2020
Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in US waters of the Western North Atlantic Ocean – AMAPPS III

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

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

Contents

List of Figures iii

List of Tables iii

List of Abbreviations and Acronyms iv

1 Overview of 2020 1

1.1 Background 1

1.2 Summary of 2020 field activities 1

1.3 Summary of 2020 analyses 2

2 Progress of at-sea monitoring of the distributions of pelagic seabirds in the northeast US shelf ecosystem: Northeast Fisheries Science Center 7

2.1 Abstract 7

3 Progress of sea turtle ecology research: Northeast and Southeast Science Centers 8

3.1 Abstract 8

3.2 Field work 8

3.3 Analytical work 10

3.3.1 Loggerhead sea turtles respond to a major hurricane in the Northwest Atlantic 10

3.3.2 Projected shifts in loggerhead habitat due to climate change 11

3.3.3 Estimating the complex patterns of survey availability for a highly-mobile marine animal 12

4 Progress of research related to passive acoustic data: Northeast and Southeast Fisheries Science Centers 13

4.1 Abstract 13

4.2 Expanding the knowledge on the dive depths of multiple beaked whale species 13

4.3 Integrating passive acoustic towed array data of sperm whales into abundance estimates 14

4.4 Improving classification methods of beaked whales on bottom mounted recorders 15

4.5 Assessing the detection of seismic surveys along the US eastern seaboard 17

4.6 Detailed observations of True's beaked whale foraging behavior 18

4.7 Publicly accessible data efforts 18

4.8 Acknowledgements 19

5 Progress of research related to cetacean distribution and abundance estimation: Northeast and Southeast Fisheries Science Centers 20

5.1 Abstract 20

5.2 Fieldwork 20

5.3 Analytical work ... 21
5.3.1 Spatial density modeling using the generalized additive model framework ... 21
5.3.2 Spatial density modeling using the Bayesian hierarchical framework ... 21
5.3.3 Integrating visual and passive acoustic data ... 21
5.3.4 Trend analyses ... 22
5.3.5 Availability bias of cetaceans ... 22
5.4 Database development and data archiving ... 22
5.5 Acknowledgements ... 23
6 Progress on ecosystem research: Northeast Fisheries Science Center ... 24
6.1 Abstract ... 24
6.2 Video plankton recorder ... 24
6.3 Prey sampling near feeding North Atlantic right whales in southern New England ... 30
6.4 Active acoustic data ... 31
6.5 Including prey density covariates in marine mammal spatial distribution models ... 31
6.6 Midwater trawl data ... 32
6.7 Integrating active acoustic and trawl data ... 32
7 References ... 35

List of Figures

Figure 3-1 Leatherback turtle fieldwork in the fall of 2020 10

Figure 4-1 Locations of high-frequency acoustic recording packages (HARPs) 15

Figure 4-2 Acoustic kernel densities of presence/absence (1/0) of beaked whale click types 17

Figure 6-1 Comparisons of plankton densities per VPR haul 26

Figure 6-2 VPR images of mysids in multiple orientations 27

Figure 6-3 Length frequencies of mysids generated by Visual Plankton 28

Figure 6-4 Pairs of VPR images taken from the black-and-white and new color cameras. 29

Figure 6-5 Mean concentration (individuals per 100m^3) of most abundant zooplankton taxa 30

Figure 6-6 Mean concentrations of juvenile and adult stages of *Calanus finmarchicus* 31

Figure 6-7 18-kHz (top panel) and 38-kHz (lower panel) echograms 32

Figure 6-8 Headrope depth as a function of wire out 33

Figure 6-9 Scope as a function of the maximum depth of each midwater trawl haul (gray symbol) 34

List of Tables

Table 1-1 General information on the 2020 data collection projects under AMAPPS 3

Table 1-2 List of 2020 published manuscripts involving data collected under AMAPPS 4

Table 1-3 List of 2020 published web articles involving AMAPPS research 5

Table 1-4 List of 2020 presentations involving AMAPPS research 6

List of Abbreviations and Acronyms

Abbreviation	Meaning
AMAPPS	Atlantic Marine Assessment Program for Protected Species
BOEM	Bureau of Ocean Energy Management
CTD	Conductivity, temperature and depth sensor sampling device
DenMod	Density Modeling technical working group
DTAG	Digitally acoustic recording tag
EcoMon	Northeast Fisheries Science Center's Ecosystem Monitoring program
ESA	Endangered Species Act
GFDL	Global climatic model
GMT	Greenwich mean time zone
HARP	High-frequency acoustic recording package
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
SEFSC	Southeast Fisheries Science Center
VIAME	Video and Image Analytics for a Marine Environment software
VPR	Video plankton recorder

1 Overview of 2020

1.1 Background

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

To conduct this work National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) has inter-agency agreements with the Bureau of Ocean Energy Management (BOEM) and the US Navy. Scientists from NMFS's Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) developed the products resulting from the interagency agreements.

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

This report focuses on documenting the fieldwork conducted and briefly describing the analyses preformed in 2020. For a detailed report on results of the many analyses conducted during 2020, please refer to the final report for AMAPPS II (Palka et al. in review).

1.2 Summary of 2020 field activities

Fieldwork in 2020 was limited due to Covid-19 restrictions. However, we were able to safely complete some fieldwork without any Covid-19 incidences (Table 1-1).

During 13 October 2019 to 25 January 2020, we completed the NEFSC and SEFSC two aerial line transect abundance surveys covering Atlantic waters from Florida to Nova Scotia, from the coastline to shelf break at about the 2,000 m depth contour. See the 2019 AMAPPS annual report (NEFSC and SEFSC 2020) for more details.

During 24 September to 23 October 2020, we conducted several day trips (departing from Massachusetts ports) for leatherback turtle (*Dermochelys coriacea*) tagging, where we deployed 11 camera tags. See Chapter 3 in this document for more details.

The fieldwork that we cancelled due to Covid-19 restrictions included:

- a 2-week small boat field project in May 2020 to satellite tag leatherback turtles in coastal North Carolina;
- a 2-week small boat field project in August 2020 to satellite tag leatherback turtles in coastal Massachusetts waters;

- a June 2020 cruise on the NOAA ship *Gordon Gunter* to perform laparoscopies and tag loggerhead turtles (*Caretta caretta*) in waters offshore of Massachusetts to North Carolina;
- a 2-week EcoMon shipboard cruise during May 2020 where 2 observers surveyed for seabirds and marine mammals;
- a 2-week EcoMon shipboard cruise during August 2020 where 2 observers surveyed for seabirds and marine mammals;
- a 2-week EcoMon shipboard cruise during October 2020 where 2 observers surveyed for seabirds and marine mammals; and
- a 60-day shipboard cruise during March and April 2020 to estimate abundance of marine mammals and seabirds in waters south of Cape Hatteras, NC on the NOAA ship *Gordon Gunter*.

1.3 Summary of 2020 analyses

In regards to seabird ecology research, during 2020, we described the spatiotemporal patterns of birds seen at sea during the previously collected AMAPPS shipboard surveys. For more details, see Chapter 2 in this document and the AMAPPS II final report (Palka et al. in review).

In regards to sea turtle ecology research, during 2020, we made significant progress on assembling a more robust and user-friendly turtle ecology database containing the tag data and supporting data. We also made progress on three research projects. For one project, we analyzed loggerhead sea turtle behavior in the Mid-Atlantic Bight and the environmental conditions observed from turtle-borne satellite tags in relation to Hurricane Irene (Tables 1-2 and 1-3). For the second project, we used a high-resolution global climate model and the loggerhead turtle satellite tag dataset to project changes in the future distribution of suitable bathythermal habitat along the northeastern continental shelf of the US. For the third project, we explored the diving and surfacing behavior of loggerhead turtles in US waters. We also entered into the planning stages of a collaboration with the BOEM leatherback sound exposure project entitled "Behavioral Response of Sea Turtles from Controlled Exposures to a Mobile Impulsive Sound Source". For more details on all the projects, see Chapter 3 in this document and the AMAPPS II final report (Palka et al. in review).

In regards to passive acoustic research, during 2020, we continued to work on 6 ongoing analyses involving towed hydrophone array data and bottom-mounted recorder data collected during previous AMAPPS surveys. One, we expanded our knowledge of dive depths of beaked whale species. Two, we integrated passive acoustic towed array and visual sightings data for sperm whales into abundance estimates. Three, we are continuing to improve automated classification methods for identifying beaked whales on bottom-mounted recorders. Four, we are assessing the geographical source of seismic airgun detections along the US eastern seaboard from bottom-mounted recorders off the shelf break. Five, we are describing True's beaked whale (*Mesoplodon mirus*) foraging behavior through passive acoustic, visual, and genetic datasets. Finally, six, we are creating a publicly accessible data interface to host all of our passive acoustic analyses detection output from AMAPPS and non-AMAPPS supported data. For more details on these projects, see Chapter 4 in this document and the AMAPPS II final report (Palka et al. in review).

In regards to research related to the distribution and abundance of cetaceans, during 2020 we finalized the density habitat modeling for 18 cetacean species or species guilds using the two-step generalize additive model framework (Tables 1-2 to 1-4). We also extended the statistical aspects of the Bayesian hierarchical density spatial modeling framework and applied it to large whale AMAPPS data. We developed an alternative statistical model that incorporated the practical situation where only a subset on acoustic array detection can fully be annotated into the statistical framework that integrates passive acoustic and visual line transect data resulting in estimates of abundance and availability bias correction factors for sperm whales. We started investigating the use of multivariate autoregressive state-space models to estimate trends in abundance using visual sightings data collected during 1992 to 2016 for cetacean species inhabiting the waters of the US Atlantic and the Canadian Gulf of Maine and Scotian shelf. We also updated the availability bias correction factor for short-finned pilot whales (*Globicephala macrorhynchus*) and Cuvier's beaked whales (*Ziphius cavirostris*) using DTAG (digitally acoustic recording tag) data that Dr. Andrew Read kindly shared with us (funded by the US Navy and Duke University). For more details on these projects, see Chapter 5 in this document and the AMAPPS II final report (Palka et al. in review).

In regards to research related to marine mammal ecosystem research, during 2020 we continued and expanded several ongoing projects. We further improved and sped up the processing of video plankton recorder (VPR) images of plankton. We processed plankton samples collected in the winter of 2020 that were in the area of feeding whales including the North Atlantic right whales (*Eubalaena glacialis*). We processed 4 more years of active acoustic echosounder data and 3 more years of midwater trawl data. Then we compared the VPR data to the active acoustic data, compared the VPR image generated length frequencies to measured length frequencies from bongo net plankton sampled contemporaneously, and compared the active acoustic data to the midwater trawl data. These comparisons are useful when interpreting the relationships between marine mammal densities and potential prey densities. One such relationship was the updated analysis of incorporating prey density information as a covariate in marine mammal density spatial habitat models as a means of improving species distribution models. For more details on these projects, see Chapter 6 in this document and the AMAPPS II final report (Palka et al. in review).

Table 1-1 General information on the 2020 data collection projects under AMAPPS

Field collection project (lead center)	Platform	Dates	Location	Chapter
Aerial abundance surveys (SE[1])	NOAA Twin Otter	7 December 2019 – 25 January 2020	New Jersey to Florida	2019 AMAPPS annual report (NEFSC and SEFSC 2020)
Turtle Ecology (NE)	*R/V Selkie*	24 September – 23 October 2020	Massachusetts state waters	3

[1] The NEFSC conducted the northern portion of this survey (Maine to New Jersey) during 13 October to 24 November 2019, as reported in the 2019 AMAPPS annual report (NEFSC and SEFSC 2020).

Table 1-2 List of 2020 published manuscripts involving data collected under AMAPPS

Crowe LM, Hatch JM, Patel SH, Smolowitz RJ, Haas HL. 2020. Riders on the storm: Loggerhead sea turtles detect and respond to a major hurricane in the Northwest Atlantic Ocean. Movement Ecology 8:32.
Garrison LP. 2020. Abundance of marine mammals in waters of the U.S. East Coast during summer 2016. Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, 75 Virginia Beach Dr., Miami, FL 33140. PRBD Contribution #PRBD-2020-04; 17 pp.
Hayes SA, Josephson E, Maze-Foley K, Rosel R (eds.). U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2019. NOAA Tech Memo NMFS NE 264; 479 pp.
Palka D. 2020. Cetacean abundance estimates in US northwestern Atlantic Ocean waters from summer 2016 line transect surveys. Northeast Fish Sci Cent Ref Doc 20-05; 60 p
Sigourney DB, Chavez-Rosales S, Conn PB, Garrison L, Josephson E, Palka D. 2020. Developing and assessing a density surface model in a Bayesian hierarchical framework with a focus on uncertainty: insights from simulations and an application to fin whales (*Balaenoptera physalus*). PeerJ, DOI 10.7717/peerj.8226.
White TP, Veit RR. 2020. Spatial ecology of long-tailed ducks and white-winged scoters wintering on Nantucket Shoals. Ecosphere 11(1):e03002.

Table 1-3 List of 2020 published web articles involving AMAPPS research

Riders on the storm: Loggerhead sea turtles detect and respond to a major hurricane in the Northwest Atlantic Ocean
NOAA Fisheries Feature News: Technology helps unlock the world of beaked whales. Published 8 May 2020.
NOAA Fisheries Feature Story: Surveys collect data year-round on marine life along the US east coast. Published 23 Jan 2020.
The Wildlife Society: Loggerhead behavior changes during hurricanes. Published 18 September 2020
Oceanbites: Crushed it: Sea turtles can help us understand hurricanes in the mid-Atlantic. Published 16 September 2020
Pieuvre.ca: Ouragans: des tortues à la rescousse (translation: Hurricanes: turtles to the rescue). Published 10 September 2020
Mind Bounce: Loggerhead turtles report on hurricanes. Published 04 September 2020
The Poetry of Science: At Loggerheads with the Storm. Published 04 September 2020
The Conscious Earth: Did you ever wonder what sea turtles do during hurricanes?. Published 03 September 2020
News4Jax: Satellite trackers reveal what happened when a hurricane rolled over sea turtles. Published 03 September 2020
Earth.com: Sea turtles recorded their own behavior during a hurricane. Published 02 September 2020
Inside Ecology: Loggerhead turtles record a passing hurricane. Published 02 September 2020
Laboratory Equipment: Loggerhead turtles record Hurricane Irene. Published 02 September 2020
(e) Science News: Loggerhead turtles record a passing hurricane. Published 01 September 2020
Environmental News Network: Loggerhead turtles record a passing hurricane. Published 01 September 2020
EurekAlert: Loggerhead turtles record a passing hurricane. Published 01 September 2020
phys.org: Loggerhead turtles record a passing hurricane. Published 01 September 2020
Saving Seafood: Loggerhead turtles record a passing hurricane. Published 01 September 2020
Scienmag: Loggerhead turtles record a passing hurricane. Published 01 September 2020
Science Daily: Loggerhead turtles record a passing hurricane. Published 01 September 2020
MVTimes: Turtles prove good research assistants. Published 01 September 2020
NOAA Fisheries Feature Story: Loggerhead Turtles Record a Passing Hurricane. Published 26 August 2020
New Scientist: Sea turtles carrying thermometers could improve hurricane forecasts. Published 20 August 2020

Table 1-4 List of 2020 presentations involving AMAPPS research

D. Palka presented to the Atlantic Scientific Review group meeting (24 February 2020) a talk and PowerPoint presentation on an update of AMAPPS activities.
D. Palka presented to the Aircraft Operational Control (AOC) stakeholders virtual meeting (28 May 2020) a talk and PowerPoint presentation entitled “NEFSC and SEFSC aircraft needs for AMAPPS”.
D. Palka presented to NOAA Protected Resources Science Board (12 Jun 2020) the talk and PowerPoint presentation entitled “AMAPPS: past and future”.
D. Sigourney was invited by the NMFS Southeast Fisheries Science Center and Southeast Regional Office to present a seminar on the development of the method to combine visual and passive acoustic data to estimate abundance of sperm whales (September 2020).
NEFSC and SEFSC provided to BOEM Accomplishments of AMAPPS II and Plans for AMAPPS III (December 2020).

2 Progress of at-sea monitoring of the distributions of pelagic seabirds in the northeast US shelf ecosystem: Northeast Fisheries Science Center

Harvey Walsh[1], Elizabeth Josephson[2]

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

2.1 Abstract

In previous years, observers surveyed for seabirds and marine mammals while on the EcoMon cruises conducted by the Northeast Fisheries Science Center. Due to Covid-19, the Northeast Fisheries Science Center cancelled the EcoMon cruises during the spring, summer, and fall of 2020. We are planning to put observers on both the spring 2021 EcoMon cruise (12 – 27 May 2021 on the NOAA ship *Gordon Gunter*) and the summer 2021 EcoMon cruise (6 – 19 August 2021 on the NOAA ship *Pisces*).

During 2020, the seabird data collected on the 2017 to 2019 EcoMon cruises were analysed, mapped, and documented in the AMAPPS II final report (Palka et al. in review). These data showed seasonal changes in the species composition. For example, across the shelf-break front in Southern New England waters, shorebirds dominated the sightings in the spring surveys, while during summer, Great Shearwater (*Ardenna gravis*) accounted for 50% of the sightings and Wilson's Storm-petrel (*Oceanites oceanicus*) accounted for another 25%. Another example of analyses related to the AMAPPS seabird data was the integration of previously collected AMAPPS seabird data and other NMFS data that identified important interactions between diving marine birds, prey, and oceanography on Nantucket Shoals (White and Veit 2020). For more details on all of these projects, see the AMAPPS II final report (Palka et al. in review).

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

Heather Haas[1], Kate Choate[2], Leah Crowe[2], Joshua Hatch[1], Rick Rogers[2], Samir Patel[2], Christopher Sasso[3].

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

3.1 Abstract

During 2020, the Turtle Ecology Team attempted as much fieldwork as possible. In May, we had 2 weeks of small boat leatherback turtle (*Dermochelys coriacea*) research planned in coastal North Carolina. The primary objective was to deploy satellite tags on migrating leatherbacks. In June, we had a loggerhead turtle (*Caretta caretta*) research cruise scheduled on the NOAA ship *Gordon Gunter*. Primary cruise objectives were to deploy satellite tags on loggerheads and to perform laparoscopies on as many loggerheads as possible to validate hormone based sex ratio estimates. Although we had put substantial effort into planning for these field activities, the pandemic restrictions resulted in the cancellation of the activities. In late summer and early fall of 2020, we planned small boat work in coastal Massachusetts to deploy satellite tags and suction cup tags on leatherbacks. Restrictions prevented us from deploying the satellite tags (because close contact between researchers would have been required to capture the leatherbacks in preparation for satellite tag attachment). With mitigation measures in place, we were able to undertake the higher resolution suction cup tagging of leatherback sea turtles in coastal Massachusetts in the early fall. Gathering a second year of foraging and diving data will allow us to begin to examine year-to-year variation.

In 2020, we made significant progress on assembling a more robust and user-friendly Turtle Ecology database. Most AMAPPS turtle ecology data are now stored on a central Oracle database with a supporting data dictionary of Oracle Tables and Views. With additional data incoming, the maintenance of this data system will require continued investment, but we now have the skeleton in place, which marks a milestone in our database development efforts. This year we also made significant progress on three manuscripts (one published, one in external review, and one in internal review, see Section 3.3 below). In 2020 we also entered into the planning stages of a collaboration with the BOEM leatherback sound exposure project (Behavioral Response of Sea Turtles from Controlled Exposures to a Mobile Impulsive Sound Source; BOEM Contract: 140M0120P0032), with fieldwork expected in the following year(s).

3.2 Field work

From 24 September to 23 October 2020, we successfully conducted several day trips for leatherback tagging within Massachusetts state water and deployed 11 camera tags. For three deployments, the tag detached within 5 minutes; however, for the remaining 8 deployments we recorded on average 151.7 minutes of footage. For the first time, our program deployed tags overnight – six of these deployments were recovered the next day (we recovered 2 tags on the beach. We found the remaining tags floating nearby to the deployment site).

The first deployment occurred in Vineyard Sound, the second in Cape Cod Bay and the remaining 9 occurred in Nantucket Sound. The Cape Cod Bay deployment was less than 5 minutes. Overall, for turtles tagged in Vineyard Sound and Nantucket Sound, we documented regular foraging on jellyfish, similar to leatherback behavior documented in previous years of camera tagging in this region. Dives generally lasted less than ten minutes regardless of the time of day.

Camera tags were composed of several commercially available components working independently of each other. For the base of the tag, we used syntactic foam and attached two suction cups. We created a foam base designed to hold a Paralenz dive camera, a Holohil radio transmitter, and a Wildlife Computers Mk10 satellite transmitter. We used galvanic timed releases to detach the tag from the turtle. This year we deployed tags scheduled to release between 2 to 4 hrs and so we recovered them the same day. We also scheduled several tags to release within 16 to 24 hrs and then we recovered them the next day. For the longer deployments, although the Paralenz dive camera only recorded for a maximum of 3 hours, the satellite transmitters continued to record high-resolution dive data. We secured the satellite tags to the foam base by a 50 cm monofilament tether wound through the foam base and around the galvanic timed release. Upon release from the turtle, the satellite tag unraveled from the galvanic release, remaining attached to the foam base by the tether. This allowed the antenna of the satellite tag to properly orient out of the water to continue transmitting as the tag was freely floating waiting for us to recover it. As a result, for recovery, we tracked the radio transmitter using a Yagi antenna and tracked the satellite tag using a goniometer, which every 30 secs provided an estimate of distance and direction from the boat.

We deployed the camera tags from the *R/V Selkie* equipped with a specially designed tagging platform using the same techniques developed over the last few years. With the aid of a spotter pilot (George Breen and Rick Brown), we would search for leatherback turtles within Cape Cod Bay, Nantucket Sound and Vineyard Sound. Once the spotter pilot found a leatherback, he would direct *Selkie* to the turtle, orienting the boat to approach from behind the animal. The spotter pilot continuously informed the research boat of the turtle's direction, orientation, and when it was rising to the surface for a breath. This allowed the *Selkie* to be within close proximity of the animal during a surfacing event and in position to approach the turtle for tag deployment. When the turtle was at the surface, the *Selkie* approached at less than 5 knots putting the turtle on the starboard side adjacent to the tagging platform. Then when the turtle was within reach, we shifted the boat engines to neutral and a researcher on the tagging platform placed the camera tag. We placed the tag near the anterior edge of the carapace and on the smooth flat space either left or right of the central ridge depending on orientation of the turtle to the tagging platform. The camera tag placement provided a forward facing view that typically included the entire head and a portion of the neck.

The field team included Lisa Conger, Leah Crowe, Heather Haas, Joshua Hatch, and Samir Patel. We conducted the work under ESA Permit #22218. To remain compliant with all Covid-19 protocols, only 4 people were on the boat at one time during a day at-sea.

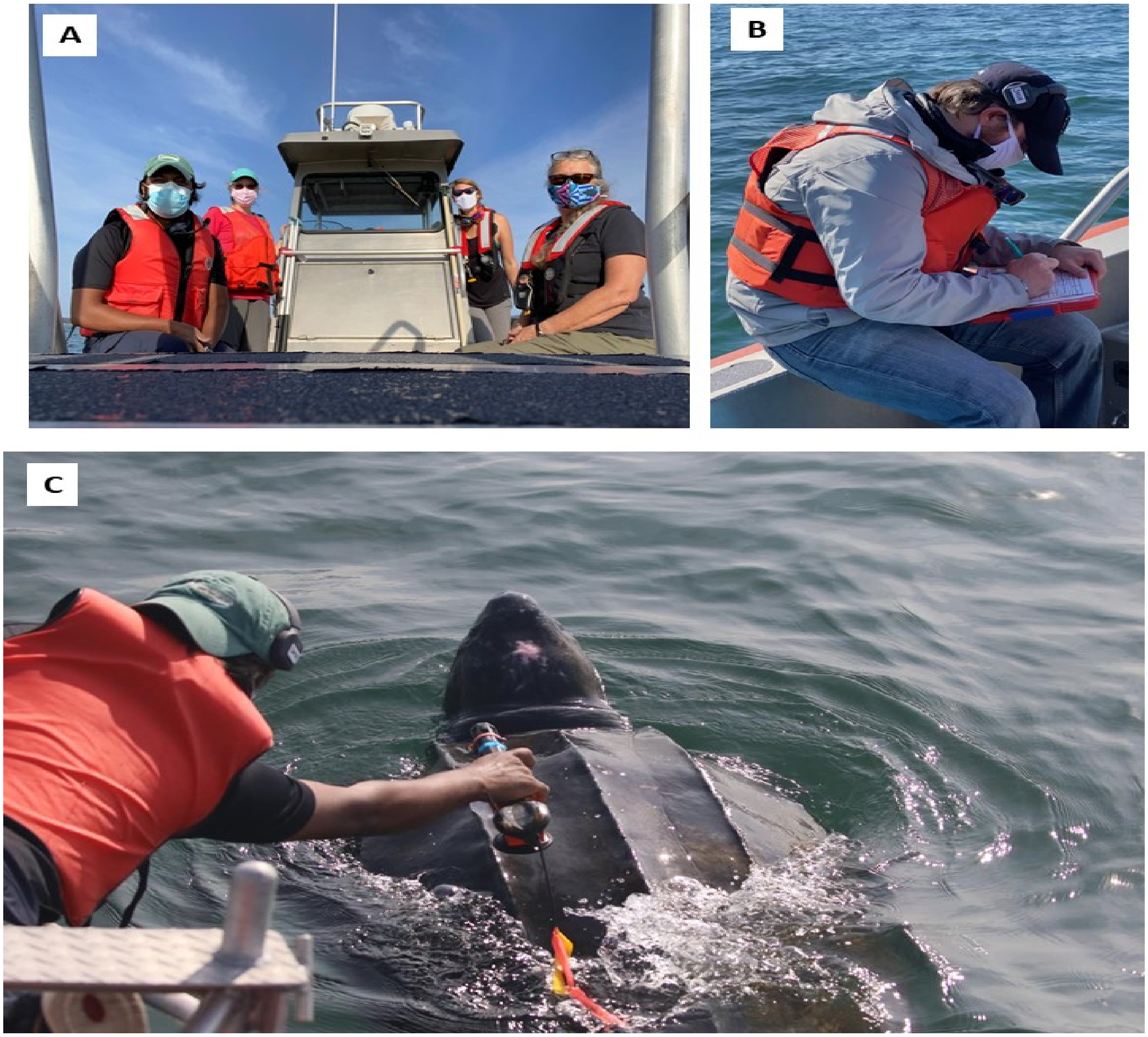

Figure 3-1 Leatherback turtle fieldwork in the fall of 2020
(A) This shows a 4 person field crew aboard the *R/V Selkie* at the start of the sampling season. (B) This shows a data recorder using a clipboard during operations. (C) This shows a leatherback turtle about to get a suction cup tag (ESA Permit #22218).

3.3 Analytical work

3.3.1 Loggerhead sea turtles respond to a major hurricane in the Northwest Atlantic

In this study, we analyzed loggerhead sea turtle behavior in the Mid-Atlantic Bight and the environmental conditions observed from turtle-borne satellite tags in relation to Hurricane Irene. We envisioned this project as a way to address several simultaneous goals. One of our primary long-term research goals is to provide information on diving and surfacing behavior, but the mechanics of doing that accurately across more than 200 tags is complicated. Here we took a first crack at the issue by using a subset of the turtles (n = 18) and looking primarily at dive duration. A second long-term goal is to provide information on how turtles respond to perturbations, including those related to offshore energy development, so we inched closer to that goal by framing this study as an investigation of loggerhead behavior during a major ecosystem-level perturbation (Hurricane Irene) in the important Mid-Atlantic foraging grounds. The third motivation for this project was to continue to highlight the relevance and utility of oceanographic data collected by turtle-borne tags.

We analyzed the movements and dive behavior of juvenile and adult-sized loggerhead sea turtles (n = 18) that were foraging in the Middle Atlantic Bight as Hurricane Irene moved through the region. The satellite tags deployed on these turtles transmitted location data and dive behavior as well as sea surface temperature and temperature-depth profiles during this time. We observed behavioral and environmental shifts during and after the hurricane as compared to conditions before the storm. During the hurricane, most of the turtles (n = 15) moved north of their pre-storm foraging grounds. Following the storm, some turtles left their established foraging sites (n = 8) moved south by 7.3 to 135.0 km, and for the others that remained (n = 10), 12% of the observed dives were longer (0.54 to 1.11 hrs) than dives observed before the storm. The *in situ* data collected by the turtle-borne tags captured the cooling of the sea surface temperature (mean difference = 4.47°C) and the deepening of the thermocline relative to the pre-storm conditions. Some of the loggerhead behavior observed relative to a passing hurricane differed from the regular pattern of seasonal movement expected for turtles that forage in the Middle Atlantic Bight. These data documented shifts in sea turtle behavior and distribution during an ecosystem-level perturbation and the recorded *in situ* data demonstrated that loggerheads observe environmental changes to the entire water column, including during extreme weather events.

This study is relevant to AMAPPS objectives because it documents that a shift in sea turtle distribution and diving behavior can influence the availability values used in creating abundance estimates from aerial surveys, and abundance estimates that assume constant sea turtle behavior through time may appear more accurate than they are. Analysis of visual survey data collected after extreme weather events or other perturbations should consider that turtles might leave an area and/or alter their dive patterns. This study provided one example of how loggerhead behavior and distribution changed during an ecosystem perturbation, suggesting that we cannot assume consistency of turtle behavior through time.

This research was a collaboration between the Northeast Fisheries Science Center and the Coonamessett Farm Foundation. Funding for the turtle satellite-tagging project was from the Sea Scallop Research Set Aside program (NA11NMF4540024) and by a US Department of Interior, Bureau of Ocean Energy Management Inter-Agency Agreement (M10PG00075).

We published this study in Crowe et al. (2020) that included the following supplementary information:

1. Location source for tagged turtles and previously observed proportions of tagged turtles in the Mid-Atlantic Bight by month;
2. Interactive map of turtle tracks before, during, and after Hurricane Irene; and
3. Location, dive, and temperature-depth data generated from this study.

3.3.2 Projected shifts in loggerhead habitat due to climate change

We conducted this project to add to our knowledge of possible sea turtle distribution shifts associated with expected changes in oceanography due to climate change. Warming ocean temperatures are already having a measurable impact on ecological processes, and sea turtles are susceptible to climate and ecosystem changes, particularly those associated with temperature. Here we used a high-resolution global climate model, GFDL CM2.6, and a large satellite tagging dataset to project changes in the future distribution of suitable bathythermal habitat for loggerheads along the northeastern continental shelf of the United States. Between 2009 and 2018, we deployed nearly 200 satellite tags on loggerheads within the Mid-Atlantic Bight of the Northwest Atlantic continental shelf region, a seasonal foraging area for loggerheads. We used tag location data combined with depth and remotely sensed sea surface temperature to characterize the species' current thermal range in the Middle Atlantic Bight. Our preliminary results suggest that loggerhead thermal habitat and seasonal duration will likely increase in northern regions of the Northwest Atlantic shelf, as far north as the Gulf of Maine. This change in spatiotemporal range for sea turtles in a region of high anthropogenic use may prompt adjustments to the local protected species conservation measures.

This project is a collaboration between Coonamessett Farm Foundation, University of Dartmouth, Atlantic White Shark Conservancy, Northeast Fisheries Science Center Protected Species Branch, and the Geophysical Fluid Dynamics Lab. The following organizations funded this study:

- The scallop industry Sea Scallop Research Set Aside program administered by the Northeast Fisheries Science Center;
- U.S. Department of the Interior, Bureau of Ocean Energy Management through Interagency Agreement M19PG00007 with the U.S. Department of the Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center;
- National Oceanic and Atmospheric Administration Saltonstall-Kennedy Grant Program; and
- National Marine Fisheries Protected Species Toolbox Initiative.

We documented this research in Patel et al. (in review), which is currently in review at Scientific Reports. A preliminary preprint that has not undergone peer review is available through Research Square. Do not consider this preliminary manuscript as validate information because the peer review process is still ongoing.

3.3.3 Estimating the complex patterns of survey availability for a highly-mobile marine animal

We undertook this project to summarize loggerhead diving and surfacing behavior to provide the first step in developing correction factors for line-transect survey availability bias. However, the data can also be useful to the broader scientific community interested in sea turtle behavior and mitigating anthropogenic risks associated with fisheries bycatch, offshore energy development, or vessel traffic. We used data from over 200 animal-borne data loggers to characterize the diving and surfacing behavior of cryptic loggerhead turtles in the northwest Atlantic. Our data covered a large geographic area off the east coast of North America and allowed us to calculate estimates for and variations in three metrics that can be used to assess availability bias: average dive duration, average surface duration, and the proportion of time at the surface. We used a Stochastic Partial Differential Equation approach to construct spatiotemporal regression models for all 3 of the availability bias metrics. Analytic results are still in internal review. Preliminary results show overall average dive and surface durations of approximately 15 min, with turtles spending approximately half of the time at the surface. We also derived monthly prediction surfaces of the 3 metrics over a 20 km × 20 km grid to investigate the seasonal and spatial variability.

This project is a collaboration between the Northeast Fisheries Science Center, Southeast Fisheries Science Center, and the Coonamessett Farm Foundation. The lead author is Joshua Hatch, with co-authors that include Heather L Haas, Christopher Sasso, Samir H Patel, and Ronald J Smolowitz. We will submit a document to a peer-reviewed journal during 2021. Funding for part of this project came from the U.S. Department of the Interior, Bureau of Ocean Energy Management through Interagency Agreements M14PG00005, M10PG00075, and M19PG00007 with the US Department of the Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center.

4 Progress of research related to passive acoustic data: Northeast and Southeast Fisheries Science Centers

Annamaria DeAngelis[1], Danielle Cholewiak[1], Melissa Soldevilla[2]

[1] Northeast Fisheries Science Center, 166 Water Street, Woods Hole, Massachusetts 02543
[2] Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149

4.1 Abstract

The goal of the AMAPPS-related research conducted by the Northeast and Southeast Fisheries Science Center's passive acoustic groups is to collect acoustic data that complement visual-based analyses of animal occurrence and abundance, particularly for species that are difficult to detect by visual observation or in times of year and regions where we do not conduct visual surveys. In 2020, there were several ongoing primary analyses involving towed hydrophone array data and bottom-mounted recorder data collected during AMAPPS surveys. The analyses included in this chapter are:

1. expanding the knowledge of dive depths of beaked whale species;
2. integrating passive acoustic towed array data for sperm whales into abundance estimates;
3. improving automated classification methods for identifying beaked whales on bottom-mounted recorders;
4. assessing the detection of seismic surveys along the US eastern seaboard on bottom-mounted recorders;
5. describing detailed observations of True's beaked whale foraging behavior; and
6. creating publicly accessible data interfaces.

These analyses are in collaboration with scientists from San Diego State University, Scripps Institution of Oceanography, and the NOAA Science Centers.

4.2 Expanding the knowledge on the dive depths of multiple beaked whale species

In DeAngelis et al. (2017) we reported the dive depths of Cuvier's beaked whales (*Ziphius cavirostris*) and Gervais'/True's beaked whales (*Mesoplodon europaeus*/ *Mesoplodon mirus*) using a towed linear hydrophone array and the multipath arrival of surface reflected clicks. At the time of that paper, we had low beaked whale species richness in our data, and had not yet characterized True's beaked whale clicks, leading to an ambiguous classification of Gervais'/True's beaked whales. Now, upon recording True's beaked whales and characterizing their foraging clicks (DeAngelis et al. 2018), we have been able to reduce the uncertainty surrounding the species identification for beaked whale clicks in the 35 to 70 kHz range, increasing our capability to classify these clicks as either True's or Gervais' beaked whales. However, ambiguity still remains for events with few clicks, and so we still have an ambiguous category as the acoustic similarities between these two beaked whale species exists and requires further evaluation. Despite this, passive acoustic monitoring of beaked whales has been fruitful in classifying the family to a species level and can continue to be an asset and compliment to visually collected data.

We are in the process of using the methods in DeAngelis et al. (2017) to increase our understanding of North Atlantic beaked whale dive depths (Cuvier's, True's, Gervais', Sowerby's (*Mesoplodon bidens*), Blainville's (*Mesoplodon densirostris*) beaked whales). Many of which have little foraging information reported in the literature. In 2016, the Northeast and Southeast Fishery Science Centers conducted concurrent summer shipboard surveys in which we deployed similar towed hydrophone arrays from the ships. Using those data, we detected and classified the aforementioned beaked whale species and have started to manually calculate the dive depths of those detections (please refer to the AMAPPS II Final Report (Palka et al. in review) for details on the survey and analysis).

In 2020, with the collaboration of the Southwest Fisheries Science Center, we were able to convert much of the manual process of using surface reflections to estimate the dive depth of beaked whales to an automated one in R using the custom-built package PAMpal (Sakai et al. 2020), reducing 1 to 2 months of labor to 2 days. This is a significant reduction in labor and will help to provide results in a more timely and cost-effective manner. We have begun to examine the precision of this automation and so far, the results look promising (a difference of about 28 m between methods in one instance). The automated method has also resulted in more clicks passing the threshold of acceptance in the dive depth calculations (manual method n = 37, automated method n = 198 for one event). In 2021, we are looking to continue this comparison for the 38 events calculated manually and reported in the AMAPPS II Final Report (Palka et al. in review). Our goal is to make sure that we are still reporting depths with similar levels of accuracy and by increasing our sample size in the number of clicks used per event there is not a significant reduction in precision. These efforts will go towards assessing the foraging habitat of a variety of beaked whale species, and towards estimating a detection function for our towed hydrophone array per beaked whale species, which can aid in estimating the abundance of beaked whale species.

4.3 Integrating passive acoustic towed array data of sperm whales into abundance estimates

We are currently undergoing two efforts in addressing this question. One is in using the data collected in 2013 and analyzed for the AMAPPS II Final Report (Palka et al. in review). We used these data to generate the methods of incorporating passive acoustic data of sperm whales into abundance estimates derived by visually collected data. Over 2020, we continued to refine the 2013 passive acoustic input to the statistical model. The results from that work are currently in a draft manuscript and can be found in more detail in the AMAPPS II Final Report (Palka et al. in review).

We have also begun analyzing sperm whale data collected by the towed hydrophone array for the 2016 abundance survey conducted on the NOAA ship *Henry B. Bigelow* (HB1603). Please see the AMAPPS II Final Report survey chapters 5 and 6 for more survey details on this survey. Learning from the integration work done with the 2013 dataset, we are analyzing the 2016 dataset for all acoustic events containing the "usual" clicks that sperm whales emit during foraging using the acoustical software package Pamguard (v. 2.01.03, Gillespie et al. 2009). Whenever possible, we annotated the entire event and saved every click. An "event" is a proxy for an individual clicking sperm whale. In instances when there are multiple whales clicking in close spatial proximity to each other and we cannot annotate every click with confidence, we generated a capture history for the event in which the time bin is one minute starting with the first click and ending with the last click. If the starts and/or ends of events are ambiguous, an "X" is marked in the corresponding one-minute bin. A "1" is marked in a one-minute bine when the number of individual clicking whales is apparent, but attributing each click to a whale is ambiguous. A "0" is marked in a one-minute bin when no whale is clicking in that one-minute time bin. All sperm whale events were localized in two dimensions, regardless if they contained ambiguity in bearings over instances in time using the Pamguard's Target Motion Analysis Module's 2D simplex optimization algorithm. At the time of this report, we annotated all of the passive acoustic data collected from the first of three legs of the HB1603 survey, so far resulting in 66 events.

We will use these acoustic events to continue to improve abundance estimates using the integration method described in the AMAPPS II Final Report (Palka et al. in review). We are also planning to apply the method to estimate the dive depth that we used for beaked whales to the sperm whale events

(DeAngelis et al. 2017; Westell 2018). Once corrected for depth, we will use that information to look more closely at the foraging ecology of sperm whales. We will also be examining whether there are any changes in sperm whale presence and/or dive depth with the change of EK60 mode (active/passive).

4.4 Improving classification methods of beaked whales on bottom mounted recorders

From 2015 through 2019, we collected archival, bottom-mounted recorder data along the shelf break of the US eastern seaboard, in collaboration with the Scripps Institution of Oceanography. Starting in 2016, we deployed 8 high-frequency acoustic recording packages (HARPs, Wiggins and Hildebrand 2007), at about 900 m depth, in waters from Georges Bank to the Blake Spur (Figure 4-1). We programmed the HARPs to sample continuously at 200 kHz, for approximately a year at a time. The distribution of recording sites complemented data collection at 3 additional sites supported by Duke University and the US Navy (Figure 4-1). In collaboration with our partners at Scripps Institution of Oceanography, we are using the data from these sites for a number of analyses, including assessing the distribution of cetacean species.

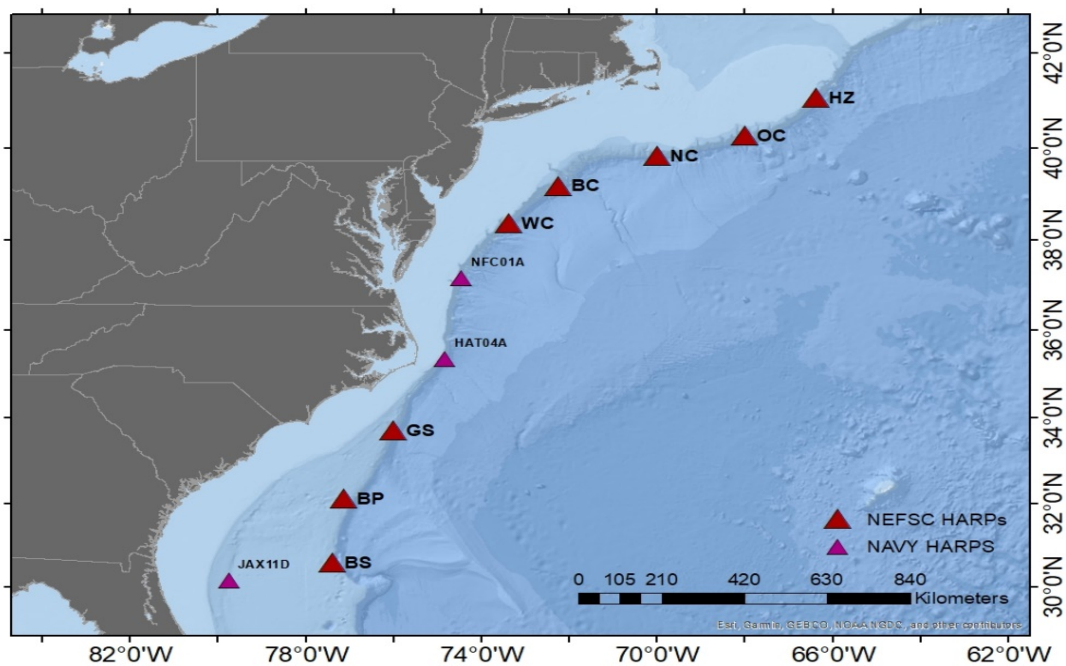

Figure 4-1 Locations of high-frequency acoustic recording packages (HARPs)
We deployed the recording packages between 2015 and 2019. The red triangles indicate sites managed by the NEFSC and SEFSC; the purple triangles indicate sites managed by Duke University and the US Navy.

One of our main analysis goals in 2020 was to improve the automated classification of beaked whale species from these datasets. We had previously automatically detected and classified beaked whale encounters to the species level using analyst-assisted software (Baumann-Pickering et al. 2013). To improve upon these results, we selected a subset of sites for detailed analyses of beaked whale encounters, to better train the automated classification algorithms. We reviewed and edited acoustic encounters using the open-software *DetEdit* (Solsona-Berga et al., 2020). This program displays a range of signal features, including time series of received levels, long-term spectral averages, inter-click intervals, as well as spectral and waveform plots of selected clicks and scatter plots of peak frequency and received levels, both computed as a peak-to-peak and a transformed received level using the root-mean-square. We reviewed individual acoustic encounters to remove false detections and provided a consistent detection threshold. As part of this work, we also evaluated the performance of an existing network-based classifier intended for delphinids to assess its accuracy. From 1 site, we quantified the discrepancies between the network-based classifier and the manually reviewed detections with *DetEdit*, implementing a comparison framework using a modified version of the Triton software (Wiggins et al. 2010) to quantify both outputs' similarities and differences. We are currently in the process of refining these network-based classifiers to improve the click-level classification for beaked whale and delphinid species across sites. In addition, in preparation for planned analyses to assess the effects of anthropogenic noise on acoustic detection rates of beaked whales, we also conducted preliminary analyses to explore the relationship between the presence of 3 beaked whale species (Cuvier's, Sowerby's and Gervais') and a suite of candidate explanatory covariates at one site (NFC in Figure 4-1). At this site, the preliminary results indicate considerable inter-annual variability, seasonality, and diel patterns between species (Figure 4-2); analyses are ongoing and we will expand the analysis to other sites once we refine the automated classification algorithms.

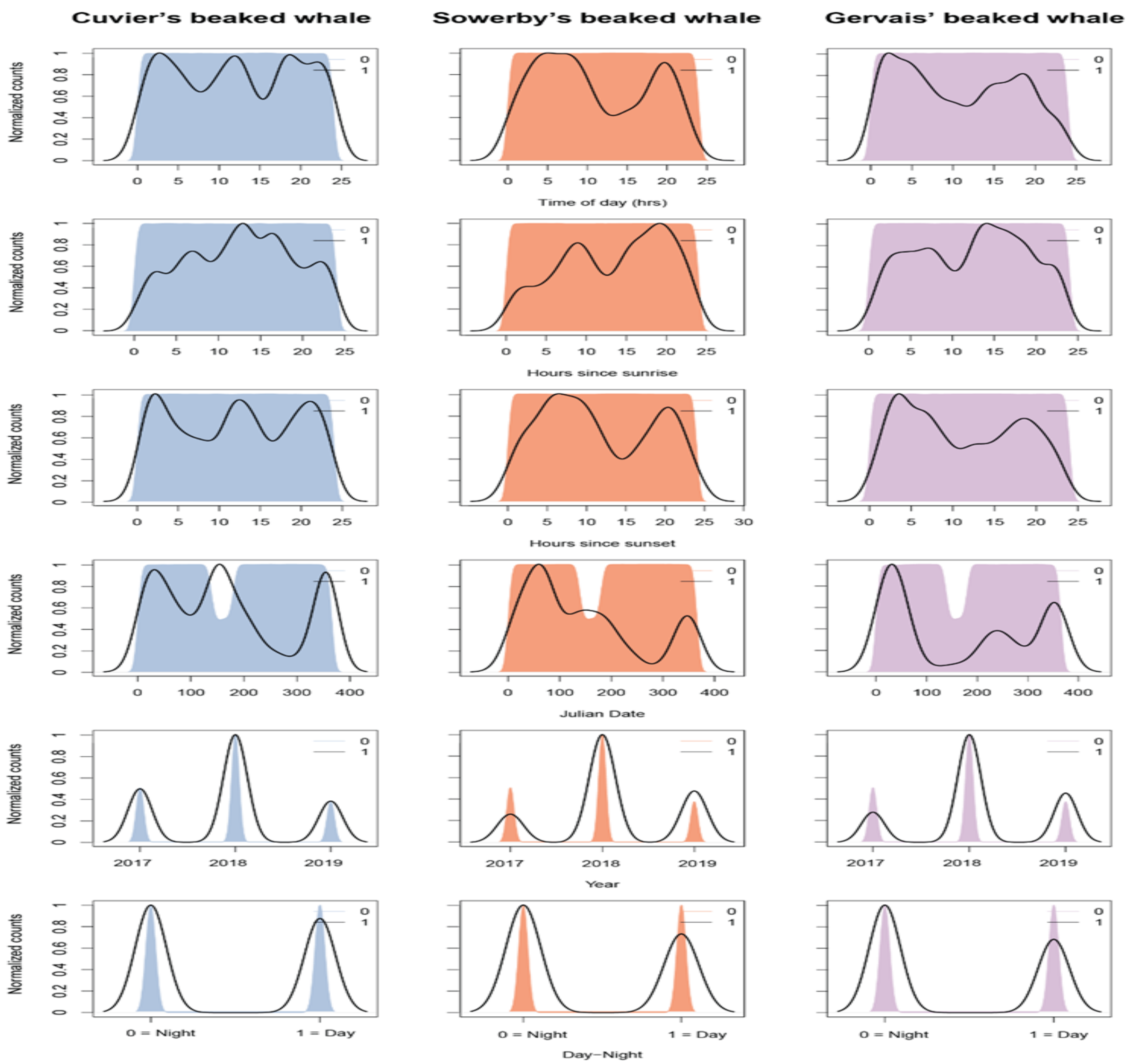

Figure 4-2 Acoustic kernel densities of presence/absence (1/0) of beaked whale click types
Counts are in 1-minutes segments for a suite of explanatory covariates. Shaded color indicates the distribution of each covariate when beaked whales were absent, and solid black line indicates the distribution when beaked whales were present. Figure courtesy of A. Solsona-Berga.

4.5 Assessing the detection of seismic surveys along the US eastern seaboard

Using the HARP data from all sites (Figure 4-1), we are also conducting analyses of the occurrence and distribution of seismic survey airgun noise detected along the US eastern seaboard for one full year, from 2016 to 2017. We are assessing the prevalence of airgun noise across sites, the range at which these signals may be detected, and contributions of this noise to the soundscape of the US shelf break ecosystem. We initially detected airgun presence using a matched filter detector, where we filtered the time series with a 10th order Butterworth bandpass filter between 25 and 200 Hz. We computed a cross-correlation on the filtered time series; when a correlation coefficient reached a threshold of $2 \cdot 10^{-6}$ above the median, a trained analyst manually verified the detections (Rafter et al. 2020).

Our preliminary analyses revealed the detection of airgun signals at all HARP sites, from Heezen Canyon to Blake Spur. In the first full month of deployment (May 2016), we detected airguns nearly the entire month (30/31 days) at Heezen, Oceanographer, Babylon and Wilmington Canyon areas. Airgun detections were consistently high across all sites north of Cape Hatteras, NC. At the sites south of Cape Hatteras, NC only some months had high activity. We are comparing the timing of these events across sites to determine putative time-delay-of-arrivals of seismic signals between pairs of sites. We are using the resultant data to estimate the direction and range of the source activities. You can find more details on this analysis in the AMAPPS II Final Report (Palka et al. in review).

4.6 Detailed observations of True's beaked whale foraging behavior

During the 2017 and 2018 NEFSC shipboard surveys, we collected dedicated focal follow data on True's beaked whales (*Mesoplodon mirus*), and deployed one digital acoustic recording tag (DTAG) for 13 hrs. The goals of these studies were to examine the foraging behavior and fine-scale habitat use of True's beaked whales and other deep-diving odontocetes, and to collect data that improve our capacity for abundance estimation of these cryptic species. In 2020, we have continued to conduct detailed analyses of these data. During the 2018 NEFSC survey, we collected focal follow data on 10 groups of True's beaked whales across 7 different days, for an estimated combined 85 sightings of these groups. We were able to track groups across 56 bounce dives and 10 foraging dives. Bounce dives lasted 13 min on average (ranging from 3 to 25 min); foraging dives lasted 40 min on average (ranging from 35 to 56 min). We detected all foraging dives on our towed hydrophone array. Once the group was on a foraging dive, we attempted to stay within visual or acoustic detection range of the group (i.e., within 1 to 2 km) and to use the acoustic information to assist the visual sightings team to relocate the group. On average, we detected echolocation clicks for 13 min during a foraging dive. In several cases, it was likely that we moved out of acoustic detection range of the group while they were still actively echolocating and foraging. Thus, it is possible that the duration of our acoustic encounter does not fully represent the actual group vocal period.

During the 2018 survey, we deployed a DTAG on a single individual in a group of about 5 animals. During 2020, we continue to analyze these data in conjunction with the visual and passive acoustic data. The tagged animal's foraging dives lasted 32.7 min on average (ranging from 26.1 to 38.9 min), and included an average of 18 min of active echolocation. Overall, the average dive time between surfacings for the tagged animal was 13.55 min (± 8.67 min). The whale was at the surface for an average of 2.95 min (± 2.43 min) between dives, and took an average of 9 breaths while in the surfacing phase. Over the duration of the tag attachment, the whale was at the surface for approximately 16% of the time (139 min / 851 min).

You can find further details of these analyses and results in the AMAPPS II Final Report (Palka et al. in review). We are finalizing these analyses and anticipate submitting a manuscript of the results during 2021.

4.7 Publicly accessible data efforts

In 2020, we pursued a collaboration with Jeff Walker to create a publicly available website to host all of our passive acoustic analyses detection output as an interactive map (Passive Acoustic Cetacean Map). The website is in a beta stage but will display the results for all AMAPPS supported analyses that we have analyzed to date as well as results from other non-AMAPPS supported analyses.

In conjunction with the website, we are also in the process of standardizing and converting all of our detections data into an Oracle database. We are in the process of creating a data model for these data and their corresponding metadata as well as creating a streamlined process of uploading the detections from Oracle onto the Passive Acoustic Cetacean Map website.

4.8 Acknowledgements

We would like to thank the people who contributed towards the data analysis (Annabel Westell, Simone Baumann-Pickering, Kait Frasier, Alba Solsona-Berga, Liam Mueller-Brennan, Jenny Trickey, Christopher Tremblay), database creation (Murali Mood, Genevieve Davis, Jessica McCordic, Sofie Van Parijs), and code optimization (Taiki Sakai) that we used when writing this report. We are also grateful to Scripps Institution of Oceanography for their ongoing contributions towards analyses with the data from the HARPs and for their insightful input.

5 Progress of research related to cetacean distribution and abundance estimation: Northeast and Southeast Fisheries Science Centers

Debra Palka[1], Samuel Chavez-Rosales[2], Douglas Sigourney[2], Elizabeth Josephson[2], Laura Aichinger Dias[3], Lance Garrison[4]

[1] Northeast Fisheries Science Center, 166 Water Street, Woods Hole, Massachusetts 02543
[2] Integrated Statistics, Inc., 16 Sumner St., Woods Hole, MA 02543
[3] Cooperative Institute for Marine and Atmospheric Studies, 4600 Rickenbacker Causeway, Miami, FL 33149
[4] Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149.

5.1 Abstract

We have 3 general goals related to this aspect of the AMAPPS project. First, is to collect broad-scale and fine-scale data over multiple years on the seasonal distribution and abundance of marine mammals (cetaceans and pinnipeds), marine turtles, and seabirds using direct aerial and shipboard surveys of coastal and offshore U.S. Atlantic Ocean waters. The second goal is to use these data to assess the population size of surveyed species at regional scales. Finally, another goal is to use these data to develop density-habitat models and associated tools to translate the survey data into seasonal, spatially explicit density estimates of the species or species guild. During fiscal year 2020, we met the first goal by conducting an aerial survey covering all US Atlantic waters during October 2019 to January 2020 that we reported on in the 2019 AMAPPS annual report. To address the other goals, during 2020, we developed seasonal, spatially explicit density estimates incorporating habitat characteristics using 2 statistical frameworks that used generalized additive models and Bayesian hierarchical models. We also estimated correction factors for availability bias for Cuvier's beaked whales (*Ziphius cavirostris*) and short-finned pilot whales (*Globicephala macrorhynchus*) using time-depth tag data provided by a project funded by the US Navy and Duke University. For several species, we estimated rates of change in abundance between 1992 and 2016 using multivariate autoregressive state-space models. We also further developed a novel method to integrate visual and passive acoustic line transect data to estimate abundance accounting for availability bias for sperm whales. We briefly summarize these projects in this chapter and provide more details in the AMAPPS II final report (Palka et al. in review).

5.2 Fieldwork

During 13 October 2019 to 25 January 2020, we completed the NEFSC and SEFSC two aerial line transect abundance surveys covering Atlantic waters from Florida to Nova Scotia, from the coastline to shelf break at about the 2,000 m depth contour. During 13 October to 24 November 2019, the NEFSC surveyed waters north of New Jersey and during 7 December 2020 to 25 January 2020, the SEFSC surveyed waters south of New Jersey. In total, the two planes completed about 20,080 km of on-effort track lines. The observers detected about 962 groups of cetaceans consisting of 4,841 individuals from 24 species or species groups and about 1,000 groups consisting of about 1,300 individual sea turtles from 5 species or species groups. See the 2019 AMAPPS annual report (NEFSC and SEFSC 2020) for more details.

5.3 Analytical work

5.3.1 Spatial density modeling using the generalized additive model framework

In 2020, we finalized the density habitat modeling for 18 cetacean species or species guilds using the two-step generalize additive model framework. This involved first estimating the density of animals in each grid cell and 8-day timeframe using mark-recapture distance sampling to account for perception bias. Then we multiplied this density estimate by a species-survey platform-specific correction factor to account for availability bias. We then modeled these spatiotemporal stratified bias corrected density estimates by habitat covariates to result in average seasonal spatially explicit maps of density and its associated abundance and confidence intervals. We documented the methodology and results in the AMAPPS II final report (Palka et al. in review). We found that since 2014 several species appear to have shifted within US waters and even to outside of US waters, particularly during the summer months. This resulting in large interannual variability when focusing on any particular portion of US waters, such as the BOEM wind-energy areas. The species with the most dramatic shifts included sei whales (*Balaenoptera borealis*), long-finned pilot whales (*Globicephala melas*), common dolphins (*Delphinus delphis*), and harbor porpoises (*Phocoena phocoena*). Other species with less dramatic shifts included humpback whales (*Megaptera novaeangliae*), fin whales (*Balaenoptera physalus*), Atlantic white sided dolphins (*Lagenorhynchus acutus*), and common bottlenose dolphins (*Tursiops truncatus*).

5.3.2 Spatial density modeling using the Bayesian hierarchical framework

In 2020, our work on Bayesian hierarchical density surface models focused on extending the model framework described in Sigourney at al. (2020) to other species of large whales. We re-ran the same models from the generalized additive model framework (Palka et al. in review) in the Bayesian framework. We explored different distributions, specifically a negative binomial distribution and using interaction terms in the Bayesian hierarchical density surface model framework. We also have started to explore fitting models with the R package Nimble that has the potential to speed up computation time significantly. We provide more details on the method and results for minke whales in the AMAPPS II final report (Palka et al. in review). During 2020, in addition to minke whales, we applied the model to sperm whales, fin whales, sei whales, humpback whales, and pilot whales. We are currently assessing the results and determining if further analysis of these species is required. Future work will focus on incorporating hierarchical methods for distance sampling, applying Bayesian methods for model selection and investigating different methods for modelling group size in a Bayesian hierarchical density surface model framework.

5.3.3 Integrating visual and passive acoustic data

During 2020, we worked on integrating passive acoustic data with visual line-transect data focusing on revising the code and running simulations to test the methods that integrate the two streams of data. We also included more data from the towed array that we integrated into the analysis. We focused on finalizing an alternative method that could accommodate situations where only a subset on acoustic array detection could be fully annotated and analyzed. We presented our method to colleagues at the Southeast Fisheries Science Center in August 2020, and we presented the methods and preliminary results at the annual meeting of DenMod (a working group focusing on density modeling techniques that is funded by the US Navy) in November 2020. Finally, we finished writing a draft of a manuscript that describes the method and provides results from both simulation testing and a case study with sperm whale data collected in 2013 from the AMAPPS shipboard cruises conducted by the NEFSC. We provided a copy of a draft manuscript to the members of the DenMod working group to review and we have scheduled a meeting in February 2021 for the DenMod members to review the manuscript and provide feedback on how to improve the method. Our near term goal is to finalize a draft manuscript and submit to a journal for peer review this spring 2021. More information on the passive acoustic aspects is in section 4.3 of this document and more information on the method and recent progress is in the AMAPPS II final report (Palka et al. in review).

5.3.4 Trend analyses

During 2020, we started investigating the use of multivariate autoregressive state-space models to estimate abundance trends during 1992 to 2016 for cetacean species that inhabit the waters of the US Atlantic and the Canadian Gulf of Maine and Scotian shelf (the AMAPPS study area). Estimating trends and understanding the interannual variability of the distribution and abundance of cetaceans are important because they enable managers to effectively develop management measures and to understand the potential effects of human-induced interactions with these species.

This statistical technique accounts for inter-annual variability by incorporating process and observation errors, and incorporating biotic and abiotic environmental covariates that could influence the abundance trends. This project is a work in progress. Preliminary analyses of trends of harbor porpoises and common dolphins are in the AMAPPS II final report (Palka et al. in review). Since then we have also investigated humpback whales and Risso's dolphins. This investigation has shown shifts in the summer distribution and abundance of most of these species, where the shift are correlated to environmental covariates. The Atlantic Scientific Review group will review this statistical technique in February 2021. In 2021, we plan to include the abundance estimates from the upcoming summer 2021 abundance survey, extend the trends analysis to as many species as the data support, and then submit a journal article to a peer-reviewed journal.

5.3.5 Availability bias of cetaceans

During 2020, Dr. Andrew Read from Duke University kindly shared additional DTAG dive time data from 52 short-finned pilot whales (*Globicephala macrorhynchus*) and 2 Cuvier's beaked whales (*Ziphius cavirostris*) that resulted from a US Navy funded project. The data were analyzed to measure the time spent above and below the surface using the same methods used previously (described in Palka et al. 2017). This information is then used to estimate a correction factor for availability bias that results from fast flying aerial line transect abundance surveys.

Detailed description of the methods and results are in the AMAPPS II final report (Palka et al. in review). In brief, both species demonstrated the typical pattern of a series of shallow dives interspersed with deeper dives, where the maximum depths of a dive varied with and between individual whales. The availability bias correction factors derived from the Atlantic Cuvier's beaked whale data from this analysis (aerial = 0.154; shipboard = 0.698) were surprisingly similar to the correction factors derived from Cuvier's beaked whale data that were tagged in Southern California (aerial = 0.142; shipboard = 0.764). The new Atlantic short-finned pilot whale correction factors were also similar to the Atlantic short-finned pilot whale factors from Palka et al. 2017 (aerial = 0.653); although 20 of the 52 tags used in the current analysis were the same animals used in the Palka et al. (2017) analyses. Thus, more than doubling the sample size with animals from different years from the same general region, did not change the average dive patterns.

5.4 Database development and data archiving

During 2020, we updated and improved the NEFSC Oracle database that contains all of the AMAPPS abundance sightings and effort data, along with associated habitat covariates. In addition, we developed scripts that produced the figures and tables in the Appendix I of the AMAPPS II final report (Palka et al.

in review), that documents the results of the seasonal density-habitat models for each species or species guild.

5.5 Acknowledgements

We would like to acknowledge all of the many scientific observers, NOAA pilots, and NOAA ships' crewmembers who have spent hours on or over the Atlantic Ocean. Without their dedication, we could not have collected some much high quality data. We would like to thank Dr. Andrew Read (from Duke University) and his fellow researchers who kindly provided us the DTAG data from the Cuvier's beaked whales and short-finned pilot whales that they tagged in waters off North Carolina. We would like to thank Dr. Kevin Friedlander (from the Northeast Fisheries Science Center) who shared the zooplankton and bottom temperature data used in trend analyses. In addition, we would like to thank Kim Hyde (from the Northeast Fisheries Science Center) who was instrumental on providing many of the environmental covariates used in the density-habitat models.

6 Progress on ecosystem research: Northeast Fisheries Science Center

Elisabeth Broughton[1], Michael Jech[1], Harvey Walsh[2], Chris Orphanides[2]

[1] Northeast Fisheries Science Center, 166 Water Street, Woods Hole, Massachusetts 02543
[2] Northeast Fisheries Science Center, 28 Tarzwell Drive, Narragansett, RI, 02882

6.1 Abstract

We continue to gain insight into what influences the patterns of distribution and density of protected species (marine mammals, sea turtles, and sea birds) by understanding and documenting the physical and biological characteristics that are associated with them. Such insight could potentially allow the discrimination between changes in cetacean populations that are due to natural environmental variability versus anthropogenic impacts. In addition, such insights can improve population assessments by incorporating ecosystem aspects into single or multiple species population assessments. These research goals relate to a couple of the AMAPPS objectives that we address in this chapter. One such goal is to identify currently used viable technologies and explore alternative platforms and technologies to improve population assessment studies, if necessary. Another goal is to assess the population size of surveyed species at regional scales; and develop models and associated tools to translate these survey data into seasonal, spatially explicit density estimates incorporating habitat characteristics.

Oceanographic and plankton data collections were limited for the NEFSC in 2020 due to Covid-19 cancellations of most research cruises this year. However, we made good progress on analyses of previously collected data. In this section, we highlight the progress made during 2020 in several ongoing projects that used AMAPPS data sets. We upgraded the Video Plankton Recorder (VPR) cameras and data processing programs and standardized the VPR image data for inclusion in geographic plankton distributions. We processed the data collected from the bongo nets, active acoustic echosounder, and midwater trawls that we collected on AMAPPS and other cruises. We continued studies that compared the VPR data to the active acoustic data, compared the VPR image generated length frequencies to measured length frequencies from bongo net plankton sampled contemporaneously, and we compared the active acoustic data to the midwater trawl data. These comparisons are useful when interpreting the relationships between marine mammal densities and potential prey densities. One such relationship was the updated analysis of incorporating prey density information as a covariate in marine mammal density spatial habitat models.

6.2 Video plankton recorder

Orphanides et al. (2019) utilized the data from VPR hauls made on the 2018 R/V *Endeavor* cruise, EN1801, to compare from the same image, the ctenophore (*Mertensia ovum*) area measurements generated by a program called Visual Plankton that uses pixel brightness to area measurements calculated using length and width when measured by hand. The process of matching the hand-measured regions of interest to the Visual Plankton processed regions of interest revealed that Visual Plankton program only processed regions of interest smaller than 300K. Consequently, in 2020 we re-wrote the Visual Plankton sub-programs affecting processing size to take advantage of the capabilities of newer computers to process images up to 1500K in size. We have now reprocessed all VPR haul data conducted during the AMAPPS cruises. Comparisons of plankton densities generated by the old and rewritten programs indicated that the older version of Visual Plankton had accurate density calculations for smaller size categories like copepods, hydromedusa, and pteropods; however, the older version under-estimated the density calculations of larger size categories such as salps, ctenophores, shrimp, and euphausiids. For comparison, we grouped plankton species into larger taxonomic categories and calculated the mean density for each haul from the HB1303 cruise using the old and re-written versions of Visual Plankton (Figure 6-1). The gelatinous category included ctenophores, hydromedusa, and salps and the crustacea category includes shrimp, amphipods, and euphausiids.

The VPR captures plankton images as the plankton passes the camera lens when they are in all orientations, movement positions, and even partially out of the frame (Figure 6-2). When using image-derived data for comparison studies we must account for the orientation. Currently, we assign a count of 1 to images with multiple zooplankters of a single species. This will negative affect the plankton densities calculations, particularly in high-density situations such as benthic swarming, phytoplankton blooms or spawning events.

We generated 3 sets of length frequencies for the mysid images from a 2002 survey on the R/V *Gloria Michelle* (GM2002) that focused on sampling right whale prey fields (Figure 6-3). VPR image data used to generate plankton densities for modeling, prey fields, and geographical distributions can utilize all images taken. Data used for comparisons to acoustic data, which also sees plankton in all orientations, may be able to use all images or it may be more accurate to include only images that depict the full animal. Data used to compare automated length frequencies to net sampled plankton measurements should include only regions of interest of plankton imaged in the same orientations used to make the hand measurements. The Visual Plankton program uses pixel brightness to define a whole region of interest, so species with strong variations in brightness may not be accurately measured. This is easily noticeable in species like ctenophores and hydromedusa where the ctens (also called comb plates) and organs are bright, while the gelatinous areas between the organs are dark. It also occurs with some frequency in shrimplike species, including mysids, where the carapace and tail fan tend to be brighter than the abdominal segments.

The large VPR image data sets made possible by the AMAPPS cruises have highlighted our limitations in data processing. Even with computer advancements and programming upgrades to include larger images, we are at the upper limits of the math-based matrix analysis Visual Plankton image identification programs that we have been using. We applied for and received a grant from the NOAA High Performance Computing and Communications program to upgrade the VPR cameras to color (Figure 6-4) and to begin to adapt the Video and Image Analytics for a Marine Environment (VIAME) software for regions of interest identification. VIAME is an open-source system for analysis of underwater video and imagery for fisheries stock assessment developed by Kitware, in cooperation with NOAA's Automated Image Analysis Strategic Initiative. Leveraging the capabilities of Machine Learning presents an opportunity to improve the speed, accuracy, and cost of plankton image identification. Improving the data analytics associated with plankton image data; especially analytics, data transfer, querying, curating, and sharing will make fine scale plankton data available for distribution, modeling, and other studies. The project is using VPR data collected during the AMAPPS cruises to evaluate VIAME as a tool to increase the quality and speed up the availability of plankton data by improving processing speed, accuracy of automated identification, accuracy of measurements, and sharing of completed data. We have started by using images from GM2002 to prototype and document the adaptation of VIAME machine learning to identify regions of interest in VPR images.

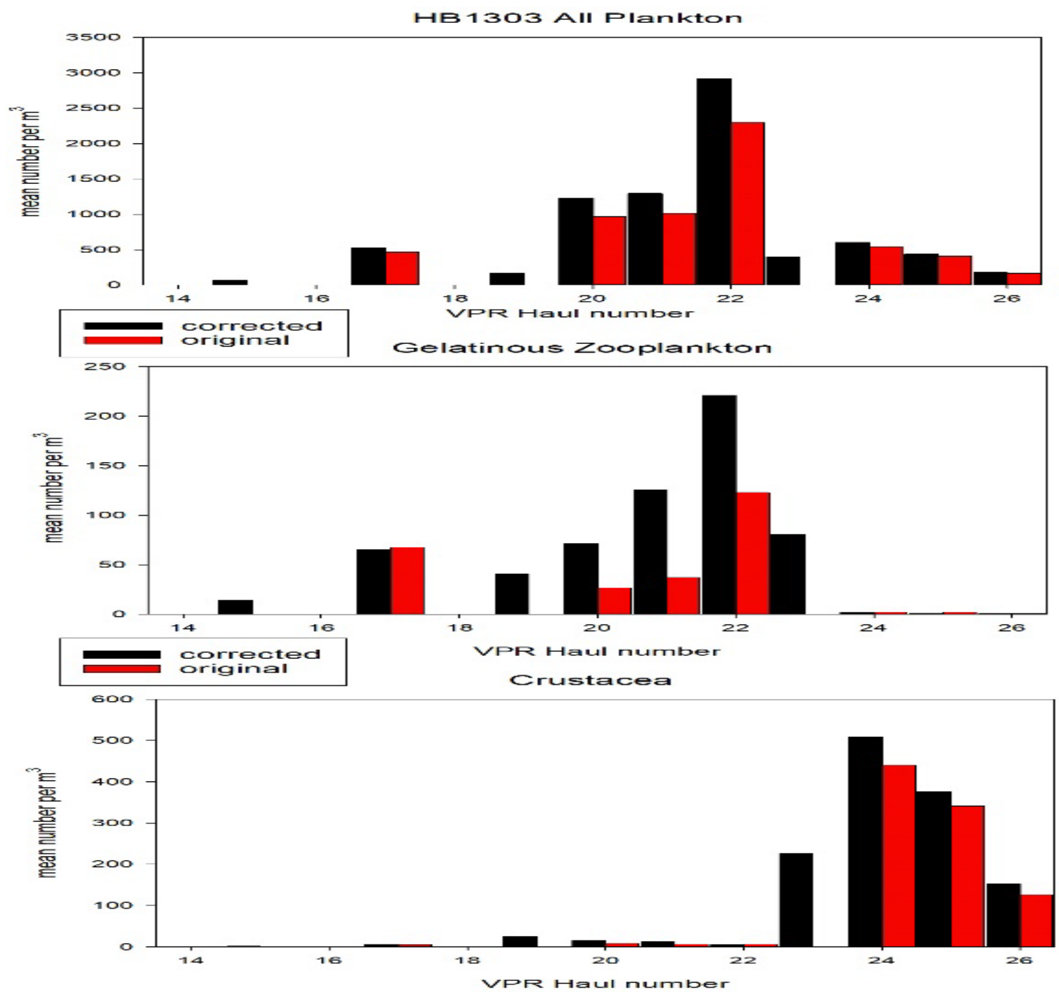

Figure 6-1 Comparisons of plankton densities per VPR haul
We collected these data on the 2013 AMAPPS survey on the NOAA ship *Henry B. Bigelow*. Densities depicted are of all plankton species (top), the Gelatinous category (middle panel), and Crustacea category (bottom panel).

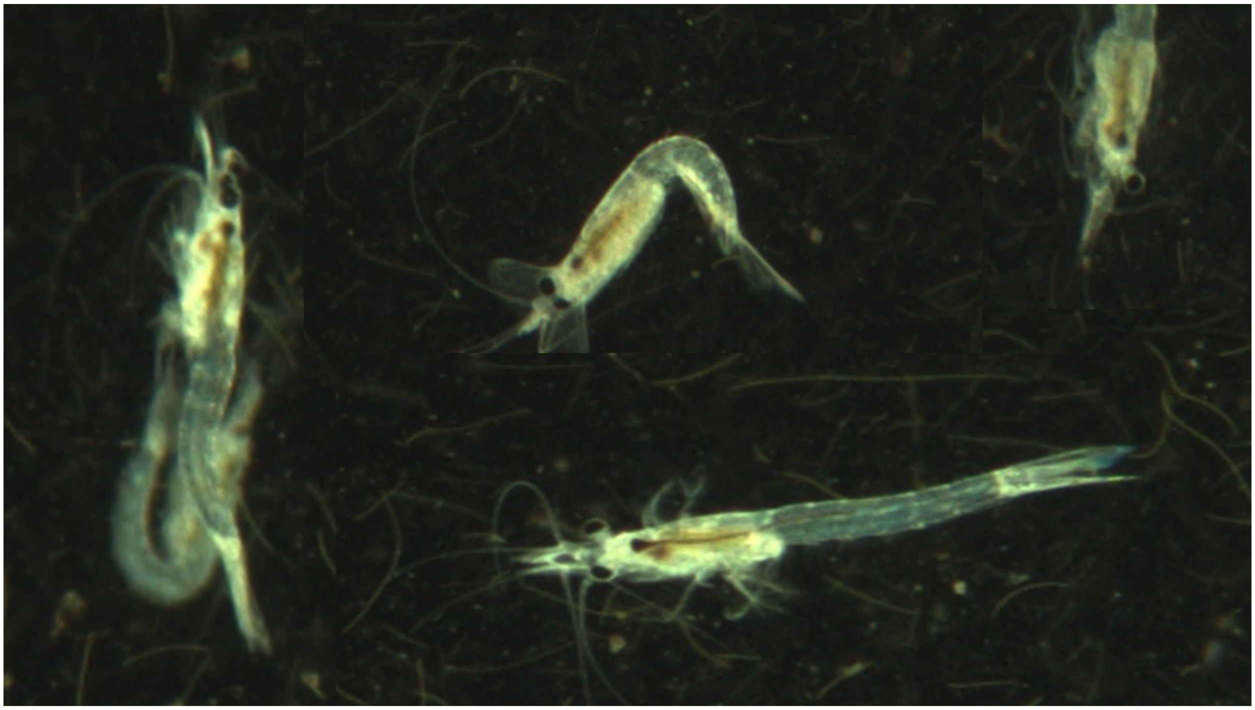

Figure 6-2 VPR images of mysids in multiple orientations
We collected these images during a 2002 survey on the R/V *Gloria Michelle* (GM2002).

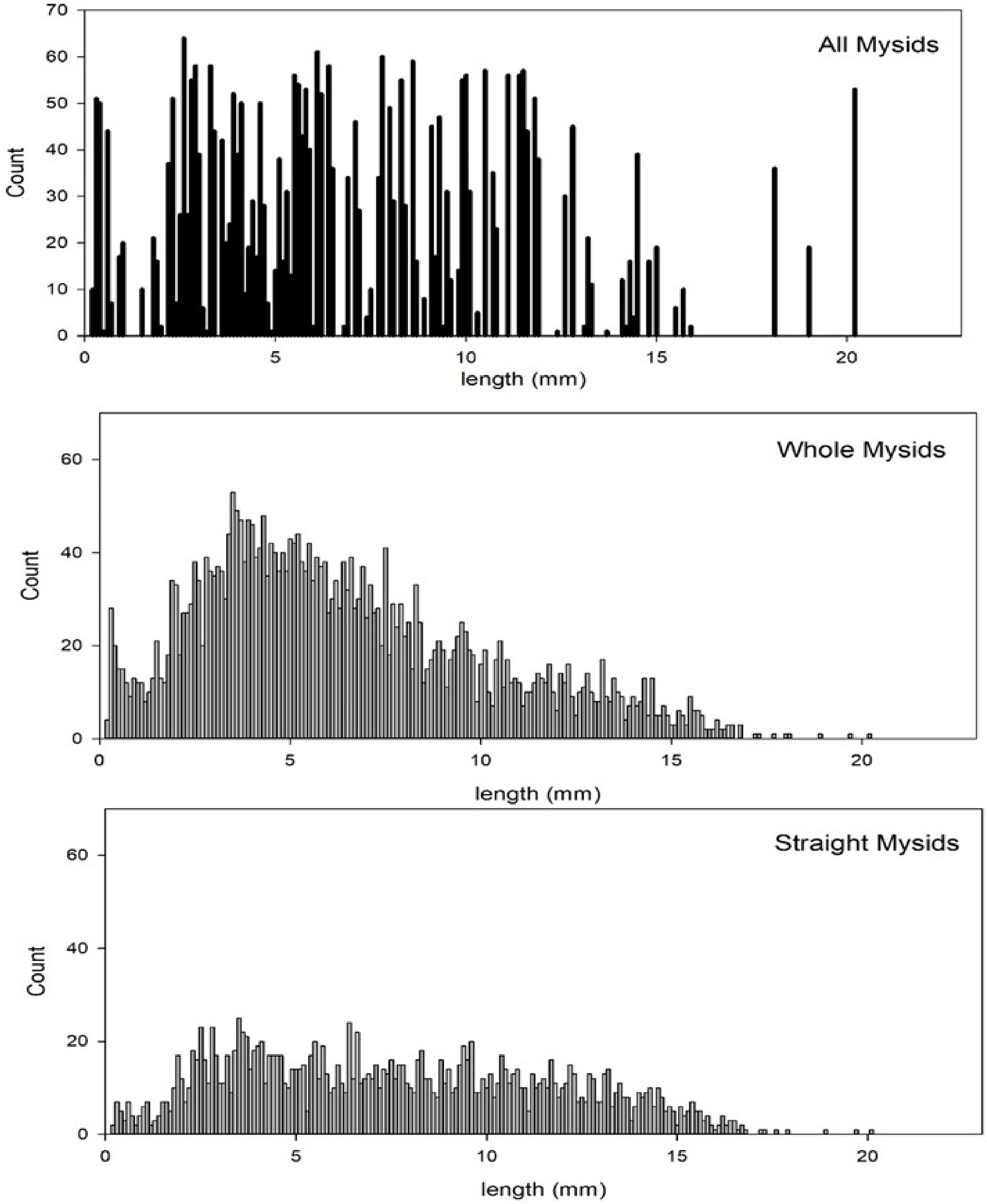

Figure 6-3 Length frequencies of mysids generated by Visual Plankton
These data were from VPR haul 02 on the GM2002 cruise. The three length frequencies show all mysid images (top), images depicting only a whole mysid (middle), and images only of mysids in a straight position with a side view orientation (bottom).

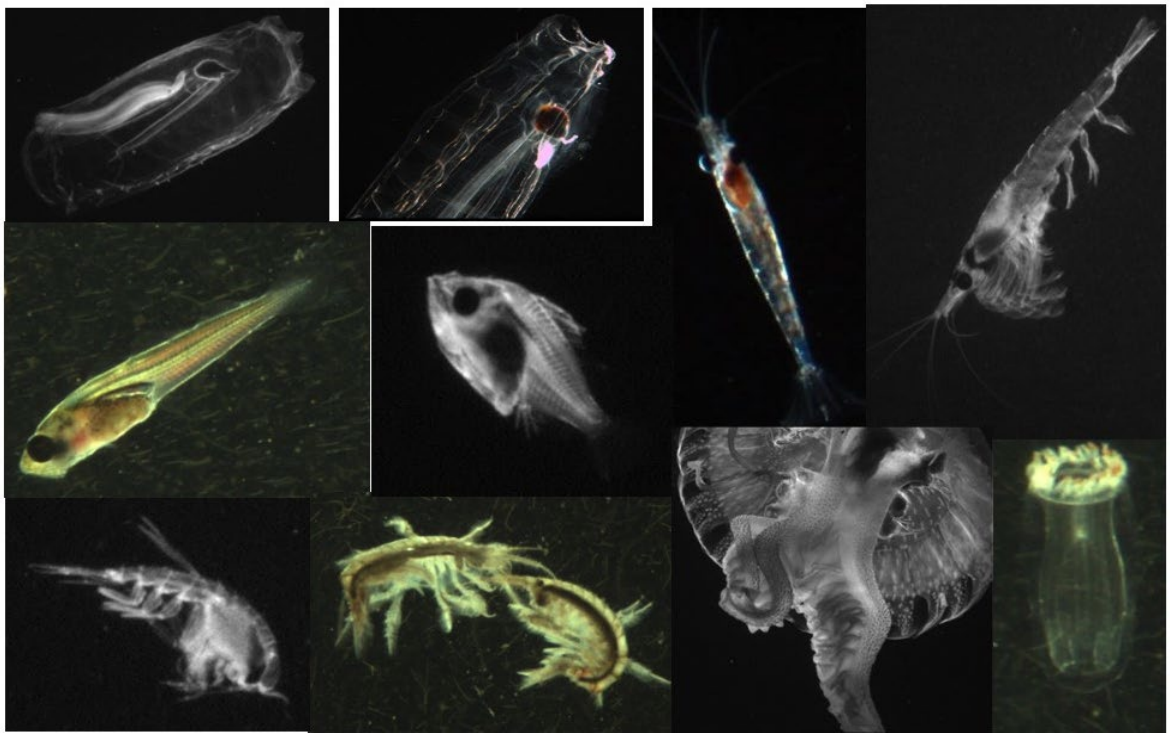

Figure 6-4 Pairs of VPR images taken from the black-and-white and new color cameras.
Depicted clockwise from the top left: *Salpa aspera*, euphasiids, medusa, amphipod, and larval fish.

6.3 Prey sampling near feeding North Atlantic right whales in southern New England

We conducted two short zooplankton and oceanographic sampling trips during the winter of 2020 when whales, including the North Atlantic right whale (*Eubalaena glacialis*) were feeding near Nantucket Shoals in Southern New England. AMAPPS did not fund the collection of the data but did partially fund the analyses of the data. We conducted plankton sampling on the R/V *Gloria Michelle* using the NEFSC's Ecosystem Monitoring (EcoMon) program gear and protocols. In addition, we incorporated a VPR and echosounder to fully characterize the oceanography and prey field. We made 9 bongo tows and 6 VPR tows on 24 to 25 February 2020 and 12 March 2020. As part of the ongoing U.S.-Poland Joint Fishery Ecology Studies Project, the Morski Instytut Rybacki (a Polish national fisheries organization) processed the net samples using current NEFSC plankton protocols.

From the bongo net collections, *Calanus finmarchicus* and balanidae (a barnacle) larvae were the most abundant zooplankton collected (Figure 6-5). The juvenile copepodite stage C3 and C4 were the most abundant stage of *Calanus finmarchicus* (Figure 6-6). We are currently aligning the net collections with the VPR and acoustic echosounder backscatter data to examine vertical distribution patterns of the different taxa.

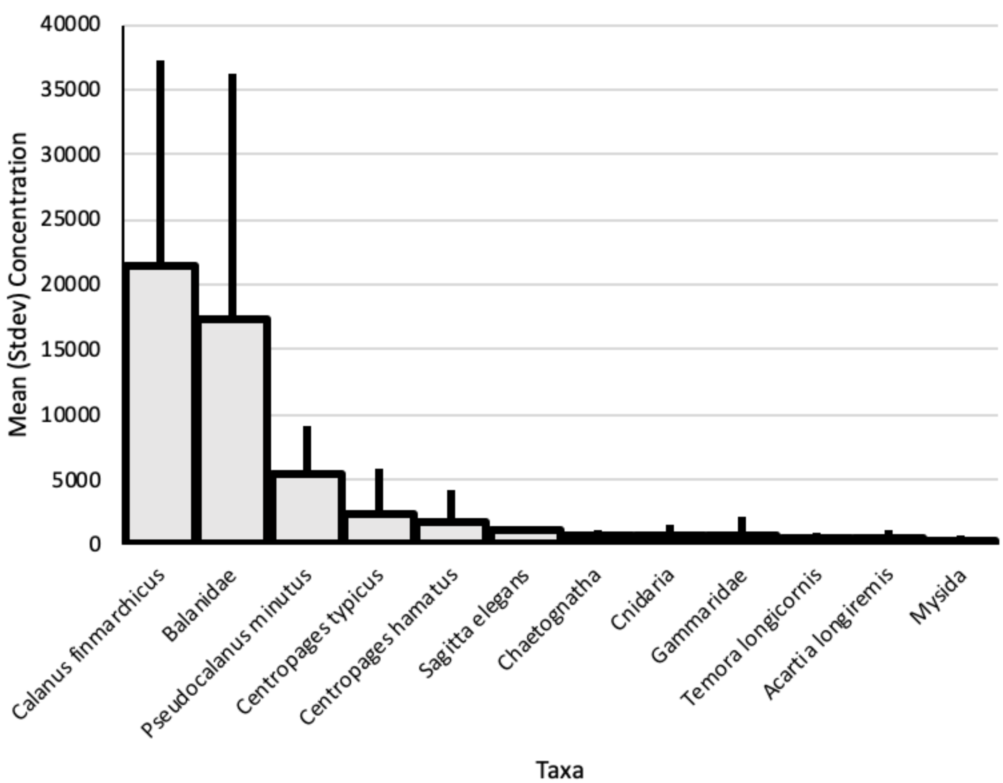

Figure 6-5 Mean concentration (individuals per 100m^3) of most abundant zooplankton taxa
We collected the samples from bongo tows near Nantucket Shoals in the winter of 2020. Bars represent the mean. The line represents the standard deviation.

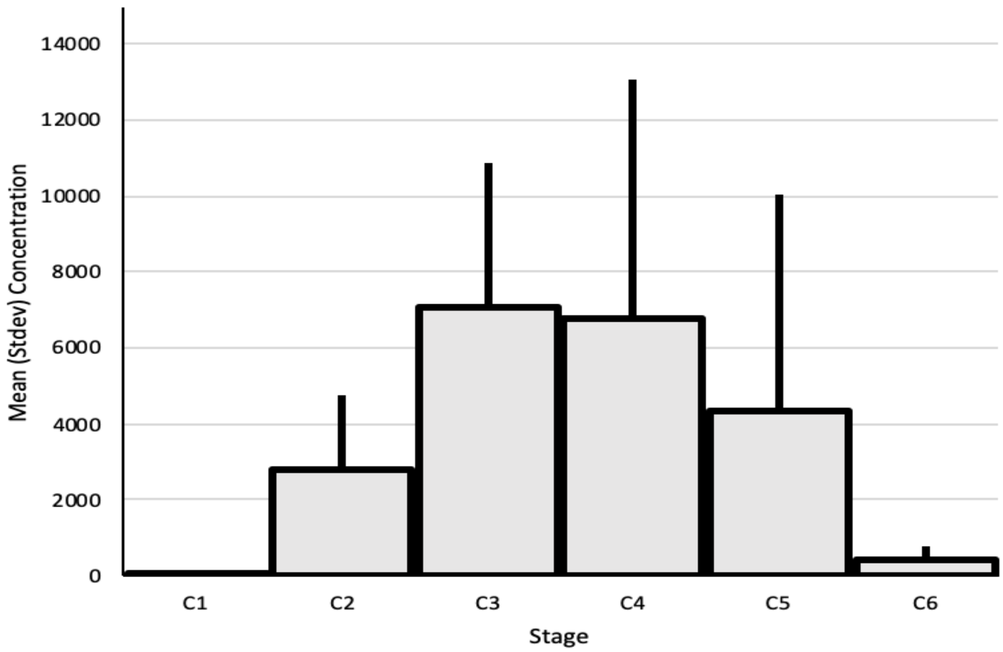

Figure 6-6 Mean concentrations of juvenile and adult stages of *Calanus finmarchicus*
Juvenile are the C1 to C5 copepodite stage, adult is the C6 stage. We collected the samples from bongo tows near Nantucket Shoals in the winter of 2020. Bars represent the mean concentration (individuals per 100 m^3). The line represents the standard deviation.

6.4 Active acoustic data

In 2020, we collated and processed active acoustic echosounder data collected during AMAPPS cruises in 2014, 2015, and 2016. Processing of the active acoustic data required cleaning the data of noise (e.g., background, transient, and impulse noise), eliminating echoes from the seabed and the CTD (conductivity, temperature, and depth) sensor deployments, and scrutinizing the data for other inconsistencies and erroneous echoes (Figure 6-7). Processing steps and routines have been developed and implemented in Echoview.

6.5 Including prey density covariates in marine mammal spatial distribution models

The existing habitat covariates used in the marine mammal species spatial distribution models (section 5.3.1 and 5.3.2 in this report), while proven useful, act as proxies for water-column characteristics that directly influence marine mammal distribution and abundance. In this study, we examined spatial organism structure within the water column as it related to marine mammal distribution as a means of improving species distribution models. We used 5 active acoustic echosounding frequencies to examine potential prey distribution in the water column and related that to marine mammal distribution with generalized additive models. During 2020, we processed two more years of echosounding data (2011 and 2016 surveys) and added that to the 2013 data that we had used for a proof of concept pilot study. In addition, we added several other metrics of water column structure to those used in the pilot study and are now in the process of updating the marine mammal density function to align with previous abundance estimate studies. We began the process of merging these data with marine mammal sightings data and plan to model these data during 2021 and submit the resulting findings as a manuscript to a peer-reviewed journal. Additional details are in the AMAPPS II Final Report (Palka et al. in review).

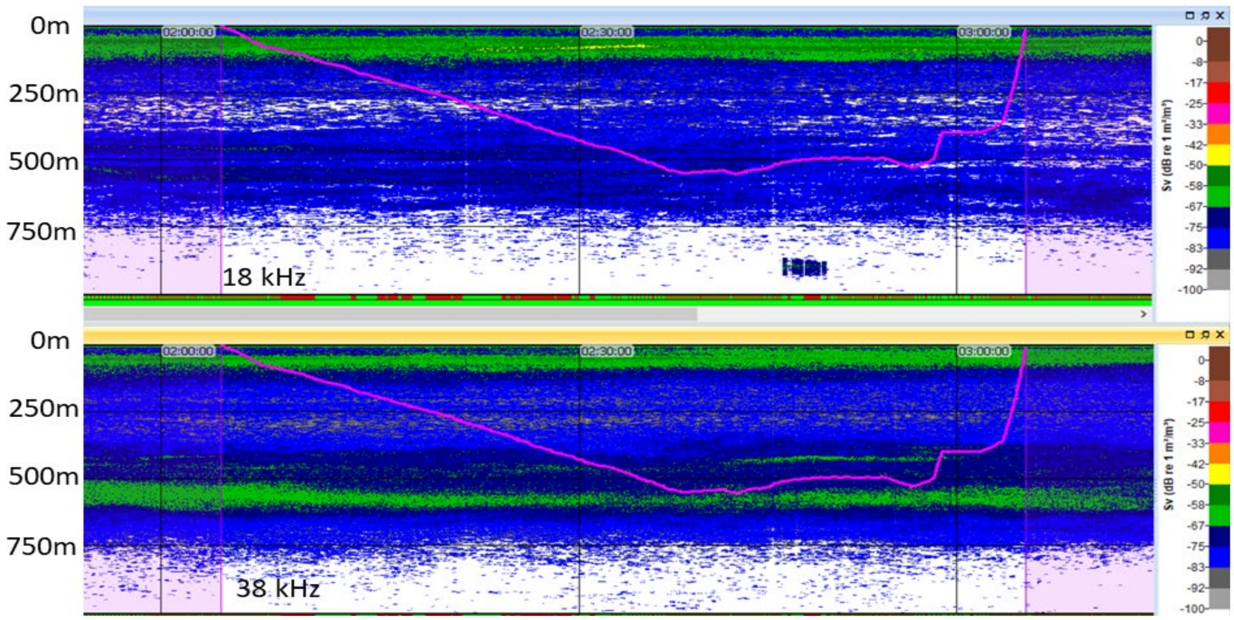

Figure 6-7 18-kHz (top panel) and 38-kHz (lower panel) echograms
These echograms are from the shipboard Simrad EK60 scientific echosounders with the trawl profile (pink line) overlaid on the echograms. These data have been "cleaned" for background, transient, and impulse noise. The data were collected 20 July 2016 from 0200 to 0300 GMT. We targeted the trawl to sample the scattering layer in the 38-kHz echogram.

6.6 Midwater trawl data

During 2020, we collated and processed catch and mensuration data for midwater trawl hauls conducted during AMAPPS cruises in 2014, 2015, and 2016. Catch data included individuals identified to the lowest taxonomic level possible, taxa weights (i.e., total weight of all individuals per taxon), and fork lengths of all individuals per taxon (or a subsample of up to about 100 individuals if the number of individuals was greater than about 100). As part of two other projects focusing on the mesopelagic community (Deep-See and Ocean Twilight Zone), catches from midwater trawl hauls conducted in 2018 and 2019 were subsampled and individuals were genetically identified. We compared these genetic identifications to taxa identification from AMAPPS trawl catches to see if there were any systematic biases in identification. We found that visual taxonomic identification was consistent for all taxa, with the possible exception of two myctophid species, *Benthosema glaciale* and *Hygophum hygomii*, which could have been confused for some tows. We have identified these tows and recommend that the family, Myctophidae, as the lowest taxon for these.

6.7 Integrating active acoustic and trawl data

One goal of collecting trawl data in conjunction with acoustic data is to match the species identified in the trawl with the acoustic scattering features. To do that, we need to isolate the acoustic data that the trawl actually sampled, i.e., be able to overlay the trawl path on the acoustic data. Integrating the trawl paths with the acoustic data required developing regressions between the wire out (length of trawl warp/cable that connects the trawl to the ship) and trawl depth (e.g., headrope depth). We needed this to estimate the distance from the ship to the trawl, while monitoring the trawl depth, and use those to calculate the distance and depth behind the ship where the trawl sampled. The scopes (the length of trawl warp needed to fish the net at a specified depth) were fairly consistent among trawl hauls (e.g., Figure 6-8), but there was some depth dependence of scope and maximum depth of the trawl path (Figure 6-9) where shallower trawl hauls had greater variability in scope.

We converted the setback (distance and depth behind the ship) to depth and time using vessel speed to overlay the trawl paths on the recording of the acoustic data (Figure 6-7). This allows us to isolate the acoustic data sampled by the trawl and then analyze acoustic scattering patterns (e.g., multifrequency relationships) and volume backscatter as a proxy of organism density.

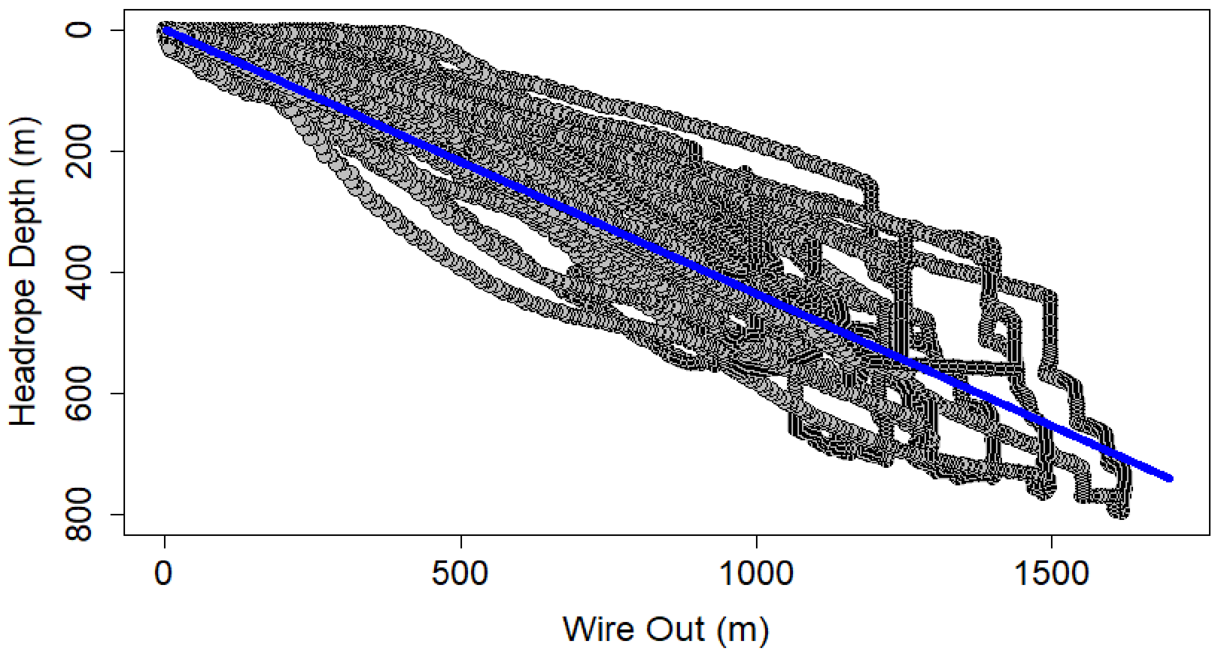

Figure 6-8 Headrope depth as a function of wire out
The wire out information was from all midwater trawl tows during the 2016 NOAA ship *Henry B. Bigelow* (HB1603) AMAPPS cruise. The regression is Headrope Depth = 0.435·Wire Out+0 m (R^2 = 0.957), or in terms of scope the regression is Wire Out = 2.2·Headrope Depth + 0 m (R^2 = 0.957).

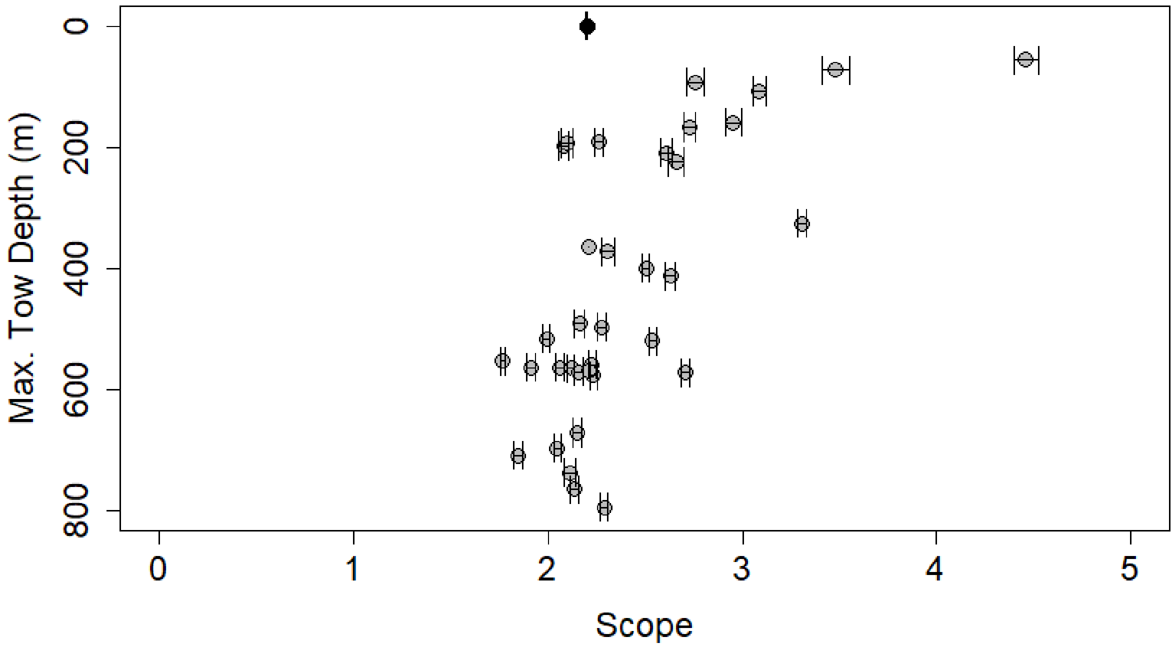

Figure 6-9 Scope as a function of the maximum depth of each midwater trawl haul (gray symbol)
We defined scope as the wire out needed to fish the net at a specific depth, where depth · scope = wire out. Data are from the 2016 NOAA ship *Henry B. Bigelow* (HB1603) AMAPPS cruise. The solid symbol is the mean scope arbitrarily displayed at 0 m, and the error bars are 95% confidence intervals.

7 References

Baumann-Pickering S, McDonald MA, Simonis AE, Solsona Berga A, Merkens K, Oleson EM, Roch M, Wiggins S, Rankin S, Yack TM, Hildebrand J. 2013. Species-specific beaked whale echolocation signals. J. Acoust. Soc. Am. 134: 2293-2301.

Crowe LM, Hatch JM, Patel SH, Smolowitz RJ, Haas HL. 2020. Riders on the storm: loggerhead sea turtles detect and respond to a major hurricane in the Northwest Atlantic Ocean. Movement Ecology 8(1): 1-13.

DeAngelis AI, Valtierra R, Van Parijs SM, Cholewiak D. 2017. Using multipath reflections to obtain dive depths of beaked whales from a towed hydrophone array. J. Acoust. Soc. Am. 142: 1078-1087.

DeAngelis AI, Stanistreet JE, Baumann-Pickering S, Cholewiak DM. 2018. A description of echolocation clicks recorded in the presence of True's beaked whale (*Mesoplodon mirus*). J. Acoust. Soc. Am. 144: 2691-700.

Gillespie D, Mellinger DK, Gordon J, McLaren D, Redmond P, McHugh R., Trinder P, Deng XY, Thode A. 2009. PAMGUARD: Semiautomated, open source software for real-time acoustic detection and localization of cetaceans. J. Acous. Soc. Am. 125: 2547-2547.

Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC). 2020. 2019 Annual report of a comprehensive assessment of marine mammal, marine turtle, and seabird abundance and spatial distribution in US waters of the Western North Atlantic Ocean – AMAPPS II. NEFSC Technical Report.

Orphanides CD. 2019. Relating marine mammal distribution to prey abundance. Ph.D. Dissertation. Graduate School of Oceanography, University of Rhode Island, Kingston, RI.

Palka D, Aichinger Dias L, Broughton E, Chavez-Rosales S, Cholewiak D, Davis G, DeAngelis A, Garrison L, Haas H, Hatch J, Hyde K, Jech M, Josephson E, Mueller-Brennan L, Orphanides C, Pegg N, Sasso C, Sigourney D, Soldevilla M, Walsh H. in review. Atlantic Marine Assessment Program for Protected Species: FY15 – FY19. Washington DC: US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 20xx-xxx. xx p.

Patel SH. Winton MV, Hatch JM, Haas HL, Saba VS, Fay G, Smolowitz RJ. (in review). Projected shifts in loggerhead sea turtle habitat in the Northwest Atlantic Ocean due to climate change. Scientific Reports.

Rafter MA, Rice AC, Thayre BJ, O'Neill E, Wiggins SM, Frasier KE, Baumann-Pickering S, Hildebrand JA, Cholewiak DM, Van Parijs SM. 2020. Passive Acoustic Monitoring for Marine Mammals in the Western Atlantic June 2017–June 2018. Final Report. Marine Physical Laboratory Technical Memorandum 640 June 2020.

Sakai T, Barlow J, Griffiths E, Oswald M, Baumann-Pickering S, Oswald J. 2020. Package "PAMpal".

Sigourney DB, Chavez-Rosales S, Conn PB, Garrison L, Josephson E, Palka D. 2020. Developing and assessing a density surface model in a Bayesian hierarchical framework with a focus on uncertainty: insights from simulations and an application to fin whales (*Balaenoptera physalus*). PeerJ, DOI 10.7717/peerj.8226.

Solsona-Berga A, Frasier KE, Baumann-Pickering S, Wiggins SM, Hildebrand JA. 2020. DetEdit: A graphical user interface for annotating and editing events detected in long-term acoustic monitoring data. (D. Schneidman-Duhovny, Ed.) PLOS Comput. Biol. 16: e1007598.

Westell A. 2018. Exploring sperm whale depredation of long lines in the Norwegian Sea using passive 3D tracking. MSc Thesis, The University of St Andrews, 1-99.

Wiggins SM, Hildebrand JA. 2007. High-frequency Acoustic Recording Package (HARP) for broadband, long-term marine mammal monitoring. *In* 2007 Symposium on Underwater Technology and Workshop on Scientific Use of Submarine Cables and Related Technologies (pp. 551-557). IEEE.

Wiggins SM, Roch MA, Hildebrand JA. 2010. TRITON software package: Analyzing large passive acoustic monitoring data sets using MATLAB. J. Acoust. Soc. Am. 128: 2.

White TP, Veit R. 2020. Spatial ecology of long-tailed ducks and white-winged scoters wintering on Nantucket Shoals. Ecosphere 11-1.