2022

Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in U.S. Waters of the Western North Atlantic Ocean

AMAPPS III

Pilot whales (*Globicephala* sp.) taken from NOAA Twin Otter's 3-camera system. NEFSC MMPA Permit #21371

27 June 2023

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Abbreviations and acronyms

Abbreviation	Description
AMAPPS	Atlantic Marine Assessment Program for Protected Species
BOEM	Bureau of Ocean Energy Management
CFF	Coonamessett Farm Foundation
CIMAS	Cooperative Institute for Marine and Atmospheric Studies
EcoMon	Ecosystem Monitoring
ESA	Endangered Species Act
FMC	Forward motion compensated
GPS	Global positioning system
HARP	High frequency acoustic recording package
HYCOM	HYbrid Coordinate Ocean Model
MBTA	Migratory Bird Treaty Act
MMPA	Marine Mammal Protection Act
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OBIS-SEAMAP	Ocean Biodiversity Information System- Spatial Ecological Analysis of Megavertebrate Populations
PIT tag	Passive Integrated Transponder tag
SEFSC	Southeast Fisheries Science Center
VIAME	Video and Image Analytics for Multiple Environments
VPR	Video plankton recorder
WHOI	Woods Hole Oceanographic Institution

1 Overview of 2022

1.1 Background

The Atlantic Marine Assessment Program for Protected Species (AMAPPS) is a comprehensive multi-agency research program in the U.S. 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 U.S. 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 U.S. 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 involves 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 2022.

1.2 Summary of 2022 field activities

A summary of field activities we conducted in 2022 is in Table 1-1. The data presented here are preliminary and subject to change as we perform further auditing and analyses.

Aboard a NOAA Twin Otter aircraft, the NEFSC and SEFSC conducted an aerial survey during 1 November 2021 - 16 February 2022. The main goal of the survey was to test a camera system as a survey tool for line-transect surveys for marine mammals and sea turtle distribution and abundance estimation. To investigate different habitats, we established survey tracklines off Cape Cod, MA, Cape Hatteras, NC and Cape Canaveral, FL. We flew nearly 96 hours that led to recording visually detected sightings of 447 marine mammals, 731 sea turtles, 85 seals, and 510 fish sightings. In addition, we collected over 276,000 images including 2,786 images with animals of 14 marine mammal, 5 sea turtle, 2 seal, and 12 fish species or species groups. We downloaded the images with animals to the Video and Image Analytics for Multiple Environments (VIAME) website, a free and open-source suite of computer vision tools for object detection, tracking, rapid model generation and other related analyses. Within each image, we manually annotated all animals with a polygon outlining the animal's shape. We will then use these annotations to train a species detection neural network algorithm. More information is in Chapter 2.

We completed three shipboard surveys in 2022 as part of the sea monitoring program of the distributions of pelagic seabirds. This included two surveys conducted during Ecosystem Monitoring surveys, and one aboard an East Coast Ocean Acidification survey supported by the NOAA Ocean Acidification Program. Cruises sampled regions from the Scotian Shelf to the Florida east coast, where we completed over 7,000 km of visual transect lines. We recorded 21,016 sightings of birds, marine mammals, sea turtles, fishing gear, and marine debris. Most sightings were pelagic seabird species, and varied by survey, season and region. Wilson's storm-petrels (*Oceanites oceanicus*) and great shearwaters (*Puffinus gravis*) were the most frequently detected birds on all three surveys. Common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*), and humpback whales (*Megaptera novaeangliae*) were the most frequently detected marine mammals. More information is in Chapter 3.

During 2022, the AMAPPS Turtle Ecology team completed fieldwork to deploy satellite tags on loggerhead turtles (*Caretta caretta*) in May and June off the mid-Atlantic Bight (15 tags). The team also deployed satellite tags on leatherback turtles (*Dermochelys coriacea*) in May off North Carolina (10 tags), and in August and September off Massachusetts (12 tags). The objectives of these fieldwork activities were to gather information on turtle behavior and dive patterns, and collect biological samples. More information is in Chapter 4.

1.3 Summary of 2022 analyses

Analysis activities we conducted in 2022 are in Table 1-2. Papers published in 2022 in Table 1-3; papers in review as of 31 December 2022 in Table 1-4; and presentations in Table 1-5.

The Turtle Ecology team continued developing the Oracle database that stores the satellite tag data of loggerhead and leatherback turtles and their associated metadata. This team also made considerable progress on four manuscripts. Two manuscripts were recently published as peer-reviewed articles (estimated the complex patterns of survey availability for loggerhead turtles; and estimated surface availability metrics of leatherback turtles tagged off North Carolina to Massachusetts; Table 1-3). In addition, two papers are in progress (exploring the overlap between loggerhead distribution and scallop fishing effort; and documenting leatherback surfacing behavior). More information is in Chapter 4.

The passive acoustic team published a paper that improved our understanding of the acoustic abundance and diving ecology of sperm whales (*Physeter macrocephalus*) by using a large towed array dataset, tracking their dive depth, and examining how their dive relates to the seafloor (Table 1-3). The team also has a manuscript in prep that is examining the spatial-temporal distribution of beaked whales along with their foraging behavior during the 2016 summer months. In addition, we continue to add all AMAPPS collected towed array data to our online passive acoustic detection website hosted by the Northeast Fisheries Science Center. More information is in Chapter 5.

The visual sightings abundance team updated the environmental data time series from 2010 to 2021 using newer consistent data sources. We used the AMAPPS visual sightings data in two published 2022 peer-reviewed articles (documented northeasterly movement of cetacean species distributions; and showed environmental forecasts could predict the arrival of humpback whales). The visual AMAPPS data were also used in 5 papers that were in review as of December 2022. Two of these papers estimated the design-based cetacean abundance using the summer 2021 shipboard and aerial line transect abundance survey data. Another paper developed a new analysis method to estimate abundance using both visual and tow-array cetacean detections from a shipboard abundance survey. Another demonstrated the usefulness of echosounding to model marine mammal distribution and abundance with direct measurements of prey rather than relying on environmental proxies. The last paper combined marine mammal, fish and invertebrate surveys in an ensemble modeling approach to assess the relative importance and capacity of the environment and other marine species to predict the distribution of coastal and offshore bottlenose dolphin ecotypes. In addition, the team is in progress in 3 other studies (extending the Bayesian hierarchical density surface model predictions to produce a package that a user can determine the probability that the abundance of a user-chosen whale species, within a user-chosen wind energy area for a user-defined time frame is above a user-defined threshold; estimating the

Table 1-1 General information on the 2022 field data collection projects

Field collection project[1]	**Platform(s)**[1]	**Dates in 2022, unless Specified**	**Location**	**Chapter**
Digital aerial abundance survey (NEFSC)	NOAA Twin Otter airplane	1 Nov - 23 Dec 2021	Shelf waters off Cape Cod, MA	2
Digital aerial abundance survey (SEFSC)	NOAA Twin Otter airplane	3 Jan - 16 Feb	Shelf waters off Cape Hatteras, NC and Cape Canaveral, FL	2
Spring Ecosystem monitoring seabird survey (NEFSC)	NOAA ship *Henry B. Bigelow*	1 - 16 Jun	Shelf waters from Maine to Rhode Island	3
Summer East Coast Ocean Acidification seabird survey (NEFSC)	NOAA ship *Ronald H. Brown*	6 Aug - 22 Sep	Shelf waters from Nova Scotia to Florida	3
Fall Ecosystem monitoring seabird survey (NEFSC)	NOAA ship *Pisces*	1-10 Nov	Shelf waters from Maine to Rhode Island	3
Leatherback turtle satellite tagging (SEFSC + NEFSC)	R/V Coriacea; NOAA Twin Otter airplane	14 Apr - 1 May	off Florida	4
Leatherback satellite tagging (NEFSC + SEFSC)	R/V *Julius*	16 - 27 May	off North Carolina	4
Loggerhead turtle satellite tagging (NEFSC + Coonamessett)	F/V *Kathy Ann*	23 - 28 May; 20 - 27 Jun	Mid-Atlantic Bight	4
Leatherback satellite tagging (SEFSC + NEFSC)	M/V *Warren Jr* & R/V *Coriacea*	22 Aug - 4 Sep	off Massachusetts	4
Leatherback turtle Sound Exposure Project (NEFSC + Coonamessett)	None	Postponed to summer 2023	off Massachusetts	4

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

spatiotemporal abundance of sea turtles using the 2-step generalized additive models; and starting to develop a neural network algorithm that will hopefully identify animals in images that were taken during an aerial abundance survey). More information is in Chapter 6.

The oceanographic team is identifying oceanographic characteristics associated with top predators, such as cetaceans, tuna, and sharks, and estimating densities and biomass of the prey that top predators are feeding on. We collected prey data during AMAPPS abundance and other surveys using midwater trawls and other types of nets, using active acoustics, and using a video plankton recorder. Using the active acoustic and video plankton recorder data, we are developing neural network techniques to refine and improve the identification and classification of regions of interest. Another way we are improving the classification of the acoustic data to taxonomic levels that are biologically and ecologically meaningful is to merge the trawl catch and active acoustic data. We have published the surface and bottom temperature and salinity data collected during the 2021 AMAPPS abundance survey on the NOAA ship *Henry B. Bigelow*. We also confirmed the presence of Atlantic bluefin tuna (*Thunnus thynnus*) larvae and cephalopod paralarvae in samples collected on the 2021 AMAPPS abundance survey. We then provided these tuna data to outside researchers for population genetics and Close Kin Mark Recapture Studies using genetic techniques. We are using the cephalopod data representing 33 unique taxa in a genetic project. More information is in Chapter 7.

To create an operational platform that leverages the increased resolution of satellite imagery, proof-of-concept research, advances in cloud computing, and machine learning to monitor the world's oceans, we formed the Geospatial Artificial Intelligence for Animals initiative. This initiative contracted with the Maxar Technologies' GeoHIVE platform to crowdsource image annotation of bowhead whales (*Balaena mysticetus*). They found that whales are challenging to discriminate and may not be suitable for approaches that down sample the imagery and serve it up online as RGB files. This means, for such small objects as whales, we need to view the native resolution imagery. More information is in Chapter 8.

1.4 Acknowledgements

Three agencies contributed funding for the 2022 data collection and analyses discussed in this document:

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

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

Table 1-2 Description of analysis projects conducted during 2022

2022 Analysis Projects	Purpose	Chapter
Distribution and ecology of sea turtles	Document distribution and ecology of loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) turtles equipped with satellite tags	4
Surface availability metrics of leatherback turtles	Provide summary statistics of availability metrics from leatherback satellite tag data	4
Surface availability metrics of loggerhead turtles	Characterize spatiotemporal dive-surfacing behavior of loggerhead turtles using satellite tag data collected during 9 years	4
Distribution of loggerhead and scallop fishery	Document the overlap between loggerhead turtles and the scallop fishery	4
Leatherback surfacing behaviors	Use tag data and machine learning techniques to examine leatherback surfacing behaviors.	4
Sperm whale passive acoustic abundance and foraging	Estimate sperm whale (*Physeter macrocephalus*) abundance using only passive acoustic data from 2016 NEFSC shipboard survey	5
Beaked whales passive acoustic distribution and foraging ecology	Use acoustic detections from summer 2016 towed array and bottom mounted HARPs[1] to describe spatial, temporal and depth distribution patterns	5
Update environmental time series	Use new consistent data sources to update the environmental data time series from 2010 to 2021.	6
Cetacean habitat shifts	Document species that shifted their habitats between 2010 and 2017 using spatiotemporal density models	6
Spatiotemporal density models and abundance estimates	Apply generalized additive models to quantify abundance and relationships between sea turtles and habitat	6
Forecast migratory humpback whale arrival	Use SubX forecast sea surface temperature and humpback whale (*Megaptera novaeangliae*) density estimates to forecast their arrival	6
Abundance for Stock Assessment Reports	Use visual data from 2021 shipboard and aerial surveys to estimate abundance of 27 species using design-based methods	6
Acoustic and visual abundance estimate of sperm whales	Estimate sperm whale abundance by integrating passive acoustic and visual sightings shipboard data	6
Use prey characteristics to develop cetacean density models	Use active acoustic backscatter data (representing middle level trophic level taxa) to develop spatiotemporal cetacean density models	6
Compare cetacean distribution to ecosystem characteristics	Predict distribution of bottlenose dolphin (*Tursiops truncatus*) ecotypes using an ensemble model using data from marine mammal, fish and invertebrate surveys	6
Abundance of whales in wind energy areas	Extend Bayesian hierarchical density surface models to wind energy areas to predict probability of abundance above a user-chosen threshold	6
Develop species identification algorithm	Develop neural network algorithm to assist finding and identifying animals within camera images taken from aerial abundance surveys	6
Process prey data	Process and analyze prey data collected from midwater trawls and other types of nets, from active acoustics, and on video plankton recorders	7

2022 Analysis Projects	Purpose	Chapter
Develop species identification algorithm	Develop neural network algorithm to assist finding and identifying species or species groups in active acoustic data	7
Develop species identification algorithm	Develop neural network algorithm to assist finding and identifying species in video plankton recorder data	7
Distribution and abundance of bluefin tuna larvae	Identify presence of Atlantic bluefin tuna (*Thunnus thynnus*) larvae and conduct close kin mark recapture studies using genetic techniques.	7
Identify cephalopod paralarvae	Identify presence of cephalopod paralarvae and conduct genetic analyses to determine species.	7
Archive data and make publicly available	Archive sightings, passive acoustic, tag and ecosystem data and make data and analysis products publicly available	4-7
Investigate if satellite imagery can be used to monitor cetaceans	Geospatial Artificial Intelligence for Animals initiative attempted to identify bowhead whales (*Balaena mysticetus*) in satellite imagery.	8

[1] HARPs = high frequency acoustic recording packages

Table 1-3 Manuscripts published during 2022

Published Papers
Chavez-Rosales S, Josephson E, Palka D, Garrison L. 2022. Detection of habitat shifts of cetacean species: A comparison between 2010 and 2017 habitat suitability conditions in the Northwest Atlantic Ocean. Front. Mar. Sci. 9:877580. https://doi.org/10.1002/jwmg.22208
Hatch JM, Haas HL, Sasso CR, Patel SH, Smolowitz RJ. 2022. Estimating the complex patterns of survey availability for a highly-mobile marine animal. Journal of Wildlife Management 86:e22208. https://doi.org/10.1002/jwmg.22208
Rider M, Haas H, Sasso C. 2022. Surface availability metrics of leatherback turtles (*Dermochelys coriacea*) tagged off North Carolina and Massachusetts, United States. U.S. Dept Commer Northeast Fish Sci Cent Tech Memo 286. 13 p. https://doi.org/10.25923/82c1-4a85
Westell A, Sakai T, Valtierra R, Van Parijs SM, Cholewiak D, DeAngelis A. Sperm whale acoustic abundance and dive behaviour in the western North Atlantic. Sci Rep. 2022 Oct 7;12(1):16821. PMID: 36207450; PMCID: PMC9546825. https://doi.org/10.1038/s41598-022-20868-3
Stepanuk J, Kim H, Nye JA, Roberts JJ, Halpin PN, Palka DL, Pabst DA, McLellan WA, Barco SG, Thorne LH. 2022. Subseasonal forecasts provide a powerful tool for dynamic marine mammal management. Frontiers in Ecology and Environment. Front Ecol Environ 2022. https://doi.org/10.1002/fee.2506

Table 1-4 Manuscripts in review as of 31 December 2022

In Review Manuscripts
Garrison LP, Aichinger Dias L. 2023. Abundance of marine mammals in waters of the southeastern U.S. Atlantic during summer 2021. U.S. Dept Commer Southeast Fish Sci Cent Ref Doc PRBD-2023-01. 23. https://doi.org/10.25923/ce0d-9e10
Holzwarth-Davis T. 2023. Oceans and Climate Branch CTD Data Report: TD-REPORT-2021002HB Northeast Fisheries Science Center (U.S.). https://doi.org/10.25923/jx96-4v91.
Khan CB, Goetz KT, Cubaynes HC, Robinson C, Murnane E, Aldrich T, Sackett M, Clarke PJ, LaRue MA, White T, Leonard K, Ortiz A, Lavista Ferres JM. 2023. A biologist's guide to the galaxy: Leveraging artificial intelligence and very high-resolution satellite imagery to monitor marine mammals from space. J. Mar. Sci. Eng., 11, 595. https://doi.org/10.3390/jmse11030595
Orphanides CD, Jech JM, Palka DL, Collie J. 2023. Relating marine mammal distribution to water column prey structure derived from echosounding. Mar Ecol Prog Ser 711:101-119. https://doi.org/10.3354/meps14290
Palka, DL. 2023. Cetacean abundance in the U.S. Northwestern Atlantic Ocean, summer 2021. U.S. Dept Commer, Northeast Fish Sci Cent Ref Doc. 23-08; 59p. https://doi.org/10.25923/7cab-7s69
Roberts, SM, Jacoby A-M, Roberts JJ, Leslie J, Payne KL, Read AJ, Halphin RN, Barco S, Garrison L, McLellan W, Palka D, Nye JA. 2023. Tight spatial coupling of a marine predator with soniferous fishes: Using joint modelling to aid in ecosystem approaches to management.Diversity and Distributions; 00:1-16. https://doi.org/10.1111/ddi.13746
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*).

Table 1-5 Presentations made in 2022

Presentations
DeAngelis A, Ackerknecht T, Baumann-Pickering S, Bell J, Cholewiak D, Cohen R, Field C, Frasier K, Hildebrand J, Mueller-Brennam L, Sakai T, Soldevilla M, Solsona-Berga A, Trickey JS, Valtierra R, Westell A, Van Parijs S. 2022. Combining spatial and temporal acoustic datasets to examine the summer presence of beaked whales off the east coast of the U.S. Poster presentation at the 9th International Workshop on Detection, Classification, Localization, and Density Estimation of Marine Mammals Using Passive Acoustics, March 2022, Oahu, HI.
DeAngelis A, Ackerknecht T, Baumann-Pickering S, Bell J, Cholewiak D, Cohen R, Field C, Frasier K, Hildebrand J, Mueller-Brennam L, Sakai T, Soldevilla M, Solsona-Berga A, Trickey JS, Valtierra R, Westell A, Van Parijs S. 2022. Combining spatial and temporal acoustic datasets to examine the summer presence of beaked whales off the east coast of the U.S. Poster presentation at the 24th Biennial Conference on the Biology of Marine Mammals, August 2022, Palm Beach, FL.
Westell A, Sakai T, Valtierra R, Van Parijs S, Cholewiak D, DeAngelis A. 2022. Acoustic detections of sperm whales in the western North Atlantic: insights into their foraging ecology and abundance. Oral presentation at the 9th International Workshop on Detection, Classification, Localization, and Density Estimation of Marine Mammals Using Passive Acoustics, March 2022, Oahu, HI.
Westell A, Sakai T, Valtierra R, Van Parijs S, Cholewiak D, DeAngelis A. 2022. Acoustic detections of sperm whales in the western North Atlantic: insights into their foraging ecology and abundance. Poster presentation at the 24th Biennial Conference on the Biology of Marine Mammals, August 2022, Palm Beach, FL.
Jech J.M. 2022. Acoustic Observations of Nekton and Zooplankton along the Northeast Continental Shelf Break. Invited presentation to the Acoustical Society of America Meeting, Nashville, TN, 5-9 December 2022.

2 Digital aerial abundance surveys during 1 November 2021 to 15 February 2022: Northeast and Southeast Fisheries Science Centers

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

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2.1 Summary

As part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS), aboard a National Oceanic and Atmospheric Administration (NOAA) Twin Otter aircraft, the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) conducted an aerial survey during 1 November 2021 - 16 February 2022. The main goal of the survey was to test a camera system as a survey tool for line-transect surveys for marine mammals and sea turtle distribution and abundance estimation. We established survey tracklines off Cape Cod, MA, Cape Hatteras, NC and Cape Canaveral, FL to encounter high densities of most common species. The aircraft flew at 600 and 1500 ft at about 100 – 110 knots over the ground. We trialed the cameras with 85, 100, and 135 mm lenses. We flew nearly 96 hours that included the transits to and from the survey tracklines. These efforts resulted in sightings of 447 marine mammals, 731 sea turtles, 85 seals, and 510 fish sightings and over 276,000 images including 3,540 images that we selected based on the presence of animals to be used to train a species detection neural network algorithm.

2.2 Objectives

Future offshore wind developments may use turbines over 900 ft tall that would interfere with the current standard protocol of conducting the aerial line transect abundance surveys at an altitude of 600 ft. Thus, in the future we will have to conduct aerial surveys at an altitude of about 1500 ft or higher. However, because it is harder to visually detect animal groups when a survey is conducted at such high altitudes, the higher altitude surveys will result in fewer visually detected animal groups and less reliable species identifications. Thus, to estimate the distribution and abundance of marine mammals and sea turtles in the future, the main goal of the current survey was to develop a data collection process for surveys conducted at an altitude of 1500 ft that would be automated, replicable, adaptable, and relied on collecting digital line transect images from a belly-mounted camera system. More specifically, the goal of this survey involved:

1) creating a catalog of images for species occupying the waters of the eastern U.S. to be used to train a species detection neural network algorithm;
2) evaluating the logistic issues involved in conducting, processing and analyzing a digital line-transect survey; and
3) comparing the results from a survey conducted at 600 ft altitude (as done in the past) to the results from a survey conducted at 1500 ft altitude (as may have to be done in the future).

2.3 Cruise period and area

We divided the survey into 2 legs. Leg 1, led by the NEFSC, was during 1 November - 23 December 2021 off Cape Cod, MA. Leg 2, led by the SEFSC, was during 3 January - 16 February, 2022 off Cape Hatteras, NC and Cape Canaveral, FL (Figure 2-1). We chose these regions to encounter most of the U.S. Atlantic marine mammals and sea turtle species in relatively high-density regions.

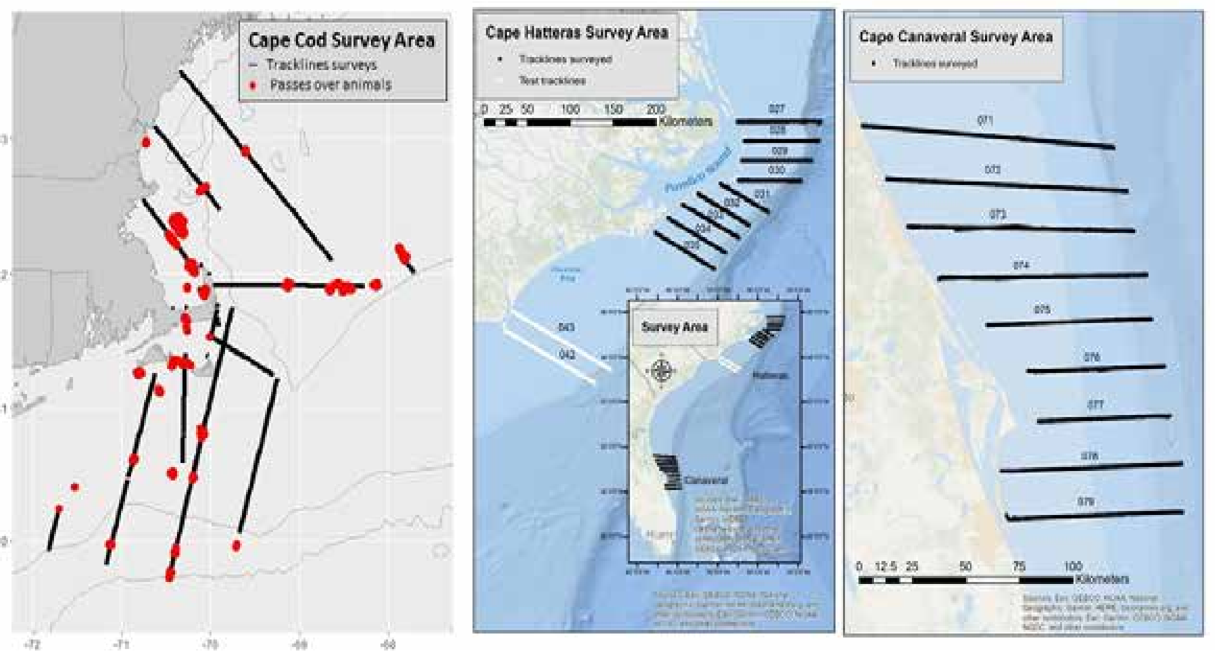

Figure 2-1 Survey areas during the 1 November 2021 – 16 February 2022 aerial survey
Completed track lines (black lines), and locations of passes over animals to collect image series (red regions).

2.4 Methods

During both legs, we conducted the survey aboard a DeHavilland Twin Otter DHC-6 aircraft flying at approximately 100 – 110 knots speed over ground. We selected two target altitudes to conduct the survey: 600 and 1500 ft, although we also explored 1000 and 1200 ft. The first leg focused on trialing the camera system, developing the data collection procedures, and collecting as many images of as many species as possible, where we used the cameras only after we detected an animal group. The second leg focused on conducting routine line transect surveys where the camera system was run continuously; ideally 4 - 6 flights conducted at the North Carolina and Florida regions (2 – 3 at 600 ft and 2 – 3 at 1500 ft) in the best possible sea conditions (under Beaufort sea state 3).

During both legs, we flew surveys only when wind speeds were less than 15 knots or approximately sea state 4 or less on the Beaufort scale. The survey was conducted typically along tracklines oriented approximately perpendicular to the shoreline and were the same as used in the past line-transect abundance surveys.

During both legs, two pilots flew two teams of three marine mammal observers. The forward team consisted of two observers stationed in bubble windows on the left and right side of the aircraft and an associated data recorder. The aft team consisted of a right-sided bubble observer, a data recorder and a forward motion compensated (FMC) computer operator. The FMC computer operator monitored the cameras and entered data associated with the camera mount system as well as notes about sightings in the

FMC computer (Figure 2-2). Bubble window observers relayed data (e.g. effort, sighting angle, sea state, glare, etc.) to the data recorders, who entered data separately by each team in a laptop computer running data acquisition software (VOR during leg 1 and VisSurvey during leg 2) that was connected to a handheld Global Positioning System (GPS) (Figure 2-2). VOR outputted text data files read into Excel. VisSurvey outputted to a Microsoft Access Database.

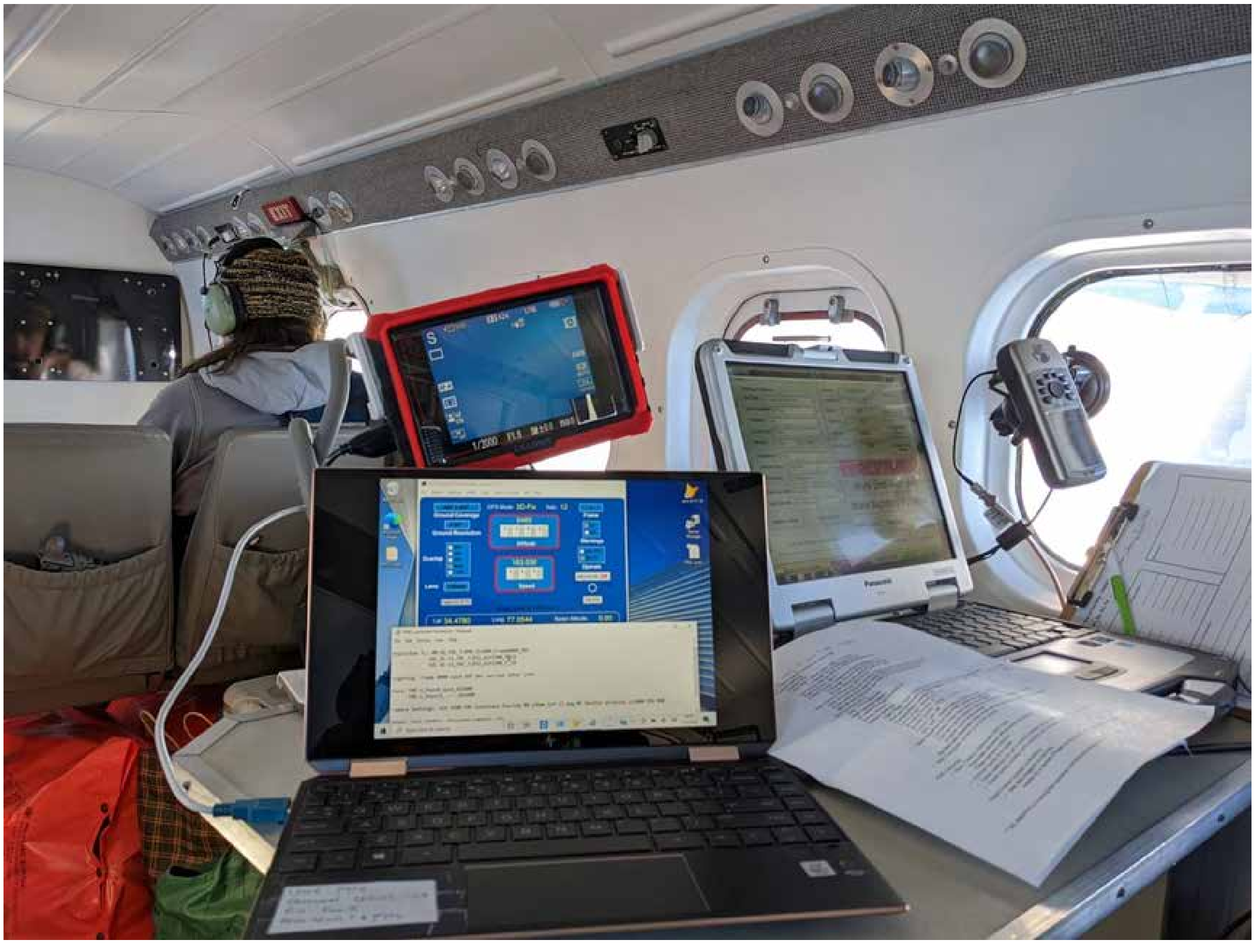

Figure 2-2 Computer set up
Forward motion compensating (FMC) computer (left side of image) with monitor of view from center camera (red rimmed). Data acquisition computer, VisSurvey, connected to a handheld GPS (right side of image).

In the belly window port, we installed a system of three Sony A7R III cameras (A-left, B-center and C-right) mounted on a forward motion compensated platform (Figure 2-3). At 600 ft altitude, with 85mm lenses where cameras A and C were set with an 'inward' inclination of 21° relation to the mount resulted in 0.97 cm pixel resolution on the ground. At 1500 ft altitude, with 135mm lenses on an inclination of 13° resulted in 1.52 cm pixel resolution on the ground. Overlap between frames was initially set to 0% but changed to 40% during most marine mammal sightings. All cameras were set to continuously shoot, at a shutter priority speed of 1/2000, manual focus and ISO at a minimum of 800; however later in the survey, ISO was set to Auto.

The two teams operated independently from each other using two separate intercom channels. The FMC computer operator could communicate with both data recorders to input data on sightings into the FMC computer, which produced text and kml files.

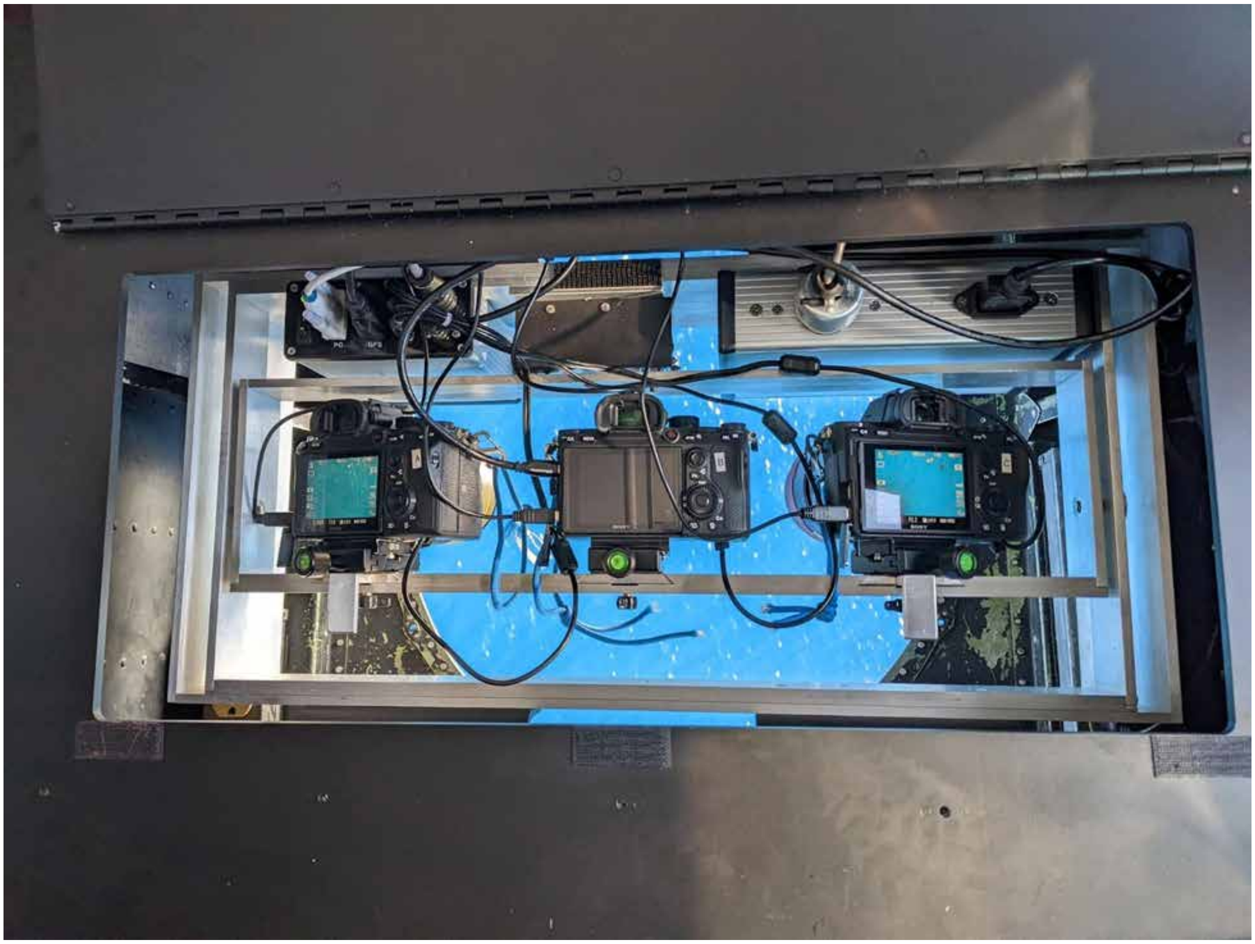

Figure 2-3 Three Sony cameras mounted on the forward motion compensated platform Platform positioned on the belly window.

During on-effort periods, that is when the plane was flying level over tracklines and at survey altitude and speed, observers searched visually from the trackline (0˚) to approximately 60˚ above vertical. When a sea turtle, marine mammal, or other organism was observed, the observer waited until it was perpendicular to the aircraft and then measured the angle to the organism (or the center of the group) using a digital inclinometer. If the forward observers initially saw a mammal sighting, they waited until it was aft of the aircraft to allow the aft team an opportunity to see the group, before the plane went off-effort to investigate the group, if needed.

At this point, the data collection protocols for legs 1 and 2 differed slightly due to the different goals. During leg 1, after a group was detected, if it was determined that the group could be relocated, then the survey went off-effort and the plane circled back and flew multiple passes over the group perhaps from different angles while collecting images, with the goal of obtaining as many images as possible (Figure 2-4). During leg 2, which was simulating a normal survey, we prioritized circling a group only to unconfirmed or uncommonly seen mammal species, and to obtain more images. We recorded sea turtle and large fish (mostly sharks and rays) sightings independently by each team and did not circle on them, in most cases.

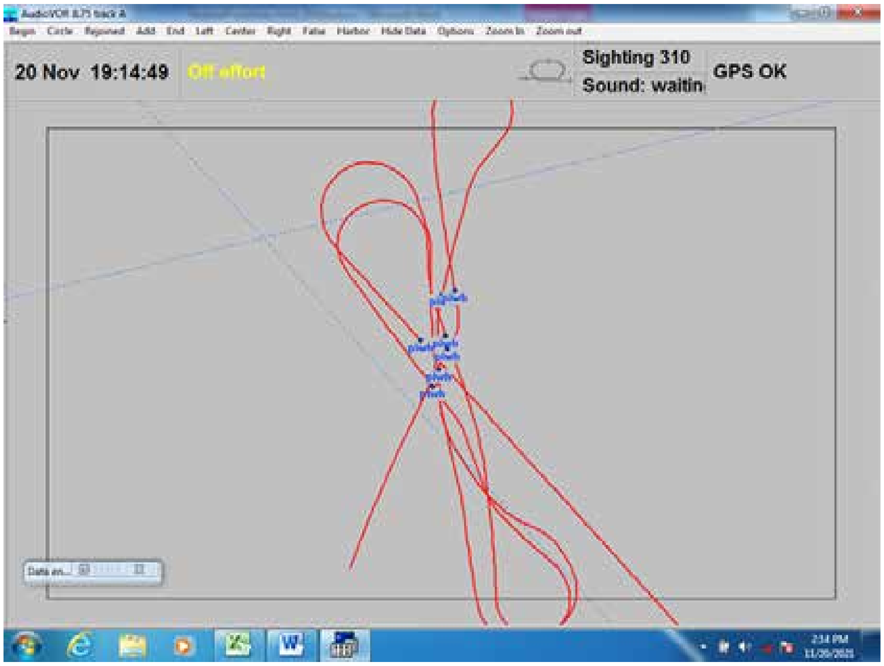

Figure 2-4 Example of multiple passes over a group of pilot whales (Globicephala sp.) Red line is the plane's path; blue dots are locations of the group of pilot whales.

During both legs, at the end of a survey day, we audited the data based on error logs maintained by observers during flight and we copied the data from all the computers to an external hard drive and transferred to a cloud-based storage. We removed the memory cards from the cameras and transferred all images to external hard drives. Then we renamed the image files based on camera and survey year. For example, an image labeled B2200401.JPG indicated it was from camera B, taken during 2022 and was image number 00401. After we downloaded images from the cameras, we distributed the cards to observers for further processing, which consisted of selecting images with animals based on the time of visually recorded sightings (going back and forward roughly one minute from the moment of entry in the sightings databases). We then renamed the selected animal images based on date, camera, species observed on the image and altitude flown. For example, an image labeled 2022-01-13_B2200401_riwh_Alt1500.JPG represented an image taken on 13 January 2022 from camera B during 2022 and it was a right whale while flying at an altitude of 1500 ft. If during the revision process to select images with animals we detected additional or other species, then we added the additional species names to the file name.

After we processed and archived the images, we downloaded the images with animals to the Video and Image Analytics for Multiple Environments (VIAME) website, a free and open-source suite of computer vision tools for object detection, tracking, rapid model generation and other related analyses. Within each image, we manually annotated all animals with a polygon outlining the animal's shape. Later we will used these annotations to train a species detection neural network algorithm.

2.5 Results

During leg 1, we flew nine survey days during 07 November 2021 – 15 December 2021 (Table 2-1). The first flight on 7 November 2021 was a test flight to set up data collection and the camera systems, where we targeted buoys, fishing boats, and seals to practice conducting passes over an object to capture a series of images using the camera systems. We flew flights at various altitudes, 600, 1000, 1200, and 1500 ft to trail the new cameras and the various zoom lenses (85, 100, and 135 mm). On good weather days (Beaufort < 4) we flew survey track lines to find animals to conduct multiple passes over them to capture images. On a few of the poor weather days (Beaufort > 4) we conducted photogrammetry flights over seal haul out sites. We did not attempt surveys on other days with bad weather conditions (winds over 15 – 20 knots). Other non-survey days included mandatory crew rest days; although in nearly all cases, the weather was not conducive to surveying on the crew rest days.

During leg 2, we flew 12 survey days during 3 January 2022 – 16 February 2022 (Table 2-1). The first flight on 6 January 2022, along tracklines 042 and 043, was a test flight to set up data collection and the camera systems. We did not fly when winds were over 15 – 20 knots. We also did not fly on some days due to mandatory crew rest days and 2 days due to a non-COVID medical issue with a pilot. We did not fly a few near-shore parts of tracklines in the Canaveral area because of restricted air space (Figure 2-1). We flew seven survey days off Cape Hatteras, NC along tracklines 027 – 035, including 5 days at 600 ft and 2 at 1500 ft. We flew the Cape Canaveral area along tracklines 071 – 078 in 5 days, including 3 days at 600 ft and 3 at 1500 ft. On average, we flew when the seas were a 3 on the Beaufort scale (Table 2-1). However, in the Cape Hatteras, NC area we experienced a slightly overall higher sea state in relation to Cape Canaveral, FL (average 3.3 and 2.8, respectively).

In total over both legs, we flew nearly 96 hours that included the transits to and from the survey tracklines (Table 2-1). These efforts lead to recording sightings of 447 marine mammals, 731 sea turtles, 85 seals, and 510 fish sightings (Tables 2-2 – 2-4). The total number of marine mammal sightings is unique, while the total number of turtle and fish sightings may include duplicates between both teams. We collected over 276,000 images including 3,540 images that we selected based on the presence of 1 or more animals per image.

During this project, we recorded 16 species (or species groups) of marine mammals as visual sightings (Table 2-2; Figure 2-5). In addition, all species but the visually detected Cuvier’s beaked whale (*Ziphius cavirostris*) and minke whale (*Megaptera novaeangliae*) were also in at least one image. Example images of dwarf or pygmy sperm whales (*Kogia* spp.), fin (*Balaenoptera physalus*), unidentified beaked whales, and short-beaked common dolphins (*Delphinus delphis*) are in Figure 2-6.

Table 2-1 Daily schedule of flight days

Date	Operation	Flight Duration (hr:min)	Tracklines	Altitude (ft)	Cetacean Sightings	Turtle Sightings	Fish Sightings	Seal Sightings	Number Images	Images with Animals	Ave Sea State	Area
7-Nov-21	Test	2:20	NA	600, 1500	4	0	0	7	1,167	42	5.1	Cape Cod
8-Nov-21	Focus on Passes	3:02	A/20	600, 1500	4	0	0	12	2,463	59	5.3	N. of Cape
9-Nov-21	Focus on Passes	3:46	A/06, A/56	600, 750, 1500	25	0	0	4	990	97	3.8	S. of Cape
11-Nov-21	Survey+Passes	3:50	A/04, A/05	600, 1500	12	0	0	2	1,095	95	3.8	S. of Cape
13-Nov-21	Survey+Passes	3:44	A20, A21	600, 1500	27	0	3	9	1,542	49	2.4	N. of Cape
17-Nov-21	Survey+Passes	4:47	A/06, A/07	600, 1200	17	0	8	9	795	37	2.9	S. of Cape
20-Nov-21	Survey+Passes	4:15	A/22, A/34	600, 1000, 1200, 1500	25	0	0	3	2,124	447	3.1	N. of Cape
2-Dec-21	Seal Survey	0:34	A/32, A/34, A/54	600, 1000, 1200	0	0	0	38	1,773	341	5.5	S. of Cape
15-Dec-21	Seal Survey+Passes	1:34	NA	750, 1500	51	0	0	1	8,334	103	3.0	S. and E. of Cape
6-Jan-23	Test Survey	2:37	042, 043	600	2	9	5	0	14,116	22	3.0	Hatteras
12-Jan-23	Survey	8:16	027 - 034	600	18	14	54	0	39,123	348	3.4	Hatteras
13-Jan-23	Survey	7:03	027 - 032	1500	37	15	33	0	16,950	256	3.3	Hatteras
19-Jan-23	Survey	3:23	033 - 035	600	4	18	8	0	11,280	31	4.0	Hatteras
23-Jan-23	Survey	4:11	030 - 032	600	27	15	16	0	13,752	165	3.9	Hatteras
24-Jan-23	Survey	7:01	027 - 032	1500	66	43	30	0	21,396	369	2.6	Hatteras
25-Jan-23	Survey	6:11	027 - 032	600	34	20	58	0	26,709	220	2.9	Hatteras
31-Jan-23	Survey	6:42	071 - 073	1500	22	85	27	0	15,093	130	2.3	Canaveral
1-Feb-23	Survey	3:54	071 - 074	600	12	40	16	0	15,896	35	3.2	Canaveral
10-Feb-23	Survey	2:55	071, 073	600	0	10	4	0	6,452	5	4.4	Canaveral
11-Feb-23	Survey	7:36	071 - 079	1500	23	168	56	0	29,241	135	2.6	Canaveral
12-Feb-23	Survey	8:03	071 - 079	600	37	294	192	0	45,912	554	1.5	Canaveral
Total		**95:42**			**447**	**731**	**510**	**85**	**276,203**	**3,540**		

Table 2-2 Numbers of cetaceans visually detected and photographed

Species Common Name	**Species Scientific Name**	**Number Groups Sighted**	**Number Animals Sighted**	**Number Images**
Atlantic Spotted Dolphin	*Stenella frontalis*	6	1,057	90
Common Bottlenose Dolphin	*Tursiops truncatus*	208	1,496	327
Common Bottlenose or Atlantic Spotted Dolphin	*T. truncatus or S. frontalis*	20	460	54
Cuvier's Beaked Whale	*Ziphius cavirostris*	3	3	0
Fin Whale	*Balaenoptera physalus*	3	5	9
Harbor Porpoise	*Phocoena phocoena*	13	20	27
Humpback Whale	*Megaptera novaeangliae*	17	26	18
Minke Whale	*B. acutorostrata*	2	2	0
North Atlantic Right Whale	*Eubalaena glacialis*	11	11	19
Pilot Whales spp	*Globicephala sp.*	15	92	63
Pygmy or Dwarf Sperm Whale	*Kogia sp.*	0	0	6
Risso's Dolphin	*Grampus griseus*	7	35	4
Short-beaked Common Dolphin	*Delphinus delphis*	82	1,944	782
Sperm Whale	*Physeter macrocephalus*	2	2	1
Unidentified Dolphin	Cetacea	56	365	116
Unidentified Ziphiid	Ziphiidae	2	9	1
Total Cetacean		**447**	**5,525**	**1,517**

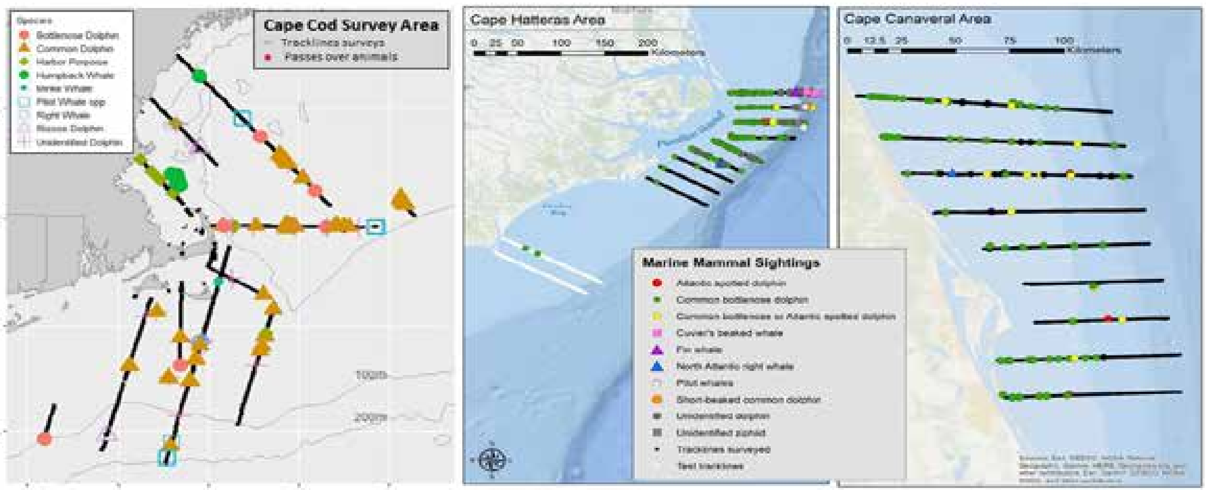

Figure 2-5 Location of cetacean sightings

Figure 2-6 Examples of cetaceans photographed by the camera system
Top left: Kogia spp.; top right: fin whale (Balaenoptera physalus); bottom left: beaked whales; bottom right: common dolphins (Delphinus delphis). Images have been cropped for visualization; animals not to scale.

The species of sea turtle recorded included loggerhead (*Caretta caretta*), green (*Chelonia mydas*), Kemp's ridley (*Lepidochelys kempii*) and leatherbacks (*Dermochelys coriacea*) (Table 2-3; Figure 2-7). We photographed all turtle species using the camera system (Figure 2-8).

Table 2-3 Numbers of sea turtle and seals visually detected and photographed

Species Common Name	Species Scientific Name	Number Groups Sighted	Number Animals Sighted	Number Images
Green Turtle	*Chelonia mydas*	10	10	7
Hardshell Turtle	-	551	596	214
Kemp's Ridley Turtle	*Lepidochelys kempii*	42	45	49
Leatherback Turtle	*Dermochelys coriacea*	4	4	1
Loggerhead Turtle	*Caretta caretta*	124	128	87
Total Turtles		**731**	**783**	**358**
Gray Seal	*Halichoeus grypus*	56	3,800	360
Unidentified Seal	Phocidae	29	41	82
Total Seals		**85**	**3,841**	**442**

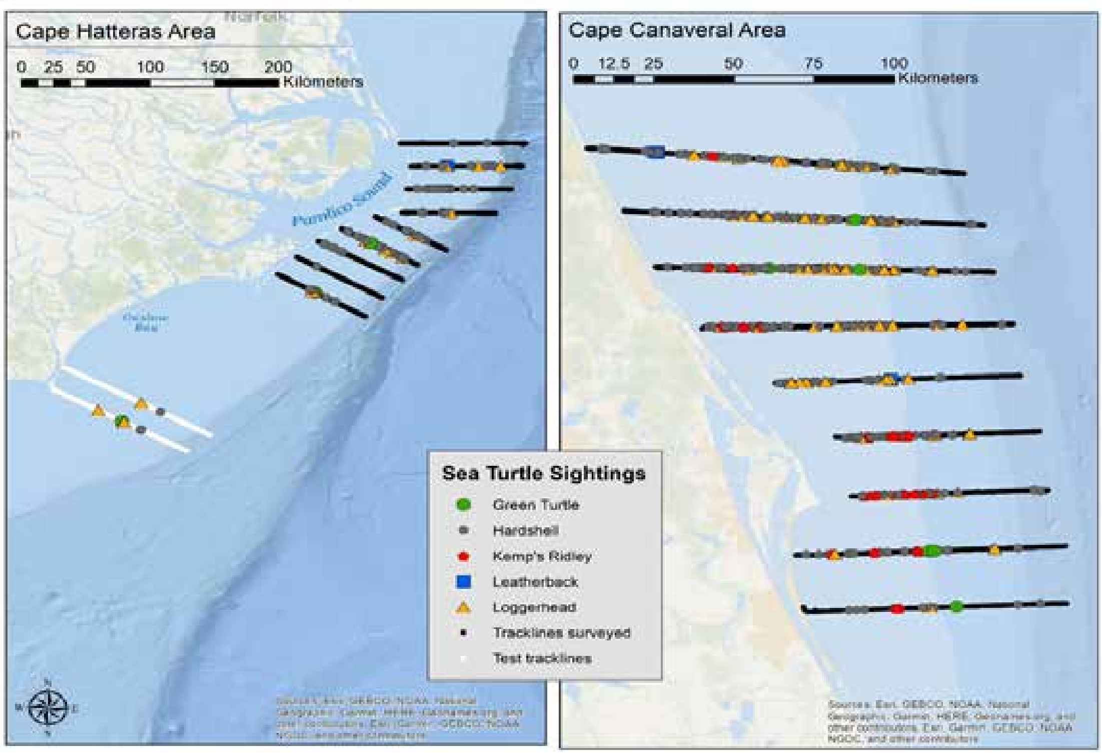

Figure 2-7 Location of sea turtle sightings

Figure 2-8 Examples of sea turtles photographed by the camera system
Top left: green turtle (Chelonia mydas); top right: loggerhead turtle (Caretta caretta); bottom left: Kemp's Ridley turtle (Lepidochelys kempii); bottom right: leatherback turtle (Dermochelys coriacea). Images have been cropped for visualization; animals not to scale.

We detected gray seals (*Halichoeus grypus*) as visual sightings at sea and in the images on land and at sea (Table 2-3, Figures 2-9 and 2-10).

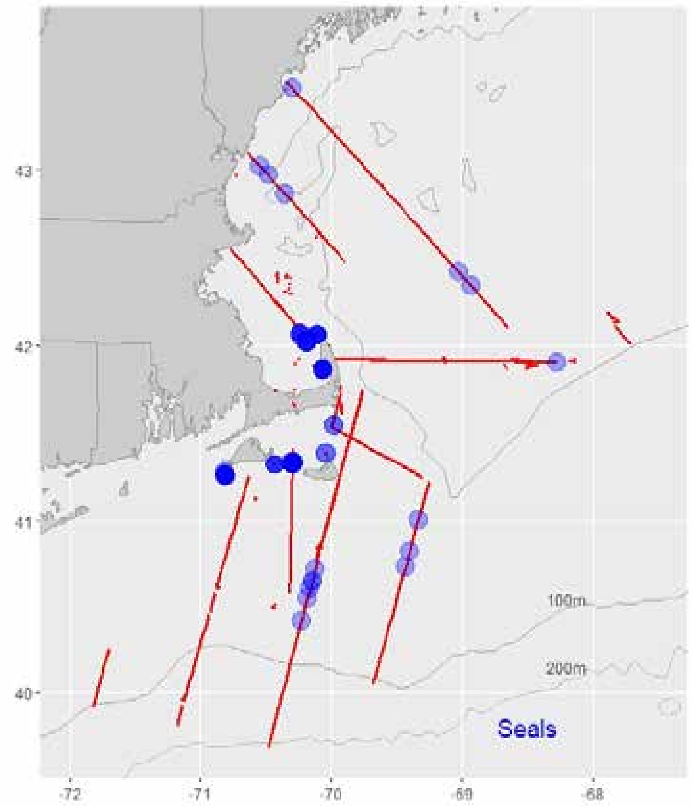

Figure 2-9 Location of seal sightings

Figure 2-10 Examples of gray seals (Halichoeus grypus) photographed by the camera system

We recorded multiple species of large fish as visual sightings and in the images (Table 2-4; Figure 2-11), where example images of sharks and rays are in Figure 2-12.

Table 2-4 Numbers of fish species visually detected and photographed

Species Common Name	Species Scientific Name	Number Groups Sighted	Number Animals Sighted	Number Images
Basking Shark	*Cetorhinus maximus*	0	0	2
Blue Shark	*Prionace glauca*	3	3	0
Black Tip Shark	*Carcharhinus limbatus*	0	0	1
Chilean Devil Ray	*Mobula tarapacana*	5	5	3
Cownose Ray	*Rhinoptera bonasus*	0	0	17
Giant Devil Ray	*Mobula mobular*	3	5	2
Great White Shark	*Carcharodon carcharias*	4	4	2
Hammerhead Shark	Sphyrnidae	217	459	367
Mako Shark	*Isurus*	0	0	1
Oceanic Manta Ray	*Manta birostris*	42	73	0
Ocean Sunfish	*Mola mola*	96	119	67
Sailfin	*Istiophorus sp.*	0	0	2
Spotted Eagle Ray	*Aetobatus narinari*	0	0	4
Tuna sp.	Thunnini	2	3	0
Unid Ray School	Batoidea	1	1	1
Unid Small Fish	-	2	2	0
Unid. Large Fish	-	4	4	0
Unid. Ray	Batoidea	11	18	0
Unid. Shark	Elasmobranchii	120	279	0
Total Fish		**510**	**975**	**469**

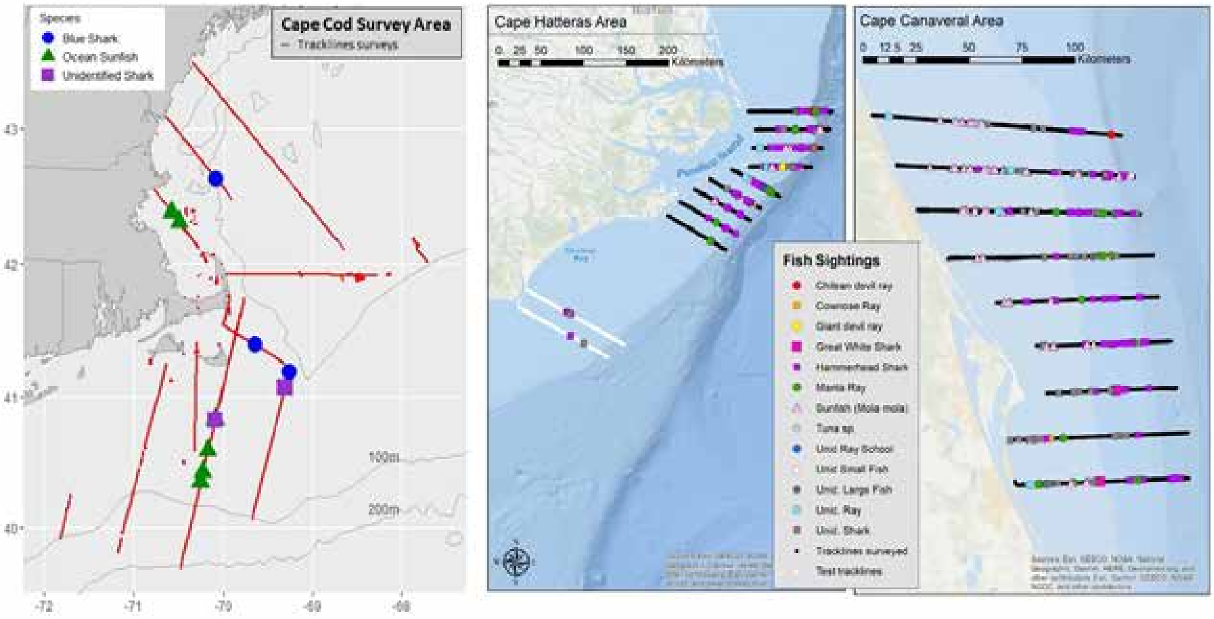

Figure 2-11 Locations of large fish sightings

Figure 2-12 Examples of large fish photographed by the camera system
Top left: hammerhead shark (Sphyrnidae); top right: oceanic manta ray (Manta birostris); bottom left: giant devil ray (Mobula mobular); bottom right: oceanic manta ray. Images have been cropped for visualization; animals not to scale.

2.6 Disposition of data

The data presented here are preliminary and subject to change as we preform further auditing, processing and analyses. We archived the data and images collected during the aerial survey at the SEFSC in Miami, FL and at the NEFSC in Woods Hole, MA. We also archived the final audited version of the data in the NEFSC Oracle database. We will also archive the complete data set at the National Centers for Environmental Information (https://www.ncei.noaa.gov/).

2.7 Permits

Permit No. 21938 issued to the SEFSC by NMFS and Permit No. 21371 issued to the NEFSC by NMFS authorized the marine mammal research activities during the survey.

2.8 Acknowledgements

We would like to thank the airplane's crew and observers that were involved in collecting these data: Casey Marwine, Kyler Johnson, Josh Rannenberg, Chris Licitra, Mason Carroll, Corey Accardo, Rachel Hardee, Richard Holt, Paul Nagelkirk and Nick Metheny.

NOAA Aircraft Operations Center funded flight time and other aircraft costs, including the staff time and travel of the pilots. The scientists time and travel were funded by the three sources of funds specified in

section 1.4 of this document (that is, NMFS, and the two interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the U.S. Navy). 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 scientists on the SEFSC survey. While, Azura Consulting LLC and Integrated Statistics, Inc., contract NFFM7320 staffed the scientists on the NEFSC survey.

3 Sea monitoring of the distributions of pelagic seabirds in the northeast U.S. shelf ecosystem: Northeast Fisheries Science Center

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3.1 Summary

Three shipboard surveys were completed in 2022 as part of the sea monitoring of the distributions of pelagic seabirds. Two surveys were conducted during Ecosystem Monitoring (EcoMon) surveys and one was aboard an East Coast Ocean Acidification survey supported by the National Oceanic and Atmospheric Administration's (NOAA) Ocean Acidification Program. Cruises sampled regions from the Scotian Shelf to the Florida east coast. Over 7000 kilometers of visual transect lines were completed during the three surveys. A total of 21,016 sightings of birds, marine mammals, sea turtles, fishing gear, and marine debris were recorded. Most sightings were pelagic seabird species, and varied by survey season and region. Wilson's storm-petrels (*Oceanites oceanicus*) and great shearwaters (*Puffinus gravis*) were most frequently sighted birds on all three surveys. Common dolphins (*Delphinus delphis*), bottlenose dolphins (*Tursiops truncatus*), and humpback whales (*Megaptera novaeangliae*) were the most frequently sighted marine mammals.

3.2 Methods

The primary goal of conducting the pelagic seabird surveys was to collect abundance and distribution data of seabirds and the secondary goal was to collect abundance and distribution data for other marine megafauna including marine mammals, sea turtles, sharks, and other large pelagic fishes.

The data collection protocol was based on a standardized 300-m strip transect methodology, like that used by various agencies in North America and Europe (Tasker 1984; Anon 2011; Ballance 2011) including previous Atlantic Marine Assessment Program for Protected Species (AMAPPS) and Bureau of Ocean Energy Management (BOEM) surveys. Observers collected data on all seabirds within a 300-m strip on one side of the ship's track line. Observers searched from the bow to 90° to either the port or the starboard side, depending on which side had the best viewing conditions. Observers conducted surveys on the flying bridge during the HB2204 survey on the NOAA ship *Henry B. Bigelow* and survey PC2205 on the NOAA ship *Pisces*, whenever possible. Observations were made from the ship's bridge on survey RB2203 on the R. They collected data in sea states up to a Beaufort 7, in light rain, fog, and when ship speeds were between 8 and 12 knots (below 8 knots, the data becomes questionable to use for abundance estimates).

Data was collected using SeaLog on HB2204 and PC2205 and SeaScribe during RB2203. Both draw global position system (GPS) coordinates, as well as time from a GPS device, so each observation received data on the latitude-longitude position, time stamp, and ship's course. The standard data collected for observations included species identification, distance between the ship and the animal, number of individuals, association, behavior, flight direction, flight height, and if possible or applicable, age, sex, and plumage status. Both applications were also used to collect data on other marine megafauna; observers also recorded other species that were both inside and outside of the 300-m strip survey zone.

During surveys, the on-effort observer utilized binoculars (10x42) to scan within the survey strip. When there were two observers onboard, they alternated two-hour shifts, with a person on-effort collecting data and the other off-effort (not collecting data). If an animal proved elusive, observers used a pair of 20x60 Zeiss imaged-stabilized binoculars to attain positive identifications. To aide in approximating distance observers used custom-made range finders based on height above water and the observers' personal body measurement (Heinemann 1981).

3.3 Results

Two surveys were conducted during Ecosystem Monitoring surveys and one was aboard an East Coast Ocean Acidification survey supported by the NOAA's Ocean Acidification Program (Table 3-1; Figure 3-1). Sighting data are being summarized.

Table 3-1 Summary of 2022 pelagic seabird surveys
Total sightings were inside and outside the 300-m survey zone and included birds and megafauna. HB = Henry B. Bigelow; RB = Robert H. Brown; PC = Pisces

Cruise	Program	Start Date	End Date	Duration (days)	Distance (km)	Total Sightings
HB2204	Ecosystem Monitoring	1-Jun	16-Jun	16	2,341	4,157
RB2203	East Coast Ocean Acidification	6-Aug	22-Sep	38	3,706	12,973
PC2205	Ecosystem Monitoring	1-Nov	10-Nov	10	1,122	3,886

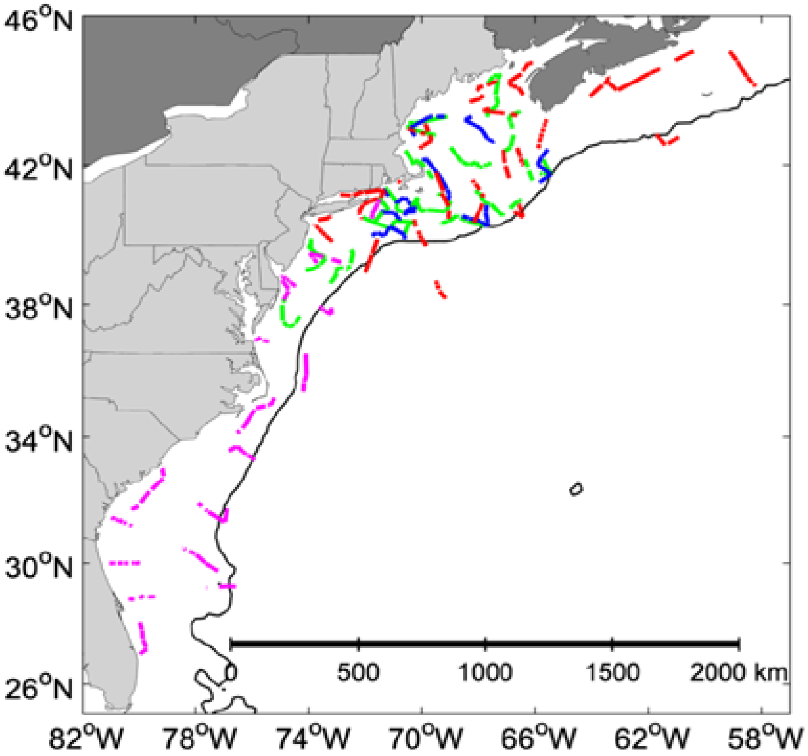

Figure 3-1 Location of on-effort survey effort

June HB2204 Ecosystem Monitoring survey track lines (green). Red (August) and magenta (September) track lines of the RB2203 East Coast Ocean Acidification survey. November Ecosystem Monitoring PC2205 survey track lines (blue).

3.4 Disposition of data

The data are maintained in the Atlantic Marine Assessment Program for Protected Species (AMAPPS) Oracle database and has been transmitted to the National Centers for Coastal Ocean Science for addition to the seabird compendium database.

3.5 Acknowledgements

We acknowledge the officers and crew of NOAA ships *Ronald H. Brown*, *Henry B. Bigelow* and *Pisces*. We would also like to thank Dr. Joseph Salisbury of the University of Maine for providing a berth for an observer aboard their East Coast Ocean Acidification cruise. The analysis time and data collection was funded by the three sources of funds specified in section 1.4 of this document (National Marine Fisheries Service, and the 2 interagency agreements with the Bureau of Ocean Energy Management and the U.S. Navy).

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

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4.1 Summary

During 2022, the Atlantic Marine Assessment Program for Protected Species (AMAPPS) Turtle Ecology team completed fieldwork to deploy satellite tags on loggerhead turtles (*Caretta caretta*) in May and June off the mid-Atlantic Bight (15 tags). The team also deployed satellite tags on leatherback turtles (*Dermochelys coriacea*) in May off North Carolina (10 tags), and in August and September off Massachusetts (12 tags). The objectives of these fieldwork activities were to gather information on turtle behavior and dive patterns, and collect biological samples. The team also participated in a U.S. Coast Guard Equivalent Fast Rescue Boat Certification course, using the newly acquired R/V *Coriacea*. In addition to fieldwork, the team continued developing the Oracle database that stores the satellite tag data and associated metadata. The team also made considerable progress on 4 manuscripts, of which 2 were recently published as peer-reviewed articles (estimating the complex patterns of survey availability for loggerhead turtles; and surface availability metrics of leatherback turtles tagged off North Carolina and Massachusetts) and 2 are in progress (overlap between loggerhead distribution and scallop fishing effort; and leatherback surfacing behavior).

4.2 Field work

During 2022, the AMAPPS Turtle Ecology team completed several field work trips. In April/May the SEFSC-led leatherback satellite tagging off Florida allowed the AMAPPS team to gain valuable experience on the new R/V *Coriacea*, which was slated for AMAPPS turtle work later in 2022. In May, the Southeast Fisheries Science Center (SEFSC) and the Northeast Fisheries Science Center (NEFSC) collaborated on leatherback satellite tagging off North Carolina aboard R/V *Julius*. In May/June, the NEFSC collaborated with Coonamessett Farm Foundation (CFF) for loggerhead satellite tagging cruises in the Mid-Atlantic Bight aboard the F/V *Kathy Ann*. This research was funded from an Atlantic Sea Scallop Research Set Aside Cooperative Agreement, with Heather Haas as an NEFSC point of contact to represent AMAPPS Turtle Ecology priorities. In August/September, the SEFSC and NEFSC collaborated for leatherback satellite tagging aboard M/V *Warren Jr*. and R/V *Coriacea* in Massachusetts state and federal waters.

The NEFSC took possession of a new research vessel, R/V *Coriacea*, procured with National Marine Fisheries Service (NMFS) Turtle Ecology funds (not with Bureau of Ocean Energy Management (BOEM) AMAPPS funds). This boat is equipped with specialized features that assist with turtle sighting and tagging, including a bow pulpit, an offset tagging platform, and an observation platform (Figures 4-1 and 4-2).

Figure 4-1 R/V Coriacea underway in May 2022

Figure 4-2 View of the bow pulpit and offset tagging platform (not extended)

From 31 October – 4 November 2022, the turtle and mammal teams from the NEFSC participated in a U.S. Coast Guard Equivalent Fast Rescue Boat Certification course (Figure 4-3). This training is required when operating a small boat from a National Oceanic and Atmospheric Administration (NOAA) platform. The course included topics such as pre-operation checks, equipment, in-water victim rescue operations, maneuvering around rocks and similar hazards, running alongside another vessel underway, helicopter transfers, towing, searching, pivot turns, heavy weather operations, sponson and valve repair, launch and recovery, and re-righting. The Turtle Ecology team now has two members (Haas and Patel) who have participated in and passed the written and practical exams for this course.

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Figure 4-3 NEFSC colleagues aboard the R/V Coriacea during Fast Rescue Boat Certification course The person with the clipboard is calculating bearings to be used in a search operation.

4.2.1 Leatherback turtles fieldwork

From 14 April – 1 May 2022, the NEFSC joined the SEFSC off Florida for leatherback satellite tagging aboard the R/V *Coriacea* with support from aircraft NOAA Twin Otter 56. While this fieldwork was not within the AMAPPS scope, it was a good opportunity for the AMAPPS field team to get experience with their new small boat, R/V *Coriacea*. Vessel crew included Heather Haas (NEFSC), Chris Sasso and

Michael Judge (SEFSC), Samir Patel (CFF), Terry Norton (Georgia Sea Turtle Center), and Brian Stacy (NOAA veterinarian), while aerial observers included Jesse Wicker and Laura Dias (SEFSC). Although no leatherbacks were tagged during this cruise, the team got valuable experience with the new capture boat. After this fieldwork, the small boat was brought back to the manufacturer for several modifications aimed at making subsequent fieldwork more successful. The work was conducted under NMFS ESA Permit No. 21233-04 issued to the SEFSC.

From 16 – 27 May 2022, the SEFSC led fieldwork off North Carolina aboard R/V *Julius* to deploy 10 satellite tags on leatherback sea turtles. Five of these tags are still actively transmitting data (as of mid-December 2022). The main objectives of this research were to collect data on surface behavior, describe the turtles' migratory routes, and to anticipate potential conflicts between human activities and habitat use. 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 to be counted during aerial surveys intended to document presence and estimate abundance. In addition, blood and tissue samples were collected for biochemistry and genetic analyses, and EKG and fat depth measurements were conducted. Fieldwork crew included Chris Sasso, Annie Gorgone, and Larisa Avens (SEFSC), Emily Christiansen, Lori Westmoreland, and Heather Broadhurst (North Carolina Aquariums), Mitch Rider (University of Miami), Matthew Godfrey, Sara Finn, and Kimmy Miller (NC Wildlife Resources Commission), Craig Harms (North Carolina State University, Center for Marine Sciences and Technology) and Megan Cabot (North Carolina State University, College of Veterinary Medicine). All tagging and capture activities were conducted under NMFS ESA Permit No. 21233-04 issued to the SEFSC.

During 22 August – 4 September 2022, the NEFSC and SEFSC collaborated for leatherback satellite tagging, departing from Woods Hole, MA aboard M/V *Warren Jr.* with support from R/V *Coriacea*. Most of this trip was spent in waters south of Nantucket, MA, where 12 leatherback sea turtles were successfully tagged (Figure 4-4). One day was spent in Nantucket Sound, but that location did not yield any turtles. Flipper and Passive Integrated Transponder (PIT) microchip tags were applied in addition to the satellite tag. Blood and tissue samples were taken for biochemistry and genetic analyses. Of the 12 tags deployed, 8 of them are still actively transmitting data (as of mid-December 2022). This cruise supported AMAPPS goals as well as our Regional Ecosystem Research project, which began in FY21. The main goals of this cruise were to continue collecting leatherback surfacing behavior and build upon our knowledge of coastal leatherback sea turtle movements and habitat use. Understanding the proportion of time leatherbacks spend at the surface of the water and how that might vary seasonally and/or spatially provides necessary corrections for availability of the turtles to be counted during AMAPPS aerial surveys intended to estimate abundance. 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. Chris Sasso (SEFSC) was the point of contact for the AMAPPS leatherback sea turtle research, in collaboration with Heather Haas (NEFSC). In addition, field crew for this cruise included Leah Crowe and Samir Patel (Integrated Statistics), Michael Judge (SEFSC), Mitch Rider (University of Miami), and Emily Christiansen (NC Aquariums veterinarian). The deployment of leatherback tags was conducted under the NMFS ESA Permit No. 21233-04 issued to the SEFSC.

In September and October of 2022, the NEFSC and CFF collaborated to tag leatherback turtles in Massachusetts waters with short-term suction cup tags in support of the leatherback sound exposure project funded by BOEM. However, between unfavorable weather conditions, a broken propeller on the sparker boat, COVID cases among the field crew, and a lack of turtle sightings by the spotter plane, no leatherbacks were tagged during two fieldwork days. We plan to regroup in the summer of 2023 to continue fieldwork for this project. 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. Short-term suction cup tags equipped with cameras will be deployed on leatherback turtles, which will record dive behavior, location, and ambient sound. After tag deployment, we will conduct controlled sound exposure experiments using a sparker (as used for seismic surveys) which emits a low frequency, high-intensity impulsive sound. The camera tags will record the turtles before, during, and after the sound exposure experiments to determine any changes in movement patterns or behavior.

Figure 4-4 Samir Patel and Emily Christiansen (aboard the Takacat) with a leatherback sea turtle
This was during the August leatherback satellite tagging cruise (NEFSC/SEFSC collaboration) south of Nantucket, MA (NMFS Permit No. 21233-04).

4.2.2 Loggerhead turtles

The NEFSC collaborated with CFF from 23 – 28 May 2022 for loggerhead satellite tagging aboard the F/V *Kathy Ann* in the Mid-Atlantic Bight. This research was funded from an Atlantic Sea Scallop Research Set Aside Cooperative Agreement, with Heather Haas as an NEFSC point of contact to represent AMAPPS Turtle Ecology priorities. Weather conditions were less than ideal on this trip, with wind, rain, fog, and cooler temperatures throughout the week. Although weather conditions were not favorable, two loggerheads were successfully tagged during this trip (Figure 4-5). One of these satellite tags transmitted data until late June 2022 while the other transmitted data until mid-August 2022. The team also attached two flipper tags and inserted a Passive Integrated Transponder (PIT) tag (for identification purposes) in both of the loggerhead turtles. Biological samples (blood and skin) were collected for future biochemistry, stable isotope, and genetic analyses conducted by research collaborators. Fieldwork crew included Samir Patel, Liese Siemann, Taylor Irwin, and Tanner Fernandes (CFF), and Kate Choate and Brian Galvez (Integrated Statistics). The work was conducted under U.S. Permit No. 23639 issued to CFF.

A second loggerhead satellite tagging trip led by CFF was conducted from 20 – 27 June 2022 aboard the F/V *Kathy Ann* in the Mid-Atlantic Bight. The team deployed 13 tags during this trip. Flipper and PIT (microchip) tags were applied to each turtle. Biological samples (blood and skin) were collected for future biochemistry, stable isotope, and genetic analyses. Data from these satellite tags will provide us with information related to surface duration, dive depth, and migratory routes. Of the 13 satellite tags deployed, one never transmitted any data, 5 transmitted data until September 2022, 2 transmitted until October 2022, 1 transmitted data until mid-November 2022, and 4 were still actively transmitting (as of late November 2022) approximately 5 months post deployment. Field crew included Samir Patel (CFF), Mitch Rider (University of Miami), Lily Grinhauz and Liz Clark (University of Massachusetts Amherst), and Zachary Forbes (Roger Williams University). The work was conducted under U.S. Permit No. 23639 issued to CFF.

Figure 4-5 Satellite-tagged loggerhead turtle aboard the F/V Kathy Ann
Tanner Fernandes, Kate Choate, Liese Siemann, and Taylor Irwin (from left to right) aboard the F/V Kathy Ann during the May 2022 loggerhead satellite tagging cruise (U.S. Permit No. 23639).

4.3 Progress in sea turtle analyses

During 2022, we continued to develop our Turtle Ecology Oracle database, improving its organization and documentation. After extensive database improvements over the last couple of years, we have been able to maintain the current system and make adjustments as needed. We were able to finalize our data dictionary, confirming that all definitions match the tables and views in the database.

This year we also made considerable advancement on four manuscripts, two were published (Hatch et al. (2022) and Rider et al. (2022)) and are described in more detail below. The other two manuscripts are in progress. One of the in progress manuscripts is Hatch et al., which examines the overlap between loggerhead turtle distribution and scallop fishing effort. This draft manuscript uses turtle distribution data from AMAPPS, but incorporates other goals and funding sources. The other in progress manuscript is Rogers et al., which analyzes multiple data streams from a high resolution animal-born tag and machine learning to examine leatherback surfacing behavior.

4.3.1 Estimating the complex patterns of survey availability for loggerhead turtles

Hatch et al. (2022) represents a core AMAPPS Sea Turtle Ecology deliverable on the availability of loggerhead sea turtles to visual survey efforts. We used information from animal-borne data loggers to characterize the dive-surfacing behavior of loggerhead turtles in the Northwest Atlantic. Our data from 245 turtles, spanning 9 years and covered a large geographic area off the east coast of North America. This allowed us to estimate three metrics and their variability that relate to availability bias affecting visual surveys: average dive duration, average surface duration, and the proportion of time at the surface. We used a spatial differential equation approach to construct spatiotemporal regression models for the availability bias metrics. Model predictions showed pronounced individual, spatial, and temporal (seasonal) variation among the 245 turtles. The average dive duration was 14.5 ± 1.36 minutes (standard error), average surface duration was 15.1 ± 2.77 minutes, and average proportion of time at the surface was 0.50 (95% CI = 0.41–0.59). Our results contribute new insights into loggerhead turtle behavior and provide information that enables survey counts to be used to estimate absolute abundance estimates. The spatiotemporal estimates for each of these metrics are publicly available (in association with the paper).

We thank J. Gutowski and the captains, crew, and scientists on the F/V *Kathy Ann* and F/V *Ms Manya* for their expert fieldwork. We have had numerous contributions from varying scientists and appreciate their efforts, in particular the contributions from E. Matzen, L. Crowe, L. Siemann, M. Weeks, and M. Winton. We thank D. Palka for helpful comments on an earlier version of the manuscript.

4.3.2 Surface availability metrics of leatherback turtles tagged off North Carolina and Massachusetts

Rider et al. (2022) provides preliminary information on leatherback surfacing behavior. The AMAPPS Turtle Ecology program is not yet finished with a five-year program designed to collect and analyze leatherback sea turtle behavioral data. To address immediate needs of U.S. federal agencies for data on leatherback surfacing information, we provided 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 Turtle Ecology study plan includes more data collection and more sophisticated data analysis, so this current document is offered as 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, leatherback turtles, caught off Massachusetts and North Carolina, were equipped with satellite-linked transmitters that relayed the proportion of time an individual spent within the first 2 m of a water column during a 6-hour period. Twenty-nine turtles were tagged, with 11 tags deployed off Massachusetts and 18 off North Carolina. Mean time at depth increased from December through May and then decreased for the rest of the year. The standard deviation indicated a high amount of variability.

Users of these preliminary data should realize that additional data collection and analyses are needed to provide accurate and precise estimates of leatherback surfacing behavior.

We thank the boat operator Annie Gorgone and the entire field research team for making the collection of these data possible. We also thank our colleagues Joshua Hatch, Kate Choate, and Rick Rogers for their advice and data management. We are grateful to Drs. Debra Palka, Michael Simpkins, and Scott Benson for reviewing this manuscript and providing useful comments.

4.4 Disposition of data

The Turtle Ecology team at the NEFSC in Woods Hole, MA maintains all data collected from fieldwork, including satellite tag data, in the NEFSC's Oracle database.

4.5 Permits

Fieldwork during 2022 was conducted under U.S. Permit No. 21233 issued to the SEFSC by the NMFS and U.S. Permit No. 23639 issued to CFF by the NMFS.

4.6 Acknowledgements

Sources of funds, in addition to the three sources of funds specified in section 1.4 of this document (NMFS, and the two interagency agreements with the Bureau of Ocean Energy Management (BOEM) and the U.S. Navy) include the following:

- for the project on estimating the complex patterns of survey availability for loggerhead turtles (section 4.3.1) we received funding from the scallop industry Sea Scallop Research Set Aside program administered by the NEFSC; and
- for the project on the overlap between loggerhead turtle distribution and scallop fishing effort (section 4.3) we received funding from the NMFS Protected Species Toolbox Initiative and the Sea Scallop Research Set Aside program administered by the NEFSC.

4.7 References cited

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Rider M, Haas H, Sasso C. 2022. Surface availability metrics of leatherback turtles (*Dermochelys coriacea*) tagged off North Carolina and Massachusetts, United States. U.S. Dept Commer Northeast Fish Sci Cent Tech Memo 286. 13 p. https://doi.org/10.25923/82c1-4a85

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

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5.1 Summary

The goal of the AMAPPS-related research conducted by the Northeast and Southeast Fisheries Science Center's (NEFSC and SEFSC) passive acoustic groups is to collect acoustic data that complement visual-based analyses of animal occurrence and abundance. One of our focuses is on species that are difficult to detect by visual observers. In 2022, we improved our understanding of the diving ecology of sperm whales (*Physeter macrocephalus*) by using a towed array dataset with a large sample size (>200 individuals), tracking their dive depth, and examining how their dive relates to the seafloor (e.g. close to the seafloor or in the water column). We also examined the spatial-temporal distribution of beaked whales along with their foraging behavior during the 2016 summer months. We published our findings of sperm whale acoustic abundance and foraging ecology, and have a manuscript in preparation describing the summer distribution and niche partitioning of beaked whales. We continue to add all AMAPPS collected towed array data to our online passive acoustic detection website hosted by the Northeast Fisheries Science Center. We will also work with NCEI to determine the best way to archive the towed passive acoustic data.

5.2 Passive acoustics to determine sperm whale abundance and diving behavior

5.2.1 Methods

Westell et al. (2022) used the towed array data collected from the 2016 northeast shipboard survey to estimate the acoustic abundance of foraging sperm whales and study dive behavior. The acoustic abundance methodology are described in the AMAPPS 2021 Annual Report (NEFSC and SEFSC 2022). To describe sperm whale dive behavior patterns, we used the methods established by DeAngelis et al. (2017) to calculate the depth of each detected click in a sperm whale click train. To investigate how the detected and successfully localized sperm whales were using the water column to forage, plots of click depths over time were manually reviewed and categorized. If a click train lasted for more than five minutes and a descent, bottom phase, and ascent were discernible (Watwood et al. 2006), it was categorized as U shaped. Other patterns included just a dive descent, dive ascent, and a shallow flat dive. For the U-shaped click trains, the click depths were binned by 400 m intervals and the depth bin at which the bottom phase occurred was identified. A sperm whale was classified as diving in the water column when the 90th percentile of the click depths occurred in a depth more than 400 m above the seafloor.

5.2.2 Results

Results from the acoustic abundance estimation of foraging sperm whales is described in the AMAPPS 2021 Annual Report (NEFSC and SEFSC 2022). Westell et al. (2022) described the results from examining the diving behavior of the detected sperm whales. We localized 265 click trains in 3D and the click depths were examined for patterns. Of these click trains, 44 were categorized as U shaped, and the remaining were partial dives (70 descents and 31 ascents), flat and shallow (9), or were uncertain/ had no pattern (111) (Figure 5-1). The lack of a clear pattern in click depths could be the result of interference in the acoustic recordings due to wave motion and/or issues with accurately detecting the surface reflected echoes required for 3D localization. These results were also presented at two scientific conferences (Westell et al. 2022b; Westell et al. 2022c).

Sperm whales exhibited multiple foraging strategies, with bottom phases (associated with foraging) recorded at depths of 400 - 800 m, 800 - 1200 m, and at depths greater than 1200 m. These results are consistent with previous studies that found sperm whales will adapt their foraging strategy, including the depth that they dive to, depending on prey and habitat type (Fais et al. 2014; Teloni et al. 2008). In addition, for the majority (73%) of click trains with U shaped dives, the sperm whales were foraging in the water column (more than 400 m above the seafloor) (Figure 5-2).

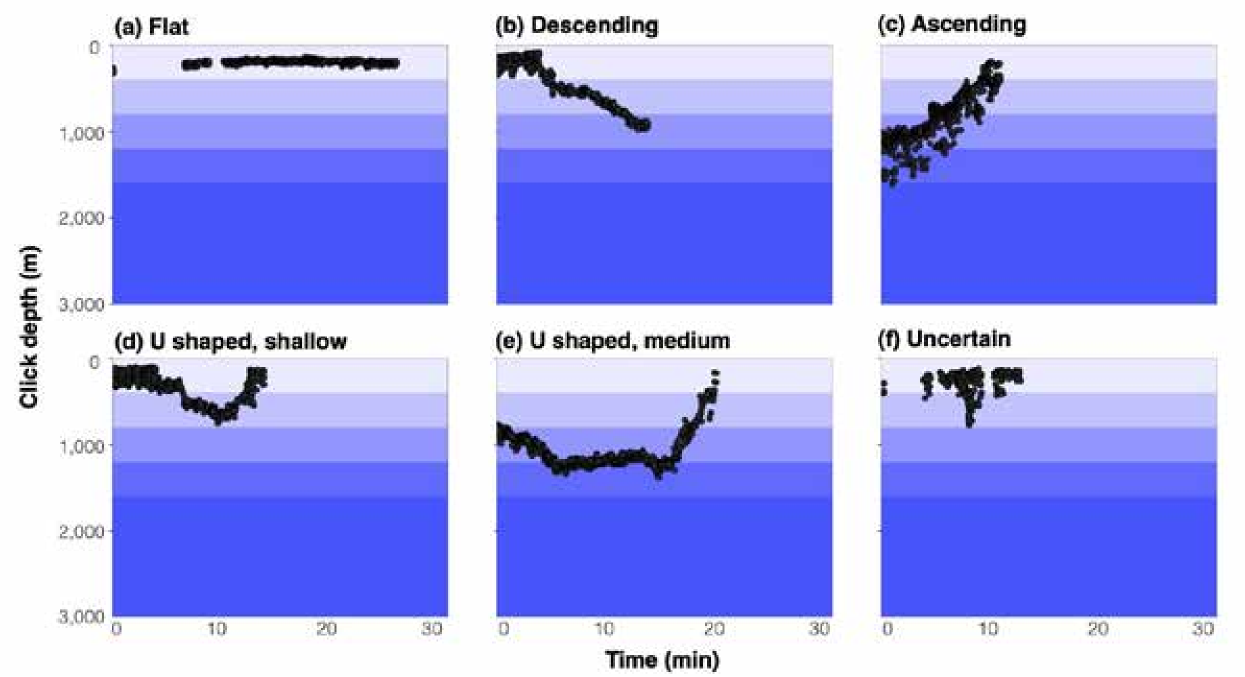

Figure 5-1 Examples of clicks depths (m) over time (min) for different dive categories
Events were categorized as (a) flat and shallow, (b) descending, (c) ascending, (d) U shaped and shallow, (e) U shaped and medium depth, and (f) uncertain or no pattern.

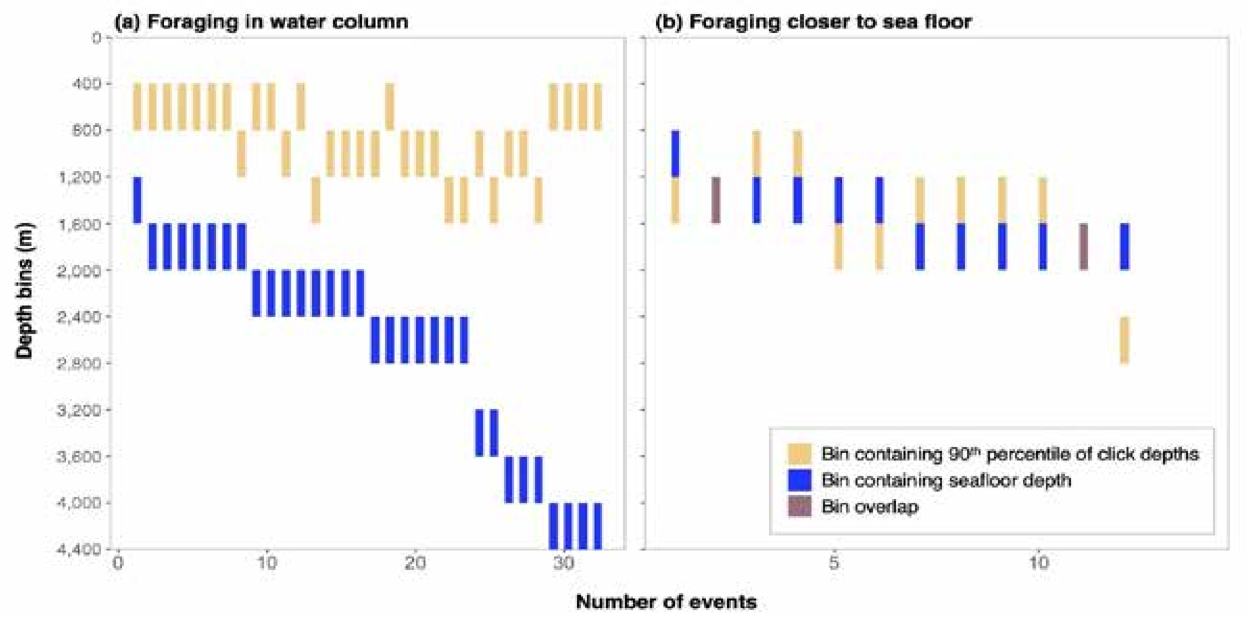

Figure 5-2 Dive depths of U shaped click patterns
Whales were categorized as diving in the water column if (a) the bin including the 90th percentile of the click depths was more than 400 m above the bin including the seafloor depth (n = 32 events) or was categorized as diving closer to the seafloor if (b) within 400 m of the bin including the seafloor depth (n = 12 events).

5.3 Examine distribution and foraging behavior of beaked whales

5.3.1 Methods

We continued examining the spatial, temporal, and depth distributions of beaked whales during the summer months (July and August) of 2016. This included data collected from 11 high frequency acoustic recording packages (HARPs; Table 5-1) and data collected from towed hydrophone arrays during two joint AMAPPS abundance surveys (Table 5-2). The entire eastern U.S. seaboard was divided into 11 regions to facilitate comparisons between the HARP and towed array datasets. Periods in which the National Oceanographic and Atmospheric Administration (NOAA) ships were actively using their echosounders were removed from the analysis as beaked whales have been shown to have a negative acoustic response to shipboard echosounders (Cholewiak et al. 2017). As stated in the AMAPPS 2021 Annual report (NEFSC and SEFSC 2022), the towed hydrophone data were analyzed using PAMGuard (Gillespie et al. 2008), and the HARP data were analyzed using detEdit (Solsona-Berga et al. 2020). For both datasets, beaked whale clicks were annotated and grouped into one-minute bins. Bins containing five or more clicks were used in the analysis. Additionally, with the towed array data, beaked whale clicks were grouped into "events", which presumably represents individuals (as best as possible). Events longer than two minutes were used to estimate the echolocation depth of a foraging individual (DeAngelis et al. 2017) using a combination of the package *PAMPal* (https://github.com/TaikiSan21/PAMpal) in R (R Development Core Team 2016) and custom scripts in Matlab (MathWorks Inc., Natick, MA) as described in DeAngelis et al. (2023). Species weighted mean depths and weighted standard deviations were calculated for each region. Environmental variables sea surface temperature (SST, Simons 2020) and bathymetry (taken from the GEBCO database, https://www.gebco.net/data_and_products/gridded_bathymetry_data/) were attributed to each beaked whale event from the towed array datasets to examine proximity to seafloor, and to understand their relationship to species-specific presence. Species classification trees were created using the *rpart* package in R from the HARP datasets to better understand species distribution.

Table 5-1 Deployment information from high frequency acoustic recording packages (HARPs)
Information includes site abbreviation and description of location (Site), position (Latitude, Longitude), bottom depth at site (Bottom Depth), sampling rate of recorder (Sample Rate), recording period (Start Date, End Date), and number of days included in this analysis (Number of Analysis Days).

Site	Latitude	Longitude	Bottom Depth (m)	Sample Rate (kHz)	Start Date	End Date	Number of Analysis Days
BC - Babylon Canyon, off New Jersey	39-11.463 N	72-13.722 W	1000	200	4/20/2016	6/10/2017	62
WC- Wilmington Canyon, off Delaware	38-22.449 N	73-22.241 W	1000	200	4/20/2016	6/29/2017	62
NC - Nantucket Canyon, off Massachusetts	39-49.943 N	69-58.926 W	977	200	4/21/2016	5/24/2017	62
HZ - Heezen Canyon, off Georges Bank	41-03.710 N	66-21.095 W	845	200	4/22/2016	6/19/2017	62
OC - Oceanographer Canyon, off Georges Bank	40-15.799 N	67-59.174 W	450	200	4/24/2016	5/18/2017	62
BS - Blake Spur, off Georgia	30-35.027 N	77-23.443 W	1005	200	4/27/2016	6/26/2017	62
BP - Blake Plateau, off South Carolina	32-06.362 N	77-05.659 W	945	200	4/28/2016	6/27/2017	62
GS - Gulf Stream, off North Carolina	33-39.938 N	76-00.083 W	953	200	4/29/2016	6/27/2017	62
HA – off Cape Hatteras, NC	35-18.110 N	74-52.737 W	1021	200	4/29/2016	2/6/2017	62
JA – off Jacksonville, FL	30-09.110 N	79-46.213 W	736	200	4/26/2016	6/25/2017	62
NF - off Norfolk, VA	37-09.991 N	74-27.996 W	968	200	4/30/2016	6/28/2017	62

Table 5-2 Deployment information for towed array datasets
Information includes survey name and leg (Survey), sampling rate of towed array (Sample Rate), recording period (Start Date, End Date), and number of days included in this analysis that excludes days the shipboard echosounder was in active mode (Number of Analysis Days).

Survey	Sample Rate (kHz)	Start Date	End Date	Number of Analysis Days
NEFSC Leg1	192	6/28/2016	7/13/2016	6
NEFSC Leg2	192	7/19/2016	8/3/2016	8
NEFSC Leg3	192	8/11/2016	8/24/2016	7
SEFSC Leg1	500	7/1/2016	7/14/2016	5
SEFSC Leg2	500	7/20/2016	8/4/2016	16
SEFSC Leg3	500	8/10/2016	8/24/2016	14

5.3.2 Results

Results of presence of North Atlantic beaked whale species from the HARP datasets can be found in the 2021 Annual Report (NEFSC and SEFSC 2022). Here, we focus on the results from the towed hydrophone array dataset, as well as the comparison between the two recorder types. These results were also presented at two scientific conferences (DeAngelis et al. 2022a; DeAngelis et al. 2022b).

After removing periods when the echosounder was in active mode, a total of 16,911 min (NEFSC data) and 25,713 min (SEFSC data) were appropriate for this analysis. A total of 394 beaked whale events were detected, of which 333 events were localized in two dimensions (some could not be localized due to the ship changing course, or not enough clicks detected to localize the animal), and 191 events were localized in three dimensions (Table 5-2). These results showed that beaked whales generally dove to between 800 and 1200 m, with slight variability between regions (Figure 5-3).

Further statistical analysis is required to understand the relationship between bathymetry and beaked whale echolocation depth. We truncated the data to display events that were found in ≤ 3000 m water depth as beaked whales outfitted with time-depth recorder tags have not exceeded this limit (e.g. Schorr et al. 2014) Preliminary results suggest that Cuvier's beaked whales (*Ziphius cavirostris*) are more likely to be foraging along the seafloor, True's beaked whales (*Mesoplodon mirus*) and Gervais' beaked whales (*Mesoplodon europaeus*) equally likely to be foraging in the water column as along the seafloor, and Blainville's beaked whales (*Mesoplodon densirostris*) exclusively foraging along the seafloor (Figure 5-4). There was not a large enough sample size to say anything about Sowerby's beaked whales (*Mesoplodon bidens*; n= 2).

Combining the towed array and HARP datasets provided a comprehensive view of species distribution along the eastern seaboard (Figure 5-5). The normalized minute presence takes into account the number of minutes a species was present per recording effort. Cuvier's and Gervais' were detected in all regions, which would not have been found using one data type alone. Blainville's were detected in all regions south of Virginia (WC site), Sowerby's were in all regions north of Cape Hatteras, NC (HA site), and True's were in all regions north of Virginia (NF site). Using classification trees arrived at similar results as solely using the number of positive presence minutes (Figure 5-6). From these results sites were empirically separated into a northern region ranging from Massachusetts to Maryland [sites OC (Oceanographer Canyon), HZ (Heezen Canyon), NC (Nantucket Canyon), WC (Wilmington Canyon), and BC (Babylon Canyon)]. The southern region ranged from Virginia to Florida [sites NF (off Norfolk, VA), HA (off Cape Hatteras, NC), GS (Gulf Stream of North Carolina), BP (Blake Plateau), and BS (Blake Spur)]. The classification trees indicated that Gervaiis' beaked whales were more likely to occur at the southern sites, and Sowerby's beaked whales at the northern sites at levels ≥ 22 min. True's occurred in the northern sites at low levels (<22 min) and Blainville's at low levels at the southern sites. These results align with what is currently known about Mesoplodont sp. distributions. Cuvier's are absent from the classification tree, most likely due to their presence at all sites at various levels, confirming their cosmopolitan distribution. We are currently running statistical analyses on the towed array data to examine the relationship between species-specific presence, sea surface temperature, salinity, chlorophyll a, and bathymetry. Results from that analysis will help in the interpretation of the classification tree from the HARP data, as well as identify covariates that may be important to the different species.

Previous studies have indicated that the HARP in the Cape Hatteras, NC (site HA) region is in a location where a resident population of Cuvier's resides (Foley et al. 2021). We thus use the percent positive minutes found at the Cape Hatteras, NC HA HARP site (6.8%) as a proxy for acoustic levels of a resident population during our study period, and postulate that any percent positive minutes equal to or exceeding 6.8% could indicate other areas of resident beaked whale populations. From our data, other regions that meet this criterion are the Oceanographer Canyon (OC) region from the towed array data for True's beaked whale (8.0%) and the Blake Plateau (BP) region off South Carolina from the HARP data for Gervais' beaked whale (7.0%). Most of the towed array detections in the Oceanographer Canyon (OC) region cluster around Bear Seamount, an area we have identified from the dedicated ITS.DEEP surveys (part of AMAPPS) as being a reliable location for studying True's beaked whales (NEFSC and SEFSC 2019). We thus would like to propose that these two areas (Bear Seamount for True's and Blake Plateau for Gervais') contain resident populations and are candidates for learning more about these cryptic and poorly studied beaked whale species.

This project will aim to be completed and submitted to a peer-reviewed journal in 2023.

Table 5-3 Number of beaked whale event types from the towed array dataset per species
Events longer than 2 min (BWE2) were suitable candidates for depth estimation.

Species Common Name	Species Scientific Name	Event Type	Total Number of Events	Number of Events Unable to be Localized	Number of Events Localized in 2D (and in 3D)
Blaninville's Beaked Whale	*Mesoplodon densirostris*	<2 min	9	6	3
Blaninville's Beaked Whale	*Mesoplodon densirostris*	BWE2	35	1	34 (31)
Cuvier's Beaked Whale	*Ziphius cavirostris*	<2 min	75	17	58
Cuvier's Beaked Whale	*Ziphius cavirostris*	BWE2	109	8	101 (82)
Gervais' Beaked Whale	*Mesoplodon europaeus*	<2 min	27	10	17
Gervais' Beaked Whale	*Mesoplodon europaeus*	BWE2	46	4	42 (37)
Sowerby's Beaked Whale	*Mesoplodon bidens*	<2 min	5	-	5
Sowerby's Beaked Whale	*Mesoplodon bidens*	BWE2	3	1	2 (2)
True's Beaked Whale	*Mesoplodon mirus*	<2 min	19	5	14
True's Beaked Whale	*Mesoplodon mirus*	BWE2	51	9	42 (35)
True's/Gervais' Beaked Whale	*M. mirus or M. europaeus*	<2 min	6	-	6
True's/Gervais' Beaked Whale	*M. mirus or M. europaeus*	BWE2	9	-	9 (4)

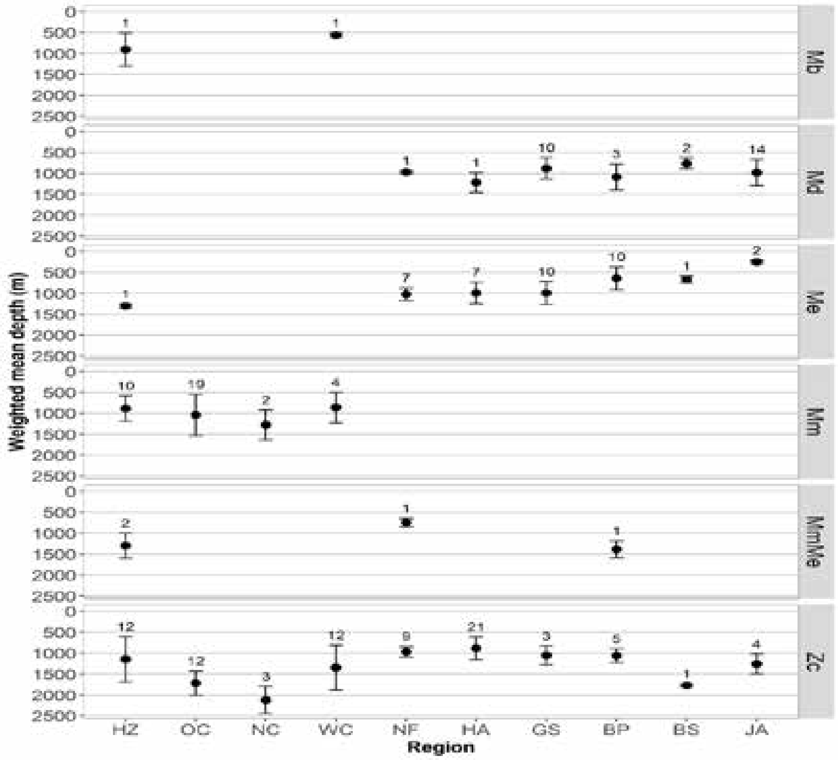

Figure 5-3 Beaked whale species specific regional differences in depths
Weighted mean depths are shown with their weighted mean standard deviations. The number of events used to generate the weighted means and standard deviations are shown above the error bars. Mb = Mesoplodon bidens; Md = Mesoplodon densirostris; Me = Mesoplodon europaeus; Mm = Mesoplodon mirus ; MmMe = Mesoplodon mirus or Mesoplodon europaeus; Zc = Ziphius cavirostris.

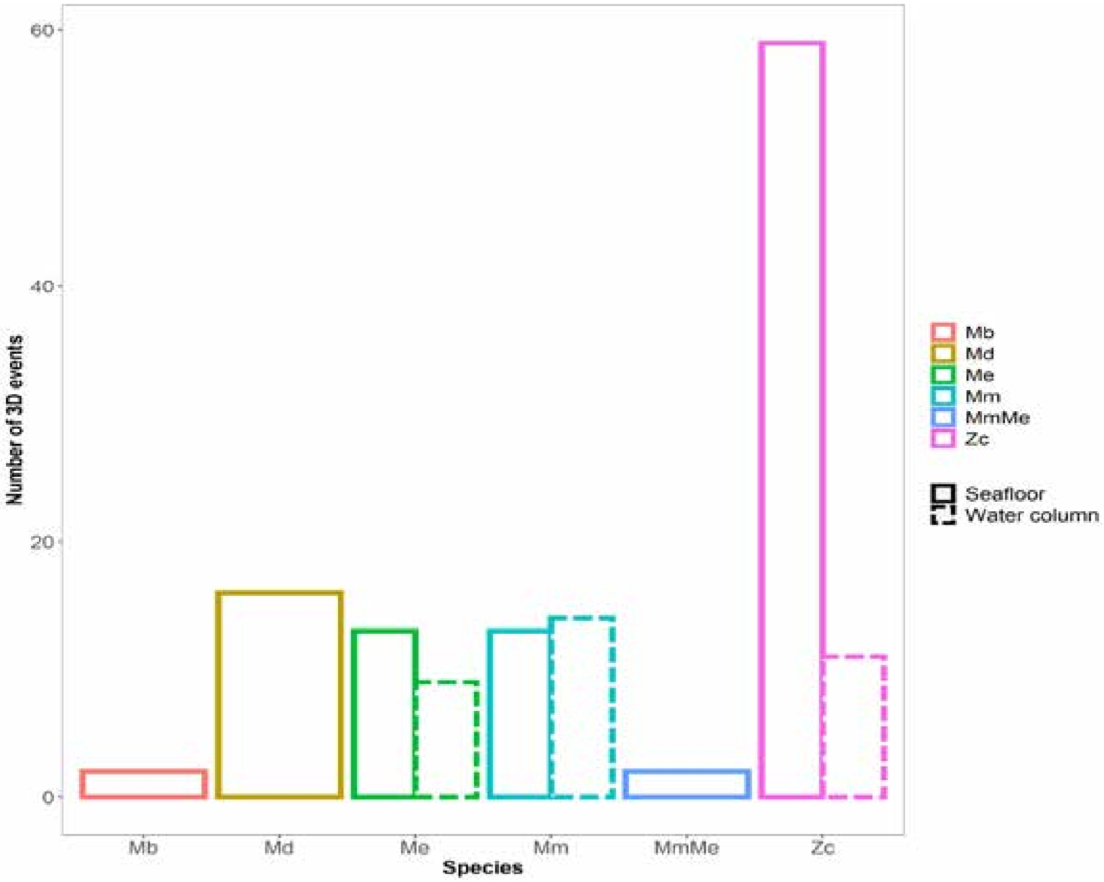

Figure 5-4 Beaked whale diving proximity to the seafloor
Only events in 3000 m of water or less are shown as the known physiological dive depth limit of beaked whales is 3000 m. Mb = Mesoplodon bidens; Md = Mesoplodon densirostris; Me = Mesoplodon europaeus; Mm = Mesoplodon mirus ; MmMe = Mesoplodon mirus or Mesoplodon europaeus; Zc = Ziphius cavirostris.

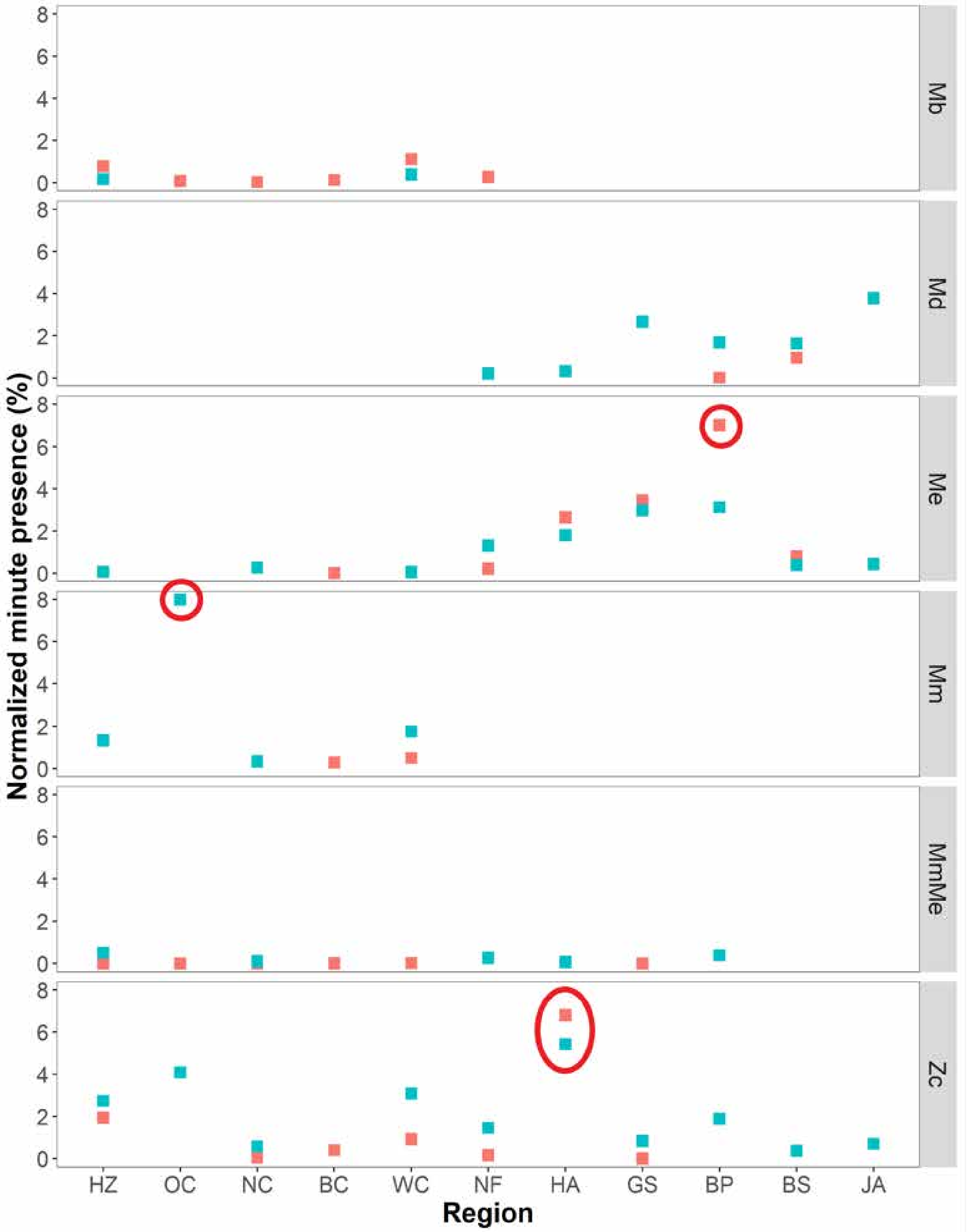

Figure 5-5 Beaked whale species presence along the U.S. eastern seaboard
Combining towed array (teal squares) and HARP (red squares) datasets. The normalized minute presence takes into account the number of minutes a species was present per recording effort. Regions that contain possible resident populations of a species are circled in red. Mb = Mesoplodon bidens; Md = Mesoplodon densirostris; Me = Mesoplodon europaeus; Mm = Mesoplodon mirus ; MmMe = Mesoplodon mirus or Mesoplodon europaeus; Zc = Ziphius cavirostris. Region definitions are in Table 5-1.

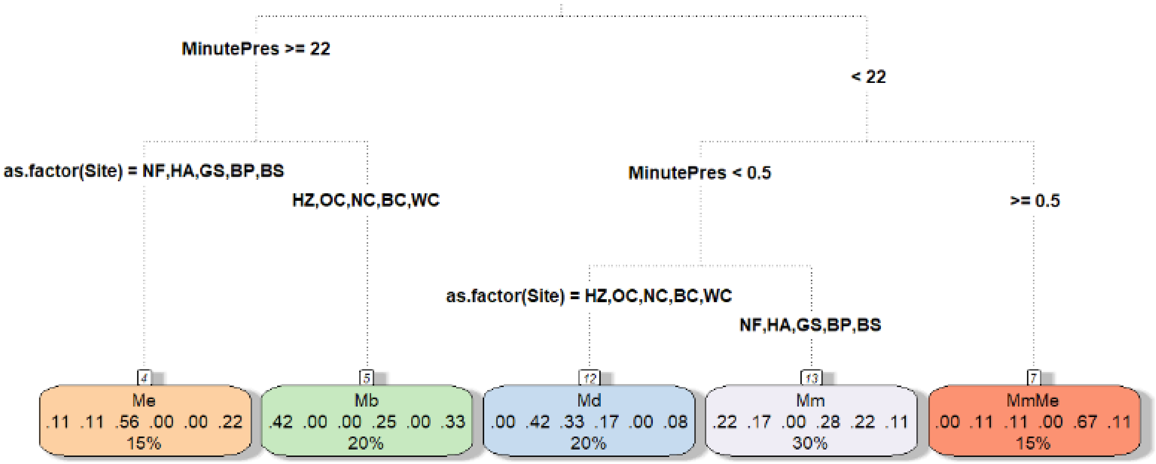

Figure 5-6 Classification tree using the high frequency acoustic recording package (HARP) dataset
To understand the distribution of beaked whale species, the sites (defined in Table 5-1) are shown as branches. Within each node shows the predominant species predicted as the header, and the percentages of all beaked whale species belonging in each node, reading right to left.

5.4 Disposition of data

All whale detection data are on the NEFSC Passive Acoustic Research Group's Passive Acoustic Cetacean Map: https://apps-nefsc.fisheries.noaa.gov/pacm/#/. We are also in the process of uploading all of our detections and deployment data into our Oracle database.

5.5 Acknowledgements

Taiki Sakai (Southwest Fisheries Science Center) was instrumental in automating the dive depth method. Peter Corkeron and Sofie Van Parijs assisted with the classification trees used in the beaked whale distribution project. The analysis time was funded by the three sources of funds specified in section 1.4 of this document (National Marine Fisheries Service, and the two interagency agreements with the Bureau of Ocean Energy Management and the U.S. Navy).

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

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6.1 Summary

One of goal of the Atlantic Marine Assessment Program for Protected Species (AMAPPS) is to collect and analyze sighting data to describe the spatiotemporal distribution, abundance and trends of marine mammals and sea turtles, as they relate to their physical and biological environment. During 2022, we collected new sightings data (described in Chapter 2), updated the environmental data time series from 2010 to 2021 using newer consistent data sources, and using the AMAPPS visual sightings data we published two papers and have five more in review, as of December 2022. The 2022 published papers:

1. identified northeasterly distribution shift of most cetacean species; and
2. documented environmental forecasts could predict the arrival of humpback whales (*Megaptera novaeangliae*) 2 weeks in advance of their actual arrival.

The five papers in review as of December 2022:

1. documented the design-based cetacean abundance estimates using the summer 2021 shipboard and aerial line transect abundance survey data (2 papers);
2. developed a new analysis method to estimate abundance using both visual and tow-array cetacean detections from a shipboard abundance survey;
3. demonstrated the usefulness of echosounding to model marine mammal distribution and abundance with direct measurements of prey rather than relying on proxies; and
4. combined marine mammal, fish and invertebrate surveys in an ensemble modeling approach to assess the relative importance and capacity of the environment and other marine species to predict the distribution of coastal and offshore bottlenose dolphin ecotypes.

In addition, we are in-progress on three other studies that:

1. extend the Bayesian hierarchical density surface model predictions to produce a package that a user can determine the probability that the abundance of a user-chosen whale species, within a user-chosen wind energy area for a user-defined time frame is above a user-defined threshold;
2. estimate the spatiotemporal abundance of sea turtles using the 2-step generalized additive modeling techniques; and
3. develop a neural network algorithm that will hopefully identify animals in images that were taken during an aerial abundance survey.

6.2 Update environmental data time series

During 2022, we updated the dynamic environmental covariates to include data from all years for the period 2010 to 2021. In previous years, some of the satellite-derived data were from the MODIS-Aqua sensor. To provide a consistent time series from 2010 to 2021 we shifted to use the OC-CCI (European Space Agency Ocean Color) dataset that comprises of globally merged MERIS, Aqua-MODIS, SeaWiFS, VIIRS and Sentinel3A-OLCI data with associated per-pixel uncertainty information.

The data collection covered the complete AMAPPS study area and it was processed with the protocols described in Palka *et al* (2017) according to the location of the centroid of each 10 x 10 km^2 spatial stratum and averaged over each 8-day temporal stratum starting 4 January of each year. We decreased the number of dynamic contemporaneous environmental characteristics to 11, based on the data availability and importance reported in Palka *et al* (2021). The update included habitat covariates that describe water-column characteristics such as mixed layer depth, bottom temperature and salinity derived HYCOM (HYbrid Coordinate Ocean Model) (Table 6-1).

In addition, we initiated the process to acquire the high-resolution remote sensing data for the dynamic contemporaneous environmental characteristics using OC-CCI datasets. To improve the spatial resolution, we are going to acquire the values of the environmental characteristics at the location of the centroids of 4 x 4 km^2 spatial strata averaged over each 8-day temporal stratum starting 4 January of each year.

The latitudinal distribution and variability of the data generated by OC-CCI (SST, chlorophyll a, primary productivity, particulate inorganic carbon, and particulate organic carbon) are shown in Figure 6-1. The latitudinal distribution and variability of the data generated by HYCOM (bottom temperature and salinity) are shown in Figure 6-2.

Table 6-1 Updated dynamic contemporaneous habitat covariates
These will be considered in future species specific density-habitat modeling frameworks

Dynamic Covariate Abbreviation	Description	Original Resolution	Source
SST	Sea surface temperature multi-scale ultra-high resolution (MUR) (ºC)	1 km mapped to 2 km	https://podaac.jpl.nasa.gov/dataset/ MUR-JPL-L4-GLOB-v4.1
SSTF	Strength of sea surface temperature fronts using (unitless)	1 km mapped to 2 km	Original source data - https://www.oceancolour.org/, fronts calculated using Belkin & O'Reilly (2009)
CHLA	Chlorophyll-a concentration (mg/m^3)	1 km mapped to 2 km	Original source data - https://www.oceancolour.org/, then derived by OCI algorithm
CHLAF	Strength of chlorophyll fronts (unitless)	1 km mapped to 2 km	Original source data - https://www.oceancolour.org/, fronts calculated using Belkin & O'Reilly (2009)
PIC	Particulate inorganic carbon (mol/m^3)	1 km mapped to 2 km	https://www.oceancolour.org/
POC	Particulate organic carbon (mg/m^3)	1 km mapped to 2 km	https://www.oceancolour.org/
PP	Primary productivity (mgCarbon/(m^2 · yr)	1 km mapped to 2 km	Original source data - https://www.oceancolour.org/, PP calculated using Behrenfeld and Falkowskip (1997) and Eppley (1972)
MLP	Mixed layer thickness (m)	1/12°	https://hycom.org/dataserver/glb-analysis
SALINITY	Surface salinity (psu)	1/12°	https://hycom.org/dataserver/glb-analysis
BTEMP	Bottom temperature (ºC)	1/12°	https://hycom.org/dataserver/glb-analysis
DGSNW	Distance to Gulf Stream north wall (m)		https://ocean.weather.gov/gulf_stream.php
DGSSW	Distance to Gulf Stream south wall (m)		https://ocean.weather.gov/gulf_stream.php

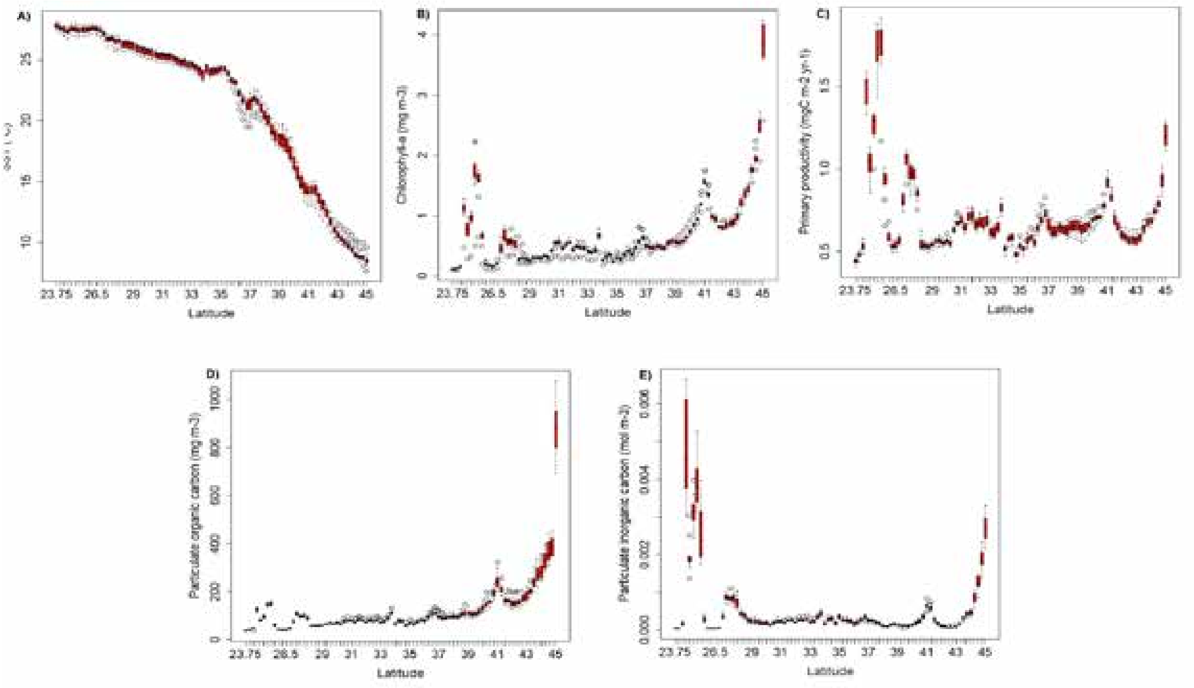

Figure 6-1 Mean of the data generated by remote sensing binned by 0.5 degree
A) Sea surface temperature; B) Chlorophyll a; C) Primary productivity; D) Particulate inorganic carbon; and E) Particulate organic carbon.

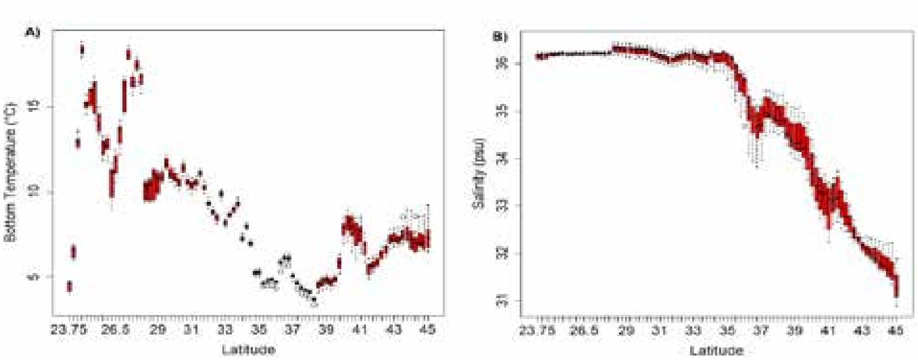

Figure 6-2 Mean of the data generated by HYCOM binned by 0.5 degree
A) Bottom temperature; B) Salinity.

6.3 Habitat shifts

Chavez-Rosales et al. (2022) documented an overall 178 km northeastward spatial distribution shift of the seasonal core habitat of Northwest Atlantic cetaceans that was related to changing habitat/climatic factors. Species-specific habitat suitability regions were derived using generalized additive models developed from the data collected on the AMAPPS abundance sighting surveys conducted during 2010 – 2017. Spatiotemporal distribution shifts varied by season and species (Figure 6-3). For example, for Sowerby's beaked whales (*Mesoplodon bidens*), only studied during the summer, the core habitat weighted centroid between 2010 and 2017 moved only 5 km towards the southeast. In contrast, for common bottlenose dolphins (*Tursiops truncatus*), the core habitat weighted centroid moved towards the northeast in all seasons, where the farthest was during fall (753 km) and the least was during winter (211 km). Other examples include the short-finned pilot whales (*Globicephala macrorhynchus*) whose core habitat weighted centroid moved towards the northeast in the fall and winter (296 and 218 km, respectively) and towards the southwest in spring and summer (120 and 149 km, respectively). For harbor porpoises (*Phocena phocena*), the core habitat weighted centroid moved farthest during winter (397 km towards the northeast) and less than 20 km in the other seasons.

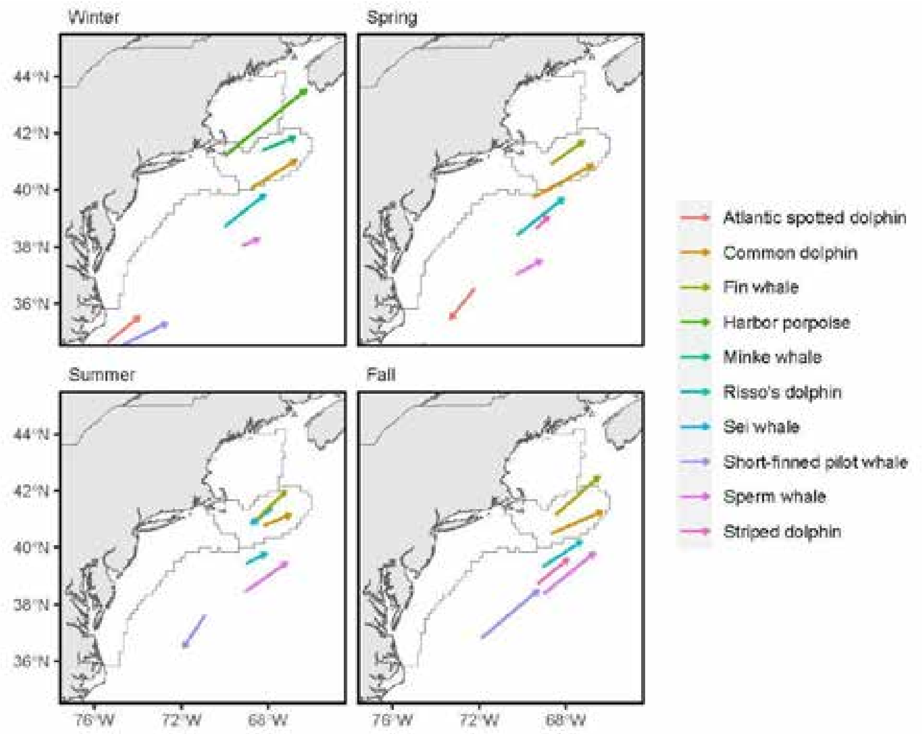

Figure 6-3 Direction and magnitude of core habitat shifts, by species
Magnitude of change of the seasonal weighed centroid is represented by the length of the arrow. The tail of the arrow is the location of the habitat centroid in 2010 and the tip is that in 2017.

6.4 Design-based cetacean abundance estimates

During June to September 2021, the Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) conducted shipboard and aerial line transect abundance surveys with the goal of collecting the data necessary to estimate abundance of as many cetacean species as possible within all U.S. Atlantic waters. For details of the data collection protocols see the cruise reports in the 2021 AMAPPS annual report (NEFSC and SEFSC 2022). During 2022, the sightings data were analyzed and abundance estimated (Garrison and Aichinger Dias in review; Palka, in review), where the final documents were published in 2023. To estimate abundance, we collected data following the two-independent-team procedure that we then analyzed using mark-recapture distance sampling analysis methods—to account for perception bias—and by using dive time patterns—to account for availability bias. The abundance estimates (Table 6-2) are reported in the 2022 draft Atlantic and Gulf of Mexico Marine Mammal Stock Assessment Report (Hayes et al. 2022).

Table 6-2 Summer 2021 cetacean abundance estimates
Total abundance (abun) estimates are the sum of the estimates derived from the northeast (NE) and southeast (SE) shipboard and aerial surveys. CV= coefficient of variation.

Species Common Name	Species Scientific Name	NE Abun	CV of NE Abun	SE Abun	CV of SE Abun	Total Abun	Total Abun CV
Atlantic spotted dolphin	*Stenella attenuata*	8,112	0.22	23,394	0.37	31,506	0.28
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	4,632	0.55	0	-	4,632	0.55
Blainville's beaked whale	*Mesoplodon densirostris*	0	-	2,936	0.26	2,936	0.26
Blue whale	*Balaenoptera musculus*	26	1.02	0	-	26	1.02
Bottlenose dolphin spp.	*Tursiops truncatus*	37,721	0.34	26,866	0.34	64,587	0.24
Clymene dolphin	*Stenella clymene*	2,268	0.5	19,510	0.8	21,778	0.72
Common dolphin	*Delphinus delphis*	85,035	0.61	8,065	0.86	93,100	0.56
Cuvier's beaked whale	*Ziphius cavirostris*	1,742	0.39	2,928	0.31	4,670	0.24
False killer whale	*Pseudorca crassidens*	753	1.13	545	0.68	1,298	0.72
Fin whale	*Balaenoptera physalus*	2,240	0.39	12	1.02	2,252	0.39
Gervais' beaked whale	*Mesoplodon europaeus*	0	-	8,595	0.24	8,595	0.24
Harbor porpoise	*Phocoena phocoena*	85,765	0.53	0	-	85,765	0.53
Humpback whale	*Megaptera novaeangliae*	863	0.36	7	1.04	870	0.36
Killer whale	*Orcinus orca*	0	-	73	0.99	73	0.99
Kogia	*Kogia sp.*	4,012	0.54	5,462	0.47	9,474	0.36
Long-finned pilot whale	*Globicephala melas*	5,711	0.62	0	-	5,711	0.62
Minke whale	*B. acutorostrata*	5,630	0.58	0	-	5,630	0.58
Pantropical Spotted Dolphin	*Stenella attenuata*	0	-	2,757	0.5	2,757	0.5
Risso's dolphin	*Grampus griseus*	39,612	0.5	4,455	0.45	44,067	0.45
Sei whale	*Balaenoptera borealis*	34	0.99	0	-	34	0.99
Short-finned pilot whale	*G. macrorhynchus*	3,745	0.67	15,004	0.38	18,749	0.33
Sowerby's beaked whale	*Mesoplodon bidens*	492	0.5	0	0	492	0.5
Sperm whale	*Physeter macrocephalus*	3,789	0.38	2,106	0.44	5,895	0.29
Spinner dolphin	*Stenella longirostris*	3,181	0.65	0	-	3,181	0.65
Striped dolphin	*Stenella coeruleoalba*	38,522	0.34	9,752	0.49	48,274	0.29
True's beaked whale	*Mesoplodon mirus*	4,480	0.34	0	-	4,480	0.34

6.5 Bayesian hierarchical density models of large whales

In 2022, we continued work on extending the Bayesian hierarchical density surface model described in Sigourney et al. (2020) to several species of large whales which included fin whales (*Balaenoptera physalus*), humpback whales, sei whales (*B. borealis*), minke whales (*B. acutorostrata*) and sperm whales (*Physeter macrocephalus*). As North Atlantic right whales (*Eubalaena glacialis*) are the focus of intense investigation by other studies, we did not include them in the current analysis. Specifically, we focused on the following aspects of the Bayesian hierarchical density surface model:

1) developing a comprehensive model selection process;
2) continuing to develop and apply a hierarchical distance sampling method that allows partially pooling of detection functions among species;
3) integrating methods to diagnose extrapolations within the AMAPPS study area;
4) developing a method to separate ambiguous sightings of fin and sei whales; and
5) making predictions for wind energy areas using the Bayesian machinery.

In the current analyses, we developed a rigorous model selection process that included evaluating models both outside of and within the Bayesian hierarchical density-surface model framework. We started with an exploratory analysis within a 2-step generalized additive model framework and used the Akaike Information Criteria and deviance explained as criteria to assess model fit. After ranking the top model from the two-step analysis, we further evaluated models using cross-validation. For each species, we took the final top five models from this process and ranked them in the Bayesian hierarchical density surface model framework using Watanabe's Information Criterion (Watanabe 2010; Vehtari et al. 2016). In addition to environmental covariates, we also compared models with and without random effects for year to test for annual variation in density.

We also continued work using Bayesian hierarchical distance sampling methods by including species as random effects when modeling detection functions. This approach has the advantage of sharing information across species helping to inform detection functions for data poor species. To group species together by survey platform we used the same species groupings detailed in the AMAPPS II Final Report (Palka et al. 2021). We used model selection to choose the best model for each species group and survey platform combination. We have inserted these models into the Bayesian hierarchical density-surface model framework for each large whale species.

We also focused on diagnosing extrapolations within the AMAPPS study area using the R package dsmextra (Bouchet et al. 2020). We plan to use these functions to isolate where and under what seasons we are attempting to predict abundance estimates using values of environmental parameters that were not included in the environmental space used to develop the model. Preliminary testing has demonstrated that diagnosing and removing extrapolated predictions can substantially reduce uncertainty in estimates of density and abundance.

During abundance surveys there are a number of sightings that the onboard observers classified as a "FISE"; meaning the observer was certain that the whale was either a fin whale or sei whale but uncertain which species. We initially developed methods to prorate these sightings as either a fin or sei to increase sample sizes, which is particularly important for sei whales where sample sizes are small. However, we have considered this classification as certain and do not propagate the model uncertainty of assigning a FISE to the fin or sei category. In 2022, we developed and tested a method to assign the FISE sightings to either a fin or sei whale, while propagating the assignment uncertainty into final density estimates. Preliminary testing with simulated data demonstrated that this method could increase precision and accuracy of the abundance estimate. We integrated this method into the Bayesian modeling framework for sei whales.

Finally, we are currently fitting the Bayesian hierarchical density surface models to the proposed wind energy areas in the U.S. Atlantic waters. Then we can make posterior predictions of abundance of a user chosen species, within a user chosen wind energy area, and during a user chosen season. We utilized the Bayesian machinery to quantify changes in abundance in terms of posterior probabilities. Specifically, over the course of an average year, we made 8-day predictions of the probability that the abundance within a wind energy area for a species is above a user-defined threshold. The threshold could be, for example, the potential biological removal level for a species or some pre-defined level of allowed takes. This information could then be incorporated into the decision making progress for wind energy development (Figure 6-4).

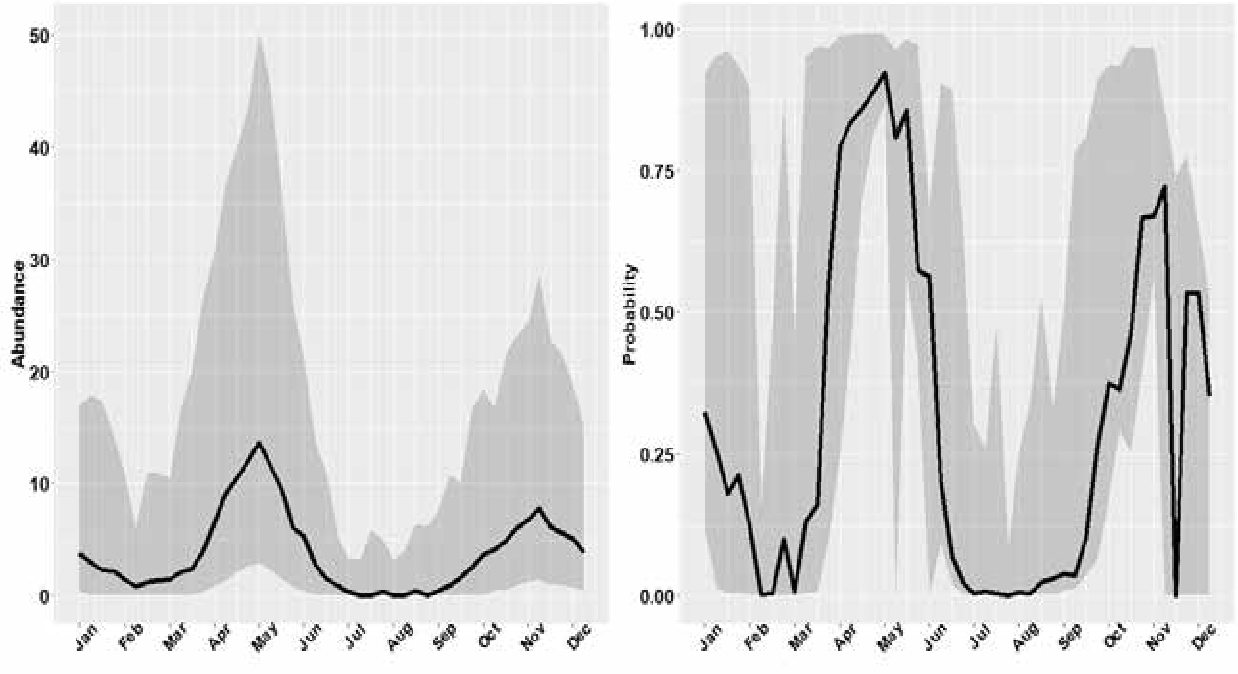

Figure 6-4 Changes in abundance and probability of whales
Left frame: Changes in abundance of humpback whales (Megaptera novaeangliae) within the Massachusetts-Rhode Island wind energy area averaged over 8 years (2010-2017). Right frame: Changes in the median posterior probability of abundance exceeding 5 humpback whales within the wind energy area, averaged over 8 years (2010-2017).

6.6 Integrating visual and passive acoustic data

In 2022, we focused on finishing revisions and submitting this manuscript to a peer-reviewed journal. We received several constructive reviews and worked to address those reviews. We mainly focused on making some changes to the model structure and re-testing the model with simulations. We also worked on revising some of the appendices and main text to explain the model structure. Simulation results demonstrated relatively low bias and good precision of the proposed method. We have made changes to the text and re-submitted (Sigourney et al. in review). All code will be publicly available on a GitHub repository.

6.7 Loggerhead turtle abundance analysis

During 2022, we completed a draft analysis for the loggerhead sea turtle (*Caretta caretta*) data collected primarily from the AMAPPS NEFSC and SEFSC aerial surveys conducted from 2010 to 2020 that resulted in 6,869 detected groups (Table 6-3).

The data were analyzed using the methodology described in Palka et al. (2017) used for cetacean species. In summary, the area was subdivided into spatiotemporal grid cells of 10x10 km cells and 8-day time periods, the environmental data covered the extent of the AMAPPS study area, and the survey data were aggregated in the same spatiotemporal grid cells. Density estimates in sampled cells resulting from the mark–recapture distance sampling analysis were used as the response variable in density-habitat generalized additive models. Thus, a density model was produced for loggerhead turtles that modeled the relationship between the spatiotemporal density and a combination of environmental predictors.

The density model produced revealed a good correspondence between the seasonal model predictions and historical date deposited in the OBIS-SEAMAP (Ocean Biodiversity Information System- Spatial Ecological Analysis of Megavertebrate Populations) website from 1967 to 2020 (Figure 6-5).

Table 6-3 Number of loggerhead turtle (Caretta caretta) groups
Groups detected in the northeast (NE) and southeast (SE) aerial surveys

Year	NE Sightings	SE Sightings
2010	60	606
2011	68	925
2012	68	1,429
2013	0	60
2014	4	311
2015	0	283
2016	826	631
2017	326	497
2018	0	0
2019	16	663
2020	6	90
Total	1,374	5,495

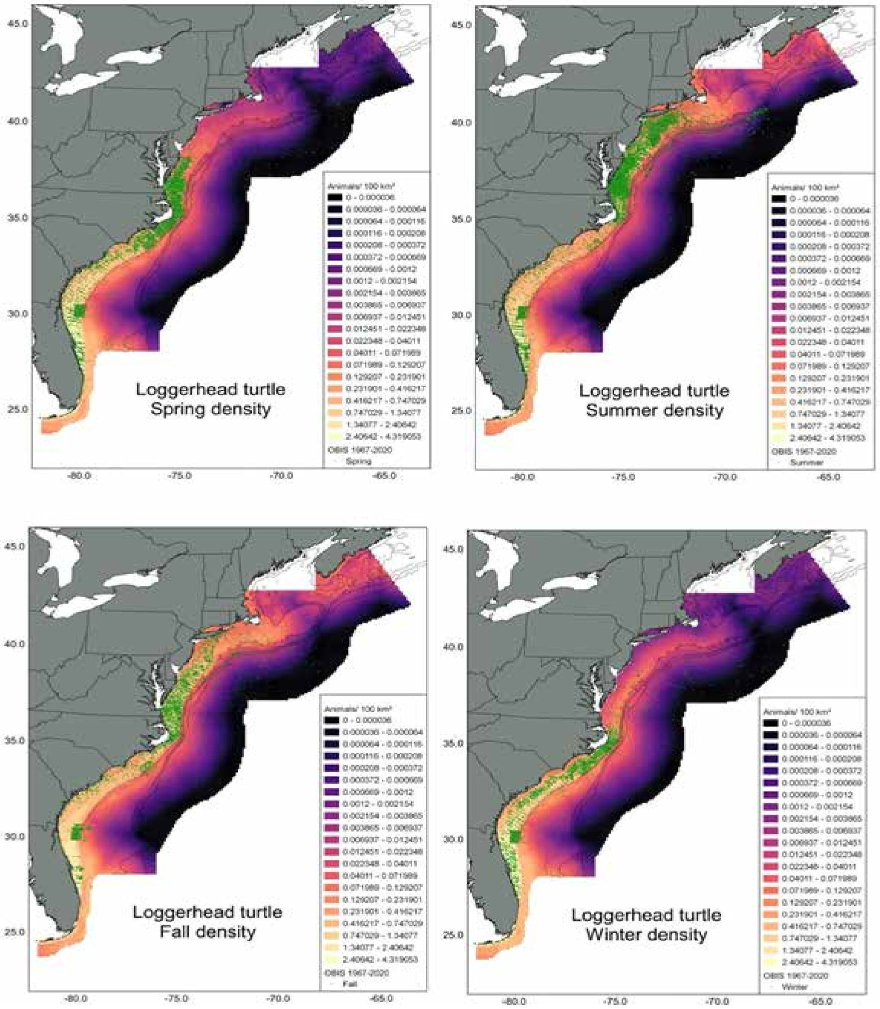

Figure 6-5 Loggerhead turtle (Caretta caretta) preliminary seasonal density maps
The green dots are sightings from 1967 to 2020 that were downloaded from the OBIS-SEAMAP website.

6.8 Development of neural network species identification algorithm

Future NMFS line transect aerial abundance surveys using the National Oceanic and Atmospheric Administration (NOAA) Twin Otter aircraft will need to be conducted at 1500 ft altitude or higher because of the presence of the future development of tall offshore wind energy turbines. To insure high levels of correctly identified species, the future aerial abundance surveys will probably need to collect digital images in addition or instead of visual detections. Because this will result in extremely large numbers of images, NEFSC has started the process of developing a species detection neural network algorithm to identify potential marine mammals, sea turtles and sea birds in images captured during the higher altitude line transect abundance surveys. This process involved first collecting large numbers of images with animals from aerial surveys at the same time that visual observers were recording the locations of animal groups. After the images were downloaded from the cameras and archived (as explained in Chapter 2), images with animals were identified by the locations of the visually recorded animals and then manually identified to species. Next, the images with identified animals were downloaded to the Video and Image Analytics for Multiple Environments (VIAME) website, a free and open-source suite of computer vision tools for object detection, tracking, rapid model generation and other related analyses. Within each image, each individual animal is currently being manually annotated with a polygon outlining the animal's shape (Figure 6-6). The goal is to use these annotations to train a species detection neural network algorithm. Then this algorithm can help us go through the thousands of images captured during an abundance survey to indicate which images have potential animals. The counts of animals in the images could then be used to calculate an abundance estimate.

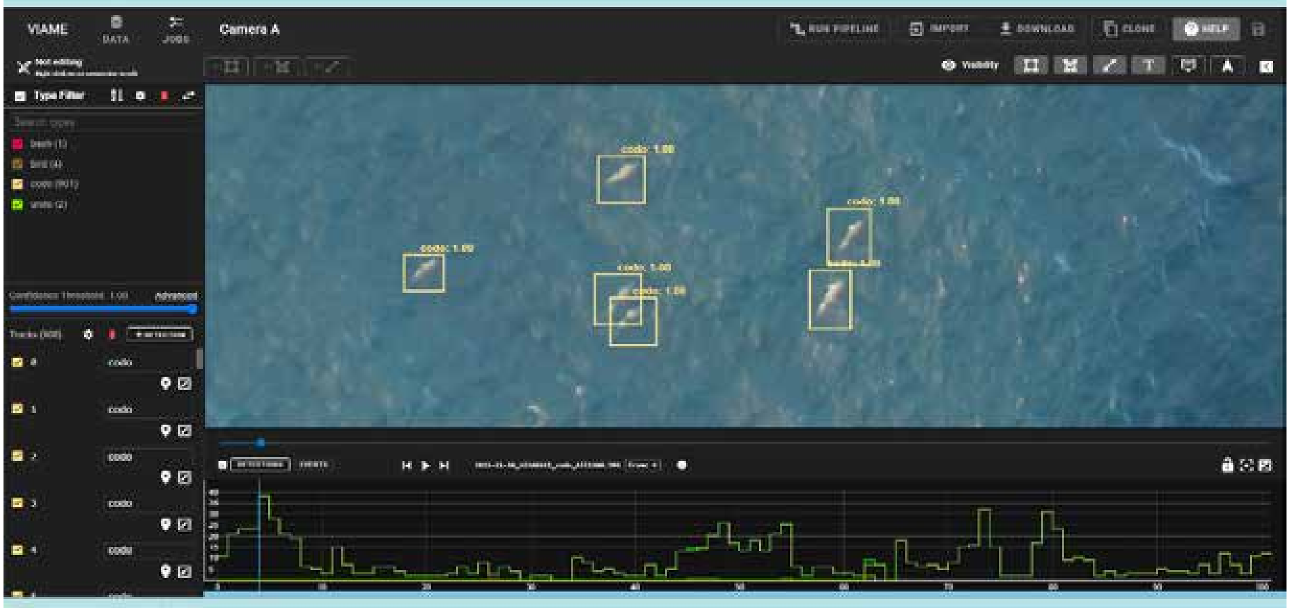

Figure 6-6 Screenshot of the VIAME web program DIVE with annotated dolphins
CODO is the species code for common dolphins (Delphinus delphis). The left part of the figure is the species list, the center section is the current image with annotations, and the bottom is the number of annotations in each frame in this series of images.

6.9 Other studies that used AMAPPS sightings data

Stepanuk et al. (2022) used humpback whale abundance data collected from AMAPPS abundance surveys, along with other sources, to assess the utility of subseasonal forecasts for dynamic management of marine mammal populations. This paper modeled the density of humpback whales along 10 km segments of trackline with either satellite sea surface temperature or SubX forecasted sea surface temperature data to predict weekly mean humpback whale density from March to August of each year from 1995 to 2016. Results showed that the environmental forecasts could predict the arrival of humpbacks 2 weeks in advance of their actual arrival.

Orphanides et al. (in review) used AMAPPS abundance cetacean sightings and echosounder data to investigate the utility of echosounder-based predictive variables to model marine mammal distribution and abundance. The echosounder-based potential prey characteristics collected on the NEFSC shipboard surveys in 2011, 2013, and 2016 were used in 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 then built generalized additive models using primarily these acoustically derived variables to explain marine mammal distribution data collected during the same surveys. The resulting models explained between 12% and 37% of the deviance, similar to that found in the generalized additive models that used proxy variables for prey distribution (Palka et al. 2021). The resulting models reflected aspects of foraging depth and prey preference. This work demonstrated the usefulness of echosounder data to model marine mammal distribution and abundance with direct measurements of prey rather than relying on proxies. This paper was subsequently published in 2023.

Roberts et al. (in review) used AMAPPS sightings abundance data in a study that combined marine mammal, fish and invertebrate survey data in an ensemble modeling approach to assess the relative importance and capacity of the environment and other marine species to predict the distribution of coastal and offshore bottlenose dolphin ecotypes. They found that coastal bottlenose dolphin distribution predictions were slightly improved when using only fish versus only environmental variables. While the opposite was concluded for offshore bottlenose dolphins (environmental variables provided a better prediction). This paper was subsequently published in 2023.

6.10 Acknowledgements

The analysis time and data collection was funded by the three sources of funds specified in section 1.4 of this document (National Marine Fisheries Service, and the 2 interagency agreements with the Bureau of Ocean Energy Management and the U.S. Navy).

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7 Progress on analyses of oceanographic, active acoustic, and plankton data: Northeast Fisheries Science Center

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7.1 Summary

To identify oceanographic characteristics associated with top predators, such as cetaceans, tuna, and sharks, and to estimate densities and biomass of the prey that top predators are feeding on, prey data have been collected during AMAPPS abundance and other surveys. Prey data were collected from midwater trawls and other types of nets, from active acoustics, and on video plankton recorders. During 2022, active acoustic and video plankton recorder data were processed and analyzed using standard methods. In addition, for both of these data types, machine learning and neural network techniques are being developed to refine and improve the identification and classification of regions of interest. Another way of improving the classification of the acoustic data to taxonomic levels that are biologically and ecologically meaningful being used is to merge trawl catch and active acoustic data. Surface and bottom temperature and salinity data collected during the 2021 Atlantic Marine Assessment Program for Protected Species (AMAPPS) abundance survey on the National Oceanic and Atmospheric Administration (NOAA) ship *Henry B. Bigelow* has been published. The presence of bluefin tuna larvae and cephalopod paralarvae in samples from the 2021 AMAPPS abundance survey were confirmed. The tuna data were provided to outside researchers for population analysis and Close Kin Mark Recapture Studies using genetic techniques. The cephalopod data representing 33 unique taxa are being used to identify species collected in northeast U.S. waters.

7.2 Midwater trawl data

Midwater trawl catch data from AMAPPS surveys in 2014, 2015, and 2016, and Deep-See cruises in 2018, 2019, and 2022 have been audited and examined for taxonomic consistency and swimbladder presence/absence and type (physostomous, physoclistous, lipid-filled). Swimbladder types were obtained via a literature search completed by M. Jech and the NOAA Central Library (Shinn 2021).

Trawl catches in 2018 and 2019 were processed on board and samples were flash frozen by Joel Llopiz and colleagues at the Woods Hole Oceanographic Institution (WHOI). These specimens were analyzed for diet, age, maturity, sex, and taxonomic identification using genetic methods. The genetic IDs were compared among all cruises to generate a consistent taxonomic list of midwater trawl catches.

Lucinda Quigley (graduate student at WHOI) and co-authors have submitted a manuscript entitled "Otolith characterizations and integrative species identification of mesopelagic fishes from the western North Atlantic Ocean" to a special issue in Frontiers in Marine Science, Current Research on Fish Otoliths and their Applications.

In addition, Annette Govindarajan (WHOI scientist) utilized the specimens for taxonomic identification of genetic material for a manuscript entitled "Assessing mesopelagic fish diversity and diel vertical migration with environmental DNA" and submitted it to another special issue of Frontiers of Marine Science, Advances in Ocean Exploration. These manuscripts utilize specimens collected during the 2014 survey.

Trawl mensuration data have been collated for all midwater trawl hauls. Mensuration data include cruise and trawl ID, and time-series data for headrope and footrope depth, horizontal mouth opening, vessel speed, and amount of trawl warp wire out for each trawl haul. Mensuration data were synchronized with active acoustic (EK60) data by aligning mensuration data with active acoustic transmissions (i.e., "ping"). This alignment was done so that the trawl profile could be aligned correctly with the EK60 data (i.e., the time/distance offset between the acoustic transducers on the ship and the location of the net are accounted for; Figure 7-1).

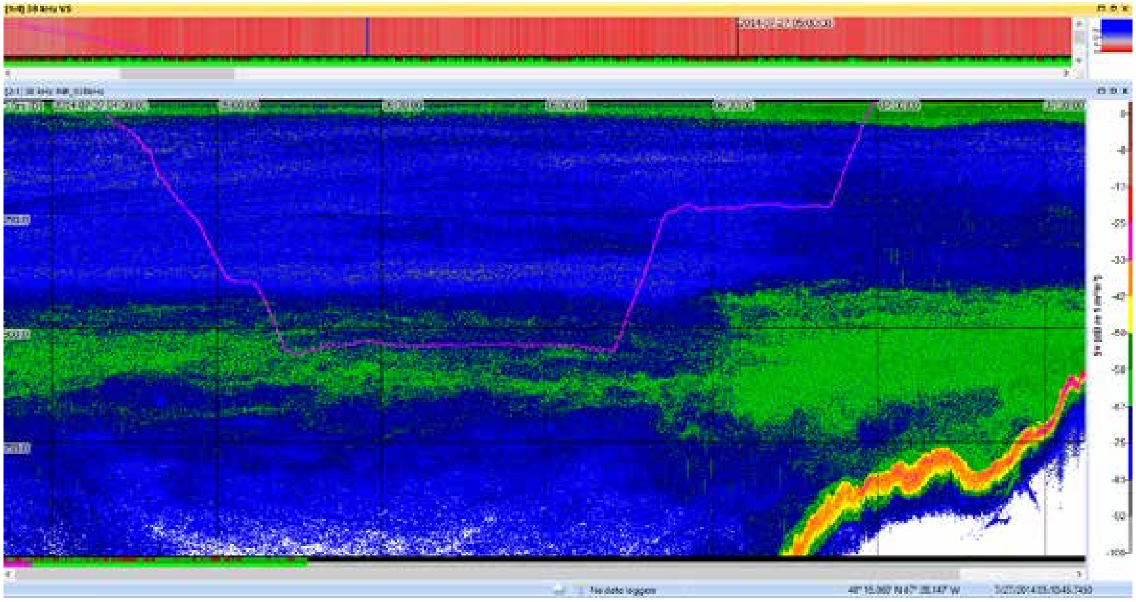

Figure 7-1 38-kHz echogram from data collected on the NOAA ship Henry B. Bigelow
Data collected during HB201403 (27 July 2014) showing deep-scattering layers (green features from 500 - 750 m), the seabed echo (red-orange feature at the lower right), and a midwater trawl profile (pink lines) overlaid on the echogram. The trawl profile is corrected for the offset in time/distance between the transducers and the location of the net.

7.3 Active acoustic data

Automated processes to "clean" (e.g., remove erroneous seabed echo detections, impulse and transient noise, near-surface acoustic interference and bubble scattering) the acoustic data have been developed in Echoview and custom-built Python code.

Methods to classify the multifrequency EK60 data (e.g., volume backscatter data, S_v dB re m^2 m^{-3}) have been and are being developed. "Standard" methods (e.g., dB-differencing, frequency responses) have been implemented in Echoview. New methods to classify EK60 data are being developed in Python using machine learning techniques. Supervised approaches include using theoretical acoustic models of zooplankton, fish, and swimbladder scattering to inform classification models using convolutional neural networks and other deep-learning techniques. Unsupervised approaches include clustering (e.g., K-means, random forest) and self-learning methods.

7.4 Merging trawl and active acoustic data

The overall goal of merging trawl catch and active acoustic data is to develop and improve classification of the acoustic data to taxonomic levels that are biologically and ecologically meaningful (Jech 2022). For example, we would like to estimate densities and biomass of the prey that top predators, such as cetaceans, tuna, and sharks are feeding on.

Volume backscatter data (S_v) are extracted by selecting data between the midwater trawl headrope and footrope (see synchronizing acoustic and trawl data above and Figure 7-2).

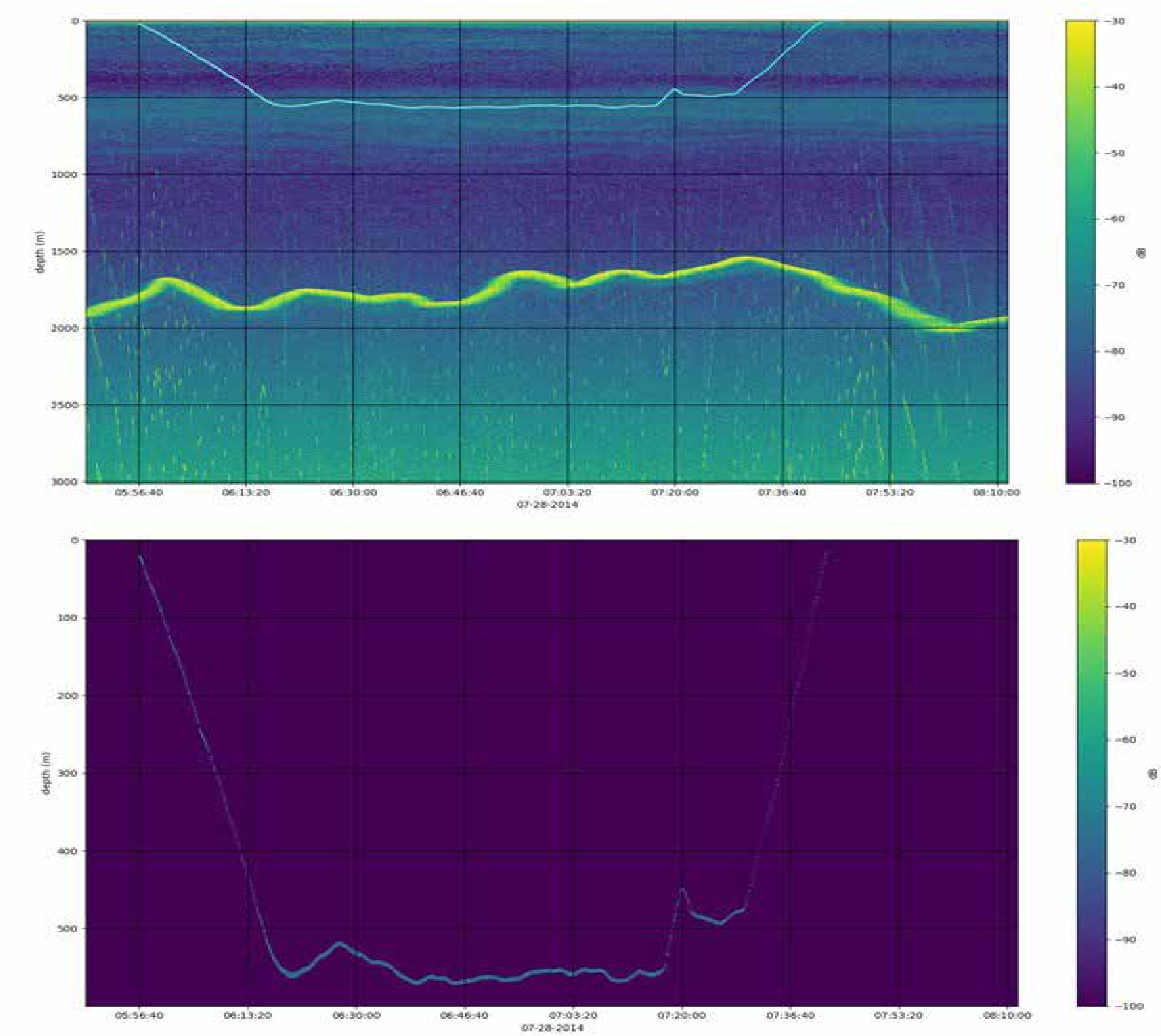

Figure 7-2 Echogram of 38-kHz Volume backscatter data (Sv) data
Data collected on 28 July 2014 from 0548 to 0805 GMT on the HB201403 cruise (upper panel). The midwater trawl haul profile is denoted by the cyan lines. The lower panel shows the S_v data that correspond to the midwater trawl haul.

The extracted multifrequency S_v data can then be used to develop classification algorithms using conventional methods (e.g., “dB differencing” or comparison of frequency responses) or more advanced analytical methods such as machine learning techniques. As an example, we can code the frequency response of the S_v data extracted from the trawl haul shown in Figure 7-2 and begin to visually investigate patterns (Figure 7-3).

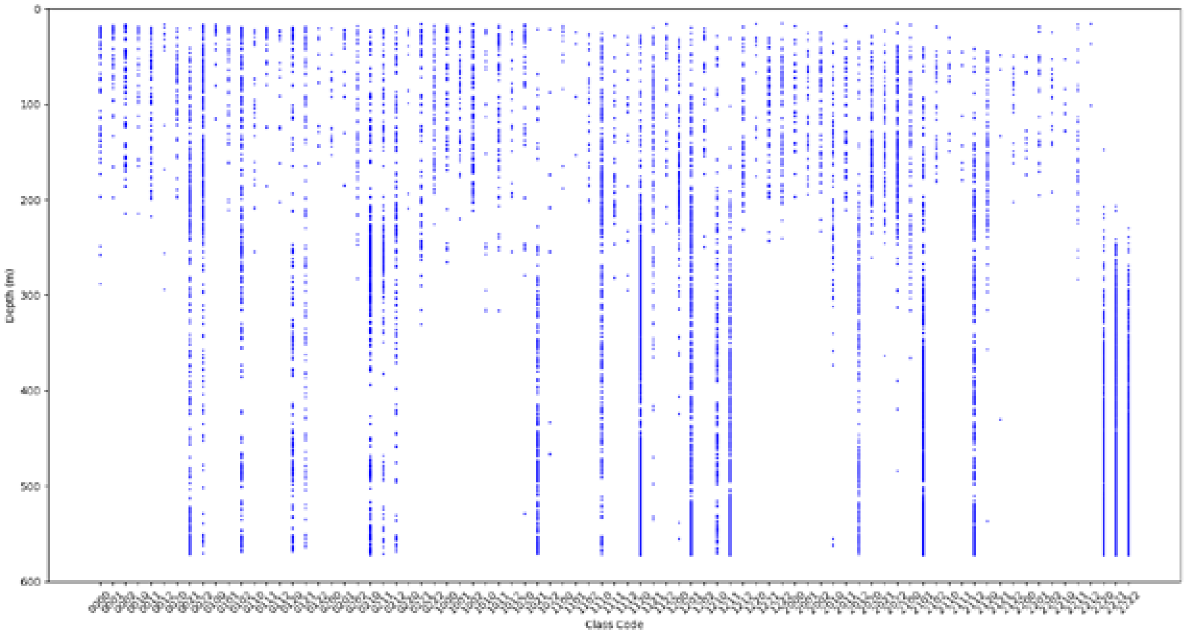

Figure 7-3 Frequency response codes (abscissa) as a function of depth
The codes indicate the shape of the multifrequency response curve, where a "0" indicates flat, "1" indicates descending, and "2" indicates rising slopes between pairs of frequencies. 18, 38, 70, 120, and 200 kHz data were present in this data set, so a code of "2220" (third column from the right) means the slope of the response curve was rising from 18 to 120 kHz, then was flat to 200 kHz, which indicates a fluid-like scatterer.

There appears to be a depth-dependence in the frequency response where some codes are present at shallow depths only, others at deeper depths, and some throughout the water column (Figure 7-3). The codes indicate an acoustic response by the scatterers, and we can begin to match the acoustic response to the species captured in the midwater trawl to develop classification schemes to a taxonomic level that will be biologically and ecologically meaningful.

7.5 Video plankton recorder data

Data from the Video Plankton Recorder (VPR) has been processed with the existing programs Autodeck and Visual Plankton using black and white images. These results have provided timely data and an accurate comparison with previous years. In addition we will be using these results as a quantitative baseline for the ongoing identification work utilizing the machine learning program from the Video and Image Analytics for Multiple Environments (VIAME) website.

Color image regions of interest, extracted by Autodeck, are being annotated using the DIVE image annotation program within VIAME (Figure 7-4). Regions of interest are identified to the lowest taxonomic level possible and annotated using taxonomic hierarchy so they can be sorted using standardized taxonomic codes. Artificial Intelligent programs such as VIAME require massive numbers of images to effectively train image identification algorithms. Hand annotation of individual VPR hauls to create the required image database within the NEFSC will take years. Public, accurately curated, image databases such as Monterey Bay Aquarium Research Institute's FathomNet are aggregating images from multiple sources, in the future including the AMAPPS VPR images, to help reduce the time needed to have working algorithms.

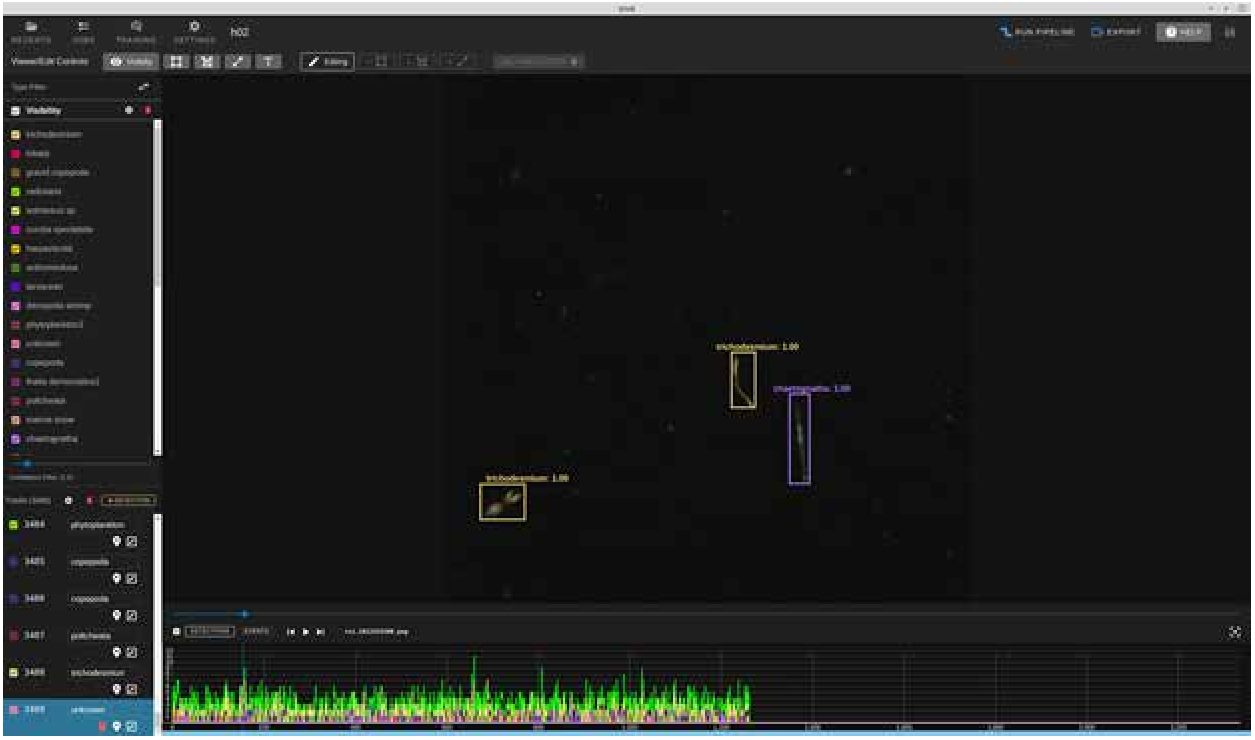

Figure 7-4 Screenshot of the DIVE annotation program with annotated plankton
Left is the species list, center is the current image with annotations, and bottom is the number of annotations in each frame.

Working with DIVE to hand annotate images has revealed several advantages over processing hauls with the program Visual Plankton. DIVE allows the annotation of multiple and overlapping images within a frame, correcting the past problem of counting multiple planktors in close proximity as one individual (Figure 7-5). This has also revealed species associations that are not identifiable through net sampling.

To take full advantage of the numerous capabilities of the VIAME program combined with the advanced computer graphics we have modified our image extraction process. Instead of extracting multiple small regions of interest from within an image frame, we worked with Seascan Inc to modify the Autodeck program to quantitatively extract full frame images. Grabbing the full frame fixes the error of multiple regions of interest grabs of a single gelatinous zooplankton (Figure 7-5). Multiple DIVE annotations of a single haul with a variety of color corrections and extraction parameters are being compared to select optimal image parameters for use with DIVE and VIAME.

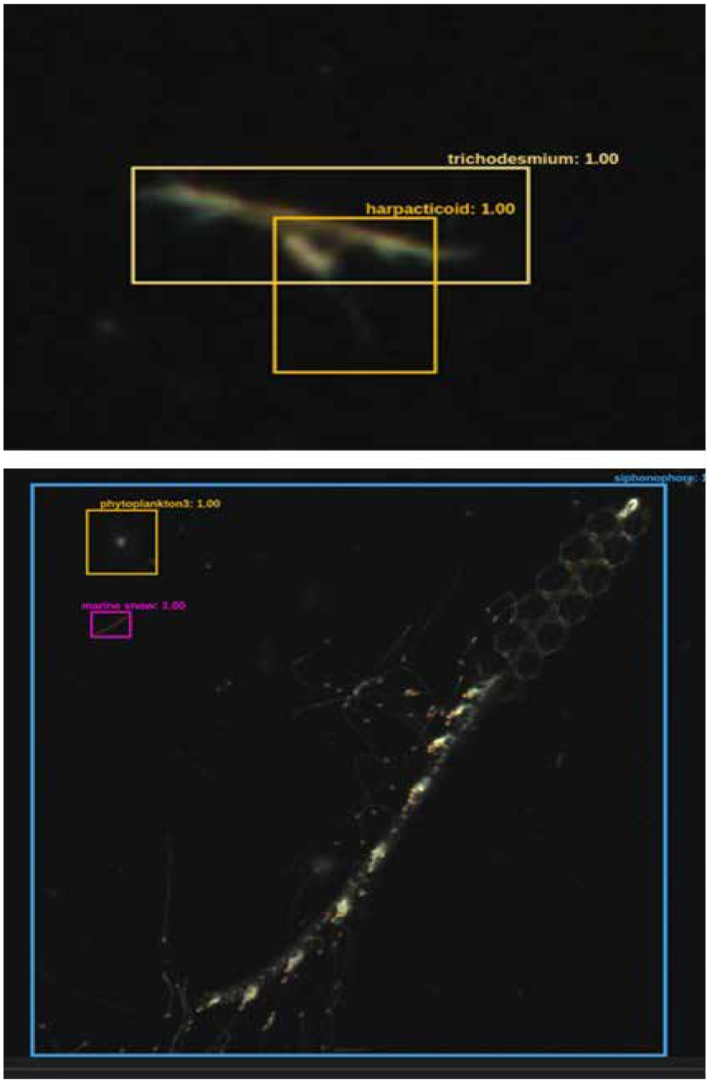

Figure 7-5 Annotated plankton
TOP: Annotated image of the phytoplankton trichodesmium and an associated harpacticoid copepod identified as two individuals using DIVE. Previously, this region of interest would have been counted as one individual. BOTTOM: Annotated image of a Physonectes Siphonophore annotated as a single individual. Previously each bright area in the blue bounding box would have been classified as a separate region of interest.

7.6 Oceanographic data

Oceanographic data has been processed but not yet uploaded to the Oceans and Climate Branch database because the database is being updated to accept the irregular tow profiles created by VPR and Neuston tows. The surface and bottom sea surface temperature and salinity patterns from the 2021 AMAPPS abundance survey on the NOAA ship *Henry B. Bigelow* (HB2102) are reported in Holzwarth-Davis (2023).

7.7 Plankton data

The sorting of plankton samples for larval fishes, cephalopod paralarvae, and zooplankton is underway. Larval fish (n = 34,171), fish eggs (n = 24,020), and cephalopod paralarvae (n = 834) has been removed from the 232 ethanol preserved plankton samples collected during HB2102. The presence of Atlantic bluefin tuna (*Thunnus thynnus*) larvae in these samples has been confirmed, and work is underway to quantify and measure these samples. Additionally, some bluefin larvae have been provided to outside researchers for Close Kin Mark Recapture Studies using genetic techniques. We have also undertaken a project to genetically identify cephalopod paralarvae using samples from AMAPPS surveys. In total, we were able to obtain data from 325 paralarvae representing 33 unique taxa. Work to verify identifications is ongoing.

Sample processing of the HB2102 formalin preserved oblique bongo tow samples (n = 185) by the Morski Instytut Rybacki in Szczecin, Poland is complete for fish larvae (Table 7-1) and in process for zooplankton.

Table 7-1 Twenty most abundant larvae fish collected on the 2021 oblique bongo tows From the 2021 HB2102 survey on the NOAA ship Henry B. Bigelow

Taxa	Common Name	Minimum Body Length (mm)	Maximum Body Length (mm)
Paralichthyidae	Flatfishes	1	21.3
Stromateidae	Butterfishes	1	7.2
Serranidae	Seabasses	1.4	7.2
Clupidae	Herrings	1	39
Engraulidae	Anchovies	1.8	13.5
Labridae	Wrasses	1	14
Myctopidae	Lanternfishes	0.9	21
Sciaenidae	Drums	1.2	5.1
Triglidae	Searobins	1.2	8.7
Phycidae	Hakes	1	17.5
Ophidiidae	Cusk-eels	1	29.3
Merlucciidae	Silver Hakes	1.5	18.5
Gonostomatidae	Bristlemouths	1.2	32
Pomatomus saltatrix	Bluefish	1.5	4.9
Uranoscopidae	Stargazers	2.3	6.7
Scombridae	Tunas	1.8	8.9
Lophiidae	Goosefishes	3.1	14.3
Paralepididae	Barracudians	1	47
Stomiiformes	Dragonfishes	1	8.7
Gobiidae	Gobies	1.3	12

7.8 Disposition of data

Trawl catch data are in Open Office spreadsheets. These spreadsheets contain deployment information (cruise ID, trawl ID, date, time, latitude, and longitude), catch data, and length data.

Active acoustic data are archived at the NEFSC and at NOAA's National Center for Environmental Information (NCEI) facility in Boulder, Colorado https://www.ncei.noaa.gov/maps/water-column-sonar/.

Oceanographic data are maintained by the NEFSC Oceans and Climate Branch and accessed through the NCEI World Ocean Database https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html

7.9 Acknowledgements

The analysis time and data collection was partially funded by the three sources of funds specified in section 1.4 of this document (National Marine Fisheries Service, and the two interagency agreements with the Bureau of Ocean Energy Management and the U.S. Navy).

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8 Annotated dataset of bowhead whales in very high resolution satellite imagery: Northeast Fisheries Science Center and Alaska Fisheries Science Center

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Monitoring marine mammals is of broad interest to governments and individuals around the globe. Very high-resolution satellites hold the promise of reaching remote and challenging locations to fill gaps in our knowledge of marine mammal distribution. The time has come to create an operational platform that leverages the increased resolution of satellite imagery, proof-of-concept research, advances in cloud computing, and machine learning to monitor the world's oceans. The Geospatial Artificial Intelligence for Animals initiative was formed to address this challenge with collaborative innovation from government agencies, academia, and the private sector (Khan et al., 2023). As part of this initiative, Maxar Technologies' GeoHIVE platform used crowdsourcing to annotate images of bowhead whales (*Balaena mysticetus*). Crowdsourcing is a way to harness the energy of a large pool of talent through an online platform to accomplish a challenging goal. This innovative approach has become quite popular in recent years with many different varieties including hackathons, citizen science, and data science competitions. During the Discovery campaign, Maxar Technologies hosted image chips online for a group of annotators to indicate which images contained whales. The Discovery campaign resulted in a large number of false detections (primarily whitecaps) which were resolved during the Validation campaign. Suggestions for improving future campaigns include providing additional training material to annotators and reducing false positives by first running an initial campaign to identify whether or not there are any objects in the imagery before running annotation campaigns. However, whales are challenging to discriminate and may not be suitable for approaches that down sample the imagery and serve it up online as RGB files. Our subject matter experts found it difficult to confirm species with this degraded imagery during the Validation campaign. It was considered that the native resolution imagery would be needed to identify the species of whales because of their small size (relative to the area covered by each satellite image).

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