2021

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 III

Bubble feeding humpback whales during August 2021. Credit: P. Nagelkirk NEFSC MMPA Permit #21371

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

Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149

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List of Abbreviations and Acronyms

Abbreviation	Meaning
AMAPPS	Atlantic Marine Assessment Program for Protected Species
AMAR	Autonomous multichannel acoustic recorder
BOEM	Bureau of Ocean Energy Management
CFF	Coonamessett Farm Foundation
CIMAS	Cooperative Institute for Marine and Atmospheric Studies
CTD	Conductivity, temperature and depth sensor sampling device
DenMod	Density Modeling technical working group
DTAG	Digitally acoustic recording tag
EcoMon	Northeast Fisheries Science Center’s Ecosystem Monitoring program
ERDDAP	Environmental Research Division Data Access Program
ESA	Endangered Species Act
FY	Fiscal year
GAM	Generalized additive model
GFDL	Global climatic model
GMT	Greenwich mean time zone
GOMMAPS	Gulf of Mexico Marine Assessment Program for Protected Species
GPS	Global Positioning System
HARP	High-frequency acoustic recording package
ITS.DEEP	Integrated Technologies for Deep Diver Ecology Program
MARU	Marine passive acoustic recording units
MBTA	Migratory Bird Treaty Act
MMPA	Marine Mammal Protection Act
NCEI	NOAA’s National Center for Environmental Information
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PPM	Percent positive minutes
SEFSC	Southeast Fisheries Science Center
VIAME	Video and Image Analytics for a Marine Environment software
VHF	Very high frequency
VPR	Video plankton recorder

1 Overview of 2021

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 provides spatially explicit information in a format useful to marine resource managers. This information will also 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. Scientists from NMFS's Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) developed the products resulting from the interagency agreements.

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

This report focuses on documenting the fieldwork conducted and briefly describing the progress of analyses performed during 2021.

1.2 Summary of 2021 Field Activities

A summary of field activities we conducted in 2021 is in Table 1-1. The data presented here are preliminary and subject to change as we perform further auditing and analyses.

During 12 June to 15 September 2021, the NEFSC and SEFSC lead a large-scale line transect abundance survey for marine mammals, sea turtles, and sea birds using ships and planes (Table 1-1). We conducted visual line-transect surveys over about 15,200 km of trackline by a NOAA Twin Otter. In addition, we conducted visual and passive acoustic transect surveys over 11,647 km by the NOAA ships *Gordon Gunter* and *Henry B. Bigelow*. Together, these surveys covered all Atlantic waters from the tip of Florida to Nova Scotia, from the coast to beyond the US exclusive economic zone, to about 200 nmi offshore (Figure 1-1). We visually detected about

- 2,300 groups of 34 species (or species guilds) of cetaceans
- 1,400 groups of 5 species/guilds of sea turtles
- 11,200 groups of seabirds species/guilds
- 1,500 groups of opportunistically recorded fish species/guilds

In addition, we surveyed using passive acoustic towed hydrophone arrays for about 650 hrs. We are currently post-processing the passive acoustic data to evaluate the number of acoustic detections. We also sampled the ecosystem by collecting hours of active acoustic EK60 backscatter data, 70 CTD casts, 180 bongo with CTD deployments, 33 VPR with CTD deployments, and 47 Frame net with CTD deployments. We will be using these various types of data for a variety of analyses. One, estimating abundance for as many species as the data support using design-based distance sampling techniques for the Stock Assessment Reports. Two, updating the spatiotemporal density-habitat models to document recent distribution patterns, intra- and inter-annual trends, and relationships between animal density and habitat factors. Three, updating the spatiotemporal distribution of acoustically active cetaceans. Four, documenting spatiotemporal distributions of larval tuna, cephalopods and other planktonic species. More information on the aerial surveys is in Chapter 2, the southern shipboard survey is in Chapter 3, and the northern shipboard survey is in Chapter 4.

During May, August, and October 2021, the NEFSC piggy-backed on 3 NOAA Ecosystem Monitoring (EcoMon) research cruises to conduct a 300 m strip transect survey during daylight hours when the ship was traveling at 6 or more knots (Table 1-1). These cruises covered waters from Virginia to Maine and surveyed nearly 5,000 km of track line in 35 survey days. During the May cruise the observers recorded 8,408 seabirds (4.35/km) and 982 marine mammals (0.51/km). In August, they recorded 4,319 birds (2.60/km) and 580 marine mammals (0.35/km). In contrast, in October, they recorded 1,797 seabirds (1.33/km) and 411 (0.31/km) marine mammals. More information is in Chapter 5.

During September 2021, the NEFSC planned to conduct a shipboard survey to assess the fine-scale habitat usage and foraging ecology of deep-diving cetaceans on the shelf break offshore of Georges Bank (Table 1-1). However, due to Hurricane Ida and positive tests for Covid-19, we had to postpone the survey until the summer/fall of 2022. More information is in Chapter 6.

During February/March and May 2021, the AMAPPS Turtle Ecology team deployed 31 satellite tags on loggerhead turtles (*Caretta caretta*) off North Carolina and in the mid-Atlantic Bight, respectively. During May and August/September 2021, the team deployed 3 satellite tags on leatherback turtles (*Dermochelys coriacea*) off North Carolina and Massachusetts, respectively. Our objectives for these fieldwork activities were to gather information on turtle behavior and dive patterns and to collect biological samples. More information is in Chapter 7.

During November 2021 to February 2022, we conducted a pilot study to explore the use of a 3-camera system that records images for the belly window port in the NOAA Twin Otter planes (Table 1-1). We will describe this project in detail in the 2022 AMAPPS annual report, although we provide a short description in section 9.2.2 in this document.

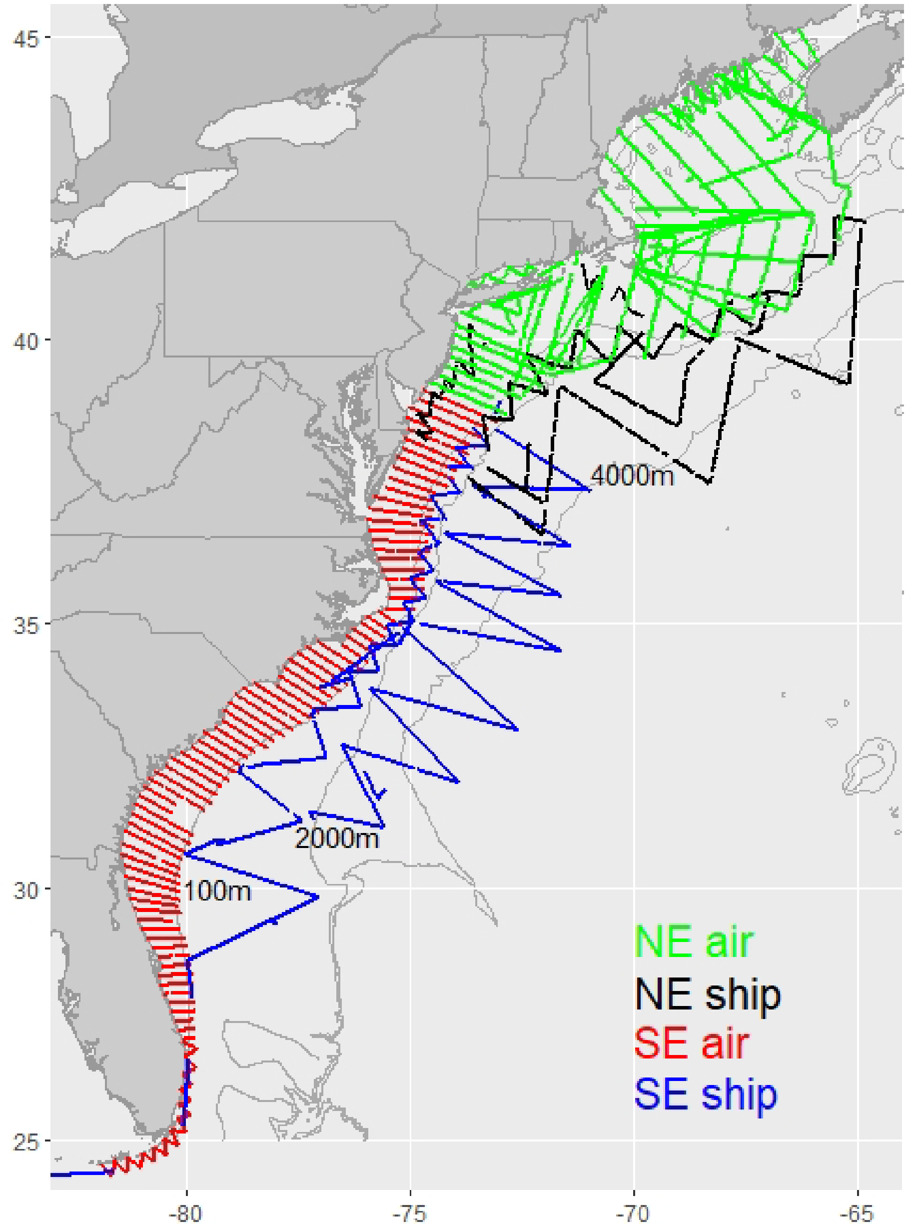

Figure 1-1 On-effort track lines during summer 2021 abundance survey using ships and planes

Table 1-1 General information on the 2021 field data collection projects

Field collection project[1]	Platform(s)[1]	Dates in 2021	Location	Chapter
Summer abundance survey (SEFSC)	NOAA Twin Otter airplane	17 Jun – 31 Jul	Shelf waters from New Jersey to Florida	2
Summer abundance survey (NEFSC)	NOAA Twin Otter airplane	1 Aug – 15 Sep	Shelf waters from Nova Scotia to New Jersey	2
Summer abundance survey (SEFSC)	NOAA ship *Gordon Gunter*	12 Jun – 5 Sep	Offshore waters from New Jersey to Florida	3
Summer abundance survey (NEFSC)	NOAA ship *Henry B. Bigelow*	16 Jun – 23 Aug	Offshore waters from Massachusetts to Virginia, including Canadian waters	4
Spring Ecosystem monitoring seabird survey (NEFSC)	NOAA ship *Gordon Gunter*	14 – 26 May	Shelf waters from Maine to Maryland	5
Summer Ecosystem monitoring seabird survey (NEFSC)	NOAA ship *Pisces*	6 – 18 Aug	Shelf waters from Maine to Maryland	5
Fall Ecosystem monitoring seabird survey (NEFSC)	NOAA ship *Pisces*	16 – 25 Oct	Shelf waters from Maine to North Carolina	5
Shelf break ecology survey (NEFSC)	NOAA ship *Pisces*	Cancelled (4 – 20 Sep)	Cancelled due to Hurricane Ida and Covid. Postponed until summer 2022.	6
Loggerhead satellite tagging (NEFSC+SEFSC)	Small boat; F/V *Kathy Ann*	Feb – Mar; 24 – 28 May	North Carolina; Mid-Atlantic bight	7
Leatherback suction cup tagging (NEFSC+SEFSC)	R/V Julius & R/V Selkie; M/V Warren Jr.	10 – 22 May; Aug - Sep	North Carolina; Massachusetts	7
Leatherback sound exposure project (NEFSC)	None	Cancelled	Cancelled due to permitting issues. Postponed until 2022.	7
Pilot study of aerial camera system (NEFSC & SEFSC)	NOAA Twin Otter airplane	1 Nov 2021 – 15 Feb 2022	Maine to Florida	9

[1] NEFSC = Northeast Fisheries Science Center; SEFSC = Southeast Fisheries Science Center; NOAA = National Oceanic and Atmospheric Administration

1.3 Summary of 2021 Analyses

The analyses we conducted during 2021 that used the marine mammal, sea turtle and seabird visual, acoustic and tag data are in Table 1-2. Details of the methods and preliminary results (when available) are in Chapters 7 to 9. The products (data and processed products) resulting from these analyses are in peer-reviewed papers, blogs and web stories, presentations at virtual meetings, and public websites (Tables 1-3 to 1-7).

Table 1-2 Description of AMAPPS analysis projects conducted in 2021

2021 Analysis Projects	Purpose	Chapter
Distribution and ecology of sea turtles	Document distribution and ecology of loggerhead and leatherback turtles equipped with satellite tags	7
Surface availability metrics of leatherback turtles	Provide simple summary statistics of availability metrics since only mid-way through the satellite tag data collection phase	7
Surface availability metrics of loggerhead turtles	Characterize dive-surfacing behavior of loggerhead turtles using satellite tag data collected during 9 years	7
Climate driven shifts in loggerhead turtles	Project shifts in habitat distribution using current satellite tag distribution and forecasting climate models	7
Estimate risk of gas embolism in sea turtles during routine dives	Determine factors contributing to development of gas embolisms in sea turtles, when they ascent rapidly	7
Sperm whale abundance estimate	Estimate sperm whale abundance using only acoustic data from 2016 NEFSC shipboard survey	8
Acoustic spatiotemporal distribution of beaked whales	Use acoustic detections from summer 2016 to 2019 towed array and bottom mounted HARPs[1] to describe distribution	8
Dolphin acoustic classifier	Train a random forest machine learning classifier to identify species of acoustic vocalizations using towed array data from 2016 ship survey	8
Beaked whale acoustic classifier	Train and test a neural network algorithm using HARP data	8
Seismic impact analysis	Identify, locate, and estimate range to seismic airgun presence for 11 HARPs	8
Baleen whale daily presence	Update and expand analyses to document daily presence of blue, fin, humpback, sei, and right whales from HARPs	8
Process new survey data	Process, check quality, and archive abundance survey and associated habitat covariate data	9
Spatiotemporal density models and abundance estimates	Apply generalized additive models to quantify abundance and relationships between marine mammals and sea turtles and habitat	9
Cetacean habitat shifts	Document species that shifted their habitats between 2010 and 2017 using spatiotemporal density models	9
Bayesian hierarchical density model	Improve modeling framework to speed up computing time and apply updated model to large whale data	9
Acoustic and visual abundance estimate of sperm whales	Finalize methods to estimate sperm and beaked whale abundance by integrating passive acoustic and visual sightings shipboard data	8 and 9

2021 Analysis Projects	Purpose	Chapter
Estimate abundance for Stock Assessment Reports	Use visual data from 2021 shipboard and aerial surveys to estimate abundance of 27 species using design-based methods	9
Compare cetacean distribution to ecosystem characteristics	Use active acoustic backscatter data (representing middle level trophic level taxa) to develop spatiotemporal cetacean density models	9
Forecast migratory humpback whale arrival	Use SubX forecast sea surface temperature and humpback density estimates to forecast their arrival	9
Archive data and make publically available	Archive sightings, passive acoustic, tag and ecosystem data and make data and analysis products publically available	2-9

[1] HARP = High-frequency Acoustic Recording Package

Table 1-3 Published paper products developed in 2021

Published Papers
Carroll EL, McGowen MR, McCarthy ML, Marx FG, Aguilar N, et al. 2021. Speciation in the deep - genomics and morphology reveal a new species of beaked whale *Mesoplodon eueu*. Proceedings of the Royal Society B. 288(1961):20211213. (*Used biopsy samples of True's beaked whale collected during AMAPPS deep diver surveys*)
Hernández CM, Richardson DE, Rypina IR, Chen K, Marancik KE, Shulzitski K, Llopiz JK. 2021. Support for the Slope Sea as a major spawning ground for Atlantic bluefin tuna: evidence from larval abundance, growth rates, and particle-tracking simulations. Canadian Journal of Fisheries and Aquatic Sciences, 20 October 2021. (*Used bluefin tuna larvae collected during AMAPPS shipboard surveys*)
Miller DL, Fifield D, Wakefield E, Sigourney DB. 2021. Extending density surface models to include multiple and double-observer survey data. PeerJ 9:e12113. (*Used visual sightings data collected during AMAPPS shipboard and aerial surveys*)
Palka D, Aichinger Dias L, Broughton E, Chavez-Rosales S, Cholewiak D, Davis G, DeAngelis A, Garrison L, Haas H, Hatch J, Hyde K, Jech M, Josephson E, Mueller-Brennan L, Orphanides C, Pegg N, Sasso C, Sigourney D, Soldevilla M, Walsh H. 2021. Atlantic Marine Assessment Program for Protected Species: FY15 – FY19. Washington DC: US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-051. 330 p. (*Used marine mammal, sea turtle, and seabird data collected under AMAPPS*)
Patel S, Winton MV, Hatch JM, Haas HL, Saba VS, Fay G, Smolowitz RJ. 2021. Projected shifts in loggerhead sea turtle habitat in the Northwest Atlantic Ocean due to climate change. Sci. Rep. 11:8850. (*Used satellite tagged loggerhead turtle data collected under AMAPPS co-funded field work*)
Robinson NJ, García-Párraga D, Stacy B, Costidis AM, Blanco G, Clyde-Brockway C, Haas HL, Harms CA, Patel S, Indra N, Stacy NI, Fahlman A. 2021. A baseline model to estimate risk of gas embolism in sea turtles during routine dives. Frontiers in Physiology. (*Used satellite tagged loggerhead turtle data collected under AMAPPS co-funded field work*)
Virgili A, Hedon L, Authier M, Calmettes B, Claridge D, Cole T, et al. 2021. Towards a better characterization of deep-diving whales' distributions by using prey distribution model. PLoS ONE 16(8):e0255667. (*Used sightings data of deep-diving species collected during AMAPPS surveys*)
Weiss SG, Cholewiak D, Frasier KE, Trickey JS, Baumann-Pickering S, Hildebrand JA, Van Parijs SM. 2021. Monitoring the acoustic ecology of the shelf break of Georges Bank, northwestern Atlantic Ocean - new approaches to visualizing complex acoustic data. Marine Policy 130: 104570. (*Used 2015 HARP data*).

Table 1-4 Manuscripts in review at end of 2021

In Review Manuscripts
Chavez-Rosales S, Josephson E, Palka D, Garrison L. *In review*. Detection of habitat shifts of cetacean species: A comparison between 2010 and 2017 habitat suitability conditions in the Northwest Atlantic Ocean. Frontiers in Marine Science Marine Megafauna. (*Used visual sightings data collected during AMAPPS shipboard and aerial surveys*)
Hatch J. Haas H, Sasso C, Patel S, Smolowitz R. *In review*. Estimating the complex patterns of survey availability for a highly-mobile marine animal. Journal of Wildlife Management and Wildlife Monographs. (*Used loggerhead dive data collected during AMAPPS co-funded field work*)
Orphanides, CD, Jech, JM, DL Palka, JC Collie. *In review*. Relating marine mammal distribution to water column structure and prey fields derived from echosounding. (*Used active acoustic backscatter and visual sightings data collected during AMAPPS shipboard surveys*)
Rider, M, Haas HL, Sasso C. *In review.* Preliminary surface availability metrics of leatherback turtles (*Dermochelys coriacea*) tagged off North Carolina and Massachusetts, United States. NEFSC Center Reference Document. (*Used leatherback dive data collected during AMAPPS*)
Sigourney DB, DeAngelis A, Cholewiak D, Palka D. *In review*. Integrating passive acoustic data using a towed hydrophone array with visual line transect data to estimate surface availability and abundance: A case study with sperm whales (*Physeter macrocephalus*). (*Used passive acoustic and visual sightings data collected during AMAPPS shipboard surveys*)
Stepanuk J, Kim H, Nye JA, Roberts JJ, Halpin PN, Palka DL, Pabst DA, McLellan WA, Barco SG, Thorne LH. *In review*. Subseasonal forecasts provide a powerful tool for dynamic marine mammal management. Frontiers in Ecology and Environment. (*Used visual sightings data collected during AMAPPS shipboard and aerial surveys*)

Table 1-5 Presentations during 2021

Presentations
Chavez-Rosales S. AMAPPS. Presented to the Marine Science Division of the United Nations Environmental Program, Nairobi Kenya 17 Apr 2021.
NEFSC & SEFSC. Accomplishments of AMAPPS II and Plans for AMAPPS III. Presented to BOEM in December 2020 and GARFO 27 May 2021.
Sigourney D, DeAngelis A. Technical review of draft paper on the integration of visual and passive acoustic data. Presented to the Navy sponsored DENMOD Density Surface Model Uncertainty Estimation Working Group at a virtual meeting on 12 Feb 2021.

Table 1-6 Blogs and web stories presented in 2021

Blogs and Web Stories
NEFSC cruise blogs. Jun – Aug 2021. NOAA ship *Henry. B. Bigelow*'s AMAPPS abundance survey.
NOAA Fisheries Science Highlights.1 Sep 2021. AMAPPS: Updated marine mammal model viewer.
NOAA/SEFSC Feature story. 16 Jun 2021. Tag, you're it! Tracking sea turtle movements with satellite tags
NOAA/SEFSC Feature story. 16 Jul 2021. Experts collaborate on mission to document protected species

Table 1-7 Public data websites available in 2021

Public Data Websites
AMAPPS density map viewer website to display and download spatiotemporal cetacean densities from Palka et al. 2021 "Atlantic Marine Assessment Program for Protected Species: FY15 – FY19. Appendix 1".
Data compendium for Patel et al. 2021 "Projected shifts in loggerhead sea turtle thermal habitat in the Northwest Atlantic Ocean due to climate change".
Marine Mammal Research Surveys in NOAA's Southeast Region displays maps of aerial and ship-based mammal sightings and links to data.
OBIS-SEAMAP. NEFSC and SEFSC visual sightings and effort data from shipboard and aerial AMAPPS surveys.
Passive Acoustic Cetacean Map. Woods Hole (MA): NOAA Northeast Fisheries Science Center v1.0.6.
Northwest Atlantic Seabird Catalog. NEFSC and SEFSC seabird sightings and effort data from shipboard AMAPPS surveys.

1.4 Acknowledgements

Three agencies provided partial funding for the 2021 data collection and analyses discussed in this document:

- US Department of the Interior, Bureau of Ocean Energy Management Environmental Studies Program through Interagency Agreement M14PG00005 with the US Department of Commerce, National Oceanic and Atmospheric Administration
- US Department of the Navy, Office of the Chief of Naval Operations through Interagency Agreement N689620IP with the US Department of Commerce, National Oceanic and Atmospheric Administration
- US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Services

We acknowledged additional funding sources for specific projects within the following chapter's acknowledgements section.

2 Aerial abundance surveys during 17 June to 15 September 2021: Northeast and Southeast Fisheries Science Centers

Laura Aichinger Dias[1, 2], *Debra Palka*[3], *Jesse Wicker*[1,2], *Anthony Martinez*[2] *and Lance Garrison*[2]

[1]Cooperative Institute for Marine and Atmospheric Studies, 4600 Rickenbacker Causeway, Miami FL 33149
[2]NOAA Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami FL 33149
[3]NOAA Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543

2.1 Summary

As part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS), the Southeast Fisheries Science Center (SEFSC) and Northeast Fisheries Science Center (NEFSC) conducted an aerial survey on the continental shelf waters of the US east coast, from Maine to the Florida Keys. The SEFSC conducted their portion during 17 June to 31 July 2021 and the

NEFC's portion during 01 August to 15 September 2021. Both surveys were aboard a NOAA Twin Otter aircraft at an altitude of 600 feet and a speed of 100-110 knots over ground. Survey tracklines were oriented approximately perpendicular to the shoreline. The main goal of this survey was to assess the distribution and abundance of marine mammals and sea turtles in the US Atlantic waters in conjunction with companion shipboards surveys also conducted by the SEFSC and NEFSC. We reported the results from the shipboard surveys in Chapters 3 and 4. We designed the aerial survey for analysis using Distance sampling and a two-team (independent observer) approach to correct for perception bias in resulting abundance estimates. We surveyed about 15,200 km of on-effort tracklines on-effort, where we saw 9,600 cetaceans in 690 sighting groups of 13 identified species. Common dolphins (*Delphinus delphis*) consisted of 53% of all detected cetaceans, followed by 19% common bottlenose dolphins (*Tursiops truncatus*) and 6% Risso's dolphins (*Grampus griseus*). The most common large whales were, in order, minke whales (*Balaenoptera acutorostrata*), fin whales (*B. physalus*) and humpback whales (*Megaptera novaeangliae*). We saw 1,639 sea turtles in 1,371 sighting groups. Unidentified hardshell turtles comprised 46% of the turtles, followed by loggerheads (*Caretta caretta*) with 39%. We also opportunistically recorded 7,071 fish, comprising of cownose rays (54%; *Rhinoptera bonasus*), ocean sunfish (7%; *Mola mola*), and a variety of sharks: blues (*Prionace glauca*), great whites (*Carcharodon carcharias*), hammerheads (*Sphyrnidae* sp.), threshers (Alopias sp.), tigers (*Galeocerdo cuvier*) and mako sharks (*Isurus* sp.).

2.2 Objectives

The goal of this survey was to conduct line-transect surveys using the Distance sampling approach to assess the abundance and spatial distribution of marine mammals and turtles in waters over the continental shelf (up to about the 200 m isobath) of the eastern US.

2.3 Cruise Period and Area

The SEFSC conducted their portion of the survey during 17 Jun to 31 Jul 2021 in the area extending from New Jersey to Key West, Florida (Figures 1-1 and 2-1). The NEFSC conducted their portion of the survey during 1 Aug – 15 Sep 2021 in the area extending from New Jersey to Nova Scotia, Canada. Due to COVID-19 restrictions, the pilots and scientists Sheltered-In-Place for 1 week before starting the survey and underwent weekly COVID-19 testing.

2.4 Methods

We conducted the survey aboard a DeHavilland Twin Otter DHC-6 flying at an altitude of 183 m (600 ft) above the water surface and a speed-over-ground of about 100 to 110 knots. We typically flew the surveys only when wind speeds were less than 20 knots or approximately sea state 4 or less on the Beaufort scale. We conducted the survey along tracklines oriented approximately perpendicular to the shoreline, starting at a random point. We spaced the mid-Atlantic tracklines latitudinally at approximately 20 km intervals.

Two pilots and 2 teams of 3 marine mammal observers each were onboard the aircraft. 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 bubble windows allowed downward visibility from approximately 0° (straight down on the trackline) to 60° upward towards the horizon. The belly observer could see approximately 35° on either side of the trackline. Therefore, the aft team had limited visibility off 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.

We recorded data separately by each team in a laptop computer running data acquisition software. We recorded location via a Global Positioning System (GPS) and the data recorders entered environmental conditions assessed by the observers (e.g., sea state, glare, sun penetration, visibility, etc.) and effort information. During on effort periods (times when the plane flew level over tracklines and at survey altitude and speed) observers searched visually from the trackline (0˚) to approximately 60˚ above vertical. When an observer detected a sea turtle, marine mammal, or other organism they waited until the group was perpendicular to the aircraft and then the observers measured the angle to the organism (or the center of the group) using a digital inclinometer. The belly observer on the SEFSC portion reported the interval for the sighting based on markings on the window (1 to 4 and left or right), while for the NEFSC portion, observers reported the angle (left or right) to the nearest integer using markings on the belly window (10° intervals). If the forward observers initially saw a mammal sighting, they waited until it was aft of the airplane to allow the aft team an opportunity to see the group. Once both teams had the chance to see it, observers may have asked the pilots to depart from the trackline to circle the sighting to verify species, count group sizes and potentially take photographs. This was necessary more often on the SEFSC portion due to the possibility of confusing the species identification of the dolphins. Observers recorded sea turtle sightings independently by each team and rarely, if ever, circled on them. We also recorded fish sightings opportunistically and independently by each team.

Once back from the survey, we audited the data based on error logs maintained by observers and other data editing protocols. For sightings not already matched during the flights, we determined duplicate sightings (seen by both teams) by matching data from both teams based on the following criteria: time between occurrences was < 15 seconds, sightings were on the same side of the plane or on the trackline (when known); angles differed <= 15 degrees; and counts of individuals were equal or similar.

2.5 Results

During the SEFSC portion, we flew 22 days during 17 Jun to 31 Jul 2021 covering 9,007 km over 105 tracklines. The average sea state during this portion was 2.5 on the Beaufort scale (Table 2-1; Figure 2-1).

During the NEFSC portion, we flew 17 days during 01 Aug to 15 Sept 2021 covering 6,191 km of tracklines. The average sea state during the survey was 2.9 on the Beaufort scale (Table 2-2; Figure 2-1).

Table 2-1 Daily summary of on-effort southeast portion of aerial abundance survey

Date in 2021	Track Length (km)	Number of Cetacean Sightings	Number of Turtle Sightings	Average Sea State
17-Jun	280.4	1	69	2.9
18-Jun	612.6	10	184	1.7
20-Jun	321.9	2	48	2.5
21-Jun	187.6	1	8	2.8
23-Jun	160.8	8	27	2.1
24-Jun	387.9	8	38	2.9
26-Jun	161.7	1	28	2.9
28-Jun	230.5	8	35	2.6
29-Jun	528.6	9	43	3.1
30-Jun	748.0	13	43	2.8
01-Jul	423.8	16	47	2.2
03-Jul	418.3	14	21	2.3
04-Jul	536.8	16	24	2.0
05-Jul	717.5	16	14	2.1
06-Jul	599.4	4	12	2.5
07-Jul	272.2	12	26	2.6
10-Jul	442.8	11	118	2.0
15-Jul	454.3	14	60	2.9
28-Jul	568.4	26	127	1.7
29-Jul	117.8	2	5	3.6
30-Jul	246.5	4	32	3.1
31-Jul	589.5	14	77	2.8
TOTAL	9,007.3	210	1,086	2.5

Table 2-2 Daily summary of on-effort northeast portion of aerial abundance survey

Date in 2021	Track Length (km)	Number of Cetacean Sightings	Number of Turtle Sightings	Average Sea State
01-Aug	255.3	20	25	2.7
02-Aug	412.5	11	73	3.2
03-Aug	383.7	17	112	2.3
04-Aug	428.8	41	119	2.4
06-Aug	309.8	18	71	3.1
07-Aug	356.4	24	34	3.3
08-Aug	237.6	31	10	2.4
15-Aug	365.3	48	47	2.9
16-Aug	337.6	20	30	3.1
17-Aug	702.8	77	277	2.4
18-Aug	364.4	52	54	3.0
31-Aug	299.6	10	17	3.1
01-Sep	479.1	35	25	3.0
04-Sep	385.8	22	31	3.3
07-Sep	389.8	21	115	2.6
11-Sep	39.4	1	0	4.4
14-Sep	442.8	32	87	2.8
TOTAL	6,190.7	480	1,127	2.9

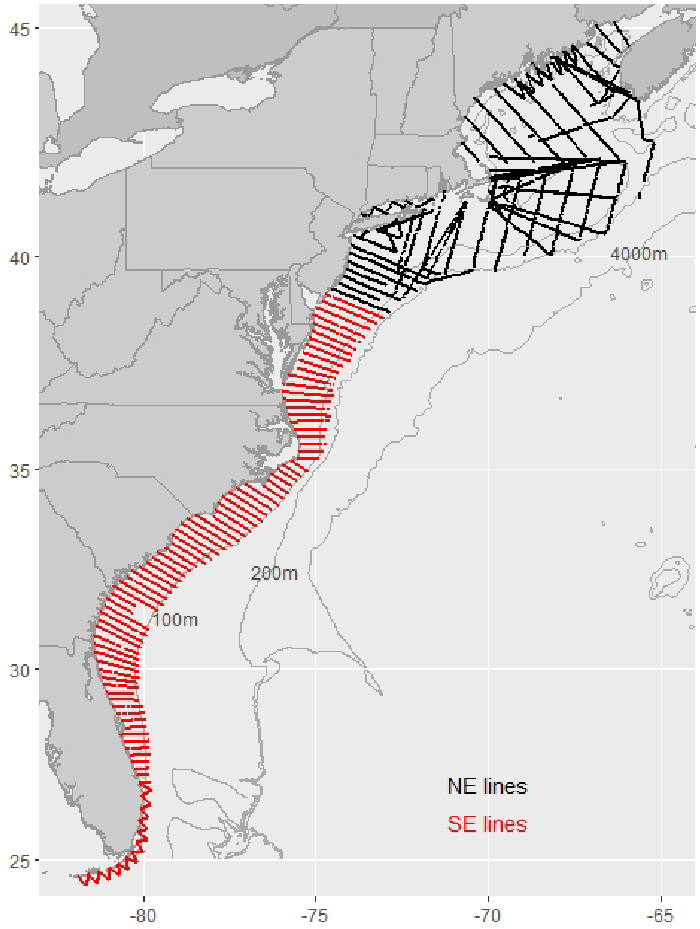

Figure 2-1 On-effort tracklines of 2021 summer aerial abundance survey (15 Jun – 15 Sep 2021)

We detected 9,600 cetaceans in 690 sighting groups (Table 2-3). The most frequently detected species was the common dolphin (*Delphinus delphis*; Figure 2-2) located mostly on the northeastern edge of Georges Bank, with lower densities on the mid-Atlantic shelfbreak deeper than 100m. The second most frequently detected species was the common bottlenose dolphin (*Tursiops truncatus*; Figures 2-2 and 2-3) with the highest densities south of Virginia to Florida. Species commonly generally detected in deeper waters included the Atlantic spotted dolphin (*Stenella frontalis*; Figure 2-2) seen south of New Jersey, and Risso's dolphins (*Grampus griseus*; Figure 2-3) and pilot whales (*Globicephala* sp.; Figure 2-4) seen north of North Carolina. Species detected mostly north of New York included harbor porpoise (*Phocoena phocoena*; Figure 2-5), Atlantic white-sided dolphins (*Lagenorhynchus acutus*; Figure 2-5) and all the large whales (Figure 2-6).

We detected 1,639 sea turtles in 1,371 sighting groups (Table 2-4; Figures 2-7 to 2-8). Loggerhead turtles (*Caretta caretta*) were the most commonly identified species and they were widely distributed south of Long Island, NY. Leatherback turtles (*Dermochelys coriacea*; Figure 2-7) ranged from Maine to Florida. Green turtles (*Chelonia mydas*; Figure 2-8) were primarily between New Jersey and North Carolina and along Florida. Kemp's ridley turtles (*Lepidochelys kempii*; Figure 2-8) were sparse and close to shore. Unidentified hardshell turtles accounted for 46% of all turtle sightings (Table 2-4; Figure 2-8).

Opportunistic fish sightings included primarily shark and ray species and ocean sunfish (*Mola mola*) (Table 2-5; Figures 2-9 to 2-11).

Of interest were the 3 sighting groups of 15 Cuvier's beaked whales (*Ziphius cavirostris*; Figure 2-4), including one group off North Carolina that we were able to photograph (Figure 2-12). Also of interest were the 2 groups of single North Atlantic right whales (*Eubalaena glacialis*; Figure 2-6), where 1 animals was in waters nearly 200 m deep that was south of Long Island, NY near Hudson Canyon.

The data presented here are preliminary and subject to change as we conduct further auditing and analyses.

2.6 Disposition of Data

The SEFSC (in Miami, FL) manages and archives all the SEFSC data. The NEFSC (in Woods Hole, MA) manages and archives all the NEFSC data. In addition, the NEFSC and SEFSC final audited versions are in the NEFSC ORACLE database. Marine mammal and sea turtle sightings recorded by the forward team and associated effort will be available online at OBIS-SEAMAP (http://seamap.env.duke.edu/). The complete data set will be archived and publicly available at the National Centers for Environmental Information (https://www.ncei.noaa.gov/). The data presented here are preliminary and subject to change as we perform further auditing and analyses.

2.7 Permits

The SEFSC conducted the marine mammal research activities during the survey under Permit No. 21938 issued to the SEFSC by the National Marine Fisheries Service (NMFS). The NEFSC conducted marine mammal research activities during the survey under Permit No. 21371 issued to the NEFSC by NMFS, under the SARA Permit No. DFO-MAR-2021-06 issued to the NEFSC by the Fisheries and Oceans Canada, and under the Government of Canada Overflight Clearance Number 0743-US-2021-08-TC.

2.8 Acknowledgements

We would like to thank the airplane's crew and observers that were involved in collecting these data. In addition to the 3 sources of funds specified in section 1.4 of this document (NMFS, and the 2 interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy), NOAA Aircraft Operations Center funded flight time and other aircraft costs. The SEFSC, NEFSC, and NOAA Aircraft Operations Center funded the staff time of the pilots and scientists. The Cooperative Institute for Marine and Atmospheric Studies (CIMAS), a Cooperative Institute of the University of Miami and the National Oceanic and Atmospheric Administration, cooperative agreement NA20OAR4320472 staffed the SEFSC survey. While, Azura Consulting LLC and Integrated Statistics, Inc., contract NFFM7320 staffed the NEFSC survey.

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 2-3 Summary of cetacean sightings during 2021 aerial abundance survey

Common Name	Scientific Name	SE Sightings	SE Animals	NE Sightings	NE Animals	All Sightings	All Animals
Atlantic spotted dolphin	*Stenella frontalis*	27	452	0	0	27	452
Common bottlenose dolphin	*Tursiops truncatus*	137	1,325	58	510	195	1,835
Bottlenose/Spotted dolphin	*T. truncatus* or *S. frontalis*	6	56	0	0	6	56
Common dolphin	*Delphinus delphis*	3	35	125	5,238	128	5,273
Common/Whitesided dolphin	*D. delphis/L. acutus*	0	0	11	179	11	179
Cuvier's beaked whale	*Ziphius cavirostris*	2	11	1	4	3	15
Fin whale	*Balaenoptera physalus*	0	0	13	17	13	17
Fin/Sei whale	*B. physalus/B. borealis*	0	0	2	5	2	5
Harbor porpoise	*Phocoena phocoena*	0	0	84	229	84	229
Humpback whale	*Megaptera novaeangliae*	0	0	14	17	14	17
Minke whale	*B. acutorostrata*	0	0	50	50	50	50
North Atlantic right whale	*Eubalaena glacialis*	0	0	2	2	2	2
Pilot whales	*Globicephala* sp.	16	219	27	255	43	474
Risso's dolphin	*Grampus griseus*	10	233	46	384	56	617
Sperm whale	*Physeter macrocephalus*	0	0	2	2	2	2
Whitesided dolphin	*Lagenorhynchus acutus*	0	0	17	209	17	209
Stenella unidentified dolphin	*Stenella* sp.	1	22	0	0	1	22
Unidentified dolphin	-	7	29	19	103	26	132
Unidentified whale	-	1	3	9	11	10	14
TOTAL		210	2,385	480	7,215	690	9,600

Table 2-4 Summary of sea turtle sightings during 2021 aerial abundance survey

Common Name	Scientific Name	SE Sightings	SE Animals	NE Sightings	NE Animals	All Sightings	All Animals
Green Turtle	*Chelonia mydas*	93	108	13	13	106	121
Hardshell turtle	-	497	667	85	89	582	756
Kemp's ridley turtle	*Lepidochelys kempii*	15	15	2	2	17	17
Leatherback turtle	*Dermochelys coriacea*	61	62	37	40	98	102
Loggerhead turtle	*Caretta caretta*	420	482	148	161	568	643
TOTAL		1,086	1,334	285	305	1,371	1,639

Table 2-5 Summary of opportunistic fish sightings during 2021 aerial abundance survey

Common Name	Scientific Name	SE Sightings	SE Animals	NE Sightings	NE Animals	All Sightings	All Animals
Atlantic devil ray		2	2	0	0	2	2
Basking shark	*Cetorhinus maximus*	0	0	26	33	26	33
Billfish sp.	-	1	1	0	0	1	1
Blue shark	*Prionace glauca*	0	0	125	128	125	128
Chilean devil ray	*Mobula tarapacana*	7	7	39	55	46	62
Cownose ray	*Rhinoptera bonasus*	84	453	33	3,476	117	3,929
Great white shark	*Carcharodon carcharias*	0	0	25	31	25	31
Hammerhead sharks	*Sphyrnidae* sp.	64	80	55	111	119	191
Mako shark sp.	*Isurus* sp.	0	0	1	1	1	1
Manta rays sp.	*Manta* sp.	30	30	6	6	36	36
Thresher sharks sp.	*Alopias* sp.	0	0	1	1	1	1
Tiger shark	*Galeocerdo cuvier*	0	0	3	3	3	3
Tuna sp.	-	0	0	10	128	10	128
Ocean sunfish	*Mola mola*	45	103	365	413	410	516
Unidentified ray	-	17	318	8	11	25	329
Unidentified shark	-	138	201	421	1,479	559	1,680
TOTAL		388	1,195	1,118	5,876	1,506	7,071

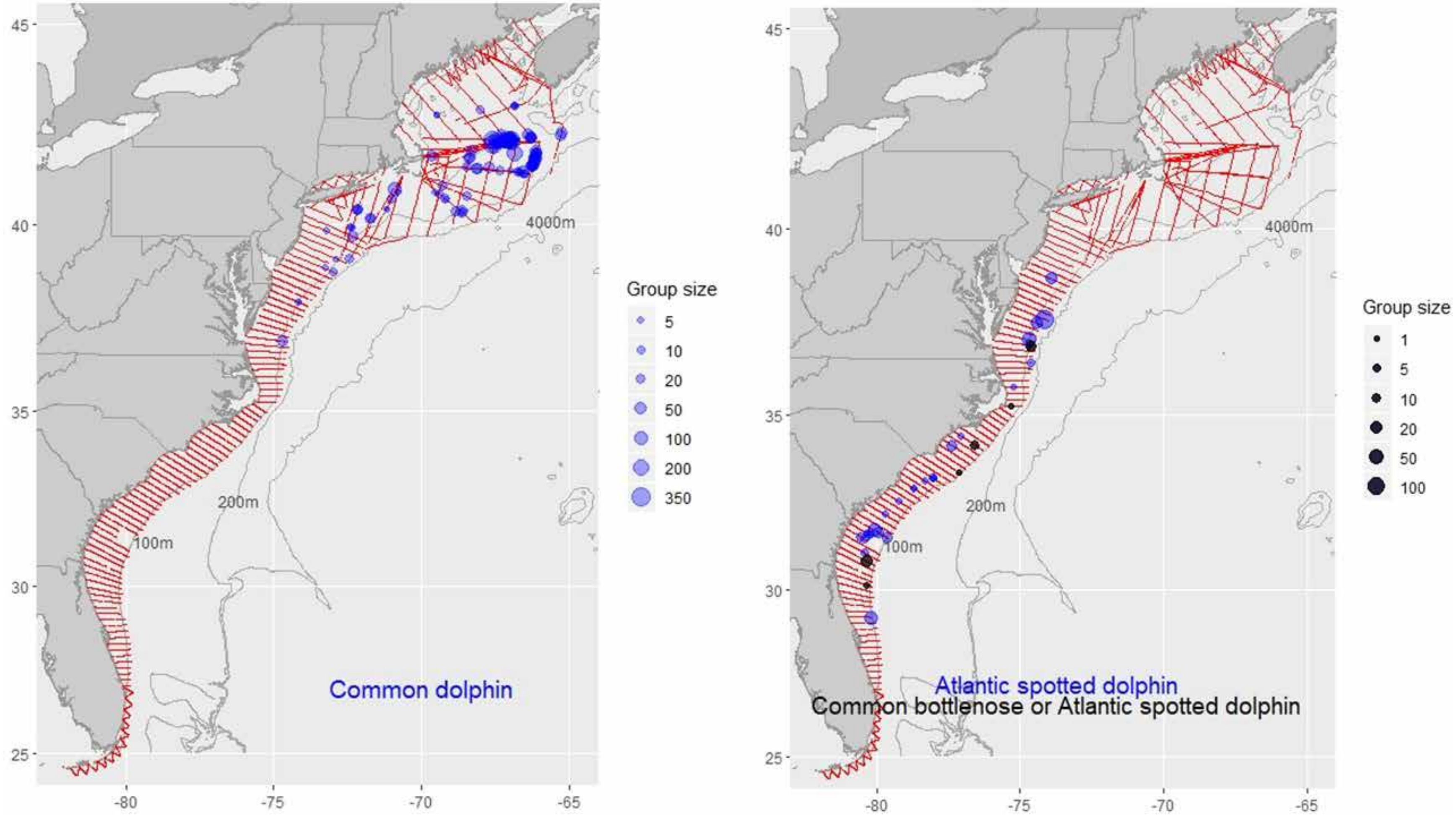

Figure 2-2 Common and Atlantic spotted dolphin sightings during 2021 summer aerial survey

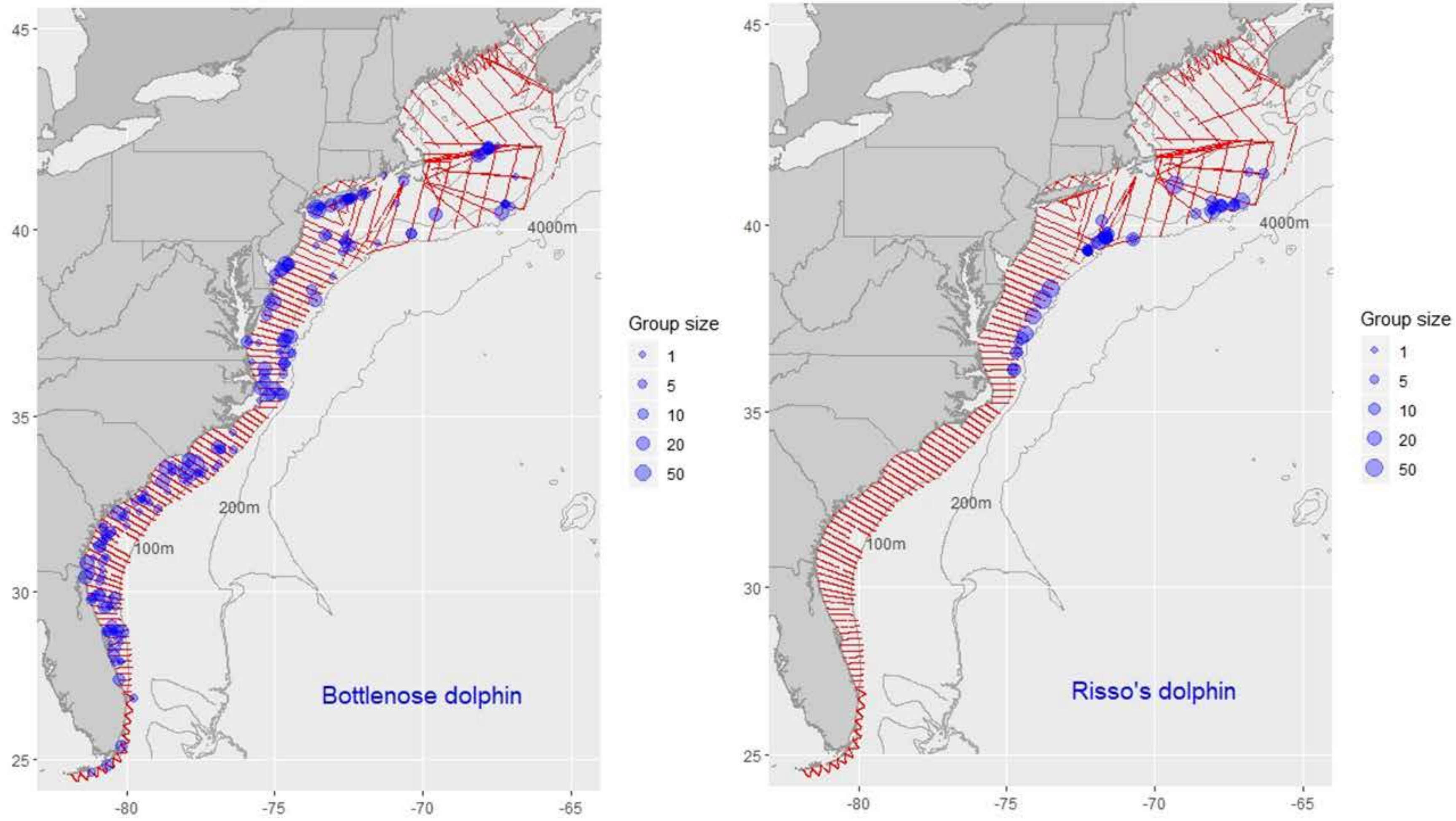

Figure 2-3 Bottlenose dolphin and Risso's dolphin sightings during 2021 summer aerial survey

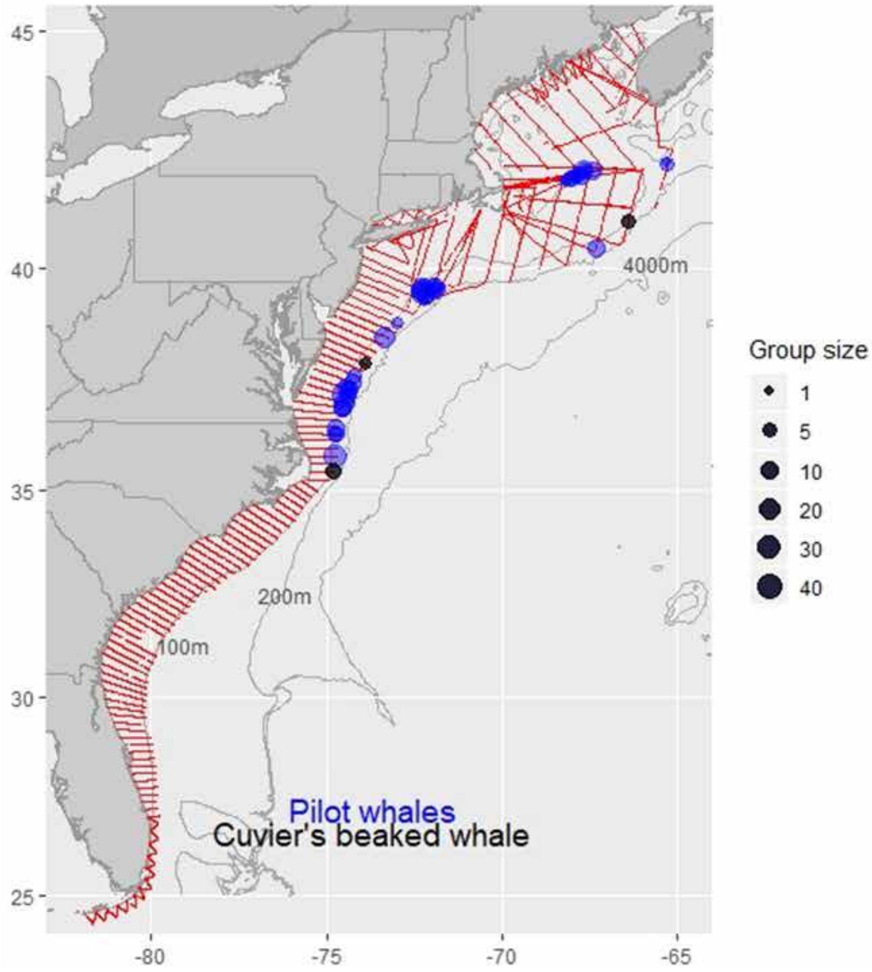

Figure 2-4 Pilot whales and Cuvier's beaked whale sightings during summer 2021 aerial survey

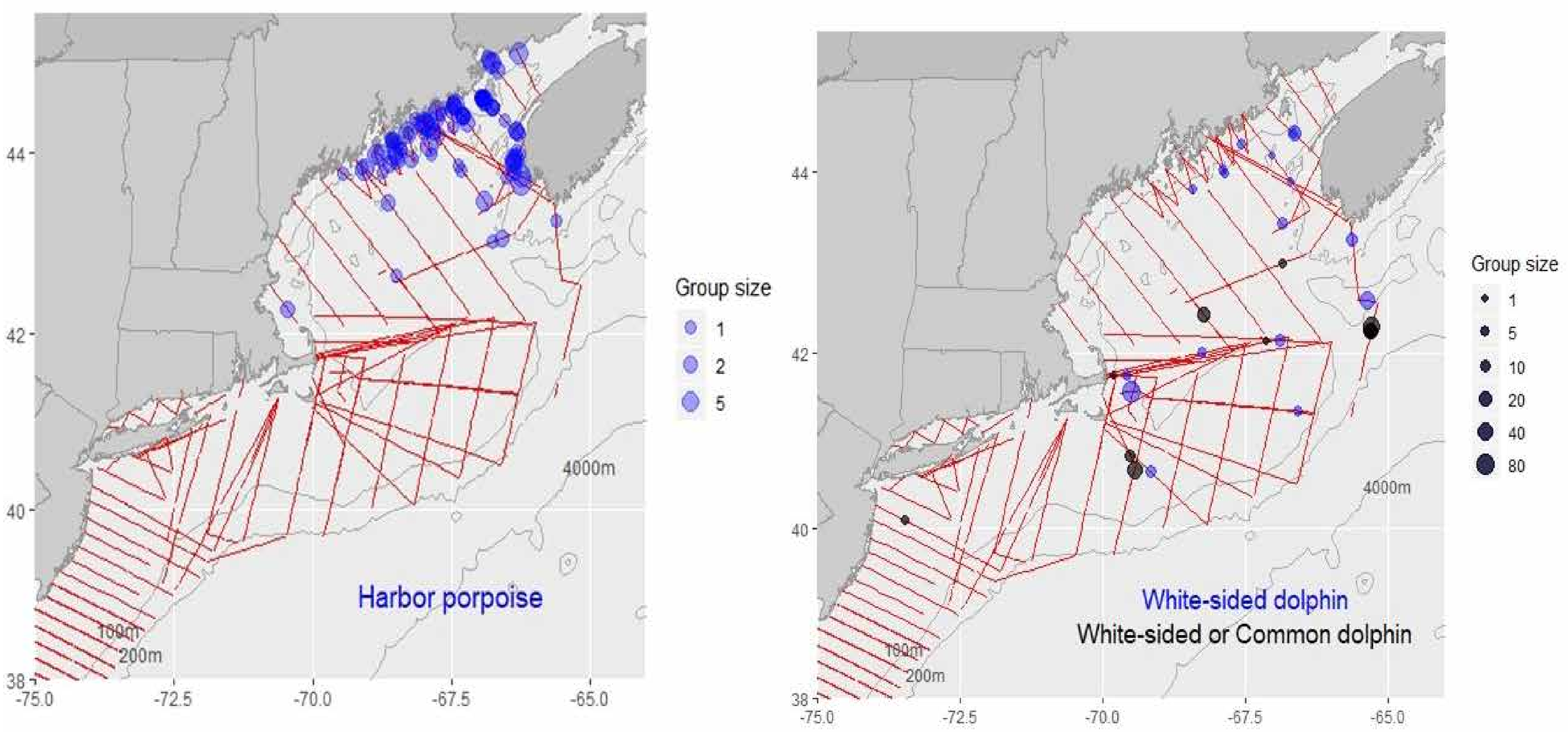

Figure 2-5 Harbor porpoise and Whitesided dolphin sightings during summer 2021 aerial survey

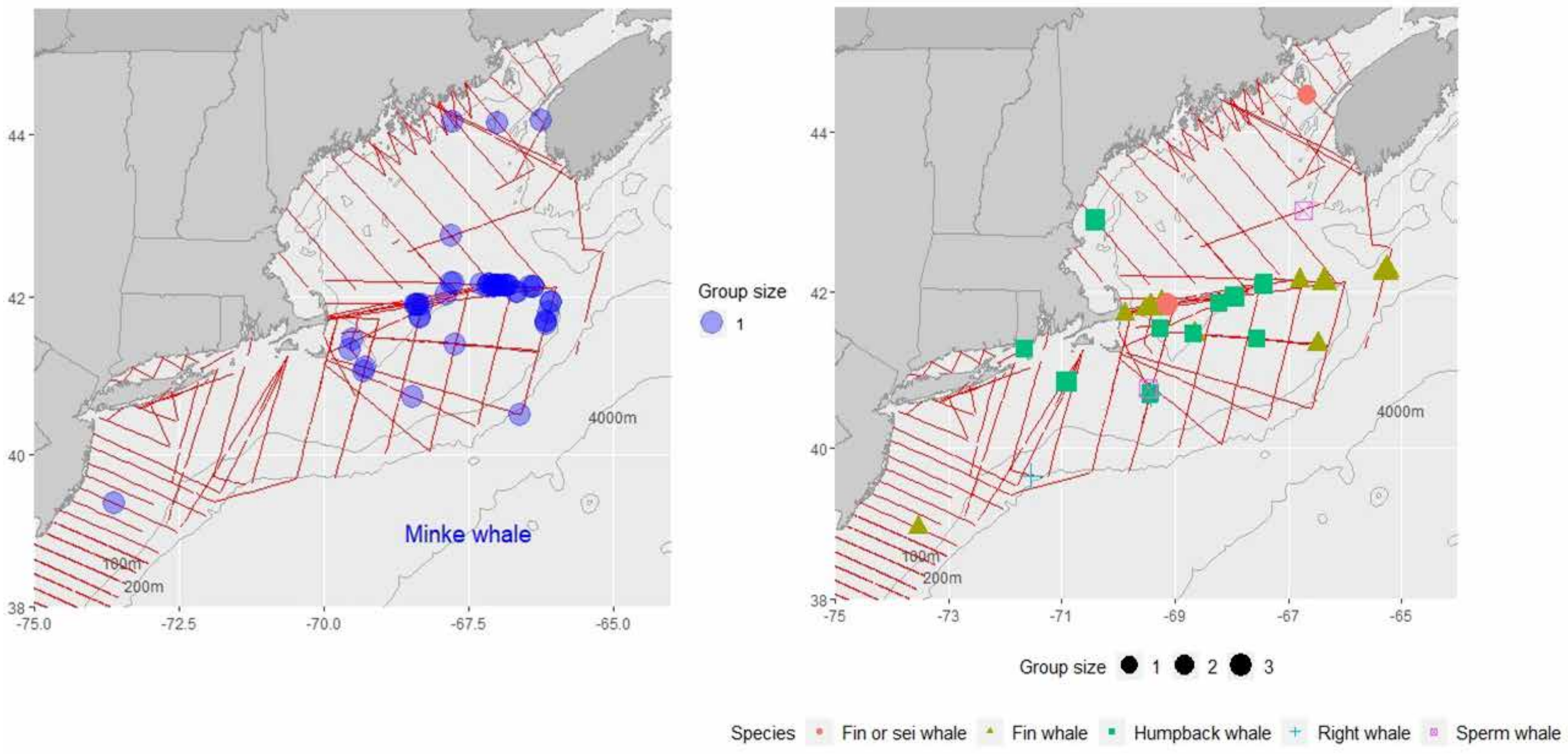

Figure 2-6 Minke, fin, humpback, right, and sperm whale sightings during 2021 summer aerial survey

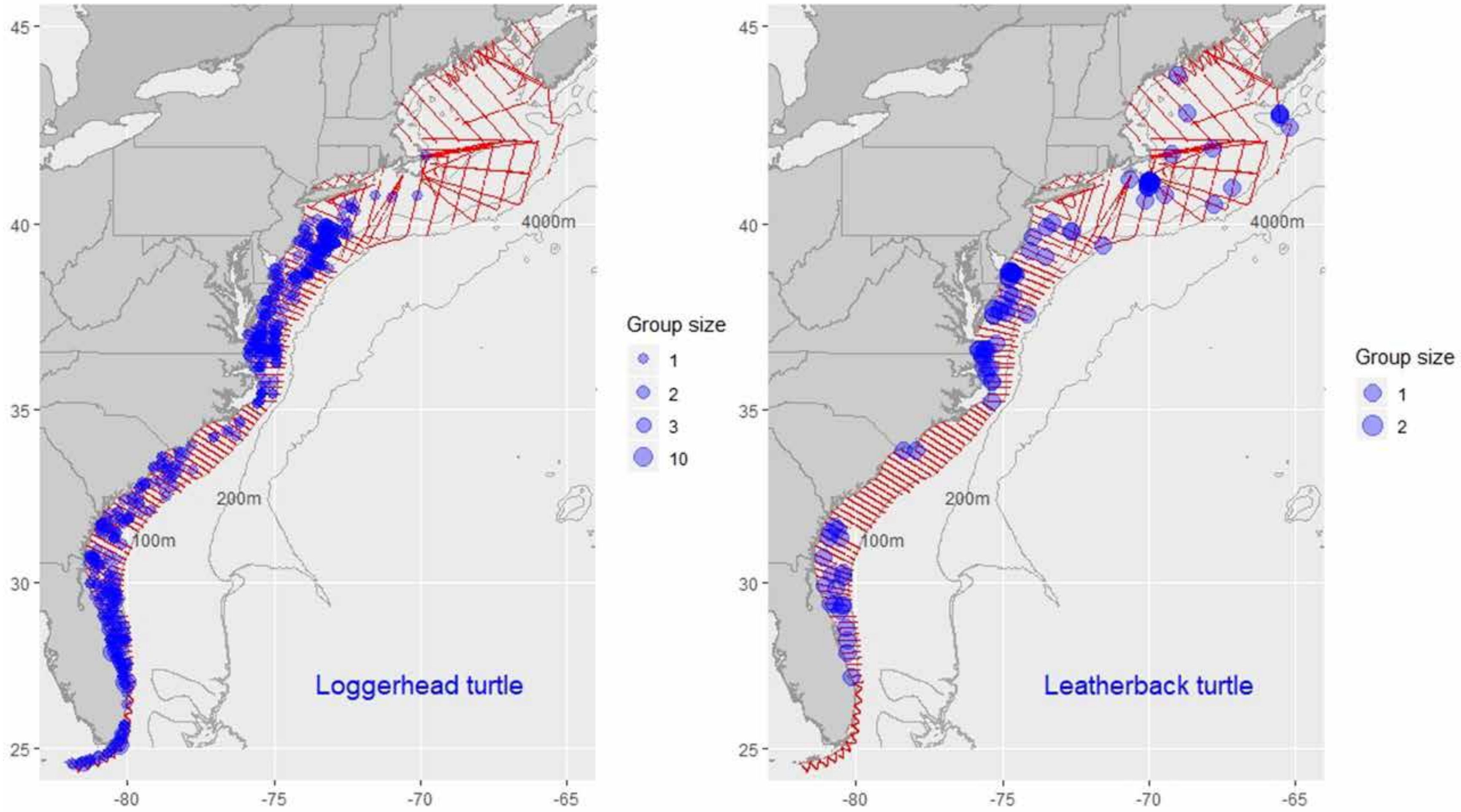

Figure 2-7 Loggerhead and leatherback turtle sightings during summer 2021 aerial survey

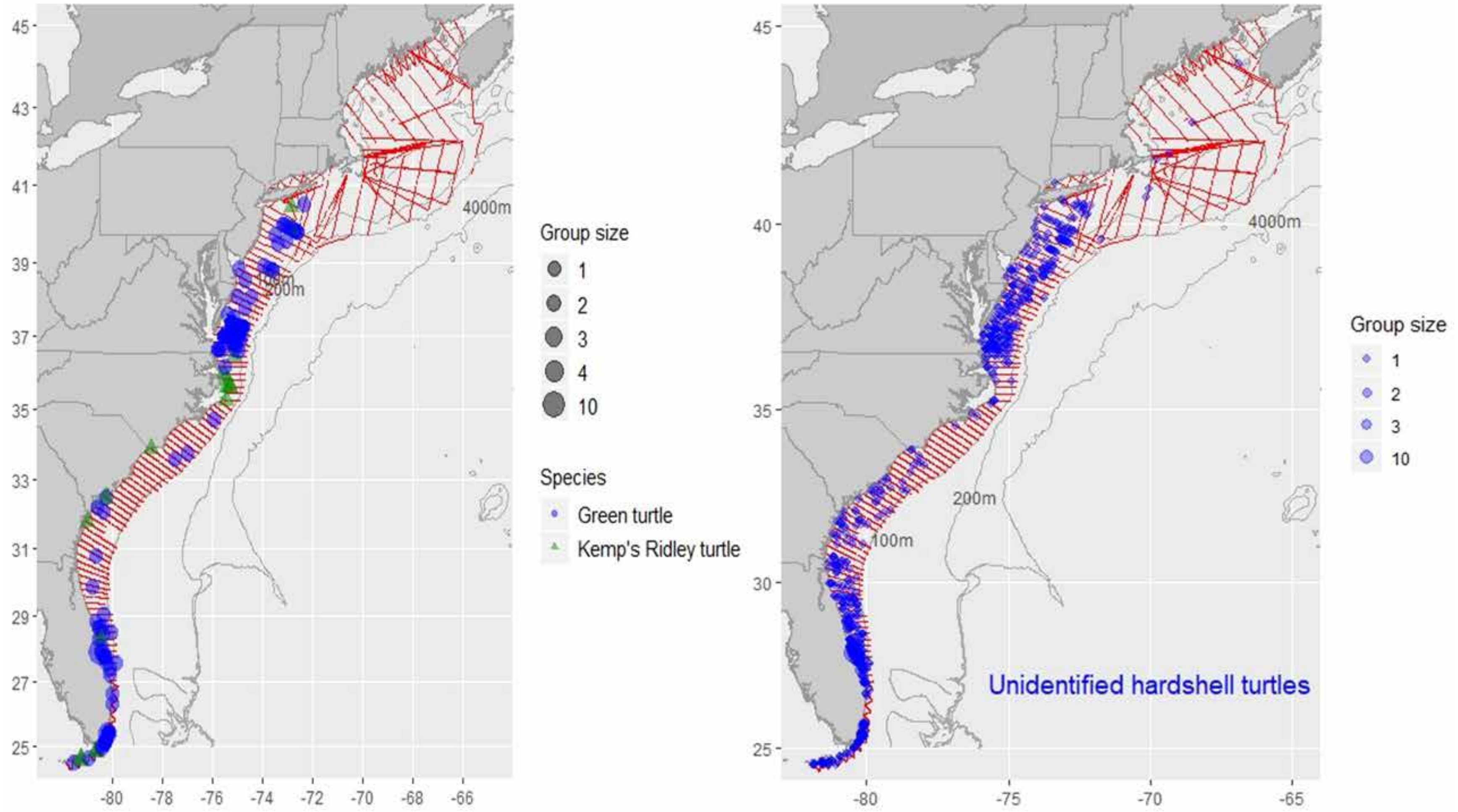

Figure 2-8 Green, Kemp's Ridley and unidentified turtle sightings during summer 2021 aerial survey

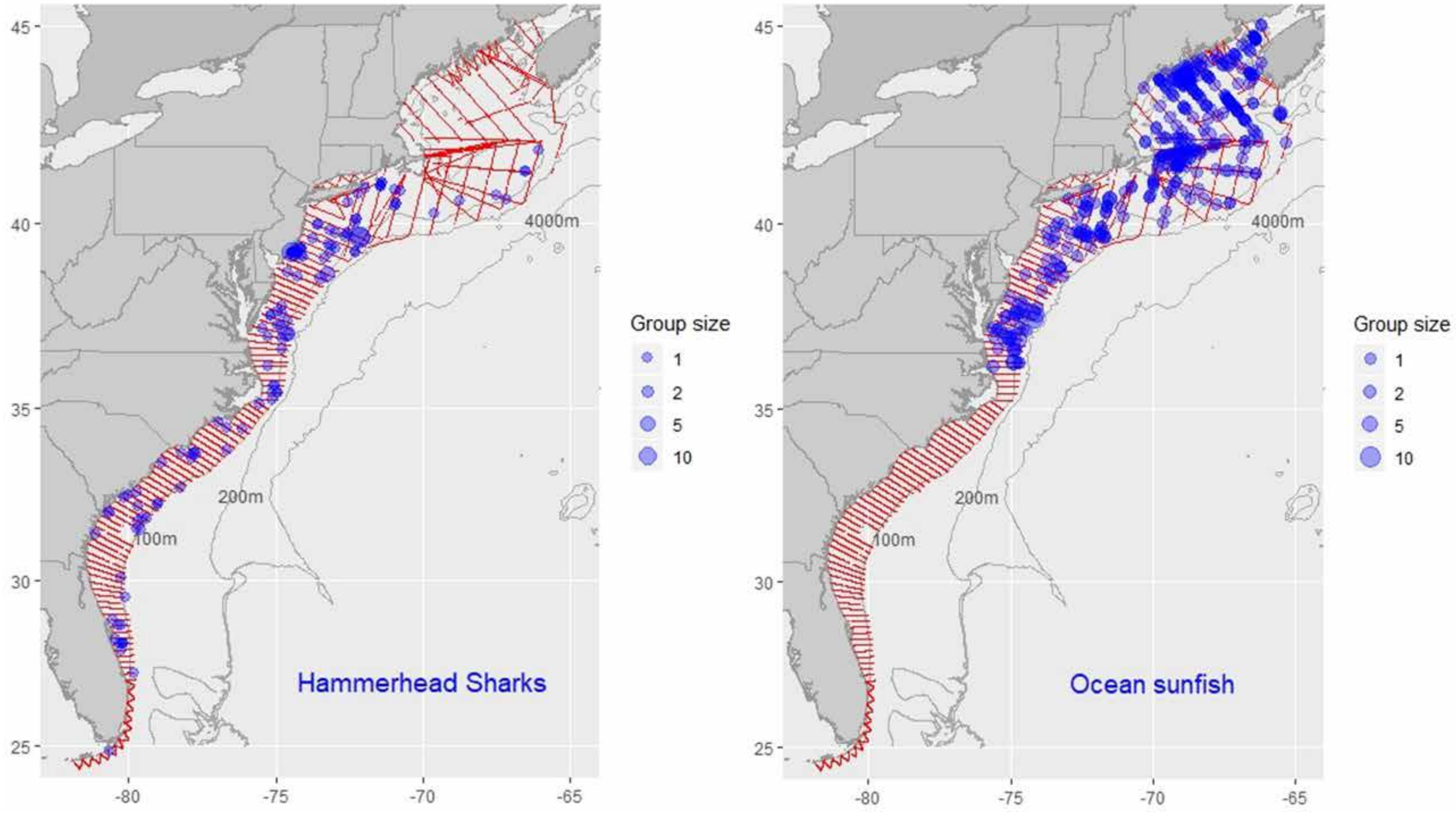

Figure 2-9 Hammerhead sharks and ocean sunfish sightings during the summer 2021 aerial survey

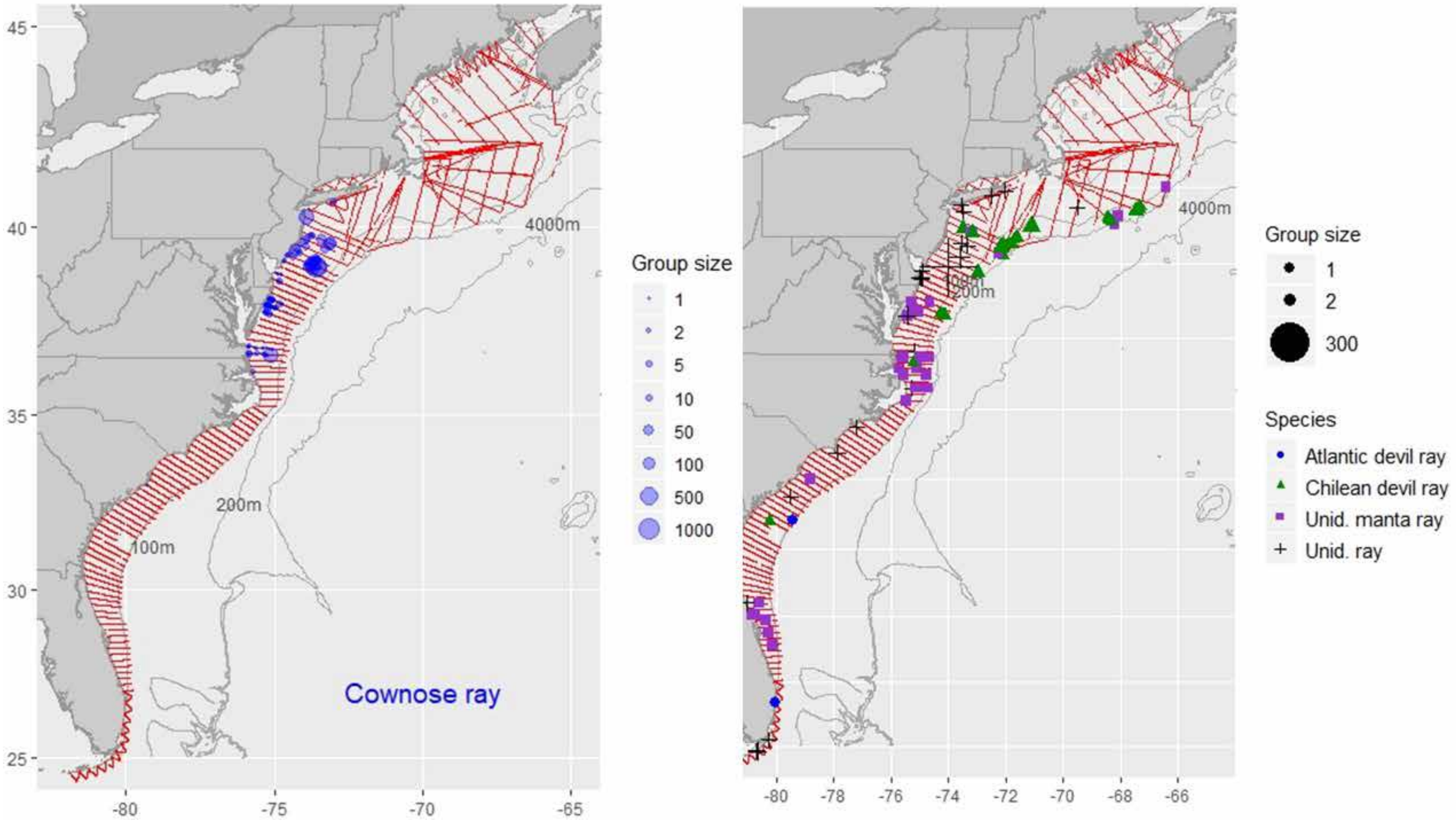

Figure 2-10 Ray sightings during summer 2021 aerial survey

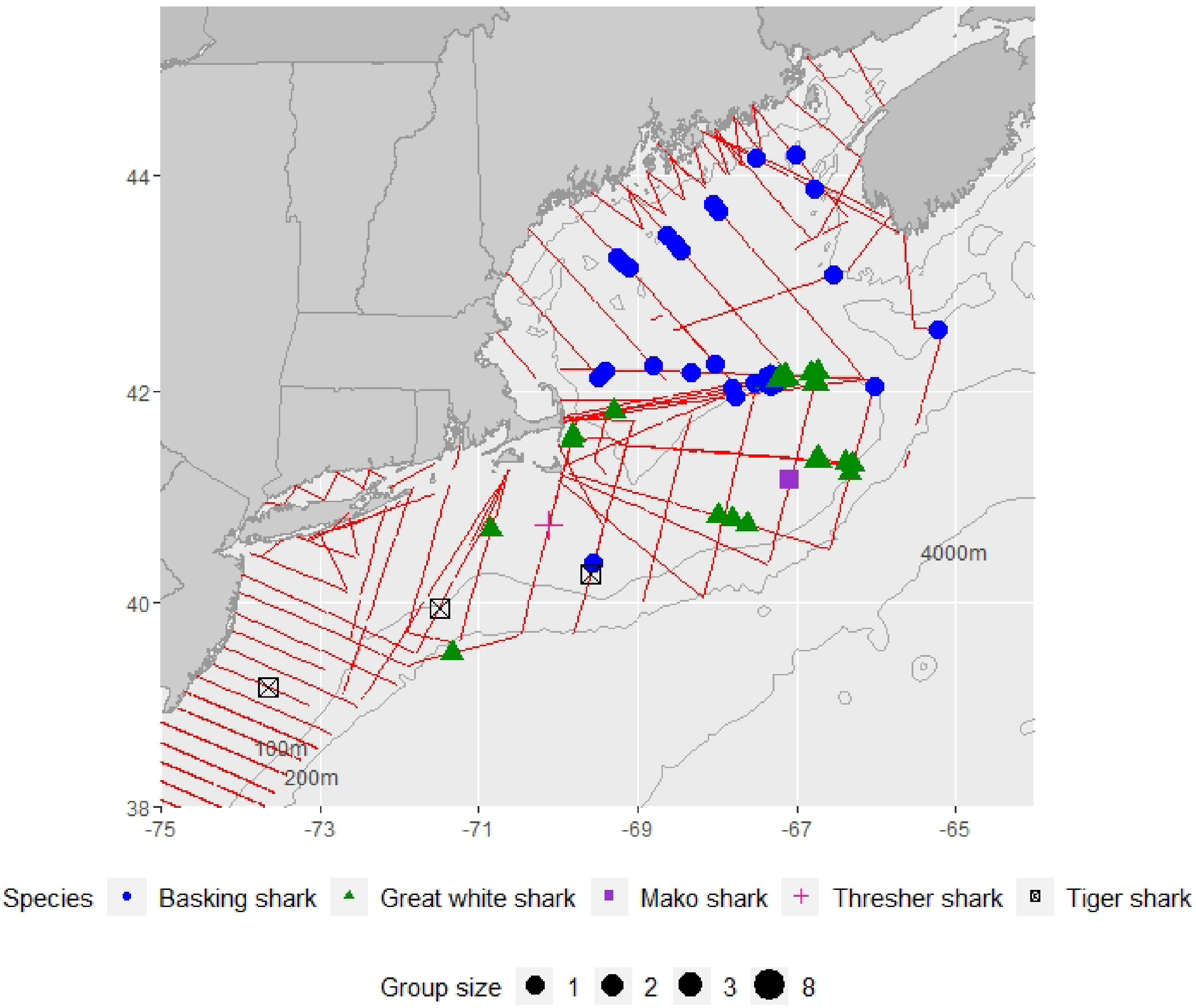

Figure 2-11 Large fish sightings during summer 2021 aerial survey

Figure 2-12 Cuvier's beaked whales. Credit: SEFSC MMPA Permit #21938

3 Southern leg of shipboard abundance survey during 12 June to 5 September: Southeast Fisheries Science Center

Laura Aichinger Dias[1,2], *Jonathan Reid*[1,2,3], *Melissa Soldevilla*[2,] *Anthony Martinez*[2], *Lance Garrison*[2]

[1] Cooperative Institute for Marine and Atmospheric Studies, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149
[2] Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149
[3] Marine Conservation Research, 94 High St, Kelvedon, Essex, CO5 9AA UK

3.1 Summary

During 12 June to 5 September 2021, divided in 3 legs, the Southeast Fisheries Science Center (SEFSC) conducted a shipboard abundance survey targeting marine mammals, sea turtles, and seabirds on the NOAA ship *Gordon Gunter*. The survey area was south of New Jersey, between 25°N and 38°N and 70°N and 87°W, covering waters offshore of the 200 m depth contour. We used the 2 independent team protocols targeting marine mammals and sea turtles using line transect sampling techniques. In addition, we had a team targeting sea birds using strip transect sampling techniques, a team monitoring a towed hydrophone array, and a team collecting physical and biological oceanographic data. In Beaufort sea states of 6 and less, we surveyed about 6,293 km of on-effort track lines at 10 knots. We recorded 631 groups of cetaceans and 5,900 individuals of seabirds. Common bottlenose dolphins (*Delphinus delphis*), sperm whales (*Physeter macrocephalus*), and pilot whales (*Globicephala* sp.) were the most common species. Other detected large whales included a few fin whales (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*). A sighting worth noting due its rarity in the Atlantic was killer whales (*Orcinus orca*) off the coast of South Carolina during the third leg. We also collected about 340 hrs of passive acoustic data via towed hydrophone array during daytime survey effort when in waters deeper than 75 m. From the array, we collected 126 detections of vocally active cetacean groups. During the night, we collected additional active acoustic data. We also collected data from 35 CTD (conductivity, temperature, and depth) casts throughout the study area.

3.2 Objectives

The objectives of this survey were to:

- Conduct a 2-team independent visual line-transect survey to estimate the abundance and spatial distribution of marine mammal stocks in the US western North Atlantic waters.
- Conduct passive acoustic surveys simultaneously with visual surveys to provide supplemental information on marine mammal abundance and spatial distribution.
- Collect data on the distribution and abundance of seabirds and other marine life.
- Periodically collect oceanographic and environmental data utilizing scientific echosounders to quantify acoustic backscatter from small fish and zooplankton.
- Collect vertical profiles of hydrographic parameters using conductivity, temperature, and depth sensors.
- Recover and redeploy autonomous acoustic moorings (NRS07).

3.3 Cruise Period and Area

The cruise was on the NOAA ship *Gordon Gunter* and designated as GU2103. We divided the cruise period into 3 legs: 12 Jun to 2 Jul 2021, 9 to 27 Jul 2021, and 15 Aug to 5 Sep 2021. Scientists, crew, and backup personnel sheltered in place for the week before each leg, in accordance with the NOAA Covid-19 protocols. The study area (Figure 3-1) included waters south of New Jersey (about 38° N latitude), to the tip of Florida (about 25° N latitude), east of waters off Mississippi in the Gulf of Mexico (about 87° W longitude), and west of the economic exclusive zones (about 70°W longitude).

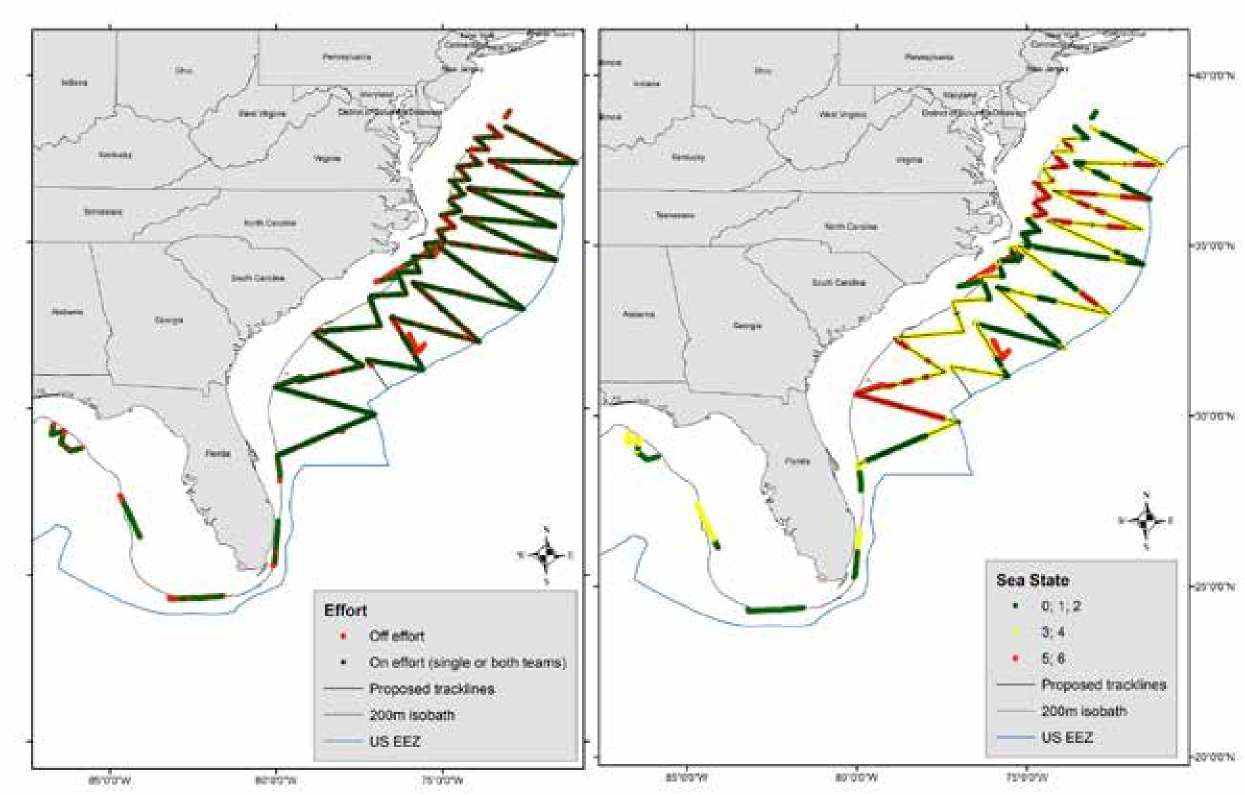

Figure 3-1 Proposed tracklines, accomplished effort, and sea state conditions during GU2103

3.4 Visual Survey Operations

3.4.1 Methods

During the survey, we implemented the 2-team independent approach with Distance sampling to estimate the detection probabilities for marine mammal sightings (Laake and Borchers, 2004). This method uses 2 teams of visual marine mammal observers that operate independently of each another. One team of 2 observers worked on the vessel’s flying bridge that is 13.9 m above the water. The second team of 2 observers worked on the bridge deck (a.k.a bridge wings) that is 11.2 m above the water. Both teams utilized pedestal mounted big eye binoculars (25x150 powered) located on the port and starboard sides of the ship. A centralized data recorder was inside the ship and communicated with both teams via discreet VHF channels. Using the big eye binoculars, observers relayed the relative bearing and distance as reticle readings of sightings to the data recorder. If observing with unaided eyes (a.k.a. naked eye), the location of sightings was in approximate relative bearings and distance in meters from the ship. We defined marine mammal sightings as systematic records of cetaceans consisting of one or more individuals observed at the same location and time.

Visual survey effort commenced with daylight at approximately 0700 eastern daylight time and ended at 1900 eastern daylight time, depending on operational requirements and survey conditions. Survey speed was typically 18 km per hr (10 kt) but varied with ship traffic and sea conditions, such as ocean currents.

Before commencing effort and subsequently every 20 minutes, observers on the flying bridge relayed to the data recorder the survey conditions, such as Beaufort sea state, cloud cover, glare presence and intensity, visibility through the big eyes and presence or absence of precipitation. Visual teams were "on effort" whenever the ship was steadily cruising on a prescribed or transit trackline and observers were actively searching for marine mammals through the big eye binoculars. Whenever an observer suspected or had in fact seen a marine mammal, the observer relayed the data on the relative bearing and distance to the data recorder as a "cue". A cue is a descriptor of what the observer saw first that drew the attention of the observer to the location of the potential sighting and could be classified as a "marine mammal", "splash", "blow", "birds", "other", etc. Once both observers from that team focused on the cue, the team went "off effort". The data recorder documented data for each team using a custom written visual data acquisition program (VisSurvey) installed on a networked laptop that generates a single Microsoft Access® Database.

We conducted the survey primarily in "passing mode". That means the ship maintained a steady course and speed while observers identified marine mammal species to the lowest taxonomic level possible and estimated the number of individuals in each sighting. Observers could discuss amongst themselves to identify the species. However, each observer independently estimated the group size counts reported as the minimum, maximum, and best numbers of individuals in each sighting. Under circumstances determined by the Field Party Chief, for sightings of special interest, such as killer whales, the ship could go off-effort and approach the group to obtain photographs (termed "closing mode"). During this survey, if species identification was difficult due to conditions and both teams had detected the same sighting, observers could request the ship to slow down. Similarly, when both teams detected beaked whales, the data recorder could ask for the ship to slow down to allow for improved acoustic recordings.

To match sightings across teams, the data recorder (mainly based on location) with input from observers, determined if both or just one team detected a sighting. Once the data recorded determined that both teams detected the same sighting, the data recorder indicated that all 4 observers could communicate on the same radio channel. Once the recorder entered that sighting into the data-recording program and data values finalized, both teams resumed communication with the data recorder on separate radio channels.

Observers were "off effort" under the following situations: whenever the ship was maneuvering and turning onto a new trackline; if other operations were taking place (e.g., safety drills, etc.); during unfavorable survey weather (rain, sea state >6, poor visibility due to fog, lightning within 4 nm); and whenever not actively searching for marine mammals through the big eyes (naked eye observations were recorded as off effort). Sightings observed under such conditions were off effort. Off-effort sightings also included sightings detected by non-mammal observers, mammal observers off duty, or other crew (including ship's crew). Observers from the flying bridge team only opportunistically recorded non-marine mammal sightings, such as sea turtles and fish.

During the third leg, we used a single team of marine mammal observers that operated from the flying bridge, and consisted of port and starboard big eye binoculars and one data recorder who also acted as a naked eye observer.

3.4.2 Results

During this cruise, we visually surveyed on effort for 6,193 km of trackline (Table 3-1; Figure 3-1). Between 12 Jun and 31 Aug 2021, the ship surveyed the predetermined study area (i.e. from Florida to New Jersey). On 1 Sep 2021, the ship started a 3-day transit into the Gulf of Mexico to return to its homeport in Pascagoula, MS. Overall survey conditions were moderate to good with an average sea state of 3.3 on the Beaufort scale (Table 3-1; Figure 3-1). Scientific personnel are in Table 3-2. We detected 631 marine mammal sightings from 19 confirmed species (Table 3-3). Common bottlenose dolphins, sperm whales, and pilot whales were the most common species. Of the beaked whales we detected, we mostly had to record them as unidentified Mesoplodons and Ziphiids. However, when we were able to detect them closely we recorded them as Blainville's, Cuvier's or Gervais' beaked whales. The baleen whales we detected included fin and humpback whales. A sighting worth noting due its rarity in the Atlantic was killer whales off the coast of South Carolina during the third leg (Figures 3-2 to 3-4).

Table 3-1 Daily cruise and survey operations during GU2103

Leg	Date	Activity	Visual Effort (km)	Average Sea State	Number of Sights	Acoustic Effort (hr)	Number of Acoustic Detections
NA	6/1	Travel day	-	-	-	-	-
NA	6/2	Load/setup	-	-	-	-	-
NA	6/3	Load/setup	-	-	-	-	-
NA	6/4	Load/setup	-	-	-	-	-
NA	6/5	SIP	-	-	-	-	-
NA	6/6	SIP	-	-	-	-	-
NA	6/7	SIP	-	-	-	-	-
NA	6/8	SIP	-	-	-	-	-
NA	6/9	SIP; COVID-19 test	-	-	-	-	-
NA	6/10	SIP	-	-	-	-	-
NA	6/11	SIP	-	-	-	-	-
1	6/12	Depart Newport, RI	-	-	-	-	-
1	6/13	Survey ops (mammals, seabirds)	8.2	2.0	12	2.0	4
1	6/14	Survey ops (CTD, mammals, seabirds)	137.5	2.5	41	2.5	4
1	6/15	Survey ops (CTD, mammals, seabirds)	104.1	4.9	16	-	-
1	6/16	Survey ops (CTD, mammals, seabirds)	148.8	3.2	32	-	-
1	6/17	Survey ops (CTD, mammals, seabirds)	120.6	3.3	53	-	-
1	6/18	Survey ops (CTD, mammals, seabirds)	152.7	2.2	24	-	-

Leg	Date	Activity	Visual Effort (km)	Average Sea State	Number of Sights	Acoustic Effort (hr)	Number of Acoustic Detections
1	6/19	Survey ops (CTD, mammals, seabirds)	92.9	5.4	4	8.0	3
1	6/20	Survey ops (CTD, mammals, seabirds)	149.0	4.4	27	11.5	20
1	6/21	Shelter TS Claudette	-	-	-	-	-
1	6/22	Shelter TS Claudette	-	-	-	-	-
1	6/23	Shelter TS Claudette; Survey ops (mammals, seabirds)	19.4	5.0	5	-	-
1	6/24	Survey ops (CTD, mammals, seabirds)	163.5	5.6	20	12.0	18
1	6/25	Survey ops (CTD, mammals, seabirds)	164.5	4.2	13	12.0	6
1	6/26	Survey ops (CTD, mammals, seabirds)	184.1	4.1	12	12.5	6
1	6/27	Survey ops (CTD, mammals, seabirds)	178.4	4.3	7	12.0	4
1	6/28	Survey ops (CTD, mammals, seabirds)	140.3	4.4	17	12.0	13
1	6/29	Survey ops (CTD, mammals, seabirds)	188.6	3.1	18	13.0	9
1	6/30	Survey ops (CTD, mammals, seabirds)	216.9	2.9	17	12.5	3
1	7/1	Survey ops (mammals, seabirds)	100.4	5.4	7	-	
1	7/2	Transit to Charleston, SC; Survey ops (seabirds)	-	-	-	-	-
NA	7/3	In port	-	-	-	-	-
NA	7/4	In port	-	-	-	-	-
NA	7/5	In port	-	-	-	-	-
NA	7/6	In port	-	-	-	-	-
NA	7/7	In port; COVID-19 test	-	-	-	-	-
NA	7/8	In port; Shelter TS Elsa	-	-	-	-	-
2	7/9	Depart Charleston, SC; Survey ops (seabirds)	-	-	-	-	-
2	7/10	Survey ops (CTD, mammals, seabirds)	174.0	3.8	1	13.0	3
2	7/11	Survey ops (CTD, mammals, seabirds)	147.5	4.1	4	13.0	2
2	7/12	Survey ops (CTD, mammals, seabirds)	224.8	3.2	6	13.0	5
2	7/13	Survey ops (CTD, mammals, seabirds)	180.2	2.7	9	12.0	3
2	7/14	Survey ops (mammals, seabirds)	186.9	1.4	31	13.0	5
2	7/15	Survey ops (CTD, mammals, seabirds)	180.9	1.7	50	13.0	6
2	7/16	Survey ops (CTD, mammals, seabirds)	174.4	2.8	23	13.0	3
2	7/17	Survey ops (CTD, mammals, seabirds)	198.3	2.5	16	13.0	4

Leg	Date	Activity	Visual Effort (km)	Average Sea State	Number of Sights	Acoustic Effort (hr)	Number of Acoustic Detections
2	7/18	Survey ops (CTD, mammals, seabirds)	190.8	4.3	2	12.0	2
2	7/19	Survey ops (acoustics and seabirds)	-	-	-	4.0	2
2	7/20	Survey ops (acoustics and seabirds); Mechanical issue detected; Transit to Norfolk, VA	-	-	-	3.0	1
NA	7/21	In port; Mechanical issue	-	-	-	-	-
NA	7/22	In port; Mechanical issue; Travel day	-	-	-	-	-
NA	7/23	In port; Mechanical issue	-	-	-	-	-
NA	7/24	In port; Mechanical issue	-	-	-	-	-
NA	7/25	In port; Mechanical issue	-	-	-	-	-
NA	7/26	In port; Mechanical issue	-	-	-	-	-
NA	7/27	In port; Mechanical issue	-	-	-	-	-
NA	7/28	In port	-	-	-	-	-
NA	7/29	Break	-	-	-	-	-
NA	7/30	Break	-	-	-	-	-
NA	7/31	Break	-	-	-	-	-
NA	8/1	Break	-	-	-	-	-
NA	8/2	Break	-	-	-	-	-
NA	8/3	Break	-	-	-	-	-
NA	8/4	Break	-	-	-	-	-
NA	8/5	Break	-	-	-	-	-
NA	8/6	Travel day	-	-	-	-	-
NA	8/7	SIP	-	-	-	-	-
NA	8/8	SIP	-	-	-	-	-
NA	8/9	SIP	-	-	-	-	-
NA	8/10	SIP; COVID-19 test	-	-	-	-	-
NA	8/11	SIP	-	-	-	-	-
NA	8/12	SIP	-	-	-	-	-
NA	8/13	SIP	-	-	-	-	-
NA	8/14	COVID loss	-	-	-	-	-
3	8/15	Depart Norfolk, VA; Survey ops (seabirds)	-	-	-	-	-
3	8/16	Survey ops (mammals, seabirds)	76.7	0.8	33	-	-
3	8/17	Survey ops (mammals, seabirds)	123.6	1.2	43	-	-
3	8/18	Survey ops (CTD, mammals, seabirds)	169.7	2.4	16	1.0	n/a
3	8/19	Survey ops (CTD, mammals, seabirds)	126.1	2.6	17	-	-
3	8/20	Survey ops (CTD, mammals, seabirds)	136.7	2.3	9	-	-
3	8/21	Shelter bad weather offshore	-	-	-	-	-
3	8/22	Shelter bad weather offshore	-	-	-	-	-
3	8/23	Shelter bad weather offshore	-	-	-	-	-

Leg	Date	Activity	Visual Effort (km)	Average Sea State	Number of Sights	Acoustic Effort (hr)	Number of Acoustic Detections
3	8/24	Survey ops (CTD, mammals, seabirds)	116.9	3.0	3	11.0	n/a
3	8/25	Survey ops (CTD, mammals, seabirds)	194.4	3.2	2	12.0	n/a
3	8/26	Survey ops (CTD, mammals, seabirds)	116.9	5.0	3	11.0	n/a
3	8/27	Survey ops (CTD, mammals, seabirds)	122.2	5.0	0	10.0	n/a
3	8/28	Survey ops (CTD, mammals, seabirds)	164.1	4.8	0	12.0	n/a
3	8/29	Survey ops (CTD, mammals, seabirds); NRS07 recovery/redeployment	103.0	2.9	0	6.0	n/a
3	8/30	Survey ops (CTD, mammals, seabirds)	158.6	2.0	2	11.0	n/a
3	8/31	Survey ops (CTD, mammals, seabirds)	122.8	2.3	4	12.0	n/a
3	9/1	Transit into GoMx; Survey ops (mammals and seabirds)	137.3	2.5	6	11.0	n/a
3	9/2	Transit into GoMx; Survey ops (mammals and seabirds)	126.0	1.2	19	11.0	n/a
3	9/3	Transit into GoMx; Survey ops (mammals and seabirds)	128.8	2.8	1	-	-
3	9/4	Transit into GoMx; Survey ops (mammals and seabirds)	141.6	2.5	6	-	-
NA	9/5	Arrive in Pascagoula, MS	-	-	-	-	-
NA	9/6	Travel day	-	-	-	-	-
TOTAL	-	-	6,193.1	3.3	631	340.0	126.0

Table 3-2 Scientific personnel during GU2103

Name	Affiliation	Role	Legs
Anthony Martinez	SEFSC Miami	Field Party Chief	1, 2 and 3
Laura Dias	SEFSC Miami, CIMAS	MMO, Data manager	1 and 2
Amy Brossard	SEFSC Miami, CIMAS	Marine Mammal Observer	1 and 2
Melody Baran	CIMAS	Marine Mammal Observer	1, 2 and 3
Heidi Malizia	CIMAS	Marine Mammal Observer	1, 2 and 3
Paula Olson	CIMAS	Marine Mammal Observer	1, 2 and 3
Adam U	CIMAS	Marine Mammal Observer	1 (until 7/05)
Mary Applegate	CIMAS	Marine Mammal Observer	1, 2 and 3
Tom Ninke	CIMAS	Marine Mammal Observer	1, 2 and 3
Juan Carlos Salinas	CIMAS	Marine Mammal Observer	1, 2 and 3
Jonathan Reid	CIMAS	Acoustician tech	1 and 2
Ashley Cook	CIMAS	Marine Mammal Observer	3
Chris Haney	CIMAS	Sea bird observer	1, 2 and 3
Stormy Paxton	CIMAS	sea bird observer	1, 2 and 3

Affiliations: SEFSC = NOAA Southeast Fisheries Science Center; CIMAS = Cooperative Institute for Marine and Atmospheric Studies at the University of Miami.

Table 3-3 Marine mammal sightings for each leg during GU2103

Species or Taxa	Number of Sightings – Leg 1	Number of Sightings – Leg 2	Number of Sightings – Leg 3	Number of Sightings – Total
Atlantic spotted dolphin	18	1	2	21
Atlantic spotted dolphin + Common bottlenose dolphin	1	0	0	1
Blainville's beaked whale	1	1	0	2
Clymene dolphin	2	0	0	2
Common bottlenose dolphin	21	8	43	72
Common bottlenose or Atlantic spotted dolphin	4	1	2	7
Cuvier's beaked whale	1	3	3	7
Dwarf sperm whale	3	8	5	16
False killer whale	5	0	0	5
Fin whale	4	0	0	4
Gervais' beaked whale	3	3	0	6
Humpback whale + Unidentified dolphin	1	0	0	1
Killer whale	0	0	1	1
Melon-headed or Pygmy killer or False killer whale	1	0	0	1
Pantropical spotted dolphin	1	4	0	5
Pilot whales	39	1	5	45
Pilot whales + Atlantic spotted dolphin	1	0	0	1
Pilot whales + Common bottlenose dolphin	1	0	0	1
Pilot whales + Short-beaked common dolphin	1	0	0	1
Pilot whales + Striped dolphin	1	0	0	1
Pilot whales + Unidentified dolphin	4	0	0	4
Pygmy or Dwarf sperm whale	5	21	14	40
Risso's dolphin	25	1	4	30
Risso's dolphin + Common bottlenose dolphin	1	0	0	1
Risso's dolphin + Short-beaked common dolphin	1	0	0	1
Risso's dolphin + Unidentified dolphin	1	0	0	1
Sei or Fin or Bryde's-like whale	1	0	0	1
Short-beaked common dolphin	1	0	0	1
Sperm whale	38	5	10	53
Spinner dolphin	0	0	1	1
Stenella dolphin	8	2	3	13
Striped dolphin	5	0	0	5
Unidentified baleen whale	4	0	0	4
Unidentified dolphin	81	12	31	124

Species or Taxa	Number of Sightings – Leg 1	Number of Sightings – Leg 2	Number of Sightings – Leg 3	Number of Sightings – Total
Unidentified large whale	6	1	2	9
Unidentified Mesoplodont	11	28	15	54
Unidentified odontocete	9	17	12	38
Unidentified rorqual	2	0	0	2
Unidentified small whale	4	1	1	6
Unidentified Ziphiid	9	24	10	43
TOTAL	325	142	164	631

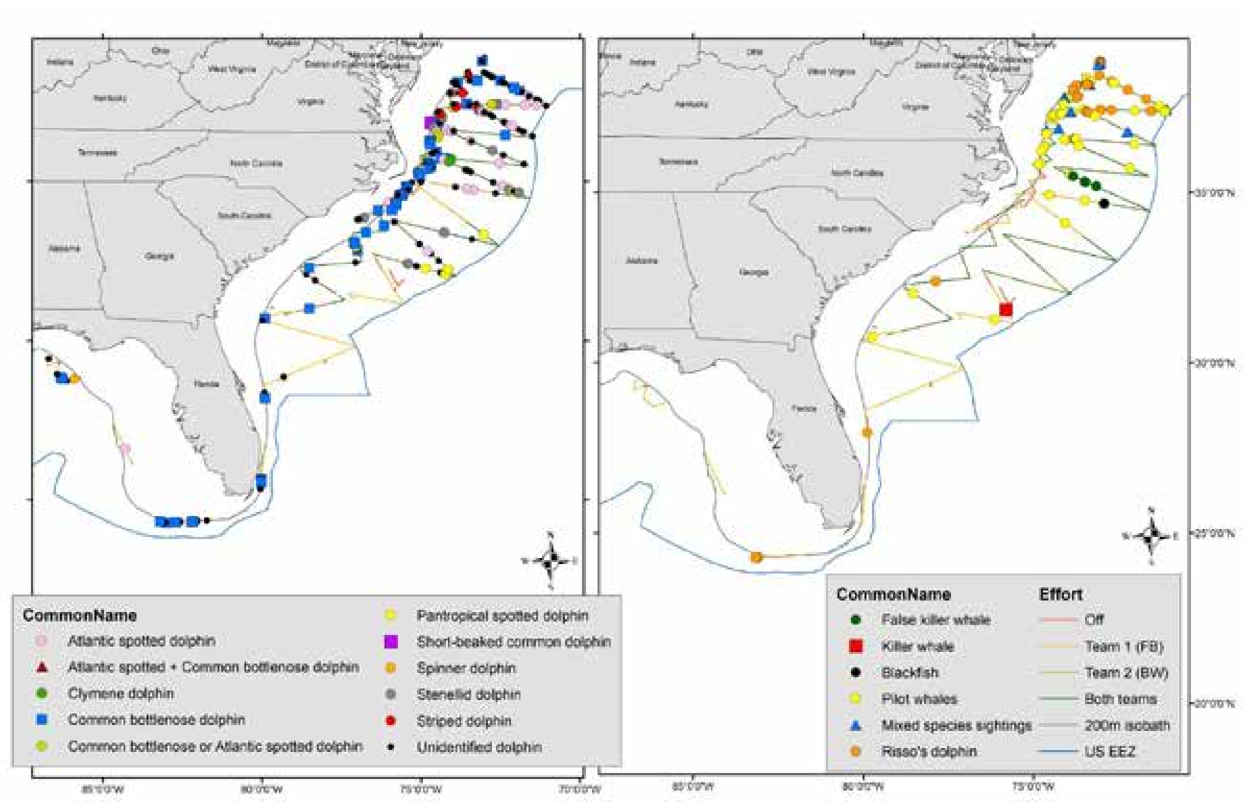

Figure 3-2 Small and large delphinids observed during GU2103

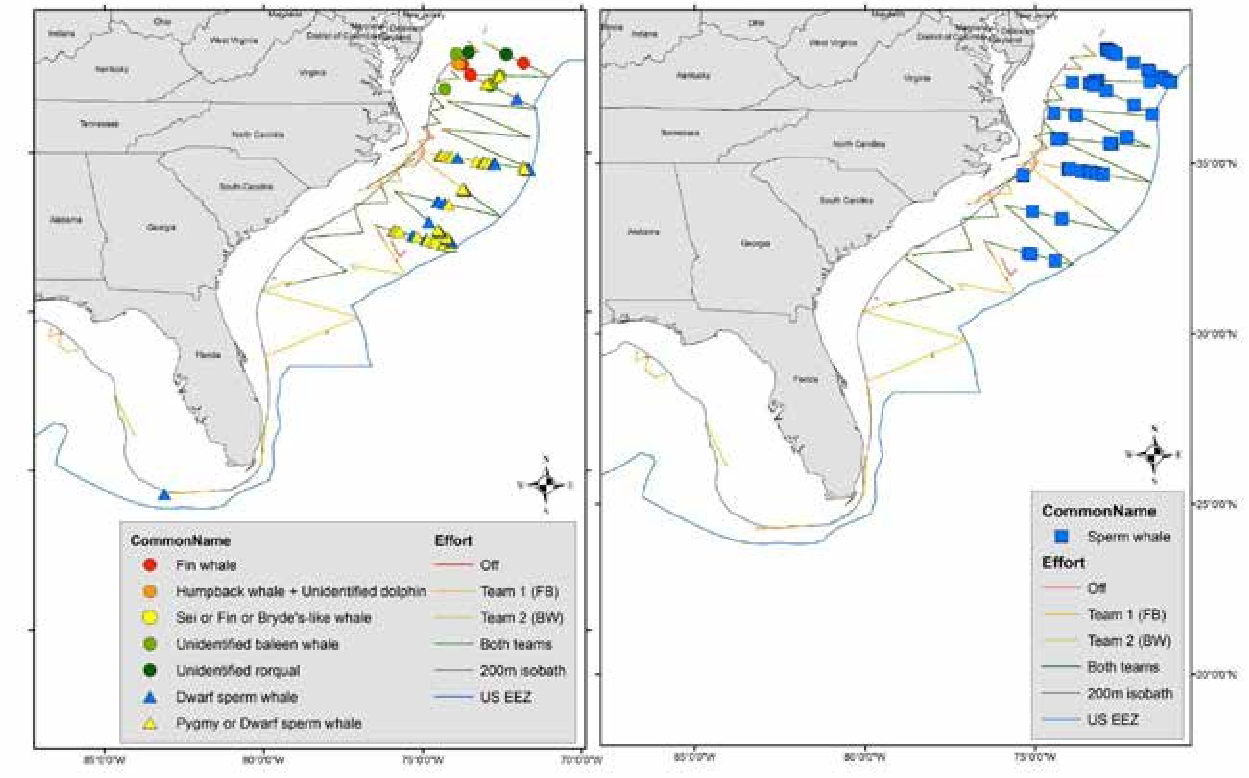

Figure 3-3 Baleen, pygmy and dwarf and sperm whales observed during GU2103

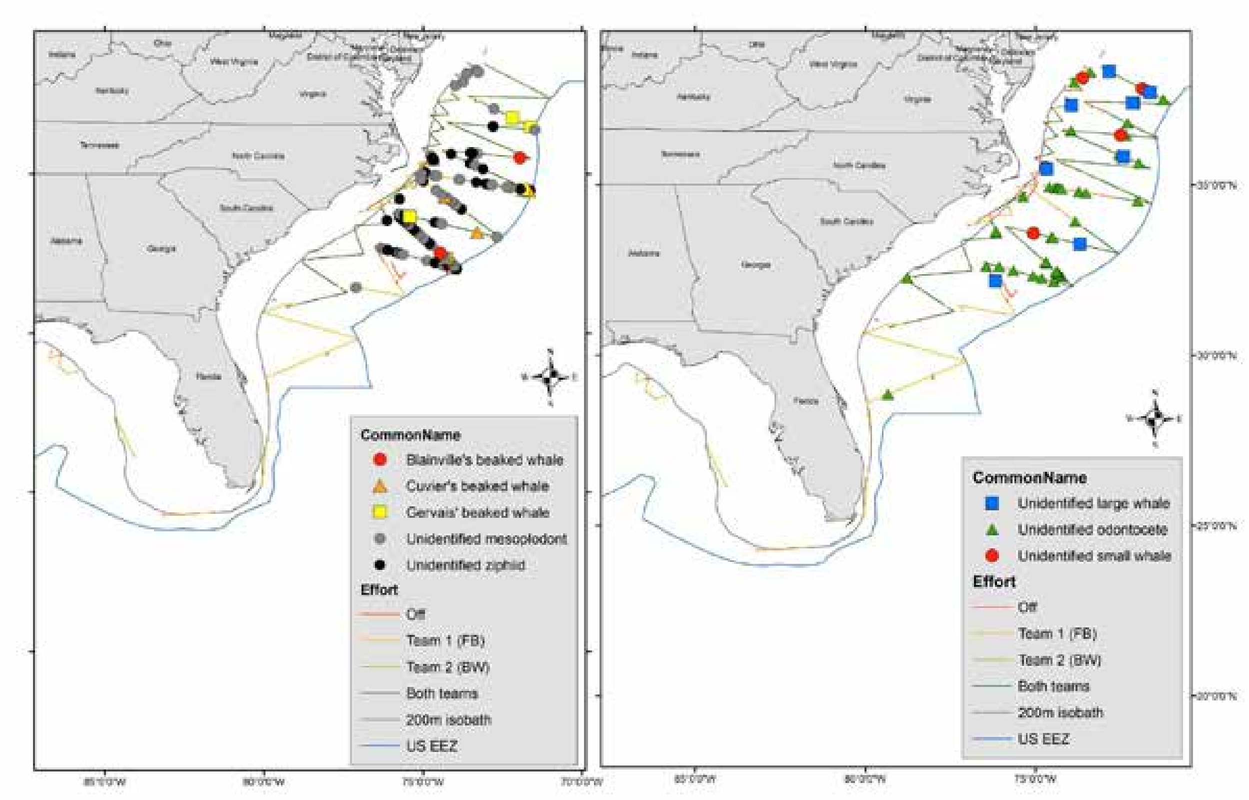

Figure 3-4 Beaked whales and unidentified cetaceans observed during GU2103

3.5 Towed Array Passive Acoustic Operations

3.5.1 Methods

We conducted passive acoustic surveys using a towed hydrophone array concurrent with visual surveys during daylight hours when environmental conditions allowed. We suspended passive acoustic surveys during portions of the tracklines that occurred in water depths shallower than 75 m and in sea states greater than 6. We conducted passive acoustic monitoring for odontocetes using a modular towed hydrophone array deployed approximately 300 m behind the ship and weighted with 13.6 kg (30 lbs) lead wire. We did not measure hydrophone depth on this cruise due to a faulty pressure sensor in the towed array. Depth averaged 12 ± 1.3m on prior cruises at this speed, tow distance, and weighting. On 14 Jun 2021, a predatory fish possibly severely damaged the tow cable near the array connector. We cut off the damaged portion of the tow cable and attached a new connector. We turned the tow cable around on the winch so that the connector with the emergency repairs remained on the dry end connected to the deck cable. We removed all the weights and reattached it to the new end at the same distances along the cable to ensure minimal variation to the average depth of hydrophone. After we completed testing of the repaired tow cable passive acoustic operations resumed on 19 June 2021. Subsequent recordings were of reasonably high quality; however, we intermittently received radio communications by the array due to the lack of electrical shielding in the area with emergency repairs.

The custom-built 5-element mixed-frequency oil-filled end array (Rankin et al. 2013) included paired pre-amplifier and hydrophone elements capable of recording a broad range of frequencies.

We optimized sensors 1, 3, and 5 for greater detection ranges of the mid-frequency recordings by using APC International 42-1021 hydrophones with custom-built pre-amplifiers. The APC 42-1021 hydrophones have a -212 dB re V/uPa sensitivity with a flat frequency response (+/- 4 dB) from 1 to 45 kHz. The corresponding pre-amplifiers provided a highpass filter with 45 dB gain above 5 kHz. We optimized sensors 2 and 4 for recording the full bandwidth of high-frequency echolocation signals by using Reson TC4013 hydrophones with custom-built pre-amplifiers. The TC4013 hydrophones have a -212 dB re V/uPa sensitivity with a flat frequency response (+/- 2 dB) from 5 to 160 kHz. The corresponding pre-amplifiers provide a high-pass filter with 50 dB gain above 5 kHz. We digitized the data from sensors 1, 2, 4, and 5 for recordings with a custom 12 channel SailDAQ soundcard (www.sa-instrumentation.com) sampling 16 bits at 500 kHz, yielding a recording bandwidth of 1-250 kHz. We routed the SailDAQ output from sensors 1 and 5 through a custom Magrec amplifier and Mark of the Unicorn Traveler mk3 audio interface for real-time aural monitoring.

During legs 1 and 2, an acoustic technician monitored acoustic signals while the array was in the water. During mealtimes, visual and acoustic teams went off monitoring effort, but acoustic data continued recording. Due to the absence of an acoustic technician on Leg 3, we recorded the acoustic data but did not monitor these data. We used the software PAMGUARD (v.2.00.16BETA; Gillespie et al. 2008) to control the SailDAQ, to record acoustic data and metadata to hard disk, and for real-time monitoring, including logging effort and encounter details and obtaining bearings to acoustic detections. We continuously recorded all acoustic data as 4-minute, 4-channel wav files to 2 TB external SATA hard drives. Acoustic field technicians continuously monitored data aurally and visually through spectrographic analysis using both PAMGUARD and Ishmael (Mellinger 2001) software and detected and localized acoustically-active odontocetes in real-time using PAMGUARD's automated click detectors, hyperbolic bearing calculator, and manual target motion analyses as well as Ishmael's hyperbolic bearing calculator for manually-selected whistles. The software mapped the acoustic localizations and compared the acoustic locations with visual sighting locations using a custom-written acoustic version of VisSurvey. The acoustic VisSurvey version is capable of receiving and plotting visual sighting information along with acoustic bearings and localizations to improve correlations between acoustic and visual detections in real-time. Metadata describing acoustic encounters included individual click detections with corresponding time, localization, and localization quality information.

3.5.2 Results

During the survey, we recorded over 340 hours of acoustic data from the towed array. Of those, 232 hours recorded during legs 1 and 2 yielded real-time detections of 126 cetacean encounters (Table 3-1; Figure 3-5). During real-time monitoring, acoustic detections were broadly categorized as Risso's dolphin clicks, sperm whale clicks, dwarf/pygmy sperm whale clicks, beaked whale (Family Ziphiidae) clicks, dolphin (Family Delphinidae) vocalizations (whistles and clicks), or unidentified odontocetes (clicks only; Table 3-4; Figure 3-5). Preliminary acoustic detections include 23 sperm whale encounters, 1 *Kogia* sp. encounter, and 15 unidentified beaked whale encounters. Sperm whale encounters may represent either individuals or groups of individuals. In post-processing at a future date, we may assign some of the unidentified odontocete encounters as beaked whale encounters. When acoustic detections of odontocetes were not identifiable to the species level, we correlated the locations of the acoustic event with visual sightings when localization was possible. We will reanalyze and verify in post processing the recordings with visually verified species identifications to develop acoustic species classification algorithms for acoustic species identification. We will also use the acoustic data to improve estimates of sperm whale and beaked whale abundance.

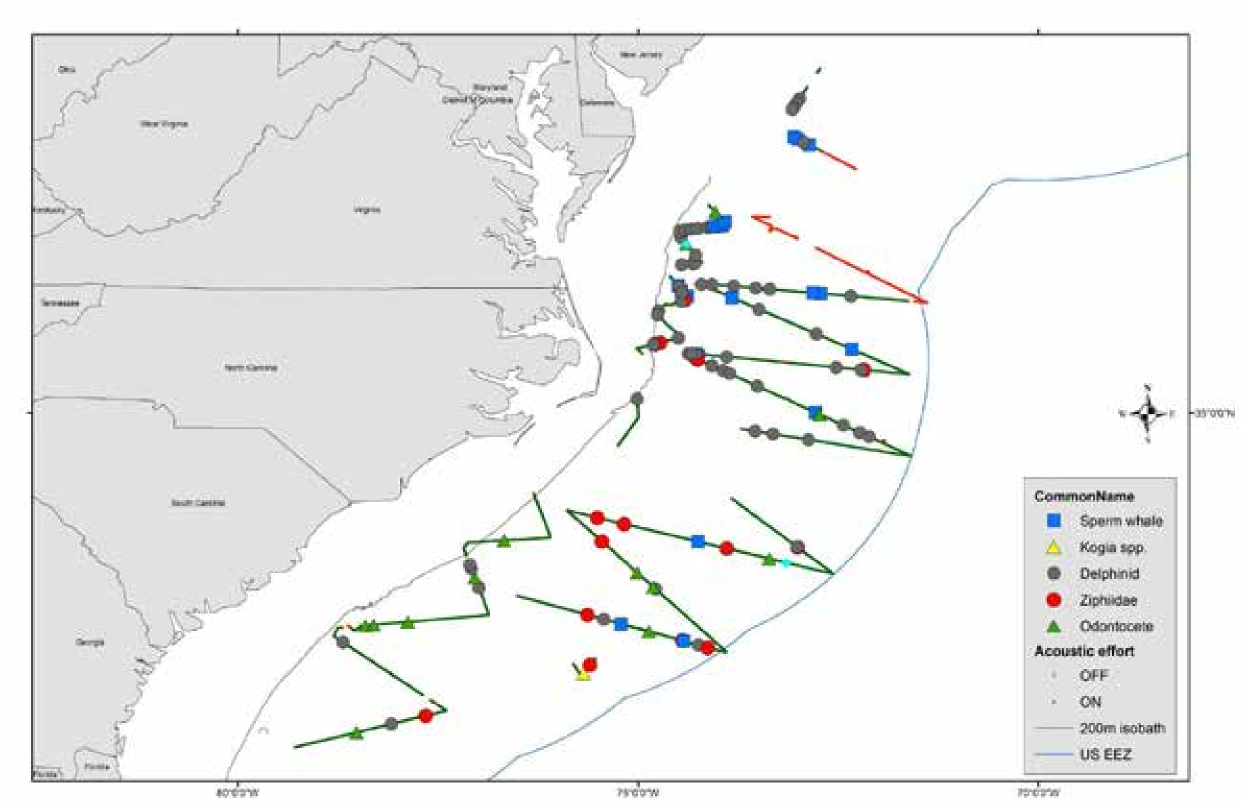

Figure 3-5 Acoustic effort and marine mammal detections during GU2103

Table 3-4 Marine mammal acoustic detections for each leg during GU2103

Leg 3 detections are to be determined during post-processing due to no dedicated acoustician on board.

Species or Taxa	Number of Sightings – Leg 1	Number of Sightings – Leg 2	Number of Sightings – Leg 3	Number of Sightings – Total
Sperm whale	20	3	-	23
Kogiidae	0	1	-	1
Ziphiidae	5	10	-	15
Odontocete	10	11	-	21
Delphinid	55	10	-	65
Unidentified	0	1	-	1
TOTAL	90	36	-	126

3.6 Passive Acoustic Mooring

As part of NOAA’s Ocean Noise Reference Station Network project, we refurbished the NRS07 buoy during this cruise. The Noise Reference Station buoy continuously recorded sounds up to 2.5 kHz for 2 yrs with the objective of collecting calibrated long-term recordings of ambient noise to allow comparisons of noise conditions among sites in US waters and over time. We recovered and redeployed the Noise Reference Station buoy on 29 Aug 2021.

3.7 Seabird Survey Operations

Sea bird observers conducted counts of all birds detected within a 300m strip transect from the ship during all legs of the survey. Sea bird observers were generally on effort while marine mammal operations surveyed but also performed observations while marine mammal observers were off effort. Sea bird observations took place during 44 sea-days and identified 30 different species. The most abundantly observed species were greater shearwater, followed by Wilson's storm petrel, Cory's shearwater and sooty tern (Table 3-5).

3.8 Scientific Echosounder Data Collection

The scientific echosounder recorded data during the nighttime from the end of the survey day until commencement of acoustic effort the following morning. We did not perform a calibration of the echosounder during this survey.

3.9 Environmental Data

We collected environmental data at predetermined stations using a conductivity, temperature, and depth sensor (CTD) unit. CTD casts recorded vertical profiles of depth, conductivity, salinity, temperature, and oxygen content to a maximum depth of approximately 500m. We performed CTD casts daily, before commencing visual survey effort in the morning. We performed 34 CTD casts throughout the study area (Figure 3-6).

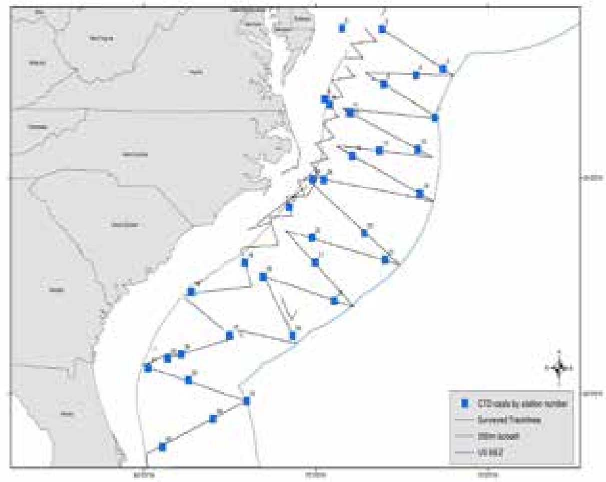

Figure 3-6 CTD casts performed during GU2103

Table 3-5 Sea bird species observed during GU2103

Sea Bird Species	Number of individuals
Arctic Tern	1
Audubon's Shearwater	186
Black-capped Petrel	582
Black Tern	23
Brown Booby	20
Brown Pelican	9
Bridled Tern	25
Band-rumped Storm-Petrel	59
Cory's Shearwater	826
Common Tern	3
Great Black-backed Gull	4
Greater Shearwater	1,463
gull species	1
Herring Gull	5
Laughing Gull	69
Leach's Storm-Petrel	566
Masked Booby	6
Magnificent Frigatebird	2
Manx Shearwater	2
Parasitic Jaeger	5
Pterodroma (gadfly petrel)	3
Pomarine Jaeger	10
Red-billed Tropicbird	12
Red-necked Phalarope	89
Royal Tern	64
Sandwich Tern	50
Sooty Shearwater	10
Sooty Tern	732
South Polar Skua	2
Trindade Petrel	11
unidentified tubenose (procellariiformes)	89
unidentified large shearwater	2
unidentified jaeger	1
unidentified larid (gull or tern)	1
unidentified phalarope	9
unidentified shearwater	19
unidentified storm-petrel	32
unidentifed tern	5
unidentifed tropicbird	9
Wilson's Storm-Petrel	861
White-tailed Tropicbird	36
TOTAL	5,904

3.10 Marine Mammal Biopsy Sampling

We did not conduct marine mammal biopsy sampling during this survey.

3.11 Plankton Sampling

We did not collect plankton samples during this survey.

3.12 Disposition of Data

The SEFSC in Miami, FL stored and managed all data collected during this survey. We archived the final audited versions in the NEFSC ORACLE database. Marine mammal and sea turtle sightings recorded by the primary team and associated effort will be available online at OBIS-SEAMAP (http://seamap.env.duke.edu/). The complete data set will be archived and publicly available at the National Centers for Environmental Information (https://www.ncei.noaa.gov/). The data presented here are preliminary and subject to change as we perform further auditing and analyses.

3.13 Permits

We conducted the marine mammal research activities during this survey under the National Marine Fisheries Service (NMFS), Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) Permit No. 21938 that was awarded to the SEFSC.

3.14 Acknowledgements

We thank the marine mammal observers who participated in the SEFSC surveys and thank the crew of the NOAA Ship *Gordon Gunter*. In addition to the 3 sources of funds specified in section 1.4 of this document (NMFS and the 2 interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy), the NOAA Office of Marine and Aviation Operations funded the ship time and other ship costs. The SEFSC and the NOAA Office of Marine and Aviation Operations funded staff time of the crew and scientists. The Cooperative Institute for Marine and Atmospheric Studies (CIMAS), a Cooperative Institute of the University of Miami and the National Oceanic and Atmospheric Administration, cooperative agreement NA20OAR4320472 carried out some of the staff time.

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4 Northern leg of shipboard abundance survey during 27 June to 23 August 2021: Northeast Fisheries Science Center

Debra Palka[1]*, Annamaria DeAngelis*[1]*, Jennifer Wallace*[2]*, Elisabeth Broughton*[1]*, Harvey Walsh*[3]*, and Michael Jech*[1]

[1]Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543
[2] Integrated Statistics, Inc. 16 Sumner St., Woods Hole, MA 02543
[3] Northeast Fisheries Science Center, 28 Tarzwell Dr., Narragansett, RI 02882

4.1 Summary

During 16 Jun to 23 Aug 2021, divided in 2 legs, the Northeast Fisheries Science Center (NEFSC) conducted a shipboard line transect abundance survey targeting marine mammals, sea turtles and seabirds on the NOAA ship *Henry B. Bigelow*. The survey area was between 36°N and 42°N and 65°W and 74°W, south of Massachusetts to east of Virginia in waters offshore of the 100 m depth contour. We used the 2 independent team's data collection protocols targeting marine mammals and sea turtles using visual line transect sampling techniques. In addition we had a team targeting sea birds using strip transect sampling techniques; a team monitoring a passive acoustic towed hydrophone array; and a team collecting physical and biological oceanographic data. In Beaufort sea states of 6 and less, we surveyed about 5,354 km of on-effort track lines at about 10 knots. We recorded over 1000 groups (10,000 individuals) of cetaceans, 31 groups (32 individuals) of sea turtles, and 5,300 individuals of seabirds. The most abundant species we detected were striped dolphins (*Stenella coeruleoalba*), common dolphins (*Delphinus delphis*), and common bottlenose dolphins (*Tursiops truncatus*). The most common large whales were sperm whales (*Physeter macrocephalus*) and fin whales (*Balaenoptera physalus*). We detected about 18 loggerhead turtles (*Caretta caretta*) and about 9 leatherback turtles (*Dermochelys coriacea*). In addition, we detected 15 basking sharks (*Cetorhinus maximus*) and 20 ocean sunfish (*Mola mola*). We also collected passive acoustic data via towed hydrophone array during daytime surveys when in waters deeper than 100 m. Using this array we collected about 310 hrs of data during 30 days, resulting in 705 real-time detections of vocally-active cetacean groups. During the day and night, we collected active acoustic backscatter data and we completed 296 nekton and plankton sampling events. This included 36 casts of the 19+CTD, 180 bongo deployments, 33 VPR hauls, deployments, and 47 Frame net deployments.

4.2 Objectives

The main objectives of the survey included:

- Collect data needed to determine the distribution and abundance of cetaceans, sea turtles, and sea birds within the study area.
- Collect vocalizations of cetaceans using passive acoustic hydrophones to augment the visual data.
- Collect data needed to determine the distribution and relative abundance of plankton and other trophic levels using nets with CTDs, visual plankton recorder and the EK-60.
- Collect hydrographic and meteorological data.

- If possible, collect biopsy samples and photo-identification images of cetaceans.

Sub-objectives related to main objective 3 (plankton and other trophic levels) were:

- Sample plankton and nekton along the visual team's track lines to quantify the lower trophic levels in the slope ecosystem.
- Compare the signal strength of the ship's active acoustics, especially the EK60, to sampled plankton and nekton densities.
- Confirm the existence of a Mid-Atlantic slope spawning area for the Atlantic bluefin tuna (*Thunnus thynnus*) by collecting larval samples for genetic species confirmation and aging that may be able to begin to demarcate the spawning area.
- Conduct fine scale oceanographic and plankton sampling transects in the windfarm areas to provide an environmental baseline for future research and to study cross shelf transport.
- Use the oceanographic sampling to increase understanding of the physical processes affecting water masses along the shelf slope and Gulf Stream boundaries.

4.3 Cruise Period and Area

The cruise was on the NOAA ship *Henry B. Bigelow* and designated as HB2102. We divided the cruise period into 2 legs: 16 Jun to 11 Jul 2021 and 27 Jul to 23 Aug 2021. Scientists, crew, and backup personnel sheltered in place for the week before a leg, in accordance with the Covid-19 protocols. The study area (Figure 4-1) included waters south of Cape Cod (about 42° N latitude), north of North Carolina (about 36° N latitude), west of the southern tip of Nova Scotia (about 65° W longitude), and east of the US coast (about 75°W longitude). This is waters shallower than about 4500 m which includes international waters and waters within the US and Canadian economic exclusive zones.

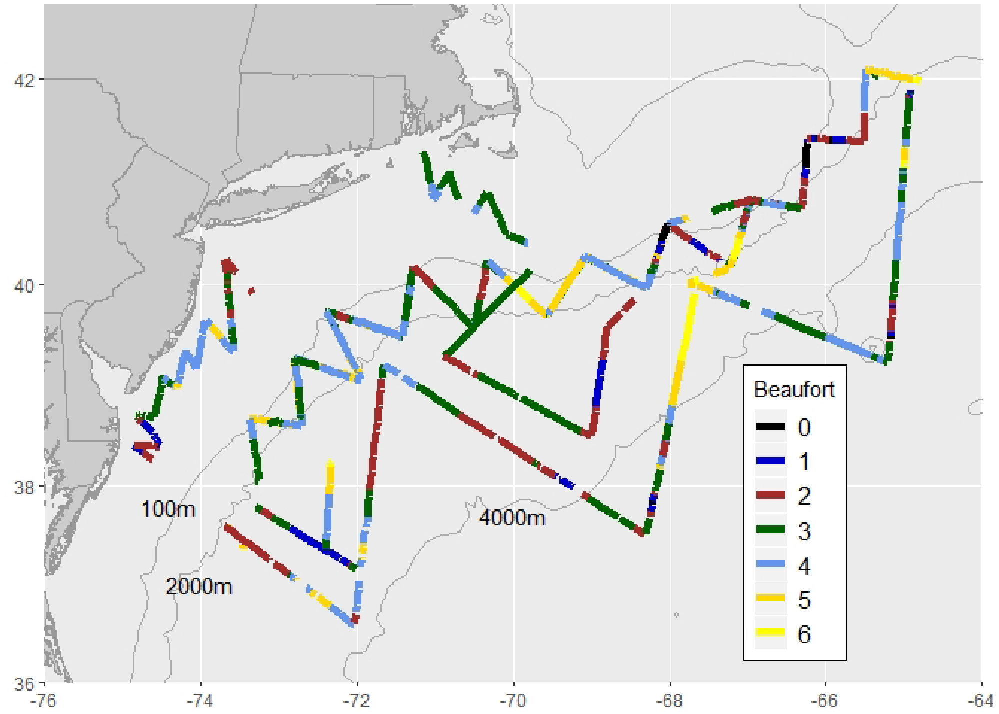

Figure 4-1 Track lines surveyed while on effort in various Beaufort sea states during HB2103

4.4 Methods

4.4.1 Visual Marine Mammal and Turtle Sighting Team

We conducted a line transect sighting survey during daylight hours (approximately 0600 to 1800 with a one hour break at lunchtime) using the 2 independent team data collection procedure. We surveyed during good weather conditions (Beaufort 5 and below) while traveling at about 10 knots, as measured over the ground.

Scientific personnel formed 2 visual marine mammal-sea turtle sighting teams. The flying bridge team was 15.1 m above the sea surface, while the anti-roll tank team was 11.8 m above the sea surface. To detect animal groups, each team had 2 people searching using 25x150 powered binoculars, 1 on-effort person searching using naked eye and recording the sightings data detected by all team members, and 1 off-effort observer who could rest. Every 30 minutes observers on each team rotated positions within the team. The teams rotated platforms every other on-effort day. The composition of the teams slightly changed between the 2 legs.

The ship's Science Computer System recorded the ship’s position, date, time, ship's speed and course, water depth, surface temperature, salinity, and conductivity, along with other variables every second. Scientists recorded the sightings and visual team effort data onto hand held data entry computerized systems called VisSurv-NE (version 6), which L. Garrison initially developed, and D. Palka customized.

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

Both teams searched waters from 90˚ starboard to 90˚ port, where 0˚ was the track line that the ship traveled. When either team detected an animal group (porpoise, dolphin, whale, seal, turtle, and a few large fish species), we recorded the following data within the VisSurv-NE data entry program into a sightings data file:

- time we initially detected the sighting (automatically recorded to the nearest second)
- ship’s location (automatically recorded)
- species composition of the group
- radial distance between the team's platform and the location of the sighting, estimated either visually when not using the binoculars or by reticles when using binoculars
- bearing between the line of sight to the group and the ship’s track line, measured by a polarus mounted near the observer or a polarus at the base of the binoculars
- best estimate of group size
- direction of swim
- number of calves
- initial sighting cue
- initial behavior of the group
- comments on unusual markings or behavior.

In addition, VisSurv-NE routinely recorded the ship’s location every 12 seconds into a separate GPS data file.

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

- time of recording
- position of each observer
- weather conditions entered by recorder: swell direction relative to the ship’s travel direction and height (in meters); apparent Beaufort sea state in front of the ship percent cloud coverage; how clear the horizon is (clear, good, fair (thin haze), poor (thick haze), or very obscured horizon); percentage of area covered with glare; and strength of glare within the glare swath (none, slight, moderate, or severe)
- weather conditions entered by ship’s Science Computer System: depth (m), sea surface temperature (°C), wind speed (knots), and ship’s true heading.

4.4.2 Visual Seabird Sighting Team

From an observation station on the flying bridge, about 15.1 m above the sea surface, 2 observers, working solo on a 2 hour rotation, conducted a visual daylight survey for seabirds during approximately 0600 to 1800 hours with a 2 hour break at lunchtime. We employed a modified 300 m strip and line-transect methodology that has been used by various agencies in North America and Europe (e.g., Anon 2011, Ballance 2011; Tasker 2004). We collected data on seabird distribution and abundance by identifying and enumerating all birds seen within a 300 m arc on one side of the ship between the bow and 90°, while the ship was underway. We chose the side based on the best viewing conditions. We maintained a visual unaided eye watch of the 300 m survey strip, with frequent scans of the perimeter using hand-held binoculars (10x42 or 8x42) for cryptic and/or hard to detect species. We used binoculars and digital SLR cameras with 400 mm lenses to confirm species identification. To estimate distance, we used custom range finders based on height above water and the observers' height (Heinemann 1981).

Operational limits are higher for seabird surveys as compared to visual marine mammal and sea turtle surveys. As a result, seabird survey effort was possible in sea states up to and including Beaufort 7, in light rain, fog, and ship speeds between 8 and 12 knots. We suspended seabird survey effort if the ship's speed over ground fell below 6 knots.

The seabird team used 2 software programs, SeaScribe (BRI 2020) and SeeBird. Both programs drew GPS coordinates and time from an external source (Bluetooth GPS puck or the ship's computer system through a NMEA data feed) so each observation received a stamp with the latitude-longitude location of the ship, the time, and ship's course. Standard data collected for observations included species, distance, number of individuals, association, behavior, and if possible or applicable, age, sex, and plumage status. We counted ship-following species once and subsequently carefully monitored them to prevent re-counts. We recorded all birds, including non-marine species, such as raptors, doves, and Passerines. In addition, as feasible, we recorded observations of non-avian animals and marine debris as well. We recorded flocks of seabirds in the regular sighting data module, with species counted within a given flock receiving a special "flock" notation in the comment section, along with an estimated distance to that flock from the transect line. Every night we conducted quality assurance and data integrity checks and then saved the data to computer disk and to an external backup drive.

4.4.3 Passive Acoustic Detection Team

The passive acoustic team consisted of 2 people who operated the system in 2-hour shifts, from 0545 to 1800. We deployed the hydrophone array at 0545 each morning, and typically retrieved it from 1130 to 1230 for the midday bongo/CTD casts. Daytime data collection usually ended at 1800, at the end of the visual survey day. The acoustic team collected data during all hours when the visual team was on-effort, except along inshore track lines, where shallow bottom depths (100 m and less) prohibited safe deployment of the array. The acoustic team also collected data on some occasions when weather conditions prevented the visual team from operating.

The hydrophone array consists of 1 modular, oil-filled section, containing 3 hydrophones (High Tech Inc., HTI-96-Min), and a depth sensor (Keller America, PA7FLE). For Leg 2 of the survey, we attached an external depth sensor (Dive Gear Express, Sensus Ultra) to the array as the internal one failed at the end of Leg 1. We towed the array 300 m behind the ship. Array depth typically varied between 5 and 12 m when deployed at the typical survey speed of 10 kts. We extracted sound speed data at the tow depth of the array from morning and midday CTD casts.

The recording system routed the acoustic data into a custom-built Acoustic Recording System that encompassed all signal conditioning, including A/D conversion, filtering, and gain. It filtered the data at 1000 Hz, and added 10 dB of gain to the recording system. The recording system also incorporated two National Instruments soundcards (NI USB-6356). Both soundcards sampled the same hydrophone pair at 500 kHz with a 16-bit resolution, one soundcard went to a "recording" only computer, the other to a "tracking" computer for real-time monitoring. The acoustical software program PAMGUARD (http://www.pamguard.org/home.shtml) recorded the digitized acoustic data directly onto hard drives, which also recorded simultaneous GPS data, continuous depth data, and allowed manual localization of incoming acoustic signals as well as entry of corresponding notes. Whenever possible, we matched vocally active groups that we acoustically tracked with visual detections in real-time. We will use this relationship to assign species identifications to groups classified as an unambiguous species. We established communication protocols between the acoustic team and the visual team situated on the flying bridge to facilitate this process.

Different from previous years, during daylight hours we switched the echosounder state between active and passive modes based on space rather than time. We ran even numbered tracklines along the shelf break with the echosounders in active mode, and ran odd number tracklines along the shelf break with the echosounders in passive mode. We reversed this pattern if we ran the same trackline more than once. For the longer offshore tracklines, we switched the echosounders based on a short-term temporal schedule. That is, during the survey day we ran in active mode from 0500 to 0700, 1000 to 1300, and 1600 to 1800 (local time). In addition, we ran in active mode during the nighttime plankton collections.

During occasions when the visual team could not survey due to weather and the passive acoustic team could survey, the acoustics team led opportunistic echosounder playback experiments when we acoustically detected beaked whales. To resolve left/right ambiguity the ship slowed down to 4 knots and make small maneuvers to stay within the vicinity of the beaked whale detection (within about 2 km). Upon detecting and recording a beaked whale for at least 3 to 5 min and receiving consistent click trains, we switched the 18 kHz of the EK60 to active mode for at least 1.5 min. Then using PAMGUARD we recorded any changes in acoustic behavior from the focal beaked whale resulting from this introduction of the EK60 active acoustics.

Additionally, we conducted three clover leaf passes with all echosounders in active mode around three autonomous multichannel acoustic bottom mounted recorders (AMARs) deployed by the Department of Fisheries and Oceans Canada for the purposes of examining any longer term effects of scientific echosounders on beaked whale detections. These instruments were recording since the summer of 2020. Canadian scientists then recovered these instruments at the end of August 2021. We plan to conduct a joint analysis of these data in the upcoming year.

4.4.4 Hydrographic, Nekton, and Plankton Characteristics

4.4.4.1 Oceanographic Sampling

The ship’s Scientific Computer System logger system continuously recorded oceanographic data from the ship's sensors. A SEACAT 19+ and a SECAT 911 with rosette Conductivity, Temperature, and Depth Profiler (CTD) measured water column conductivity, temperature, and depth. The 911 also had a WetLabs EcoFlur fluorometry and turbidity sensor, a PAR sensor and a dissolved Oxygen sensor. Once a day, we conducted a vertical profile with the 19+ CTD, where we attached a Niskin bottle to the wire above the CTD. Each time we deployed the 911 we collected a water sample with a Niskin bottle. The water sample from the Niskin bottles will calibrate the conductivity sensors of the CTDs. We also recorded the calculated sound speeds from vertical profiles for 5 m, 10 m and 15 m depths for the daily calibration of the passive acoustic sensors.

4.4.4.2 Plankton Sampling

We equipped a 61 cm Bongo plankton net with two 333 μm nets and a CTD mounted on the wire 1 m above the nets. We deployed this system approximately 3 times a day: once before the day's surveying started (about 0500 to 0530), at lunchtime (about 1200 when the ship stopped surveying), and again after the visual teams finished surveying for the day (approximately 1800, depending on weather and the time of sunset). We towed the Bongo in a double oblique profile using standard Ecosystem Monitoring (EcoMon) protocols, where the ship's speed was approximately 1.5 kts through the water. We let out the wire at about a speed of 50 m/min and a wire-in speed of 20 m/min. Tows were to within 5 m of the bottom or to 200 m depth, if the bottom depth exceeded 205 m. Upon retrieval, we rinsed the samples from the nets using seawater. We preserved the samples from the 6B3I (60 cm Bongo-333 µm mesh-Ichthyoplankton) net in 95% ethanol that we changed to new ethanol after 24 to 48 hrs. We preserved the samples from the 6B3Z (60 cm Bongo-333 µm mesh-Zooplankton) in 5% formaldehyde and seawater. At the end of the survey, we transported the samples to the Narragansett, RI National Marine Fisheries Science (NMFS) lab for future identification.

4.4.4.3 Phytoplankton Sampling

We connected an Imaging Flow Cytobot developed by Robert Olsen and Heidi Sosik of Woods Hole Oceanographic to the ship's flow through seawater system. The Cytobot continuously sampled 5 ml aliquots of seawater taken from the 3 m intake depth and imaged all phytoplankton that were in a size range of 10 to 100 µm. This system allowed for real time visualization of the phytoplankton in the sampling area.

4.4.4.4 Nighttime Oceanographic and Plankton Sampling

During the nighttime hours when the marine mammal/turtle and seabird visual sighting teams were off-effort, we conducted physical and biological sampling of the water column by employing a combination of underway and station-based sampling.

Sampling equipment included the following:

- Seabird 911 and 19+CTDs for oceanography and hydrography (max depth 3000 m)
- V-fin color Video Plankton Recorder (VPR) to collect images of plankton and ground-truth EK60 acoustic data (max depth 300 m)
- Imaging Flow Cytobot to collect images of phytoplankton
- 61cm Bongo net with 333 µm mesh nets to sample plankton
- 1x2 m modified Frame net with a 333 µm mesh net to provide increased sample volume of ichthyoplankton samples.

4.4.4.5 Active Acoustic Sampling

We collected multifrequency (18, 38, 70, 120, and 200 kHz) scientific echosounder data with Simrad EK60 General Purpose Transceivers and the EK80 software. This system collected data to 3000 m depth at a nominal transmit rate of 1 transmit (i.e., ping) per 2 sec (0.5 Hz). The system recorded data on an external hard drive. After the cruise, we copied the data to the NEFSC network drives. We set the echosounders to active mode during night hours.

4.4.4.6 V-fin VPR Sampling

We towed the VPR opportunistically targeting areas with interesting oceanographic features or areas with strong signals on the EK60. To increase tow speeds of 4 to 5 knots, we towed the VPR from the aft hydrographic winch. The VPR setup included a Seabird SBE49 Fastcat CTD, and a Wet Labs Eco-Flur fluorometer with turbidity sensor that provided the hydrographic conditions associated with each volume of water imaged by the VPR. We set the camera imaging area to the largest area possible; thus, sampling an area of about 345 ml 9 times per second. Using this setting, we maximized the chances of capturing images of gelatinous zooplankton and macroplankton that we most likely detect by the 120 and 200 kHz frequencies of the EK60.

We conducted 2 types of tows. The first type was a stepped tow with 5 to 10 min spent at each depth to provide temporally fine scale plankton data that will assist in the ground truthing of the EK60 data, and to examine plankton patchiness. The second type was a tow-yo haul used to describe the water column hydrographic structure and plankton depth distributions.

4.4.4.7 Bluefin Tuna Spawning Area Sampling

In areas where the salinity exceeded 35 psu and sea surface temperature exceeded 23°C, we collected ichthyoplankton targeting Atlantic bluefin tuna. We sampled water along a transect with stations set 5 nmi apart. To compare the sampling efficiency of the different net samplers we conducted 2 tows at each station: one with a 61cm Bongo net and a second with a weighted 1x2 m Frame net (333 µm net). Both tows were for about 10 mins in a "W" shaped path from the surface to 10 m depth. We combined the samples from both nets of the bongo into a single jar and preserved it in 95% ethanol. In a different jar, we preserved the Frame net samples in 95% ethanol. Since ethanol desiccates the samples, we replaced the ethanol after 24 to 48 hrs. At the end of the cruise, we transported all samples preserved in ethanol to the Narragansett, RI NMFS lab for future identification.

4.5 Results

Scientists involved in this survey are in Table 4-1.

Table 4-1 Scientific personnel involved in the 2 legs of this survey
Leg 1 was during 26 Jun to 11 Jul 2021 and leg 2 was during 27 Jul to 23 August 2021.

Personnel	Leg	Title	Organization
Debra Palka	1, 2	Chief Scientist	NMFS, NEFSC, Woods Hole, MA
Elisabeth Broughton	1, 2	Oceanographer	NMFS, NEFSC, Woods Hole, MA
Michael Force (FN[1])	1, 2	Seabird Observer	Integrated Statistics, Woods Hole, MA
Allison Black	1	Seabird Observer	Integrated Statistics, Woods Hole, MA
Thomas Johnson	2	Seabird Observer	Integrated Statistics, Woods Hole, MA
Samuel Chavez-Rosales	1, 2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Todd Pusser	1, 2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Michelle Klein	1, 2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Alison Ogilvie	1, 2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Kelsey Stone	1, 2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Felipe Triana	1, 2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Brian Galvez	1	Mammal Observer	Integrated Statistics, Woods Hole, MA
Sharon Hsu	1	Mammal Observer	Integrated Statistics, Woods Hole, MA
Suzanne Yin	2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Lisa Barry	2	Mammal Observer	Integrated Statistics, Woods Hole, MA
Jennifer Turek-Wallace	1, 2	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Annamaria DeAngelis	1	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Samara Haver	2	Passive Acoustics	Integrated Statistics, Woods Hole, MA
Genevieve Davis	1, 2	Back up	Integrated Statistics, Woods Hole, MA

[1]FN = Foreign National

4.5.1 Visual Marine Mammal and Turtle Sighting Team

The visual marine mammal and turtle teams surveyed about 5,350 km while on effort during at least part of 38 of the 50 possible sea-days (Figure 4-1). In addition, we had 4 days for transiting between port and the study area. The weather conditions were too poor to survey on the other 12 sea-days (Table 4-2). The teams surveyed about 60% of the on-effort survey track lines in good weather conditions, Beaufort sea state 3 or less, which is about 10% less than that experienced during the 2016 abundance survey in the same time and area.

Table 4-2 Length (in km) of on-effort visual teams' track lines by Beaufort sea state condition

Attribute	0	1	2	3	4	5	6	Total
Length	61.24	289.11	1,071.48	1,777.38	1,521.32	949.73	199.77	5,353.82
Percent	1.14	5.40	20.01	33.20	28.42	17.74	2.73	100

During the on-effort track lines, the teams detected 31 cetacean species or species groups, 3 turtle species or species groups, and 7 fish species or species groups (Tables 4-3 and 4-4). For cetaceans, the upper team detected 883 groups (9,280 individuals) and the lower team detected 864 groups (7,264 individuals). For turtles, the upper team detected 23 groups (24 individuals) and the lower team detected 31 groups (32 individuals). Note, the upper team sometimes detected the same group as the lower team. In addition, the teams detected only 1 group of 15 basking sharks and the upper (and lower) teams detected 17 (12) ocean sunfish.

Distribution maps of sighting locations of the cetaceans, turtles, seals, and fish are in Figures 4-2 to 4-4. The most abundance species (Figures 4-2) were striped dolphins (*Stenella coeruleoalba),* common dolphins (*Delphinus delphis*) and bottlenose dolphins (*Tursiops truncatus*). Striped dolphins were found in deeper waters (mostly 1000 m or deeper) than common dolphins (mostly 1000 m or shallower), while bottlenose dolphins were found throughout the study area. Of interest, the teams detected 1 group (68 individuals) of Clymene dolphins (*Stenella clymene*), 1 group of killer whales (*Orcinus orca*), 2 groups (about 300 individuals) of spinner dolphins (*Stenella longirostris*), 7 groups (38 individuals) of false killer whales (*Pseudorca crassidens*), 3 blue whales (*Balaenoptera musculus*), and 2 minke whales (*Balaenoptera acutorostrata*) (Figure 4-3). The most common large whales (Figure 4-4) were fin whales (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*).

Table 4-3 Numbers of groups and individuals of cetacean species

Animals detected by the two marine mammal - turtle visual teams (upper and lower) during on-effort track lines. One or both teams could have detected a group.

Species Common Name	Species Latin Name	Groups Lower	Groups Upper	Individuals Lower	Individuals Upper
Atlantic spotted dolphin	*Stenella frontalis*	16	35	408	914
Blue whale	*Balaenoptera musculus*	2	1	3	1
Bottlenose dolphin spp.	*Tursiops truncatus*	100	107	1,128	1,236
Clymene dolphin	*Stenella clymene*	1	1	68	60
Common dolphin	*Delphinus delphis*	49	59	1,336	1,663
Cuvier’s beaked whale	*Ziphius cavirostris*	9	8	23	20
Dwarf sperm whale	*Kogia simus*	18	11	23	14
False killer whale	*Pseudorca crassidens*	2	7	14	38
Fin whale	*Balaenoptera physalus*	78	106	100	139
Fin/sei whales	*B. physalus or B. borealis*	8	1	11	3
Humpback whale	*Megaptera novaeangliae*	26	23	36	29
Killer whale	*Orcinus orca*	1	0	2	0
Minke whale	*B. acutorostrata*	2	1	2	1
Pilot whales spp.	*Globicephala* sp.	43	39	330	268
Pygmy sperm whale	*Kogia breviceps*	0	4	0	6
Pygmy/dwarf sperm whales	*Kogia* sp.	6	3	4	16
Risso’s dolphin	*Grampus griseus*	89	88	511	519
Risso's/Bottlenose dolphin	*Grampus/Tursiops*	9	2	39	5
Sei whale	*Balaenoptera borealis*	1	2	1	3
Sowerby’s beaked whale	*Mesoplodon bidens*	4	5	10	14
Sperm whale	*Physeter macrocephalus*	113	103	166	157
Spinner dolphin	*Stenella longirostris*	2	1	205	295
Stenella spp.	*Stenella spp.*	35	40	671	800
Stenella/Delphinus	*Stenella/ Delphinus*	8	12	148	325
Striped dolphin	*Stenella coeruleoalba*	36	40	1,283	1,679
True's beaked whale	*Mesoplodon mirus*	6	5	14	16
White-sided dolphin	*Lagenorhynchus acutus*	0	4	0	25
Unid. Dolphin	*Delphinidae*	91	99	594	922
Unid. Whale	*Mysticeti*	79	48	79	52
Unid. Mesoplodon	*Mesoplodon spp.*	8	6	17	18
Unid. Ziphiid	*Ziphiidae*	22	22	38	42
TOTAL		864	883	7,264	9,280

Table 4-4 Numbers of groups and individuals of large fish and turtles
Animals detected by the 2 marine mammal - turtle visual teams (upper and lower) during on-effort track lines. One or both teams could have detected a group.

Species Common Name	Species Latin Name	Groups Lower	Groups Upper	Individual Lower	Individual Upper
Basking shark	*Cetorhinus maximus*	0	1	0	15
Manta, Chilean devil ray	*Mobula tarapacana*	1	1	1	1
Manta, Spinetail devil ray	*Mobula mobular*	2	2	4	4
Manta, unid	*Mobula* sp.	8	5	8	5
Manta, unid black and white	*Mobula* sp.	1	5	1	5
Ocean sunfish	*Mola mola*	9	9	12	17
Shark spp.	-	14	17	14	18
Leatherback turtle	*Dermochelys coriacea*	6	4	7	4
Loggerhead turtle	*Caretta caretta*	17	17	17	18
Unid hardshell turtle	*Chelonioidea*	8	2	8	2

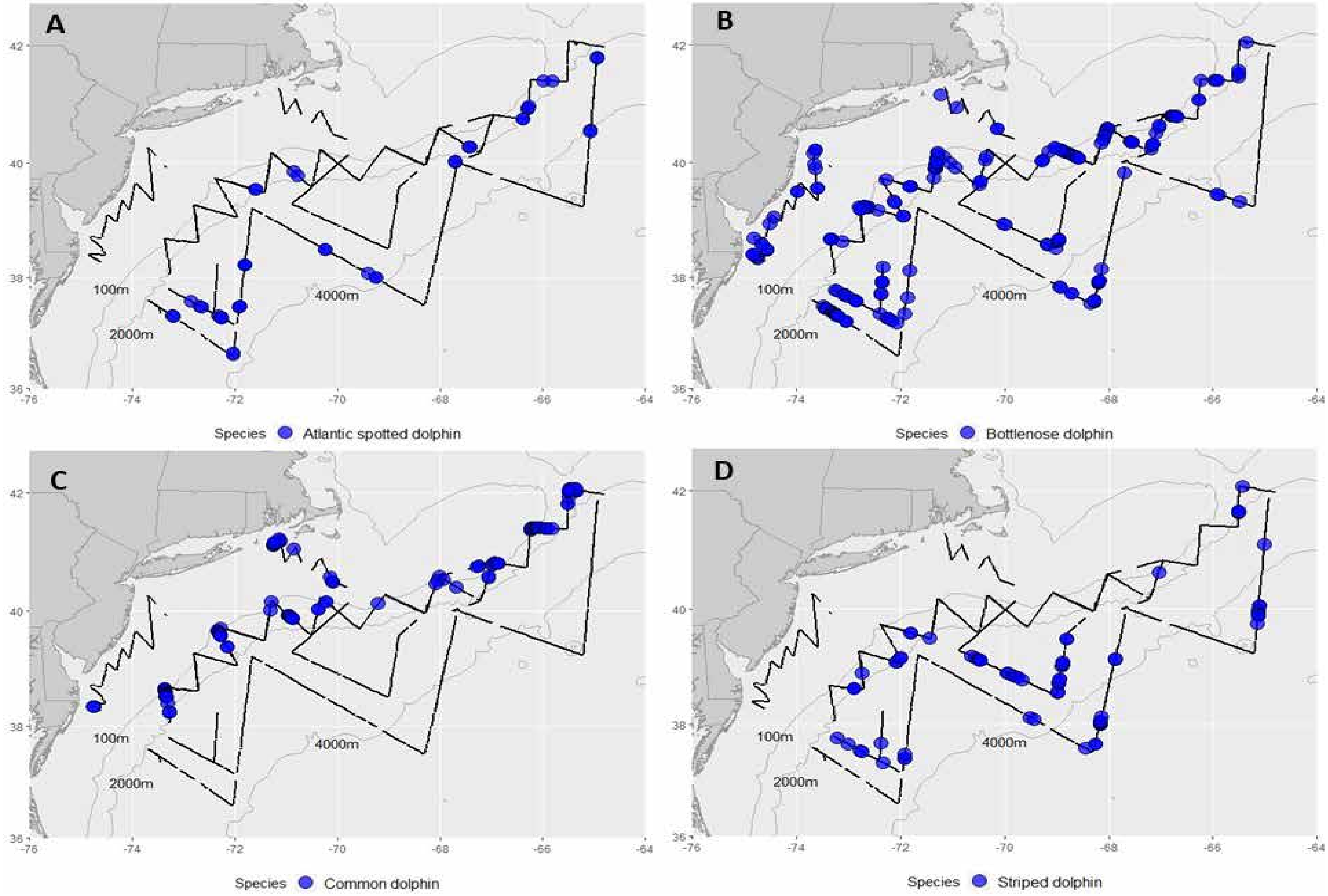

Figure 4-2 Small dolphins observed during HB2102

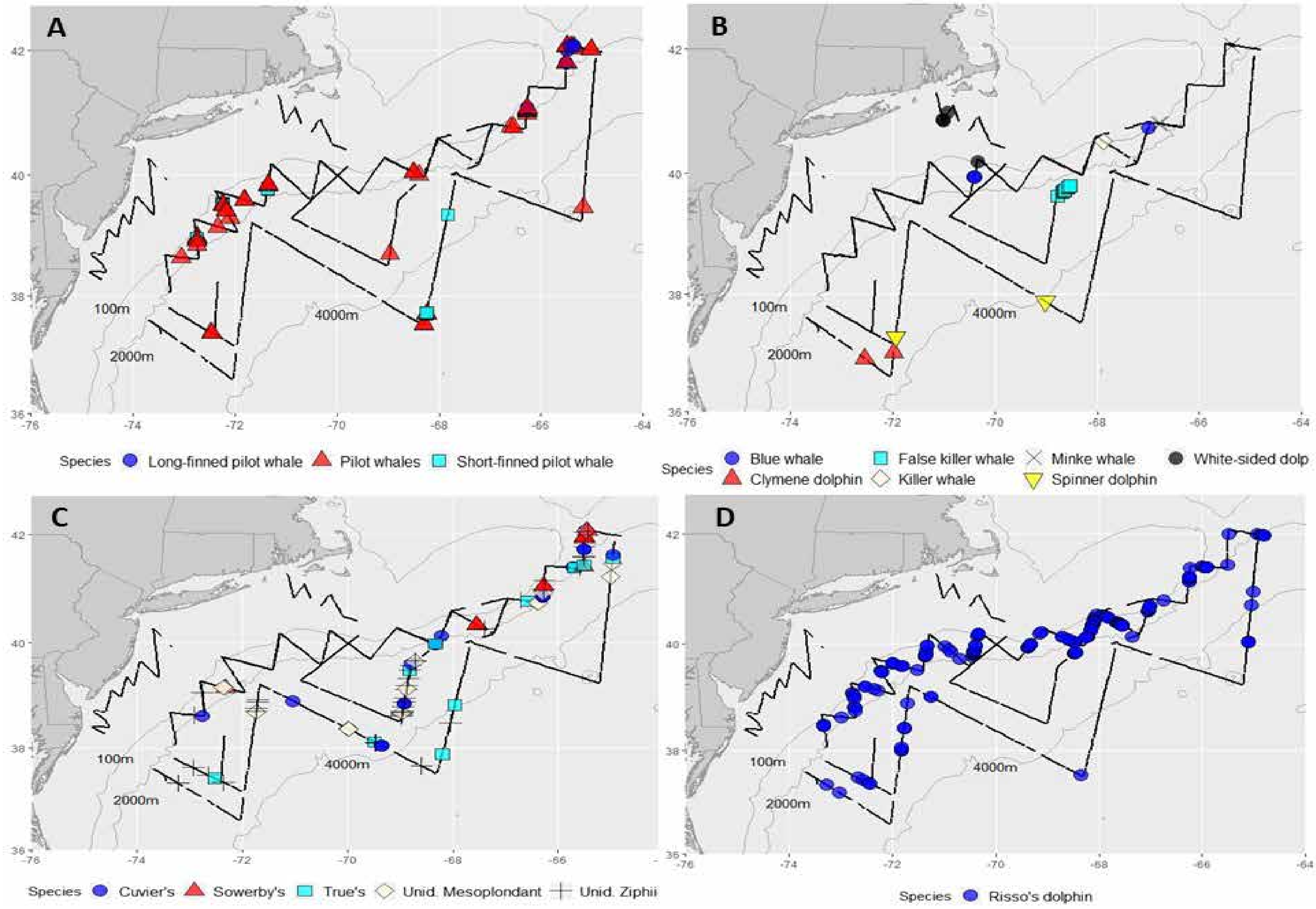

Figure 4-3 Large dolphins and small whales detected during HB2102

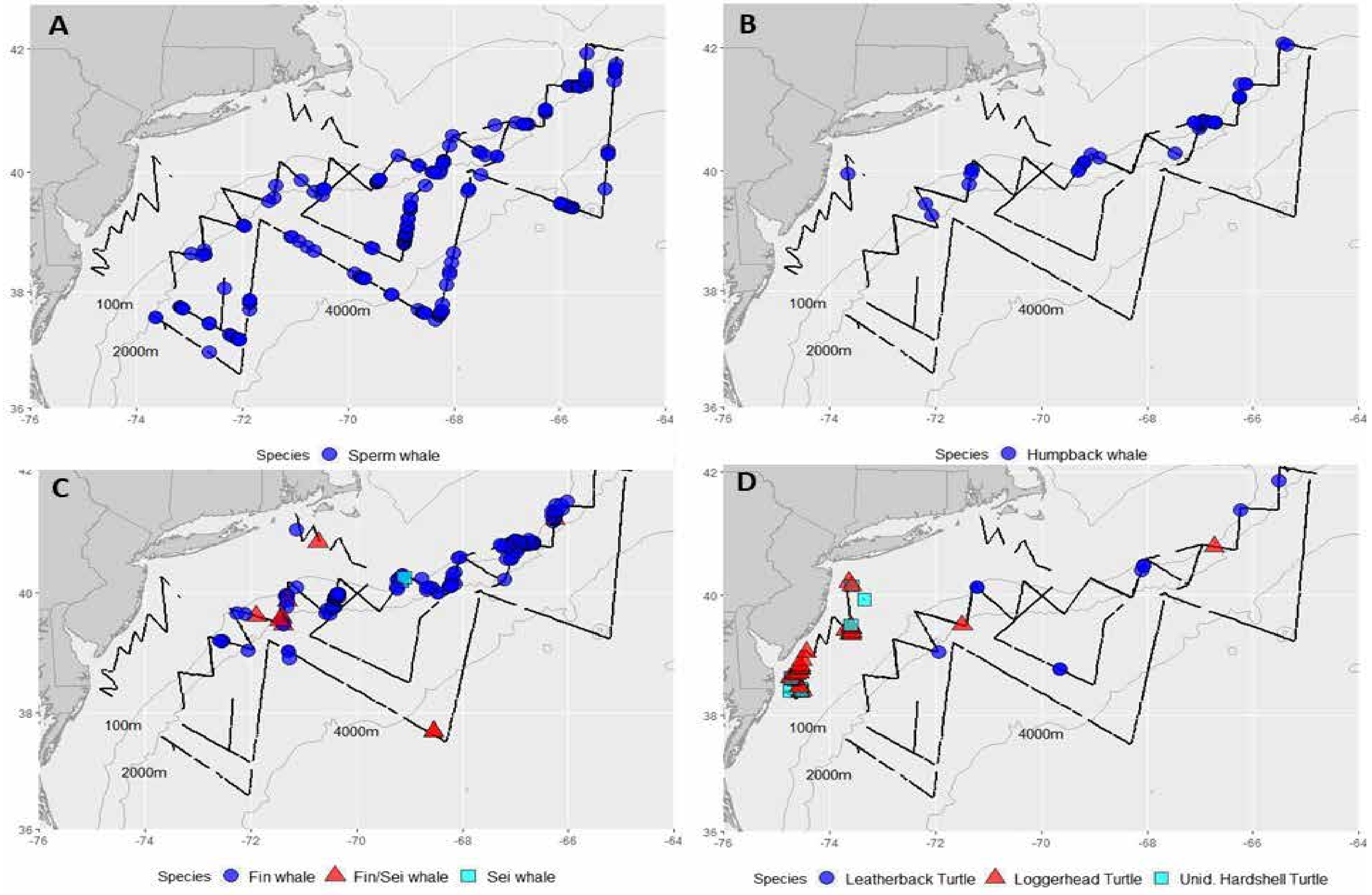

Figure 4-4 Large whales and sea turtles observed during HB2102

4.5.2 Visual Seabird Sighting Team

The observers stood watch on 42 days of the cruise totaling 5,407 km on 169 transects (Table 4-5), averaging 128 km per day (ranging 110 to 132 km per day). The seabird team counted 3,695 observations in the survey zone. Birds were the dominant observation, but the team also counted marine mammals, sea turtles, fish, and marine debris (Table 4-6).

Table 4-5 Seabird observer effort during HB2102

Month	Number of Survey Days	Daily Average Number of Transects	Total Number of Transects	Daily Average Transect Distance (km)	Total Transect Distance (km)
June	14	5.0	70	132.6	1856.6
July	7	3.1	22	110.7	774.9
August	21	3.7	77	132.2	2776.0
TOTAL	42	4.0	169	128.7	5407.4

Table 4-6 Numbers of observations of bird families and non-bird categories by seabird observers

Category	Number in Zone	Total
Alcidae (auks, murres, and puffins)	0	1
Charadriidae (plovers and lapwings)	1	1
Hirundinidae (swallows)	18	23
Hydrobatidae (northern storm-petrels)	571	617
Icteridae (Troupials and Allies)	1	3
Laridae (gulls, terns, and skimmers)	61	77
Oceanitidae (southern storm-petrels)	963	1,073
Parulidae (new world warblers)	4	5
Phaethontidae (tropicbirds)	6	11
Phalacrocoracidae (cormorants and shags)	1	1
Procellariidae (shearwaters and petrels)	1,800	3,418
Procellariiformes	2	2
Scolopacidae (sandpipers and Allies)	23	41
Stercorariidae (skuas and jaegers)	3	15
Sulidae (boobies and gannets)	9	11
Troglodytidae (wrens)	0	1
Marine Mammals	205	210
Sea Turtle	2	2
Fish	20	31
Insect	0	1
Marine Debris	5	5
TOTAL	3,695	5,549

The seabird team recorded 15 families of birds during the survey (Table 4-6). Storm-petrels and Shearwaters (Procellariidae) dominated the seabird sightings. Distributions of the sightings detected by the seabird team are in Figures 4-5 to 4-7. The species this team saw the most of were great shearwaters (*Puffinus gravis*) and Wilson's storm-petrels (*Oceanites oceanicus*; Table 4-7; Figure 4-6). Several notable sightings (Figure 4-7A) included the 93 endangered black-capped petrels (*Pterodroma hasitata*), 8 white-tailed tropicbirds (*Phaeton lepturus*), 3 red-billed tropicbirds (*Phaethon aethereus*), and 4 Trindade petrel (*Pterodrama arminjoniana*).

Table 4-7 Number of birds within the survey zone and total counts

Common Name	Scientific Name	Number in Zone	Total Individuals
Great shearwater	*Puffinus gravis*	1,205	1,763
Wilson's storm-petrel	*Oceanites oceanicus*	951	1,026
Leach's storm-petrel	*Oceanodroma leucorhoa*	423	438
Audubon's shearwater	*Puffinus lherminieri*	360	541
Cory's shearwater	*Calonectris diomedea*	219	801
Band-rumped storm-petrel	*Oceanodroma castro*	144	168
Common tern	*Sterna hirundo*	39	44
Red-necked phalarope	*Phalaropus lobatus*	22	40
Barn swallow	*Hirundo rustica*	18	23
White-faced storm-petrel	*Pelagodroma marina*	12	47
Black-capped petrel	*Pterodroma hasitata*	9	93
Brown booby	*Sula leucogaster*	7	7
Herring gull	*Larus argentatus*	6	10
Leach's/Band-rumped	*Oceanodroma leucorhoa/ castro*	4	11
Great black-backed gull	*Larus marinus*	4	5
Laughing gull	*Larus atricilla*	4	5
Least tern	*Sternula antillarum*	4	7
White-tailed tropicbird	*Phaeton lepturus*	4	8
Manx shearwater	*Puffinus puffinus*	3	4
Royal tern	*Sterna maxima*	2	2
Northern waterthrush	*Parkesia noveboracensis*	2	2
Red-billed tropicbird	*Phaethon aethereus*	2	3
Trindade petrel	*Pterodrama arminjoniana*	2	4
Unidentified storm-petrel	*Oceanodroma sp*	2	2
Northern gannet	*Morus bassanus*	2	3
Semipalmated plover	*Charadrius semipalmatus*	1	1
Brown-headed cowbird	*Molothrus ater*	1	2
Bridled tern	*Sterna anaethetus*	1	3
Unidentified tern	*Sterna sp*	1	1
Louisiana waterthrush	*Parkesia motacilla*	1	1
Yellow warbler	*Setophaga petechia*	1	1
Double-crested cormorant	*Phalacrocorax auritus*	1	1
Sooty shearwater	*Puffinus griseus*	1	1
Unidentified shearwater	Puffinus sp	1	211
Wilson's snipe	*Gallinago delicata*	1	1
Long-tailed jaeger	*Stercorarius longicaudus*	1	1
Parasitic jaeger	*Stercorarius parasiticus*	1	1
Pomarine jaeger	*Stercorarius pomarinus*	1	9
Atlantic puffin	*Fratercula arctica*	0	1
Red-winged blackbird	*Agelaius phoeniceus*	0	1
Black-and-white warbler	*Mniotilta varia*	0	1
South polar skua	*Stercorarius maccormicki*	0	1
Unidentified jaeger	*Stercorarius sp*	0	2
Unidentified skua	*Stercorarius sp*	0	1
Masked booby	*Sula dactylatra*	0	1
Carolina wren	*Thryothorus ludovicianus*	0	1
TOTAL		3,463	5,300

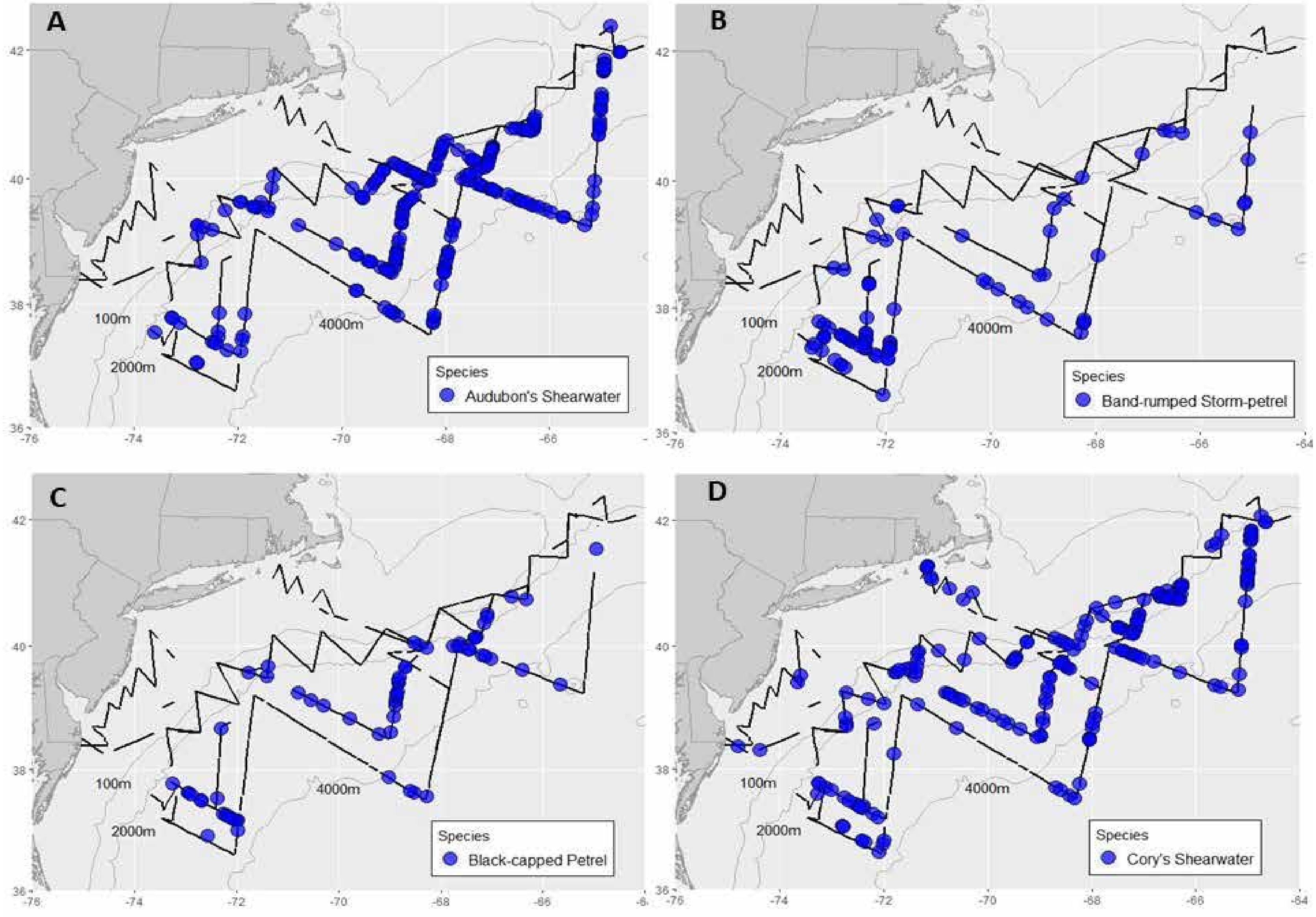

Figure 4-5 Common seabird species detected during HB2102

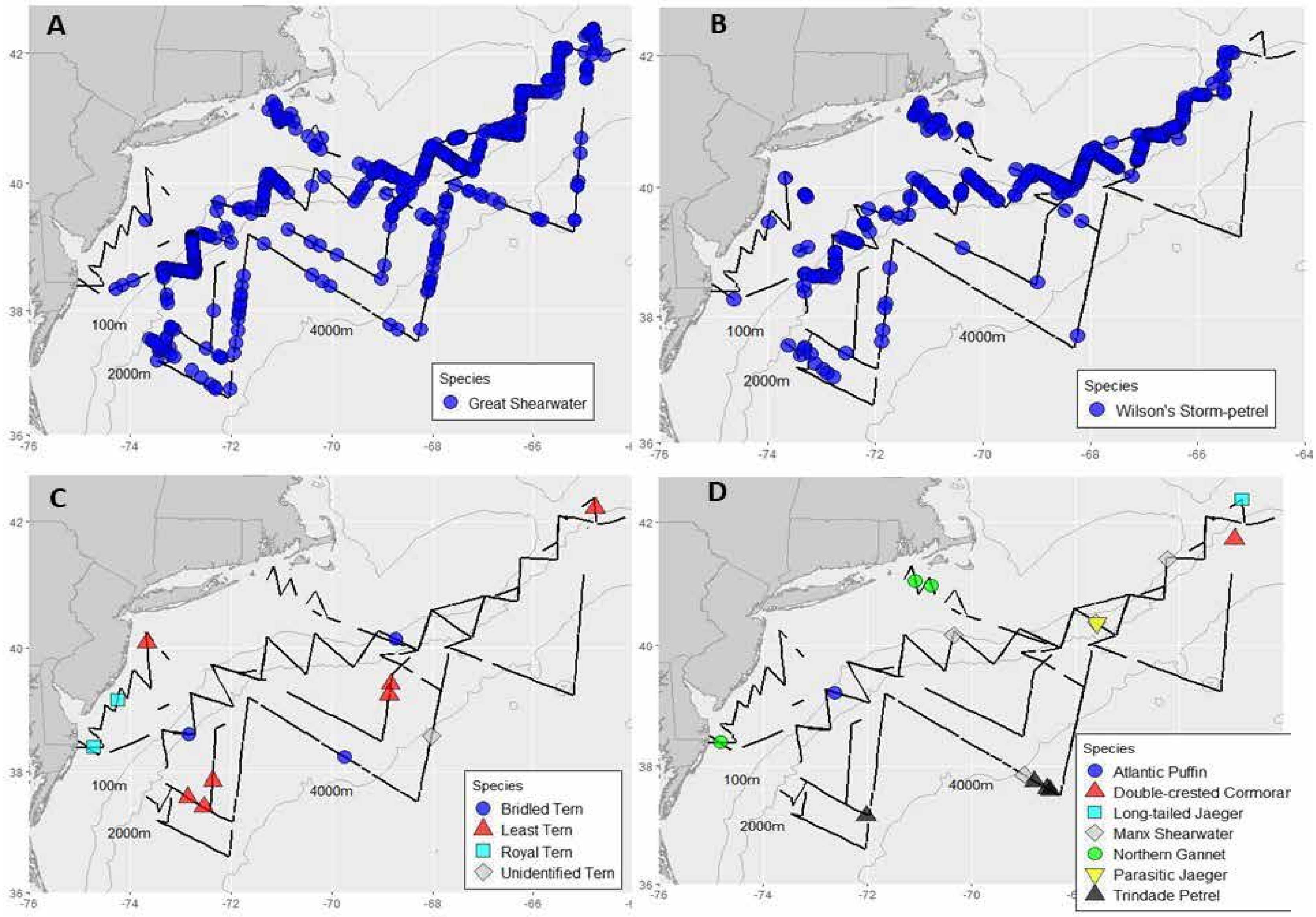

Figure 4-6 More seabirds detected on HB2102

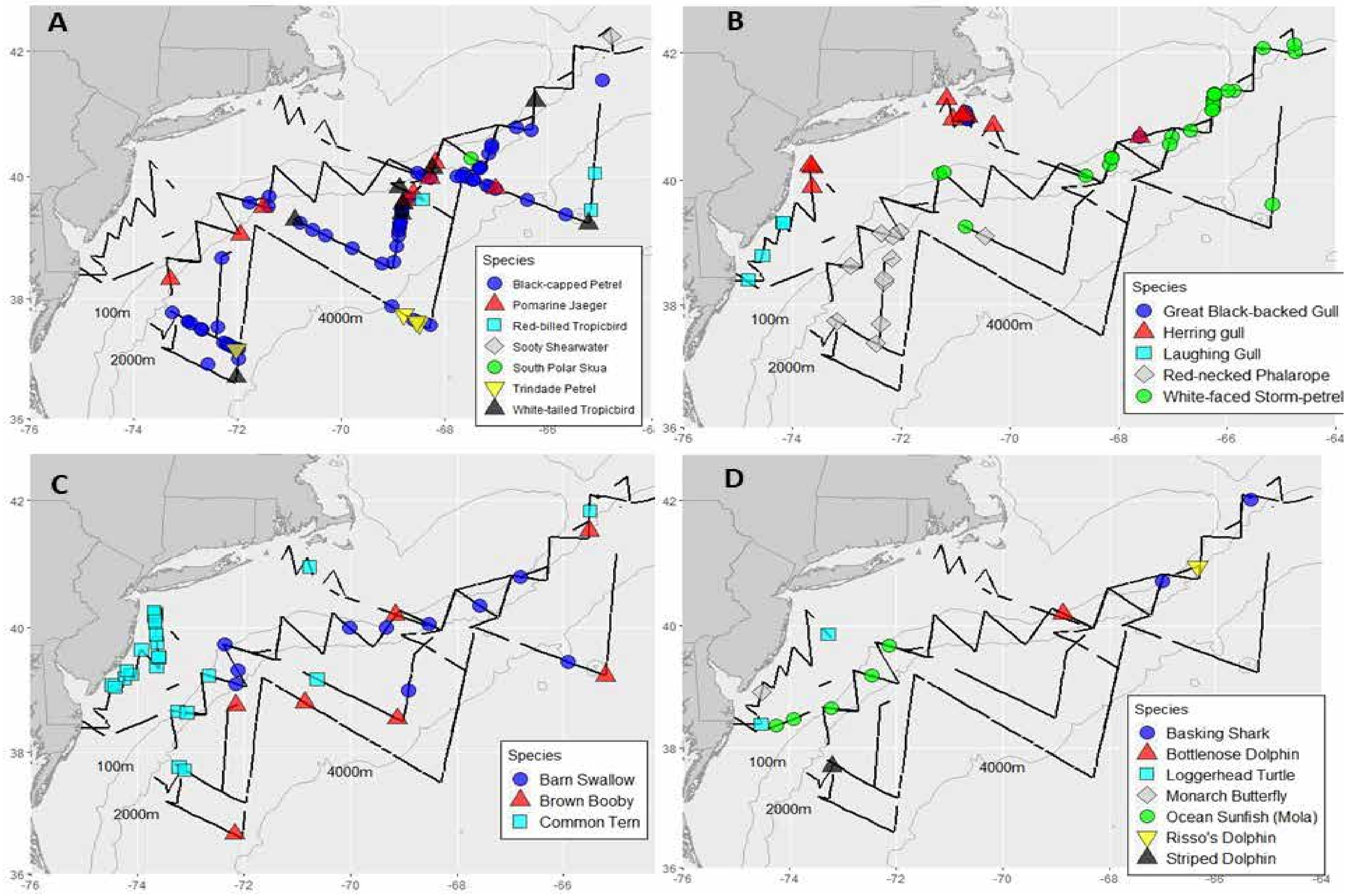

Figure 4-7 Seabirds, land birds, marine mammals, and turtles detected by seabird team on HB2102

Dolphins dominated the other sightings (Table 4-8), with common dolphins the most frequently detected. Other fauna we recorded including ocean sunfish, sharks, tuna, and sea turtles (Table 4-8). The most abundant non-animal observation we recorded was balloons.

Table 4-8 Number of non-birds within the survey zone and total counts by seabird observers

Common Name	Number in Zone	Total
Common dolphins	200	200
Striped dolphin	3	3
Cuvier's beaked whale	2	2
Bottlenose dolphin	0	4
Risso's dolphin	0	1
Loggerhead turtle	2	2
Ocean sunfish	14	14
Whale shark	4	5
Basking shark	1	2
Unidentified flying fish	1	1
Yellowfin tuna	0	9
Monarch butterfly	0	1
Latex balloon	3	3
Mylar balloon	2	2

4.5.3 Passive Acoustic Detection Team

Over the course of the survey, we conducted acoustic monitoring effort on 30 survey days resulting in 307 hrs of recording on survey tracklines (Table 4-9). We conducted the acoustic monitoring during the daytime visual survey effort, as well as opportunistic times before night oceanography operations started. We did not deploy the hydrophone array on days when the visual survey teams surveyed in shallow coastal waters.

Table 4-9 Summary of passive acoustic recording effort

Activity	Leg 1	Leg 2	Total
Days with towed array effort	13	17	30
Towed array recording hours	138.0	168.8	306.8

We acoustically classified sperm whales and beaked whales, when possible. We only classified delphinid encounters to species when there was a clear correspondence to visual sightings in real-time. We documented 559 groups of vocally-active odontocetes and 146 encounters with sperm whales when acoustic localization and tracking resulted in direct correspondence with visual sightings, or if acoustic characteristics matched what has been previously described in the literature, like for sperm whales and beaked whales (Figure 4-8; Table 4-10). The length of continuous sperm whale click recordings ranged from a few minutes to an hour and a half. We will finalize the calculation of the number of individual sperm whales from each leg through localization and tracking in post-processing analyses. Approximately 56% of the delphinid groups of 8 species corresponded to simultaneous visual detection, allowing for acoustic species assignment while in the field. At times, delphinid acoustic activity was so intense and prolonged that it precluded acoustic detections of any other species. In some cases, large schools of dolphins that covered a broad spatial range were difficult to localize accurately in real-time, making a direct comparison with visual sighting locations impossible. Additionally, in many cases it was impossible in real time to acoustically differentiate between subgroups of animals that the visual team distinguished and counted as separate sightings. These issues result in an underestimate of acoustic detections as compared to visual detections, which we will address in post-processing analyses. We will post-process the passive acoustic data to extract acoustic events of interest, compare visual and acoustic detection rates, and evaluate performance of species-specific classifiers.

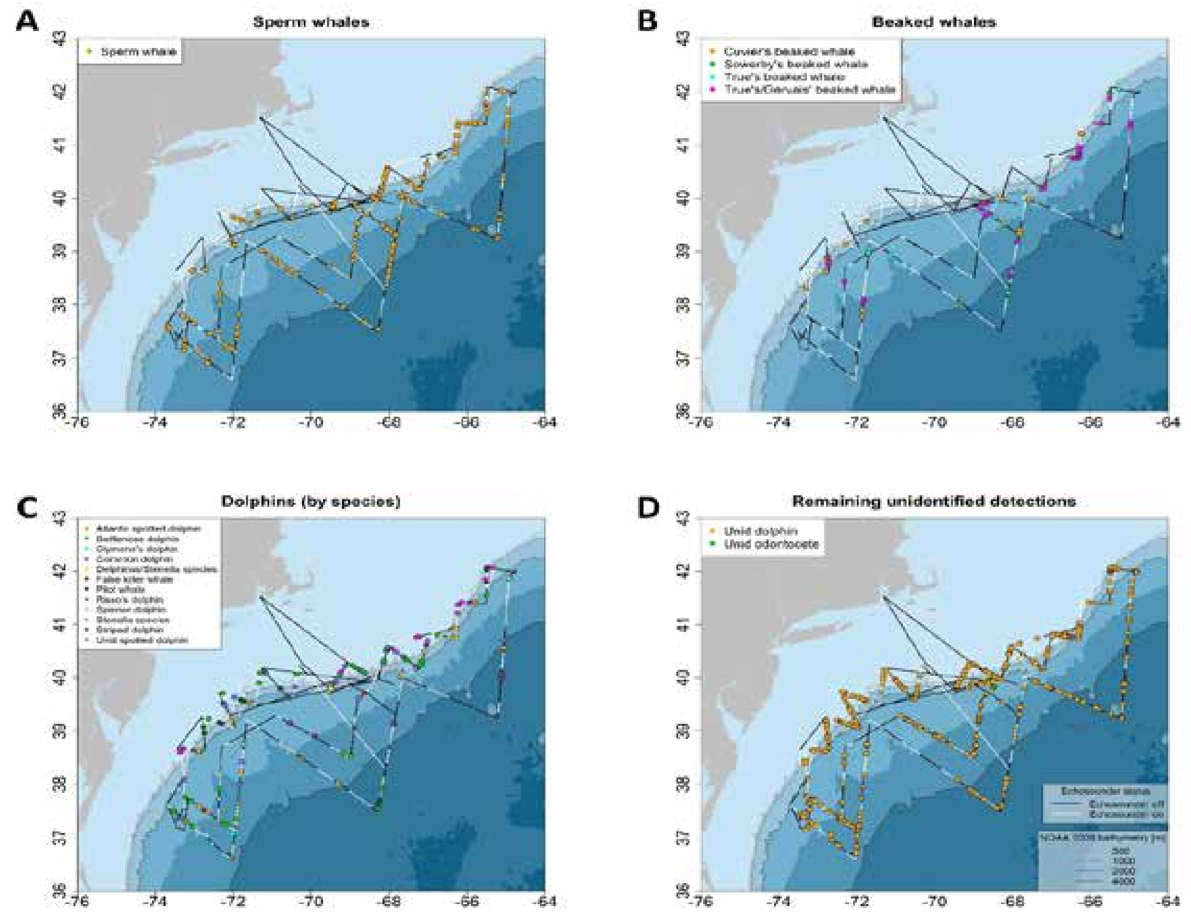

Figure 4-8 Summary of acoustic encounters detected in real-time during HB2102 survey
A) Sperm whale detection periods, B) beaked whale detections, C) classified dolphin detections, and D) unclassified dolphin and odontocete detections. Present are the contour lines and the ship's tracklines colored by echosounder state.

Table 4-10 Summary of acoustic encounters detected in real-time during HB2102
Groups without species assignment include both those not detected visually, as well as those not definitively linked to a visual sighting in real-time. In many cases, acoustic encounters include multiple individuals or groups (in the case of sperm whales), multiple subgroups (in the case of delphinids), or likely single individuals (in the case of beaked whales).

Species	Leg 1	Leg 2	Total
Bottlenose dolphin	16	27	43
Common dolphin	2	11	13
Atlantic spotted dolphin	4	11	15
Striped dolphin	3	7	10
Clymene’s dolphin	2	0	2
Spinner dolphin	1	0	1
Unidentified spotted dolphin	1	0	1
Delphinis/Stenella sp.	0	2	2
Stenella sp.	3	4	7
Risso's dolphin	10	18	28
Pilot whales	5	7	12
False killer whale	0	1	1
Unidentified dolphin	127	234	361
Cuvier's beaked whale	15	4	19
True's beaked whale	7	1	8
True’s/Gervais’ beaked whale	10	23	33
Sowerby’s beaked whale	0	2	2
Sperm whale	55	91	146
Unidentified odontocete	0	1	1
TOTAL	261	444	705

During Leg 1, we also attempted 7 echosounder playback experiments (Table 4-11) on 30 June 2021 just offshore of Hydrographer Canyon in about 2000 m of water. There were not enough clicks in most of the encounters (6 out of 8) to turn the echosounder into active mode. We will further review in the post-processing analysis the 2 experiments in which the 18 kHz of the EK60 switched to active mode. There were no opportunities during Leg 2 to conduct more playback experiments.

Table 4-11 Summary of opportunistic echosounder playback experiments

Experiment Number	Target Species	Additional Species Present	EK60 Switched into Active Mode?
1	True’s beaked whale	None	N
2	True’s/Bervais’ beaked whale	Cuvier’s beaked whale	Y
3	True’s beaked whale	None	N
4	True’s/Bervais’ beaked whale	Sperm whale	N
5	True’s/Bervais’ beaked whale	None	N
6	True’s/Bervais’ beaked whale	Unidentified dolphin	N
7	True’s/Bervais’ beaked whale	Cuvier’s beaked whale and Unidentified dolphin	Y

4.5.4 Oceanographic, Plankton, and Nekton Samples

The ship’s Scientific Computer System logger system continuously recorded oceanographic data from the ship's sensors (Table 4-12). We sampled using active acoustics and collected data at 298 sampling events (Table 4-13; Figure 4-9). More details from these sampling stations and gear types are below.

Table 4-12 Scientific Computer System (SCS) data collected continuously every second

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

Table 4-13 Summary of oceanographic and plankton operations conducted during HB2102

Operation	Number
CTD 19/19+ Water Cast Profile	18
CTD Profile 911+ vertical	9
CTD Profile 911+ water	9
CTD/Bongo	180
CTD/FrameNet	47
CTD/VPR TOW	33
TOTAL	296

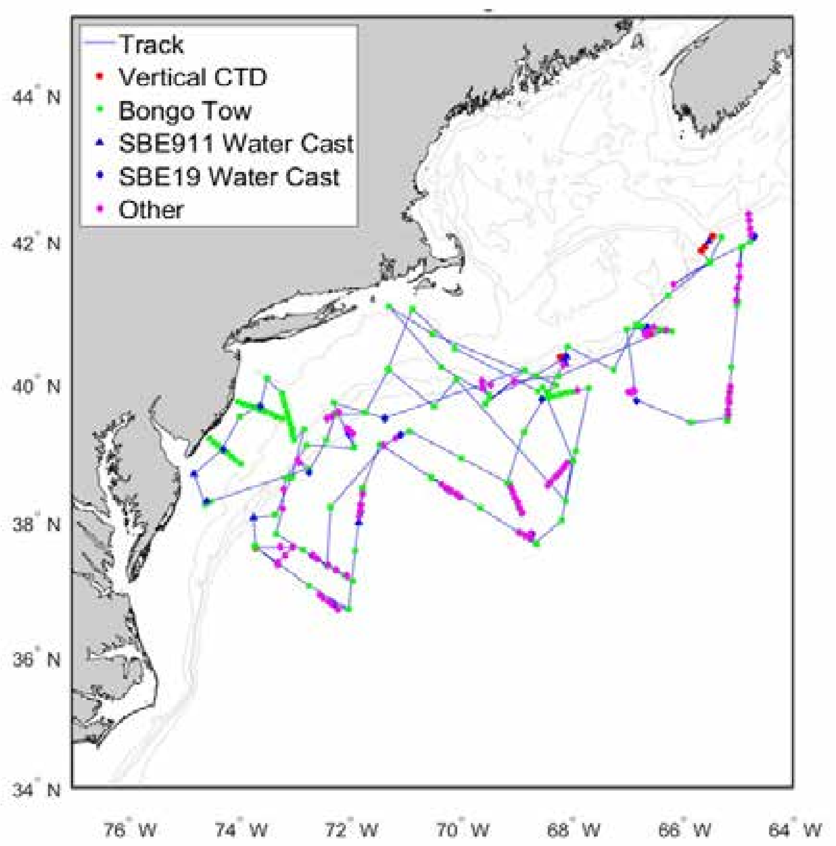

Figure 4-9 Oceanographic and plankton sampling conducted during HB2102
Other samples include either Video Plankton Recorder (VPR) hauls or 1x2m Frame net tows.

4.5.4.1 V-fin VPR Sampling

This is the first time we used a color VPR on an AMAPPS survey. On the first leg, due to gear failure, our VPR sampling was limited. We repaired the VPR between legs. Due to warm air temperatures that overheated the winch during the second leg, our tow-yo type sampling was limited.

We processed VPR hauls at sea to extract in focus color images and remove non-biological images, such as bubbles. We will use these images to create a new image library on VIAME (https://viame.kitware.com/) to create a machine-learning algorithm that will automatically identify the images to the lowest taxonomic level possible. After the cruise, using the same files, we extracted the images in a black and white format to use in the older Visual Plankton software to identify and enumerate the images. This dual processing will allow us to compare the machine-learning algorithm to the older matrix based identifications.

Gelatinous zooplankton was the dominant species seen during the cruise. Scaphozoan jellyfish (5 to 10 cm) were in large numbers at the surface during deployment times. In the top 20 m of the water column several species of Scaphozoan jellyfish, a salp (*Thalia democratica*), and dolids were plentiful. Species of zooplankton found deeper in the water column included euphausiids, copepods, and larval fish. (Figure 4-10).

Figure 4-10 Sample images collected by the VPR
Clockwise from top left: Euphausiid, *Thalia democratica*, dolid, larval fish, copepod, and scaphozoa.

4.5.4.2 Bluefin Tuna Spawning Area Sampling

We conducted paired tows along 14 transect lines. On 2 of the transects we only conducted bongo tows because either the concentrations of salp were so high they overfilled the nets or the water currents were so strong it made towing the large Frame net impractical. For gelatinous zooplankton over 5 cm in size, such as medusa or the heteropod *Carinaria sp.*, we rinsed, enumerated individuals on a log sheet, and then discarded them over the side.

4.5.4.3 Plankton Sample Processing

We have started processing the ethanol samples from the Frame net and Bongo collections. So far, from 47 Frame net samples and 6 Bongo net samples we sorted, removed, and counted larval fish, fish eggs, and cephalopod paralarvae (Table 4-14). Our next step is to identify and further analyze these sorted samples.

Table 4-14 Numbers and types of plankton samples currently sorted

Net Type	Number of Hauls	Number of Fish Larvae	Number of Fish Eggs	Number of Cephalopod Paralarvae
1x2 m Frame net	47	8,180	4,621	269
60-cm Bongo	6	682	1,527	10

4.5.4.4 Phytoplankton Sampling

The Imaging Flow Cytobot imaged all plankton in a size range of 10 to 100 μm within 5 ml aliquots of filtered seawater. Numbers of images per aliquot ranged from a low of 15 in the Gulf Stream and to over 3000 in inshore waters.

The public can access the images and data (Figure 4-11) at https://ifcb-data.whoi.edu/. We will post process the images by sorting them into categories based on phytoplankton type, and annotating each image with the location and environmental data from the ship's Scientific Computer System and CTD casts.

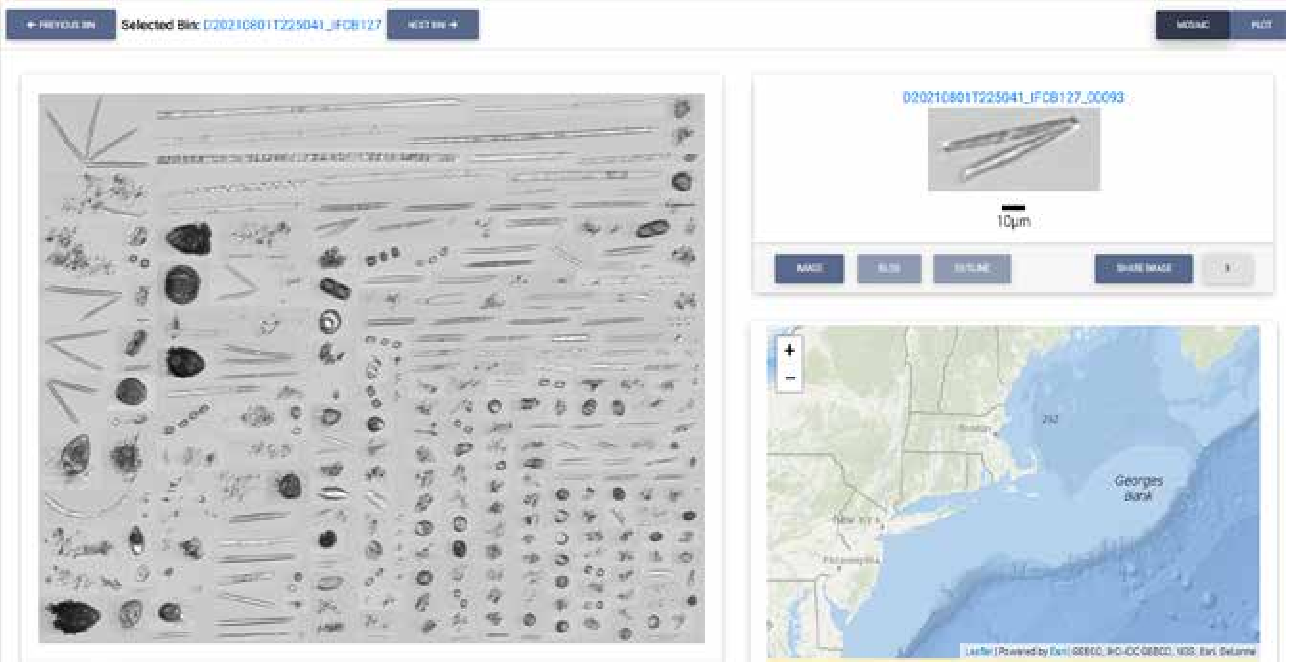

Figure 4-11 Imaging Flow Cytobot images as shown on the dashboard website
Clicking on each image brings up a full sized image with its associated metadata, as shown on the right side.

4.5.4.5 Oceanographic Sampling

Oceanographic sampling covered a wide variety of unique hydrographic conditions. We focused sampling on transects across the Northeast Channel. In addition, when we were along the southern New England and Georges Bank shelf breaks, we focused on waters in and around canyons (specifically, Hudson, Atlantis, Hydrographer, Welker, Lydonia, Munson, and Nygren Canyons).

4.5.4.6 Active Acoustic Sampling

We collected multifrequency echosounder data using the Simrad scientific EK60 general-purpose transceivers and EK80 software. The split beam transducers mounted to a retractable keel were at 11^{o} for the 18 kHz data and 7^{o} for the 38, 70, 120, and 200 kHz data. The EK60 collected data to 3000 m.

We switched the echosounder state between active and passive modes based on location rather than time during daylight hours (as was done in previous AMAPPS abundance surveys). When we surveyed even numbered tracklines along the shelf break for the first time, we ran the echosounders in active mode. When surveying the odd number tracklines along the shelf break we run with the echosounders in passive mode. We reversed this if we surveyed the same trackline more than once. For the longer offshore tracklines, we adjusted the echosounders based on a temporal schedule. The echosounder was in active mode from 0500 to 0700, 1000 to 1300, and 1600 until 0700 the following day.

We operated the echosounders in active mode during night hours to facilitate plankton and other biological sampling.

4.5.4.7 Special Sampling

Two researchers requested we collect special zooplankton samples during this cruise.

4.5.4.7.1 Ann Bucklin: University of Connecticut

We collected 99 samples of salps that we rinsed in filtered seawater to remove all other plankton, placed the samples in individual vials and immediately frozen them in the -80°C freezer. After the survey, we transferred the samples to a liquid nitrogen dewar for transport to the University of Connecticut. There researchers will genetically code the salp species. The salp species we preserved were mostly *Thalia democratica*, although we also preserved samples of *Salpa* sp., *Iasis zonata*, and *Cyclosalpa* sp.

4.5.4.7.2 Lanna Cheng: Scripps Institution of Oceanography

While at sea, we searched all plankton samples to identify the insect *Halobates sp.* that is typically on the surface of the ocean. If we could find individuals, then we were to preserve them in 75% ethanol for genetics studies. Unfortunately, we did not encounter any specimens of *Halobates sp.*

4.6 Disposition of the Data

The Protected Species Branch at the NEFSC in Woods Hole, MA maintains all visual and passive acoustic data that we collected. We will archive the final audited versions in the NEFSC ORACLE database. Marine mammal and sea turtle sightings recorded by the primary team and associated effort will be available online at OBIS-SEAMAP (http://seamap.env.duke.edu/). We will archive the complete data set at the National Centers for Environmental Information (https://www.ncei.noaa.gov/) so that it is publically available. We will submit the seabird data to the seabird compendium. The data presented here are preliminary and subject to change as we perform further auditing and analyses.

We archive all active acoustic data at the NEFSC and at NOAA's National Center for Environmental Information (NCEI) facility in Boulder, CO so that they are publically available.

The Oceans and Climate Branch at the NEFSC in Woods Hole, MA processes all hydrographic data we collected. Hydrographic data are accessible through the World Ocean Database: https://www.ncei.noaa.gov/products/world-ocean-database.

The Oceans and Climate Branch at the NEFSC in Narragansett RI maintains all plankton samples that we collected. Taxonomists in Woods Hole and Narragansett Plankton will identify all samples in ethanol. We will send the plankton samples in formaldehyde to Poland for identification. After identification and enumeration are complete, the plankton data will be maintained on the NEFSC's Oracle database and available by request.

The Oceans and Climate Branch at the NEFSC in Woods Hole, MA will process and maintain all VPR data. VPR oceanographic data and images are available by request.

Woods Hole Oceanographic Institution will maintain all Imaging Flow Cytobot data. Metadata and images are accessible through their website https://ifcb-data.whoi.edu/. Select the cruise timeframe from the bar graph on the top of the page.

The data presented here are preliminary and subject to change as we perform further auditing and analyses.

4.7 Permits

The NEFSC conducted the marine mammal research activities during the survey under Permit No. 21371 issued to the NEFSC by NMFS, and under the SARA Permit No. DFO-MAR-2021-06 issued to the NEFSC by the Fisheries and Oceans Canada.

4.8 Acknowledgements

We would like to thank the crew of the NOAA ship *Henry B. Bigelow* and the scientists that were involved in collecting these data. In addition to the 3 sources of funds specified in section 1.4 of this document (NMFS, and the 2 interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy), the NOAA Office of Marine and Aviation Operations funded ship time and other ship costs. NEFSC and the NOAA Office of Marine and Aviation Operations provided staff time of the crew and scientists. Azura Consulting LLC and Integrated Statistics, Inc., contract NFFM7320 with the NEFSC, carried out some of the staff time.

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

Harvey Walsh[1], *Debra Palka*[2]

[1] Northeast Fisheries Science Center, 28 Tarzwell Dr., Narragansett, RI 02882
[2] Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543

5.1 Summary

To conduct comprehensive visual surveys of seabirds, marine mammals, turtles, large pelagic fish, and marine debris on shipboard cruises, we piggybacked on research cruises conducted by the National Oceanic and Atmospheric Administration (NOAA) or other organizations. On each cruise, 2 dedicated observers alternated conducting a 300 m strip transect survey during daylight hours when the ship was traveling at 6 or more knots. During 2021, the observers joined 3 the Northeast Fisheries Science Center's (NEFSC) Ecosystem Monitoring (EcoMon) cruises. These cruised covered waters from Maryland to Maine and surveyed nearly 5,000 km of track line in 35 survey days. Despite the fact that the surveys were in the same general region, the numbers of detected seabirds and marine mammals varied dramatically by season. In the spring cruise, observers recorded over 8,400 seabirds (4.35/km) and 980 marine mammals (0.51/km). In contrast, during the fall, observers detected 1,800 seabirds (1.33/km) and 411 (0.31/km) marine mammals.

5.2 Objective

The goal of this at-sea monitoring program is to conduct comprehensive visual surveys of seabirds, marine mammals, turtles, large pelagic fish, and marine debris on shipboard cruises being conducted on the Northwest Atlantic US shelf ecosystem by piggy-backing on research cruises conducted by NOAA or other organizations. Collecting seabird and marine mammal data concurrently with other biological data and abiotic factors will help to understand the spatiotemporal distributions of the species and relationships with other trophic levels within the changing marine ecosystem on the Northeast Atlantic US shelf.

5.3 Methods

The observers conducted a standardized 300 m strip transect methodology and recorded the data into the SeaScribe data entry program (BRI 2020). We describe further the protocols and data entry program in section 4.4.2 of this document.

5.4 Results

During 2021, seabird/marine mammal observers piggybacked on 3 EcoMon surveys led by the NEFSC and conducted on 2 NOAA vessels during 3 seasons (Table 5-1). All surveys covered waters from Maryland to Maine, with the fall survey also covering some mid-Atlantic shelf waters (Figure 5-1).

EcoMon's principal objective is to survey the hydrographic, planktonic, and pelagic components of the Northeast US continental shelf ecosystem. Specifically, to quantify the spatial distribution of the following parameters: water currents, water properties, phytoplankton, microzooplankton, mesozooplankton, sea birds, sea turtles, and marine mammals.

Despite the fact that the surveys were in the same general region, the numbers of detected seabirds and marine mammals varied dramatically by season. The observers recorded over 8400 seabirds in the spring, with only about 1800 in the fall (Table 5-2). The large spring (GU2102) count included 3,829 red phalaropes (*Phalaropus fulicarius*), 851 Wilson's storm-petrels (*Oceanites oceanicus*), 556 unidentified terns (*Sterna sp*.), 582 Leach's storm-petrels (*Oceanodroma leucorhoa*), and 543 northern fulmars (*Fulmarus glacialis*). The top 3 most numerous species in the summer (PC2104) were 1,599 Wilson's storm-petrels, 1,436 great shearwaters (*Puffinus gravis*), and 255 unidentified phalaropes. In contrast in the fall (PC2106), the 3 most numerous species were 402 great shearwaters, 343 Manx shearwaters (*Puffinus puffinus*), and 275 Cory's shearwaters (*Calonectris diomedea*).

All 3 offshore surveys recorded a handful of land birds (Table 5-3). All surveys detected bottlenose dolphins (*Tursiops truncatus*), common dolphins (*Delphinus delphis*), fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), pilot whales (*Globicephala* sp.), and North Atlantic right whales (*Eubalaena glacialis*; Table 5-4). They also detected a few loggerhead turtles (*Caretta caretta*) and leatherback turtles (*Dermochelys coriacea*) only in the fall. In addition, they also opportunistically recorded a variety of fish and debris items (Tables 5-5 and 5-6).

Table 5-1 Summary of EcoMon cruises seabird observers piggybacked on during 2021
For each cruise, the summary includes the ship, start, and end date of on-watch observation effort, and resulting number of days with some effort and track line length.

Cruise Designation	Ship	Start Date	End Date	On-effort Length (km)	Number of Effort Days	Observers
GU2102	NOAA Ship Gordon Gunter	14-May-21	26-May-21	1,932	12	Allison Black Douglas Gochfeld
PC2104	NOAA Ship Pisces	06-Aug-21	18-Aug-21	1,664	13	Allison Black Douglas Gochfeld
PC2106	NOAA Ship Pisces	16-Oct-21	25-Oct-21	1,346	10	Allison Black Thomas Johnson
TOTAL				4,942	35	

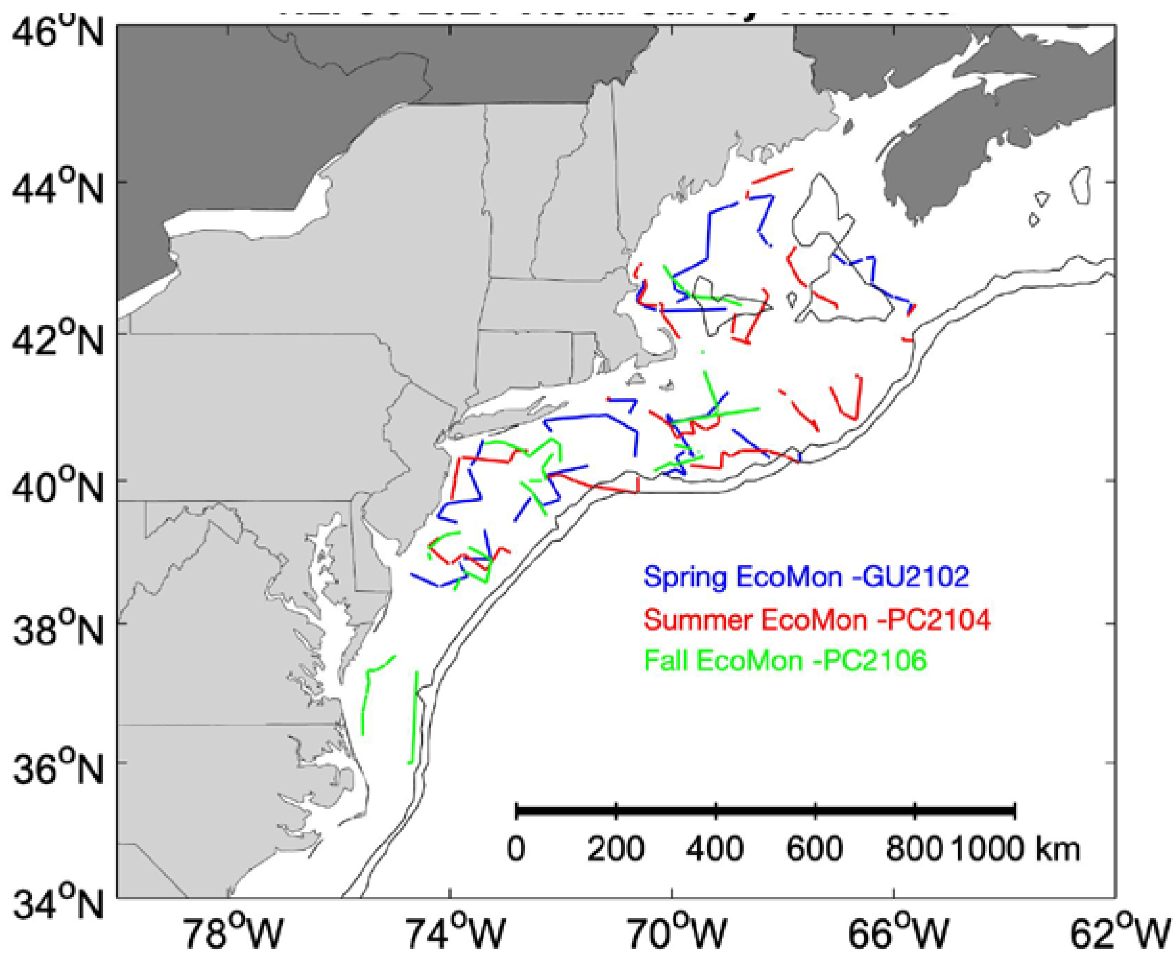

Figure 5-1 Locations of the 2021 EcoMon cruises with seabird observers

Table 5-2 Numbers of seabirds recorded during each of the 2021 EcoMon cruises

Species	GU2102	PC2104	PC2106	Species	GU2102	PC2104	PC2106
American golden plover	0	0	1	Razorbill	2	0	9
Arctic tern	38	0	0	Red-necked phalarope	109	144	0
Atlantic puffin	151	6	0	Red-throated loon	8	0	1
Audubon's shearwater	0	220	0	Red phalarope	3,829	52	33
Barolo shearwater	0	1	0	Ring-billed gull	0	0	12
Black-capped petrel	0	0	43	Roseate tern	2	0	0
Black-legged kittiwake	0	0	59	Ruddy turnstone	0	1	0
Black scoter	0	0	13	Semipalmated sandpiper	0	3	0
Black tern	1	0	0	Sooty shearwater	205	20	8
Bonaparte's gull	1	0	27	South polar skua	6	4	2
Brown booby	1	3	1	Surf scoter	0	0	88
Common eider	0	0	16	Thick-billed murre	5	0	0
Common loon	70	0	4	Unidentified Alcid	6	0	0
Common murre	3	0	0	Unidentified bird	1	0	0
Common tern	312	23	0	Unidentified gull	76	0	0
Common/Roseate tern	1	0	0	Unidentified jaeger	3	1	3
Cory's shearwater	0	132	275	Unidentified large gull	2	0	0
Dark scoter	0	0	10	Unided large shorebird	0	22	0
Double-crested cormorant	150	6	3	Unidentified loon	4	0	0
Dovekie	16	2	0	Unidentified murre	1	0	0
Dunlin	0	0	15	Unidentified phalarope	0	255	2
Forster's tern	3	0	0	Unidentified shearwater	4	2	0
Great black-backed gull	43	94	27	Unidentified shorebird	12	2	2
Great blue heron	1	0	6	Unidentified Skua	3	2	0
Great cormorant	1	0	0	Unided small shorebird	36	9	0
Great egret	2	0	0	Unidentified small tern	1	0	0
Great shearwater	193	1,436	402	Unidentified storm-petrel	1	2	0
Great skua	0	1	1	Unidentified Sulid	1	0	0
Greater yellowlegs	0	0	1	Unidentified tern	556	2	11
Herring gull	219	73	188	Unidentified yellowlegs	0	0	2
Laughing gull	141	16	11	White-faced storm-petrel	0	3	1
Leach's storm-petrel	582	142	0	White-winged scoter	68	0	28
Least sandpiper	0	3	0	Wilson's storm-petrel	851	1,599	15
Least tern	0	1	0	TOTAL	8,408	4,319	1,797
Lesser black-backed gull	3	3	23				
Long-tailed duck	0	0	1				
Long-tailed jaeger	1	1	0				
Manx shearwater	26	9	343				
Northern fulmar	543	0	8				
Northern gannet	104	17	77				
Northern waterthrush	0	1	0				
Parasitic Jaeger	9	0	1				
Pomarine Jaeger	1	4	24				

Table 5-3 Numbers of land birds recorded during each of the 2021 EcoMon cruises

Species	GU2102	PC2104	PC2106
Barn swallow	16	6	0
Blackburnian warbler	3	0	0
Brown creeper	0	0	1
Brown-headed cowbird	0	1	1
Cape May warbler	1	0	0
Cedar waxwing	0	2	0
Chimney swift	4	0	0
Chipping sparrow	1	0	0
Common yellowthroat	1	0	0
Dark-eyed junco	0	0	1
dragonfly spp.	0	1	0
Eastern meadowlark	0	0	1
Golden-crowned kinglet	0	0	1
Gray catbird	0	0	1
Magnolia warbler	1	0	0
Marsh wren	0	0	1
Merlin	0	0	1
Monarch butterfly	0	3	1
Mourning dove	0	0	4
Myrtle Warbler	0	0	1
Northern rough-winged swallow	1	0	0
Palm warbler	1	0	2
Peregrine falcon	0	0	4
Prairie warbler	1	0	0
Savannah sparrow	1	0	0
Tree swallow	0	2	0
Unidentified blackbird	1	0	0
Unidentified passerine	1	0	1
Unidentified peep	0	0	6
Unidentified warbler	0	1	0
White-throated sparrow	0	0	1
Wood duck	0	0	8
Yellow-rumped warbler	1	0	2
TOTAL	34	16	38

Table 5-4 Numbers of marine mammals recorded during each of the 2021 EcoMon cruises

Species	GU2102	PC2104	PC2106
Atlantic white-sided dolphin	0	65	0
Bottlenose dolphin	76	161	58
Common dolphin	645	248	301
Fin whale	21	21	2
Humpback whale	16	5	17
Leatherback turtle	0	0	1
Loggerhead turtle	0	0	2
Long-finned pilot whale	35	1	0
Minke whale	0	4	0
Pilot whale	28	2	8
Right whale	2	4	6
Risso's dolphin	0	20	0
Sperm whale	0	1	0
Unidentified beaked whale	1	1	0
Unidentified cetacean	4	0	0
Unidentified dolphin	141	40	8
Unidentified large whale	7	2	8
Unidentified small whale	0	2	0
Unidentified whale	6	3	0
TOTAL	982	580	411

Table 5-5 Numbers of fish recorded during each of the 2021 EcoMon cruises

Species	GU2102	PC2104	PC2106
Basking shark	3	0	0
Ocean sunfish	3	5	7
Portuguese man o' war	0	2	10
Unidentified fish	0	1	0
Unidentified large fish	2	1	2
Unidentified manta ray	1	0	0
Unidentified ray	0	4	0
Unidentified shark	9	10	0
Unidentified thresher shark	2	0	0
Unidentified tuna	0	25	0
TOTAL	20	48	19

Table 5-6 Numbers of non-animals recorded during each of the 2021 EcoMon cruises

Item	GU2102	PC2104	PC2106
Balloon	29	0	0
Fishing gear	23	50	0
Fixed gear--lobster	0	25	0
Fixed gear--unidentified	0	1	0
Latex balloon	47	12	0
Mylar balloon	124	24	0
Plastic	1	20	0
Styrofoam	1	0	0
TOTAL	225	132	0

5.5 Disposition of the Data

The Protected Species Branch at the NEFSC in Woods Hole, MA maintains all visual data collected during these surveys. We will archive these data in the NEFSC's Oracle database and submit them to the seabird compendium.

The data presented here are preliminary and subject to change as we perform further auditing and analyses.

5.6 Permits

The NEFSC conducted the marine mammal research activities during these surveys under Permit No. 21371 issued to the NEFSC by NMFS.

5.7 Acknowledgements

We would like to thank the crew of the NOAA ships *Gordon Gunter* and *Pisces* and the scientists involved in collecting these data. In addition to the 3 sources of funds specified in section 1.4 of this document (NMFS, and the 2 interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy), the NOAA Office of Marine and Aviation Operations funded ship time and other ship costs. The NEFSC and the NOAA Office of Marine and Aviation Operations staffed the crew and scientists. Azura Consulting LLC and Integrated Statistics, Inc., contract NFFM7320 with the NEFSC provided the staff time for the scientific observers.

6 Shipboard shelf break ecology survey: Northeast Fisheries Science Center

Danielle Cholewiak

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

6.1 Summary

The Northeast Fisheries Science Center planned a shipboard survey from 5 to 20 Sep 2021, covering the shelf break and offshore of Georges Bank (Figure 6-1) where there is a consistent presence of deep-diving cetacean species. This was part of a series of surveys from the Integrated Technologies for Deep Diver Ecology Program (ITS.DEEP). The primary goals were to test and integrate multiple new technologies to assess the ecology and distribution of deep-diving cetaceans, including beaked whales (*Ziphiidae*), dwarf and pygmy sperm whales (*Kogia* sp.), and sperm whales (*Physeter macrocephalus*). We intended the 2021 survey to integrate data on multispecies presence with prey data to assess fine-scale habitat use and foraging ecology.

A team of 11 scientists from 5 institutions planned to participate in the survey on the NOAA ship *Pisces*. Prior to the survey, the scientists and crew participated in 2 COVID-related shelter-in-place periods. Hurricane Ida interrupted the first period, where several members of the ship's crew had to return home, and thus the ship could not sail due to insufficient staffing. After new augmenters came to New England, the scientists and crew started the second shelter-in-place period. During that period, 2 members tested positive for COVID-19, again rendering the ship unable to sail due to insufficient staffing levels. After that, now due to lack of time, we cancelled the survey.

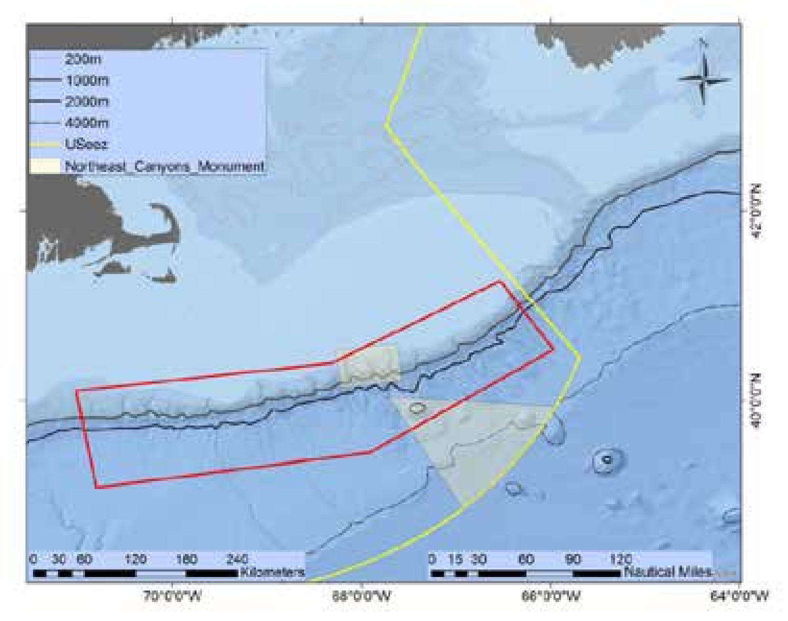

Figure 6-1 Planned survey study area for the deep diver ecology cruise

7 Progress of sea turtle ecology research: Northeast and Southeast Science Centers

Heather Haas[1], *Chris Sasso*[2]

[1] Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543
[2] Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149

7.1 Summary

During 2021, the AMAPPS Turtle Ecology team completed fieldwork to deploy satellite tags on loggerhead turtles (*Caretta caretta*) in February and March off North Carolina (9 tags), and in May off the mid-Atlantic Bight (22 tags). The team also deployed satellite tags on leatherback turtles (*Dermochelys coriacea*) in May off North Carolina (2 tags), and in August and September off Massachusetts (1 tag). The objectives of these fieldwork activities were to gather information on turtle behavior and dive patterns, and collect biological samples. In addition to fieldwork, the team continued developing the Oracle database of all of the satellite tag data and associated metadata. The team also made considerable progress on 4 manuscripts of which we recently published 2 peer-reviewed papers (projected shift in loggerhead habitat due to climate change; baseline model for estimating the risk of gas embolism in sea turtles during routine dives) and 2 manuscripts are in review (surface availability metrics of leatherback turtles and loggerhead turtles).

7.2 Fieldwork

During 2021, the AMAPPS Turtle Ecology team completed several fieldwork trips.

In February and March, the Northeast Fisheries Science Center (NEFSC) collaborated with their Gear Research team to deploy satellite tags on loggerhead sea turtles off North Carolina, gathering valuable information on turtle behavior such as surface duration and dive depth.

In May, the Southeast Fisheries Science Center (SEFSC) and NEFSC collaborated on satellite tagging leatherback sea turtles off North Carolina on the *R/Vs Julius* and *Selkie*. The main objectives of this research were to gather data on leatherback surfacing behavior and habitat use.

In May, Coonamessett Farm Foundation (CFF), funded from an Atlantic Sea Scallop Research Set Aside Cooperative Agreement, led a loggerhead research cruise aboard the *F/V Kathy Ann*. Heather Haas was the NEFSC Point of Contact to represent AMAPPS Turtle Ecology priorities. During this cruise, researchers deployed satellite tags on loggerheads off the Mid-Atlantic Bight.

In August and September, SEFSC, NEFSC, and others collaborated for leatherback satellite tagging aboard the *M/V Warren Jr*. in Massachusetts state waters and in federal waters. This cruise allowed us to gain experience in leatherback field operations in an area south of the Massachusetts islands.

7.2.1 Loggerhead Fieldwork

February and March 2021. NEFSC deployed 9 satellite tags on loggerhead sea turtles off North Carolina in February and March 2021, thanks to collaboration from the Gear Research Team. We applied flipper and PIT (microchip) tags to each turtle. In addition, we collected biological samples (skin) for future stable isotope and genetic analyses from each loggerhead. The data from these tags will provide us with a greater understanding of turtle behavior including surface duration, dive depth, and migratory routes. Of the 9 satellite tags deployed on loggerheads, 2 tags transmitted data until September 2021, 4 tags transmitted through October 2021, 1 tag transmitted until November 2021, and 2 tags transmitted data as recently as December 2021 that is about 9 months post-deployment.

Field crew included Eric Matzen, Brian Galvez, Blake Price, and Charlie Locke (captain), with remote tagging support from Heather Haas, Samir Patel, Rick Rogers, and Kate Choate.

The team conducted this work under US Permit No. 17225 issued to the Gear Research Team and US Permit No. 22218 issued to the Turtle Ecology Team.

May 24 to 28, 2021. We collaborated to deploy loggerhead satellite tags on a cruise from May 24 - 28, 2021 aboard the *F/V Kathy Ann*. CFF, funded from an Atlantic Sea Scallop Research Set Aside Cooperative Agreement, led the cruise aboard the *F/V Kathy Ann*. Heather Haas was the NEFSC Point of Contact to represent AMAPPS Turtle Ecology priorities. The team deployed 22 satellite tags (13 owned by CFF, 7 owned by NEFSC, and 2 owned by University of North Carolina) on loggerheads off the Mid-Atlantic Bight (Figure 7-1). This brought our collaborative total loggerhead satellite tags deployed to 31 for calendar year 2021. The team also attached two flipper tags and inserted a PIT tag (for identification purposes) in each of the 22 loggerheads. The team collected biological samples (blood and skin) for future stable isotope and genetic analyses conducted by research collaborators.

Fieldwork crew included Samir Patel, Liese Siemann, Farrell Davis, and Luisa Garcia (CFF), Sophie Mills (Purdue University Fort Wayne), and Laura St. Andrews (Purdue University Fort Wayne).

The team conducted this research under US Permit No. 23639 issued to Coonamessett Farm Foundation.

Figure 7-1 Satellite tag affixed to carapace of a loggerhead sea turtle aboard the *F/V Kathy Ann*
US Permit No. 23639.

7.2.2 Leatherback Fieldwork

May 10 to 22, 2021. NEFSC and SEFSC collaborated for leatherback satellite tagging off North Carolina using *R/V Julius* and *R/V Selkie*. The main areas of focus were to collect data on surface behavior, describe the turtles' migratory routes, and to anticipate potential conflicts between human activities and habitat use. That is, we were interested in how long leatherbacks spend at the surface of the water at different times of year and at different locations, so that it would be possible to estimate how often the turtles are visible during aerial surveys intended to document presence and estimate abundance. This year we encountered conditions surprisingly different from those of previous years, with record cold temperatures and almost constant high winds during the weeks we conducted the study. Biological observations also reflected the difference in weather. We observed a decrease in numbers of potential leatherback prey, like jellyfish, and other fish species. In addition, we observed a near absence of leatherbacks in very nearshore waters where we normally find them. Although these conditions were unusual, unexpected, and not those that typically facilitate leatherback capture, it was important to document the anomaly, as it highlights the need to collect data over multiple years to capture the variability. Despite all of these challenges, we were able to successfully tag 2 leatherback turtles, whose tags are transmitting well and providing valuable information to compare and contrast with results from turtles tagged in previous years (Figure 7-2).

Fieldwork crew included Chris Sasso, Annie Gorgone, Larisa Avens, and Blake Price (SEFSC), Craig Harms (North Carolina State University), Emily Christiansen (NC Aquariums veterinarian), Mitch Rider (University of Miami), Heather Haas and Joshua Hatch (NEFSC), Samir Patel (CFF), and Matthew Godfrey (NC Wildlife Resources Commission).

The team conducted this research under the NMFS ESA Permit No. 16733 issued to the SEFSC.

Figure 7-2 Pursuing a leatherback sea turtle with a breakaway hoop net
US Permit No. 21233-03 to NMFS SEFSC.

August and September 2021. In August and September 2021, SEFSC, NEFSC, and others collaborated for leatherback satellite tagging departing from Woods Hole, MA aboard the *M/V Warren Jr*. We had an unexpected opportunity to receive charter vessel time in 2021, so we used the charter time to support AMAPPS and our new Regional Ecosystem Research project. In 2021, NEFSC and partners began a Regional Ecosystem Research project of Assessing Multi-species Habitat Use and Connectivity of Marine Protected Areas in the Gulf of Maine (https://coastalscience.noaa.gov/project/assessing-multi-species-habitat-use-and-connectivity-of-marine-protected-areas-in-the-gulf-of-maine/). The turtle ecology component of this project includes support in FY22 and FY23 that will augment AMAPPS funds to tag leatherbacks in key animal habitat and wind development areas south of Martha's Vineyard and Nantucket. We used this 2021 ship time to set the stage for more concentrated effort in FY22 and FY23. The main goals of this cruise were to continue collecting data on the surfacing behavior of leatherback turtles, and to fill a data gap regarding coastal leatherback sea turtle movements and habitat use. Understanding the seasonal and spatially varying proportions of time leatherbacks spend at the surface (Figure 7-3) provides the necessary corrections for availability of the turtles counted during AMAPPS aerial abundance surveys. In addition, characterizing relative importance of different habitats and vertical use of the water column for leatherbacks in the region is essential for determining overlap with and impacts of wind energy development and fishing activities.

The cruise faced several challenges including COVID-19 mitigation complications, impacts from two hurricanes, communication issues with the contracted plane, and the need to establish small boat launch and recovery protocols on the contracted ship. This cruise allowed for the first integration of shipboard operations with typical AMAPPS leatherback small boat operations expanding our offshore range for locating, pursuing, capturing, tagging, and tracking these turtles. With the availability of shipboard support, we were able to first refine logistics in a nearshore environment and then when weather conditions allowed, move further offshore to trial the approach further offshore. This fieldwork was remarkable in that Hurricane Henri was at the beginning and then Hurricane Ida was at the end of the fieldwork. In combination with typical daily weather variability, these hurricanes shortened the planned 2-week field effort to 5 days with conditions allowing on-water operations to occur. Passage of Hurricane Henri coincided with an apparent shift in the leatherback's distribution in nearshore waters. As a result, we did not see any leatherbacks in the areas where they found them during the first 4 days of operations in Nantucket Sound, Vineyard Sound, and Cape Cod Bay. On the final day, conditions allowed offshore work on Nantucket Shoals where we sighted leatherbacks (along with numerous large ocean sunfish (*Mola mola*). As a result, we captured 1 large female leatherback, which we measured and collected blood and skin samples for biochemistry and isotope analyses, respectively. We also applied flipper and microchip PIT tags, in addition to a satellite tag.

Chris Sasso (SEFSC) was the Point of Contact for the AMAPPS leatherback sea turtle research, in collaboration with Heather Haas (NEFSC). In addition, Annie Gorgone (SEFSC), Larisa Avens (SEFSC), Lisa Conger (NEFSC), Samir Patel (NEFSC), Mitch Rider (University of Miami), and Emily Christensen (NC Aquariums veterinarian) participated in the fieldwork.

The team conducted this research under the NMFS ESA Permit No. 16733 issued to the SEFSC.

Figure 7-3 Leatherback sea turtle surfacing in Nantucket Shoals during September 2021
US Permit No. 16733.

2021. In 2021, we anticipated conducting fieldwork with the Coonamessett Farm Foundation to support a leatherback sound exposure project funded by the Bureau of Ocean Energy Management (BOEM). However, due to permitting issues, we delayed this work until 2022. In 2021, we focused on logistical issues, where NEFSC will supply logistics and vessel support in return for sharing availability data. The goal of this project is to determine the impacts of impulsive sounds on the behavior of free-swimming leatherback turtles in Massachusetts (and federal) waters. We will deploy short-term suction cup tags equipped with cameras (built by Loggerhead Instruments) on leatherback turtles to record dive behavior, location, and ambient sound. After tag deployment, we will conduct controlled sound exposure experiments using a sparker (used for seismic surveys) emitting a low frequency, high-intensity impulsive sound. The camera tags will record the turtles before, during, and after the controlled sound exposure experiments to document any changes in movement patterns or behavior.

7.3 Progress in Sea Turtle Analyses

In 2021, we continued to develop our Turtle Ecology Oracle database, improving its organization and documentation. One important addition was a new Oracle View that streamlines the pre-processing of satellite tag data in preparation for interpolation of hourly positions. After extensive database improvements last year, we maintain the current system and make adjustments as needed. In preparation for manuscript development, we assembled multiple data streams of high resolution data related to leatherback surfacing behavior.

This year we also made considerable progress on 4 manuscripts, of which 2 are in review, and 2 recently published (see below).

7.3.1 Preliminary Surface Availability Metrics of Leatherback Turtles

Rider, MJ, HL Haas, C Sasso. In review at NEFSC for publication as a Center Reference Document. Preliminary surface availability metrics of leatherback turtles (*Dermochelys coriacea*) tagged off North Carolina and Massachusetts, United States.

This manuscript provides preliminary information on leatherback surfacing behavior. The AMAPPS Turtle Ecology program is mid-way through a five-year program designed to collect and analyze leatherback sea turtle behavioral data. To address immediate needs of US federal agencies for data on leatherback surfacing information, we are providing simple summary statistics from our partially completed project. Because of the imminent need for data in the midst of an ongoing project, we followed the procedural and methodological precedent set in NEFSC 2011. The AMAPPS III Turtle Ecology study plan includes more data collection and more sophisticated data analysis, so this current document is a preliminary product to take advantage of existing data while we continue to pursue the longer-term AMAPPS III data collection and analysis goals.

Between 2017 and 2019, we caught leatherback turtles off the coasts of Massachusetts and North Carolina using a 2-m breakaway hoop net. Upon a successful capture, we equipped the turtles with satellite-linked transmitters (Wildlife Computers MK-10AF) via a tether attached to the caudal peduncle. In addition to reporting location, we programmed these transmitters to record depth metrics, such as time at depth, within 6 hr bins. Time at depth refers to the proportion of time a turtle spent within specific depth bins. For this study, we defined the time at depth-2 as the first 2 depth bins, which together represent the proportion of time spent in water shallower than 2 m including time when the sensor was dry at the surface.

We tagged 29 turtles, 11 tags deployed in Massachusetts waters and 18 in North Carolina waters. Along the east coast of the United States and Canada, the tagged turtles moved as far south as Florida and as far north as Nova Scotia with concentrated movements between North Carolina and Massachusetts. Some turtles moved far off the North American continental shelf as far east as the central Northwest Atlantic Ocean and as far south as Panama. Mean time at depth-2 appeared to increase from December through May and then decreased from June through November. The standard deviation for each month was large, indicating a high amount of variability in the time at depth across all dives and turtles. Median time at depth-2 demonstrated the same pattern as the mean. Researchers should consider several issues before using these data to account for availability bias in the analysis of line-transect data producing density and abundance estimates.

7.3.2 Surface Availability for Loggerhead Turtles

Hatch, JM, HL Haas, CR Sasso, SH Patel, RJ Smolowitz. In review at Journal of Wildlife Management. Estimating the complex patterns of survey availability for a highly-mobile marine animal.

This manuscript represents a core AMAPPS Sea Turtle Ecology deliverable. In it, we used information from 9 yrs of animal-borne data loggers to characterize the dive-surfacing behavior of loggerhead turtles in the northwest Atlantic. Our data from 245 turtles covered a large geographic area off the east coast of North America, and allowed us to present estimates for and variation in 3 metrics to assess availability bias affecting visual surveys: average dive duration, average surface duration, and the proportion of time at the surface. We used a Stochastic Partial Differential Equation approach to construct spatiotemporal regression models for the availability bias metrics. Draft model predictions showed pronounced individual, spatial, and seasonal variation among the turtles. We predicted the 3 availability bias metrics onto a 20 km × 20 km grid to further explore seasonal variations. Estimates for average dive duration, average surface duration, and proportion of time at the surface will be available.

7.3.3 Projected Shifts in Loggerhead Habitat Due to Climate Change

Patel S, Winton MV, Hatch JM, Haas HL, Saba VS, Fay G, Smolowitz RJ. 2021. Projected shifts in loggerhead sea turtle habitat in the Northwest Atlantic Ocean due to climate change. Sci. Rep. 11:8850.

This project, described in the AMAPPS 2020 Annual Report (Palka et al. 2021), was a collaboration between Coonamessett Farm Foundation, University of Dartmouth, Atlantic White Shark Conservancy, Northeast Fisheries Science Center Protected Species Branch, and the Geophysical Fluid Dynamics Lab. The manuscript was in review at Scientific Reports at the time of the 2020 Annual Report and then published in 2021. In an effort to provide the public with easy access to the data products resulting from this manuscript, a GitHub repository (https://github.com/NEFSC/READ-PSB-TE-Patel_et_al_2021_sci_rep) was established. A user can download or visualize the data using a Leaflet map.

7.3.4 Model to Estimate Risk of Gas Embolism in Sea Turtles During Routine Dives

Robinson NJ, García-Párraga D, Stacy BA, Costidis AM, Blanco GS, Clyde-Brockway CE, Haas HL, Harms CA, Patel SH, Stacy NI, Fahlman A. 2021. A Baseline model for estimating the risk of gas embolism in sea turtles during routine dives. Front Physiol. 2021 Sep 1;12:678555. PMID: 34539425; PMCID: PMC8440993.

This project determined the factors that contribute to the development of gas embolisms in sea turtles, which has been largely associated with fisheries bycatch and submerged gear interactions, when the turtle makes a rapid ascent to the surface. This could be a significant threat to sea turtles, so we wanted to better understand how they managed gas embolisms during routine dives. We created a mathematical model to estimate partial pressures of N_2, O_2, and CO_2 in the major body-compartments of diving loggerheads, leatherbacks, and green turtles (*Chelonia mydas*). We adjusted a published model for estimating gas dynamics in marine mammals and penguins to build the sea turtle model. To parameterize the sea turtle model, we used values from previously published literature and from 22 necropsies. We applied the model to data collected from free-swimming individuals of the 3 study species. We varied factors such as percentage of body fat and cardiac output within the model to see how they affected the risk of gas embolisms. Results suggested that cardiac output likely plays a significant role in the development of gas embolisms, especially in deeper-diving leatherback sea turtles. This model suggested that sea turtles are at high risk of gas embolisms during routine diving behavior as well. This study revealed that turtles likely have additional behavioral, anatomical, and/or physiological adaptations to decrease the likelihood of gas embolisms, although we could not incorporate them into this model. Additional research is necessary to identify these adaptations so they can be included in the model to more thoroughly understand the factors driving the development of gas embolisms.

This project was a collaboration between the following: Fundación Oceanogràfic de la Comunidad Valenciana; National Oceanic and Atmospheric Administration/National Marine Fisheries Service/Office of Protected Resources; Virginia Aquarium and Marine Science Center; Instituto de Biología de Organismos Marinos; The Leatherback Trust; Northeast Fisheries Science Center; North Carolina State University; Coonamessett Farm Foundation; University of Florida; and Global Diving Research, Inc.

7.4 Acknowledgements

The 2021 data collected and analyses discussed in this chapter came in part from 3 sources of funds specified in section 1.4 of this document (NMFS, and the 2 interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy).

In addition to the above 3 sources, the project on projecting shifts in loggerhead habitats (section 7.3.3) received funding from the scallop industry Sea Scallop Research Set Aside program administered by the Northeast Fisheries Science Center, by the National Oceanic and Atmospheric Administration Saltonstall-Kennedy Grant Program, and by the National Marine Fisheries Protected Species Toolbox Initiative.

In addition to the above 3 sources, the loggerhead data logger deployments in the project on the baseline model for estimating gas embolism risk (section 7.3.4) received funding from the scallop industry Sea Scallop Research Set Aside program administered by the Northeast Fisheries Science Center. Leatherback and green turtle data logger deployments received funding from the Leatherback Trust.

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8 Progress on passive acoustic data collection and analyses: Northeast and Southeast Fisheries Science Centers

Annamaria DeAngelis[1], *Annabel Westell*[2], *Danielle Cholewiak*[1], *Genevieve Davis*[2], *and Melissa Soldevilla*[3]

[1] Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543
[2] Integrated Statistics, Inc. 16 Sumner St., Woods Hole, MA 02543
[3] Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami FL 33149

8.1 Summary

The goal of the AMAPPS-related research 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. We focus particularly on species that are difficult to detect by visual observers or in times of year and regions with no visual surveys. In 2021, we had 7 ongoing primary analyses involving bottom-mounted recorder data and towed hydrophone array data collected during AMAPPS surveys. One, use recent developments in estimating deep diver's echolocation depth to correct acoustic slant ranges to true perpendicular distances for abundance estimates of sperm whales (*Physeter macrocephalus*). Two, assess beaked whale species distribution using temporal and spatial datasets, also accounting for their vertical distribution in the water column. Three, work with a new classification system to assess its classification efficacy in our towed array datasets. Four, improve our beaked whale classification system for bottom-mounted datasets to obtain more reliable detections and classifications of beaked whales. Five, demonstrate how using a widely spaced network of bottom-mounted sensors can locate distant seismic survey sound sources and show that marine mammal species along the east coast of the US may interact with anthropogenic sounds from different continents. Six, using passive acoustic monitors, document the distribution of baleen whales along the eastern seaboard continental shelf and shelf break, with the latest results presented for humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), blue (*Balaenoptera musculus*), sei (*Balaenoptera borealis*), and North Atlantic right whales (*Eubalaena glacialis*). Seven, contribute to creating a website to host all passive acoustic detections by the Northeast Fisheries Science Center and collaborators.

8.2 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 even more reliably sighted species are not visual at night or under poor conditions. Data collected from acoustic studies provide 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 (NEFSC and SEFSC) 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.
- 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.

8.3 Data Collection

In 2021, we did not deploy any additional passive acoustic recorders, besides the towed hydrophone array as described in Chapters 3 and 4. All data analyzed this year were from previously collected datasets. We will analyze the towed array datasets collected in 2021 in FY22 and FY23.

8.4 Analysis Methods

8.4.1 2016 Sperm Whale Acoustic Abundance

We estimated sperm whale abundance using acoustic data collected in 2016 during the NEFSC shipboard survey (Palka et al. 2016). Over 39 days, from 27 Jun 27 to 25 Aug 2016, we completed 5,661 km of on-effort acoustic line transects between North Carolina and Maine. We used a shipboard echosounder on alternating days throughout the survey. The goal of this analysis was to detect and localize in 3D as many sperm whales as possible before conducting a distance analysis using depth-corrected perpendicular distances. We processed over 350 hours of on-effort acoustic data using the PAMGUARD click detector (Gillespie et al. 2008), where we marked events containing usual clicks and localized the location of the animals in 2D using the Target Motion Analysis module’s 2D Simplex Optimisation algorithm. We define an event as a series of clicks organized into click trains attributed to a single individual. We truncated events that had a slant range of more than 6500 m and excluded events with a duration of less than 2 minutes. We used the methods described by DeAngelis et al. (2017) to calculate average dive depths and perpendicular distances in custom Matlab scripts. We also conducted an additional manual review of the slant delay measurements to remove likely false detections of surface reflected echoes. For events within the truncation distance that we did not localize in 3D or where we rejected the average depth, we used the first quartile (25th) of the average depths as an assumed depth to calculate the perpendicular distance. We then used the R package Distance (Thomas et al. 2010) to conduct 2 distance analyses: using slant ranges and using depth corrected perpendicular distances. We selected the best detection function based on the Akaike’s Information Criterion score, the Kolmogorov-Smirnov test, the Cramer-von Mises test, and quantile-quantile plots. We then compared the following attributes of the 2 distance analyses: probability of detection, effective half strip width, and abundance estimates. We also used a regression analysis following that of (Cholewiak et al. 2017) to determine whether the shipboard echosounder had an effect on sperm whale detections and could potentially bias the detection function. To investigate how the sperm whales localized in 3D were using the water column to forage, we categorized events based on the section of the water column that the whale descended to and/or produced the majority of the tracked foraging clicks.

8.4.2 2016 Summer Distribution of Beaked Whales

During June to September 2016, the NEFSC and SEFSC conducted 2 separate AMAPPS abundance shipboard surveys on the NOAA ships *Henry B. Bigelow* and *Gordon Gunter*, respectively. As part of those surveys, we deployed a towed hydrophone array to collect information on the distribution of vocalizing marine mammal species (Palka et al. 2016). Separate from the shipboard surveys, 11 High-frequency Acoustic Recording Packages (HARPs) were deployed at approximately 100 nmi spacing along the east coast of the US along the 1,000 m bathymetric line annually from 2016 to 2019. We are combining both of these datasets to assess the acoustic spatial and temporal distribution of beaked whale species, Cuvier’s beaked whale (*Ziphius cavirostris*), Blainville’s beaked whale (*Mesoplodon densirostris*), Gervais’ beaked whale (*Mesoplodon europaeus*), True’s beaked whale (*Mesoplodon mirus*), and Sowerby’s beaked whale (*Mesoplodon bidens*). We restricted the analysis to the summer months of July and August 2016 when both NOAA ships *Henry B. Bigelow* and *Gordon Gunter* conducted the line-transect cetacean abundance surveys. We described the corresponding towed hydrophone datasets and analyses in the AMAPPS II final report (Palka et al. 2021). In short, we used the acoustic software PAMGUARD to detect and manually review beaked whale detections to classify the species identification and determine the 3D localizations. For the HARP data, we ran a beaked whale detector that extracted timestamps of candidate beaked whale signals (Baumann-Pickering et al. 2013). We then manually reviewed the signals in Matlab 2017a using detEdit (Solsona-Berga et al. 2020) to classify the candidate beaked whale signals.

We marked beaked whales as present or absent in one-minute time bins for all detected beaked whale events, on both the towed array and HARP datasets. This facilitated the comparison of the percent of time with detected echolocation clicks that we termed the "percent positive minutes" per species (PPM). In addition to spatial and temporal assessments of beaked whale detections, we also compared the vertical distribution of detected depths of beaked whales among species using the towed hydrophone array datasets, following the methodology described in DeAngelis et al. (2017).

8.4.3 2016 Dolphin Classification

Delphinid acoustic classification has been challenging in passive acoustic monitoring due to the high spectral variability of vocalizations within and between delphinid species. A promising approach developed by the Southwest Fisheries Science Center for classifying delphinids relies on machine learning to examine features of various vocalization types (whistles, clicks, burst pulses) via a random forest classification model (Rankin et al. 2017). An undergraduate from the NOAA Hollings Scholarship Program built this classification model for delphinid detections using the 2016 NEFSC summer survey (HB1603) dataset. This required first examining the visual sightings data to extract time periods of known single species encounters (no other species sighted within 18.5 min), which we termed “possible encounters”. Then, using the acoustic software PAMGUARD, verify that there was only 1 species sighted by comparing the position of the sighting with the acoustic localization of the vocalizations recorded on the towed hydrophone array, which we termed “verified encounters”. We used the verified subset of data to train a random forest classifier, using the R package banter (Rankin et al. 2017) and PAMPal (Sakai 2020).

8.4.4 Beaked Whale Neural Network Classification System

As part of a collaborative effort with Scripps Institution of Oceanography to better understand beaked whale species distribution and acoustic response to various anthropogenic sources, in 2021 we continued working on an automated detector and classifier. We need this detector/classifier to handle large datasets (i.e., data from 11 HARPs deployed continuously over 3 years), to reduce the false positive detections generated by misidentified dolphin clicks, and to improve beaked whale species classification as they become better characterized in the literature (DeAngelis et al. 2018; Clark et al. 2019). Classifier development included a neural network approach, which uses a multi-stage detector and clustering algorithm to group similar detections into 5-minute bins. The classifier incorporates information from the waveform, inter-click-interval, and click spectra to parse detections into groups. We compiled a training dataset for each beaked whale species from select HARP sites deployed over various years, where we manual reviewed the data. We then tested the neural network algorithm across other times in the HARP data that contained a manual review but were not in the training data.

8.4.5 Seismic Impact Analysis

We continued analyses on a passive acoustic dataset collected along the shelf break of the US eastern seaboard from April 2016 through June 2017. The dataset were from HARPs at 11 sites, spanning over 2000 km from Georges Bank (off Massachusetts) to the Blake Spur (off Florida). Initial analyses included the use of a matched filter detector to identify seismic airgun presence. We filtered the time series with a 10th order Butterworth bandpass filter between 25 and 200 Hz. We computed a cross-correlation on the filtered time series; when a correlation coefficient reached a threshold of $2 \cdot 10^{-6}$ above the median, a trained analyst manually verified the detections (Rafter et al. 2020).

Remotely detected airgun pulses often “ramp up” or “ramp down” leading to the appearance of the airguns fading in and out gradually, or starting/stopping abruptly. We used these gaps to align periods of concurrent seismic survey detection across multiple recorder sites to localize the source of the signal. Using the automated detection files as a guide, we manually reviewed spectrograms (600 sec window, 0-300 Hz viewing bandwidth, FFT: 2048 pts, 95% overlap) looking for “starts”, “stops”, and “gaps” in the detected seismic activity, between 0 and 100 Hz. We used custom-written Matlab code to determine the bearing and estimated the distance to the source of seismic pulses using signals detected across at least 4 HARPs.

8.4.6 Baleen Whale Analyses

We analyzed all recording units for the daily presence of blue, fin, humpback, sei and North Atlantic right whales, using the low-frequency detection and classification system (Baumgartner and Mussoline 2011). This detection software creates conditioned spectrograms and creates contours (“pitch tracks”) through tonal signals using a set of user-defined criteria. The software classified potential baleen whale vocalizations based on a comparison to a pre-programmed call library for each individual species. We then manually reviewed the pitch tracks to determine daily acoustic presence for each of the baleen whale species mentioned above, following Davis et al. (2017; 2020). Analyses are still ongoing, adding to the previously analyzed recorders, summarized in Palka et al. (2021). Here we present new results for the HARP sites, including humpback whale results and for additional sites. We did not present results for minke whales in this report, nor additional analyses from the Marine passive acoustic recording units (MARU) sites. In addition to minke whales, we are still completing analyses of the other baleen whale species on several sites.

8.5 Analysis Results

8.5.1 2016 Sperm Whale Acoustic Abundance

We detected sperm whales on all survey days, and on all but 5 of the 54 transect lines (accounting for 4.9% of the effort) (Figure 8-1). We localized 699 detections of sperm whale usual clicks in 2D. Slant range varied from 31 m to over 30 km. We rejected 2D localization of 109 events due to a lack of convergence in the bearings. Thus, we included 431 events in the distance analyses, and calculated an average dive depth for 274 of these events (Table 8-1, Figure 8-2). The weighted mean of average depths was 620 m (standard deviation = 280 m), and the first and third quartiles were at 411 m and 821 m, respectively. Results from the regression indicated that the echosounder did not have a significant effect on sperm whale detections ($p = 0.37$).

We used the first quartile of the average depths (411 m) as an assumed depth for the 9 events with implausible depth estimates and for the 157 events not included in 3D localization due to a short duration ($n = 28$), lack of multipath surface reflected echoes ($n = 128$), or click depths >4000 m ($n = 1$). We coerced the perpendicular distance of 34 events (7.9%) to 0 m because the average depth was greater than the slant range. We also tested assuming the average depth of 620 m as the assumed depth but did not accept this assumption because it resulted in coercing too many detections in the first bin, which signified that it overestimated the depth of those whales without a calculated depth.

The distribution of the truncated slant ranges and perpendicular distances with fitted detection functions are in Figure 8-3. The best fitting models were a hazard rate key function with no adjustment terms fitted to the slant ranges, and a half normal key function with simple polynomial adjustment terms of order 2 fitted to the perpendicular distances. Analyses are ongoing, and we will submit a manuscript in FY22 (Westell et al. in prep).

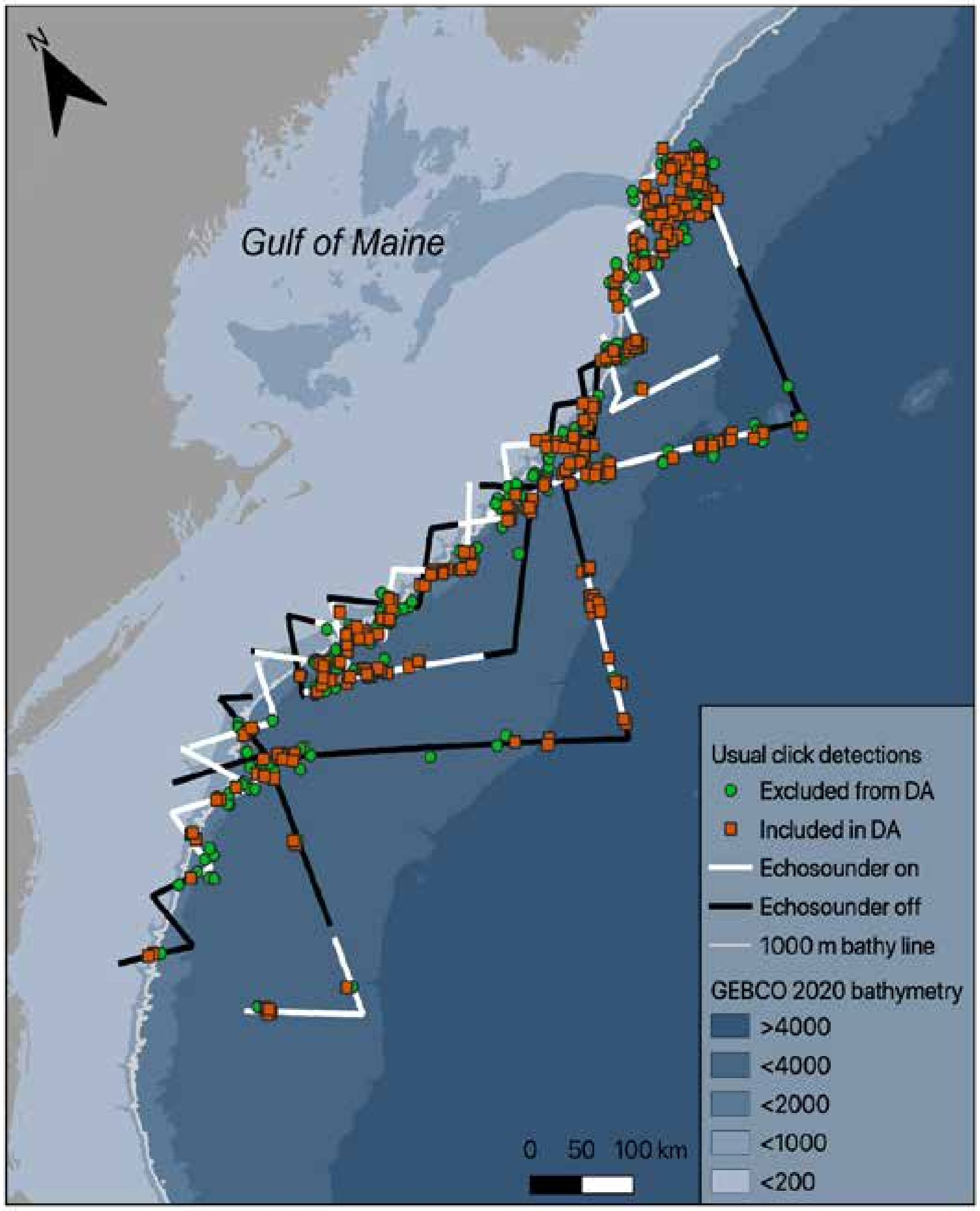

Figure 8-1 On-effort acoustic line transect surveys completed by the NEFSC
Data from 27 Jun to 25 Aug 2016. Black lines indicate the echosounder was passive and white lines indicate it was active. Green and orange points indicate detections of sperm whale usual click trains (n = 712). Green points are events excluded (n = 281) from the distance analysis (DA) and orange squares are the events included (n = 431) in the distance analysis.

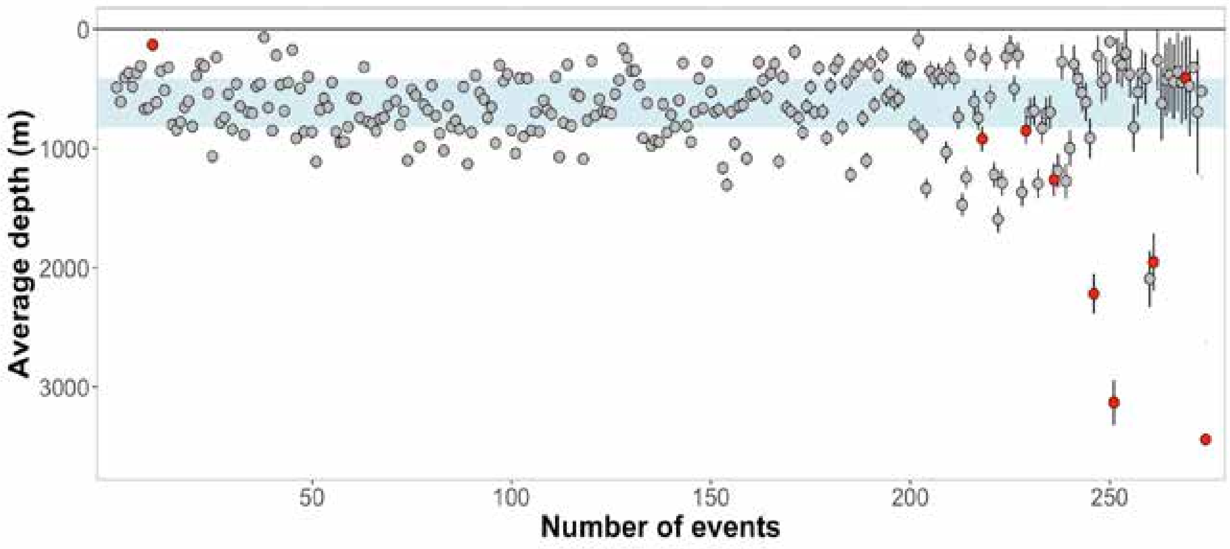

Figure 8-2 Average sperm whale dive depth with depth error
Depths calculated from 274 events. The depth error ranged from 2% to 171% of the average depth, but was mainly <20%. We rejected the average depth for 9 events (red points). Interquartile range highlighted in blue (Quantile 1 = 411 m, Quantile 3 = 821 m).

Table 8-1 Number of events containing usual sperm whale clicks in each step of the analysis

Analysis Step	Number of Events
Detected and marked	712
Localized in 2D	699
Passed manual review of 2D convergence	590
Slant range <= 6500 m	431*
Passed manual review of slant delay	274**

*Events used in distance analysis. **Events included in dive depth calculation.

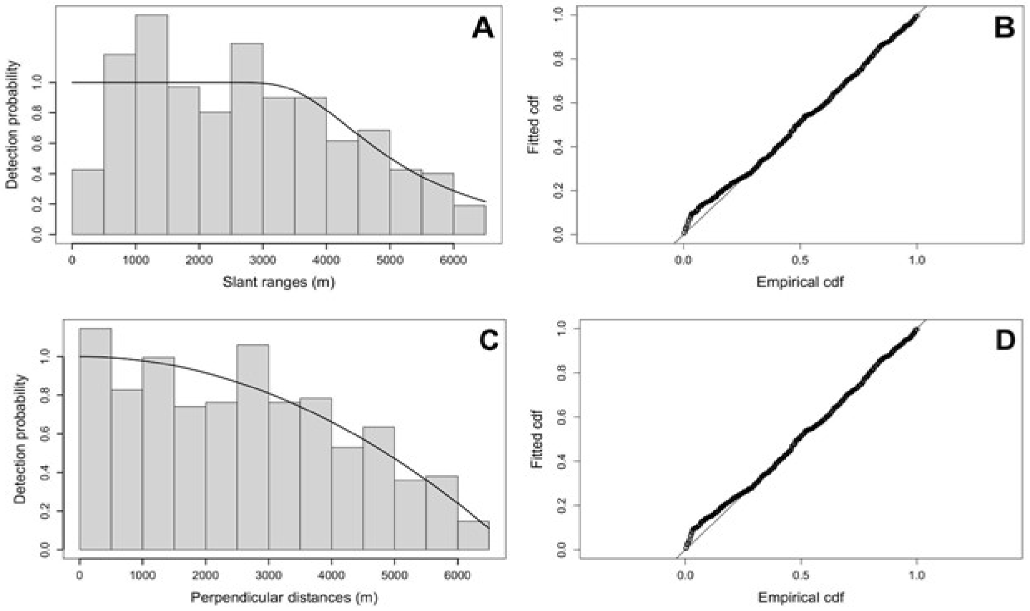

Figure 8-3 Fitted line transect models for acoustic detections of sperm whales
Histogram bars represent the perpendicular slant ranges (A) or depth corrected perpendicular horizontal distances (C) of sperm whale detections (n = 431) truncated at 6500 m. Solid line represents the fitted model. Corresponding quantile-quantile plots in B and D.

8.5.2 2016 Summer Distribution of Beaked Whales

We reviewed 89,280 mins of data per HARP site (total minutes = 982,080). From these data, we assessed the presence of beaked whales at a daily level. We detected beaked whales from all sites except at Jacksonville, FL (JX; Figures 8-4 and 8-5). Cuvier’s beaked whales were present nearly daily at Heezen Canyon (HZ), on the southeast side of Georges Bank (91.9% of recording days, 1.9% PPM) and at the Cape Hatteras, NC (HAT) site (64.5% of recording days, 6.8% PPM).

Cuvier’s beaked whales were present at Oceanographer Canyon (OC; southern side of Georges Bank), Blake Plateau (BP; off Georgia), and Blake Spur (BS; off Florida).

Blainville’s beaked whales were only present at the southernmost sites Blake Plateau and Blake Spur, where more detections were at the Blake Spur site off Florida (48.4% of recording days, 1.0% PPM).

Sowerby’s beaked whales were mainly present at the Wilmington Canyon, off Virginia (WC; 83.9% of recording days, 1.1% PPM) and Heezen Canyon sites (67.7% of recording days, 0.8% PPM), but we also infrequently detected them on other recorders north of Wilmington Canyon. We did not detect any south of Wilmington Canyon, off Virginia.

True’s beaked whales were present only at Nantucket Canyon (NC; south of Massachusetts) (24.2% of recording days, 0.3% PPM), Babylon Canyon (BC, east of New Jersey; 32.3% of recording days, 0.3% PPM), and Wilmington Canyon (32.3% of recording days, 0.5% PPM).

Gervais’ beaked whales were mainly present south of Cape Hatteras, NC, but there were a few sporadic recordings of them at the Babylon Canyon site (1.6% of recording days, <0.1% PPM) and the Newfoundland site (NFC; 17.7% of recording days, 0.2% PPM). We detected the most detections of Gervais' beaked whaled at the Babylon Canyon site (98.4% of recording days, 7.0% PPM) and Cape Fear, NC Gulf Stream (GS) sites (80.6% of recording days, 3.4% PPM).

Due to the similarities in click characteristics between True's and Gervais' beaked whales (DeAngelis et al. 2018), some detections could not be confidently attributed to either species and we thus labeled them as MmMe. These detections were present at sites from Heezen Canyon to Wilmington Canyon (HZ, OC, NC, BC, WC), along with the Cape Fear, NC Gulf Stream site and represented <0.1% of detection positive minutes (or 1.6% to 4.8% of recording days) at each of these sites.

We are still analyzing the towed array datasets following the percent positive minute's protocols. So far we have estimated the dive depth for 144 beaked whale events (which we defined as a clusters of click trains separated to an individual level as best as possible). Of those, 69 were Cuvier's, 4 Gervais', 6 Sowerby's, 57 True's, and 8 MmMe events (Table 8-2). The weighted mean for the MmMe class was the deepest (1,773 m ± 686 m), followed by Cuvier's (1,515 m ± 562 m), Gervais' (1,107 m ± 230 m), True's (978 m ± 407 m), then Sowerby's (865 m ± 413 m). Results from the AMAPPS 2016 abundance survey conducted on the NOAA ship *Gordon Gunter* (GU1605) are pending. In FY22, we plan to submit the results of this analysis as a manuscript for peer review (DeAngelis et al. in prep).

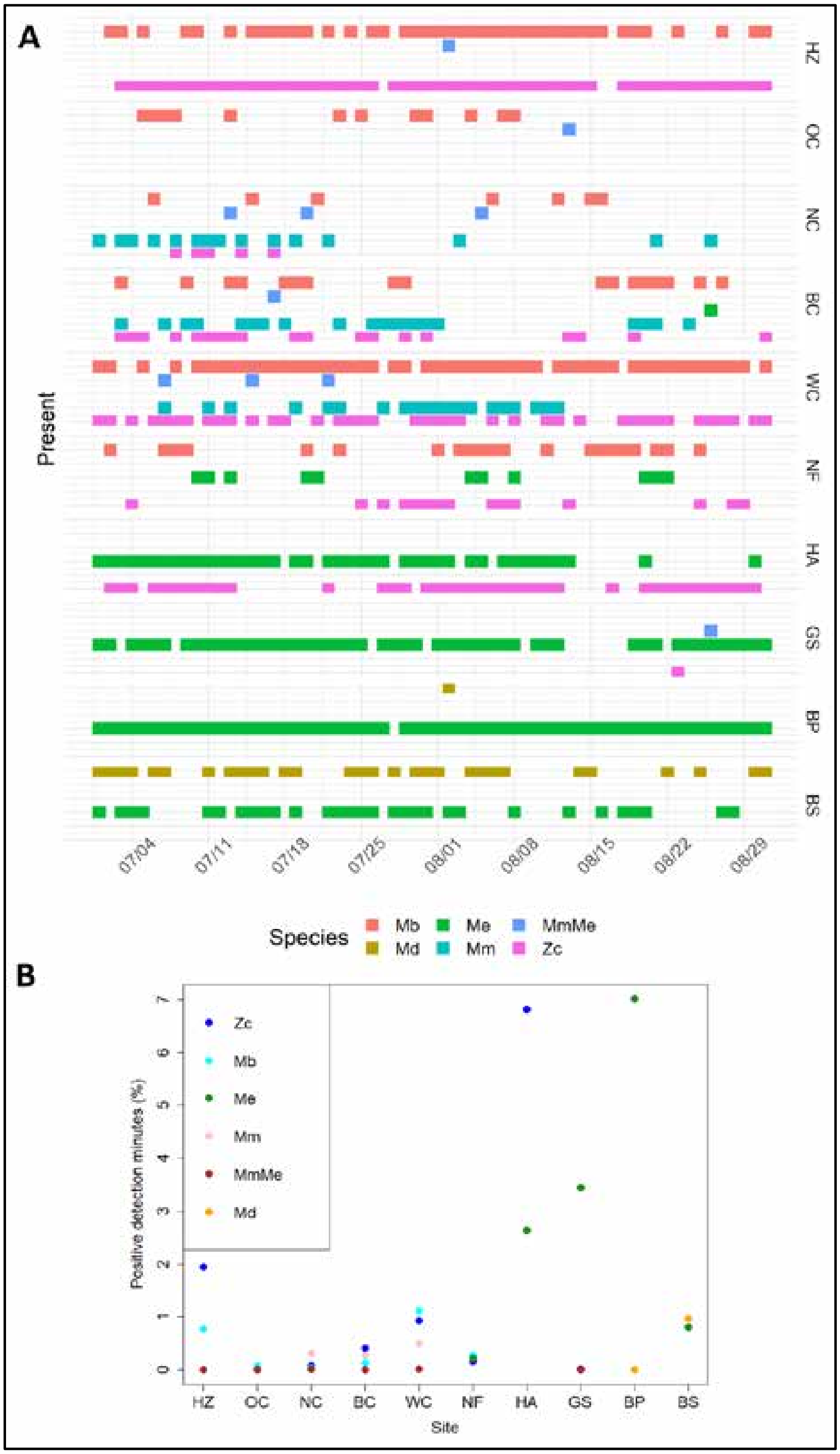

Figure 8-4 Daily presence and percent positive detection minutes of beaked whales on HARPs
Data from 11 HARP sites collected during 1 Jul to 31 Aug 2016. Points represent only sites with beaked whale species present. Since Jacksonville (JX) had no detections of beaked whales, we did not show it. Gaps represent absence of a species at that site.

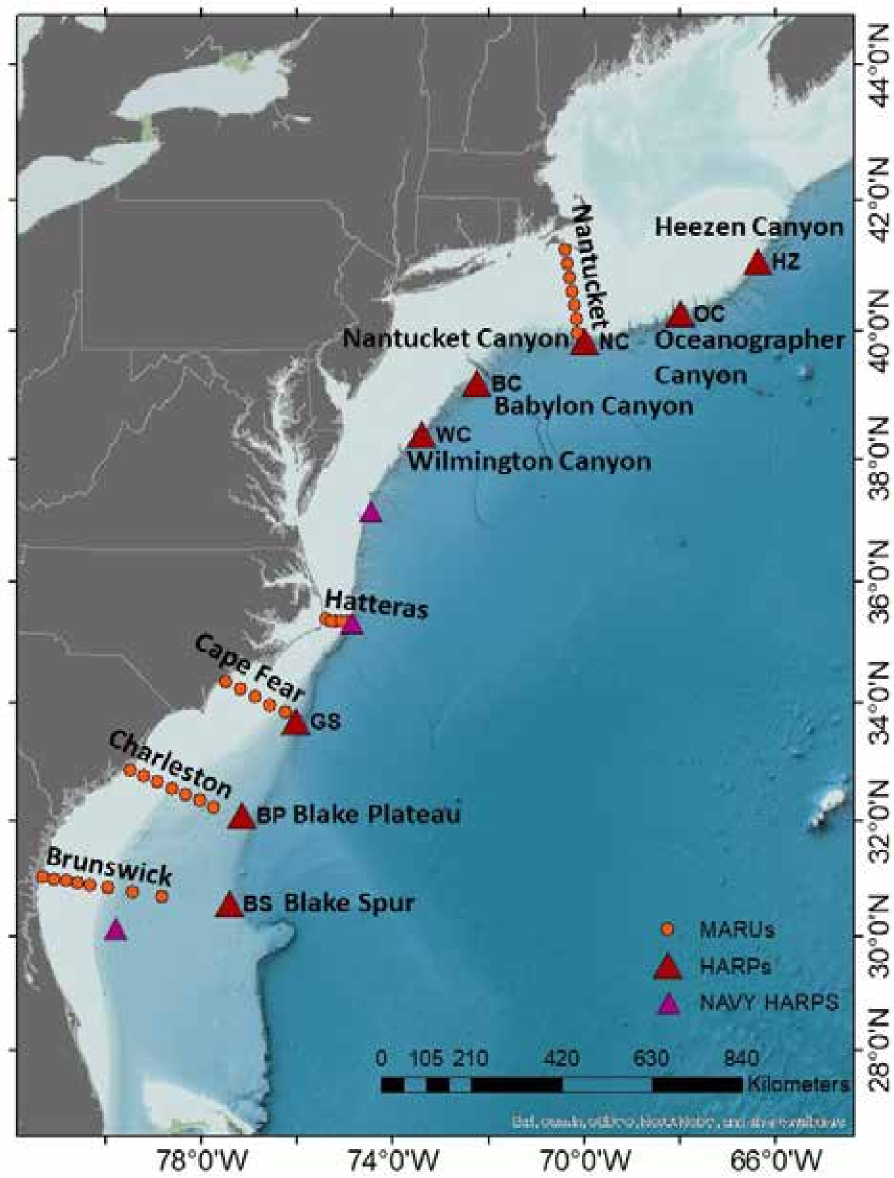

Figure 8-5 Locations of MARUs and HARPs deployed by NMFS between 2015 and 2019
AMAPPS II partially funded the red and orange deployments. The additional HARP sites supported by Duke University and the US Navy are in purple. Note that exact positions and numbers of recorders varied between years, due to logistical constraints and recorder failures. Positions shown in map are approximate.

Table 8-2 Dive depth statistics per beaked whale species recorded in the HB1603 dataset

Species	Sample Size	Weighted Average Depth (m)	Weighted Standard Deviation (m)	25th Percentile	75th Percentile
Cuvier’s	69	1,515	562	620	2,196
Gervais’	4	1,107	230	640	1,241
Sowerby’s	6	865	413	549	1,353
True’s	57	978	407	478	1,379
MmMe	8	1,773	686	675	2,125

8.5.3 2016 Dolphin Classification

From the dataset collected on the 2016 NOAA ship *Henry B. Bigelow* abundance survey (HB1603), we recorded a sufficiently large enough number of acoustic recordings to use as input in a classifier for common dolphins (*Delphinus delphis*), pilot whales (*Globicephala* sp.), Risso’s dolphin (*Grampus griseus*), bottlenose dolphin (*Tursiops truncatus*), and striped dolphins (*Stenella coeruleoalba*; Table 8-3). There were not enough samples for Atlantic spotted dolphin (*Stenella frontalis*) or false killer whales (*Pseudorca crassidens*), thus we did not build a classifier for these species. We created classifiers including (Table 8-4) and excluding (Table 8-5) bottlenose dolphins in the training datasets, as bottlenose dolphins exhibit a large variety of whistle types. Testing the classifiers indicated that including bottlenose dolphins greatly reduced the reliability of the classifier. We believe that the small sample sizes from just HB1603 contribute to this difference in performance, as reflected in the large confidence intervals in each species class. To increase the sample size of acoustic events for all species, we will add the acoustic events from the 2021 abundance survey (HB2102) dataset in the upcoming year. We will also test creating a species binary classifier with BANTER (that is, testing if it is species X or not), which may perform better than trying to include all species, similar to the McCullough et al. (2021) approach with false killer whales.

Table 8-3 Delphinid species examined for training the classifier

Rows in bold indicate species that had enough data to be used to build the classifier.

Species	Number of Possible Single Species Encounters	Number of Verified Single Species Encounters
Common dolphin	**10**	**6**
Pilot whale	**6**	**5**
Risso's dolphin	**15**	**4**
Bottlenose dolphin	**8**	**3**
Striped dolphin	**16**	**8**
Atlantic spotted dolphin	2	1
False killer whale	1	1

Table 8-4 Confusion matrix including bottlenose dolphin detections

Species/ Species	Common Dolphin	Risso's Dolphin	Pilot Whale	Striped Dolphin	Bottlenose Dolphin	Percent Correct	95% Confidence Interval
Common dolphin	5	0	0	1	0	83.3	35.9-99.6%
Risso's dolphin	1	1	0	1	1	25.0	0.6-80.6%
Pilot whale	0	0	3	1	1	60.0	14.7-94.7%
Striped dolphin	1	1	0	3	3	37.5	8.5-75.5%
Bottlenose dolphin	0	0	0	1	2	66.7	9.4-99.4%
TOTAL						53.8	33.4-73.4%

Table 8-5 Confusion matrix excluding bottlenose dolphin detections

Species/ Species	Common Dolphin	Risso's Dolphin	Pilot Whale	Striped Dolphin	Percent Correct	95% Confidence Interval
Common dolphin	5	0	0	1	83.3	35.9-99.6%
Risso's dolphin	1	3	0	0	75.0	19.4-99.4%
Pilot whale	0	0	4	1	80.0	28.4-99.5%
Striped dolphin	0	1	0	7	87.5	47.3-99.7%
TOTAL					82.6	61.2-95.0%

8.5.4 Beaked Whale Neural Net Classification

A reliable neural net classification model typically results from a training datasets with at least 1,000 5-min bins of vocalizations per species. Thus, for species in which we had fewer 5-min bins, we augmented the data for that species until we had 1,000 5-min bins. After training the neural net classification, we tested the resulting classification model. Testing the classification model with the training dataset resulted with all precision and recall values for beaked whale scoring above 98%. Testing the classification model with a novel test dataset also resulted similarly high, with all precision and recall values scoring above 97%. We are now testing the model on a more novel dataset from the most recent Navy HARP deployment to confirm that the results indeed indicate a well-trained model and not an over fitted model. Once we complete the neural net, we will apply it to all HARP data collected in the western North Atlantic. This will allow us to complete several specific projects, such as assessing the impact of sonar on beaked whale detections, documenting species richness across multiple years and sites, and describing beaked whale distributions in the Western Atlantic from the 3 years of HARP data. We are drafting a manuscript for peer review on this classification approach.

8.5.5 Seismic Impact Analysis

We detected airguns on 21 to 292 days, representing 5% to 69% of the study period, spanning all months of the year at all sites. We detected airgun pulses across 7 hydrophones on at least 30 days and across 10 hydrophones on at least 11 days, indicating that the sounds were detectable across all US Atlantic waters. Localization analyses suggest that many signals originated from the northeastern coast of South America, presumably from the oil fields along the South American coast. Some signals also originated from along the coast of North America, with others potentially originating from the mid-Atlantic. The airgun activity originating from the coast of South America occurred throughout the year in 2016, and the activity along the North American eastern seaboard seemed to primarily occur in the springs and summers of 2016 and 2017. We are finalizing these analyses and drafting a manuscript for peer review.

8.5.6 Baleen Whale Analyses

We detected humpback whales at all sites along the US Atlantic coast, with the highest presence found at the sites north of Wilmington Canyon off Maryland (WAT-HZ through WAT-WC; Figure 8-6). While detected on fewer days, there were still humpback acoustic presence at the 3 sites from Cape Fear, NC Gulf Stream site to Blake Spur, off Florida (WAT-GS, WAT-BP, and WAT-BS), with detections occurring mainly during spring months.

The last year of data from June 2018 to June 2019 at these sites had frequent humpback and sei whale acoustic detections. In addition, we detected from 0 to 2 days of North Atlantic right whale occurrence throughout. We are still analyzing the last year of data for fin and blue whales. Although, where we have already analyzed for fin and blue whales (WAT-HZ and WAT-BS), we detected both species regularly, except for summer months at the northernmost site at Heezen Canyon on the southeastern edge of Georges Bank (WAT-HZ). At the southernmost Blake Spur site off Florida (WAT-BS), we sporadically detected blue whales during the fall and winter months of 2018, and fin whales during February to March of 2019. Analysis for humpback, blue, and fin whales is currently underway for the Blake Spur site (WAT-BS) in 2017.

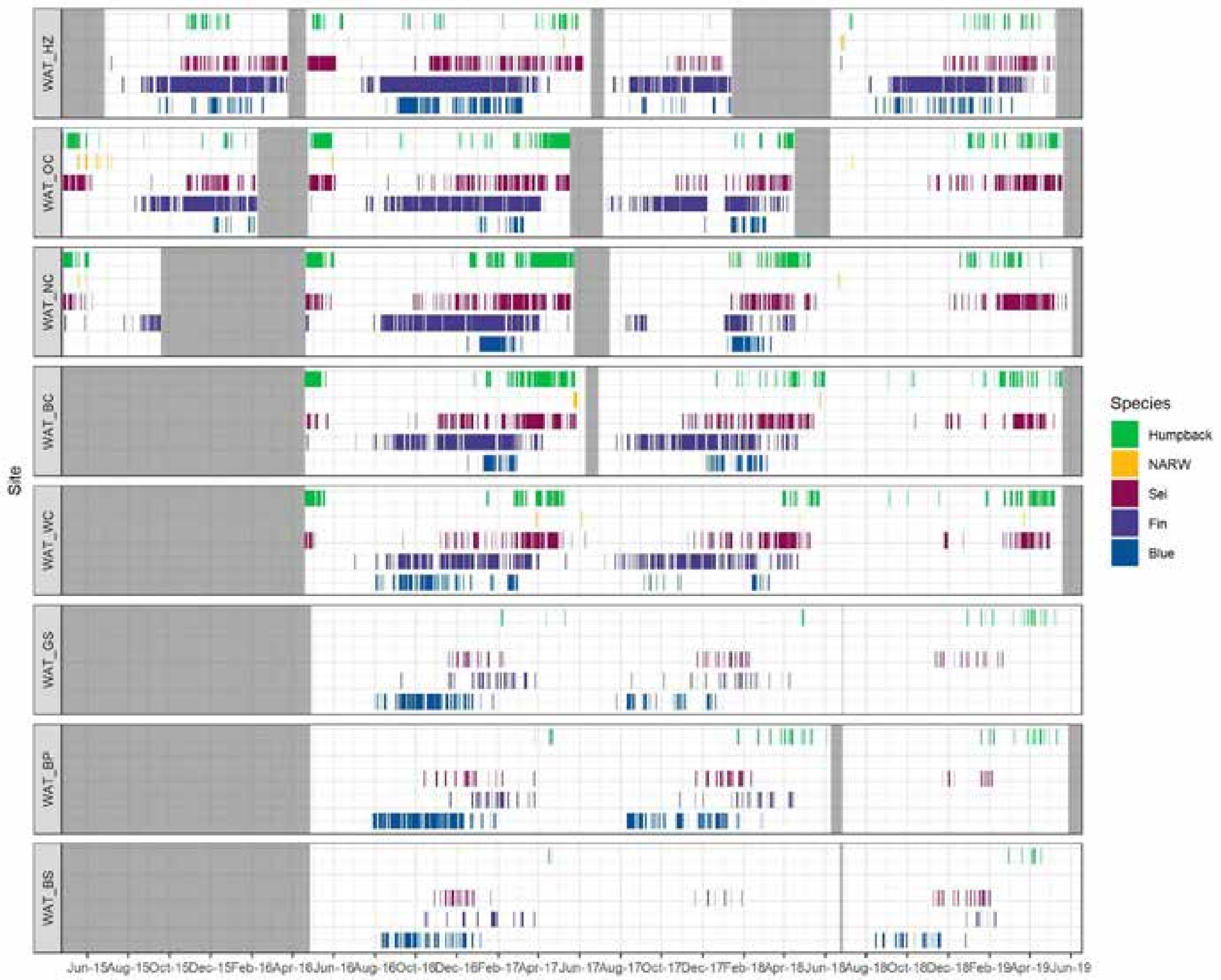

Figure 8-6 Daily presence of five baleen whale species by HARP site from 2015 to 2019

We ordered HARP sites from north at the top to south at the bottom, starting with Heezen Canyon (HZ) in the north and ending with Blake Spur (BS) in the south. See Figure 8-5 for the site locations. Humpback whale presence are in green, North Atlantic right whales (NARW) in gold, sei whales in red, fin whales in purple, and blue whales in blue. Grayed out areas indicate periods with no available data.

8.5.7 Public Availability of Acoustic Data

We are uploading all passive acoustic detection metadata from the AMAPPS project to the Passive Acoustic Cetacean Map website, which is a public interface to view all existing Northeast Fisheries Science Center Passive Acoustic Analyses. There is contact information supplied where the public can request a copy of all acoustic detections of interest.

8.6 Acknowledgements

Julianne Wilder, Liam Mueller-Brennan, Nicholas Hayes, and Nicole Pegg contributed to the acoustic analyses included in this report. Colleagues at Scripps Institution of Oceanography created the beaked whale neural net and contributed to the seismic survey analyses and localization, in particular Simone Baumann-Pickering, Alba Solsona Berga, Kaitlin Frasier, Macey Rafter, and Annebelle Kok. Colleagues at the SWFSC assisted in the dolphin classification system and dive depth automation, specifically Shannon Rankin, Taiki Sakai, Eric Archer, Anne Simonis, Cory Hom-Weaver, and from Pacific Islands Fisheries Science Center Jennifer McCullough.

In addition to the 3 sources of funds specified in section 1.4 of this document (NMFS, and the 2 interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy), the Navy's Living Marine Resources Program and NOAA Fisheries provided funding.

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9 Progress on visual sightings data collection and analyses: Northeast and Southeast Fisheries Science Centers

Debra Palka[1], *Samuel Chavez-Rosales*[2], *Doug Sigourney*[2], *Elizabeth Josephson*[2], *Laura Aichinger Dias*[3], *Lance Garrison*[4], *Chris Orphanides*[5]

[1] Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543
[2] Integrated Statistics, Inc. 16 Sumner St., Woods Hole, MA 02543
[3] Cooperative Institute for Marine and Atmospheric Studies, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149
[4] Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149
[5] Northeast Fisheries Science Center, 28 Tarzwell Drive, Narragansett, RI 02891

9.1 Summary

During 2021, the Northeast and Southeast Fisheries Science Centers updated the time series of spatiotemporal explicit dynamic environmental data. Both Centers conducted a pilot aerial survey study during 1 Nov 2021 to 15 Feb 2022 to trial a 3-camera system in a forward motioned compensating mount installed in the downward looking belly window port of the NOAA Twin Otter. More information on this pilot study will be available in the 2022 AMAPPS annual report. In addition to collecting and processing these new data, during 2021 the Centers used previously collected AMAPPS data from 2010 to 2017 to develop habitat density models of cetaceans and sea turtles using either or both the Generalized Additive Model framework and the Bayesian Hierarchical Density Surface Model framework. We used the AMAPPS abundance cetacean data in several ongoing analyses. Chavez-Rosales et al. (in review) used the density-habitat models to document seasonal habitat shifts into more northern and deeper waters. Sigourney et al. (in review) used the AMAPPS visual and passive acoustic data to estimate the abundance of sperm whales (*Physeter macrocephalus*) that included corrections for perception and availability bias. Orphanides et al. (in review) used the AMAPPS visual cetacean data and concurrently collected active acoustic backscatter data to include prey characteristics in the density-habitat models. Stepanuk et al. (in review) used the humpback whale (*Megaptera novaeangliae*) abundance data from AMAPPS and other sources to assess the utility of using SubX forecasted sea surface temperature to predict their arrival to foraging grounds. We have also started developing design-based abundance estimates using the summer of 2021 shipboard and aerial survey data. We also used the AMAPPS data to improve the analytical methods behind the Bayesian hierarchical density framework (Sigourney et al. in prep) and extend the variance propagation method used on double-observer data (Miller et al. 2021). In addition to peer-reviewed journal papers, we have made these results and raw data more publically available. We updated the AMAPPS map viewer website with the recently developed Generalized Additive Model spatiotemporal density maps and data. We started archiving the monthly averaged spatiotemporal density maps and data on a public GitHub repository. We started archiving the satellite-derived habitat variables on the publically available Environmental Research Division Data Access Program (ERDDAP) website. In addition, we started archiving the AMAPPS datasets at the National Centers for Environmental Information website.

9.2 Data Collection

9.2.1 Habitat Data

In 2021 and continuing on into 2022, we continuously update our time series of satellite-derived dynamic environmental data that we use as candidate covariates in the density-habitat spatiotemporal models for the cetaceans and sea turtles. Staff from the Northeast Fisheries Science Center (NEFSC) Ecosystem Dynamics and Assessment Branch were instrumental in retrieving the most up-to-date data from the most complete, clean (and ever changing) sources and in processing those data to quality check them, correct errors, and account for cloud coverage (as needed). These data include satellite-derived chlorophyll, primary productivity, particulate organic carbon, particulate inorganic carbon, sea surface temperature, strength of sea-surface temperature fronts. We are in the process of putting all of these data on the publicly available ERDDAP website.

We also updated our time series of Hycom ocean model-derived dynamic environmental data: mixed layer depth, mixed layer thickness, surface salinity, and bottom temperature.

In addition, we obtained the latest Gulf Stream north and south walls locations from the Naval Oceanographic Office to update our time series of distances to the north and south walls.

9.2.2 Aerial 3-Camera System

During 1 Nov 2021 to 15 Feb 2022, the NEFSC and SEFSC dedicated the AMAPPS aerial survey conducted to trial a new 3-camera system that takes images from the belly window port in the NOAA Twin Otters (Figure 9-1). The reason we are experimenting with a camera system is in the future offshore wind energy turbines that will be in the study area of the aerial abundance surveys will be nearly 1,000 feet tall. Since the current altitude of the aerial abundance surveys is 600 feet, we will have to fly future surveys at higher altitudes to safely fly over the wind turbines. Consequently, we want to develop a camera system to assist human observers when we conduct a survey at 1,500 feet.

We set the 3 mirrorless Sony cameras into a forward motioned compensating mount that rotates for each shot to eliminate image blur that would normally occur because of the forward motion of the plane. The 3-camera arrangement allows adjustments so that the outside cameras point obliquely to increase the side-to-side coverage, thus increasing the photographed swath of water under the plane. A video monitor connected to the center vertical camera allows a camera operator to see what it is viewing, as if looking through the camera's eyepiece. We connected the mount and cameras to a remotely controlling program that runs on a laptop (Figure 9-2). The flight and camera parameters we enter into the controlling program determines the amount of required forward motion compensation and the forward-backward overlap between consecutive images. The controller program also receives data from an external GPS to record the location, altitude, speed, etc. The program automatically stores all recorded data into a database to match the recorded data to the acquired images. Aerial Imaging Solutions LLC developed the camera mount and controller program.

During this pilot study, we experimented with 85, 100, and 135 mm lenses at various altitudes (600, 1,200, and 1,500 ft). At 1,500 ft altitude the 135 mm lenses results in a 1.5 cm ground resolution (Figure 9-3).

The 2022 AMAPPS annual report will have more details of this survey.

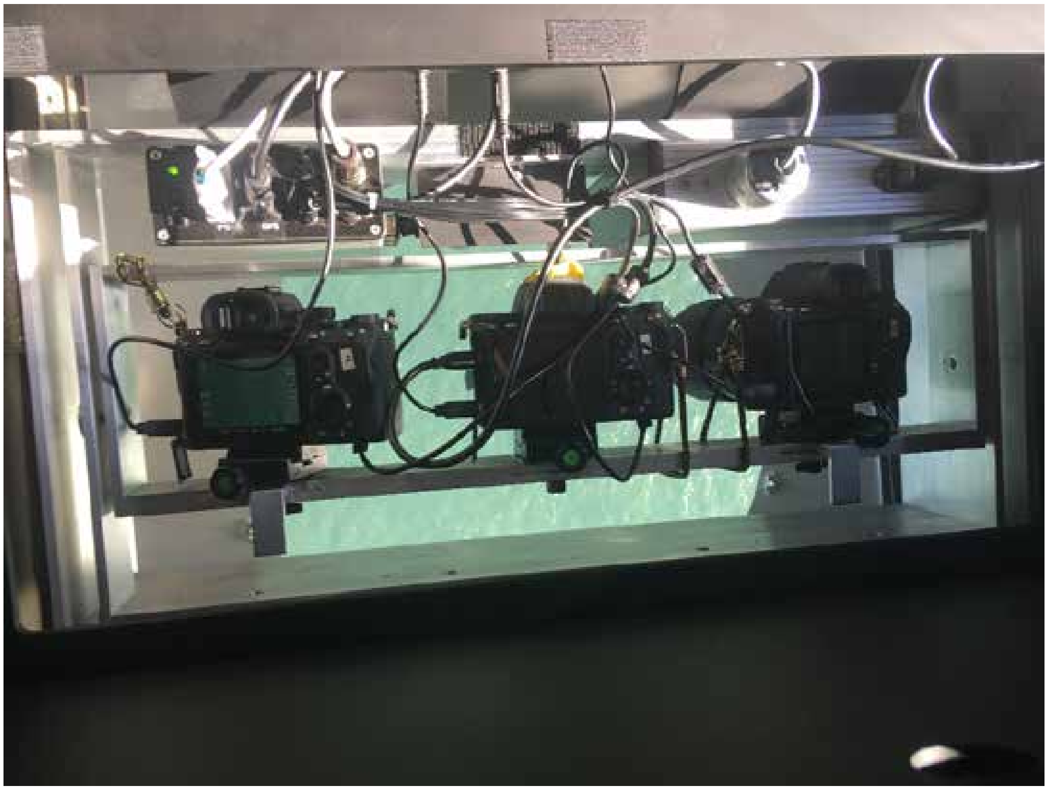

Figure 9-1 Cameras in forward motioned compensating mount in Twin Otter's belly window port

Figure 9-2 Camera system's controller computer (blue screen) and video monitor (red rim)

Figure 9-3 Sample of images from camera system
(A) Atlantic devil ray. (B) Atlantic spotted dolphin. (C) Kemp's ridley sea turtle. (D) Humpback whale.

9.3 Analytical Work

9.3.1 GAM Habitat-Density Models of Cetaceans

During 2021, we finalized the density habitat models for 18 cetacean species or species guilds using a 2-step process. Step 1involves standard 2-team distance sampling line transect analyses using data collected by dedicated shipboard and aerial abundance surveys conducted by the Northeast and Southeast Fisheries Science Centers during 2010 to 2017. Step 2 involves modelling the gridded spatiotemporal density estimates resulting from step 1 as a function of 6 static physiographic characteristics and 19 dynamic environmental covariates using generalized additive models (GAM). In the first step, we estimate the density of animals in each grid cell and 8-day timeframe using mark-recapture distance sampling to account for perception bias. Then we multiplied this density estimate by a species-survey platform-specific correction factor to account for availability bias. In the second step, we develop a GAM analysis of the spatiotemporal stratified bias corrected density estimates as function of habitat covariates to result in average seasonal spatially explicit maps of density and its associated abundance and confidence intervals. We documented the methodology and results in the AMAPPS II final report (Palka et al. 2021). The most important covariates, their frequency, and the mean deviance explained by the covariate when included in a model are in Table 9-1. The most important single habitat covariates included ocean physical conditions (bottom temperature, surface temperature, surface salinity, and distance to the Gulf Stream; Table 9-1A), and location (latitude, bottom depth, and distance to either the 1000 m or 200 m depth contour; Table 9-1B). For several species, the most important covariates were the inter- and intra-annually changing distance to the Gulf Stream (Table 9-1C).

Table 9-1 Covariates included in the habitat models

MDE is the mean deviance explained by the covariate when included in a model. Frequency is the number of models with the covariate.

A. Dynamic Covariates	**MDE**	**Frequency**
Bottom temperature	8.6	12
Sea surface temperature	7.4	5
Salinity	7.3	3
Distance to the Gulf Stream north wall	6.1	6
SST fronts	5.2	7
Chlorophyll fronts	5.3	4
Primary productivity	5.0	4
Distance to the Gulf Stream south wall	4.4	2
Chlorophyll A	4.3	4
Ocean mixed layer depth	4.0	4
Ocean mixed layer thickness	3.8	5
Particulate inorganic carbon	3.0	4
Sea surface height anomaly	1.9	1
Particulate organic carbon	1.6	2
B. Static Covariates	**MDE**	**Frequency**
Latitude	14.3	13
Depth	10.0	5
Distance to the 1000m isobath	9.5	7
Distance to the 200m isobath	7.6	5
Distance to the 125m isobath	6.6	3
Distance to shore	5.4	4
Seafloor slope	3.2	2
C. Interaction Covariates	**MDE**	**Frequency**
Yr-8 day period : Distance to Gulf Stream south wall	28.18	1
Yr-8 day period : Latitude	16.1	2
Yr-8 day period : Distance to Gulf Stream north wall	14.38	1
Yr-8 day period: Sea surface temperature	8.66	1
Yr-8 day period: Chlorophyll fronts	8.13	1

9.3.2 Cetacean Habitat Shifts

During the development of the GAM habitat-density models for cetaceans, we identified that since 2014 several species habitat shifted within US waters and even to outside of US waters. To more clearly identify the distribution shifts, if any, we further analyzed the species-specific core habitat between 2010 and 2017. This analysis indicated that the weighted centroid of the core habitat showed an average shift of 178 km toward the northeast for all the species and seasons across the study area, with the exception of humpback whales. In addition, we identified correlated environmental conditions that perhaps promoted the latitudinal changes in animal distribution. For example, many common dolphins (Delphinus delphis) (Figure 9-4) in all seasons showed a northward displacement within the AMAPPS study area. We will submit these findings to a peer-reviewed journal (Chavez-Rosales et al. in review).

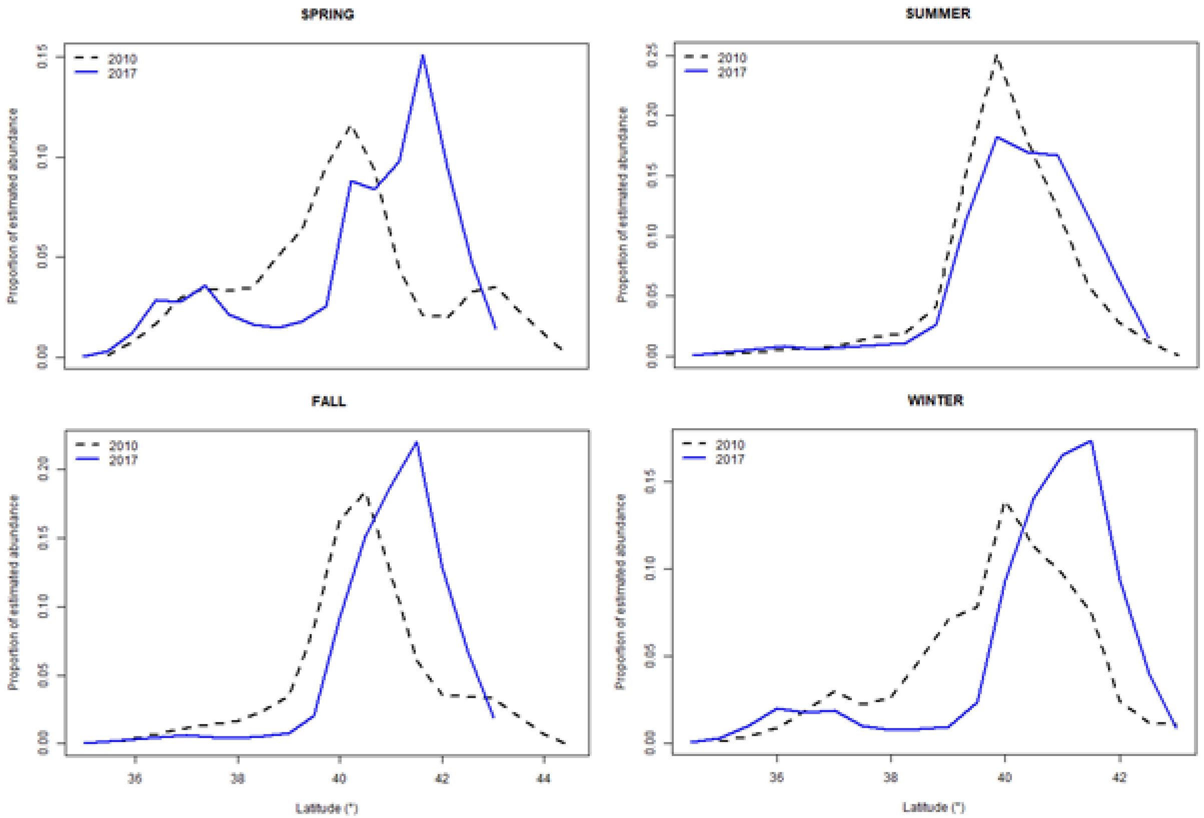

Figure 9-4 Estimated latitudinal distribution changes between 2010 and 2017 for common dolphin
Dotted line is the proportion of the estimated 2010 abundance. Blue line is the proportion of the estimated 2017 abundance.

9.3.3 GAM Habitat-Density Models of Sea Turtles

During 2021, we developed draft models of the surface spatiotemporal density for all hard-shell turtles as a group and for loggerhead turtles as a single species. We applied the same 2-step methodology as used for the cetacean habitat-density models, in which we modeled the species density distribution as a function of 6 static physiographic characteristics and 19 dynamic environmental covariates.

The plan for 2022 is to finalize the 2-step process to estimate the surface spatiotemporal density estimates, then apply the spatiotemporal availability bias correction factor as developed by Hatch et al. (in review) to estimate the spatiotemporal density estimates corrected for perception and availability bias. We will then submit this analysis to a peer reviewed journal (Chavez-Rosales et al. in prep).

9.3.4 Bayesian Hierarchical Density Models of Large Whales

In 2021, we continued developing the Bayesian Hierarchical Density Surface Model framework (Sigourney et al. 2020). Primarily, we focused on fitting models to large whale data. We completed an analysis of minke whales and presented the results in the AMAPPS II Final Report (Palka et al. 2021). Resulting estimates and spatiotemporal patterns were similar to that derived from the GAM framework, although the measures of variability resulting from the Bayesian framework included more sources of variability than that from GAM framework.

We are currently working on including a hierarchical distance sampling method that pools species as random effects to estimate species-specific detection functions. Conceptually this is similar to the GAM framework of estimating a species-specific detection function, although the methods are different. We tested the hierarchical distance sampling method on simulated data and then applied it to large whale data. We also integrated the hierarchical distance sampling method into the Bayesian Hierarchical Density Surface Model framework and re-analyzed the minke whale data. Results from the new hierarchical distance sampling method were comparable to the original minke whale (*Balaenoptera acutorostrata*) analysis; thus, indicating the hierarchical distance sampling method appears to work well within the larger framework. We are currently finishing analyses of all large whale species and preparing a manuscript for publication (Sigourney et al. in prep.).

To decrease processing time of the Bayesian model framework, we also worked on recoding the model framework using the new R package NIMBLE (de Valpine et al. 2017; 2021). The Nimble package includes Markov Chain Monte Carlo sampling algorithms that greatly increase computational efficiency and thus reduces the time required to fit models. This will make future analyses easier and faster.

We also focused on exploring different methods for modelling group size within the Bayesian Hierarchical Density Surface Model framework. We compared different methods with simulations and started experimenting with the R package HierarchicalDS that uses a data augmentation approach to model group size. We plan to compare methods for species with large and small group sizes.

Finally, in 2021 we collaborated with colleague Dr. David Miller from the University of St. Andrews on a paper that focused on extending a variance propagation method to double-observer survey data (Miller et al. 2021). The new method was included in the R package DSM. This paper used AMAPPS data on fin whales and compared the results from a Bayesian Hierarchical Density Surface Model framework analysis to a new analysis with the DSM package.

9.3.5 Integrating Visual and Passive Acoustic Data

In 2021, we focused on finalizing the analyses and preparing a manuscript on the methodology we developed to integrate visual and passive acoustic line transect shipboard data collected simultaneously. We applied this method to sperm whale (*Physeter macrocephalus*) data to produce an abundance estimate incorporating both perception and availability bias. We finished simulation testing of the method, finalized the analysis of sperm whales from the 2013 AMAPPS shipboard survey by the NEFSC and developed a publicly available GitHub Repository for the code. In addition, we met with members of the DenMod working group in February 2021 to review a draft of the current manuscript and the model code and received feedback. Feedback was generally positive and constructive. We completed a final draft (Sigourney et al., in review). We are currently working on final revisions and plan to submit the manuscript to a peer-reviewed journal in the spring of 2022.

9.3.6 Design-Based Abundance Estimates Using Summer 2021 Sightings Data

The data reported in chapters 2 to 4 document the line transect abundance data collected by the NEFSC and SEFSC during June to September 2021 using ships and planes. We are in the process of using standard design-based distance sampling methods for 2-team data to produce species specific stratified abundance estimates for all US waters (Figure 1-1) for as many species as the data support (probably about 21 species or species groups). We expect draft documents of the results to be reviewed by the Atlantic Scientific Review Group in late 2022 or early 2023. The finalized results will be included in the Atlantic and Gulf of Mexico Marine Mammal Stock Assessment Reports and in peer-reviewed papers.

9.3.7 Active acoustic data to improve cetacean distribution models

Orphanides et al. (in review) used AMAPPS data to investigate the utility of echosounder-based predictive variables to model marine mammal distribution and abundance. We collected the marine mammal density distributions and echosounder-based potential prey characteristics on the NEFSC shipboard surveys conducted in 2011, 2013, and 2016. We used an algorithm to classify echosounder backscatter data into 4 prey categories: 1) fish with swim bladders, 2) larval fish and zooplankton, 3) fluid-like zooplankton, and 4) fish with no swim bladder. We used another set of algorithms to quantify the spatial structure of the prey in the water column calculating backscattering strength, location, dispersion, occupied areas, evenness, and aggregation. We then built GAMs using primarily these acoustically derived variables to explain marine mammal distribution. The resulting GAMs explained between 12% and 37% of deviance, similar to that found in the GAM models that used proxy variables for prey distribution. The resulting models reflected aspects of foraging depth and prey preference. This work demonstrates the usefulness of echosounding to model marine mammal distribution and abundance with direct measurements of prey rather than relying on proxies.

9.3.8 Forecasting arrival of migratory humpbacks at foraging grounds

Stepanuk et al. (in review) used humpback abundance (*Megaptera novaeangliae*) data from AMAPPS, along with other sources, to assess the utility of subseasonal forecasts for dynamic management of marine mammal populations. This paper modeled the density of humpbacks along 10 km segments of trackline with either satellite sea surface temperature or SubX forecasted sea surface temperature data to predict weekly mean humpback density from March to August of each year from 1995 to 2016. Preliminary results showed the environmental forecasts could predict arrival of humpbacks 2 weeks in advance of their actual arrival.

9.4 Database Development, Website Development and Data Archiving

9.4.1 AMAPPS Map Viewer Website

In 2021, we updated the AMAPPS map viewer website to display the recently developed cetacean seasonal spatiotemporal distributions and abundance estimates using the 2010 to 2017 AMAPPS shipboard and aerial survey data (see section 9.3.1). This website allows the user to display and download the density estimates for each 10-km2 grid cell. The user can also use the curser to outline an area of interest and download just the data inside the user-defined area.

In addition, we are in the process of making the monthly species-specific spatiotemporal maps and data available on a public GitHub repository.

9.4.2 Archiving Data

We are preparing several datasets, including AMAPPS, for archival at the National Centers for Environmental Information (NCEI). We collected these data during ship-based and aerial surveys in the Atlantic and Gulf of Mexico over multiple years. Most of this data were from dedicated surveys collecting data on the distribution and abundance of marine mammals and sea turtles in US waters. We are also including in the archive packages the ship-based in-situ environmental data (such as conductivity, temperature, and depth (CTD casts)) collected at the same time as the marine mammal data. Examples of the datasets already archived for the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) include the ship-based (GU1801) and aerial survey data (TO18Wi).

9.5 Acknowledgements

Funding for the 2021 data analyses discussed in this chapter came in part from 3 sources of funds specified in section 1.4 of this document (NMFS, and the 2 interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy). The SEFSC and NEFSC provided some staff. Other staff time came from the Cooperative Institute for Marine and Atmospheric Studies (CIMAS), a Cooperative Institute of the University of Miami and the National Oceanic and Atmospheric Administration, cooperative agreement NA20OAR4320472, and the Azura Consulting LLC and Integrated Statistics, Inc. contract NFFM7320 with the NEFSC.

The NOAA Fisheries Advanced Study Program project also provided support for the project involving the active acoustic data to improve marine mammal distribution patterns (section 9.3.7).

An award from the Modeling, Analysis, Predictions and Projections (MAPP) program at the National Oceanographic and Atmospheric Administration (NOAA) Climate Office (Award number 78874) provided funds for the project using AMAPPS humpback abundance data to forecast their arrive to foraging grounds (section 9.3.8).

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