2016

Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in US Waters of the Western North Atlantic Ocean – AMAPPS II

True's beaked whale (*Mesoplodon mirus*)
Collected under MMPA Research permit #775-1875
Photo credit: NOAA/NEFSC/Erin LaBrecque

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BACKGROUND

The Atlantic Marine Assessment Program for Protected Species (AMAPPS) is a comprehensive multi-agency research program in the US Atlantic Ocean, from Maine to the Florida Keys. Its aims are to assess the abundance, distribution, ecology, and behavior of marine mammals, sea turtles, and seabirds throughout the US Atlantic and to place them in an ecosystem context (http://www.nefsc.noaa.gov/psb/AMAPPS/). This information can then provide spatially explicit information in a format that can be used when making marine resource management decisions and will provide enhanced data to managers and other users by addressing data gaps that are needed to support conservation initiatives mandated under the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), National Environmental Policy Act (NEPA) and Migratory Bird Treaty Act (MBTA).

To conduct this work NOAA's National Marine Fisheries Service (NMFS) currently has inter-agency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy. The 2016 products of these inter-agency agreements are being developed by NMFS's Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC).

Because of the broad nature and importance of the AMAPPS work, AMAPPS has evolved beyond the above agencies into larger collaborative programs involving researchers from a variety of domestic and international organizations. These collaborative efforts have the benefit of increasing the amount of funds and personnel for field and analytical work.

This report documents the work conducted by NMFS during 2016.

SUMMARY OF 2016 ACTIVITIES

During 2016 under the AMAPPS program, NMFS conducted field studies to collect cetacean, sea turtle, seal, and sea bird seasonal distribution, abundance and biological data (Table 1). In addition, NMFS staff continued to analyze past and present data collected under AMAPPS I and II (Table 2). A summary of the 2016 projects follows, with more details in the appendices.

Field activities

During 27 June – 28 September 2016, the NEFSC and SEFSC conducted 2 shipboard and 2 aerial line transect surveys covering US Atlantic waters from Florida to Maine, from the coastline to the US exclusive economic zone (EEZ) and slightly beyond. Note, the Canadians conducted a concurrent abundance aerial line transect survey around Nova Scotia and Newfoundland. The US aerial abundance surveys using NOAA Twin Otter airplanes targeted marine mammals and sea turtles in Atlantic continental shelf waters from the shore to about the 100 or 200 m depth contour, depending on the location (Figure 1; Table 1). The shipboard abundance surveys using NOAA ships targeted marine mammals, sea turtles and seabirds in the shelf break waters starting from the offshore edge of the plane's survey area to waters farther offshore up to the US EEZ and slightly beyond. In total the surveys completed about 33,963 km of track lines: 10,735 km from the ships and 23,228 km from the planes.

During these four shipboard and plane surveys observers detected about 2,300 groups of cetaceans (over 25,000 individuals) of 28 positively identified species and about 1,920 groups of sea turtles (over 2,060 individuals) from 4 species. The most frequently detected dolphins included: common bottlenose dolphins (*Tursiops truncatus*) ranging from about 28°N – 42°N on the continental shelf and shelf break; Atlantic spotted dolphins (*Stenella frontalis*) ranging from 30°N – 40°N also on the shelf and shelf break; short-beaked common dolphins (*Delphinus delphis*) ranging from 37°N – 41°N mostly in only the shallow shelf break waters; in contrast to striped dolphins (*Stenella coeruleoalba*) ranging from 38°N – 42°N in the deeper shelf break and further offshore waters. The most frequently detected large whales were fin whales (*Balaenoptera physalus*) who ranged along the entire US coastline and sperm whales (*Physeter macrocephalus*) who ranged mostly in waters deeper than 1000 m. Of interest are the 3 blue whales (*Balaenoptera musculus*) detected on Georges Bank in waters about 100 – 200 m deep, the 40+ false killer whales (*Pseudorca crassidens*). The most frequently detected turtle was the loggerhead turtle (*Caretta caretta*), with about 1000 individuals that ranged from 26°N – 41°N mostly in waters on the continental shelf.

The two shipboard surveys allow for other types of data collection including seabird detections, passive acoustic recordings, biopsies, physical oceanographic measurements and biological samples of fish and plankton. On the NEFSC shipboard survey there were about 2,000 detections of bird groups that consisted of about 4,700 individuals from 35 positively identified species. About 927 hours of passive acoustic towed array data and recordings from 59 sonobuoys were collected on the two ships with at least 12 species preliminarily identified, including 4 beaked whale species. Of particular interest is the first confirmed recording of True's beaked whales (*Mesoplodon mirus*) that was associated with visual confirmations. A total of 74 animals from 7 species were biopsied for genetic structure studies. Also, the following were deployed from the two ships to measure physical and/or biological oceanography characteristics: 145 XBT's (expendable bathy thermograph sensors), 104 CTD's (conductivity, temperature, and depth sensors), 119 bongo nets, 42 Neuston nets, 26 VPR (visual plankton recorder) tows and 35 midwater trawl tows. All visual line-transect data have been or will be submitted to OBIS-SEAMAP and thus will be publically available at http://seamap.env.duke.edu/. More information is found in Appendices A – D.

During 14 October – 31 December 2016, the NEFSC and SEFSC conducted aerial abundance line transect surveys covering US Atlantic waters from North Carolina to Nova Scotia, from the coastline to about the 2000 m depth contour (Figure 3; Table 1). The aerial surveys using NOAA Twin Otter airplanes at an altitude of 600 feet (183 m) and a speed of 110 knots targeted marine mammals and sea turtles. The surveys completed about 12,908 km of track lines. The survey methods used during the fall survey were the same as that used in the summer. Throughout the coast there were at least 5188 cetaceans from 421 groups, 110 turtles from 4 species, and 50 seals from 2 species. See Appendices C and D for more information.

To advance loggerhead sea turtle research we collaborated on existing loggerhead turtle tagging cruises, where a loggerhead was tagged on the northwestern edge of the Gulf Stream, which was farther offshore than in previous years. This animal then migrated onto the heart of Georges Bank, an area not used by previously tagged loggerheads but an area where loggerheads have previously been visually detected. The other field effort was a collaboration with Canadian researchers on their ship to tag additional loggerheads in Canadian waters using AMAPPS tags. Unfortunately there were exceptionally low numbers of loggerheads so deployment was rescheduled for the summer of 2017. See Appendix E for more information.

To advance leatherback turtle (*Dermochelys coriacea*) research we conducted a pilot study in Vineyard Sound, MA. A leatherback turtle was successfully tagged with a satellite-linked suction cup tag developed by the Canadian Department of Fisheries and Oceans. This success suggests this tagging approach may be an efficient way to gain behavioral data at a fraction of the cost of traditional tagging efforts. See Appendix E for more information.

Analyses

During 2016 a journal paper was published documenting the collaborative project that used videography to describe in-water behavior of loggerhead turtles. In addition, we are collaborating with colleagues to develop and evaluate methods to estimate spatially and temporally explicit densities of tagged loggerhead turtles. See Appendix E for more information.

To update and improve models of the spatial/temporal distribution of marine mammals and sea turtles in 2016 new sighting and effort abundance data were processed and archived, and we continued downloading the habitat variables that will be associated with the sightings and effort data. The two statistical model frameworks (Bayesian Hierarchical models and Generalized Additive models) were updated and improved. During 2016 spatial/temporal maps and abundance estimates were developed for 17 species/species guilds using Generalized Additive Models. In addition we started investigating methods to evaluate trends in the abundance estimates of coastal bottlenose dolphins. More information is found in Appendix F.

During 2016 we started developing methods that potentially could improve abundance estimates for sperm whales by integrating visual sightings and passive acoustic towed array data. More information is found in Appendices F and G.

Passive acoustic data, which complement the visual-based data, were collected via ship towed hydrophone arrays and bottom-mounted archival recorders. One analysis conducted in 2016 involved generating 3-D locations of beaked whales to determine the depth of the vocalizing animal and quantifying acoustic detection rates for beaked whales, with the goals of comparing to visual detection rates and estimating acoustic abundance for this taxon, if possible. Another project involved processing the first set of deployed MARUs (Marine Autonomous Recording Units, Cornell University, Bioacoustics Research Program) that were off North Carolina, South Carolina and Georgia to detect and classify vocalizing large whales (North Atlantic right whales (*Eubalaena glacialis*), sei whales (*Balaenoptera borealis*), fin whales and blue whales). These MARUs are part of a series of recording units that will be used to document migratory pathways of baleen whales along the eastern seaboard continental shelf. In addition work continues on collaborating with other researchers on refining the Atlantic version of a Real-time Odontocete Call Classification Algorithm (ROCCA) and developing and populating the passive acoustic database called Tethys. More information is found in Appendix G.

To gain a better understanding of the underlying processes that may drive the distribution and abundance of predators, such as marine mammals, sea turtles, and sea birds, the relationships between hydrographic characteristics of the water column and distributions of lower trophic level organisms, such as fish and plankton, are being compared relative to the distribution patterns of the protected species. During 2016, the processing of the physical and biological oceanographic data collected during the 2016 *Bigelow* cruise (Appendix A) started. Of note, blue fin tuna (*Thunnus thynnus*) larvae were present in similar areas documented in the 2013 AMAPPS cruise, which could indicate a previously unknown spawning area. In addition, during 2016 analyses integrating the physical and biological prey data with the marine mammal data were continued. More information is found in Appendix H.

Table 1. General information on the AMAPPS NMFS field data collection projects that occurred during 2016: the project name (NMFS principal investigating center), platforms used, dates and general location of the field study, and the appendix within this document where more information on the project can be found.

2016 field collection projects	Platform(s)	Dates in 2016	Location	Appendix
Summer abundance survey (NEFSC)	NOAA ship *Henry B. Biglow*	27 Jun – 25 Aug	Shelf edge and deeper waters from New Jersey to Maine	A
Summer abundance survey (SEFSC)	NOAA ship *Gordon Gunter*	30 Jun – 19 Aug	Shelf edge and deeper waters from New Jersey to Florida	B
Summer aerial survey (SEFSC)	NOAA Twin Otter airplane	3 Jul – 9 Aug	Continental shelf waters from New Jersey to Florida	C
Summer aerial survey (NEFSC)	NOAA Twin Otter airplane	14 Aug – 28 Sep	Continental shelf waters from New Jersey to Maine	D
Fall aerial survey (NEFSC)	NOAA Twin Otter airplane	15 Oct – 18 Nov	Continental shelf waters from New Jersey to Nova Scotia	D
Fall aerial survey (SEFSC)	NOAA Twin Otter airplane	23 Nov – 31 Dec	Continental shelf waters from New Jersey to North Carolina	C
Loggerhead turtle tagging (NEFSC)	Fishing Vessel *Kathy Ann*	16 – 21 May; 21 – 26 Aug	Mid-Atlantic continental shelf and shelf edge	E
Leatherback turtle tagging (NEFSC & SEFSC)	Small boats	13 – 17 Oct	Vineyard Sound, MA	E

Table 2. A brief description of the purpose of the AMAPPS National Marine Fisheries Service analysis projects that occurred during 2016 and the appendix where more information can be found.

2016 analysis projects	Purpose	Appendix
Document in-water behavior of loggerhead turtles	Videography were used to document how loggerheads utilize the water column	E
Estimate density distributions of tagged loggerhead turtles	Investigate several methods to estimate spatial- and temporal-distributions of tagged loggerhead turtle densities	E
Spatially- and temporally-explicit density models and abundance estimates	Develop Bayesian hierarchical and generalized additive models to quantify relationship between marine mammals and sea turtles and habitat	F
Estimate abundance and trends of coastal bottlenose dolphins	Using aerial visual data from AMAPPS and previous surveys estimate abundance of the coastal morphotype of bottlenose dolphins and investigate methods to assess trends	F
Process new data	Process and check quality of survey data and associated habitat covariate data	F
Acoustic and visual abundance estimate of sperm whales	Estimate sperm whale abundance by integrating passive acoustic and visual sightings data from NEFSC 2013 shipboard data	F & G
3-D localization of beaked whales	Refined methodology of using acoustic data to generate 3-D localizations of beaked whales	G
East Coast Migratory Corridor 2.0 project	Analyze first deployment of MARUs from Cape Hatteras, NC to New Brunswick, Georgia to detect large whales and deploy other MARUs.	G
Process and compare EK60 active acoustic backscatter, VPR and net tow data	Process active acoustic backscatter data (represents middle level trophic level taxa), and plankton/fish data collected from VPR and net tows so they can be compared to distributions of marine mammals, sea turtles and sea birds	H

Figure 1. Track lines completed during the summer July – September 2016 AMAPPS shipboard and aerial surveys conducted by the Northeast and Southeast Fisheries Science Centers.

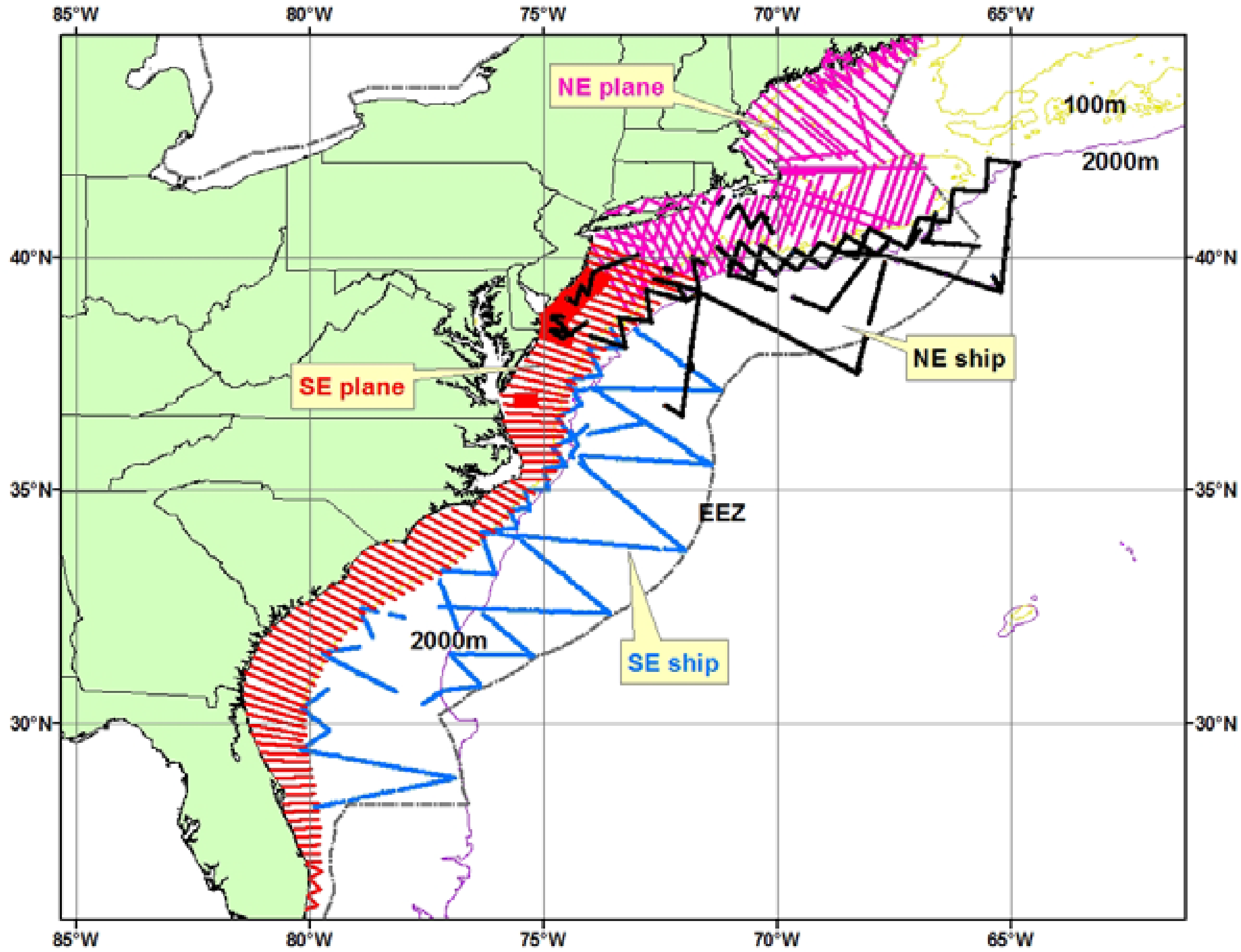
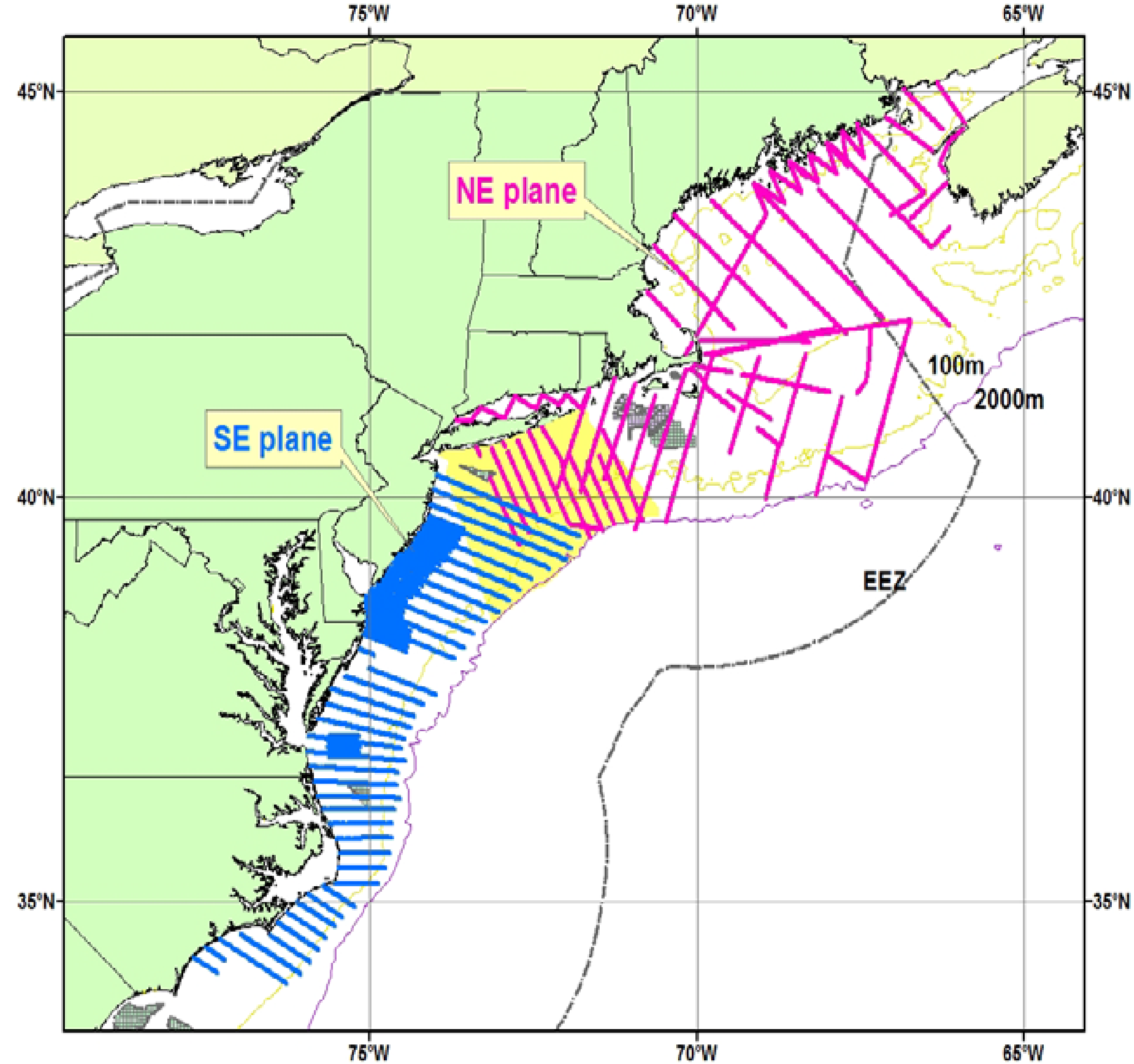


Figure 2. Track lines completed during the fall October – December 2016 AMAPPS shipboard and aerial surveys conducted by the Northeast and Southeast Fisheries Science Centers.



Appendix A: *Northern leg of shipboard abundance survey during 27 June – 25 August 2016: Northeast Fisheries Science Center*

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SUMMARY

During 27 June – 25 August 2016 divided in three legs, the Northeast Fisheries Science Center (NEFSC) conducted a shipboard abundance survey targeting marine mammals, sea turtles and seabirds on the NOAA ship *Henry B. Bigelow*. The survey area was between 36 and 42N and 65 and 74W, covering waters offshore of the 100 m depth contour. There were 2 independent teams targeting marine mammals and sea turtles using line transect sampling techniques, a team targeting targeting sea birds using strip transect sampling techniques, a team monitoring a towed hydrophone array, and a team collecting physical and biological oceanographic data. Track lines were covered at about 10 knots. In Beaufort sea states of six and less, about 5354 km of on-effort track lines were surveyed. Over 1200 groups (16,000 individuals) of cetaceans, 26 groups (27 individuals) of sea turtles and 1977 groups (4677 individuals) of seabirds were recorded. Common dolphins (*Delphinus delphis*) were the most commonly detected species. The most common large whales were fin whales (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*). Over 19 loggerhead turtles (*Caretta caretta*) were detected. In addition, 1 seal, over 23 basking sharks (*Cetorhinus maximus*) and 22 ocean sunfish (*Mola mola*) were also detected. Passive acoustic data were collected via towed hydrophone array during all daytime survey effort, and at night during Leg 3. Approximately 496 hrs of array data were collected, with over 800 detections of vocally-active cetacean groups. In addition, 29 sonobuoy deployments were conducted to acoustically sample for large whales. During the day and night active acoustic sampling and 411 sampling events were completed. This included 189 casts of the 19+CTD, 119 bongo deployments, 26 VPR hauls, deployments, 42 neuston deployments, and 35 midwater trawls.

OBJECTIVES

The main objectives of the survey were: 1) determine the distribution and abundance of cetaceans, sea turtles and sea birds within the study area; 2) collect vocalizations of cetaceans using passive acoustic arrays; 3) determine the distribution and relative abundance of plankton and other trophic levels, 4) collect hydrographic and meteorological data, and 5) when possible, collect biopsy samples and photo-identification pictures of cetaceans.

Sub-objectives related to main objective 3 (plankton and other trophic levels) were: 1) sample plankton and nekton along the visual team's track lines to quantify the lower trophic levels in the slope ecosystem; 2) compare the signal strength of the ship's active acoustics, especially the EK60, to sampled plankton and nekton densities; 3) confirm the existence of a Mid-Atlantic slope spawning area for *Thunnus thynnus* (bluefin tuna) by collecting larval samples for genetic species confirmation and aging which may be able to begin to demarcate the spawning area; 4) begin to develop methods and protocols to quantitatively sample gelatinous zooplankton; and 5) use the oceanographic sampling to increase understanding of the physical processes affecting water masses along the shelf slope and Gulf Stream boundaries.

CRUISE PERIOD AND AREA

The cruise was on the NOAA ship *Henry B. Bigelow* and was designated as HB1603. The cruise period was divided into three legs: 27 Jun – 14 Jul; 18 Jul – 5 Aug; 9 Aug – 25 Aug 2016. The study area (Figure A1) included waters south of Cape Cod (about 42° N latitude), north of North Carolina (about 36° N latitude), west of the southern tip of Nova Scotia (about 65° W longitude), and east of the US coast (about 74° 30' W longitude). This is waters shallower than about 4500 m which includes international waters and waters within the US and Canadian economic exclusive zones (EEZ).

METHODS

VISUAL MARINE MAMMAL-TURTLE SIGHTING TEAM

A line transect survey was conducted during daylight hours (approximately 0600-1800 with a one hour break at lunchtime) using the two independent team procedure. Surveying was conducted during good weather conditions (Beaufort five and below) while traveling at about 10 knots, as measured over the ground.

Scientific personnel formed two visual marine mammal-sea turtle sighting teams. The teams were on the flying bridge (15.1 m above the sea surface) and anti-roll tank (11.8 m above the sea surface). To detect animal groups, both teams were composed of two on-effort observers who searched using 25x150 powered binoculars, one on-effort observer who searched using naked eye and recorded the sightings data detected by all team members, and one off-effort observer who could rest. Every 30 minutes observers on each team rotated positions within the team. The teams rotated platforms every four on-effort days. The composition of the teams slightly changed every leg.

Position, date, time, ship's speed and course, water depth, surface temperature, salinity, and conductivity, along with other variables (Table A1) were obtained from the ship's Science Computer System (SCS). These data were routinely collected and recorded every second at least while during visual survey operations. Sightings and visual team effort data were entered by the scientists onto hand held data entry computerized systems called VisSurv-NE (version 4) which was initially developed by L. Garrison and customized by D. Palka.

At times when it was not possible to positively identify a species or when training the observers on species identifications, survey effort was discontinued (termed went off-effort) and the ship headed in a manner to intercept the animals in question. When the species identification and group size information were obtained, the ship proceeded back to the point on the track line where effort ended (or close to this point).

Both teams searched waters from 90˚ starboard to 90˚ port, where 0˚ is the track line that the ship was traveling on. For either team, when an animal group (porpoise, dolphin, whale, seal, turtle and a few large fish species) was detected the following data were recorded with VisSurv-NE:

1) Time sighting was initially detected, recorded to the nearest second,
2) Species composition of the group,
3) Radial distance between the team's platform and the location of the sighting, estimated either visually when not using the binoculars or by reticles when using binoculars,
4) Bearing between the line of sight to the group and the ship's track line; measured by a polarus mounted near the observer or a polarus at the base of the binoculars,

5) Best estimate of group size,

6) Direction of swim,

7) Number of calves,

8) Initial sighting cue,

9) Initial behavior of the group, and

10) Any comments on unusual markings or behavior.

At the same time, the location (latitude and longitude) of the ship when this information was entered was recorded using the ship's GPS location via the SCS system which was connected to the data entry program VisSurv-NE. In addition, VisSurv-NE routinely recorded the ship's location every 12 seconds.

The following effort data were recorded within VisSurv-NE every time one of the factors changed (at least every 30 minutes when the observers rotate):

1) Time of recording,

2) Position of each observer, and

3) Weather conditions:

(a) entered by recorder: swell direction relative to the ship's travel direction and height (in meters), apparent Beaufort sea state in front of the ship, percent cloud coverage, how clear the horizon is (clear, good, fair (thin haze), poor (thick haze) and very obscured horizon), percentage of area covered with glare and strength of glare within the glare swath (none, slight, moderate, severe).

(b) Entered by ship's SCS system: depth (m), sea surface temperature (°C), and wind speed (knots), and ships true heading.

VISUAL SEABIRD SIGHTING TEAM

From an observation station on the flying bridge, about 15.1 m above the sea surface, two observers, working solo on a two hour rotation, conducted a visual daylight survey for seabirds during approximately 0600 – 1800 hours with a one hour break at lunchtime. Seabird observation effort employed a modified 300 m strip and line-transect methodology. Data on seabird distribution and abundance were collected by identifying and enumerating all birds seen within a 300 m arc on one side of the bow while the ship was underway. Seabird observers maintained a visual unaided eye watch of the 300 m survey strip, with frequent scans of the perimeter using hand-held binoculars for cryptic and/or hard to detect species. Binoculars were used for distant scanning and to confirm identification. Ship-following species were counted once and subsequently carefully monitored to prevent re-counts. All birds, including non-marine species, such as raptors, doves, and Passerines, were recorded.

Operational limits are higher for seabird surveys compared to visual marine mammal and sea turtle surveys. As a result, seabird survey effort was possible in sea states up to and including a low Beaufort 8. Seabird survey effort was suspended, however, if the ship's speed over ground fell below six knots.

All data were entered in real time into a Panasonic Toughbook laptop running *Seebird (vers 4.3.7)*, a data collection program developed at the Southwest Fisheries Science Center. The software was linked to the ship's navigation system via a serial cable. The following data were collected for each sighting: species identification, number of birds within a group, distance between the observer and the group, angle between the track line and the line of sight to the group, behavior, flight direction, flight height, age, sex and, if possible, molt condition. The sighting record received a corresponding time and GPS fix once the observer accepted the record and the software wrote it to disk. *Seebird* also added a time and location fix every 5 minutes. *Seebird* incorporates a time synchronization feature to ensure the computer clock matches the GPS clock to assist with post-processing of the seabird data with the ship's SCS data. All data underwent a quality assurance and data integrity check each evening and saved to disk and to an external backup dataset.

PASSIVE ACOUSTIC DETECTION TEAM

The passive acoustic team consisted of 3 – 4 people who operated the system in two-hour shifts, from 0545 – 1800 during the first two legs and as much as 24 hours per day on leg 3. The hydrophone array was deployed at 0545 each morning, and was typically retrieved from 1130 – 1230 for the midday bongo/CTD casts. Daytime data collection usually ended at 1800, at the end of the visual survey day. The acoustic team collected data during all hours when the visual team was on-effort, except along inshore track lines, where shallow bottom depths (50 m and less) prohibited safe deployment of the array. The acoustic team also collected data on some occasions when weather conditions prevented the visual team from operating. In addition night recordings were collected during leg 3.

The hydrophone array was comprised of two modular, oil-filled sections, separated by 30 m of cable. The end-array consisted of 3 "mid-frequency" elements (APC International, 42-1021), 2 "high-frequency" elements (Reson, TC 4013), and a depth sensor (Keller America, PA7FLE). The in-line array consisted of 3 "mid-frequency" elements (APC International, 42-1021). The array was towed 300 m behind the ship. Array depth typically varied between 8 – 12 m when deployed at the typical survey speed of 10 kts. Sound speed data at the tow depth of the array were extracted from morning and midday CTD casts.

Acoustic data were routed to a custom-built Acoustic Recording System that encompassed all signal conditioning, including A/D conversion, filtering, and gain. Data were filtered at 1000 Hz, and variable gain between 20 – 40 dB was added depending on the relative levels of signal and noise. The recording system incorporated two National Instruments soundcards (NI USB-6356). One soundcard sampled the six mid-frequency channels at 192 kHz, the other sampled the two high-frequency channels at 500 kHz, both at a resolution of 16 bits. Digitized acoustic data were recorded directly onto laptop and desktop computer hard drives using the software program Pamguard (http://www.pamguard.org/home.shtml), which also recorded simultaneous GPS data, continuous depth data, and allowed manual entry of corresponding notes. Two channels of analog data were also routed to an external RME Fireface 400 soundcard and a separate desktop computer, specifically for the purpose of real-time detection and tracking of vocal animals using the software packages WhalTrak and Ishmael. Whenever possible, vocally-active groups that were acoustically tracked were matched with visual detections in real-time, for assignment of unambiguous species classification. Communication was established between the acoustic team and the visual team situated on the flying bridge to facilitate this process.

Passive acoustic recordings were also opportunistically collected using the ship's centerboard-mounted hydrophone, in situations when animals of interest were particularly close to the ship.

In addition to collecting towed array data, the passive acoustic team also deployed sonobuoys (AN-SSQ-53F) periodically throughout the survey. After deployment of the sonobuoy, the ship typically moved to a distance of approximately 1.5 – 2 km for acoustic monitoring. Sonobuoys were monitored visually and aurally through the software programs Raven or Pamguard.

HYDROGRAPHIC, NEKTON, AND PLANKTON CHARACTERISTICS

Oceanographic Sampling

The ship's SCS logger system continuously recorded oceanographic data from the ship's sensors. A SEACAT 19+ Conductivity, Temperature, and Depth Profiler (CTD) was used to measure water column conductivity, temperature and depth. On the first leg the 19+ was also equipped with a WetLabs EcoFlur fluorometry and turbidity sensor. The CTD was mounted on a 322 conducting core cable allowing the operator to see a real time display of the instrument depth and water column temperature, salinity, density and sound speed on a computer monitor in the ship's Dry Lab. Once a day, a vertical profile was conducted with the CTD, where a Niskin bottle was attached to the wire above the CTD. The Niskin bottle was used to collect a water sample which will be used to calibrate the conductivity sensor of the CTD. The calculated sound speeds from the vertical profiles were used for the daily calibration of the passive acoustic sensors. Additional vertical profiles to delimitate sound speed were conducted as needed for further acoustic calibrations.

Plankton sampling (Legs 1, 2, and 3)

On all three legs a 61 cm bongo plankton net equipped with two 333 μm nets and a CTD mounted on the wire 1 m above the nets was deployed approximately three times a day: once before the day's surveying started (about 0500 – 0530), at lunch time (about 1200 when the ship stopped surveying), and again after surveying was completed for the day (approximately 1800, depending on weather and the time of sunset). The bongo was towed in a double oblique profile using standard ECOMON protocols. The ship's speed through the water was approximately 1.5 kts. Wire-out speed was 50 m/min and wire-in speed was 20 m/min. Tows were to within 5 m of the bottom or to 200 m depth, if the bottom depth exceeded 205 m. Upon retrieval, samples were rinsed from the nets using seawater. The 6B3I net was preserved in 95% ethanol which was changed to new ethanol after 24 – 48 hrs. The 6B3Z net was preserved in 5% formaldehyde and seawater. Samples were transported to the Narragansett, RI National Marine Fisheries Science (NMFS) lab for future identification.

Phytoplankton Sampling (Leg 1)

During leg 1 an Imaging Flow Cytobot developed by Robert Olsen and Heidi Sosik of Woods Hole Oceanographic was connected to the ship's flow through seawater system, which was at a depth of 3 m. The cytobot continuously sampled 5 ml aliquots of seawater imaging all phytoplankton in a size range of 10 to 100 μm. The system allowed for real time visualization of the phytoplankton.

Nighttime Oceanographic and Plankton Sampling

During night on Legs 1 and 2 when the marine mammal/turtle and seabird visual sighting teams were off-effort, physical and biological sampling of the water column was conducted by employing a combination of underway and station-based sampling. Sampling decisions were made opportunistically with several goals in mind. 1) To sample plankton and nekton along the visual team's track lines to quantify the lower trophic levels in the slope ecosystem. 2) To compare the signal strength of the ship's active acoustics, especially the EK60, to sampled plankton and nekton densities. 3) To confirm the existence of a Mid-Atlantic slope spawning area for *Thunnus thynnus* (bluefin tuna) by collecting larval samples for genetic species confirmation and aging which may be able to begin to demarcate the spawning area. 4) To begin to develop methods and protocols to quantitatively sample gelatinous zooplankton. 5) To use the oceanographic sampling to increase understanding of the physical processes affecting water masses along the shelf slope and Gulf Stream boundaries.

Sampling equipment included:

- Seabird 911 and 19+CTDs for oceanography and hydrography (max depth 3000 m)
- V-fin black and white Video Plankton Recorder (VPR) to collect images of plankton and ground-truth EK60 acoustic data (max depth 300 m)
- Imaging Flow Cytobot (IFCB) to collect images of phtyoplankton
- 61cm Bongo net to sample plankton
- 1x2 m modified Neuston net to provide increased ichthyoplankton sampling

Nightime Midwater Trawl Sampling (Legs 1 and 2)

During Legs 1 and 2 a shallow-water midwater trawl was used as the primary trawl, and a polytron midwater rope trawl was brought as a backup to collect biological samples and verify species composition of acoustic backscatter. The midwater trawls used 3.5 m^2 suberkrub doors, and 1.8 m^2 suberkrub doors were brought as backups. The shallow-water midwater trawl used 100-lb tom weights, whereas the polytron trawl used 600-lb tom weights. The trawls were rigged similarly. The shallow-water midwater trawl was fished at speeds of about 2 – 2.5 knots and the polytron fished at about 4 – 4.5 knots. The midwater trawl was deployed during survey operations, and targeted on acoustic backscatter to a maximum depth of about 1000 m. The maximum depth was set by the amount of trawl wire available. The duration and depth of the trawls were not standardized and were dependent on the amount of acoustic backscatter observed.

The midwater trawl was monitored in real time with the Simrad FS70 trawl monitoring system. The FS70 used the third-wire constant tension winch and provided real-time visual display of the mouth opening and depth of the net.

The trawl catches were brought on board and placed in the checker/sorting table on the back deck. The catch was sorted and then processed using the FSCS on-board entry system, version 1.6. Fish and invertebrates were identified to the lowest taxonomic level possible. Most of the catch was then discarded, though some samples were preserved and brought back to the lab, particularly the unique and questionable samples.

Active Acoustic Sampling (Legs 1, 2, and 3)

Active acoustic data were collected during the survey on all three legs to characterize spatial distributions of potential prey and investigate relationships among predator (marine mammals), prey, and oceanography. Active acoustic data were collected with the NOAA ship *Henry B. Bigelow*'s multi-frequency (18, 38, 70, 120, and 200 kHz) scientific EK60 echo sounders and split-beam transducers mounted downward-looking on the retractable keel. Data were collected to 3000 m, regardless of bottom depth. The ping interval was set to 2 pings per second, but actual ping rate were slower due to two-way travel time and signal processing requirements of the EK60. The EK60 was synchronized to the ES60 on the bridge, the Acoustic Doppler Current Profiler (ADCP), and Simrad ME70 multibeam to alleviate acoustic interference among acoustic instruments. At daily intervals throughout the survey EK60 data were recorded in passive mode to assist with noise removal post-processing procedures and to investigate effects of the echo sounders on passive acoustic detections. Survey speeds for underway acoustic data collection were 10 – 12 kts.

Active acoustic data were collected continuously but with the EK60 in passive mode on every other day during daytime operations. Active acoustic data were only collected every other day during daylight so that impacts could be investigated between active acoustic transmissions and detection of marine mammals made by both the visual observers and the passive acoustic hydrophone. On passive mode days all transmissions were turned off, except at times when the bridge needed depth information. Acoustic data in active mode were collected continuously during nighttime operations.

V-fin VPR Sampling (Legs 1 and 2)

The VPR was towed opportunistically targeting areas too shallow to tow the larger net gear, areas with interesting oceanography, or areas with strong signals on the EK60. The V-fin was towed from the aft hydrographic winch allowing increased tow speeds of 4 – 5 knots. The v-fin was also equipped with a Seabird SBE49 Fastcat CTD and a Wet Labs Eco-Flur fluorometer and turbidity sensor which provided the hydrographic conditions for each volume of water imaged. The camera imaging area was set to image the largest area possible, sampling an area of about 345 ml sixteen times a second. The largest camera setting was used to image gelatinous zooplankton and the macroplankton that is most likely imaged by the 120 and 200 kHz frequencies of the EK60.

Two types of tows were conducted. The first type was a single depth tow that targeted distinct layers on the EK60 to provide temporally fine scale plankton data to assist in the ground truthing of the EK60 data and to examine plankton patchiness. The second type was a tow-yo haul which was used to describe water column hydrographic structure and plankton depth distributions. Tow-yo hauls were conducted if there were no distinct layers on the EK60 or the oceanography looked interesting.

Bluefin Tuna Spawning Area Sampling (Legs 1, 2 and 3)

In areas where the depth exceeded 1000 m and the sea surface temperature exceeded 22°C sampling was conducted to collect ichthyoplankton, in particular bluefin tuna (*Thunnus thynnus*). A standard 61 cm bongo double oblique tow was conducted to 200 m to provide a standardized sample that can be compared to the NEFSC's ECOMON or the SEFSC's Seamap data sets. A second tow was conducted with a weighted 1x2 m neuston towed in a "W" shaped path from the surface to 25 m depth. The neuston net is a more effective ichthyoplankton sampler and will be used to provide larvae to both academic and NMFS researchers for age and genetics studies. Sampling was also conducted within the Gulf Stream to test the theory that the larval Bluefin tuna are being transported north from known spawning areas by the Gulf Stream.

RESULTS

Scientists involved in this survey are detailed in Table A2.

VISUAL MARINE MAMMAL-TURTLE SIGHTING TEAM

The visual marine mammal and turtle team surveyed about 5354 km while on effort during at least parts of 39 of the 48 possible sea-days (with an additional 6 days that were considered transit days between port and the study area). The weather conditions were too poor to survey on the other 9 sea-days (Table A3). About 70% of the on-effort survey track lines were conducted in good weather conditions, Beaufort sea state 3 or less.

During the on-effort portions of the track lines, 30 cetacean species or species groups, 3 turtle species or species groups, 1 seal species group, and 6 fish species or species groups were recorded (Tables A4 – A5). For cetaceans, the upper team detected 1,234 groups (16,183 individuals) and the lower team detected 1,216 groups (13,594 individuals). For turtles, the upper team detected 22 groups (22 individuals) and the lower team detected 26 groups (27 individuals). Note some, but not all, groups of cetaceans and turtles detected by one team were also detected by the other team. Only one seal was detected. In addition, 23 (16) basking sharks and 18 (12) ocean sunfish was detected by the upper (and lower) teams.

Distribution maps of sighting locations of the cetaceans, turtles, seals and fish are displayed in Figures A2 – A11. Note these are locations of sightings seen by only the upper team. The most abundance species (Figures A2 – A3) were striped dolphins (*Stenella coeruleoalba)* and common dolphins (*Delphinus delphis*), where the striped dolphins were found in deeper waters (mostly 1000 m or deeper) than the common dolphins (mostly 1000 m or shallower). The most common large whales (Figures A7 – A8) were fin whales (*Balaenoptera physalus*) and sperm whales (*Physeter microcephalus*). Of interest, 6 groups (37 individuals) of false killer whales (*Pseudorca crassidens*), 3 blue whales (*Balaenoptera musculus*), and 3 minke whales (*Balaenoptera acutorostrata*) were detected (Figure A8).

Biopsy samples were collected from five animals, 1 bottlenose dolphin, 2 common dolphins from one group, and 2 spinner dolphins from one group (Figure A12).

VISUAL SEABIRD SIGHTING TEAM

Seabird survey effort was conducted on at least parts of 44 out of 48 sea-days totalling 6,655 km. This included about 550 km conducted in Beaufort 6 and 7 conditions which was not surveyed by the visual teams (Figure A13). Nomenclature of species identifications followed that reported in The Clements Checklist of Birds of the World. 6th edition, Cornell University Press 2007, with electronic updates to 2016.

A summary of the 4677 birds seen while on effort broken down by species is presented in Table A6, where the locations of most of the species are mapped in Figures A13 – A19. This survey recorded 34 species of birds and 11 unidentified species groups (e.g., unidentified shearwater, unidentified storm-petrel or unidentified shore bird). Five species comprised 88% of the total birds seen. In declining order of abundance these were: Great Shearwater *(Puffinus gravis)*, Wilson's Storm-Petrel *(Oceanites oceanicus)*, Cory's Shearwater *(Calonectris diomedea)*, Audubon's Shearwater *(Puffinus lherminieri)*, and Leach's Storm-Petrel *(Oceanodroma leucorhoa)*, which was similar to other summer surveys in this same general region.

These widespread species were occasionally found in small scale clusters, particularly storm-petrels, which would often concentrate in upwelling areas seaward of the shelf break. Meanwhile others, such as Black-capped Petrel *(Pterodroma hasitata*; Figure A15*)* and Bridled Tern *(Onychoprion anaethetus*; Figure A17) are tropical and sub-tropical species closely linked to their preferred habitat; in this case, warm Gulf Stream water. Extensive warm surface waters may have had an influence on the abundance and distribution of Audubon's Shearwater (Figure A13). This species was unusually abundant and widespread with several being seen as far north as Canadian waters around 42°N. Similarly, the large number of White-faced Storm-Petrels *(Pelagodroma marina*; Figure A16*)* seen this year, another warm water species, may be due to the same factors. Notably, several White-faced Storm-Petrels were seen off Nova Scotia (40 – 42°N) which was previously considered extremely unusual, though they were seen in the same general area during previous AMAPPS summer surveys.

This year's survey confirms patterns seen in past summer AMAPPS shipboard surveys for the Barolo Shearwater *(Puffinus baroli*; Figure A14). Its status in North American waters, inferred from only a handful of sightings in the last 100 years, is poorly known. It is very rare anywhere in the northwest Atlantic. The normal breeding range includes islands off northwest Africa (Canary Islands, Azores, Desertas and Salvage), but the species at-sea distribution is less clear. The one we saw on this survey, combined with several sightings detected in the last few years, strongly support the current hypothesis that the Barolo Shearwater is in fact a regular but rare late-summer to early-fall visitor to deep waters far off New England and Nova Scotia.

All other seabirds were regularly occurring northwest Atlantic Ocean species. The most obvious exception were the nine White-faced Tropicbird (*Phaeton lepturus*; Figure A18). This species is rare this far north in the Atlantic Ocean—yet another tropical species likely responding to the widespread warm surface water present this year.

PASSIVE ACOUSTIC DETECTION TEAM

Over the course of the survey, acoustic monitoring effort was conducted on 41 survey days, with a total of 496 hrs of recording on survey tracklines (Table A7). This total includes daytime survey effort, as well as additional nighttime effort that was conducted during Leg 3. The hydrophone array was not deployed on days during which shallow, coastal lines were surveyed.

Real-time monitoring resulted in the detection of 517 groups of vocally-active odontocetes, not including sperm whales (Figure A20, Table A8). Sperm whales and beaked whales were acoustically classified when possible. Delphinid encounters were only classified to species when there was clear correspondence to visual sightings in real-time. Approximately 18% of the delphinid groups corresponded to simultaneous visual detection, allowing for acoustic species assignment in the field (Table A8). Seven species of delphinids were represented in the data, along with sperm whales and several species of beaked whales. At times, delphinid acoustic activity was so intense and prolonged that it precluded acoustic detections of any other species. In some cases, large schools of dolphins that covered a broad spatial range were difficult to localize accurately in real-time, making a direct comparison with visual sighting locations impossible. Additionally, in many cases it was impossible in real time to acoustically differentiate between subgroups of animals that were visually distinguished and counted as separate sightings, resulting in an underestimate of acoustic detections as compared to visual detections. Both of these latter issues will be addressed in post-processing analyses. Post-processing of passive acoustic data will be conducted to extract acoustic events of interest, compare visual and acoustic detection rates, and evaluate performance of species-specific classifiers.

Sperm whales were detected on at least 35 survey days, for a total of 314 vocally-active groups (Table A9). In some cases, these acoustic events represent multiple individuals. Sperm whale acoustic detections are under-represented in Leg 1, where more effort was focused on tracking delphinid groups. Total number of individual sperm whales on each leg will be calculated through localization and tracking in post-processing analyses.

In addition, 29 sonobuoys were deployed throughout the survey (Figure A21). Sonobuoys were used as “point” sampling stations, specifically to add acoustic monitoring for large whales. Each station was monitored for at least 20 minutes, and up to several hours. Four of the sonobuoys failed upon deployment; the remaining 25 worked with varying degrees of success. Sperm whales and dolphins were frequently recorded. Data will be post-processed to identify all baleen whale acoustic detections.

OCEANOGRAPHIC, PLANKTON, and NEKTON SAMPLES

During the day and night active acoustic sampling and 411 sampling events were completed. This included 189 casts of the 19+CTD, 119 bongo deployments, 26 VPR hauls, deployments, 42 neuston deployments, and 35 midwater trawls (Table A10; Figure A22). More details from these sampling stations and gear types are below.

Acoustic Sampling (Legs 1, 2 and 3)

Active acoustic data were collected during all nights of all three legs. During leg 2, data were post-processed on board in near real time and midwater trawl sampling was based on acoustic observations. Active acoustics were collected during all nights. During daylight hours, when visual observations were being collected, the echo sounders were on at all times but were set to passive mode (transmitting off) every other day and to active mode (transmitting on) on the other days.

In oceanic waters east of the continental shelf, there was a consistent acoustic deep scattering layer from about 600 to 800 m, which was consistently present day and night (Figure A23). At night, a portion of this layer migrated to the surface (Figure A23). In addition, there was a thin scattering layer centered at about 1700 m. The presence and acoustic intensity of the shallower layers (<500 m) tended to be dependent on proximity to the shelf break, canyon features, the Gulf Stream, and warm-core rings.

Future analysis will involve post-processing of the data to remove unwanted signal (e.g., from the seafloor) and noise. Differences in scattering levels at the different frequencies will be used to identify features attributable to different kinds of scatters and the net and VPR data will be used to ground-truth the taxonomic composition of these features. The distribution of different kinds of scatters will then be examined in light of bathymetry, hydrography, and the distribution of marine mammal predators.

V-fin VPR Sampling (Legs 1 and 2)

All VPR hauls were processed while on the ship. Images (ROIs) were identified to large taxonomic groupings by Visual Plankton software then hand corrected to smaller categories to better quantify gelatinous zooplankton. Notably, salp numbers were lower than in previous years and there was no dominant species. Six species of salps had been identified: *Salpa aspera, Salpa* *fusiformes*, *Iasis zonata*, *Thetys vagina*, *Thalia democratica*, and *Cyclosalpa* sp. This is the first time *I. zonata* and *Cyclosalpa* sp have been identified from an AMAPPS cruise that have been in the same area during the same time of the year.

Bluefin Tuna Spawning Area Sampling (Legs 1, 2 and 3)

Preliminary ichthyoplankton processing of some neuston samples discovered numerous larvae identified as Bluefin tuna (Figure A24 – A25). These microscope based identifications will be confirmed by genetic analysis.

Midwater Trawl Sampling (Leg 2)

Midwater trawl sampling was conducted during Leg 2 during nighttime operations. We conducted 35 midwater trawl hauls, most of them in oceanic waters east of the continental shelf (Figure A26). We identified the individuals to the lowest taxonomic level possible while at sea. In some cases this was species, others were at the Genus and Family level.

The shallow tows were dominated by myctophids such as *Benthosema* and *Diaphus* species, along with hatchetfish and numerous families of cephalopods. The deep tows captured shortfin squid (*Illex illecebrosus*), other cephalopod species, and a number of mesopelagic fish species, such as slender snipe eels (*Nemichthys scolopaceus*), ridgehead species (Melamphaidae), viperfish (*Chauliodus sp.*), and bristlemouths (Gonostomatidae). We are currently auditing the trawl data and then it will be archived in the NEFSC fish database.

Phytoplankton Sampling (Leg 1)

The Imaging Flow Cytobot (IFCB) imaged all plankton in a size range of 10 to 100 μm within 5 ml aliquots of filtered seawater. Numbers ranged from a low of 15 images per aliquot in Gulf Stream and oceanic waters to over 2000 per aliquot in inshore waters. The majority of the images were of phytoplankton, especially dinoflagellates (Figure A27). To compliment the IFCB data, a Wetlabs Eco-flur turbidity and fluorescence sensor was added to the Seabird 19+ CTD.

Images have all been uploaded to the Woods Hole Oceanographic Institute IFCB dashboard website http://ifcb-data.whoi.edu/mvco. Next, the images will be sorted into categories based on phytoplankton type and environmental data from the ship's SCS system and CTD sampling will be associated with each image. Future improvements to the website will allow geographical mapping.

Oceanographic Sampling (Legs 1, 2 and 3)

Oceanographic sampling covered a wide variety of unique hydrographic conditions. The mid-Atlantic shelf break and offshore areas were dominated by the Gulf Stream which was closer to the shelf break than in previous summers (Figures A28 – A29). Salinities were above 36 psu (practical salinity unit) and there was not a strong thermocline (A30). The inshore position of the Gulf Stream offered a unique opportunity to conduct sampling within the Gulf Stream and in the oceanic waters beyond the Gulf Stream.

Sampling along the southern New England and Georges Bank shelf breaks focused on the canyon areas. Sampling included the areas in and around Hudson, Atlantis, Hydrographer, Welker, Lydonia, Munson, and Nygren Canyons. In the offshore area south and east of Georges Bank sampling covered a large warm core ring, Balanus Seamount, and the Northeast Channel.

Special Sampling

There were two researchers that requested special gelatinous zooplankton samples to be collected during this cruise.

Ann Bucklin: University of Connecticut, Avery Point, CT

Requested geographically spaced samples of *Salpa aspera* for genetic studies. We collected 27 samples of salps that were preserved in 95% ethanol (Figure A31). Samples will be used to genetically code the salp species found in the northwest Atlantic. Salp species saved were mostly *Salpa aspera* but included samples of *Salpa fusiformes, Iasis zonata, Thetys vagina* and *Cyclosalpa* sp for comparisons.

Tony Moss: Auburn University, Auburn, AL

Requested species of rare ctenophores and salps for taxonomic study. We were only able to supply specimens of one of the requested genus of salp, *Cyclosalpa* sp. We collected two samples that were preserved in 5% formaldehyde and seawater and two samples from the same sampling station that were preserved in 95% ethanol.

DISPOSITION OF THE DATA

All visual and passive acoustic data collected will be maintained by the Protected Species Branch at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, MA. Visual sightings data will be archived in the NEFSC's Oracle database and later submitted to OBIS SEAMAP.

All active acoustic data are archived at the NEFSC and at NOAA's National Center for Environmental Information (NCEI) facility in Boulder, CO. The data will be publically available when they are archived at NCEI.

All hydrographic data collected will be maintained by the Oceans and Climate Branch at the NEFSC in Woods Hole, MA. Hydrographic data can be accessed through the Oceanography web site http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html or the NEFSC's Oracle database.

All plankton samples collected will be maintained by the Oceans and Climate Branch at the NEFSC in Narragansett RI. Plankton samples in ethanol will be identified by taxonomists in Woods Hole and Narragansett. Plankton samples in formaldehyde will be sent to Poland for identification. After identification and enumeration are complete plankton data can be accessed through the NEFSC's Oracle database.

All VPR data will be processed and maintained by the Oceans and Climate Branch at the NEFSC in Woods Hole, MA. VPR oceanographic data and images are currently available by request only.

All Imaging Flow Cytobot data will be maintained by Woods Hole Oceanographic Institution. Metadata and images can be accessed through the IFCB website http://ifcb-data.whoi.edu/IFCB101_BigelowJun2016

Table A1. SCS data collected continuously every second during the survey and stored in a user created file.

Date (MM/DD/YYYY)	
Time (hh:mm:ss)	TSG-Conductivity (s/m)
EK60-38kHz-Depth (m)	TSG-External-Temp (ºC)
EK60-18kHz-Depth (m)	TSG-InternalTemp (ºC)
ADCP-Depth (m)	TSG-Salinity (PSU)
ME70-Depth (m)	TSG-Sound-Velocity (m/s)
ES60-50kHz-Depth (m)	MX420-Time (GMT)
Doppler-Depth (m)	MX420-COG (º)
Air-Temp (ºC)	MX420-SOG (Kts)
Barometer-2 (mbar)	MX420-Lat (DDMM.MM)
YOUNG-TWIND-Direction (º)	MX420-Lon (DDMM.MM)
YOUNG-TWIND-Speed (Kts)	Doppler-F/A-BottomSpeed (Kts)
Rel-Humidity (%)	Doppler-F/A-WaterSpeed (Kts)
Rad-Case-Temp (ºC)	Doppler-P/S-BottomSpeed (Kts)
Rad-Dome-Temp (ºC)	Doppler-P/S-WaterSpeed (Kts)
Rad-Long-Wave-Flux (W/m^2)	High-Sea Temp (ºC)
Rad-Short-Wave-Flux (W/m^2)	POSMV – Time (hhmmss)
ADCP-F/A – GroundSpeed (Kts)	POSMV – Elevation (m)
ADCP-F/A – WaterSpeed (Kts)	POSMV – Heading (º)
ADCP-P/S – GroundSpeed (Kts)	POSMV – COG (Kts)
ADCP-P/S – WaterSpeed (Kts)	POSMV – SOG (Kts)
Gyro (º)	POSMV – Latitude (DDMM.MM)
POSMV – Quality (1=std)	POSMV – Longitude (DDMM.MM)
POSMV – Sats (none)	POSMV – hdops (none)

Table A2. Scientific personnel involved in the three legs of this survey. FN = Foreign National.

Personnel	Title	Organization
Leg 1 (27 Jun – 14 Jul 2016)		
Debra Palka	Chief Scientist	NMFS, NEFSC, Woods Hole, MA
Elisabeth Broughton	Oceanographer	NMFS, NEFSC, Woods Hole, MA
Michael Force (FN)	Seabird Observer	Integrated Statistics, Woods Hole, MA
Nicholas Metheny	Seabird Observer	Integrated Statistics, Woods Hole, MA
Rachel Hardee	Mammal Observer	Integrated Statistics, Woods Hole, MA
Richard Holt	Mammal Observer	Integrated Statistics, Woods Hole, MA
Todd Pusser	Mammal Observer	Integrated Statistics, Woods Hole, MA
Suzanne Yin	Mammal Observer	Integrated Statistics, Woods Hole, MA
Carol Roden	Mammal Observer	Integrated Statistics, Woods Hole, MA
Erin LaBreque	Mammal Observer	Integrated Statistics, Woods Hole, MA
Jennifer Gatzke	Mammal Observer	Integrated Statistics, Woods Hole, MA
Sam Chavez	Mammal Observer	Integrated Statistics, Woods Hole, MA
Annamaria Izzi	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Julianne Gurnee	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Leg 2 (18 Jul – 5 Aug 2016)		
Debra Palka	Chief Scientist	NMFS, NEFSC, Woods Hole, MA
Elisabeth Broughton	Oceanographer	NMFS, NEFSC, Woods Hole, MA
Michael Jech	Oceanographer	NMFS, NEFSC, Woods Hole, MA
Michael Force (FN)	Seabird Observer	Integrated Statistics, Woods Hole, MA
Nicholas Metheny	Seabird Observer	Integrated Statistics, Woods Hole, MA
Deborah Epperson	Mammal Observer	BSEE[1]
Rachel Hardee	Mammal Observer	Integrated Statistics, Woods Hole, MA
Richard Holt	Mammal Observer	Integrated Statistics, Woods Hole, MA
Todd Pusser	Mammal Observer	Integrated Statistics, Woods Hole, MA
Suzanne Yin	Mammal Observer	Integrated Statistics, Woods Hole, MA
Carol Roden	Mammal Observer	Integrated Statistics, Woods Hole, MA
Erin LaBreque	Mammal Observer	Integrated Statistics, Woods Hole, MA
Jennifer Gatzke	Mammal Observer	Integrated Statistics, Woods Hole, MA
Annamaria Izzi	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Samara Haver	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Leg 3 (9 Aug – 25 Aug 2016)		
Danielle Cholewiak	Chief Scientist	Integrated Statistics, Woods Hole, MA
Michael Force (FN)	Seabird Observer	Integrated Statistics, Woods Hole, MA
Nicholas Metheny	Seabird Observer	Integrated Statistics, Woods Hole, MA
Peter Duley	Mammal Observer	NMFS, NEFSC, Woods Hole, MA
Jessica Aschettino	Mammal Observer	Integrated Statistics, Woods Hole, MA
Salvador Cerchio	Mammal Observer	Integrated Statistics, Woods Hole, MA
Todd Pusser	Mammal Observer	Integrated Statistics, Woods Hole, MA
Suzanne Yin	Mammal Observer	Integrated Statistics, Woods Hole, MA
Carol Roden	Mammal Observer	Integrated Statistics, Woods Hole, MA
Erin LaBreque	Mammal Observer	Integrated Statistics, Woods Hole, MA
Jennifer Gatzke	Mammal Observer	Integrated Statistics, Woods Hole, MA
Genevieve Davis	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Tina Yack	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Kathryn Scurci	Passive Acoustics	Integrated Statistics, Woods Hole, MA

[1]BSEE= Bureau of Safety and Environmental Enforcement

Table A3. Within each Beaufort sea state condition, total length (in km) of visual teams' track lines while on and off effort.

	Track Line Length (km) Within Beaufort Sea State Levels							
Effort	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Off	1.68	42.14	52.13	119.73	151.13	124.27	-	491.08
On	111.62	539.58	1,445.17	1,600.99	1,412.40	237.76	6.30	5,353.82
Total	**113.30**	**581.72**	**1,497.30**	**1,720.72**	**1,563.53**	**362.03**	**6.30**	**5,844.90**

Table A4. Number of groups and individuals of cetacean species detected by the two marine mammal - turtle visual teams (upper and lower) during on-effort track lines. Note, some, but not all, groups detected by one team were also detected by the other team.

Species		Number of Groups		Number of Individuals	
		Lower	**Upper**	**Lower**	**Upper**
Atlantic spotted dolphin	*Stenella frontalis*	15	12	367	291
Blainville's beaked whale	*Mesoplodon densirostris*	0	1	0	3
Blue whale	*Balaenoptera musculus*	3	3	3	3
Bottlenose dolphin spp.	*Tursiops truncatus*	81	90	805	949
Common dolphin	*Delphinus delphis*	94	98	4846	5789
Cuvier’s beaked whale	*Ziphius cavirostris*	32	23	94	62
Delphinus/Stenella	*Delphinus/Stenella*	23	28	519	1493
Dwarf sperm whale	*Kogia simus*	8	5	15	9
False killer whale	*Pseudorca crassidens*	6	4	37	42
Fin whale	*Balaenoptera physalus*	106	98	169	144
Fin/sei whales	*B. physalus or B. borealis*	9	31	17	41
Gervais’ beaked whale	*Mesoplodon europacus*	7	4	18	13
Humpback whale	*Megaptera novaeangliae*	46	54	76	73
Minke whale	*B. acutorostrata*	0	3	0	3
Pilot whales spp.	*Globicephala spp.*	89	86	784	684
Pygmy sperm whale	*Kogia breviceps*	3	6	4	6
Pygmy/dwarf sperm whales	*Kogia spp.*	14	17	23	21
Risso’s dolphin	*Grampus griseus*	144	168	934	1113
Risso's/Bottlenose dolphin	*Grampus/Tursiops*	8	12	53	72
Sei whale	*Balaenoptera borealis*	2	3	4	5
Sowerby’s beaked whale	*Mesoplodon bidens*	3	3	9	8
Sperm whale	*Physeter macrocephalus*	96	93	142	143
Spinner dolphin	*Stenella longirostris*	0	1	0	160
Stenella spp.	*Stenella spp.*	24	22	522	384
Striped dolphin	*Stenella coeruleoalba*	55	60	1969	2334
True's beaked whale	*Mesoplodon mirus*	3	8	11	18
White-sided dolphin	*Lagenorhynchus acutus*	1	1	19	19
Unid. Dolphin	*Delphinidae*	194	170	1917	2057
Unid. Whale	*Mysticeti*	82	68	100	83
Unid. Mesoplodon	*Mesoplodon spp.*	68	62	137	161
Total Cetaceans		**1,216**	**1,234**	**13,594**	**16,183**

Table A5. Number of groups and individuals of large fish, turtles, and seals detected by the two marine mammal - turtle visual teams (upper and lower) during on-effort track lines. Note, some, but not all, groups detected by one team were also detected by the other team.

Species		**Number of Groups**		**Number of Individuals**	
		Lower	**Upper**	**Lower**	**Upper**
Basking shark	*Cetorhinus maximus*	16	23	16	23
Billfish spp.		4	4	4	4
Manta ray spp.	*Manta spp.*	54	40	54	40
Ocean sunfish	*Mola mola*	22	18	22	18
Shark spp.		36	51	94	122
Tuna spp.		7	6	63	83
Leatherback turtle	*Dermochelys coriacea*	5	6	5	6
Loggerhead turtle	*Caretta caretta*	17	15	18	15
Unid hardshell turtle	*Chelonioidea*	4	1	4	1
Unid seal	*Pinniped*	0	1	0	1
Balloons		275	262	333	345

Table A6. Number of groups and individual birds detected by the sea bird team.

Name		Number of Groups	Number of Individuals	Relative Num of Individuals
Arctic Tern	*Sterna paradisaea*	2	4	0.001
Audubon Shearwater	*Puffinus lherminieri*	186	444	0.095
Baltimore Oriole	*Icterus galbula*	1	1	0.000
Band-rumped Storm-petrel	*Oceanodroma castro*	83	121	0.026
Barolo Little Shearwater	*Puffinus boroli assimilis*	1	1	0.000
Black-capped Petrel	*Pterodroma hasitata*	37	40	0.009
Black-crowned Night Heron	*Nycticorax nycticorax*	1	1	0.000
Bridled Tern	*Sterna anaethetus*	4	4	0.001
Brown Booby	*Sula leucogaster*	3	3	0.001
Brown-headed Cowbird	*Molothrus ater*	2	3	0.001
Common Loon	*Gavia immer*	2	2	0.000
Common Tern	*Sterna hirundo*	6	6	0.001
Cory's Shearwater	*Calonectris diomedea*	415	790	0.169
Double-crested Cormorant	*Phalacrocorax auritus*	2	2	0.000
Great Black-backed Gull	*Larus marinus*	10	11	0.002
Greater Shearwater	*Puffinus gravis*	453	1285	0.275
Herring Gull	*Larus argentatus*	22	35	0.007
Laughing Gull	*Larus atricilla*	27	30	0.006
Leach's Storm-petrel	*Oceanodroma leucorhoa*	253	329	0.070
Leach's/Hartcourt's Storm-petrel	*Oceanodrama leucorhoa/castro*	8	12	0.003
Least Sandpiper	*Calidris minutilla*	4	19	0.004
Long-tailed Jaeger	*Stercorarius longicaudus*	2	2	0.000
Manx Shearwater	*Puffinus puffinus*	13	13	0.003
Non-marine non-passerine	NA	1	1	0.000
Northern Fulmar	*Fulmarus glacialis*	1	1	0.000
Osprey	*Pandion haliaetus*	1	1	0.000
Parasitic Jaeger	*Stercorarius parasiticus*	6	6	0.001
Passerine	*Passerine*	14	17	0.004
Pomarine Jaeger	*Stercorarius pomarinus*	8	8	0.002
Red-footed Booby	*Sula sula*	1	1	0.000
Royal Tern	*Sterna maxima*	3	3	0.001
Shorebird	NA	19	128	0.027
Sooty Shearwater	*Puffinus griseus*	5	5	0.001
South Polar Skua	*Stercorarius maccormicki*	2	2	0.000
Trindade Petrel	*Pterodrama arminjoniana*	8	8	0.002
Unidentified jaeger	*Stercorarius sp*	1	1	0.000
Unidentified phalarope	Phalaropus sp	3	25	0.005
Unidentified pterodroma	*Pterodroma sp*	1	1	0.000
Name		Number of	Number of	Relative

		Groups	Individuals	Num of Individuals
Unidentified shearwater	*Puffinus sp*	2	2	0.000
Unidentified storm-petrel	*Oceanodroma sp*	2	2	0.000
Unidentified tern	*Sterna sp*	4	4	0.001
Unidentified tropicbird	*Phaeton sp*	1	1	0.000
White-faced Storm-petrel	*Pelagodroma marina*	13	13	0.003
White-tailed Tropicbird	*Phaeton lepturus*	8	9	0.002
Wilson's Storm-petrel	*Oceanites oceanicus*	336	1280	0.274
Total		1977	4677	1.000

Table A7. Summary of passive acoustic recording effort.

	Leg 1	Leg 2	Leg 3	Total
Days with towed array effort	12	15	14	41
Towed array recording hours	119.3	166.3	210.6	496.3
Number of sonobuoy deployments	11	13	6	29
Sonobuoy recording hours	22.8	32.7	6.9	62.4

Table A8. Summary of acoustic events detected in real-time during the HB 16-03 survey. Species were assigned to acoustic detections when acoustic localization and tracking resulted in direct correspondence with visual sightings. Groups without species assignment include both those that were not visually detected, as well as groups that could not be definitively linked to visual sightings in real-time. Note that in many cases, acoustic detections include multiple individuals (in the case of sperm whales) or multiple subgroups (in the case of delphinids).

Species	Leg 1	Leg 2	Leg 3	Total
Bottlenose dolphin	4	2	6	12
Common dolphin	4	1	4	9
Atlantic spotted dolphin	4	3	4	11
Striped dolphin	5	9	9	23
Stenella spp.	1	0	0	1
Risso's dolphin	3	11	6	20
Pilot whales	8	3	6	17
False killer whales	1	0	0	1
Cuvier's beaked whale	6	19	4	29
Gervais' beaked whale	1	2	0	3
True's beaked whale	0	4	2	6
Sowerby's beaked whale	0	0	2	2
Unidentified Mesoplodont	0	2	6	8
Unidentified Ziphiid	0	0	38	38
Mixed species groups	2	0	2	4
Groups without species assignment	82	68	183	333
Total	**121**	**124**	**272**	**517**

Table A9. Summary of acoustic detections of sperm whales as detected in real-time. Some detections may include multiple individuals. Data will be post-processed to identify additional encounters.

	Leg 1	Leg 2	Leg 3	Total
Days with sperm whale detections	10	14	13	37
Number of groups detected	24	139	151	314

Table A10. The number of hydrographic, nekton, and plankton sampling stations.

Sampling Type	Leg 1	Leg 2	Leg 3	Total
911+CTD				
Profile		1		**1**
Water		14		**14**
CTD 19/19+				
Profile	1	6	1	**8**
Water	13	15	19	**47**
Bongo				
Oblique	45	32	42	**119**
Neuston				
Oblique	25	5	12	**42**
VPR				
Tow-yo	12	8		**20**
Single depth	4	2		**6**
Midwater trawl		35		**35**

Figure A1. Beaufort sea states that the tracklines (colored lines) were surveyed under during HB1603. The US exclusive economic zone (EEZ) and the 100 m, 2000 m, and 4000 m depth contours are also displayed.

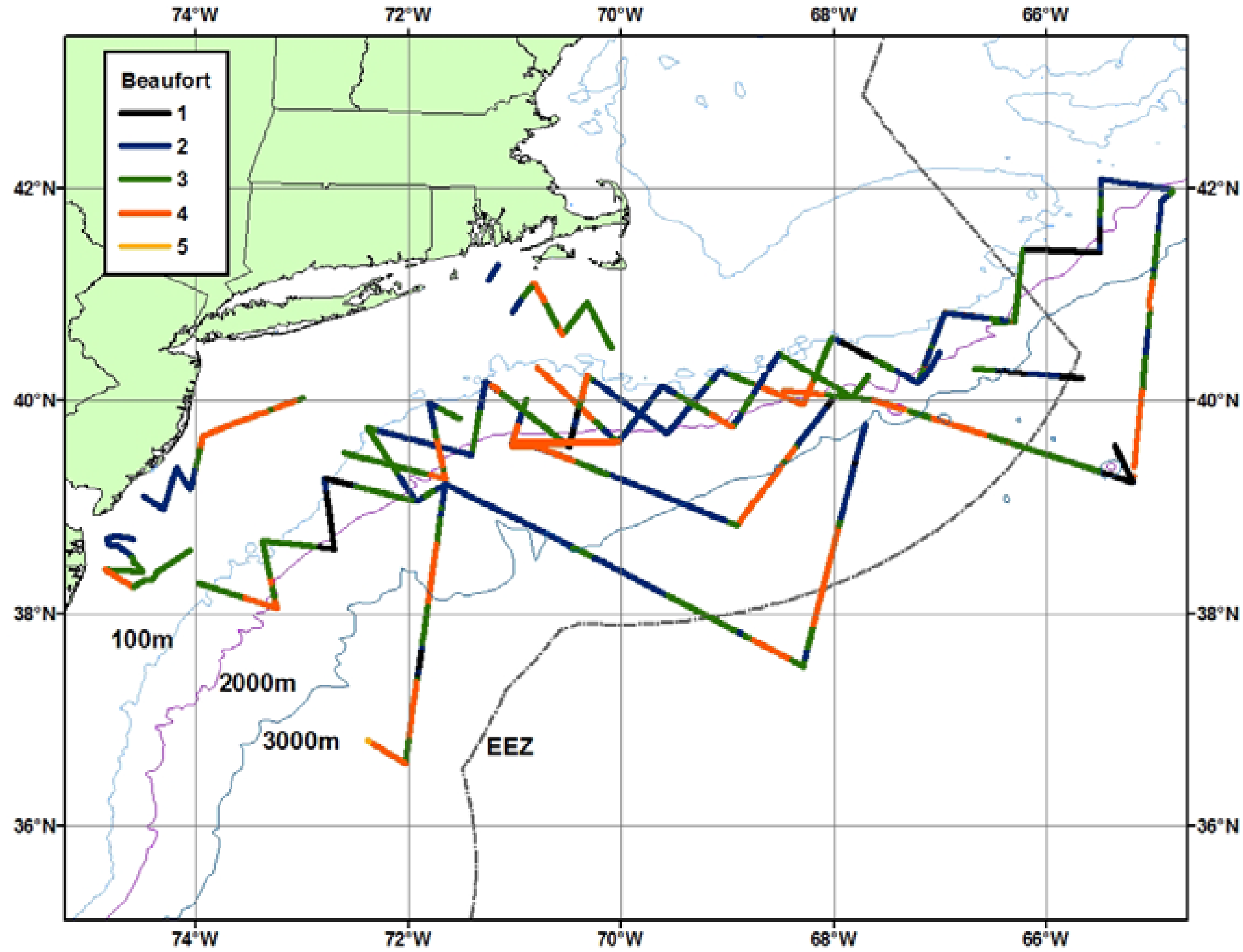
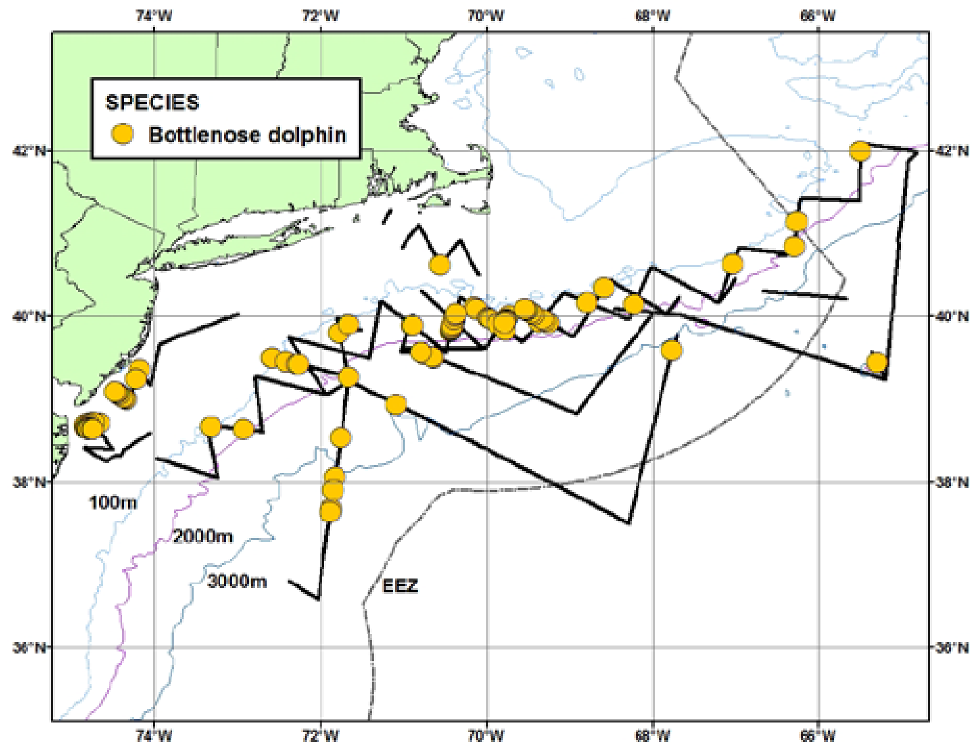


Figure A2. Location of bottlenose dolphin (*Tursiops truncatus*; top) and common dolphin (*Delphinus delphis*; bottom) sightings detected by the upper team during HB1603.



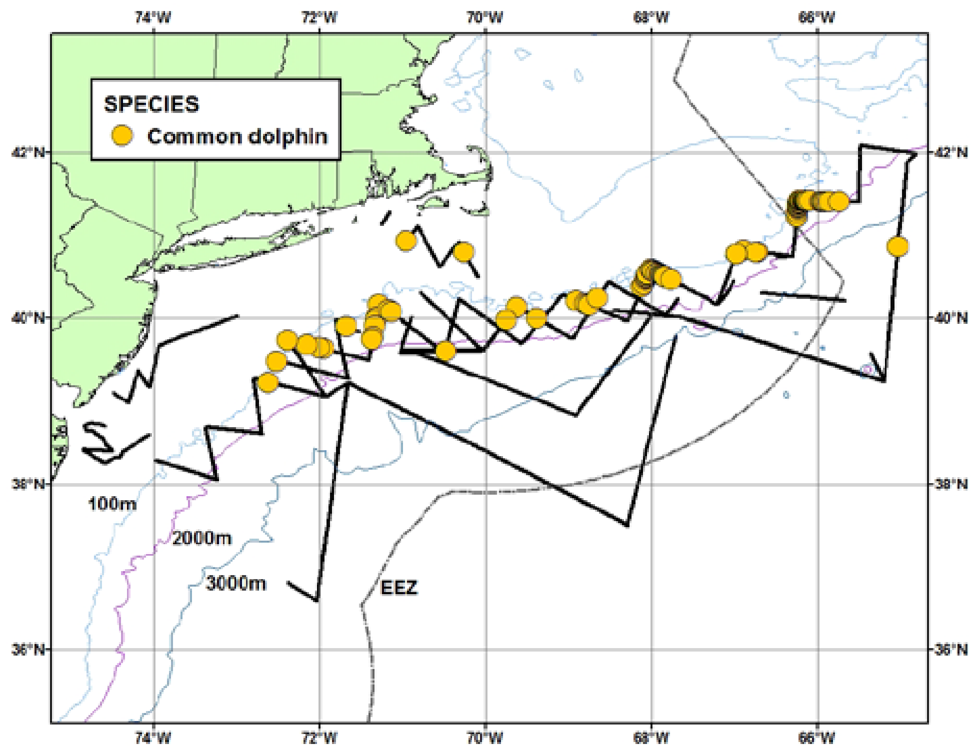


Figure A3. Location of Risso's dolphin (*Grampus griseus*; top) and striped dolphin (*Stenella coeruleoalba*; bottom) sightings detected by the upper team during HB1603.

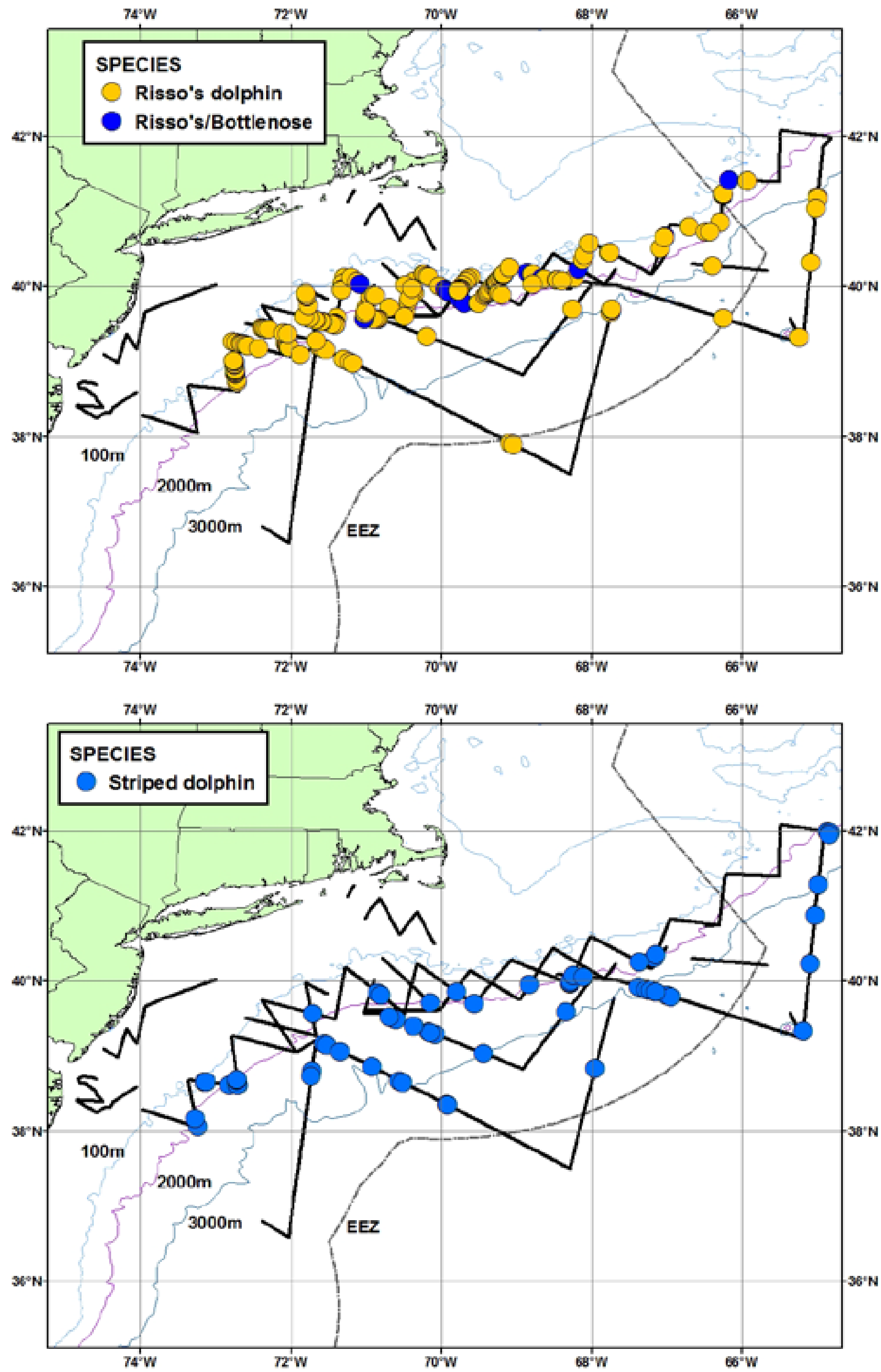


Figure A4. Location of Atlantic spotted dolphin (*Stenella frontalis*; top), white-sided dolphin (*Lagenorhynchus acutus*; top), Delphinus/Stenella (top), Stenella spp. (top) and unidentified dolphin (bottom) sightings detected by the upper team during HB1603.

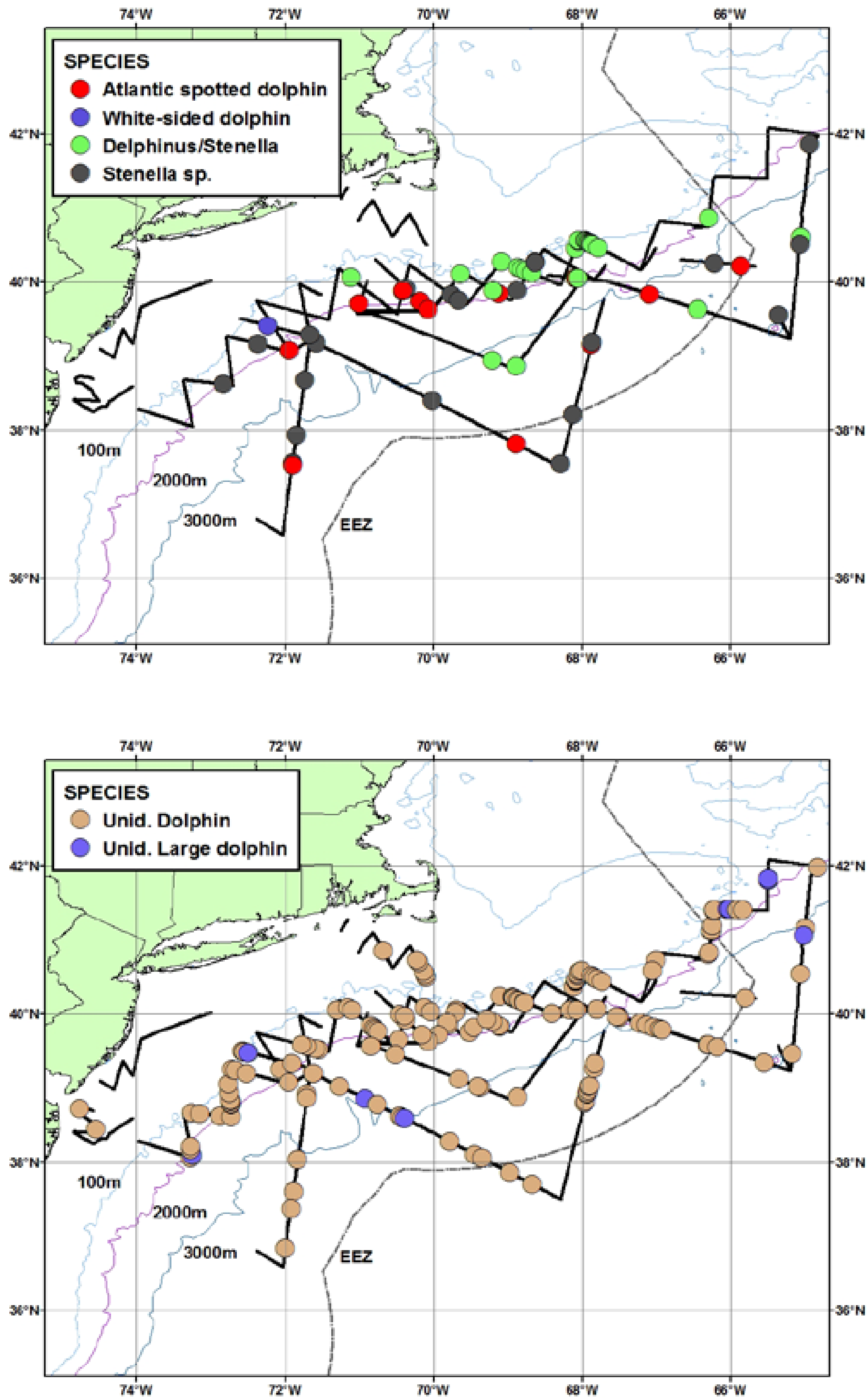
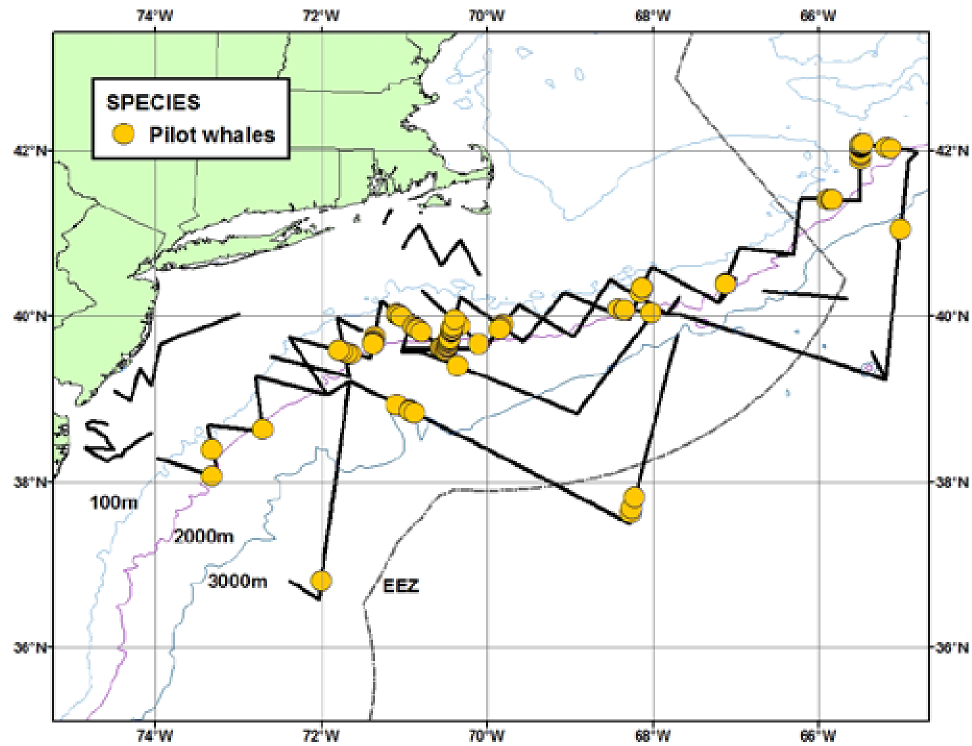


Figure A5. Location of pilot whale (*Globicephala spp.*; top), dwarf sperm whale (*Kogia simus*; bottom), pygmy sperm whale (*Kogia breviceps*; bottom) and dwarf/pygmy sperm whale (bottom) sightings detected by the upper team during HB1603.



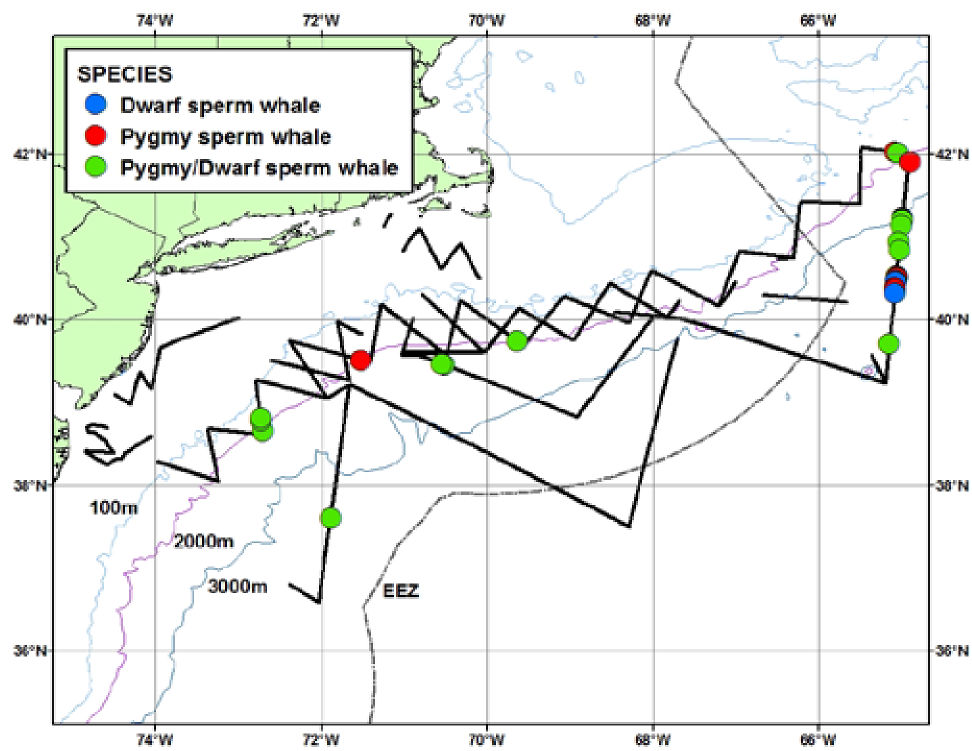


Figure A6. Location of Blainville's beaked whale (*Mesoplodon densirostris*; top), Cuvier's beaked whale (*Ziphius cavirostris*; top), Gervais' beaked whale (*Mesoplodon europacus*; top), Sowerby's beaked whale (*Mesoplodon bidens*; top), True's beaked whale (*Mesoplodon mirus*; top) and unidentified beaked whales (bottom) sightings detected by the upper team during HB1603.

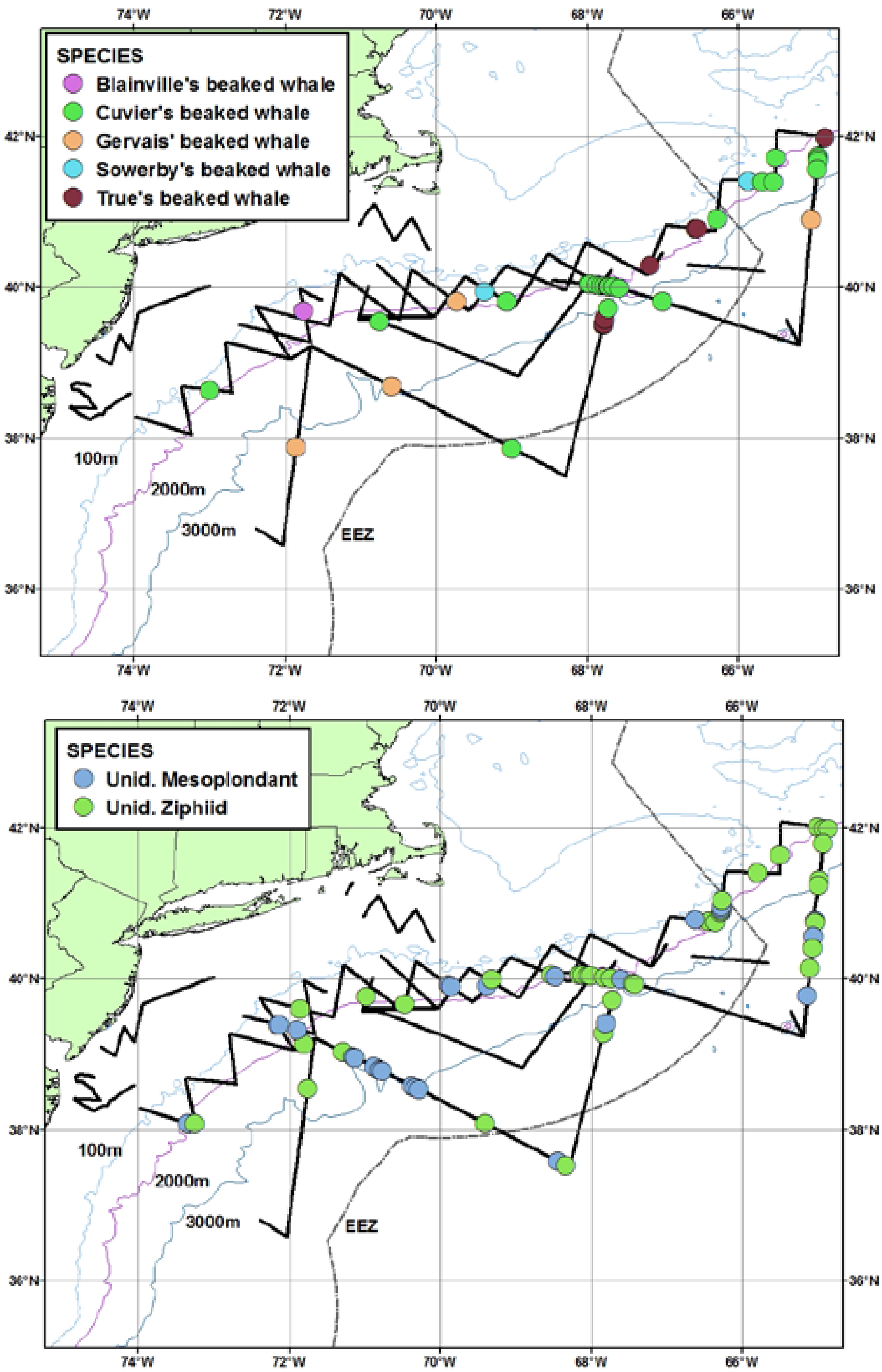
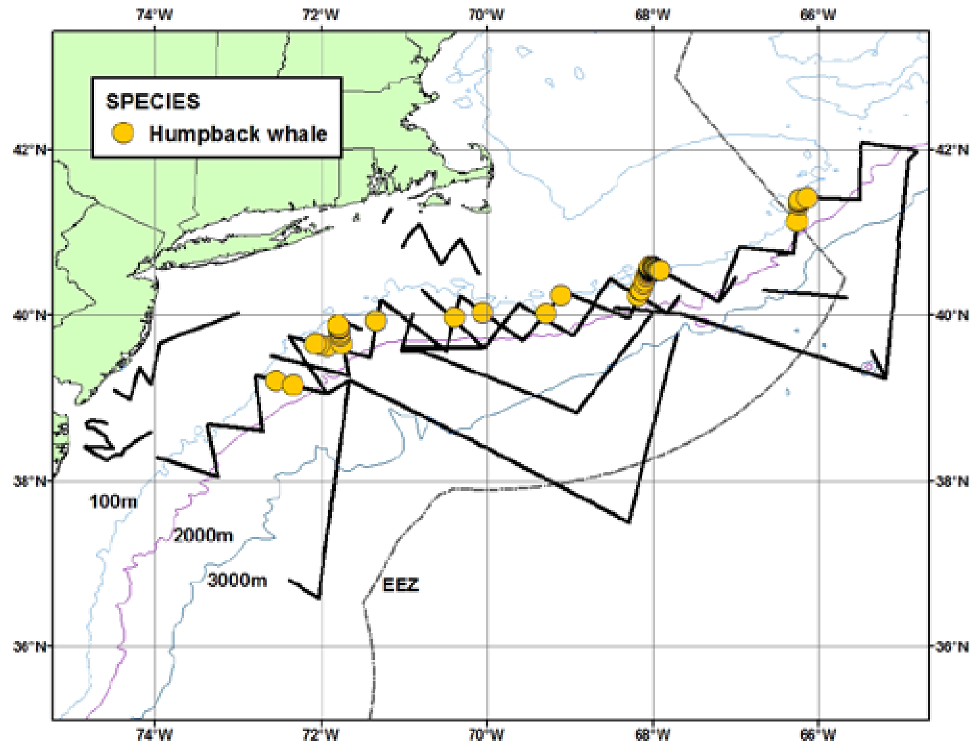


Figure A7. Location of humpback whale (*Megaptera novaeangliae*; top), fin whale (*Balaenoptera physalus*; bottom); sei whale (*Balaenoptera borealis*; bottom) and fin/sei whale (bottom) sightings detected by the upper team during HB1603.



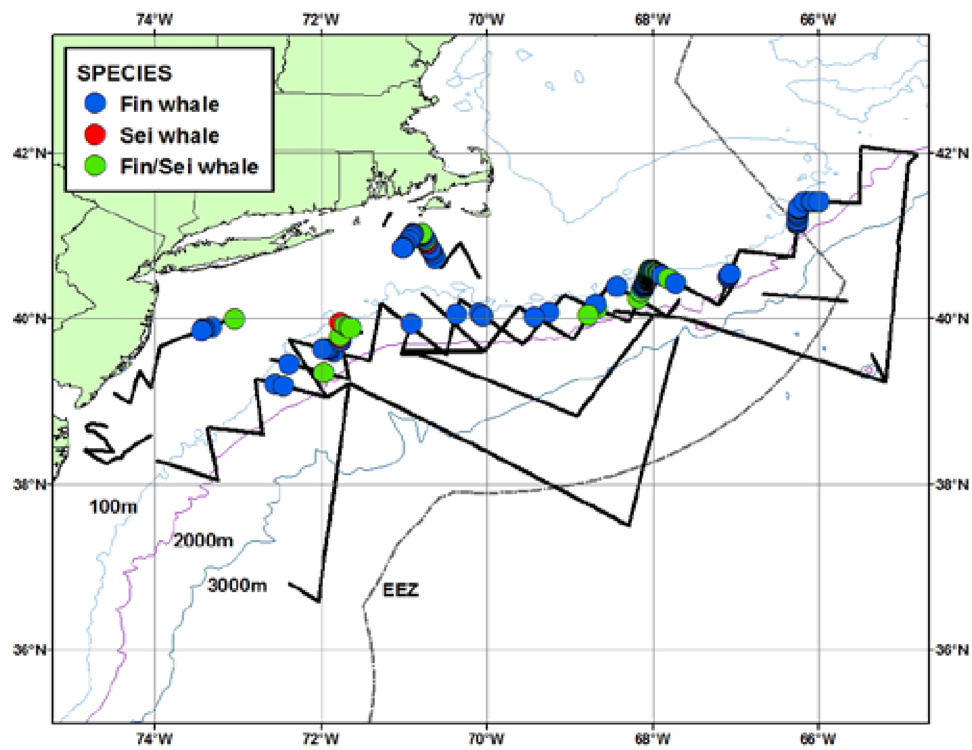
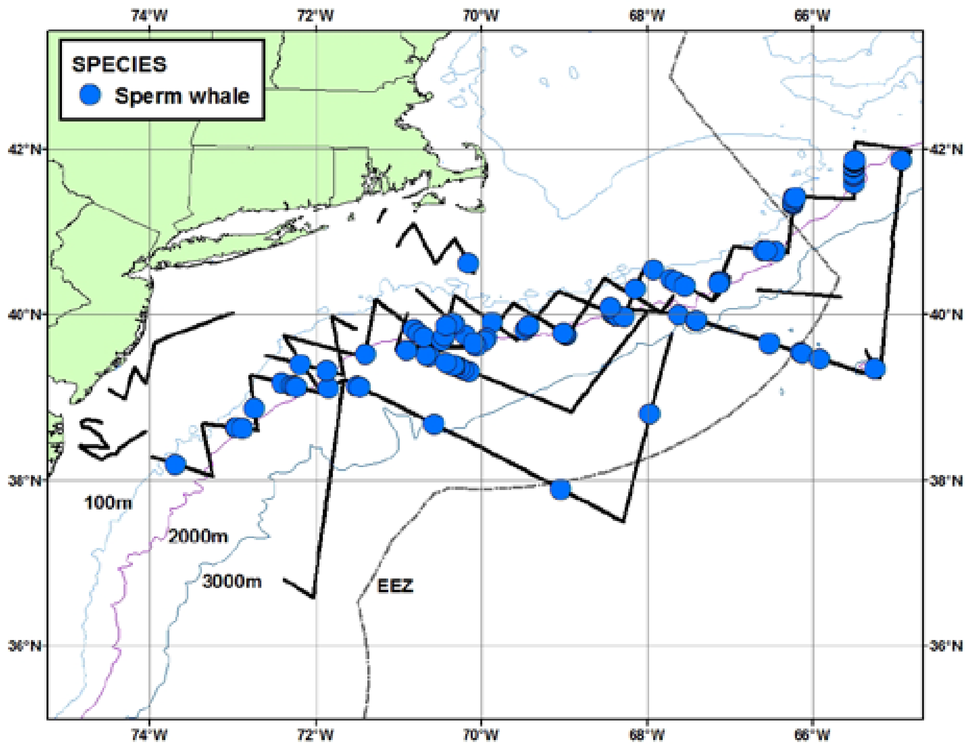


Figure A8. Location of sperm whale (*Physeter macrocephalus*; top), blue whale (*Balaenoptera musculus*; bottom); false killer whale (*Pseudorca crassidens*; bottom) and minke whale (*Balaenoptera acutorostrata*; bottom) sightings detected by the upper team during HB1603.



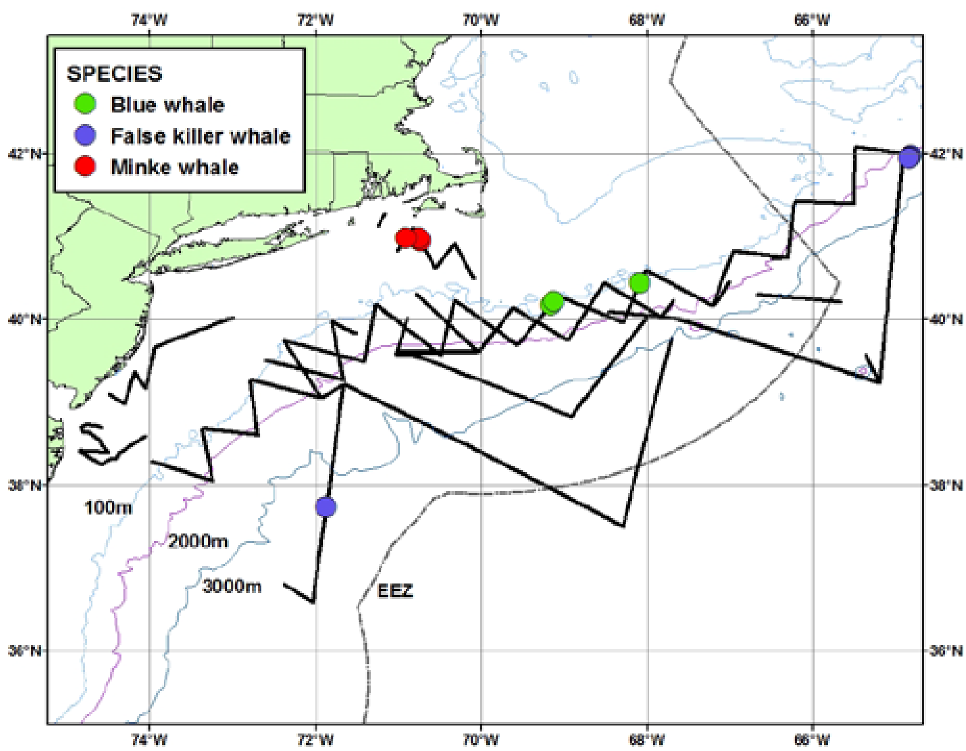
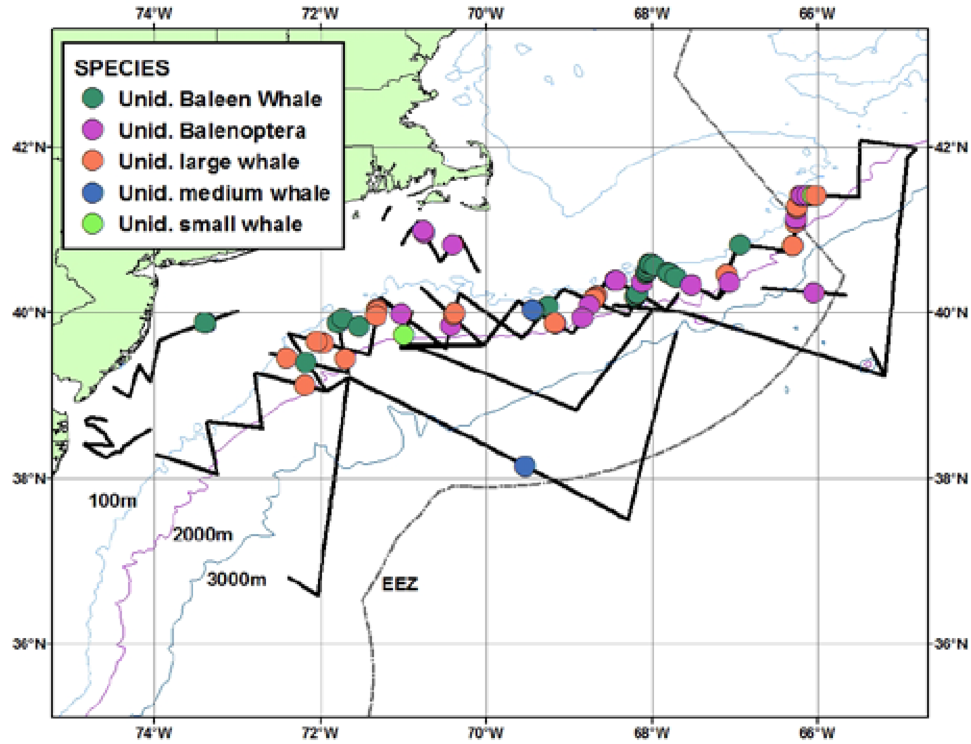


Figure A9. Location of unidentified whales (top), leatherback turtle (*Dermochelys coriacea*; bottom); loggerhead turtle (*Caretta caretta*; bottom) and unidentified turtle (bottom) sightings detected by the upper team during HB1603.



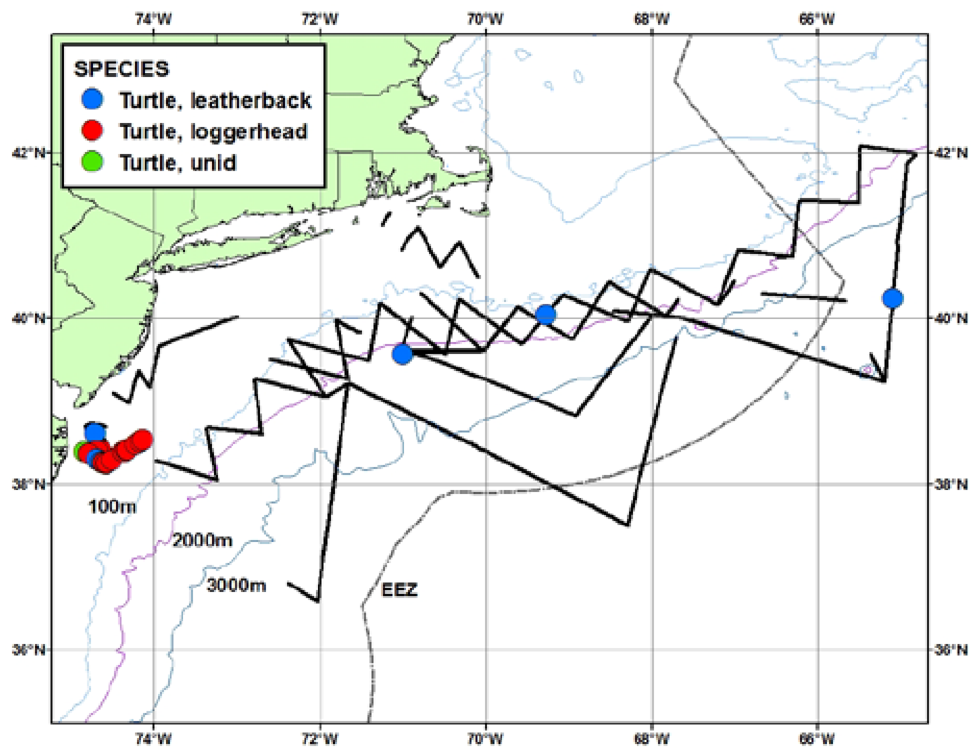


Figure A10. Location of tuna (top), unidentified shark (top) and manta ray (*Manta spp.;* bottom) sightings detected by the upper team during HB1603.

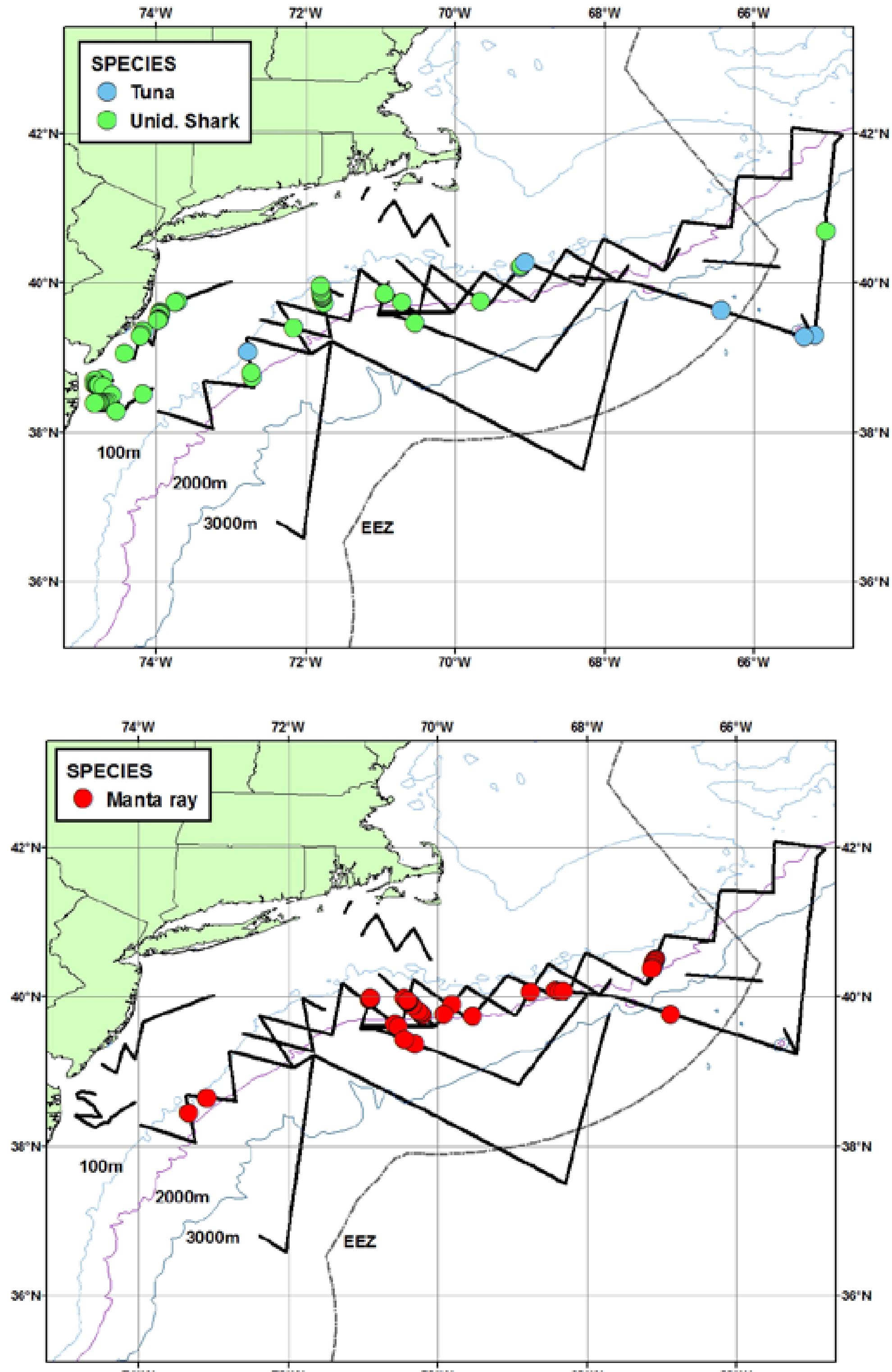
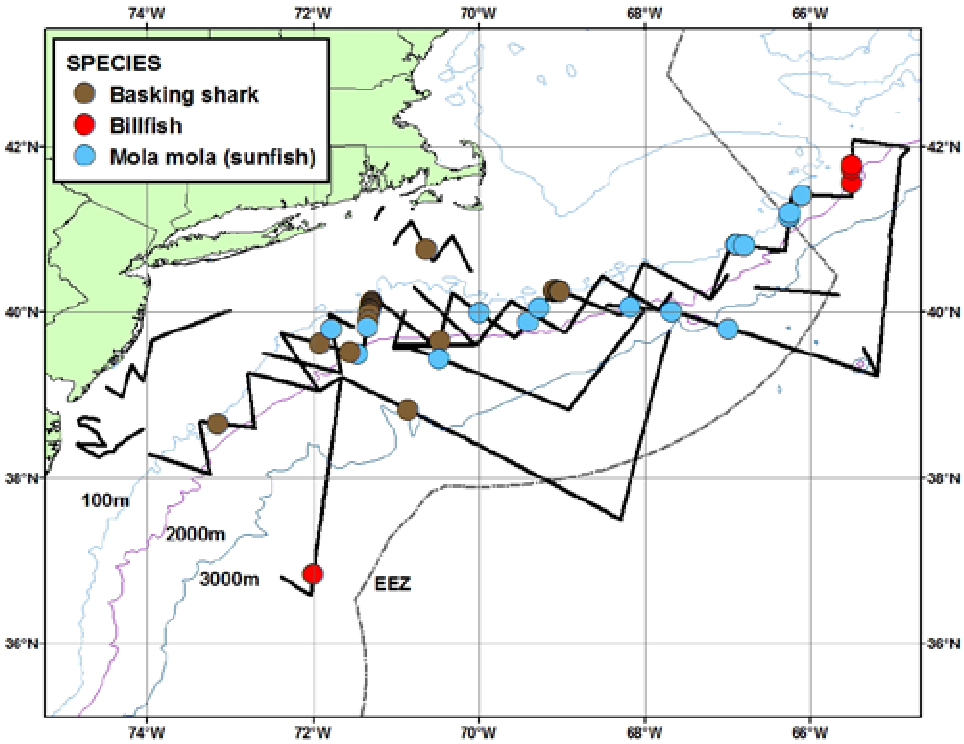


Figure A11. Location of basking shark *Cetorhinus maximus;* top), unidentified billfish (top), sunfish (*Mola mola*; top) and balloon (bottom) sightings detected by the upper team during HB1603.



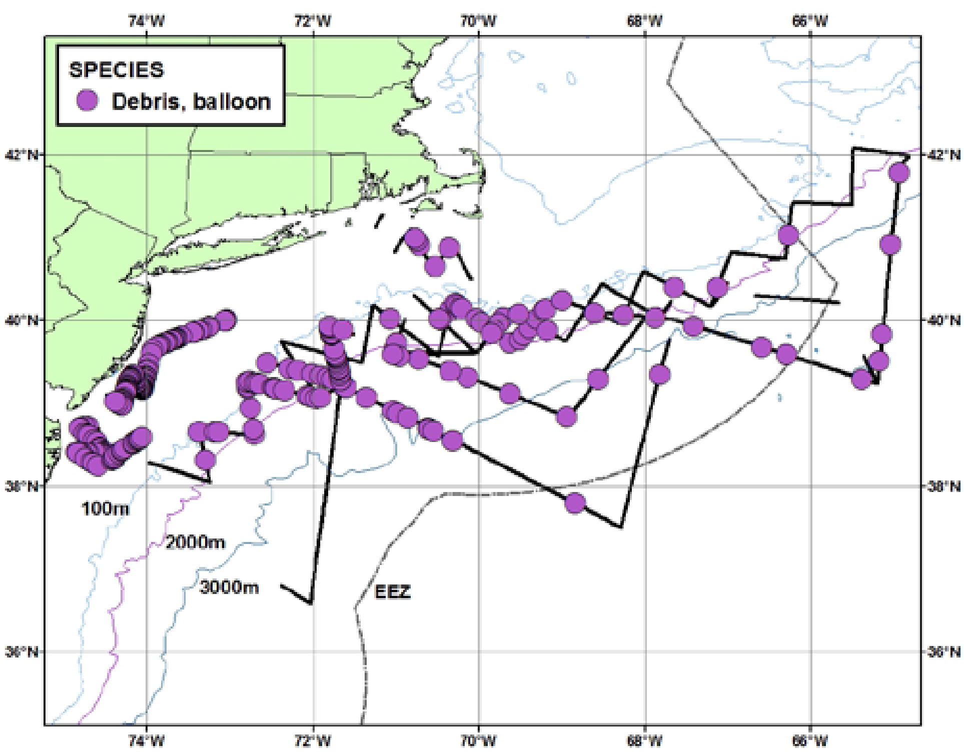


Figure A12. Location of the sites where biopsies were obtained during HB1603.

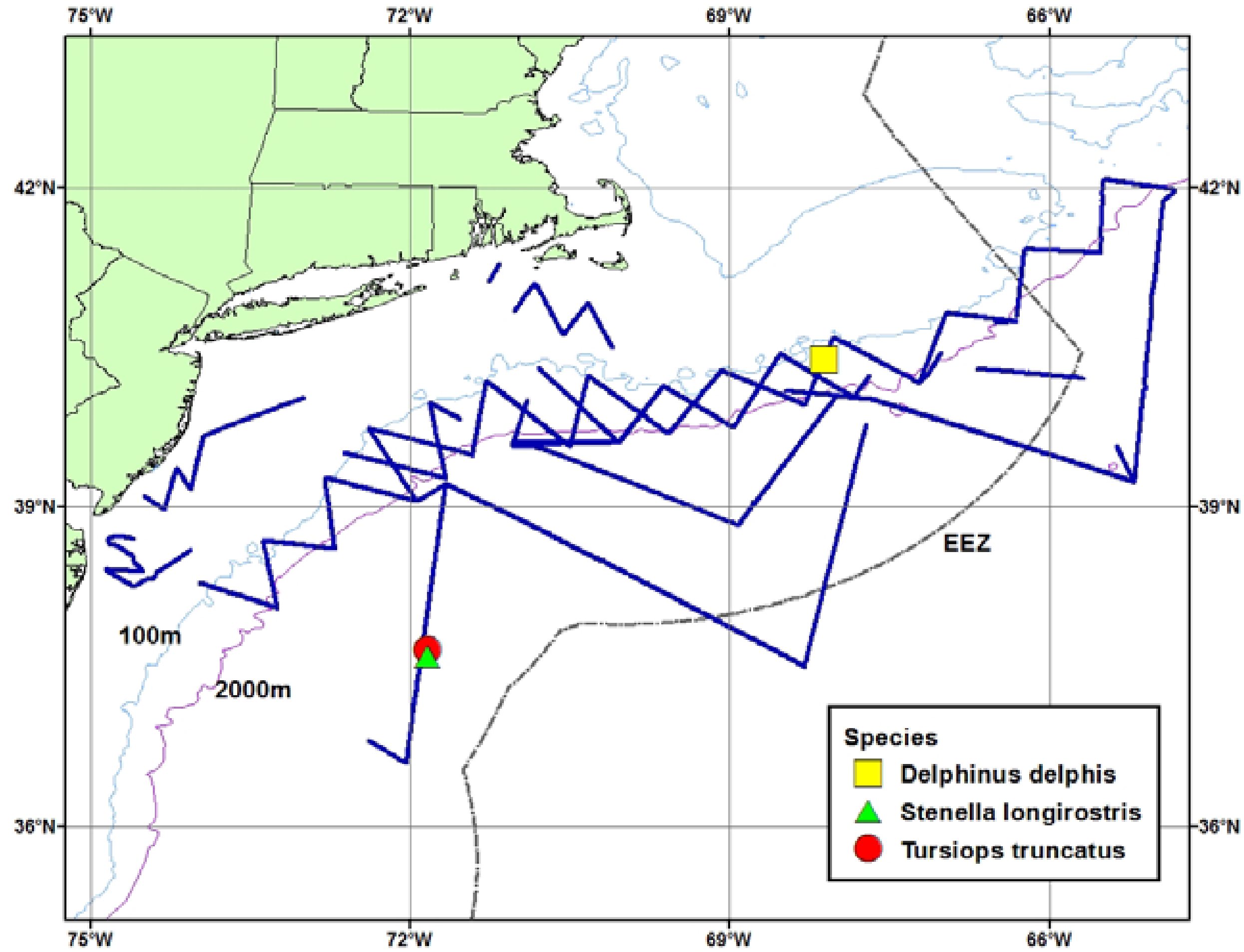
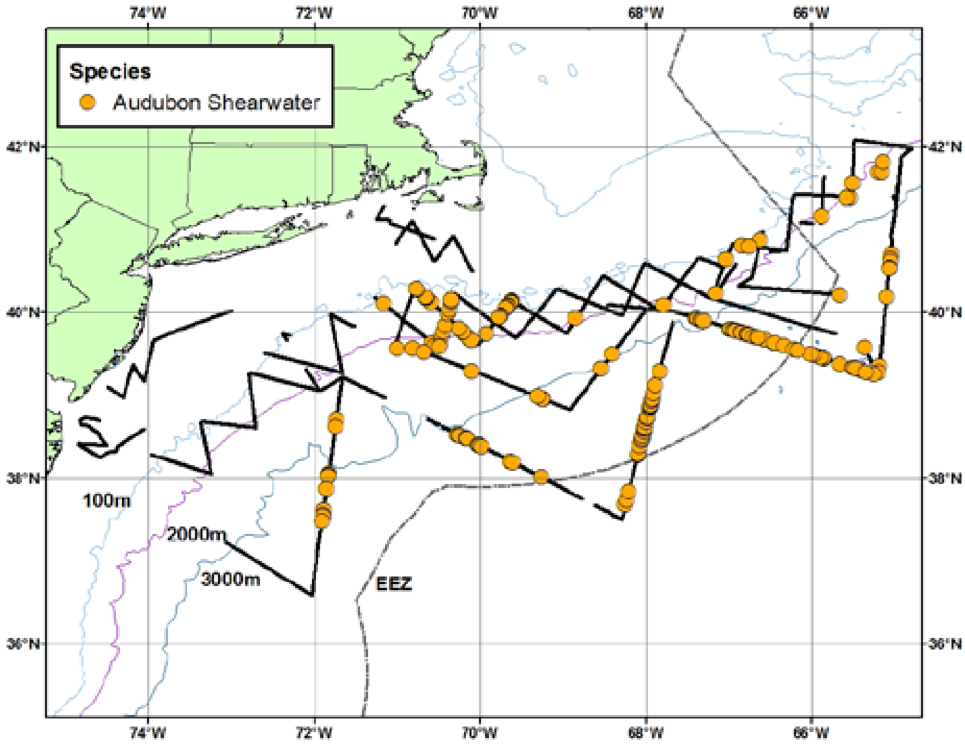


Figure A13. Location of Audubon Shearwater (*Puffinus lherminieri;* top) and Cory's Shearwater (*Calonectris diomedea*; bottom) sightings detected by the seabird team during HB1603.



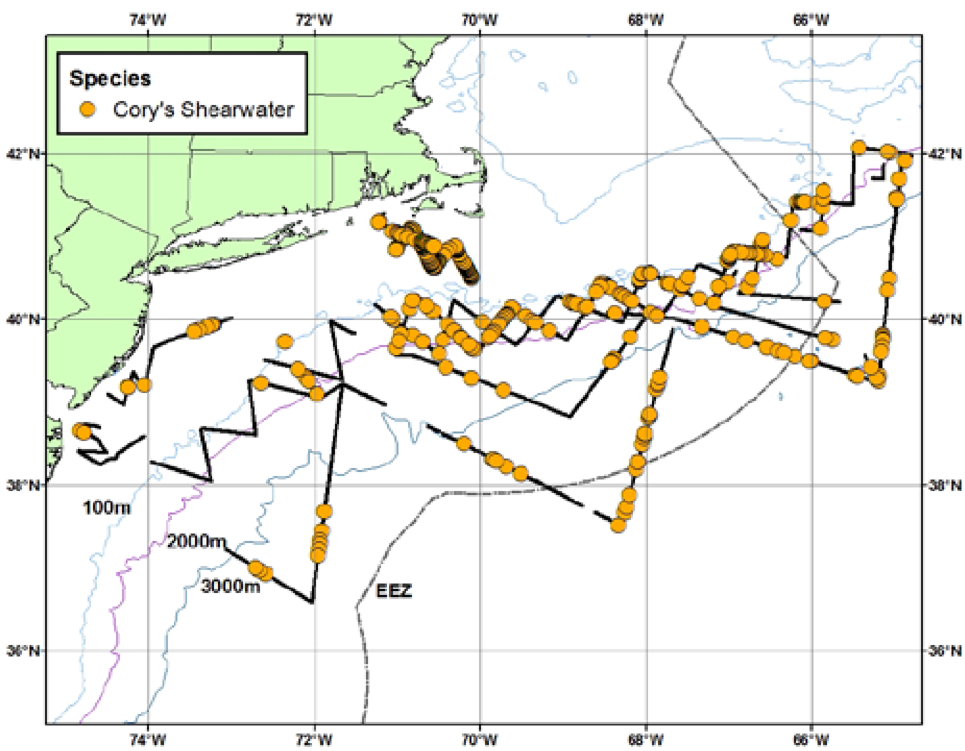
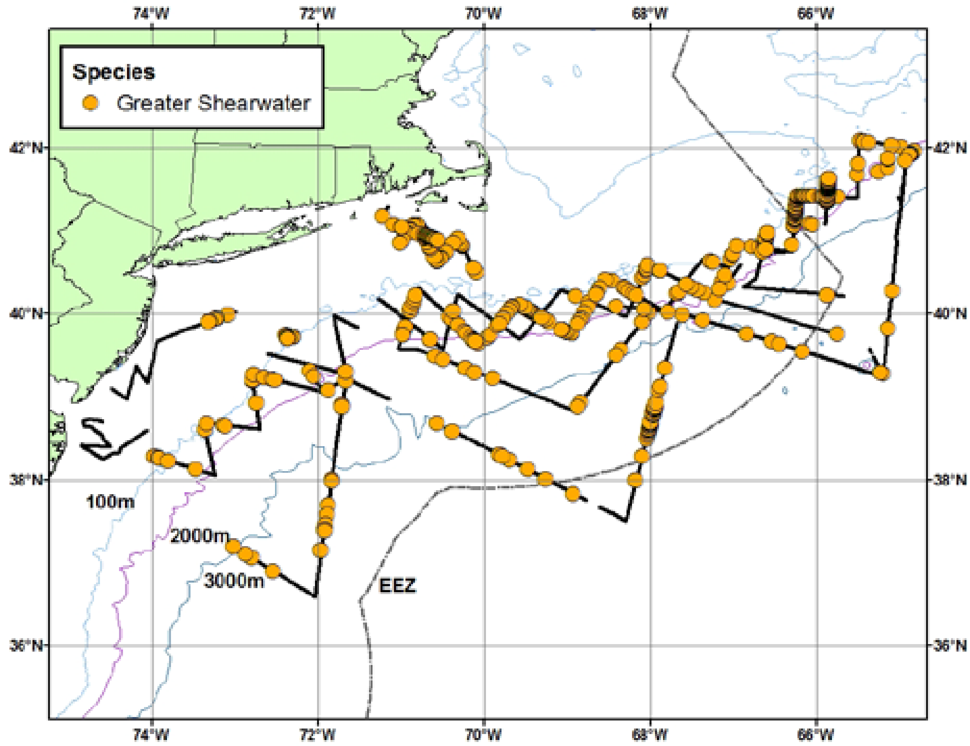


Figure A14. Location of Greater Shearwater (*Puffinus gravis;* top), Barolo Little Shearwater (*Puffinus boroli assimilis*; bottom), Manx Shearwater (*Puffinus puffinus*; bottom), Sooty Shearwater (*Puffinus griseus*; bottom) and unidentified shearwater (bottom) sightings detected by the seabird team during HB1603.



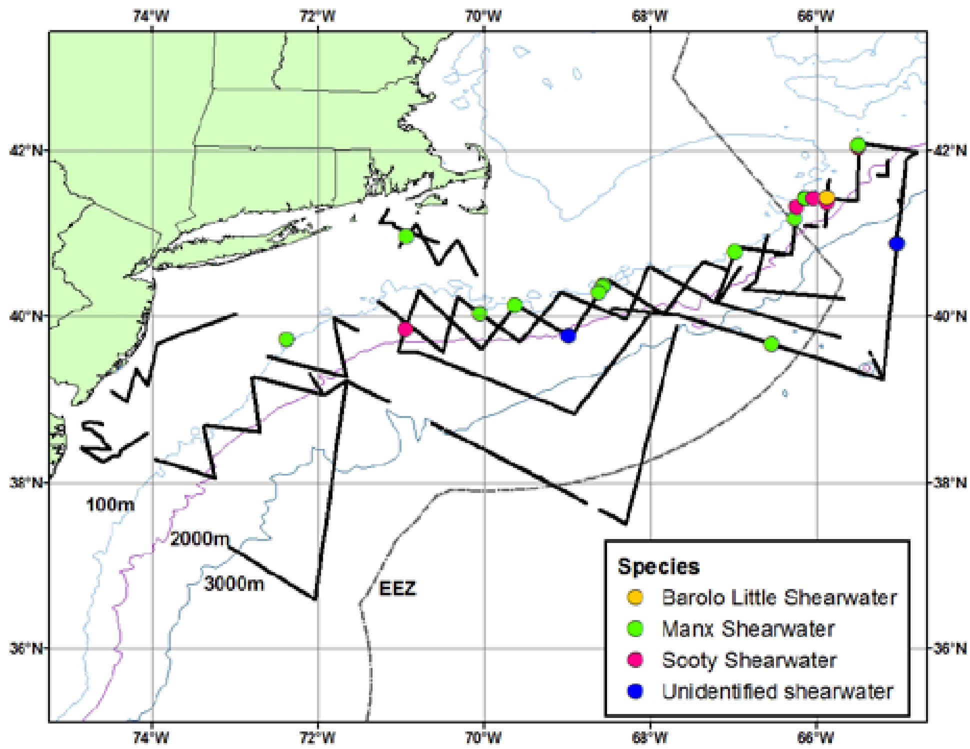
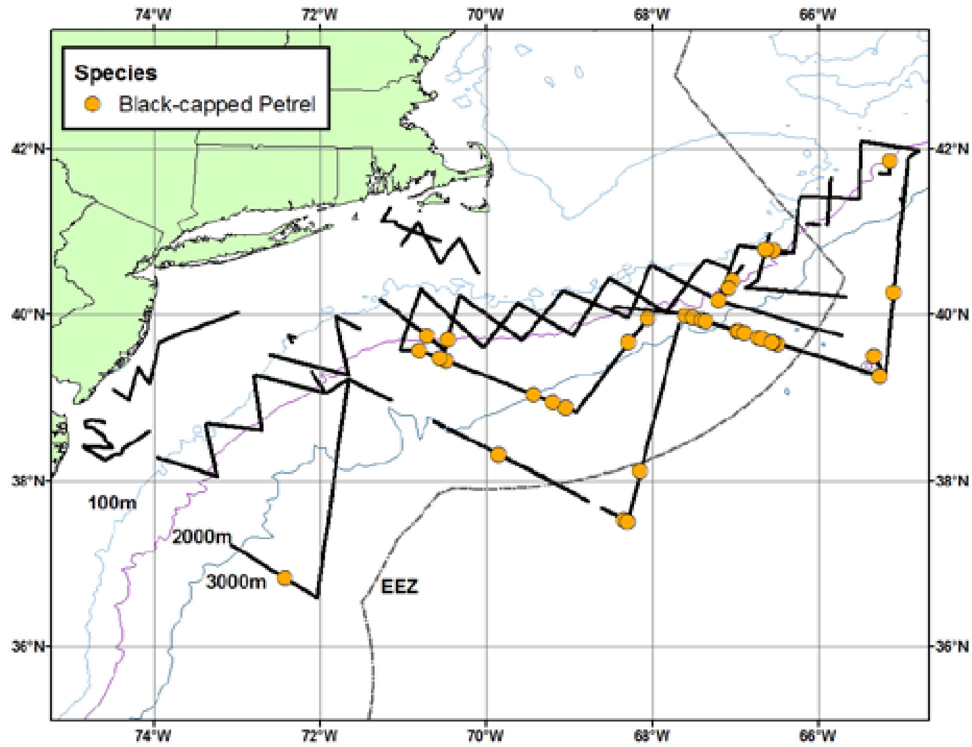


Figure A15. Location of Black-capped Petrel (*Pterodroma hasitata;* top) and Band-rumped Storm-petrel (*Oceanodroma castro*; bottom) sightings detected by the seabird team during HB1603.



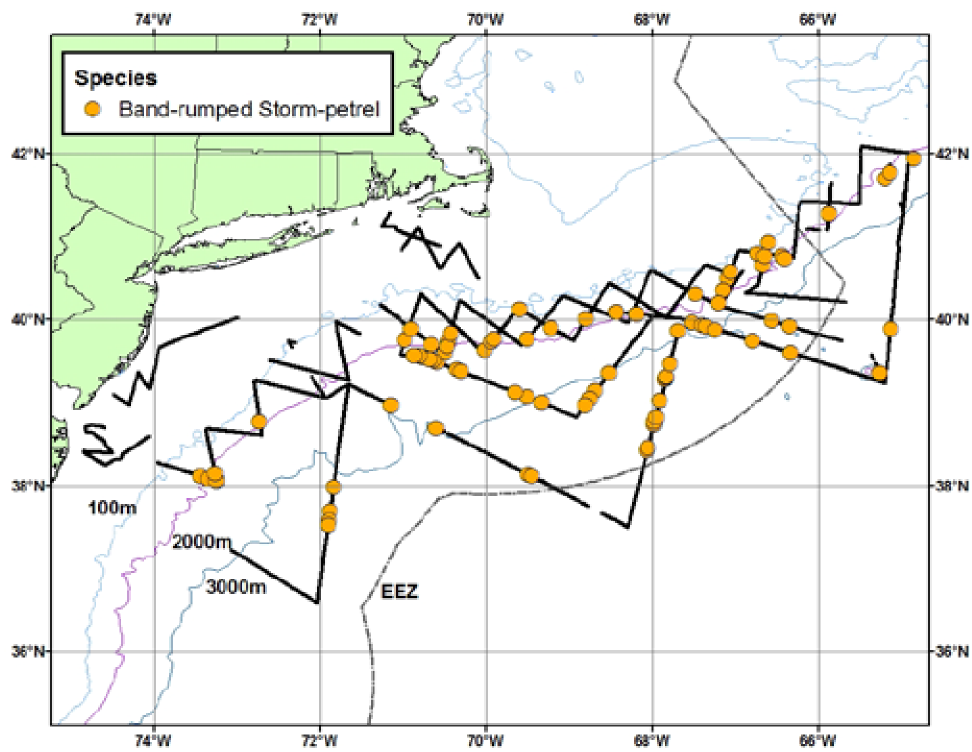
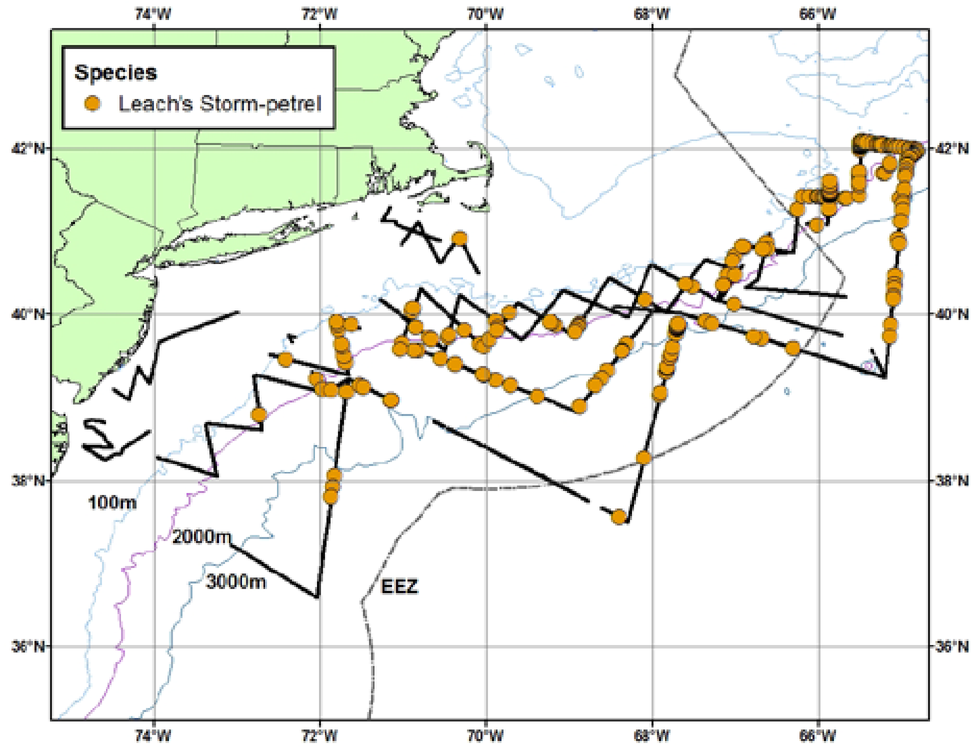


Figure A16. Location of Leach's Storm-petrel (*Oceanodroma leucorhoa;* top), Leach's/Hartcourt's Storm-petrel (*Oceanodrama leucorhoa/castro*; bottom), Trindade Petrel (*Pterodrama arminjoniana*; bottom); White-faced Storm-petrel (*Pelagodroma marina*; bottom) and unidentified storm-petrel (bottom) sightings detected by the seabird team during HB1603.



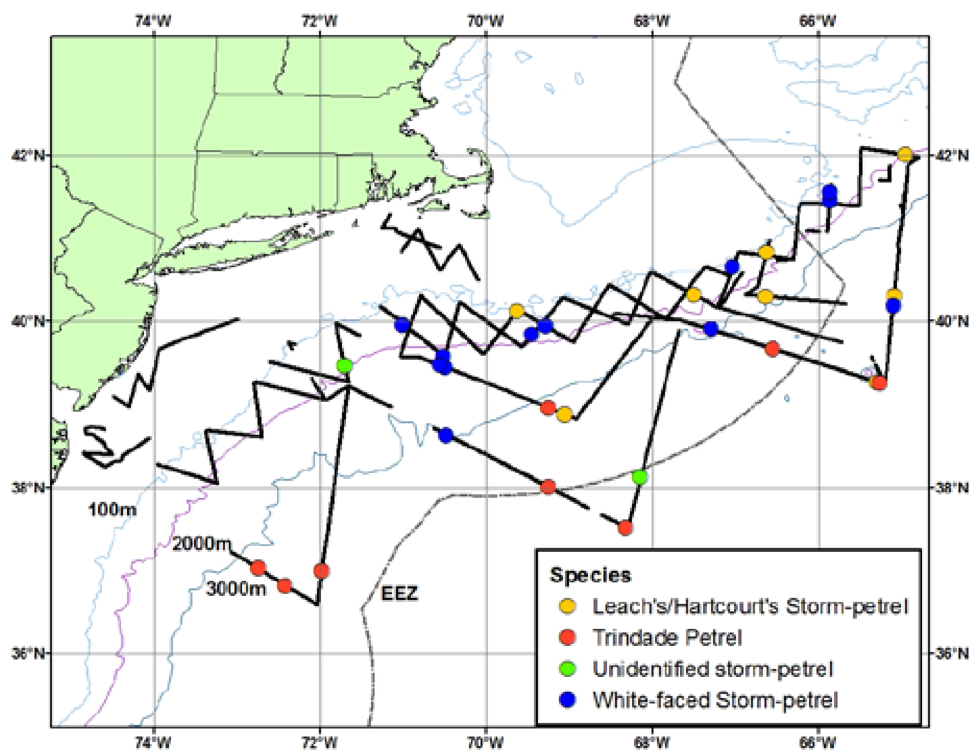
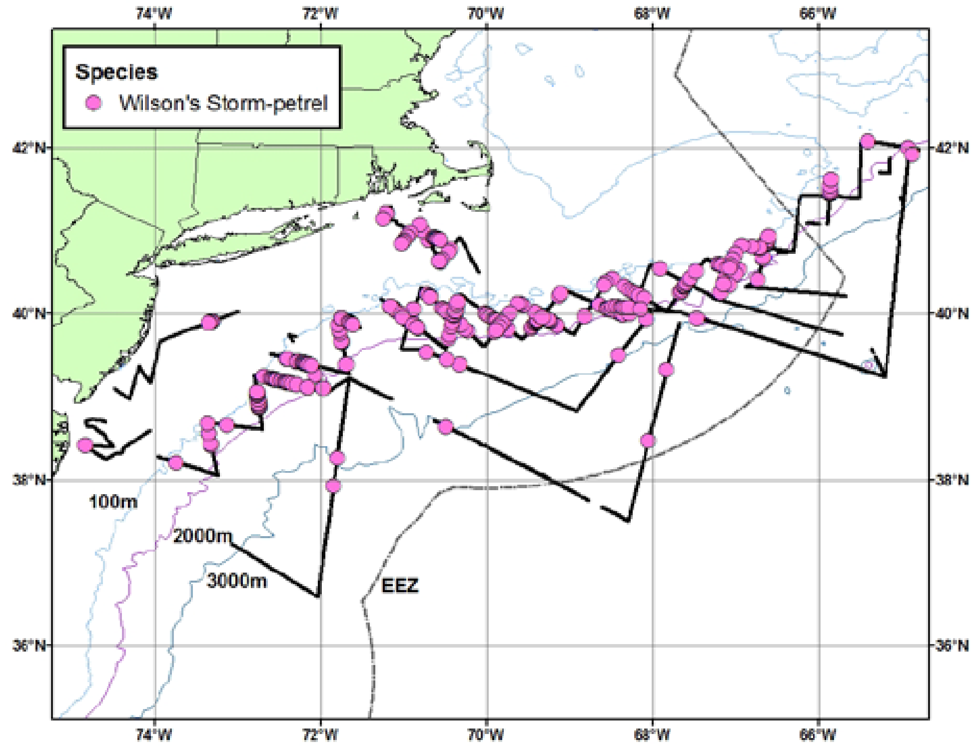


Figure A17. Location of Wilson's Storm-petrel (*Oceanites oceanicus;* top), Arctic Tern (*Sterna paradisaea*; bottom), Bridled Tern (*Sterna anaethetus*; bottom), Common Tern (*Sterna hirundo*; bottom), Royal Tern (*Sterna maxima*; bottom) and unidentified tern (bottom) sightings detected by the seabird team during HB1603.



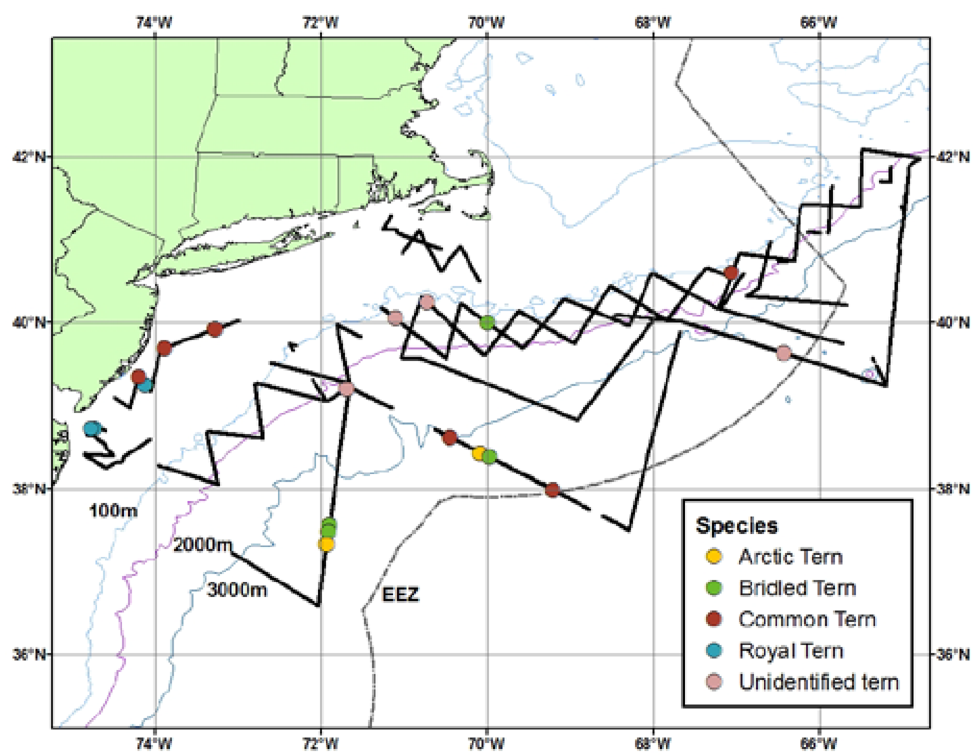
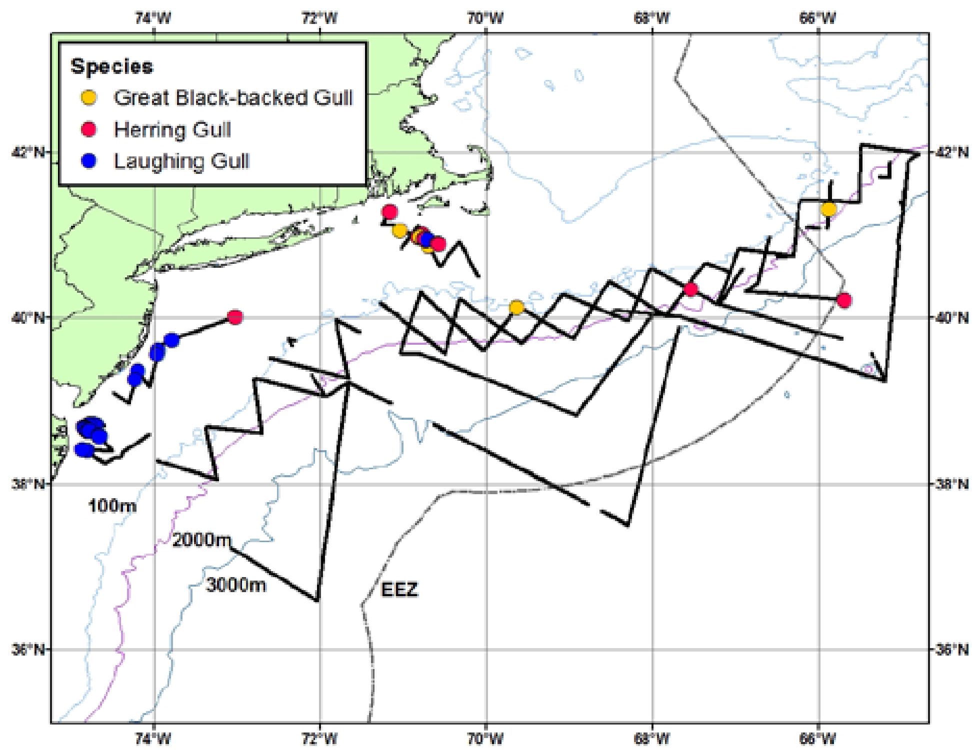


Figure A18. Location of Great Black-backed Gull (*Larus marinus;* top), Herring Gull (*Larus argentatus*; top), Laughing Gull (*Larus atricilla*; top), Brown Booby (*Sula leucogaster*; bottom), Red-footed Booby (*Sula sula*; bottom), White-tailed Tropicbird (*Phaeton lepturus*; bottom) and unidentified tropicbird (*Phaeton sp*; bottom) sightings detected by the seabird team during HB1603.



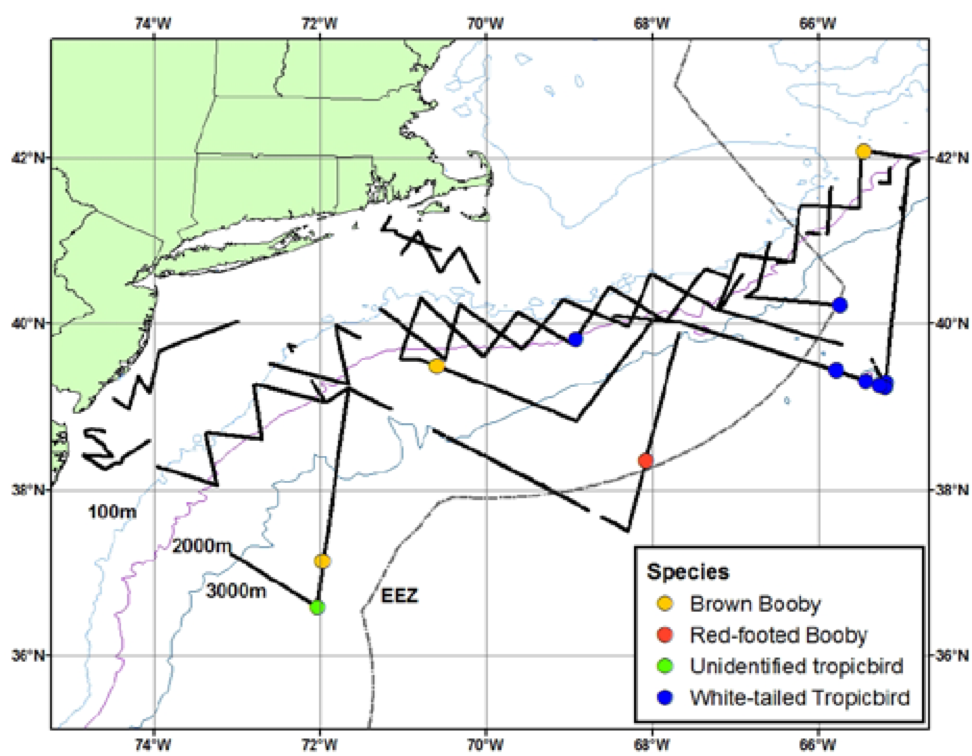


Figure A19. Location of Common Loon (*Gavia immer;* top), Double-crested Cormorant (*Phalacrocorax auritus*; top), Least Sandpiper (*Calidris minutilla*; top), Long-tailed Jaeger (*Stercorarius longicaudus*; top), Northern Fulmar (*Fulmarus glacialis*; top), Parasitic Jaeger (*Stercorarius parasiticus*; top), Pomarine Jaeger (*Stercorarius pomarinus*; top), South Polar Skua (*Stercorarius maccormicki*; top), unidentified jaeger (*Stercorarius sp*; top), passerine bird (bottom), Osprey (*Pandion haliaetus*; bottom), non-marine non-passerine bird (bottom), Brown-headed Cowbird (*Molothrus ater*; bottom), Black-crowned Night Heron (*Nycticorax nycticorax*; bottom) and Baltimore Oriole (*Icterus galbula*; bottom) sightings detected by the seabird team during HB1603.

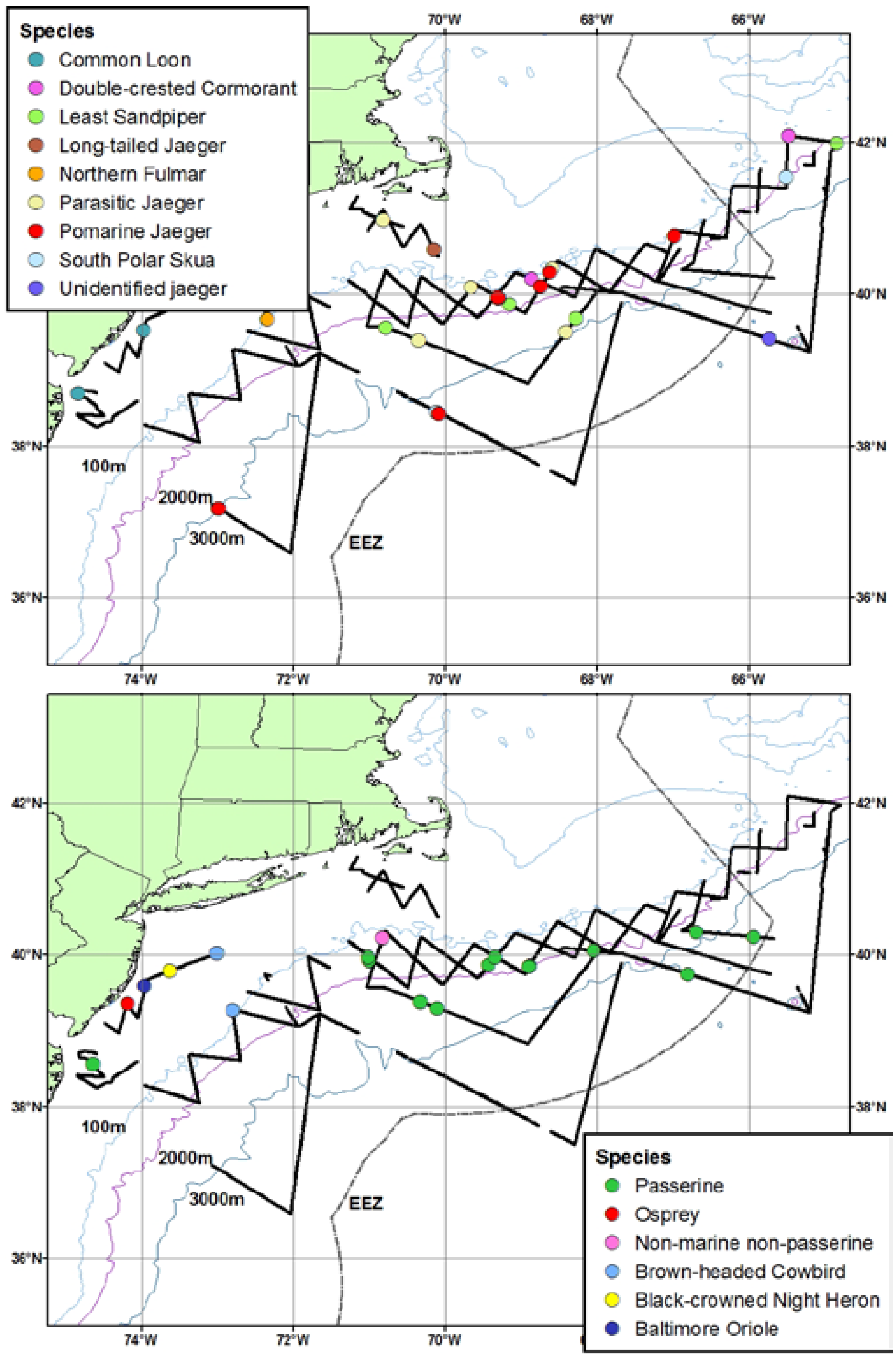


Figure A20. Acoustic recording effort and location of the NOAA ship *Henry B. Bigelow* during acoustic detection of vocally-active cetacean groups. Inshore tracklines were considered too shallow for deployment of acoustic equipment; therefore, acoustic monitoring was not conducted in those areas, though some inshore vessel transits are depicted.

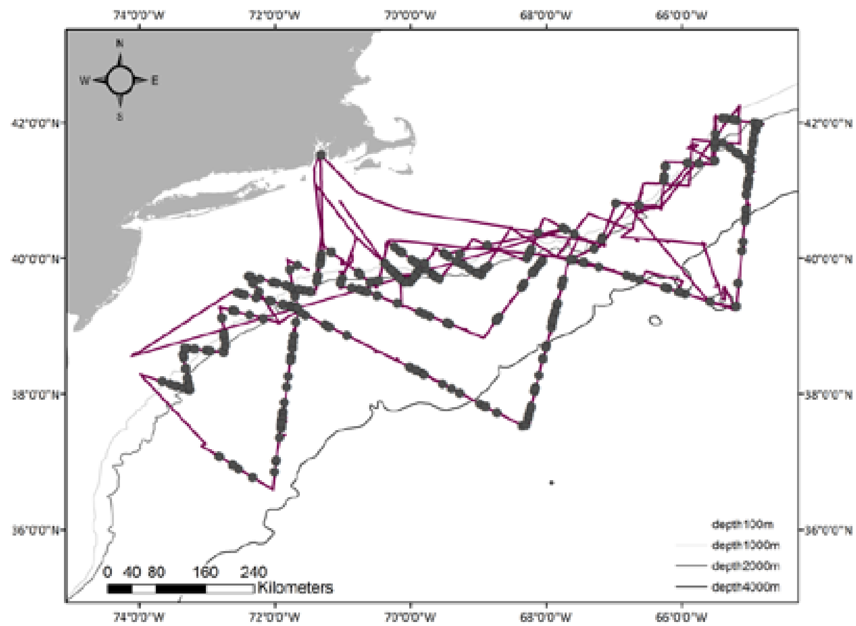


Figure A21. Locations of 29 sonobuoy deployments conducted during the HB16-03 survey.

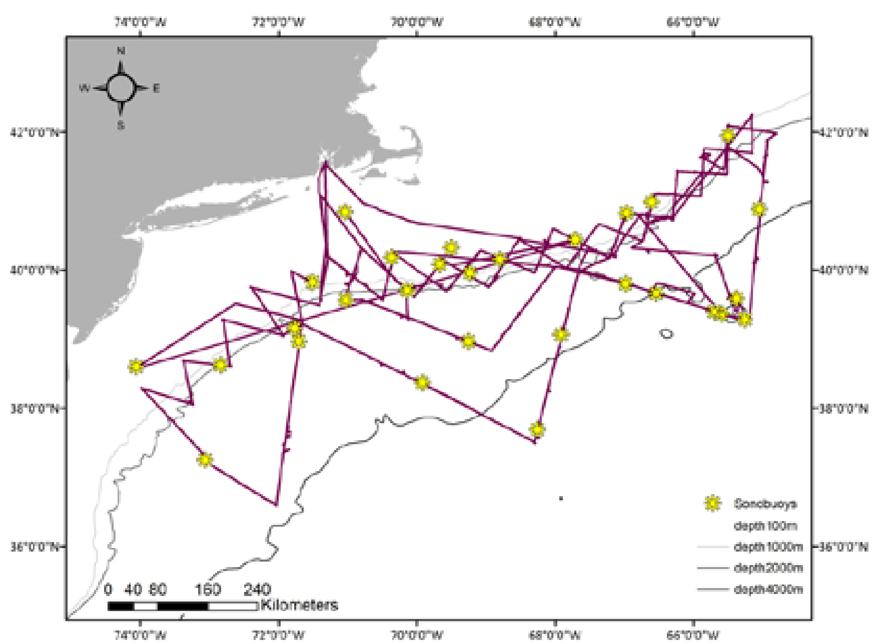


Figure A22. Locations of the CTD operations conducted during the HB1603 AMAPPS survey

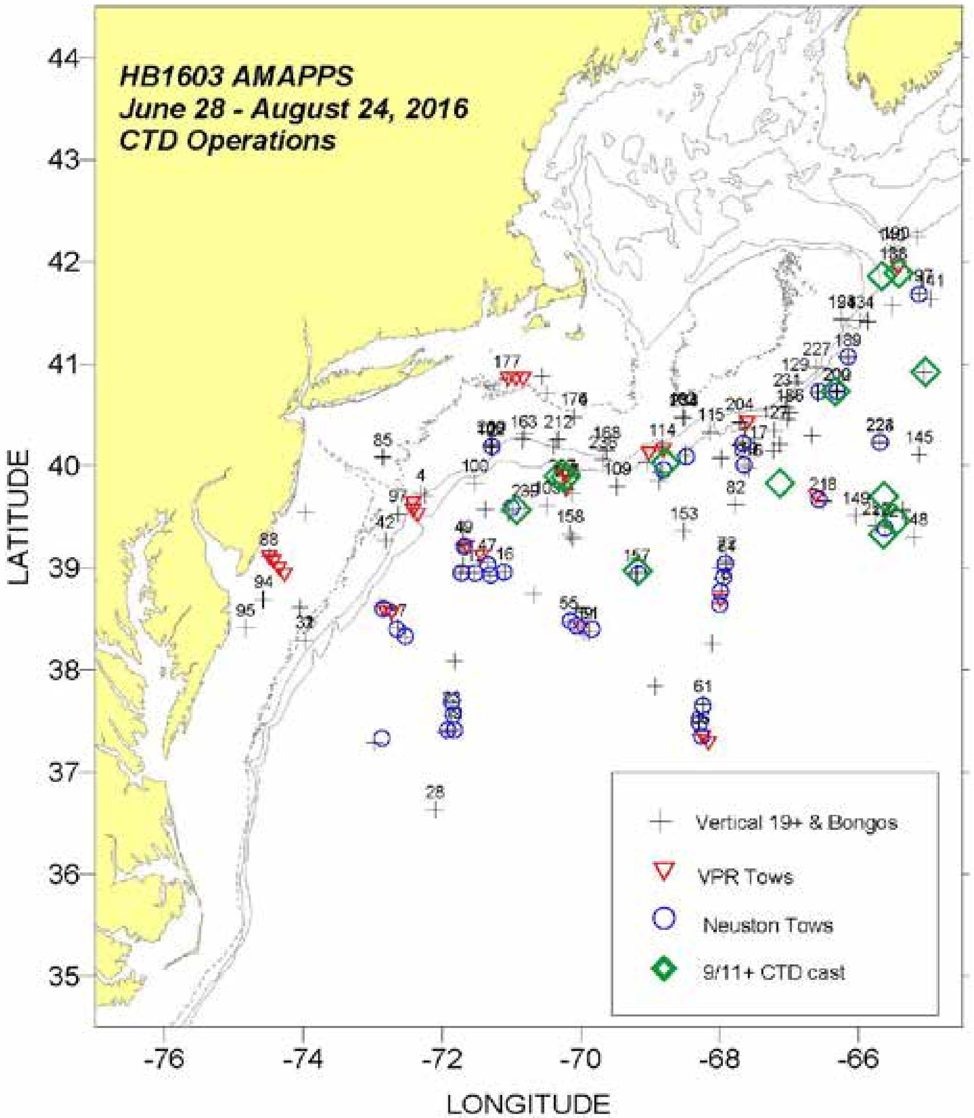


Figure A23. 18-kHz echogram spanning approximately 20 hours. This echogram highlights the acoustic backscattering patterns observed near the Mt Balanus and Bear Seamounts, the nocturnal migration of the mesopelagic community from depths of about 500 m to the surface, and the consistent deep scattering layer (DSL) at about 700 m. There is also a very light scattering layer at about 1700 m, which we were not able to sample with the midwater net.

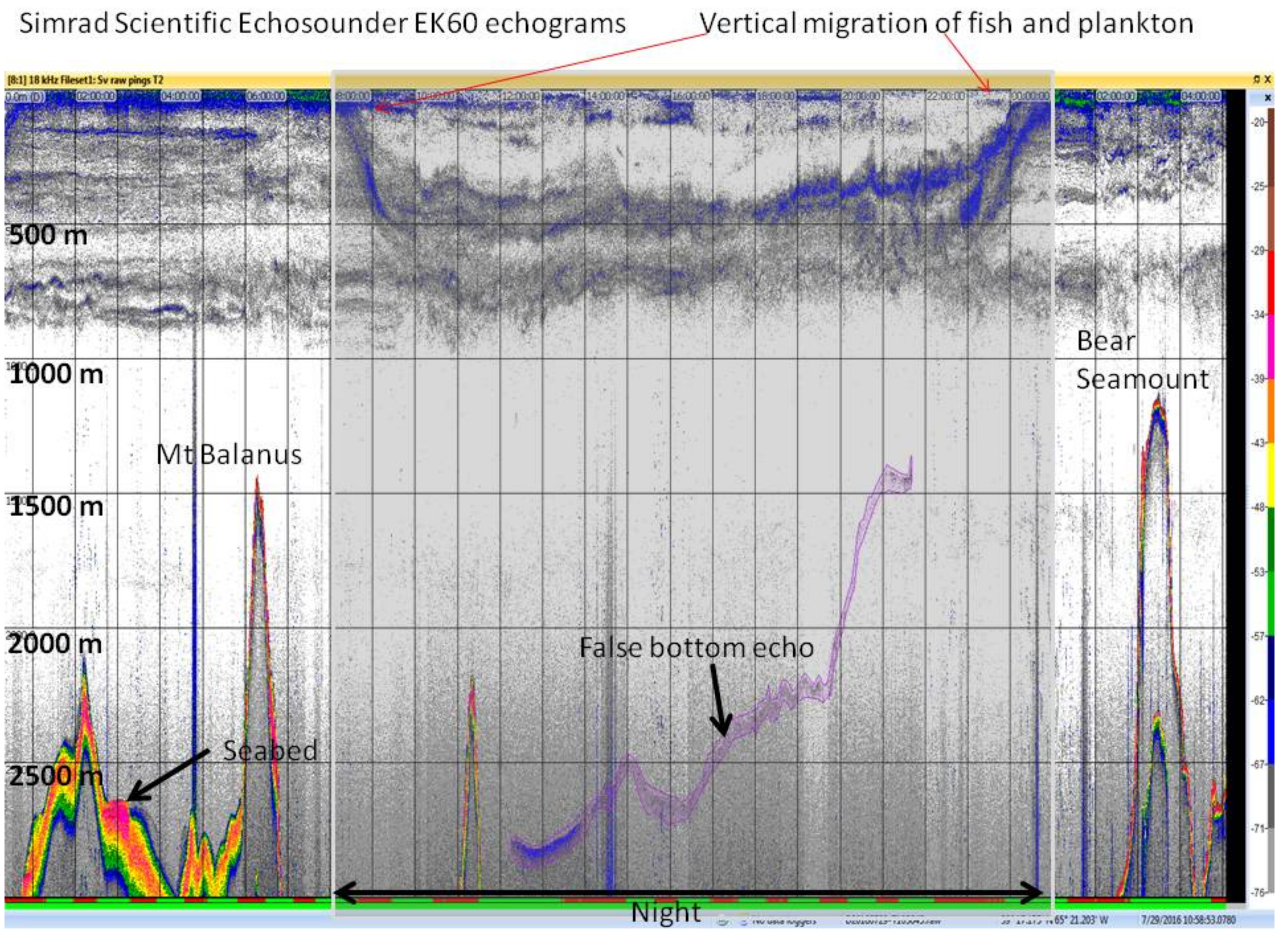
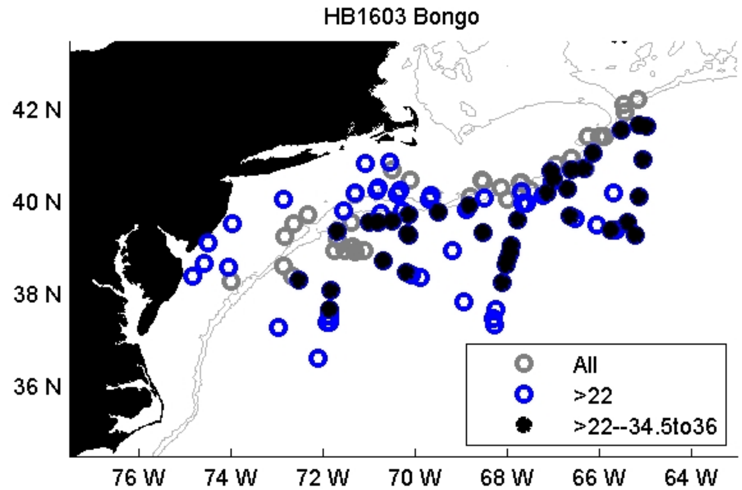


Figure A24. Bongo and neuston sampling during HB16-03. Stations with the highest probability of having larval tuna, based on literature bluefin spawning hydrographic parameters, are shown in black.



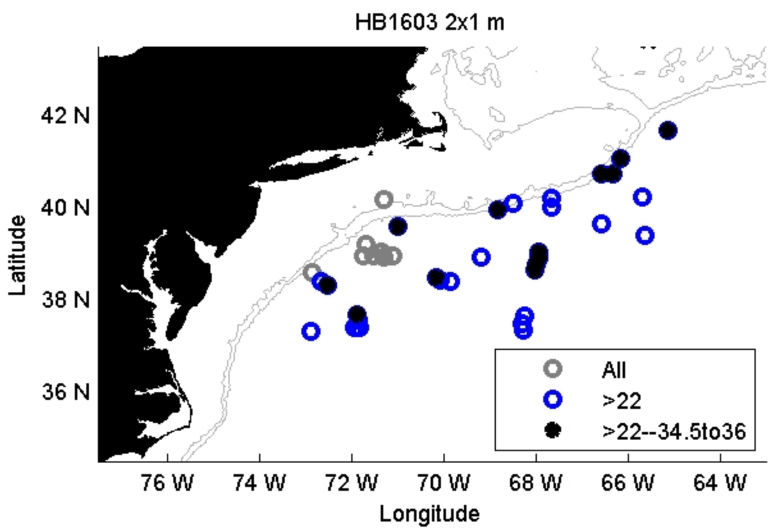


Figure A25. Image of bluefin tuna larva, *Thunnus thynnus*, collected from the neuston net. Identifications will be confirmed by future genetic analysis.

Figure A26. Midwater trawl locations that were deployed only during Leg 2 during HB1603.

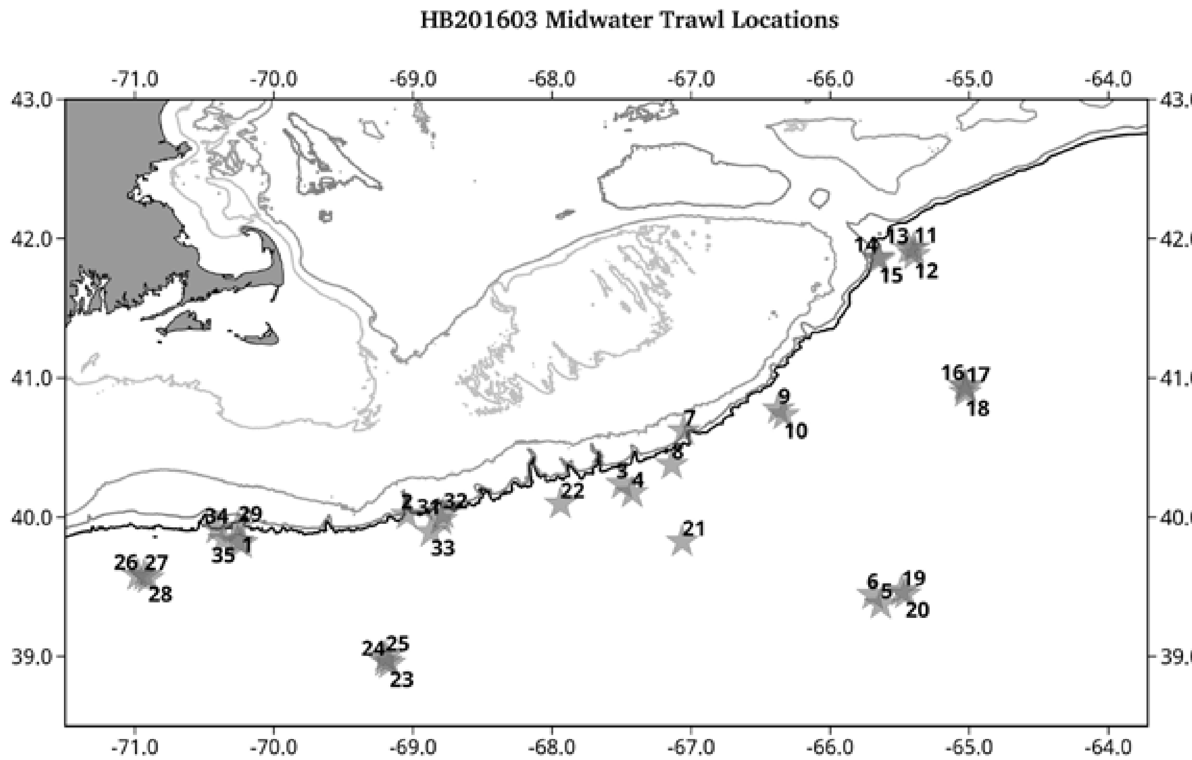


Figure A27. Imaging Flow Cytobot images as shown on the IFCB dashboard website. Clicking on each image brings up a full sized image with all the associated metadata.

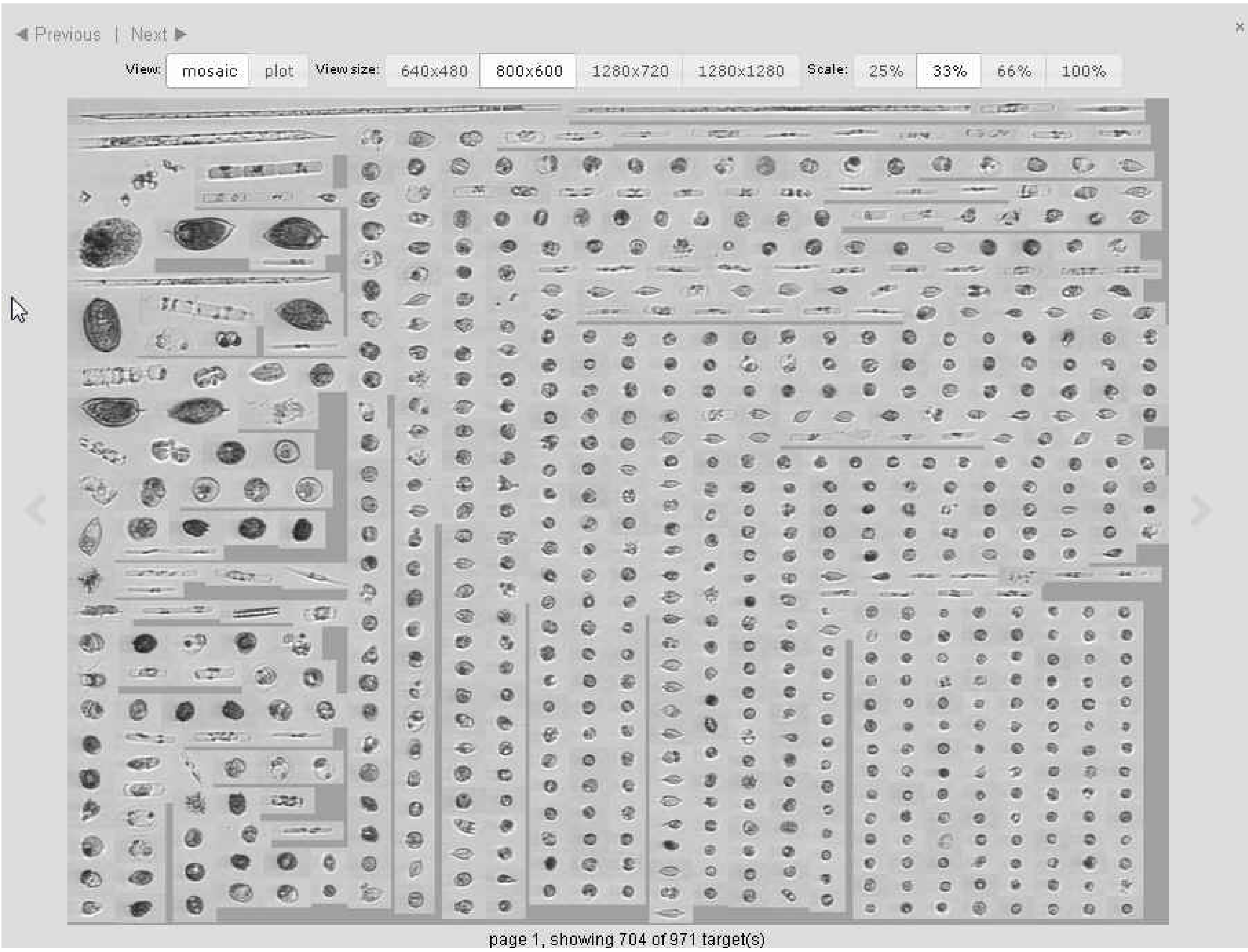


Figure A28. Average sea surface temperature for the week of July 18th showing the location of the Gulf Stream (dark red), and a large warm core ring south east of Georges Bank.

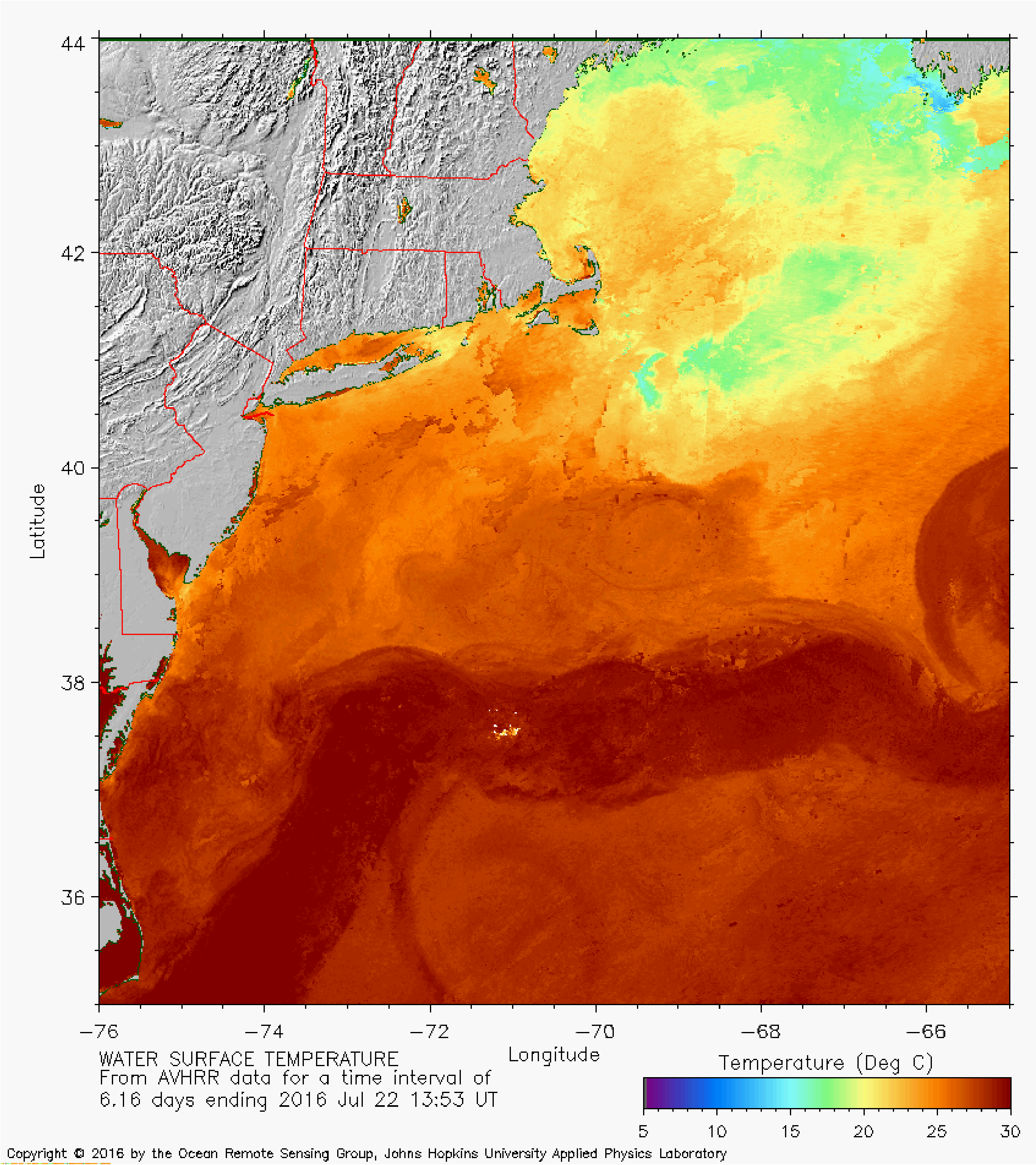


Figure A29. Smoothed sea surface temperature (°C) during HB1603 AMAPPS survey, as determined from data collected from CTD deployments at + locations.

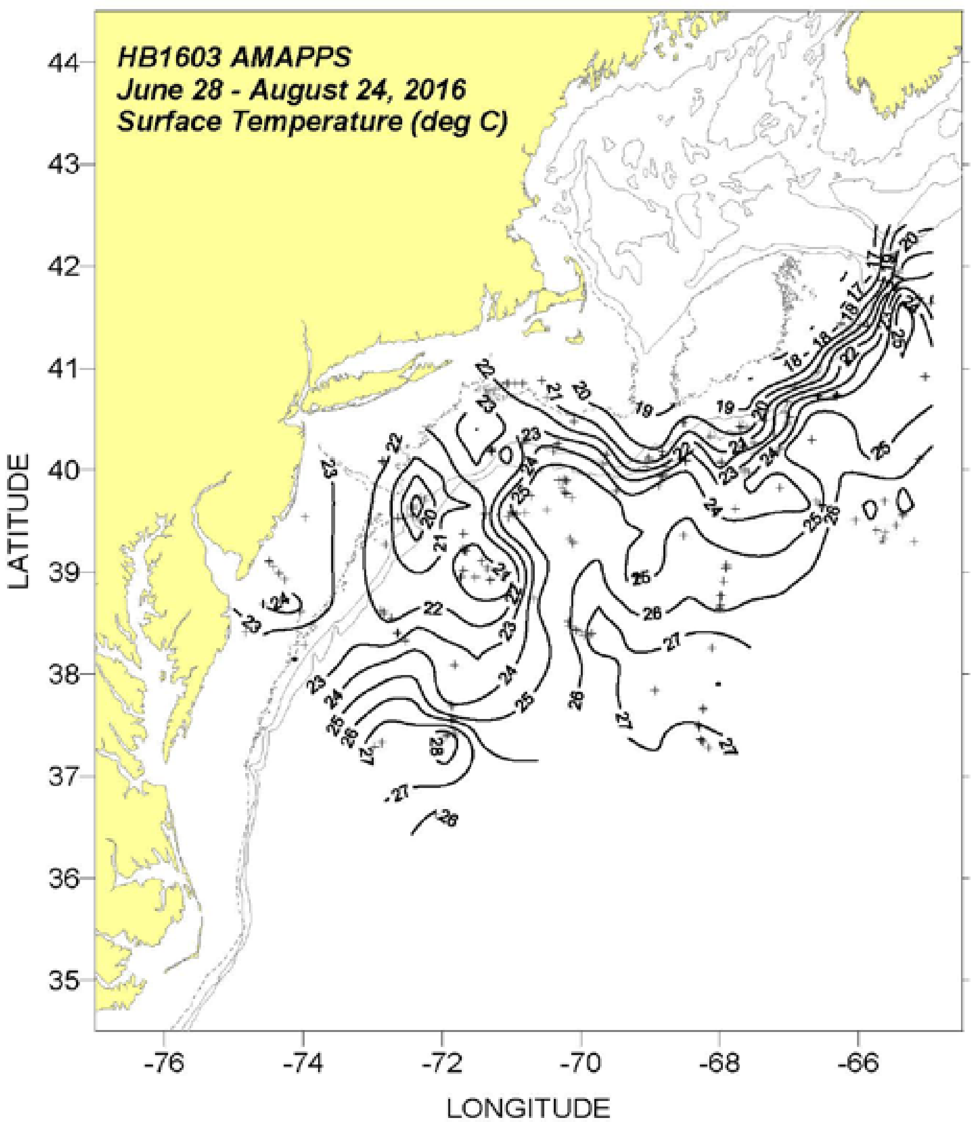


Figure A30. Smoothed surface salinity (psu) during HB1603 AMAPPS survey, as determined from data collected from CTD deployments at + locations.

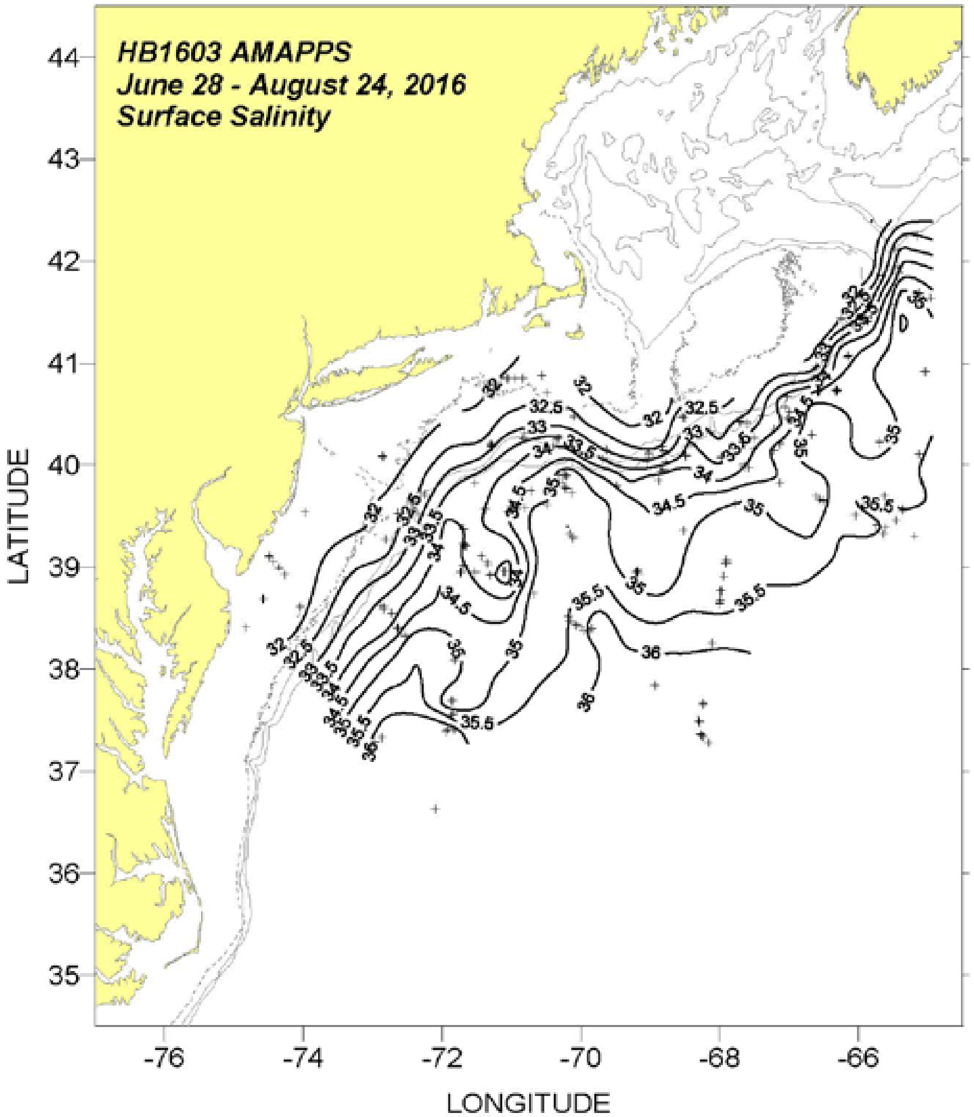
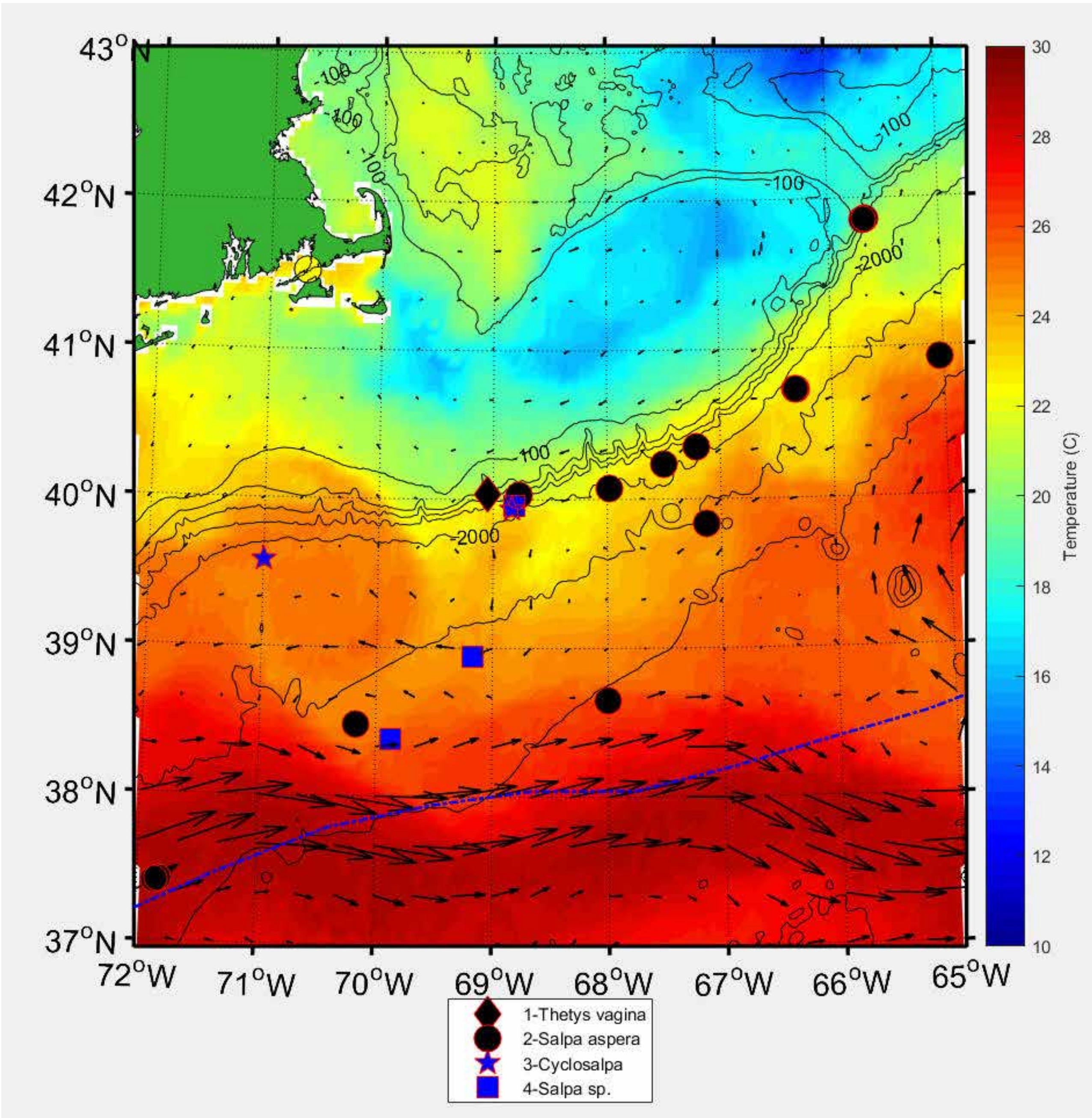


Figure A31. Salp special sample collection for Anne Buckin with the mean sea surface temperature and currents during the sampling period.



Appendix B: *Southern leg of shipboard abundance survey during 30 June – 19 August 2016: Southeast Fisheries Science Center*

Lance P. Garrison[1], Anthony Martinez[1], Melissa Soldevilla[1], Laura Aichinger Dias[1, 2]

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SUMMARY

As part of the AMAPPS program, the Southeast Fisheries Science Center conducted shipboard surveys of continental slope and shelf break waters along the US East Coast from Central Florida to Delaware during 30 June – 19 August, 2016 (designated Cruise code GU16-05). The marine mammal survey was designed for analysis using Distance sampling, and a two-team (independent observer) approach was used to correct for perception bias in resulting abundance estimates. A passive acoustic hydrophone array was towed during the survey to monitor vocalizing cetaceans. In addition, sonobuoys were deployed at locations of large whale sightings and at the “corners” of the track lines. Opportunistic cetacean biopsy samples and photographs were also collected. Oceanographic and environmental data were collected using scientific echosounders (EK60) during nighttime and CTD sensors and XBT casts during the day. A total of 5,381 km of survey effort was accomplished in good to fair weather conditions (average sea state of 3.2 in the Beaufort scale). A total of 509 marine mammal sightings were recorded from at least 17 different species (not including unidentified taxa). The most common delphinid species seen were bottlenose dolphins (*Tursiops truncatus*) and pilot whales (*Globicephala spp*). Large whale sightings included fin whales (*Balaenoptera physalus*), minke whales (*B. acutorostrata*) and sperm whales (*Physeter macrocephalus*). A notably high number of beaked whale sightings were recorded throughout the cruise. The hydrophone array was deployed and monitored for approximately 431 hours during the survey yielding 513 acoustic detection events. In addition, 30 sonobuoys were deployed. A total of 179 hydrographic profiles were collected including 145 XBTs and 34 CTDs. In total, 19 biopsy samples were collected from six different species.

OBJECTIVES

The objectives of this survey were: 1) conduct visual line-transect surveys to estimate the abundance and spatial distribution of cetaceans in U.S. Atlantic waters; 2) conduct passive acoustic surveys simultaneous with visual surveys to provide supplemental information on cetacean abundance and spatial distribution; 3) opportunistically collect tissue samples (biopsies) of select species; 4) collect oceanographic and environmental data including scientific echosounders (EK60) to quantify acoustic backscatter due to the presence of small fish and zooplankton; and 5) collect vertical profiles of hydrographic parameters (e.g., temperature, salinity, oxygen concentration) using Conductivity, Temperature, and Depth sensors (CTD) and Expendable Bathythermographs casts (XBT).

CRUISE PERIOD AND AREA

The survey took place on the *NOAA Ship Gordon Gunter* (*Gunter*) and was scheduled to be divided into three legs between 27 June – 26 August, 2016 and with two in port periods (Table B1). After a three-day delay due to mechanical issue and crew replacement, leg 1 started on 30

June and ended on 14 July. Leg 2 went from 20 July – 4 August, and leg 3 from 10 August – 19 August. In port periods were in Norfolk, VA from 15 – 19 July and in Charleston, SC from 5 – 9 August. Between 20 – 26 August, the ship cruised into the Gulf of Mexico in transit to her home port of Pascagoula, MS; this transit portion is not included in this report. The study area included waters from the 200 m isobath to the US Exclusive Economic Zone (US EEZ) line and from Delaware to Central Florida (Figure B1). For leg 1, visual and acoustic operations began on 1 July and ended on 14 July. Visual and acoustic operations for the 2nd leg started on 20 July and ended on 4 August. On 1 August the NOAA Ocean Noise Reference Station number seven (NRS07) was recovered. For leg 3, visual and acoustic operations began on 10 August. On 16 August the ship was deviated to Charleston, SC for personnel transfer; visual and acoustic operations resumed on 17 August until the 19th. Between 20 – 25 August, the ship transited into the Gulf of Mexico where an adrift weather buoy was recovered and returned to the National Data Buoy Center and High-frequency Acoustic Recording Packages (HARPs) were deployed. The ship reached her home port in Pascagoula, MS on 26 August.

METHODS

VISUAL MARINE MAMMAL SIGHTING TEAM

Standard ship-based, line-transect survey methods for cetaceans, similar to those used previously in the Pacific Ocean, Atlantic Ocean, and Gulf of Mexico, were used (e.g., Barlow 1995; Mullin and Fulling 2003; Fulling *et al.* 2003). The survey was conducted using the "independent observer" approach with Distance sampling to estimate detection probabilities for observed marine mammal groups. This approach was similar to that used during the summer of 2004 (Garrison *et al.* 2011). The survey was conducted along track lines in a zig-zag design varying between 22 and 184 nm each and totaling 3,103 nm (5,747 km) (Figure B1). Lines between these track lines and to/from land were determined transit lines (some transit lines were surveyed by the visual teams while others were cruised during the night). Effort began and ended with daylight (roughly from 07:00 to 19:00 EST) and survey speed was typically 18 km hr^{-1} (10 knots) but varied with currents, sea conditions and ship traffic in the area. The "independent observer" method uses two teams of visual observers that operate independently of one another. On the *Gunter*, this consists of the flying bridge (or upper, height above water = 13.9 m) team and the bridge wing (or lower, height above water = 11.2 m) team. The teams consist of two big-eye (25x150 powered binoculars) observers stationed on the flying bridge, two big-eye observers on the bridge wings, and the central data recorder (Über). Observers were considered "on effort" whenever actively searching for cetaceans through the big-eyes and the ship was steadily cruising on a track line, including some transit lines. All sightings recorded under these circumstances were considered "on effort". Observers went "off effort" when they encountered a sighting (after the time of cue entry) and stayed off until that sighting was concluded. When on effort, observers scanned their viewing area from the track line at 0° bearing to the beam (90° left or right depending on the side). When a possible marine mammal was detected, the observer immediately called out a "cue" to the Über observer and provided information on bearing, distance, and the type of cue (mammal, splash, etc). The observer team attempted to make species identification to the lowest taxonomic level possible and group size estimates (independent estimate by each observer). When reliable identification and counts were performed, the observers went back on effort. Observers were also considered to be off effort, whenever the ship was maneuvering and turning into a new track line, if other operations were taking place (e.g. safety drills, small boat deployment, biopsying, etc.), due to weather (rain, sea state above 6, which limits the effectiveness of visual line transect survey effort) and whenever not actively searching for cetaceans through the big-eyes. Sightings recorded under such conditions were considered "off effort" and may also have included sightings detected by non-observers (e.g. acoustician), observers off duty or other crew (including ship's crew). Each observer stayed 30 minutes in each position; the Über stayed for 1.5 hour. For each cetacean sighting, time, position, bearing, reticle (a measure of radial distance), species, group-size, behavior, bottom depth, sea surface temperature, and associated animals (e.g., seabirds, fish) were recorded. The bearing and radial distance for groups sighted without the 25x150 powered binoculars and close to the ship were estimated by naked-eye. Survey effort data were automatically recorded every minute and included the ship's position and heading, effort status, observer positions, and environmental conditions which could affect the observers' ability to sight animals (e.g., Beaufort sea state, track line glare, etc). Further survey operations and effort are summarized in Table B1. Scientific crew onboard GU16-05 is listed in Table B2.

<u>*PASSIVE ACOUSTIC SURVEY*</u>

Passive acoustic surveys were conducted during daylight hours when conditions allowed simultaneous with visual surveys. Passive acoustic surveys were suspended during portions of the track lines that occurred in water depths shallower than 75 m. Passive acoustic monitoring for odontocetes was conducted using a towed hydrophone array deployed approximately 300 m behind the ship. Hydrophone depth varied depending on survey speed, ship turns, and current. The hydrophone array towed at 10 ± 2 m depth at standard survey speed of 10 kts (86% of the survey). The custom-built five-element mixed-frequency oil-filled hydrophone array (Rankin *et al.* 2013) included paired pre-amplifier and hydrophone elements capable of recording a broad range of frequencies. Sensors 1, 3, and 5 were optimized for greater detection ranges for mid-frequency recordings by using APC International 42-1021 hydrophones with custom-built pre-amplifiers. The APC 42-1021 hydrophones have a -212 dB re V/uPa sensitivity with a flat frequency response (+/- 4 dB) from 1 to 45 kHz. The corresponding pre-amplifiers provided a highpass filter with 45 dB gain above 5 kHz. Sensors 2 and 4 were optimized for recording the full bandwidth of high-frequency echolocation signals by using Reson TC4013 hydrophones with custom-built pre-amplifiers. The TC4013 hydrophones have a -212 dB re V/uPa sensitivity with a flat frequency response (+/- 2 dB) from 5 to 160 kHz. The corresponding pre-amplifiers provide a high-pass filter with 50 dB gain above 5 kHz. Data from sensors 1, 2, 4, and 5 were digitized for recording through a custom 12 channel SailDAQ soundcard (*www.sa-instrumentation.com)* sampling 16 bits at 500 kHz, yielding a recording bandwidth of 1-250 kHz. SailDAQ output from sensors 1 and 5 were routed through a custom Magrec amplifier and Mark of the Unicorn (MOTU) Traveler mk3 audio interface for real-time aural monitoring. Acoustic signals were monitored by a team of two acoustic technicians who rotated through a primary and on-call secondary position every 2 hours while the array was deployed. The software program Pamguard (Gillespie *et al.*, 2008) was used to control the SailDAQ, to record acoustic data and metadata to hard-disk, and for real-time monitoring including logging effort and encounter details and obtaining bearings to acoustic detections. All acoustic data were continuously recorded as four-channel wav files to 2 TB external SATA hard drives. Acoustic field technicians continuously monitored data aurally and visually through spectrographic analysis using both Pamguard and Ishmael (Mellinger 2001) software and attempted to detect and localize acoustically-active odontocetes in real-time using Pamguard's click detectors, hyperbolic bearing calculator, and target motion analyses and Ishmael's hyperbolic bearing calculator for manually selected whistles. Acoustic localizations were mapped and compared with visual sighting locations using a custom-written acoustic version of VisSurvey. The acoustic VisSurvey version is capable of receiving and plotting visual sighting information along with acoustic bearings and localizations to improve correlation of acoustic and visual detections in real-time. Metadata describing acoustic encounters included individual click detections with corresponding time, localization, and localization quality information.

In addition to the towed array, directional sonobuoys were used for acoustic detection, localization, and recording of low-frequency sounds produced by baleen whales which are too low in frequency to be detectable by the towed array system. Sonobuoys were deployed as triads, when possible, for point-transect sampling of baleen whales during daylight hours concurrent with visual surveys. The sonobuoy deployment strategy was to 1) deploy three sonobuoys spaced 2 km apart within 2 km at predetermined locations at the outer corners of survey transects; and 2) opportunistically deploy three sonobuoys spaced 2 km apart within 2 km of all visually-sighted baleen whales. The expendable Directional Frequency Analysis and Ranging (DIFAR) sonobuoys contain a compass in the sensor head and transmit 3 types of continuous signal back to the ship on a VHF radio carrier in an analog multiplexed format. The three signals are acoustic sound pressure, east/west particle velocity and north/south particle velocity. The acoustic signal frequency range is approximately 10 Hz to 4,000 Hz, which is well suited for large whale vocalizations that have their greatest sound energy concentrated below 1,000 Hz. Prior to deployment, all sonobuoys were programmed for DIFAR mode, a hydrophone depth of 305 m, and a broadcast duration of 8 hours. The VHF radio signals transmitted by the sonobuoys were received by two omni-directional antennas (Diamond X30 144 MHz [primary] and MORAD Custom 168 MHz [backup]) mounted on the aft mast of the ship at 26 m above the waterline. The signal gain from the 144 MHz and 168 MHz antennas was enhanced by Advanced Receiver Research custom 140-144 MHz and P160VDG 160-170 MHz preamplifiers and DC injectors, respectively. The radio reception ranges from the sonobuoys averaged 20.5 km, with a maximum reception range of 24 km. When the ship was running at survey speed (approximately 10 kts) each sonobuoy could be effectively received and recorded for approximately one hour before the ship moved out of radio reception range. The amplified sonobuoy signals were split in the lab and received on up to three WinRadios (G39WSBe), each tuned to the broadcast frequency programmed for one of the deployed sonobuoys. Analog signals from the three WinRadios were digitized with an RME Fireface UC audio interface sampling 16 bits at 48 kHz. Using Pamguard (Gillespie *et al.* 2008) v1.15.03 software with a custom DIFAR demultiplexing module (Miller *et al.* 2015), digitized acoustic data were recorded directly to computer hard-drives as 3-channel, 48 kHz wav files stored on 2 TB SATA disks housed in an external RAID enclosure. Additionally, Pamguard DIFAR and Logger modules were used to record sonobuoy deployment locations, ship track line from GPS, recording effort, and metadata logs.

BIOPSY SAMPLING

Cetacean biopsy tissue samples were collected from *Gunter* and the *R3* (7-m rigid-hulled inflatable boat). Samples were collected using a modified .22 caliber dart rifle fitted with custom designed biopsy heads that extracted a small plug of tissue from the animals, usually including skin and blubber. A portion of the skin can be genetically analyzed for species identification and gender determination, as well as evaluation of population structure. Another portion of the skin can be used for stable isotopes analysis. Blubber samples can be analyzed for a variety of contaminants or to measure hormone levels. Data on each sampling attempt were recorded and included GPS location, time, date, sampler, species, body location where the dart struck, behavioral reaction, and whether or not a sample was obtained. A complete log of the biopsy data is maintained at the Lafayette, LA and Miami, FL laboratories. Biopsy sampling was attempted only by qualified personnel and after all pertinent group size and biological information was recorded by the visual team.

ACTIVE ACOUSTIC SAMPLING

The scientific echosounder (EK60) was operational only during nighttime hours. No calibration was performed.

HYDROGRAPHIC SAMPLES

Environmental data were collected at predetermined stations using a Conductivity, Temperature and Depth (CTD) unit and expendable bathythermographs (XBT). CTD casts were submerged up to 5,000 m deep and recorded vertical profiles of salinity, temperature, oxygen content, and fluorescence. XBT profiles recorded only temperature up to a depth of 750 m. CTD data were recorded on a daily basis, typically at the beginning of the survey day. XBT casts were made at regular intervals along the track line throughout the cruise at stations typically spaced 20 – 80 km apart. Constant records of environmental parameters including water temperature, salinity, and weather conditions (e.g., wind speed, wind direction) were collected in situ via the ship's Scientific Computer System (SCS).

SEABIRD SURVEYS

No seabird data was collected during GU16-05.

RESULTS

VISUAL MARINE MAMMAL SIGHTING TEAM

Visual cetacean surveys were conducted between 1 July and 19 August 2016. A total of 5,381 km of survey effort was accomplished with 509 cetacean sightings (Table B1, Figure B1). Weather conditions were good to fair throughout much of the survey, with sea states of Beaufort 2 – 4 on most survey days, averaging 3.2 throughout the cruise (Table B1; Figure B2). As expected, the majority of sightings occurred along the continental shelf break. A variety of delphinids were encountered during the survey, with bottlenose dolphins (*Tursiops truncatus*) and pilot whales (*Globicephala* sp.) being the most common species, 16.1% and 11.8% of total sightings respectively (Figure B3; Table B3). Large whale sightings included fin (*Balaenoptera physalus*), minke (*B. acutorostrata*) and sperm whales (*Physeter macrocephalus*), the latter with 7.3% of total sightings (Table B3; Figure B4). A notably high number of beaked whale sightings were recorded throughout the cruise consisting of 15.9% of the total sightings, which included Cuvier's (*Ziphius cavirostris*) and Gervais (*Mesoplodon europaeus*) beaked whales as well as unidentified Ziphiids and *Mesoplodon* sp. (Table B3; Figure B5). Of the total number of sightings, 1.6% were of mixed species groups (Table B3).

PASSIVE ACOUSTIC SURVEY

Two passive acoustic technicians monitored the signals continuously and recorded and classified cetacean sounds (e.g., echolocation clicks, whistles, etc.) along with anthropogenic noises. During the survey, over 431 hours of acoustic data were recorded with the towed array yielding 513 detections (Table B1; Figure B6). During real-time monitoring, acoustic detections were broadly categorized as Risso's dolphin clicks, sperm whale clicks, possible beaked whale clicks, unidentified delphinid vocalizations (whistles and clicks), or unidentified odontocetes (clicks only). Unidentified acoustic detections of odontocetes were made throughout the survey and were correlated with visual sightings when localization was possible. These recordings with visually verified species identifications will be reanalyzed and verified in post processing to develop acoustic species classification algorithms for direct acoustic species identification. Acoustic data will also be used to improve estimates of sperm whale abundance.

In addition to data collected by the towed array, 30 sonobuoys were deployed over the course of the survey: 6 failed, 6 during sightings and 18 at triad corners stations (Figure B7). Most deployed sonobuoys successfully broadcast radio signals (83%). Sonobuoy data were not actively monitored in real-time. Post-processing will include baleen whale call detection, and localization when possible. The two acoustic field technicians only cursorily monitored the recordings for data quality and received radio signal strength while focusing their effort on towed array monitoring.

BIOPSY SAMPLING

A total of 19 unique samples were collected from six different species; the biopsies were then sectioned into a total of 70 subsamples for genetic, stable isotope, contaminant and hormonal analyses among others. Of the total samples collected, 14 were sampled from the *Gunter's* bow and four pilot whale biopsies and samples from a dead sperm whale were collected from the *R3* (Table B4; Figure B8).

ACTIVE ACOUSTIC SAMPLING

Active acoustic backscatter data were collected only during nighttime hours along the pre-established track lines and stored on hard drives for archiving and later data analysis.

HYDROGRAPHIC SAMPLES

A total of 179 hydrographic profiles were collected including 145 XBT stations and 34 CTD stations (Figure B9). All data from the CTDs and the SCS are maintained at the Miami, FL Laboratory for analysis, editing, and archiving.

DISPOSITION OF DATA

All data collected during the cruise including visual survey data, passive acoustic data, EK60 data, SCS data, XBT and CTD data, are archived and managed at the Southeast Fisheries Science Center, Miami, FL. Genetic samples are stored at the Southeast Marine Mammal Molecular Genetics Laboratory in Lafayette, LA. All other samples are stored at the SEFSC in Pascagoula, MS.

PERMITS

The SEFSC was authorized to conduct marine mammal research activities during the cruise under Permit No. 14450-04 issued to the SEFSC by the National Marine Fisheries Service (NMFS).

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Table B1. Summary of survey effort during GU16-05.

Leg	Date	Event	Visual Effort (km)	Ave. Sea State	Num. Sights.	Num. Biopsies	Acoustic Effort (hrs)	Num. Ac. Detcs.	Num. SBs
In port	27-29 Jun	Delayed due to mechanical issue and crew replacement	0.0	NA	0	0	0	0	0
1	30-Jun	Depart Norfolk, VA	0.0	NA	0	0	0	0	0
1	1-Jul	Marine Mammal Survey	87.5	3.4	9	0	6.5	14	0
1	2-Jul	Marine Mammal Survey	84.3	3.3	35	0	10.4	21	0
1	3-Jul	Marine Mammal Survey	142.8	2.3	33	0	11.5	22	1
1	4-Jul	Marine Mammal Survey	196.6	3.5	4	0	12.2	15	2
1	5-Jul	Marine Mammal Survey	93.0	5.0	14	0	11.6	20	1
1	6-Jul	Marine Mammal Survey	99.5	2.7	39	0	12.1	32	0
1	7-Jul	Marine Mammal Survey	130.8	3.4	9	1	12.5	11	0
1	8-Jul	Marine Mammal Survey	171.1	3.9	6	0	12.4	16	1
1	9-Jul	Marine Mammal Survey	141.8	4.6	26	0	12.4	31	0
1	10-Jul	Marine Mammal Survey	97.5	2.5	23	1	12.4	22	0
1	11-Jul	Marine Mammal Survey	138.1	2.0	17	0	12.7	14	1
1	12-Jul	Marine Mammal Survey	173.2	2.0	8	0	12.2	3	6

1	13-Jul	Marine Mammal Survey	149.9	3.5	6	0	12.0	8	0
1	14-Jul	Marine Mammal Survey	98.4	4.1	11	0	10.6	13	0
In port	15-19 Jul	Norfolk, VA	0.0	NA	0	0	0.0	0	0
2	20-Jul	Marine Mammal Survey	103.5	2.6	24	1	8.5	17	2
2	21-Jul	Marine Mammal Survey	125.5	2.0	19	0	11.3	11	0
2	22-Jul	Marine Mammal Survey	205.8	1.9	11	0	12.4	7	3
2	23-Jul	Marine Mammal Survey	196.5	2.4	9	0	12.9	4	0
2	24-Jul	Marine Mammal Survey	125.2	3.3	11	0	12.0	9	0
2	25-Jul	Marine Mammal Survey	115.5	4.4	25	1	11.9	28	0
2	26-Jul	Marine Mammal Survey	119.8	5.0	7	0	10.7	13	0
2	27-Jul	Marine Mammal Survey	34.2	5.0	0	0	2.8	1	0
2	28-Jul	Marine Mammal Survey	107.9	3.0	6	1	7.3	10	0
2	29-Jul	Marine Mammal Survey	57.8	5.4	0	0	11.8	4	0
2	30-Jul	Marine Mammal Survey	79.7	1.7	10	4	11.2	6	0
2	31-Jul	Marine Mammal Survey	197.7	3.8	2	0	11.9	9	3
2	1-Aug	Marine Mammal Survey, NRS station recovery	118.1	2.9	2	0	8.8	10	0

2	2-Aug	Marine Mammal Survey	180.8	2.7	11	1	12.1	8	0
2	3-Aug	Marine Mammal Survey	188.3	3.1	9	3	10.6	9	0
2	4-Aug	Marine Mammal Survey	133.6	2.9	6	0	10.5	11	0
In port	5-9 Aug	Charleston, SC	0.0	NA	0	0	0.0	0	0
3	10-Aug	Marine Mammal Survey	59.7	4.7	2	0	10.6	9	0
3	11-Aug	Marine Mammal Survey	176.6	4.6	5	0	11.8	11	0
3	12-Aug	Marine Mammal Survey	196.8	2.5	9	0	12.0	14	0
3	13-Aug	Marine Mammal Survey	198.6	3.6	3	0	11.9	8	0
3	14-Aug	Marine Mammal Survey	187.2	1.6	36	1	12.0	16	3
3	15-Aug	Marine Mammal Survey	153.4	2.0	19	0	10.9	17	0
3	16-Aug	Personnel transfer to Charleston	0.0	NA	6	0	0.0	0	0
3	17-Aug	Marine Mammal Survey	154.2	3.1	0	0	10.5	12	3
3	18-Aug	Marine Mammal Survey	188.6	2.2	14	3	11.7	11	0
3	19-Aug	Marine Mammal Survey	171.8	2.3	23	2	11.8	16	4
Total			**5381.3**	**3.2**	**509**	**19**	**431.2**	**513**	**30**

Table B2. Scientific crew onboard GU16-05.

Name	Legs	Affiliation	Title	Sex	Citizenship
Anthony Martinez	1, 2, 3	Miami - SEFSC	Field Party Chief (FPC)	M	US
Laura Dias	1, 2, 3	Miami - University of Miami (CIMAS)	Data manager	F	Brazil
Katrina Ternus	1, 2, 3	Miami – Worldwide Services Inc. (IAP)	Acoustician	F	US
Jesse Wicker	1, 2	Miami - CIMAS	Observer	M	US
Gina Rappucci	3	Miami – IAP	Observer	F	US
Matt Maiello	1	Miami – SEFSC	Observer	M	US
Christen Nagy	1	Miami – guest volunteer	Observer	F	US
Carrie Sinclair	2, 3	Pascagoula – SEFSC	Observer	F	US
Mark Grace	2, 3	Pascagoula – SEFSC	Observer	M	US
Melody Baran	1, 2, 3	Pascagoula – IAP	Observer	F	US
Paula Olson	1, 2, 3	Pascagoula – IAP	Observer	F	US
Amy Whitt	1, 2, 3	Pascagoula – IAP	Observer	F	US
Mary Applegate	1, 2, 3	Pascagoula – IAP	Observer	F	US
Heidi Malizia	1, 2, 3	Pascagoula – IAP	Observer	F	US
Thomas Ninke	1, 2, 3	Pascagoula – IAP	Observer	M	US
Kerry Dunleavy	1, 2, 3	Pascagoula – IAP	Acoustician	F	US

Table B3. Cetacean sightings recorded during GU16-05.

Species	Leg 1	Leg 2	Leg 3	Total
Atlantic spotted dolphin	18	6	5	29
Atlantic spotted dolphin+Bottlenose dolphin	2	0	0	2
Bottlenose dolphin	41	32	9	82
Bottlenose dolphin+Bottlenose/Spotted dolphin	1	1	0	2
Bottlenose/Spotted dolphin	0	2	0	2
Clymene dolphin	2	0	0	2
Common dolphin	2	2	0	4
Cuvier's beaked whale	4	6	10	20
False killer whale	1	0	0	1
Fin whale	0	3	0	3
Gervais' beaked whale	0	0	1	1
Killer whale	0	1	0	1
Melon-headed/Pygmy killer whale	0	0	1	1
Melon-headed/Pygmy killer whale+Bottlenose dolphin	1	0	0	1
Minke whale	1	0	0	1
Pantropical spotted dolphin	1	3	3	7
Pilot whales	44	16	0	60
Pilot whales+Bottlenose dolphin	2	0	0	2
Pilot whales+unid. dolphin	0	1	0	1
Pygmy/Dwarf sperm whale	4	5	26	35
Risso's dolphin	9	2	4	15
Sperm whale	19	11	7	37
Spinner dolphin	1	0	0	1
Stenella sp.	1	3	3	7
Striped dolphin	6	0	0	6
Unid. Baleen Whale	0	1	0	1
unid. dolphin	45	25	7	77
unid. large whale	1	3	1	5
Unid. Mesoplondont	5	5	10	20
unid. odontocete	12	2	10	24
unid. small whale	4	9	6	19
Unid. Ziphiid	13	13	14	40
Grand Total	**240**	**152**	**117**	**509**

Table B4. Cetacean samples collected during GU16-05.

Species	**Total unique samples**	**Genetics (skin - DMSO)**	**Stable isotope (skin - frozen)**	**Contaminants (blubber - frozen)**	**Hormones (blubber - frozen)**	**Other**	**Total Subsamples**
Globicephala sp	4	4	4	4	2	0	14
Physeter macrocephalus	1	2	1	1	1	4	9
Stenella attenuata	4	4	4	4	1	0	13
Stenella frontalis	3	3	3	3	3	0	12
Stenella longirostris	1	1	1	1	1	0	4
Tursiops truncatus	6	6	5	4	3	0	18
Grand Total	**19**	**20**	**18**	**17**	**11**	**4**	**70**

Figure B1. Proposed track lines and accomplished survey effort during GU16-05.

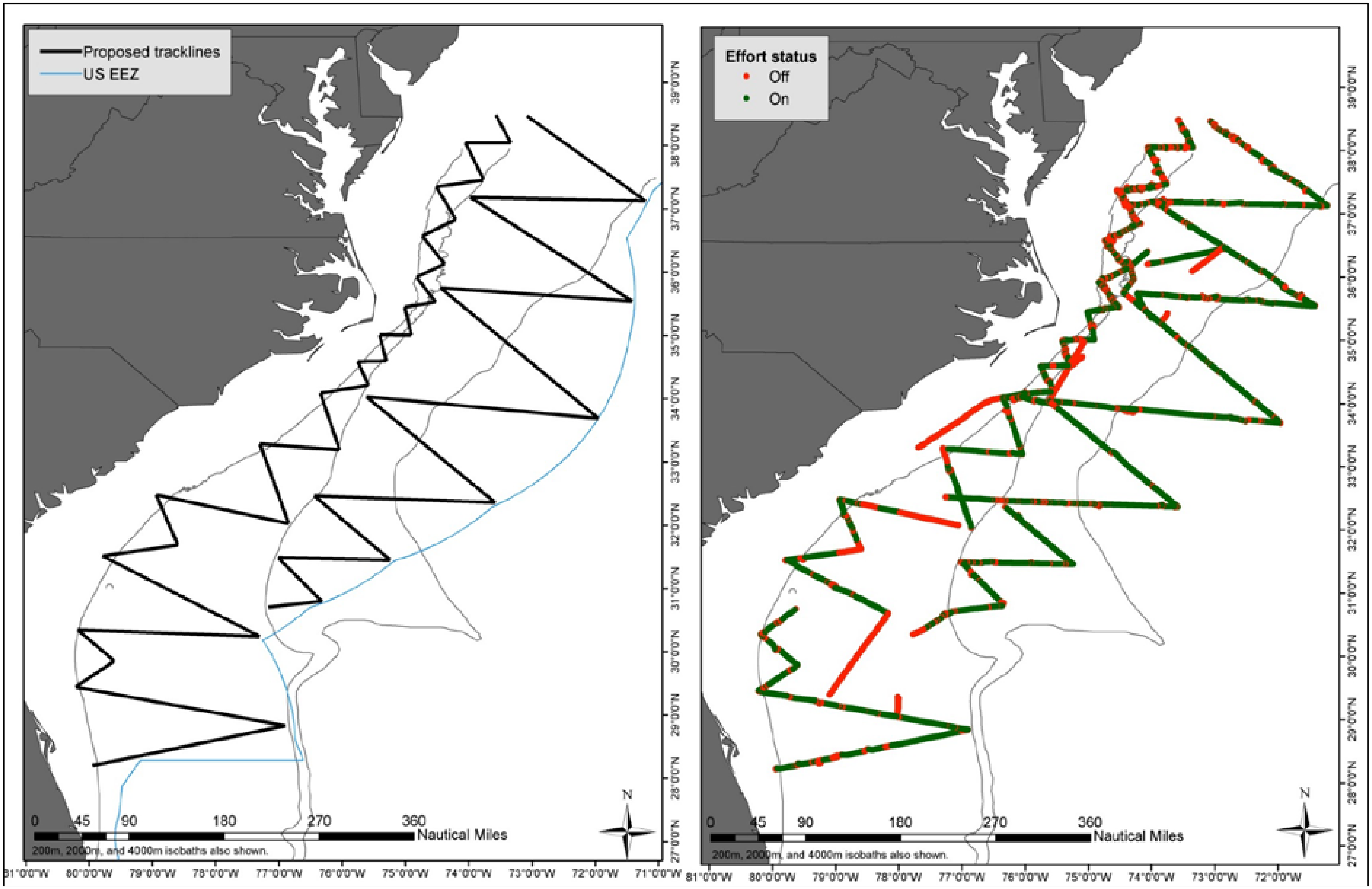


Figure B2. Sea state conditions during survey effort for GU16-05.

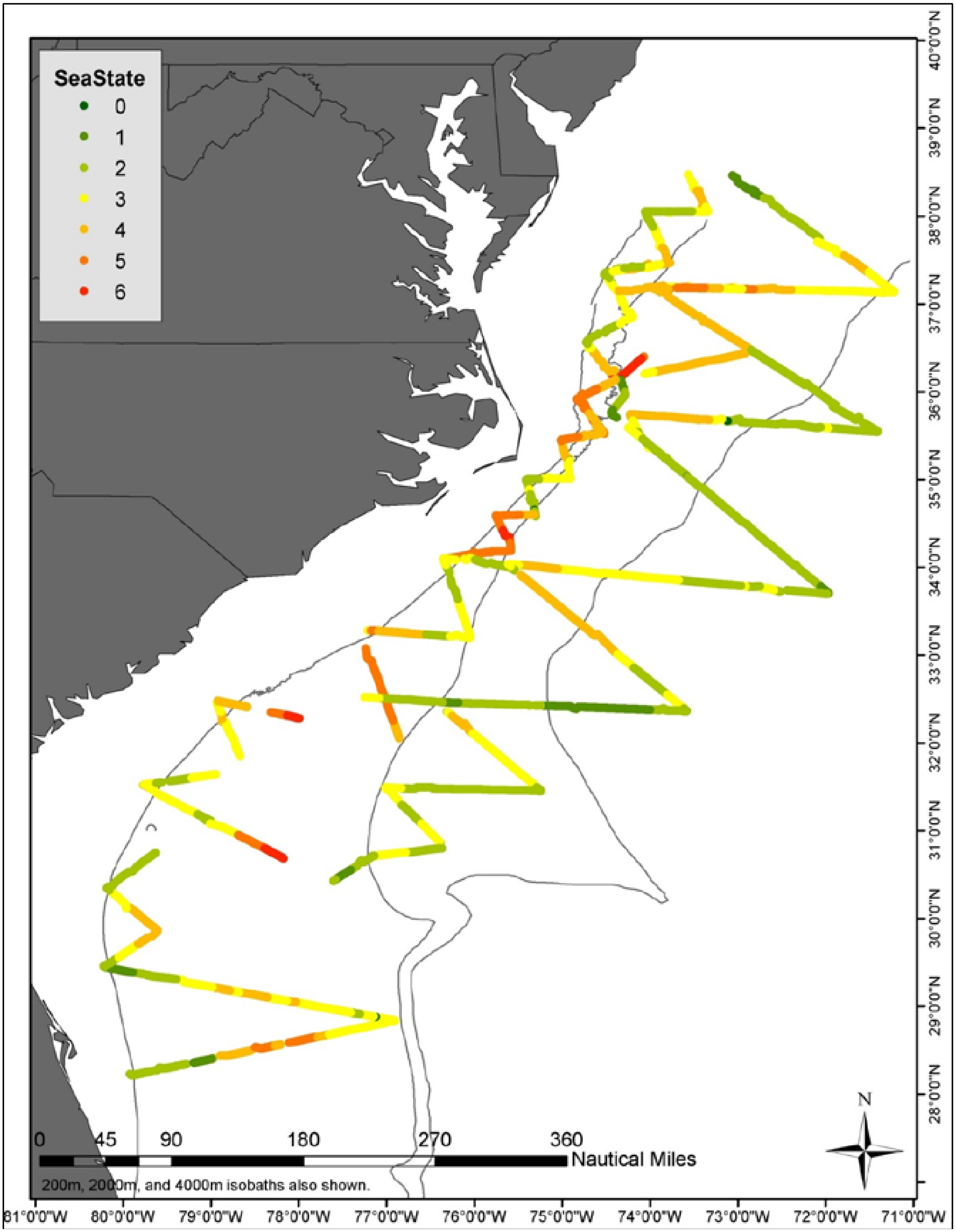


Figure B3. Delphinid sightings recorded during GU16-05.

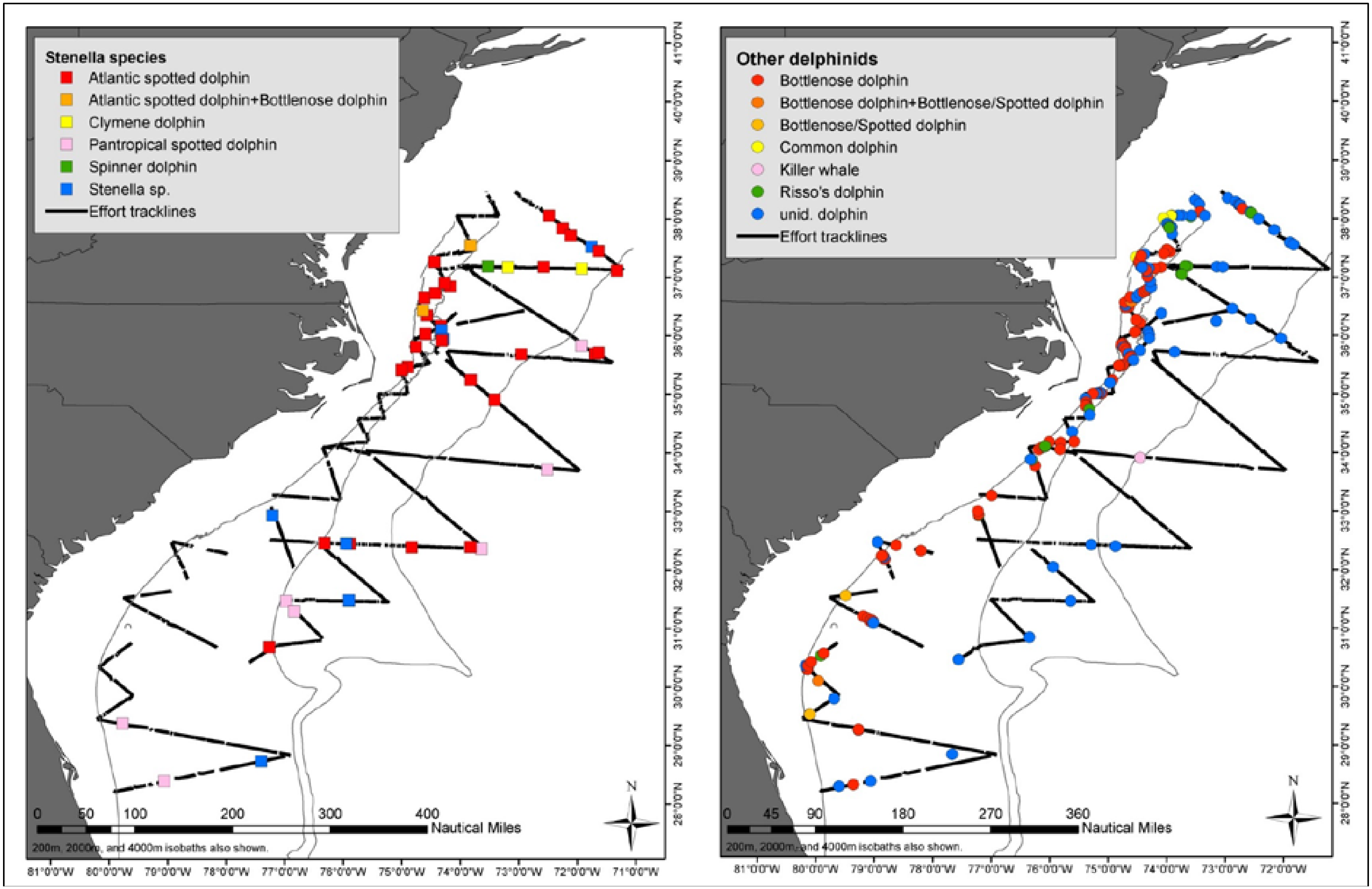


Figure B4. Large whale sightings during GU16-05.

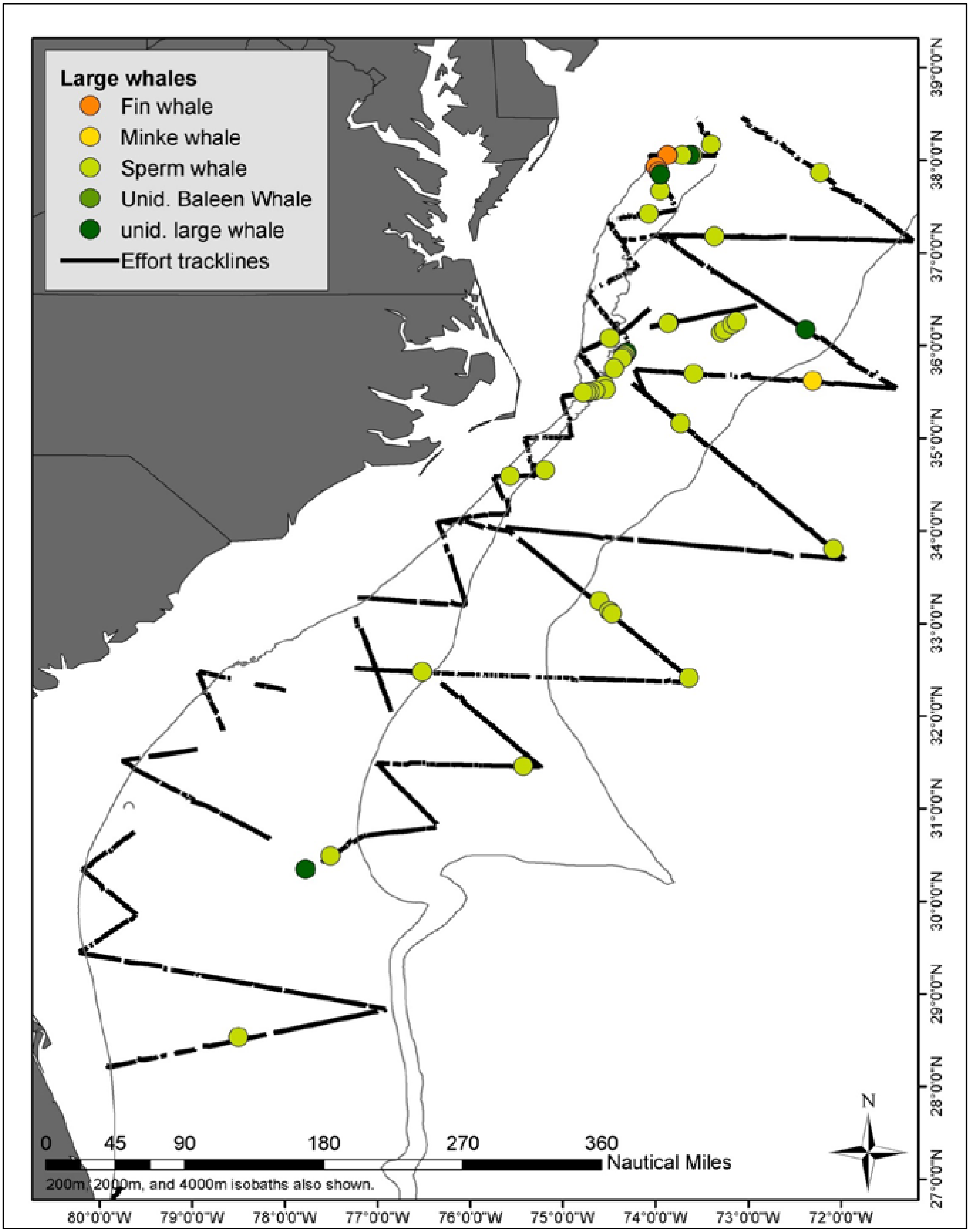


Figure B5. Medium sized whale sightings during GU16-05.

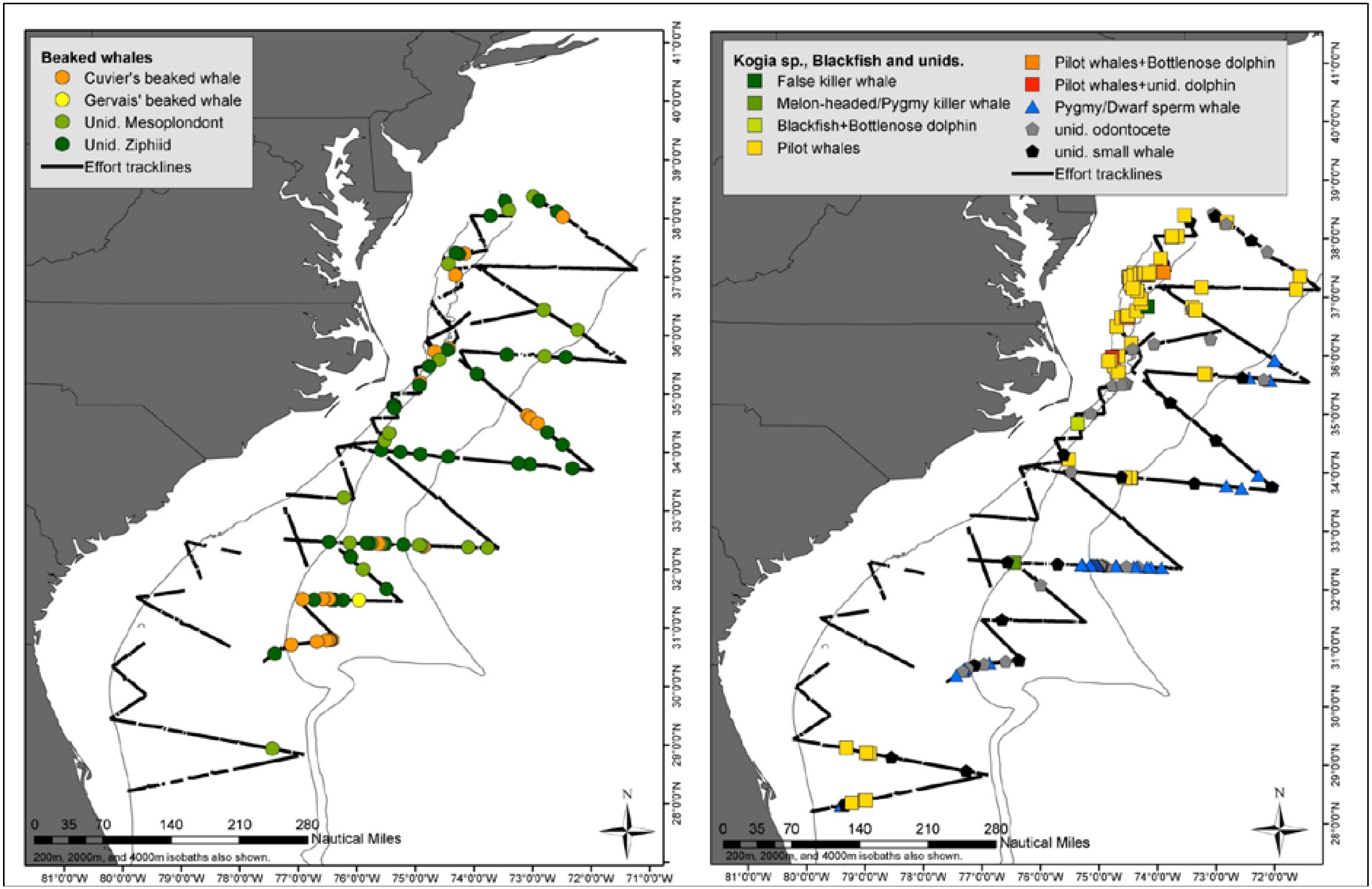


Figure B6. Acoustic detections during GU16-05.

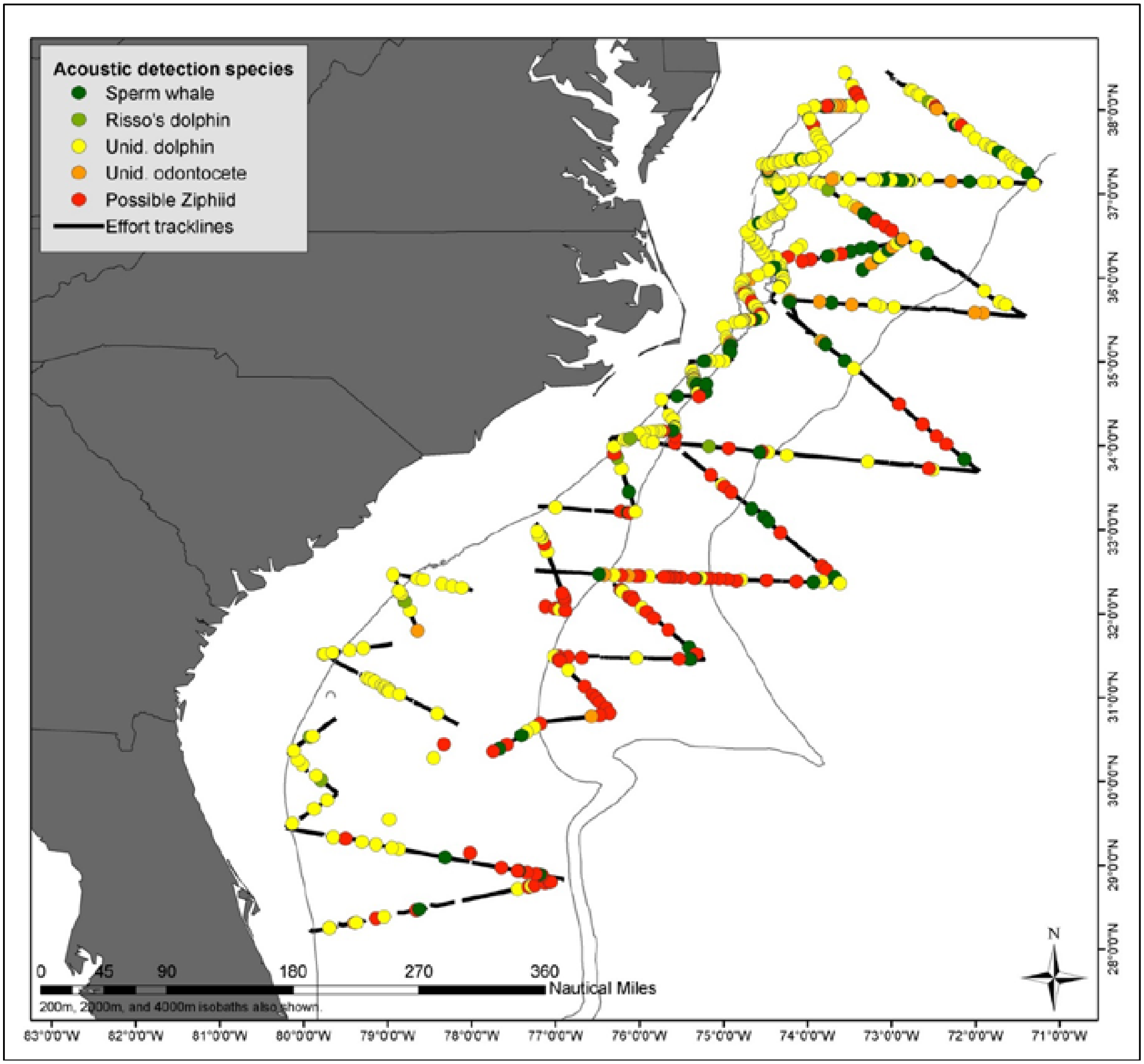


Figure B7. Sonobuoys deployed during GU16-05.

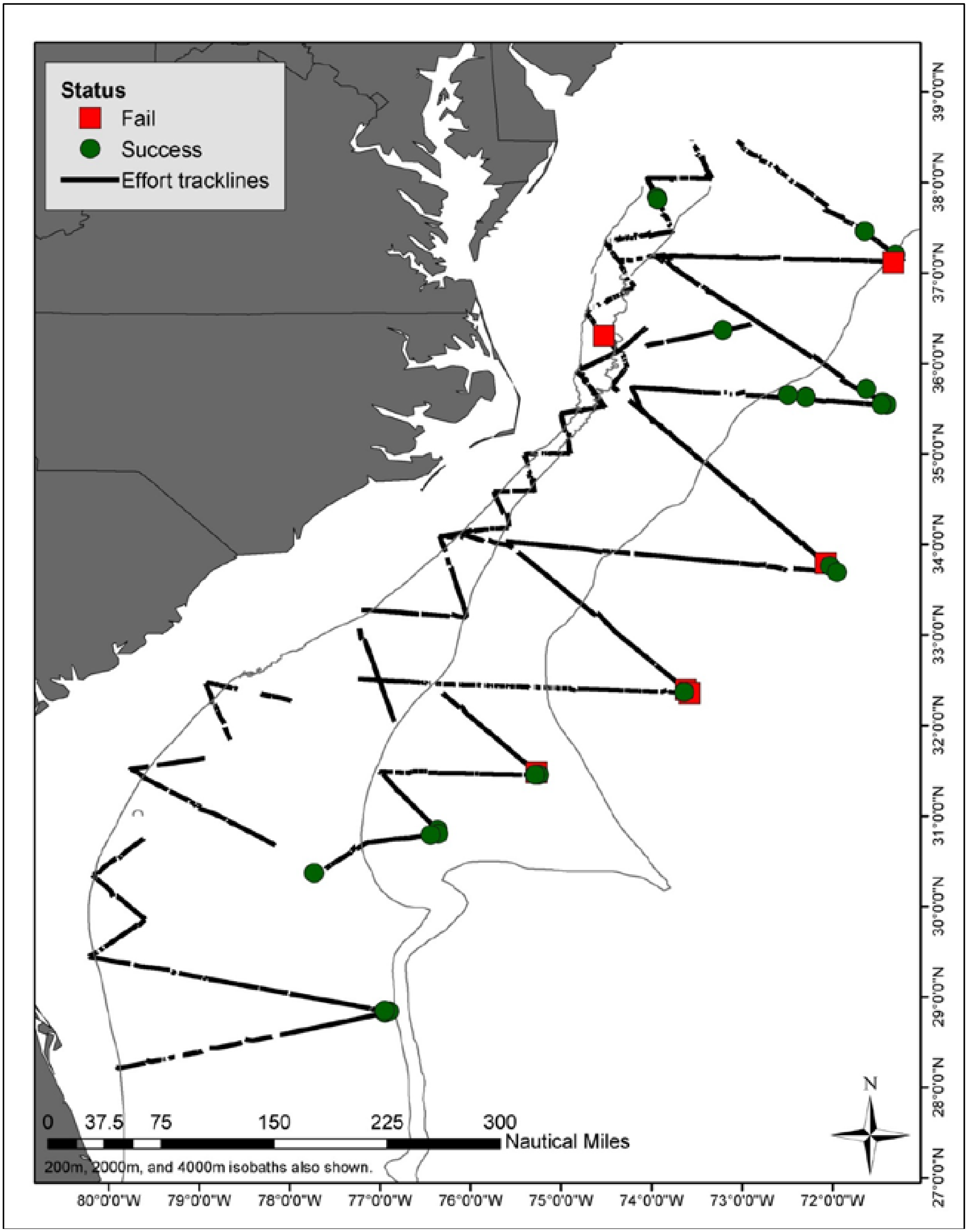


Figure B8. Samples collected during GU16-05.

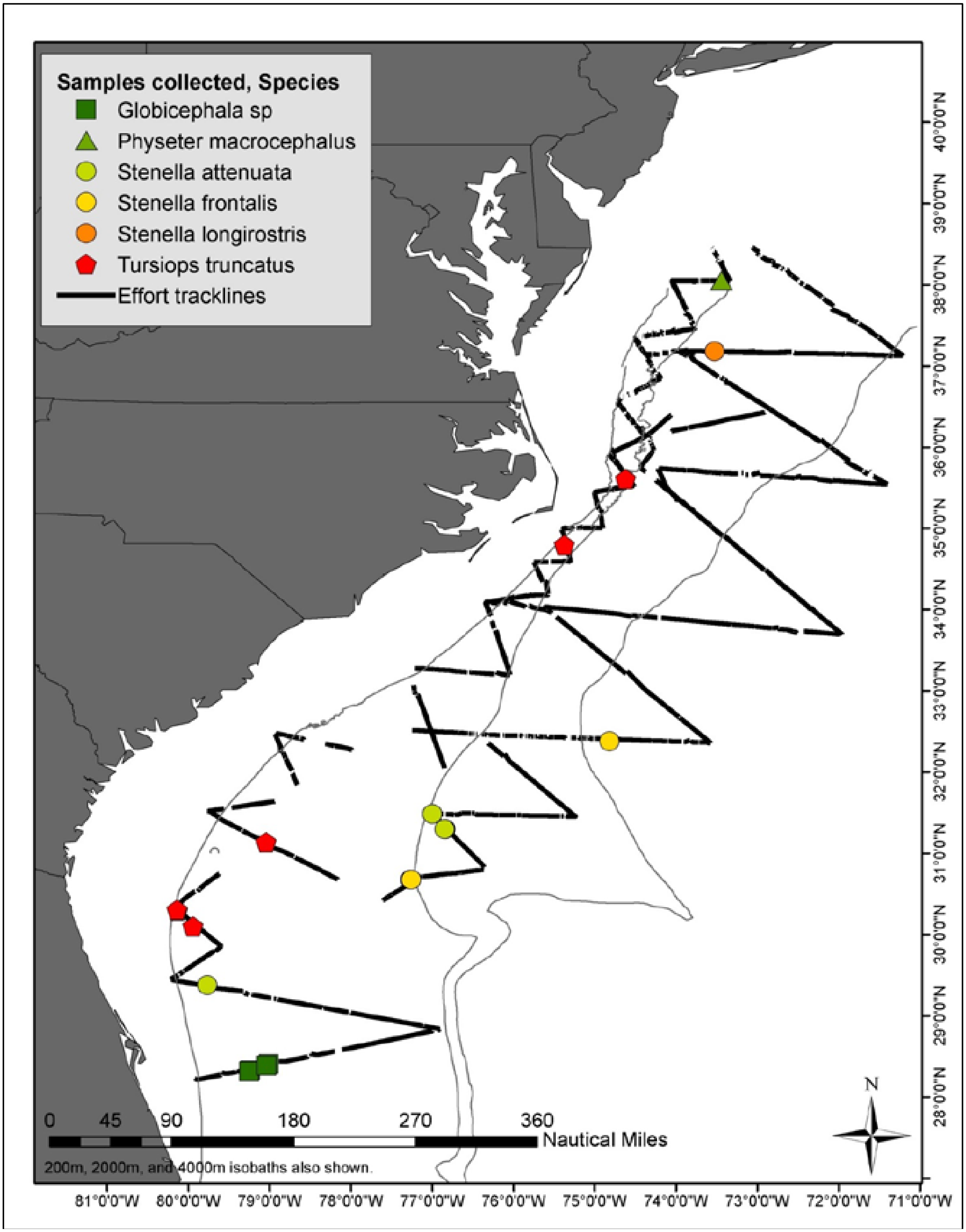
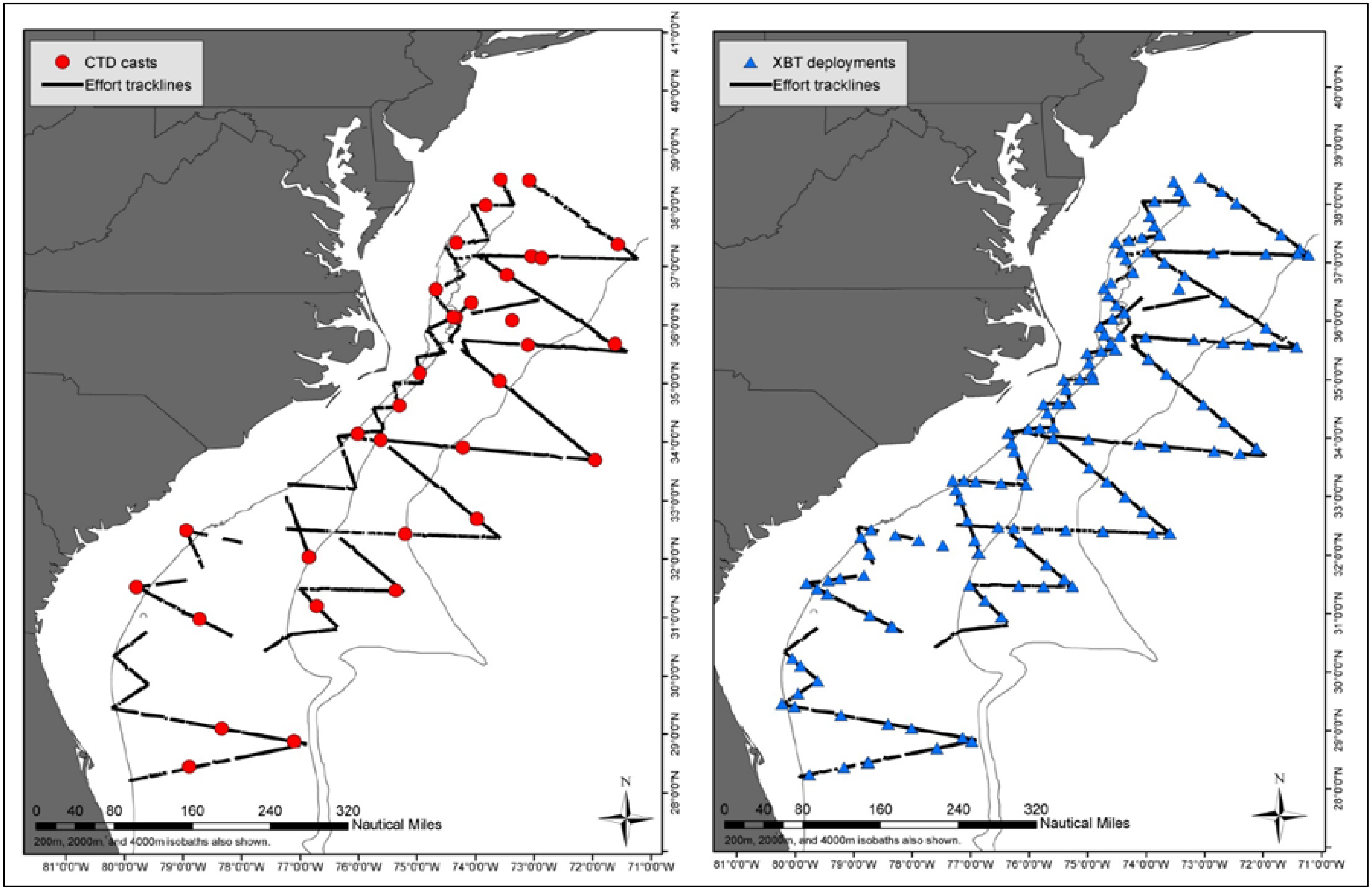


Figure B9. CTDs and XBTs performed during GU16-05.



Appendix C: *Southern leg of aerial abundance surveys during the summer (3 July – 9 August 2016) and fall (23 November – 31 December) 2016: Southeast Fisheries Science Center*

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SUMMARY

As part of the AMAPPS program, the Southeast Fisheries Science Center conducted aerial surveys of continental shelf waters (up to the 200 m isobath) along the US east coast from New Jersey to Florida in the summer and continental shelf and slope waters (up to the 2,000 m isobath) from New Jersey to North Carolina in the fall. The surveys were conducted during 2016 between 3 July - 9 August and 23 November - 31 December aboard a NOAA Twin Otter aircraft at an altitude of 600 feet (183 m) and a speed of 110 knots. The surveys covered waters from New Jersey to Fort Lauderdale, FL following track lines oriented perpendicular to the shoreline that were latitudinally spaced 20 km apart. “Fine-scale” track lines were surveyed in waters off the coast of New Jersey, Delaware and Virginia. In the summer, a total of 11,356 km of track lines were surveyed on-effort and in the fall the total was 5,919.0 km. At least nine species of marine mammals were identified in the summer and six species in the fall (not including unidentified taxa), with the majority being common bottlenose dolphins during both surveys. Four species of sea turtles were recorded in the summer while three were recorded in the fall; in the summer the vast majority of turtles were identified as loggerhead and in the fall as unidentified hardshell. The surveys were designed for analysis using Distance sampling and a two-team (independent observer) approach to correct for perception bias in resulting abundance estimates. The data collected from these surveys will be analyzed to estimate the abundance and spatial distribution of cetaceans and turtles along the US east coast.

OBJECTIVES

The goal of the surveys was to conduct line-transect surveys using the Distance sampling approach to estimate the abundance and spatial distribution of marine mammals and turtles in waters over the continental shelf and slope (shoreline to 2,000 m isobath) of the eastern US from New Jersey to southeastern Florida.

CRUISE PERIOD AND AREA

The summer survey was conducted during 3 July – 9 August and extended from New Jersey to Fort Lauderdale, FL, and from the coast line to about the 200 m depth contour (Figure C1). The fall survey was performed from 23 November – 31 December, 2016 and the study area extended from New Jersey to southern North Carolina, and from the coast line to about the 2,000 m depth contour (Figure C9).

METHODS

The surveys were conducted aboard a DeHavilland Twin Otter DHC-6 flying at an altitude of 183m (600 ft) above the water surface and a speed of approximately 200 kph (110 knots).

Surveys were typically flown only when wind speeds were less than 20 knots or approximately sea state 4 or less on the Beaufort scale. The surveys were conducted along track lines oriented perpendicular to the shoreline and spaced latitudinally at approximately 20 km intervals from a random start point (Figure C1; Figure C9). Off the coasts of New Jersey, Delaware and Virginia within designated “Wind Lease Areas”, fine-scale track lines were flown that were spaced 5 km apart (Figure C1; Figure C9).

There were two pilots and six scientists onboard the airplane. The scientists operated as two teams to implement the independent observer approach to correct for perceptiopn bias (Laake and Borchers 2004). The forward team (Team 1) consisted of two observers stationed in bubble windows on either side of the airplane and an associated data recorder. The bubble windows allowed downward visibility including the track line. The aft team (Team 2) consisted of a belly observer looking straight down through a belly port, an observer stationed on the right side of the aircraft observing through a large window, and a dedicated data recorder. The side bubble window observer was stationed in a large “vista” window that provided track line visibility while the belly observer can see approximately 35 degrees on either side of the track line. Therefore, the aft team has limited visibility of the left side of the aircraft. The two observer teams operated on independent intercom channels so that they were not able to cue one another to sightings.

For the fall survey, between 23-25 November only, Team 1 composed of a left, right, belly and data recorder. After 13 December the survey was conducted with two teams per the usual protocol described above.

Data were entered by each team’s data recorder onto a laptop computer running data acquisition software that recorded GPS location, environmental conditions entered by the observer team (e.g., sea state, glare, sun penetration, visibility, etc.) and effort information.

During on effort periods (e.g., level flight at survey altitude and speed), observers searched visually from the track line (0˚) to approximately 50˚ above vertical. When a turtle, mammal, or other organism was observed, the observer waited until it was perpendicular to the aircraft and then measured the angle to the organism (or the center of the group) using a digital inclinometer or recorded the angle in 10˚ intervals based upon markings on the windows. The belly observer only reported the interval for the sighting. Fish species were recorded opportunistically.

Sea turtle sightings were recorded independently, without communication, by each team. For marine mammal sightings, if the sighting was made initially by the forward team, they waited until it was aft of the airplane to allow the aft team an opportunity to observe the group before notifying the pilots to circle over the group. Once both teams had the opportunity to observe the group, the observers asked the pilots to break effort and circle the group. The aircraft circled over the majority of the marine mammal groups sighted to verify species identification and group sizes and to take photographs. The data recorders indicated at the time of the sighting whether or not the group was recorded by one or both teams.

Post survey, the turtle data were reviewed to identify duplicate sightings by the two teams based upon time, location, and position relative to the track line.

RESULTS

Summer survey:

The survey was conducted during 3 July – 9 August 2016. A total of 11,356 km of track lines were covered on effort along 123 track lines (Table C1, Figure C1). The average sea state during the survey was 2.5 on the Beaufort scale with the majority of the survey effort flown in sea states of 2 or 3 (Table C1; Figure C1). On 12 July a survey was started but aborted due to deteriorating conditions.

There were a total of 1,494 unique sightings of sea turtles for a total of 1,630 individuals (Table C2, Figures C2 – C3). Turtles were identified as loggerhead turtles (*Caretta caretta*), leatherback turtles (*Dermochelys coriacea*), Kemp's ridley (*Lepidochelys kempii*), green (*Chelonia mydas*) and unidentified hardshells (Table C2). Of these, the vast majority of identified turtle sightings were of loggerhead turtles (Table C2; Figure C2). Most of turtle sightings were recorded off the New Jersey, Delaware and Virginia coasts (Figures C2 – C3).

There were a total of 183 groups of marine mammals sighted for a total of 2,178 individuals (Table C3, Figures C4 – C6). The primary species observed was common bottlenose dolphins (*Tursiops truncatus*) with 111 sightings and 1,130 individuals, followed by Atlantic spotted dolphins (*Stenella frontalis*) with 31 sightings and 398 individuals (Table C3; Figure C4). Only four common dolphin (*Delphinus delphis*) sightings were recorded but they yielded a total of 274 individuals (Table C3; Figure C4). Large whales included one sighting of fin (*Balaenoptera physalus*) and sperm (*Physeter macrocephalus*) whales each (Table C3; Figure C6).

Opportunistic fish species sighted included primarily hammerhead sharks (*Sphyrnidae* spp.), ocean sunfish (*Mola mola*) and rays (Figures C7 – C8).

Fall survey:

The survey, conducted 23 November – 31 December 2016, resulted in 10 good weather survey-days. During 23 – 25 November 2016, only Team 1 (forward) was operational. During the rest of the survey the normal two team procedure was operational. Only the northern portion of the survey area was able to be surveyed (Figure C9). A total of 5,919 km of track lines were surveyed on effort along 71 track lines (Table C4; Figure C9). The average sea state during the survey was 2.7 on the Beaufort scale with the majority of the survey effort flown in sea states of 2 or 3 (Figure C9).

There were a total of 89 unique sightings of sea turtles for a total of 115 individuals (Table C5, Figure C10). Turtles were identified as loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), Kemp's ridley (*Lepidochelys kempii*), and unidentified hardshells (Table C5). Of these, most identified turtle sightings were of loggerhead turtles (Table C5, Figure C10). Most turtle sightings were recorded off the coast of Virginia and North Carolina (Figure C10).

A total of 113 cetacean sightings including 1,275 individuals were recorded (Table C6, Figures C11-C12). The primary species observed was common bottlenose dolphins (*Tursiops truncatus*) with 76 sightings and 568 individuals; interestingly, a cluster of 12 sightings with 73 dolphins was recorded off the coast of Delaware on 23 November (Figure C11). Common dolphins (*Delphinus delphis*) were the second most commonly sighted species, with 19 sightings and 582 individuals (Table C6, Figure C11). Only one sighting of two fin whales (*Balaenoptera physalus*) was observed (Table C6, Figure C12).

Opportunistic fish species sighted included primarily ocean sunfish (*Mola mola*) and hammerhead sharks (*Sphyrnidae* spp.) (Figure C13).

DISPOSITION OF DATA

All data collected during the aerial surveys are archived and managed at the Southeast Fisheries Science Center, Miami, FL. The final clean version is also archived in the Northeast Fisheries Science Center ORACLE database. The line transect data are available online on OBIS-SEAMAP.

PERMITS

The SEFSC was authorized to conduct marine mammal research activities during the survey under Permit No. 14450-04 issued to the SEFSC by the National Marine Fisheries Service (NMFS).

ACKNOWLEDGEMENTS

The funds for this project came from the Bureau of Ocean Energy Management (BOEM) and the US Navy through the respective Interagency Agreements for the AMAPPS project. Flight time and other aircraft costs were funded by NOAA Aircraft Operations Center. Staff time was provided by the NOAA Fisheries Service, Southeast Fisheries Science Center and NOAA Aircraft Operations Center. We would also like to thank the airplane's crew and observers that were involved in collecting these data.

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Laake, J.L. and Borchers, D.L. 2004. Methods for incomplete detection at distance zero. In: Advanced Distance Sampling. Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., and Thomas, L. (eds.). Oxford University Press, 411 pp.

Table C1. Daily summary of effort and sightings during SE AMAPPS aerial survey summer 2016.

Date	Effort (km)	Number of Cetacean Sightings	Number of Turtle Sightings	Average Sea State
7/3/16	254.1	1	27	2.8
7/4/16	658.4	11	110	2.4
7/6/16	395.0	9	81	2.2
7/8/16	505.7	12	54	2.8
7/11/16	830.8	20	91	2.8
7/12/16	25.1	0	0	3.3
7/13/16	519.9	17	34	2.9
7/17/16	425.8	10	31	2.7
7/18/16	706.4	18	42	1.9
7/19/16	280.1	1	5	3.4
7/20/16	460.7	8	11	2.3
7/21/16	699.9	5	22	2.5
7/22/16	293.5	11	41	2.0
7/24/16	634.8	2	74	3.2
7/26/16	781.6	14	213	2.0
7/27/16	714.9	11	172	2.3
7/28/16	386.1	6	82	2.0
8/5/16	607.5	10	164	2.1
8/7/16	819.2	3	79	2.7
8/8/16	403.5	3	89	1.4
8/9/16	953.4	11	72	2.5
Total	**11,356.5**	**183**	**1,494**	**2.5**

Table C2. Summary of turtle sightings during SE AMAPPS aerial survey summer 2016.

Species	Number of Sightings	Number of Animals
Green Turtle	46	50
Hardshell	747	817
Kemp's Ridley	15	15
Leatherback	80	83
Loggerhead	606	665
Total	**1,494**	**1,630**

Table C3. Summary of cetacean sightings during SE AMAPPS aerial survey summer 2016.

Species	Number of Sightings	Number of Animals
Atlantic spotted dolphin	31	398
Bottlenose dolphin	111	1,130
Bottlenose/Spotted dolphin	10	16
Common dolphin	4	274
False killer whale	1	9
Fin whale	1	2
Pilot whales	7	186
Risso's dolphin	3	65
Rough-toothed dolphin	1	7
Sowerby's beaked whale	1	6
Sperm whale	1	1
Stenella sp.	1	38
unid. Dolphin	10	44
Unid. Mesoplondont	1	2
Total	**183**	**2,178**

Table C4. Daily summary of effort and sightings during SE AMAPPS aerial survey fall 2016.

Date	Effort (km)	Number of Cetacean Sightings	Number of Turtle Sightings	Average Sea State
11/23/16	370.7	12	3	2.6
11/24/16	773.0	6	1	3.1
11/25/16	930.0	16	2	2
12/13/16	780.7	6	0	2.6
12/16/16	544.9	2	0	2.8
12/20/16	230.7	3	0	3.8
12/23/16	564.8	8	5	2.4
12/26/16	813.2	29	39	2.9
12/28/16	253.2	9	2	3.2
12/31/16	657.7	22	37	2.9
Total	**5,919.0**	**113**	**89**	**2.7**

Table C5. Summary of turtle sightings during SE AMAPPS aerial survey fall 2016.

Species	Number of Sightings	Number of Animals
Hardshell	60	73
Kemp's Ridley	1	1
Leatherback	3	3
Loggerhead	25	38
Total	**89**	**115**

Table C6. Summary of cetacean sightings during SE AMAPPS aerial survey fall 2016.

Species	Number of Sightings	Number of Animals
Bottlenose dolphin	76	568
Clymene dolphin	1	9
Common dolphin	19	582
Fin whale	1	2
Pilot whales	5	34
Risso's dolphin	7	71
unid. Odontocete	1	6
unid. small whale	1	1
Unid. Ziphiid	2	2
Total	**113**	**1,275**

Figure C1. Effort track lines, renewable energy areas and sea state during SE AMAPPS aerial survey summer 2016.

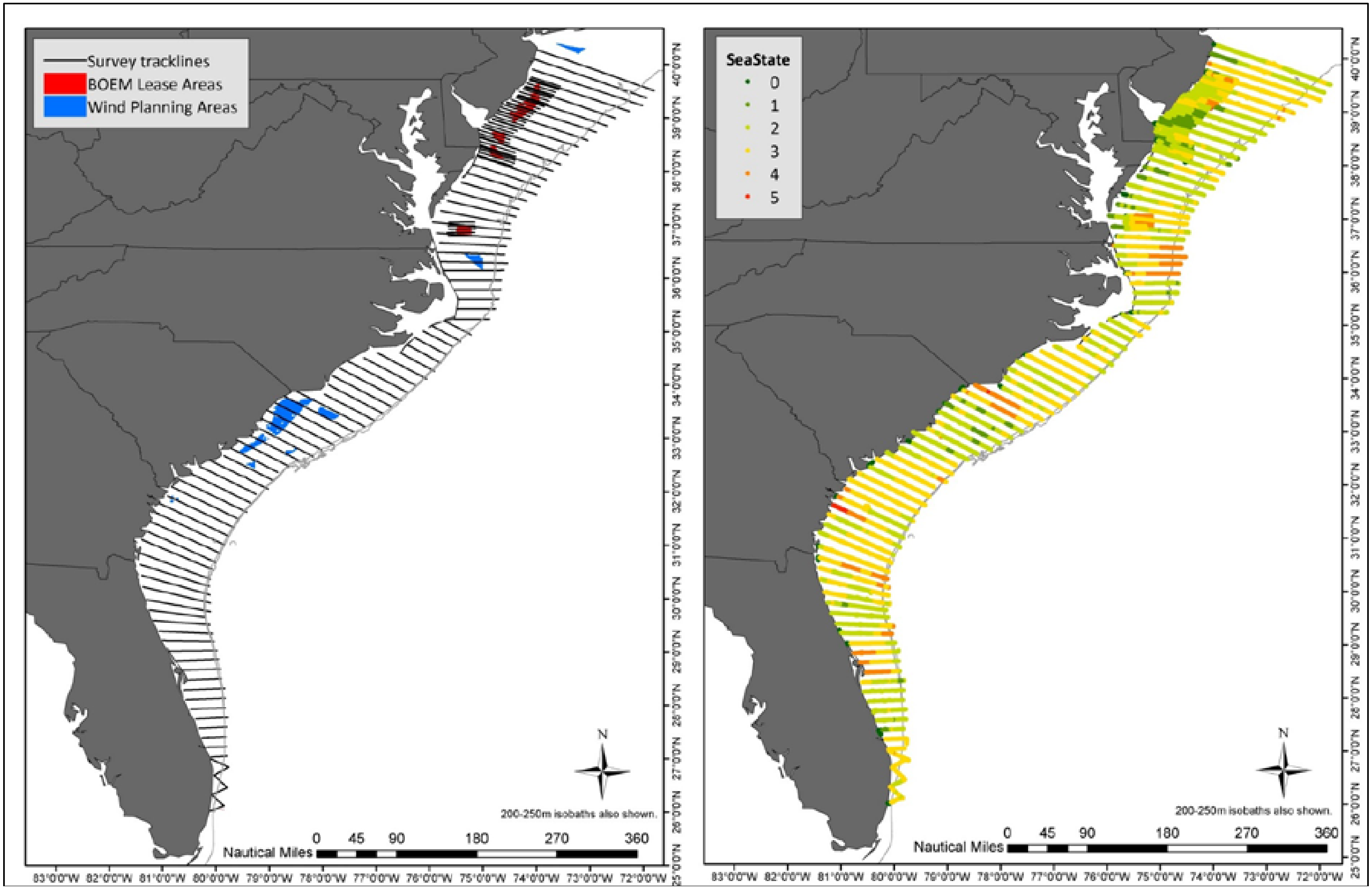


Figure C2. Loggerhead and hardshell turtle sightings during SE AMAPPS aerial survey summer 2016.

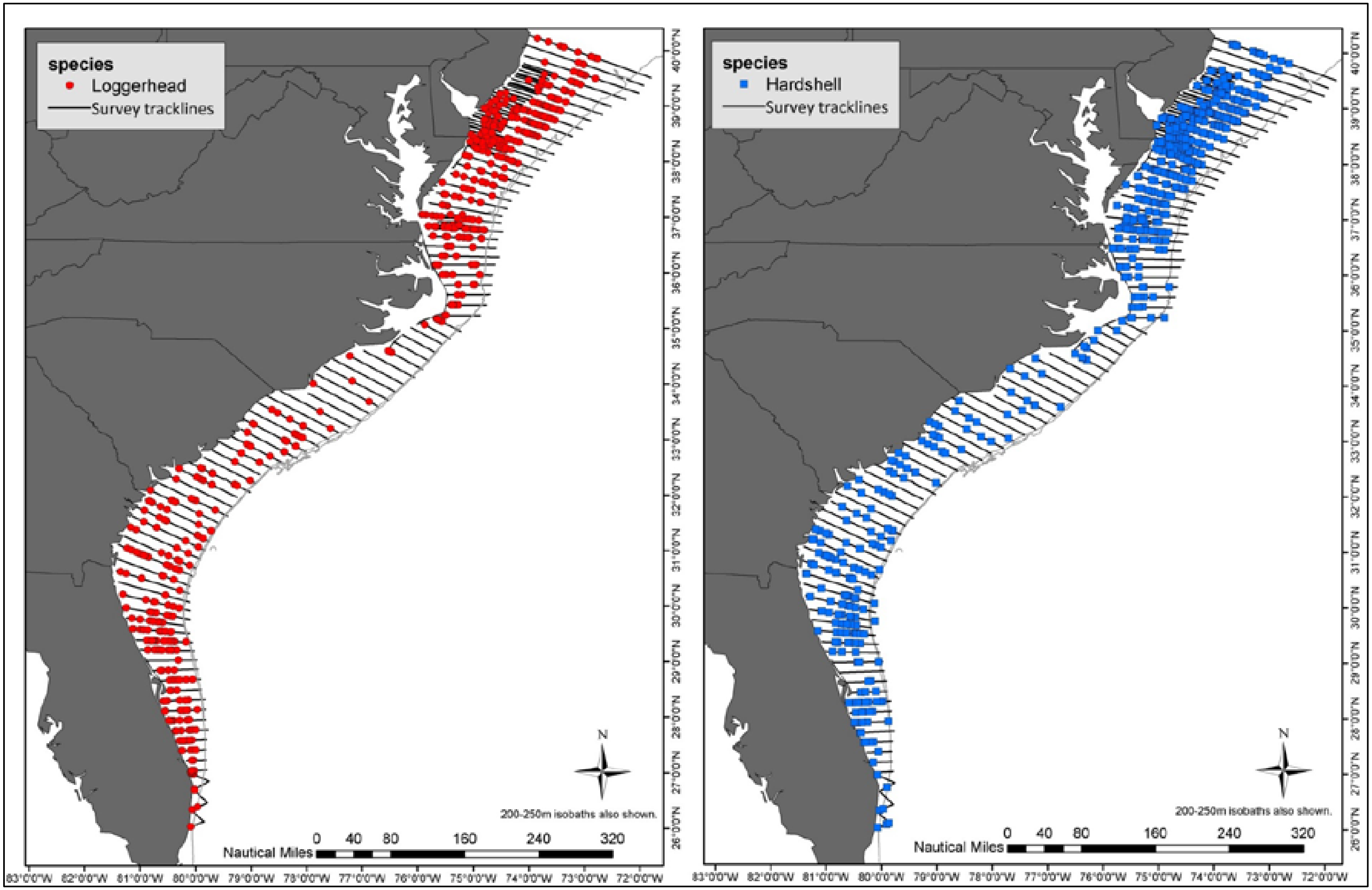


Figure C3. Green, kemp's and leatherback turtle sightings during SE AMAPPS aerial survey summer 2016.

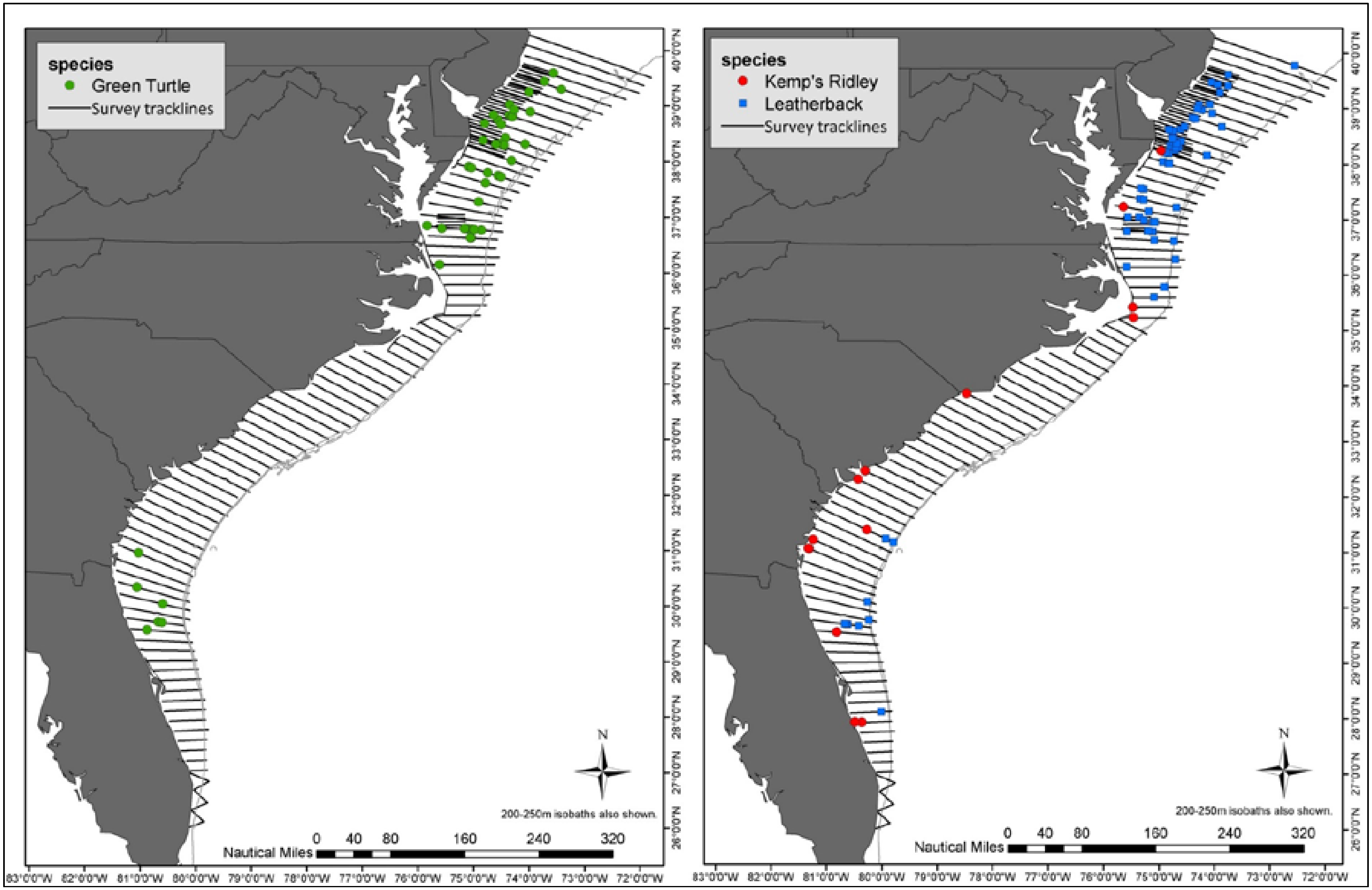


Figure C4. Dolphin sightings during SE AMAPPS aerial survey summer 2016.

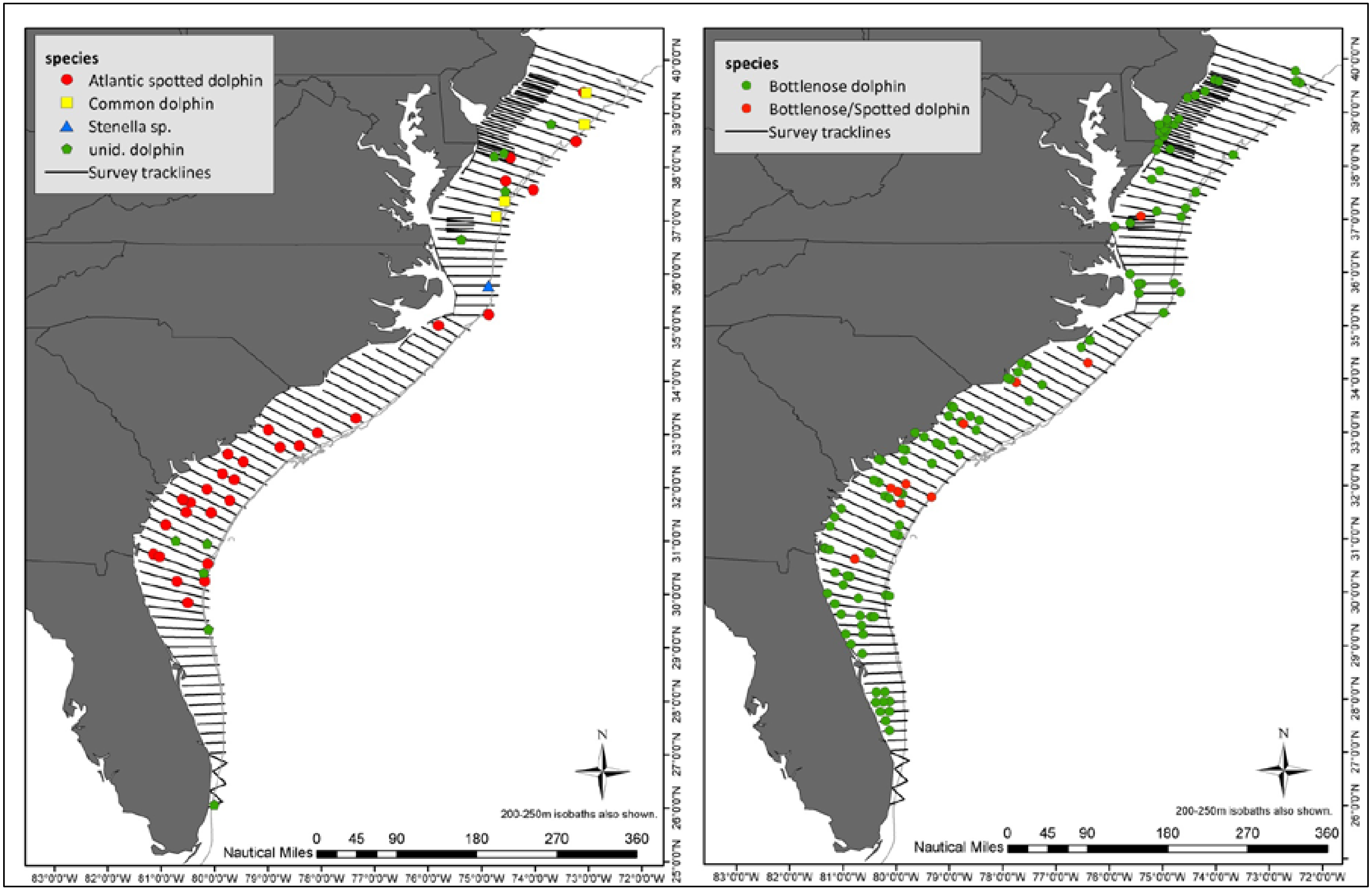


Figure C5. Other delphinids and beaked whale sightings during SE AMAPPS aerial survey summer 2016.

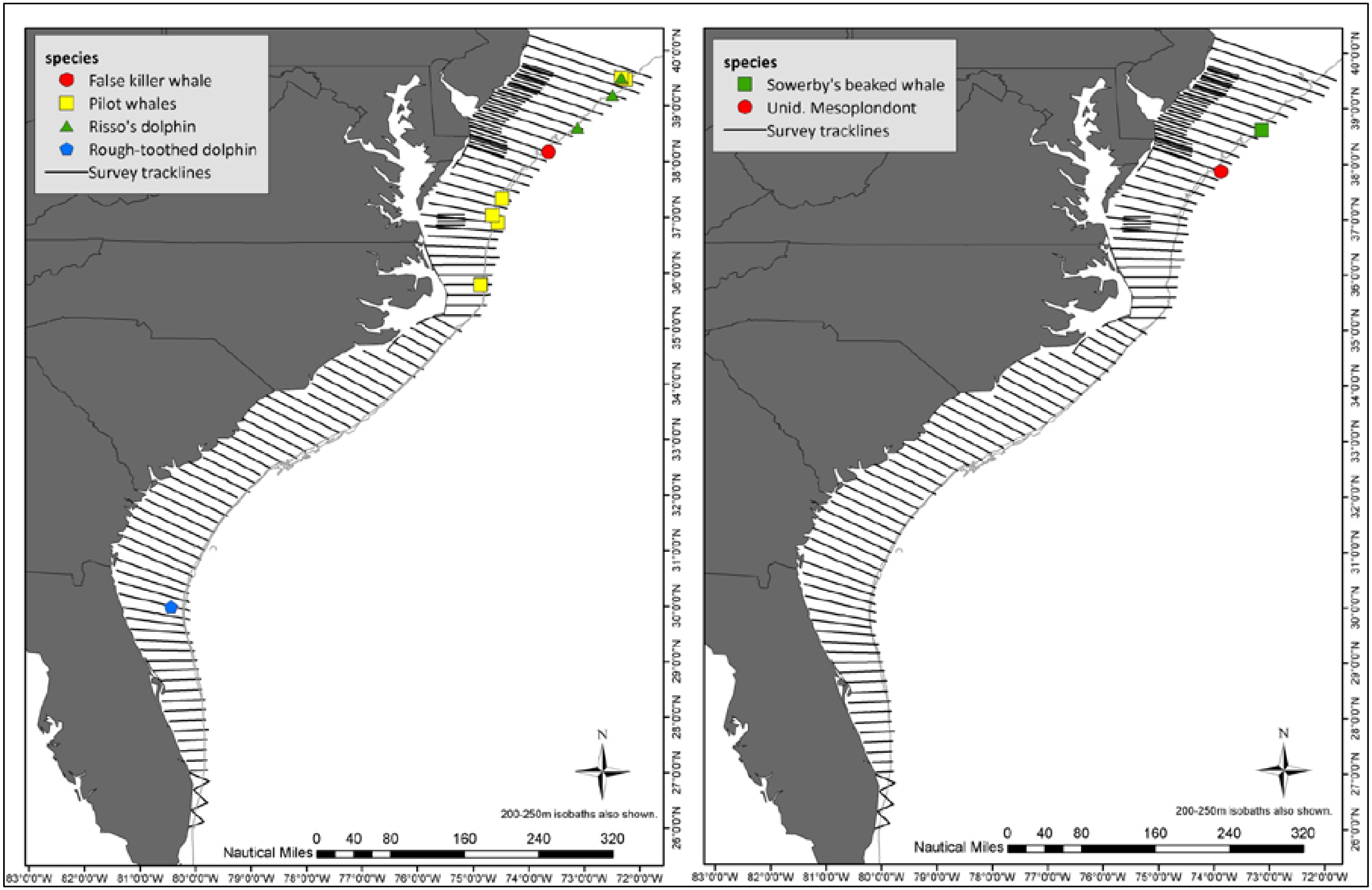


Figure C6. Large whale sightings during SE AMAPPS aerial survey summer 2016.

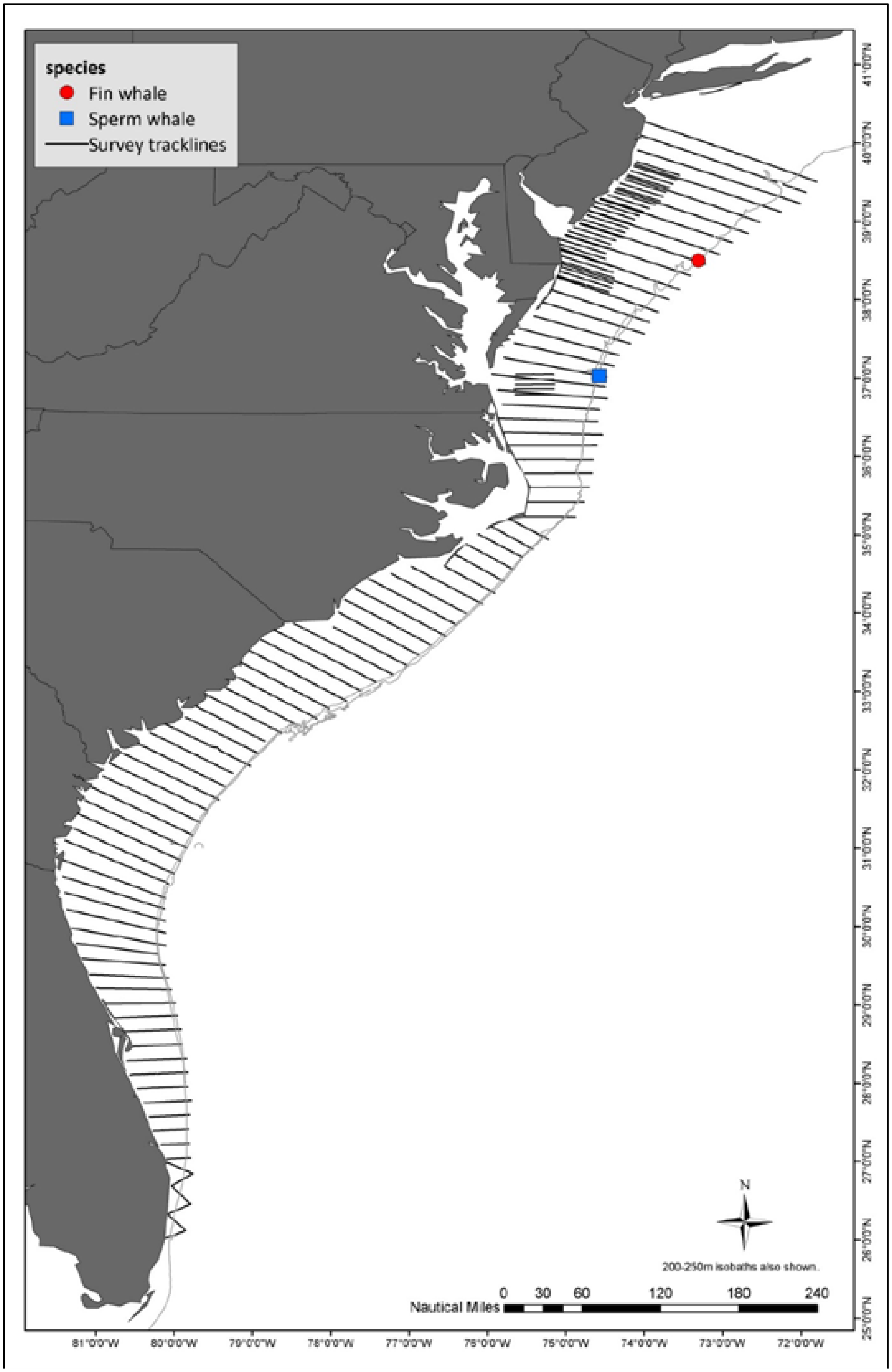


Figure C7. Fish sightings during SE AMAPPS aerial survey summer 2016.

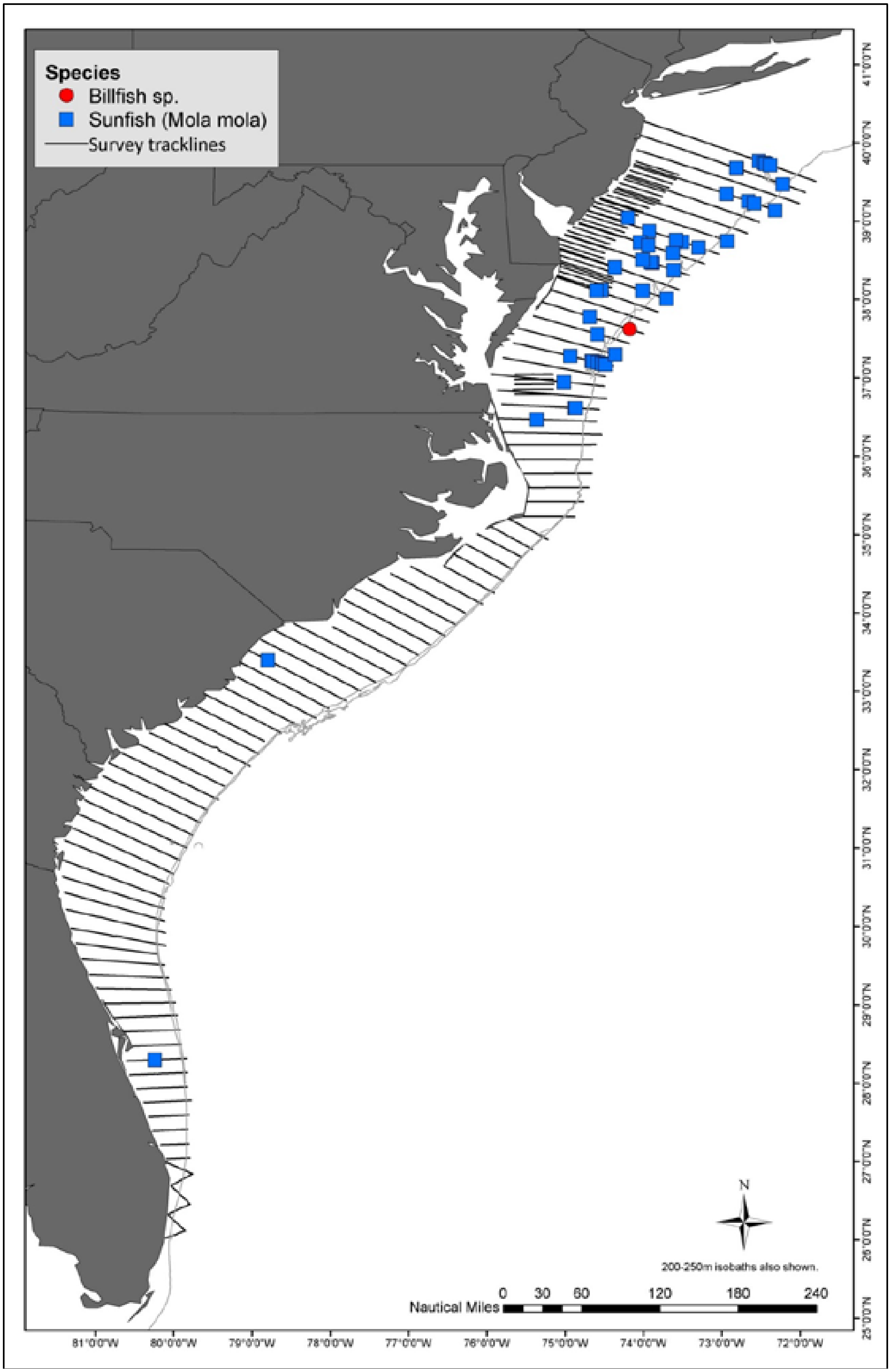


Figure C8. Shark and ray sightings during SE AMAPPS aerial survey summer 2016.

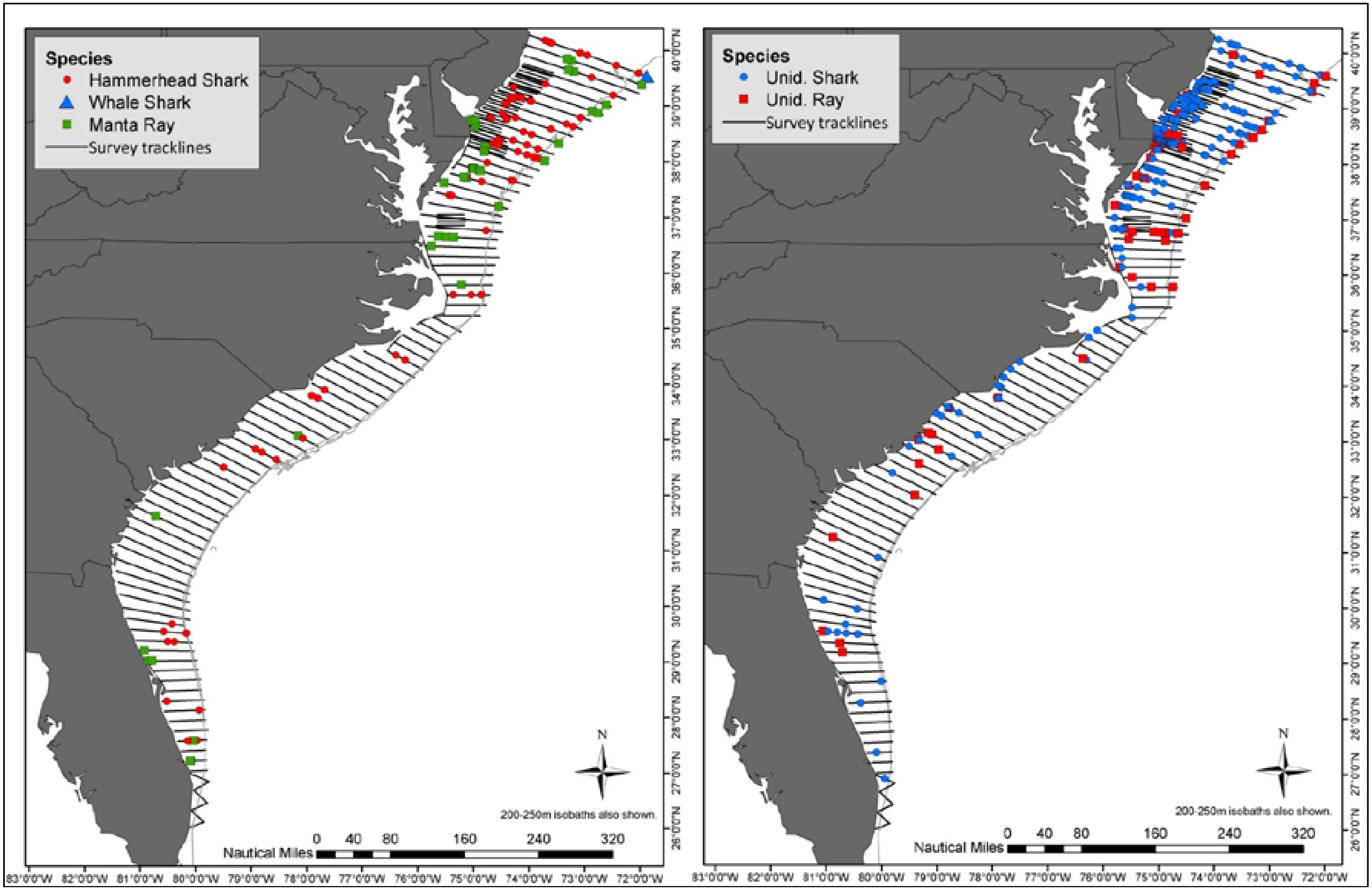


Figure C9. Effort track lines, renewable energy areas and sea state during SE AMAPPS aerial survey fall 2016.

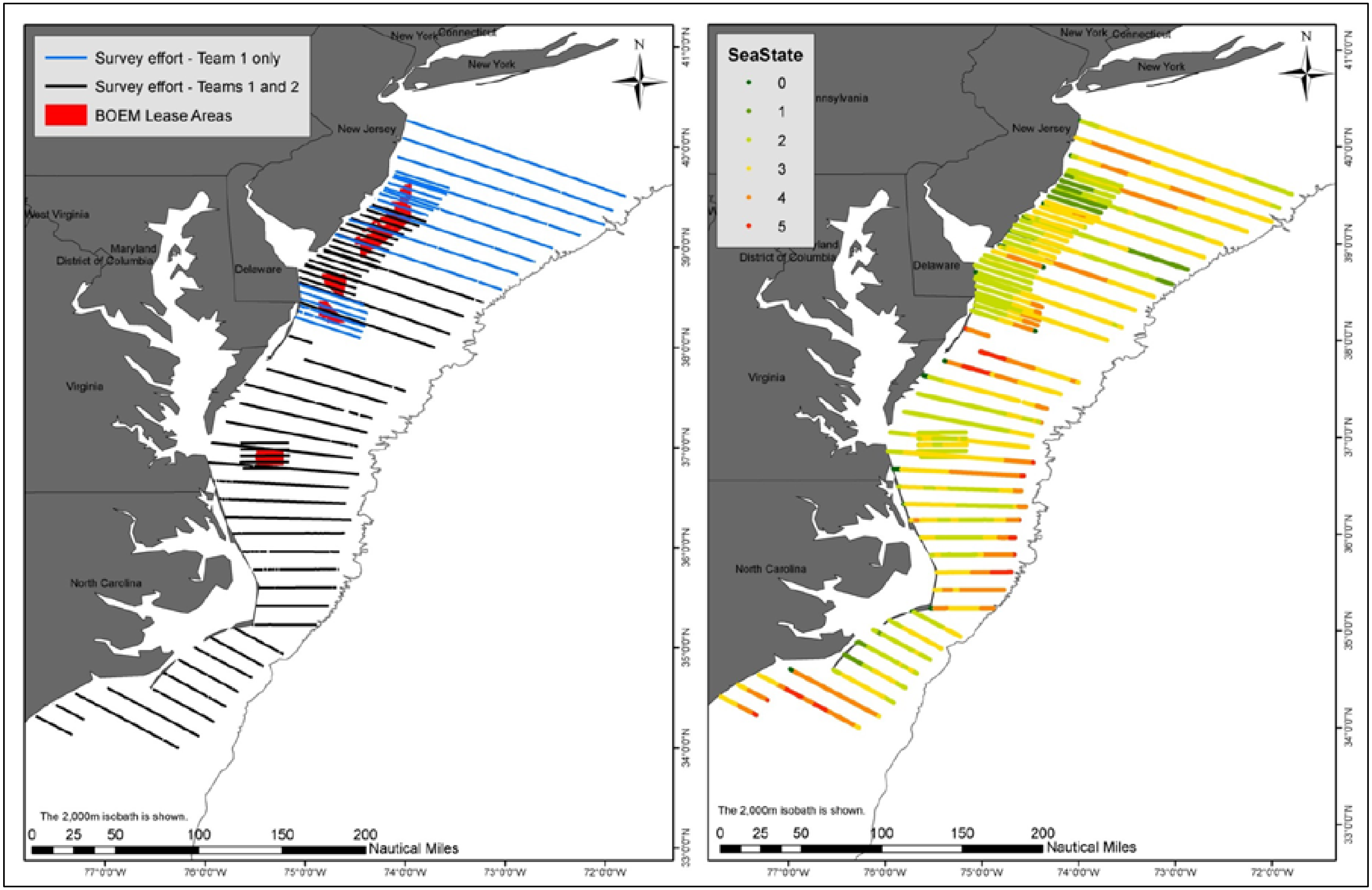


Figure C10. Turtle sightings during SE AMAPPS aerial survey fall 2016.

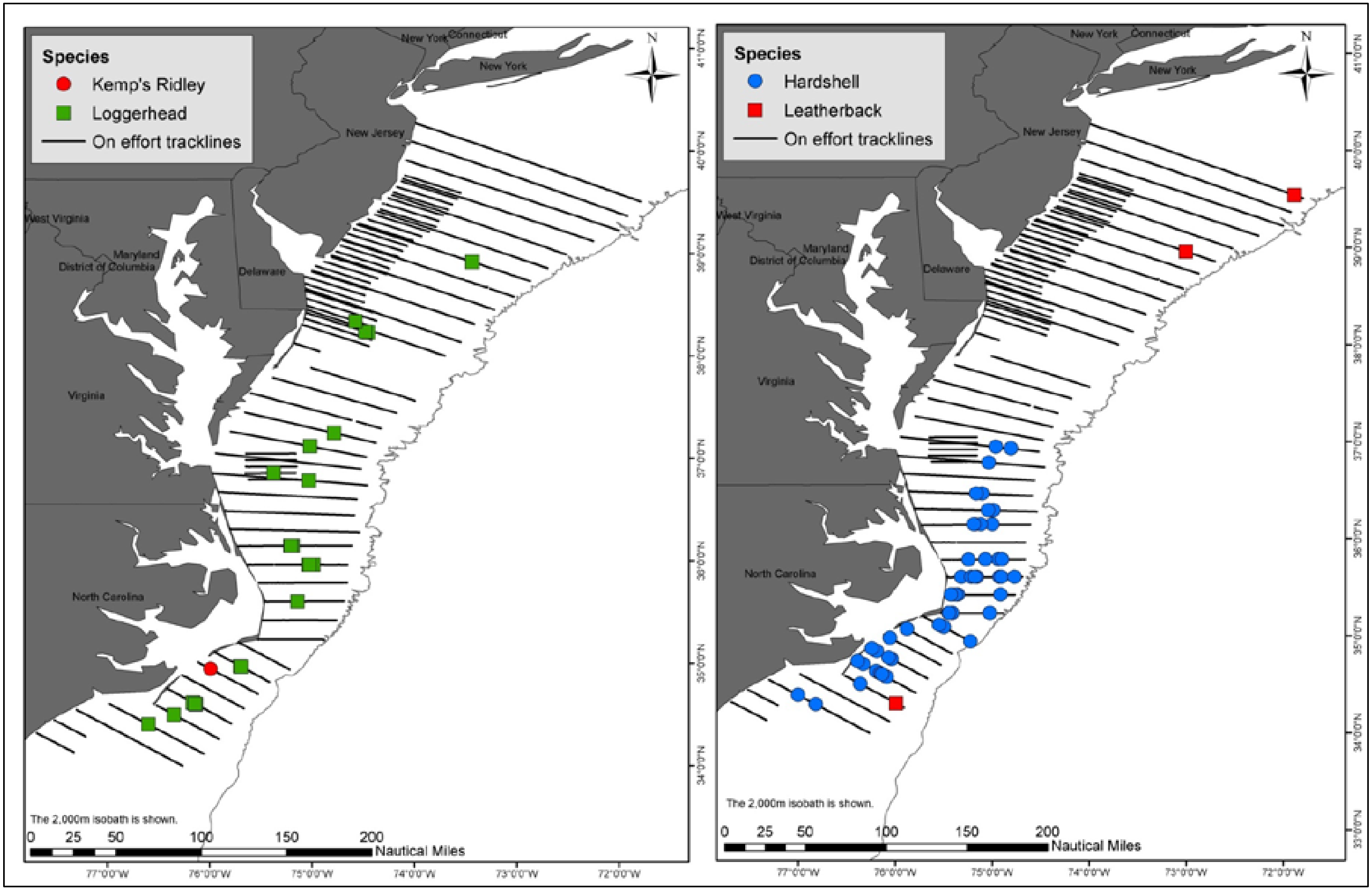


Figure C11. Delphinid sightings during SE AMAPPS aerial survey fall 2016.

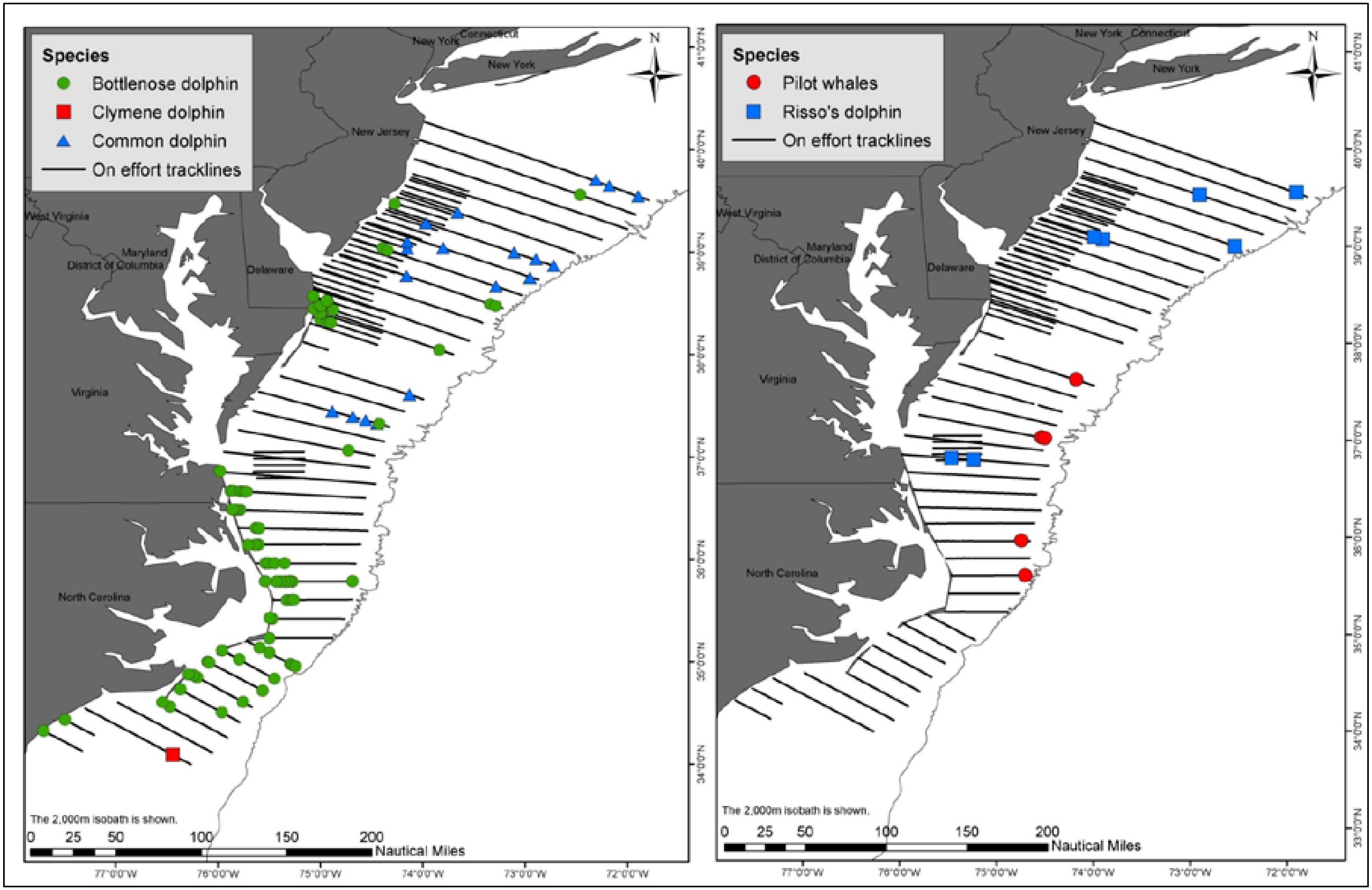


Figure C12. Unidentified cetaceans and baleen whale sightings during SE AMAPPS aerial survey fall 2016.

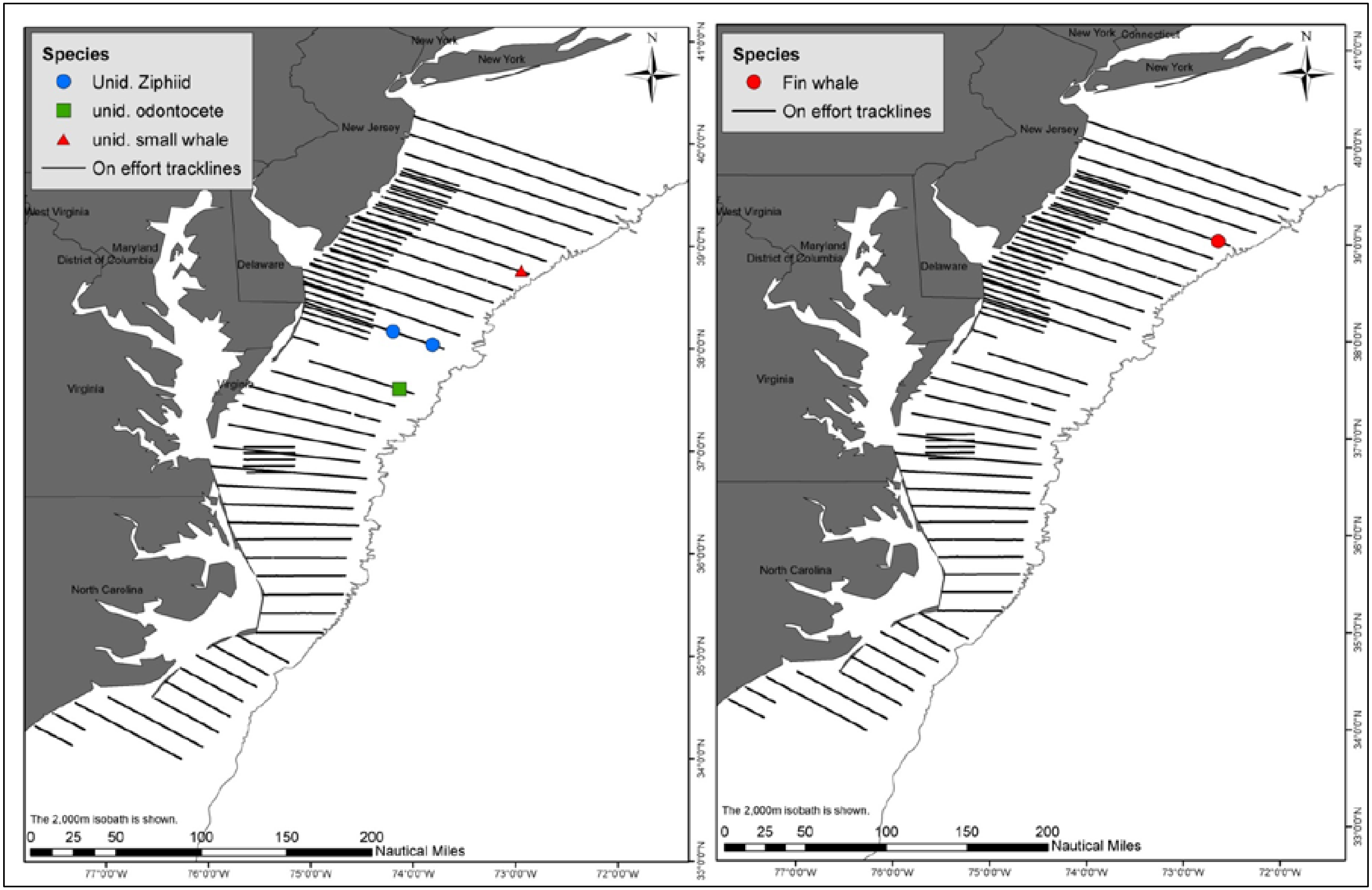
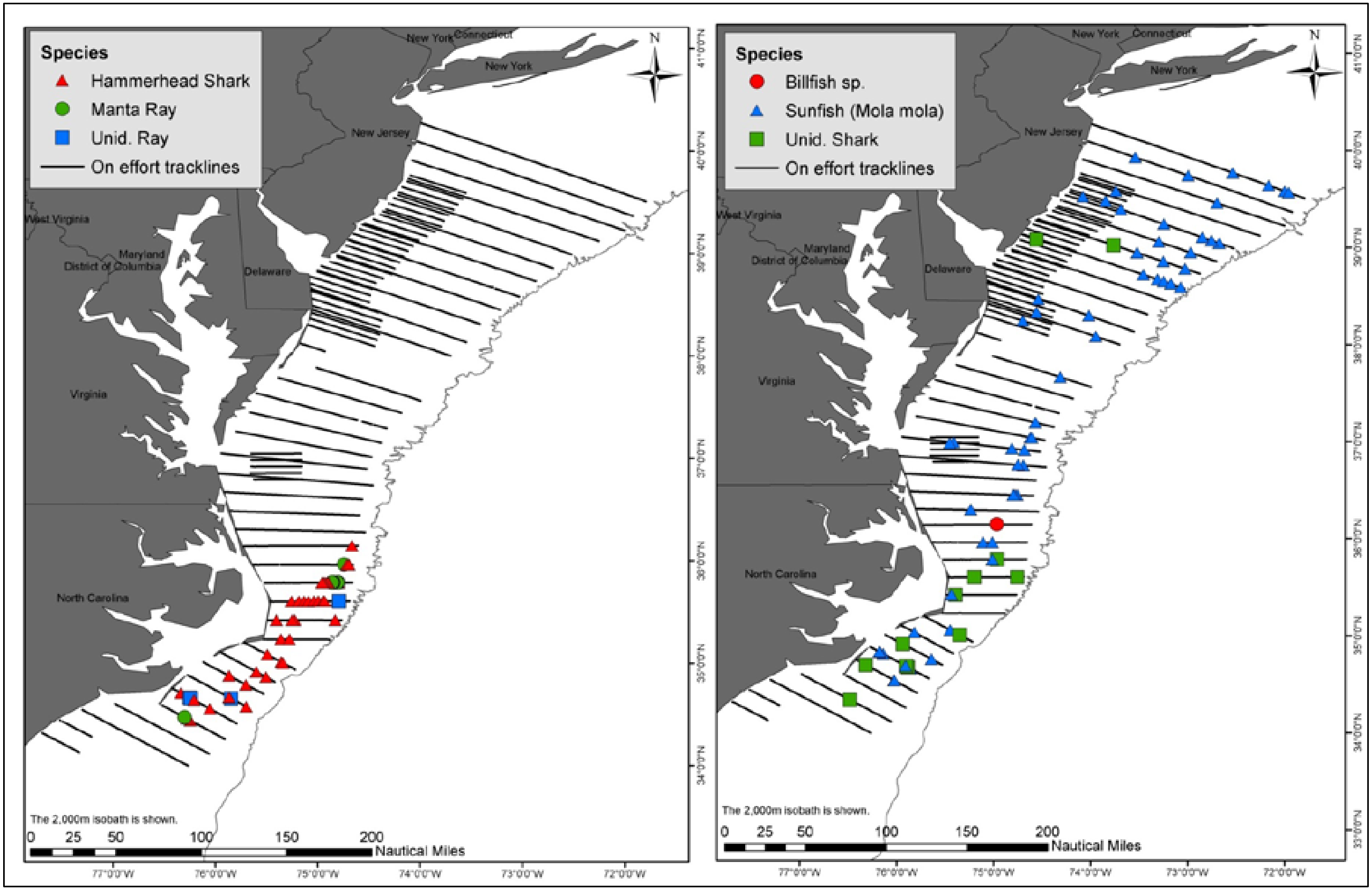


Figure C13. Opportunistic fish sightings during SE AMAPPS aerial survey fall 2016.



Appendix D: *Northern leg of aerial abundance survey during the summer (14 August – 28 September 2016) and fall (14 October – 17 November): Northeast Fisheries Science Center*

Debra L. Palka
Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543

SUMMARY

During 14 August 2016 – 28 September 2016 and 15 October – 18 November 2016, the Northeast Fisheries Science Center (NEFSC) conducted aerial abundance surveys targeting marine mammals and sea turtles. The southwestern extent was New Jersey and the northeastern extent was the southern tip of Nova Scotia, Canada. This survey covered waters from the coast line to about the 100 m depth contour (summer) or the 2000 m depth contour (fall). The summer survey coordinated with another aerial survey south of this study area in US waters and north of this area in Canadian waters, along with shipboard surveys which covered waters deeper than 100 m. The fall survey coordinated only with another US southern aerial survey. During both surveys track lines were flown 183 m (600 ft) above the water surface, at about 200 kph (110 knots), and the two-independent team methodology was used to collect data. In Beaufort sea states of five and less, during the summer about 11,782 km of on-effort track lines were accomplished, where 95% of this effort was in Beaufort 3 and below. Due to the fall survey about 6989 km of on-effort track lines were accomplished. The front team detected 5,415 individual cetaceans from 352 groups during the summer and 3,193 individual cetaceans from 308 groups during the fall. The back team detected 1,919 individual cetaceans from 210 groups during the summer and 1,453 individuals from 211 groups in the fall. This was from 16 species or species groups. During both surveys, common dolphins (*Delphinus delphis*) were the most frequently detected species, where the most common large whales were humpback whales (*Megaptera novaeangliae*). Over 400 turtles from 4 species and 1 species group were detected during the summer, where most were loggerhead turtles (*Caretta caretta*). In contrast, during the fall less than 20 individual turtles were detected, where half of those were leatherback turtles (*Dermochelys coriacea*) In addition, seals, basking sharks (*Cetorhinus maximus*), ocean sunfish *(Mola mola*) and a variety of other sharks were also detected, where the magnitude during the summer was substantially larger than that seen during the fall.

OBJECTIVES

The objectives of these aerial flights were to collect the data needed to estimate abundance of cetaceans and turtles in the study area and to investigate how the animal's distribution and abundance relate to their physical and biological ecosystem.

CRUISE PERIOD AND AREA

The surveys were conducted during 14 August 2016 – 28 September 2016 and 15 October – 18 November 2016, where the first and last days of each time period were transit days for the relocation of the aircraft. The study area of both time periods extended from New Jersey to the southern tip of Nova Scotia, Canada. The summer aerial survey covered waters from the coast line to about the 100 m depth contour (Figure D1) while the summer shipboard survey covered waters farther offshore (Appendix A). The fall aerial survey covered waters from the coast line to about the 2000 m depth contour (Figure D2).

The proposed track lines cover the entire region using a broad scale strategy providing an overall spatial coverage. In addition the New York State Offshore Planning Area (http://www.dos.ny.gov/opd/programs/offshoreResources/) was surveyed at a higher coverage level.

METHODS

Both surveys were conducted on a DeHavilland Twin Otter DHC-6 aircraft covering track lines at an altitude of 183 m (600 ft) above the water surface, at about 200 kph (110 knots), when Beaufort sea state conditions were six and below, and when there was at least two miles of visibility. Though the aim was to survey in sea state conditions of four or less.

When a cetacean, seal, turtle, sunfish, or basking shark was observed the following data were collected:

- Time animal passed perpendicular to the observer;
- Species identification;
- Species identification confidence level (certain, probable, not sure);
- Best estimate of the group size;
- Angle of declination between the track line and location of the animal group when it passed abeam (measured to the nearest one degree by inclinometers or marks on the windows, where 0º is straight down);
- Cue (animal, splash, blow, footprint, birds, vessel/gear, windrows, disturbance, or other);
- Swim direction (0º indicates animal was swimming parallel to the track line in the same direction the plane was flying, 90º indicates animal was swimming perpendicular to the track line and towards the right, etc.);
- If the animal appeared to react to the plane (yes or no);
- If a turtle was initially detected above or below the surface, and;
- Comments, if any.

Other fish species were also recorded opportunistically. All species identifications were recorded to the lowest taxonomic level possible.

At the beginning of each leg, and when conditions changed the following effort data were collected:

- Initials of person in the pilot seats and observation stations;
- Beaufort sea state (recorded to one decimal place);
- Water turbidity (clear, moderately clear, turbid very turbid, and unknown);
- Percent cloud cover (0-100%);
- Angle glare swath started and ended at (0-359º), where 0º was the track line in the direction of flight and 90º was directly abeam to the right side of the track line;
- Magnitude of glare (none, slight, moderate, and excessive); and
- Subjective overall quality of viewing conditions (excellent, good, moderate, fair, and poor).

In addition, the location of the plane was recorded every two seconds with a GPS that was attached to the data entry program. Sightings and effort data were collected by a computer program called VOR.exe, version 8.75 originally created by Phil Lovell and Lex Hiby.

To correct for perception bias, data were collected to estimate the parameter *g(0)*, the probability of detecting a group on the track line. This was accomplished by using the two independent team data collection method (Laake and Borchers 2004). In addition, the approximate area that a species can be detected was determined, when possible by the front team. This was accomplished by recording the time a group was initially seen and then also collected the time and angle of declination of that same group when it was perpendicular to the observers position. The initial time a group was seen was identified in the sightings data by a species identification of “FRST”.

Onboard, in addition to two pilots, were six scientists who were divided into two teams. One team, the primary forward team, consisted of a recorder and two observers viewing through the two forward large right and left bubble windows. The other team, the independent back team, consisted of one observer viewing through a back belly window, one observer viewing from the right back large visa window, and a recorder. The two teams operated on independent intercom channels so that they were not able to cue one another to sightings.

The belly window observer was limited to approximately a 30º view on both sides of the track line. The observers viewing from the front two bubble windows and the back side visa window searched from straight down to the horizon, with a concentration on waters between straight down (0º) and about 50º up from straight down.

When at the end of track lines or about every 30 – 40 minutes, scientists rotated between the observations positions. When both teams could not identify the species of a group that was within about 60º of the track line and there was a high chance that the group could be relocated or the species was thought to have been a right whale then sighting effort was broke off, and the plane returned to the group to confirm the species identification and group size. The marine mammal and turtle data were reviewed after the flights to identify duplicate sightings that were made by the two teams based upon time, location, and position relative to the track line.

RESULTS

The observers and pilots that participated during both surveys are listed in Table D1.

During the summer, 17 of the 44 possible flight days had sufficiently good weather to conduct the survey. There were about 11,782 km of “on-effort” track lines, where 95% of the track lines were surveyed in Beaufort 3 and less (Table D2).

During the fall, 11 of the 41 possible flight days had sufficiently good weather to fly. There were about 6,989 km of “on-effort” track lines, where 83% of the track lines were surveyed in Beaufort 3 and less (Table D2).

During the summer survey while on the on-effort portions of the track lines, 1919 and 5415 individual cetaceans within 210 and 352 groups were detected by the back and front teams, respectively (Table D3). The locations of sightings seen on the on-effort transect legs, by species, are displayed in Figures D3 – D10, where dolphins are in Figures D3 – D5, whales in Figure D6, turtles in Figure D7 and other species are in Figures D7 – D10. The sightings included nine species of identifiable cetaceans: common bottlenose dolphins (*Tursiops truncatus*; Figure D3), common dolphins (*Delphinus delphis*; Figure D3), striped dolphins (*Stenella coeruleoalba*; Figure D5), Risso’s dolphins (*Grampus griseus*; Figure D4), white-sided dolphins (*Lagenorhynchus acutus*; Figure D3), harbor porpoise (*Phocoena phocoena*; Figure D4), fin whales (*Balaenoptera physalus*; Figure D6), humpback whales (*Megaptera novaeangliae*; Figure D5), pilot whales (*Globicephaia* spp; Figure D5), sperm whales (*Physeter microcephalus*; Figure D5), minke whales (*B. acutorostrata*; Figure D4) and an unidentified beaked whale (*Ziphiidae*). Over 400 sea turtles were detected (Figure D7), where most were loggerhead turtles and unidentified hardshell turtles, and a handful of leatherback turtles (*Dermochelys coriacea*), Kemp's ridley turtles (*Lepidochelys kempii*) and green turtles (*Chelonia mydas*). In addition, about 130 unidentified seals were seen mostly off the coast of Maine (Figure D6). Six species of sharks were identified (basking sharks (*Cetorhinus maximus*; Figure D7), blue sharks (*Prionace glauca*; Figure D8), great white sharks (*Carcharodon carcharias*; Figure D10), hammerhead sharks (*Sphyrnidae spp*; Figure D8), thresher sharks (*Alopias macrourus*; Figure D10), tiger sharks (*Galeocerdo cuvier*; Figure D10), along with many other unidentified sharks (Figure D10). Ocean sunfish (*Mola mola*; Figure D9) and rays (Figure D9) were also identified.

During the summer survey common dolphins were the most commonly detected species, where most were on Georges Bank. Other species like harbor porpoises and seals were mostly detected close to the Maine shoreline. The front team detected only 17 groups of white-sided dolphins but there were in total about 720 animals. The most common large whales were humpback whales (mostly on Georges Bank) and minke whales (spread out throughout the entire survey area). The turtles were mostly south of Long Island in the New York study area. The numbers of sharks detected this survey were larger than in previous years. The basking and blue sharks were mostly offshore in the Gulf of Maine, while the hammerhead sharks were mostly south of Long Island, and species like the ocean sunfish were commonly found in both areas.

During the fall survey while on the on-effort portions of the track lines, 1453 and 3193 individual cetaceans within 211 and 308 groups were detected by the back and front teams, respectively (Table D5). The locations of sightings seen on the on-effort transect legs, by species, are displayed in Figures D11 – D10, where dolphins are in Figures D11 and D12, whales in Figure D13, turtles and seals in Figure D14 and other species are in Figure D15. The sightings included 11 species of identifiable cetaceans: common bottlenose dolphins (*Tursiops truncatus*; Figure D11), common dolphins (*Delphinus delphis*; Figure D), Risso's dolphins (*Grampus griseus*; Figure D12), white-sided dolphins (*Lagenorhynchus acutus*; Figure D12), harbor porpoise (*Phocoena phocoena*; Figure D11), fin whales (*Balaenoptera physalus*; Figure D13), humpback whales (*Megaptera novaeangliae*; Figure D13), pilot whales (*Globicephaia* spp; Figure D12), right whales (*Eubalaena glacialis*; Figure D13), Sowerby's beaked whales (*Mesoplodon bidens*), and sperm whales (*Physeter microcephalus*; Figure D13). The detected Sowerby's beaked whale was near the 2000 m depth contour south of Rhode Island in the New York Planning Area and it was only detected by the back team. Only 15 and 7 sea turtles were detected by the back and front teams, respectively (Figure D14), where most were leatherback turtles (*Dermochelys coriacea*). In addition, over 260 seals were seen mostly off the coast of Maine (Figure D14). Three species of sharks were identified (basking sharks (*Cetorhinus maximus*; Figure D15), and blue sharks (*Prionace glauca*; Figure D15). Ocean sunfish (*Mola mola*; Figure D15) and manta rays (Figure D15) were also identified.

During the fall survey common and white-sided dolphins were the most commonly detected species. Common dolphins were most on Georges Bank, while the white-sided dolphins were mostly on the borders of Georges Bank and also slightly farther north in the central Gulf of Maine. Other species like harbor porpoises and seals were mostly detected close to the Maine shoreline, as was seen during the summer survey. The most commonly detected large whale were humpback whales (mostly on Georges Bank). The turtles were mostly in Long Island Sound and south of Long Island in the New York study area, though the magnitude seen in the fall was substantially less than seen in the summer. The numbers of sharks detected during the fall survey were substantially lower than seen during the summer. The basking and ocean sunfish were mostly still offshore in the Gulf of Maine as seen in the summer.

DISPOSITION OF DATA

All data collected during these surveys will be maintained by the Protected Species Branch at NEFSC in Woods Hole, MA and are available from the NEFSC's Oracle database. The line transect data will also be available on OBIS-SEAMAP.

PERMITS

NEFSC was authorized to conduct these research activities during this survey under US Permit No. 17355 issued to the NEFSC by the NMFS Office of Protected Resources. The NOAA aircraft was granted diplomatic overflight clearance in Canadian airspace with the Overflight Clearance number 0790-US-2014-12 for the summer survey and 0669-US-2016-010 for the fall survey. The Species at Risk Management Division of the Canadian Fisheries and Oceans concluded a permit under SARA was not needed.

ACKNOWLEDGEMENTS

Funds for this project came from the Bureau of Ocean Energy Management (BOEM) and the US Navy through the respective Interagency Agreements for the AMAPPS project. Flight time and other aircraft costs were funded by NOAA Aircraft Operations Center (AOC). Staff time was also provided by the NOAA Fisheries Service, NEFSC and NOAA AOC. We would like to thank the pilots and observers involved in collecting these data for their efforts and dedication to this project.

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Laake JL, Borchers DL. 2004. Methods for incomplete detection at distance zero, In: Advanced distance sampling, edited by S. T. Buckland, D. R. Andersen, K. P. Burnham, J. L. Laake, and L. Thomas, pp. 108–189, Oxford University Press, New York.

Table D1. List of observers and pilots, along with their affiliations, that participated in the 2016 Northeast AMAPPS aerial surveys.

Name	Affiliation
SUMMER OBSERVERS	
Leah Crowe	Integrated Statistics, Inc, Woods Hole, MA
Robert DiGiovanni	Integrated Statistics, Inc, Woods Hole, MA
Rachel Hardee	Integrated Statistics, Inc, Woods Hole, MA
Richard Holt	Integrated Statistics, Inc, Woods Hole, MA
Val Sherlock	Integrated Statistics, Inc, Woods Hole, MA
Allison Henry	Northeast Fisheries Science Center, Woods Hole, MA
Christin Khan	Northeast Fisheries Science Center, Woods Hole, MA
Debra Palka	Northeast Fisheries Science Center, Woods Hole, MA
Peter Duley	Northeast Fisheries Science Center, Woods Hole, MA
Tim Cole	Northeast Fisheries Science Center, Woods Hole, MA
SUMMER PILOTS	
Bill Carrier	NOAA Aircraft Operations Center, Tampa, FL
Jacob Blaauboer	NOAA Aircraft Operations Center, Tampa, FL
Chris Kerns	NOAA Aircraft Operations Center, Tampa, FL
David Cowan	NOAA Aircraft Operations Center, Tampa, FL
JC Clark	NOAA Aircraft Operations Center, Tampa, FL
FALL OBSERVERS	
Corey Accardo	Integrated Statistics, Inc, Woods Hole, MA
Robert DiGiovanni	Integrated Statistics, Inc, Woods Hole, MA
Rachel Hardee	Integrated Statistics, Inc, Woods Hole, MA
Richard Holt	Integrated Statistics, Inc, Woods Hole, MA
Nicholas Metheny	Integrated Statistics, Inc, Woods Hole, MA
Jennifer Gatke	Integrated Statistics, Inc, Woods Hole, MA
Debra Palka	Northeast Fisheries Science Center, Woods Hole, MA
FALL PILOTS	
Frank Centinello	NOAA Aircraft Operations Center, Tampa, FL
Shanae Coker	NOAA Aircraft Operations Center, Tampa, FL
Jason Clark	NOAA Aircraft Operations Center, Tampa, FL

Table D2. Length of on-effort track lines (in km) surveyed by Beaufort sea state during the summer and fall NE 2016 AMAPPS aerial surveys.

SUMMER	**Beaufort Sea State**						
	0	1	2	3	4	5	Total
Track length (km)	1466.0	4167.6	2943.1	2637.3	529.1	39.1	11,782.2
% of total	12.44	35.37	24.98	22.38	4.49	0.33	100

FALL	**Beaufort sea state**						
	0	1	2	3	4	5	Total
Track length (km)	2.8	374.1	2614.7	2843.7	970.8	182.8	6,988.9
% of total	0.04	5.35	37.41	40.69	13.89	2.62	100

Table D3. During the summer 2016 NE AMAPPS aerial survey, the number of groups and individuals of cetaceans detected on-effort by the front and back teams. Some of the groups seen by the back team were also seen by the front team.

		Number of Groups		Number of Individuals	
Species		**Back**	**Front**	**Back**	**Front**
Common bottlenose dolphin	*Tursiops truncatus*	16	23	63	276
Common dolphin	*Delphinus delphis*	32	68	751	2997
Common or white-sided dolphin	-	10	14	91	191
Striped dolphin	*Stenella coeruleoalba*	0	1	0	60
Risso's dolphin	*Grampus griseus*	10	16	111	147
White-sided dolphin	*Lagenorhynchus acutus*	7	17	384	719
Harbor porpoise	*Phocoena phocoena*	76	75	235	255
Fin whale	*Balaenoptera physalus*	4	12	4	15
Fin or sei whale	*B. physalus or B. borealis*	1	3	1	3
Humpback whale	*Megaptera novaeangliae*	7	25	7	29
Minke whale	*B. acutorostrata*	8	18	8	25
Pilot whale spp	*Globicephaia spp*	15	24	121	171
Sperm whale	*Physeter macrocephalus*	0	1	0	6
Unid beaked whale	*Ziphiidae*	1	0	1	0
Unid dolphin	*Delphinidae*	18	43	136	487
Unid large whale	*Mysticeti*	5	12	6	33
Total cetaceans		**210**	**352**	**1919**	**5414**

Table D4. During the summer 2016 NE AMAPPS aerial survey, the number of groups and individuals of other species detected on-effort by the front and back teams. Some of the groups seen by the back team were also seen by the front team.

Species		**Number of Groups**		**Number of Individuals**	
		Back	**Front**	**Back**	**Front**
Leatherback turtle	*Dermochelys coriacea*	7	13	7	13
Loggerhead turtle	*Caretta caretta*	196	313	202	319
Kemp's ridley turtle	*Lepidochelys kempii*	1	1	1	1
Green turtle	*Chelonia mydas*	4	2	4	2
Unid hardshell turtle	-	52	71	56	71
Basking shark	*Cetorhinus maximus*	65	93	69	107
Blue shark	*Prionace glauca*	279	222	332	243
Great white shark	*Carcharodon carcharias*	0	1	0	1
Hammerhead shark	*Sphyrnidae* spp.	49	55	92	93
Manta ray	*Cephalopterus manta*	48	57	63	75
Ocean sunfish	*Mola mola*	186	254	227	293
Thresher shark	*Alopias macrourus*	1	1	1	1
Tiger shark	*Galeocerdo cuvier*	3	1	3	1
Tuna	-	33	42	569	581
Unid shark	-	174	208	237	365
Whale shark	*Rhincodon typus*	4	1	4	1
Unid seal	*Pinnipedia*	67	64	139	127
Total all species		**1379**	**1751**	**3925**	**7708**

Table 5. During the fall 2016 NE AMAPPS aerial survey, the number of groups and individuals of cetaceans detected on-effort by the front and back teams. Some of the groups seen by the back team were also seen by the front team.

Species		**Number of Groups**		**Number of Individuals**	
		Back	**Front**	**Back**	**Front**
Common bottlenose dolphin	*Tursiops truncatus*	4	7	15	39
Common dolphin	*Delphinus delphis*	64	60	494	1031
Common or white-sided dolphin	-	2	24	7	255
Risso's dolphin	*Grampus griseus*	23	22	205	214
White-sided dolphin	*Lagenorhynchus acutus*	38	66	435	1089
Harbor porpoise	*Phocoena phocoena*	44	45	194	190
Fin whale	*Balaenoptera physalus*	4	7	5	7
Humpback whale	*Megaptera novaeangliae*	6	14	9	20
Pilot whale spp	*Globicephaia spp*	6	13	36	70
Right whale	*Eubalaena glacialis*	0	2	0	2
Sowerby's beaked whale	*Mesoplodon bidens*	1	0	1	0
Sperm whale	*Physeter macrocephalus*	0	1	0	1
Unid dolphin	*Delphinidae*	16	37	49	265
Unid large whale	*Mysticeti*	3	10	3	10
Total cetaceans		**211**	**308**	**1453**	**3193**

Table D6. During the fall 2016 NE AMAPPS aerial survey, the number of groups and individuals of other species detected on-effort by the front and back teams. Some of the groups seen by the back team were also seen by the front team.

Species		**Number of Groups**		**Number of Individuals**	
		Back	**Front**	**Back**	**Front**
Leatherback turtle	*Dermochelys coriacea*	7	2	7	2
Loggerhead turtle	*Caretta caretta*	4	3	4	3
Kemp's ridley turtle	*Lepidochelys kempii*	3	1	3	1
Unid hardshell turtle	-	1	1	1	1
Total turtles		**15**	**7**	**15**	**7**
Basking shark	*Cetorhinus maximus*	5	6	5	6
Blue shark	*Prionace glauca*	3	3	3	3
Hammerhead shark	*Sphyrnidae* spp.	3	0	3	0
Manta ray	*Cephalopterus manta*	3	2	3	2
Ocean sunfish	*Mola mola*	42	65	44	70
Tuna	-	1	0	1	0
Unid shark	-	3	3	3	3
Total fish		**60**	**79**	**62**	**84**
Gray seal	*Halichoerus grypus*	16	12	51	183
Harbor seal	*Phoca vitulina*	3	1	6	1
Unid seal	*Pinnipedia*	24	36	40	76
Total seals		**43**	**49**	**97**	**260**
Total all species		**329**	**443**	**1627**	**3544**

Figure D1. Completed on-effort track lines of summer (14 August 2016 – 28 September 2016) NE AMAPPS survey, by Beaufort sea state. The 100 m depth contours (blue lines), New York State Offshore Planning Area (gray shading) and the US exclusive economic zone (EEZ; black line) are also shown.

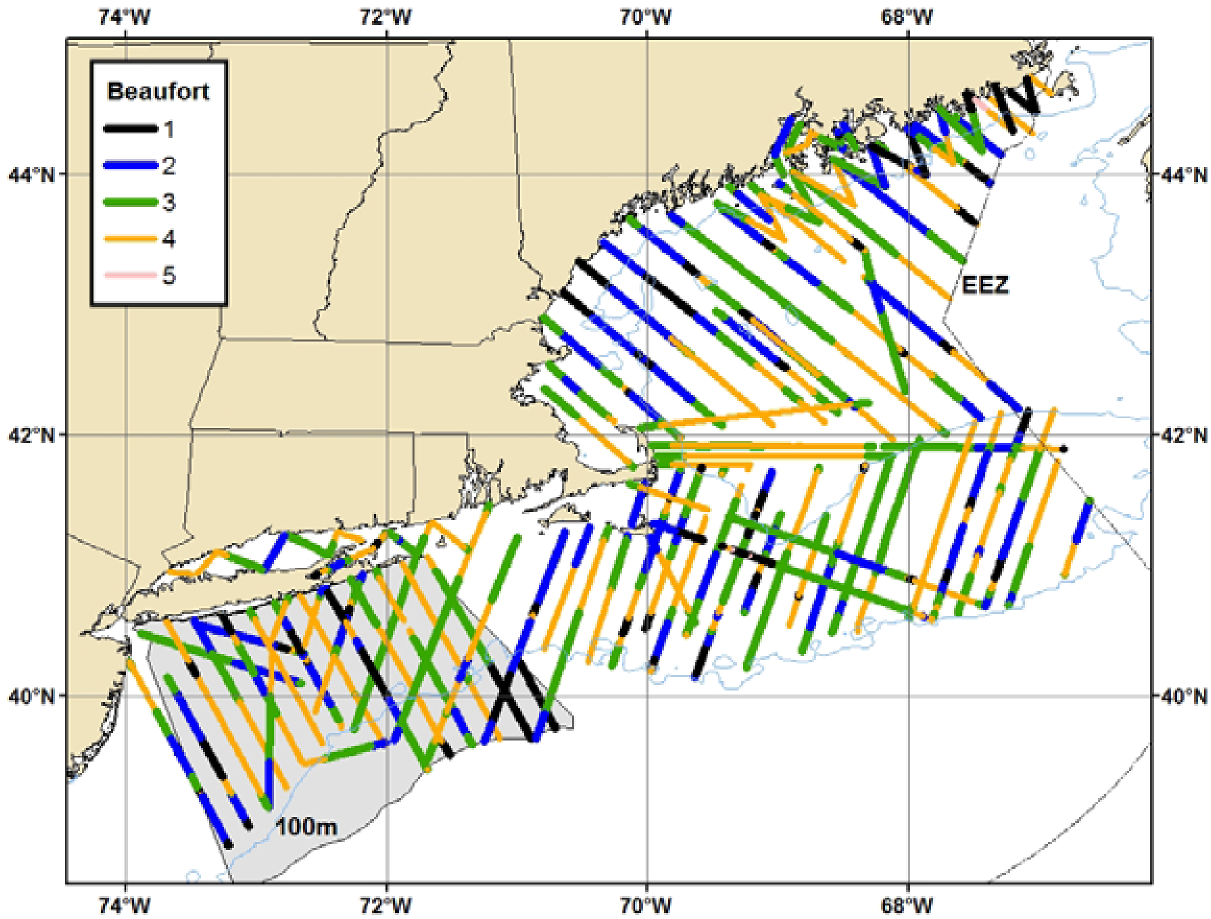


Figure D2. Completed on-effort track lines of fall (15 October 2016 – 18 November 2016) NE AMAPPS survey, by Beaufort sea state. The 100 m depth contours (blue lines), 2000 m depth contour (purple line), New York State Offshore Planning Area (blue shading) and the US exclusive economic zone (EEZ; gray line) are also shown.

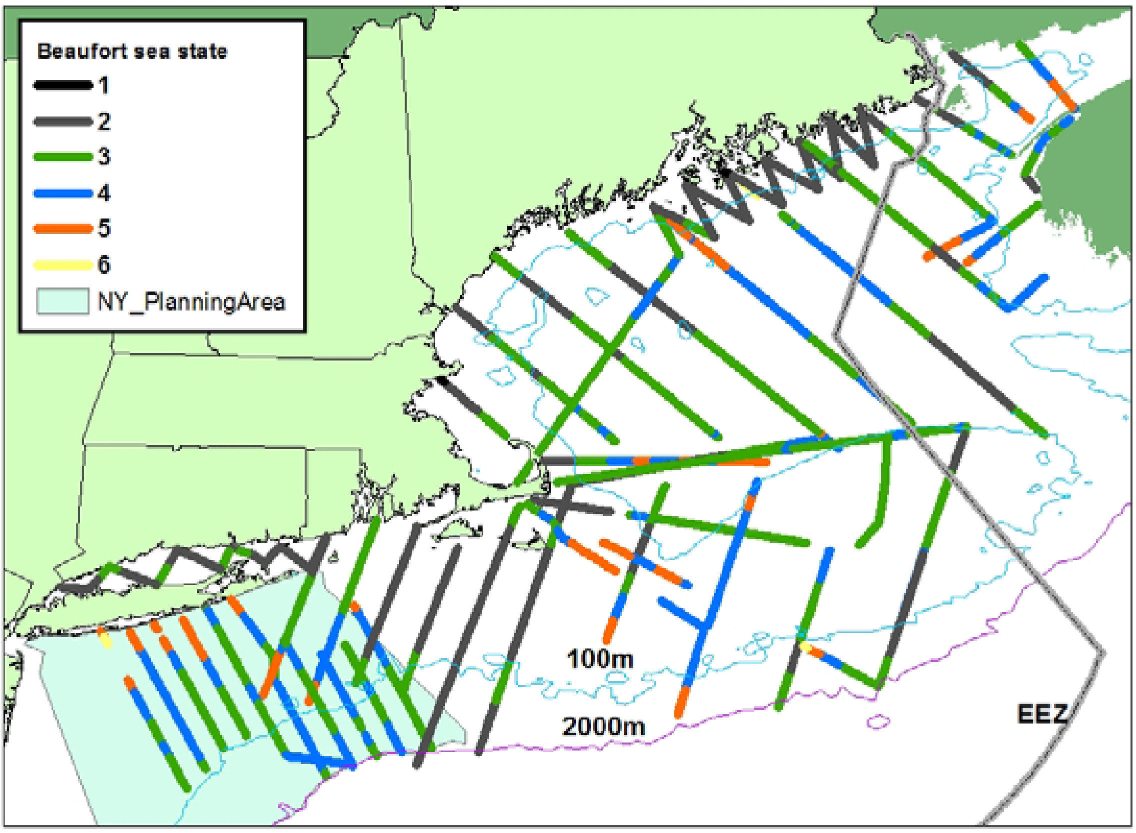
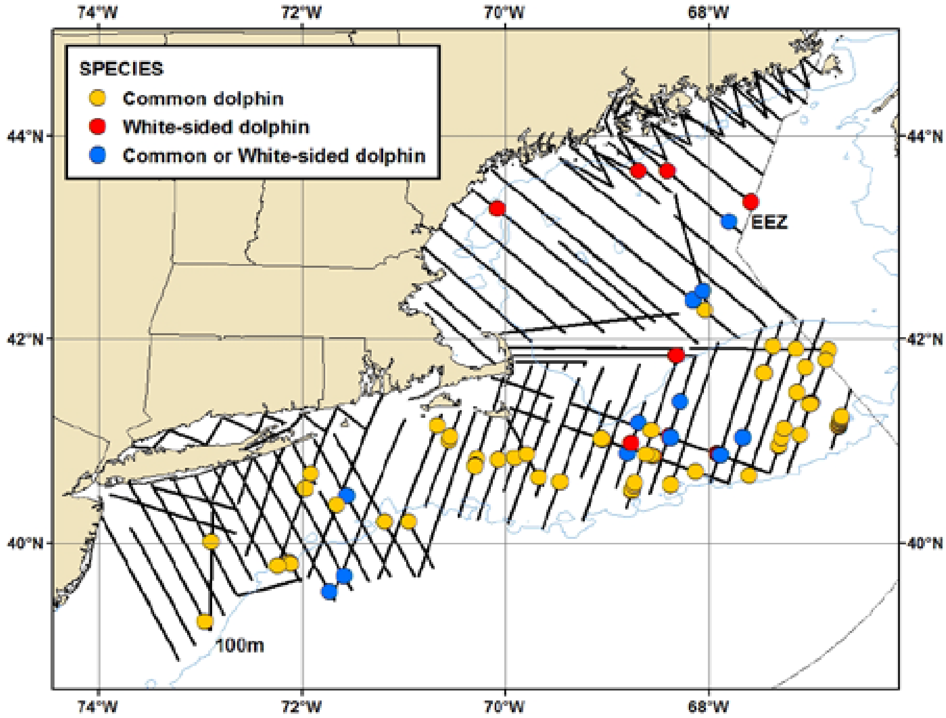


Figure D3. From NE AMAPPS 2016 summer survey, locations of common dolphins (*Delphinus delphis*; top), white-sided dolphins (*Lagenorhynchus acutus*; top) and bottlenose dolphins (*Tursiops tursiops*; bottom) detected by the front team.



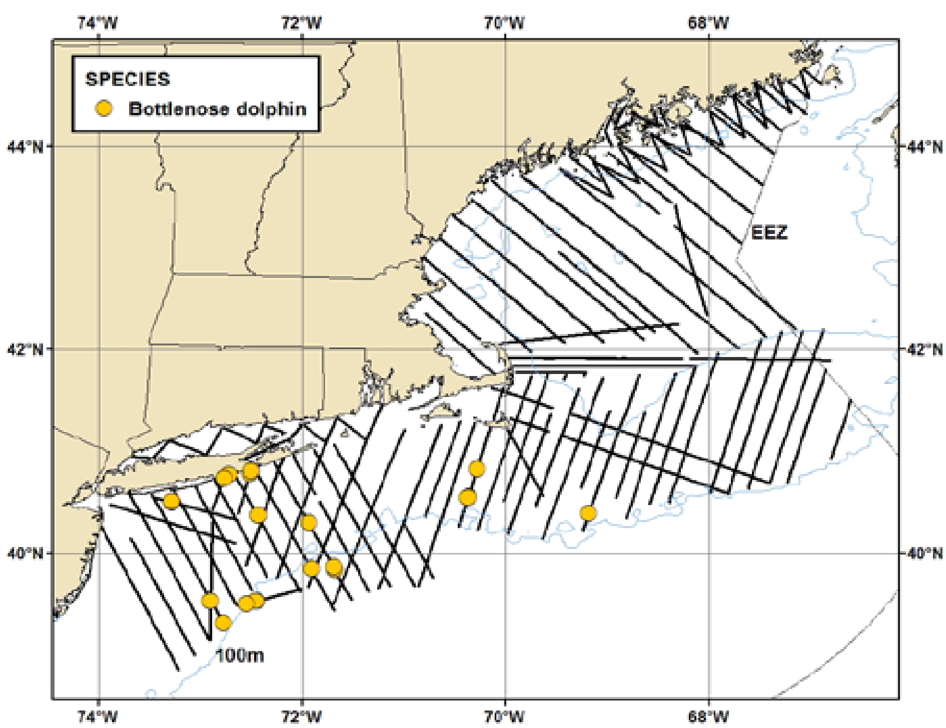
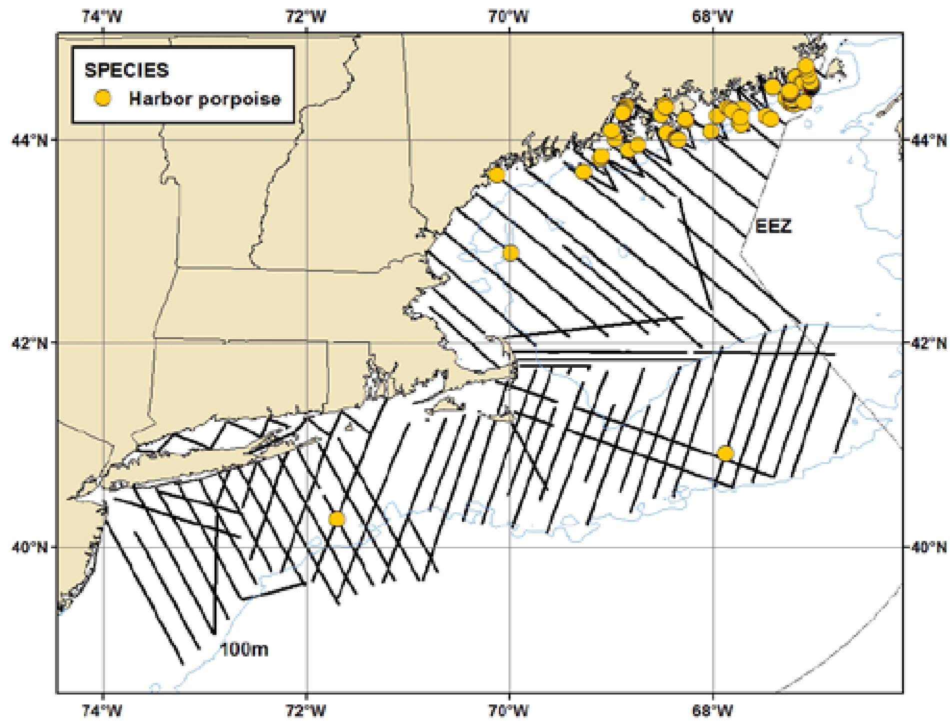


Figure D4. From NE AMAPPS 2016 summer survey, locations of harbor porpoises (*Phocoena phocoena*; top), Risso's dolphins (*Grampus griseus*; bottom) and minke whales (*Balaenoptera acutorostrata*; bottom) detected by the front team.



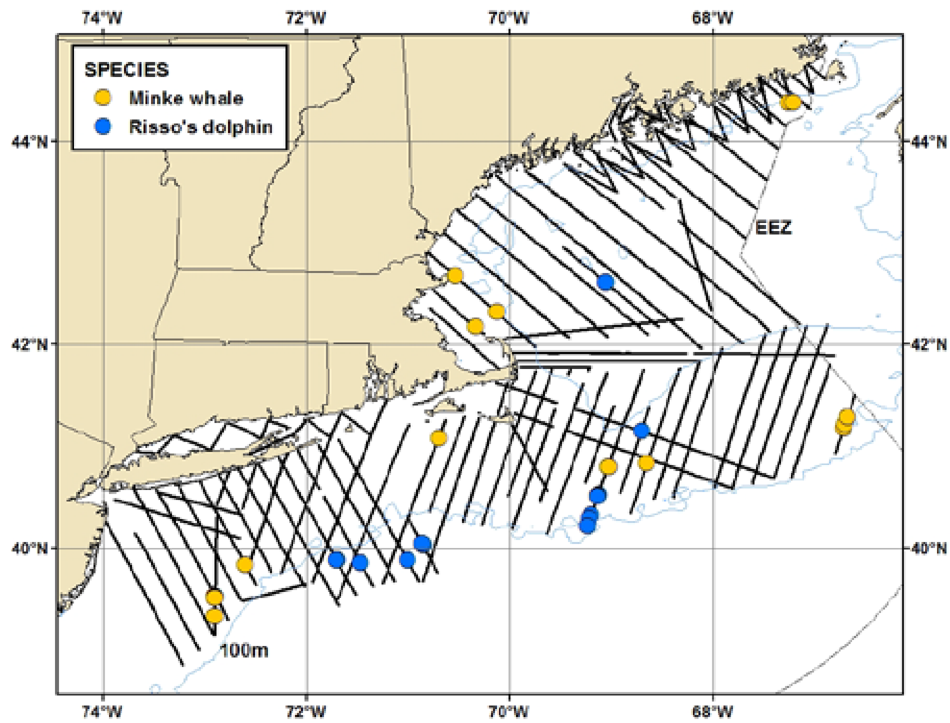


Figure D5. From NE AMAPPS 2016 summer survey, locations of striped dolphins (*Stenella coeruleoalba*; top), pilot whales (*Globicephaia* spp; top), sperm whales (*Physeter microcephalus*; top) and humpback whales (*Megaptera novaeangliae*; bottom) detected by the front team.

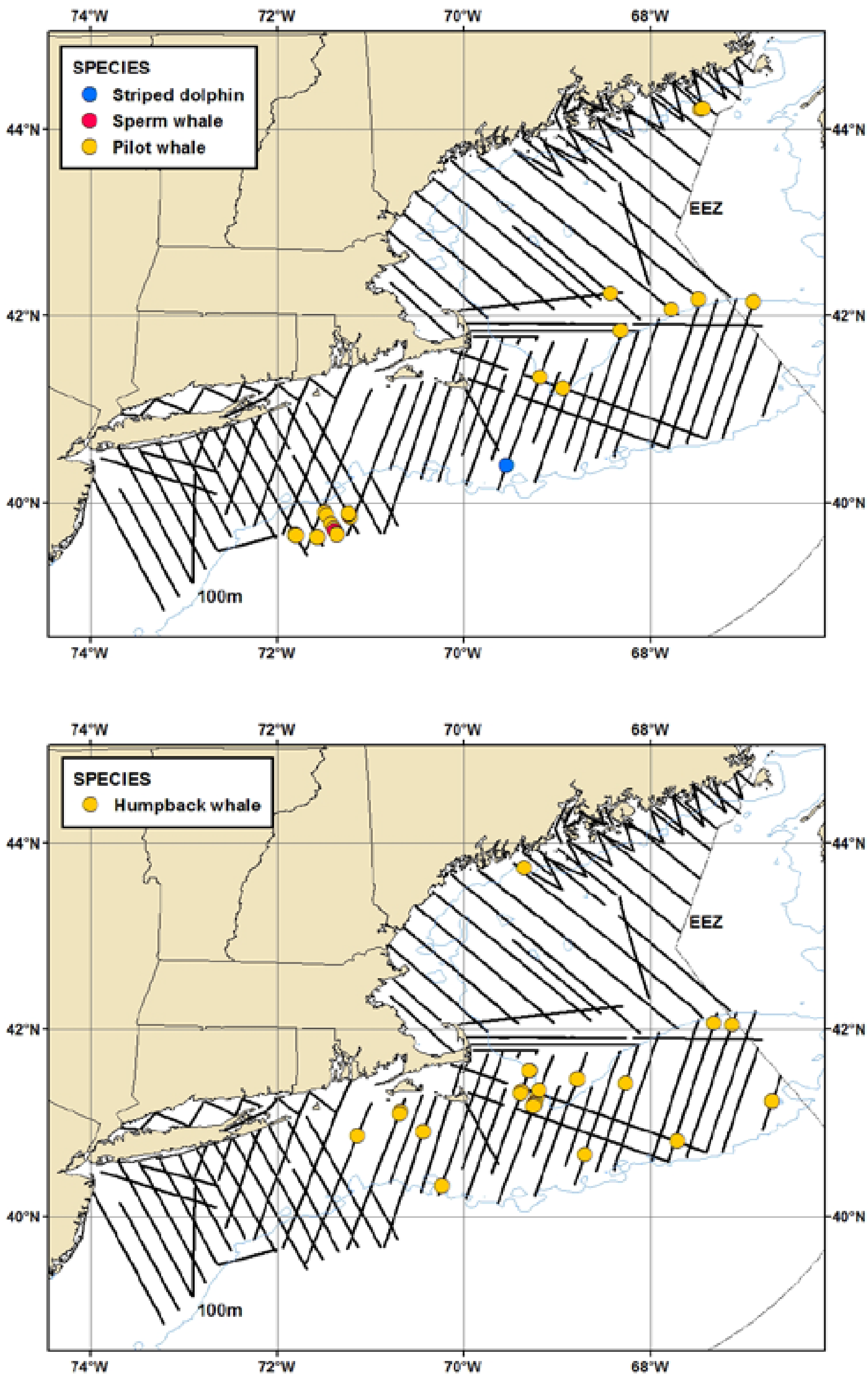
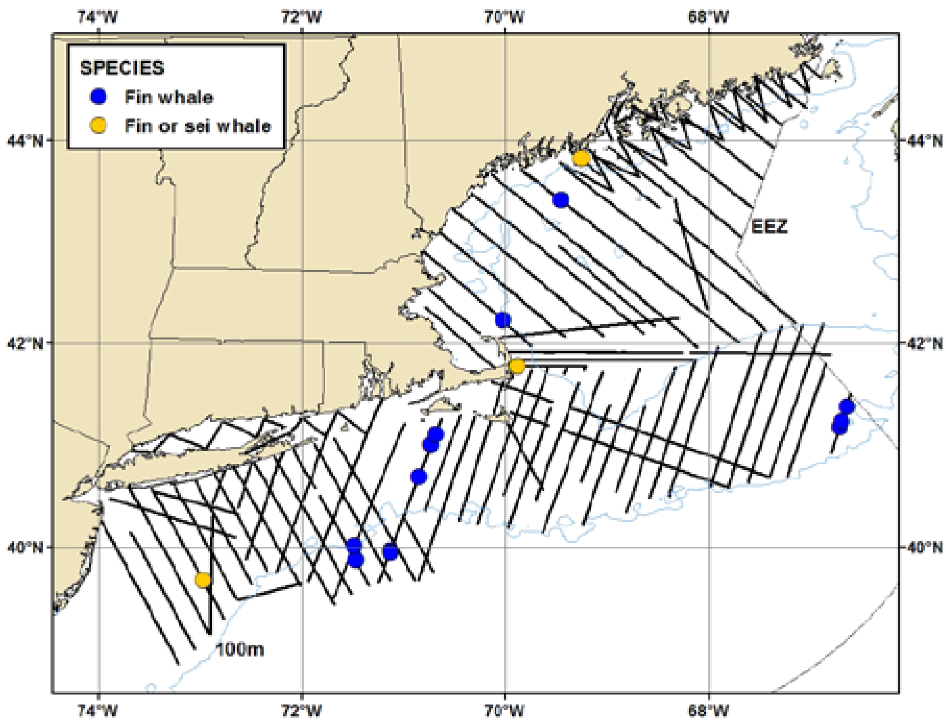


Figure D6. From NE AMAPPS 2016 summer survey, locations of fin whales (*Balaenoptera physalus*; top), fin or sei whales (top), unidentified seals (bottom), unidentified dolphins (bottom) and unidentified whales (bottom) detected by the front team.



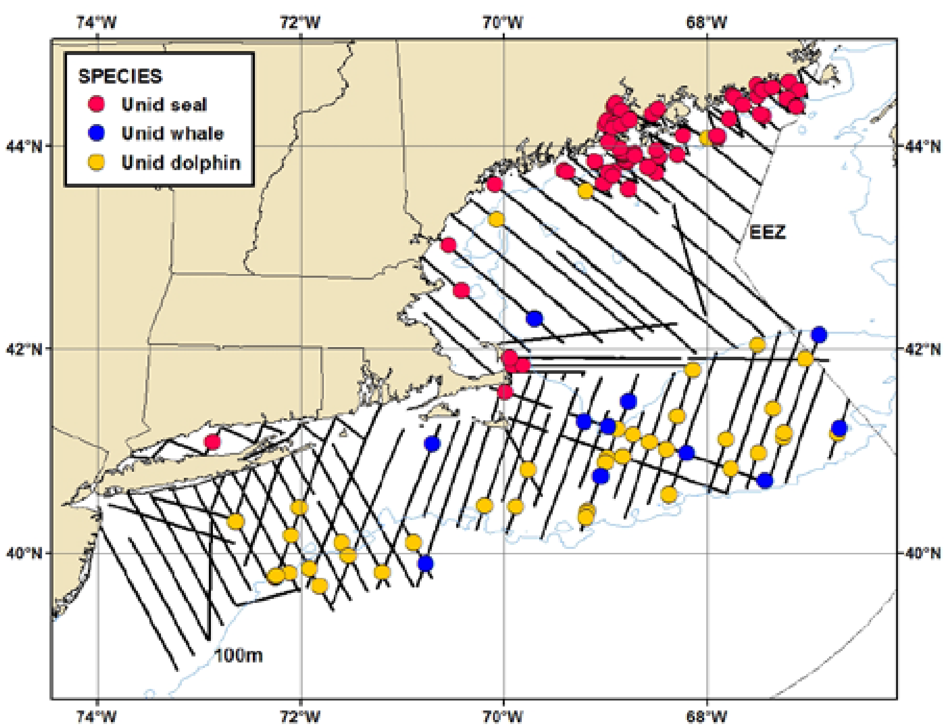
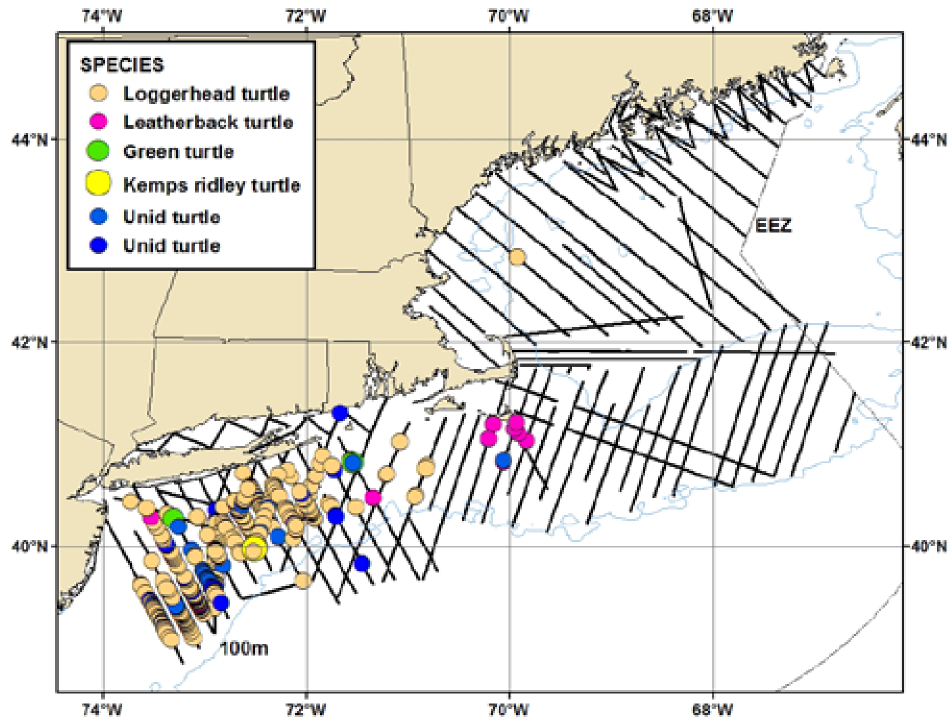


Figure D7. From NE AMAPPS 2016 summer survey, locations of loggerhead turtles (*Caretta caretta*; top), leatherback turtles (*Dermochelys coriacea*; top), green turtles (*Chelonia mydas*; top), Kemp's ridley turtles (*Lepidochelys kempii*; top), unidentified turtles (top), and basking sharks (*Cetorhinus maximus*; bottom) detected by the front team.



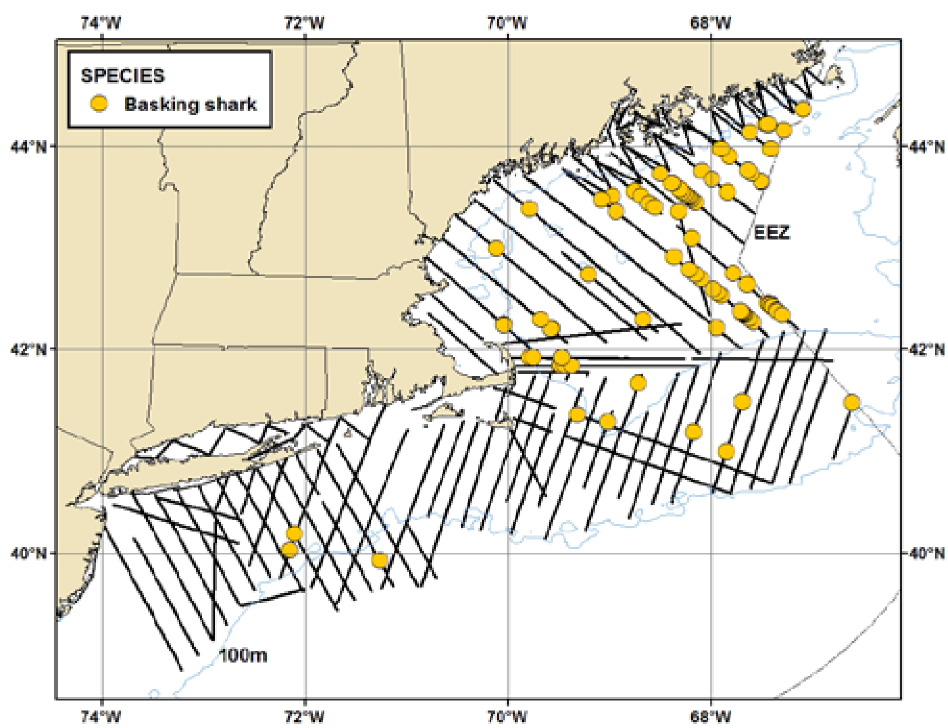
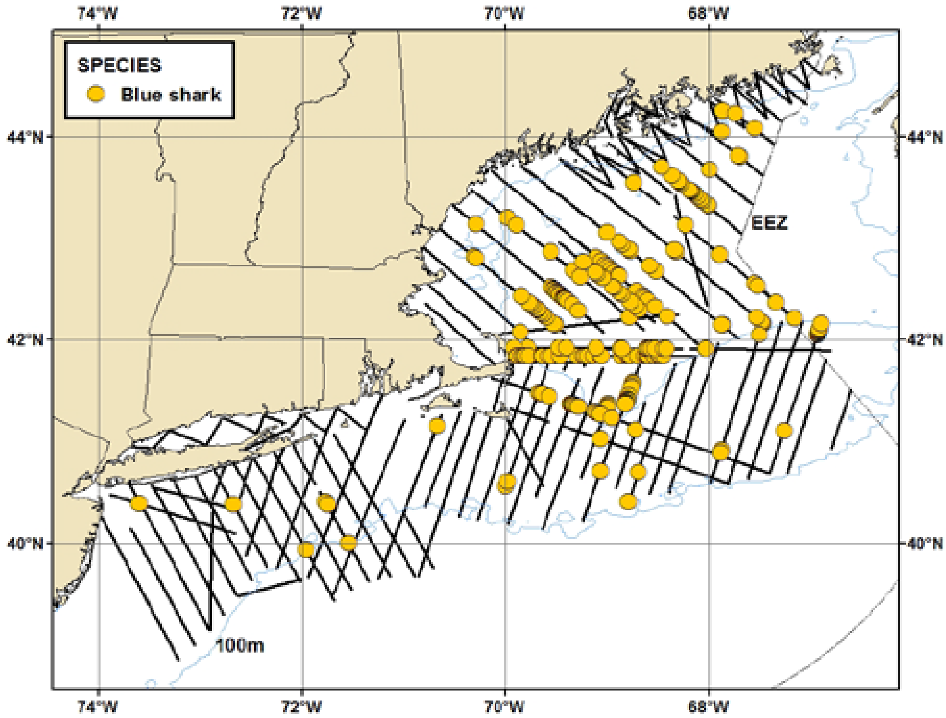


Figure D8. From NE AMAPPS 2016 summer survey, locations blue sharks (*Prionace glauca*; top) and hammerhead sharks *Sphyrnidae* spp. bottom) detected by the front team.



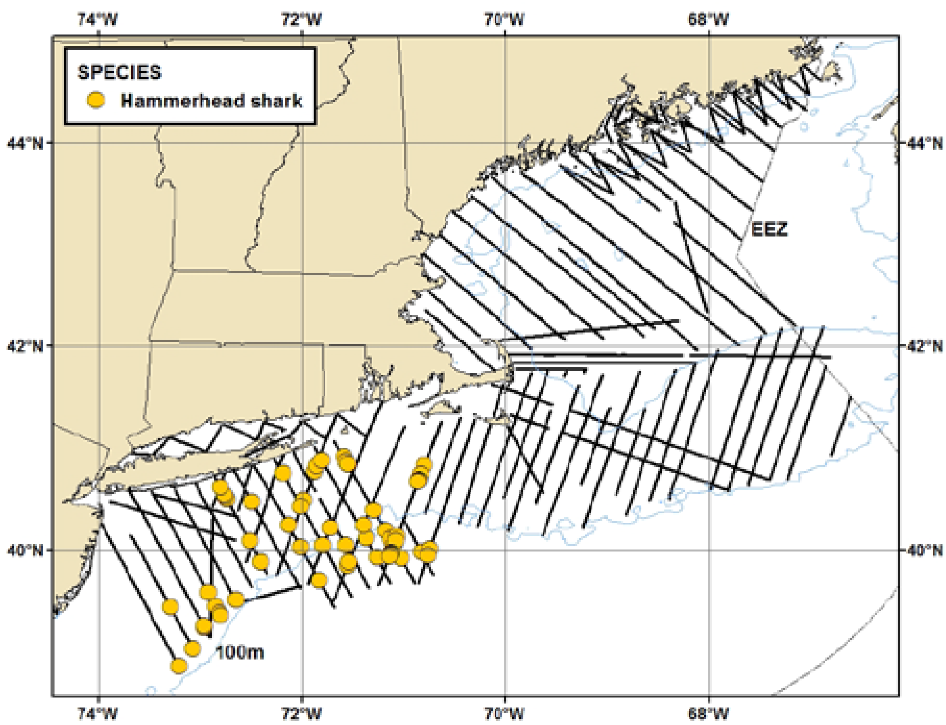


Figure D9. From NE AMAPPS 2016 summer survey, locations ocean sun fish (*Mola mola*; top), manta rays (*Cephalopterus manta*; bottom) and unidentified rays (bottom) detected by the front team.

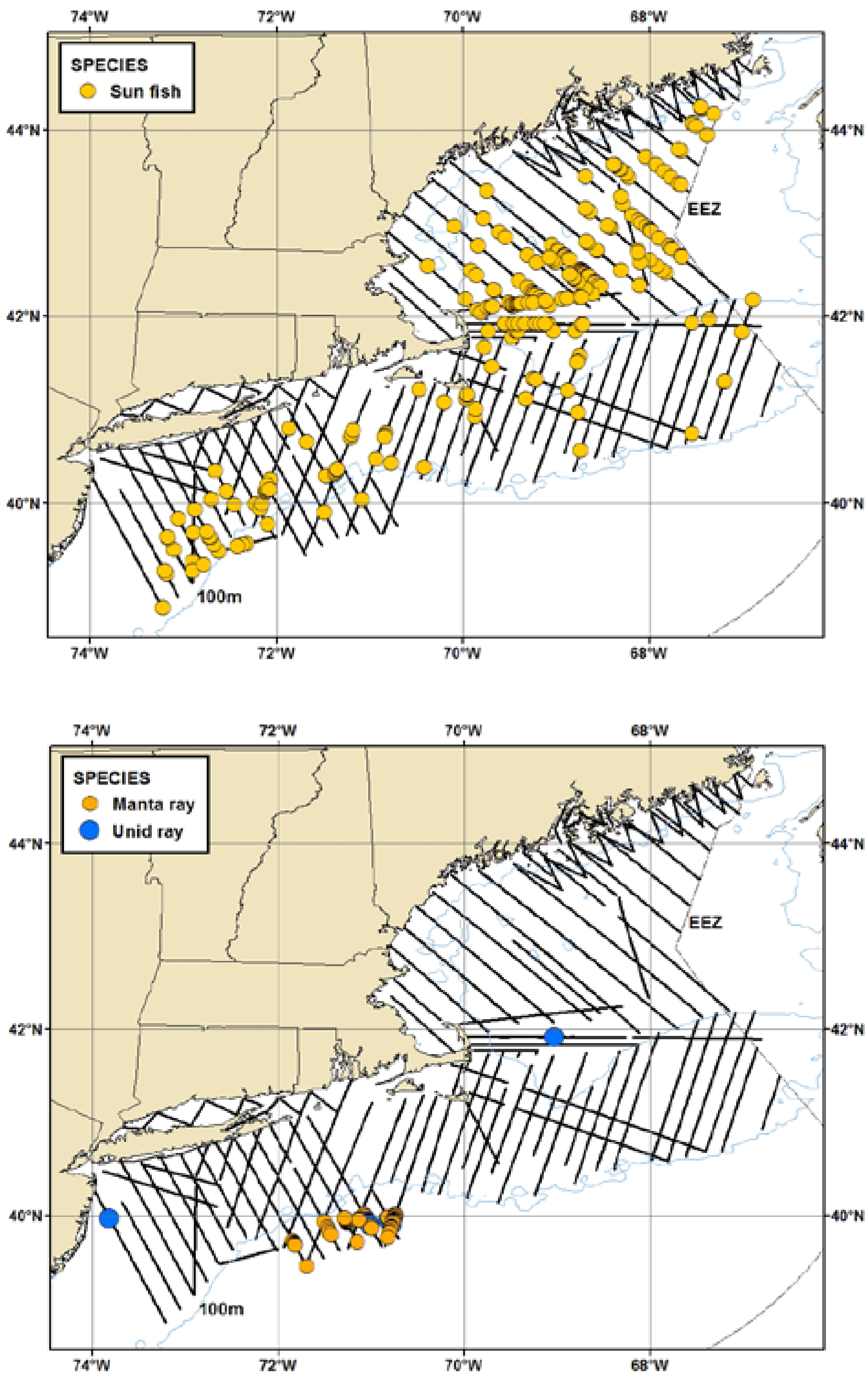
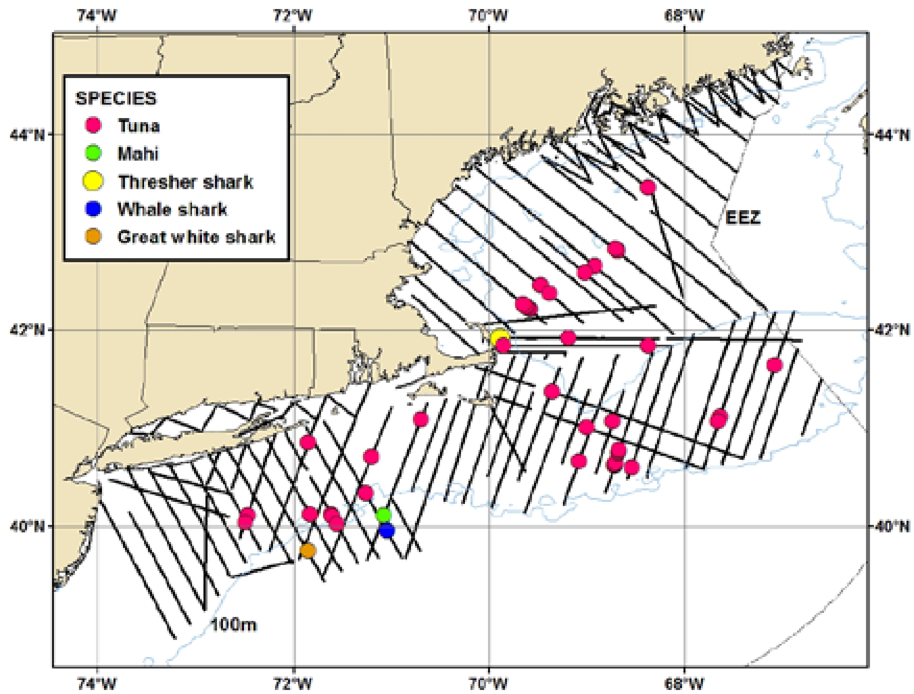


Figure D10. From NE AMAPPS 2016 summer survey, locations of tuna (top), *Mahi mahi* (top), thresher sharks (*Alopias macrourus*; top), whale sharks (*Rhincodon typus*; top), great white sharks (*Carcharodon carcharias*; top), and unidentified sharks (bottom) detected by the front team.



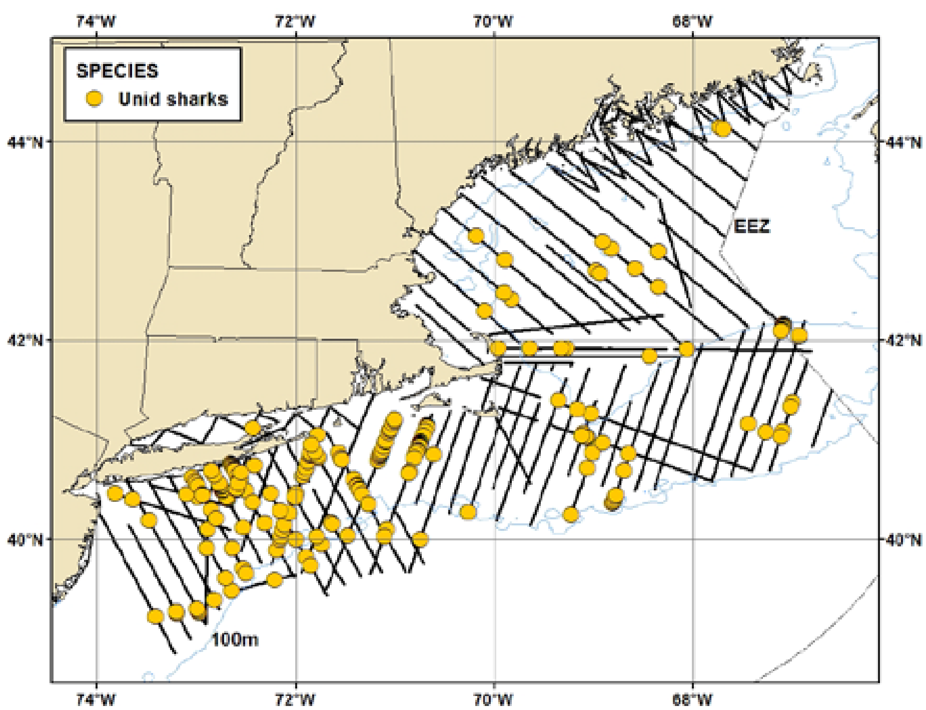
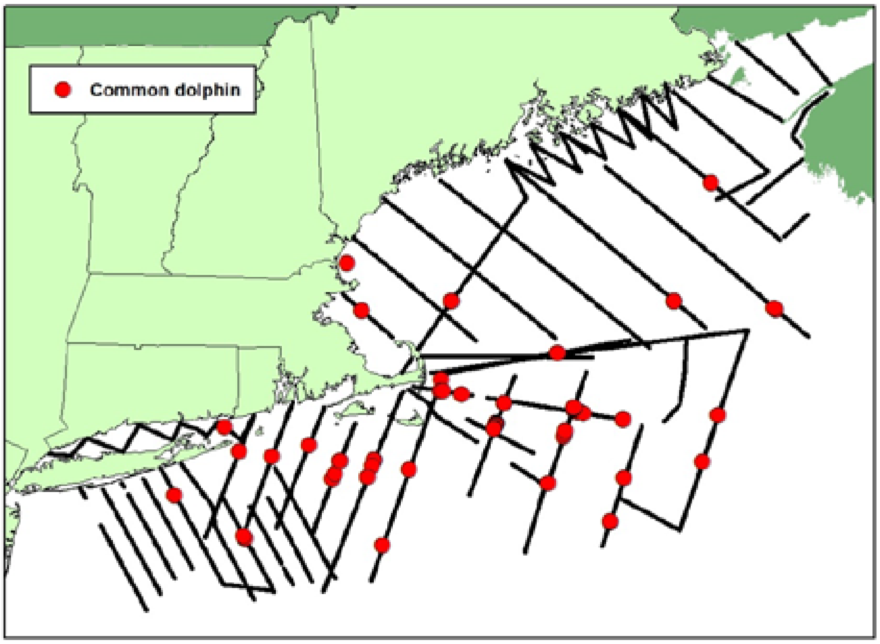


Figure D11. From NE AMAPPS 2016 fall, locations of common dolphins (*Delphinus delphis*; top) and harbor porpoises (*Phocoena phocoena*; bottom) detected by the front team.



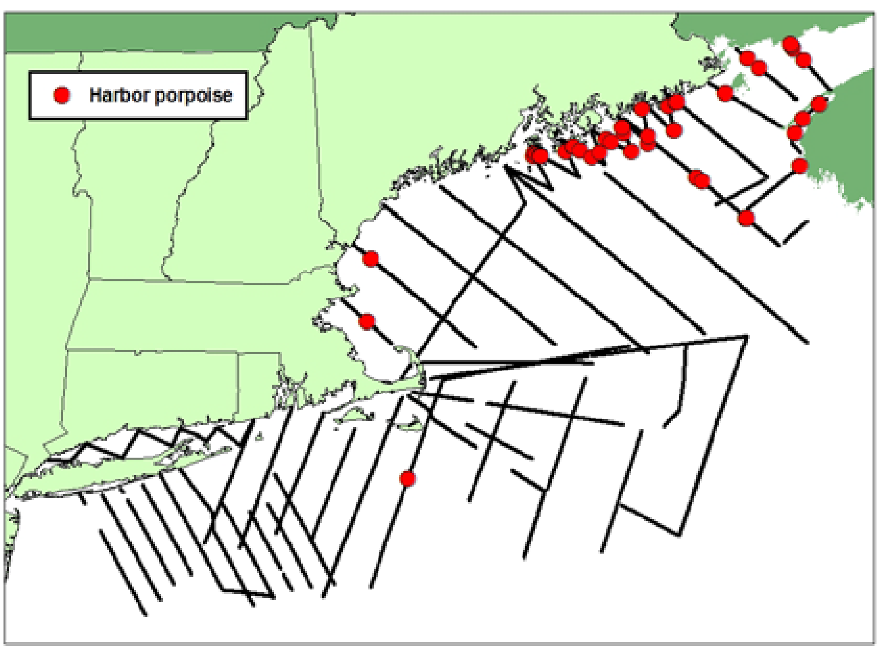
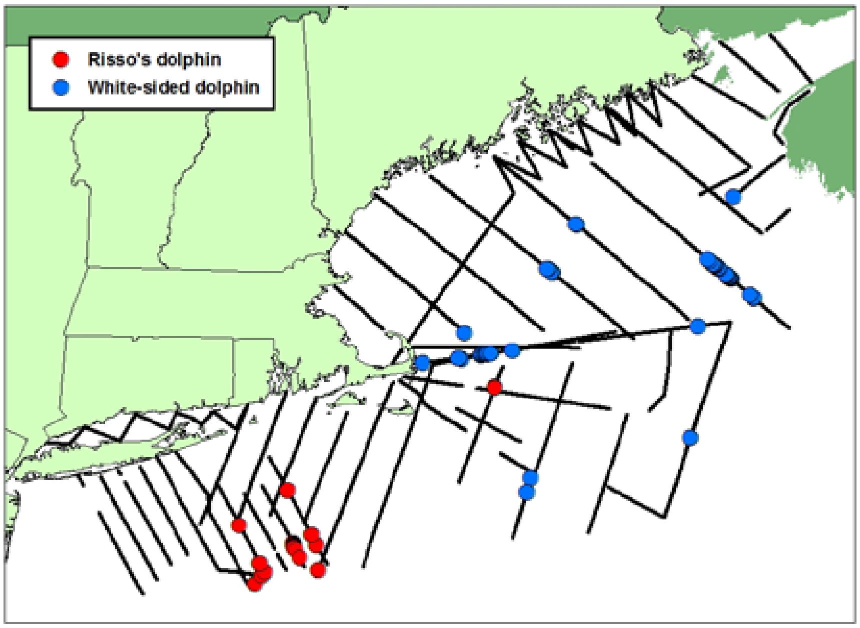


Figure D12. From NE AMAPPS 2016 fall, locations of Risso's dolphins (*Grampus griseus*; top), white-sided dolphins (*Lagenorhynchus acutus*; top), bottlenose dolphins (*Tursiops truncatus*; bottom), pilot whales (*Globicephaia spp*; bottom), and unidentified dolphins (bottom) detected by the front team.



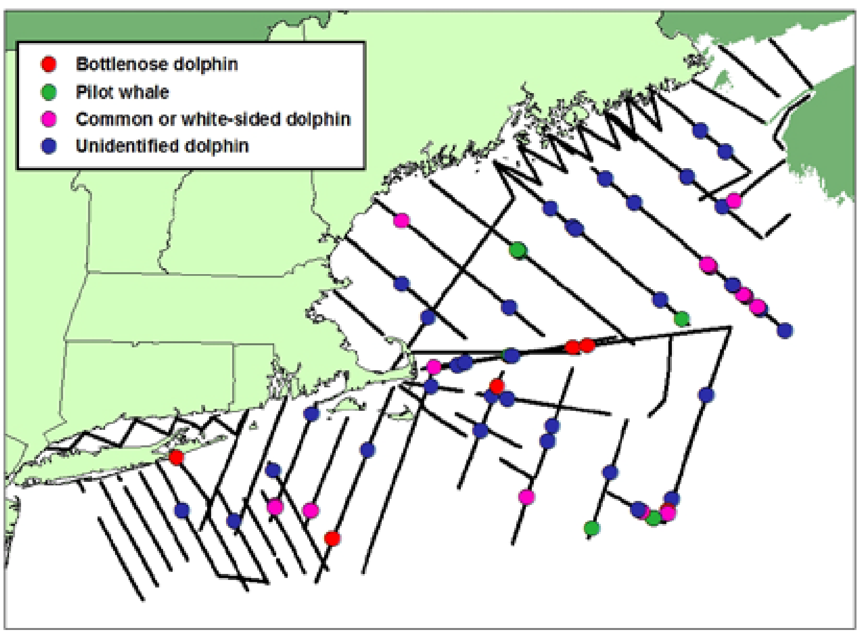


Figure D13. From NE AMAPPS 2016 fall, locations of fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*; detected off effort), right whales (*Eubalaena glacialis*), sei whales (*B. borealis*; detected off effort), and sperm whales (*Physeter macrocephalus*) detected by the front team.

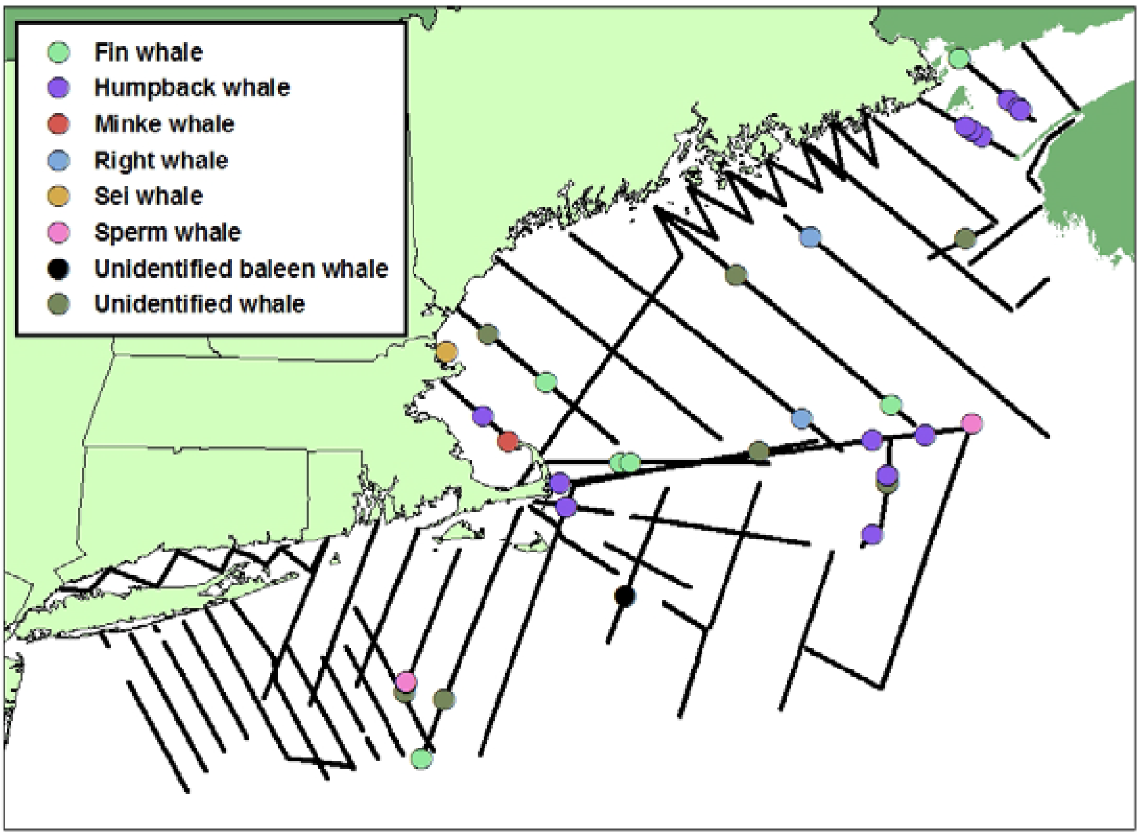
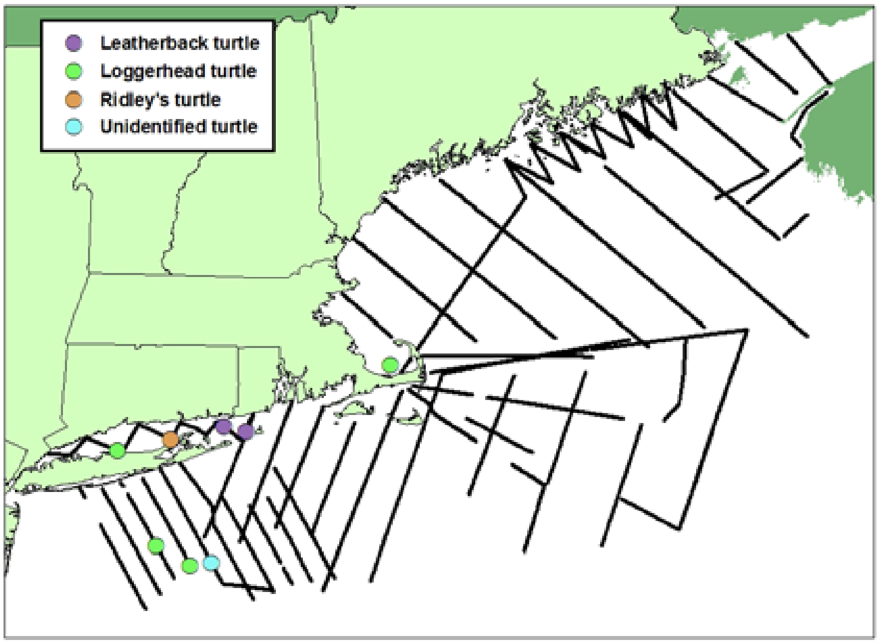


Figure D14. From NE AMAPPS 2016 fall, locations of leatherback turtles (*Dermochelys coriacea*; top), loggerhead turtles (*Caretta caretta*; top), Ridley's turtles (*Lepidochelys kempii*; top), unidentified turtles (top), gray seals (*Halichoerus grypus*; bottom), harbor seals (*Phoca vitulina*; bottom), and unidentified seals (bottom) detected by the front team.



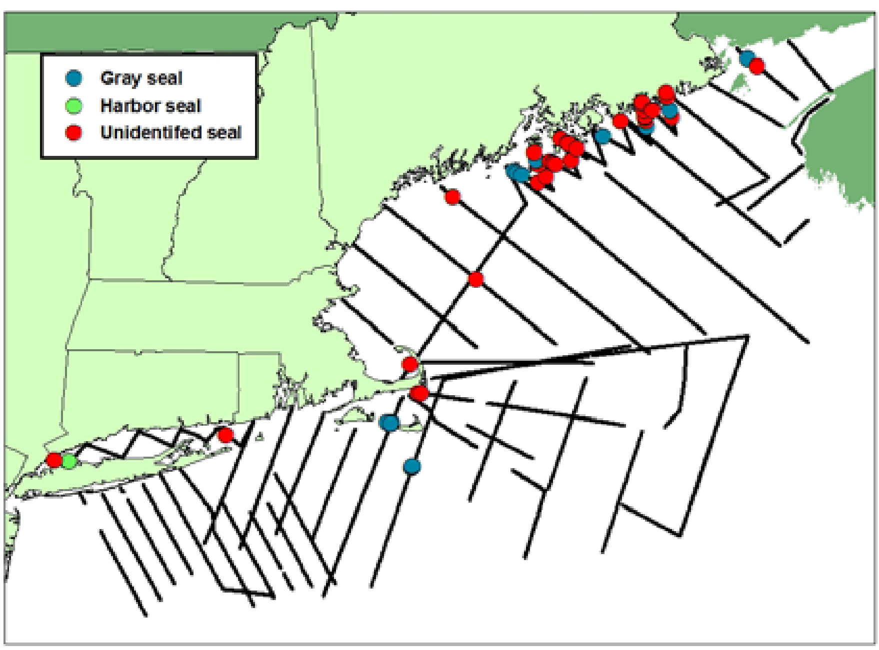
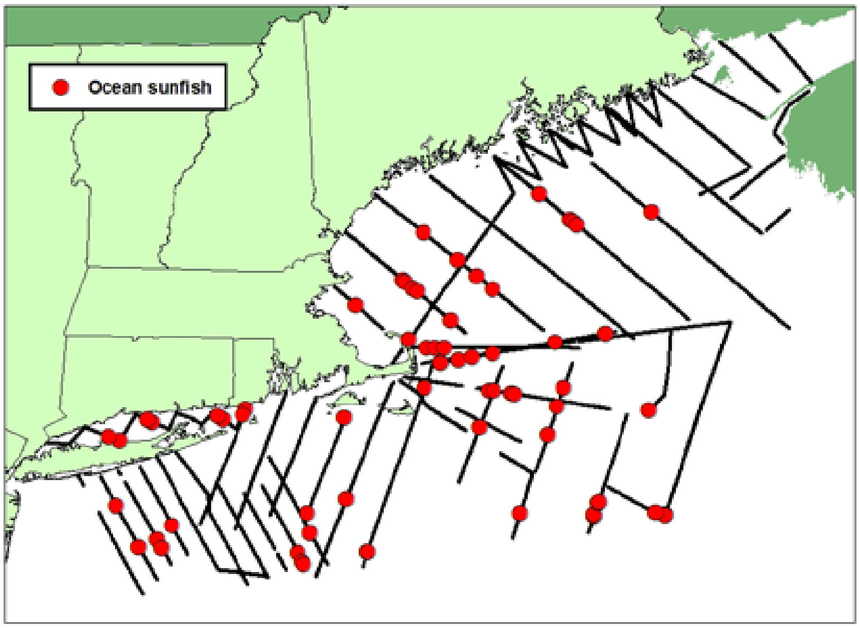
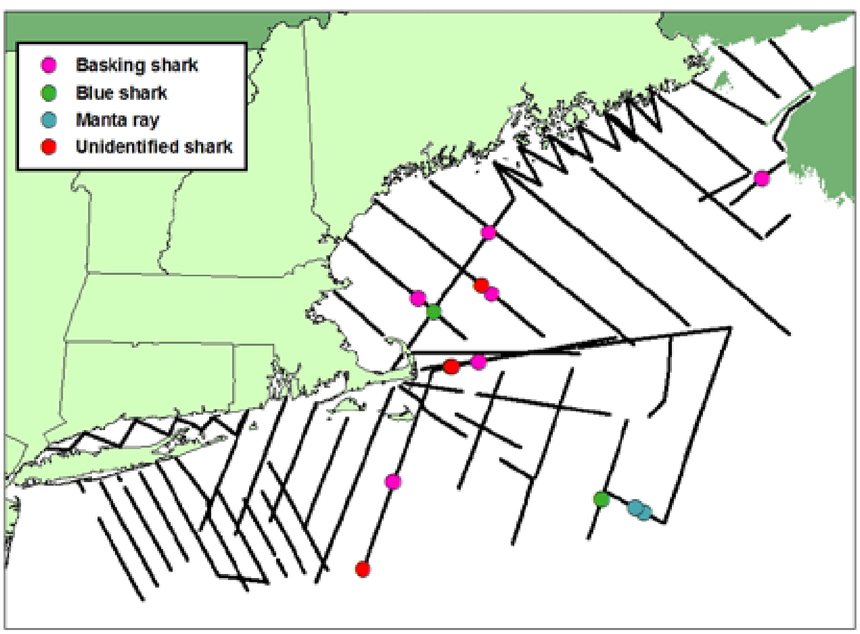


Figure D15. From NE AMAPPS 2016 fall, locations of ocean sun fish (*Mola mola*; top), basking sharks (*Cetorhinus maximus*; bottom), blue sharks (*Prionace glauca*; bottom), manta rays (*Cephalopterus manta*; bottom) and unidentified sharks (bottom) detected by the front team.





Appendix E: *Progress on sea turtle tagging - field work and analyses*

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SUMMARY

As no ship time northeast of Long Island was available in 2016, no AMAPPS loggerhead turtle tagging cruises were planned in 2016. To advance loggerhead research, we collaborated on existing loggerhead tagging cruises; explored options for obtaining behavioral data on loggerheads northeast of Long Island; documented loggerhead behavior in the mid-Atlantic region; formalized our collaboration with Canada's Department of Fisheries and Oceans (DFO); and we worked with many collaborators to begin estimating the density of tagged turtles. We also began a little pilot work on leatherback turtles.

OBJECTIVES

The AMAPPS program coordinates the data collection and analysis efforts of the NMFS Northeast and Southeast Fisheries Science Centers to accomplish six primary objectives, three of which are relevant to the AMAPPS Turtle Ecology task:

A. Collect data on distribution and abundance at fine scales using visual and acoustic survey techniques;

B. Conduct tag telemetry studies within surveyed regions of marine turtles, pinnipeds and seabirds to develop corrections for availability bias in the abundance survey data and collect additional data on habitat use and life-history, residence time, and frequency of use;

C. Explore alternative platforms and technologies to improve population assessment studies;

To advance these above goals, in absence of dedicated AMAPPS ship time and in consideration that the majority of our funding focuses on NE loggerheads, we participated in the following collaborations.

1) Continued loggerhead research

- a) Collaborated with Coonamesett Farm Foundation (CFF) on loggerhead tagging cruises
- b) Used videography to reveal loggerhead behavior
- c) Collaborated with Canada on loggerhead research
- d) Estimated density of tagged loggerheads

2) Investigated more efficient leatherback tagging

PROJECTS

To further AMAPPS goals, we participated in several collaborative projects:

Project	Notes on Cruise Period and Area
1) Continued loggerhead research	
a) Collaborated on US tagging cruises	CFF lead; May 16-21, August 21-26; Mid-Atlantic and offshore
b) Used videography to reveal behavior	No new field work
c) Collaborated with Canada	Participated in DFO cruises in Canada, but no AMAPPS tags deployed.
d) Estimated density of tagged loggerheads	No field work
2) Investigated more efficient leatherback tagging	Small boat day trips October 13-17

METHODS and RESULTS

1) CONTINUED LOGGERHEAD RESEARCH

a) Collaborated with Coonamesett Farm Foundation (CFF) on Loggerhead Tagging Cruises

Funded under another source, CFF organized two cruises intended to sample Mid-Atlantic shelf turtles as well as turtles off the continental shelf. We have a working hypothesis that turtles northeast of Long Island are primarily entering the area via offshore waters, rather than via a continental shelf migration. All tags deployed were consistent with AMAPPS protocols. AMAPPS purchased approximately half (12 of the tags deployed), but did not pay any vessel charter costs. Due to logistical constraints, we were only able to deploy one tag in offshore waters (on the northwestern edge of the Gulf Stream); and that one turtle did migrate directly toward Cape Cod, up through the Great South Channel, then onto the heart of Georges Bank. We hope to investigate further whether tagging turtles on the Gulf Stream is a more efficient way of collecting behavior data for turtles in shelf waters northeast of Long Island.

b) Used Videography to Reveal Loggerhead Behavior

The involvement of AMAPPS funds in this project was initiated when there was a focus on what animals were doing within the AMAPPS area of interest. At that time, we used funds to purchase appropriate software and to contract Dr. Dodge to code approximately 24 hours of video of in-situ loggerhead behavior. The vast majority of project costs (ship charter, rental and purchase of ROVs, Days at Sea labor costs, data management, the other half of the video coding costs, quantitative analysis, manuscript preparation, and publication costs) were funded by Coonamessett Farm Foundation through the Atlantic Sea Scallop Research Set Aside and to a much lesser extent by the Northeast Fisheries Science Center. This project has resulted in a paper:

> Patel, S. H., Dodge, K. L., Haas, H. L., & Smolowitz, R. J. (2016). Videography Reveals In-Water Behavior of Loggerhead Turtles (*Caretta caretta*) at a Foraging Ground. Front. *Mar. Sci*, *3*, 254

where AMAPPS was in the acknowledgements:

"This project was funded in part by… the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC, through Inter-Agency Agreement Number M10PG00075 with the National Marine Fisheries Service as the Atlantic Marine Assessment Program for Protected Species."

c) Collaborated with Canada

In December 2015 we established a formal collaborative relationship with Canada's Department of Fisheries and Oceans (DFO) Dr. Michael James to work collaboratively on shared research goals. An excerpt of this agreement is pasted below:

> *This letter documents my intention to partner with you on loggerhead satellite tagging research in the northern Northwest Atlantic Ocean. I can share ten to fifteen SMRU satellite tags for you to deploy in 2016 on loggerhead sea turtles in the vicinity of Georges Bank, the Northeast Channel, Browns Bank; along the Scotian Shelf and Slope, and elsewhere in Canadian waters. I will share the resulting satellite telemetered data with you to support your research on the biology and movements of loggerhead turtles using Canadian foraging habitat. I will also retain the data for use to support NEFSC and AMAPPS priorities related to availability, distribution, and abundance. For this collaboration, we both agree to acknowledge each other's funders in published research.*
>
> *This collaborative approach should allow us both (DFO and NEFSC NMFS) to use our resources as efficiently as possible. By working together we can accomplish more than any of us could do alone. As we have seen from our previous deployments, many loggerheads tagged in Canada move south in US shelf waters, and those loggerheads that are seasonally resident in Canadian waters will provide AMAPPS with behavioral data to fill important gaps in our estimates of availability to visual observers.*

Fifteen tags, parameterized exactly as the rest of the AMAPPS tags, were shipped to Canada in late spring of 2016. Canada experienced an exceptionally low number of loggerheads in 2016 (as documented by both directed sighting efforts and standardized fishery observing efforts), so deployments are planned for 2017.

d) Estimated Density of Tagged Loggerheads

As reported in the final report for AMAPPS I, we have a contract in place to estimate the distribution of tagged loggerheads using at least two different methodologies, evaluate how sensitive the results are to the methodologies, and select a preferred approach for this application. Research was accomplished under this contact in 2016, and we expect a manuscript to be submitted to a peer-reviewed journal in 2017.

2) INVESTIGATED MORE EFFICIENT LEATHERBACK TAGGING

To make the most of the AMAPPS funds for a pilot study on leatherback research, we are investigating more efficient ways to tag leatherback turtles. Leatherback at-sea tagging programs are typically more expensive than loggerhead projects due to the involvement of flight time as well as costs associated with having a veterinarian on board.

In order to make leatherback tagging more efficient, we are exploring ways to deploy tags opportunistically and without the need to bring the leatherback on board. One of the avenues we are pursuing is the deployment of a DFO-supported, satellite-linked suction cup tag. This new type of tag can be deployed without bringing the animal onboard and it is satellite linked so it can be deployed an order of magnitude longer than traditional suction cup tags. Because of the satellite link, it does not need to be monitored in real time; thus we can deploy it, carry on with our other research, and return to pick it up later. On October 17, 2016 working in consultation with Dr. James and in collaboration with CFF, we successfully deployed a preliminary version on a leatherback turtle in Vineyard Sound. The success of this deployment suggests that this tagging approach may be an efficient way to gain behavioral data (including availability estimates) at a fraction of the cost of traditional tagging. In addition, we plan to investigate the possibility of satellite tagging leatherbacks in North Carolina during their migration in May 2017. Dr James is planning to participate as well to test the final version of the suction cup. If leatherbacks are found to be numerous enough and feeding at the surface, it will be possible to capture them in future years for long term tag deployments as well.

DISPOSITION OF THE DATA

Data from all satellite tags purchased by AMAPPS, as well as all satellite tags deployed by Coonamessett Farm Foundation in support of Research Set Aside objective are maintained in an Oracle Database at NEFSC.

PERMITS

The deployment of loggerhead and leatherback tags was authorized under the US Permit No. 16556 issued to the NEFSC.

ACKNOWLEDGEMENTS

We acknowledge the substantial contributions of our collaborators at Coonamessett Farm Foundation and Fisheries and Oceans Canada. We also thank James Gutowski of Viking Village Fisheries and the captains, crew, and scientists on the F/V *Kathy Ann* for their expert field work. This project was funded in part by the scallop industry Sea Scallop Research Set Aside program administered by the Northeast Fisheries Science Center under grants from NA10NMF4540472 to NA14NMF4540079; by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC, through an Inter-Agency Agreement with the National Marine Fisheries Service as the Atlantic Marine Assessment Program for Protected Species (AMAPPS); and by the Northeast Fisheries Science Center.

Appendix F: *Progress on processing input data and developing density models, maps and abundance estimates: Northeast and Southeast Fisheries Science Centers*

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SUMMARY

To develop animal density models and abundance estimates incorporating environmental data, during 2016 we accomplished the following: processed and archived the recently collected shipboard and aerial survey data; started obtaining and processing the static and dynamic environmental data corresponding to the recently collected survey data; and further developed the generalized additive model and Bayesian hierarchical model frameworks that are being used to model the spatial/temporal distribution of marine mammals and sea turtles. In addition, a hidden Markov modeling approach is being developed that uses the passive acoustic data of the deep diving sperm whales to account for availability bias that can then be combined with the visual survey data to estimate abundance and density-environmental spatial models. Another related project that started in 2016 uses the AMAPPS 2010 – 2016 survey data plus previously collected data to investigate trends in abundance of common bottlenose dolphins (*Tursiops truncatus*).

INTRODUCTION

One of the objectives of the AMAPPS project is to develop spatially- and temporally-explicit density maps of marine mammals, sea turtles, and sea birds that incorporate environmental variables. To achieve this objective, the Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) are continuing to develop a Generalized Additive Modeling (GAM) framework and a hierarchical Bayesian framework and import new data into these modeling frameworks. This appendix provides a brief progress report of the work conducted in 2016 that relates to the estimation of the density maps, abundance estimates and trends in abundance.

RESULTS

During 2016 work was related to improving and updating the input data and the generalized additive model (GAM) and Bayesian hierarchical frameworks that estimate density-habitat relationships and abundance estimates. In addition we are developing methods to integrate passive acoustic and visual data of sperm whales, and to investigate trends in abundance using the AMAPPS and previously calculated abundance estimates.

INPUT DATA

Survey data

During 2016 the newly collected shipboard and aerial survey data were processed, errors checked for, archived in the NEFSC Oracle database and then submitted to OBIS-SEAMAP.

The marine mammal and turtle data were also provided to Jason Roberts and his team at Duke University to be used in their density models being developed for the Navy. In addition the seabird data collected on the NMFS shipboard surveys were sent to the USFWS Seabird Compendium database.

Environmental data

During 2016, we updated the dynamic variables for the years 2014 – 2015.

GENERALIZED ADDITIVE MODELING FRAMEWORK

During 2016, the 2-step modeling process previously established for the GAM framework was followed. Step 1 involved estimating the abundance corrected for availability bias for all grid cells that had survey effort, using the Distance analysis technique proposed by Thomas *et al.* (2010). Step 2 involved using the static and dynamic environmental covariates as explanatory variables for the distribution and abundance patterns estimated in Step 1. Following this process, we developed 19 spatially- and temporally-explicit density models (Table F1) and their correspondent average density, lower 95%, upper 95%, and CV maps using the shipboard and aerial survey data collected during 2010 – 2013 for 14 single species and 3 species guilds (pilot whales spp., Kogia spp., unidentified beaked whales).

Examples of the density maps, seasonal average abundance estimates produced for the AMAPPS study area, and for the offshore energy development areas with its associated coefficient of variation and confidence intervals are presented in Tables F2 – F3 and Figures F1 – F3.

BAYESIAN HIERARCHICAL FRAMEWORK

The Bayesian hierarchical framework used to model and predict the spatial distribution of protected species in the Atlantic Ocean, can be referred to as a “one-stage approach” because both the observation uncertainty (equivalent to Step 1 in the GAM framework) and process uncertainty (equivalent to Step 2 in the GAM framework) are integrated within one comprehensive modeling framework (Miller *et al.* 2013). The Bayesian approach allows for straightforward probabilistic conclusions to be derived directly from the posterior distributions of the model. In addition, the Bayesian framework allows for prior information to be integrated into future predictions.

During 2016, the Bayesian framework was expanded in several ways to allow more flexibility. One way was to include the Tweedie distribution in addition to the over-dispersed Poisson and negative binomial distributions. Using the Tweedie probability distribution, the model was able to capture the over-dispersion in the data without having to include an additional random term as was the case with the other distribution models. We applied this updated model to several species of large whales which included fin whales, humpback whales, minke whales and sperm whales. The output from these models was used to make predictive maps and was subsequently compared to output from the GAM models. The Tweedie model approach produced estimates with substantially lower uncertainty than that produced from the distributions within the Bayesian framework. We are continuing to evaluate the accuracy of the output from these models.

To allow more flexibility and options, we also started exploring ways to incorporate nonparametric approaches such as GAMs into the Bayesian framework and exploring methods to include spatio-temporal autocorrelation in the models using state of the art programs such as Template Model Builder. These approaches may help to reduce uncertainty and produce more accurate results.

COMBINING ACOUSTIC AND VISUAL DATA

Sperm whales spend a large part of their time below the ocean's surface, and they are easily detected during shipboard abundance surveys by visual observers when they are at the surface, and by passive acoustic towed hydrophones when they are below the surface. The goal of an AMAPPS project is to attempt to use both of these data types to attempt to estimate a more precise abundance estimate. More on how the passive acoustic sperm whale data were processed can be found in Appendix G. The modeling process of integrating these data types are further described here. This project is being funded by AMAPPS and the NMFS toolbox project.

A hidden Markov model (HMM) approach is being explored to model the passive acoustic data collected during the 2013 shipboard abundance survey with the goal to calculate the probability of transitioning to the surface from below (which has a similar function that an availability bias correction factor has). The resulting probability could then be combined with visual line transect data that were simultaneously collected to calculate one overall estimate of abundance using both sources of data to account for perception bias (using the visual data) and availability bias (using the acoustic data). In addition this model could feasibly output spatially and temporally varying estimates of an availability bias correction factor that might be able to be applied to other datasets.

The first phase of this project was to use simplified simulated data to test the basic HMM model framework. Results from this demonstrated that the approach was able to accurately estimate abundance with more precise estimates of uncertainty when compared to estimates that only used one source of data. Then the second phase was to incorporate the HMM framework into the density-habitat Bayesian framework (as described above), with the goal of improving on the current species distribution models particularly for deep diving species. We are currently working on applying this framework to real data on sperm whales.

ABUNDANCE TREND ANALYSIS

Using the summer aerial survey data of bottlenose dolphins (*Tursiops truncatus*) from 2002, 2004, 2010, 2011, and 2016, the abundance estimates and trends of coastal bottlenose dolphins is being explored. The 2010 – 2016 data were collected under AMAPPS. The abundance estimates are being calculated using standard mark-recapture distance sampling methods in R. The probably that a detected bottlenose dolphin is a coastal animal was derived using a logistic regression, where the response variable was whether a biopsied bottlenose dolphin was the coastal or offshore morphotype, and the explanatory variables were bottom depth, latitude and their interaction. Several techniques are currently being explored to estimate the temporal trend of these point estimates.

REFERENCES CITED

Miller, D.L., L.M. Burt, E.A. Rexstad and L Thomas. 2013. Spatial models for distance sampling data: recent developments and future directions. Methods in Ecology and Evolution. doi: 10.1111/2041-210X.12105

Table F1. Seasonal habitat models for species and species guilds developed during 2016 under the GAM framework.

Species	Habitat Models
Atlantic spotted dolphin	Spring, Summer, Fall
Beaked whale, Cuvier's	Summer
Beaked whale, Sowerby's beaked whale	Summer
Beaked whales, unidentified	Summer
Common bottlenose dolphin	Spring, Summer, Fall, Winter
Fin whale	Spring, Summer, Fall
Harbor porpoise	Spring
Harbor porpoise	Summer
Harbor porpoise	Fall
Humpback whale	Spring, Summer, Fall
Kogia spp	Summer
Minke whale	Spring, Summer, Fall
Pilot whale spp.	Spring, Summer, Fall
Risso's dolphin	Spring, Summer, Fall
Sei whale	Spring, Summer, Fall
Shorted-beaked common dolphin	Spring, Summer, Fall
Sperm whale	Spring, Summer, Fall
Striped dolphin	Summer
White-sided dolphin	Spring, Summer, Fall

Table F2. Example of average abundance estimates for the AMAPPS study area. Availability bias correction: aerial 0.93, CV=0.138; shipboard 1.0, CV= 0.0.

Season	Abundance	CV	95% Confidence Interval
Spring (March- May)	111,042	0.215	83,588 - 138,496
Summer (June-August)	118,697	0.213	87,342 - 150,052
Fall (September-November)	183,510	0.185	138,850 - 228,171

Table F3. Example of average seasonal abundance estimates for the offshore energy development areas.

Season	Location	Abundance*	95% Confidence Interval	CV
Spring	Rhode Island/ Massachusetts	1,161	868 - 1,454	0.192
(March-May)	New York	232	165 - 298	0.197
	New Jersey	536	398 - 674	0.183
	Delaware/ Maryland	454	340 - 567	0.190
	Virginia	690	525 - 855	0.174
	North Carolina	2,301	1,826 - 2,775	0.149
	South Carolina/ North Carolina	17	2 - 32	0.608
	Georgia	0	0 - 0	1.1
	Florida	0	0 - 0	4.5
Summer	Rhode Island/ Massachusetts	3,246	2,582 - 3,911	0.134
(June-August)	New York	313	231 - 395	0.175
	New Jersey	467	353 - 582	0.187
	Delaware/ Maryland	318	240 - 397	0.212
	Virginia	239	180 - 297	0.251
	North Carolina	663	511 - 814	0.245
	South Carolina/ North Carolina	1	0 - 1	0.963
	Georgia	0	0 - 0	1.9
	Florida	0	0 - 0	4.8
Fall	Rhode Island/ Massachusetts	3,760	2,992 - 4,528	0.130
(September- November)	New York	505	374 - 636	0.150
	New Jersey	936	709 - 1,164	0.153
	Delaware/ Maryland	714	539 - 889	0.169
	Virginia	852	644 - 1,059	0.172
	North Carolina	2,296	1,796 - 2,796	0.157
	South Carolina/ North Carolina	7	1 - 13	0.827
	Georgia	0	0 - 0	1.5
	Florida	0	0 - 0	5.3

***** The mean abundance is rounded to the nearest integer. If the mean abundance was rounded to zero, the CV calculation was performed using the actual abundance value predicted by the habitat model.

Figure F1. Example annual abundance trend calculated with the habitat models in the AMAPPS study area.

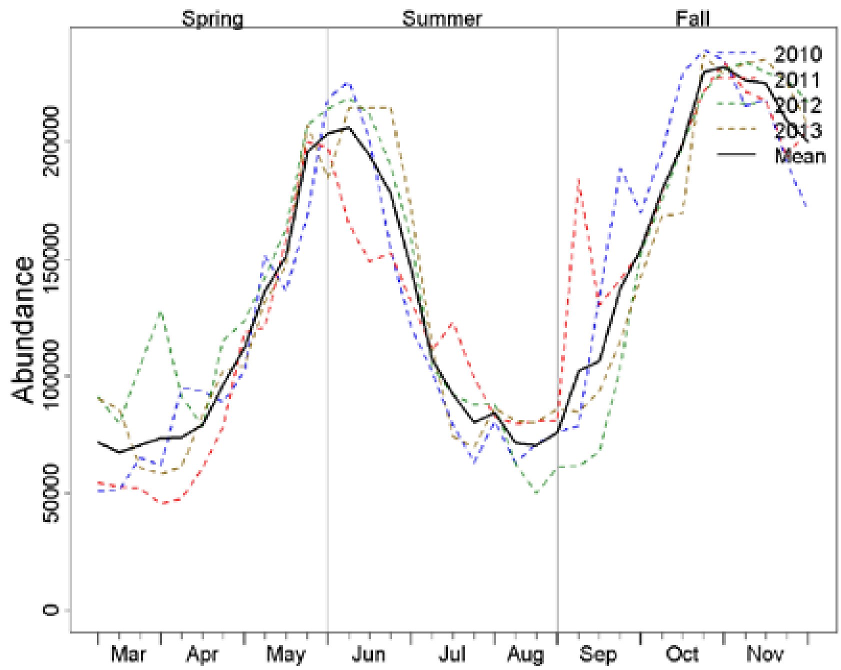


Figure F2. Example annual abundance trend calculated with the habitat models for the offshore energy development areas

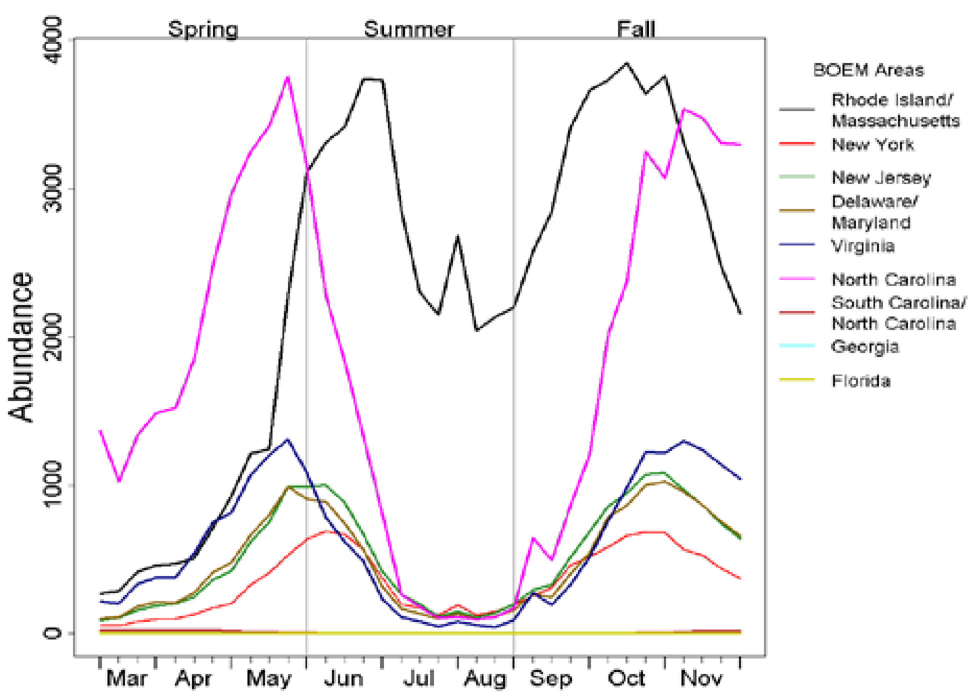
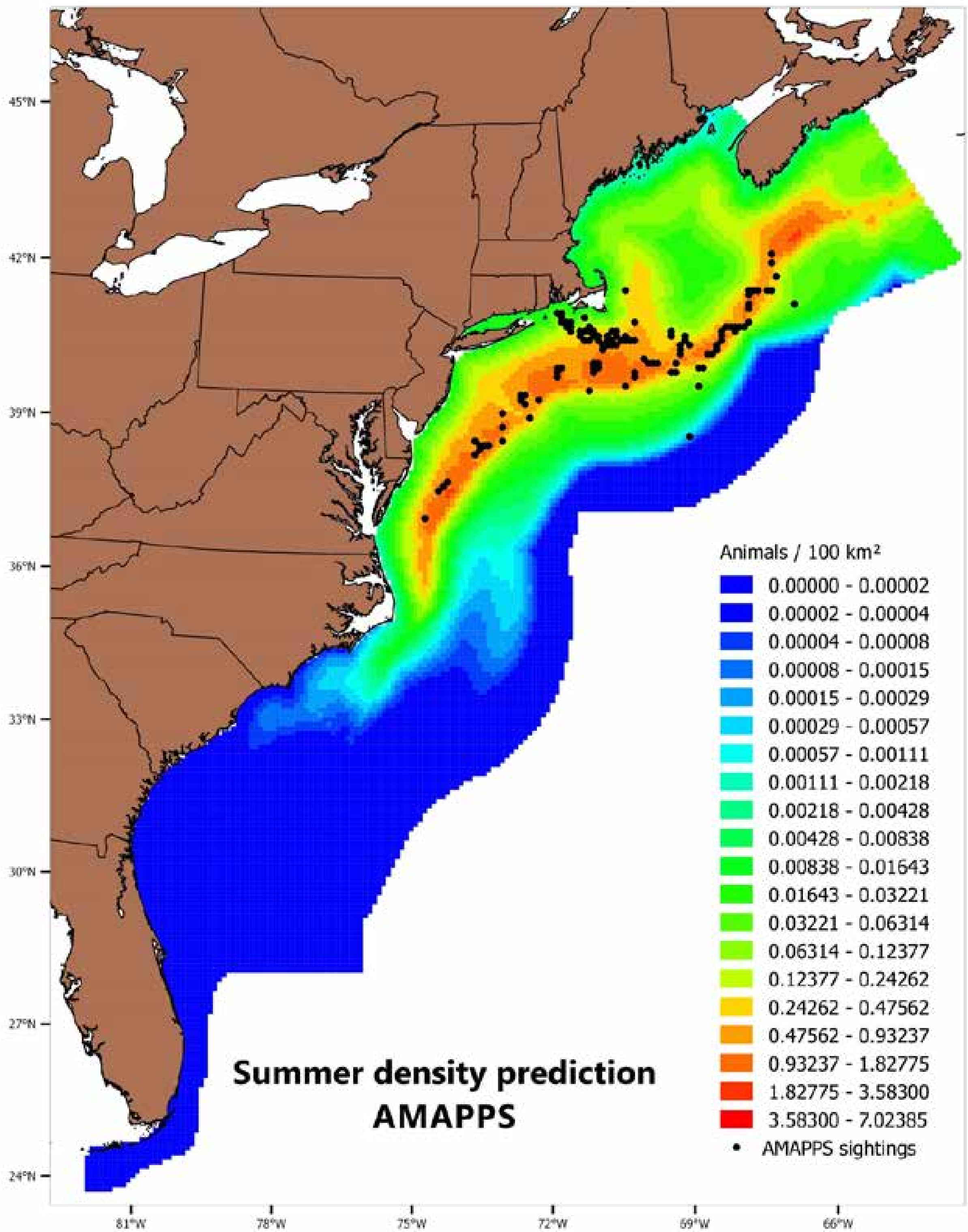


Figure F3. Example summer average density estimates. The black circles indicate grid cells with one or more animal sightings.



Appendix G: *Progress on passive acoustic data collection and data analyses: Northeast and Southeast Fisheries Science Centers*

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SUMMARY

The goal of the AMAPPS-related work conducted by the Northeast and Southeast Fisheries Science Center's passive acoustic groups is to collect acoustic data that complement visual-based analyses of animal occurrence and abundance, particularly for species that are difficult to detect by visual observers, or in times of year and regions where visual surveys are not conducted. In 2016, there were several ongoing primary analyses involving towed array and bottom-mounted recorder data collected during AMAPPS surveys. These were: (1) improving abundance estimates for sperm whales (*Physeter macrocephalus*) by integrating visual and acoustic data to better document distribution and evaluate availability bias; (2) quantifying acoustic detection rates for beaked whales, with the goals of comparing to visual detection rates and estimating acoustic abundance for this taxon, if possible; and (3) documenting migratory pathways of baleen whales along the eastern seaboard continental shelf.

Two other ongoing collaborative projects related to AMAPPS are the Tethys acoustic database and the Real-Time Odontocete Call Classification Algorithm (ROCCA) project. The Tethys acoustic database (http://tethys.sdsu.edu/), developed in collaboration with scientists from the Scripps Institution of Oceanography and the other NOAA Science Centers utilizes standardized formats for archival of metadata associated with our acoustic data collection and analyses, including AMAPPS data. Tethys is currently being used to archive the metadata associated with the deployments of AMAPPS bottom-mounted recorders, as well as metadata associated with analyses of baleen whale detections. Development of Tethys is continuing to increase functionality, with the goal of incorporating additional recorder platforms, including towed array data in the future. Another ongoing collaboration is the continued development of the automated classifiers for odontocete species, known as ROCCA. This work has expanded to include sperm whales, beaked whales, and echolocation for delphinids. AMAPPS data were incorporated into ongoing testing of classifiers.

BACKGROUND AND OBJECTIVES

Passive acoustic technologies have become a critical component of marine mammal monitoring, contributing information about the spatial and temporal occurrence, distribution, and acoustic behavior for a variety of species. Some species, such as beaked whales, have low visual detection rates (Barlow *et al.* 2005); while even more reliably sighted species cannot be detected visually at night or when conditions are poor. Data collected from acoustic studies provide important new insights about species occurrence, including abundance estimation for species that are often poorly detected visually (e.g., Marques *et al.* 2009), presence of species in regions that are difficult to otherwise survey (e.g., Moore *et al.* 2012), and the response of individuals to anthropogenic activities that produce underwater sound (e.g., Castellote *et al.* 2012). Archival recorders, gliders, and towed hydrophone arrays offer the opportunity to collect data on cetacean occurrence and distribution that complements traditional visual survey methodologies.

The goals of the passive acoustic groups at the Northeast and Southeast Fisheries Science Centers include improving our understanding of cetacean acoustic ecology, so that we may improve abundance estimation and develop more effective monitoring and management strategies where needed.

The main objectives of incorporating passive acoustic data into AMAPPS include:

1) Improve abundance estimates of odontocetes in the western North Atlantic using acoustic data collected from towed hydrophone arrays, particularly for sperm whales, beaked whales, and delphinids;
2) Improve our understanding of the spatial and temporal distribution and relative abundance of baleen whales along the western North Atlantic using bottom-mounted archival recorders; and
3) Evaluate the efficacy of towed hydrophone array and archival recorder data collection with comparison to traditional visual data collection to determine where data from these different platforms may be integrated.

METHODS

Processing of passive acoustic data took place using a variety of software packages. Automated detection and tracking of sperm whales (*Physeter macrocephalus*) and beaked whales from towed hydrophone array data were conducted using Pamguard (version 1.12.05 Beta, Gillespie et al. 2008), as well as custom-written Matlab scripts. Abundance estimation was conducted using the software package DISTANCE. Visual and aural reviews of spectrograms and extraction of delphinid whistles were conducted using the software packages Raven (version 1.4, Bioacoustics Research Program 2011) and Xbat (Figueroa and Robbins 2008), executed in Matlab. Bottom-mounted recorder data were reviewed for baleen whale acoustic activity using custom-written software, the Low-Frequency Detection Classification System (LFDCS, Baumgartner et al. 2013).

RESULTS

ACOUSTIC ABUNDANCE ESTIMATES OF SPERM WHALES

Analyses in 2016 focused on developing a methodology to combine visual sightings and acoustic detections of sperm whales to generate a combined abundance estimate and better predictions of sperm whale distributions. Initial modeling efforts were focusing on data collected during the NEFSC 2013 summer shipboard survey. Acoustic databases were converted from Microsoft Access to SQL to maintain cohesion with the acoustical software package Pamguard. The 2013 dataset was reviewed and cleaned, and Matlab routines were customized to extract details on sperm whale echolocation events, including the time, bearing and radial distances to all clicks. Model development was conducted by a member of the AMAPPS team and analyses are ongoing (see Appendix F for more details on the progress of the modeling efforts).

ACOUSTIC DETECTIONS OF BEAKED WHALES (FAMILY: ZIPHIIDAE)

Analyses focused on refining methodology using acoustic data to generate 3-D localizations of beaked whales, and initiating processing of the 2016 survey data. A manuscript on using multipath reflections to determine depths of beaked whales using a towed hydrophone array was submitted to the Journal of the Acoustical Society of America, and is currently in review. Cuvier's beaked whales (*Ziphius cavirostris*) were found on average at 1122 m (weighted stdev= 312m) and Gervais' beaked whales (*Mesoplodon europaeus*) at 827 m (weighted stdev= 120m).

Post-processing of the NEFSC 2016 shipboard survey data is in process, using the software package Pamguard. Analysis steps include running the Pamguard click detector (pre-filter: 16-90 kHz; trigger filter: 20-90 kHz; threshold 10 dB) over all sound files, and reviewing detections to identify putative beaked whale events following a set of established criteria. So far, a total of 43 beaked whale classified events were found in Leg 1 of the 2016 survey (Table G1).

BALEEN WHALE OCCURRENCE ALONG MIGRATORY CORRIDOR LINES

Five lines of MARUs (Marine Autonomous Recording Units, Cornell University, Bioacoustics Research Program) were deployed along the shelf off the coasts of Rhode Island, North Carolina, and Georgia (Figure G1). This is as part of a large-scale project to monitor baleen whale migratory movements. Each line consists of 5 – 8 recording units. Recordings from the first deployment (November 2015 – April 2016) for the four southernmost lines (Cape Hatteras, NC; Cape Fear, NC; Charleston, SC; and New Brunswick, Georgia) were processed using the Low Frequency Detection and Classification System (Baumgartner and Mussoline 2011). Calls by North Atlantic right whales, sei whales, fin whales, and blue whales were detected and classified. Initial analyses focused on determining daily presence of North Atlantic right whales, based on the occurrence of up-calls. Right whales were considered present on any given day if three or more up-calls were detected. Results from the first deployment indicate that right whales were detected off Cape Hatteras from November to mid-May, but were only detected on a few days from November to March on the recorders off Cape Fear and Charleston. Right whale presence was low but consistent off Brunswick from November through March (Figure G2). This work helps document movements of right whales and highlights their use of near-shore habitats in the southeast. Analyses of other baleen whale species will be initiated in 2017.

DISPOSITION OF DATA

Acoustic data are stored on-site at the Northeast and Southeast Fisheries Science Centers.

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Table G1. Acoustic detections of beaked whales and number of individuals localized (in parentheses) in analyses of NEFSC AMAPPS 2016 Leg 1 shipboard survey data. Positive, probable and possible indicate the degree of certainty that a given acoustic event is correctly classified as a beaked whale.

Species	Positive	Probable	Possible
Cuvier's	19 (17)	2 (2)	5 (1)
Sowerby's	2 (2)	0 (0)	0 (0)
Gervais'/True's	10 (9)	2 (0)	3 (1)
Total	31 (28)	4 (2)	8 (2)

Figure G1. Map of bottom-mounted recorders deployed in conjunction with a study of baleen whale migratory movements and habitat use.

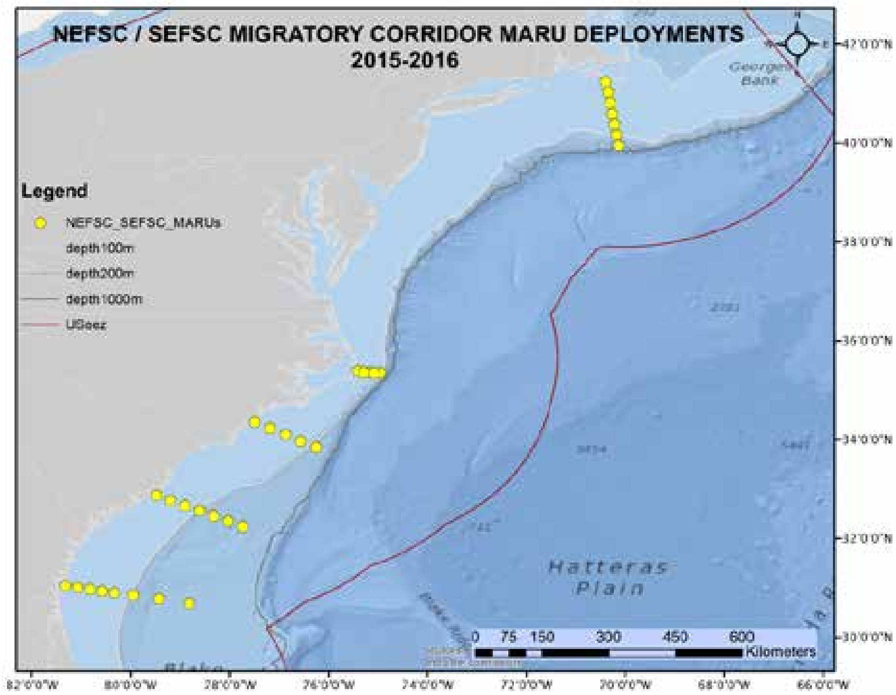
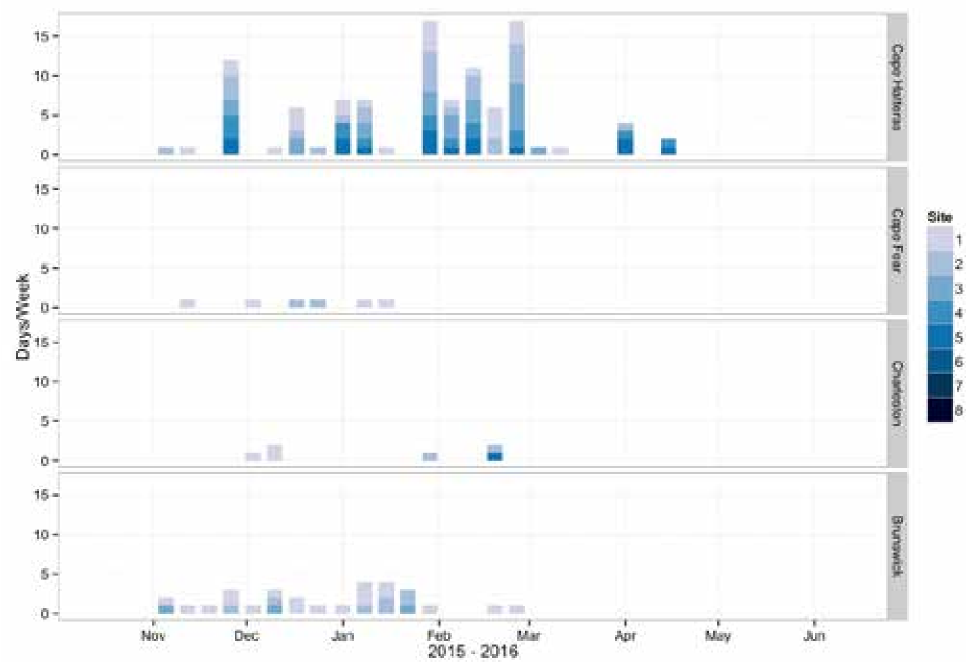


Figure G2. Number of days per week with right whale acoustic presence documented on bottom-mounted recorders deployed from Cape Hatteras, NC, to Brunswick, GA. Each line of recorders included 5-8 units; total number of days per week per recorder are displayed here. Recorder site indicated by color shading, with site 1 being closest to shore.



Appendix H: *Progress on analyses of oceanographic, acoustic, and plankton data: Northeast Fisheries Science Center*

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SUMMARY

To gain a better understanding of the underlying processes that may drive the distribution and abundance of predators, such as marine mammals, sea turtles, and sea birds, the relationships between hydrographic characteristics of the water column and distributions of lower trophic level organisms, such as fish and plankton, are being compared to the distribution patterns of the above protected species predators. During 2016 new active acoustic backscatter data and plankton samples and images were collected during the Northeast AMAPPS shipboard data during July to August 2016 (see Appendix A for details). Since that survey some of these summer 2016 data have been further analyzed and are reported here. The 2016 VPR data indicate the salp species composition and distribution differ from patterns from previous years. The 2016 ichthyoplankton data from Neuston and bongo samples showed numerous blue fin tuna (*Thunnus thynnus*) larvae were present, indicating the larval tuna found in 2013 was not a onetime occurrence. Further genetic species identifications need to be made to determine if this is a new tuna population or an already recognized southern population that has moved northward. In addition, during 2016 analyses integrating the physical and biological prey data with the marine mammal data using previously collected data were continued.

BACKGROUND AND OBJECTIVES

One of the objectives of the AMAPPS initiative is to develop spatially explicit density maps of cetaceans, sea turtles, and sea birds that incorporate environmental habitat characteristics. To describe the environmental habitat characteristics of the marine mammals, sea turtles, and sea birds detected on the shipboard surveys, environmental sampling procedures were designed to determine distributions of lower trophic levels and physical oceanography. Hydrographic, active acoustic and plankton data were previously collected during the 2009, 2011, 2013, 2014, and 2015 on AMAPPS Northeast Fisheries Science Center (NEFSC) surveys.

DATA COLLECTION AND PROCESSING

Active acoustic, plankton and physical oceanographic data were collected during the 2016 NEFSC summer AMAPPS marine mammal, sea turtle and seabird shipboard survey, as detailed in Appendix A of this document. In summary, during the day and night active acoustic sampling and 411 sampling events were completed. This included 189 casts of the 19+CTD (conductivity, temperature and depth sensor), 119 bongo deployments, 26 visual plankton recorder (VPR) hauls, deployments, 42 neuston deployments, and 35 midwater trawls. The processing status of data collected in 2016 is presented in Table H1. Additional analyses of these new data and previously collected data are discussed next.

ANALYSES

Analyses, additional to those conducted on the ship (Appendix A), that have been conducted in 2016 includes further processing of the VPR data, further processing of the ichthyoplankton data from the neuston and bongo samples, and work integrating prey and marine mammal distributions.

VPR (Legs 1 and 2)

While on the shipboard survey in the summer of 2016, regions of interest in the images were identified to large taxonomic groupings by Visual Plankton software (developed by Cabell Davis of the Woods Hole Oceanographic Institution) then hand corrected to smaller categories to better quantify gelatinous zooplankton and dominant species.

Since then the compressed data from the VPR were downloaded to specialized image processing computers. Data were decompressed, oceanographic data files were created, and in focus regions of interest (ROIs) were extracted from each image frame using Autodeck programming from Seascan. Interpolated profiles of temperature, salinity, density, raw chlorophyll and raw turbidity values were created for each tow-yo type haul using MATLAB. Hauls from Leg 2 had only temperature, salinity, and density profiles due to a cable failure. Each haul's ROI set was processed to remove images taken during deployment and retrieval. ROI sets were further processed to remove duplicate images caused by frame overlap or multiple grabs of larger taxa such as salps. ROIs were then identified to general taxonomic grouping using a modified version of Visual Plankton. In the lab hauls have been hand corrected to create more specific categories of targeted and dominant species.

The salp species identified during 2016 were notably different from previous years (Table H2), where *Iasis zonata* and *Cyclosalpa* sp were identified for the first time on an AMAPPS summer cruise which have been in similar areas and times of the year.

Also during 2016 the chain form of another salp species, *Thetys vagina* (Figure H1), was captured by the midwater trawl, but not imaged by the VPR. Because *T. vagina* aggregate forms (blastozoid) create chains many meters in length, they are too large to be captured by any type of plankton net or VPR used on these cruises.

Physical oceanographic characteristics measured from a pair of VPR tows north through the center of Atlantis Canyon, near the Pioneer Array, were recently post-processed and revealed a tidal front highlighting the complex oceanography possible in the canyons (Figure H2).

BLUEFIN TUNA (Legs 1, 2, & 3)

Ichthyoplankton removal and enumeration from neuston and bongo samples continues. Samples with the highest probability of the presence of tuna (*Thunnus thynnus*) larvae are being given priority (Figure A24 in Appendix A). Numerous tuna larvae have been found in the samples that have been processed indicating the larval tuna found in 2013 was not a onetime occurrence (Richardson *et al*. 2016). Larvae from the neuston net will be shared with other NMFS centers and academics. These larvae will be genetically analyzed to confirm species identification and provide population information. Selected larvae will have their otoliths removed to determine their age.

Once all samples have been processed, the distribution data will be used to begin to delimitate the east coast spawning area and to confirm/disprove the theory that the Gulf Stream transported the larvae from their known spawning areas in the Florida Straits and Gulf of Mexico. The genetic data will show whether this is a new population or an already recognized southern population that has moved north, possibly due to the effects of climate change.

RELATING PREY TO MARINE MAMMAL DISTRIBUTION

Work has begun to relate marine mammal presence to prey density in the shelf-slope frontal region, where prey density is determined through the use of multifrequency echosounder data (EK60). The aim is to explain some degree of the patchiness seen in the marine mammal distribution by the potential prey distribution that was documented in the echosounder data. These echosounder data were also complemented by other types of data collected by CTDs, XBTs, VPR, and net tows. As part of a recently completed PhD thesis (LaBrecque 2016) the Mid-Atlantic Bight shelf break region was targeted to investigate this relationship because of the high biodiversity of marine mammals and the increased heterogeneity of the EK60 data. In addition, another PhD thesis project has started work on this same general topic.

LaBrecque (2016) processed the EK60 data to classify organism types by following the methods outlined in Jech and Michaels (2006). The spatial distributions of these organism types were related to the dynamic hydrographic processes of the shelf-slope region, and finally the coupled active acoustic and hydrographic data were related to marine mammal distributions which ultimately described the fine scale distribution of marine mammals in a rich ecosystem context (Figure H3).

The general plans of the other PhD project are to use methods from Trenkel and Berger (2013) on the EK60 data from some of the 2010 – 2016 NE shipboard surveys to classify organism types into at least four major scattering groups using distinctive acoustic frequency responses from each group (Figure H4). The groups include gas-filled swimbladder-bearing fish, small gas bearing organisms such as larval fish or phytoplankton, fluid-like zooplankton such as copepods and euphausids, and larger fish without a swimbladder, such as mackerel. Further classification algorithms are planned to be developed to examine beaked whale prey at depth because not all the frequencies used in the Trenkel and Berger (2013) algorithm reach the depth at which beaked whales feed. The visual survey track lines will then be processed to identify schools of prey and quantify prey density, biomass, and prey depth. The spatial scale of these prey fields will be examined along with those of marine mammal observations. By providing information on spatial scales of observations along the trackline, this research will provide insight into the optimal spatial scales for modelling marine mammal distribution. These echosounder data will also be complemented by data collected by CTDs, XBTs, VPR, and net tows. In addition to the visual marine mammal sightings data, it is proposed to use the passive acoustic detections to develop multi-species or multi-guild habitat models for the shelf break region along the track lines. These models will be based primarily on measures of prey in the water column in an attempt to discern ecological niches. They would complement current abundance models like those described in Appendix F and in the future could provide a prey component that could be incorporated as an additional parameter into current abundance model techniques.

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Table H1. Processing status of oceanographic and plankton samples collected in summer 2016. Identified = sample is processed but data have not yet been posted to a public database, shipped = sample is in Poland being identified, in progress = samples are being processed.

Sampling Type	Leg 1	Leg 2	Leg 3	Total	Status
911+CTD					
Profile		1		1	in progress
Water		14		14	in progress
CTD 19/19+					
Profile	1	6	1	8	in progress
With gear	86	47	52	185	in progress
Water	13	15	19	47	in progress
Bongo					
6B3I	45	32	42		in progress
6B3Z	45	32	42	119	shipped
Neuston					
Oblique	25	5	12	42	in progress
VPR					
Tow-yo	12	8		20	identified
Single depth	4	2		6	identified
Midwater trawl		35		35	identified

Table H2. Salp populations detected along the northeastern Atlantic determined from net and VPR sampling during 2009 – 2016.

Area	2009	2011	2013	2015	2016
Georges Bank shelf break					
	Thalia democratica	*Thalia democratica*	*Salpa aspera, Thalia democratica*	*Salpa aspera*	dolids, *Salpa aspera, Salpa fusiformes,Thetys vagina, Iasis zonata*
Nantucket Shoals					
	-	-	*Thalia democratica*	-	*Salpa aspera, Thalia democratica*
Mid-Atlantic Bight shelf break and offshore					
	Thalia democratica	*Thalia democratica*	dolids, *Salpa aspera*	-	dolids, *Salpa aspera, Cyclosalpa sp, Thetys vagina*

Figure H1. *Thetys vagina*, solitary form (oozoid).

Figure H2. Temperature (top) and salinity (bottom) patterns as measured on VPR hauls number 17 (left) and 18 (right) that were towed approximately 8 nm north though the middle of Atlantis Canyon. Bottom depths started at 1712 m and ended at 356 m.

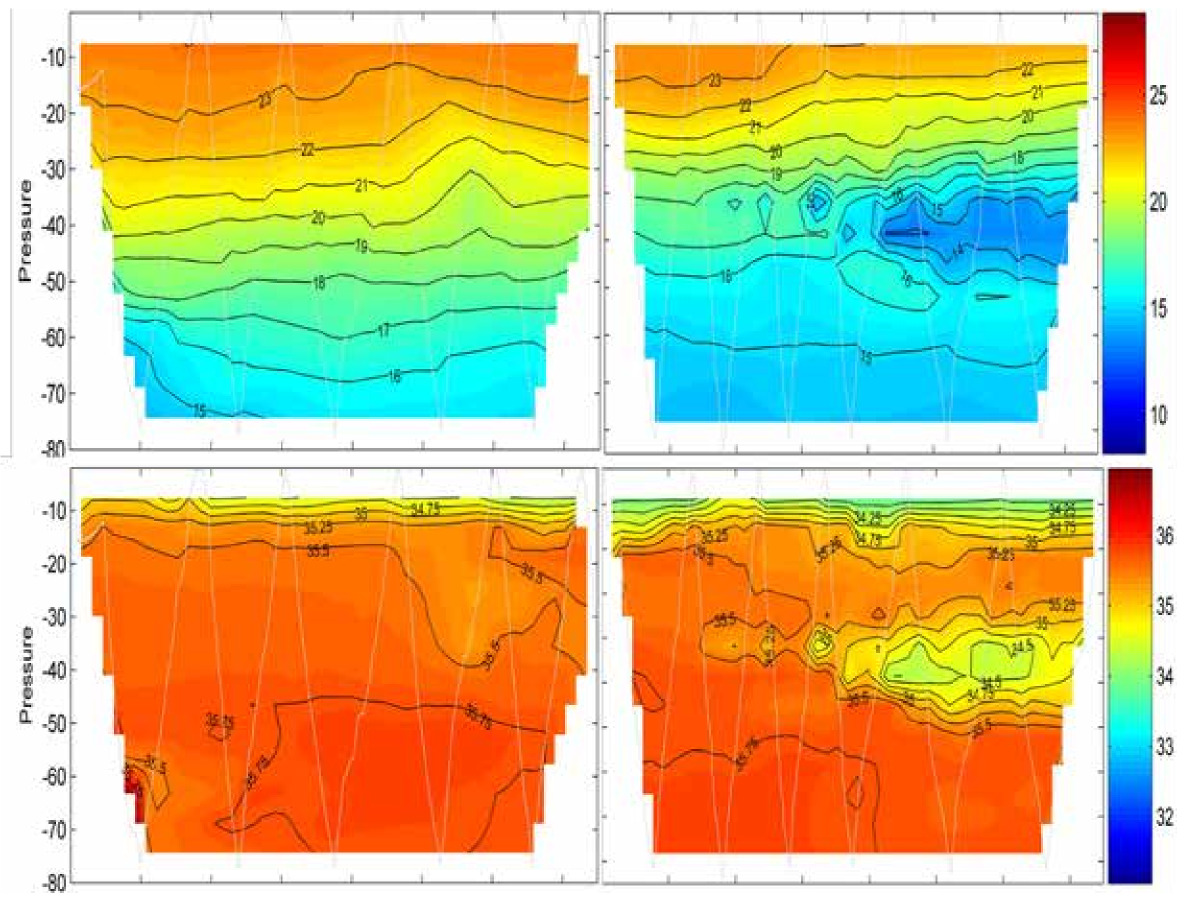

Figure H3. Categorized backscatter, water temperature and presence of marine mammals from a shelf break transect of Georges Bank. The intense colored backscatter patterns represent potential prey. Light blue are hypothesized to be Atlantic herring or in general fish with swimbladders. Dark blue and red are assumed to be Euphausiids or shrimp. The black band across the surface is the upper 10 m of the water column that was removed due to low quality of backscatter information. The black contour line overlays are contours of the water temperature (°C). Groups of marine mammals are indicated as symbols above the water column.

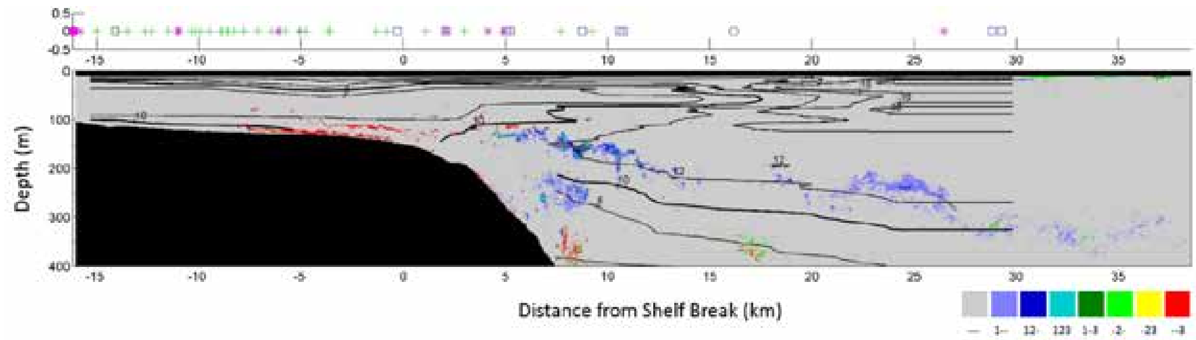

Figure H4. Example of preliminary classification of organism types following the methods outlined in Trenkel and Berger (2013) who classified organisms into four major scattering groups using distinctive acoustic frequency responses from each group.