2018
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*). Photo taken by Salvatore Cerchio.

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1.1 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. 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 National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) has inter-agency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy. The 2018 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 2018.

1.2 Summary of 2018 Activities

During 2018 under AMAPPS, NMFS conducted field studies to collect cetacean, sea turtle, seal, and sea bird seasonal distribution, abundance and biological data (Table 1.1). In addition, NMFS staff continued to analyze past and present data collected under AMAPPS I and II (Table 1.2), resulting in papers (Table 1.3) and presentations (Table 1.4). A summary of the 2018 projects follows, with more details in the following chapters.

1.2.1 Field Activities

During 18 October 2017 – 04 January 2018, the NEFSC and SEFSC conducted two aerial line transect abundance surveys covering US Atlantic waters from Florida to Maine, from the coastline to shelf break at about the 2000 m depth contour. The surveys using NOAA Twin Otter airplanes targeted marine mammals and sea turtles (Figure 1.1; Table 1.5). In total the two planes completed about 15,250 km of on-effort track lines. The observers detected about 480 groups of cetaceans consisting of about 4,800 individuals from 17 species or species groups and about 560 groups consisting of about 600 individual sea turtles from 5 species or species groups. The most frequently detected dolphins were common dolphins (*Delphinus delphis*) and common bottlenose dolphins (*Tursiops truncatus*). The most frequently detected large whales were humpback whales (*Megaptera novaeangliae*) and minke whales (*Balaenoptera acutorostrata*). Of interest are the groups of pygmy sperm whales (*Kogia breviceps*) and beaked whales (Ziphiidae). The most frequently detected turtle species was the loggerhead turtle (*Caretta caretta*), with about 200 individuals that ranged from 30°N – 41°N mostly in waters on the continental shelf with large aggregations off Georgia/northern Florida, North Carolina/Virginia, and Long Island, NY. All visual line-transect data have been or will be archived in the NEFSC Oracle data base, the NOAA Fisheries InPort and submitted to the publically available OBIS-SEAMAP website. More information is found in Chapters 2 and 3.

During May, June, July, August, September and November 2018, visual detection data of primarily seabirds, but also marine mammals, turtles, and large pelagic fish were collected during 7 cruises including spring, summer and fall Ecosystem Monitoring (EcoMon) cruises and a deep diving cetacean ecology cruise. To further utilize the NOAA ships to survey additional habitats in a variety of seasons, observers also collected data while the ship was transiting between scientific cruises. These surveys covered waters from Maine in the Atlantic Ocean to Louisiana in the Gulf of Mexico. The 300 m strip transect methodology was used to collect the data by one or two on-effort observers when the ship was travelling during daylight hours. During these cruises over 10,700 sightings of birds and other marine megafauna were recorded in the survey zone and 18,021 in total. All data are archived in the NEFSC Oracle data base and submitted to the Seabird Compendium who will also submit it to the publically available OBIS-SEAMAP website. More information is found in Chapter 4.

During 3 – 8 April 2018, the National Science Foundation ship *R/V Endeavor* operated by the University of Rhode Island (URI) conducted a Rhode Island Endeavor Program (RIEP) research cruise intended to explore marine mammal distribution, in particular the North Atlantic right whale (*Eubalaena glacialis*), relative to prey layers and physical oceanography south of New England in wind energy regions. AMAPPS contributed contractor funds for one marine mammal observer and partial time for one staff member to run a Video Plankton Recorder (VPR). In the waters surrounding two right whale sightings *Calanus finmarchicus* and ctenophores (*Pleurobrachia*) were detected using the VPR, bongo nets and active acoustics collected with a tow body equipped with 38, 120, and 206 kHz EK60 transducers. To descript the physical oceanographic features the following sampling methods were used: CTDs (Conductivity Temperature Depth sensor), XBTs (expendable bathythermograph), ADCP (Acoustic Dopler Current Profiler), and underway thermosalinograph (TSG) temperature and salinity data. All visual line-transect data have been or will be archived in the NEFSC Oracle data base and submitted to the publically available OBIS-SEAMAP website. More information is found in Chapter 5.

Leatherback tagging occurred during May 2018 in North Carolina where seven turtles were tagged with towable GPS tags. Turtles remained in the mid-Atlantic and will provide extremely important surfacing time data to be used to improve abundance estimates derived from aerial surveys. One leatherback was tagged in August in Cape Cod Bay, MA as well. More information is found in Chapter 6.

During 20 July – 19 August 2018, NEFSC and partners conducted a shipboard survey primarily on the region offshore of Georges Bank to test and integrate multiple new technologies to assess the ecology and distribution of deep diving cetacean species, such as beaked whales and sperm whales (*Physeter microcephalus*). This survey focused primarily on True's beaked whale (*Mesoplodon mirus*) habitat. The scientific crew included a visual observation team scanning for marine mammals and sea turtles, an additional observer collecting data on avian sightings, and a passive acoustic team monitoring a towed hydrophone array. New technologies that were tested on this survey included: a prototype tetrahedral passive acoustic array to conduct 3-D localization of vocalizing animals, drifting autonomous recording buoys with suspended hydrophone arrays, and a deep-water passive acoustic mooring deployed in water depths over 2000 m. Additionally, water samples were collected to conduct baseline testing of the efficacy of environmental DNA (eDNA) as a sampling tool within the vicinity of known cetacean groups. Approximately 3900 km were surveyed by the marine mammal visual team; passive acoustic data were collected over an additional 570 km. CTD data were collected at 8 stations, with bongo sampling conducted at 5 stations to assess the presence of larval bluefin tuna (*Thunnus thynnus*), and water samples collected at 3 stations to test for cetacean eDNA at depths up to 1500 m. Fifteen paired water samples were collected from the vicinity of 3 species of cetacean groups for eDNA testing. Seven biopsies were collected; four from True's beaked whales and 3 from other species. Focal follow data were collected for approximately 10 different True's beaked whale groups. One digital acoustic recording tag (DTAG) was deployed on a True's beaked whale for approximately 13 hrs, during which time data were recorded from 9 foraging dives. More information is found in Chapter 7.

1.2.2 Analyses

Satellite-linked telemetry tags that were attached to loggerhead sea turtles were analyzed to estimate their distribution and relative density (Winton et al. 2018; Table 1.3). Some of the telemetry loggerhead turtle tags also collected temperature-depth profiles which provided information on how the animals utilized the water column and provided a unique dataset on fine scale in-situ measurements that can be used to improve oceanographic models (Patel et al. 2018; Table 1.3). More information is found in Chapter 6.

One of the AMAPPS objectives is to assess the population size of surveyed species at regional scales and develop models and associated tools to translate these survey data into seasonal, spatially-explicit density estimates and maps incorporating habitat characteristics. In 2018 to achieve these objectives, the 2017 aerial survey data were error-checked, integrated with the rest of the survey data, and archived in the NEFSC Oracle database and at the OBIS-SEAMAP website. The spatially- and temporally-explicit habitat-density models developed from data from 2010-2013 are being updated using all data up to 2018 and include several new environmental variables: chlorophyll fronts, SST fronts, North Atlantic oscillation index and distance to the Gulf Stream north and south walls. The different versions and different options of the R package "mgcv" were extensively evaluated to determine the effects on the results of the density-habitat models. To account for grid cells that have very low survey effort and so can unduly impact the density estimate, an algorithm was developed to reallocate survey effort and sightings from cells with less than 1 km for shipboard surveys and 2 km for aerial surveys to neighboring cells on the same track line. Additional streamlining of the scripts to input, output and process the data have made the process more flexible and robust. The 2016 shipboard and aerial survey data were analyzed using design-based Distance methods to estimate abundance of 27 species and have been incorporated into the draft Atlantic Stock Assessment Reports. The model that integrates visual line transect and passive acoustic data to estimate a dive time adjusted abundance estimate for sperm whales is continuing to be developed and has been expanded to also analyze beaked whale passive acoustic and visual sightings data. More information is found in Chapter 8.

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 visually, or in times of year and regions where visual surveys are not conducted. In 2018, there were several ongoing primary analyses involving bottom-mounted recorder data and towed hydrophone array data collected during AMAPPS surveys. These are: (1) documenting distribution of baleen whales along the eastern seaboard continental shelf and shelf break, with results presented for North Atlantic right whales, sei whales (*Balaenoptera borealis*), and blue whales (*Balaenoptera musculus*); (2) assessing the acoustic ecology of shelf break habitats, including the temporal and spectral overlap between cetacean species groups and anthropogenic noise; and (3) quantifying acoustic detection rates and acoustic characterization of beaked whales recorded on towed hydrophone arrays, with the goals of comparing to visual detection rates and compiling sufficient data for acoustic abundance estimation for these taxa. In addition, work is continuing on the Tethys acoustic database in collaboration with scientists from San Diego State University, Scripps Institution of Oceanography and the NOAA Science Centers. More information is found in Chapter 9.

Table 1.1. General information on the Atlantic Marine Assessment Program for Protected Species (AMAPPS) 2017/2018 field data collection projects: the project name (principal investigating center), platforms used, dates and general location of the field study, and the chapter within this document where more information on the project can be found.

2017/18 field collection projects	Platform(s)	Dates	Location	Chapter
Fall abundance survey (SEFSC)	NOAA Twin Otter airplane	18 Oct – 20 Nov 2017	Continental shelf waters from New Jersey to Florida	2
Fall abundance survey (NEFSC)	NOAA Twin Otter airplane	21 Nov 2017 – 04 Jan 2018	Continental shelf waters from New Jersey to Maine	3
Rhode Island Endeavor Program research survey	R/V *Endeavor*	3 Apr – 8 Apr 2018	South of Massachusetts on shelf break	5
Tag loggerhead turtles	F/V *Kathy Ann*	20 May – 26 May 2018	Mid-Atlantic and Gulf Stream waters	6
Tag leatherback turtles	Small boats	Day trips in May and August 2018	Off North Carolina and Massachusetts, respectively	6
Ecosystem monitoring seabird survey	NOAA Ship *Henry B. Bigelow*	23 May – 05 Jun 2018	Maine to Delaware on shelf	4
Ship transit seabird survey	NOAA Ship *Gordon Gunter*	11 Jul – 16 Jul 2018	Rhode Island to Florida on shelf break	4
Deep diving cetacean ecology cruise	NOAA Ship *Gordon Gunter*	20 Jul – 19 Aug 2018	Southern Georges Bank on shelf break	4 and 7
Ship transit seabird survey	NOAA Ship *Henry B. Bigelow*	01 Aug – 06 Aug 2018	Rhode Island to Bahamas	4
Ecosystem monitoring seabird survey	NOAA Ship *Gordon Gunter*	22 Aug – 30 Aug 2018	Georges Bank and Mid-Atlantic to North Carolina	4
Ship transit seabird survey	NOAA Ship *Gordon Gunter*	02 Sep – 09 Sep 2018	Louisiana to North Carolina in Gulf of Mexico and Atlantic shelf	4
Ecosystem monitoring seabird survey	R/V *Hugh R. Sharp*	01 Nov – 13 Nov 2018	Rhode Island to North Carolina on shelf	4

Table 1.2. A brief description of the purpose of the Atlantic Marine Assessment Program for Protected Species (AMAPPS) analysis projects that occurred during 2018 and the chapter where more information can be found.

2018 Analysis Projects	Purpose	Chapter
Compare cetacean distribution to ecosystem characteristics	Process active acoustic backscatter data (represents middle level trophic level taxa), and plankton/fish data collected from samples to compare to distributions of marine mammals	5
Distribution and ecology of sea turtles	Document distribution and ecology of loggerhead and leatherback turtles equipped with satellite tags	6
Spatially- and temporally-explicit density models and abundance estimates	Improve Bayesian hierarchical and generalized additive model methodology to quantify relationship between marine mammals and sea turtles and habitat	8
Estimate abundance for Stock Assessment Reports	Using visual data from 2016 shipboard and aerial surveys estimate abundance of 27 species using design-based mark-recapture Distance methods	8
Process new survey data	Process, check quality and archive abundance survey and associated habitat covariate data	8
Acoustic and visual abundance estimate of sperm whales	Develop methods to estimate sperm and beaked whale abundance by integrating passive acoustic and visual sightings shipboard data	8 and 9
East Coast Migratory Corridor 2.0 project	Document migratory pathways of baleen whales along the eastern seaboard continental shelf and shelf break: right whales and sei whales	9
East Coast Migratory Corridor 2.0 project	Evaluate accuracy of automated detectors for North Atlantic blue whale song	9
Shelf Break Acoustic Ecology	Assess the temporal and spectral overlap between different cetacean species groups and anthropogenic activities, using HARP data collected along the shelf break	9
Distribution of beaked whales	Analyses of multiple AMAPPS datasets to assess the occurrence of beaked whales using towed hydrophone array data	9
Archive data	Archive sightings, passive acoustic, tag and ecosystem data	2-9

Table 1.3. List of 2018 published manuscripts involving data collected under AMAPPS

DeAngelis AI, Stanistreet JE, Baumman-Pickering S, **Cholewiak DM** 2018. A description of echolocation clicks recorded in the presence of True's beaked whale (*Mesoplodon mirus*). The Journal of the Acoustical Society of America, 144(5), 2691-2700.

Patel SH, Barco SG, Crowe LM, Manning JP, Matzen E, Smolowitz RJ, **Haas HL**. 2018. Loggerhead turtles are good ocean-observers in stratified mid-latitude regions. Estuarine, Coastal and Shelf Science 213: 128-136.

Virgili A, Authier M, Boisseau O, Canadas A, Claridge D, Cole, T, Corkeron P, Doremus G, David L, Di-Meglio N, Dunn C, Dunn TE, Garcia-Baron I, Laran S, Lauriano G, Lewis M, Louzao M, Mannocci L, Martinez-Dedeira J, **Palka D**, Panigada S, Pettex E, Roberts JJ, Ruiz L, Saavedra C, Begona Santos M, Van Canneyt O, Vazquez Bonales JA, Monestiez P, Ridouz V. 2018. Combining multiple visual surveys to model the habitat of deep-diving cetaceans at the basin scale. Global Ecol Biogeogr. 1-15.

Winton MV, Fay G, **Haas HL**, Arendt M, Barco S, James M, Sasso C, Smolowitz R. 2018. Estimating the distribution and relative density of tagged loggerhead sea turtles in the western North Atlantic from satellite telemetry data using geostatistical mixed effects models. Mar Ecol Prog Ser 586: 217-232.

Winship AJ, Kinlan BP, White TP, Leirness JB, Christensen J. 2018. Modeling at-sea density of marine birds to support Atlantic marine renewable energy planning: Final report. U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Sterling, VA. OCS Study BOEM 2018-010. x+67 pp.

BOEM (Bureau of Ocean Energy Management). 2018. Findings from Atlantic Marine Assessment Program for Protected Species. BOEM Science Notes June 2018.

Field posts and press releases on various NEFSC AMAPPS field work 2011 - 2018.

Table 1.4. List of 2018 presentations involving data collected under AMAPPS

Allen CD, **Haas HL**, Smolowitz RJ, Patel SH, Seminoff JA. 2018. Corticosterone concentrations in migratory loggerhead sea turtles. Presentation at 38th Annual Symposium on Sea Turtle Biology and Conservation; Japan.

Davis G, **Cholewiak D**, **DeAngelis A**, **Weiss S**, Baumgartner M, **Gurnee J.** and others. 2018. Passive Acoustic Monitoring Projects: NOAA Northeast Fisheries Science Center. Talk presented at Marine Mammal Passive Acoustics and Spatial Ecology (MAPS) meeting, Duke University; May 2018.

Davis G, Baumgartner M, Johnson H, **Van Parijs S**. 2018. Catching up with the times: creating accessible, updates North Atlantic Right Whale presence tools. Talk presented at Right Whale Consortium; New Bedford, MA; November 2018.

Haas H. 2018. Collaborative turtle research in the greater Atlantic region. Presentation at the New York Bight Sea Turtle Workshop; New York; 30 January 2018.

Hernandez C, Richardson D, Rypina, I, Chen K, Pratt L, Llopiz, J. 2018. Larval habitat suitability for Atlantic bluefin tuna spawned in the Slope Sea. Poster at Ocean Sciences Meeting; Portland, Oregon; 12-16 February 2018.

Hernandez C, Richardson D, Rypina I, Chen K, Pratt L, Llopez J. Larval habitat suitability for Atlantic bluefin tuna spawned in the Slope Sea. Presented at the summer meeting of the Southern Northeast Chapter of the American Fisheries Society; 28 June 2018.

Palka DL, **VanParijs S**. 2018. Update on AMAPPS with focus on work in New York area. Presentation at the First Annual New York Bight Whale Monitoring Workshop; East Setauket, NY; 13 June 2018.

Palka DL. 2018. Marine mammals and surveys. Presentation at the New York State of the Science Workshop; Woodbury, NY; 13-14 November 2018.

Richardson D, Marancik K, Hernandez C, **Broughton E**, **Walsh H**. 2018. Atlantic tuna spawning off the Northeast US. 2018. Presentation at the summer meeting of the Southern Northeast Chapter of the American Fisheries Society; 28 June 2018.

Sigourney DB, **Cholewiak D**, **Palka D**. 2018. Integrating passive acoustic data with visual line transect surveys to refine population estimates and estimate availability bias for sperm whales (*Physeter macrocephalus)*. Presentation at the Science and Technology Protected Species Toolbox mini-symposium; San Diego, CA; 1 March 2018 and the DenMod meeting; San Diego, CA; October 2018.

Sigourney D, **Chavez-Rosales S**, **Palka D**, **Lance Garrison L**, **Josephson E**. 2018. Fitting a species distribution model to line transect data of humpback whales (*Megaptera novaeangliae*) in the western Atlantic using a Bayesian hierarchical framework: Implications for uncertainty. Presentation at the DenMod meeting; San Diego, CA; October 2018.

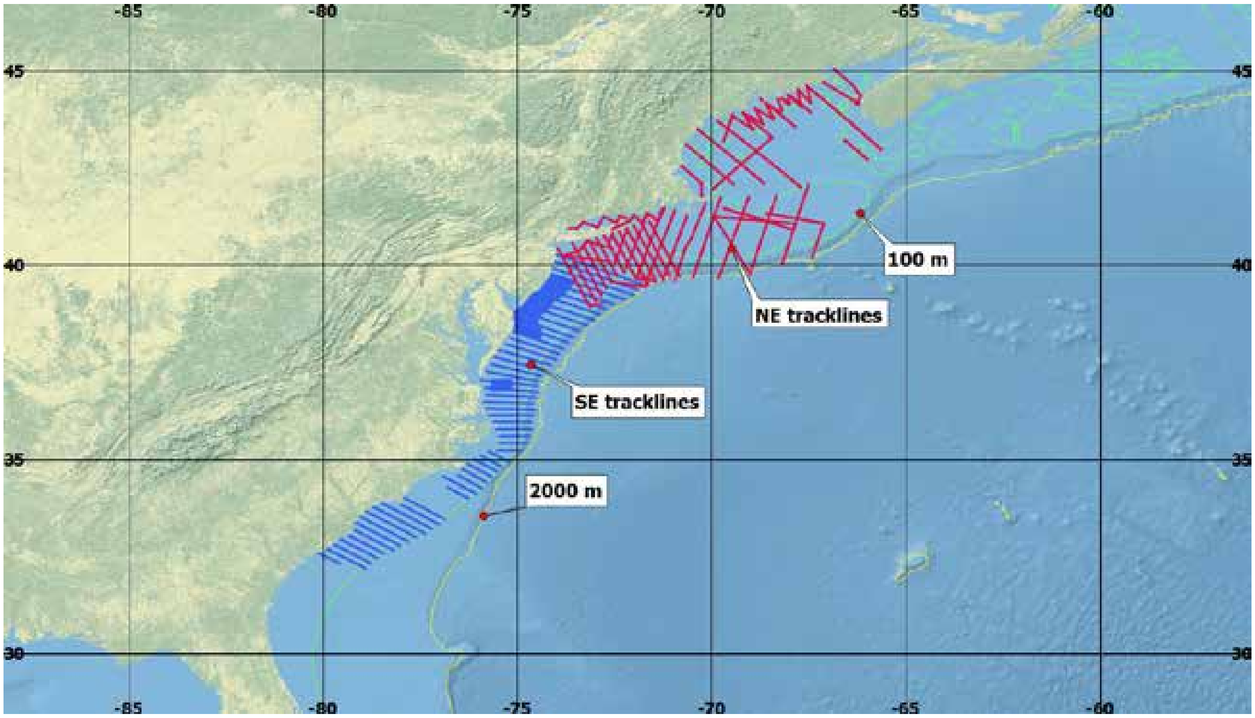
Van Parijs S, **Cholewiak D**, **Davis G**, **DeAngelis A**, **Weiss S**, **Gurnee J**. 2018. Atlantic species ecology and the effects of anthropogenic noise. Talk presented at Navy Species Monitoring Technical Review Meeting; San Diego, CA; March 2018.

Yang T, **Haas HL**, Smolowitz RJ, Patel SH, James MC, Williard A. 2018. Blood biochemistry and hematological reference intervals for migrating loggerhead turtles (*Caretta caretta*) in the Northwest Atlantic. Presentation at the Southeast Regional Sea Turtle Meeting; Myrtle Beach, SC.

Table 1.5 Detected species during the Southeast and Northeast Fisheries Science Centers' abundance aerial surveys, 18 October 2017 – 04 January 2018 and preliminary number of groups and individuals per species.

Species		Groups	Individuals
Atlantic spotted dolphin	*Stenella frontalis*	17	375
Common bottlenose dolphin	*Tursiops truncatus*	93	777
Atlantic spotted/bottlenose dolphin	-	3	28
Common dolphin	*Delphinus delphis*	121	2543
Common or white-sided dolphin	-	34	186
Risso's dolphin	*Grampus griseus*	9	22
White-sided dolphin	*Lagenorhynchus acutus*	14	75
Harbor porpoise	*Phocoena phocoena*	98	208
Fin whale	*Balaenoptera physalus*	4	4
Humpback whale	*Megaptera novaeangliae*	9	15
Minke whale	*B. acutorostrata*	5	5
Pilot whale spp	*Globicephaia spp*	18	239
Pygmy sperm whale	*Kogia breviceps*	1	1
Unid beaked whale	*Ziphiidae*	2	6
Stenella spp	*Stenella spp.*	2	9
Unid dolphin	*Delphinidae*	47	295
Unid large whale	*Mysticeti*	3	3
TOTAL CETACEANS	-	480	4,791
Leatherback turtle	*Dermochelys coriacea*	61	62
Loggerhead turtle	*Caretta caretta*	203	216
Kemp's ridley turtle	*Lepidochelys kempii*	10	10
Green turtle	*Chelonia mydas*	34	36
Unid hardshell turtle	-	256	277
TOTAL TURTLES	-	564	601

Figure 1.1. Track lines completed during 18 October 2017 – 04 January 2018 aerial surveys conducted by the Northeast and Southeast Fisheries Science Centers.



2 Southern leg of aerial abundance survey during Oct – Nov 2017: Southeast Fisheries Science Center

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2.1 Summary

As part of the AMAPPS program, the Southeast Fisheries Science Center conducted aerial surveys of continental shelf and slope waters (up to the 2,000 m isobath) along the US east coast from New Jersey to South Carolina. The survey was conducted 18 October – 20 November 2017 aboard a National Oceanic and Atmospheric Administration (NOAA) Twin Otter aircraft at an altitude of 600 feet (183 m) and a speed of 110 knots. Survey tracklines were oriented perpendicular to the shoreline and latitudinally spaced 20 km apart. Fine-scale tracklines were surveyed closer to the shores of New Jersey, Delaware and Virginia over renewable energy leasing areas. The survey was designed for analysis using Distance sampling and a two-team (independent observer) approach to correct for perception bias in resulting abundance estimates. A total of 7,502.7 km of trackline were surveyed on-effort on an average sea state of 2.5 on the Beaufort scale. Cetacean records totaled 132 sightings from at least seven different species (not including unidentified taxa). Nearly 60% of the sightings were of common bottlenose dolphins (*Tursiops truncatus*), followed by pilot whales (*Globicephala* sp.;14%) and Atlantic spotted dolphins (*Stenella frontalis*; 13%). Sea turtles totaled 555 sightings of four different species, with loggerhead turtles (*Caretta caretta*) accounting for 36% of all sightings. In addition, more than 45% of the sightings were of turtles classified as “Hardshell”. The data collected during this survey will be analyzed to estimate the abundance and spatial distribution of cetaceans and turtles along the US east coast.

2.2 Objectives

The goal of the survey was to conduct line-transect surveys using the Distance sampling approach to estimate the abundance and spatial distribution of cetaceans and turtles in waters over the continental shelf and slope (shoreline to 2,000 m isobath) of the eastern USA.

2.3 Cruise Period and Area

This survey was conducted 18 October – 20 November, 2017. The study area extended from New Jersey to South Carolina and up to the 2,000 m isobath. Additional effort was conducted in the inshore waters off New Jersey, Delaware and Virginia over renewable energy leasing areas (Figure 2.1).

2.4 Methods

The survey was 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 15 knots or approximately sea state 4 or less on the Beaufort scale. The survey was conducted along tracklines oriented perpendicular to the shoreline and spaced latitudinally at approximately 20 km intervals starting at a random point (Figure 2.1). Fine-scale tracklines over renewable energy leasing areas were spaced at approximately 5 km apart (Figure 2.1).

To conduct the survey, two pilots and two teams of three marine mammal observers each were onboard the airplane. Both teams operated independently to implement the independent observer approach to correct for visibility bias (Laake and Borchers 2004). The forward team (Team 1) consisted of two observers stationed in bubble windows on the left and right side of the airplane and an associated data recorder. The aft team (Team 2) consisted of a belly observer looking straight down through a belly port window, an observer stationed on the right side of the aircraft observing through a bubble window, and a dedicated data recorder. The side bubble window observers were stationed in large "vista" windows that provided downward visibility including the trackline while the belly observer can see approximately 35-40 degrees on either side of the trackline. Due to this configuration, the aft team had 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. Exceptionally on 20 November, due to staffing issues, the survey was flown with one team with four observers: left and right bubbles, belly and a data recorder.

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 trackline (0˚) to approximately 60˚ 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. The belly observer only reported the interval for the sighting based on markings on the window (1 thru 4 on the left or right). Fish species were recorded opportunistically.

Sea turtle sightings were recorded independently, without communication, by each team. For cetacean 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 sighting. Once both teams had the opportunity to observe the group, the observers asked the pilots to break effort and circle the sighting. The aircraft circled over the majority of the cetacean 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, an R script produced an output identifying unique turtle sightings that were seen by one or both teams based upon time, location, and position relative to the trackline.

2.5 Results

The survey was conducted 18 October – 20 November 2017, during 16 survey-days. A total of 7,502.7 km of trackline were surveyed on effort along 83 tracklines (Table 2.1, Figure 2.1). The average sea state during the survey was 2.5 on the Beaufort scale (Table 2.1, Figure 2.1).

A total of 132 cetacean sightings including 1,637 individuals were recorded (Table 2.2, Figure 2.2). The primary species observed was the common bottlenose dolphins (*Tursiops truncatus*) with 78 sightings and 725 individuals, followed by pilot whales (*Globicephala* sp.) with 18 sightings and 239 individuals and Atlantic spotted dolphins (*Stenella frontalis*) with 17 sightings and 375 individuals. Three sightings of six humpback whales (*Megaptera novaeangliae*) were also recorded.

There were a total of 555 unique sightings of sea turtles for a total of 592 individuals (Table 2.3, Figure 2.3). Loggerhead turtles (*Caretta caretta*) were the most commonly identified species with 201 sightings, followed by leatherback (*Dermochelys coriacea*) with 60 sightings and green turtles (*Chelonia mydas*) with 34 sightings. Kemp's ridley (*Lepidochelys kempii*) accounted for nine sightings. Unidentified hardshell accounted for 251 sightings.

Opportunistic fish species sighted included primarily ocean sunfish (*Mola mola*) with 132 sightings and 36 sightings of hammerhead sharks (*Sphyrnidae* spp.) (Table 2.4, Figure 2.4).

2.6 Disposition of Data

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

2.7 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).

2.8 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 National Oceanic and Atmospheric Administration (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.

2.9 References Cited

Laake JL, Borchers DL. 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 2.1. Daily summary of effort and sightings during the southeast aerial survey, fall 2017

Date in 2017	On Effort (km)	Number of Cetacean Sightings	Number of Turtle Sightings	Ave Sea State
18-Oct	772.5	5	14	3.3
19-Oct	635.3	9	33	3.1
20-Oct	200.2	2	7	4.0
21-Oct	900.3	16	142	1.9
22-Oct	657.3	10	63	2.7
27-Oct	976.8	8	75	2.6
28-Oct	462.0	10	25	2.5
31-Oct	447.7	15	50	2.2
1-Nov	426.3	1	37	2.4
2-Nov	45.3	0	12	0.8
7-Nov	491.3	16	22	0.0
12-Nov	378.7	2	28	1.8
13-Nov	144.1	6	19	3.6
16-Nov	408.1	16	12	2.8
18-Nov	499.3	15	14	2.6
20-Nov	57.5	1	2	2.9
TOTAL	7502.7	132	555	2.5

Table 2.2. Summary of cetacean sightings during the southeast aerial survey, fall 2017

Species	Number of Sightings	Number of Animals
Atlantic spotted dolphin	17	375
Bottlenose dolphin	78	725
Bottlenose/Spotted dolphin	3	28
Common dolphin	3	220
Humpback whale	3	6
Pilot whales	18	239
Pygmy sperm whale	1	1
Risso's dolphin	1	5
Stenella sp.	1	4
unid. dolphin	2	3
Unid. Mesoplondont	1	3
unid. odontocete	4	28
TOTAL	132	1637

Table 2.3 Summary of sea turtle sightings during the southeast aerial survey, fall 2017

Species	Number of Sightings	Number of Animals
Green Turtle	34	36
Hardshell	251	272
Kemp's Ridley	9	9
Leatherback	60	61
Loggerhead	201	214
TOTAL	555	592

Table 2.4 Summary of opportunisitic fish sightings during the southeast aerial survey, fall 2017

Species	Number of Sightings	Number of Animals
Hammerhead Shark	36	36
Manta Ray	2	3
Sunfish (*Mola mola*)	132	160
Unid. Ray	6	10
Unid. Shark	19	38
TOTAL	196	248

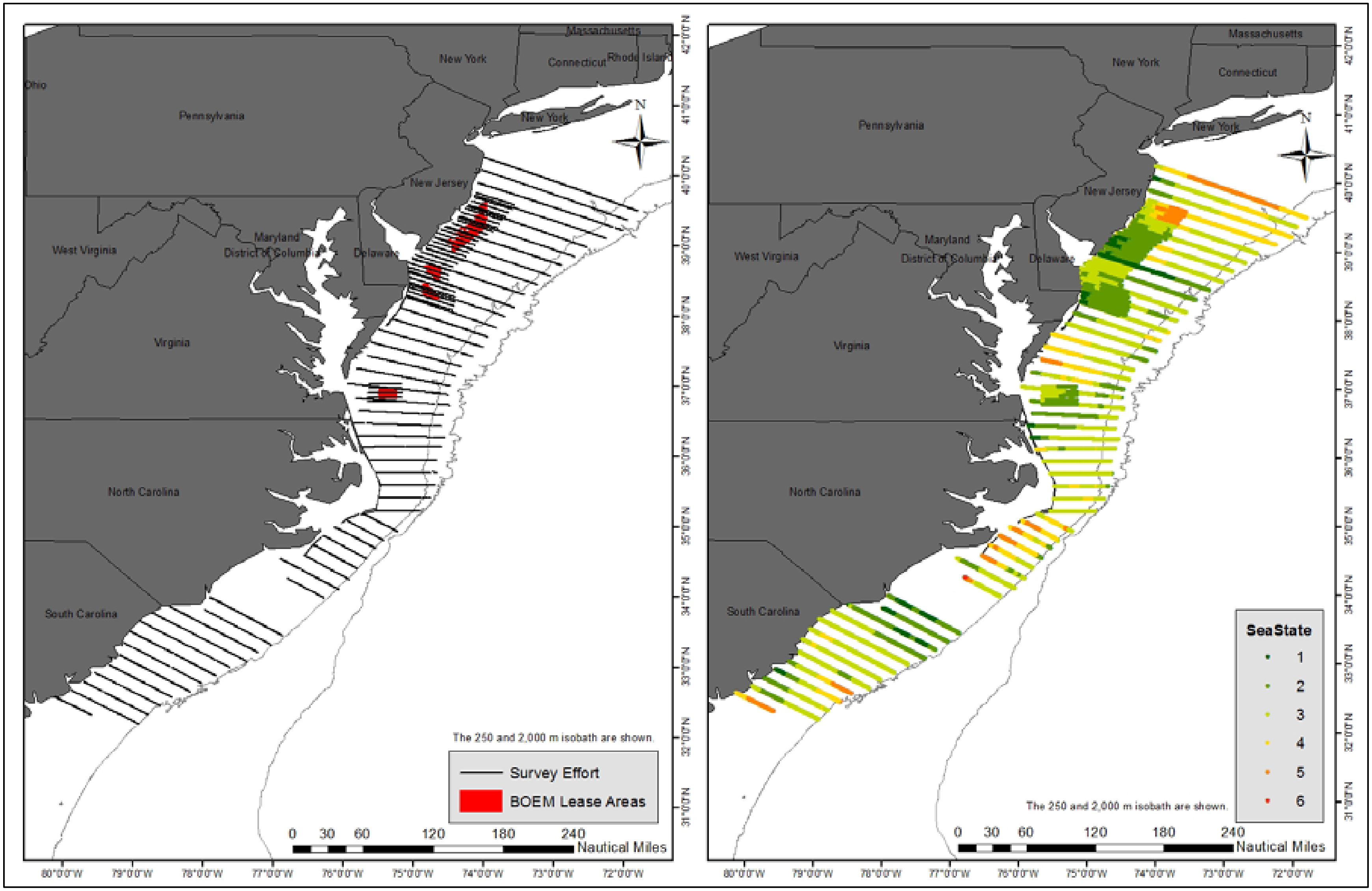

Figure 2.1 On-effort tracklines, renewable energy areas and sea state during southeast aerial survey, fall 2017

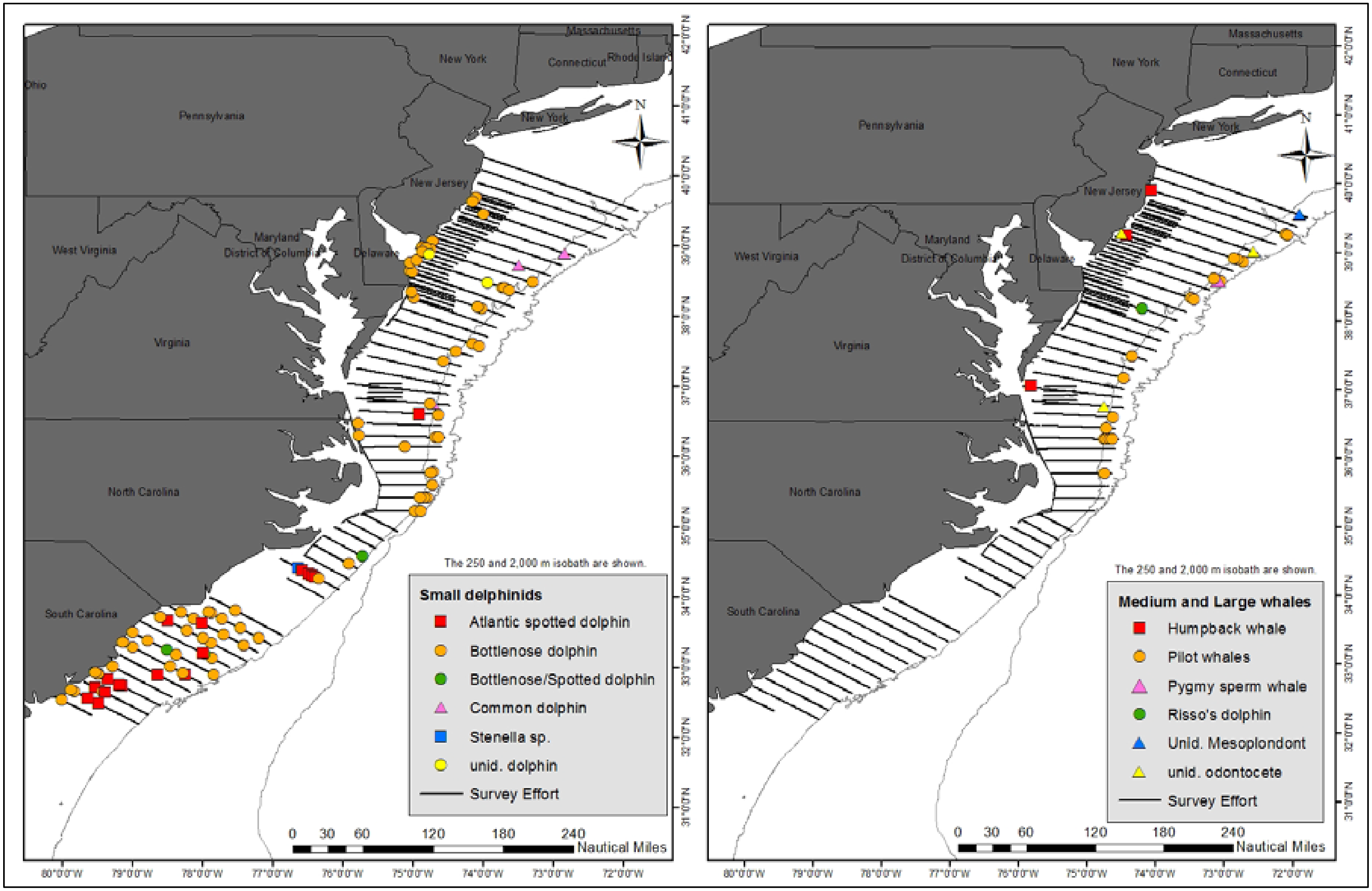

Figure 2.2 Cetacean sightings during the southeast aerial survey, fall 2017

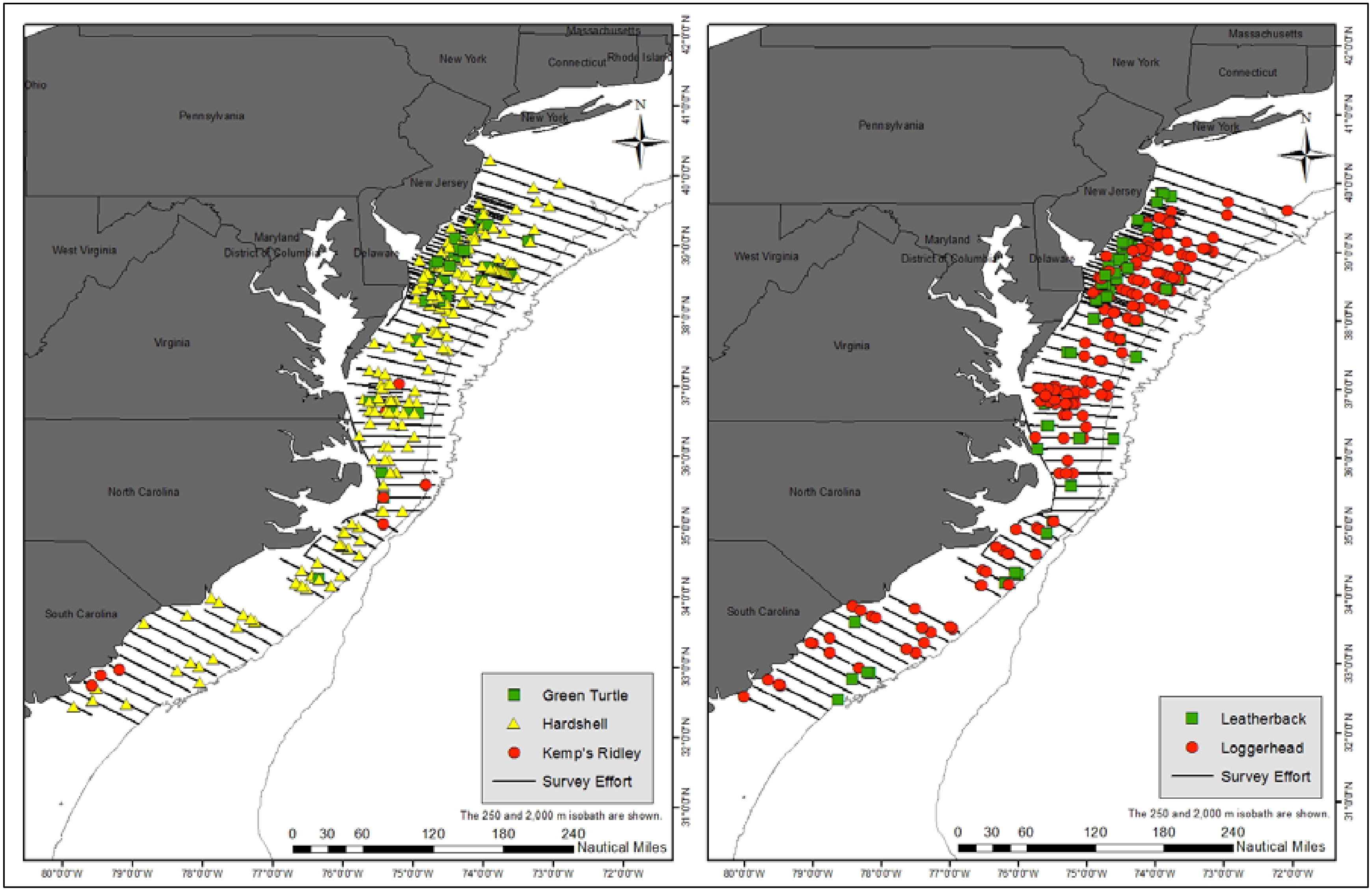

Figure 2.3 Sea turtle sightings during the southeast aerial survey, fall 2017

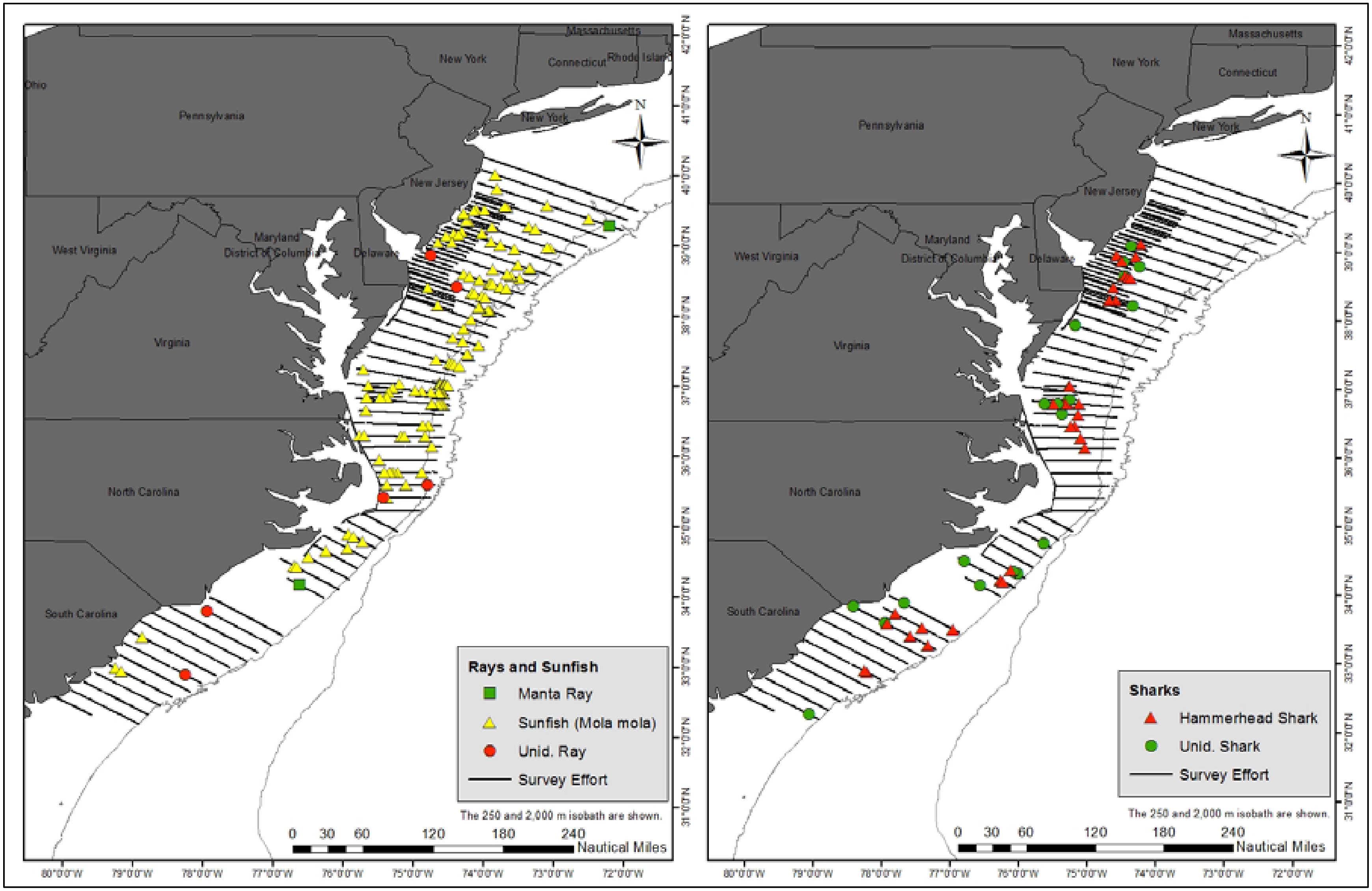

Figure 2.4 Opportunistic fish sightings durine the southeast aerial survey, fall 2017

3 Northern leg of aerial abundance survey during 21 November 2017 – 04 January 2018: Northeast Fisheries Science Center

Debra L. Palka

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3.1 Summary

During 21 November 2017 – 04 January 2018, 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 off of Nova Scotia, Canada in the Gulf of Maine. This survey covered waters from the coast line to about the 2000 m depth contour with a higher coverage over the New York State Offshore Planning Area. This survey coordinated with the southeast aerial survey that flew south of this study area in US waters. Track lines were flown 183 m (600 ft) above the water surface, at about 200 kph (110 knots). The two-independent team methodology was used to collect data. In Beaufort sea states of six and less, about 7,738 km of on-effort track lines were surveyed, where 93% of this effort was in Beaufort 3 and below. The front team detected 2,872 individual cetaceans from 271 groups. The back team detected 982 individual cetaceans from 161 groups. This was from 13 cetacean species or species groups. Common dolphins (*Delphinus delphis*) were the most frequently detected species. The most common large whale was humpback whales (*Megaptera novaeangliae*), though less than 10 individuals were detected. Only 9 turtles from 3 identified species and 1 species group were detected. In addition, seals and ocean sunfish (*Mola mola*) were also detected.

3.2 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.

3.3 Cruise Period and Area

This survey was conducted during 21 November 2017 – 04 January 2018. The study area extended from New Jersey to the waters south of Yarmouth, Nova Scotia, Canada, from the coast line to about the 2000 m depth contour (Figure 3.1). An associated aerial survey was conducted in US waters from New Jersey and south.

The proposed track lines covered the entire region using a broad scale strategy providing an overall spatial coverage. In addition the New York State Offshore Planning Area was surveyed at a higher coverage level.

3.4 Methods

The aerial surveys were conducted on a DeHavilland Twin Otter DHC-6 aircraft over Atlantic Ocean waters off the east coast of the U.S. and Canada. Track lines were flown 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.

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. 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 help 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 right and left bubble windows. The other team, the independent back team, consisted of one observer viewing through the back belly window, one observer viewing from the right back visa window, and a recorder. The two observer 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 bubble window and back side visa window observers searched from straight down to the horizon, with a concentration on waters between straight down (0º) and about 60º 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.

3.5 Results

The observers and pilots who collected these data are listed in Table 3.1.

Ten of the 39 possible flight days had sufficiently good weather to conduct the survey, in addition 1 day which had sufficiently good weather to look at seal haul out sites but not good enough to conduct an abundance survey was also flown over seal haul out sites. During the on-effort portions of the flights about 7,738 km of track lines were covered, where about 93% of the track lines were surveyed in Beaufort 3 and less (Table 3.2).

On the on-effort portions of the track lines, 982 and 2,872 individual cetaceans from 13 cetacean species or species groups that were within 161 and 271 groups were detected by the back and front teams, respectively (Table 3.3). In addition, seals, turtles, and several fish species were also identified (Table 3.4). The locations of sightings seen on the on- and off-effort transect legs, by species, are displayed in Figures 3.2 – 3.9, where identified dolphins and porpoises are in Figure 3.2 – 3.4, identified whales in Figure 3.5, and unidentified whales and dolphins in Figure 3.6. Ocean sunfish locations are depicted in Figure 3.7, turtles in Figure 3.8 and seals are in Figure 3.9.

By far, the most commonly detected species was the common dolphin (*Delphinus delphis*) who were seen everywhere from New York to Maine to Georges Bank. White-sided dolphins (*Lagenorhynchus acutus*), humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*) and ocean sunfish (*Mola mola*) were also spread out through the entire study area. Harbor porpoises (*Phocoena phocoena*) were prevalent, but in contract to their summer restricted distribution, at this time of the year they were spread out for Rhode Island to Maine. Risso's dolphins (*Grampus griseus*), most of the common bottlenose dolphins (*Tursiops truncatus*), and the single beaked whale group (*Ziphiidae*) were located on the deeper portion of the shelf edge.

At this time of year only a few turtles were detected. One leatherback turtle (*Dermochelys coriacea*) was on the northern edge of Georges Bank. The rest were seen south of New York or in Long Island Sound.

Seals were seen spread out from Long Island, NY, along Cape Cod, up to the coast of Maine, with a few on Georges Bank and farther offshore Maine.

3.6 Disposition of Data

All data collected during this survey will be maintained by the Protected Species Branch at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, MA and are available from the NEFSC's Oracle database. The line transect data are available on the OBIS-SEAMAP website.

3.7 Permits

NEFSC was authorized to conduct these research activities during this survey under US Permit No. 17355 issued to the NEFSC by the National Marine Fisheries Service Office of Protected Resources. The National Oceanic and Atmospheric Administration (NOAA) aircraft was granted diplomatic overflight clearance in Canadian airspace with the Overflight Clearance number 0696-US-2017-12-TC. The Species at Risk Management Division of the Canadian Fisheries and Oceans concluded a permit under SARA was not needed.

3.8 Acknowledgments

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 the 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.

3.9 References Cited

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Table 3.1 List of observers and pilots that participated in the November 2017 – January 2018 northeast aerial survey

Observer Names	Affiliation
Robert DiGiovanni	Integrated Statistics, Inc, Woods Hole, MA
Jen Gatzke	Integrated Statistics, Inc, Woods Hole, MA
Rachel Hardee	Integrated Statistics, Inc, Woods Hole, MA
Richard Holt	Integrated Statistics, Inc, Woods Hole, MA
Valentina Sherlock	Integrated Statistics, Inc, Woods Hole, MA
Karen Vale	Integrated Statistics, Inc, Woods Hole, MA
Peter Duley	Northeast Fisheries Science Center, Woods Hole, MA
Debra Palka	Northeast Fisheries Science Center, Woods Hole, MA
Christin Khan	Northeast Fisheries Science Center, Woods Hole, MA
Pilot Names	**Affiliation**
Connor Maginn	NOAA[1] Aircraft Operations Center, Tampa, FL
Shanae Coker	NOAA Aircraft Operations Center, Tampa, FL
Chris Woods	NOAA Aircraft Operations Center, Tampa, FL
Rick deTriquet	NOAA Aircraft Operations Center, Tampa, FL
Lindsay Norman	NOAA Aircraft Operations Center, Tampa, FL

[1]NOAA: National Oceanic and Atmospheric Administration

Table 3.2 Length of on-effort track lines (in km) surveyed by Beaufort sea state levels.

Feature	0	1	2	3	4	5	TOTAL
Track length (km)	0	471.1	2922.2	3793.5	442.6	108.7	7,738.1
Percent of total	0	6.09	37.76	49.02	5.72	1.4	100

Table 3.3 Number of groups (Grps) and individuals (Indiv) of cetaceans detected on-effort by the front and back teams. Some of the groups were seen by both teams

Common Name	Scientific Name	Grps Back	Grps Front	Indiv Back	Indiv Front
Common bottlenose dolphin	*Tursiops truncatus*	9	10	29	31
Common dolphin	*Delphinus delphis*	53	104	611	2,181
Common/white-sided	-	22	21	138	141
Risso's dolphin	*Grampus griseus*	4	6	10	14
White-sided dolphin	*Lagenorhynchus acutus*	6	10	57	56
Harbor porpoise	*Phocoena phocoena*	47	68	90	159
Fin whale	*Balaenoptera physalus*	2	3	2	3
Humpback whale	*Megaptera novaeangliae*	1	6	1	9
Minke whale	*B. acutorostrata*	2	3	2	3
Stenella spp	*Stenella spp*	1	0	5	0
Unid beaked whale	*Ziphiidae*	0	1	0	3
Unid dolphin	*Delphinidae*	13	37	36	270
Unid large whale	*Mysticeti*	1	2	1	2
TOTAL CETACEANS		161	271	982	2,872

Table 3.4. 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.

Common Name	Scientific Name	Grps Back	Grps Front	Indiv Back	Indiv Front
Leatherback turtle	*Dermochelys*	0	1	0	1
Loggerhead turtle	*Caretta caretta*	0	2	0	2
Kemp’s ridley turtle	*Lepidochelys*	1	1	1	1
Unid hardshell turtle	-	0	5	0	5
Blue shark	*Prionace glauca*	0	1	0	1
Ocean sunfish	*Mola mola*	3	8	3	9
Unid shark	-	2	1	2	1
Gray seal	*Halichoerus*	1	6	1	7
harbor seal	*Phoca vitulina*	0	4	0	5
Unid seal	*Pinnipedia*	45	74	48	102
TOTAL		213	374	1,037	3,006

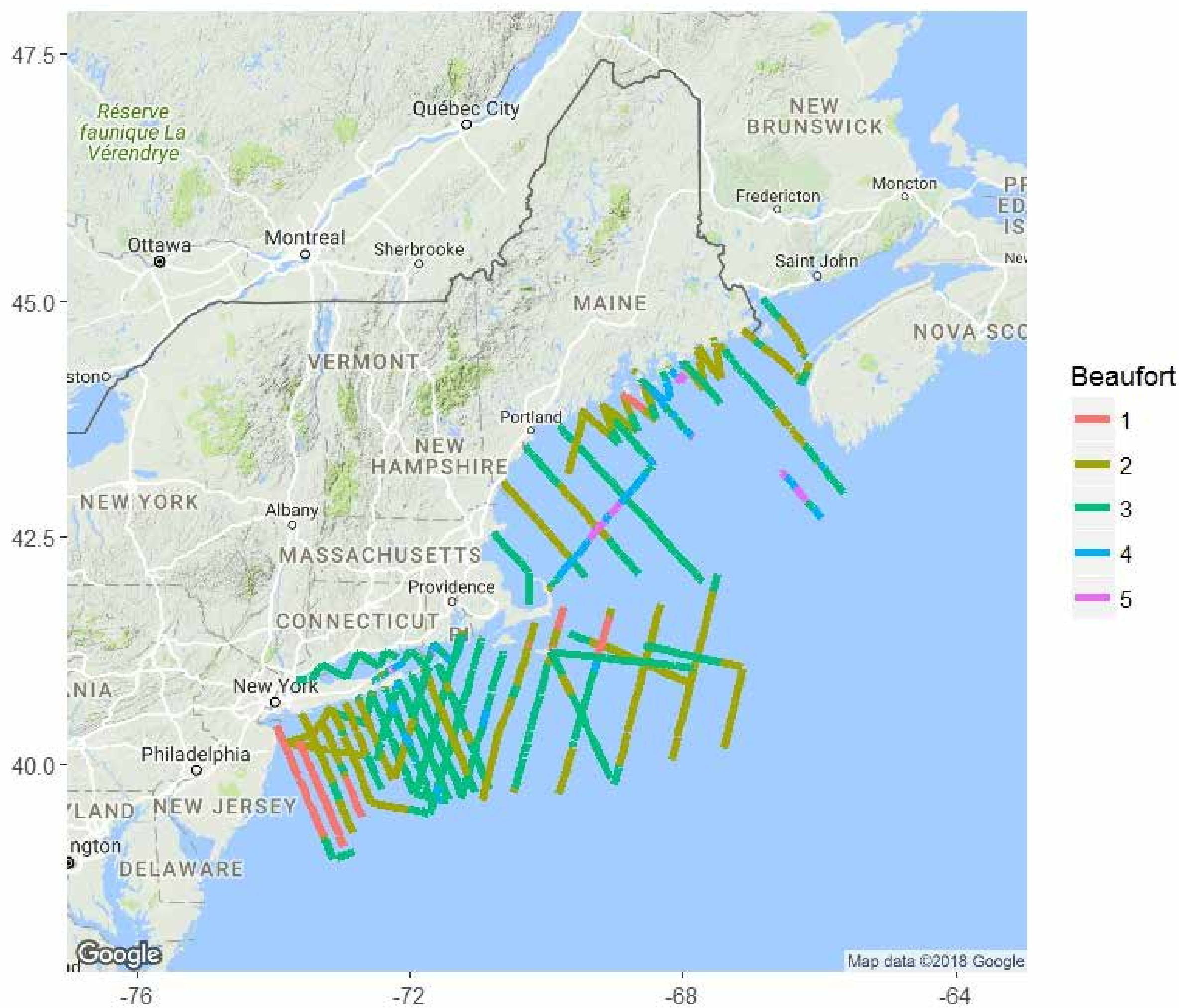

Figure 3.1 Completed on-effort track lines by Beaufort sea state

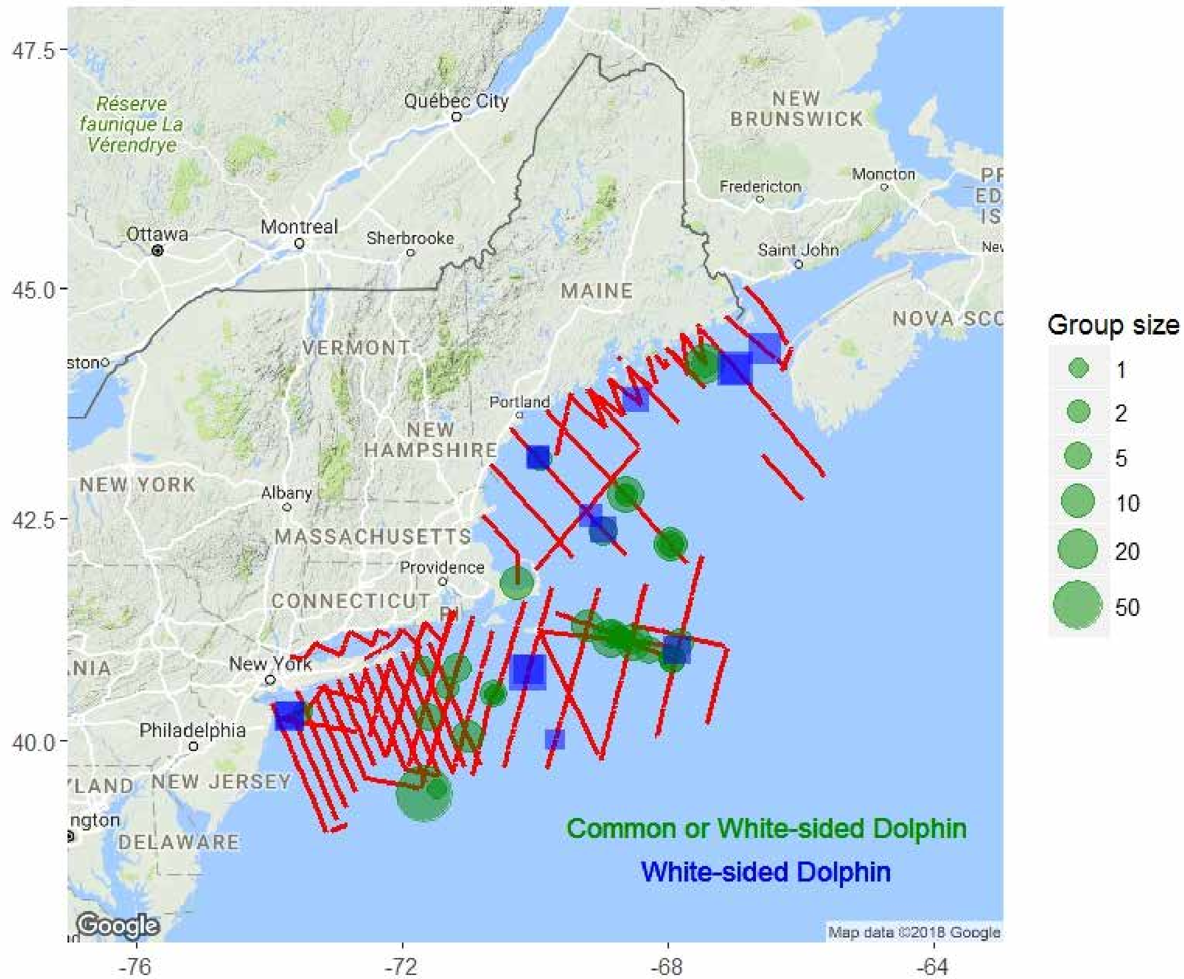

Figure 3.2 Locations of common dolphins (*Delphinus delphis*) and white-sided dolphins (*Lagenorhynchus acutus*) detected by either the front or bak team

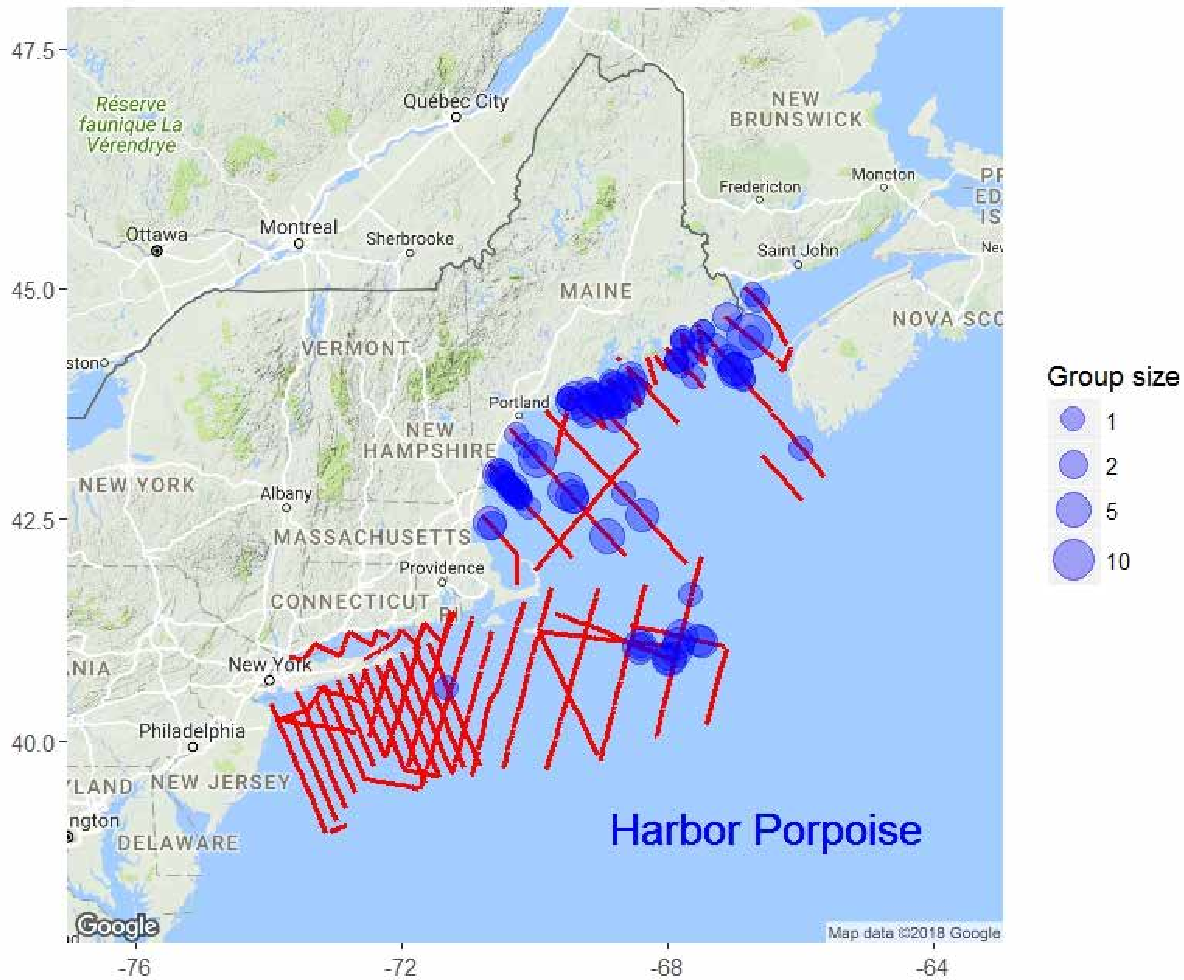

Figure 3.3 Locations of harbor porpoises (*Phocoena phocoena*) detected by either the front or back team

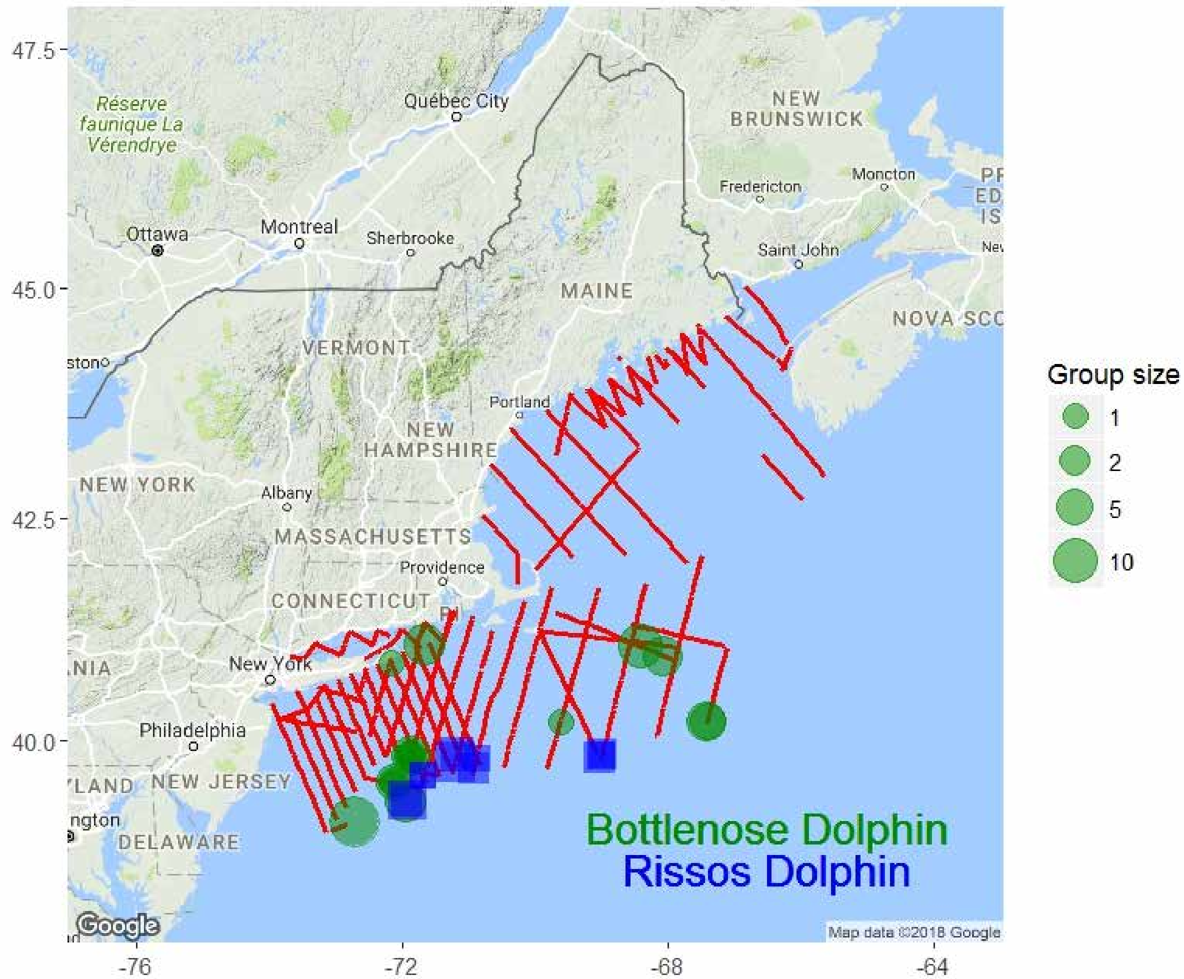

Figure 3.4 Locations of common bottlenose dolphins (*Tursiops truncatus*), and Risso's dolphins (*Grampus griseus*) detected by either the front or back team

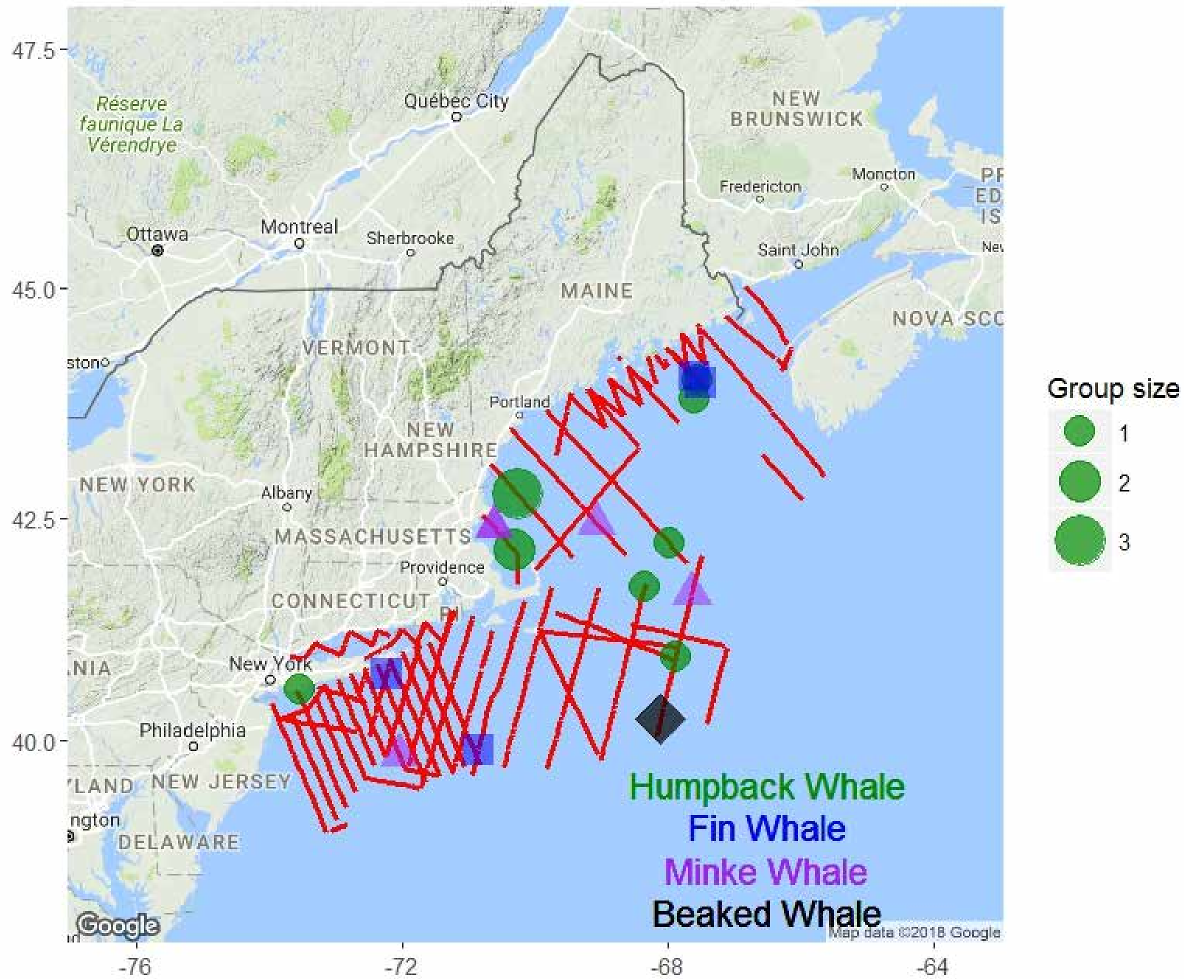

Figure 3.5 Locations of humpback whales (*Megaptera novaeangliae*), fin whales (*Balaenoptera physalus*), minke whales (*B. acutorostrata*) and beaked whales detected by either the front or back team

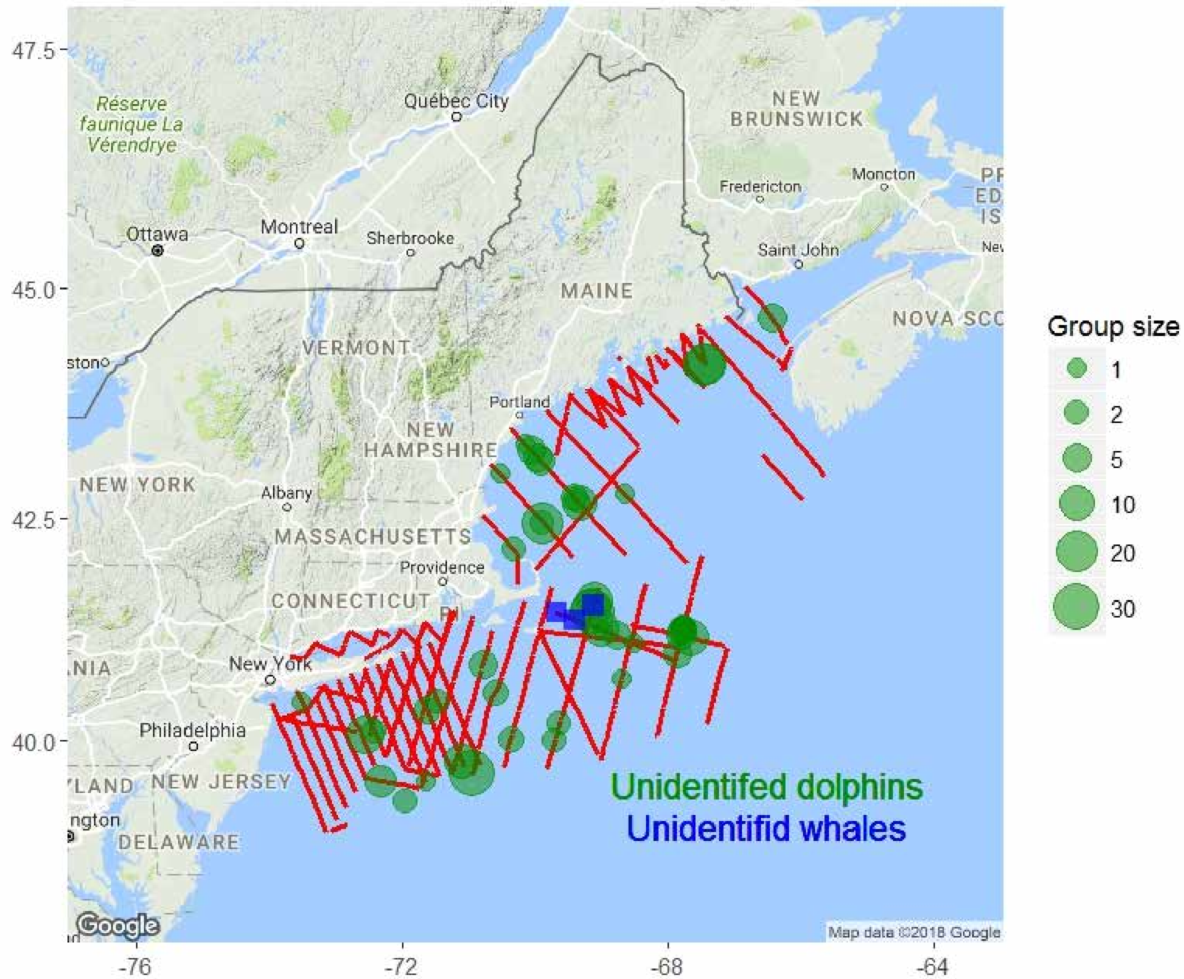

Figure 3.6 Locations of unidentified dolphins and whales detected by either the front or back team.

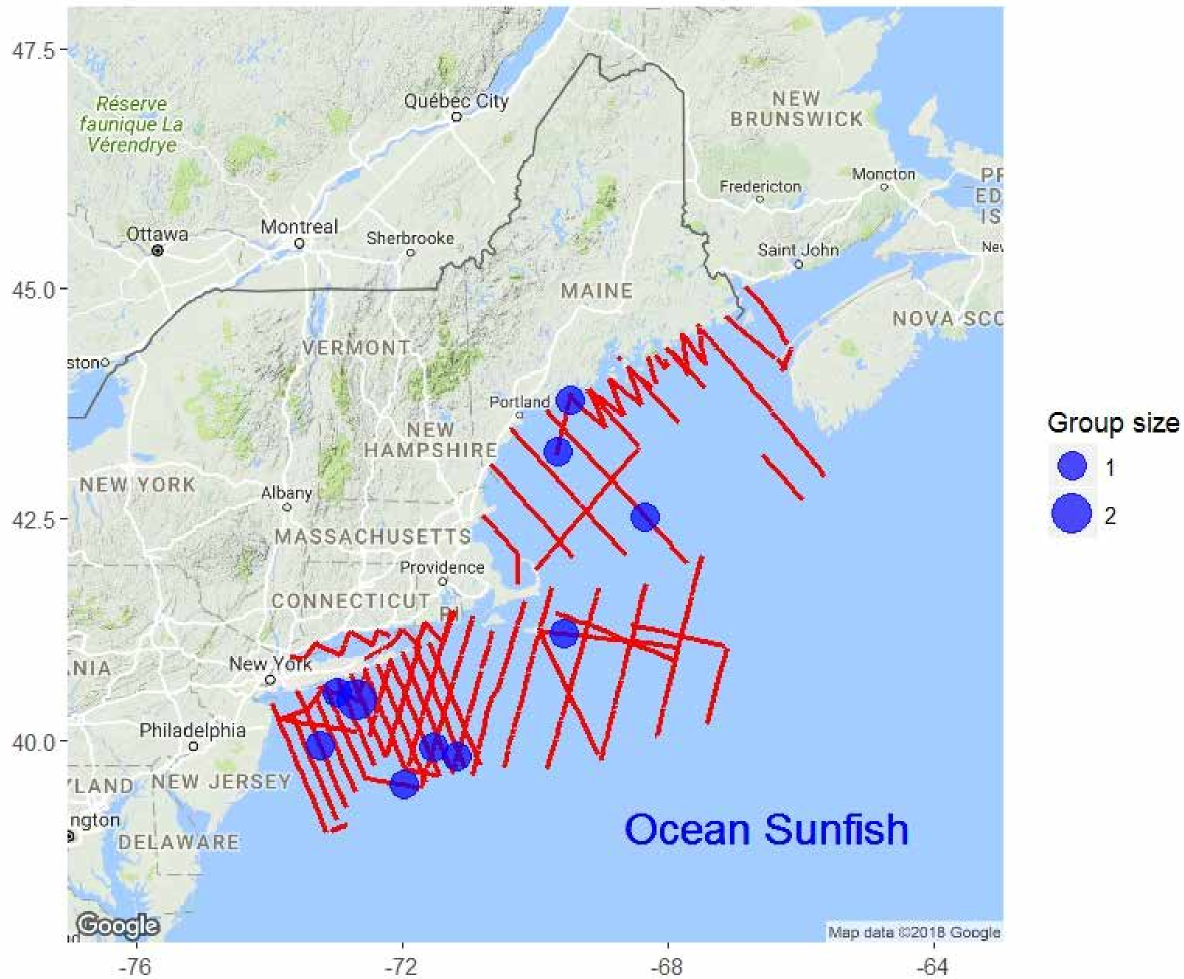

Figure 3.7 Locations of ocean sunfish (*Mola mola*) detected by either the front or back team

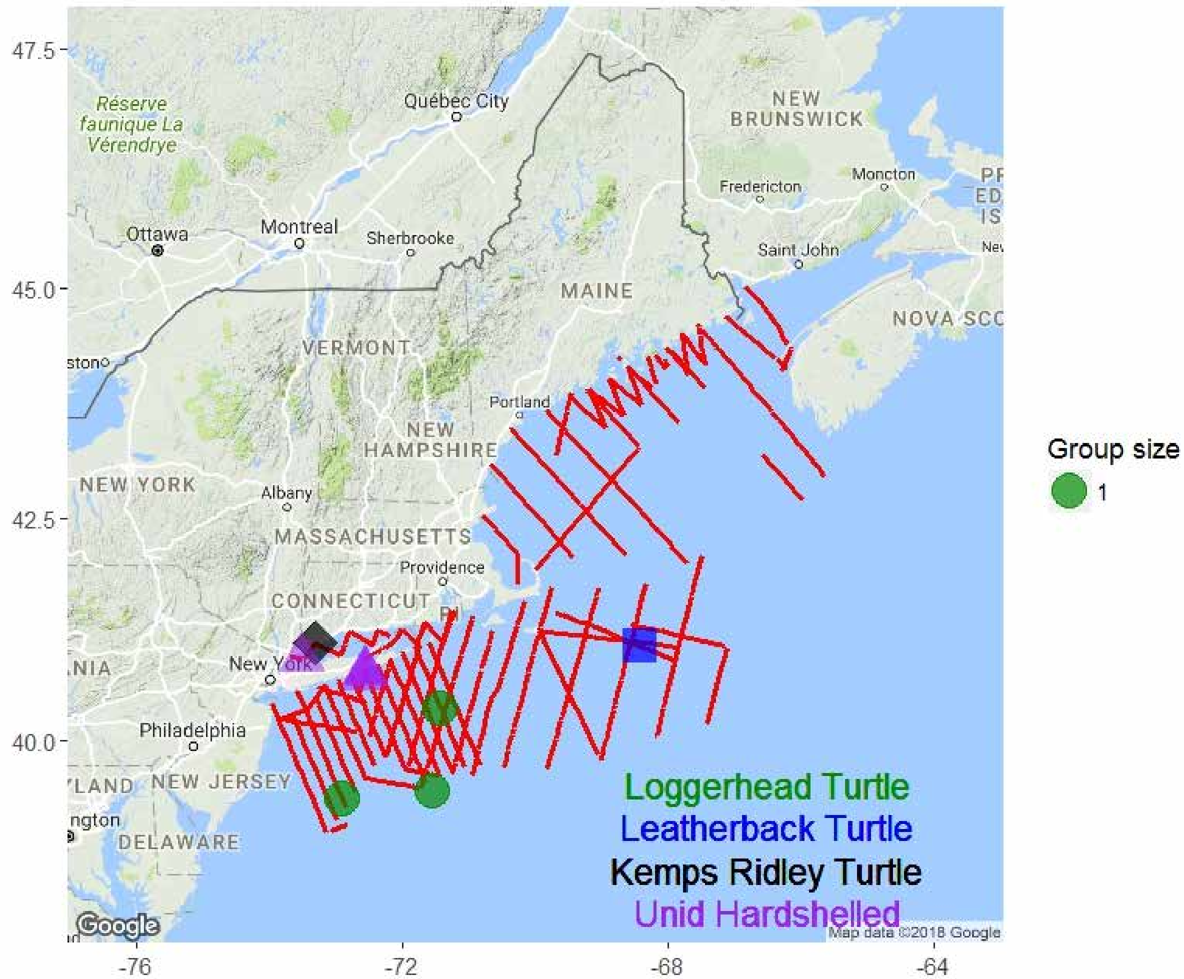

Figure 3.8 Locations of loggerhead turtles (*Caretta caretta*), leatherback turtles (*Dermochelys coriacea*), Kemps Ridley's turtles (*Lepidochelys kempii*), and unidentified turtles detected by either the front or back team

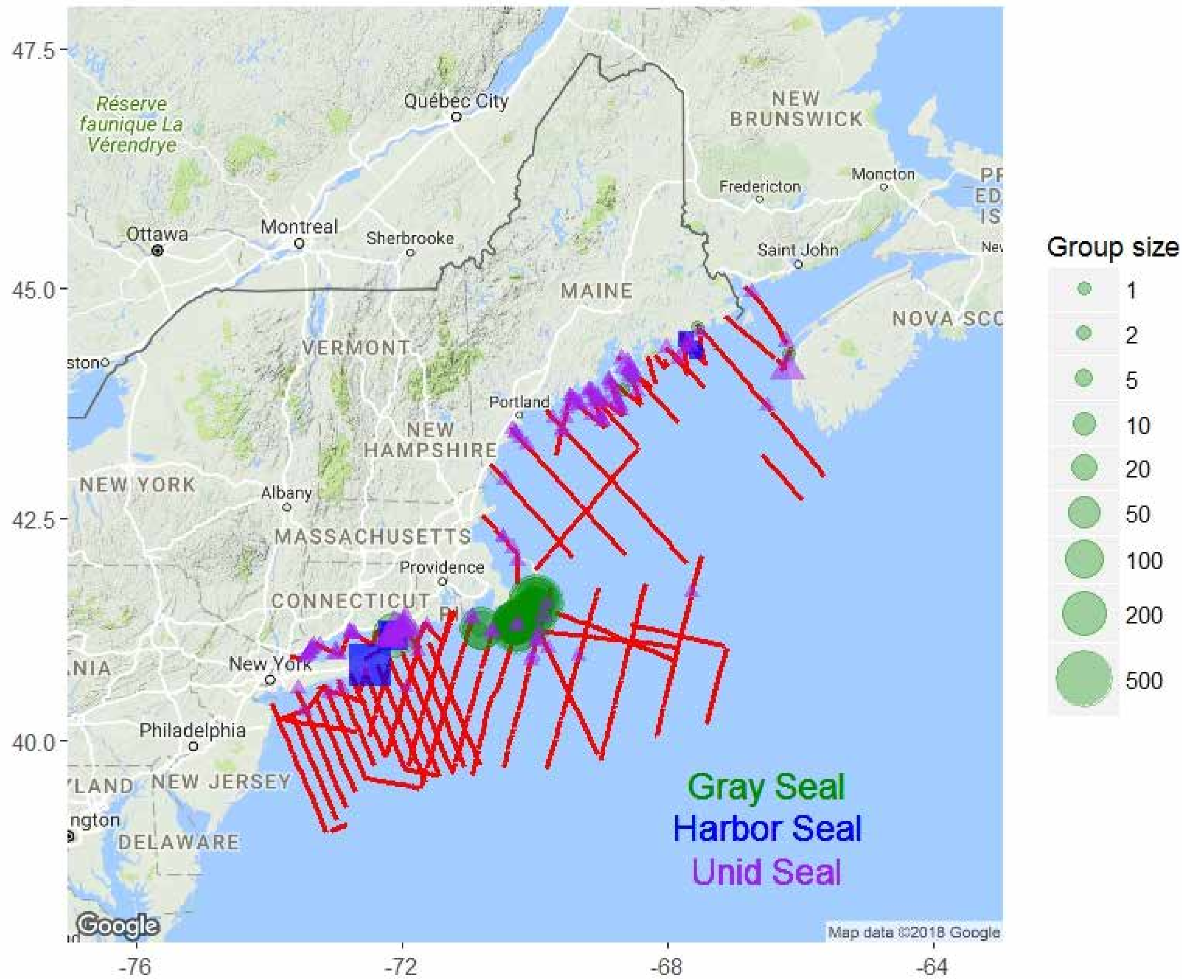

Figure 3.9 Locations of gray seals (*Halichoerus grypus*), harbor seals (*Phoca vitulina*) and unidentified seals detected by either the front or back team.

4 At-sea monitoring of the distributions of pelagic seabirds in the northeast US shelf ecosystem: Northeast Fisheries Science Center

Harvey J. Walsh[1], Nicholas Metheny[2], Tom Johnson[2]

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[2] Integrated Statistics, Inc., 16 Sumner St., Woods Hole, MA 02543

4.1 Summary

Seven shipboard surveys were completed in 2018 during Ecosystem Monitoring Surveys (EcoMon), a beaked whale survey, and National Oceanic and Atmospheric Administration (NOAA) ship transits. Cruises sampled regions from the Gulf of Maine to the Gulf of Mexico. A total of 10,711 sightings of birds and other marine megafauna were recorded in the survey zone and 18,021 in total. The majority of sea bird species for each cruise varied by survey season and region but was dominated by Storm-Petrels and Shearwaters. Wilson's Storm-Petrels (*Oceanites oceanicus*), Great Shearwaters (*Puffinus gravis*), and Sooty Shearwaters (*Ardenna grisea*) were most frequently sighted birds on the spring (HB1803) and summer (GU1804) EcoMon surveys of the Northeast US Shelf and the transit north from Key West, Florida, to Newport, Rhode Island, (GU18TN). Greater Shearwaters, Wilson's Storm-Petrels, and Leach's Storm-Petrels (*Oceanodroma leucorhoa*) were the most abundant species sighted on the beaked whale survey (GU1803) off the shelf of Georges Bank. Wilson's Storm-Petrel and Sooty Tern (*Onychoprion fuscatus*) were the most abundant birds on the transit from Miami, Florida to Newport, Rhode Island (HB18TN), which included a track into and out of the Tongue of the Ocean off the Bahamas. Observers also counted 117 endangered Black-capped Petrels (*Pterodroma hasitata*) on the offshore transit between South Carolina to North Carolina. Dominant species shifted on the Northeast US Shelf in the fall. Northern Gannets (*Morus bassanus*) and Bonaparte's Gulls (*Chroicocephalus Philadelphia*) were the most abundant on the fall EcoMon (S11802). Finally, the transit from Norfolk, Virginia, to Pascagoula, Mississippi, (GU18TS) through the Gulf of Mexico had a different bird community that was dominated by sightings of Black Terns (*Chlidonias niger*), Royal Terns (*Thalasseus maximus*), Cory's Shearwater (*Calonectris diomedea*), and Sooty Tern.

4.2 Objective

The goal of the at-sea monitoring is to provide comprehensive visual surveys of seabirds, marine mammals, turtles, large pelagic fish, and marine debris in the Northeast US Shelf Ecosystem.

4.3 Methods and Results

The protocol used during the surveys is based on a standardized 300 meter strip transect survey, one that is used by various agencies in North America and Europe (Anon 2011, Ballance 2011, Tasker 2004).

Cruise reports for four cruises, HB1803, GU18TN, HB18TN, and S11802 are provided as Appendices in this chapter.

4.4 Disposition of Data

The visual census data from each cruise is maintained in an Oracle Database at the Northeast Fisheries Science Center and distributed to the Seabird Compendium.

4.5 Acknowledgements

We acknowledge the officers and crew of National Oceanic and Atmospheric Administration (NOAA) ships *Henry B. Bigelow* and *Gordon Gunter* and the R/V *Hugh R. Sharp* for great ship support. This project was funded 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.

4.6 References Cited

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Ballance LT. 2011. Seabird Survey Instruction Manual, PICEAS 2011. Ecosystems Studies Program Southwest Fisheries Science Center, La Jolla, California.

Tasker ML, Hope Jones P, Dixon T, Blake BF. 1984. Counting seabirds at sea from ships; a review of methods employed and a suggestion for a standardized approach. Auk 101: 567 – 577.

Table 4.1 Summary of 2018 seabird surveys
Number of sightings (no.) within the 300-m survey zone and total include birds and megafauna.

Cruise	Program	Start Date	End Date	Num of Days	Sightings in Survey Zone	Total Sightings
HB1803	Ecosystem Monitoring	23-May	04-Jun	13	3026	5472
GU18TN	Ship transit	11-Jul	16-Jul	6	1094	1666
GU1803	Beaked whale survey	21-Jul	18-Aug	13	1111	1214
HB18TN	Ship transit	01-Aug	06-Aug	6	665	2651
GU1804	Ecosystem Monitoring	22-Aug	30-Aug	9	1459	2267
GU18TS	Ship transit	02-Sep	09-Sep	8	838	1246
S11802	Ecosystem Monitoring	01-Nov	12-Nov	10	2518	3505

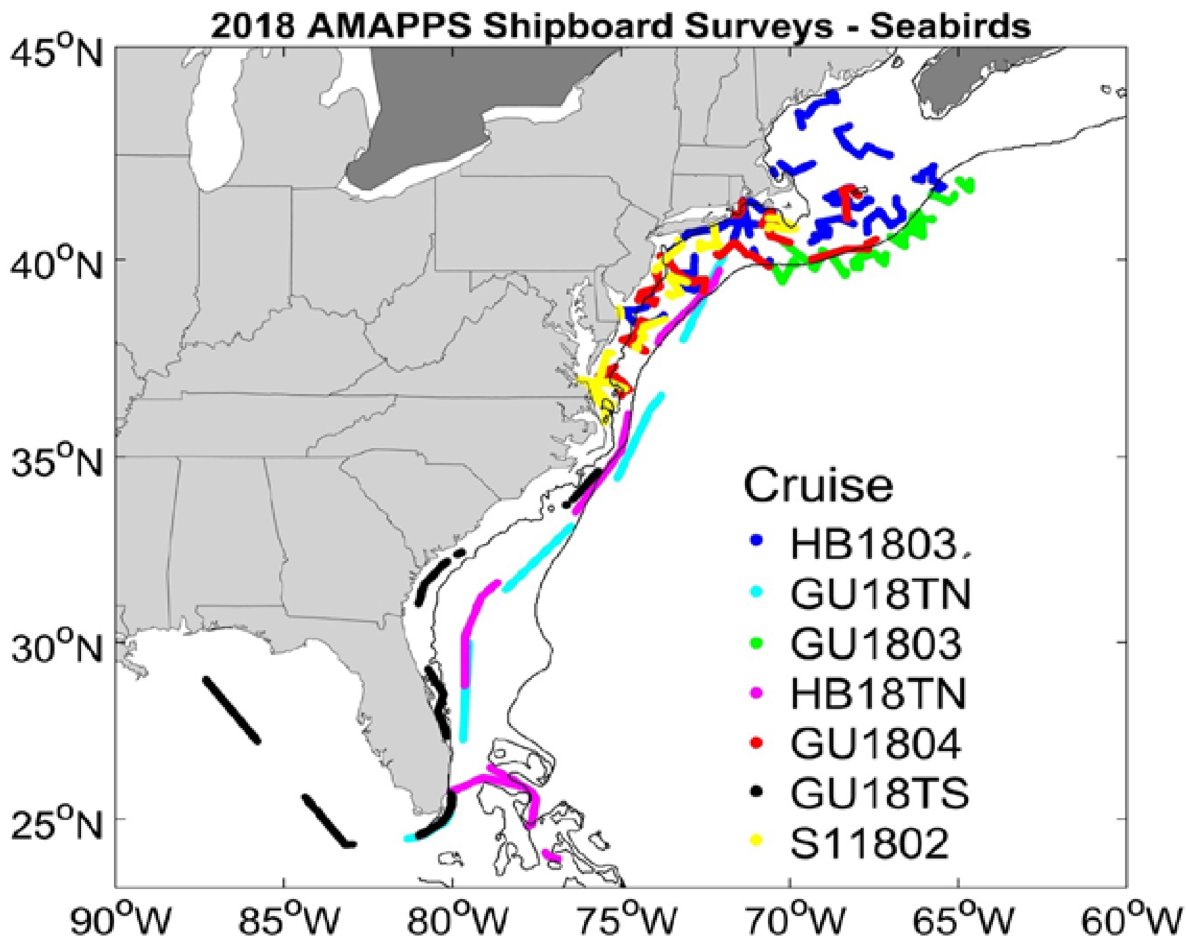

Figure 4.1Locations of the 2018 seabird surveys

4.7 Appendix I. Seabird Survey Report 23 May -5 June 2018

Nicholas Metheny[1] ***procellateryx@gmail.com***
[1]Integrated Statistics, 16 Sumner St, Woods Hole, MA, 02543

Marine Species Observers: **Nicholas Metheny and John Loch**

4.7.1 Objective

The primary goal of conducting seabird surveys aboard the NOAA Ship *Henry B. Bigelow* in May/June 2018 was to gather data on the abundance and distribution of seabirds as a part of longer term monitoring efforts for these far-ranging apex predators. the secondary objective is to also collect data, when possible, data on the abundance and distribution of other marine megafauna including, marine mammals, sea turtles, sharks, and other large pelagic fishes.

Collecting this data in conjunction with other biological data and abiotic factors will help better complete our “picture” of possible changes occurring in the marine ecosystem in the Northwest Atlantic.

4.7.2 Methods

The protocol used for this survey is based on a standardized 300 meter strip transect survey, one that is used by various agencies in North America and Europe (e.g., Anon 2011, Ballance 2011; Tasker 2004).

The survey strip is 300 meters wide, with observers collecting data on all seabirds within that strip, from the bow to 90 degrees to either the port or the starboard side (depending on viewing conditions). Observations can be made in seas up to a Beaufort 7, in light rain, fog, and ship speeds between 8-12 knots (below 8 knots, the data becomes questionable to use for abundance estimates).

Surveys were conducted on the flying bridge (15 m) of the NOAA Ship *Henry B. Bigelow*.

The software used to collect survey data was, SeeBird version 4.3.7. This program draws GPS coordinates, as well as time from the ship's navigation through a NMEA data feed, so each observation has a time stamp, latitude longitude location, and ship's course. Due to some initial issues with the Ship Computer System (SCS), a GPS puck was used to replace the ship's navigation feed on the first day of the survey, until the SCS issue was fixed and a reliable feed was established on the flying bridge. The standard data collected for observations included, species, distance, number of individuals, association, behavior, flight direction, flight height, and if possible or applicable, age, sex, and plumage status. Flocks of seabirds that were once recorded in a SeeBird sub-module, have been incorporated into the regular sighting data module with species counted within a given flock being given a special notation in the comment section, marking them as part of a flock, along with an estimated distance to that flock from the transect line. On another note, while SeeBird was not specifically designed to collect data on other marine megafauna, other such observations were recorded anytime an animal was seen, both in and outside of the survey zone.

During surveys, individual observers took two-hour shifts, to prevent observer fatigue. Observers utilized binoculars (10x42 or 8x42) for general scanning purposes within the survey strip, however, if an animal proved elusive a pair of 20x60 Zeiss imaged-stabilized binoculars were used to attain positive identifications. To aide in approximating distance, observers used custom made range finders based on the height above water and the observers' personal body height (Heinemann 1981).

4.7.3 Results

4.7.3.1 Seabird Sightings

Over the course of the cruise approximately 1,300 nautical miles were surveyed, from the mouth of the Delaware Bay to Georges Banks and into the Gulf of Maine. A total of 2,893 birds were observed in the survey zone, within an additional 1,951 birds observed outside the zone (on and off effort). As is usual at this time of year Wilson's Storm Petrels (*Oceanites oceanicus*) outnumbered all other seabirds totaling 992 individuals seen in the survey; this being followed by Sooty Shearwaters (*Ardenna grisea*) at 580 individuals seen in the survey zone. A fair number of alcid species were observed this year (compared to years past), with survey lines going very close to two breeding colonies in the Gulf of Maine, accounting for a fraction of the Atlantic Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), and Black Guillemot (*Cepphus grille*) sightings.

Of special, note was the sighting of a wayward Franklin's Gull (*Leucophaeus pipixcan*) that was a far east of its normal migration route. Furthermore, there were frequent sightings of South Polar Skua (*Stercorarius maccormicki*), sometimes several times in a day depending on the area the ship was traversing.

Table 4.2 Number of birds seen

Common Bird Name	Scientific Name	Number Observed in Zone	Total Observed
Atlantic Puffin	*Fratercula arctica*	10	22
Black Guillemote	*Cepphus grylle*	4	5
Dovekie	*Alle alle*	6	10
Common Murre	*Uria aalge*	1	1
Razorbill	*Alca torda*	1	3
Razorbill/Murre		0	1
Common Loon	*Gavia immer*	33	80
Red-throated Loon	*Gavia stellata*	0	1
Cory's Shearwater	*Calonectris borealis*	22	32
Great Shearwater	*Puffinus gravis*	249	379
Sooty Shearwater	*Ardenna grisea*	580	1242
Manx Shearwater	*Puffinus puffinus*	13	23
Unidentified Shearwater		0	1
Wilson's Storm Petrel	*Oceanites oceanicus*	992	1430
Leach's Storm Petrel	*Oceanodroma leucorhoa*	185	148
Unidentified Storm Petrel		0	40
Unidentified Petrel		0	1
Northern Fulmar	*Fulmarus glacialis*	155	249
Arctic Tern	*Sterna paradisaea*	64	67
Common Tern	*Sterna hirundo*	123	192

Common Bird Name	Scientific Name	Number Observed in Zone	Total Observed
Unidentified Tern		38	74
Great Black-backed Gull	*Larus marinus*	102	262
Herring Gull	*Larus argentatus*	160	362
Bonaparte's Gull	*Chroicocephalus philadelphia*	1	1
Laughing Gull	*Leucophaeus atricilla*	29	30
Franklin's Gull	*Leucophaeus pipixcan*	1	1
White-Winged Scoter	*Melanitta fusca*	5	9
Parasitic Jaeger	*Stercorarius parasiticus*	2	5
Long-tailed Jaeger	*Stercorarius longicaudus*	1	3
Unidentified Jaeger		0	1
South Polar Skua	*Stercorarius maccormicki*	23	43
Double Cresred Cormorant	*Phalacrocorax auritus*	0	20
Northern Gannet	*Morus bassanus*	36	45
Red Phalarope	*Phalaropus fulicarius*	1	1
Red-necked Phalarope	*Phalaropus lobatus*	27	28
Unidentified Phalarope		7	7
Magnolia Warbeler	*Setophaga magnolia*	2	2
Barn Swallow	*Hirundo rustica*	2	3
Cedar Waxwing	*Bombycilla cedrorum*	1	1
Red-bellied Woodpecker	*Melanerpes carolinus*	1	1
Gray Catbird	*Dumetella carolinensis*	1	1
American Goldfinch	*Spinus tristis*	1	1
American Redstart	*Setophaga ruticilla*	1	1
Cuckcoo sp	*Coccyzus sp*	1	1
Passerine		10	10
Peregrine Falcon	*Falco peregrinus*	0	1
Osprey	*Pandion haliaetus*	2	3
TOTAL		2893	4844

4.7.3.2 Marine Mammal, Sea Turtle, and Large Fishes Sightings

The most commonly seen marine mammal, was the common dolphin (*Delphinus delphis*) accounting for approximately 75% of all mammal sightings, followed by pilot whales (*Globicephala sp*) at around 9%. Of the large whales seen, humpback whales (*Megaptera novaengliae*) made up a majority of individuals. Of special note were a small pod of Atlantic white-sided dolphins (*Lagenorynchu acutus*) as well as sperm whales (*Physeter macrocephalus*) and a group of un-identified beaked whales (*Mesoplodon sp.*).

Only one loggerhead sea turtle (*Caretta caretta*) was sighted. Probably mostly due to the limited time spent in warmer southern waters or in the Gulf Stream. Of special note were a large number of sunfish (*Mola mola*) and basking sharks (*Cetorhinus maximus*) that were seen off of New England. Several sunfish individuals were seen breaching clear out of the water.

Table 4.3 Other sighted marine megafauna

Common Name	Sciencific Name	Number Observed
Fin whale	*Balaenoptera physalus*	2
Humpback whale	*Megaptera novaeangliae*	22
Minke whale	*Balaenoptera acutorostrata*	2
Unidentified whale		4
Unidentified small whale		1
Unidentified large whale		5
Sperm whale	*Physeter macrocephalus*	2
Pilot whale	*Globicephala sp.*	43
Risso's dolphin	*Grampus griseus*	6
Common dolphin	*Delphinus delphis*	336
Bottlenose dolphin	*Tursiops truncatus*	15
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	5
Unidentified dolphin		1
Mesoplodon sp		2
Loggerhead sea turtle	*Caretta caretta*	1
Ocean sunfish	*Mola mola*	41
Basking shark	*Cetorhinus maximus*	29
Blue shark	*Prionace glauca*	1
School of tuna (larger/small)		6
School of fish		3

4.7.4 Literature Cited

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4.8 Appendix II Seabird Survey Report 11 July -16 July 2018

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Marine Species Observers: **Nicholas Metheny and Andrew Dreelin**

4.8.1 Objective

The primary goal of conducting seabird surveys aboard the NOAA Ship *Gordon Gunter* in July 2018 was to gather data on the abundance and distribution of seabirds as a part of longer term monitoring efforts for these far-ranging apex predators. The secondary objective was to also collect data, when possible, on the abundance and distribution of other marine megafauna including, marine mammals, sea turtles, sharks, and other large pelagic fishes.

The data collected this trip is unique in that it was not a part of a dedicated research effort, rather it was a transit of the vessel northward from Key West, Florida to Newport, Rhode Island in waters not often surveyed by observers.

4.8.2 Methods

The protocol used for this survey is based on a standardized 300 meter strip transect survey, one that is used by various agencies in North America and Europe (e.g., Anon 2011, Ballance 2011; Tasker 2004).

The survey strip is 300 meters wide, with observers collecting data on all seabirds within that strip, from the bow to 90 degrees to either the port or the starboard side (depending on viewing conditions). Observations can be made in seas up to a Beaufort 7, in light rain, fog, and ship speeds between 8-12 knots (below 8 knots, the data becomes questionable to use for abundance estimates).

Surveys were conducted on the flying bridge (13.7 m) of the NOAA Ship *Gordon Gunter*.

The software used to collect survey data was, SeeBird version 4.3.7. This program draws GPS coordinates, as well as time from the ship's navigation through a NMEA data feed, so each observation received a time stamp with the latitude longitude location, time, and ship's course. The standard data collected for observations included, species, distance, number of individuals, association, behavior, flight direction, flight height, and if possible or applicable, age, sex, and plumage status. Flocks of seabirds that were once recorded in a SeeBird sub-module, have been incorporated into the regular sighting data module with species counted within a given flock being given a special notation in the comment section, marking them as part of a flock, along with an estimated distance to that flock from the transect line. On another note, while SeeBird was not specifically designed to collect data on other marine megafauna, other such observations were recorded anytime an animal was seen, both in and outside of the regular survey zone specified for seabird data collection.

During surveys, individual observers took two-hour shifts, to prevent observer fatigue. Observers utilized binoculars (10x42 or 8x42) for general scanning purposes within the survey strip, however, if an animal proved elusive a pair of 20x60 Zeiss imaged-stabilized binoculars were used to attain positive identifications. To aide in approximating distance observers used custom made range finders based on height above water and the observers' personal body measurement (Heinemann 1981).

4.8.3 Results

4.8.3.1 Seabird Sightings

Over the course of the cruise approximately 677 nautical miles were surveyed from Key West, FL to Newport, RI, with significant portions of the survey occurring in off shelf waters. A total of 957 birds were observed in the survey zone, within an additional 503 birds observed outside the zone. Great Shearwater (*Puffinus gravis*) outnumbered all seabirds seen within the survey zone, totaling 345. Wilson's Storm Petrels (*Oceanites oceanicus*) had the second highest count of birds seen in the survey zone at 265 individuals; however, Wilson's Storm Petrels outnumbered all other seabirds in total (in and outside the zone) at 572 individuals observed. These seabirds are followed by Sooty Terns (*Onychoprion fuscatus*) Bridled Terns (*Onychoprion anaethetus*) and Cory's Shearwaters (*Calonectris borealis*) in relative abundance at totals of 93, 71, and 71 individuals, respectively.

Table 4.4 Total number of birds observed

Common Bird Name	Scientific Name	Number Observed in Zone	Total Observ ed
Cory's Shearwater	*Calonectris borealis*	71	115
Great Shearwater	*Puffinus gravis*	345	391
Audubon's Shearwater	*Puffinus lherminieri*	39	56
Wilson's Storm Petrel	*Oceanites oceanicus*	264	572
Leach's Storm Petrel	*Oceanodroma leucorhoa*	9	10
Band-rumped Storm Petrel	*Oceanodroma castro*	32	47
Leach's/Harcourt's Storm Petrel		0	2
Unidentified Storm Petrel		1	1
Black-capped Petrel	*Pterodroma hasitata*	9	20
Parasitic Jaeger	*Stercorarius parasiticus*	1	1
Bridled Tern	*Onychoprion anaethetus*	71	78
Sooty Tern	*Onychoprion fuscatus*	93	114
Sooty/Birdled Tern		2	33
Royal Tern	*Thalasseus maximus*	1	1
Brown Noddy	*Anous stolidus*	4	4
Brown Booby	*Sula leucogaster*	4	4
Double Crested Cormorant	*Phalacrocorax auritus*	1	1
Magnificent Frigatebird	*Fregata magnificens*	1	1
Red-billed Tropicbird	*Phaethon aethereus*	1	1
Whimbrel	*Numenis phaeopus*	1	1
Willet	*Tringa semipalmata*	1	1
Yellowlegs sp	*Tringa sp*	1	1
Sandpiper sp	*Calidris sp*	1	1
Barn Swallow	*Hirundo rustica*	2	2
Brown-headed Cowbird	*Molothrus ater*	2	2
TOTAL		957	1460

4.8.3.2 Marine Mammal and Sea Turtle Sightings

The most commonly seen marine mammal, was the Atlantic spotted dolphin (*Stenella frontalis*) accounting for accounting for approximately 37% of all mammal sightings, followed by the striped dolphin (*Stenella coeruleoalba*) at around 30%. It should be noted that striped dolphins consisted of the largest individual pod seen at 60 individuals. The only large whale seen was an individual sperm whale (*Physeter microcephalus*). Only one loggerhead sea turtle (*Caretta caretta*) and green sea turtle (*Chelonia mydas*) were seen this trip.

Table 4.5 Other sighted marine megafauna

Common Name	Scientific Name	Number observed
Sperm whale	*Physeter macrocephalus*	1
Risso's dolphin	*Grampus griseus*	6
Common dolphin	*Delphinus delphis*	34
Bottlenose dolphin	*Tursiops truncatus*	13
Striped dolphin	*Stenella coeruleoalba*	60
Atlantic spotted dolphin	*Stenella frontalis*	73
Unidentified dolphin	-	11
Green sea turtle	*Chelonia mydas*	1
Loggerhead sea turtle	*Caretta caretta*	1

4.8.4 Literature Cited

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4.9 Appendix III: Seabird Survey Report 1-6 August 2018

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Marine Species Observers: **Tom Johnson and Doug Gochfeld**

4.9.1 Objective

The primary goal of conducting seabird surveys aboard NOAA Ship *Henry B. Bigelow* in August 2018 was to use a one-way ship transit to gather abundance and distribution data for seabirds. The secondary objective was to collect abundance and distribution data for other marine megafauna including marine mammals, sea turtles, sharks, and other large pelagic fishes. The ship departed Miami, FL, visited the Atlantic Undersea Test and Evaluation Center (AUTEC) range at Andros Island, Bahamas to collect acoustic data for the ship, and then transited north to NAVSTA Newport, RI.

To maximize the value of seabird data collected during this short, opportunistic transit (not a dedicated, stand-alone biological survey), we requested a course approximating the steep contour of the continental shelf edge during a large portion of the transit, especially as we headed north between Cape Hatteras and the Hudson Canyon. The ship's officers graciously honored this request when operations and conditions allowed. This route allowed us to sample the steep shelf contour as well as cross over several productive shelf-edge canyons.

Collecting and interpreting this data in conjunction with other biological data and abiotic factors will help establish baseline status and distribution information for a suite of relatively poorly known organisms. It will also help to illustrate any changes occurring in the marine ecosystem in the western North Atlantic between Florida, the Bahamas, and New England. The data collected during this short cruise are only a small piece in the larger puzzle of our understanding of this complex marine ecosystem.

4.9.2 Methods

The protocol used for this survey is based on a standardized 300 meter strip transect survey used by various agencies in North America and Europe (e.g., Anon 2011, Ballance 2011; Tasker 2004).

The survey strip is 300 meters wide. Observers collect data on all seabirds within that strip, between the bow and 90 degrees to one side of the ship (chosen based on viewing conditions). Observations were made in seas up to Beaufort 7, in light rain, fog, and ship speeds between 8-12 knots (below 8 knots, the data becomes questionable for use in abundance estimates).

Surveys were conducted from the flying bridge (15 m) of NOAA Ship *Henry B. Bigelow* (R 225).

We used the software "SeeBird version 4.3.7" loaded on a Panasonic Toughbook computer to collect data. This software draws GPS coordinates and time from the ship's computer system through a NMEA data feed so each observation receives a stamp with the latitude longitude location, time, and ship's course. During this particular cruise, course data was not reliably included with the computer feed, so this category should be regarded with caution in the data; to account for this, observers manually entered the course in the "notes" field during course changes. The standard data collected for observations included species, distance, number of individuals, association, behavior, and if possible or applicable, age, sex, and plumage status. Flocks of seabirds were recorded in the regular sighting data module, with species counted within a given flock given a special "flock" notation in the comment section, along with an estimated distance to that flock from the transect line. While SeeBird was not specifically designed to collect data on non-avian marine megafauna, observations of these animals were recorded as well.

During daylight hours on survey days, observers alternated on two-hour shifts to prevent observer fatigue. Observers utilized binoculars (10x42 or 8x42) for general scanning purposes within the survey strip. Identifications were frequently confirmed or supported using digital SLR cameras with 400 mm lenses. It should be emphasized that photographic documentation of seabirds is an integral part of the identification and therefore the survey process, and camera equipment should be a standard part of the seabird observer's toolkit. To estimate distance, observers used custom range finders based on height above water and the observers' height (Heinemann 1981). At the beginning of the cruise, we checked our distance estimates at the dock in Miami using GPS measurements and satellite imagery, and then used fixed points on the ship's jack staff relative to the ocean and horizon to continually check at-sea estimates.

4.9.3 Results

The ship covered approximately 1400 nautical miles between Miami, FL, the AUTEC range at Andros Island, Bahamas, and the continental shelf north to Newport, RI.

4.9.3.1 Seabird Sightings

During the survey, we recorded a total of 1,858 total birds, including 463 birds within the 300 meter strip closest to the ship ("in the zone"). Seabird activity was relatively light overall, typical of summer in this region. Wilson's Storm-Petrel (*Oceanites oceanicus*) and Sooty Tern (*Onychoprion fuscatus*) were the most common seabird species that we identified. It should be noted that the Sooty Terns were primarily found in warm, subtropical water in the Florida-Bahamas region. The number of Black-capped Petrels (*Pterodroma hasitata*; 117) that we detected offshore from South Carolina and North Carolina on 4-5 August is notable since this endangered species is thought to have a world population of only ~5000 individuals (Farnsworth 2010). Two regionally rare seabird species were observed during the cruise: White-tailed Tropicbird (*Phaethon lepturus*; 2) and White-faced Storm-Petrel (*Pelagodroma marina*; 5). Both are expected in very small numbers during the region in August, but their presence was still welcomed by the excited observers. Small numbers of a broad diversity of migrating shorebirds and a few songbirds were also found during the survey. Seabird taxonomy/ names refer to new 2018 eBird nomenclature.

Table 4.6 Total number of birds observed

Common Name	Scientific Name	Total	Number in Zone
Black-bellied Plover	*Pluvialis squatarola*	1	0
Ruddy Turnstone	*Arenaria interpres*	2	2
Stilt Sandpiper	*Calidris himantopus*	1	1
Least Sandpiper	*Calidris minutilla*	2	2
Pectoral Sandpiper	*Calidris melanotos*	8	8
Peep (small sandpiper) sp.	*Calidris sp. (small)*	2	2
Short-billed Dowitcher	*Limnodromus griseus*	11	11
Dowitcher sp.	*Limnodromus sp.*	1	1
Red-necked Phalarope	*Phalaropus lobatus*	13	7
Phalarope sp.	*Phalaropus sp.*	1	0
Solitary Sandpiper	*Tringa solitaria*	6	6
Greater Yellowlegs	*Tringa melanoleuca*	1	0
Shorebird sp.	*Charadriiformes sp.*	10	0
Pomarine Jaeger	*Stercorarius pomarinus*	1	1
Laughing Gull	*Leucophaeus atricilla*	67	35
Brown Noddy	*Anous stolidus*	48	9
Sooty Tern	*Onychoprion fuscatus*	327	59
Bridled Tern	*Onychoprion anaethetus*	50	15
Sooty/ Bridled Tern	*Onychoprion fuscatus/ anaethetus*	70	0
Least Tern	*Sternula antillarum*	2	2
Tern sp.	*Sterninae sp.*	3	0
White-tailed Tropicbird	*Phaethon lepturus*	2	1
Wilson's Storm-Petrel	*Oceanites oceanicus*	485	220
White-faced Storm-Petrel	*Pelagodroma marina*	5	2
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	2	0
Band-rumped Storm-Petrel	*Oceanodroma castro*	6	1
Storm-petrel sp.	*Oceanitidae/ Hydrobatidae sp.*	453	0
Black-capped Petrel	*Pterodroma hasitata*	117	25
Cory's Shearwater	*Calonectris diomedea*	97	37
Great Shearwater	*Ardenna gravis*	12	4
Audubon's Shearwater	*Puffinus lherminieri*	29	9
Magnificent Frigatebird	*Fregata magnificens*	17	0
Brown Booby	*Sula leucogaster*	1	0
Barn Swallow	*Hirundo rustica*	4	2
Prairie Warbler	*Setophaga discolor*	1	1

4.9.3.2 Non-avian Sightings

We detected 793 non-avian animals (including 789 mammals) during the survey, with 189 individuals inside the zone. Due to the difficulty of accurately counting groups of marine mammals at sea, these numbers should be considered estimates instead of exact counts. Most marine mammal sightings were either too brief or too distant to facilitate species-level identification – 83% of the marine mammals recorded (658/789) were recorded with general identifications. Cetaceans were relatively scarce during the majority of this short cruise. Our only exceptional observation was of large numbers of pilot whales (*Globicephala* sp.) along the continental shelf edge offshore from the Mid-Atlantic coastline on 5-6 August, where many groups of 10-50 animals were seen at the surface during the calm conditions.

Few fish and zero marine turtles were observed during the survey.

Table 4.7 Non-avian fauna

Common Names	Scientific Names	Total	Number in Zone
Atlantic spotted dolphin	*Stenella frontalis*	46	40
Common bottlenose dolphin	*Tursiops truncatus*	50	20
Risso's dolphin	*Grampus griseus*	8	0
Short-beaked common dolphin	*Delphinus delphis*	26	0
Dolphin sp.	*Delphinidae sp.*	171	2
Pilot whale sp.	*Globicephala sp.*	466	125
Odontocete sp.	*Odontoceti (general)*	20	0
Whale sp.	*Odontoceti (whale)*	1	0
Fin whale	*Balaenoptera physalus*	1	0
Ocean sunfish	*Mola mola*	2	0
Portuguese Man-o-War	*Physalia physalis*	2	2

4.9.4 Acknowledgments

We would like to thank the officers and crew of NOAA Ship *Henry B. Bigelow* under command of Jeffrey Taylor for accommodating us during the August transit. Nick Metheny provided assistance with the methodology and software for this cruise; his Spring EcoMon 2018 cruise report also served as a model for this report.

4.9.5 Literature Cited

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4.10 Appendix IV: Seabird Survey Report 1-13 November 2018

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Marine Species Observers: **Nicholas Metheny and John Loch**

4.10.1 Objective

The primary goal of conducting seabird surveys aboard the R/V *Hugh R. Sharp* in November 2018 was to gather data on the abundance and distribution of seabirds as a part of longer term monitoring efforts for these far-ranging apex predators. The secondary objective was to also collect data, when possible, on the abundance and distribution of other marine megafauna including, marine mammals, sea turtles, sharks, and other large pelagic fishes.

Collecting this data in conjunction with other biological data and abiotic factors will help better complete our “picture” of possible changes occurring in the marine ecosystem in the Northwest Atlantic from the Outer Banks to the Bay of Fundy.

4.10.2 Methods

The protocol used for this survey is based on a standardized 300 meter strip transect survey, one that is used by various agencies in North America and Europe (e.g., Anon 2011, Ballance 2011; Tasker 2004).

The survey strip is 300 meters wide, with observers collecting data on all seabirds within that strip, from the bow to 90 degrees to either the port or the starboard side (depending on viewing conditions). Observations can be made in seas up to a Beaufort 7, in light rain, fog, and ship speeds between 8-12 knots. Given the limitations of the R/V *Hugh R. Sharp*, some of the data was collected below the standard 8 knots, which was noted in the data.

Surveys were conducted on the flying bridge (11 m) of the R/V *Hugh R. Sharp*.

The software used to collect survey data was, SeeBird version 4.3.7. This program draws GPS coordinates, as well as time from the ship's navigation through a NMEA data feed, so each observation received a stamp with the latitude longitude location, time, and ship's course. The standard data collected for observations included, species, distance, number of individuals, association, behavior, flight direction, flight height, and if possible or applicable, age, sex, and plumage status. Flocks of seabirds that were once recorded in a SeeBird sub-module, have been incorporated into the regular sighting data module with species counted within a given flock being given a special notation in the comment section, marking them as part of a flock, along with an estimated distance to that flock from the transect line. On another note, while SeeBird was not specifically designed to collect data on other marine megafauna, other such observations were recorded anytime an animal was seen, both in and outside of the survey zone.

During surveys, individual observers took two-hour shifts, to prevent observer fatigue. Observers utilized binoculars (10x42 or 8x42) for general scanning purposes within the survey strip, however, if an animal proved elusive a pair of 20x60 Zeiss imaged-stabilized binoculars were used to attain positive identifications. To aide in approximating distance observers used custom made range finders based on height above water and the observers’ personal body measurement (Heinemann 1981).

4.10.3 Results

4.10.3.1 Seabird Sightings

Over the course of the cruise approximately 710 nautical miles were surveyed, from the mouth of the Delaware Bay, south to the Outer Banks up to the waters south of Martha's Vineyard. A total of 2,410 birds were observed in the survey zone, within an additional 977 birds observed outside the zone (on and off effort). As is usual at this time of year, migration is under way with the appearance of multiple high arctic breeders, and the gradual disappearance of the usual summer denizens. At the species level, Northern Gannets (*Morus bassanus*) and Bonaparte's Gulls (*Chroicocephalus philadelphia*) were the most abundant, making up 17% and 15% of the total count of birds recorded, respectively. Great Shearwaters (*Puffinus gravis*) and Herring Gulls (*Larus argentatus*) follow next in the most abundant birds surveyed, each making up approximately 9.5% of the total count. As a group Scoters (*Melanitta sp*.) made up a little over 19% of the count, with Surf Scoters (*Melanitta perspicilllata*) being the most abundant, followed by Black Scoters (*Melanitta Americana*) and then White-winged Scoters (*Melanitta fusca*) with only a handful of individuals seen of this species.

Of special note, a single large flock of 250 Snow Geese (*Chen caerulescens*) a species not usually seen on offshore surveys, was sighted migrating southward. Of further note, 11 identified passerine species were seen on their way south, with the most unusual of these being seen at sea being a Brown Creeper (*Certhia americana*).

Table 4.8 Total number of birds observed and distance distribution on survey zone

Common Name	Scientific Name	Zone 1	Zone 2	Zone 3	Zone 4	TOTAL
Razorbill	*Alca torda*		4	9		13
Common Loon	*Gavia immer*	1	3	20	30	54
Red-throated Loon	*Gavia stellata*			8	2	10
Unidentified Loon				1		1
Cory's Shearwater	*Calonectris borealis*	1	2			3
Great Shearwater	*Puffinus gravis*	24	82	168	45	319
Manx Shearwater	*Puffinus puffinus*	3	1	14	6	24
Unidentified Storm-petrel					3	3
Northern Fulmar	*Fulmarus glacialis*	3		1	3	7
Black Scoter	*Melanitta americana*	1	2	162	123	288
Surf Scoter	*Melanitta perspicilllata*		4	70	33	107
White-winged Scoter	*Melanitta fusca*				4	4
Unidentified Scoter	*Melanitta sp*			3	251	254
Lesser Scaup	*Aythya affinis*				12	12
Unidentifed Duck			40		9	49
Royal Tern	*Thalasseus maximus*	5	1	6	9	21
Great Black-backed Gull	*Larus marinus*	37	77	113	4	231
Herring Gull	*Larus argentatus*	71	75	159	13	318
Ring-billed Gull	*Larus delawarenisis*		1	2		3
Laughing Gull	*Leucophaeus atricilla*	18	43	91	8	160
Bonaparte's Gull	*Chroicocephalus philadelphia*	16	64	421	7	508
Black-legged Kittiwake	*Rissa tridactyla*	4	10	22	11	47
Unidentified small gull				1		1
Parasitic Jaeger	*Stercorarius parasiticus*	1		3	1	5
Pomarine Jaeger	*Stercorarius pomarinus*			3		3
Brown Pelican	*Pelecanus occidentalis*	6	1	17	5	29
Double Crested Comorant	*Phalacrocorax auritus*	1	3	16	14	34
Northern Gannet	*Morus bassanus*	67	121	272	127	587
Red Phalarope	*Phalaropus fulicarius*	2				2
Unidentified phalarope	*Phalaropus sp*				4	4
Sanderling	*Calidris alba*		3			3
Red-breasted Merganser	*Mergus serrator*	1				1
Unidentified grebe				1		1
Snow Goose	*Chen caerulescens*				250	250
Great Blue Heron	*Ardea herodias*		3			3
Golden-crowned Kinglet	*Regulus satrapa*	1				1
Ruby-crowned Kinglet	*Regulus calendula*	1				1
American Goldfinch	*Spinus tristis*	1			1	2
Pine Siskin	*Spinus pinus*	1		1		2
American Robin	*Turdus migratoris*		1			1

Common Name	Scientific Name	Zone 1	Zone 2	Zone 3	Zone 4	TOTAL
Black-throated Blue Warbler	*Steophaga caerulescens*				1	1
Yellow Warbler	*Steophaga petechia*	1				1
Dark-eyed Junco	*Junco hyemalis*	2				2
Brown-headed Cowbird	*Molothrus ater*	1				1
Brown Creeper	*Certhia americana*	1				1
Red-breasted Nuthatch	*Sitta canadensis*	2				2
Passerine sp		7	4	1	1	13
TOTAL		280	545	1585	977	3387

4.10.3.2 Marine Mammal, Sea Turtle, and Large Fishes Sightings

The most commonly seen marine mammal, was the common dolphin (*Delphinus delphis*) accounting for approximately 74% of all mammal sightings, followed by bottlenose dolphins (*Tursiops truncatus*), at approximately 18%. Of the large whales, humpback whales (*Megaptera novaengliae*) were the only ones seen, and only in two separate sightings. Of special note was a sighting of a grey seal (*Halichoerus grypus*) sighted south of Martha's Vineyard.

Only three loggerhead sea turtle (*Caretta caretta*) were sighted in the warmer waters off the Mid-Atlantic. Of special note was the one ocean sunfish (*Mola mola*) seen in the Mid Atlantic.

Table 4.9 Number of other sighted marine megafauna groups by survey zone

Common Name	Scientific Name	Zone 1	Zone 2	Zone 3	Zone 4	TOTAL
Grey seal	*Halichoerus grypus*			1		1
Common dolphin	*Delphinus delphis*		22	56	7	85
Bottlenose dolphin	*Tursiops truncatus*		7	14		21
Unidentified dolphin	*Delphinidae sp*		5			5
Humpback whale	*Megaptera novaengilae*				2	2
Loggerhead sea turtle	*Caretta caretta*			2	1	3
Ocean sunfish	*Mola mola*		1			1
School of tuna			1			1
TOTAL			36	74	10	120

4.10.4 Literature Cited

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5 Pilot study linking biological and physical oceanography to marine mammal sightings: University of Rhode Island, 3-8 April 2018

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5.1 Summary

During 3-8 April 2018, the National Science Foundation ship *R/V Endeavor* operated by the University of Rhode Island (URI) conducted a Rhode Island Endeavor Program (RIEP) research cruise intended to explore North Atlantic right whale (*Eubalaena glacialis*) distribution relative to prey layers and physical oceanography south of New England in wind energy regions. The protocols developed and fine-tuned during this pilot study built off a similar study in 2017 and could provide potential methods used for a future high resolution AMAPPS process study conducted in regions of interest such as potential energy development regions. AMAPPS contributed contractor funds for one marine mammal observer and partial time for one staff member to run a Video Plankton Recorder (VPR). The cruise ran transects for sighting marine mammals and deployed a variety of oceanographic and prey sampling methodologies that included: bongo nets, CTDs (Conductivity Temperature Depth sensor), XBTs (expendable bathythermograph), VPR, ADCP (Acoustic Dopler Current Profiler), underway thermosalinograph (TSG) temperature and salinity data, and active acoustics collected with a tow body equipped with 38, 120, and 206 kHz EK60 transducers. The weather on the cruise was quite challenging and limited marine mammal observations. However, on the last day we did sight two right whales in an area where numerous other right whales had been observed in the previous two weeks. We sampled the nearby habitat extensively and are currently working up these data and developing a manuscript. Preliminary analysis suggests right whales were feeding on a layer of zooplankton at roughly 35-40 meters depth below a slight thermocline. Copepod concentrations were primarily a mix of *Calanus finmarchicus* and *Pseudocalanus* species, but appeared to be present in densities that were not high enough to make right whale foraging energetically worthwhile. Surprisingly, the VPR detected few copepods, but high densities of the ctenophore (*Pleurobrachia*). These unexpected findings suggest that right whales may be feeding on a mix of zooplankton in this region rather than focusing on *Calanus finmarchicus*, and that ctenophores could potentially contribute to their diet. Further research is planned on the Endeavor for the spring of 2019 to further investigate right whale foraging in this area.

5.2 Objectives

The Rhode Island Endeavor Program (RIEP) is designed to provide University of Rhode Island (URI) researchers and Rhode Island's educator's access to the scientific research and educational capabilities of an ocean-going research vessel. This particular research cruise was designed as the centerpiece of an undergraduate honors science class in which the undergraduate students participated in data collection while at sea and shared their experiences using telepresence via the URI Graduate School of Oceanography (GSO) Inner Space Center. The cruise's marine mammal focus was chosen because of the potential for students to experience multiple types of oceanographic sampling that examine the linkages between several trophic levels. The protocols developed during this pilot study could be potential methods to be used for high resolution sampling of a future AMAPPS process study conducted in regions of interest such as potential energy development regions.

5.3 Cruise Period and Area

The cruise was conducted 3-8 April 2018 on the *R/V Endeavor*. The study area was continental shelf and shelf edge south of Narragansett Bay, Rhode Island (Figure 5.1).

5.4 Methods

5.4.1 Overview

The data collection plan was to conduct a mix of marine mammal observing and oceanographic and prey sampling, much of it conducted simultaneously. Upon finding a group of whales, we planned to extensively sample the physical and biological oceanography in that area with a variety of instruments. This created a unique dataset allowing the exploration of the physical and biological linkages defining water column habitat for marine mammals and their prey. The cruise ran transects for sighting marine mammals, deployed a VPR, bongo nets, CTDs, and XBTs. Plus, we also recorded underway physical oceanographic data and gathered active acoustic data on prey layers using a tow body equipped with 38 and 120 kHz Simrad EK60 echosounders, and a 206 kHz Biosonics DT-X echosounder. A contractor (funded with AMAPPS funds), a NEFSC federal staff member, who is also a doctoral graduate student at GSO, and one other NEFSC federal staff member participated in the research cruise by running the marine mammal, zooplankton, VPR, and active acoustic portions of the cruise.

5.4.2 Marine Mammals

Marine mammal surveying was conducted from the flying bridge of the R/V *Endeavor* using the naked eye, handheld binoculars, and two “Big Eye” (25x150) binoculars mounted 10.2 m above the waterline that were calibrated at the dock. Marine mammal observers rotated every half an hour between the two Big Eye stations and a recording station where observation took place using either naked eyes or handheld binoculars. Marine mammal observers recorded effort and sightings using a custom-built software program (VisSurvey) employed on National Oceanic and Atmospheric Administration (NOAA) marine mammal research cruises. Among the data recorded in this software were the sighting species, distance, latitude, longitude, time, date, behavior, and swim direction. The remaining data were provided by the observer, with the distance from the ship coming from the Big Eyes.

Additional right whale observations in the weeks before, during, and after our Endeavor research cruise were documented in the sightings database database maintained by the North Atlantic Right Whale Consortium (Figure 5.1). Sightings in this database included those observed by mariners, and those recorded during aerial surveys in March and April 2018 conducted by the NOAA Northeast Fisheries Science Center.

5.4.3 Plankton

Bongo nets were towed in double oblique fashion to within 5 m of the bottom while the ship traveled between 1.5 and 2.0 knots. Nets of 333 and 150 μ were deployed on the two 61 cm diameter bongo frames. A shipboard computer system (SCS) monitored bottom depth, GMT, the ship's position, and surface water temperature while a CTD deployed on the wire just above the bongo nets recorded oceanographic information along the cast. Samples were washed down into the cod end of the net with salt water and flushed into a sieve. Samples from the 333 µ net were preserved in formalin, while the samples from the 150 µ net were preserved in ethanol and the ethanol was changed after 24-48 hours. Zooplankton samples from bongo nets were sent to the Polish Sorting Center for processing species and quantities. These samples are still being processed. The sample from the 333 µ net taken near the right whales was split in half and one half was sent to the Polish Sorting Center while the other half was processed at the University Rhode Island. Zooplankton was identified to species, while *Calanus finmarchicus* was identified to stage. Regional historical zooplankton data from bongo samples on NOAA's ECOMON surveys will also be examined to provide context to the observations recorded on this cruise.

The Video Plankton Recorder (VPR) was deployed four times during the Endeavor research cruise, each time paired with deployment of the active acoustic tow body (Figure 5.1).The VPR was typically towed in a tow-yo mode, oscillating in a sawtooth pattern throughout the water column, and tows times ranged from 38 to 79 minutes. The tow associated with the right whale sightings was deployed for 38 minutes. We first operated this deployment in tow-yo mode, and then the instrument was set at particular depths associated with prey layers within a layer of organisms observed in real time echosounding data. Data were summarized first with an automated classification system that classified observed organisms and estimated density per m^3 (Tang et al. 1998). The data were then further hand-processed for finer organism identification and measurement of ctenophore sizes.

We mounted two Simrad EK60 echosounders (38 and 120 kHz) and one Biosonics DT-X echosounder (206 kHz) on a custom-made tow body crafted from a former Klein side-scan sonar towfish. The tow body was deployed from a boom on the port side that was located approximately 4 meters forward of the stern. When deployed, the tow body was stable and horizontal while towed 2-3 meters below the surface at 3-4 knots. We attempted to calibrate the echosounders using standard methods (Foote et al. 1987, Demer et al. 2015) and a 38.1-mm tungsten carbide sphere with 6% cobalt binder. Additional calibration steps were taken during post-processing using the steps suggested in the Echoview (Echoview 2018) and the Simrad EK500 operation manual (Simrad 1996).

Echosounding data were processed using Echoview 8.0 software. Background noise removal was evaluated using noise cleaning established techniques (Ryan et al. 2015). Interference from the Simard EK60s was evident on the data collected by the Biosonics DT-X and was manually removed by drawing polygons around the affected area and replacing these data with the median of a moving window. Classification of echosounding data to organism type is currently underway. Predicted target strengths of *Calanus finmarchicus* and *Pleurobrachia* were calculated using Distorted Wave Born Approximation (DWBA) (Lawson et al. 2004). Organism's target strengths will then be used to classify potential zooplankton prey types in the water column along the cruise track and their estimated densities.

5.4.4 Physical Oceanography

CTDs and XBTs recorded physical oceanographic conditions at specific locations or while on towed instrumentation. CTD instrumentation was attached the cable for bongo net tows, attached to the VPR tow body, and on a separate CTD rosette. One XBT was deployed in the region of the right whale sightings (Figure 5.1). CTDs deployed in the area of right whales included one on the CTD rosette, a second attached to the bongo net cable, and a third on the VPR tow body.

Two instruments recorded oceanographic information throughout the cruise. The ADCP recorded currents at depth while the TSG recorded surface salinity and temperature. The ADCP current data was examined at 21 meters depth, where the ADCP data was most complete. Current data in the U and V directions were summarized into its component parts (mean, trend, inertial, diurnal, semidiurnal, and residual). Simulations were run examining potential plankton transport over the course of the cruise and in the region of the right whale observations. Analysis of the TSG data has not yet been completed. Additional data to be examined in relation to this cruise include satellite data of chlorophyll and sea surface temperature, as well as ocean model data of currents in the region.

5.5 Results

5.5.1 Overview

The short cruise was plagued by bad weather, which made sighting marine mammals difficult to impossible. The wind and white-caps picked up shortly after leaving port, with winds averaging roughly 20 knots for the cruise. In the afternoon of the second day, we had to retreat to the leeward side of Block Island until mid-day of the following day. The conditions had become unworkable as significant wave height sustained 3 m in the study area (at the Block Island NOAA buoy #44097). Aside from the time spent steaming toward shelter and sheltering behind Block Island, we conducted oceanographic sampling and observed for marine mammals during daylight hours. At about 3:10 pm EST on the last full day of the cruise, we sighted one right whales, and later spotted a second, and proceeded to sample the area for prey and oceanographic characteristics until approximately 10 pm (Figure 5.2). The following sections focus on these right whale sightings and the prey and oceanographic sampling in the region of the sightings.

5.5.2 Marine Mammals

On 7 April 2018 we sighted two right whales (Figure 5.2) and one gray seal. After sighting the first right whale, we broke transect and monitored the location and dive pattern of this whale. Right whales were sighted 17 times and the average re-sighting time of right whales was 12 minutes, ranging from 1 to 31 minutes, and re-sighting locations did not suggest travel in a consistent direction, both of which were consistent with foraging. The whales were not observed surface feeding and were diving to depth. Photographs were taken in an attempt to identify specific whales and preliminary identification suggested one animal was a 9 year old juvenile female that had been sighted in the southern New England region previously.

The North Atlantic Right Whale Consortium documented additional right whale sightings in this area before and shortly after our cruise (Figures 5.1 and 5.2). From 18 March 18 to 11 April 2018, 47 right whales were sighted among 28 groups that contained from 1 to 6 animals. Repeat sightings of the same animals may be included in this count.

5.5.3 Plankton

The bongo sample in the region of the right whales (Figure 5.2) was dominated by *Pseudocalanus* and *Calanus finmarchicus*, where *Psuedocalanus* out numbered *Calanus* by roughly 2 to 1 (Table 5.1). The later stages of *Calanus* were the most prevalent and stage five was present in the highest numbers (Table 5.2). Future analysis will quantify the caloric value of zooplankton collected in the bongo sample relative to that needed to make right whale foraging energetically worthwhile.

The VPR was deployed 4 times during the cruise. The VPR cast (Figure 5.2) in the right whale region found almost no copepods but many jellyfish, particularly the ctenophore *Pleurobrachia* (Figure 5.3). Counts of *Pleurobrachia* between 36 and 42 m depth averaged 43 m^{-3}, with a maximum of 493 m^{-3}. The maximum density during the entire VPR tow was 1,233 m^{-3}. Individual *Pleurobrachia* were also measured and will be used to calculate the acoustic target strength. The median length was 3.88 mm (std=1.17, range=1.80-8.03) and a median width was 2.56 mm (std=1.17, range=1.52-4.57).

The echosounding tow body was deployed 5 times during the course of the cruise. The acoustics showed a distinct and consistent layer at roughly 35-40 m depth that was increasingly distinct with increasing echosounder frequencies (Figure 5.4). Preliminary attempts at classifying acoustic backscatter based on target strength and relative frequency response suggests the layer consisted of zooplankton with a possible mix of copepods and ctenophores (Figure 5.5). The theoretical acoustic patterns for ctenophores and copepods overlap to some degree with the echosounding frequencies available on this cruise, making it difficult to distinguish between the two classifications. Preliminary acoustic analysis of the VPR region did not match the predicted acoustic pattern expected from ctenophores and therefore the signal may have been contaminated by other mobile organisms in the area not detected by the VPR.

5.5.4 Physical Oceanography

A total of three XBTs were launched for supplementary oceanographic information while underway CTD instruments were included on the bongo net tows, on a separate CTD rosette, and on the VPR. Between all instruments, 17 CTD deployments occurred (Figure 5.1). A CTD deployment in the right whale region showed a slight thermocline and picnoline at about 33 m depth (Figure 5.6).

Assessment of measured ADCP currents on the cruise, both over the whole course of the cruise and specifically in the right whale sighting region, suggested that currents were dominated by tidal and Coriolis forces, resulting in little net displacement over time. Simulated plankton movement based on ADCP measurements showed a circular movement over the course of the 24 hrs, with a maximum displacement of only about 100 m, finishing roughly 85 m from its starting point (Figure 5.7). This suggests that right whale zooplankton prey were unlikely to be displaced any significant distance during our investigation of the right whale foraging area. So, prey was unlikely to be swept out of the area during our study. For our bongo and VPR sampling to be relevant to the right whale sightings (roughly 1 nm between our sampling and the nearest right whale sighting), the prey layers need to be consistent across the region and between the sampling areas. Preliminary classification analysis of the acoustics data suggest a consistent layer of zooplankton, however further quantification is needed.

5.6 Disposition of 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 plankton samples collected will be maintained by the Oceans and Climate Branch at the NEFSC in Narragansett RI. 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.

5.7 Permits

The marine mammal research activities were authorized to be conducted under US Permit No. 17355 issued to the NEFSC by the NMFS Office of Protected Resources.

5.8 Acknowledgements

Salary for one contractor and overtime salary for one NMFS federal employee were paid for with funds from the Bureau of Ocean Energy Management (BOEM) and the US Navy through the respective Interagency Agreements for the AMAPPS project. Staff time for the NMFS federal employees were provided by the NOAA Fisheries Service, NEFSC. We would like to thank the crew of the *R/V Endeavor*, the University of Rhode Island students and instructors that were involved in planning and collecting these data for their efforts and dedication to this project.

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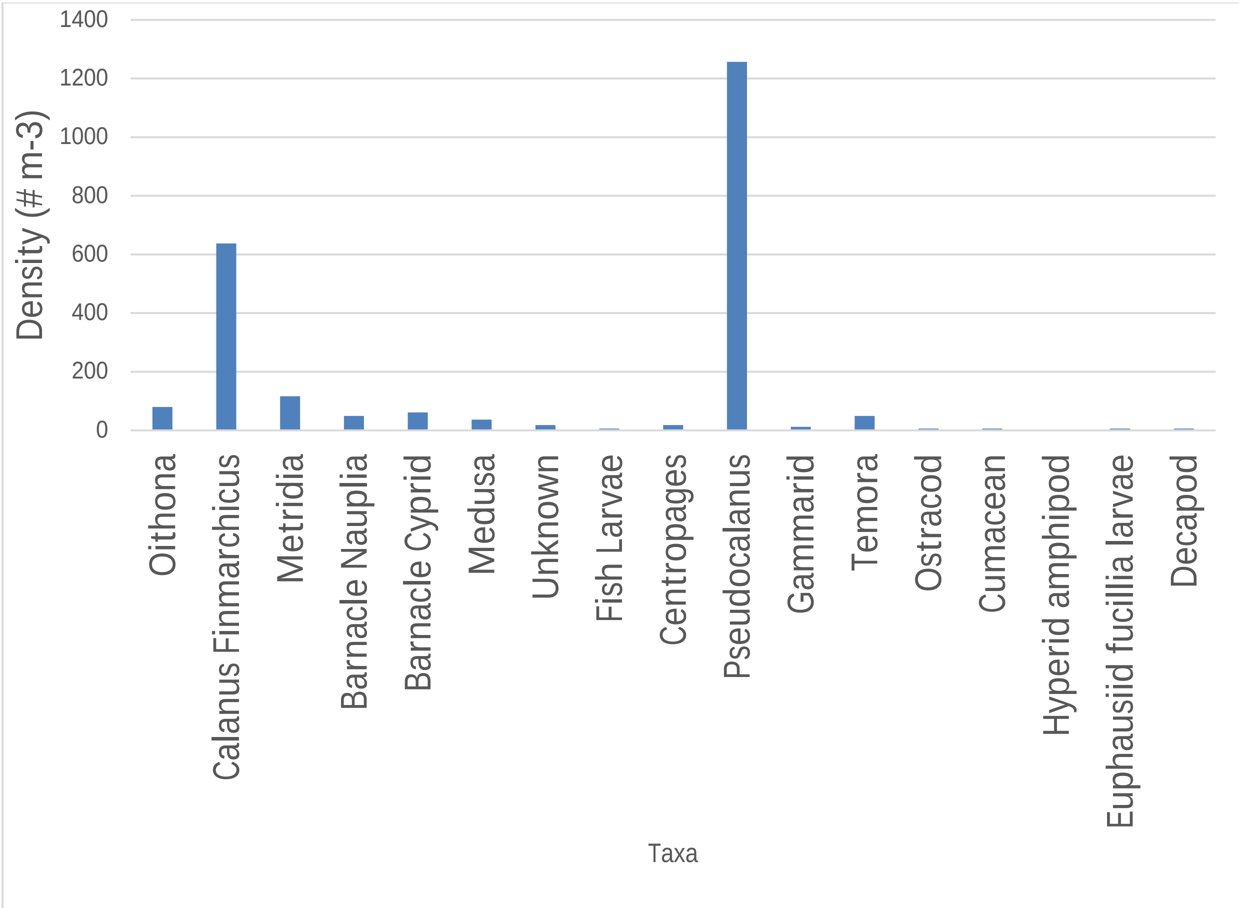

Figure 5.1 Density of zooplankton captured in the 333 μ bongo net tow in the region of North Atlantic right whales (*Eubalaena glacialis*)

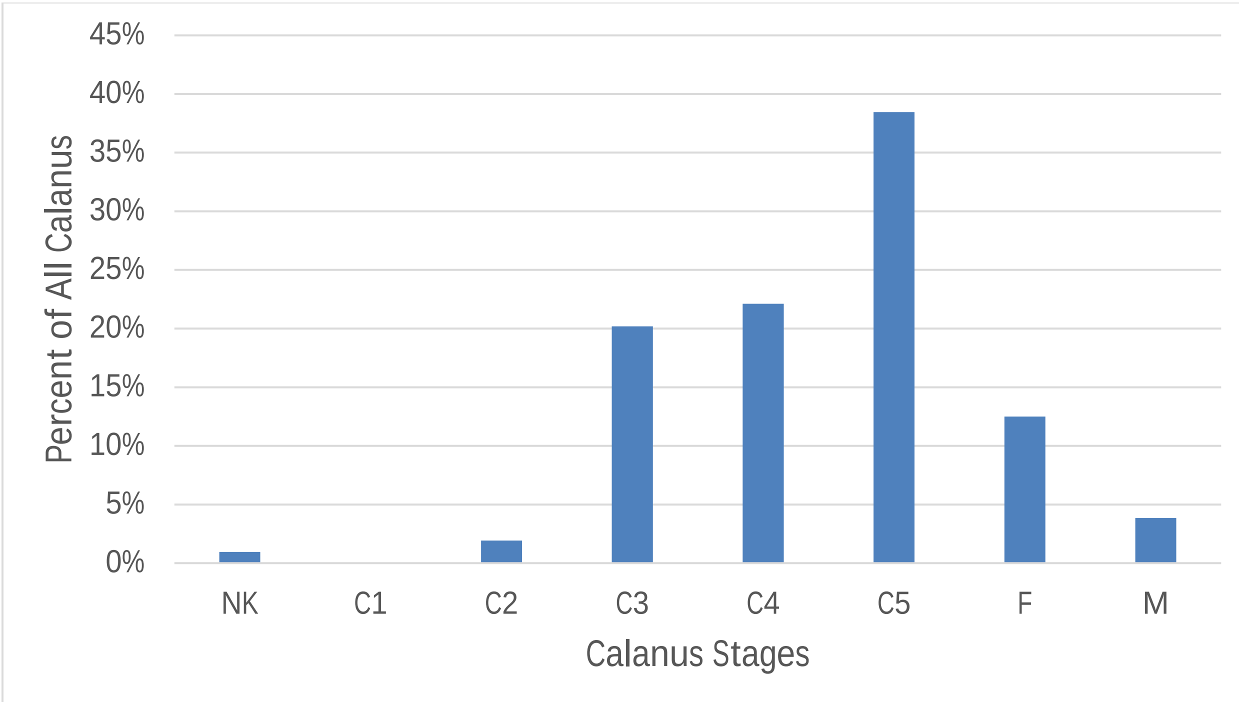

Figure 5.2 Percentage of *Calanus finmarchicus* stages observed in the 333 µ bongo net tow in the region of North Atlantic right whales (*Eubalaena glacialis*)

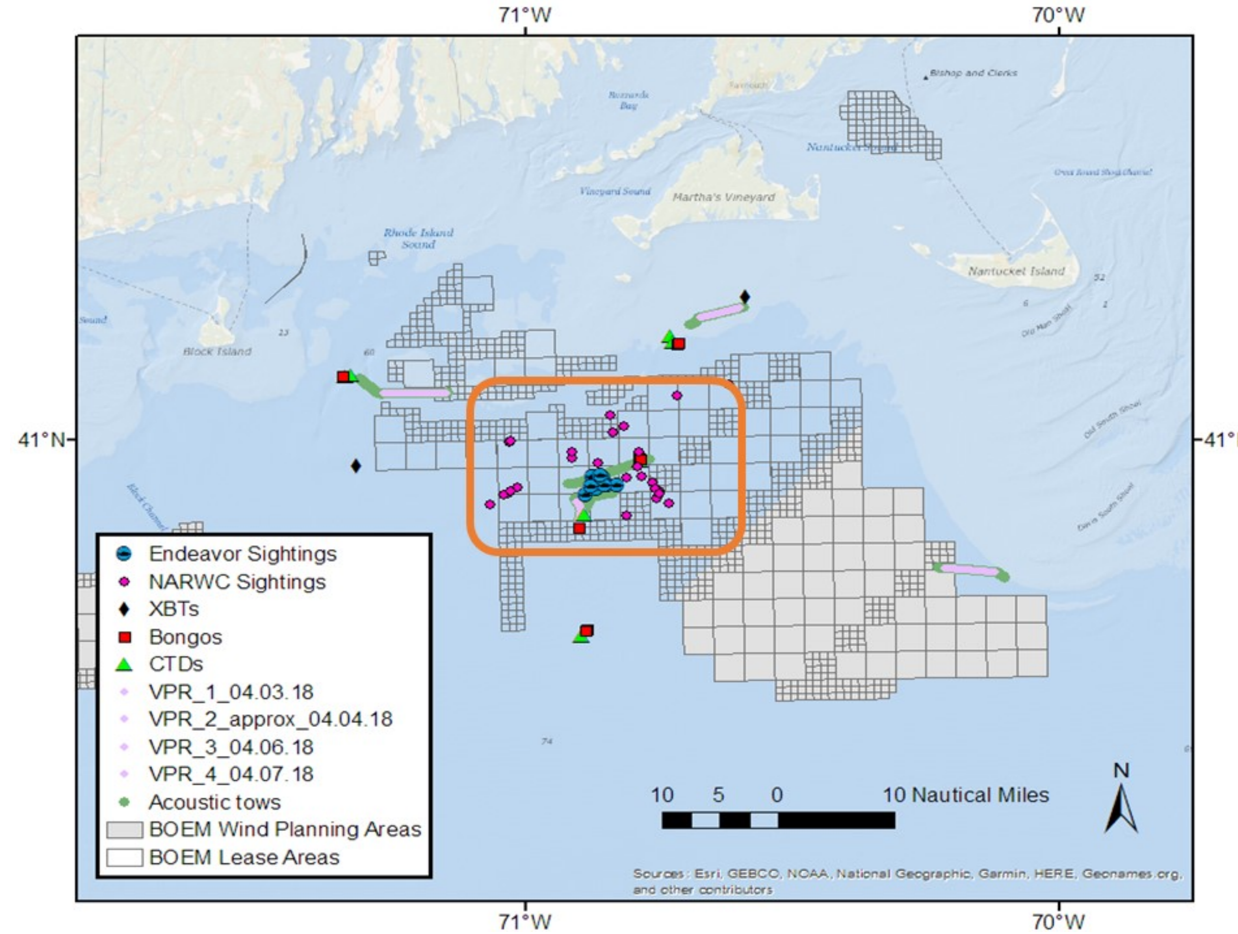

Figure 5.3 Study area, right whale sightings, and oceanographic sampling locations. Focus of study is within the orange outline

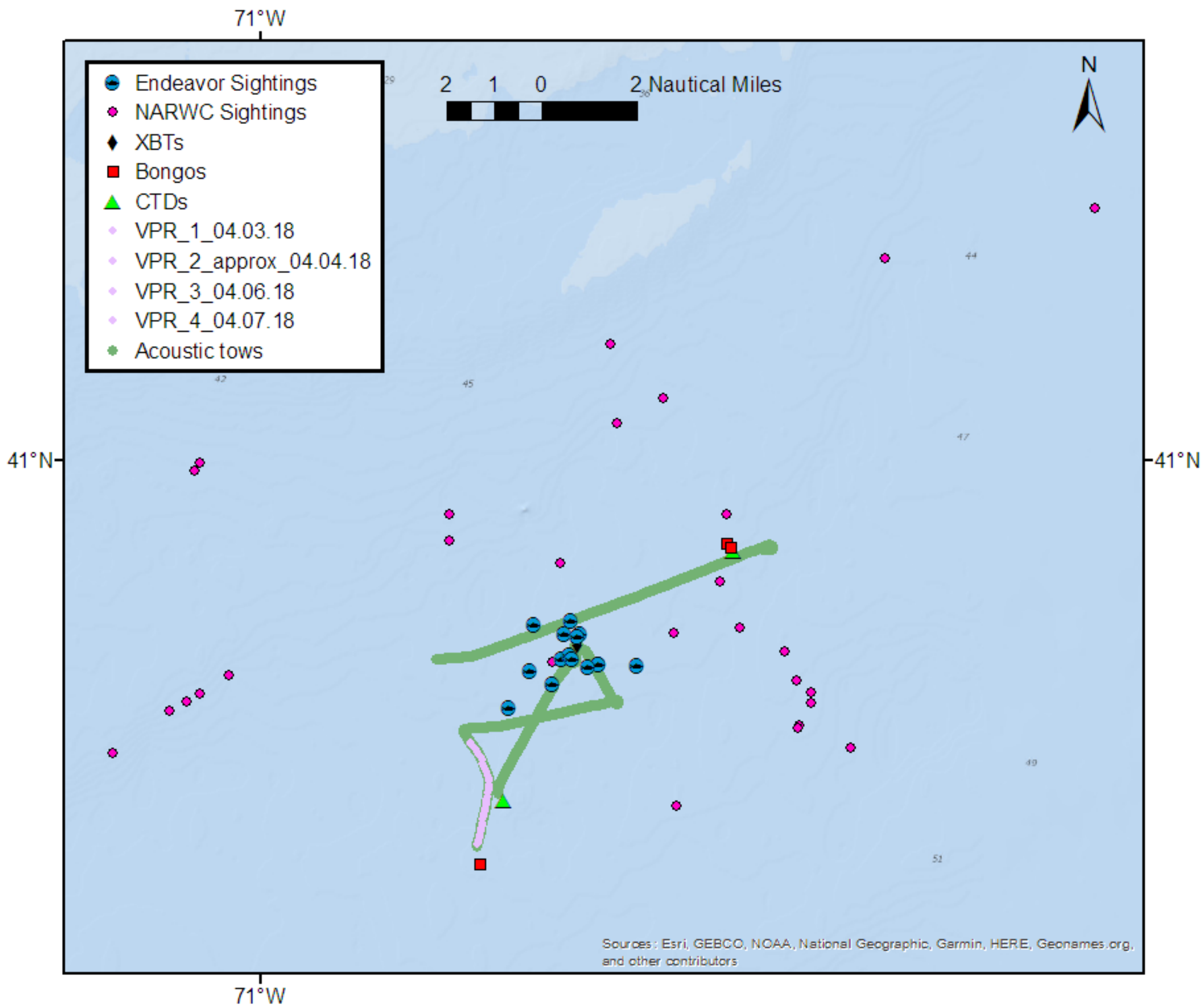

Figure 5.4 Close up of primary study area with North Atlantic right whale (*Eubalaena glacialis*) sightings, and oceanographic sampling locations

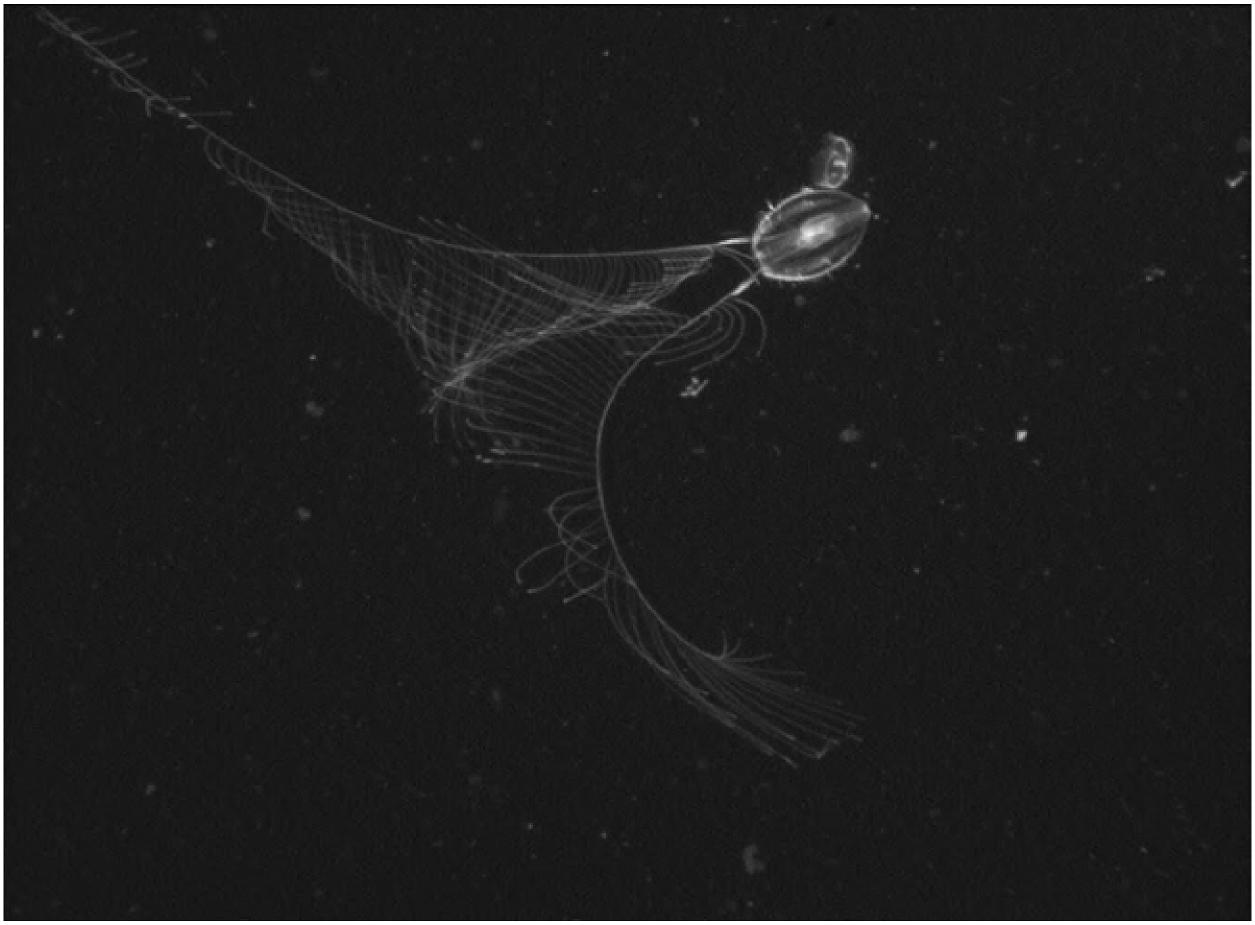

Figure 5.5 Video plankton recorder photo of a ctenophore (*Pleurobrachia*) taken in the region of the North Atlantic right whale (*Eubalaena glacialis*) sightings

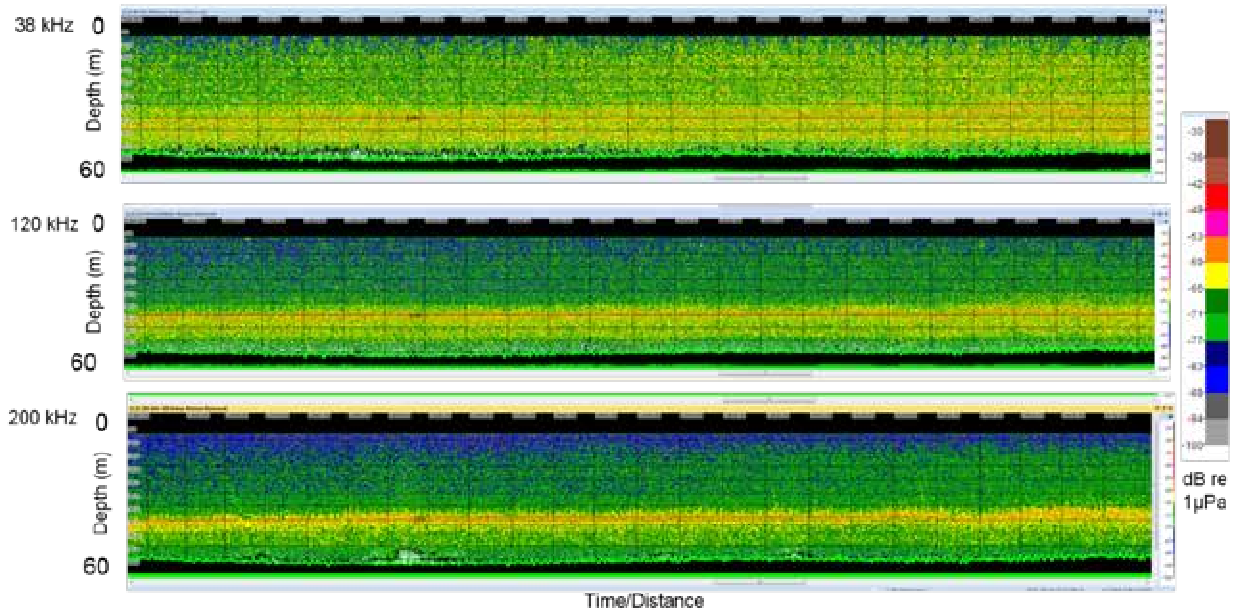

Figure 5.6 Example acoustic returns showing potential zooplankton layer at roughly 35-40 m depth. The gridding represents 5 m depth and 100 m depth intervals, stretching about 1.3 nmi

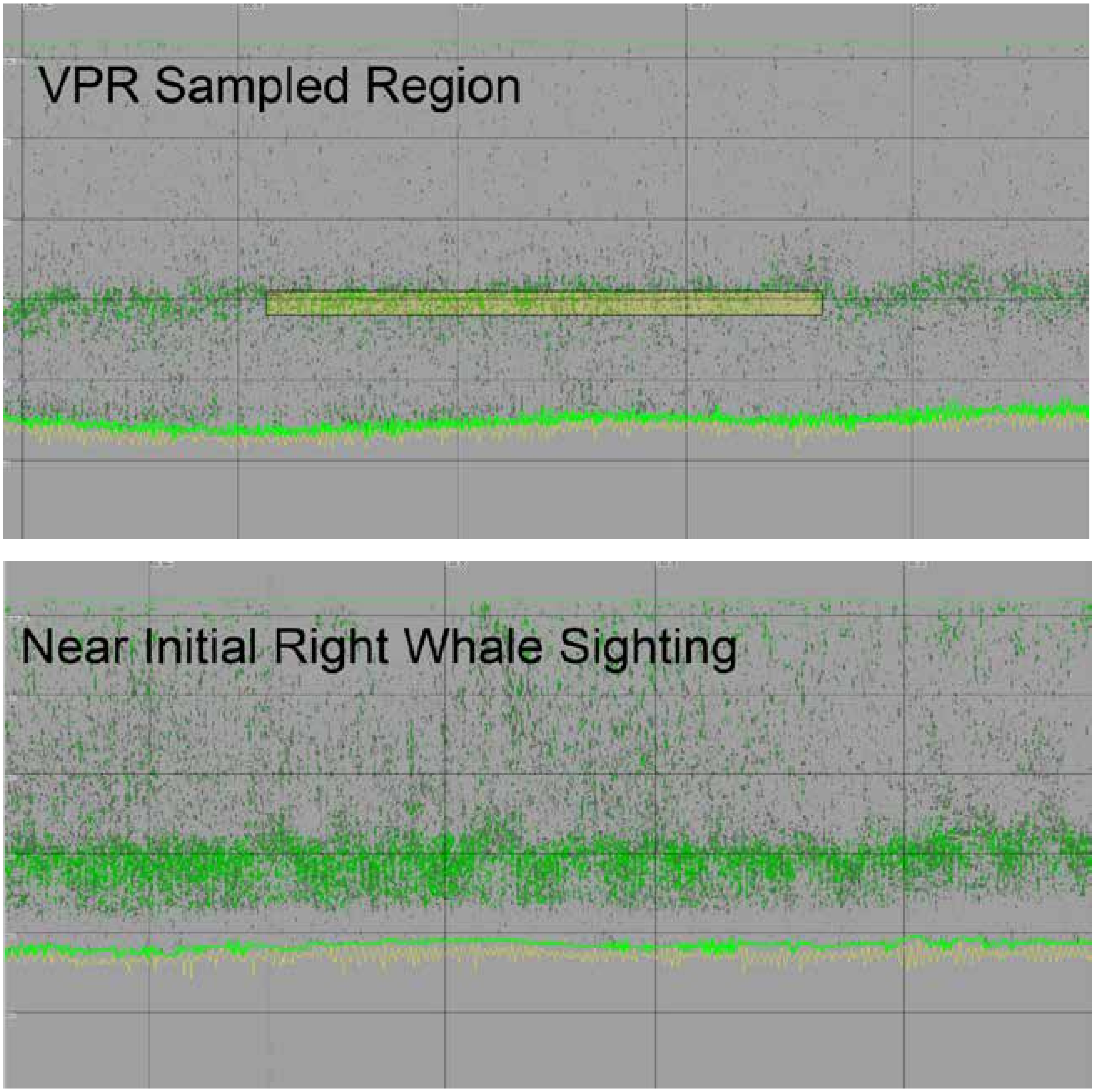

Figure 5.7 Preliminary acoustic classification in the region of the video plankton recorder (VPR) tow and near the initial North Atlantic right whale (*Eubalaena glacialis*) sighting. Ctenophore classification (green) overlaid on top of copepod classification (dark gray). Note, areas fitting the classification for both ctenophores and copepods are shown as ctenophore classification. The zooplankton layer is centered at roughly 40 m depth in the VPR sampled region and just below 40 m depth in the right whale region. The bright green line in the bottom third of the images is the detected ocean bottom. The gridding represents 5 m depth and 100 m depth intervals, stretching about 1.3 nmi

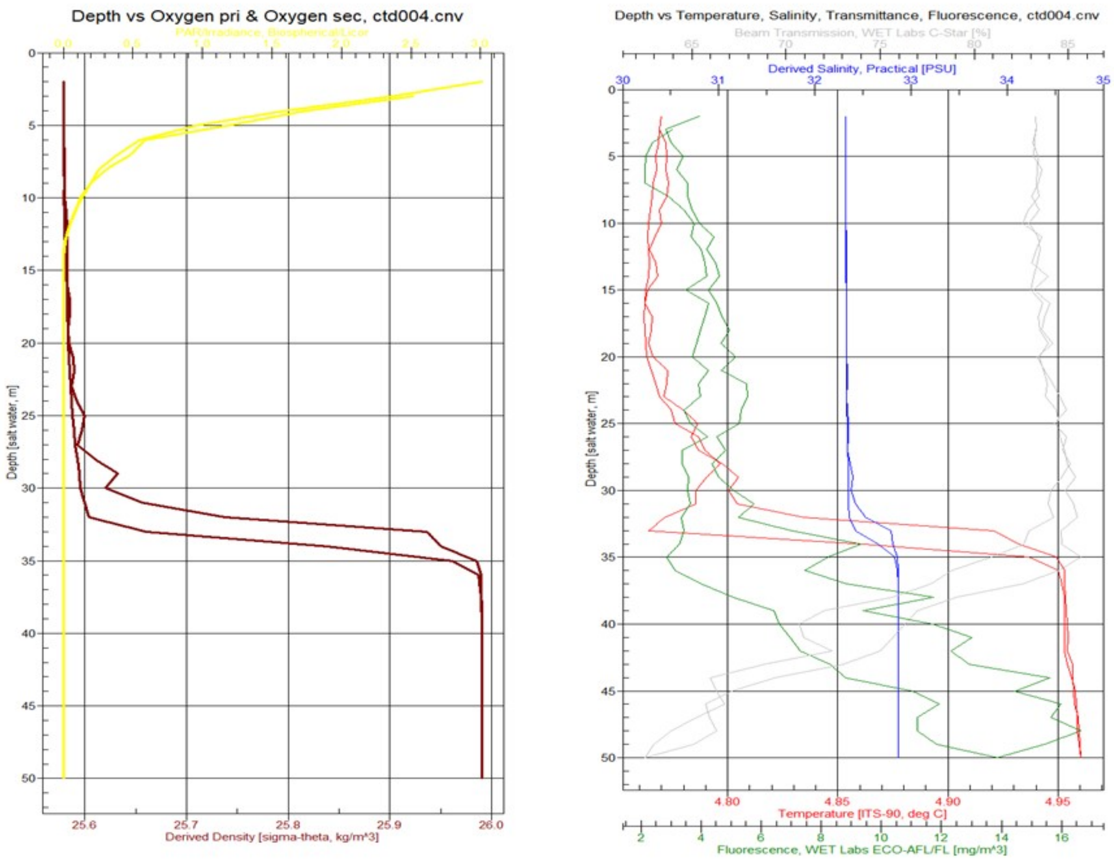

Figure 5.8 Depth profile of oxygen (left panel), temperature, salinity, transmittance, and fluorenscene (right panel) in the region of the North Atlantic right whale (*Eubalaena glacialis*) sightings

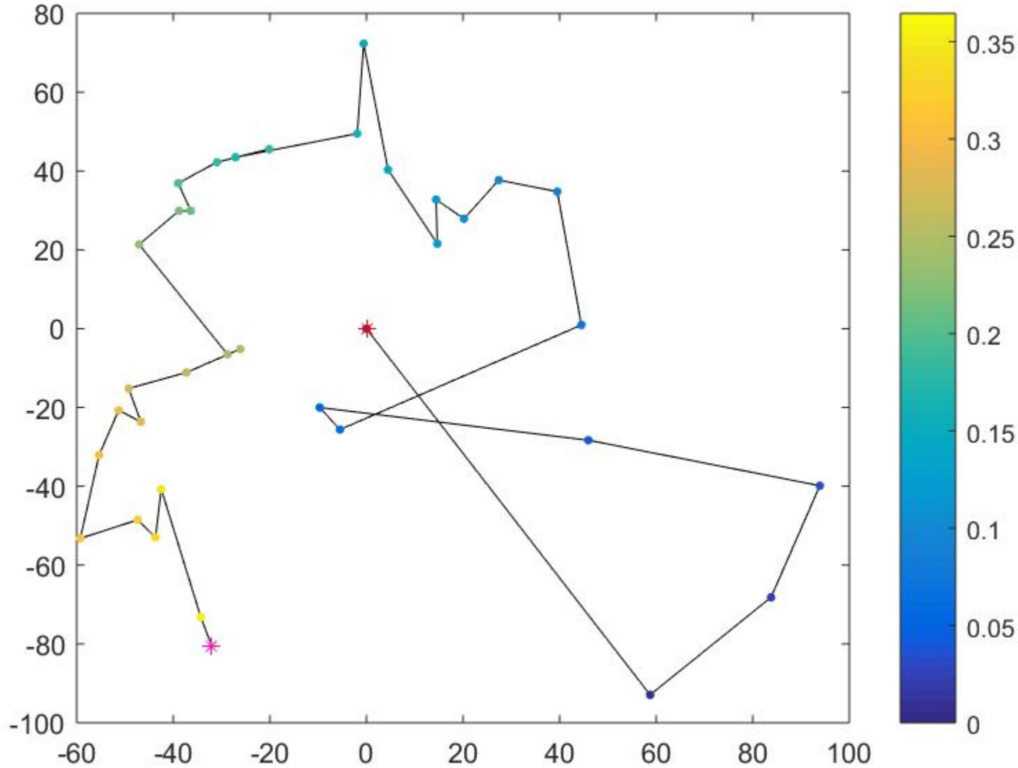

Figure 5.9 Simulation of a particle track on the day the North Atlantic right whales (*Eubalaena glacialis*) were detected. Simulation based on Acoustic Dopler Current Profiler (ADCP) measurements at 21 m depth

6 Sea turtle tagging 2018: Northeast and Southeast Fisheries Science Centers

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6.1 Summary

Leatherback tagging occurred during May 2018 in North Carolina where seven turtles were tagged with towable GPS tags. Turtles remained in the mid-Atlantic and will provide extremely important surfacing time data to be used to improve relative abundance estimates from aerial surveys. One leatherback was tagged in August in Cape Cod Bay, MA as well.

6.2 Objectives

The Atlantic Marine Assessment Program for Protected Species (AMAPPS) program coordinates the data collection and analysis efforts of the National Marine Fisheries Service (NMFS) Northeast and Southeast Fisheries Science Centers (NEFSC and SEFSC) to accomplish six primary objectives, three of which are relevant to the AMAPPS Turtle Ecology task:

- Collect data on distribution and abundance at finer scales using visual and acoustic survey techniques;
- 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;
- Explore alternative platforms and technologies to improve population assessment studies;

To advance these goals in 2018, in absence of dedicated AMAPPS ship time, the NEFSC and SEFSC collaborated on the satellite tagging of leatherbacks in North Carolina and Massachusetts.

6.3 Cruise Periods and Areas

No formal AMAPPS cruises were planned for 2018. To further AMAPPS goals, we participated in several collaborative projects (Table 6.1).

Table 6.1 Collaborative projects in 2018

Project	Notes on Cruise Period and Area
Loggerhead tagging cruises	CFF lead cruise; May 20-26; Mid-Atlantic and offshore (Gulf Stream)
Distribution of tagged loggerheads	No field work. Collaborative analytic work with UMASSD continues, and a product is expected in 2019
Leatherback tagging in NC and MA	Small boat day trips May and August

6.4 Methods and Results

Leatherback turtles were captured and satellite tagged from small vessels with the assistance of a spotter plane to locate turtles. Once located, turtles were captured via a large hoop net and then brought aboard a floating platform (TAKAKAT) for tagging as well as measurements and health monitoring. The towed satellite tags performed excellent. The data on surface time will be used as correction factors for aerial survey estimates. The tags are providing much needed information on leatherback use of Atlantic waters along the U.S. coast. Data are still being transmitted and we plan for additional tag deployments in 2019 at both locations.

We also did pilot testing of several suction cup tags, which can be used to descript surfacing behavior, foraging behavior, and dive behavior. This work is in collaboration with Department of Fisheries and Oceans Canada and Coonamessett Farm Foundation (funded by NMFS' Bycatch Reduction and Engineering Program.)

The loggerhead tagging cruise deployed 35 tags, most of which were purchased by Coonamessett Farm Foundation.

Together with other partners, the AMAPPPS Turtle Ecology team had two publications in 2018. Each paper is listed below along with a short description of its content and relevance. Note that in the citations, the names of AMAPPS Turtle Ecology team members and those receiving AMAPPS funds are shown in bold.

Estimating the distribution and relative density of tagged loggerhead sea turtles in the western North Atlantic from satellite telemetry data using geostatistical mixed effects models.

CITATION:

Winton MV, Fay G, Haas HL, Arendt M, Barco S, James M, **Sasso C**, Smolowitz R. 2018. Estimating the distribution and relative density of tagged loggerhead sea turtles in the western North Atlantic from satellite telemetry data using geostatistical mixed effects models. Mar Ecol Prog Ser 586: 217-232.

ABSTRACT:

Movement and location data collected via satellite-linked telemetry tags are often used to inform spatial conservation measures for threatened marine populations. Most applied telemetry studies aim to reconstruct the continuous utilization distribution underlying reported locations to characterize the relative intensity of space use. However, commonly applied space use estimators do not directly estimate the underlying distribution of interest and, perhaps more importantly, ignore correlations in space and time that may bias estimates. Here we describe how geostatistical mixed effects models, which explicitly account for spatial and/or temporal correlation using Gaussian random fields, can be applied to estimate utilization distributions from satellite telemetry data. We use simulation testing to compare the performance of the proposed models with several conventional space use estimators. Our results suggest that geostatistical mixed effects models outperform conventional estimators when the number of tag transmissions changes over time, a common source of bias in satellite telemetry studies that is rarely addressed. We illustrate this approach via application to satellite telemetry location observations collected from 271 large juvenile and adult loggerhead sea turtles in the western North Atlantic from 2004 to 2016. We demonstrate how such models can be used to predict the overall spatial distribution of tagged individuals, as well as seasonal shifts in densities at smaller time scales. For tagged loggerheads, overall predicted densities were greatest in the shelf waters along the US Atlantic coast from Florida to North Carolina, but monthly predictions highlight the importance of summer foraging habitat in the Mid-Atlantic Bight.

RELEVENCE: This publication is significant because of the magnitude of the underlying dataset, the availability of estimated distribution maps, and the insight on the potential global important of the Mid-Atlantic foraging grounds.

This publication represents an unusually large and robust dataset which was been compiled across many governmental and non-governmental programs. AMAPPS-purchased satellite tags constitute ~ 40% of the assembled data. Collaborating institutions include:

- Department of Fisheries Oceanography, School for Marine Science and Technology, University of Massachusetts Dartmouth, New Bedford, MA
- Protected Species Branch, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA
- South Carolina Department of Natural Resources, Charleston, SC
- Virginia Aquarium & Marine Science Center, Virginia Beach, VA
- Fisheries and Oceans Canada, Dartmouth, Nova Scotia B2Y 4A2, Canada
- Protected Resources and Biological Division, NOAA Fisheries, Southeast Fisheries Science Center, Miami, FL
- Coonamessett Farm Foundation, East Falmouth, MA

This publication represents the first AMAPPS maps of estimated distribution to be published in a peer reviewed journal. Figure 5 of the paper shows the overall and monthly log density of tagged loggerhead sea turtles within the AMAPPS study area. The associated shapefiles are available to the public for download here.

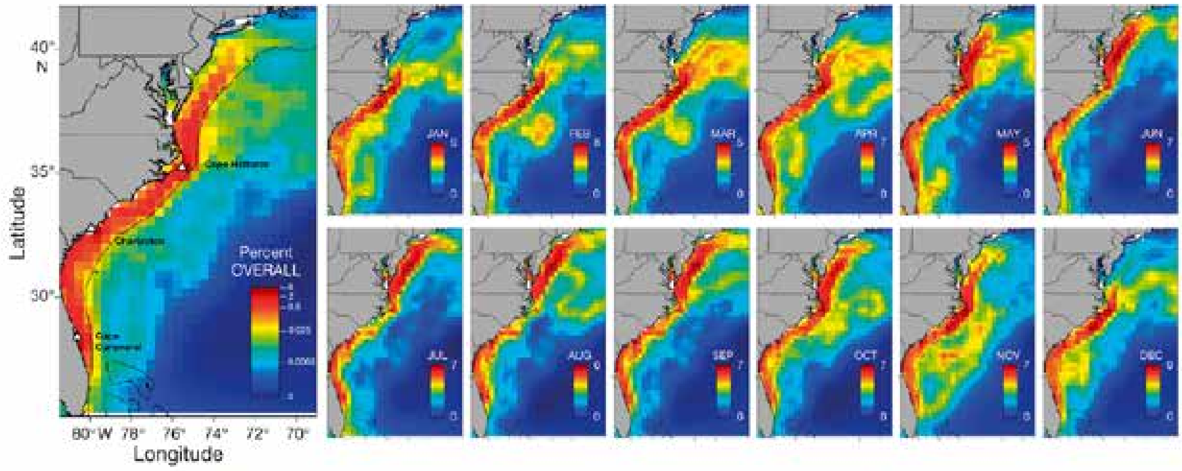

Fig. 5. Overall (left panel) and monthly (right panels) log density of tagged loggerhead sea turtles per 40 km resolution grid cell as predicted using a space-time geostatistical mixed effects model. Model predictions were based on daily locations of 271 large juvenile and adult loggerhead turtles tagged from 2004 to 2016. Predicted densities were scaled from 0 to 1 in each month for comparison purposes. The key indicates the proportion of the predicted density included in each grid cell. In each month, scale bars are consistent with the overall plot with the exception of the maximum value, which is indicated. The black line denotes the 200 m bathymetric contour. White triangles in the overall panel indicate the location of Cape Hatteras, North Carolina; Charleston, South Carolina; and Cape Canaveral, Florida

Figure 6.1 Density map of loggerhead turtles (*Caretta caretta*)

This publication is also significant in that it suggests the Mid Atlantic foraging ground may be more important to loggerheads than previously thought. While the seasonal occurrence of loggerheads in the Mid-Atlantic Bight has been well-documented, the extent of the region's importance to the broader western North Atlantic population remains unclear. A preliminary analysis of aerial survey data collected in the summer of 2010 estimated that only 5% of the surveyed population occurred north of Cape Hatteras from June to September (Northeast Fisheries Science Center & Southeast Fisheries Science Center 2011). Our results in this paper suggest that the Mid-Atlantic Bight foraging grounds may support a larger proportion of the population, with over 50% of the predicted relative density of tagged loggerheads occurring north of Cape Hatteras from June to October.

<u>Loggerhead turtles are good ocean-observers in stratified mid-latitude regions.</u>

CITATION:

Patel SH, Barco SG, **Crowe LM**, Manning JP, **Matzen E**, Smolowitz RJ, **Haas HL**. 2018. Loggerhead turtles are good ocean-observers in stratified mid-latitude regions. Estuarine, Coastal and Shelf Science 213: 128-136.

ABSTRACT:

Since 2009, we have deployed 167 satellite tags on loggerheads within the U.S. Mid-Atlantic Bight of the Northwest Atlantic Ocean. These tags collect and transmit location, temperature and depth information and have yielded 18,790 temperature-depth profiles during the highly stratified season (01 June–04 October) for the region. This includes 16,371 profiles exceeding the mixed-layer depth, and, of those, 11,591 full water column profiles reaching the ocean floor. The US Mid-Atlantic Bight is a dynamic ecosystem that is difficult to model due to a combination of complex seasonal water masses and currents and a limited set of tools for taking

in situ measurements. This region is also prime foraging habitat for loggerhead sea turtles during the late-spring to summer months. Here we suggest that the habitat usage of loggerhead turtles in the Mid-Atlantic Bight make them good ocean observers within this difficult to model, highly stratified region. The use of turtle-borne telemetry devices has the potential to improve resolution of in-situ temperature through depth data and in turn improve oceanographic model outputs. It is imperative that model outputs are continuously updated, as they are regularly used to inform management and conservation decisions

RELEVENCE: This publication is relevant in that it focuses on a geographic area with planned energy development. It documents the utility of turtle-borne data loggers, illustrates that loggerheads use the full water column, and makes the resulting data available to the public.

The Mid-Atlantic Bight is a highly productive and dynamic marine environment which is inhabited by several protected species and is slated for considerable energy development. Despite the biological and ecological importance of the region, models of its thermal (sea surface temperature, mixed layer depth, and bottom temperature) lack accuracy, partially due to data gaps. Improving the accuracy of thermal models would improve habitat modeling in cases where surface temperature, mixed layer depth, or bottom temperature are predictors of habitat use.

Sea turtle anatomy makes them ideal candidates as ocean observers. The loggerhead carapace is comprised of bone covered by keratinous scutes. The vertebral scutes of late stage juvenile and adult loggerheads are well suited for tag attachment because a) they can be easily cleaned without harming the turtle, b) their proteins adhere well to epoxy, and c) uneven keels disappear well before adulthood.

Loggerheads carried most data loggers through the mixed layer depth to the ocean floor. All 162 tags present in the Mid Atlantic Bight exceeded the mixed layer depth, and a total of 16,371 profiles captured this ocean feature. Most (160 of 162) tags went to the bottom recording a total of 11,591 full water column profiles. These data add new information about our knowledge of loggerhead dives in this important Mid-Atlantic region.

The location, depth, and temperature data associated with this project are available to the public for download here.

6.5 Disposition of Data

Data from all satellite tags purchased by AMAPPS, as well as all Sea Mammal Research Unit (SMRU) satellite tags deployed by Coonamessett Farm Foundation in support of Research Set Aside objective are maintained in an Oracle Database at NEFSC. Data from all leatherback tags are maintained by the SEFSC.

6.6 Permits

The deployment leatherback tags were authorized under the US Permit No. 16733 issued to the SEFSC. Loggerhead research was primarily under US Permit No. 16556 issued to the NEFSC.

6.7 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. Research was funded in part by the scallop industry Sea Scallop Research Set Aside program administered by the Northeast Fisheries Science Center under grants; by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC, through Inter-Agency Agreement Number with the National Marine Fisheries Service as the Atlantic Marine Assessment Program for Protected Species (AMAPPS); and by the Northeast Fisheries Science Center.

7 Shipboard shelf break ecology survey 20 July – 19 August 2018: Northeast Fisheries Science Center

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7.1 Summary

The Northeast Fisheries Science Center (NEFSC) conducted a shipboard survey of shelf break and offshore waters from 20 July – 19 August 2018. This focused primarily on the region offshore of Georges Bank, where surveys in recent years have indicated consistent presence of a community of deep-diving cetacean species. This was part of a series of surveys entitled the Integrated Technologies for Deep Diver Ecology Program (ITS.DEEP), where the primary goals are to test and integrate multiple new technologies to assess the ecology and distribution of deep diving cetacean species, such as beaked whales and sperm whales (*Physeter microcephalus*). This survey focused primarily on True's beaked whale (*Mesoplodon mirus*) habitat, as this is as-yet the only identified area in the world where this species can be reliably found.

The survey design varied between "exploratory", during which time pre-determined tracklines were surveyed at a speed of 13-15 km/hr; or "focal follow", when focal data were collected on targeted cetacean groups. The scientific crew included a visual observation team scanning for marine mammals and sea turtles, a single seabird observer collecting data on avian sightings, and a passive acoustic team monitoring a towed hydrophone array. New technologies that were tested on this survey included: a prototype tetrahedral passive acoustic array to conduct 3-D localization of vocalizing animals, drifting autonomous recording buoys with suspended hydrophone arrays, and a deep-water passive acoustic mooring deployed in water depths over 2000 m. Additionally, water samples were collected to conduct baseline testing of the efficacy of environmental DNA (eDNA) as a sampling tool within the vicinity of known cetacean groups. Approximately 3900 km were surveyed by the marine mammal visual team; passive acoustic data were collected over an additional 570 km. Conductivity-temperature-depth (CTD) data were collected at 8 stations, with bongo sampling conducted at 5 stations to assess the presence of larval Atlantic bluefin tuna (*Thunnus thynnus*), and water samples collected at 3 stations to test for cetacean eDNA at depths up to 1500 m. Beaked whale groups were sighted a total of 360 times, including repeat sightings of groups for which focal follow data were collected. The majority of these sightings identified to species were of True's beaked whales (163 groups, 505 individuals). An estimated 208 groups of other cetaceans were sighted, with sperm whales and Risso's dolphins (*Grampus griseus*) being the most frequently sighted groups. An estimated 530 groups of seabirds and other avian species were sighted, comprised of at least 32 species. Additionally, there were 11 sightings of sharks, rays and other fishes, including a whale shark (*Rhincodon typus*) and several manta rays, plus one unidentified sea turtle. The hydrophone arrays were monitored for 414 hours, yielding 636 acoustic detections of beaked whale groups. Fifteen paired water samples were collected from the vicinity of 3 species of cetacean groups for eDNA testing. Seven biopsies were collected, four from True's beaked whales and 3 from other species. Focal follow data were collected for approximately 10 different True's beaked whale groups. One digital acoustic recording tag (DTAG) was deployed on a True's beaked whale for approximately 13 hrs, during which time data were recorded from nine foraging dives.

7.2 Objectives

The overall objective was to document the occurrence of beaked whales and other cetacean species in the offshore waters of Georges Bank, including waters of the Northeast Canyons and Seamounts Marine National Monument, and to collect fine-scale cetacean ecology data for target species. Detailed objectives included: 1) collecting visual data for standard sightings information as well as information on movements and dive behavior; 2) collecting passive acoustic data from towed hydrophone arrays, as well as drifting and bottom-mounted recording devices to track multispecies occurrence in conjunction with prey in deep-water habitats; 3) collecting water samples for eDNA testing from the flukeprints of diving animals, in conjunction with biopsy sampling; 4) deploying suction-cup DTAGs on beaked whales; and 5) collecting oceanographic and prey data (primarily related to temperature, salinity, acoustic reflectance, and zooplankton abundance), including targeted EK60 data in areas where animals have been documented foraging.

7.3 Cruise Period and Area

The survey was conducted on the NOAA Ship *Gordon Gunter*, out of Newport, RI. The survey period was divided into two legs: July 20 – August 3 (Leg 1), and August 6 – 19 (Leg 2). The overall resulting survey period was 29 days, which included 25 days at sea and four days with transits to and from port. The primary survey region included the shelf break and offshore waters of Georges Bank and the southern edge of Browns Bank, from 39° – 42.5° N and 64° – 70.5° W.

7.4 Methods

The design for this survey was divided into two phases: 1) "exploratory", during which time the visual and acoustic teams were collecting data on all species sighted using modified line-transect methodologies, and 2) "focal follow", when groups of animals of the target species were sighted that warranted dedicated focal-follow effort. Typical survey speeds were 13 -15 km/hr (7 – 8 kts) during exploratory phases, but reduced to 3-4 km/hr (~2 kts) or less during focal follow phases. During exploratory mode, the vessel surveyed along pre-determined tracklines spanning the shelf break and offshore waters. During focal follow mode, the vessel continuously maneuvered to attempt to remain within visual range of the target cetacean group. The number of observers varied depending on survey phase and weather conditions; see below for more information. Sixteen scientists participated in the overall survey, though each survey leg only had thirteen scientists at a time (Table 7.1).

7.4.1 Visual Marine Mammal – Turtle Sighting Team

Visual surveys were conducted during daylight hours (approximately 0630-1900 ET), and in sea states up to Beaufort 6, when rain was not present. Data on all marine mammal, sea turtle, and large fish (i.e. tuna) sightings were collected by a single observation team, operating from a station located on the flying bridge, 13.7 m above the sea surface. The observation team was typically comprised of three to five observers at a time during exploratory phases. Two observers utilized 25x150-power binoculars, to scan from the bow of the ship to 90° port or starboard. A third observer scanned the trackline region using naked eye and handheld 7x50 binoculars, and recorded sightings data. While in exploratory search mode, observers rotated through their positions every 30 minutes, and then had a break of at least 30 minutes. When conditions were good, 1-2 additional observers often assisted in survey effort using handheld binoculars or naked eye. However, when Beaufort conditions exceeded a sea state 5, observer effort was frequently reduced to one person.

Sightings data were recorded onto laptop computers with the custom-built software package VisSurv-NE (version 6), which was initially developed by L. Garrison and customized by D. Palka. The following information was collected: 1) The observer who detected the sighting; 2) Time of the sighting to the nearest second; 3) Species composition of the group; 4) Radial distance to the group, estimated by reticles when using binoculars; 5) Bearing between the line of sight to the group and the ship's track line; measured by a polarus mounted at the base of the binoculars; 6) Best estimate of group size; 7) Swim direction; 8) Number of calves; 9) Initial sighting cue; 10) Initial behavior of the group, and 11) Any comments on unusual markings or behavior. The location of the ship (latitude and longitude) was recorded using the ship's GPS every 12 seconds, and every time a sighting entry was made into VisSurv-NE. At times when it was not possible to positively identify a species, the ship broke from the survey tracklines to head in the direction of the sighting, until species composition was verified.

Effort and environmental data were recorded when observers rotated or every time there was a noticeable change in environmental state. Environmental data included: apparent Beaufort sea state when scanning ahead of the ship, horizon clarity, swell height and direction relative to the ship's direction of travel, percentage of the survey area covered with glare, and magnitude of the glare within that region.

On good weather days, when beaked whales were sighted and the decision was made to initiate focal follow data collection, observer effort changed substantially. Typically, ship speed was slowed to 3-4 km/hr, and the seabird observer and members of the passive acoustic team joined the mammal team to augment visual data collection. Effort was made by all available observers to track, photograph, and collect detailed surfacing data on target beaked whale groups, while still recording sightings of additional cetacean groups in the area. In this mode, observers rotated on an as-needed basis, and there were frequently more than 3 observers on-effort at a time. When possible, species identification photographs were collected from the ship using a Canon D6 or D7 camera equipped with a 100-300 m or 500 m lens.

7.4.2 Small Boat Operations

The Southeast Fisheries Science Center foam-collared aluminum boat ("R3", AMBAR) was utilized for focal data collection with target cetacean groups. The R3 was deployed when sea states were low enough that it was considered feasible to approach and follow groups of beaked whales. A team of 3-4 personnel were deployed with each small boat launch, while the remaining shipboard observers continued to track cetacean groups and provide directions to the small boat. When small boat operations were underway, the team of visual observers remained on the flying bridge and in visual and radio contact with the small boat team at all times. The R3 approached beaked whale groups to collect identification photographs, water samples for eDNA testing, skin biopsy samples, and to deploy suction-cup DTAGs. Photographs were collected with a Canon D6 or D7 camera equipped with a 100-300 mm lens.

7.4.2.1 Biopsy and eDNA Sampling

Paired water samples for eDNA testing were collected in 1L bottles on either side of the R3, typically in or near the flukeprint of an animal upon a dive. Water samples were maintained in a cooler with frozen ice packs during daytime operations, and were transferred back to the ship for refrigerator storage either at midday or end of day. Once back aboard the ship, each paired sample (2L total) was filtered through 0.4µM filters; filters were then stored in Longmire's buffer for later analyses. Water samples were also obtained from depth through CTD casts at several locations and processed in the same way. Biopsy samples were obtained from the small boat using a crossbow and a sampling bolt equipped with a 40mm stainless steel tip. Biopsy samples were fractioned, with the skin preserved in 90% ethanol and the blubber wrapped in foil and frozen dry.

7.4.2.2 Tagging

The deployment of suction-cup DTAGs was planned in collaboration with scientists at the Woods Hole Oceanographic Institution (WHOI). Three DTAGv3, including suction cups and releases, were prepared for use during this project. Prior to departure from the dock, the NOAA Ship *Gordon Gunter* was equipped with a 4-element Yagi antenna, handheld Yagi antennae, and VHF tracking equipment. Tag reception range was tested and confirmed both while the ship was at dock, and in open water upon the ship's departure from Newport, RI. Tag range was confirmed to be up to 18 km. Tag deployment attempts were conducted using a handheld, carbon fiber pole, by an experienced tag operator. Tag deployments were planned for 4-12 hrs.

7.4.3 Passive Acoustic Operations

7.4.3.1 Towed Hydrophone Array

The passive acoustic team consisted of 4 people who operated the system in 1-2 hour shifts. The hydrophone array was deployed for up to 24 hr/day during exploratory survey mode, with periodic retrievals to check on array status. During focal follow survey mode, the array was sometimes recovered to facilitate maneuverability of the vessel. During Leg 1, the acoustic team monitored the array in real-time for 24 hr/day. During Leg 2, the acoustic team monitored the array during all daytime hours (0600-1900 ET). However, real-time monitoring at night was reduced, and data collection from the hours spanning 2100-0400 ET was typically unmonitored, but archived to be subsequently analyzed through post-processing.

The primary hydrophone array was comprised of a linear, modular, oil-filled section towed 300 m behind the ship. This array was comprised of three HTI 96-Min hydrophones as well as a depth sensor (Keller America, PA7FLE). 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 high-pass filtered at 1000 Hz to remove flow noise, and variable gain between 0 – 20 dB was added depending on the relative levels of signal and noise. The recording system incorporated two National Instruments soundcards (NI USB-6356), both sampling all three channels at 500 kHz at a resolution of 16 bits. Digitized acoustic data were recorded directly onto desktop computer hard drives using the software program Pamguard, which also recorded simultaneous GPS data, continuous depth data, and allowed manual entry of corresponding notes. Binary click detector files were created using a laptop connected to the second soundcard. Whenever possible, acoustically-active groups that were tracked were matched with visual detections in real-time, for assignment of unambiguous species classification. Frequent communication was established between the acoustic team and the visual team situated on the flying bridge to facilitate this process.

A modular tetrahedral array ("Trident" array, Proteus Technology, Figure 7.1) was also tested to improve acoustic localizations to three dimensions in real-time. The Trident consisted of four HTI 96-Min hydrophone elements arranged top right, top left, bottom aft, and bottom forward, as well as accelerometers and a depth sensor. A 75 kHz acoustic pinger was attached to the top right fin to ground truth the orientation of the Trident within the software system Pamguard. The Acoustic Recording System was modified to accommodate data input from the accelerometers and depth sensor. The data were also filtered at 1000 Hz, and 10 dB gain was added. Pamguard was used to record the incoming data from the Trident. The Trident was deployed on its own or in conjunction with the modular linear array to provide a comparison between the two arrays.

7.4.3.2 Deep-water High-frequency Acoustic Recording Package

A deep-water acoustic mooring, developed by Scripps Institution of Oceanography, was deployed to collect data on presence of vocally-active marine mammals at one offshore site for the duration of the survey period (Wiggins and Hildebrand 2007). The site was selected based on bottom depth and previous sightings of cetacean species of interest. The mooring included a high-frequency acoustic recording package, sampling at 200 kHz, recording continuously. Recovery of the mooring was planned before the conclusion of the survey.

7.4.3.3 Drifting Autonomous Spar Buoy Recorders (DASBRs)

Three drifting autonomous spar buoy recorders (DASBRs) were constructed prior to the survey, as part of a pilot project to acoustically survey for animals distant from the ship. The goal of this pilot project was to assess whether acoustic detection rates varied without the ship's presence, as compared to acoustic detections using the hydrophone array towed from the ship. DASBR design was a modified version of that described in Griffiths and Barlow (2015, 2016). Each DASBR was equipped with an ST4300 SoundTrap (Ocean Instruments) and two HTI hydrophones (HTI-96-min and HTI-92-WB). Each DASBR was also equipped with two SPOT Trace satellite trackers to track the buoy during deployment.

7.4.4 Visual Seabird Sighting Team

From an observation station on the flying bridge, a single observer conducted a visual daylight survey for seabirds during approximately 0630 – 1900h ET, with breaks as needed throughout the day. 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. The seabird observer 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 also used to confirm species 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 7. Seabird survey effort was suspended, however, if the ship's speed over ground fell below 11 km/hr (6 kts). During periods of marine mammal focal follow data collection, the seabird observer joined the marine mammal visual team; at those times seabird data were collected only opportunistically. Therefore, due to the unique objective for this survey, survey speed, and the split effort between surveying for seabirds and surveying for marine mammals required of the seabird observer, off-effort sightings were incorporated into survey effort and summary chart.

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 (SWFSC). The software was linked to the internal GPS of the Toughbook, for course over ground and heading. 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. All data underwent a quality assurance and data integrity check each evening and saved to disk and to an external backup dataset. During off-effort periods, opportunistic seabird sightings were recorded in the marine mammal database or by hand.

7.4.5 Oceanographic and Environmental Sampling

The ship's surface mapping system (SMS) collected data every 10 minutes on the ship's position, wind speed and direction (relative and true), air temperature, pressure and humidity, sea surface temperature, salinity, and fluorescence. Due to the effects of shipboard echosounders on beaked whale detection rates (Cholewiak et al. 2017), echosounders were operated in passive mode for the majority of the survey. However, active acoustic data were collected using the NOAA Ship *Gordon Gunter*'s multi-frequency (18, 38, 70, 120, and 200 kHz) Simrad EK60 echosounders under specific conditions to assess prey distribution, as well as to monitor bottom depth during Conductivity, Temperature, and Depth (CTD) operations.

CTD profile data were collected using a Seabird 911 instrument package at sites where beaked whale foraging behavior was thought to being occurring. CTD casts were conducted down to 800-1000 m depth at these locations, and water samples were collected for eDNA testing. Additionally, plankton samples were collected opportunistically as part of a collaborative effort to sample for larval bluefin tuna (*Thunnus thynnus*). In areas where seafloor depth exceed 1000 m and sea surface temperatures exceeded 22 °C, plankton tows were conducted using 61 cm bongo plankton net equipped with two 333 µm mesh nets. Tows were conducted to 200 m using standard double oblique protocols that are consistent with previously collected samples. Upon retrieval, samples were rinsed from the nets with seawater and preserved in 5% formaldehyde and seawater, as well as ethanol. Corresponding CTD data were also collected at these sites using a SEACAT 19+ CTD profiler.

7.5 Results

7.5.1 Visual Marine Mammal – Turtle Sighting Team

The visual team surveyed for over 230 hrs, covering 3500 km during daylight hours (Figure 7.2). This included both exploratory as well as focal follow data collection. The weather conditions during the first leg of the survey were generally poor, but improved during the second survey leg.

Overall, 10% of trackline coverage, and 22% of time was spent in sea state conditions of Beaufort 2 or less. Sea state conditions were within a Beaufort 3-4 range for approximately 60% of the survey (Table 7.2).

Thirteen species of cetaceans were identified during the survey (Tables 7.3 and 7.4). Three species of beaked whales were positively identified during the survey, including Cuvier's (*Ziphius cavirostris*), True's (*Mesoplodon mirus*) and Sowerby's (*Mesoplodon bidens*) beaked whales (Figure 7.3, Table 7.3). In addition, there were 100 sightings of beaked whale groups not identified to species. True's beaked whale groups were sighted over 160 times, and Cuvier's beaked whale groups were sighted over 100 times, though these numbers include focal follow data collection in which individual groups were tracked over multiple hours and sighted multiple times. Therefore these numbers do not represent unique groups. Focal follow data were collected on approximately 10 different groups of True's beaked whales. Data are being processed to quantify surface and dive intervals to inform availability bias estimates, as well as being compared with passive acoustic data to describe vocal periods during foraging activity. Photo-identification data indicated that at least two animals were sighted together on more than one day.

Among other cetacean species, sperm whales and Risso's dolphins were the most frequently encountered groups, though striped dolphins (*Stenella coeruleoalba*) were the most numerically abundant (estimated 546 individuals), followed by Risso's and common dolphins (*Delphinus delphis*) (Figure 7.4, Table 7.4). While in general few baleen whales were sighted, of note was a large aggregation of fin whales (*Balaenoptera physalus*) encountered offshore on one day. Also notable were two sightings of rough-toothed dolphins (*Steno bredanensis*). An additional 57 cetacean groups (not including beaked whales) were not identified to species. The visual team also recorded a number of fishes and sharks, and one sea turtle, with manta rays and a single whale shark being sightings of note (Table 7.4).

7.5.2 Small Boat Operations

The R3 was launched on 10 days during the survey, for a total of 59.75 hrs of running time. On the day of departure, 20 July, the boat was launched to return fleet inspectors to shore after an underway inspection. During this transit, testing of the DTAG reception was conducted out to 9 km. The R3 was launched again on 28 July to further test DTAG reception from the ship, out to a distance of 18 km.

7.5.2.1 Biopsy and eDNA Sampling

A total of 15 paired water samples were collected from within or near the fluke prints of diving animals for eDNA testing (Table 7.5). This includes 12 samples from True's beaked whales, 2 samples from Cuvier's beaked whales, and one from a pod of striped dolphins. Several of the samples collected near True's beaked whales were paired with identification photographs of the fluking individual; one of the samples was collected from the animal that was tagged (see below for more information). In addition, water samples were collected at three sites from deep CTD casts in areas where True's beaked whales were observed undertaking presumed foraging dives (see below for more information). A total of 7 biopsy samples were also collected; 4 from True's beaked whales, 2 from a single pod of pilot whales (*Globicephala* sp.), and 1 from a fin whale.

7.5.2.2 Tagging

DTAG deployments on True's beaked whales were attempted during good weather periods on several days. On 11 August, a DTAG was deployed on a True's beaked whale at 15:27 ET, one individual in a group of 5-6 animals (Figure 7.5). This was the first tag ever to be deployed on this species. Surfacing and dive data were collected on this group for at least 2 hours prior to tag deployment. After tag deployment, the small boat team collected water samples for eDNA testing and photographs of the tagged animal. Surfacing interval data were collected from the group until sunset. Over the duration of the tag attachment, the tagged animal (and presumably the group) undertook 9 foraging dives, averaging 32.7 mins/dive. The tag remained attached for approximately 13 hrs, after which it was relocated at daybreak, approximately 11 km from the deployment site. Data analyses are ongoing and will be published in conjunction with the focal follow data.

7.5.3 Passive Acoustic Detection Team

7.5.3.1 Towed Hydrophone Arrays

Over the course of the survey, towed array acoustic monitoring effort was conducted on 25 survey days (Figure 7.6). Overall, 459 hrs of recordings were collected between the linear and Trident arrays which corresponded to 4,474 km of trackline distance (Table 7.6). The linear array was monitored by an acoustician in real time for 408 hrs (89% of the total time), which corresponded to 3,908 km of trackline distance. This total includes daytime survey effort during concurrent visual survey operations and nighttime acoustic-only effort, using only the linear array. The Trident was deployed and monitored in real time and collected 6 hrs of recordings (1% of the total time) and covered 61 km. Un-monitored data collection consisted of 45 hrs (10% of the total time) and 505 km of trackline distance. These data were processed post-cruise to find beaked whale detections.

Beaked whales were detected on all survey days. Real-time monitoring of the linear array resulted in 631 acoustic detections of beaked whales (Figure 7.7, Table 7.7). Real-time monitoring of the Trident array resulted in 5 acoustic detections of beaked whales. Beaked whale detections were acoustically classified in real time as Cuvier's beaked whale, Sowerby's beaked whale or MmMe (*M. mirus or M. europaeus* species). It is likely that most or all detections in the MmMe category were clicks produced by True's beaked whale as no Gervais' beaked whales were visually detected during the survey. However, similarities exist between the clicks produced by True's and Gervais' beaked whales that currently make it difficult to determine species in real-time.

The Trident array was first tested in the shallow waters off of Newport, RI at the start of Leg 1 to assess functionality. During this short deployment, the tow cable sustained evidence of twisting, indicating that that Trident was spinning underwater. Due to concerns about the effect of this spinning on the integrity of the tow cable, the Trident was not implemented during Leg 1 of the survey. After consulting with colleagues and the manufacturer, the Trident was tested again offshore over the course of two days during Leg 2 of the survey. During this deployment, the array was able to detect the same beaked whale groups as the linear array when they were deployed together. The Trident array was able to show a change in detected beaked whale depth (equating to a descent) and was able to remove the left/right ambiguity that is inherent on linear arrays. However, this array did exhibit spinning while being towed underwater, emphasizing the importance of functioning accelerometers. The wiring of the accelerometers in this array was not fully compatible with the wiring in our Acoustic Recording System. This spinning also restricted the Trident to be towed at slow speeds ($\leq$ 6 knots) to prevent severe twisting of the tow cable.

Post-processing of the passive acoustic data collected when the array was unmonitored yielded an additional 61 beaked whale detections (Table 7.7). Detections where the click characteristics match those reported in DeAngelis et al. (2018) were labeled True's beaked whale. If there was any ambiguity in assigning either the True's or Gervais' class, the detection was left as MmMe.

The focus of real-time acoustic monitoring on this survey was to detect and localize beaked whales. Other vocally-active odontocetes were also recorded, but only opportunistically noted in real-time. Sperm whales were acoustically detected on all survey days. Delphinid encounters occurred on all survey days, and were generally not classified to species, except where detections clearly corresponded to simultaneous visual detections, such as when animals approached the bow and passed alongside the ship and hydrophone array. Delphinid species represented in the data include common bottlenose dolphins (*Tursiops truncatus*), common dolphins, Atlantic spotted dolphins (*Stenella frontalis*), striped dolphins, Risso's dolphins, rough-toothed dolphins, and pilot whales.

7.5.3.2 Deep-water High-frequency Acoustic Recording Package

The deep-water HARP was deployed on 25 July 2018, at 40° 01.967' N, 67° 59.301' W, to a bottom depth of 2085 m (Figure 7.2). The unit was successfully recovered on 18 August 2018, for a deployment duration of approximately 24 days. Data analyses are in process.

7.5.3.3 Drifting Autonomous Spar Buoy Recorders (DASBRs)

DASBR deployments were conducted on three days during Leg 2 of the survey. The first deployment was a single unit deployed on 1 August 2018 for 1.6 days. Operational difficulties in recovery of the DASBR from the ship resulted in damage to the instrument package, which delayed subsequent deployments. After repair of the unit and consultation with colleagues at SWFSC and Pacific Islands Fisheries Science Center (PIFSC) to improve recovery strategies, two subsequent deployments were conducted. Two DASBRs were deployed in pairs 1-2 km apart, on 10 August and 17 August. Deployment durations lasted from 12 hrs – 2.5 days. All recorders functioned successfully, though there were failures of several of the SPOT satellite transmitter units.

7.5.4 Visual Seabird Sighting Team

Seabird survey effort was conducted on at least parts of 18 out of 25 sea-days covering roughly 750 km. 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 1229 birds seen while surveying (on and off effort) broken down by species is presented in Table 7.8. Distribution maps of these sightings are shown in Figure 7.8. This survey recorded 32 species of birds and 5 unidentified species groups (e.g., unidentified shearwater, unidentified storm-petrel or unidentified shore bird). Five species comprised approximately 91% of the total birds seen. In declining order of abundance these were: Great Shearwater (*Puffinus gravis*) n=479, Wilson's Storm-Petrel n=327 (*Oceanites oceanicus*), Leach's Storm-Petrel

(*Oceanodroma leucorhoa*) n=263, Cory's Shearwater (*Calonectris diomedea*) n=39, and Audubon's Shearwater (*Puffinus lherminieri*) n=32.

These survey efforts were notable as many NOAA seabird surveys are not often conducted so far offshore, and with repeat effort rarely conducted in the same areas. An attempt was made to note birds observed during off-effort, and even for those not logged in *Seebird*, a few rare and unusual sightings were recorded using the Cornell Lab of Ornithology's eBird program.

Given the proximity to traditionally pelagic productive areas (shelf break, canyons, and sea mounts), it is no surprise to see Great Shearwaters, Wilson's Storm Petrels and Leach's Storm Petrels in such high abundance relative to other seabirds. More regular to inshore waters, only one Sooty Shearwater (*Puffinus griseus*) was recorded. We also spent a considerable amount to time in warm Gulf Stream waters which this may have led to the large numbers of Cory's Shearwaters, including a handful of Scopoli's Shearwaters (*Calonectris diomedea diomedea*), a likely candidate for full species status in the near future) and Audubon's Shearwaters. Other sub-tropical species recorded both on and off effort in the Gulf Stream include small numbers of Black-capped Petrels (*Pterodroma hasitata*), White-faced Storm-Petrels (*Pelagodroma marina*) and Band-rumped Storm-Petrels (*Oceandroma castro*).

Hard to classify were the observations of Brown Boobies (*Sula leucaster*), and Red-billed Tropicbirds (*Phaethon aetherus*). These tropical seabirds were clearly using the warm Gulf Stream waters but have rarely been recorded at these latitudes. More data are needed to determine if these species occur annually this far north or if the summer 2018 was an anomaly. Certainly there has been a growing trend in the increase of Brown Booby sightings along the US Atlantic seabird in the past decade.

Easier to label as true regional rarities were Masked Booby (*Sula dactylatra*), a subadult bird recorded on 13 August and Trindade Petrel (*Pterodroma arminjoniana*) on 9 August which appears to be the north-most record of these species in the western Atlantic. A Barolo Shearwater (*Puffinus baroli*) also seen on 13 August is only one of a handful recorded for North America though this species likely is underreported in deep offshore waters. And finally and perhaps most notable due to its status as a critically endangered species was a Bermuda Petrel (*Pterodroma cahow*) on 18 August near the mouth of Hydrographer Canyon.

A few Long-tailed Jaegers (*Stercorarius longicaudus*) were observed, all juvenile or subadult birds. The Parasitic Jaegers (*Stercorarius parasiticus*) and Pomarine Jaegers (*Stercorarius pomarinus*) observed were a mix of immature and adult birds. A few South Polar Skuas (*Stercorarius maccormicki*) were observed. A handful of larids were recorded in deep offshore waters: Herring Gulls (*Larus argentatus*) Great Black-backed Gull (*Larus marinus*) and Lesser Black-backed Gull (*Larus fuscus*) as well as Common Tern (*Sterna hirundo*), Least Tern (*Sterna antillarum*) and Bridled Tern (*Onychoprion anaethetus*).

A small number of non-marine bird species were observed including multiple flocks of migrating Whimbrel (*Numenius phaeopus*), Spotted Sandpiper (*Actitis macularius*) , shorebird spp, Red-necked Phalarope (*Phalaropus lobatus*), falcon spp., Brown-headed Cowbird (*Molothrus ater*), Yellow Warbler (*Setaphaga petechia*), and Bay-breasted Warbler (*Setaphaga castanea*).

7.5.5 *Oceanographic and Environmental Sampling*

CTD sampling was conducted at eight stations over the course of the survey (Figure 7.9). This included 5 stations where bongo samples were collected to assess potential larval Atlantic bluefin tuna presence. Water samples for eDNA testing were collected at 3 stations, at depths ranging from 100-1500 m. These latter stations were situated in areas where beaked whales had been observed undertaking presumed foraging dives. Active acoustic data were collected overnight on 12 August, to characterize spatial distributions of prey fields in the area where the group with the tagged beaked whale had been presumably foraging, to investigate relationships among predators, prey, and oceanography.

7.6 Disposition of Data

All visual, acoustic, tag, and oceanographic data 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 submitted to OBIS SEAMAP for public access. 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.

7.7 Literature Cited

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Table 7.1 Scientific team participating in data collection aboard the NOAA Ship *Gordon Gunter*. Leg 1 was 20 July – 3 August 2018. Leg 2 was 6 – 19 August 2018

Name	Title	Leg	Institution
Danielle Cholewiak	Chief Scientist	1,2	NOAA NMFS NEFSC
Dee Allen	Marine Mammal Observer	1,2	Marine Mammal Commission
Salvatore Cerchio	Marine Mammal Observer	1,2	New England Aquarium
Lisa Conger	Marine Mammal Observer	1,2	NOAA NMFS NEFSC
Annamaria DeAngelis	Passive Acoustics/ Mammal Observer	1,2	Integrated Statistics, Woods Hole, MA
Michelle Greene	NOAA Teacher at Sea	1	NOAA Teacher-at-Sea
Emily Griffiths	Passive Acoustics/ Mammal Observer	1,2	Integrated Statistics, Woods Hole, MA
Skye Haas	Seabird/ Marine Mammal Observer	1,2	Integrated Statistics, Woods Hole, MA
Leigh Hickmott	Marine Mammal Observer	1,2	Open Ocean Consulting
Nick Metheny	Marine Mammal Observer	1,2	Integrated Statistics, Woods Hole, MA
Bridget Mueller-Brennan	Passive Acoustics/ Mammal Observer	2	Integrated Statistics, Woods Hole, MA
Robert Pittman	Marine Mammal Observer	1,2	NOAA NMFS SWFSC
Joy Stanistreet	Passive Acoustics/ Mammal Observer	1	Department of Fisheries & Oceans Canada
Christoper Tremblay	Marine Mammal Observer	1	University of Maine
Jennifer Trickey	Passive Acoustics/ Mammal Observer	2	Scripps Institution of Oceanography
Sarah Weiss	Passive Acoustics/ Mammal Observer	2	Integrated Statistics, Woods Hole, MA

Table 7.2 Visual survey effort categorized by Beaufort sea state

Beaufort Sea State	Distance (km)	Time (hrs)
0	2.5	0.5
1	35.1	8.0
2	330.5	41.6
3	1118.6	82.2
4	1041.1	64.4
5	994.2	34.1
6	5.7	0.3
TOTAL	3528	231

Table 7.3 Number of beaked whale groups sighted by the visual team. Note that for Cuvier's (*Ziphius cavirostris*) and True's (*Mesoplodon mirus*) beaked whales, these numbers include multiple resights of the same groups during several days in which focal follow data were collected. Therefore, these number do not represent unique groups sighted, but total number of sightings, including repeats.

Species	Scientific Name	Number of Groups	Number of Individuals
Cuvier's beaked whale	*Ziphius cavirostris*	101	208
True's beaked whale	*Mesoplodon mirus*	163	505
Sowerby's beaked whale	*Mesoplodon bidens*	6	13
Unid. beaked whale	*Ziphiidae*	42	92
Unid. mesoplodont	*Mesoplodon spp.*	48	79
TOTAL		360	969

Table 7.4 Cetaceans (other than beaked whales), turtles, sharks and other fishes sighted by the visual team during Legs 1 and 2 of the survey

Species	Scientific Name	Number of Groups	Number of Individuals
Atlantic spotted dolphin	*Stenella frontalis*	3	46
Bottlenose dolphin	*Tursiops truncatus*	10	127
Common dolphin	*Delphinus delphis*	5	200
Pilot whale, spp.	*Globicephala spp.*	10	102
Risso's dolphin	*Grampus griseus*	35	201
Rough-toothed dolphin	*Steno bredanensis*	2	55
Striped dolphin	*Stenella coeruloealba*	11	564
Sperm whale	*Physeter macrocephalus*	56	80
Pygmy sperm whale	*Kogia breviceps*	2	3
Fin whale	*Balaenoptera physalus*	17	26
Fin/sei whale		1	2
Basking shark	*Cetorhinus maximus*	1	1
Manta ray	*Manta raya*	4	4
Mola mola (sunfish)	*Mola mola*	1	1
Tuna	*Scombridae*	1	1
Whale shark	*Rhincodon typus*	1	1
Unid. Dolphin	--	4	5
Unid. Large dolphin	--	34	470
Unid. Stenella	*Stenella sp.*	1	6
Unid. Lagenorhynchus	*Lagenorhynchus sp.*	1	1
Unid. Baleen whale		14	18
Unid. Large whale	--	2	4
Unid. Billfish	--	2	2
Unid. Shark	--	1	1
Unid. Turtle	--	1	1
TOTAL		220	1922

Table 7.5 Genetic samples collected during the survey, including skin biopsy samples and water samples for eDNA testing. Samples for eDNA were collected in or near flukeprints of target animals, with the exception of the CTD casts. Additionally, water samples were collected at various depths from 3 CTD casts, in areas where True's beaked whales (*Mesoplodon mirus*) had been previously observed on presumed foraging dives.

Sample type	Date Collected	Time Collected	Latitude (N)	Longitude (W)	Species
eDNA	30-Jul-18	15:35:00	39° 48.476	067° 57.105	*Mesoplodon mirus*
eDNA	30-Jul-18	16:28:00	39° 48.581	067° 57.252	*Mesoplodon mirus*
eDNA	30-Jul-18	~16:45:00			*Mesoplodon mirus*
Biopsy	30-Jul-18	17:08:00	39° 49.317'	067° 58.333'	*Mesoplodon mirus*
Biopsy	30-Jul-18	17:09:00	39° 49.257'	067° 58.310'	*Mesoplodon mirus*
eDNA	1-Aug-18	13:24:00	39° 47.477	068° 09.380	*Mesoplodon mirus*
eDNA	8-Aug-18	13:01:00	39° 57.228	068° 01.774	*Mesoplodon mirus*
eDNA	8-Aug-18	13:24:00	39° 57.584	068° 02.479	*Ziphius cavirostris*
Biopsy	8-Aug-18	15:02:00	39° 55.538'	068° 00.523'	*Mesoplodon mirus*
Biopsy	8-Aug-18	17:46:00	39° 57.294'	068° 2.064'	*Balaenoptera physalus*
eDNA	10-Aug-18	9:47:00	39° 58.588	068° 02.744	*Mesoplodon mirus*
eDNA	10-Aug-18	12:09:00	39° 58.764	068° 02.085	*Mesoplodon mirus*
eDNA	10-Aug-18	17:01:00	39° 57.279	067° 59.042	*Mesoplodon mirus*
eDNA	11-Aug-18	10:30:00	40° 00.480	067° 52.672	*Ziphius cavirostris*
eDNA	11-Aug-18	10:36:00	40° 00.951	067° 53.064	*Mesoplodon mirus*
eDNA	11-Aug-18	11:06:00	40° 00.816	067° 52.810	*Mesoplodon mirus*
Biopsy	11-Aug-18	15:26:00	40° 00.521'	067° 53.364'	*Mesoplodon mirus*
eDNA	11-Aug-18	15:43:23	40° 00.743	067° 53.454	*Mesoplodon mirus*
eDNA	11-Aug-18	15:46:49	40° 00.810	067° 53.348	*Mesoplodon mirus*
eDNA	11-Aug-18	18:18:00	40° 01.439	067° 51.887	*Stenella coeruleoalba*
Biopsy	13-Aug-18	18:45:00	40° 28.492'	066° 47.761'	*Globicephala sp.*
Biopsy	13-Aug-18	18:50:00	40° 28.259'	066° 47.771'	*Globicephala sp.*
eDNA	31-Jul-18	18:00:00	39° 49.3'	067° 58.3'	CTD Deep water
eDNA	8-Aug-18	22:48:00	39° 55.5'	068° 01.4'	CTD Deep water
eDNA	12-Aug-18	21:18:00	40° 00.8'	067° 52.9'	CTD Deep water

Table 7.6 Summary of passive acoustic recording effort during the GU 18-03 survey

Activity	Trackline Distance Covered (km)	Recording Hours
Monitored linear towed array	3,908	408
Unmonitored linear towed array	505	45
Monitored Trident towed array	61	6
TOTAL	4,474	459

Table 7.7 Summary of number of passive acoustic beaked whale detections from both data collected in real time and post-processing of unmonitored periods, from both the linear and Trident arrays. Note that an acoustic detection may represent one animal or groups of animals, and that the same group of animals was often detected multiple times during focal follow periods.

Species	Monitored Linear Towed Array	Unmonitored Linear Towed Array	Monitored Trident Towed Array
MmMe	284	5	2
True's beaked whale	0	26	0
Sowerby's beaked whale	2	0	0
Cuvier's beaked whale	345	30	3
Total	631	61	5

Table 7.8 Seabirds and other birds observed during Legs 1 and 2 of the survey by the seabird observer, including both "on effort" and "off effort" sightings.

Name	Scientific Name	Number of Groups	Number of Individuals
Audubon Shearwater	*Puffinus lherminieri*	25	32
Band-rumped Storm-petrel	*Oceanodroma castro*	5	8
Barn Swallow	*Hirundo rustica*	5	5
Barolo Shearwater	*Puffinus baroli*	1	1
Bay-breasted Warbler	*Setaphaga castanea*	1	1
Bermuda Petrel	*Pterodroma cahow*	1	1
Black-capped Petrel	*Pterodroma hasitata*	2	2
Bridled Tern	*Onychoprion anaethetus*	1	1
Brown Booby	*Sula leucogaster*	1	1
Brown-headed Cowbird	*Molothrus ater*	1	1
Common Tern	*Sterna hirundo*	1	1
Cory's Shearwater	*Calonectris diomedea*	37	39
Double-crested Cormorant	*Phalacrocorax auritus*	2	2
Great Shearwater	*Puffinus gravis*	174	479
Leach's Storm-petrel	*Oceanodroma leucorhoa*	174	263
Least Tern	*Sterna antillarum*	1	1
Lesser Black-backed Gull	*Larus fuscus*	1	1
Long-tailed Jaegers	*Stercorarius longicaudus*	1	1
Manx Shearwater	*Puffinus puffinus*	2	2
Masked Booby	*Sula dactylatra*	1	1
Parasitic Jaeger	*Stercorarius parasiticus*	1	2
Pomarine Jaeger	*Stercorarius pomarinus*	1	1
Red-billed Tropicbird	*Phaeton aethereus*	1	1
Red-necked Phalarope	*Phalaropus lobatus*	1	1
Shorebird	--	1	1
Sooty Shearwater	*Puffinus griseus*	1	1
South Polar Skua	*Stercorarius maccormicki*	2	2
Spotted Sandpiper	*Actitis macularius*	1	1
Trindade Petrel	*Pterodroma arminjoniana*	1	1
Unidentified jaeger	*Stercorarius sp.*	3	3
Unidentified shearwater	*Puffinus sp.*	7	7
Unidentified storm-petrel	*Oceanodroma sp.*	2	2
Unidentified tern	--	1	1
Whimbrel	*Numenius phaeopus*	1	23
White-faced Storm Petrel	*Pelagodroma marina*	9	11
Wilson's Storm-Petrel	*Oceanites oceanicus*	59	327
Yellow Warbler	*Setophaga petechia*	1	1
TOTAL		530	1229

Figure 7.1. Image of the Trident tetrahedral array. The cone shaped nose is on the right; on the left is the aft section of the array. Photo credit: B. Mueller-Brennan.

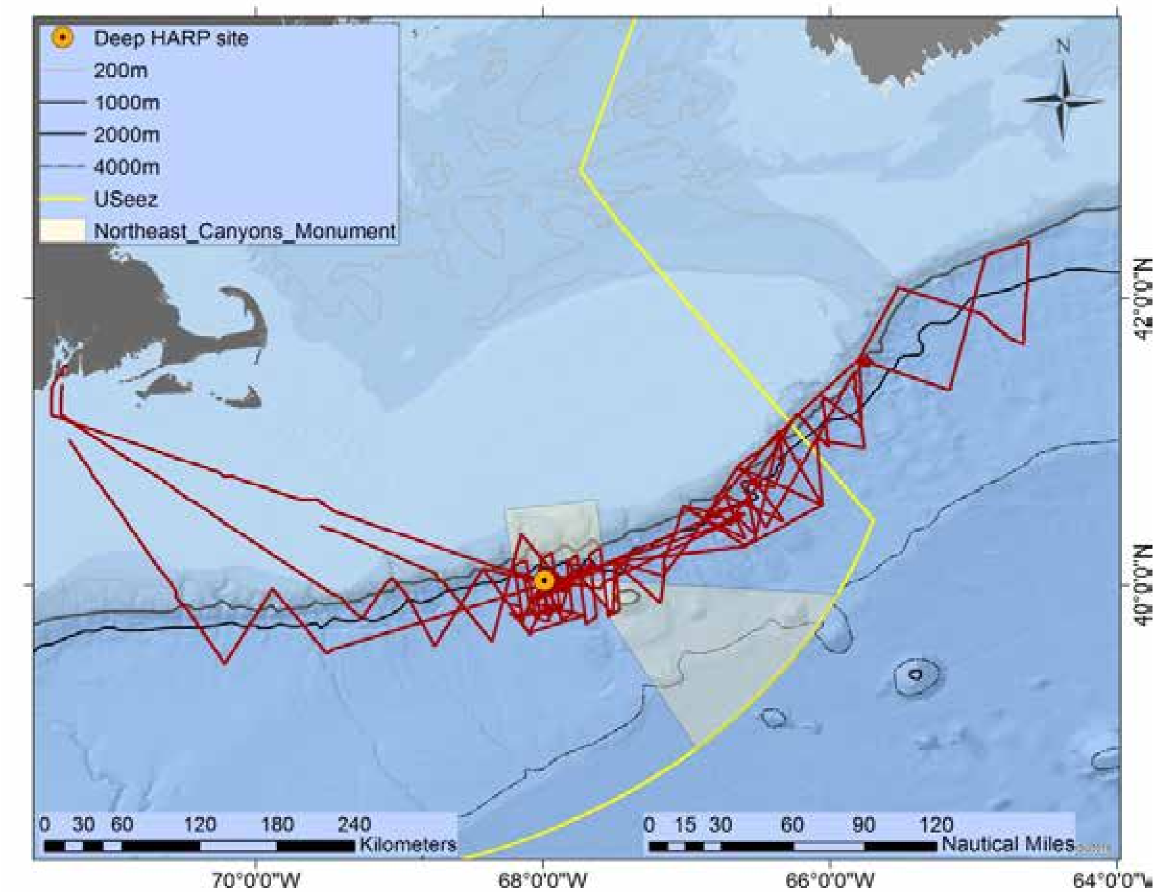

Figure 7.2. Overall survey coverage. Red lines indicate area surveyed, including both daytime and nighttime effort. The orange circle indicates the location of the deep-water HARP deployment; the Northeast Canyons and Seamounts Marine National Monument is shown in the highlighted boxes.

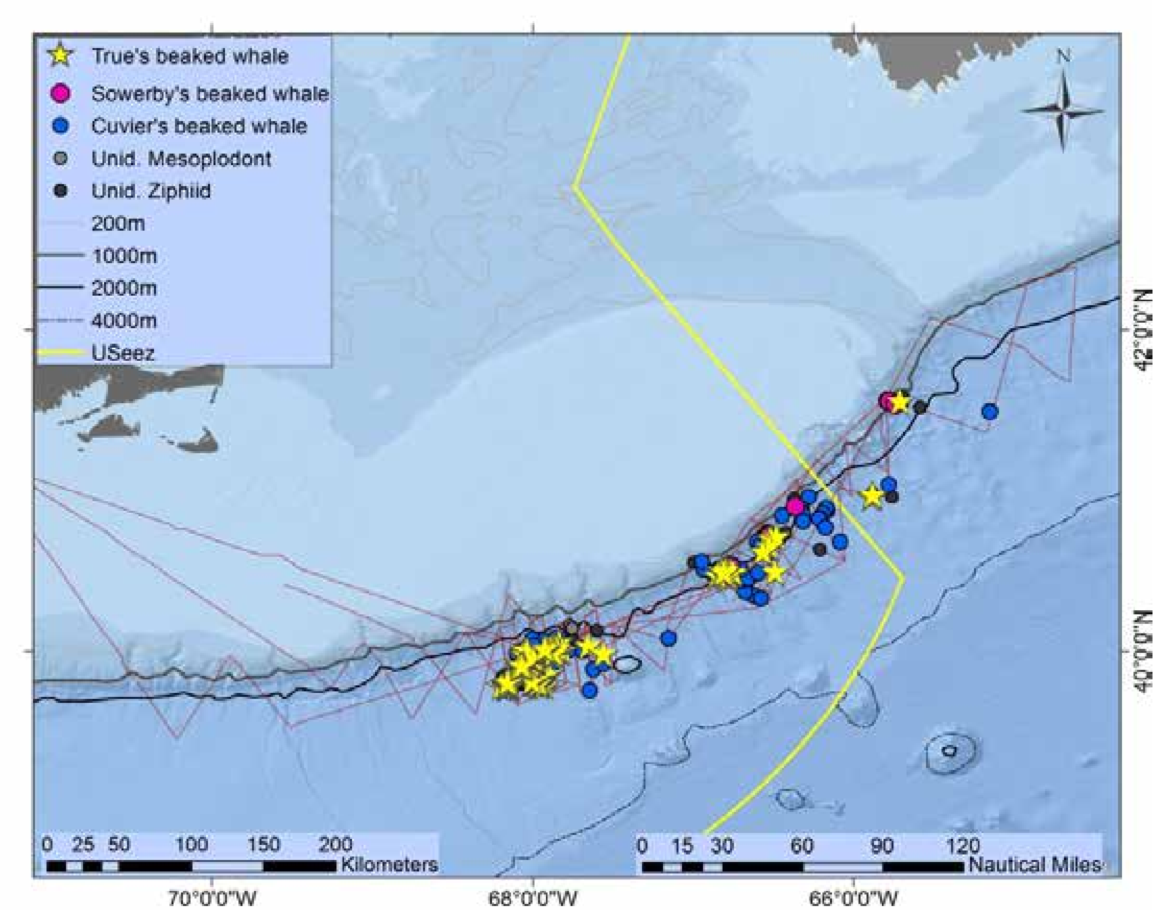

Figure 7.3. Visual sightings of beaked whales. Note that repeat sightings of True's beaked whales (*Mesoplodon mirus*) during focal follow data collection are also included here, so sightings do not necessarily indicate unique groups. Survey tracklines are in pink, including both daytime and nighttime survey coverage.

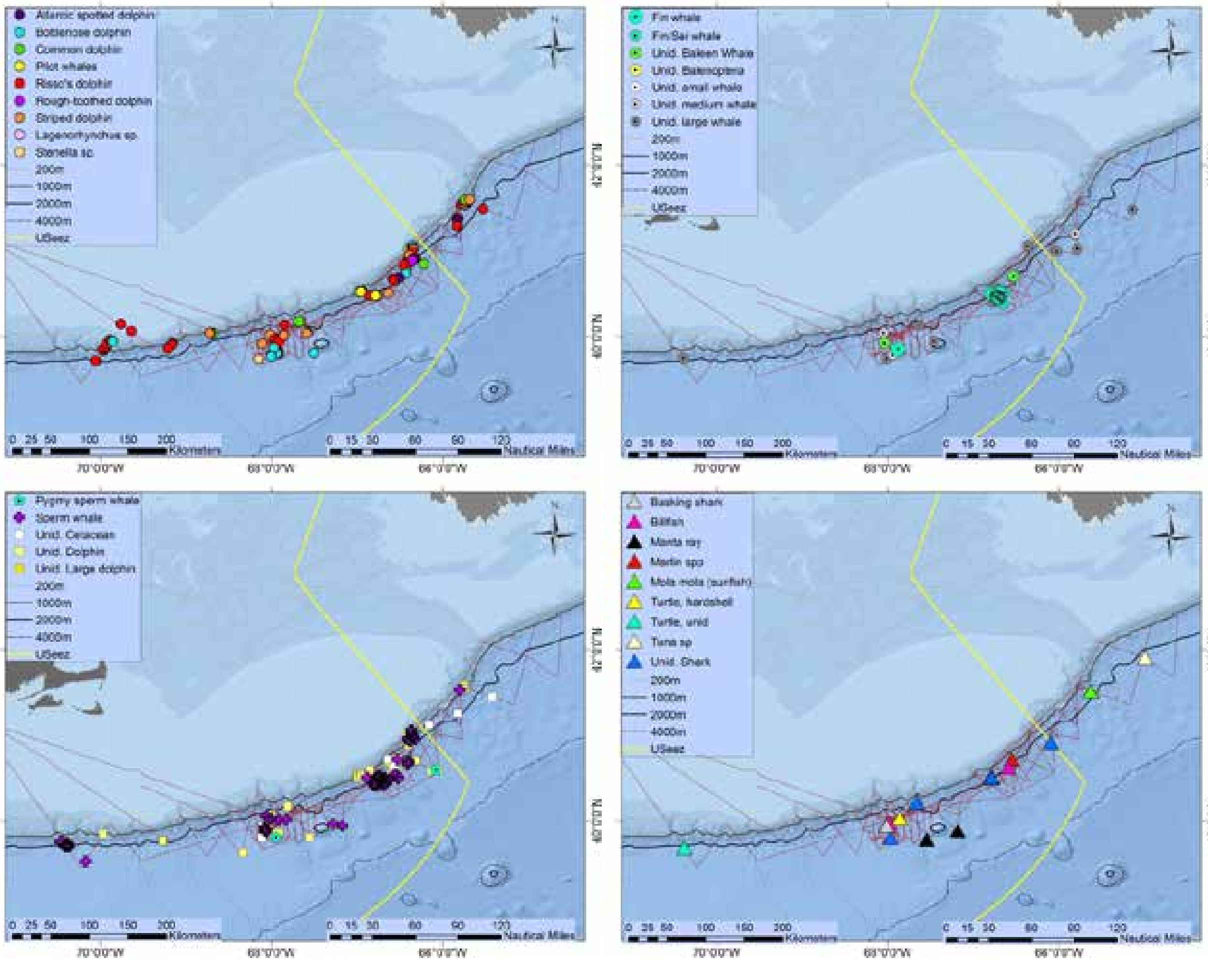

Figure 7.4. Visual sightings of cetaceans, turtles and fishes. Note that beaked whale sightings are not included here. Survey tracklines are in pink, including both daytime and nighttime survey coverage.

Figure 7.5. Photograph of True's beaked whale (*Mesoplodon mirus*) after DTAG deployment, on 11 August 2018. Tag is positioned on the right side of the body, with the antenna facing upwards. Tag deployment lasted approximately 13 hrs. Photo credit: S. Cerchio.

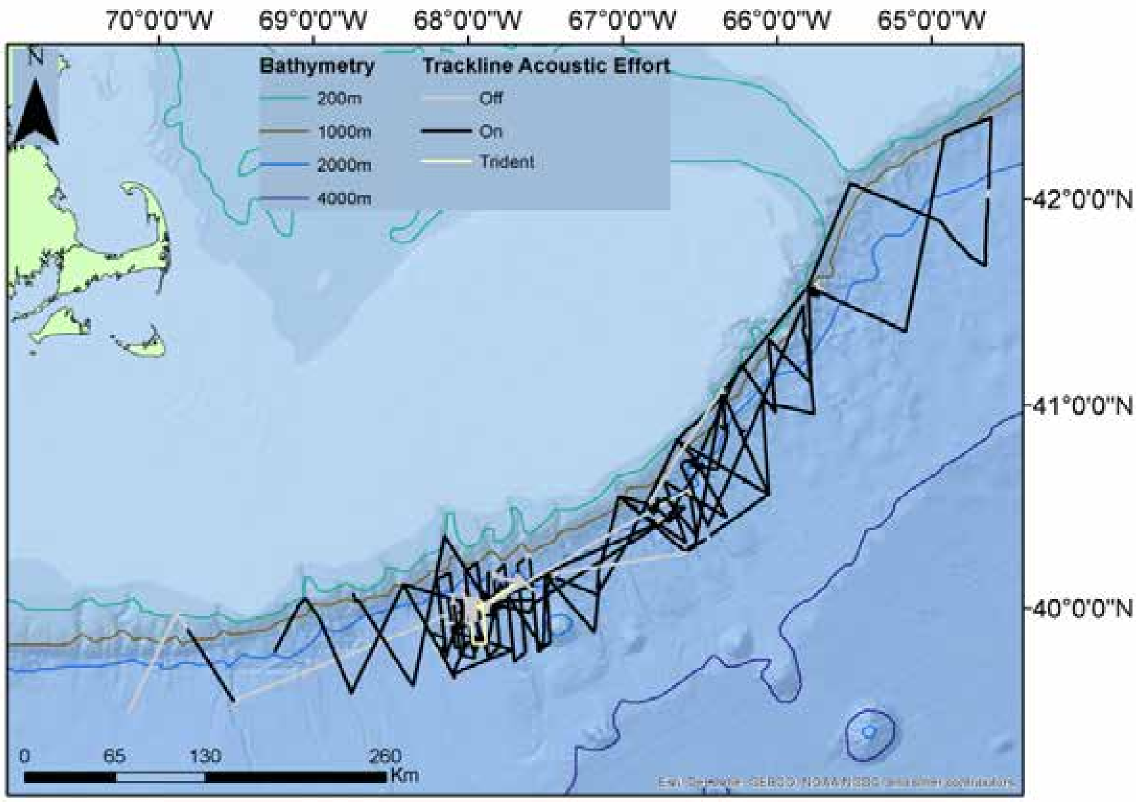

Figure 7.6. Towed hydrophone array effort during GU1803. Gray lines indicated "off effort" tracklines, in which the towed array was not deployed. Both legs 1 and 2 are shown.

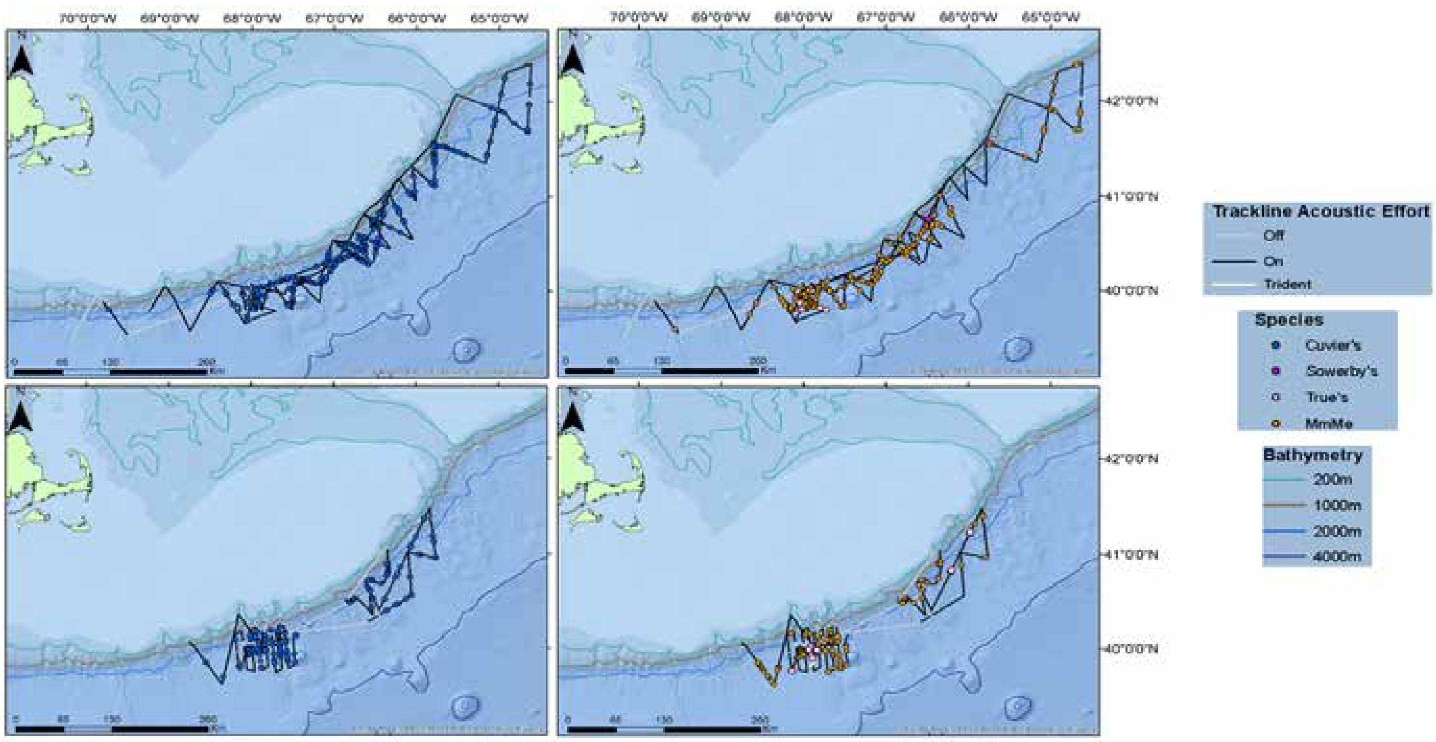

Figure 7.7. Beaked whale passive acoustic detections during Leg 1 (top) and Leg 2 (bottom). Detections of Cuvier's beaked whales (*Ziphius cavirostris*) are shown on the left and the genus *Mesoplodon* on the right. All detections from real-time monitoring and post-processing are shown for both the linear (black lines) and Trident arrays.

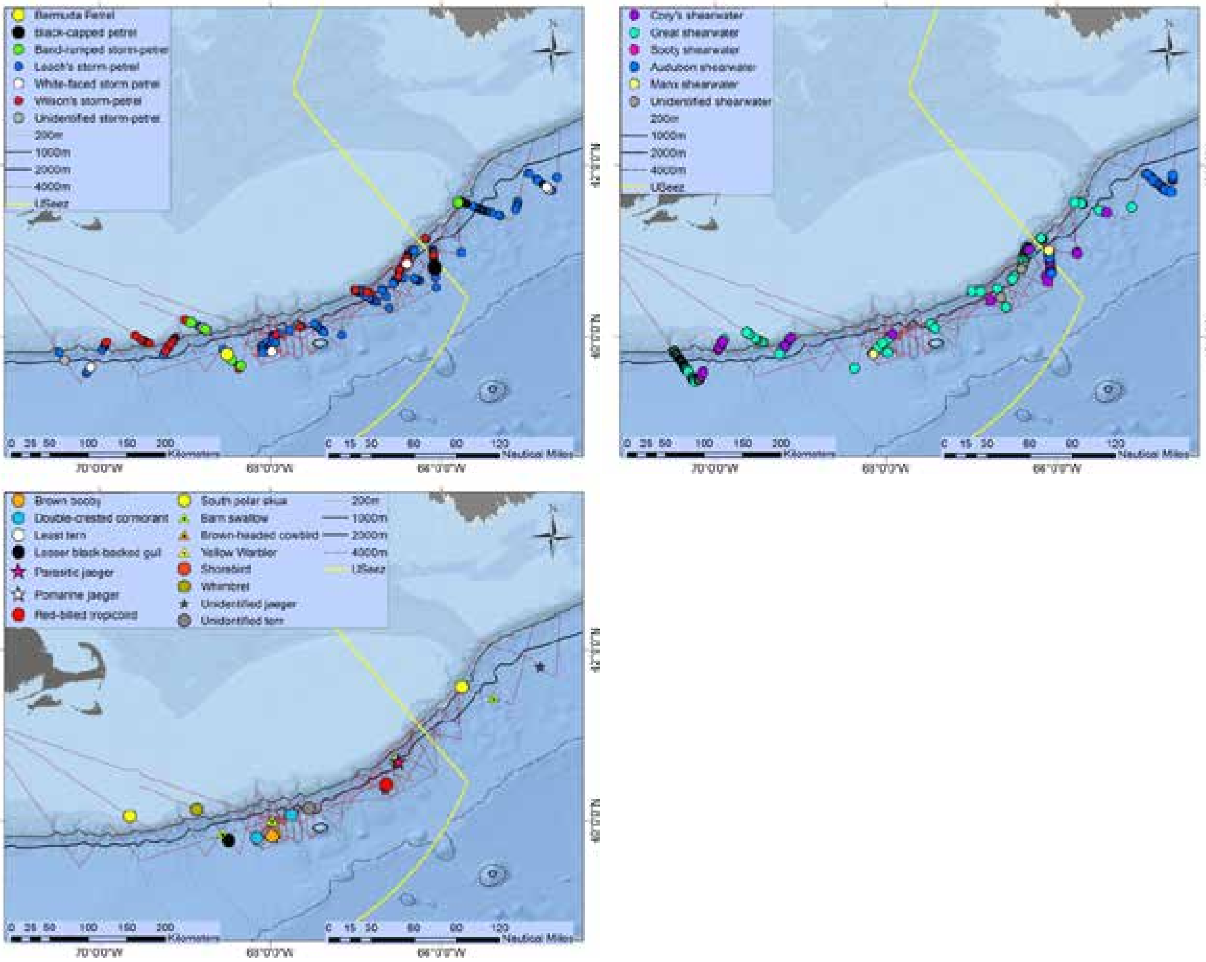

Figure 7.8. Visual sightings of seabirds and other bird species. Top panels show locations of petrels and storm-petrels (left) and shearwaters (right). Bottom panel shows locations of all other birds sighted. Survey tracklines are in pink, including both daytime and nighttime surveys coverage.

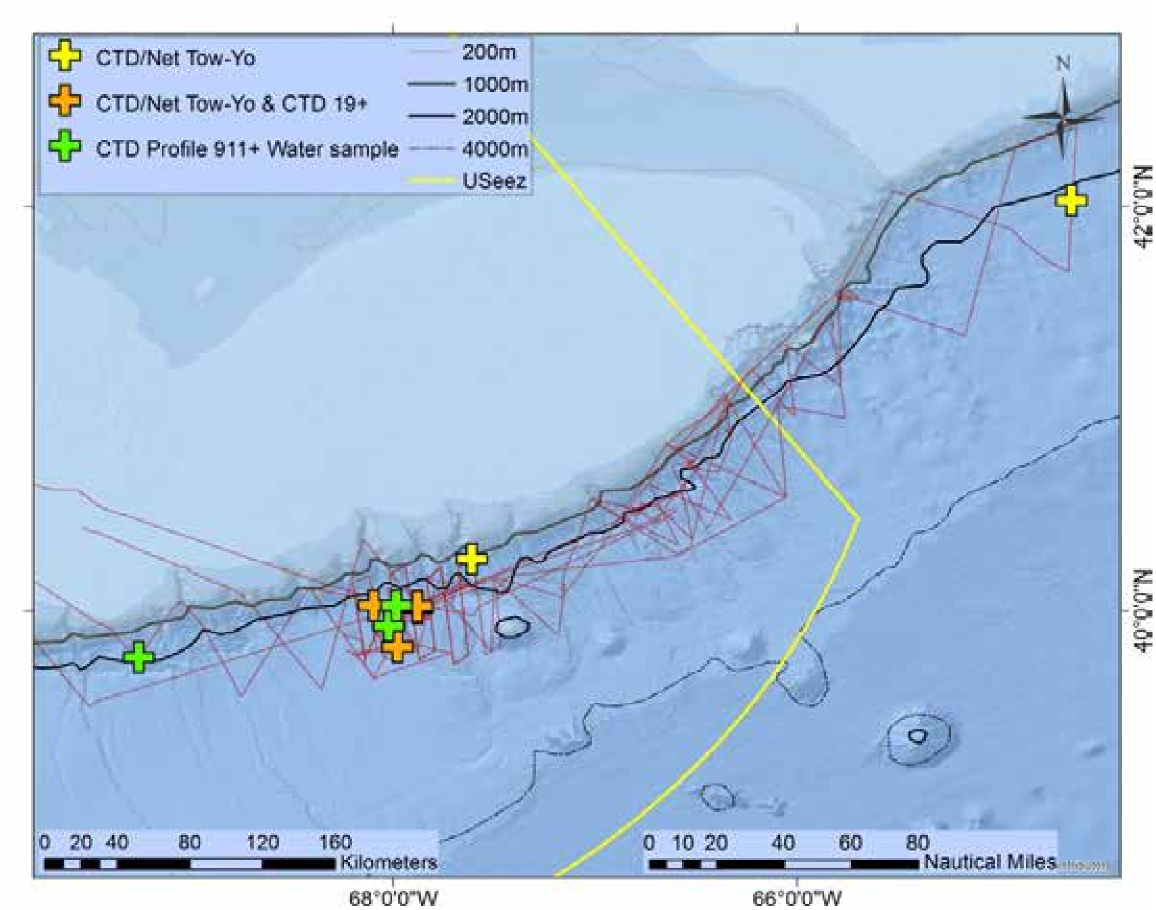

Figure 7.9. Locations of CTD (conductivity-temperature-depth) casts. The yellow and orange symbols indicate areas where bongo tows were conducted to collect samples to assess larval Atlantic bluefin tuna (*Thunnus thynnus*) presence. The green symbols indicate areas where water samples were collected at depth for environmental DNA (eDNA) testing.

8 Progress on Research Related to Density and Abundance Estimation: Northeast and Southeast Fisheries Science Centers

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8.1 Summary

One of the AMAPPS objectives is to assess the population size of surveyed species at regional scales and develop models and associated tools to translate these survey data into seasonal, spatially explicit density estimates incorporating habitat characteristics. In 2018 to achieve these objectives, the 2017 aerial survey data were error-checked, integrated with the rest of the survey data, and archived in the NEFSC Oracle database and at the OBIS-SEAMAP website. The spatially- and temporally-explicit habitat-density models developed from data from 2010-2013 are being updated using all data up to 2017 and include several new environmental variables. The different versions and different options of the R package “mgcv” were extensively evaluated to determine the effects on the results of the density-habitat models. To account for grid cells that have very low survey effort and so can unduly impact the density estimate, cell with less than 1 km for shipboard surveys and 2 km for aerial surveys were reallocated to neighboring cells on the same track line. Additional streamlining of the scripts to input, output and process the data have made the process more flexible and robust. The 2016 shipboard and aerial survey data were analyzed using design-based Distance methods to estimate abundance of 27 species and will be incorporated into the Atlantic Stock Assessment Reports. The model that integrates visual line transect and passive acoustic data to estimate a dive time adjusted abundance estimate for sperm whales is continuing to be developed and has been expanded to also analyze beaked whale passive acoustic and visual sightings data.

8.2 Objectives

The objective of AMAPPS II that was addressed in this chapter is: “Assess the population size of surveyed species at regional scales; and develop models and associated tools to translate these survey data into seasonal, spatially explicit density estimates incorporating habitat characteristics”. This can only be achieved by addressing several of the other AMAPPS objectives that relate to (1) collecting broad-scale and fine-scale data over multiple years on the seasonal distribution and abundance of marine mammals (cetaceans and pinnipeds), sea turtles, and sea birds using fixed passive acoustic monitoring and direct aerial and shipboard surveys of U.S. Atlantic Ocean waters and (2) conducting tagging studies of protected species to develop corrections for availability bias in the abundance survey data.

8.3 Survey Data

During 2018 the abundance survey data collected during the NEFSC and SEFSC shipboard and aerial surveys that were conducted from 2010 to 2017 were error-checked, audited and archived in the NEFSC Oracle database along with also at the OBIS-SEAMAP website.

To analyze the entire time series of AMAPPS data, all the survey effort and animal sightings for this time period were aggregated into the 12,138 spatial cells of $10x10km^2$ and the 8-day time periods, starting with Jan 3 of each year. This process generated cells with low survey effort that has the potential to unduly impact the density estimates. Therefore after multiple tests, it was determined that prior to the DISTANCE analysis, survey effort in cells with less than 1 km for shipboard surveys and 2 km for aerial surveys, along with the associated sightings would be transferred to adjacent cells. For example, if a track line just crosses the corner of a grid cell then a low-effort cell would be in the middle of a trackline. In this case the survey effort from the low-effort cell was split between and added to the two neighboring cells that contain the current track line. If the low-effort cell was at the beginning or end of a trackline, then all the effort was added to the neighboring cell that had the rest of the trackline.

8.4 Environmental Data

During 2018, the collection and interpolation process of the dynamic variables for the years 2010-2017 for the study area was streamlined and completed. The environmental covariates that were processed included those reported in AMAPPS I, in addition to chlorophyll fronts, SST fronts, North Atlantic oscillation index and distance to the Gulf Stream north and south walls. The complete set of dynamic variates to be considered in the modeling framework is presented in Table 8.1.

8.5 Generalized Additive Modeling (GAM) Framework

During 2018, we explored the GAM methodology to determine the best way to analyze the full time series 2010-2017 data. Specifically we re-evaluated the different versions and different options of the R package “mgcv” to determine the effects on the results of the density-habitat models using the common dolphin 2010-2013 model as an example. We also re-evaluated the effects of the model formulation. Using these results, all the data collected by AMAPPS from 2010 to 2017 were analyzed with DISTANCE to produce species specific density estimates, which accounted for perception and availability bias in the surveyed spatial-temporal cells for all years and platforms. These estimates and the environmental data were used as input data in the GAM framework and so far a total of 8 species specific draft models (Atlantic spotted dolphin, common bottlenose dolphin, common dolphin, white-sided dolphin, striped dolphin, humpback whale, minke whale and fin whale) and 1 draft model for the pilot whale group were produced. In 2019 these models will be finalized as will models for the rest of the species. It is expected to be completed by summer 2019.

Using the 2010 – 2013 cetacean models the environmental predictors of habitat suitability and cetacean occurrence in the western North Atlantic Ocean were documented in Chavez-Rosales et al. (in review).

Table 8.1 Environmental covariates considered in future habitat-density models

Covariates	Description	Resolution	SOURCE
SSTMT	SST MODIS TERRA	1 km mapped to 2 km	https://oceancolor.gsfc.nasa.gov/
SSTMA	SST MODIS AQUA	1 km mapped to 2 km	https://oceancolor.gsfc.nasa.gov/
SSTMUR	SST Multi-scale Ultra-high Resolution (MUR)	1 km mapped to 2 km	https://podaac.jpl.nasa.gov/dataset/MUR-JPL-L4-GLOB-v4.1
CHLFMA	Chlorophyll Fronts Modis Aqua	1 km mapped to 2 km	Original source data - https://oceancolor.gsfc.nasa.gov/, fronts calculated using Belkin & O'Reilly (2009)
SSTFMA	SST Fronts Modis Aqua	1 km mapped to 2 km	Original source data - https://oceancolor.gsfc.nasa.gov/, fronts calculated using Belkin & O'Reilly (2009)
SSTFMT	SST Fronts Modis Aqua	1 km mapped to 2 km	Original source data - https://oceancolor.gsfc.nasa.gov/, fronts calculated using Belkin & O'Reilly (2009)
CHLAOCI	Chlorophyll-a concentration	1 km mapped to 2 km	https://oceancolor.gsfc.nasa.gov/
PIC	Particulate inorganic carbon	1 km mapped to 2 km	https://oceancolor.gsfc.nasa.gov/
POC	Particulate organic carbon	1 km mapped to 2 km	https://oceancolor.gsfc.nasa.gov/
PP	Primary productivity	1 km mapped to 2 km	Calculated using Behrenfeld & Falkowskip (1997) & Eppley (1972) https://podaac.jpl.nasa.gov/ & https://oceancolor.gsfc.nasa.gov/,
SLA	Sea Surface Height Anomaly	1/4°	http://www.aviso.altimetry.fr/
MLD	Mix layer depth,	1/12°	https://hycom.org/dataserver/glb-analysis
SALINITY	Surface salinity (psu)	1/12°	https://hycom.org/data
BTEMP	Bottom Temperature	1/12°	https://hycom.org/data
MLP	ocean mixed layer	1/12°	https://hycom.org/dataserver/glb-analysis
NAOIM	North Atlantic Oscillation index	daily	ftp://ftp.cpc.ncep.noaa.gov/cwlinks/
DGSNW	Distance to the Gulf Stream North wall	m	https://www.opc.ncep.noaa.gov
DGSSW	Distance to the Gulf Stream South wall	m	https://www.opc.ncep.noaa.gov

8.6 Bayesian Hierarchical Model

Work on the Bayesian hierarchical framework in 2017 focused on incorporating GAMs and directly comparing the output to results from the conventional 2-step GAM approach. In 2018, we included a simulation framework to compare these two methods. This simulation approach demonstrated that the Bayesian method achieved better statistical interval coverage and lower bias than the 2-step method while propagating substantially more uncertainty. We combined these results with a fin whale analysis conducted in 2017 in a comprehensive manuscript outlining the Bayesian hierarchical method and highlighting differences in uncertainty between this method and the 2-step approach. This manuscript is currently in review at a peer-reviewed journal (Sigourney et al. in review). In addition, these updated results were presented at a Density Modelling (DenMod) meeting in October 2018.

8.7 Integrating Passive Acoustic and Line Transect Data

This project is to more accurately estimate abundance of deep diving cetaceans using data collected simultaneously from a visual line transect survey and monitoring a passive acoustic towed array. The hope is this will provide for more accurate spatially-temporally explicit availability bias corrections due to using diving patterns collected during the visual line transect survey. Sperm whales are the first species to attempt this on.

In 2018, we focused on testing the current model framework with a more thorough set of simulations that were designed to more accurately mimic sperm whale diving behavior. Specifically, we included individual variation in the diving and clicking behavior of simulated whales based on information reported in the literature for sperm whales. Results demonstrated that the model framework was robust under a number of simulated scenarios. A draft report from 2017 was revised to include these modifications to the methods and new results. Updated results of the model framework were presented at a Density Modelling (DenMod) meeting in October 2018. Future work will focus on taking the existing code and developing an R package that will be submitted to the NOAA National Protected Species Toolbox. This work is expected to be completed this by the summer 2019.

In addition to sperm whales, work in 2018 also explored applying the model to data on beaked whales. Analysis of these data is still ongoing.

8.8 Abundance Estimates using 2016 Visual Line Transect Data

Using only the 2016 shipboard and aerial survey data collected in the entire US Atlantic waters from Florida to Maine, abundance estimates have been produced from 27 species. Design-based mark-recapture Distance sampling methods were used. In addition, a species-specific correction for availability bias was also applied. These abundance estimates, when appropriate will be combined with the species-specific abundance estimates resulting from the 2016 Canadian aerial line transect surveys conducted from New Brunwick, through the Gulf of St. Lawrence, then around Newfoundland and Labrador. The methodology and results from the Northeast Fisheries Science Center’s shipboard and aerial surveys are documented in Palka (in review).

All estimates are going into the next North Atlantic Stock Assessment Report. The abundance estimates and the documentation will be reviewed by the Atlantic Scientific Review Group in May 2019, then go to public comment later in 2019.

8.9 Database Development

R scripts have been improved to make data uploads to Oracle easier and better documented, improve outputting data from the database in various formats, and improve the automatically generated maps of density-habitat model results.

8.10 Acknowledgements

We would like to thank the crews of the NOAA ships *Henry B. Bigelow* and *Gordon Gunter*, crews of the NOAA aircraft Twin Otters, and the science teams who participated in the data collection on AMAPPS shipboard and aerial surveys. This work was partially supported by the Bureau of Ocean Energy Management (BOEM) and the US Navy through Interagency Agreements for AMAPPS, as well as by the NOAA Fisheries.

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9 Progress on Passive Acoustic Data Collection and Analyses: Northeast and Southeast Fisheries Science Centers

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9.1 Summary

The goal of the Atlantic Marine Assessment Program for Protected Species (AMAPPS)-related research conducted by the Northeast and Southeast Fisheries Science Center's passive acoustic groups is to collect acoustic data that compliment visual-based analyses of animal occurrence and abundance, particularly for species that are difficult to detect by visual observation, or in times of year and regions where visual surveys are not conducted. In 2018, there were several ongoing primary analyses involving bottom-mounted recorder data and towed hydrophone array data collected during AMAPPS surveys. These are: (1) documenting distribution of baleen whales along the eastern seaboard continental shelf and shelf break, with results presented for North Atlantic right whales (*Eubalaena glacialis*), sei whales (*Balaenoptera borealis*), and blue whales (*Balaenoptera musculus*); (2) assessing the acoustic ecology of shelf break habitats, including the temporal and spectral overlap between cetacean species groups and anthropogenic noise; and (3) quantifying acoustic detection rates and acoustic characterization of beaked whales recorded on towed hydrophone arrays, with the goals of comparing to visual detection rates and compiling sufficient data for acoustic abundance estimation for these taxa. In addition, work is continuing on the Tethys acoustic database in collaboration with scientists from San Diego State University, Scripps Institution of Oceanography and the NOAA Science Centers.

9.2 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 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 develop more effective monitoring and management strategies where needed, and improve abundance estimation

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

- Improve our understanding of the spatial and temporal distribution of cetacean species in the western North Atlantic using bottom-mounted archival recorders; and
- Improve our ability to correctly identify cetacean vocalizations to species, and 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;
- 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.

9.3 Bottom-mounted Recorder Data Collection

Two deployments of MARUs (Marine Autonomous Recording Units, Cornell University, Bioacoustics Research Program), were conducted along the US eastern seaboard off the coasts of Massachusetts, North Carolina, and Georgia (Figure 9.1). MARUs were programmed to sample continuously at 2 kHz, and recorded for approximately 6 months at time. These were the last deployments of a multi-year project to monitor baleen whale migratory movements along the US east coast that started in 2015. Nine MARUs were deployed in December 2017/January2018, off Cape Hatteras, NC and Brunswick, GA. However, only 5 were recovered; the remaining units were lost at sea. A final deployment was conducted starting in late fall/winter 2018; 19 units were deployed in 3 lines off Nantucket, MA, Cape Fear, NC, and Brunswick, GA. These units will be recovered in spring 2019.

Eight HARPs (High-frequency Acoustic Recording Packages, Scripps Institution of Oceanography) were recovered and redeployed along the shelf break of the US eastern seaboard (Figure 9.1). HARPs were programmed to sample continuously at 200 kHz for one year. These were the final deployments of a multi-year project that started in 2015, to monitor the acoustic ecology of shelf break and deep water habitats, including the presence of baleen whales, odontocetes, and anthropogenic noise. HARP recoveries and redeployments were conducted in June/July 2018. The final recoveries will be conducted in summer 2019.

In addition, one deep-water HARP was deployed offshore of Georges Bank in 2000 m of water, for approximately 3 weeks in July/August 2018. This deployment was conducted in conjunction with the 2018 NEFSC AMAPPS shipboard cetacean ecology survey. This deployment was part of a pilot project to conduct fine-scale analyses of cetacean and prey co-occurrence in deep water habitats. See Chapter 7 for more details.

9.4 Mobile Passive Acoustic Data Collection

Towed hydrophone array data and drifting autonomous recorder data were collected in July/August 2018 in conjunction with the NEFSC AMAPPS shipboard cetacean ecology survey; see Chapter 7 for more details.

9.5 Database Development

The Tethys acoustic database, developed in collaboration with scientists from San Diego State University, 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 incorporation of additional recorder platforms and acoustic detection analysis data.

9.6 Data Analysis Methods

Processing of passive acoustic data took place using a variety of software packages. Bottom-mounted recorder data were reviewed for baleen whale acoustic activity both manually and using custom-written software, the Low-Frequency Detection Classification System (LFDCS, Baumgartner et al., 2013). Analyses for odontocete and anthropogenic noise presence was conducted by collaborators at Scripps Institution of Oceanography, using a combination of manual review and custom-built automated tools. Acoustic niche presentation results were created using the software package R. Towed hydrophone array data were analyzed using Pamguard (version 1.15.10, Gillespie et al. 2008), Audacity®, as well as custom-written Matlab scripts.

9.7 Analysis Results

9.7.1 Baleen Whale Occurrence along the Eastern Seaboard

Up to five lines of MARUs were deployed along the US eastern seaboard from October 2015 – spring 2019. In addition, up to 8 HARPs have been deployed along the US eastern seaboard shelf break since 2015 (3 in 2015; 8 in subsequent years). Baleen whale presence was determined on a daily basis for each recorder unit using a combination of the Low Frequency Detection and Classification System (LFDCS, Baumgartner & Mussoline 2011), as well as manual review to verify correct species presence. Calls of North Atlantic right whales (*Eubalaena glacialis*) and sei whales (*Balaenoptera borealis*), as well as song units of humpback whales (*Megaptera novaeangliae*), fin whales (*Balaenoptera physalus*), and blue whales were detected and classified. Analyses of these datasets are ongoing for a number of species and projects. A brief summary of the ongoing progress is presented here.

9.7.1.1 North Atlantic right whales

Analyses in 2018 included determining daily presence of North Atlantic right whales for HARP units deployed along the shelf break from April 2015 – June 2017. Right whales were considered present on any given day if 3 or more up-calls were detected. Notably, results indicate low but detectable occurrence of right whales along the shelf break between May and July (Figure 9.2). For example, right whales were detected on a minimum of 10 days between May – July 2015 at Oceanographer Canyon.

9.7.1.2 Sei whales

Analyses to assess sei whale presence were conducted for 32 MARU sites deployed October 2015 – July 2017 (Figure 9.1). LFDCS was used to identify acoustic detections of sei whale down sweeps. Detections were manually reviewed by day for each site; sei whales were considered “present” if there were at least 3 positive detections on that day. The total number of recording days per site ranged from a low of 115 days, to a maximum of 560 days. Sei whale vocalizations were frequently detected on the line of MARUs that were deployed south of Cape Cod, MA, with detections on up to 40% of days at one site. Although sei whales were detected for extended periods in this region, detections exhibited clear seasonality, with the highest levels of acoustic activity in the winter and spring months (Figure 9.3).

Sei whales were detected much less frequently at sites from Cape Hatteras southward, with zero acoustic detections at many sites. However, they were sparsely detected on the deeper MARUs located in the Blake Plateau on each of the southern three monitoring lines (Figure 9.3). On the southernmost line off of Brunswick, GA, they were detected at the deepest recorder a minimum of 14% of days during October – March 2015. All acoustic detections on the lines from Cape Hatteras southward occurred during fall to winter months (Figure 9.3).

9.7.1.3 Blue whales

Analyses to assess blue whale presence and quantify the accuracy of the LFDCS automated detector were conducted using data collected from April 2016- April 2017 at HARP 1 deployed near Heezen Canyon, off Georges Bank (Figure 9.1). A total of 365 days of data were analyzed. Manual spectrographic review of the entire dataset was conducted; blue whales were determined to be present if a clear song bout of at least 3 sets of song units was noted (e.g. Figure 9.4, top panel). Days with no obvious song were marked as “not present”; days where the occurrence of song was ambiguous were marked as “unknown”. LFDCS was also run over the entire dataset to automatically detect and classify blue whale signals. Manual analyses revealed blue whale presence on 52.3% of days, though the automated detector captured blue whale occurrence on only 32.9% of days (Table 9.1, Figure 9.4). Blue whale occurrence was seasonal, with detections beginning in late summer, becoming most consistent throughout the fall, and then variably present until mid-March (Figure 9.4). Further analyses are required to evaluate the rate of missed detections at other sites and years

9.7.2 Shelf Break Acoustic Ecology: Acoustic Niche Analyses of HARP data

To evaluate the spatial, temporal, and spectral overlap between different groups of cetaceans and anthropogenic signals, an “acoustic niche” visualization approach was applied to the HARP data collected at sites 1-3 (Figure 9.1) from 2015-2016 (following Van Opzeeland and Boebel 2017) . The main goal of this analysis was to assess the overlap between cetacean species and anthropogenic activities on a daily and seasonal basis. Baleen whale presence was determined on a daily basis using LFDCS, as described above. Odontocete and anthropogenic noise presence was determined using a combination of automated detectors and manual review (Varga et al. 2017). An example dataset is shown in Figure 9.5 for HARP 2, deployed near Oceanographer Canyon May 2015 - February 2016. Species were divided into groups based on the primary frequency range of their vocalizations. Dolphins were combined into one category, as were three species of beaked whales (Cuvier’s (*Ziphius cavirostris*), Gervais’ (*Mesoplodon europaeus*) and True’s (*Mesoplodon mirus*)) whose echolocation clicks exhibit a high degree of spectral overlap.

Other species were plotted separately. Anthropogenic activities that were assessed include: noise from seismic surveys (airguns), broadband vessel noise, shipboard echosounders, and underwater explosions. At the site of HARP 2, airguns were audible on 74% of days, and discrete vessel traffic was present on 59.4% of days (Table 9.2). Fin and sei whales were present for 51% and 24.3% of days, respectively. Temporally, airgun activity overlapped with all 5 species of baleen whales analyzed, including several days with North Atlantic right whale presence (Figure 9.5). Analyses are ongoing to include additional HARPs.

9.7.3 Acoustic Detections of Beaked Whales (family: Ziphiidae)

A manuscript describing the acoustic characteristics of True's beaked whales was published in 2018 (DeAngelis et al. 2018). Analyses utilized data collected during two encounters with True's beaked whales during AMAPPS surveys in 2016 and 2017. Frequency measurements were conducted using over 2100 echolocation clicks; the median peak frequencies were 43.1 kHz (in the 2016 encounter) and 43.5 kHz (in the 2017 encounter). The spectral and temporal features of these clicks resemble those described for Gervais' beaked whales; therefore further work is needed to be able to unambiguously distinguish between the species in the absence of visual sightings.

Post-processing of the data from the NEFSC 2017 cetacean ecology survey was completed using the software package Pamguard. Details on the field data collection can be found in the NEFSC/SEFSC 2017 report (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). Analysis steps included 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. During the 2017 survey, there were 180 definitive beaked whale events, 64% of which were Cuvier's beaked whales (Table 9.3, Figure 9.7). There were also a total of 64 encounters with Mesoplodon species that are most likely True's beaked whales. Some of these events were recorded during periods of focal follow data collection, with multiple encounters of visually-verified True's beaked whales. However, many of the events were recorded in the absence of visual verification, and as True's and Gervais' beaked whale clicks exhibit similarity (DeAngelis et al. 2018), they are being combined for the purposes of this report. No Gervais' beaked whales were visually identified during this survey. In addition to the 180 definitive acoustic encounters with beaked whales (Figure 9.7), there were also 19 "probable" and 40 "possible" detections.

Post-processing of the data from the SEFSC 2016 cetacean abundance survey was initiated in 2018 as well. Analysis steps are consistent with those being conducted with the NEFSC data. The Pamguard click detector (pre-filter: 16-90 kHz; trigger filter: 20-90 kHz; threshold 10 dB) was run over the entire dataset; detections will be reviewed and classified to species in ongoing analyses in 2019.

Post-processing of the data from the NEFSC 2018 cetacean ecology survey is reported with the overall results of that survey in Chapter 7.

9.7.4 Integrating Acoustic and Visual Data for Abundance Estimation

Analysis efforts continued on the topic of combining visual sightings and acoustic detections of sperm whales to improve abundance estimation and understanding of sperm whale distributions.

Modeling efforts continue to focus on data collected during the NEFSC 2013 cetacean abundance shipboard survey. Preliminary analyses were also initiated using acoustic detections of beaked whales species. Additional analyses in Pamguard were conducted to extract more detailed data on sperm whale encounters for model testing. Model development by D. Sigourney of the AMAPPS team is described in Chapter 8.

9.8 Acknowledgements

Genevieve Davis, Annamaria DeAngelis, Sarah Weiss and Zachary Pinard contributed to the acoustic analyses included in this report. We would like to thank the crew of the NOAA Ship *Gordon Gunter*, and the science teams who participated in visual and acoustic data collection on AMAPPS surveys. We thank Eric Matzen and Paul Caiger for support in the field recoveries and redeployments of the three northern HARP recorders. We thank colleagues at Cornell University for assistance in recovery and deployment of MARUs and subsequent data extraction. Colleagues at Scripps Institution of Oceanography assisted with data collection (deployment and recovery), data extraction and preliminary analyses of HARP data. In particular we thank John Hildebrand, Simone Baumann-Pickering, Jenny Trickey, Kait Frasier, and Ryan Griswold. This work was partially supported by the Bureau of Ocean Energy Management (BOEM) and the US Navy through Interagency Agreements for AMAPPS, as well as by the Navy's Living Marine Resources Program and NOAA Fisheries.

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Table 9.1. Analysis of blue whale (*Balaenoptera musculus*) song presence on HARP 1 from April 2016 – April 2017. Automated detector results were compared to a manual spectrographic analysis to determine detector performance, specifically missed detection rates. Blue whales presence was detected seasonally, see Figure 9.4.

	Total Days	Days with Detections	Percent Days	Days with No Detections	Percent Days	Days with Detections Unknown	Percent Days
Manual Review	365	191	52.3	145	39.7	29	7.9
Automated Detector	365	120	32.9	243	66.6	3	0.5

Table 9.2. Cetacean presence and detection of anthropogenic noise at HARP 2, deployed near Oceanographer Canyon from May 2015 through February 2016. See Figure 9.5 for graphical display.

Species/ Sound Source	Total Days	Days with Detections	Percent Days
Blue whales	288	14	4.9
Fin whales	288	147	51.0
Sei whales	288	70	24.3
Right whales	288	10	3.5
Humpback whales	288	25	8.7
Sperm whales	288	231	80.2
Delphinids	288	288	100.0
Sowerby's beaked whales	277	36	13.0
Cuvier's/Gervais'/True's beaked whales	277	11	4.0
Kogia spp.	287	42	14.6
Seismic Airguns	288	213	74.0
Broadband ships	288	171	59.4
Explosions	288	1	0.3
Echosounders	288	57	19.8

Table 9.3. Acoustic detections of beaked whales from the 2017 cetacean ecology shipboard survey, conducted in September 2017. Note that the Gervais'/True's category most likely represent True's beaked whales (*Mesoplodon mirus*).

Category	Number of Events Detected	Number of Localizable Events
Definite beaked whales	180	134
Cuvier's	116	93
Gervais'/ True's	64	41
Sowerby's	0	0
Probable beaked whales	19	11
Cuvier's	11	7
Gervais'/ True's	7	4
Sowerby's	1	0
Possible beaked whales	40	7
Cuvier's	30	5
Gervais'/ True's	10	2
Sowerby's	0	0

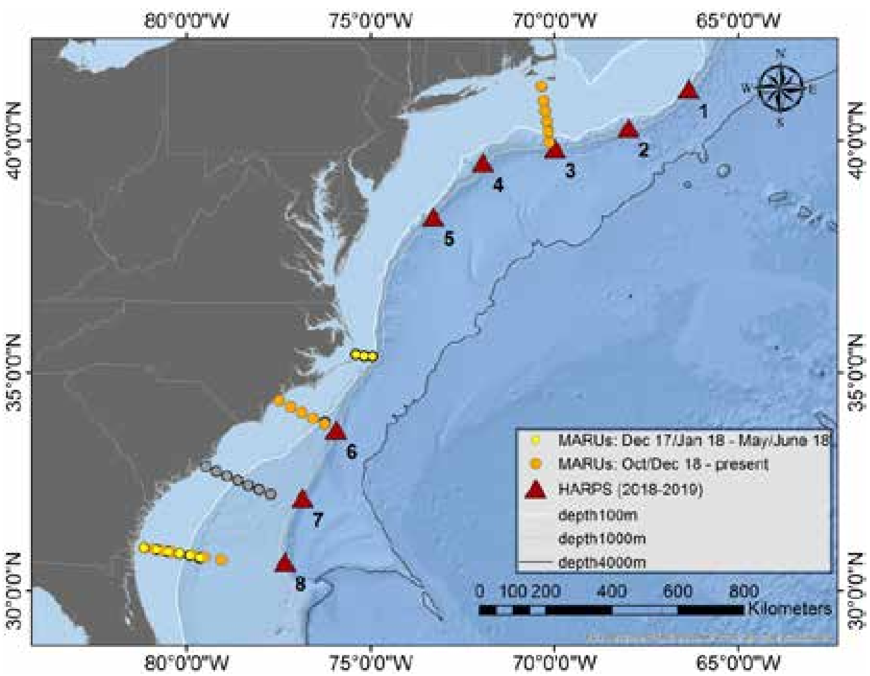

Figure 9.1. Map of bottom-mounted recorders deployed along the US eastern seaboard in conjunction with Atlantic Marine Assessment Program for Protected Species (AMAPPS) efforts in 2018. These data contribute to analyses of baleen whale migratory movements and shelf break acoustic ecology and species diversity. Two 6-month deployments of Marine Autonomous Recording Units were conducted (orange and yellow dots). The gray line of MARUs were deployed from 2015-2017, and are referenced in the text for analyses conducted in 2018. High-frequency Acoustic Recording Packages (HARPs) are labelled for sites 1-8, and were deployed for a year.

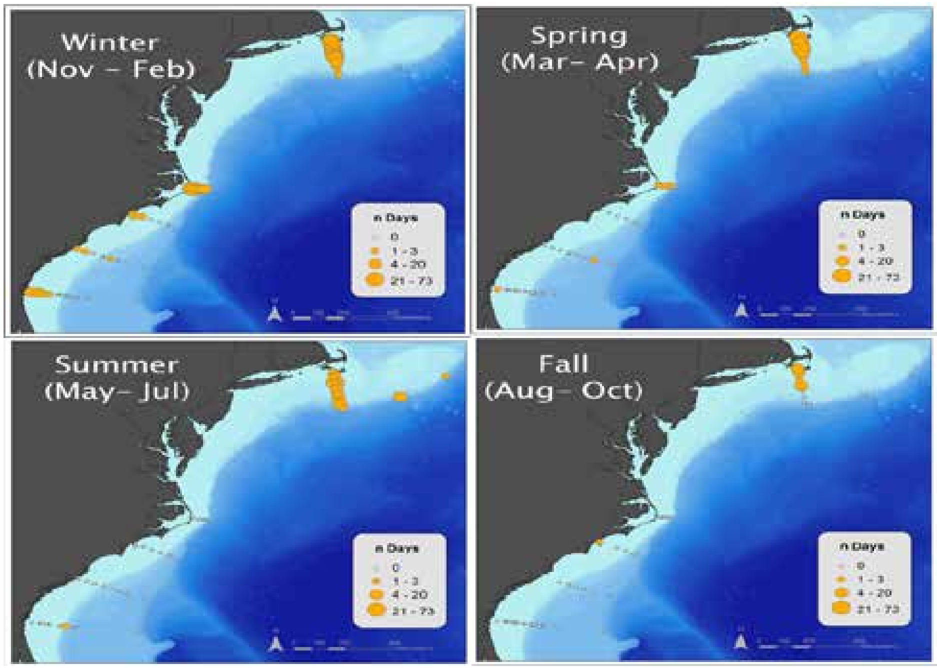

Figure 9.2. Acoustic presence of North Atlantic right whales (*Eubalaena glacialis*) from May 2015 – June 2017, by site and season. Recording units include 5 lines of MARUs deployed along the continental shelf, and 8 HARPs deployed along the shelf break from Georges Bank to the Blake Spur. Note the presence of right whales detected on the shelf break of the Georges Bank region during summer months, and across the continental shelf south of Nantucket year-round.

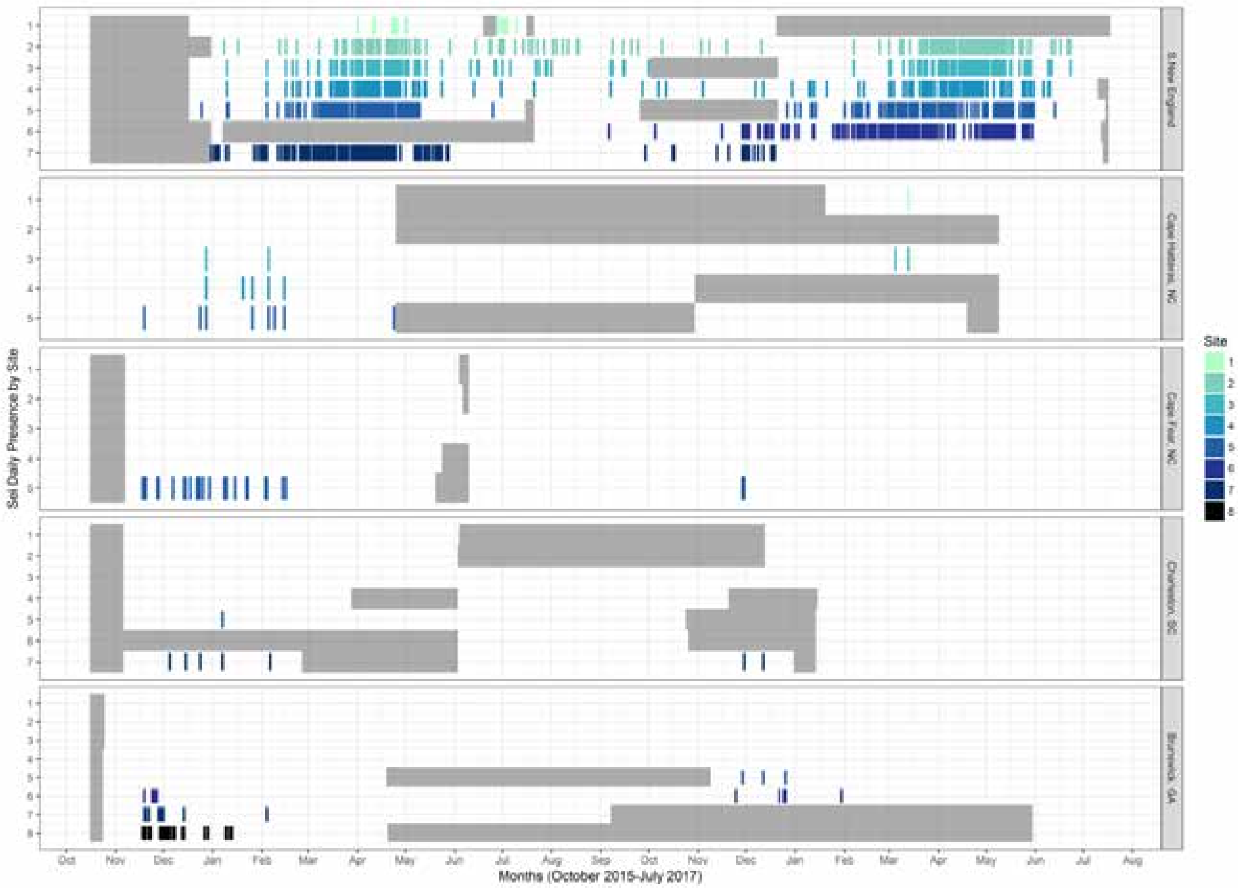

Figure 9.3. Daily occurrence of sei whale (*Balaenoptera borealis*) acoustic detections at each of 32 MARU sites, from October 2015 through July 2017. MARUs were deployed in five lines along the continental shelf (Figure 9.1). The number of MARUs per line ranged from five to eight. MARU site is indicated on the left y-axis, with Site 1 being the furthest inshore. Acoustic detections are shown as colored bars, with shading indicating site. The x-axis indicates month, starting in October 2015. MARUs were frequently lost due to weather conditions and fishing activity; periods with no monitoring effort are indicated by gray bars. Periods with no detections are white (blank).

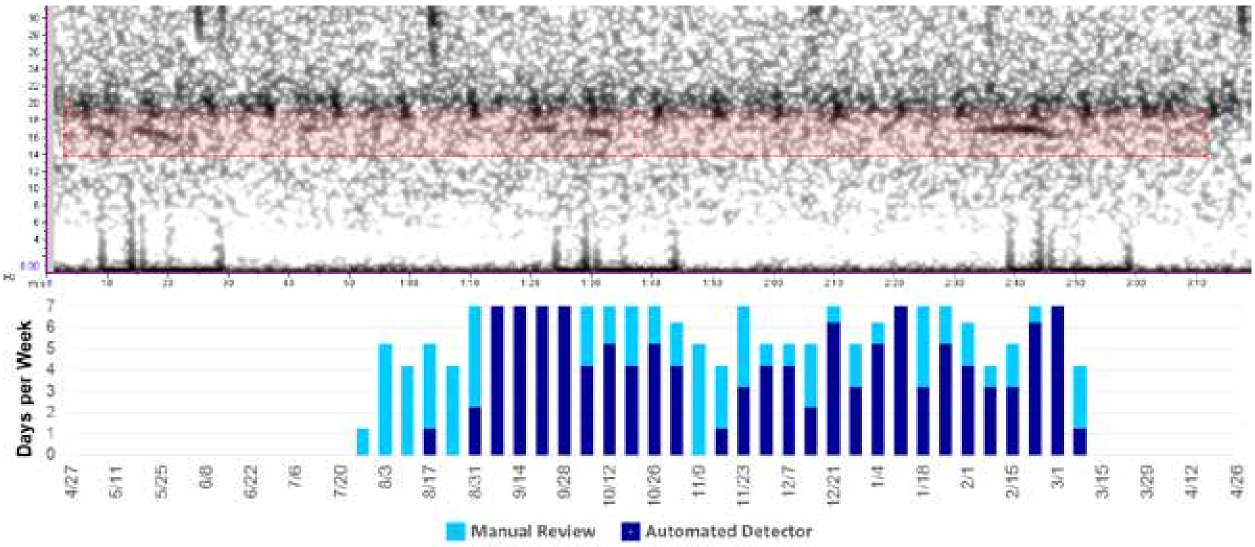

Figure 9.4. Top panel: Spectrogram example of blue whale (*Balaenoptera musculus*) song highlighted in the red box. Time (in seconds) is on the x-axis, frequency (in Hertz) is on the y-axis. Note that fin whale (*Balaenoptera physalus*) song is present a few Hz above the blue whale song. Bottom panel: Number of days per week with blue whale song detected at HARP 1 in 2016 (see Fig 9.1), as determined by both manual review of the dataset as well as through an automated detector.

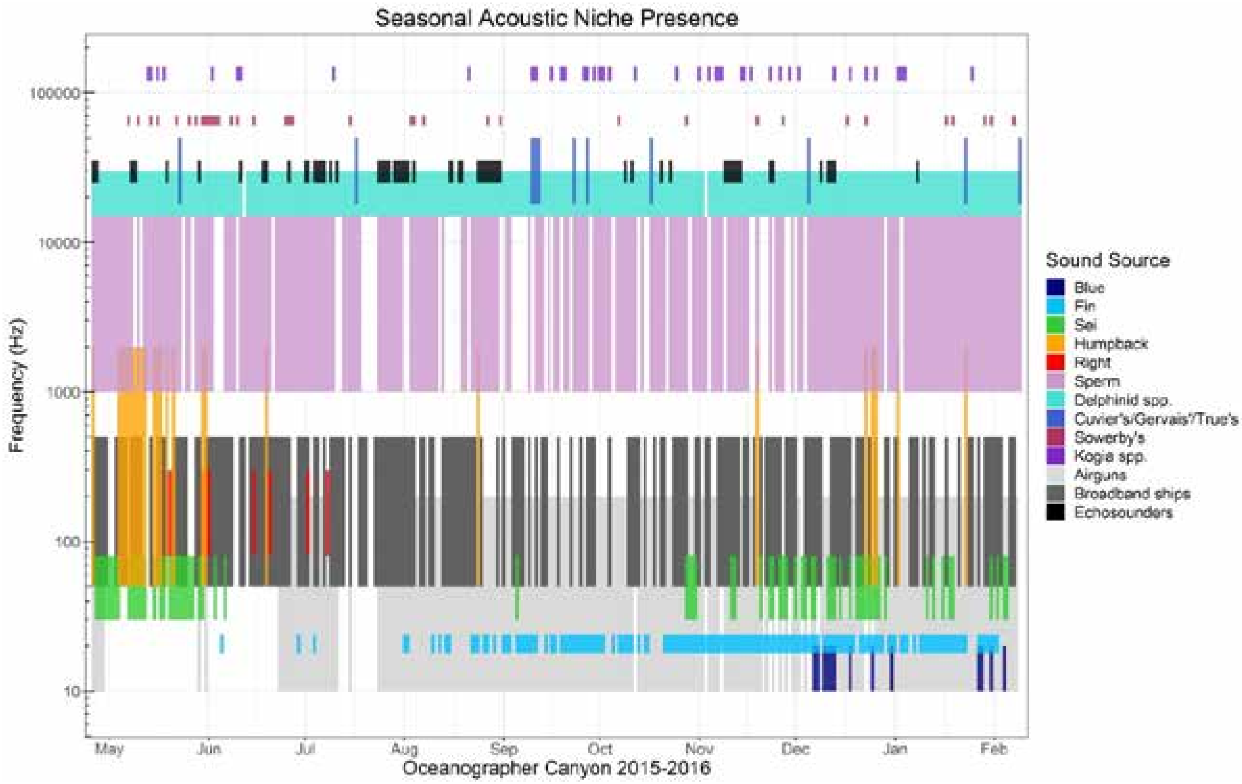

Figure 9.5. Daily presence of cetacean species groups and anthropogenic signals at the HARP 2 site from May 2015 to February 2016 (see Figure 9.1), collated according to dominant frequency ranges. Frequency in Hz is on the y-axis; note that the y-axis is displayed on a log scale. Date is on the x-axis. Baleen whale presence is shown for each species individually; delphinids are combined into one group, as are Cuvier's(*Ziphius cavirostris*), Gervais' (*Mesoplodon europaeus*) and True's (*Mesoplodon mirus*) beaked whales.

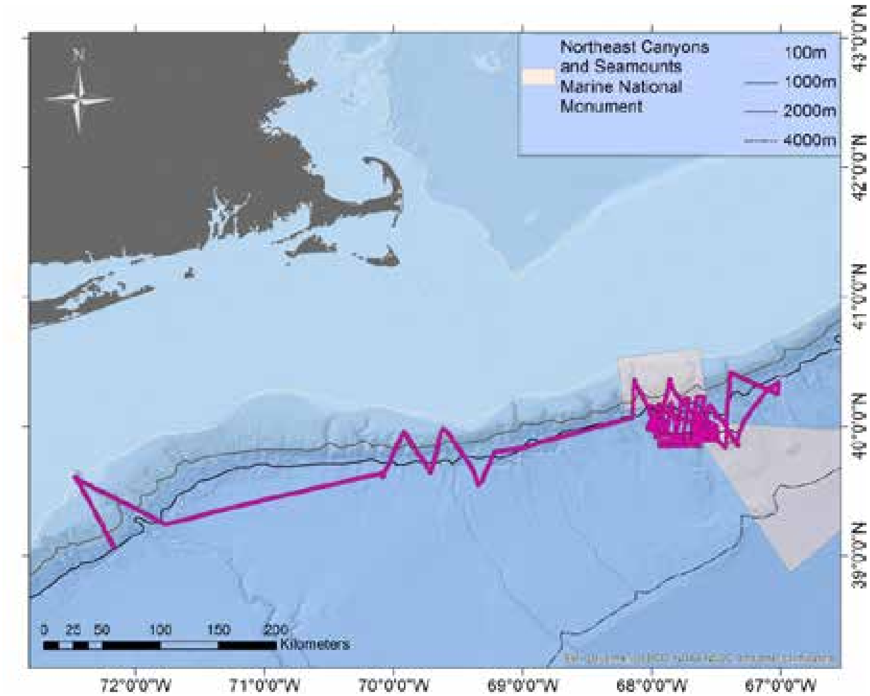

Figure 9.6. Survey tracklines from the 2017 cetacean ecology survey, conducted on the *R/V Hugh R. Sharp* from 9 – 17 September 2017. Tracklines include both daytime and nighttime effort. Passive acoustic recording was conducted during daytime and nighttime effort. The straight tracks between canyon areas were transited at night.

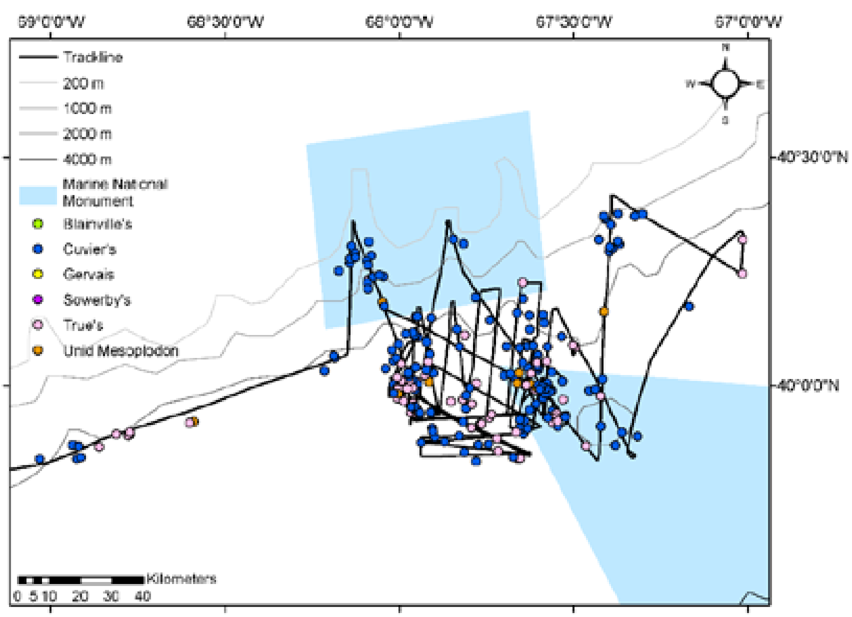

Figure 9.7. Acoustic detections of beaked whales during the 2017 cetacean ecology survey. Detections include both those noted in real-time, as well as those extracted during post-processing of the dataset. Note that each detection may represent an individual or group.