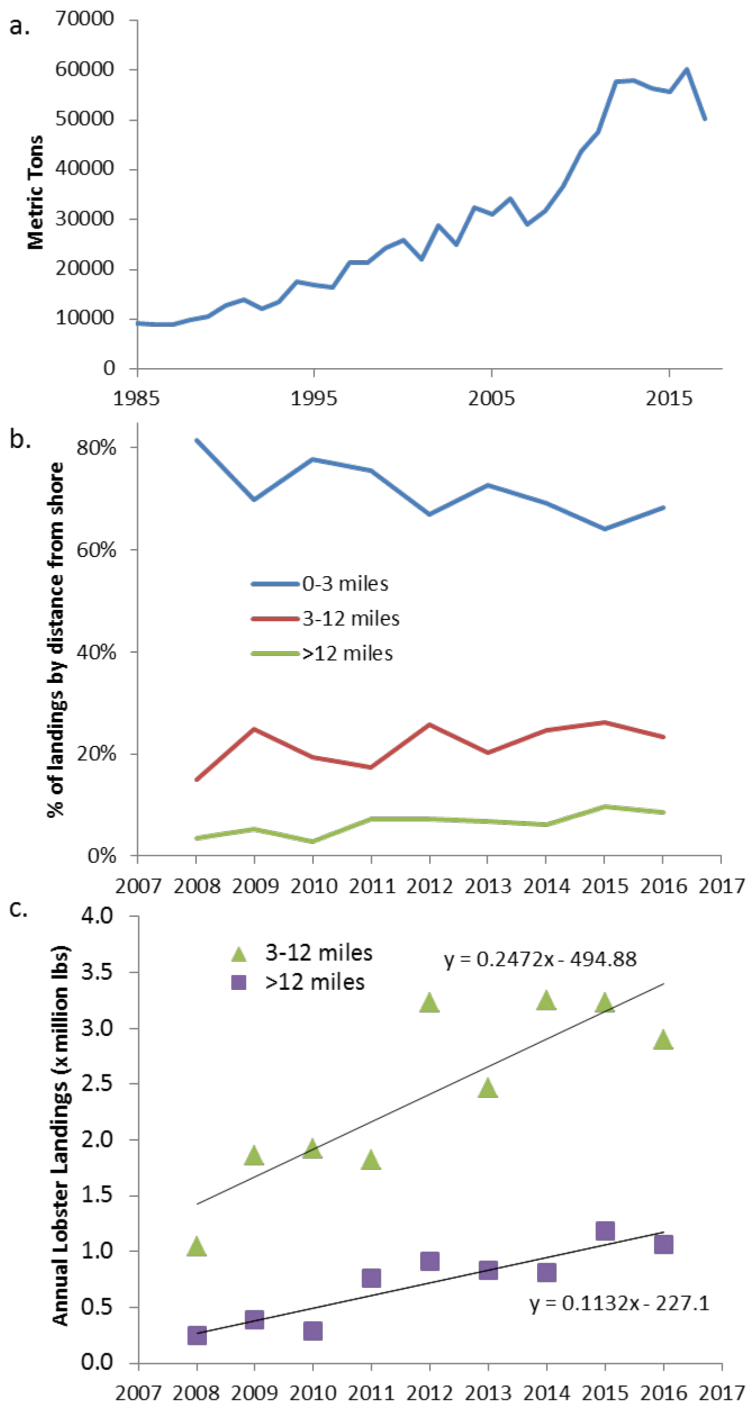

Fig 2. **American lobster landings in Maine: a) total annual landings b) relative proportion of landing by distance from shore c) increase in landings from 3-12 and >12 miles offshore from Maine's 10% harvester reporting, no VTR data included. https://www.maine.gov/dmr/commercial-fishing/landings/**

Meyer-Gutbrod and Greene (2018) followed individual whales over the past three decades to evaluate the relationship of calving and mortality rates to prey availability. They found that prey availability is a driver of decadal differences in the right whale population's recovery. Periods of low prey availability coincided with reduced birth rates (Meyer-Gutbrod and Greene 2018) and the interval between births has been observed to lengthen during periods when prey availability is low (Meyer-Gutbrod et al. 2015).

Similarly, years with few births contribute to years of decline or stagnation in population growth, indicating the pronounced effect of reproductive variability on species viability (Pace et al. 2017). That said, Meyer-Gutbrod and Greene (2018) modeled population growth rates under scenarios of high and low prey availability and found that the population should continue to grow even with poor prey availability and only fails to do so when whale mortalities reach 8 to 10 per year. It is worth noting natural mortality seems to be very rare in adult right whales: there has been no confirmed case of natural mortality in adult right whales in the past several decades (Corkeron et al. *Accepted with revision;* Henry et al. 2017; van der Hoop et al. 2013).

Right Whales Follow Prey in a Changing Ocean

The copepod *C. finmarchicus* has shifted in distribution and abundance in recent years due to unprecedented warming in the Gulf of Maine, and this is likely to impact the right whale population (Greene 2016; Mills et al. 2013; Reygondeau and Beaugrand 2011). It appears that in the last decade (~2005-2015), that there has been a general decline in *C. finmarchicus* in the Gulf of Maine (2009-2014, but 2015 was average abundance) and on Georges Bank (below average abundance since 2008) (NEFSC 2018) as well as the Scotian Shelf (Johnson et al. 2017).

Changes in plankton forage species abundance likely played a role in the changing movement patterns of right whales that began sometime in the past 10 years. There have been decreases in both acoustic detections and physical observations of right whales in the northern Gulf of Maine and the Bay of Fundy, and a concurrent increase in sightings of many of the same animals in the Canadian Gulf of St. Lawrence (Daoust et al. 2018; Davis et al. 2017; Meyer-Gutbrod et al. 2018; Meyer-Gutbrod and Greene 2018).

During winter, whales are spending more time offshore in the mid-Atlantic, and less time on the coastal calving grounds just off the southeastern U.S., where in 2017 and 2018 calving has been quite poor.

Reproduction Requires Robust Females

Reproduction depends on adequate adult female health and body condition. Reproductive females are particularly vulnerable to prey reductions because pregnancy and lactation increases caloric demand and they have less access to prey during migration to calving grounds (Fortune et al. 2013; Miller et al. 2012; Rolland et al. 2016).

Several of the ecosystem shifts mentioned earlier are likely to have negative consequences for reproduction in right whales. First, a reduction in prey will have energetics costs for females. Northward shifts in the right whales' feeding grounds, as a result of changes in prey availability, will increase energetic cost of the calving migrations from the southern calving grounds off the coast of Florida and Georgia, particularly if animals do not adapt to also calve farther north.

The cost of entanglement has also been shown to have direct and indirect consequences for right whales (van der Hoop et al. 2017b; van der Hoop et al. 2017c). This will be detailed next, but in the Gulf of Maine where ecosystem shifts are occurring more trap fishing is also occurring offshore, increasing the overlap with right whale foraging areas.

Whales have also expanded their range, foraging into the Gulf of St. Lawrence. This increased the whales' exposure to risk from fixed gear fisheries. Some of this risk has reduced by strong protections put in place by the Canadian government during the spring of 2018 (DFO/TC Canada 2018; DFO Canada 2018).

Anthropogenic Stressors

In a review of mortality sources for all large whales, entanglement in fishing gear was the number one cause, followed by natural causes and then vessel strikes. An exception to this is the right whale for which there is very little evidence of natural mortality in adult whales, likely due to shortened life spans associated with anthropogenic causes (Corkeron et al. *Accepted with revision*), as all confirmed causes of adult mortality and serious injury since 1970 have been due to fishing gear and vessel strike (Henry et al. 2017; van der Hoop et al. 2013).

The relative contribution from these two causes was approximately equal through the year 2000 (van der Hoop et al. 2013), but entanglement events resulting in death or serious injury have increased steadily since then, while ship strike frequency has remained lower with no specific trend (Fig. 1). For the recent 19 known right whale mortalities (17 in 2017 and 2 to date in 2018), the cause of death could be determined for 10. Ship strikes are implicated in five blunt force trauma cases and entanglement in the remaining five. In 2017, seven other entangled whales were observed: three were disentangled, three shed the gear, and one was not seen again.

Ship Strikes

Reducing Risk

Ship strikes are currently the second most frequently documented cause of mortality in right whales. The per capita mortality frequency has not varied much, hovering around 0.34% deaths or serious injury events per year (Fig. 1). Several management actions were implemented in U.S. and Canadian waters beginning in 2008 to reduce the risk of collisions between right whales and large vessels. Major actions include:

- Voluntary two-way routes for commercial vessels off the Southeast U.S. and in Cape Cod Bay
- Modification of the Boston, Massachusetts Traffic Separation Scheme
- Canada and the International Maritime Organization established the voluntary Area To Be Avoided concept in the Roseway Basin
- Seasonal Management Areas in habitats off of Massachusetts, ports along the Mid-Atlantic coast, and the southeastern U.S. where vessels are required to slow to speeds less than 10 knots during transits for vessels 65 ft in length or longer

- Intermittent implementation of voluntary speed restrictions in Dynamic Management Areas within which right whale aggregations are observed outside the boundaries of the Seasonal Management Areas

Several analyses have been conducted to evaluate the effectiveness of these management efforts (Conn and Silber 2013; Lagueux et al. 2011; Silber et al. 2014; van der Hoop et al. 2012). In general, while these analyses were based on a short time-series of available data, collectively they suggest that after ship-strike rules put in place, a reduction in right whale mortality from ship strikes followed, and in general were at the lowest on record per capita from 2010 through 2016.

Responding to Changing Risk

In 2017, right whale deaths by ship strike increased when 5 ship-strike mortalities were confirmed, 1 in U.S. and 4 in Canadian waters (Fig. 1), likely caused in part when right whales began to spend more time in new areas with high vessel traffic and no speed restrictions. Increased survey effort in these areas also made it more likely that these events would be observed and reported.

Entanglement

Reducing Risk

Management efforts to reduce entanglement risks in U.S. waters have focused on gear technology to make entanglements less likely to harm or kill whales, restricting where and when gear that poses a threat can be used when whales are likely to be present, and reducing the amount of gear in the water column (Fig 3). Measures are recommended through a take reduction team, as mandated under the federal Marine Mammal Protection Act. Each team comprises a variety of experts and stakeholders, who assist NOAA Fisheries in developing a take reduction plan when necessary.

Since 1997, a series of rules have been implemented based on the take reduction plan (Fig. 3). These include the sinking groundline (2009) and vertical line (2015) rules. While there appears to have been a subsequent reduction in entanglements caused by groundline (Morin et al. 2018), which moved 27,000 miles of line from the water column to the bottom (NMFS, 2014), absolute entanglement rates appear to be on the rise (Fig 1).

Increase in Entanglement Risk

Fewer but Stronger Lines in US Waters

There may also have been unintended consequences of the 2015 vertical line rule. The rule required ‘trawling up’ (using more traps per trawl) in some regions. While this reduced the number of lines, it also meant that lines had to be stronger to accommodate the increased load of multiple traps. This natural adaptation, and the fact that stronger rope was available, contributed to an increase in the severity of entanglements as found by Knowlton et al. (2016), who observed very little evidence of entanglement with ropes weaker than 7.56 kN (1700 lbsf).

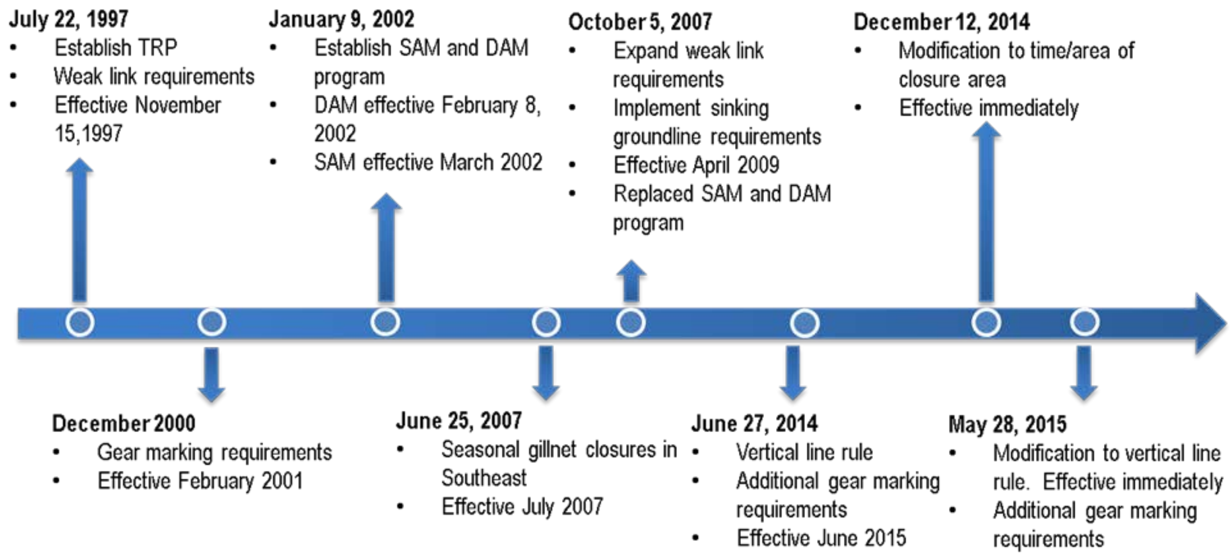

Fig 3. Timeline of significant management actions focused on reducing fishing entanglement

Entanglement Trends Upward

Knowlton et al.(2012) showed that nearly 85% of right whales have been entangled in fishing gear at least once, 59% at least twice, and 26% of the regularly seen animals are entangled annually. These findings represent a continued increase in the percentage of whales encountering and entangling in gear, which grew from to 61.5% in 1995 (Hamilton et al. 1998), to 75.6% in 2002 (Knowlton et al. 2005), confirming further the growing severity of the problem.

More Vertical Line in Right Whale Habitat

Rough estimates are that approximately 622,000 vertical lines are deployed from fishing gear in U.S. waters from Georgia to the Gulf of Maine. Notably until spring of 2018, very few protections for right whales were in place in Canadian waters. In comparison to recent decades, more right whales now spend significantly more time in more northern waters and swim through extensive pot fishery zones around Nova Scotia and into the Canadian Gulf of St. Lawrence *(Daoust et al. 2018).*

Taken together, these fisheries exceed an estimated 1 million vertical lines (100,000 km) deployed throughout right whale migratory routes, calving, and foraging areas. Figure 4 illustrates the scale of the challenge by providing fishery statistics for the various regions (data sources provided in Appendix 1).

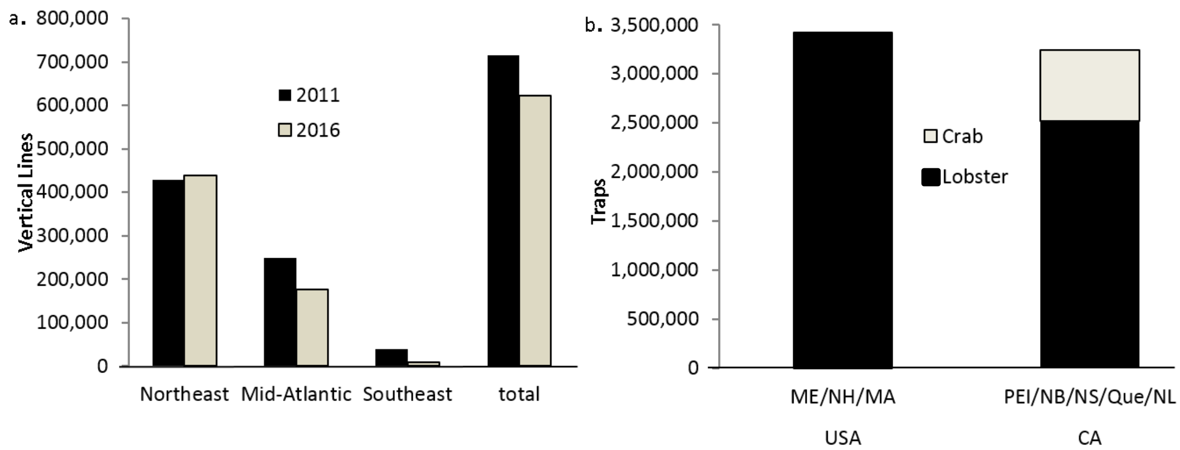

Fig 4. Index of fishing effort. a) The change in number of vertical lines in US waters from 2011 to 2016, b.) The approximate number of traps in USA Northeastern states and Canadian provinces. Data sources in Appendix 1.

Closures Are Effective, But May Not be Enough

A great deal of effort has been put into identifying entanglement 'hot-spots': relatively small areas where focused management measures can have minimal impact to fishing while providing great benefit to whales. Clear examples of this approach include the seasonal closure of Cape Cod Bay, and now the static closure within the Area 12 fishing zone of the Canadian Gulf of St. Lawrence. Both are relatively small areas where a significant portion (30 to 50+ %) of the right whale population has reliably occurred for several weeks to months over the past few years. Management actions have a population level benefit with impacts restricted to very local portions of fisheries. While still difficult choices, this has been the preferred management approach.

However, these closures, while likely very effective regionally, may not be enough. Each vertical line out there has some potential to cause an entanglement. With a 26% annual entanglement rate in a population of just over 400 animals, this translates to about 100 entanglements per year, which is significant for such a small population. But from the perspective of an individual fixed gear fisherman, they may never encounter a right whale. With more than 1 million lines out there, any single line has perhaps a 1 in 10,000 chance of entangling a whale in any one-year period. This can vary somewhat from regions with high to low densities of lines and/or whales.

However, in general, this means a fisherman and his or her descendants could go several generations without ever entangling of a right whale. Given this, it's easy to believe that *'all these entanglements are happening somewhere else'* regardless of where one fishes. Being able to directly link an entanglement with specific gear deployed at a specific place in time is rare, but by mapping known locations of gear that led to the entanglement of a right whale, one can see that there is no place within the fished area along the East Coast of North America for which entanglement risk is zero (Fig 5).

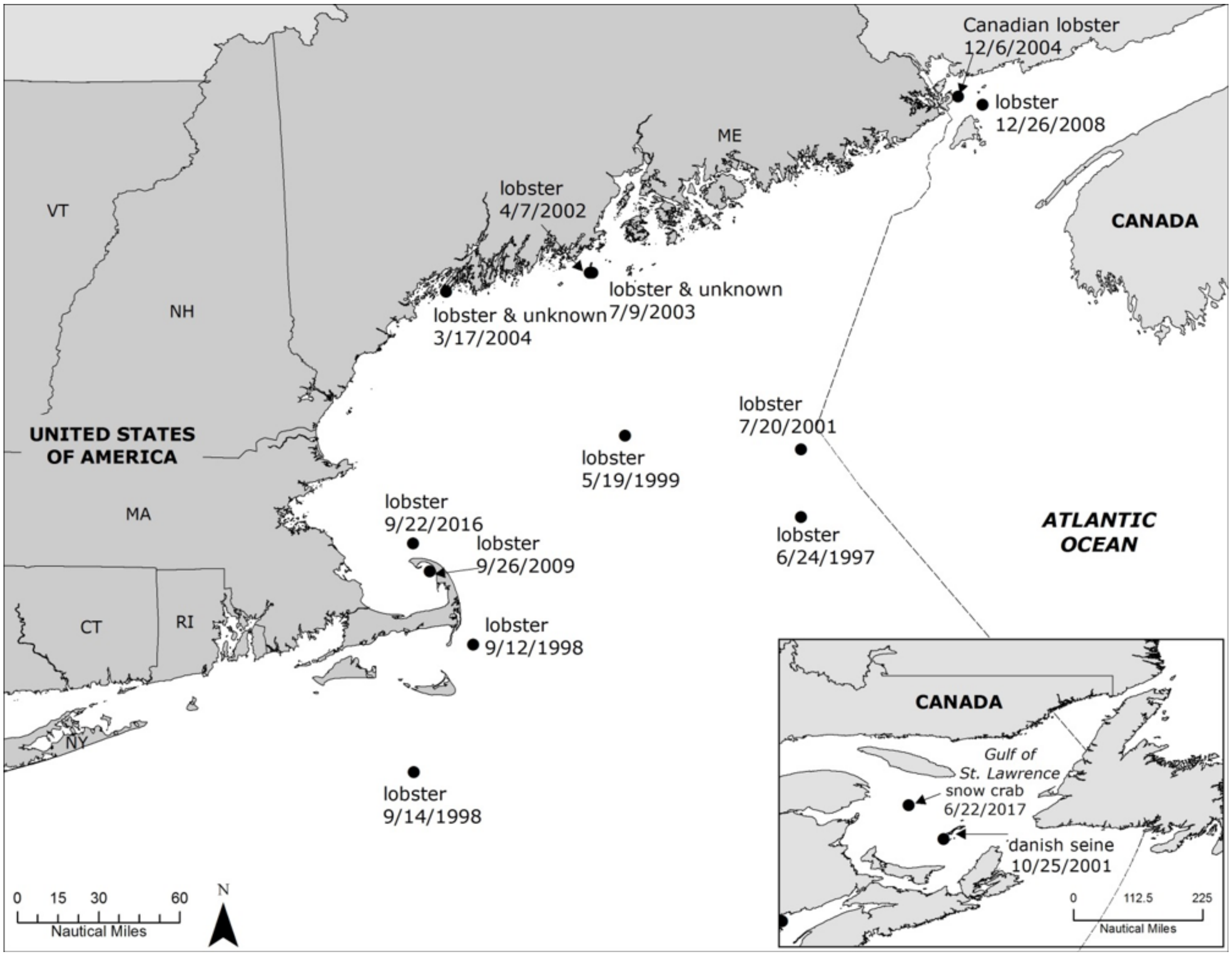

Fig 5. Right whale entanglements from 1997 through 2017 for which the set location and type of gear are known, and gear was recovered from a whale.

Sublethal Challenges- Skinny Whales and Few Calves

Fundamentally, a population increases when there are more births than deaths. Much attention has been paid to direct mortality caused by ship strikes and entanglement, but less focus has been put on the secondary effects of these and other variables where animals survive but fail to thrive because of the harm done. This is particularly evident in calving among mature females.

Biological Cost of Stressors

The abundance of photographs of known individual right whales taken over several decades have been used to develop health indicators associated with natural and human-caused stressors (Schick et al. 2013). This has been refined into a quantitative health score, including a predictive threshold below which females seem incapable of having a calf (Miller et al. 2012; Rolland et al. 2016).

We understand that right whales are exposed to numerous sublethal stressors, including fluctuating food resources (Meyer-Gutbrod and Greene 2014) and even underwater noise (Rolland et al. 2012). Several recent studies have also focused on sublethal effects of entanglement, the first of which includes increased swimming energy costs from dragging gear (van der Hoop et al. 2016). Even if disentangled, there are several injuries that can have costs lasting long after disentanglement. These include trauma wounds from rope cuts that may or may not eventually heal, and damage to baleen plates that can prevent efficient filter feeding for many years since these plates grow slowly.

Recent studies have also shown that even without accounting for injury, the drag from carrying rope and other gear for long periods of time can be energetically more expensive for a female than the migratory and developmental costs of a pregnancy (van der Hoop et al. 2017a; van der Hoop et al. 2017b; van der Hoop et al. 2017c).

Biological Demands of Right Whale Pregnancy

While serious injuries represent 1.2% of all entanglements, there are often sublethal costs to less severe entanglements. Should an entanglement occur but the female somehow disentangles and recovers, it still has the potential to reset the clock for this "capital" breeder. She now has to spend several years acquiring sufficient resources to get pregnant and carry a calf to term, the probability of a subsequent entanglement is fairly high, and this will create a negative feedback loop over time, where the interval between calving becomes longer. This is certainly a contributing factor in the longer calving interval for females, which has now grown from 4 to 10 years (Pettis et al. 2017).

Figure 6 demonstrates a simple model for estimating the probability that an animal will NOT become entangled over time. Similar to asking what are the odds of NOT getting 'heads' in 10 coin tosses, this model simply asks what are the odds of not getting entangled over time if there is a 74% chance of not getting entangled each year (Knowlton et al. 2012). Historically the median calving interval of a female right whale is 3 to 4 years (Pettis et al. 2017). The model estimates that animals have a about a 30 to 40% chance of not getting entangled during that period, or, conversely, a 60 to 70% chance of getting entangled.

With the calving interval now nearly twice as long as in the past, half as many calves are being born. So while entanglements often do not kill an animal, they may have a large impact by reducing or preventing births in the population. There is an additional variable, stress, which is much harder to quantify but known to have costs in mammals that are foraging in an environment with some mortality threat (Hernández and Laundré 2005).

It is difficult to tease out the relative effects of poor foraging conditions and the energetic costs of entanglement on the increased frequency of thin whales and the subsequent decrease in calving. Both are likely having some influence. While there are dozens of documented cases of ship strikes and entanglement linked to right whale mortality, to date there is no confirmed observation of a right whale starving to death from poor forage.

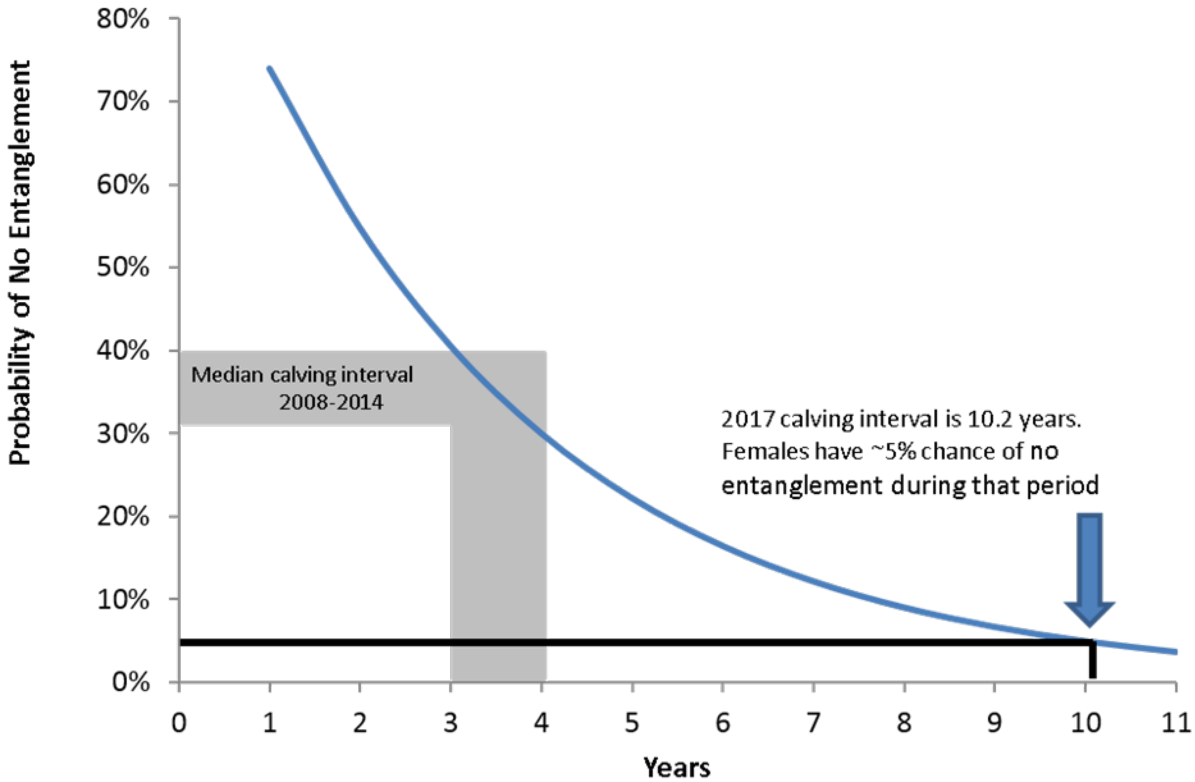

Fig 6. Cumulative annual probability of no entanglement (annual rate = 74%)

HOW LONG DO NORTH ATLANTIC RIGHT WHALES HAVE?

A Long-Lived Animal

Right whales have the potential to be a very long-lived species. In the southern hemisphere where shipping and fishing pressures are much lower, there is little evidence of human activities causing right whale mortality. There is also little evidence of natural mortality in adult animals (Corkeron et al. *Accepted with revision*). Since the ban on commercial whaling of Southern right whales in 1935 (Gambell 1993) these animals have not yet lived long enough to die of natural causes.

Meyer-Gutbrod and Greene (2018) demonstrated that even under poor foraging conditions, right whales should be able to recover if annual human-caused mortality is kept somewhere below 8-10 deaths per year. This means that in the absence of human-caused mortalities, right whales could potentially endure several decades under poor foraging conditions and still recover once environmental conditions improve. However, in the current situation in the northern hemisphere, where animals are living much shorter lives, there is great cause for concern that the risk of extinction is much higher than in the southern hemisphere, where animals are not regularly subject to human caused mortality.

An Illustration of Potential Decline, 2017-2067

A Matrix Model

In order to measure current population trends, we used a three-stage (calf, juvenile, adult) matrix population projection model (Caswell 2006) for female right whales, derived from Corkeron et al. (*Accepted with revision*), to project the future abundance of right whales. Survival values used for input into the population projection model were calculated using a Cormack-Jolly-Seber (Pace et al. 2017) variant of a mark-resight model (see Appendix 2 for details) and determined the population is declining at 2.33% per year.

We started the model estimating an abundance of 160 females alive at the end of 2017. With approximately 1.5 males per female (Pace et al. 2017), 160 females would result in an overall species abundance of about 400. It is possible that this abundance estimate may be marginally low, but since the model overestimates calving success, we assumed that these biases should cancel each other out.

Using the stage derived from the matrix model, we assumed that the 2017 starting population of 160 females was composed of 10 calves, 60 juveniles, and 90 adults. We ran 1000 stochastic projections forward 50 years (Fig. 7).We then extracted median and 95% quantile estimates of projected abundance from those projections, and estimates of the number of adult females remaining, for 5, 10, 15, 20, 25 and 50 years. Results are shown in the Table.

Results

The model projects that in 2067, 50 years from 2017, there would be 49 female North Atlantic right whales remaining, of which only 32 would be adults. In 20 to 25 years (2037-2042) there would be fewer than 50 adult females. In the near term, at the current rate of decline, all recovery in the population over the past 3 decades will be lost by 2029, with the population returning to the 1990 estimate of 123 females.

Notably, the model does not adjust for varying environmental conditions, which are known to fluctuate on a decadal time scale for North Atlantic Ecosystems (Nye et al. 2014) and are presently unfavorable. This approach may overestimate the rate of population decline but not the overall trajectory.

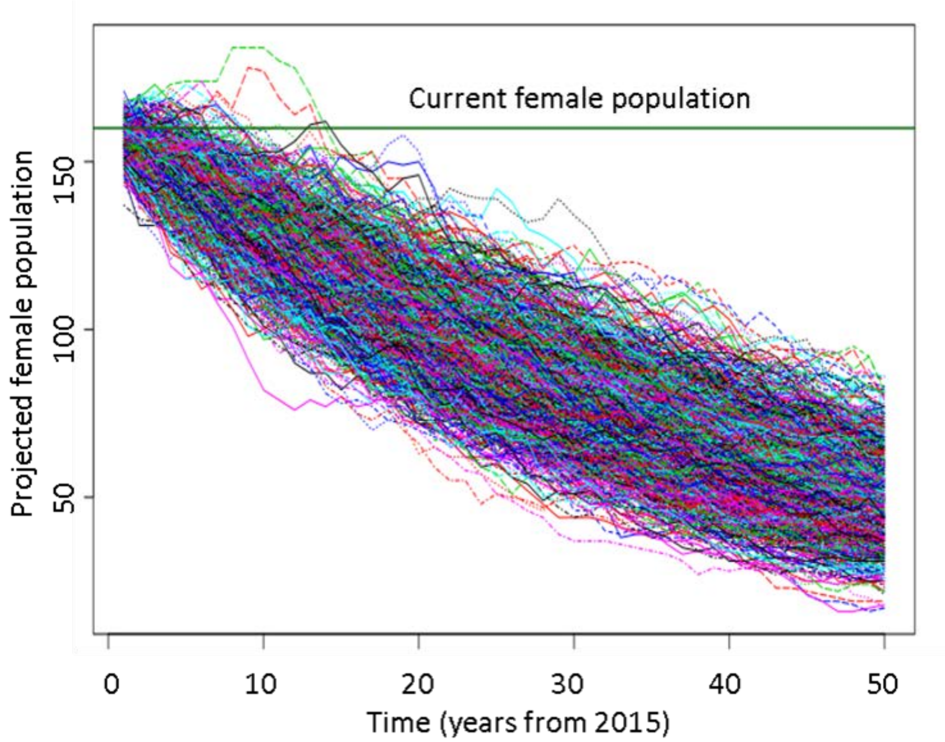

Fig. 7 Matrix population projection model output of North Atlantic right whale female population trend under current population conditions.

Table of matrix projection model output of female North Atlantic population trends for 5-year intervals, 2017-2067

Years from 2017	Number of females	Cis	Number of adult females
5	144	126 to 161	75
10	129	107 to 150	67
15	114	91 to 141	59
20	102	77 to 130	53
25	90	66 to 119	47
50	49	27 to 76	32

The threshold for functional extinction is very hard to define and likely varies by species. If the population declines to the 1990 level, there is a new threat: a repeated genetic bottleneck. Genetic bottlenecks happen when a population is so small that the genetic make-up of remaining group is not the same as that of the initial population. The effect of repeated bottlenecks is likely to mean that if the population returned to the 1990 level, that group would have less genetic diversity than the group that existed in1990. This can lead to reduced resilience and contribute to increased risk of extinction (Amos and Harwood 1998; Melbourne and Hastings 2008).

INDICATORS OF SUCCESSFUL MANAGEMENT MEASURES

Determining the management actions necessary to reverse the current population trend is beyond the scope of this document. However, the scale of the actions will need to be quite significant to be successful. Entanglement has increased dramatically and ship strikes continue to occur.

The population decline began in 2010 (Fig. 1), when entanglement was occurring at a rate of 26% among sited animals per year (Knowlton et al. 2012). Since then, the right whale range expansion has put them in the path of more shipping and more fishing gear – encountering almost twice the amount of gear owing to expansion of more fishing farther offshore in US waters and northward into Canadian waters (Fig. 4).

It is logical to conclude that to reverse the right whale decline, it may be necessary to reduce the impacts of entanglements and other harmful human interactions with right whales across their expanded range to pre-2010 levels. For recovery it may be necessary to go further, considering more modifications to fishing and shipping practices to compensate for potentially reduced forage opportunity and increased migratory costs.

Several biological indicators can be recommended for monitoring the short- and long-term effectiveness of any management actions that might be put in place to reduce the rate of both ship strikes and fishing gear entanglement.

Short-term indicators include fewer observed numbers of ship strikes and entanglements. These could be noticeable within 6 months to 1 year, but there is considerable variation around detectability of these events and the results will initially have a great deal of uncertainty. It takes approximately 1 year to conduct a population assessment and determine any changes in abundance. The assessment will alleviate some the uncertainty in detecting mortality risks that that might be mitigated by management actions. It should be noted that number of mortalities is the bluntest indicator of management success.

However, teasing the relative effects of management actions and natural variability on population size and condition will take several years of data and analysis. Metrics such as the frequency of scarring, improvements in body condition, and overall health scores could be detectable under stable environmental conditions in 2 to 3 years. Similarly, if environmental conditions are adequate for females to accumulate enough resources to calve, it will likely take at least 2 to 4 years to separate the impact of management action that reduced the frequency of, say, costly entanglements from the impact of natural variability. Ultimately, confidence in any estimate of population trajectory will emerge over 5 to 10 years.

In an ideal situation, evidence of human-caused injuries and mortality decreases, body condition improves, and the birth rate exceeds the death rate, resulting in more North Atlantic right whales.

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APPENDIX 1 Data Sources for Figure 4

Several data sources were used to construct Fig 4. All vertical line estimates in 4A were provided by Industrial Economics. Trap counts provided in 4B were acquired from a variety of sources. Raw trap counts were provided for Maine and Massachusetts. Trap counts for New Hampshire and all Canadian provinces were generated by multiplying license counts by trap limits. These were quite variable across regions, in which case the multiplier used is reported in the Table in the report.

Table 2. Data sources for trap counts and license numbers by country and regions.

Location	species	# traps	data year	Source
Maine	Lobster	2,901,000	2016	https://www.maine.gov/dmr/commercial-fishing/landings/documents/lobster.table.pdf
New Hampshire	Lobster	133,700	2010	https://www.greateratlantic.fisheries.noaa.gov/protected/whaletrp/trt/meetings/2012 meeting/Day%202/day_2_1c_new_hampshire_alwtrp_proposal.pdf
Massachussetts	Lobster	383,447	2011	http://www.lobstermen.com/wp-content/uploads/2009/10/MASS-LOBSTER-INDUSTRY-2012.pdf
Canada	**species**	**# license**	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Nova Scotia	lobster	3,249	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	748	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
New Brunswick	lobster	1,460	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	123	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Prince Edward Island	lobster	1,245	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	39	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Quebec	lobster	591	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	382	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Newfoundland	lobster	2,353	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
	crab	3,379	2016	http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/species-especes/se16-eng.htm?
Canada	**species**	trap limit range	trap multiplier used	**Source**
Nova Scotia- GOSL	lobster	225-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
Nova Scotia- GOSL	crab	75-150	150	neiges-en.html
Nova Scotia- east	crab	30-60		http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/snow-crab-neige/snow-crab-neiges2013-eng.htm
New Brunswick	lobster	240-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
	crab	75-150	150	neiges-en.html
Prince Edward Island	lobster	240-300	275	http://dfo-mpo.gc.ca/fm-gp/peches-fisheries/comm/atl-arc/lobster-notice-avis-homard-
	crab	75-150	150	neiges-en.html
Quebec	lobster	235	235	http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/lobster-homard/index-eng.htm
	crab		200	
Newfoundland	lobster	185	235	https://thisfish.info/fishery/atlantic-lobster-canada-lfa11/
		100-425		http://waves-vagues.dfo-mpo.gc.ca/Library/282426.pdf
	crab	200	200	http://dfo-mpo.gc.ca/decisions/fm-2018-gp/atl-07-eng.htm

APPENDIX 2 Model Inputs and Methods used for Population Projection

In order to determine current rate of population decline we used a simple, three-stage matrix population projection model (Caswell 2006) for female right whales, derived from Corkeron et al. (*Accepted with revision*), to project the future abundance of North Atlantic right whales. The model's three stages are: calf, juvenile and adult. Survival values used for input into the population projection model are derived from survival estimates calculated using a Cormack-Jolly-Seber (as opposed to the published Jolly-Seber, Pace et al 2017) variant of a mark-resight model (see Appendix 1 for details). We used the lower 95% credibility intervals of the median estimates of survival for 2011-2015 from the model. These were: calves: 0.86137, juveniles: 0.92684, and adult females: 0.92684. The matrix projections also assume: a calving interval of 4.75 years (the mean of median inter-calf intervals for calving females 2011-2017, from the 2017 North Atlantic Right Whale Report Card (Pettis et al. 2017), ; females maturing at 11; and a current maximum longevity of 50. With no calves born this year, this calving estimate is arguably optimistic, but the inter-calf interval estimate for 2018 would be undefined, and so is unusable. Survival and transition probabilities for stages were calculated as described in Corkeron et al. (*Accepted with revision*).The model was run in R 3.4.3 (R_Core_Team 2017), using the libraries *diagram* (Soetaert 2017), *popbio* (Stubben and Milligan 2007) and *popdemo* (Stott et al. 2016).

The matrix used for analyses is:

	calf	immat	adlt
calf	0.00000	0.00000	0.10526
immat	0.86137	0.86254	0.00000
adlt	0.00000	0.06430	0.92443

This gives an intrinsic rate of increase of 0.9767, or a decline of 2.33% per year.

To develop a stochastic projection from this model, we took a starting abundance estimate of 160 females alive at the end of 2017, as the unusually high observed mortality of right whales that year (Meyer-Gutbrod and Greene 2018) meant that starting earlier would not capture one important recent anthropogenic impact on this species. With approximately 1.5 males per female North Atlantic right whale now (Pace et al. 2017), 160 females would give an overall species abundance of ~400. It is possible that this abundance estimate may prove to be marginally low, but as the model overestimates calving success, we assume that these biases should cancel each other out. When an abundance estimate for 2017 is available (by October-November 2018) the model can be revised.

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The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

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Assessing a Long-Standing Conservation Program: Mariner's Perspectives on the North Atlantic Right Whale, *Eubalaena glacialis*, Mandatory Ship Reporting System

GREGORY K. SILBER and KRISTY WALLMO

Introduction

Policies and regulations established to protect the marine environment include measures to reduce perturbations of entire ecosystems (coral reefs: Bellwood et al., 2004), safeguard key habitats on large scales (Marine Protected Areas: Hoyt, 2011, IUCN-WCPA, 2008), and conserve marine species whose population sizes have declined to unsustainable levels (threatened or endangered species: NOAA, 2015). In the United States, the Endangered Species Act (ESA) provides legal protection for threatened and endangered marine (and terrestrial) species, while agencies including the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (FWS), and, less frequently, the U.S. Coast Guard (USCG), are charged with developing and implementing strategies and actions aimed at recovering these species, most often through reduction of ongoing anthropogenic threats.

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Establishing conservation actions may result in unintended economic or operational impacts, but subsequent assessments to determine whether they are meeting expected conservation objectives are few (Halpern, 2003; Selig and Bruno, 2010). Refining these actions through assessment and monitoring has the potential to improve both their conservation value and their cost-effectiveness (Bruner et al., 2004; Miteva et al., 2012).

In this paper we report findings from an online survey of the maritime industry designed to evaluate a Mandatory Ship Reporting (MSR) system—a long-standing program to raise awareness about and to reduce ship collisions with North Atlantic right whales, *Eubalaena glacialis*. Since 1999, provisions of the MSR have required ships weighing 300 gross tons (gt) or greater to report their location, speed, and destination to a shore-based station when entering key right whale nursery and feeding areas off the U.S. east coast.

In return, reporting ships receive a message, automatically generated, delivered directly to the ship's bridge, providing information about the risk of vessel collisions with right whales and actions mariners can take to avoid collisions (Silber et al., 2015). The MSR system is distinct from and predates other regulations in place to reduce ship collisions with right whales, such as ship speed reductions.

Our survey examined three aspects of the MSR system: 1) the degree to which mariners comply with the reporting requirements of the system, 2) the operational burden of compliance to captains and crew, and 3) their opin-

ABSTRACT—Measures established to protect living marine resources, including those for endangered marine species, are only infrequently evaluated. In this paper we report findings of an online survey designed to solicit the views of maritime industries about a long-standing endangered large whale conservation program: the Mandatory Ship Reporting (MSR) system. The MSR was established in 1999 to aid in reducing the threat of vessel collisions with the highly depleted North Atlantic right whale, Eubalaena glacialis. *Under MSR provisions, vessels ≥300 gross tons are required to report their location, speed, and destination when entering two key right whale aggregation areas. In return, reporting ships are sent an automated message about right whale vulnerability to ship collisions. The survey was intended to obtain views about the extent to which vessel operations were interrupted by the reporting requirement; how mariners utilize, if at all, information provided in the return message; whether vessel operations were modified in response to guidance provided; and the overall importance and effectiveness of the reporting systems in helping ships avoid right whale interactions.*

A total of 119 mariners with broad representation of vessel types and decades of experience at sea took part in the survey; 56 of these indicated they had entered one of the MSR areas at least once. Most (ca. 70%) indicated that they comply with the reporting requirement, distribute information on right whales and ship strikes to crew members, that they were more alert about avoiding/watching for right whales, and that the ships operation may change to avoid an interaction. Of the survey-takers who had entered the system, about half indicated the MSR system is useful for educating captains and crew about right whales and important for right whale conservation, but only about a quarter indicated that it is useful in helping ships avoid right whales. About 40% said it is an unnecessary requirement for ships. We conclude that as an outreach tool and a means to provide information directly to domestic and international mariners entering right whale habitat for over 15 years (thus, tens of thousands of ships entering these waters have received the message), the MSR almost certainly has been beneficial in educating mariners about the issue of ship strike and in providing guidance on avoiding ship strikes. Views reflected in the survey suggest that, at least from the mariners' perspective, the MSR program has provided positive conservation value; however, not all mariners took specific strike avoidance action after having received the message.

ions about the utility of the system for reducing collisions and raising awareness about right whale conservation. Though several studies have focused on maritime industry compliance with large whale conservation regulations such as ship speed reduction in seasonally and dynamically managed areas (Lagueux et al., 2011; Asaro, 2012; Silber et al., 2014), few have examined the effectiveness of these regulations in reducing ship-whale collisions (Silber and Betteridge, 2012; Laist et al., 2014; van der Hoop et al., 2014). Further, none of these studies utilized data or observations from mariners themselves.

To date, only Reimer et al. (2016) have collected data directly from mariners in a survey about receptivity to real-time conservation technology. That study found that most mariners surveyed would be interested in receiving information on endangered whales and whale alerts via ships Navigational Telex (NAVTEX) and Automatic Identification Systems (AIS), and that most believed that receiving this information would not be disruptive to their operations (Reimer et al., 2016).

To our knowledge no study has examined mariners' perceptions of existing whale conservation measures and their utility in reducing the likelihood of ship-whale collisions. Our study directly addresses this gap regarding one such conservation measure by directly canvassing mariner viewpoints on use and compliance with reporting into the MSR, its overall conservation value, and impact on ship operations. Our findings add to the limited literature on the burden and overall utility of actions aimed at conserving large whales.

Survey results suggest the conservation value of the MSR program is likely positive because mariners indicated it raised awareness about the whale-strike issue. However, because the intent of the program is to provide information only, and not all mariners altered operations after receiving guidance in the return message, the overall biological impact of program may be somewhat limited.

Background of Ship-Whale Collisions and the MSR System

Most large whale species were the focus of intensive commercial hunting and were severely depleted globally. Although a number of these populations began to rebound not long after an international moratorium on commercial whaling in 1985–1986[1], unintended ship-whale collisions and other threats to population recovery remain. In the case of the North Atlantic right whale, population growth has been slow and deaths caused by violent strikes from large ships and fatal entanglement in commercial fishing gear are among the main impediments to recovery of this species (Clapham et al., 1999; Kraus et al., 2005; NMFS[2]).

North Atlantic right whales occur near and migrate along the eastern seaboard of Canada and the United States, where large human population centers and co-occuring water-borne commerce, commercial fishing, and other activities are also concentrated. Right whale feeding/socializing aggregation areas occur in waters off New England and eastern Canada and in nursery areas off the South Carolina to Florida coasts. The right whale is vulnerable to collisions with vessels throughout its range, but the threat may be particularly high in these aggregation areas where substantial vessel traffic also occurs (NMFS[2]).

Recognizing the influence of human activities on the recovery of right whales, the international community began taking steps to reduce the impact of these threats in the 1990's. Not all ship operators, and maritime commerce industries as a whole, were familiar with the risk that vessels underway posed to right whales and other large whale species. Thus, the conservation community began addressing this concern by focusing primarily on raising mariner awareness about the issue.

Among these actions was the creation of two Mandatory Ship Reporting systems (MSR) as a means to reduce the occurrence of "ship strikes" with right whales (Silber et al., 2015; USG[3]). A proposal initiated by the United States, backed by other nations and publicly endorsed by President William J. Clinton in April 1998 (Clinton, 1998), to establish the MSR was submitted to the International Maritime Organization (IMO) in June 1998. It was approved by the IMO in December 1998. This was the first formal IMO action to reduce the threat of ship collisions with whales (Luster, 1999), and its first formal action on behalf of any endangered marine species (Johnson, 2004).

Operation of the MSR

The goal of the MSR is to provide timely information about ship-whale collisions directly to individual vessels as they enter key right whale feeding and nursery habitats. Under the system, ships are required to report their location and time of entry into the system; in return, each reporting ship receives an automated message providing information on ways to reduce the chances of a striking a whale.

Under the rule, self-propelled commercial ships $\geq$300 gt are required to report to shore-based stations when they enter either of two regions off the eastern U.S. coast where and when right whales are known to occur: one off the state of Massachusetts operates year-round; the other, off the states of Georgia and Florida, is operational annually from 15 Nov. through 15 Apr. (Silber et al., 2012a) (hereafter, referred to as WHALESNORTH and WHALESSOUTH, respectively) (Fig. 1).

Incoming messages are sent primarily via satellite and include ship

[1]International Whaling Commission. Catch limits and catches taken (https://iwc.int/catches).

[2]NMFS. 2005. Recovery plan for the North Atlantic Right Whale (*Eubalaena glacialis*). U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Off. Protect. Resourc., (http://www.nmfs.noaa.gov/pr/pdfs/recovery/whale_right).

[3]U.S. Government. 1998. Ship reporting systems for the eastern coast of the United States. Proposal submitted to the IMO's Sub-Committee on Safety of Navigation. Online at http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/imo_proposal.pdf.

name, course, speed, and destination among other things. Only reporting is required; no other changes to vessel operations are required. An automatically-generated message is returned to the reporting vessel that includes information on locations of recently-sighted right whales; procedural guidance to help prevent vessel-whale collisions; and information regarding protecting right whales from vessel strike (Fig. 2). Only vessels entering the prescribed areas are required to send a report, therefore only these vessels receive the automatic return message.

Following IMO endorsement, the USCG issued a Final Rule in the U.S. Federal Register (USCG, 2001) that codified the systems by amending the U.S. Code of Federal Regulations (33 CFR 169). The National Oceanic and Atmospheric Administration (NOAA) then added the MSR areas to relevant nautical charts and incorporated the new requirements into various navigational aids such as the U.S. Coast Pilot and elsewhere.[4]

The two MSR systems became effective on 1 July 1999 and have been in operation continuously since that time. From July 1999 to present, operation and administration of this program have been jointly run by the USCG and NOAA's NMFS. All ship-to-shore and shore-to-ship communication costs are borne by these two agencies (including a government contract to the communications provider).

Reporting data from these systems have been useful in characterizing vessel operations within the areas (Ward-Geiger et al., 2005), particularly as it relates to the recovery of right whales. Among other things, incoming MSR reports provided information on U.S. east coast port arrivals and vessel operations which helped form the basis for subsequent ship strike-reduction measures.

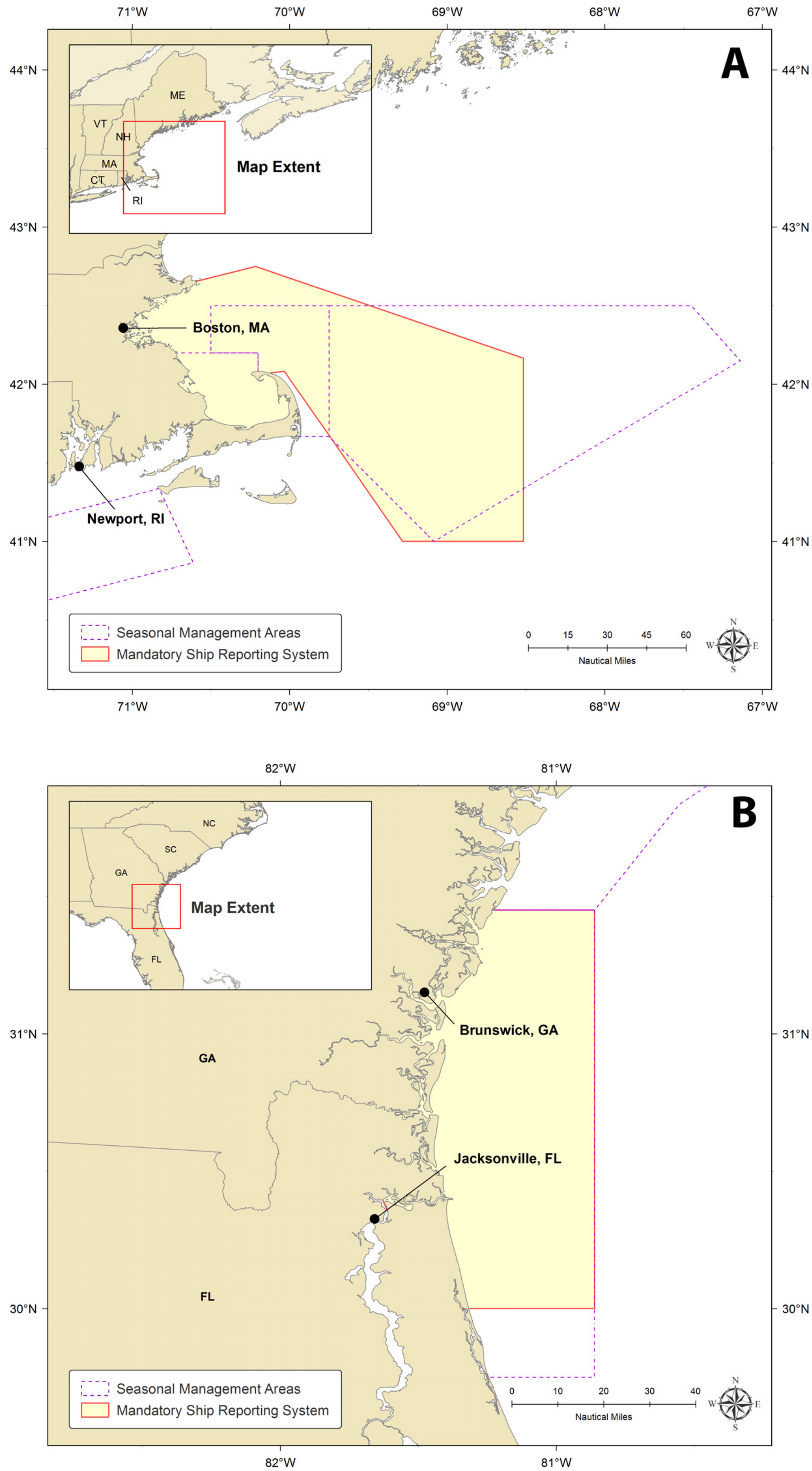

Figure 1.—Mandatory Ship Reporting System Area Boundaries. Also shown are vessel speed restriction seasonal management area boundaries (NOAA, 2008).

[4]See, for example USCG, Local Notice to Mariners. Coastal Waters from Eastport, Maine to Shrewsbury, New Jersey. Special Notices, No. 27/99. Online at http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/uscg_lnm0799.pdf.

THE CRITICALLY ENDANGERED RIGHT WHALE MAY BE ENCOUNTERED IN OFFSHORE AND COASTAL WATERS. RIGHT WHALES ARE SLOW MOVING AND AT RISK OF SERIOUS INJURY OR DEATH DUE TO COLLISIONS WITH VSLS. VSL OPERATORS ARE REMINDED TO USE CAUTION AND PROCEED AT SAFE SPEEDS IN AREAS USED BY RIGHT WHALES. INTENTIONALLY APPROACHING WITHIN 500 YARDS OF RIGHT WHALES IS PROHIBITED AND IS A VIOLATION OF U.S. LAW. A MINIMUM DISTANCE OF 500 YARDS MUST BE MAINTAINED FROM A SIGHTED WHALE UNLESS HAZARDOUS TO THE VSL OR ITS OCCUPANTS. THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) RECOMMENDS THAT OPERATORS ASSUME THAT ANY WHALE SIGHTED IS A RIGHT WHALE.

NOAA REQUIRES MOST VSLS 65 FT OR GREATER TO TRAVEL AT SPEEDS OF 10 KNOTS OR LESS IN SEASONAL MANAGEMENT AREAS USED BY RIGHT WHALES WHEN CONSISTENT WITH SAFETY OF NAVIGATION.

PLEASE REPORT ALL RIGHT WHALE SIGHTINGS AND COLLISIONS TO 978-585-8473 OR 978-585-8473 RESPECTIVELY OR TO THE COAST GUARD VIA CHANNEL 16. FOR MORE INFO, CONSULT THE U.S. COAST PILOT.

Figure 2.— USCG Mandatory Ship Reporting System WHALESNORTH automated return message.

A recent 15-plus-year retrospective analysis of incoming reports (Silber et al., 2015) determined that hundreds of individual ships made over 45,000 reports into the system between July 1999 and December 2013. While generally regarded as a successful and valued outreach tool, the current study is the first attempt to gauge the attitudes and perceptions of mariners regarding conservation benefits as well as the potential impacts to reporting vessels, and to evaluate the ongoing utility and relative value of this longstanding program.

Materials and Methods

An online survey was developed by NMFS economists and biologists during June–August 2014 to collect data on mariner awareness, attitudes, and use of the MSR system. Because the sampling strategy was opportunistic with an unknown universe, an important consideration in the survey design was to minimize the overall survey length and develop clear and concise questions. To help ensure that these considerations were met and that the overall survey was easy to comprehend, a draft instrument was tested in a focus group on 17 Sept. 2014 in Baltimore, Md., at the Maritime Institute of Technology and Graduate Studies/Pacific Maritime Institute (MITAGS-PMI).

Focus group participants were recruited from a pool of mariners who were attending a course at MITAGS-PMI and agreed to participate in a voluntary discussion about the MSR system and the survey. Based on feedback from the focus group, a final survey instrument was developed that contained eight questions and an opportunity to provide open-ended comments at the end of the survey.

The survey (Appendix I), which was implemented online in early June 2015, was programmed by a private consulting firm, ECS Federal[5], and hosted on a domain purchased specifically for the survey implementation. The target survey population was ship owners, operators, or captains who had entered either WHALESNORTH or WHALESSOUTH one or more times.

During an average year, several thousand separate trips are made into both areas (Silber et al., 2015) (some ships and masters may enter multiple times per year). The information needed to directly contact individual ship captains, owners, and/or crews to conduct a survey is not available, making a sampling frame infeasible to develop. For this reason, an opportunistic or convenience sample was necessary.

We acknowledge that this type of sampling has a number of limitations, including the inability to a) examine response bias, b) compute statistical errors, and c) make inferences to a larger population. However in our case, due to the lack of individual contact information, an opportunistic sample involving broad outreach to the generalized community was the only

[5]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

viable approach for contacting vessel operators. Ferber (1977) noted that while opportunistic samples are less desirable than samples derived from a systematic approach, they have utility for exploratory purposes or to obtain different views on the dimensions of an issue or problem.

To implement the survey, federal and private entities who engage in activities or communicate regularly with maritime entities were asked to distribute information about the survey (Appendix II). Announcements of the availability of the survey were also sent via association and government email distribution lists shortly after the survey opened.

The announcements of the survey provided potential respondents with a brief description of the survey, why their participation was important, and a link to the online survey. Two additional announcements about the survey were distributed in August and September 2015.

Respondents who chose to participate in the survey were asked eight questions. The first set of questions asked about familiarity with the MSR system and their ship transits through the MSR areas. The second set of questions asked about compliance with, burden of, and conservation potential of the MSR system. The remaining questions asked for the number of years in the industry and type of ship the respondent currently worked on (container ship, passenger vessel, etc.). The survey remained open through 10 Jan. 2016, at which time the URL for the survey was deactivated. The analysis included simple frequency counts of responses to each question.

Results

Respondent Characteristics

A total of 119 mariners took part in the survey. Of this number 85 respondents said they were aware of the MSR system (34 people who accessed the survey but entered no response whatsoever or indicated they had no experience or were not familiar with the MSR, were excluded from the analysis) and 56 indicated they had entered one of the MSR areas at least once.

Due to the publicity of the MSR and its support from the IMO, it is possible that mariners who have never entered one of the MSR areas were still familiar with the system and the reporting requirements, and therefore we considered a total of 85 survey-takers eligible to answer a subset of the survey questions. Questions that required direct experience and use of the MSR were only shown to respondents who stated they had entered an MSR area at least once.

Among the 85 respondents who were aware of the MSR, representation of vessel types was broad, and included container ships, tankers, cargo or bulk carriers, RO-RO's (i.e., car and vehicle carriers), cruise ships, passenger vessels (i.e. ferries, whale watching vessels), research ships, and pleasure craft. According to Rodrigue et al. (2017) the global maritime industry has about 100,000 vessels (>100 t) consisting of passenger, bulk carrier, general cargo, and roll-on/roll-off vessels; about 69% of shipping ton-miles is accounted for by bulk carriers. Our sample consists of captains and crew from all four types of vessels, and about 53% of respondents cited they worked on bulk carriers.

The years of service in the maritime industry ranged from 2 to 48 years, with 23% working less than 20 years and 77% working more than 20 years. The average number of years respondents have worked in the maritime industry was 26, with an average of 11 years as a crew member and 11 years as a captain.

Of the 56 respondents indicating they had entered one of the MSR areas at least once, about 44% said they entered one of the areas regularly. The number of times respondents said they entered one of the areas during a year ranged from 1 to 100, with a mean of 27.8. About 35% (n=20) indicated they enter WHALESNORTH most frequently, 29% (n=16) entered the WHALESSOUTH most often, and 35% (n=20) indicated they enter both areas about the same amount.

As noted, our data is based on an opportunistic sample of ship captains and crew. While the vessel types in our data are representative of the types of vessels in the maritime industry as described by Rodrigue et al. (2017), we cannot determine whether respondent's opinions and attitudes toward the MSR system are representative of those of the larger industry, and specifically those ships that transit the MSR areas.

Compliance with the MSR System

Most respondents comply with the reporting requirement of the MSR system. About 75% of respondents (n=42) stated that they send the required report always or most of the time; and slightly less than a fourth of them (24%) said they rarely or never send the report. About 82% (n=46) of respondents stated that they receive a return message about right whales after sending in their ships' report, while the remainder (n=10) indicated they did not receive a return message via the system.

Survey-takers were asked about their level of agreement with four statements related to the transmittal of required ship information when entering an MSR area: 1) it is relatively easy to send in the required report, 2) I generally follow the report format exactly as specified in the instructions, 3) I send in the report as soon as possible, and 4) sending in the required report takes time away from other duties I have on the ship. Of those responding to this portion of the survey, half (n=20) indicated it was easy to send in the report, with over 70% stating that they followed the required format and they sent in the report as soon as possible after entering the area. About half said that sending in the report takes time away from other duties on the ship (Fig. 3).

Attitudes Toward the MSR System

Following these statements respondents were asked about their level of agreement with four statements related to the automated right whale conser-

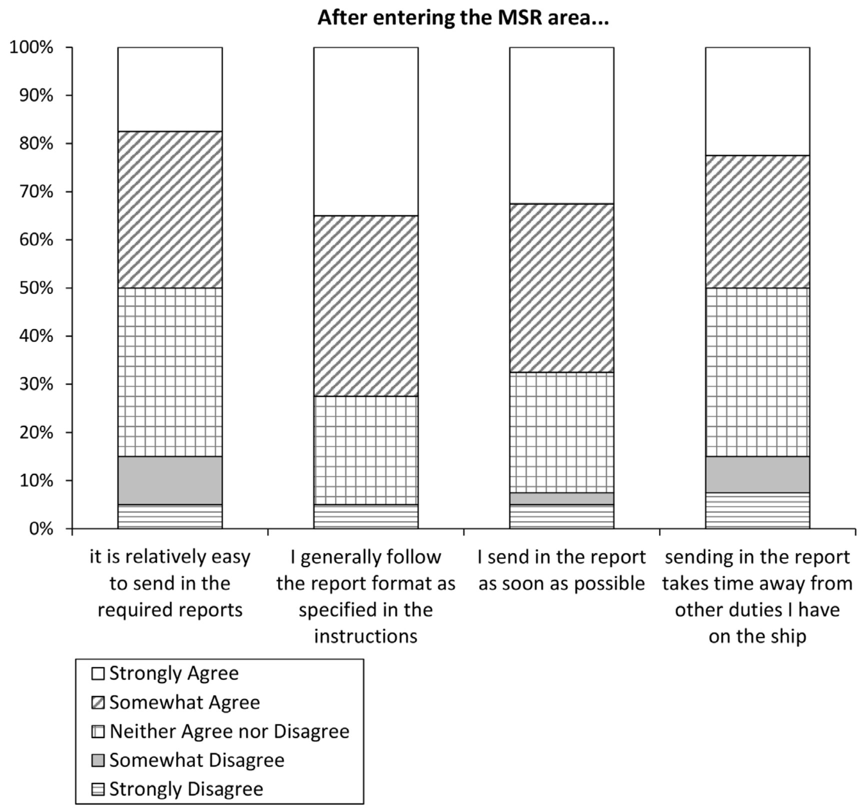

Figure 3.—Attitudes toward Mandatory Ship Reporting system ship requirements.

vation information they receive after reporting into the system: 1) I generally don't have time to read the entire message, 2) I am more alert about avoiding or watching for right whales, 3) I find the information to be useful for the captain and crew, and 4) some aspect of the ship's operation may change (e.g., speed, post extra lookouts) to avoid an interaction. Among those responding to all the questions in this section of the survey (*n*=25), 60% don't read the entire message, but over half said they are more alert about avoiding/watching for right whales and may change the ships operation to avoid an interaction. Nearly 80% of respondents stated they distributed the information in the message to captains and/or crew (Fig. 4).

All respondents who stated that they were aware of the system (*n*=85), even if they had not entered an MSR area, were asked about their level of agreement with four statements concerning general perception of the MSR system: 1) the MSR system is important for right whale conservation, 2) is an unnecessary requirement for ships, 3) has been useful in helping ships avoid right whale interactions, and 4) is a useful system for educating captains and crews about right whales. Of those responding to this set of questions (*n*=64), over half (*n*=34) indicated the MSR system is useful for educating captains and crew about right whales and important for right whale conservation, only about a quarter said it is useful for helping ships avoid right whale interactions, and about 40% said it is an unnecessary requirement for ships (Fig. 5).

In regard to the written comments portion of the survey, several respondents provided additional views about the importance of the MSR in the context of endangered whale conservation; others said it had little utility in reducing strikes of whales. A few of those providing comments reiterated that reporting into the systems was not a significant or time-consuming task, some suggested using alternative vessel tracking systems in lieu of the MSR. Apparently, a number of respondents believed the survey to include discussion of vessel speed restrictions in addition to the MSR, while others took the opportunity to comment on right whale vulnerability (or their lack of vulnerability) to ship collisions, the utility of right whale protective measures generally, or to offer suggestions on ways to diminish the impact of right whale conservation on maritime industries.

Discussion

The invitation to participate in the survey was distributed on a broad scale, and we believe that hundreds of mariners were at least aware of the survey. However, the exact number of individuals who received notification of the survey remains unknown; therefore, a response rate is also not known. We expected the number of respondents to be a small fraction of the total number reached for several reasons.

First, previous studies (Ranmuthugala et al., 2008) have shown that opportunistic sampling generates relatively low responses relative to the number of individuals targeted through broadly cast notification efforts, and there was likely considerable overlap in the entities described in Appendix II.

Second, not all mariners are familiar with the MSR program, because a) it applies only to ships sailing in waters along parts of the U.S. eastern seaboard; b) of these, not all ships enter certain U.S. east coast ports (e.g., Boston, Mass., Jacksonville, Fla.) where MSR areas are situated; and c) not all ships meet the 300 gt threshold for reporting. And, finally, there is little reason to expect ship captains sailing under a non-U.S. flag to complete a voluntary survey focused on a U.S. policy implemented by U.S. Federal agencies.

The nature of an opportunistic sam-

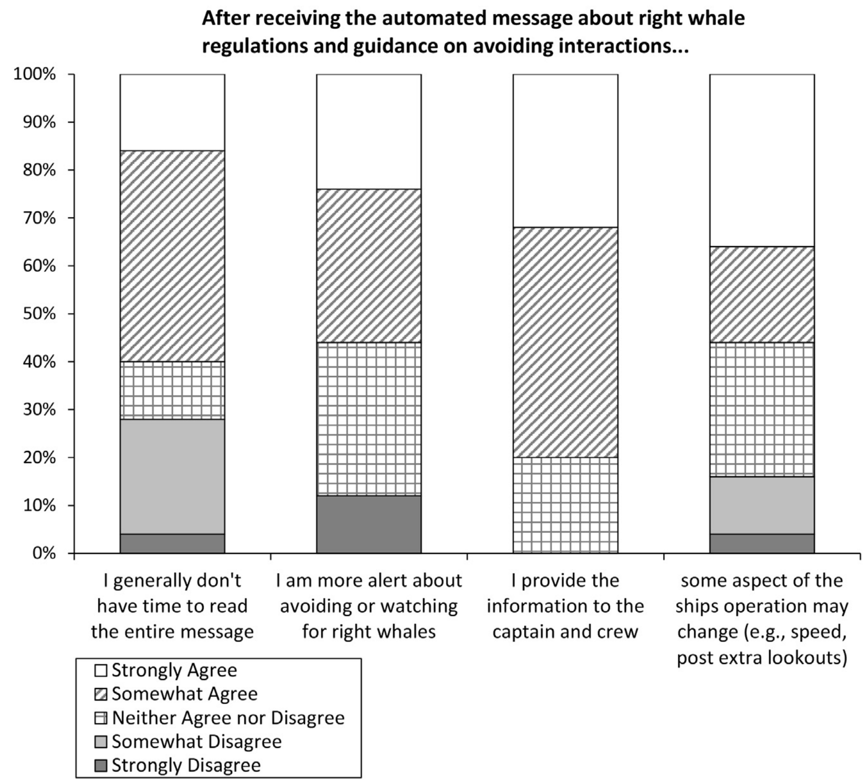

Figure 4.—Attitudes toward Mandatory Ship Reporting system automated return message containing right whale information.

ple implies that the findings are not generalizable to a larger population nor can the extent of response bias be formally identified (Pruchno et al., 2008). Previous studies comparing opportunistic samples to random samples are rare (Pruchno et al., 2008). Two studies that have compared variables of interest between these two sampling approaches suggest that sample means on variables of interest were significantly different between opportunistic and random samples (Pruchno et al., 2008; Ranmuthugala et al., 2008); thus we suggest that the results best represent only those individuals in our survey sample population.

Comments provided via the survey were varied: some indicated an awareness regarding the vulnerability of right and other whales to ship strikes, the severity of the problem, and the need to reduce this threat; others indicated that reporting, and other measures, were not needed. However, we note that responses about the efficacy of the MSR may have come from mariners who had not actually entered the systems.

A number of respondents confused the MSR with a more recent action to reduce ship collisions with right whales: seasonal vessel speed restrictions (NOAA, 2008). This is consistent with findings regarding the number of reports made incorrectly outside the boundaries of the MSR systems; namely, reporting into MSR systems was common along vessel-speed restriction seasonal management area boundaries which are unrelated to the MSR (Silber et al., 2015).

Speed restrictions likely have greater economic and operational impact to commercial maritime industries—as well as having a more quantitative, documented influence on reducing vessel strikes of right whales (Conn and Silber, 2013; Laist et al., 2014; van der Hoop et al., 2014; Martin et al., 2016)—than does the MSR because the latter involves reporting only. Therefore, some mariners may have used the survey as an opportunity to express their views about the speed restrictions.

Our results are mixed on the ease of use of the MSR system by mariners. Of respondents with direct experience with the system, about 70% followed the reporting requirements and sent the report as soon as possible after entering an MSR area, and only 15% indicated the reporting requirements were difficult to follow. However, about half of respondents felt that sending the report took time away from other duties and nearly 60% said that they did not have time to read the entire return message. In addition, about 40% of all respondents felt the MSR system is an unnecessary requirement for ships.

As a conservation measure, our results suggest that the most important function of the MSR is one of education and raising awareness, as most respondents with direct experience with the program indicated that information in the return message was distributed to their crews and that crew members were generally more aware of right whales after receiving the information. Further, about half of all respondents (including those without direct MSR experience) stated the system was good for whale conservation and considered the system a good way to raise awareness about ship-whale collisions.

Being a metric difficult or impossible to reasonably quantify, mariners, of course, cannot know the overall impact of the MSR in reducing collisions with whales. However, the goal was to attempt to ascertain whether mariners disregarded the incoming message, for example, or whether their possible actions in response to some aspect of the message may have lowered the possibility of striking a whale.

Respondents were roughly equally divided in their views on whether the system was useful in avoiding whales. Thus, there is little doubt that the MSR has served to raise mariner awareness about the depleted status of right whales and the species' vulnerability to ship collisions because hundreds of ships have made tens of thousands of reports to (and received return messages from) the MSR in the period since its implementation (Silber et al., 2015).

Inasmuch as return messages arrive in the bridge of reporting vessels as they enter right whale habitat, this feature alone has served as a frequent reminder to those operating ships in U.S. waters about an important conservation matter—and in this regard the outgoing message has been a flexible informational tool for alerting mariners about additional large whale conservation measures as they have been developed.

More broadly, an important aspect of the MSR, a feature with international implications, is that its establishment, as one of the first formal measures to address the threat of ship-whale collisions (Johnson, 2004), helped facilitate the development of additional whale conservation measures. For example, since the implementation of the MSR, the United States and several other nations have established related IMO-adopted routing measures in their waters (Silber et al., 2012a).

In addition, outgoing MSR messages have been adapted to provide alerts about other threat-reduction measures (e.g., dynamically implemented and seasonal vessel speed restrictions) and have been used to provide written information on right whale sightings. However, in regard to information dissemination, broad-based distribution programs have also been developed by a number of entities. For example, a number of ports and government agencies now rely on a number of systems (e.g., the frequently updated USCG Broadcast Notice to Mariners) to transmit information to ships, including information about right whale sightings.

The International Whaling Commission provides brochures for mariners regarding large whale ship strikes[6]; numerous non-governmental organizations maintain web sites and actively distribute information on this matter; and NMFS has developed and routinely provides interactive CD's, laminated cards, and booklets[7] regarding the threat of ship strikes of right whales.

Most of this material, however, is "passive" and has neither the immediacy of notifying ships directly through the MSR nor provides near real-time information about sighted whales. And, while various outlets provide near real-time whale sighting information through interagency cooperative efforts (NOAA, 2006), it is not clear if, and to what extent, mariners consult and use this information.

[6]Whales: collisions prevents damage to ships, and injuries to passengers, crew and whales. (https://iwc.int/index.php?cID=3199&cType=document).

[7]Interactive items online at www.greateratlantic.fisheries.noaa.gov/protected/shipstrike/training/index.html.

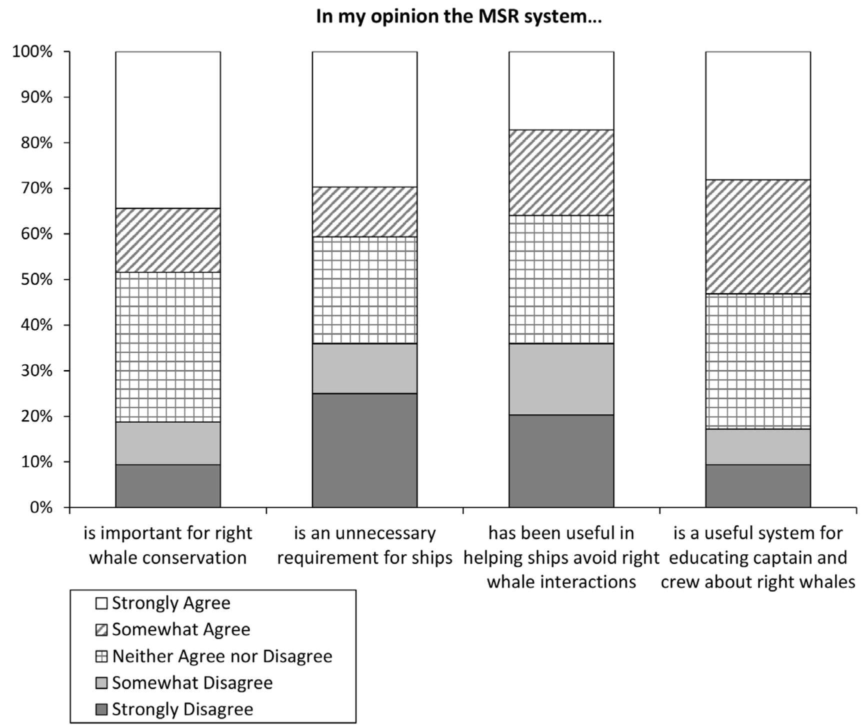

Figure 5.—General attitudes toward the Mandatory Ship Reporting system.

Our results from respondents with direct experience with the MSR indicate that the system may have some utility for directly reducing the number of whale-ship collisions, as over half stated that they are more alert after receiving the incoming MSR message and about half said some aspect of the ships operation may change as a result of the message. About 35% of all respondents stated that the MSR is useful for helping ships avoid right whale interactions. Nonetheless, information on the number of known right whale deaths from ship collisions is noted below and in van der Hoop et al. (2014), and no discernable differences are apparent in fatal strike rates in the time after sighting information was routinely provided beginning in the mid-1990's via aircraft survey programs and through the MSR beginning in 1999. Therefore, the extent to which whale sighting information provided via the MSR, or any other means, plays a role in reducing the number of ship struck whales is not clear.

One of the stated secondary purposes of the MSR was to enable the gathering of data to facilitate a better understanding of vessel operations in right whale habitat as a means to further develop conservation measures (Merrick and Cole, 2007; Silber et al., 2012a). When the MSR was established, routinely collected and archived information on vessel operations on this scale did not exist.

However, since inception of the MSR, advancing technologies are used to monitor vessel activities. In regard to monitoring U.S. port entries, systems to track vessel operations and emerging reporting requirements are far more comprehensive and precise than self-reporting under MSR protocols. Among the most important of these is the advent and use of GPS-linked VHF radio signal and satellite-transmitted Automatic Identification Systems (AIS) which are required on most ships and broadcast signals that provide detailed information on ship location, speed, and routes (Vanderlaan and Taggart, 2009; Reimer et al., 2016; Robards et al., 2016). In addition, a number of U.S. ports have Vessel Tracking Systems to aid in navigation, and some fishing vessels are required to carry Vessel Monitoring Systems.

Following the attacks of 11 September 2001, all vessels have been required to provide 96-h notice prior to calling on a U.S. port. Some of these technologies, AIS in particular, have been used to assess changes in ship operations in response to the implementation of various whale protection measures, including routing scheme changes (Vanderlaan and Tagart, 2009; Lagueux et al., 2011), vessel speed restrictions (Lagueux et al., 2011; Wiley et al., 2011; Silber et al., 2014), and dynamically managed areas (Silber et al., 2012b). Development and use of these technologies and communication systems have rendered the MSR a less than optimal means to gather and relay information to and from ships and have therefore largely supplemented the tracking of ship operations functions of the MSR.

From 1999 (when the MSR was established) to June 2016, 11 confirmed right whale deaths resulted from collisions with ships (Laist et al., 2014; Henry[8]), an average of 0.7 per year. This rate of known deaths attributed to ship strikes is roughly comparable to the 10 years prior to implementation of the MSR (1990–99; 0.6 per year); but the average decreased to 0.3 fatal strikes per year in the years 2007 through 2015 (Laist et al., 2014; Henry et al.[5]).

A number of factors could be involved in affecting these rates. We contend that variables such as whale distribution and shifts in distribution, particularly relative to large-scale shipping lanes, and overall shipping traffic volume, play roles in the occurrence and frequency of whale strikes. In the last decade, for example, the number of large vessel trips into U.S. east coast ports has fluctuated in response to shifting economic climates and increasing ship size and cargo capacities (the latter being a feature that reduces the number of trips overall) (DOT, 2013; MARAD, 2013; Silber et al., 2015).

In the context of these pervasive circumstances influencing the economics of transporting goods on worldwide scales, education and outreach efforts, while still important, may have little overall effect on rates of fatal ship strikes. Regardless, while the rather crude metric of annual deaths lacks sufficient resolution to fully evaluate the effects of the MSR, we note only that there were no immediate or overt changes in right whale ship strike-related death rates at the onset or in the time the MSR was in place.

Protection of living marine resources can be challenging in light of resource utilization by multiple industrial or commercial users. Conservation measures are generally established by incorporating the best available science and with maximum (practical) protections in mind. But such programs are not always evaluated (Clark et al., 2002; Ferraro and Pattanayak, 2006) or assessed to identify ways to optimize use of limited resources (Kapos et al., 2008) or fully utilize the provisions of available statutes.

The U.S. Government has faithfully operated the MSR for years and there is little doubt the program has conservation benefits by raising awareness of the maritime industry. Further, the MSR is one element in a suite of ship strike reduction measures that include IMO-adopted Areas To Be Avoided (Vanderlaan and Taggart, 2009), modifications of shipping routes (USCG, 2007), and voluntary and mandatory vessel speed restrictions (NOAA, 2008). However, our survey results suggest that, at least from the perspective of mariners who completed our survey, benefits of the MSR in reducing the likelihood of ships colliding with right whales are divided, but had a role in promoting education and outreach opportunities.

[8]Henry, A. G., T. V. N. Cole, L. Hall, W. Ledwell, D. Morin, and A. Reid. 2014. Mortality determinations for baleen whale stocks along the Gulf of Mexico, United States east coast, and Atlantic Canadian provinces, 2008–12. U.S. Dep. Commer., Northeast Fish. Sci. Cent., Ref. Doc. 14-10, 17 p. (https://www.nefsc.noaa.gov/nefsc/publications/crd/crd1410).

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Appendix 1.—Mandatory Ship Reporting systems survey instrument.

Right Whale Mandatory Ship Reporting System: What do you think?

The National Marine Fisheries Service, the federal agency responsible for the stewardship of living marine resources and their habitats, is sponsoring a survey to obtain mariner's feedback on the **North Atlantic right whale Mandatory Ship Reporting (MSR) system. (To find out more about the MSR system go here)**

This survey is only about the reporting system. It is **not** about the ship speed restrictions or any other right whale conservation program.

This is a voluntary survey. Your feedback will be used to evaluate and improve the MSR system. All survey responses are anonymous and confidential.

OMB Control No. 0648-xxxx. Expiration Date: xx/xx/xxxx. Public reporting burden for this information collection is estimated to average 10 minutes per response. Send comments regarding this burden estimate or other suggestions for reducing this burden to Kristy Wallmo, 301-427-8190 or Kristy.Wallmo@noaa.gov.

Responses are kept confidential as required by section 402(b) of the Magnuson-Stevens Act and NOAA Administrative Order 216-100, Confidentiality of Fisheries Statistics, and will not be released for public use except in aggregate statistical form without identification as to its source. Notwithstanding any other provisions of the law, no person is required to respond to, nor shall any person be subjected to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.

1. Are you aware of the North Atlantic right whale MSR (MSR) system?
   - ❐ Yes
   - ❐ No. *If 'No' survey will skip to Q7.*

2. During the year, about how many times do you enter one of the MSR areas?
   - ❐ I enter one of the MSR areas on a regular basis

     If box above is checked, survey will prompt: Approximately _____ times per year
   - ❐ I have entered at least one of the MSR areas but not on a regular basis. Approximately _____ times.
   - ❐ I have not entered either of the MSR areas. *If checked, survey will skip to Q6c.*

3. Which MSR area do you enter most frequently?
   - ❐ North MSR area
   - ❐ South MSR area
   - ❐ About the same amount for both areas

4. When you enter a MSR area, how often do you send a report as part of the MSR system?
   - ❐ Always
   - ❐ Most of the time
   - ❐ Some of the time
   - ❐ Rarely
   - ❐ Never

5. After sending in a report to the MSR system, have you received a message about right whale regulations and guidance on how to avoid interactions with right whales?
   - ❐ Yes
   - ❐ No

6. Please check the box that best represents your level of agreement with each statement.

	Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree
6a. After entering one of the MSR areas...					
...it is relatively easy to send in the required report	❐	❐	❐	❐	❐
...I generally follow the report format exactly as specified in the instructions	❐	❐	❐	❐	❐
...I send in the report as soon as possible	❐	❐	❐	❐	❐
...sending in the required report takes time away from other duties I have on the ship	❐	❐	❐	❐	❐
6b. After receiving the automated message about right whale regulations and guidance on avoiding interactions with right whales...					
...I generally don't have time to read the entire message	❐	❐	❐	❐	❐
...I am more alert about avoiding or watching for right whales	❐	❐	❐	❐	❐
...I provide the information to the captain and crew	❐	❐	❐	❐	❐
...some aspect of the ship's operation may change (e.g. speed, post extra lookouts) to avoid an interaction as a result of having received the message	❐	❐	❐	❐	❐
6c. In my opinion the MSR system...					
... is important for right whale conservation	❐	❐	❐	❐	❐
...is an unnecessary requirement for ships	❐	❐	❐	❐	❐
...has been useful in helping ships avoid right whale interactions	❐	❐	❐	❐	❐
...is a useful system for educating captains and crew about right whales	❐	❐	❐	❐	❐

7. How many years have you worked in the maritime industry? _______________
   (a) How many years as a crew member? _____________________________
   (b) How many years as a captain? ___________________________________

8. What type of ship do you work on? ____________________________________

Thank you very much for your participation in this survey. Your feedback will help NOAA Fisheries improve the North Atlantic Right Whale MSR system. Please add any additional comments you have concerning the MSR system in this box.

Type comments here

Appendix 2.—Communications channels used to notify users of an online survey of Mandatory Ship Reporting systems.

Federal Agencies

NOAA's Ocean Service. Regional Navigation Managers work directly with pilots, mariners, port authorities, and recreational boaters to help identify and address marine transportation system navigational safety issues. Based on our request, U.S. east coast navigation managers used their regular public and industry meetings, port facility functions, and other conduits to notify mariners about the survey.

National Geospatial Agency (NGA). The NGA's *Notice To Mariners (*msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_st=&_pageLabel=msi_portal_page_61,) is the principal publication for ships engaged in international voyages. Designed to ensure the safety of life at sea, this publication provides marine safety information and corrections to navigational aids for all U.S. Government navigation charts and publications derived from a variety of sources, both foreign and domestic. A special notice about the survey was posted in the NGA's Hydrogram and Marine Information sections of the weekly notice on 10 June 2015 (msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/UNTM/201525/Marine_Info.pdf) and again on 3 September 2015.

Maritime Administration (MARAD). The Department of Transportation's MARAD is charged with ensuring that the nation maintains adequate shipbuilding and repair services, efficient ports, and reserve shipping capacity for use in time of national emergency (www.marad.dot.gov/). It promotes maintenance of a well-balanced U.S. merchant fleet for transport of waterborne commerce, and it is capable of service as a naval and military auxiliary in time of war. MARAD promoted the MSR survey with an announcement via its distributions list, containing perhaps several thousand active mariners. Announcement by email distribution sent on 27 July 2015.

NOAA, NMFS, Northeast Regional Office. Participating members of maritime contact distribution lists were encouraged via email to take the survey by shipping industry liaisons from both NOAA's NMFS Southeast and Northeast Regional Offices on 7 July 2015. The survey was also discussed by liaisons at numerous industry meetings.

U.S. Coast Guard (USCG). The USCG's outreach program posted a blog about the survey on 6 November 2015. On average, the blog receives approximately 40,000 unique (each coming from a different IP address) views per month.

Industry Associations

World Shipping Council (WSC). With 26 companies, which utilize hundreds of ships and employ hundreds of vessel operators, the WSC represents over 90% of global liner vessel capacity and transport cabilities. At our request, the WSC sent notifications to all of its member companies on two occasions (28 July and 30 August 2015).

Chamber of Shipping of America (CSA). The CSA represents 35 U.S.-based companies that own, operate, or have commercial interest in oceangoing tankers, containers, and dry bulk vessels engaged in domestic and international trades. These entities employ hundreds of vessel operators. The CSA sent notifications about the survey to each of its member companies on two occasions (15 July and 8 August 2015). The CSA also asked a number of other industry associations to notify their members; these included InterTanko, American Waterways Operators (AWO), Cruise Lines International Association (CLIA), International Chamber of Shipping (ICS), and Baltic and International Maritime Council (BIMCO).

Just for information: InterTanko has 204 members and 236 companies whose combined fleet comprises some 3,077 tankers; AWO is the national trade association for the U.S. tugboat, towboat, and barge industry; CLIA is the world's largest cruise industry trade association; ICS membership represents national shipowners' associations in Asia, Europe, and the Americas whose member shipping companies operate over 80% of the world's merchant tonnage; BIMCO is the largest of the international shipping associations representing shipowners and its membership controls around 65 percent of the world's tonnage.

Passenger Vessel Association. The PVA represents companies who are owners, operators, and leasers of shipboard operations of passenger vessels on the waterways of the United States and Canada including car and passenger ferries, tour and excursion vessels, charter boats, eco-tour boats, and day sailing vessels. These vessels move over 200 million passengers each year. The PVA sent notification of the MSR survey to all its members on 5 August 2015.

Maritime Periodicals

Mariner's Weather Log. A publication of the National Weather Service (NWS), this journal (http://www.vos.noaa.gov/mwl.shtml) allows the NWS to maintain contact and communicate with over 10,000 shipboard observers worldwide. It is used to distribute meteorological information, worldwide environmental impact concerns, climatology studies, and the like to the maritime community. A special announcement (including a small story and photograph) appeared in the August 2015 (Vol. 59, No. 2) issue (www.vos.noaa.gov/MWL/201508/msrsurvey.shtml)

Assessing a Long-Standing Conservation Program: Mariner's Perspectives on the North Atlantic Right Whale, *Eubalaena glacialis*, Mandatory Ship Reporting System

GREGORY K. SILBER and KRISTY WALLMO

ABSTRACT—Measures established to protect living marine resources, including those for endangered marine species, are only infrequently evaluated. In this paper we report findings of an online survey designed to solicit the views of maritime industries about a long-standing endangered large whale conservation program: the Mandatory Ship Reporting (MSR) system. The MSR was established in 1999 to aid in reducing the threat of vessel collisions with the highly depleted North Atlantic right whale, Eubalaena glacialis. *Under MSR provisions, vessels ≥300 gross tons are required to report their location, speed, and destination when entering two key right whale aggregation areas. In return, reporting ships are sent an automated message about right whale vulnerability to ship collisions. The survey was intended to obtain views about the extent to which vessel operations were interrupted by the reporting requirement; how mariners utilize, if at all, information provided in the return message; whether vessel operations were modified in response to guidance provided; and the overall importance and effectiveness of the reporting systems in helping ships avoid right whale interactions.*

A total of 119 mariners with broad representation of vessel types and decades of experience at sea took part in the survey; 56 of these indicated they had entered one of the MSR areas at least once. Most (ca. 70%) indicated that they comply with the reporting requirement, distribute information on right whales and ship strikes to crew members, that they were more alert about avoiding/watching for right whales, and that the ships operation may change to avoid an interaction. Of the survey-takers who had entered the system, about half indicated the MSR system is useful for educating captains and crew about right whales and important for right whale conservation, but only about a quarter indicated that it is useful in helping ships avoid right whales. About 40% said it is an unnecessary requirement for ships. We conclude that as an outreach tool and a means to provide information directly to domestic and international mariners entering right whale habitat for over 15 years (thus, tens of thousands of ships entering these waters have received the message), the MSR almost certainly has been beneficial in educating mariners about the issue of ship strike and in providing guidance on avoiding ship strikes. Views reflected in the survey suggest that, at least from the mariners' perspective, the MSR program has provided positive conservation value; however, not all mariners took specific strike avoidance action after having received the message.

Introduction

Policies and regulations established to protect the marine environment include measures to reduce perturbations of entire ecosystems (coral reefs: Bellwood et al., 2004), safeguard key habitats on large scales (Marine Protected Areas: Hoyt, 2011, IUCN-WCPA, 2008), and conserve marine species whose population sizes have declined to unsustainable levels (threatened or endangered species: NOAA, 2015). In the United States, the Endangered Species Act (ESA) provides legal protection for threatened and endangered marine (and terrestrial) species, while agencies including the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (FWS), and, less frequently, the U.S. Coast Guard (USCG), are charged with developing and implementing strategies and actions aimed at recovering these species, most often through reduction of ongoing anthropogenic threats.

Establishing conservation actions may result in unintended economic or operational impacts, but subsequent assessments to determine whether they are meeting expected conservation objectives are few (Halpern, 2003; Selig and Bruno, 2010). Refining these actions through assessment and monitoring has the potential to improve both their conservation value and their cost-effectiveness (Bruner et al., 2004; Miteva et al., 2012).

In this paper we report findings from an online survey of the maritime industry designed to evaluate a Mandatory Ship Reporting (MSR) system—a long-standing program to raise awareness about and to reduce ship collisions with North Atlantic right whales, *Eubalaena glacialis*. Since 1999, provisions of the MSR have required ships weighing 300 gross tons (gt) or greater to report their location, speed, and destination to a shore-based station when entering key right whale nursery and feeding areas off the U.S. east coast.

In return, reporting ships receive a message, automatically generated, delivered directly to the ship's bridge, providing information about the risk of vessel collisions with right whales and actions mariners can take to avoid collisions (Silber et al., 2015). The MSR system is distinct from and predates other regulations in place to reduce ship collisions with right whales, such as ship speed reductions.

Our survey examined three aspects of the MSR system: 1) the degree to which mariners comply with the reporting requirements of the system, 2) the operational burden of compliance to captains and crew, and 3) their opin-

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ions about the utility of the system for reducing collisions and raising awareness about right whale conservation. Though several studies have focused on maritime industry compliance with large whale conservation regulations such as ship speed reduction in seasonally and dynamically managed areas (Lagueux et al., 2011; Asaro, 2012; Silber et al., 2014), few have examined the effectiveness of these regulations in reducing ship-whale collisions (Silber and Betteridge, 2012; Laist et al., 2014; van der Hoop et al., 2014). Further, none of these studies utilized data or observations from mariners themselves.

To date, only Reimer et al. (2016) have collected data directly from mariners in a survey about receptivity to real-time conservation technology. That study found that most mariners surveyed would be interested in receiving information on endangered whales and whale alerts via ships Navigational Telex (NAVTEX) and Automatic Identification Systems (AIS), and that most believed that receiving this information would not be disruptive to their operations (Reimer et al., 2016).

To our knowledge no study has examined mariners' perceptions of existing whale conservation measures and their utility in reducing the likelihood of ship-whale collisions. Our study directly addresses this gap regarding one such conservation measure by directly canvassing mariner viewpoints on use and compliance with reporting into the MSR, its overall conservation value, and impact on ship operations. Our findings add to the limited literature on the burden and overall utility of actions aimed at conserving large whales.

Survey results suggest the conservation value of the MSR program is likely positive because mariners indicated it raised awareness about the whale-strike issue. However, because the intent of the program is to provide information only, and not all mariners altered operations after receiving guidance in the return message, the overall biological impact of program may be somewhat limited.

Background of Ship-Whale Collisions and the MSR System

Most large whale species were the focus of intensive commercial hunting and were severely depleted globally. Although a number of these populations began to rebound not long after an international moratorium on commercial whaling in 1985–1986[1], unintended ship-whale collisions and other threats to population recovery remain. In the case of the North Atlantic right whale, population growth has been slow and deaths caused by violent strikes from large ships and fatal entanglement in commercial fishing gear are among the main impediments to recovery of this species (Clapham et al., 1999; Kraus et al., 2005; NMFS[2]).

North Atlantic right whales occur near and migrate along the eastern seaboard of Canada and the United States, where large human population centers and co-occuring water-borne commerce, commercial fishing, and other activities are also concentrated. Right whale feeding/socializing aggregation areas occur in waters off New England and eastern Canada and in nursery areas off the South Carolina to Florida coasts. The right whale is vulnerable to collisions with vessels throughout its range, but the threat may be particularly high in these aggregation areas where substantial vessel traffic also occurs (NMFS[2]).

Recognizing the influence of human activities on the recovery of right whales, the international community began taking steps to reduce the impact of these threats in the 1990's. Not all ship operators, and maritime commerce industries as a whole, were familiar with the risk that vessels underway posed to right whales and other large whale species. Thus, the conservation community began addressing this concern by focusing primarily on raising mariner awareness about the issue.

Among these actions was the creation of two Mandatory Ship Reporting systems (MSR) as a means to reduce the occurrence of "ship strikes" with right whales (Silber et al., 2015; USG[3]). A proposal initiated by the United States, backed by other nations and publicly endorsed by President William J. Clinton in April 1998 (Clinton, 1998), to establish the MSR was submitted to the International Maritime Organization (IMO) in June 1998. It was approved by the IMO in December 1998. This was the first formal IMO action to reduce the threat of ship collisions with whales (Luster, 1999), and its first formal action on behalf of any endangered marine species (Johnson, 2004).

Operation of the MSR

The goal of the MSR is to provide timely information about ship-whale collisions directly to individual vessels as they enter key right whale feeding and nursery habitats. Under the system, ships are required to report their location and time of entry into the system; in return, each reporting ship receives an automated message providing information on ways to reduce the chances of a striking a whale.

Under the rule, self-propelled commercial ships $\geq$300 gt are required to report to shore-based stations when they enter either of two regions off the eastern U.S. coast where and when right whales are known to occur: one off the state of Massachusetts operates year-round; the other, off the states of Georgia and Florida, is operational annually from 15 Nov. through 15 Apr. (Silber et al., 2012a) (hereafter, referred to as WHALESNORTH and WHALESSOUTH, respectively) (Fig. 1).

Incoming messages are sent primarily via satellite and include ship

[1]International Whaling Commission. Catch limits and catches taken (https://iwc.int/catches).

[2]NMFS. 2005. Recovery plan for the North Atlantic Right Whale (*Eubalaena glacialis*). U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Off. Protect. Resourc., (http://www.nmfs.noaa.gov/pr/pdfs/recovery/whale_right).

[3]U.S. Government. 1998. Ship reporting systems for the eastern coast of the United States. Proposal submitted to the IMO's Sub-Committee on Safety of Navigation. Online at http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/imo_proposal.pdf.

name, course, speed, and destination among other things. Only reporting is required; no other changes to vessel operations are required. An automatically-generated message is returned to the reporting vessel that includes information on locations of recently-sighted right whales; procedural guidance to help prevent vessel-whale collisions; and information regarding protecting right whales from vessel strike (Fig. 2). Only vessels entering the prescribed areas are required to send a report, therefore only these vessels receive the automatic return message.

Following IMO endorsement, the USCG issued a Final Rule in the U.S. Federal Register (USCG, 2001) that codified the systems by amending the U.S. Code of Federal Regulations (33 CFR 169). The National Oceanic and Atmospheric Administration (NOAA) then added the MSR areas to relevant nautical charts and incorporated the new requirements into various navigational aids such as the U.S. Coast Pilot and elsewhere.[4]

The two MSR systems became effective on 1 July 1999 and have been in operation continuously since that time. From July 1999 to present, operation and administration of this program have been jointly run by the USCG and NOAA's NMFS. All ship-to-shore and shore-to-ship communication costs are borne by these two agencies (including a government contract to the communications provider).

Reporting data from these systems have been useful in characterizing vessel operations within the areas (Ward-Geiger et al., 2005), particularly as it relates to the recovery of right whales. Among other things, incoming MSR reports provided information on U.S. east coast port arrivals and vessel operations which helped form the basis for subsequent ship strike-reduction measures.

[4]See, for example USCG, Local Notice to Mariners. Coastal Waters from Eastport, Maine to Shrewsbury, New Jersey. Special Notices, No. 27/99. Online at http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/uscg_lnm0799.pdf.

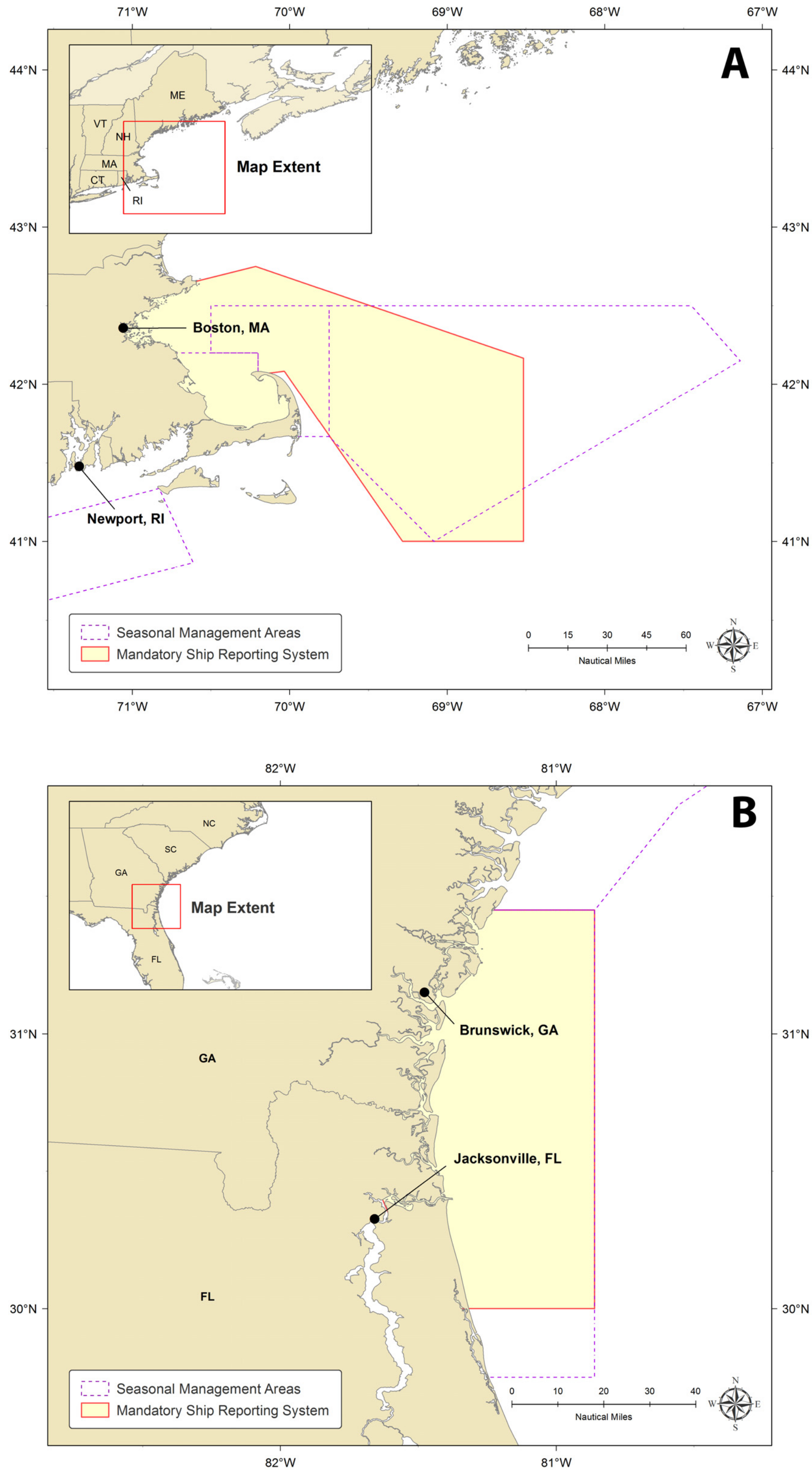

Figure 1.—Mandatory Ship Reporting System Area Boundaries. Also shown are vessel speed restriction seasonal management area boundaries (NOAA, 2008).

THE CRITICALLY ENDANGERED RIGHT WHALE MAY BE ENCOUNTERED IN OFFSHORE AND COASTAL WATERS. RIGHT WHALES ARE SLOW MOVING AND AT RISK OF SERIOUS INJURY OR DEATH DUE TO COLLISIONS WITH VSLS. VSL OPERATORS ARE REMINDED TO USE CAUTION AND PROCEED AT SAFE SPEEDS IN AREAS USED BY RIGHT WHALES. INTENTIONALLY APPROACHING WITHIN 500 YARDS OF RIGHT WHALES IS PROHIBITED AND IS A VIOLATION OF U.S. LAW. A MINIMUM DISTANCE OF 500 YARDS MUST BE MAINTAINED FROM A SIGHTED WHALE UNLESS HAZARDOUS TO THE VSL OR ITS OCCUPANTS. THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) RECOMMENDS THAT OPERATORS ASSUME THAT ANY WHALE SIGHTED IS A RIGHT WHALE.

NOAA REQUIRES MOST VSLS 65 FT OR GREATER TO TRAVEL AT SPEEDS OF 10 KNOTS OR LESS IN SEASONAL MANAGEMENT AREAS USED BY RIGHT WHALES WHEN CONSISTENT WITH SAFETY OF NAVIGATION.

PLEASE REPORT ALL RIGHT WHALE SIGHTINGS AND COLLISIONS TO 978-585-8473 OR 978-585-8473 RESPECTIVELY OR TO THE COAST GUARD VIA CHANNEL 16. FOR MORE INFO, CONSULT THE U.S. COAST PILOT.

Figure 2.— USCG Mandatory Ship Reporting System WHALESNORTH automated return message.

A recent 15-plus-year retrospective analysis of incoming reports (Silber et al., 2015) determined that hundreds of individual ships made over 45,000 reports into the system between July 1999 and December 2013. While generally regarded as a successful and valued outreach tool, the current study is the first attempt to gauge the attitudes and perceptions of mariners regarding conservation benefits as well as the potential impacts to reporting vessels, and to evaluate the ongoing utility and relative value of this longstanding program.

Materials and Methods

An online survey was developed by NMFS economists and biologists during June–August 2014 to collect data on mariner awareness, attitudes, and use of the MSR system. Because the sampling strategy was opportunistic with an unknown universe, an important consideration in the survey design was to minimize the overall survey length and develop clear and concise questions. To help ensure that these considerations were met and that the overall survey was easy to comprehend, a draft instrument was tested in a focus group on 17 Sept. 2014 in Baltimore, Md., at the Maritime Institute of Technology and Graduate Studies/Pacific Maritime Institute (MITAGS-PMI).

Focus group participants were recruited from a pool of mariners who were attending a course at MITAGS-PMI and agreed to participate in a voluntary discussion about the MSR system and the survey. Based on feedback from the focus group, a final survey instrument was developed that contained eight questions and an opportunity to provide open-ended comments at the end of the survey.

The survey (Appendix I), which was implemented online in early June 2015, was programmed by a private consulting firm, ECS Federal[5], and hosted on a domain purchased specifically for the survey implementation. The target survey population was ship owners, operators, or captains who had entered either WHALESNORTH or WHALESSOUTH one or more times.

During an average year, several thousand separate trips are made into both areas (Silber et al., 2015) (some ships and masters may enter multiple times per year). The information needed to directly contact individual ship captains, owners, and/or crews to conduct a survey is not available, making a sampling frame infeasible to develop. For this reason, an opportunistic or convenience sample was necessary.

We acknowledge that this type of sampling has a number of limitations, including the inability to a) examine response bias, b) compute statistical errors, and c) make inferences to a larger population. However in our case, due to the lack of individual contact information, an opportunistic sample involving broad outreach to the generalized community was the only

[5]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

viable approach for contacting vessel operators. Ferber (1977) noted that while opportunistic samples are less desirable than samples derived from a systematic approach, they have utility for exploratory purposes or to obtain different views on the dimensions of an issue or problem.

To implement the survey, federal and private entities who engage in activities or communicate regularly with maritime entities were asked to distribute information about the survey (Appendix II). Announcements of the availability of the survey were also sent via association and government email distribution lists shortly after the survey opened.

The announcements of the survey provided potential respondents with a brief description of the survey, why their participation was important, and a link to the online survey. Two additional announcements about the survey were distributed in August and September 2015.

Respondents who chose to participate in the survey were asked eight questions. The first set of questions asked about familiarity with the MSR system and their ship transits through the MSR areas. The second set of questions asked about compliance with, burden of, and conservation potential of the MSR system. The remaining questions asked for the number of years in the industry and type of ship the respondent currently worked on (container ship, passenger vessel, etc.). The survey remained open through 10 Jan. 2016, at which time the URL for the survey was deactivated. The analysis included simple frequency counts of responses to each question.

Results

Respondent Characteristics

A total of 119 mariners took part in the survey. Of this number 85 respondents said they were aware of the MSR system (34 people who accessed the survey but entered no response whatsoever or indicated they had no experience or were not familiar with the MSR, were excluded from the analysis) and 56 indicated they had entered one of the MSR areas at least once.

Due to the publicity of the MSR and its support from the IMO, it is possible that mariners who have never entered one of the MSR areas were still familiar with the system and the reporting requirements, and therefore we considered a total of 85 survey-takers eligible to answer a subset of the survey questions. Questions that required direct experience and use of the MSR were only shown to respondents who stated they had entered an MSR area at least once.

Among the 85 respondents who were aware of the MSR, representation of vessel types was broad, and included container ships, tankers, cargo or bulk carriers, RO-RO's (i.e., car and vehicle carriers), cruise ships, passenger vessels (i.e. ferries, whale watching vessels), research ships, and pleasure craft. According to Rodrigue et al. (2017) the global maritime industry has about 100,000 vessels (>100 t) consisting of passenger, bulk carrier, general cargo, and roll-on/roll-off vessels; about 69% of shipping ton-miles is accounted for by bulk carriers. Our sample consists of captains and crew from all four types of vessels, and about 53% of respondents cited they worked on bulk carriers.

The years of service in the maritime industry ranged from 2 to 48 years, with 23% working less than 20 years and 77% working more than 20 years. The average number of years respondents have worked in the maritime industry was 26, with an average of 11 years as a crew member and 11 years as a captain.

Of the 56 respondents indicating they had entered one of the MSR areas at least once, about 44% said they entered one of the areas regularly. The number of times respondents said they entered one of the areas during a year ranged from 1 to 100, with a mean of 27.8. About 35% (n=20) indicated they enter WHALESNORTH most frequently, 29% (n=16) entered the WHALESSOUTH most often, and 35% (n=20) indicated they enter both areas about the same amount.

As noted, our data is based on an opportunistic sample of ship captains and crew. While the vessel types in our data are representative of the types of vessels in the maritime industry as described by Rodrigue et al. (2017), we cannot determine whether respondent's opinions and attitudes toward the MSR system are representative of those of the larger industry, and specifically those ships that transit the MSR areas.

Compliance with the MSR System

Most respondents comply with the reporting requirement of the MSR system. About 75% of respondents (n=42) stated that they send the required report always or most of the time; and slightly less than a fourth of them (24%) said they rarely or never send the report. About 82% (n=46) of respondents stated that they receive a return message about right whales after sending in their ships' report, while the remainder (n=10) indicated they did not receive a return message via the system.

Survey-takers were asked about their level of agreement with four statements related to the transmittal of required ship information when entering an MSR area: 1) it is relatively easy to send in the required report, 2) I generally follow the report format exactly as specified in the instructions, 3) I send in the report as soon as possible, and 4) sending in the required report takes time away from other duties I have on the ship. Of those responding to this portion of the survey, half (n=20) indicated it was easy to send in the report, with over 70% stating that they followed the required format and they sent in the report as soon as possible after entering the area. About half said that sending in the report takes time away from other duties on the ship (Fig. 3).

Attitudes Toward the MSR System

Following these statements respondents were asked about their level of agreement with four statements related to the automated right whale conser-

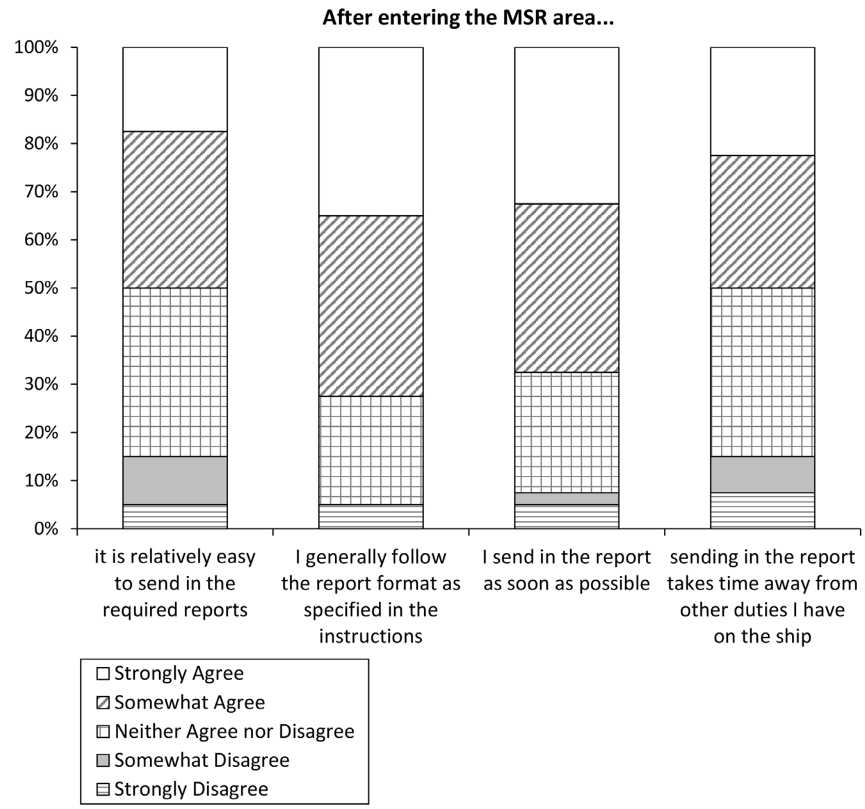

Figure 3.—Attitudes toward Mandatory Ship Reporting system ship requirements.

vation information they receive after reporting into the system: 1) I generally don't have time to read the entire message, 2) I am more alert about avoiding or watching for right whales, 3) I find the information to be useful for the captain and crew, and 4) some aspect of the ship's operation may change (e.g., speed, post extra lookouts) to avoid an interaction. Among those responding to all the questions in this section of the survey (*n*=25), 60% don't read the entire message, but over half said they are more alert about avoiding/watching for right whales and may change the ships operation to avoid an interaction. Nearly 80% of respondents stated they distributed the information in the message to captains and/or crew (Fig. 4).

All respondents who stated that they were aware of the system (*n*=85), even if they had not entered an MSR area, were asked about their level of agreement with four statements concerning general perception of the MSR system: 1) the MSR system is important for right whale conservation, 2) is an unnecessary requirement for ships, 3) has been useful in helping ships avoid right whale interactions, and 4) is a useful system for educating captains and crews about right whales. Of those responding to this set of questions (*n*=64), over half (*n*=34) indicated the MSR system is useful for educating captains and crew about right whales and important for right whale conservation, only about a quarter said it is useful for helping ships avoid right whale interactions, and about 40% said it is an unnecessary requirement for ships (Fig. 5).

In regard to the written comments portion of the survey, several respondents provided additional views about the importance of the MSR in the context of endangered whale conservation; others said it had little utility in reducing strikes of whales. A few of those providing comments reiterated that reporting into the systems was not a significant or time-consuming task, some suggested using alternative vessel tracking systems in lieu of the MSR. Apparently, a number of respondents believed the survey to include discussion of vessel speed restrictions in addition to the MSR, while others took the opportunity to comment on right whale vulnerability (or their lack of vulnerability) to ship collisions, the utility of right whale protective measures generally, or to offer suggestions on ways to diminish the impact of right whale conservation on maritime industries.

Discussion

The invitation to participate in the survey was distributed on a broad scale, and we believe that hundreds of mariners were at least aware of the survey. However, the exact number of individuals who received notification of the survey remains unknown; therefore, a response rate is also not known. We expected the number of respondents to be a small fraction of the total number reached for several reasons.

First, previous studies (Ranmuthugala et al., 2008) have shown that opportunistic sampling generates relatively low responses relative to the number of individuals targeted through broadly cast notification efforts, and there was likely considerable overlap in the entities described in Appendix II.

Second, not all mariners are familiar with the MSR program, because a) it applies only to ships sailing in waters along parts of the U.S. eastern seaboard; b) of these, not all ships enter certain U.S. east coast ports (e.g., Boston, Mass., Jacksonville, Fla.) where MSR areas are situated; and c) not all ships meet the 300 gt threshold for reporting. And, finally, there is little reason to expect ship captains sailing under a non-U.S. flag to complete a voluntary survey focused on a U.S. policy implemented by U.S. Federal agencies.

The nature of an opportunistic sam-

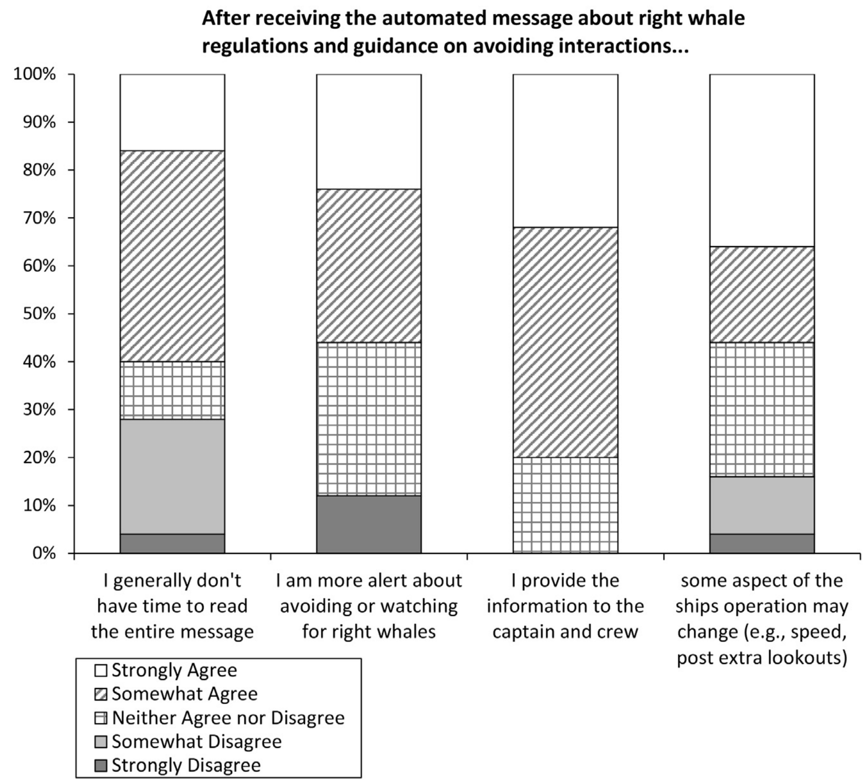

Figure 4.—Attitudes toward Mandatory Ship Reporting system automated return message containing right whale information.

ple implies that the findings are not generalizable to a larger population nor can the extent of response bias be formally identified (Pruchno et al., 2008). Previous studies comparing opportunistic samples to random samples are rare (Pruchno et al., 2008). Two studies that have compared variables of interest between these two sampling approaches suggest that sample means on variables of interest were significantly different between opportunistic and random samples (Pruchno et al., 2008; Ranmuthugala et al., 2008); thus we suggest that the results best represent only those individuals in our survey sample population.

Comments provided via the survey were varied: some indicated an awareness regarding the vulnerability of right and other whales to ship strikes, the severity of the problem, and the need to reduce this threat; others indicated that reporting, and other measures, were not needed. However, we note that responses about the efficacy of the MSR may have come from mariners who had not actually entered the systems.

A number of respondents confused the MSR with a more recent action to reduce ship collisions with right whales: seasonal vessel speed restrictions (NOAA, 2008). This is consistent with findings regarding the number of reports made incorrectly outside the boundaries of the MSR systems; namely, reporting into MSR systems was common along vessel-speed restriction seasonal management area boundaries which are unrelated to the MSR (Silber et al., 2015).

Speed restrictions likely have greater economic and operational impact to commercial maritime industries—as well as having a more quantitative, documented influence on reducing vessel strikes of right whales (Conn and Silber, 2013; Laist et al., 2014; van der Hoop et al., 2014; Martin et al., 2016)—than does the MSR because the latter involves reporting only. Therefore, some mariners may have used the survey as an opportunity to express their views about the speed restrictions.

Our results are mixed on the ease of use of the MSR system by mariners. Of respondents with direct experience with the system, about 70% followed the reporting requirements and sent the report as soon as possible after entering an MSR area, and only 15% indicated the reporting requirements were difficult to follow. However, about half of respondents felt that sending the report took time away from other duties and nearly 60% said that they did not have time to read the entire return message. In addition, about 40% of all respondents felt the MSR system is an unnecessary requirement for ships.

As a conservation measure, our results suggest that the most important function of the MSR is one of education and raising awareness, as most respondents with direct experience with the program indicated that information in the return message was distributed to their crews and that crew members were generally more aware of right whales after receiving the information. Further, about half of all respondents (including those without direct MSR experience) stated the system was good for whale conservation and considered the system a good way to raise awareness about ship-whale collisions.

Being a metric difficult or impossible to reasonably quantify, mariners, of course, cannot know the overall impact of the MSR in reducing collisions with whales. However, the goal was to attempt to ascertain whether mariners disregarded the incoming message, for example, or whether their possible actions in response to some aspect of the message may have lowered the possibility of striking a whale.

Respondents were roughly equally divided in their views on whether the system was useful in avoiding whales. Thus, there is little doubt that the MSR has served to raise mariner awareness about the depleted status of right whales and the species' vulnerability to ship collisions because hundreds of ships have made tens of thousands of reports to (and received return messages from) the MSR in the period since its implementation (Silber et al., 2015).

Inasmuch as return messages arrive in the bridge of reporting vessels as they enter right whale habitat, this feature alone has served as a frequent reminder to those operating ships in U.S. waters about an important conservation matter—and in this regard the outgoing message has been a flexible informational tool for alerting mariners about additional large whale conservation measures as they have been developed.

More broadly, an important aspect of the MSR, a feature with international implications, is that its establishment, as one of the first formal measures to address the threat of ship-whale collisions (Johnson, 2004), helped facilitate the development of additional whale conservation measures. For example, since the implementation of the MSR, the United States and several other nations have established related IMO-adopted routing measures in their waters (Silber et al., 2012a).

In addition, outgoing MSR messages have been adapted to provide alerts about other threat-reduction measures (e.g., dynamically implemented and seasonal vessel speed restrictions) and have been used to provide written information on right whale sightings. However, in regard to information dissemination, broad-based distribution programs have also been developed by a number of entities. For example, a number of ports and government agencies now rely on a number of systems (e.g., the frequently updated USCG Broadcast Notice to Mariners) to transmit information to ships, including information about right whale sightings.

The International Whaling Commission provides brochures for mariners regarding large whale ship strikes[6]; numerous non-governmental organizations maintain web sites and actively distribute information on this matter; and NMFS has developed and routinely provides interactive CD's, laminated cards, and booklets[7] regarding the threat of ship strikes of right whales.

Most of this material, however, is "passive" and has neither the immediacy of notifying ships directly through the MSR nor provides near real-time information about sighted whales. And, while various outlets provide near real-time whale sighting information through interagency cooperative efforts (NOAA, 2006), it is not clear if, and to what extent, mariners consult and use this information.

Our results from respondents with direct experience with the MSR indicate that the system may have some utility for directly reducing the number of whale-ship collisions, as over half stated that they are more alert after receiving the incoming MSR message and about half said some aspect of the ships operation may change as a result of the message. About 35% of all respondents stated that the MSR is useful for helping ships avoid right whale interactions. Nonetheless, information on the number of known right whale deaths from ship collisions is noted below and in van der Hoop et al. (2014), and no discernable differences are apparent in fatal strike rates in the time after sighting information was routinely provided beginning in the mid-1990's via aircraft survey programs and through the MSR beginning in 1999. Therefore, the extent to which whale sighting information provided via the MSR, or any other means, plays a role in reducing the number of ship struck whales is not clear.

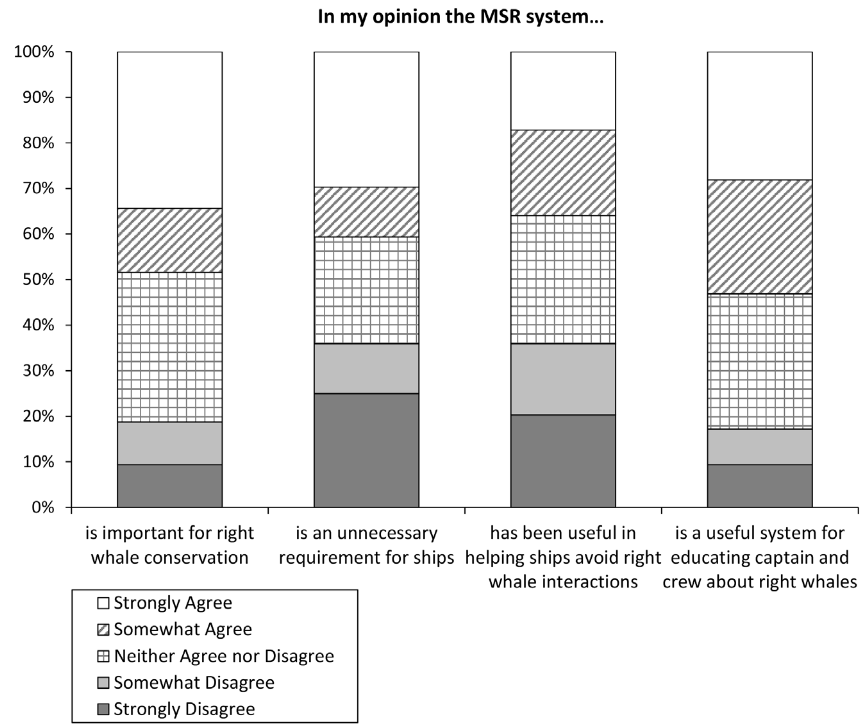

Figure 5.—General attitudes toward the Mandatory Ship Reporting system.

[6]Whales: collisions prevents damage to ships, and injuries to passengers, crew and whales. (https://iwc.int/index.php?cID=3199&cType=document).

[7]Interactive items online at www.greateratlantic.fisheries.noaa.gov/protected/shipstrike/training/index.html.

One of the stated secondary purposes of the MSR was to enable the gathering of data to facilitate a better understanding of vessel operations in right whale habitat as a means to further develop conservation measures (Merrick and Cole, 2007; Silber et al., 2012a). When the MSR was established, routinely collected and archived information on vessel operations on this scale did not exist.

However, since inception of the MSR, advancing technologies are used to monitor vessel activities. In regard to monitoring U.S. port entries, systems to track vessel operations and emerging reporting requirements are far more comprehensive and precise than self-reporting under MSR protocols. Among the most important of these is the advent and use of GPS-linked VHF radio signal and satellite-transmitted Automatic Identification Systems (AIS) which are required on most ships and broadcast signals that provide detailed information on ship location, speed, and routes (Vanderlaan and Taggart, 2009; Reimer et al., 2016; Robards et al., 2016). In addition, a number of U.S. ports have Vessel Tracking Systems to aid in navigation, and some fishing vessels are required to carry Vessel Monitoring Systems.

Following the attacks of 11 September 2001, all vessels have been required to provide 96-h notice prior to calling on a U.S. port. Some of these technologies, AIS in particular, have been used to assess changes in ship operations in response to the implementation of various whale protection measures, including routing scheme changes (Vanderlaan and Tagart, 2009; Lagueux et al., 2011), vessel speed restrictions (Lagueux et al., 2011; Wiley et al., 2011; Silber et al., 2014), and dynamically managed areas (Silber et al., 2012b). Development and use of these technologies and communication systems have rendered the MSR a less than optimal means to gather and relay information to and from ships and have therefore largely supplemented the tracking of ship operations functions of the MSR.

From 1999 (when the MSR was established) to June 2016, 11 confirmed right whale deaths resulted from collisions with ships (Laist et al., 2014; Henry[8]), an average of 0.7 per year. This rate of known deaths attributed to ship strikes is roughly comparable to the 10 years prior to implementation of the MSR (1990–99; 0.6 per year); but the average decreased to 0.3 fatal strikes per year in the years 2007 through 2015 (Laist et al., 2014; Henry et al.[5]).

A number of factors could be involved in affecting these rates. We contend that variables such as whale distribution and shifts in distribution, particularly relative to large-scale shipping lanes, and overall shipping traffic volume, play roles in the occurrence and frequency of whale strikes. In the last decade, for example, the number of large vessel trips into U.S. east coast ports has fluctuated in response to shifting economic climates and increasing ship size and cargo capacities (the latter being a feature that reduces the number of trips overall) (DOT, 2013; MARAD, 2013; Silber et al., 2015).

In the context of these pervasive circumstances influencing the economics of transporting goods on worldwide scales, education and outreach efforts, while still important, may have little overall effect on rates of fatal ship strikes. Regardless, while the rather crude metric of annual deaths lacks sufficient resolution to fully evaluate the effects of the MSR, we note only that there were no immediate or overt changes in right whale ship strike-related death rates at the onset or in the time the MSR was in place.

Protection of living marine resources can be challenging in light of resource utilization by multiple industrial or commercial users. Conservation measures are generally established by incorporating the best available science and with maximum (practical) protections in mind. But such programs are not always evaluated (Clark et al., 2002; Ferraro and Pattanayak, 2006) or assessed to identify ways to optimize use of limited resources (Kapos et al., 2008) or fully utilize the provisions of available statutes.

The U.S. Government has faithfully operated the MSR for years and there is little doubt the program has conservation benefits by raising awareness of the maritime industry. Further, the MSR is one element in a suite of ship strike reduction measures that include IMO-adopted Areas To Be Avoided (Vanderlaan and Taggart, 2009), modifications of shipping routes (USCG, 2007), and voluntary and mandatory vessel speed restrictions (NOAA, 2008). However, our survey results suggest that, at least from the perspective of mariners who completed our survey, benefits of the MSR in reducing the likelihood of ships colliding with right whales are divided, but had a role in promoting education and outreach opportunities.

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[8]Henry, A. G., T. V. N. Cole, L. Hall, W. Ledwell, D. Morin, and A. Reid. 2014. Mortality determinations for baleen whale stocks along the Gulf of Mexico, United States east coast, and Atlantic Canadian provinces, 2008–12. U.S. Dep. Commer., Northeast Fish. Sci. Cent., Ref. Doc. 14-10, 17 p. (https://www.nefsc.noaa.gov/nefsc/publications/crd/crd1410).

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Appendix 1.—Mandatory Ship Reporting systems survey instrument.

Right Whale Mandatory Ship Reporting System: What do you think?

The National Marine Fisheries Service, the federal agency responsible for the stewardship of living marine resources and their habitats, is sponsoring a survey to obtain mariner's feedback on the **North Atlantic right whale Mandatory Ship Reporting (MSR) system. (To find out more about the MSR system go here)**

This survey is only about the reporting system. It is **not** about the ship speed restrictions or any other right whale conservation program.

This is a voluntary survey. Your feedback will be used to evaluate and improve the MSR system. All survey responses are anonymous and confidential.

OMB Control No. 0648-xxxx. Expiration Date: xx/xx/xxxx. Public reporting burden for this information collection is estimated to average 10 minutes per response. Send comments regarding this burden estimate or other suggestions for reducing this burden to Kristy Wallmo, 301-427-8190 or Kristy.Wallmo@noaa.gov.

Responses are kept confidential as required by section 402(b) of the Magnuson-Stevens Act and NOAA Administrative Order 216-100, Confidentiality of Fisheries Statistics, and will not be released for public use except in aggregate statistical form without identification as to its source. Notwithstanding any other provisions of the law, no person is required to respond to, nor shall any person be subjected to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.

1. Are you aware of the North Atlantic right whale MSR (MSR) system?
   - ❒ Yes
   - ❒ No. *If 'No' survey will skip to Q7.*

2. During the year, about how many times do you enter one of the MSR areas?
   - ❒ I enter one of the MSR areas on a regular basis
     If box above is checked, survey will prompt: Approximately _____ times per year
   - ❒ I have entered at least one of the MSR areas but not on a regular basis. Approximately _____ times.
   - ❒ I have not entered either of the MSR areas. *If checked, survey will skip to Q6c.*

3. Which MSR area do you enter most frequently?
   - ❒ North MSR area
   - ❒ South MSR area
   - ❒ About the same amount for both areas

4. When you enter a MSR area, how often do you send a report as part of the MSR system?
   - ❒ Always
   - ❒ Most of the time
   - ❒ Some of the time
   - ❒ Rarely
   - ❒ Never

5. After sending in a report to the MSR system, have you received a message about right whale regulations and guidance on how to avoid interactions with right whales?
   - ❒ Yes
   - ❒ No

6. Please check the box that best represents your level of agreement with each statement.

	Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree
6a. After entering one of the MSR areas...					
...it is relatively easy to send in the required report	❒	❒	❒	❒	❒
...I generally follow the report format exactly as specified in the instructions	❒	❒	❒	❒	❒
...I send in the report as soon as possible	❒	❒	❒	❒	❒
...sending in the required report takes time away from other duties I have on the ship	❒	❒	❒	❒	❒
6b. After receiving the automated message about right whale regulations and guidance on avoiding interactions with right whales...					
...I generally don't have time to read the entire message	❒	❒	❒	❒	❒
...I am more alert about avoiding or watching for right whales	❒	❒	❒	❒	❒
...I provide the information to the captain and crew	❒	❒	❒	❒	❒
...some aspect of the ship's operation may change (e.g. speed, post extra lookouts) to avoid an interaction as a result of having received the message	❒	❒	❒	❒	❒
6c. In my opinion the MSR system...					
... is important for right whale conservation	❒	❒	❒	❒	❒
...is an unnecessary requirement for ships	❒	❒	❒	❒	❒
...has been useful in helping ships avoid right whale interactions	❒	❒	❒	❒	❒
...is a useful system for educating captains and crew about right whales	❒	❒	❒	❒	❒

7. How many years have you worked in the maritime industry? _______________

   (a) How many years as a crew member? ______________________________

   (b) How many years as a captain? ___________________________________

8. What type of ship do you work on? _____________________________________

Thank you very much for your participation in this survey. Your feedback will help NOAA Fisheries improve the North Atlantic Right Whale MSR system. Please add any additional comments you have concerning the MSR system in this box.

Type comments here

Appendix 2.—Communications channels used to notify users of an online survey of Mandatory Ship Reporting systems.

Federal Agencies

NOAA's Ocean Service. Regional Navigation Managers work directly with pilots, mariners, port authorities, and recreational boaters to help identify and address marine transportation system navigational safety issues. Based on our request, U.S. east coast navigation managers used their regular public and industry meetings, port facility functions, and other conduits to notify mariners about the survey.

National Geospatial Agency (NGA). The NGA's *Notice To Mariners (*msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_st=&_pageLabel=msi_portal_page_61,) is the principal publication for ships engaged in international voyages. Designed to ensure the safety of life at sea, this publication provides marine safety information and corrections to navigational aids for all U.S. Government navigation charts and publications derived from a variety of sources, both foreign and domestic. A special notice about the survey was posted in the NGA's Hydrogram and Marine Information sections of the weekly notice on 10 June 2015 (msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/UNTM/201525/Marine_Info.pdf) and again on 3 September 2015.

Maritime Administration (MARAD). The Department of Transportation's MARAD is charged with ensuring that the nation maintains adequate shipbuilding and repair services, efficient ports, and reserve shipping capacity for use in time of national emergency (www.marad.dot.gov/). It promotes maintenance of a well-balanced U.S. merchant fleet for transport of waterborne commerce, and it is capable of service as a naval and military auxiliary in time of war. MARAD promoted the MSR survey with an announcement via its distributions list, containing perhaps several thousand active mariners. Announcement by email distribution sent on 27 July 2015.

NOAA, NMFS, Northeast Regional Office. Participating members of maritime contact distribution lists were encouraged via email to take the survey by shipping industry liaisons from both NOAA's NMFS Southeast and Northeast Regional Offices on 7 July 2015. The survey was also discussed by liaisons at numerous industry meetings.

U.S. Coast Guard (USCG). The USCG's outreach program posted a blog about the survey on 6 November 2015. On average, the blog receives approximately 40,000 unique (each coming from a different IP address) views per month.

Industry Associations

World Shipping Council (WSC). With 26 companies, which utilize hundreds of ships and employ hundreds of vessel operators, the WSC represents over 90% of global liner vessel capacity and transport cabilities. At our request, the WSC sent notifications to all of its member companies on two occasions (28 July and 30 August 2015).

Chamber of Shipping of America (CSA). The CSA represents 35 U.S.-based companies that own, operate, or have commercial interest in oceangoing tankers, containers, and dry bulk vessels engaged in domestic and international trades. These entities employ hundreds of vessel operators. The CSA sent notifications about the survey to each of its member companies on two occasions (15 July and 8 August 2015). The CSA also asked a number of other industry associations to notify their members; these included InterTanko, American Waterways Operators (AWO), Cruise Lines International Association (CLIA), International Chamber of Shipping (ICS), and Baltic and International Maritime Council (BIMCO).

Just for information: InterTanko has 204 members and 236 companies whose combined fleet comprises some 3,077 tankers; AWO is the national trade association for the U.S. tugboat, towboat, and barge industry; CLIA is the world's largest cruise industry trade association; ICS membership represents national shipowners' associations in Asia, Europe, and the Americas whose member shipping companies operate over 80% of the world's merchant tonnage; BIMCO is the largest of the international shipping associations representing shipowners and its membership controls around 65 percent of the world's tonnage.

Passenger Vessel Association. The PVA represents companies who are owners, operators, and leasers of shipboard operations of passenger vessels on the waterways of the United States and Canada including car and passenger ferries, tour and excursion vessels, charter boats, eco-tour boats, and day sailing vessels. These vessels move over 200 million passengers each year. The PVA sent notification of the MSR survey to all its members on 5 August 2015.

Maritime Periodicals

Mariner's Weather Log. A publication of the National Weather Service (NWS), this journal (http://www.vos.noaa.gov/mwl.shtml) allows the NWS to maintain contact and communicate with over 10,000 shipboard observers worldwide. It is used to distribute meteorological information, worldwide environmental impact concerns, climatology studies, and the like to the maritime community. A special announcement (including a small story and photograph) appeared in the August 2015 (Vol. 59, No. 2) issue (www.vos.noaa.gov/MWL/201508/msrsurvey.shtml)