Northeast Fisheries Science Center Reference Document 12-29

Cetacean Abundance Estimates in US Northwestern Atlantic Ocean Waters from Summer 2011 Line Transect Survey

by Debra Palka

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TABLE OF CONTENTS

ABSTRACT

As part of the AMAPPS (Atlantic Marine Assessment Program for Protected Species) project, the Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) of NOAA Fisheries Service conducted line-transect aerial and shipboard abundance surveys to estimate the abundance of cetaceans and sea turtles in the northwestern Atlantic Ocean during Jun – Aug 2011. This manuscript focuses on abundance estimates of cetaceans detected during the NEFSC surveys that covered waters from North Carolina to the lower Bay of Fundy, from the shore to the Gulf Stream, which is about 370 km (200 nmi) offshore. In a study area of about 463,000 km^2, over 9100 km of track lines were covered. To estimate abundance the two-independent team data-collection method and the mark-recapture distance sampling (MRDS) and multiple covariate distance sampling (MCDS) analysis methods were used. Overall, approximately 342,000 cetaceans of 18 species were estimated to be present in the study area. Species specific abundance estimates for the surveyed area range from 300 – 400 sei whales (*Balaenoptera borealis*) and humpback whales (*Megaptera novaeangliae*) each, to over 40,000 animals per species of harbor porpoises (*Phocoena phocoena*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), striped dolphins (*Stenella coeruleoalba*) and short-beaked common dolphins (*Delphinus delphis*). The abundance estimates of species that also reside south of the NEFSC survey area will be updated when the SEFSC abundance estimates are available.

INTRODUCTION

The Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) of NOAA Fisheries Service conducted line-transect aerial and shipboard abundance surveys to estimate the abundance of cetaceans and sea turtles in the northwestern Atlantic during the summer of 2011. This work is part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS) project, which is a multi-agency multi-year initiative to provide comprehensive assessments of marine mammal, sea turtle and seabird abundance and spatial distributions in US waters of the western North Atlantic Ocean. The partners of AMAPPS are NOAA Fisheries Service, US Fish and Wildlife Service (USFWS), Bureau of Ocean Energy Management (BOEM), and the US Navy1.

The data collected in this project are used to improve the assessment of marine mammal stocks as required under the US Marine Mammal Protection Act (MMPA). The MMPA requires that stocks of marine mammal species in US waters be maintained at or above their optimum sustainable population level (OSP), defined as the number of animals that results in their maximum net productivity. To meet this requirement, NOAA Fisheries Service conducts research to define stock structure, abundance estimates and estimates of annual human-caused mortality. The surveys conducted during summer 2011 provide data to support updated abundance estimates for US Atlantic oceanic stocks of marine mammals. These abundance estimates were last updated from data collected during 2004 or 2006, depending on the region (Waring et al. 2012). These data and results will also be used to support environmental assessments associated with BOEM and US Navy activities, including anticipated offshore energy exploration projects.

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1 For more information see http://www.nefsc.noaa.gov/read/protspp/mainpage/AMAPPS/index.html

This manuscript focuses on providing estimates of abundance for the cetaceans detected during the shipboard and aerial line-transect surveys conducted by the NEFSC during Jun – Aug 2011 in the waters north of North Carolina. The abundance estimates of species that also reside south of the NEFSC survey area will be updated when the SEFSC abundance estimates are available.

MATERIAL AND METHODS

Study Area

The northwestern Atlantic study area covered by the NEFSC was divided into three main spatial strata (Figure 1) that represent different habitats:

- *Gulf of Maine/Bay of Fundy (GOM/BOF)*: a stratum ranging from New York, US to St. John, New Brunswick, Canada (about 40˚N – 45˚N latitude) and from the shore to about the 100 m depth contour, which was surveyed by the NOAA Twin Otter airplane;
- *Shelf Break*: a stratum ranging from Virginia to the southern tip of Nova Scotia (about 38˚N – 42˚N latitude) and in waters that are between the 100 m and 2000 m depth contours, which was surveyed by the NOAA ship *Henry B. Bigelow*; and
- *Offshore*: a stratum ranging from North Carolina to the southern tip of Nova Scotia (about 36˚N – 42˚N latitude) and in waters that are offshore of the 2000 m depth contour to beyond the US EEZ and the Gulf Steam's northern wall, which was also surveyed by the NOAA ship *Henry B. Bigelow*.

In addition, two strata were identified that cover waters that are of interest to prospective locations for alternative energy projects:

- *BOEM-MA*: a stratum south of Massachusetts on the continental shelf in waters that are about 30 – 60 m deep (around 41˚N latitude), which was surveyed by both the NOAA Twin Otter airplane and NOAA ship *Henry B. Bigelow*.
- *BOEM-MidAtl*: two small strata off the coasts of New Jersey and Delaware that are on the continental shelf in waters of about 20 – 30 m deep (between 38˚N – 40˚N latitude), which was surveyed by the NOAA ship *Henry B. Bigelow*.

Extra track lines were covered in and around the BOEM-MA and BOEM-MidAtl strata to facilitate future, more detailed habitat studies of these regions. However, to develop abundance estimates a more even coverage within a stratum is desired. Thus, for the estimates presented in this paper, the fine scale aerial tracklines in the BOEM-MA stratum and the shipboard tracklines in the BOEM-MidAtl stratum were not used (Figure 2).

Field Methods

Both the ship and airplane sighting platforms collected line transect data from two teams that searched for animals simultaneously and independently of each other. This allowed estimation of abundance corrected for perception bias (bias due to a group being missed by the observers even though it is near the surface and available to be detected (Laake and Borchers 2004)).

Aerial Abundance Survey

The 2011 NEFSC aerial abundance line transect survey covered the GOM/BOF stratum (which includes the BOEM-MA stratum) using a NOAA Twin Otter airplane during 4 – 26 Aug 2011 (Figure 3). The survey was conducted along tracklines oriented either perpendicular to the coast or at an angle aligned to cut across the expected spatial onshore-offshore animal density gradients. The survey was flown at an altitude of 183 m (600 ft) above the water surface and at a speed of approximately 200 kph (110 kts). The survey was typically flown only when surface wind speeds were less than 20 kts or approximately sea state 4 or less on the Beaufort Scale.

Data were recorded onto a laptop computer running data acquisition software that recorded GPS locations automatically every two seconds, and recorded environmental conditions, effort and sighting information whenever entered by the observer team.

On-effort time periods are when the plane is flying level at survey altitude and speed on the trackline. At this time observers concentrate their visual search for animals within the region bound by straight down to the track line (0˚ inclination angle) to approximately 300 m from the track line (about 60˚ above vertical) and from as far forward as possible to slightly behind the plane. In addition, time was also spent searching farther from the track line. When a marine mammal, turtle, or other animal group was detected, the observer waited until the animal group was perpendicular to the plane, and then measured the angle (to the nearest degree) from vertically straight down to the center of the group using a digital inclinometer or markings on the windows. Fish species were recorded opportunistically. Species identifications were recorded only when the observers were certain of the identification; otherwise, the group was identified to the lowest taxonomic level possible (e.g., “fin or sei whale” or “unidentified turtle”).

The two-simultaneous team procedure involved five scientists onboard the plane that operated as two independent teams. The front team consisted of three scientists including two observers looking through bubble windows on either side of the plane and a dedicated data recorder collecting data from only the front team. The bubble windows allowed downward visibility including the trackline and unobstructed views to the horizon. The back team consisted of two scientists including one observer looking straight down through a belly window, and a dedicated data recorder collecting data from only the back team. The belly window observer had visibility of approximately 110 m (30˚) on either side of the trackline. The two observation teams operated on independent intercom channels, and were not able to alert each another when a sighting was detected. Observers rotated between the three sighting positions about every 30 minutes, while recorders were the same people the entire flight.

Data collected included information on sightings, effort, and environmental factors. For each cetacean group detected, the following sightings data were recorded: time of initial detection; observer who detected the group; ship’s latitude and longitude; angle of declination to the center of the group; species identification; best estimate of group size; direction group was swimming towards; initial cue that caught the observers eye (animal, splash, blow, footprint, birds, vessel or gear, windrows, disturbance, bubbles or other); initial behavior (swimming, milling, breaching, charging, feeding, logging, diving or other); and comments. Effort and environmental data collected included: time and location when starting or ending a track line or when another effort variable was updated; who was in each observation station; Beaufort sea state condition (0 – 5 in one decimal increments); percent cloud cover (0-100%); location of the glare swatch; severity of the glare within that swatch (none, slight, moderate, or severe), overall quality of sighting conditions for each observer (excellent, good, moderate, fair or poor), and comments.

To account for perception bias, groups of animals that were detected by both teams (termed a duplicate sighting) were defined based upon time, location and position relative to the trackline. This determination was made both during the data collection and data analysis phases.

Search effort was suspended if the plane needed to circle a group to verify species identification and group sizes, and to take photographs. If the front team made the sighting initially and they were unable to identify a group that was within about 180 m (45°) of the track line, they waited until the sighting was aft of the plane to allow the back team an opportunity to detect the sighting, then they asked the pilots to break effort and circle the sighting. During off-effort periods, additional groups were not recorded.

Shipboard Abundance Survey

The 2011 NEFSC shipboard abundance line transect survey covered the shelf break, offshore, BOEM-MA and BOEM-MidAtl strata using the NOAA ship *Henry B. Bigelow* during 4 Jun – 31 Aug 2011 (Figure 3). Parts of the track line that were surveyed in Beaufort 4 or 5 were re-surveyed in better sighting conditions. Only the effort and sightings from the times that were surveyed in the lowest Beaufort state were included in this analysis.

Two teams of observers simultaneously collected visual line transect data. Each team consisted of three on-duty observers and one observer at rest. The upper team was located on the flying bridge, 15.1 m above the sea surface, and the lower team was on the roll tank platform that was in front of the bridge and 11.8 m above the sea surface. Within each team, two observers searched using 25x150 powered binoculars, and one observer recorded the team's data and searched using naked eye concentrating on waters close to the ship that may have been overlooked by the observers searching using high-powered binoculars. Observers changed positions within their team every 30 minutes. During daylight hours, when weather permitted (i.e., at least 3.7 km visibility and Beaufort <5), observers searched the waters in front of the ship within a region bound by 90° on both sides of the transect line, and from the ship to the horizon.

Data collected included information on sightings, effort, and environmental factors. For each cetacean group detected, the following sightings data were recorded: time of initial detection; ship's latitude and longitude; bearing between the transect line and line of sight to the location of the group; radial distance between the ship and center of the group; species composition; level of certainty of the species identification (certain, probable, not sure); best estimate of group size; initial behavior of the group (swimming, porpoising, charging, aerobatics, bow riding, breaching, diving, feeding, fluking, logging, milling, motionless, unknown or other); initial sighting cue that attracted the observer to the group (body, splash, blow, footprint, birds, vessel or gear, wind row, or other); and comments. Bearings were measured using angle rings around the tripod-mounted binoculars or angle boards mounted on the recorder's desk. Radial distances were measuring using reticles in the eyepiece of the binoculars. The best group size was considered to be the best estimate, where the size of the group was assessed as often as possible as the group passed by the ship. Effort and environmental data recorded by the observers included the following: time of the data entry event; observers' positions; swell height and direction; apparent Beaufort conditions (0 – 5 in 1 decimal increments); magnitude of the sun glare (none, slight, moderate, severe); cloud coverage (in octaves); presence of rain or fog; and approximate visibility distance. The ship's instruments collected other environmental factors and recorded the following every second: ship's location; ship's speed and course; true wind speed and direction; water depth; water surface temperature; air temperature; and water drift direction and speed.

When it was not possible to confirm the species identification or group size and the group was within a couple miles from the ship, the ship went off-effort and approached the group to a distance where it was possible to confirm the identification and/or group size. A group was approached only after it was nearly 90° abeam or after both teams detected the group. When approaching a group, both teams were off-effort, so additional sightings were not recorded.

Species were identified to the lowest taxonomic level possible. When not possible to reliably distinguish an animal to the species level, species groupings were used. For example, “pilot whale spp.” was used because it was not possible to distinguish confidently between short-finned (*Globicephala macrorhynchus*) and long-finned (*G. melas*) pilot whales, and “unidentified dolphin” was used when it was only possible to determine the animals were dolphins of some species. Most of the groups identified to a level with the word “unidentified” were not used in the abundance estimates. Therefore, all abundance estimates are negatively biased, because an unknown proportion of the unidentified groups may have included individuals of any given species.

Analytical methods

In most cases, the abundance estimation was based on the independent observer approach assuming point independence (Laake and Borchers 2004) and calculated using the mark-recapture distance sampling (MRDS) option in the computer program Distance (version 6.0, release 2, Thomas *et al.* 2009). This analysis method, which is based on the abundance of groups and the expected size of those groups, is considered an extension of the standard line-transect distance analysis. In MRDS the sighting probability on the trackline implicitly includes the estimation of *g(0)*, which is the probability of detection of a group on the trackline. The probability of sighting a particular group is the product of two components. The first probability component (DS) corresponds to the standard unconditional detection function. This is defined as the probability of one or more observer teams detecting the group of animals, given its distance and possibly covariate values, where the probability of detection declines with increasing distance from the trackline following a known functional form (typically the half-normal or hazard function). The second probability component (MR) is the conditional detection function. This is defined as the probability of one team detecting the animal group, given the other team has detected it and given its’ distance and perhaps covariate values. The MR detection function results in a probability likelihood of detection on the trackline, which was modeled using a logistic regression approach and the “capture histories” of each sighting (i.e., seen by one or both teams). Details on the derivation, assumptions, and implementation of this estimation approach are provided in Laake and Borchers (2004). As a beginning point in the MRDS analyses for each species or species group, multiple covariate distance sampling (MCDS) analyses were investigated for each team separately and for the unique sightings from both teams to determine appropriate truncation distances and get a ballpark idea of which covariates were most influential and useful.

In the GOM/BOF stratum that was surveyed by the plane, all but one of the large whale sightings were detected by only the front team. Thus, to estimate abundance, the unique sightings of large whales from both teams were analyzed as a single team using the MCDS option in the program Distance. These single-team abundance estimates were then multiplied by species-specific estimates of *g(0)* that were derived from data collected in previous years (2002 – 2006) in the same time and area, on the same type of plane, and using the same three observer stations as used in 2011. These *g(0)* estimates were also used in the last reported abundance estimates for these species in the Atlantic stock assessment report (Waring et al. 2012). The estimate of *g(0)* for fin whales (*Balaenoptera physalus*), sei whales (*B. borealis*), and whale groups that are either fin or sei whales was 0.442 (CV=0.54), and *g(0)* for humpback whales (*Megaptera novaeangliae*) and sperm whales (*Physeter macrocephalus*) was 0.803 (CV=0.79).

In conventional line-transect analyses it is assumed groups are detected before the animals react to the sighting platform. If animals respond to the sighting platform prior to detection by moving either towards (attraction) or away from (avoidance) the transect line, density will be either over- or under-estimated, respectively. Methods developed in Palka and Hammond (2001) were used to investigate whether, and at what distance, cetaceans responded to the survey ship. Then for species with significant responsive movements, the modified trial analysis method described in Palka and Hammond (2001) was used to estimate the corrected abundance estimate. In brief, this involves first estimating the critical radial distance, c_r at which significant responsive movement began, if it occurs. This is done by using generalized additive models of the ratio n_1/n_3 from various distances away from the ship, where n_1/n_3 is the ratio of the number of groups that were initially swimming away from the ship (n_3) relative to the number of groups swimming toward the ship (n_1). When there is significant responsive movement, the corrected abundance estimate is calculated by post-stratifying the data to redefine the teams. One of the post-stratified "teams" was defined by the groups that were initially detected before they reacted (beyond c_r), which is the team that creates the trials for the other team and thus fulfills the assumption of the trial analysis method (Borchers et al. 1998; Palka and Hammond 2001). The other "team" was defined by the groups that were initially detected closer than c_r, and so may have already reacted to the ship. As is suggested in Buckland et al. (2004), full independence is assumed in cases where responsive movement is occurring.

For all of the analyses, detection probabilities were estimated using perpendicular distances that were right truncated following guidance in Buckland et al. (2001), thus accounting for differences in species and observers, their searching behavior and surveying conditions, etc. Model selection was based on the Akaike Information Criterion (AIC). Possible model forms for the MCDS analyses were the half-normal and hazard key functions, modified by the cosine, simple polynomial, or hermite polynomial series expansions. Possible forms of the MRDS DS detection functions were the half-normal or hazard key functions without series expansions. In both the MRDS and MCDS procedures, covariates were included in a model based upon AIC values following guidelines in Marques and Buckland (2003) and Laake and Borchers (2004). In the MR detection function model, interactions between covariates were also considered. For the independent observer MRDS analyses, both the point independence and full independence assumption was evaluated, where the AIC of these two types of models were used to select the appropriate model for each species (or species group).

To ensure sufficient samples sizes to accurately estimate the model parameters, in a couple cases several similar species were pooled. In addition, several species that were difficult to distinguish at sea were pooled together. For example, the shipboard data from all beaked whale (Mesoplodons) sightings were pooled in a global MRDS analysis that defined the DS and MR models. The global function was then applied separately to each species subset. So, given the covariate values of the observations of each species, species-specific detection functions were then defined. Finally, using the species-specific detection functions, expected group sizes and encounter rates, a species-specific abundance estimate was derived.

In some cases, sightings were identified as one of two (or more) species. Specifically, some groups of animals were identified as either a fin or sei whale, or as some sort of Mesoplodont beaked whale, or as one of the *Kogia* whales. These types of sightings were used to estimate the abundance of the positively defined species. For example, the final abundance of fin whales was derived from sightings positively identified as fin whales in addition to sightings identified as either a fin or sei whale. This was done by defining the final abundance estimate of fin whales ($abun_{all.fin}$) to be the sum of the abundance of positively defined fin whales ($abun_{pos.fin}$) and a portion of the abundance estimate of animals identified as either a fin or sei whales ($abun_{fin/sei} * g$):

$$abun_{all.fin} = abun_{pos.fin} + \left(abun_{fin/sei} * g\right) \qquad \text{eq. 1}$$

where

$$g = \frac{abun_{pos.fin}}{abun_{joint}}$$

$$abun_{joint} = abun_{pos.fin} + abun_{pos.sei}$$

and

$$var\left(abun_{fin/sei} * g\right) = \left(\frac{g*(1-g)}{abun_{joint}-1}\right).$$

This same sort of proration of unidentified groups was also used for groups of *Mesoplodont* beaked whales and *Kogia* spp.

The coefficient of variations (CV) of the abundance estimates were estimated using the delta method and empirical variance in encounter rate between samples (Buckland et al. 2001; Fewster et al. 2009). The CV of the abundance estimates that included a portion of unidentified groups included the variance of this percentage.

RESULTS

General

The ship surveyed the shelf break, offshore, BOEM-MA, and BOEM-MidAtl strata during three legs: leg 1: 4 – 21 Jun 2011; leg 2: 29 Jun – 13 Jul 2011; and leg 3: 20 – 31 Jul 2011, where 201.5 hours of on-effort surveying was realized during 37 good weather survey days (Figure 3). The aerial sighting platform surveyed the GOM/BOF stratum during 8 – 26 Aug 2011, where 34.5 hours of on-effort surveying was realized during 8 good weather flight days (Figure 3). In total 9,125 km were covered by both platforms in all of the strata, which covered 463,220 km^2 (Table 1). About 86% of the track lines were surveyed in Beaufort sea states of 3 or less (Table 1; Figure 3).

The shipboard survey detected 27 cetacean, 3 turtle and 1 seal species or species groups, along with several fish species – in particular basking sharks (*Cetorhinus maximus*) and ocean sunfish (*Mola mola*) (Table 2). The aerial survey detected 13 cetacean, 4 turtle, and 1 seal species or species groups, along with several fish species (Table 2). The locations of the cetacean sightings detected by the two platforms are in Figures 4-19, seals in Figure 20, sharks in Figures 21-22, turtles in Figures 23-24, and ocean sunfish in Figure 25. The general distributions of the species were:

- Northerly distributed species completely located within the GOM/BOF stratum included harbor porpoises (*Phocoena phocoena),* Atlantic white-sided dolphins (*Lagenorhynchus acutus)*, minke whales (*Balaenoptera acutorostrata)*, seals (Pinniped), loggerhead turtles (*Caretta caretta),* green turtles (*Chelonia mydas)*, and leatherback turtles (*Dermochelys coriacea)*;
- Species found in the Gulf of Maine and on the shelf break included short-beaked common dolphins (*Delphinus delphis*), fin whales, sei whales, humpback whales, sunfish, and basking sharks;
- Species found mostly on the shelf break included bottlenose dolphins (*Tursiops truncatus*), Risso's dolphins (*Grampus griseus)*, and pilot whales; and
- Species found mostly in deeper waters included striped dolphins (*Stenella coeruleoalba)*, Atlantic spotted dolphins (*Stenella attenuata)*, rough-toothed dolphins (*Steno bredanensis)*, beaked whales, sperm whales, and *Kogia* spp.

Abundance Estimates

Covariates used to develop the abundance models are defined in Table 3. There were sufficient data to estimate abundance of 18 species or species groups using the shipboard and aerial survey data (Table 4). Some species groups were formed because it was difficult to distinguish them when at sea. Other species groups were formed because there were low sample sizes of the individual species. Thus, to estimate their abundance the data from all species within the species group were pooled. Species groups formed due to difficulties in distinguishing them at sea included:

- offshore and coastal forms of bottlenose dolphins;
- long-finned pilot whales and short-finned pilot whales;
- beaked whales (Cuvier's beaked whales (*Ziphius cavirostris*), Gervais' beaked whales (*Mesoplodon europaeus*), Sowerby's beaked whales (*M. bidens*), and unidentified Mesoplodonts); and
- Dwarf sperm whales (*Kogia simus*), pygmy sperm whales (*K. breviceps*), and dwarf/pygmy sperm whales (*Kogia spp.*).

Species pooled because of small sample sizes included:

- large whales detected by the plane (fin whales, sei whales, fin/sei whales, humpback whales, and sperm whales);
- fin whales, sei whales and fin/sei whales detected by the ship; and
- minke whales and humpback whales detected by the ship;

Bottlenose dolphins and common dolphins were detected in and around the BOEM-MA stratum from both platforms. However, since the plane detected only a few groups, the abundance estimates for these two species for this region were generated from the shipboard data using only the area surveyed by the ship. A few bottlenose dolphin sightings were also detected in the BOEM-MidAtl stratum. However, since the SEFSC survey covered this and the surrounding areas more thoroughly, no estimates for bottlenose dolphin sightings seen within the BEOM-MidAtl stratum were generated using NEFSC data.

The average group sizes of large whales and *Kogia* spp. were generally 1 – 2 animals per group (Table 4). Species such as harbor porpoises and beaked whales had average group sizes ranging from 1 – 4 animals. Species such as Risso's dolphins and pilot whales averaged slightly larger group sizes of 5 – 10 animals. Bottlenose dolphins, short-beaked common dolphins, and Atlantic white-sided dolphins were on average found in groups of 11 – 20 animals. While the offshore dolphins (Atlantic spotted dolphins and striped dolphins) were found in the largest groups (averaging >20 animals).

Only Risso's dolphin sightings within 1800 m (=c_r) showed evidence of responsive movement (avoidance) to the ship. This was evident by the 4.3 value of n_3/n_1, which is significantly different from one (Table 5). The abundance estimate accounting for this was 15,197 (cv=0.55).

The covariates most commonly determined to significantly contribute to the detection function DS models included Beaufort sea state, glare severity and group size, while team and group size were the most common covariates in the mark recapture MR models (Table 6). The significant covariates for the shipboard data were similar to those for the aerial data. The estimated effective strip widths derived from the average probability of the detection function from the MRDS analysis (Table 6) ranged from about 100 – 200 m for harbor porpoises, Atlantic white-sided dolphins and sperm whales (detected from the plane) to over 2000 m for sperm whales, fin and sei whales, and striped dolphins (detected from the ship).

The intermediate abundance estimates used in equation 1 to derive the final abundances of species that include some unidentified groups are found in Table 7. For example, an estimate of 273 animals (CV=0.54) detected by the ship and plane in all strata were identified as either fin or sei whales (Table 7). Using equation 1 and the data in Table 7, this abundance estimate was prorated and added to the abundance estimates of positively identified fin whales (1,368 CV=0.36) and positively identified sei whales (311 CV=0.59) to result in the final abundance estimates (Table 8) of 1,595 (CV=0.33) fin whales and 357 (CV=0.52) sei whales. The same process was used to prorate the abundance of unidentified Mesoplondonts and *Kogia* spp. (Tables 7 and 8).

The total abundance of the 18 species observed in the surveyed area was estimated to be 342,000 animals (Table 8). Abundance estimates range from 300 – 400 animals per species of sei whales and humpback whales, to over 40,000 animals per species of harbor porpoises, Atlantic white-sided dolphins, striped dolphins and short-beaked common dolphins.

No abundance was estimated for a few rarely detected species: 1 sighting of killer whales (*Orcinus orca*), 1 sighting of Pan-tropical spotted dolphins (*Stenella frontalis*), 4 sightings of rough-toothed dolphins, and 1 sighting of right whales (*Eubalaena glacialis*). In addition, the sightings identified as unidentified dolphin, Stenella spp. or unidentified whale were not added into any of the abundance estimates of positively identified species because it was not clear if the strategy used in equation 1 was the appropriate approach for such groups that could be one of many species.

DISCUSSION

Only Risso's dolphins appear to have significantly responded to the sighting platform NOAA ship *Henry B. Bigelow* by avoiding the ship. This result was also documented in the last NEFSC large-scale line transect sighting survey in these waters, which was conducted in 2004 on the *RV Endeavor*. The only other significant response on the 2004 survey was by pilot whales that appeared to have been attracted to the *RV Endeavor*, which was not observed on the NOAA ship *Henry B. Bigelow*.

For a couple of species, several models fit the data nearly as well as the model that was chosen; that is, several models were within two AIC units of the chosen model. In all these cases, the resulting abundance and CV estimates were similar to that from the chosen model. A model averaging approach could be used to incorporate this uncertainty. It would not change the abundance estimates by much, so it was not done.

Using mark-recapture distance sampling techniques and including significant covariates that affect the detection functions was used in an attempt to account for perception bias, which is caused by animals being missed, particularly on the track line, even though they are available to be detected. This might be due to, for example, poor sighting conditions or inexperienced observers. However, this analysis did not account for availability bias, which is caused by animals being missed because they are not available to be detected. This might be due to animals diving so far and so long below the surface that they are never in a position to be detected by an observer. Thus, the presented abundance estimates should be considered as surface abundance estimates and are most likely a negatively biased population estimate. In this respect, the surface abundance estimates presented in this paper are comparable to those reported in previous US stock assessment reports, which also do not account for availability bias (e.g., Waring et al. 2012).

Additional covariates could potentially help model the encounter rates or group sizes. In particular, it is possible that environmental factors, such as water temperature, bottom depth, and presence of fronts could assist in producing better abundance estimates, as they may help explain the variability in the encounter rates and group sizes. Thus, in the future including these variables into habitat and spatially explicit abundance estimates could result in better abundance estimates that are more precise and less biased.

The presented abundance estimates are from data collected from waters north of North Carolina through the Gulf of Maine and lower Bay of Fundy. For many of these species, their full habitats extend farther south or north. The abundance estimates for the portion of the habitats that extend farther south will be derived from the SEFSC's analyses of their shipboard and aerial surveys. The resulting SEFSC abundance estimates will subsequently be added to those presented here to develop the best available abundance estimate for these species. Since there were no concurrent surveys that were in the more northerly Canadian waters, there are no other estimates to add to those presented in this paper.

For the most northerly-distributed species (harbor porpoise, Atlantic white-sided dolphins, sei whales, minke whales, and humpback whales), the region covered in the present survey is similar to the regions covered in previous surveys that are presented in the Stock Assessment Reports. Thus, for these species it is possible to compare the presented 2011 abundance estimates with those estimated from previous surveys (Figures 26 – 32). However, since the surveys over the years do not cover the exact same regions the estimates are not exactly comparable. Ignoring this detail, the 2011 estimates for these northerly species are similar to past estimates reported in the Stock Assessment Reports. For harbor porpoises, minke whales, humpback whales, and fin whales the 2011 estimates are slightly lower, though not significantly so. The estimates of Atlantic white-sided dolphins have jumped up and down over the time series so there is no clear trend. The numbers of sei whales and short-beaked common dolphins seen in the current study area has increased slightly. To account for the slightly differing survey areas that were covered in the different years, the habitat and spatially explicit abundance methodology could be used to expand results from the surveyed areas to the full area surveyed in all years. After this is done, the annual abundance estimates would be more directly comparable to conduct valid trend analyses.

The groups of dolphins and whales that were labeled as unidentified dolphin, unidentified whale were not included in the abundance estimates of any of the species. Thus, the presented abundance estimates may be negatively biased due to not including these unidentified groups. However, since many of the unidentified groups were far from the ship, they may not have had a large influence on the abundance estimate if they had been included. One possible way that is being explored to include these unidentified groups into the abundance estimates of the positively identified species is to associate the positively identified and unidentified groups with habitat characteristics. If there is a strong association between the positively identified species and their habitat, then for each unidentified group it might be possible to assign a species id probability.

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Table 1. General description of each stratum covered by the NEFSC aerial (8 – 26 Aug 2011) and shipboard (4 Jun – 31 Jul 2011) surveys: including the area (in km^2), platform used, and length of track lines (in km) covered within the Beaufort sea state levels.

			Track line length (km) within Beaufort sea state levels						
Strata	Area (km^2)	Platform	0	1	2	3	4	5	total
shelf	54,376	ship	0	192.5	415.1	494.6	372.5	34.9	1509.6
offshore	197,953	ship	129.9	194.2	607.8	355.6	253.7	56.6	1597.8
GOM/BOF	199,656	plane	84.8	1714.1	1947.8	1176.4	390.1	0	5313.2
BOEM-MidAtl	2,563	ship	0	0	29.1	10.9	194.6	7.3	241.9
BOEM-MA	8,672	ship	48.5	168.1	191	54.5	0	0	462.1
TOTAL	463,220	ship + plane	263.2	2268.9	3190.8	2092	1211	98.8	9124.6
Cumulative percent of total			0.03	0.28	0.63	0.86	0.99	1.00	

Table 2. Number of detected groups by species (or species group), team and platform.

		ship		plane	
Species		upper	lower	front	back
Atlantic spotted dolphin	*Stenella attenuata*	27	19		
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	1	0	15	10
Bottlenose dolphin spp.	*Tursiops truncatus*	84	63	3	0
Short-beaked common dolphin	*Delphinus delphis*	112	114	8	5
Cuvier's beaked whale	*Ziphius cavirostris*	30	15		
Dwarf sperm whale	*Kogia simus*	12	3		
Fin whale	*Balaenoptera physalus*	40	22	7	0
Fin/sei whales	*B. physalus or B. borealis*	5	10	4	0
Gervais' beaked whale	*Mesoplodon europaeus*	4	3		
Harbor porpoise	*Phocoena phocoena*	4	1	129	60
Humpback whale	*Megaptera novaeangliae*	11	12	8	0
Killer whale	*Orcinus orca*	1	1		
Minke whale	*B. acutorostrata*	15	12	18	3
Pantropical spotted dolphin	*Stenella frontalis*	0	1		
Pilot whales spp.	*Globicephala spp.*	44	25		
Pygmy sperm whale	*Kogia breviceps*	8	5		
Pygmy/dwarf sperm whales	*Kogia spp.*	6	2		
Right whale	*Eubalaena glacialis*			1	0
Risso's dolphin	*Grampus griseus*	88	73		
Rough-toothed dolphin	*Steno bredanensis*	4	2		
Sei whale	*Balaenoptera borealis*	7	4	1	1
Sowerby's beaked whale	*Mesoplodon bidens*	7	5		
Sperm whale	*Physeter macrocephalus*	43	34	2	0
Stenella spp.	*Stenella spp.*	14	9		
Striped dolphin	*Stenella coeruleoalba*	66	43		
Unidentified dolphin	*Delphinidae*	130	97	8	5
Unidentified whale	*Mysticeti*	18	30	8	2
Unidentified *Mesoplodon*	*Mesoplodonts spp.*	11	4		
TOTAL CETACEANS		792	609	212	86
Basking shark	*Cetorhinus maximus*	16	17	61	24
Hammerhead shark	*Sphyrna spp.*			1	0
Ocean sunfish	*Mola mola*	38	15	223	63
Green turtle	*Chelonia mydas*			5	0
Leatherback turtle	*Dermochelys coriacea*	3	1	9	2
Loggerhead turtle	*Caretta caretta*	5	5	9	8
Unidentified turtle	*Chelonioidea*	6	1	1	1
Unidentified seal	*Pinniped*	1	0	18	12
TOTAL ALL SPECIES		861	648	539	196

Table 3. Description of covariates used in abundance analyses of the plane and shipboard data.

Abbreviation	Description	platform	Type	Values
beaufort	Beaufort sea state	both	continuous	0-6, in increments of 0.1
behavior	Activity the group was initially doing	both	factor	Low profile (such as, swimming, feeding, logging), Higher profile (such as, porpoising, charging, breaching)
cloud	Percent cloud cover	both	continuous	0-100, usually in increments of 10
cue	Feature of sighting that initially was detected	both	factor	Low profile (such as body or footprint), Higher profile (such as splash or blow)
glare	Severity of sun glare in the area where there is glare	both	continuous	0=none, 1=slight, 2=moderate, 3=severe
sighttime	Time of day sighting initially detected	both	continuous	6am-7pm, in decimal format (i.e., 3:30pm = 15.5)
size	Number of animals in the group	both	continuous	1-1000
species	Name of species, when multiple species are pooled	both	factor	Species name
subjective	Subjective overall average quality of the sighting conditions as determined by the observers	plane	continuous	1=excellent, 2=good, 3=moderate, 4=fair, and 5=poor
swellht	Approximate height of the swell (m)	ship	continuous	0-5 m
viz	Approximate farthest distance (m) that can be seen in front of the horizon, fog, or haze	ship	continuous	2000-16000 m

Table 4. For each sighting platform, aerial (A) and shipboard (B), and species group the following were reported: number of groups detected by the aerial front team (n-front), aerial back team (n-back), shipboard upper team (n-upper), shipboard lower team (n-lower); number of duplicate sightings (n-dups); and the expected group size (E(s)) with its coefficient of variation (CV(E(s)). Pooled species group names are in italics.

A. Aerial data

Species	n-front	n-back	n-dups	E(s)	CV(E(s))
Harbor porpoise	127	60	14	2.97	0.11
Atlantic white-sided dolphin	12	10	7	14.55	0.31
Minke whale	18	3	2	1	0
Large whales	22	1	0	1.09	0.06
Fin whale	7	0	0	1	0
Sei whale	1	1	0	1	0
Fin or Sei whale	4	0	0	1	0
Humpback whale	8	0	0	1.25	0.13
Sperm whale	2	0	0	1	0

B. Shipboard data

Species	n-upper	n-lower	n-dups	E(s)	CV(E(s))
Fin or Sei whales	47	35	16	1.3	0.13
Fin whale	37	22	13	1.3	0.17
Sei whale	7	4	2	1.1	0.30
Fin or Sei whale	3	9	1	1.2	0.22
Minke and Humpback whales	22	21	7	1.1	0.16
Minke whale	11	11	4	1.0	0.28
Humpback whale	11	10	3	1.1	0.19
Sperm whale	39	29	14	1.7	0.23
Bottlenose dolphin spp.	73	59	41	14.6	0.26
Short-beaked common dolphin	103	108	60	17.7	0.23
Atlantic spotted dolphin	21	15	14	23.9	0.42
Risso's dolphin	83	69	40	7.1	0.35
Pilot whales spp.	39	22	16	9.1	0.12
Striped dolphin	59	39	33	46.3	0.21
Beaked whales spp.	47	25	9	1.6	0.17
Cuvier’s beaked whale	26	14	4	1.6	0.27
Gervais' beaked whale	4	3	2	2.4	0.63
Sowerby's beaked whale	7	5	2	1.2	0.15
Unid. Mesoplondants	10	3	1	2.7	0.34
Kogia spp.	26	10	4	1.5	0.32
Dwarf sperm whale	12	3	2	1.5	0.44
Pygmy sperm whale	8	5	1	1.5	0.27
Dwarf/pygmy sperm whale	6	2	1	1.2	0.34

Table 5. Results from investigating evidence of responsive movement to the ship. For each species group, the following were reported: estimated critical radial distance in meters (c_r); number of groups detected closer and farther than c_r that were swimming toward the four quadrants[1]; ratio of n_3/n_1; and p-value of the binomial test where H_0: $n_3/n_1 = 1$, i.e., no responsive movement. * indicates the p-value is significant and the H_0 is rejected.

Species	c_r (m)	stratum	n_1	n_2	n_3	n_4	n_3/n_1	p-value
Fin or Sei whales	2300	close	6	4.5	6.5	5	1.1	1.00
		far	11	8.5	9.5	13	0.9	1.00
Minke and Humpback whales	1700	close	0	8	3.5	2.5	-	0.18
		far	4.5	5	8	7.5	1.8	0.48
Sperm whale	3000	close	5.5	7	0.5	7	0.1	0.09
		far	8.5	7.5	9	11	1.1	1.00
Bottlenose dolphins spp.	1550	close	4.5	7	13	5.5	2.9	0.07
		far	17	21	27.5	26.5	1.6	0.15
Short-beaked common dolphin	2300	close	15	30	27	18	1.8	0.06
		far	20	31	34	20	1.7	0.06
Atlantic spotted dolphin	600	close	2	1	4	0	2.0	0.69
		far	4	7	7	12	1.8	0.55
Risso's dolphin	1800	close	4.5	20	19.5	11	4.3[2]	0.003*
		far	15	27.5	31	15.5	2.1	0.03
Pilot whales spp.	2900	close	4	14.5	6	2.5	1.5	0.75
		far	13	11.5	5.5	6	0.4	0.13
Striped dolphin	2650	close	2	7.5	6	3.5	3.0	0.29
		far	12	17.5	16.5	23	1.4	0.51
Beaked whales spp.	2500	close	6	2.5	7.5	10	1.3	0.89
		far	10	12	11.5	9.5	1.1	0.91
Kogia spp.	2000	close	6.5	4	0.5	0	0.1	0.05
		far	8.5	4	3.5	1	0.4	0.25

1 $n_1 = 0° – 90°$; $n_2 = 90° – 180°$; $n_3 = 180° – 270°$; $n_4 = 270° – 360°$; values on the borders were randomly put into one of the neighboring quadrants; 0° indicates swimming straight ahead and parallel with the ship's movement on the track line; 90° indicates swimming perpendicular to the track line and toward the right, etc.

2 Value of ratio n_3/n_1 significantly larger than one indicating avoidance behavior when group was initially detected within $c_r = 1800$ m.

Table 6. Intermediate parameters used in the calculation of the abundance when using (A) the mark-recapture distance sampling (MRDS) in the independent observer configuration assuming point independence, (B) multiple covariate distance sampling (MCDS) procedures, and (C) MRDS in the trial configuration assuming full independence to account for the responsive movement. In each part the following is included: the right truncation distance (in meters); key model and covariates chosen for each model; Cramer-von Mises goodness-of-fit test p-value (C-vM p-value); AIC value; estimate of effective half strip width (esw) and its coefficient of variation (cv(esw)), measured in meters; and the overall probability of detecting an animal group by at least one observer (p) and its coefficient of variation (cv(p)).

A. MRDS				covariates							
Species	platform	trunc dist (m)	key model	detection function (DS)	mark-recapture (MR)	C-vM test p-value	AIC	esw (m)	CV (esw)	over all p	cv(p)
Harbor porpoise	plane	350	HN	distance+glare	distance + team + swmdir + distance:team	0.85	2117.5	186	0.07	0.35	0.20
Atlantic white-sided dolphin	plane	200	HN	distance + beaufort	1	0.43	188.3	95	0.33	0.41	0.34
Fin and Sei whales	ship	5000	HAZ	distance+size+behavior	distance+team + distance:team	0.98	1234.5	2008	0.2	0.23	0.26
Humpback and Minke whales	ship	3000	HAZ	distance+beaufort+glare	distance+size	0.37	622.2	1151	0.29	0.30	0.32
Sperm whale	ship	6000	HAZ	distance+glare+size	distance+size+cue+ team	0.54	1036.4	3946	0.12	0.53	0.14
Bottlenose dolphin spp.	ship	3000	HAZ	distance	team*(distance+size +beaufort)	0.75	1617.0	1201	0.26	0.35	0.26
Short-beaked common dolphin	ship	4000	HAZ	distance+beaufort+cue+ glare	distance + size + swmdir + distance:size + size:swmdir	0.51	2720.7	1210	0.23	0.20	0.27
Atlantic spotted dolphin	ship	2000	HAZ	distance+beaufort+swellht	distance + cue + team	0.50	363.5	1174	0.32	0.59	0.32
Pilot whales spp.	ship	5000	HAZ	distance+glare	sighttime	0.66	846.6	1355	0.53	0.16	0.60
Striped dolphin	ship	5000	HAZ	distance	distance + team + size	0.78	1207.1	3239	0.10	0.61	0.11
Beaked whales spp.	ship	4000	HAZ	distance+species	1	0.66	1153.9	1198	0.43	0.13	0.45
Kogia spp.	ship	3500	HAZ	distance+species+sighttime	distance+team	0.35	557	1849	0.20	0.22	0.37

Table 6, continued. Intermediate parameters used in the calculation of the abundance when using (A) the mark-recapture distance sampling (MRDS) in the independent observer configuration assuming point independence, (B) multiple covariate distance sampling (MCDS) procedures, and (C) MRDS in the trial configuration assuming full independence to account for the responsive movement. In each part the following is included: the right truncation distance (in meters); key model and covariates chosen for each model; Cramer-von Mises goodness-of-fit test p-value (C-vM p-value); AIC value; estimate of effective half strip width (esw) and its coefficient of variation (cv(esw)), measured in meters; and the overall probability of detecting an animal group by at least one observer (p) and its coefficient of variation (cv(p)).

B. MCDS				covariates							
Species	platform	trunc dist (m)	key model	detection function (DS)	mark-recapture (MR)	C-vM test p-value	AIC	esw (m)	CV (esw)	over all p	cv(p)
Minke whale	plane	600	HN	distance+beaufort	NA	0.55	240.4	369	0.24	0.66	0.24
Large whales	plane	2100	HN	distance + species	NA	0.65	327.0	454	0.42	0.22	0.42
Fin whale								340	0.43	0.16	0.43
Sei whale								281	0.83	0.13	0.83
Fin or Sei whales								1788	0.36	0.86	0.36
Humpback whale								1462	0.21	0.70	0.21
Sperm whale								131	1.21	0.06	1.21

C. Trial configuration - Full independence				covariates							
Species	platform	trunc dist (m)	key model	detection function (DS)	mark-recapture (MR)	C-vM test p-value	AIC	esw (m)	CV (esw)	over all p	cv(p)
Risso's dolphin	ship	4000	HAZ	1	distance + beaufort + swmdir + glare + sighttime + glare:sighttime	0.81	1211.0	1561	0.13	0.26	0.46

Table 7. For each stratum and the total of all strata, the intermediate abundance estimates used in Equation 1, where a portion of the abundance of uncertain identified sightings is added to abundance of positively identified sightings. The resulting final abundance estimates are reported in Table 8.

	GOM/BOF		Shelf		Offshore		TOTAL	
Species	N	CV(N)	N	CV(N)	N	CV(N)	N	CV(N)
Fin whale	386	0.60	982	0.45	0	0	1,368	0.36
Sei whale	134	1.08	177	0.64	0	0	311	0.59
Fin or Sei whale	42	0.59	231	0.63	0	0	273	0.54
Total	562	0.49	1,390	0.34	0	0	1,952	0.28
Cuvier's beaked whale	0	0	946	0.48	4,017	0.44	4,963	0.42
Gervais' beaked whale	0	0	0	0	1,519	1.16	1,519	1.16
Sowerby's beaked whale	0	0	1,869	1.07	1,353	1.12	3,222	0.98
Unidentified mesoplodonts	0	0	138	0.59	621	0.72	759	0.61
Total	0	0	2,952	0.71	7,510	0.43	10,462	0.44
Dwarf sperm whale	0	0	0	0	860	0.78	860	0.78
Pygmy sperm whale	0	0	50	0.68	559	0.52	609	0.48
Dwarf or pygmy sperm whale	0	0	13	1.06	301	0.63	314	0.61
Total	0	0	63	0.61	1,720	0.64	1,783	0.62

Table 8. Final abundance estimates from the NEFSC shipboard (Shelf and Offshore) and aerial (GOM/BOF) surveys conducted during Jun – Aug 2011 in waters north of North Carolina, for each stratum and the total of all strata.

	GOM/BOF		Shelf		Offshore		TOTAL	
Species	N	CV(N)	N	CV(N)	N	CV(N)	N	CV(N)
Harbor porpoise	79,883	0.32	0	0	0	0	79,883	0.32
Atlantic white-sided dolphin	48,819	0.61	0	0	0	0	48,819	0.61
Fin whale	417	0.56	1,178	0.40	0	0	1,595	0.33
Sei whale	145	1.00	212	0.54	0	0	357	0.52
Minke whale	2,538	0.87	53	0.73	0	0	2,591	0.81
Humpback whale	129	0.41	206	0.55	0	0	335	0.42
Sperm whale	287	1.40	161	0.46	1,145	0.38	1,593	0.36
Bottlenose dolphin spp.	814	0.52	13,911	0.76	12,041	0.39	26,766	0.52
Short-beaked common dolphin	2,855	0.33	54,507	0.30	9,829	0.71	67,191	0.29
Atlantic spotted dolphin	0	0	1,677	0.60	25,121	0.70	26,798	0.66
Risso's dolphin	0	0	4,521	0.48	10,676	0.72	15,197	0.55
Pilot whales spp.	0	0	9,483	0.65	2,382	0.59	11,865	0.57
Striped dolphin	0	0	3,822	0.28	43,060	0.36	46,882	0.33
Cuvier's beaked whale	0	0	946	0.48	4,016	0.44	4,962	0.37
Sowerby's beaked whale	0	0	2,007	0.99	1,646	0.93	3,653	0.69
Dwarf sperm whale	0	0	0	0	1,042	0.65	1,042	0.65
Pygmy sperm whale	0	0	63	0.61	678	0.43	741	0.40
Gervais' beaked whale	0	0	0	0	1,847	0.96	1,847	0.96
TOTAL							342,118	

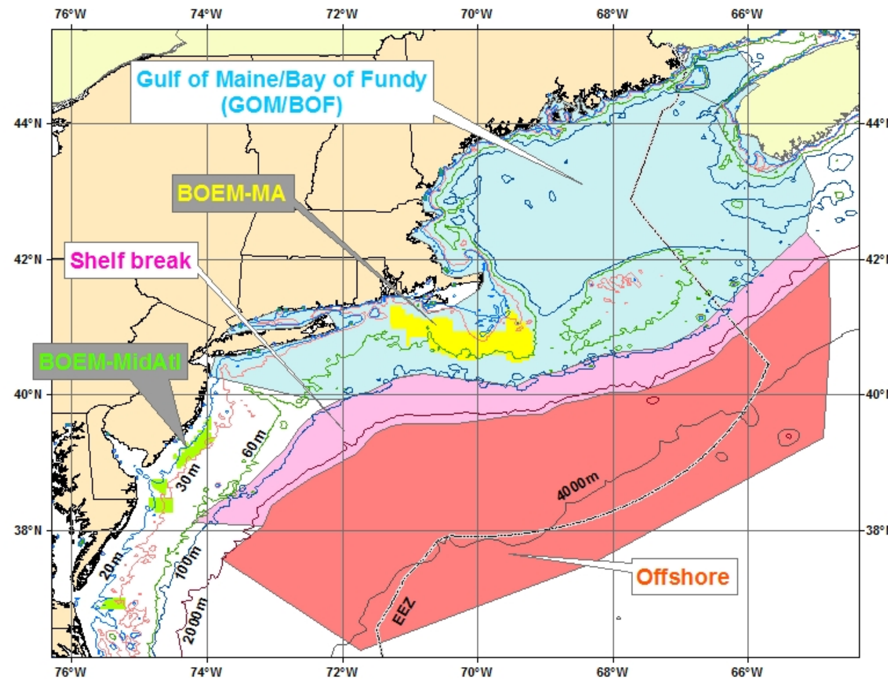

Figure 1. Spatial strata used in the NEFSC summer 2011 shipboard and aerial abundance survey.

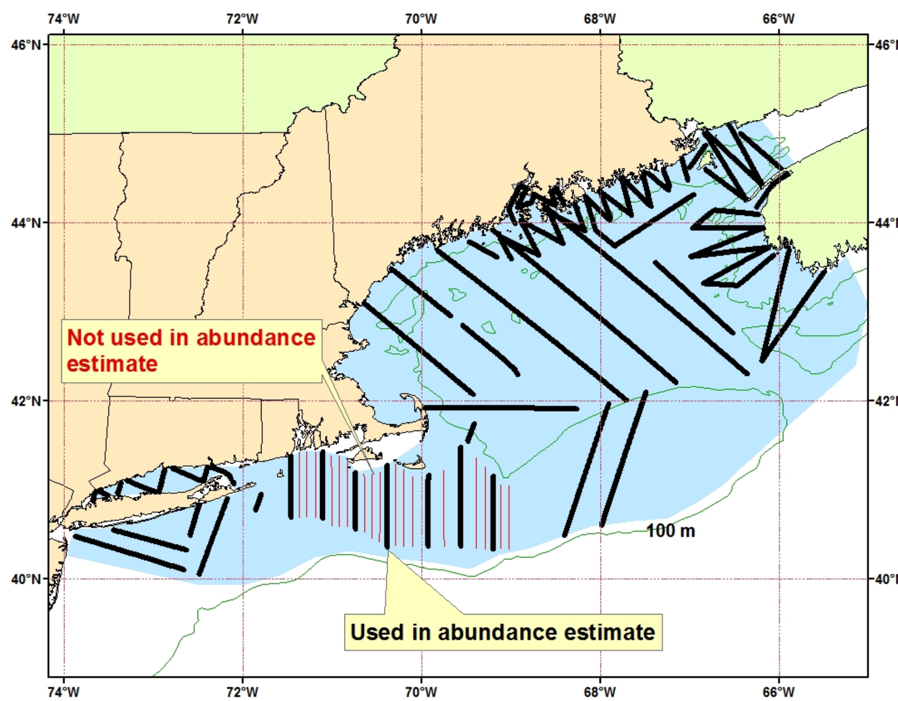

Figure 2. Location of aerial track lines used in abundance estimation (black lines) and those to be used in future habitat studies (red lines).

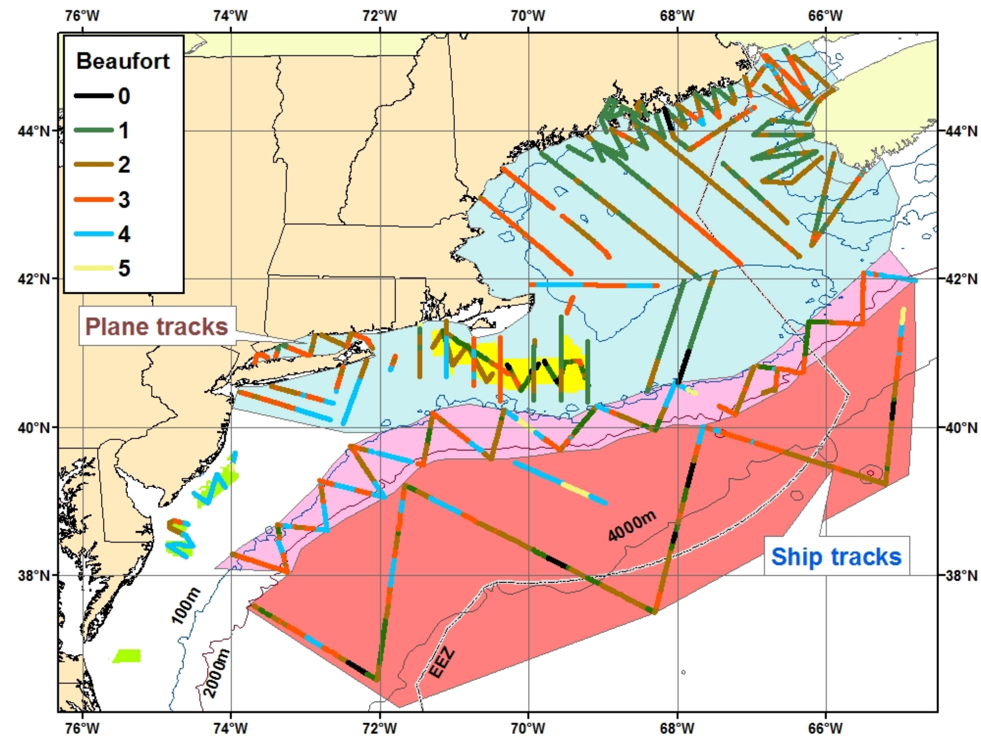

Figure 3. Location of track lines and the Beaufort conditions when the tracks were surveyed. The airplane surveyed the GOM/BOF and BOEM-MA strata while the ship surveyed the shelf break, offshore, BOEM-MA, and BOEM-MidAtl strata.

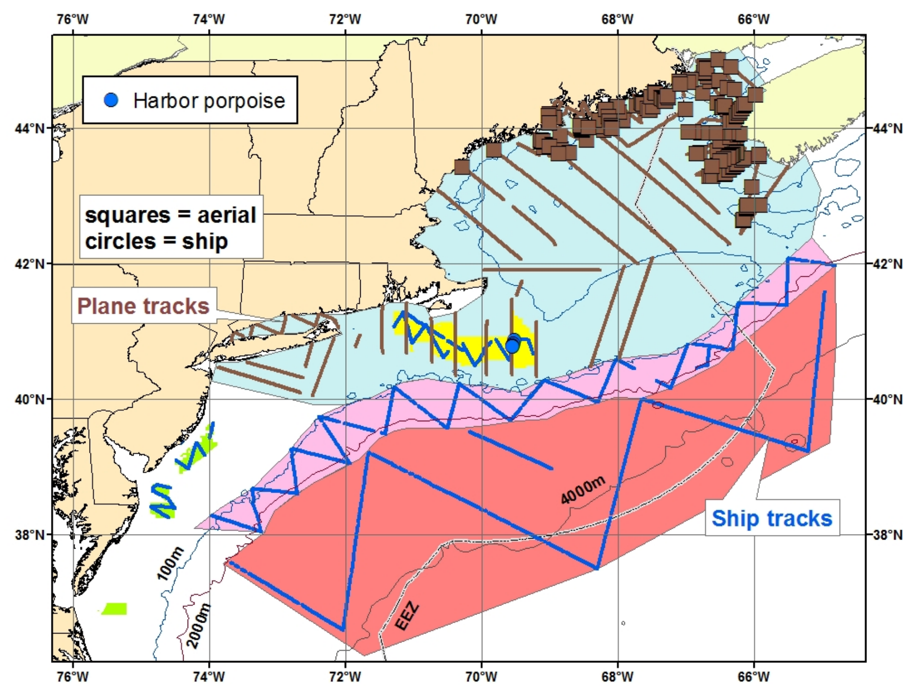

Figure 4. Location of harbor porpoise (*Phocoena phocoena*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

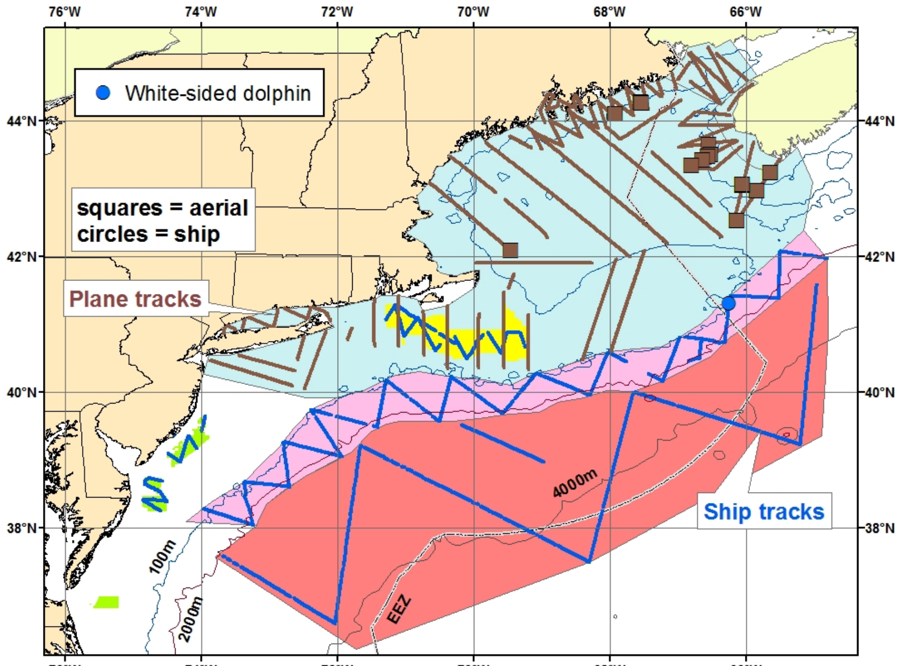

Figure 5. Location of Atlantic white-sided dolphin (*Lagenorhynchus acutus*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

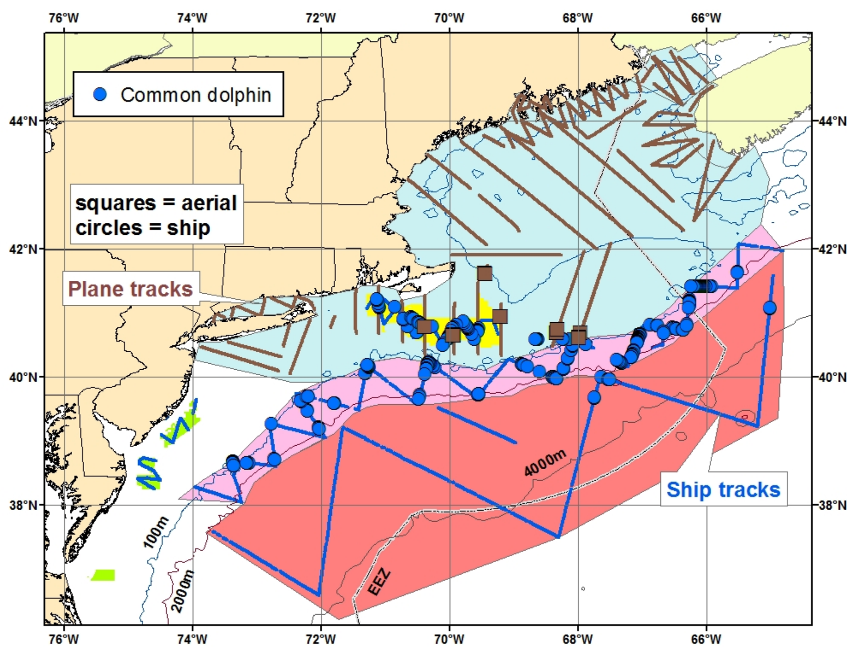

Figure 6. Location of short-beaked common dolphins (*Delphinus delphis*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

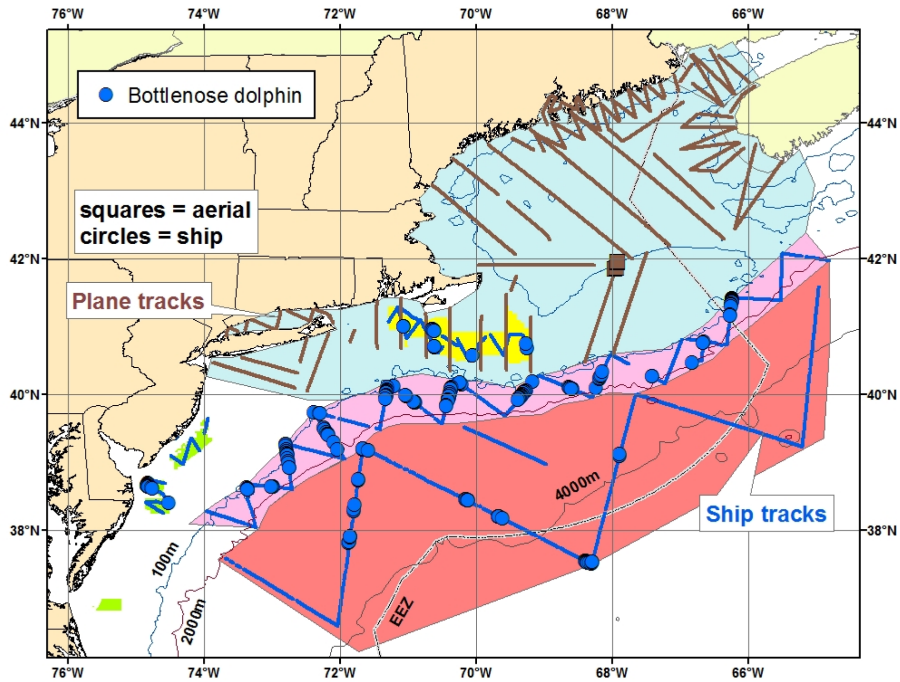

Figure 7. Location of bottlenose dolphins spp. (*Tursiops truncatus*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

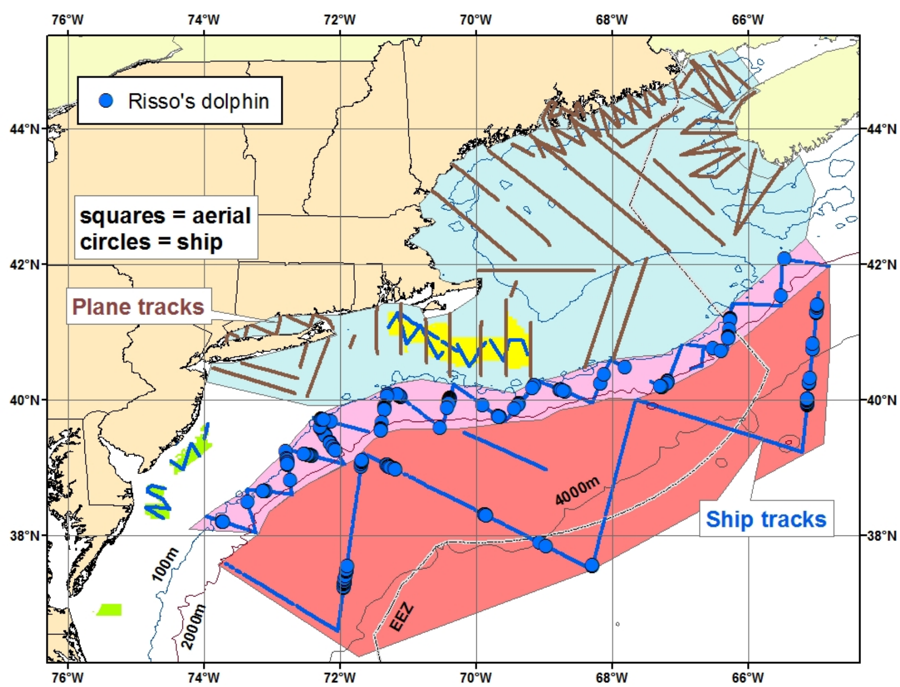

Figure 8. Location of Risso's dolphins (*Grampus griseus*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

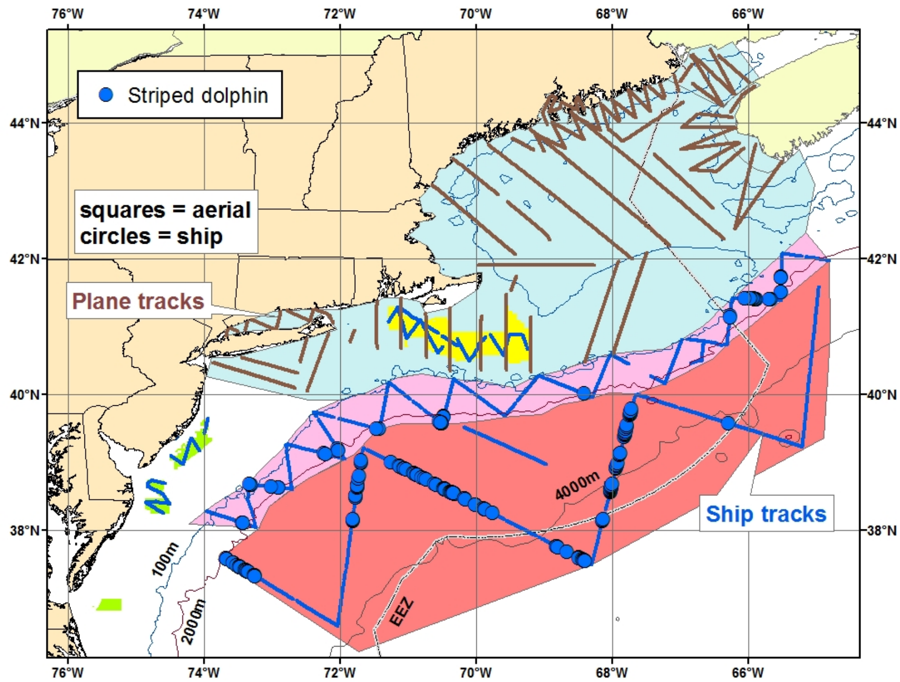

Figure 9. Location of striped dolphin (*Stenella coeuleoalba*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

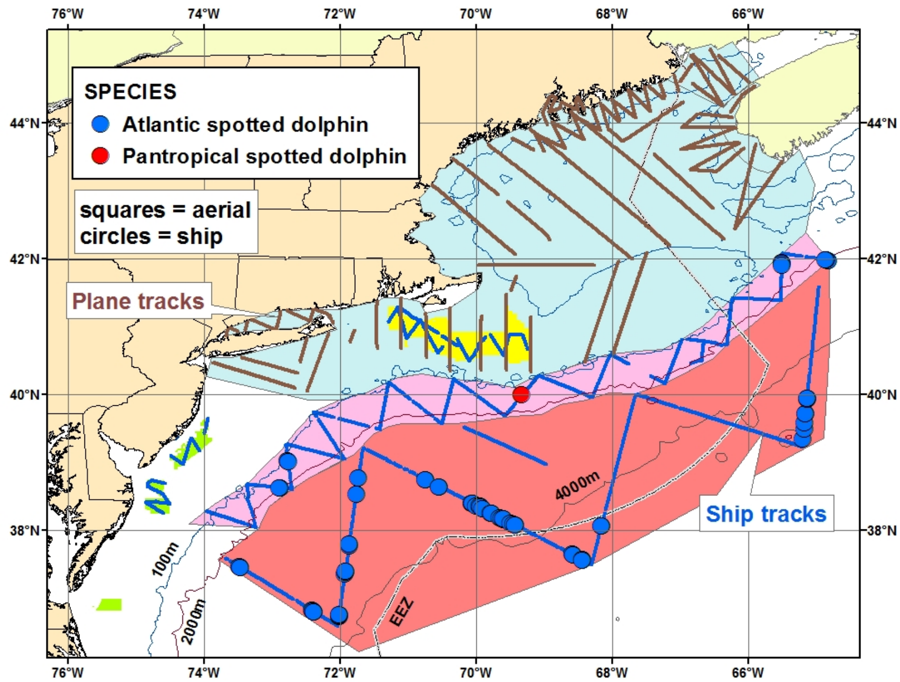

Figure 10. Location of Atlantic spotted dolphin (*Stenella attenuata*) and Pantropical spotted dolphin (*Stenella frontalis*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

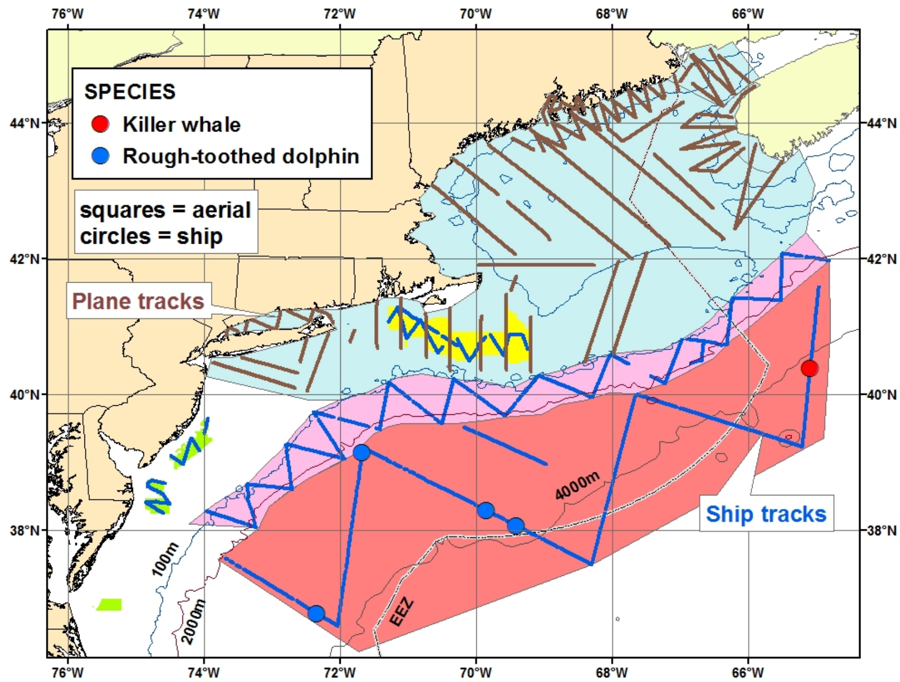

Figure 11. Location of rough-toothed dolphins (*Steno bredanensis*) and killer whale (*Orcinus orca*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

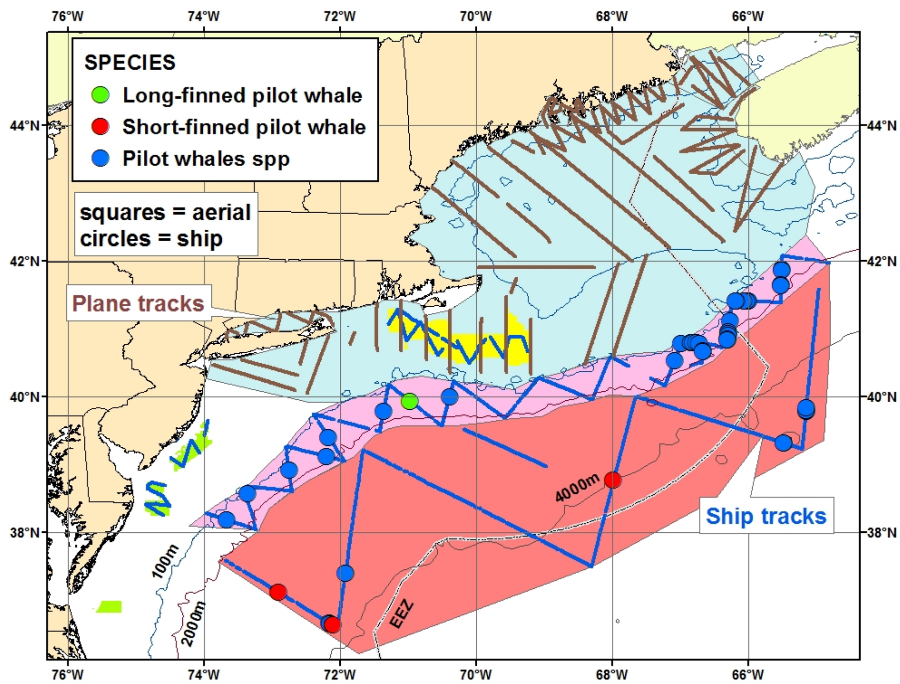

Figure 12. Location of pilot whales (*Globicephala spp.*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

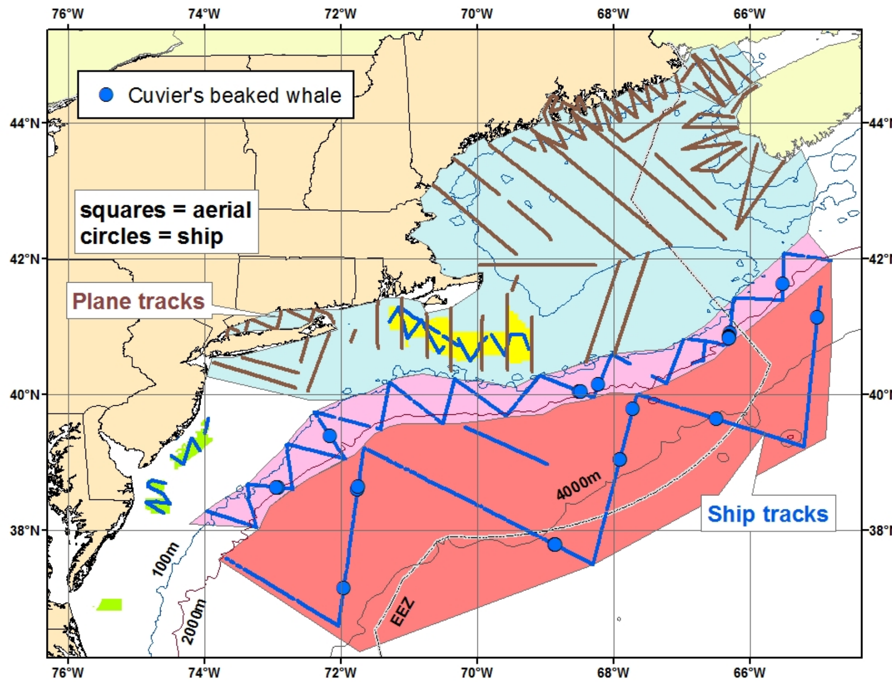

Figure 13. Location of Cuvier's beaked whales (*Ziphius cavirostris*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

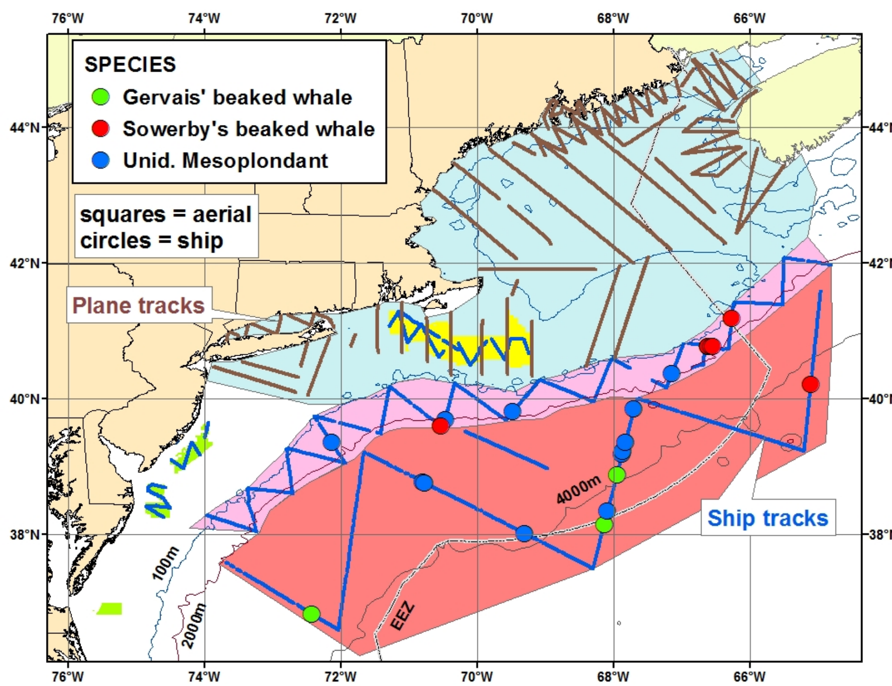

Figure 14. Location of Gervais' beaked whales (*Mesoplodon europaeus*) and Sowerby's beaked whales (*Mesoplodon bidens*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

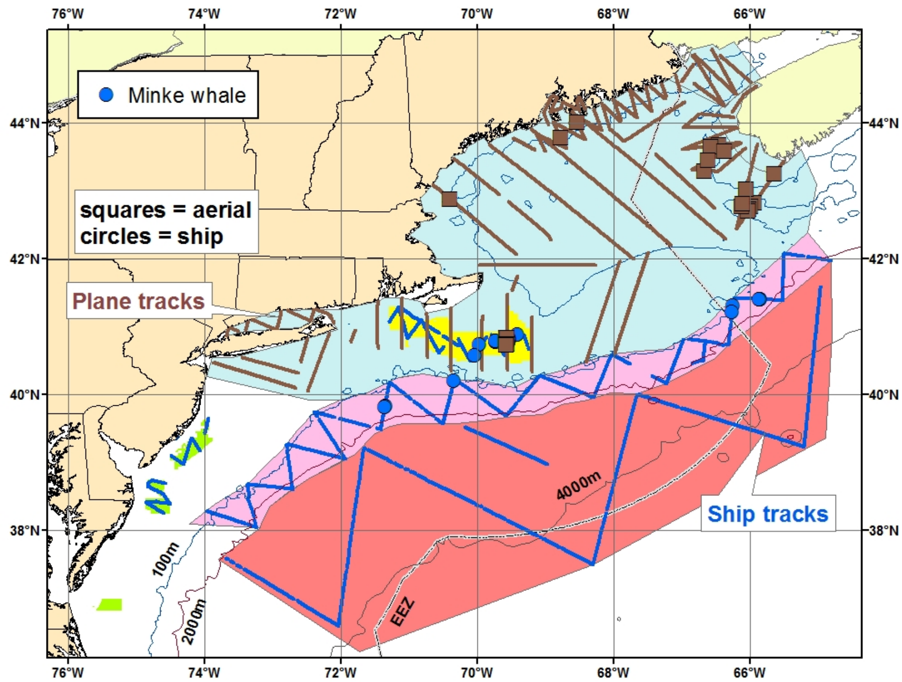

Figure 15. Location of minke whales (*Balaenoptera acutorostrata*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

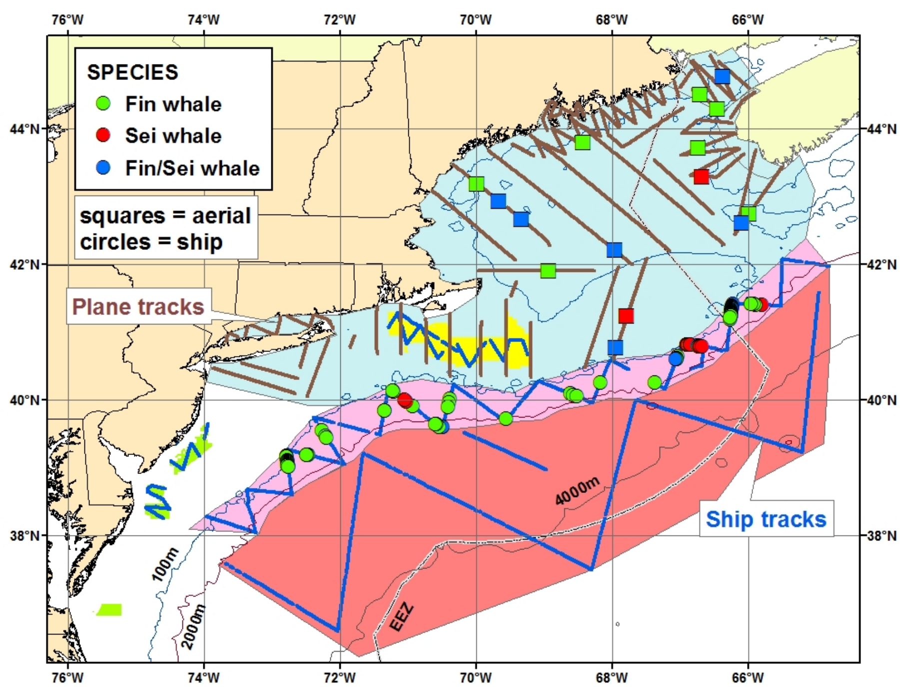

Figure 16. Location of sightings of fin whales (*Balaenoptera physalus*), sei whales (*Balaenoptera borealis*) and either a fin or sei whale as detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

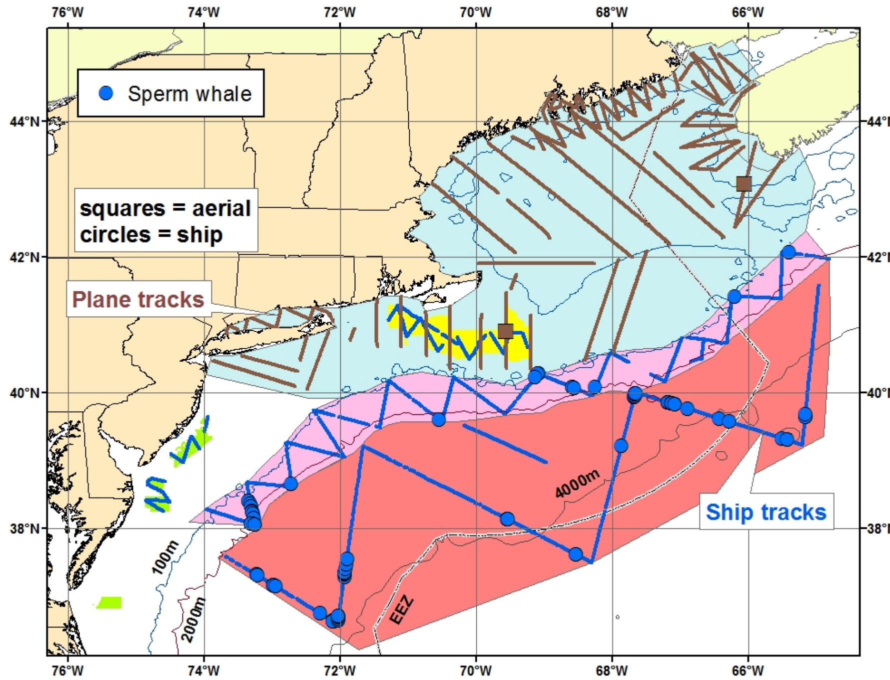

Figure 17. Location of sperm whales (*Physeter macrocephalus*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

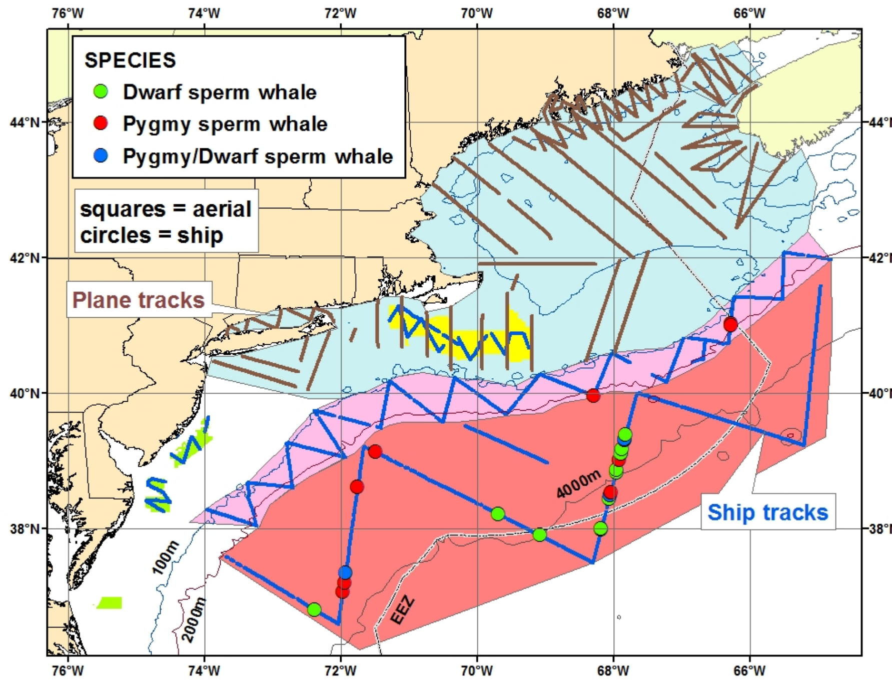

Figure 18. Location of dwarf sperm whales (*Kogia simus*) and pygmy sperm whales (*Kogia breviceps*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

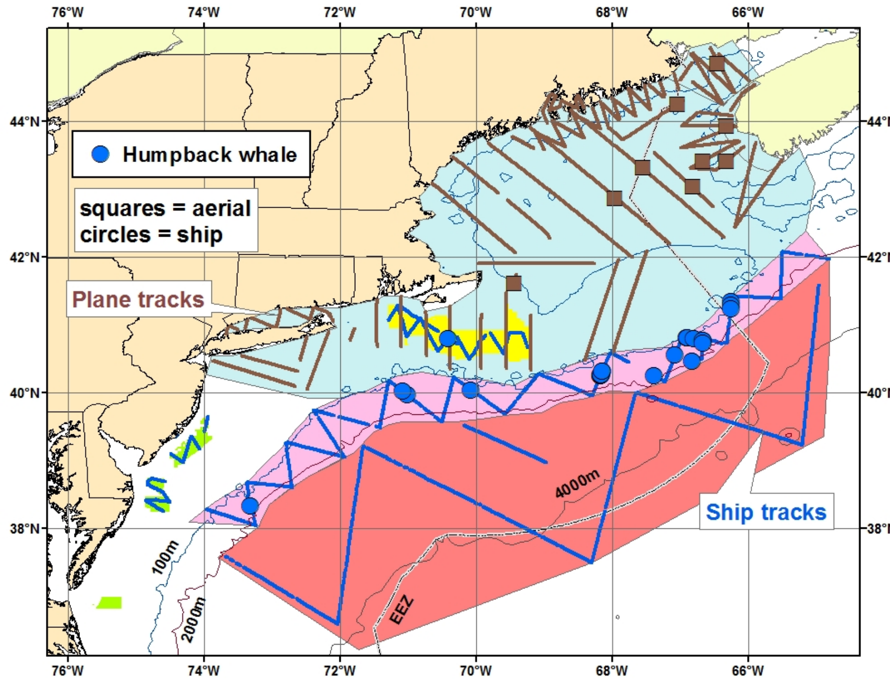

Figure 19. Location of humpback whales (*Megaptera novaeangliae*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

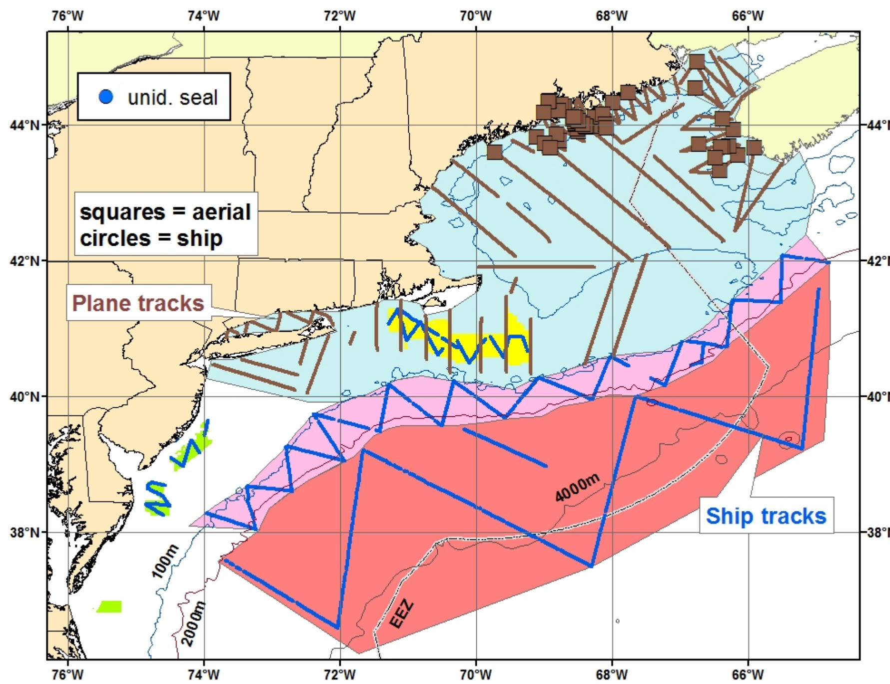

Figure 20. Location of seal (*Pinniped*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

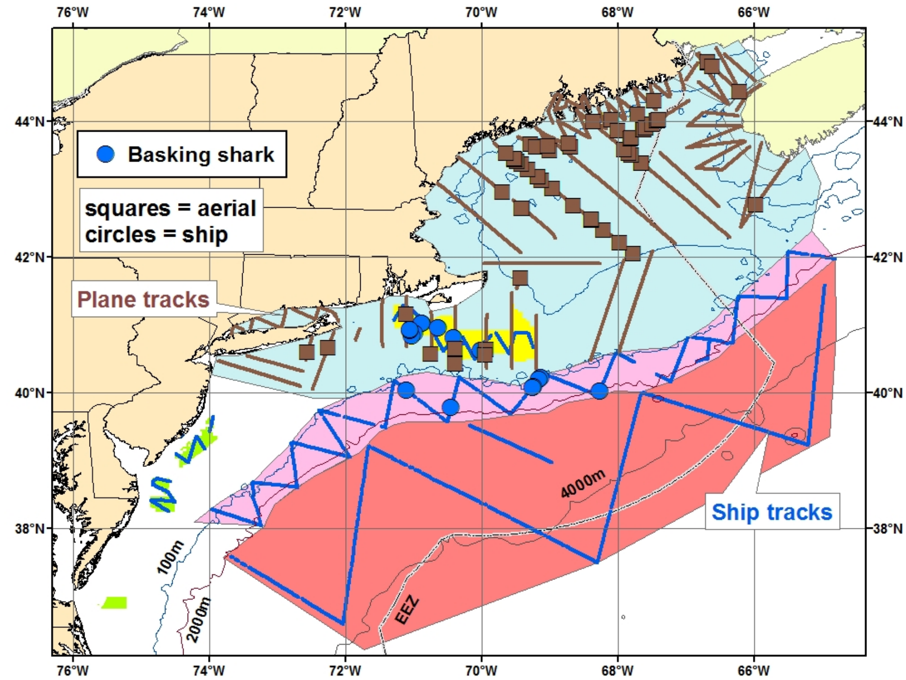

Figure 21. Location of basking shark (*Cetorhinus maximus*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

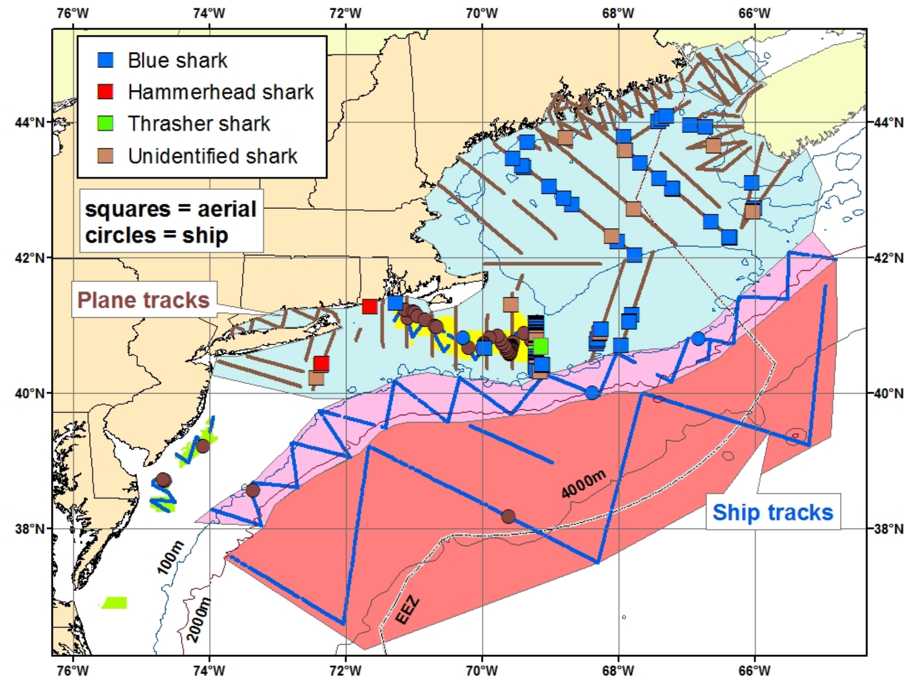

Figure 22. Location of other shark sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

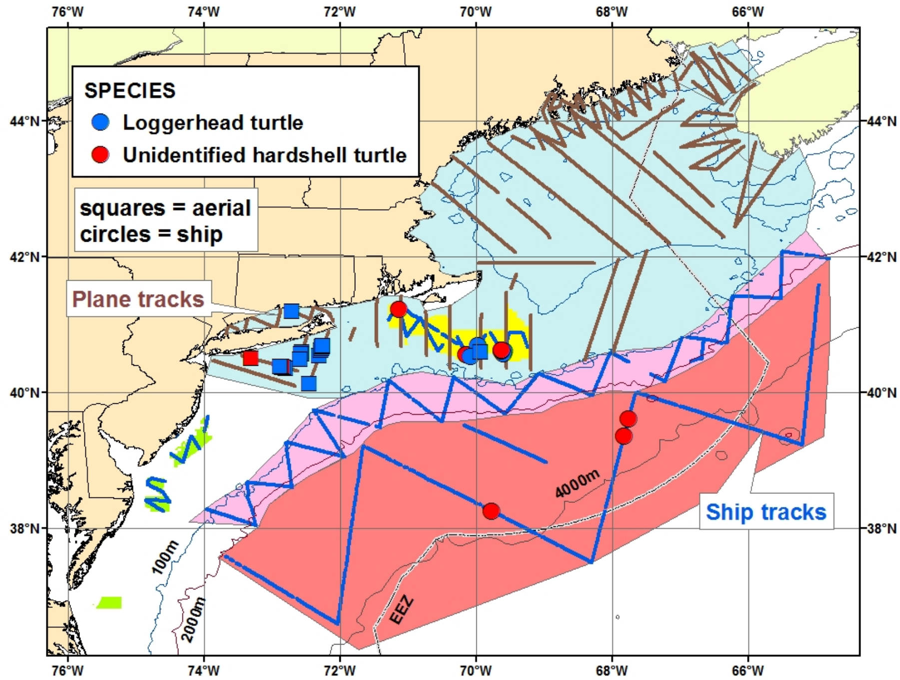

Figure 23. Location of loggerhead turtle (*Caretta caretta*) and unidentified turtle sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

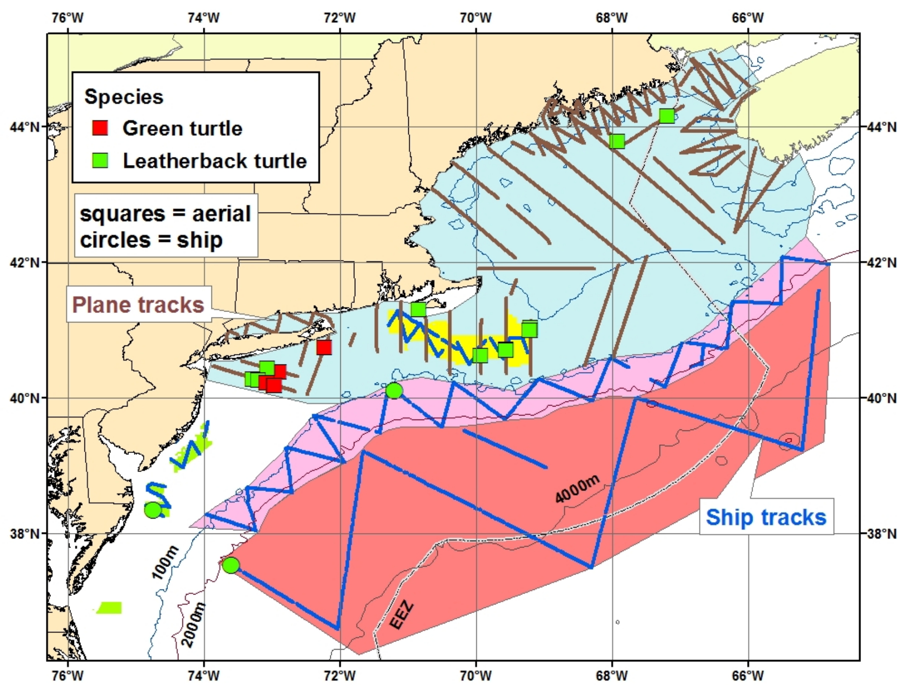

Figure 24. Location of green turtle (*Chelonia mydas*) and leatherback turtle (*Dermochelys coriacea)* sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

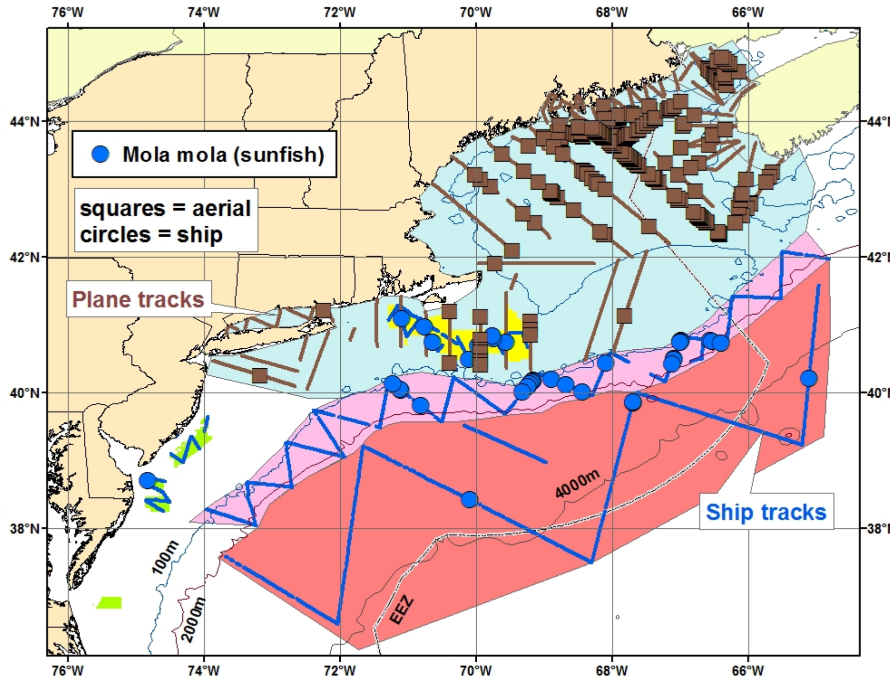

Figure 25. Location of ocean sunfish (*Mola mola*) sightings detected by the airplane (squares) and ship (circles) during Jun-Aug 2011. Plane track lines are brown; shipboard track lines are blue. The 100 m, 2000 m, and 4000 m depth contours and the EEZ are also displayed.

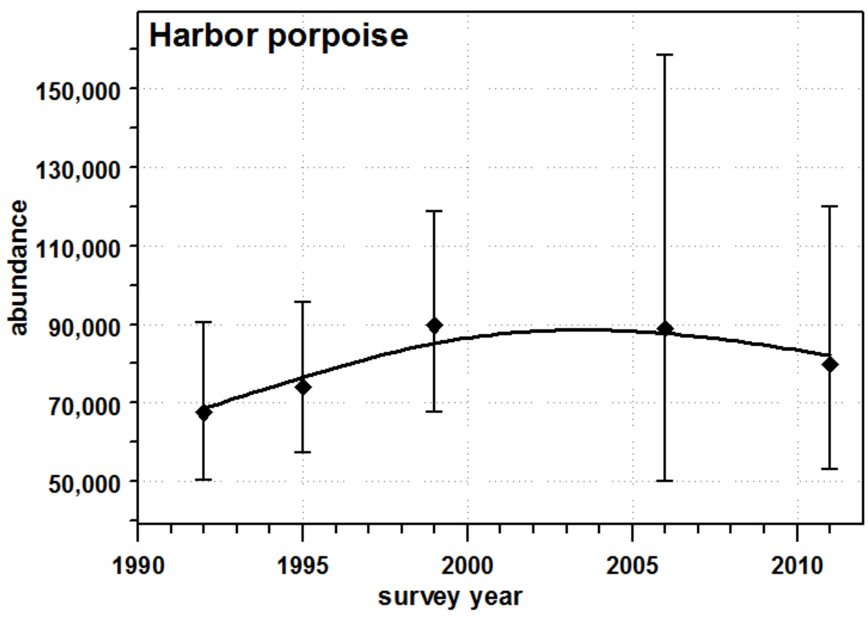

Figure 26. Harbor porpoise (*Phocoena phocoena*) estimates of abundance (diamond) and 95% confidence interval (vertical line) that have been presented in Stock Assessment Reports. Smooth line is a spline regression of the abundance estimates. Note, the surveyed areas over the years have not been the same.

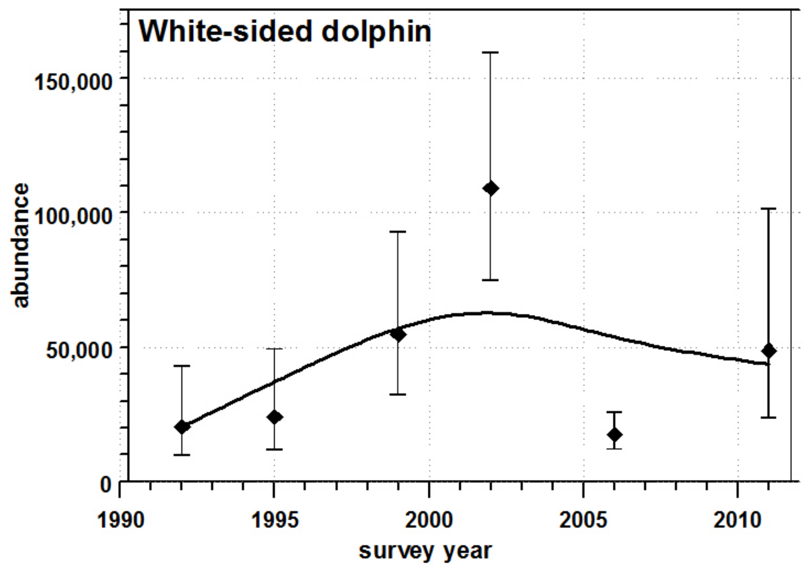

Figure 27. Atlantic white-sided dolphin (*Lagenorhynchus acutus*) estimates of abundance (diamond) and 95% confidence interval (vertical line) that have been presented in Stock Assessment Reports. Smooth line is a spline regression of the abundance estimates. Note, the surveyed areas over the years have not been the same.

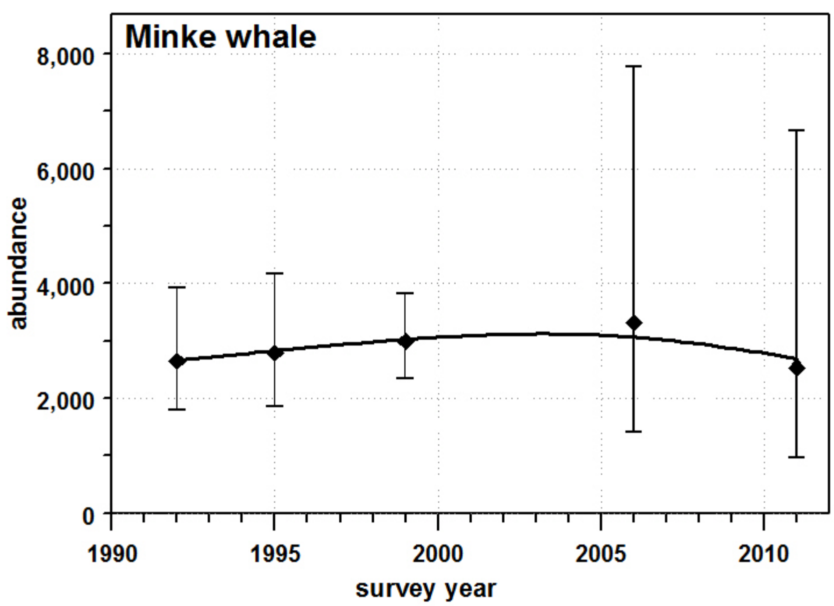

Figure 28. Minke whales (*Balaenoptera acutorostrata*) estimates of abundance (diamond) and 95% confidence interval (vertical line) that have been presented in Stock Assessment Reports. Smooth line is a spline regression of the abundance estimates. Note, the surveyed areas over the years have not been the same.

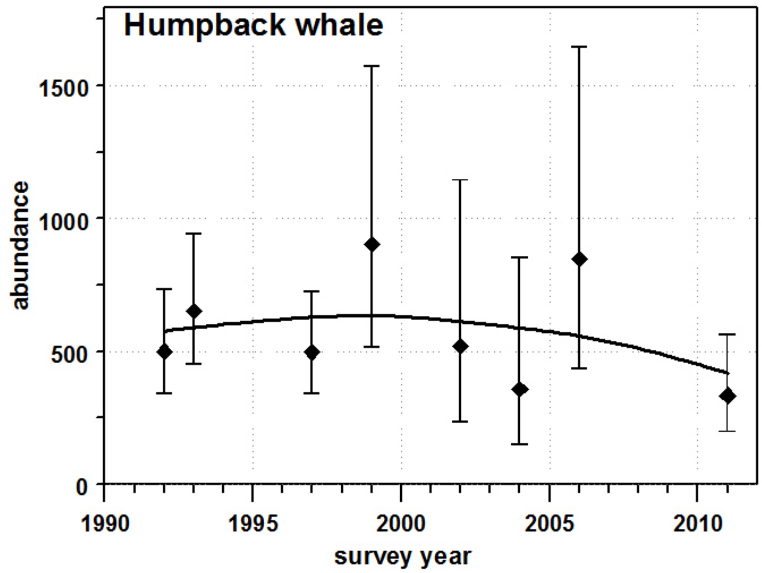

Figure 29. Humpback whale (*Megaptera novaeangliae*) estimates of abundance (diamond) and 95% confidence interval (vertical line) that have been presented in Stock Assessment Reports. Smooth line is a spline regression of the abundance estimates. Note, the surveyed areas over the years have not been the same.

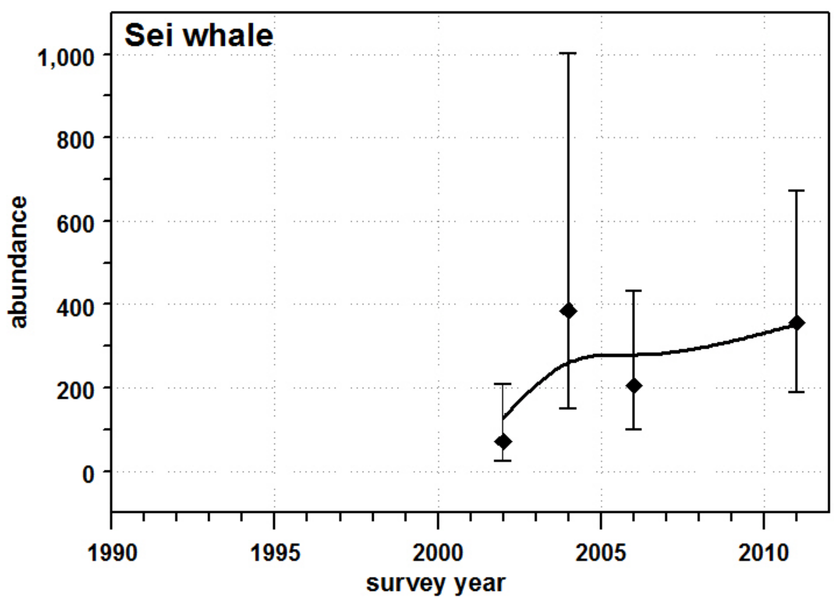

Figure 30. Sei whale (*Balaenoptera borealis*) estimates of abundance (diamond) and 95% confidence interval (vertical line) that have been presented in Stock Assessment Reports. Smooth line is a spline regression of the abundance estimates. Note, the surveyed areas over the years have not been the same.

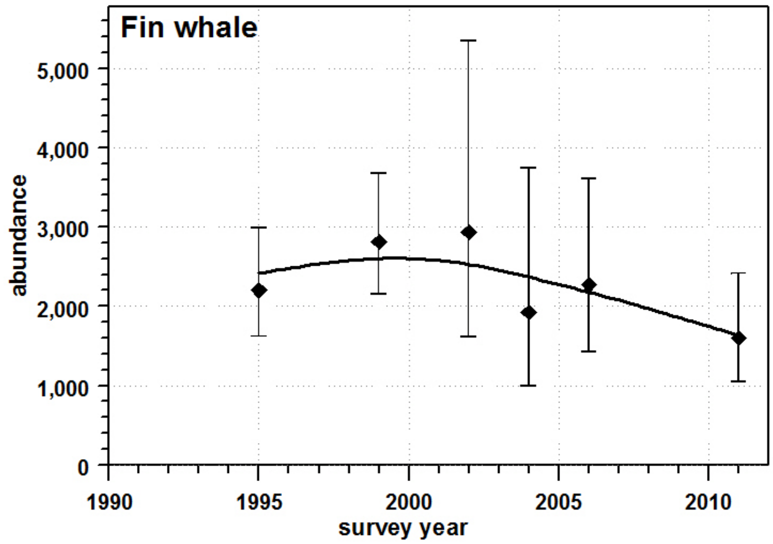

Figure 31. Fin whale (*Balaenoptera physalus*) estimates of abundance (diamond) and 95% confidence interval (vertical line) that have been presented in Stock Assessment Reports. Smooth line is a spline regression of the abundance estimates. Note, the surveyed areas over the years have not been the same. A few fin whales were seen in the 2011 SEFSC summer surveys, so the plotted 2011 estimate is slightly biased low.

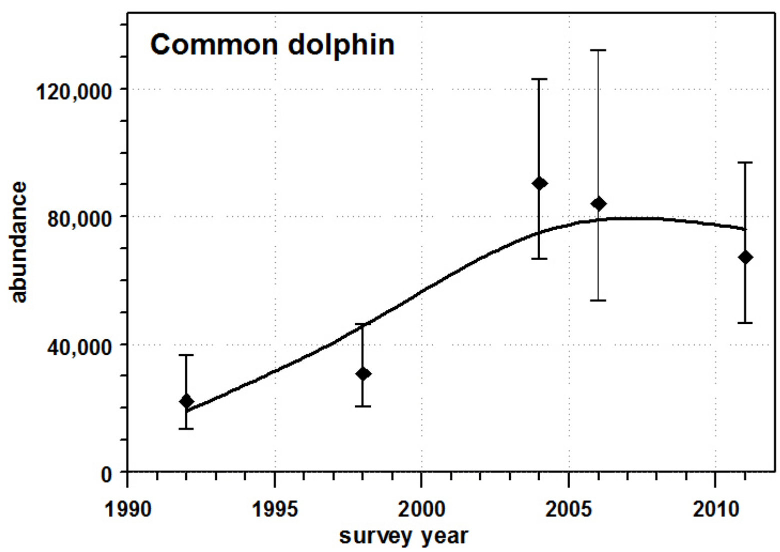

Figure 32. Short-beaked common dolphin (*Delphinus delphis*) estimates of abundance (diamond) and 95% confidence interval (vertical line) that have been presented in Stock Assessment Reports. Smooth line is a spline regression of the abundance estimates. Note, the surveyed areas over the years have not been the same. A few common dolphins were seen in the 2011 SEFSC summer surveys, so the plotted 2011 estimate is slightly biased low.

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