NOAA Technical Memorandum NMFS-NE-202

Evaluation of Northern Right Whale Ship Strike Reduction Measures in the Great South Channel of Massachusetts

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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[a]Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

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[g]McEachran, J.D.; Dunn, K.A. 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). *Copeia* 1998(2):271-290.

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ABSTRACT

Ship strike mortality remains one of the two primary causes for lack of recovery of the North Atlantic population of northern right whales (*Eubalaena glacialis*). As a result, NOAA Fisheries has identified a number of actions to reduce interactions between ships and whales. Central to this approach is the concept that ship strike mortality risk can be reduced either by slowing ships or by separating vessels and whales. More specifically, in the Great South Channel Seasonal Management Area (GSCSMA) of the southern Gulf of Maine, NOAA is considering an April–July requirement that all vessels over 300 gross tons travel no faster than 10 kts. To physically separate whales and vessels, NOAA is also considering (a) designating the Great South Channel critical habitat (GSCCH) area as an International Maritime Organization (IMO)-approved Area To Be Avoided (ATBA) and (b) narrowing (by 1 nm) the Boston Traffic Separation Scheme (TSS).

We analyzed the risk reduction of right whale ship strikes which could result from the above two proposals by using data on commercial shipping traffic and right whale sightings collected during April–July 1999–2005. During this period, 2,032 right whales were observed in the New England Mandatory Ship Reporting System (MSRS) area. Of these whales, 1,594 were sighted within the bounds of the proposed ATBA, suggesting that such a designation could greatly reduce right whale ship strikes. A narrowing of the TSS by 1 nm suggests that 77 of the 196 right whales seen in the TSS during April–July 1999–2005 would have been separated from ship traffic.

We also evaluated ship strike risk by overlaying right whale sightings on vessel tracks. This analysis suggests that during April-July there are two areas of the GSCSMA where right whales are at greatest relative risk of ship strike: (a) a diagonal track within the GSCCH proceeding northeasterly from the southwest corner of the GSCCH; and (b) that part of the TSS which passes through the GSCCH. Implementing an ATBA in the GSCCH area would reduce the relative risk of right whale ship strike in the GSCCH by 63%. Narrowing the TSS by 1 nm on the eastern side would reduce the relative risk in the GSCCH by another 11%. Though narrowing the TSS will affect fewer animals than the ATBA, the relative risk per individual whale is much greater in the TSS because of the heavier traffic there. Similar reductions in ship strike risk would accrue for fin (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in both the ATBA and a narrowed TSS.

INTRODUCTION

Ship strike mortality remains one of the two primary causes for lack of recovery of the North Atlantic population of northern right whales (*Eubalaena glacialis*; NMFS 2005; Waring et al. 2006). As a result, NOAA Fisheries has developed a series of management measures that seek to reduce interactions between ships and whales. Central to this approach is the concept that ship strike risks can be reduced either by separating vessels and whales or by slowing ships. A series of analyses support this concept (Laist et al. 2001; Jensen and Silber 2003; Nichols and Kite-Powell 2005; Pace and Silber 2005; Vanderlaan and Taggert 2007). NOAA Fisheries is now in the position to translate this research into management. Spatial and temporal aspects of ship strike mitigation measures were developed through a series of meetings within NOAA supported by a variety of analyses conducted by the Northeast and Southeast Fisheries Science Centers (e.g., Merrick 2005). The latter analyses defined a series of Seasonal Management Areas (SMAs) in which seasonal speed restrictions would be applied. Three SMAs were defined in the Northeast United States (Figure 1): Cape Cod Bay (January–May), Off Race Point (March –April), and Great South Channel (GSC) (April–July). This work led to an advanced notice of proposed rule making (June 2004; 69 FR 30857) followed by a proposed rule (June 2006; 71 FR 36299) outlining measures (http://www.nero.noaa.gov/shipstrike/) to accomplish much of the approach. The focus of the rule will be to provide for seasonal speed restrictions for vessels of 300 gt or larger (excluding sovereign flag vessels) from Maine to Florida.

NOAA is also considering other protective measures which would need to be adopted by the International Maritime Organization (IMO). These include a narrowing of the Boston Traffic Separation Scheme (TSS), and designation of the Great South Channel area as an "Area To Be Avoided" (ATBA)[1]. In 2006, NOAA and the U.S. Coast Guard (USCG) proposed to the IMO that the northern leg of the TSS be realigned and narrowed. The IMO agreed to implement this proposal on 1 July 2007, in part because of the reduction in large whale risk (Merrick 2005). NOAA and USCG are now considering a second proposal to the IMO which would designate the Great South Channel ATBA and possibly narrow the leg of the Boston TSS which passes through the Great South Channel. This report evaluates the reduction in whale/vessel collision risk of these two measures by using whale sighting and vessel track data. A simple risk model is built from these two datasets to assess the relative likelihood of a whale/vessel collision.

METHODS

DATA

Whale Sightings

The only recent systematic, broad-scale survey observations in the Gulf of Maine[2] are those from NOAA aerial surveys (Cole et al. 2007). Directed surveys for North Atlantic right whales were conducted during March–November, 1999–2005 in the area from south of Nantucket, MA northward to the Bay of Fundy in Canada, and from the New England coast eastward to the Hague Line. Surveys were accomplished using one or two high-wing, twin-engine fixed wing aircraft. One was a NOAA DeHavilland Twin Otter (1999–2005), and the other was a chartered amphibious Grumman Widgeon (1998–2000) or Grumman Goose

(2001–2003). Surveys were flown at ca. 230 m altitude (310 m in 2001), and 100 kts (185 km/hr) when visibility was good and the Beaufort sea state was 5 or less. Sightings of all marine mammals were recorded. Right whale counts used in this analysis represent the best final estimate of the number of animals at a sighting location. To obtain this estimate, after a right whale was sighted, the survey aircraft broke off effort and circled the sighting location until the observers were confident that all whales had been recorded. This is the only situation where "off-watch" observations were included in this analysis. This only affected right whale counts; the aircraft followed standard line-transect protocols and stayed on-effort when all other whale species were seen.

During 1998–2001, flights were either flown along tracklines developed for the South Channel Ocean Productivity Experiment (SCOPEX, Kenney and Wishner 1995) in the Great South Channel area, or they were directed toward areas of reported or suspected right whale concentrations. During 2002–2005, emphasis was placed on uniform coverage of the entire study area. Cole et al. (2007) describes how survey coverage was allocated and the results of the effort allocation by year. The data used in the analyses conducted here have not been corrected for effort or for unobserved animals (i.e., g(0) corrections). We assumed, for this analysis, that effort was uniformly distributed throughout the area. As such, there may be spatial and temporal bias in the sighting locations. Also, the additional "off-watch" effort for right whales described above likely provides a reasonable estimate of the animals along the track line, even without the g(0) correction. However, the actual numbers of other whales present are underestimated.

Vessel Tracks

In 1998, the United States proposed to the IMO a Mandatory Ship Reporting System (MSRS) as a mitigation tool for right whale ship strikes. The IMO, the Specialized Agency of the United Nations to address international shipping issues, is the competent international body to develop guidelines, criteria, and regulations on an international level for shipping including approval of a MSRS. The proposed MSRS was approved by the IMO later that same year (66 FR 58066; Silber et al. 2002).

Reporting under the MSRS began on 1 July 1999. All commercial vessels 300 gross tons and greater are required to report to a shore-based station when they enter two areas off the east coast of the United States: one off Massachusetts and one off Georgia and Florida. The reporting system off Massachusetts (WHALESNORTH) operates year round, while the Georgia and Florida system (WHALESSOUTH) operates from 15 November to 15 April. Upon entering the MSRS, ships report their name, call sign, course, speed, location, destination, and route. A computer server, operated under federal contract, handles and stores incoming ship reports and sends an automated-return message. Incoming reports are text messages that arrive via International Maritime Satellite (INMARSAT) or Telex (Silber et al. 2002). In return, a vessel receives an automated message that provides the latest information about right whale sightings and avoidance procedures that may prevent a collision.

Incoming ship reports were reviewed by the USCG for duplicate or erroneous records and stored in a relational database. Florida's Fish and Wildlife Research Institute (FWRI) staff (Ward-Geiger et al. 2005) then extracted records from the database in a format compatible for mapping locations within ArcInfo and ArcView. Tracks were either: (1) "simple," where a line was drawn between the point of entry into the system and the reported destination; or (2) "descriptive," which included tracks that were generated by sequentially linking more than two points along the reported route. For simple tracks from ships that reported only the name of the destination port, substitute coordinates were assigned to complete the track.

To improve the quality of inbound descriptive tracks, FWRI staff mapped every route terminus coordinate within the MSRS to verify that the end of each track falls within a reasonable distance (10-km radius) from the pilot station for the reported destination port. When a descriptive track did not meet this criterion, the Geographic Information System (GIS) completed the track by using the substitute coordinates from the appropriate pilot station.

The validity of each track was assessed based on criteria reported by Silber et al. (2002), and only tracks that met these criteria were analyzed. Tracks within each area were tallied and mapped to characterize traffic concentrations.

ANALYSIS

Great South Channel ATBA analysis

Initially, both the entire GSC SMA (Figure 1) and the MSRS area were considered as candidate ATBAs. However, large areas of the 22,980 km^2 SMA and 23,000 km^2 MSRS have relatively low densities of either whales or shipping. After additional discussion within NOAA, it was determined that the area defined by the GSC Critical Habitat provided a more appropriate ATBA (Figure 2). This area was truncated at the eastern edge of the Boston TSS, so its area (7,450 km^2) is somewhat smaller than the original critical habitat area (8,360 km^2). Boundaries of the ATBA analyzed were:

69° 33.6' W, 41° 44.4' N
68° 31.0' W, 42° 10.0' N
68° 13.0' W, 41° 38.0' N
69° 4.2' W, 41° 1.2' N

An index of vessel traffic density was developed from ship tracks reported through the northeast MSRS during 1999–2005 (Ward-Geiger et al. 2005). Because the MSRS WHALESNORTH was initiated on 1 July 1999, data from WHALESNORTH were processed on a 1 July – 31 June cycle. The ATBA that NOAA is considering is seasonal and

would be effective for the months of April through July, so data for an "analysis year" represents a re-aggregation of the yearly cycle of MSRS data. As an example, 1999/2000 analysis year includes the months of July 1999, April 2000, May 2000 and June 2000. Six years of MSRS data were analyzed: 1999/2000 to 2004/2005. Tracks entering the TSS north of Cape Cod were excluded. Vessels departing from within the MSRS (e.g., Boston) do not report into the MSRS, and thus there is underreporting of vessel tracks headed southwards in the TSS.

A spatial query polygon was used to isolate and summarize the annual subsets of tracks within the MSRS boundary, GSC critical habitat, and southern leg of the Boston TSS. All tracks which intersected the spatial query polygon were selected with ArcGIS and converted into a gridded density file. This grid was created in ArcInfo Workstation using the LineDensity command with the following parameters: kernel density interpolation, 2 km search radius (accuracy of reported locations is to the nearest minute), and 100 m cell size. Grid values represent km of ship track/km² within the relevant polygon. The final grid file of ship track density prepared by staff of FWRI for this analysis included a total of 761 vessel trips through the GSC Critical Habitat/ATBA and 421 northbound trips through the southern leg of the Boston TSS for April-July 1999-2005. This is essentially the same data reported in Ward-Geiger et al. (2005), but updated with information from 2003-2005.

Right whale sightings were analyzed by using ArcView 3.2, Spatial Analyst, and ArcGIS/ArcMap 9.2. An index of GSC SMA right whale sighting densities was calculated for the April–July, 1999–2005 period by using sighting events weighted by the number of animals seen in the event. Two parameters were used with the ArcView DENSITY function: kernel density interpolation and 100m cell size. Grid values represent whales/km² within the Gulf of Maine aerial survey area.

Both the ship track and sightings data were analyzed by using a NAD1983 UTM Zone 19N, Transverse Mercator projection.

Finally, we developed a crude risk model to identify areas of highest relative risk for right whale-vessel interactions within the MSRS. By using the Spatial Analyst function in ArcGIS/ArcMap 9.2 Tool Box, Relative Risk (RR) was calculated for subareas (e.g., the ATBA) within the MSRS as the normalized product of the right whale and ship track density indices:

$$RR = \sum_{i=1}^{n} (rwd_{ij})(std_{ij}) \Big/ \sum_{j=1}^{m} \sum_{i=1}^{n} (rwd_{ij})(std_{ij})$$

where

rwd_{ij} = right whale density in cell i in sub area j
std_{ij} = ship track density in cell i in sub area j

This produced estimates of relative risk (compared to the entire MSRS area) for two key subareas: the ATBA and the TSS. A side product of the analysis was an estimate of RR for each cell within the MSRS area. These results, by cell, were binned, contoured, and plotted by four levels of relative risk: Minimal (0<RR<0.01), Low (0.01<RR<0.05), Medium (0.05<RR<0.25), and High (0.25<RR<1.00), where RR=1.00 is the highest risk. Note that Cape Cod Bay was not included in this analysis; a separate analysis of ship strike risk is provided in Nichols and Kite-Powell (2005).

Traffic Separation Scheme Analysis

The existing TSS was designed prior to concerns over right whale ship strikes. Analyses of the northern leg of the Boston TSS showed that a slight rotation of the TSS could greatly reduce the likelihood of large whale ship strikes (Merrick 2005; D Wiley, Stellwagen Bank NMS, pers. comm.). However, the southern leg of the TSS cannot be shifted to the west and away from the great densities of right whales in the GSC because of the navigational hazards associated with the nearby Davis Bank and Nantucket Shoals. The TSS might, nonetheless, be narrowed from the existing configuration of 2 nm lanes separated by 1 nm buffer zone to 1.5 nm lanes separated by a 1 nm buffer zone. This is identical to the width change the IMO approved for the northern leg of the TSS.

We evaluated this proposal in two ways. First, we compared the number of whales sighted within the bounds of the existing TSS southern leg to a narrowed configuration. ArcView spatial query polygons were used to select the number of sightings under both lane configurations. While right whales were the focus of this analysis, data are also provided on humpback (*Megaptera novaeangliae*) and fin (*Balaenoptera physalus*) whales. Secondly, the relative risk analysis of right whale ship strike in the MSRS discussed previously provided information on the location and degree of risk in the TSS, as well as in the ATBA.

RESULTS

During April–July 1999–2005, Northeast Fisheries Science Center (NEFSC) surveys in the Gulf of Maine recorded a total of 2,533 right whale sightings (Figure 3). Of these sightings, 2,032 of the whales were seen in the MSRS area, and 1,594 were seen in the proposed ATBA (Table 1). Based on this approach and assuming vessels comply with its provision, creation of an ATBA could reduce interactions between right whales and vessels within the MSRS area by 78%. Reductions in vessel interactions with humpback and fin whales are also likely (54-58% of the sightings in the MSRS were within the ATBA).

Narrowing the TSS lanes from 2 nm to 1.5 nm each, while holding the western boundary constant, would further reduce the risk of ship strikes. Some 196 right whales were sighted within the boundaries of the southern leg of the TSS during April–July, 1999–2005. If the TSS was 1 nm nar-

Table 1. Number of large whales seen in the Gulf of Maine, Great South Channel Seasonal Management Area, Mandatory Ship Reporting System area, and proposed Area To Be Avoided: April–July 1999–2005.

Species of whale	Gulf of Maine	Seasonal Management Area	Mandatory Ship Reporting System Area	Proposed Area To Be Avoided
Right	2,533	2,218	2,032	1,594
Humpback	2,046	1,344	1,376	744
Fin	1,445	750	762	444
Total	6,024	4,312	4,170	2,782

Table 2. Number of large whales seen in current Boston Traffic Separation Scheme (TSS) and the 1 nm strip proposed to be excluded from the TSS, and the percent of animals observed in the 1 nm strip: April–July 1999–2005.

Species of whale	Original TSS	Exclusion Area	Percent of Total in Exclusion Area
Right	196	77	39%
Humpback	373	50	13%
Fin	139	28	20%
Total	708	155	22%

rower, 77 (39%) of these whales could have been at least temporarily separated from vessel traffic (Table 2). Note though that is only 4% of the whales seen in the MSRS area during the period. Risk reduction would also be observed for humpback and fin whales.

An alternative approach to evaluating right whale's ship strike risk is to explicitly consider the overlap of right whale and vessel traffic densities. Right whale sighting densities during April–July, 1999–2005 surveys varied greatly within the Gulf of Maine (Figures 3 and 4). Mean density for the Gulf of Maine was 0.03 whales/km^2 (sd = 0.13) and ranged from 0 to 2.63 whales/km^2. The ATBA encompasses most of the medium to high density sighting areas for April-July in the Gulf of Maine with the greatest sighting densities found in the southwest corner of the GSC Critical Habitat/ATBA area (Figure 4).

Mean period traffic density within the MSRS area for April-July, 1999-2005 was 5.62 km of vessel tracks/km^2 (sd = 15.88, max = 213.99). An examination of the ship tracks with the ATBA (mean = 8.73 km/km^2, sd = 13.30, max = 112.5) suggests that the densest vessel traffic within the ATBA occurs along a northeastward diagonal from the southwest corner (Figure 5). These ATBA traffic densities are, however, lower than the traffic density within the TSS itself (mean = 44.37 km/km^2, sd = 46.58, max = 188.5).

Comparing right whale sighting densities (Figure 4) and ship track densities (Figure 5) suggests that the highest potential for right whale-vessel interactions is along the southwest to northeast diagonal of the GSC and in the TSS adjacent to the GSC critical habitat area.

The risk analysis confirms that these areas are the most likely locations for right whale-vessel interactions (Figure 6). Vessel traffic through the ATBA accounts for 63% of the relative risk of right whale ship strike within the MSRS (even though 78% of the whales seen in the MSRS were seen in the ATBA area). While the number of right whales potentially interacting with vessels is lower in the TSS than in the ATBA, the risk appears to be much higher for the whales traveling through the TSS. This is due to the heavier vessel traffic through the TSS (44.37 km/km^2) compared to the ATBA (8.73 km/km^2). The portion of the TSS adjacent to the GSC critical habitat area currently accounts for 35% of the relative ship strike risk within the MSRS, even though only 10% of the MSRS whale observations occurred in the TSS. The 1 nm wide swath proposed to be excluded from the TSS accounts for 11% of the total risk of right whale ship strike in the MSRS, and as such a 1 nm narrowing of the TSS is likely to have strong conservation benefits for right whales.

In summary, implementing the ATBA and narrowing the TSS by 1 nm would reduce the relative risk of right whale ship strike within the MSRS by 74% during April-July (63% from the ATBA and 11% from the narrowing of the TSS).

DISCUSSION

Both the ATBA as presented here (aligned with the Great South Channel Critical Habitat) and the narrowing of the Boston TSS have the potential to greatly reduce the risk of ship strike of right whales (and other large whales.) Seventy-four percent of the relative risk of right whale vessel strike within the MSRS was in these areas. Together these two changes could alleviate most of the right whale ship strike risk during April–July in the MSRS area.

The analysis presented here should be viewed as an evaluation of relative risk reduction. The absolute risk reduction is difficult to measure for several reasons. First, the underlying interaction rate between whales and shipping in

the Northeast is unknown. As such, absolute risk reduction cannot be determined.

Secondly, the observations of whales in the area are only approximations of the true numbers of animals present. In addition to underestimating the number of animals present, there is considerable interannual variability in the temporal and spatial distribution of these whales. However, it is clear from this analysis and previous studies (e.g., Cetacean and Turtle Assessment Program [CETAP 1982; Kenney and Winn 1986] and SCOPEX [Kenney and Wishner 1995; Kenney et al. 1995]) that large whales concentrate in the Great South Channel in late spring and early summer.

Finally, the vessel track data used here represent an underreporting of the actual traffic, although the only systematic spatial bias in the reporting of commercial vessels ≥ 300 gt is likely the lack of tracks for vessels heading southward along the TSS. Vessels departing from within the MSRS are not required to report into the MSRS. However, missing tracks elsewhere are likely distributed in proportion to reported tracks, so that the spatial pattern of densities is most likely correct (Ward-Geiger et al. 2005 for additional discussion), but the magnitude is underestimated. We will be able to assess this once sufficient data become available from the recently implemented Automated Identification System (AIS) for vessels. A more significant problem may be the lack of data on vessels < 300 gt. These smaller vessels are also involved in ship strikes of large whales.

Narrowing the TSS by 1 nm while holding the western boundary fixed provides some conservation value, albeit less than that provided by the ATBA. More comprehensive protection would be provided by shifting or rotating the entire scheme as far westward as possible. For example, a 5 nm westward shift combined with the ATBA would result in an almost complete separation between whales and north-south vessel traffic in the Great South Channel-Georges Bank area. However, even the narrowing of the lanes has positive value, particularly if the ATBA provision results in the routing of additional northbound traffic into the TSS, thereby increasing the ship strike risk in the TSS.

Rerouting vessels around the ATBA, either to the south for SW-NE traffic or into the TSS, will eliminate a large area of potential interaction that presently exists within the Great South Channel. This is true even though individual right whales move throughout the SMA during the spring and summer and are exposed to vessel traffic at various locations. The predictably high numbers of sightings within the ATBA from year to year (Merrick 2005) suggest that the residence times in the ATBA are significantly longer than elsewhere in the SMA or Gulf of Maine. Thus, even though individuals may be seen in more than one area, they spend more time in certain areas, and are, therefore, at greater risk of vessel interactions in such areas.

ENDNOTES

1. The ATBA proposed will likely be in place annually from 1 April through 31 July and will encourage all non-sovereign flag vessels greater than 300 gross tons to avoid the area.
2. A separate but similar survey was conducted during this same time period in Cape Cod Bay by the Provincetown Center for Coastal Studies under contract to the State of Massachusetts.

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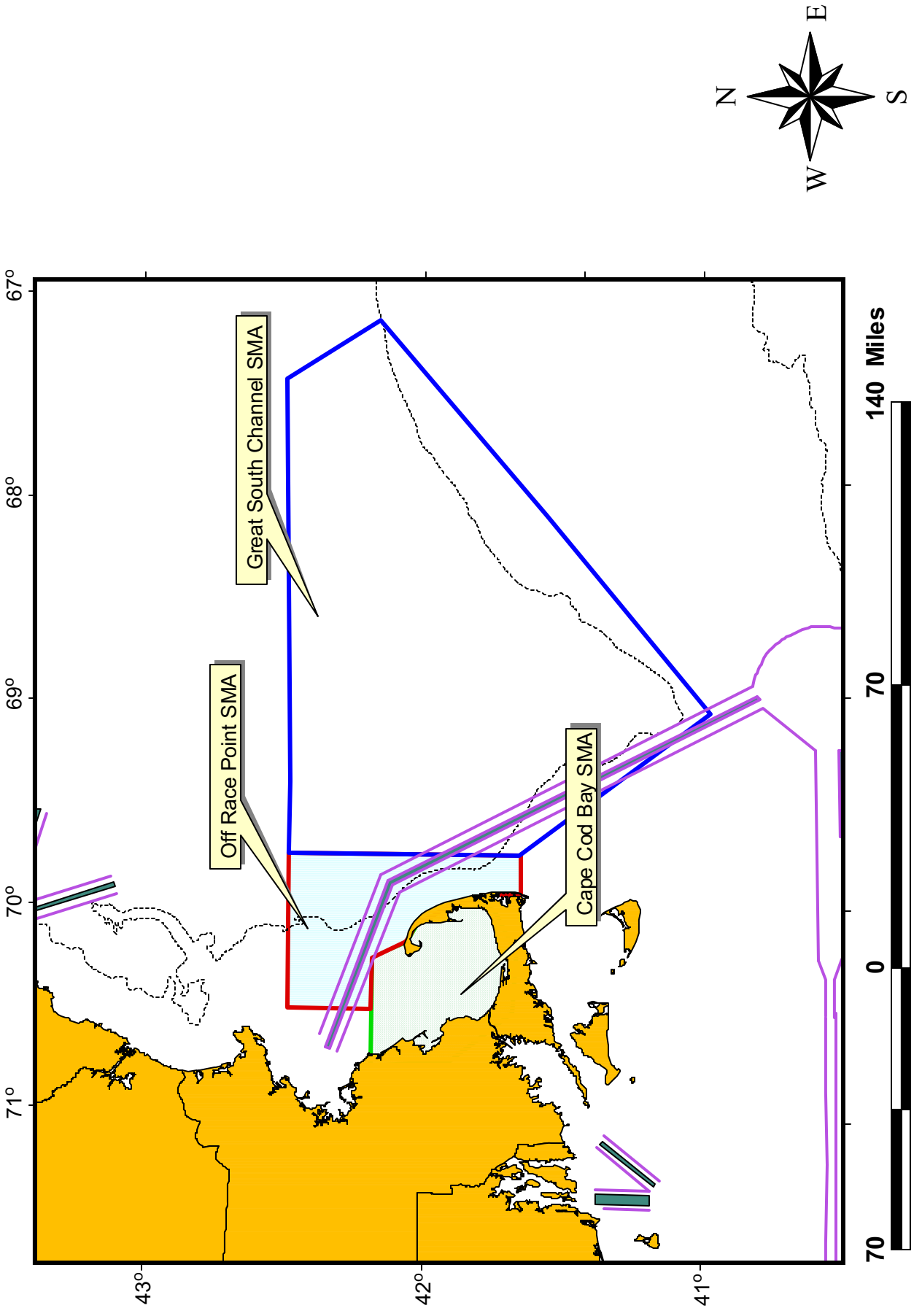

Figure 1. Northern right whale seasonal management areas (SMAs) in New England.

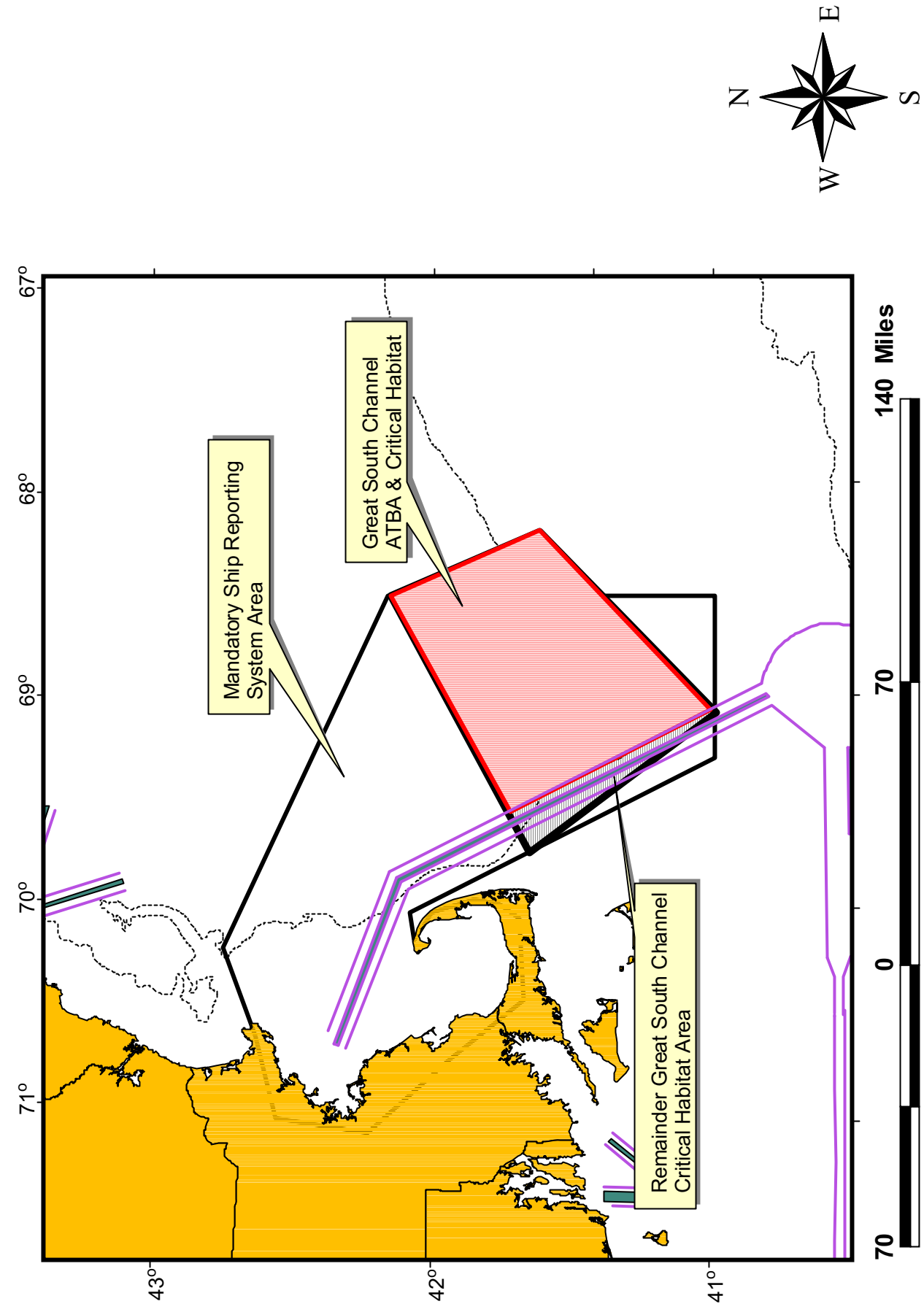

Figure 2. Mandatory Ship Reporting System, proposed Area To Be Avoided (ATBA) and Critical Habitat areas.

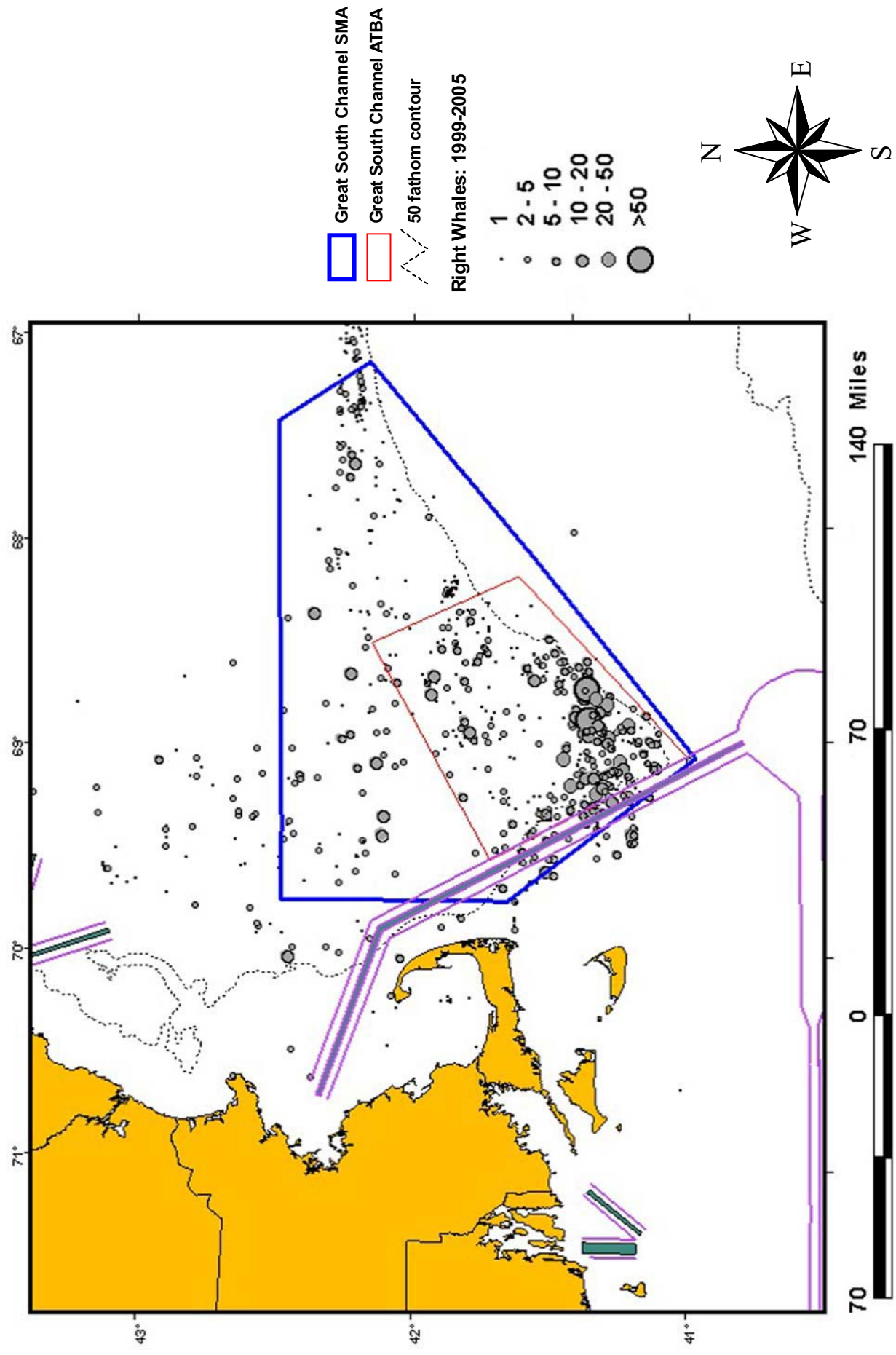

Figure 3. Northern right whale sightings during April–July, 1999–2005 shown with the Great South Channel Seasonal Management Area (SMA) and Area To Be Avoided (ATBA).

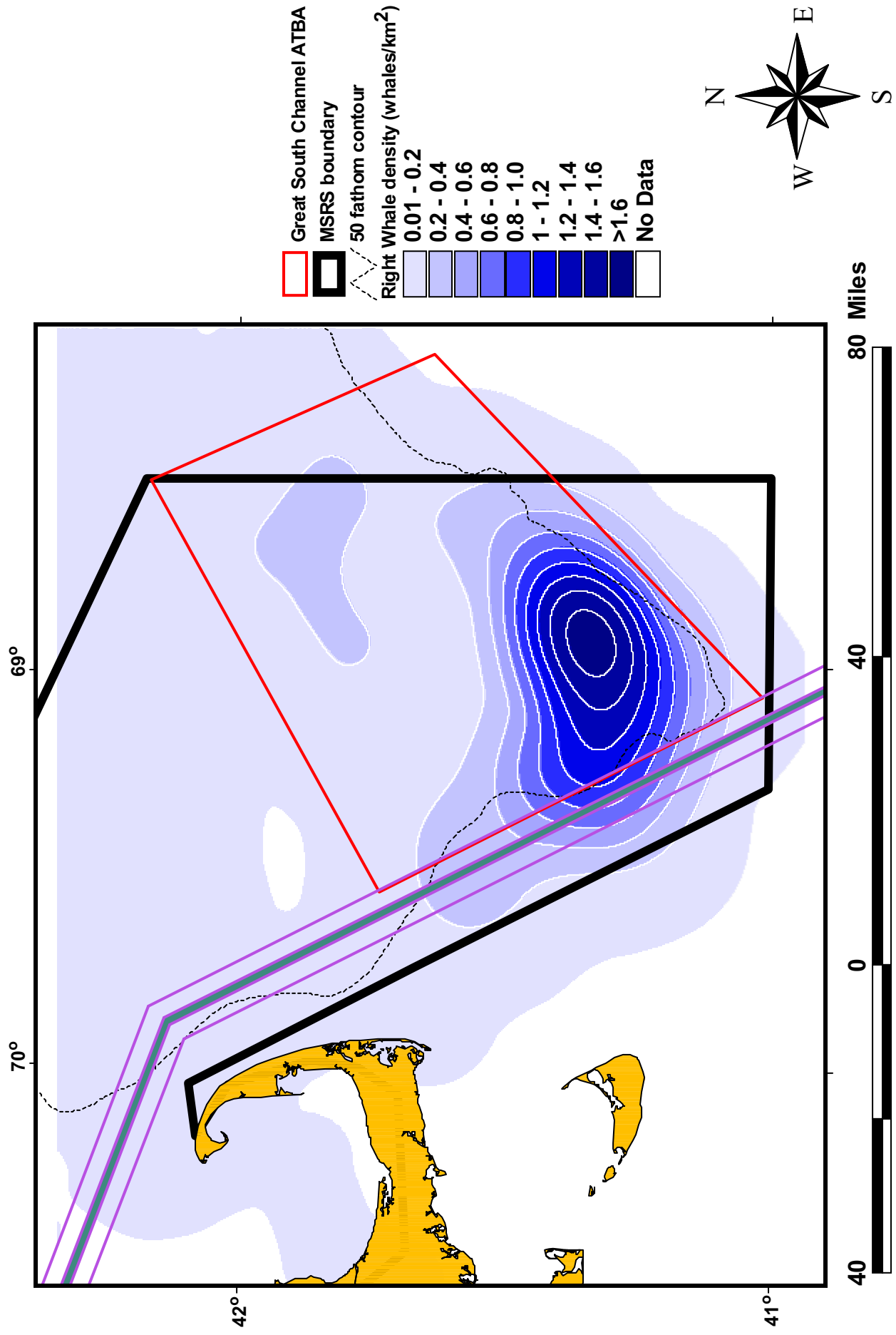

Figure 4. Northern right whale sighting densities (whales/km^2) in the Great South Channel during April–July, 1999–2005 shown with the Great South Channel Area To Be Avoided (ATBA) and Mandatory Ship Reporting System (MSRS) boundary.

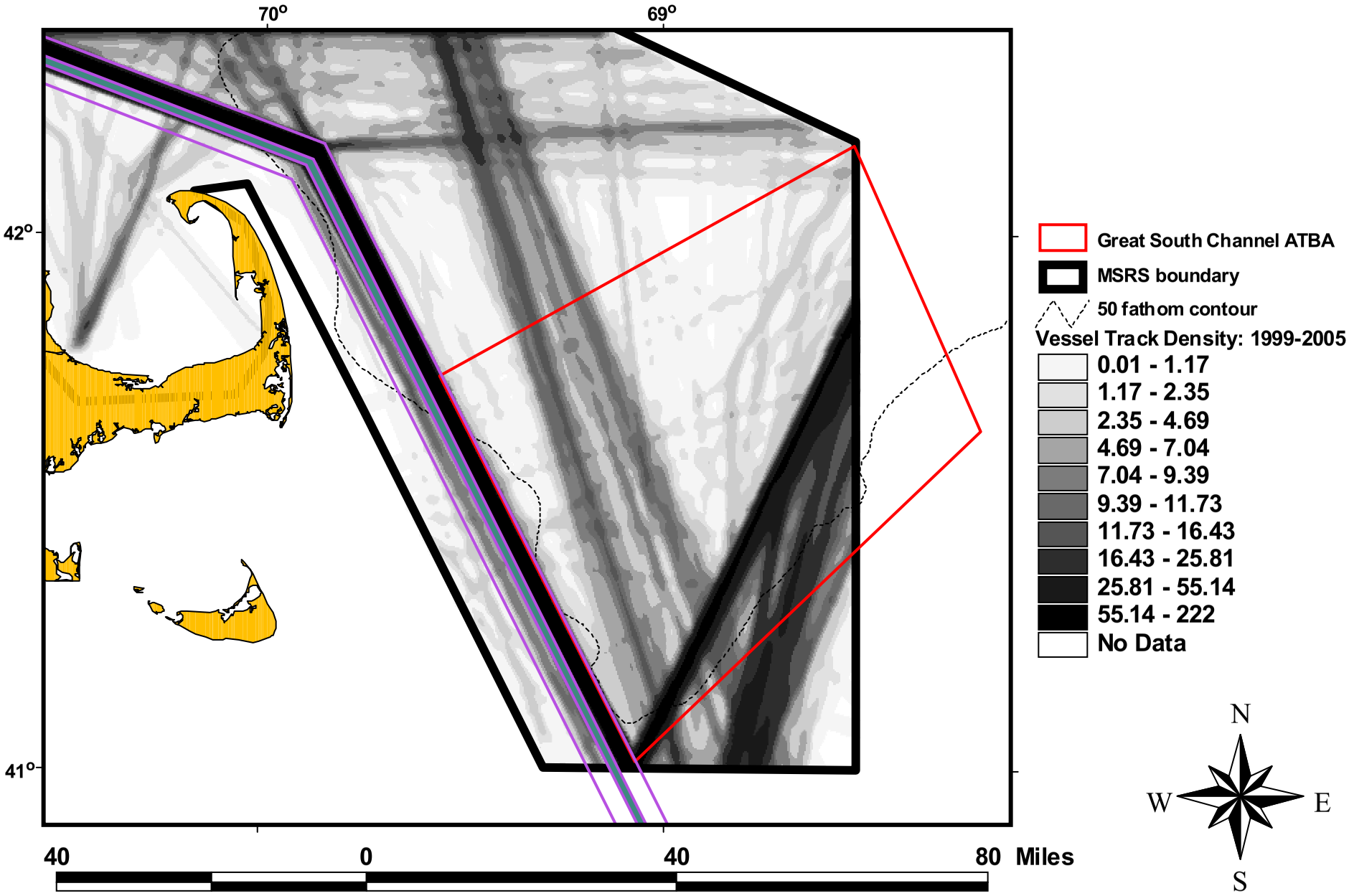

Figure 5. Mandatory ship reporting system (MSRS) boundaries and densities of ship track (km of ship track/km^2) through the potential Great South Channel Area To Be Avoided (ATBA for April–July, 1999–2005.

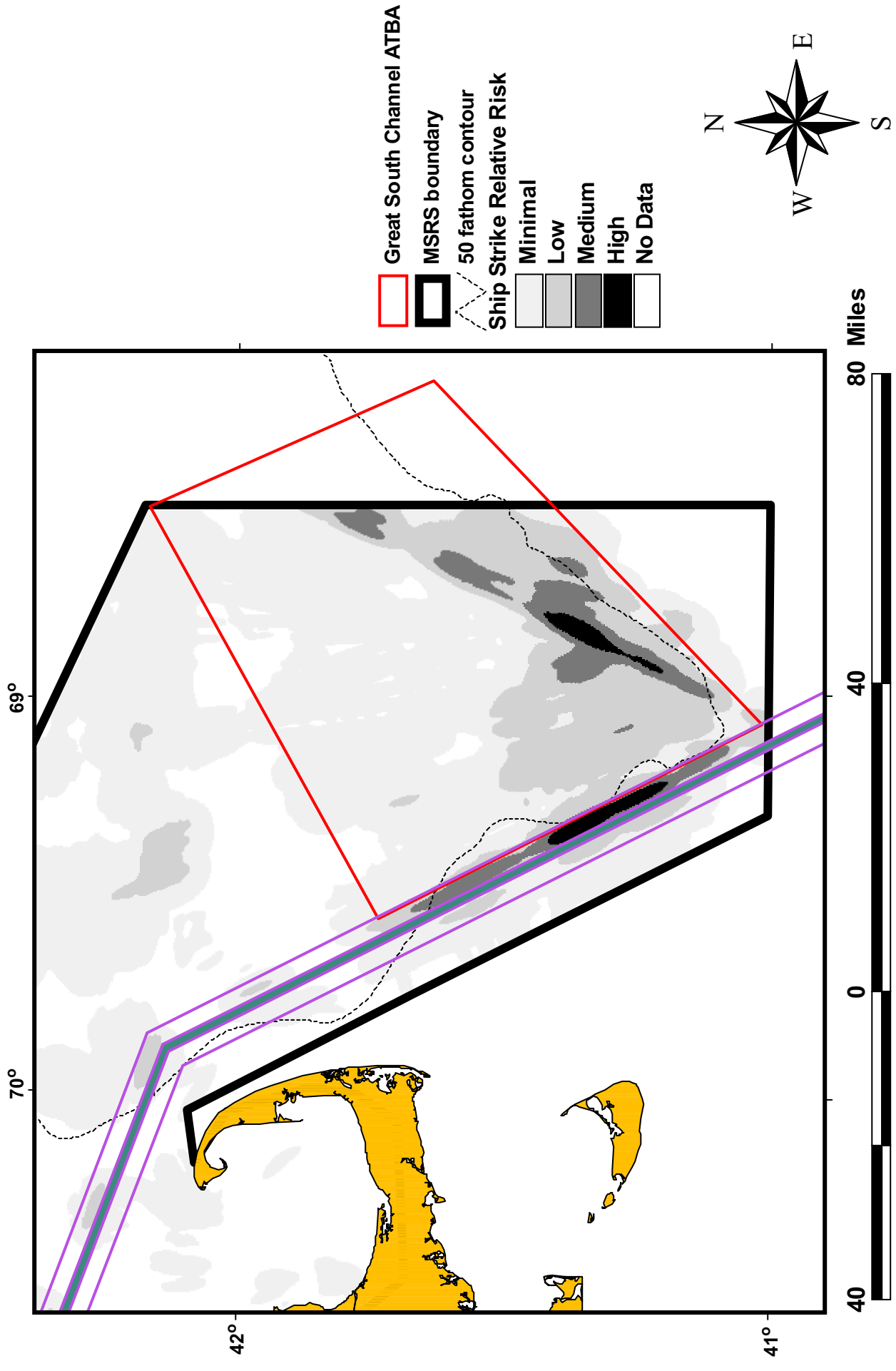

Figure 6. Relative risk of right whale interactions with vessel traffic in the Great South Channel Area To Be Avoided (ATBA) and Mandatory Ship Reporting System (MSRS) area during April–July, 1999–2005.

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