Marine Species Monitoring for the U.S. Navy's Atlantic Fleet Training and Testing (AFTT) 2020 Annual Report



Prepared For and Submitted To

National Marine Fisheries Service

Office of Protected Resources

Prepared by

Department of the Navy

In accordance with 50 Code of Federal Regulations § 216.245(e)

August 2021

Citation for this report is as follows:

DoN (Department of the Navy). 2021. *Marine Species Monitoring for the U.S. Navy's Atlantic Fleet Training and Testing (AFTT)—2020 Annual Report*. U.S. Fleet Forces Command, Norfolk, Virginia. August 2021.

List of Preparers (Main Document):

Mark P. Cotter (HDR Inc.) and Joel T. Bell (Naval Facilities Engineering Systems Command Atlantic).

List of Contributors (Technical Reports) (Alphabetized by organization):

Amy Engelhaupt (Amy Engelhaupt Consulting); Robert DiGiovanni Jr. (Atlantic Marine Conservation Society); Daniel L. Webster (Bridger Consulting Group); Andrew D. DiMatteo (CheloniData, L.L.C.); Louise M. Burt, Catriona Harris, Charles G.M. Paxton, and Len Thomas (Centre for Research into Ecological & Environmental Modelling); Heather J. Foley, Douglas P. Nowacek, Nicola Quick, Andrew J. Read, Jeanne Shearer, Rob Schick, Zachary T. Swaim, and Danielle M. Waples (Duke University); Gwen Lockhart (Environment and Ecology Inc.); Kristen Ampela, Jessica Aschettino, Dan Engelhaupt, and Michael Richlen (HDR Inc.); Brittany A. Bartlett, Jackie Bort Thornton, Cara Hotckin, Danielle V. Jones, and Deanna R. Rees (Naval Facilities Engineering Command Atlantic); John Joseph and Tetyana Margolina (Naval Postgraduate School); Monica DeAngelis (Naval Undersea Warfare Command); Will Cioffi, Brandon Southall (Southall Environmental Associates); Susan E. Parks (Syracuse University); Susan G. Barco, Sarah D. Mallette, and Sarah A. Rose (Virginia Aquarium Foundation).

Cover photo credits:

From left to right:

Cuvier's beaked whale (*Ziphius cavirostris*) with the Duke University Marine Laboratory R/V *Shearwater* off Cape Hatteras. Photographed by Joseph Fader, taken under National Marine Fisheries Service Scientific Research Permit No. 19903, issued to Andy Read, Duke University.

A common bottlenose dolphin (*Tursiops truncatus*) handles a silver-phase American eel *(Anguilla rostrata*) at the mouth of Chesapeake Bay. Photographed by Mark Cotter, taken under National Marine Fisheries Service Scientific Research Permit No. 21482, issued to Dan Engelhaupt, HDR.

A Kemp's ridley turtle (*Lepidochelys kempii*) is released with a satellite tag from the oceanfront in Virginia Beach, Virginia. The turtle was hooked by a recreational angler, recovered by the Virginia Aquarium Stranding Response Program, and tagged under a U.S. Fish and Wildlife Service permit to the National Marine Fisheries Service covering sea turtle stranding response activities in the Greater Atlantic Region. Photographed by Virginia Aquarium staff.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AFTT	Atlantic Fleet Training and Testing
AMR	Adaptive Management Review
App	application
BRS	behavioral response study
CBBT	Chesapeake Bay Bridge-Tunnel
CEE	controlled exposure experiment
CNO	Chief of Naval Operations
COMPASS	Cetacean Observation and Marine Protected Animal Survey Software
DMP	Data Management Plan
DTAG	digital acoustic tag
EIMS	Environmental Information Management System
ESA	Endangered Species Act
GOM	Gulf of Mexico
GPS	Global Positioning System
HARP	High-frequency Acoustic Recording Package
ICMP	Integrated Comprehensive Monitoring Program
JAX	Jacksonville (Florida)
kHz	kilohertz
km	kilometer(s)
LOA	Letter of Authorization
m	meter(s)
MAHWC	Mid-Atlantic Humpback Whale Photo-ID Catalog
MFAS	mid-frequency active sonar
MINEX	Mine-neutralization Exercise
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MSM	Marine Species Monitoring
N45	Energy and Environmental Readiness Division
NAHWC	North Atlantic Humpback Whale Catalog
NARW	North Atlantic right whale
NMFS	National Marine Fisheries Services
NMSDD	Navy Marine Species Density Database
NOAA	National Oceanic and Atmospheric Administration
OBIS-SEAMAP	Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations
ONR	Office of Naval Research
OPAREA	Operating Area
PAM	passive acoustic monitoring
photo-ID	photo-identification
QC	quality control
RL	received level
R/V	research vessel
SE	standard error
SPOT	Smart Position and Temperature
U.S.	United States
USWTR	Undersea Warfare Training Range
VACAPES	Virginia Capes
VAQF	Virginia Aquarium Foundation

SECTION 1 – INTRODUCTION

This report contains a summary of marine species monitoring activities funded by the United States (U.S.) Navy within the Atlantic Fleet Training and Testing (AFTT) study area during 2020. The U.S. Navy supports monitoring for a variety of protected marine species in compliance with the Letters of Authorization (NMFS 2018a, 2019) and Biological Opinions (NMFS 2018b) issued under the Marine Mammal Protection Act of 1972 (MMPA) and the Endangered Species Act of 1973 (ESA) for training and testing in the AFTT study area. Section 2 provides a summary of progress and results for each project with additional details available in individual technical reports linked directly from the corresponding sub-section. In addition to monitoring projects supporting environmental compliance for AFTT, U.S. Fleet Forces Command also sponsored acoustic monitoring associated with an Ice Exercise (ICEX) in the Beaufort Sea north of Alaska in March 2020. This monitoring is in compliance with an Incidental harassment Authorization for ICEX issued in January 2020 (85 FR 6518, pages 6518-6527).

1.1 Background

The AFTT study area includes at-sea components of the range complexes and testing ranges in the western North Atlantic Ocean and encompasses the Atlantic coast of North America and the Gulf of Mexico (GOM) (**Figure 1**). The study area covers approximately 2.6 million square nautical miles of ocean area, and includes designated U.S. Navy operating areas (OPAREAs) and special use airspace. The study area also includes several U.S. Navy testing ranges and range complexes, as well as portions of Narragansett Bay, lower Chesapeake Bay, St. Andrew Bay, and pier-side locations where sonar maintenance and testing occurs.

In order to authorize the incidental taking of marine mammals under the marine mammal Protection Act, NMFS must set forth “requirements pertaining to the monitoring and reporting of such taking” (50 Code of Federal Regulations § 216.101(a)(5)(a)). A request for a Letter of Authorization must include a plan to meet the necessary monitoring and reporting requirements, while increasing the understanding, and minimizing the disturbance, of marine mammal and sea turtle populations expected to be present. While the ESA does not have a specific monitoring requirement, the Biological Opinion issued by NMFS for the AFTT study area includes terms and conditions for continued monitoring in this region.

The U.S. Navy has invested over $41 million (**Table 1**) in compliance monitoring activities in the AFTT study area since 2009. Additional information on the program is available on the U.S. Navy’s MSM program website (http://www.navymarinespeciesmonitoring.us). The website serves as an online portal for information on the background, history, and progress of the program. It also provides access to reports, documentation, and data, as well as updates on current monitoring projects and initiatives.

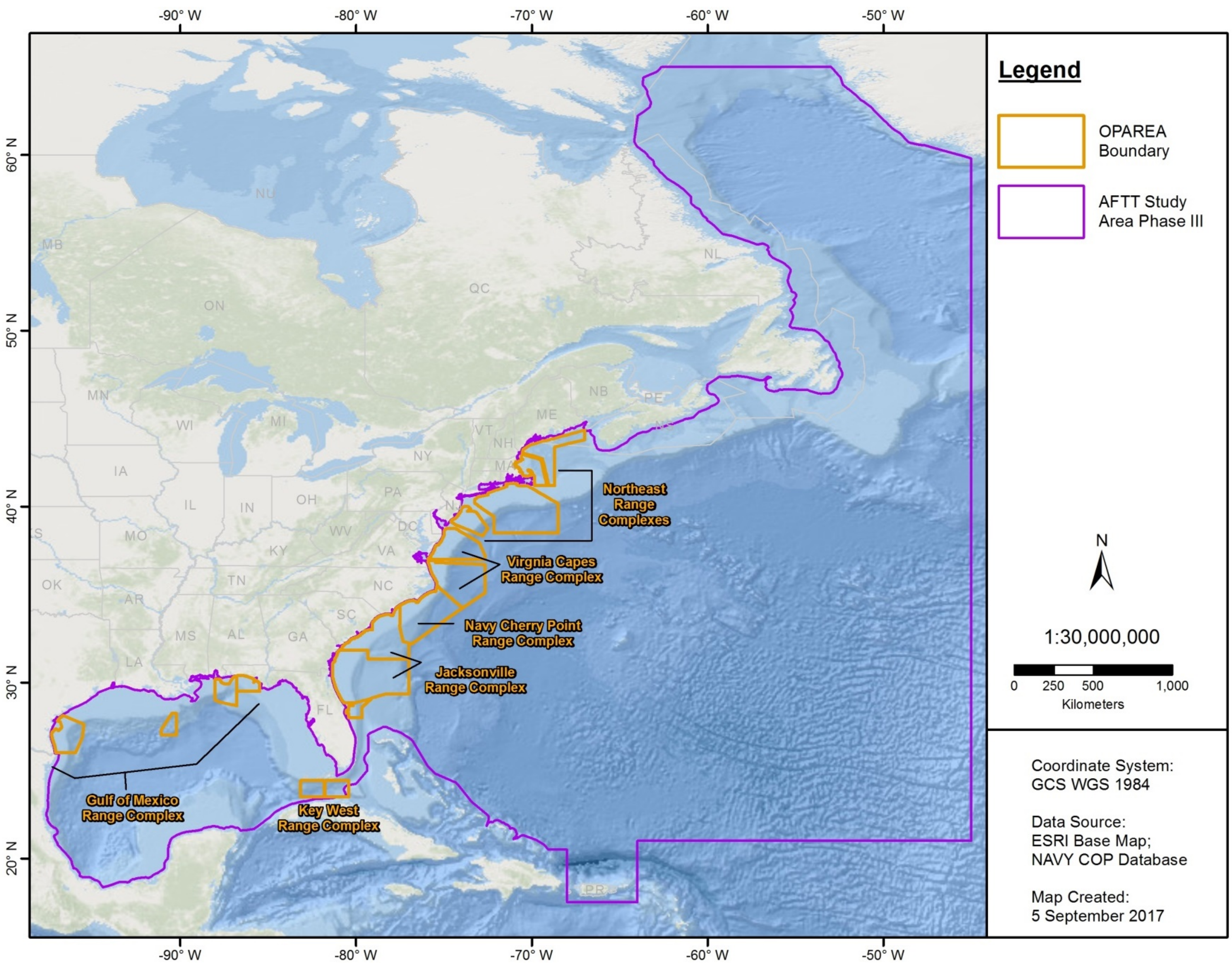

Figure 1. Atlantic Fleet Training and Testing study area.

Table 1. Annual funding for the U.S. Navy's Marine Species Monitoring Program in the AFTT study area (formerly AFAST and East Coast/Gulf of Mexico Range Complexes) during FY09–FY20.

Fiscal Year (01 Oct–30 Sept)	Funding
2009	$1,555,000
2010	$3,768,000
2011	$2,749,000
2012	$3,483,000
2013	$3,775,000
2014	$3,311,000
2015	$3,700,000
2016	$3,845,000
2017	$3,383,000
2018	$3,476,000
2019	$4,187,000
2020	$4,022,000
Total	**$41,254,000**

In addition to the compliance monitoring program for training and testing activities, the Office of Naval Research (ONR) Marine Mammals and Biology Program and the Office of the Chief of Naval Operations (CNO) Energy and Environmental Readiness Division's (N45) Living Marine Resources Program support coordinated Science & Technology, and Research & Development programs focused on understanding the effects of sound on marine mammals, including physiological, behavioral, ecological, and population-level effects (DoN 2010a). These programs currently fund several significant ongoing projects relative to potential operational impacts to marine species within some U.S. Navy range complexes. Additional information on these programs and other ocean resource-oriented initiatives can be found at the U.S. Navy's Energy, Environment, and Climate Change website.

1.2 Integrated Comprehensive Monitoring Program

The Integrated Comprehensive Monitoring Program (ICMP) provides the overarching framework for coordination of the U.S. Navy's MSM efforts (DoN 2010b) and serves as a planning tool to focus monitoring priorities pursuant to ESA and MMPA requirements and coordinate monitoring efforts across regions based on a set of common objectives. Although the ICMP does not identify specific research questions or projects, it provides a flexible, scalable, and adaptable framework within the context of adaptive-management and strategic planning. The ICMP is evaluated through the Adaptive Management Review (AMR) process to: (1) assess overall progress, (2) provide a matrix of goals and objectives, and (3) make recommendations for refinement and evolution of the monitoring program's focus and direction. This process includes an annual AMR meeting at which the U.S. Navy and NMFS jointly consider the prior-year goals, monitoring results, and related scientific advances to determine if modifications are warranted to address monitoring goals.

Using an underlying conceptual framework incorporating a progression of knowledge from occurrence to exposure/response, and ultimately consequences, the Navy developed the Strategic Planning Process (DoN 2013a) as a tool to help guide the investment of resources to most efficiently address ICMP goals. Intermediate Scientific Objectives form the basis of evaluating, prioritizing, and selecting new monitoring projects or investment topics. The Strategic Planning Process will continue to shape the future of the U.S. Navy's MSM program and serve as the basis for developing and executing new monitoring projects across the U.S. Navy's training and testing ranges (both Atlantic and Pacific).

Additional information and background on the Integrated Comprehensive Monitoring Program and Strategic Planning Process can be found on the U.S. Navy's marine species monitoring web portal.

1.3 Report Objectives

This report presents the progress, accomplishments, and results of MSM activities in the AFTT study area in 2020 and has two primary objectives:

1. Summarize findings from the U.S. Navy-funded marine mammal and sea turtle monitoring conducted in the AFTT study area during 2020, as well as analyses of monitoring data performed during this time. Detailed technical reports for these efforts are referenced throughout this report and provided as supporting documents.
2. Support the AMR process by providing an overview of monitoring initiatives, progress, and evolution of the ICMP and Strategic Planning Process for U.S. Navy marine species monitoring. These initiatives continue to shape the evolution of the U.S. Navy MSM program for 2021 and beyond, to improve our understanding of the occurrence and distribution of marine mammals and sea turtles in the AFTT study area, and their exposure and response to sonar and explosives training and testing activities.

Appendix A summarizes U.S. Navy MSM projects currently underway in the Atlantic for 2021. Additional details on these projects as well as access to data, reports, and publications can be accessed through the U.S. Navy's marine species monitoring web portal as they become available.

This page intentionally left blank.

SECTION 2 – MARINE SPECIES MONITORING ACTIVITIES

The predecessor to AFTT monitoring began in 2007 with a data collection program supporting development of an Undersea Warfare Training Range (USWTR) initially planned for Onslow Bay off the coast of North Carolina. That initial monitoring program was heavily focused on line-transect visual surveys and passive acoustic monitoring for the purpose of establishing a robust understanding of protected species distribution and occurrence. That baseline occurrence work eventually expanded to several additional study sites and formed the basis of the current monitoring program for AFTT. These long-terms study areas now primarily serve to support more recent projects involving tagging multiple species of cetaceans (**Section 2.2**), as well as behavioral response studies (**Section 2.3**).

Although monitoring for AFTT no longer has a specific focus on line-transect visual surveys, work addressing occurrence, distribution, and population and social structure continues and is threaded throughout many of the ongoing tagging and behavioral response projects as an important component of understanding the consequences to stocks and populations of exposure to training and testing activities.

2.1 Occurrence, Distribution, Population, and Social Structure

Both small vessel and shore-based monitoring in 2020 supported multi-disciplinary methods including photo-identification (photo-ID), biopsy sampling, unmanned aerial vehicle observations, and tagging. While passive acoustic monitoring was also a cornerstone of the monitoring program through much of the first decade, the focus has been shifting away from pure baseline data collection in recent years and effort directed towards species-specific studies and broader ecological analyses. A summary of accomplishments and results from visual and passive acoustic monitoring efforts for the reporting period is presented in the following subsections.

2.1.1 Visual Methods

2.1.1.1 Photo-identification Analysis off Cape Hatteras, North Carolina

As a component to supplement the Atlantic Behavioral Response Study (**Section 2.3.1**), Duke University continued photo-ID fieldwork in the Cape Hatteras study area during 2020 to confirm species, identify individuals, and conduct follow-up monitoring of satellite-tagged animals. These matching analyses build upon established photo-ID catalogs and photographs previously collected in other AFTT monitoring and study areas, including Jacksonville, Florida, and Onslow Bay, North Carolina (Waples and Read 2020). Digital photographs were obtained from seven species, with most taken of Cuvier's beaked whales (*Ziphius cavirostris*), one of the two primary focal species (along with short-finned pilot whales [*Globicephala macrorhynchus*]) of the Atlantic Behavioral Response Study (BRS). The other cetacean species that had photographs taken were sperm whale (*Physeter macrocephalus*), Atlantic spotted dolphin (*Stenella frontalis*), common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), and common bottlenose dolphin (*Tursiops truncatus*) (**Table 2**). All digital images were individually graded for photographic quality and animal distinctiveness. All images of sufficient quality and distinctiveness were then sorted by individual within a sighting and assigned temporary identifications. The best image for each individual in that sighting was selected, and these images were cropped and placed into a folder for each sighting.

Table 2. Cetacean sightings with number of photo-ID images collected for species in the Cape Hatteras study area in 2020.

Species	Common Name	Number of Sightings	Number of Photo-ID Images
D. delphis	Common dolphin	2	4
G. macrorhynchus	Short-finned pilot whale	47	2,058
P. macrocephalus	Sperm whale	1	36
S. frontalis	Atlantic spotted dolphin	3	54
T. truncatus	Bottlenose dolphin	15	37
Z. cavirostris	Cuvier's beaked whale	81	15,400
Total		**149**	**17,589**

Images of 70 newly identified animals were added to two existing photo-ID catalogs of Cuvier's beaked whales and short-finned pilot whales, and 42 new photo-ID matches (15 of Cuvier's beaked whales and 27 short-finned pilot whales) were made. To date, photo-ID catalogs for 11 species have been assembled for the Cape Hatteras area, across multiple AFTT MSM projects, with 558 individuals re-sighted across all species (**Table 3**).

Table 3. Summary of all images collected during fieldwork in the Cape Hatteras study area in 2020 showing number of new identifications, photo-ID catalog sizes, number of new re-sights, and total re-sights to date.

Species	New Images Collected	New Identifications	Catalog Size	New Re-sights	Re-sights To Date
B. physalus	0	0	1	0	0
D. delphis	4	0	46	0	1
G. macrorhynchus	2,058	51	1,311	27	463
G. griseus	1	0	46	0	6
Kogia sp.	0	0	1	0	0
M. novaeangliae	0	0	2	0	0
P. macrocephalus	36	0	20	0	1
S. clymene	0	0	3	0	0
S. frontalis	54	0	24	0	0
T. truncatus	37	0	349	0	19
Z. cavirostris	17,589	19	196	15	68

Short-finned Pilot Whales

Totals of 51 new identifications and 27 new re-sights were added to the short-finned pilot whale catalog in 2020 (**Table 3**). The current re-sight rate of short-finned pilot whales is 35 percent, up slightly from 34 percent in 2019. More than 200 short-finned pilot whales have been seen on three or more occasions and six animals have been re-sighted more than seven times. Most of the pilot whales that have been sighted the most frequently have either been satellite-tagged or biopsied.

Short-finned pilot whale individuals have been documented returning to the Cape Hatteras area over extended periods. More than 110 pilot whales have records of five or more years between their first and last sightings and 20 individuals have histories that span 10 or more years (**Table 4**). These long-term re-sights demonstrate that both male and female short-finned pilot whales exhibit strong, but perhaps intermittent, site fidelity to the Cape Hatteras area. In addition to Cape Hatteras, systematic photo-ID comparisons between other study areas (Onslow Bay, North Carolina; Jacksonville, Florida; and Norfolk Canyon, Virginia) have resulted in varying degrees of matching success. Forty matches have been made between Cape Hatteras and Norfolk Canyon, four between Cape Hatteras and Onslow Bay, and none between Cape Hatteras and Jacksonville.

Comparing photo-ID catalogs provides information about the long-distance movements of individuals within this population. One individual, "M-042," was first photographed in Hatteras in May 2007, then was subsequently matched to past images collected by NMFS researchers during a 2004 Gulf of Mexico research cruise. This whale was eventually re-sighted and matched to the Norfolk Canyon study area from images taken in January 2019, almost 15 years after the initial sighting in the Gulf of Mexico (**Figure 2**). The re-sighting of this individual also represents the longest documented geographic distance observed between all photo-ID matching efforts by Duke University to date (**Figure 3**).

Table 4. Frequency distribution of the number of years between first and last sightings of photo-identified short-finned pilot whales in the Cape Hatteras study area.

Number of Years Between First and Last Sighting	Number of Individuals
Less than 1	133
1 to 2	49
2 to 3	44
3 to 4	55
4 to 5	70
5 to 6	17
6 to 7	21
7 to 8	40
8 to 9	13
9 to 10	1
10 to 11	13
11 to 12	7
Total	**463**

Figure 2. Photographs of short-finned pilot whale individual "M-042" in the Gulf of Mexico in June 2004 (top), re-sighted in Cape Hatteras in May 2007 (middle), and re-sighted in Norfolk Canyon in January 2019 (bottom).

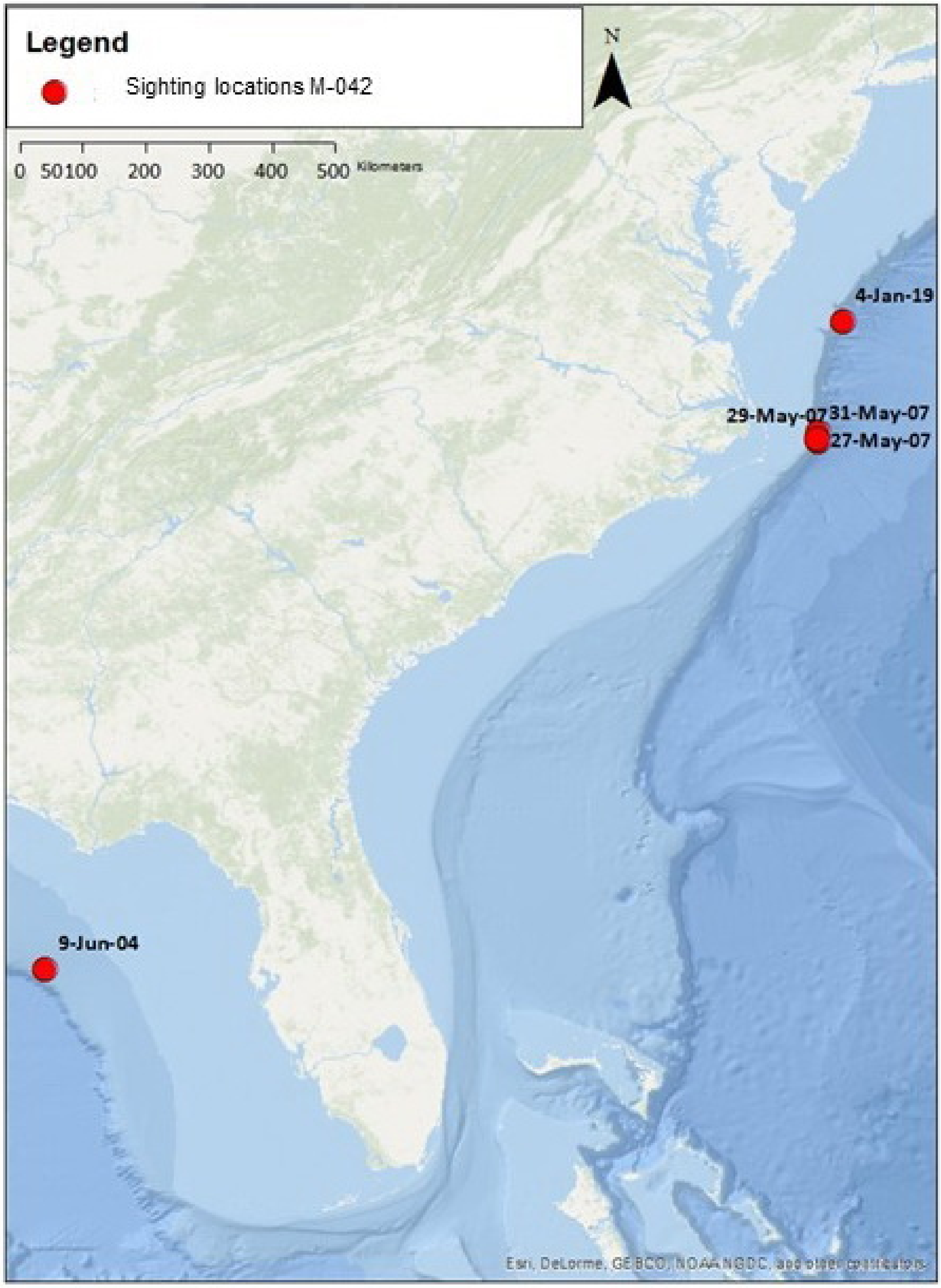

Figure 3. Sighting locations of individual "M-042" in the Gulf of Mexico (2004), off Cape Hatteras, North Carolina (May 2007), and off Virginia in the Norfolk Canyon study area (January 2019).

Cuvier's Beaked Whales

Nineteen new identifications were added to the Cuvier's beaked whale photo-ID catalog during 2020, and 15 new re-sights were made (**Table 3**). The current re-sight rate for Cuvier's beaked whales in the Cape Hatteras area is up to 35 percent, compared to re-sight rates of 30 percent in 2019 and 24 percent in 2018. To date, 37 of the 68 (54 percent) matched Cuvier's beaked whales have been seen across multiple years, and nine of those have been re-sighted more than three years apart. Fourteen Cuvier's beaked whales were tagged in 2020 as part of the BRS project, and four of those individuals were matched to the photo-ID catalog. Two of the animals tagged in 2020 were tagged in previous years during earlier field efforts (May 2016 and June 2019). Photo-ID matching of Cuvier's beaked whales has shown individual whales associating in the same groups over short time periods (days to weeks), but there is no evidence of long-term social associations in the Cape Hatteras study area.

In addition to taking photographs of the dorsal fin and body scarring, used for photo-ID, Duke researchers also attempt to obtain high-quality images of the head of each animal. These photographs are used to identify adult male Cuvier's beaked whales (with erupted teeth) to better understand the demographics of this population (**Table 5**). Animals are classified as adult males if they have erupted teeth at the tip of their lower rostrum, or extensive linear scarring, which is believed to be caused from interactions with other adult males (McSweeney et al. 2007, Falcone et al. 2009). Currently, animals are classified as adult females only if photographed with a dependent calf (an individual <50 percent of the body length of the other individual surfacing in proximity; McSweeney et al. 2007). Researchers in Hawai'i (McSweeney et al. 2007, Baird 2016) use the accumulation of cookie cutter shark (*Isistius brasiliensis*) scars to differentiate adult females from sub-adult animals, but these scars are rarely seen on Cuvier's beaked whales off Cape Hatteras. Researchers in the Mediterranean (Coomber et al. 2016) use pigmentation patterns to differentiate males and females, but these patterns may vary between regions. Whales are classified as sub-adult males if photographs show teeth just beginning to erupt from the lower jaw. There is currently no method based on Cape Hatteras photographs to classify whales as sub-adult females. Most animals in the catalog have not yet been identified to age or sex class. These include animals where there is a photograph of the head as well as the body, but the whales have no erupted teeth and minimal scarring, as well as whales with minimal scarring but no head photograph. These also include animals with moderate amounts of scarring but no photograph of their heads to confirm whether or not they are adult males. Many of these non-classified whales are likely adult or sub-adult females or sub-adult males.

Table 5. Age class and gender classification of Cuvier's beaked whales based on photographs.

Age Class	Gender	Defining Characteristics
Adult	Male	Erupted teeth, extensive linear scarring
Adult	Female	Presence of a dependent calf
Subadult	Male	Teeth beginning to erupt
Subadult	Female	None at present time
Unknown	Unknown	No photograph of head; or photograph of head but no erupted teeth/minimal scarring

Follow-up monitoring of the health of satellite-tagged animals continues to be an important focus of photo-ID efforts. Photographic re-sightings of tagged individuals exist for four species: Cuvier's beaked whale, short-finned pilot whale, Risso's dolphin, and common bottlenose dolphin. A single Risso's dolphin was re-sighted on the day after it was tagged in 2016, and a single common bottlenose dolphin was re-sighted five days after tagging in 2014. Most re-sightings have been of satellite-tagged short-finned pilot whales and Cuvier's beaked whales.

To date, 80 short-finned pilot whales have been satellite-tagged off Cape Hatteras, and 30 of these (38 percent) have been re-sighted. Most of these re-sightings occurred within the same field season but 11 (37 percent) have been re-sighted across multiple years after being tagged. Seventy-two Cuvier's beaked whales have been satellite-tagged from 2014 through 2020. Photo-ID provides a useful means to document and assess the long-term effects of tagging on individual short-finned pilot whales and Cuvier's beaked whales. In general, there are few instances of long-term damage to the dorsal fin of tagged animals and most individuals appear to be well-healed.

Duke is planning to contribute their sighting history data of Cuvier's beaked whales to a project coordinated by Erin Falcone and Greg Schorr of MarEcoTel. A proposal to support this project has been submitted to the Office of Naval Research; it is a collaborative project involving multiple scientists with the goal of comparing vital rates of Cuvier's beaked whales across distinct populations. Data will be contributed from several well-studied populations of this species around the world that experience a range of military sonar activity. Pigmentation and scarring-density metrics will be applied uniformly to all images in the participating photo-ID catalogs, and each Cuvier's beaked whale will be classified to age (calf, adult, or juvenile) and sex. Estimation of vital rates for each population will require age- and sex-linked life-history data from a large sample of individual animals, and therefore it is important to have adequate samples of photo-ID data from each region; the Hatteras photo-ID catalog is the largest in this dataset and will be an extremely important contribution to this comparative analysis.

For more information on this study, refer to the annual progress report for this project (Waples and Read 2021).

2.1.1.2 Pinniped Haul-out Surveys in Lower Chesapeake Bay and Coastal Waters of Virginia

Harbor seals (*Phoca vitulina*) and gray seals (*Halichoerus grypus atlantica*) are year-round coastal inhabitants in eastern Canada and New England and occur seasonally in the mid-Atlantic U.S. between September and May (Hayes et al. 2021). In previous years, there was some debate about the southern range extent for harbor and gray seal stocks in the Western North Atlantic. In Virginia, reports from local anglers, Chesapeake Bay Bridge Tunnel (CBBT) staff, and the Virginia Aquarium & Marine Science Center have indicated that seals have been using the CBBT rock armor or "islands" to haul out on for many years, but over the last decade, in increasing numbers. Additionally, annual pinniped stranding numbers have increased in Virginia since the early 1990s (Costidis et al. 2019).

Until 2018, National Oceanic and Atmospheric Administration (NOAA) Stock Assessment Reports indicated that the gray and harbor seal populations range from Labrador to New Jersey; with scattered sightings and strandings reported as far south as North Carolina for gray seals and Florida for harbor seals (Hayes et al. 2018). Other researchers have reported that harbor and gray seal distribution along the U.S. Atlantic coast appears to be expanding or shifting (DiGiovianni et al. 2011; Johnston et al. 2015; DiGiovianni et al. 2018). The range expansion of the harbor seal may be due to rapid growth of gray seal populations in Canada and Northeastern U.S., which could be causing the displacement of harbor seals at haul-out sites due to physical interference or competitive exclusion (Cammen et al. 2018; Pace et al. 2019; Wood et al. 2019). Within the last decade, harbor seals have been observed returning seasonally, from fall to spring, to haul-out locations in coastal Virginia, and gray seals are occasionally observed during the winter, but not on a consistent basis (Ampela et al. 2021; Jones and Rees 2020). More recently, NOAA Stock Assessment Reports indicate the southern extent for the harbor seal population range is now North Carolina. However, the geographic range for the gray seal population remains the same (Hayes et al. 2021).

In 2014, the U.S. Navy initiated a study that aims to investigate seal presence at select haul-out locations in the lower Chesapeake Bay and coastal waters of Virginia, which are important areas to Navy training and testing activities. Haul-out counts, camera traps, and photo-ID methods are being utilized in order to acquire a better understanding of the seals' seasonal occurrence, habitat use, and haul-out patterns in this area. This study will provide valuable baseline information for the future assessment of seal movement, site fidelity, and abundance in the mid-Atlantic region.

A series of systematic counts of all seal species were conducted at two different survey areas (**Figure 4**); 1) in the lower Chesapeake Bay along the CBBT, on the four "islands" (referred to as CBBT 1, CBBT 2, CBBT 3, and CBBT 4), and 2) on the southern tip of the Eastern Shore, which is comprised of about five main haul-out locations.

For the 2019/2020 field season, vessel-based counts were conducted at the CBBT (in collaboration with Virginia Department of Game and Inland Fisheries and HDR Inc.) and Eastern Shore (in collaboration with The Nature Conservancy) survey areas. Dedicated haul-out surveys started in the fall (November) and ended in the spring (April) to ensure the documentation of seal arrival and departure for the season. The aim was to conduct vessel surveys at the CBBT and Eastern Shore survey areas at least two times per month during the field season. During each survey, the number of seals hauled out and in the water was recorded with associated environmental data (e.g., air and water temperature). Photographs of seals were collected between counts for photo-ID for a mark-recapture study to estimate local population abundance, and to develop a local catalog. An experimental approach for estimating abundance was also attempted using seal count data for the 2016–2020 field seasons from the CBBT and Eastern Shore survey areas as well as satellite telemetry data on harbor seal activity in Virginia waters (Ampela et al. 2021). For the abundance estimates, a total mean seal count for the study area was produced for each season and combined with a telemetry correction factor that was based on the mean proportion of time (h) that tagged seals spent ashore (Huber et al. 2001; Thompson et al. 1997).

For the 2019/2020 season, time-lapse camera traps were utilized to provide a more complete picture of the seasonal occupancy of seals in Virginia. Multiple trail cameras were installed at seven different haul-out locations within the two different survey areas; 1) in the lower Chesapeake Bay at the CBBT islands, and 2) on the southern tip of the Eastern Shore. Each camera recorded images throughout the local seal occupancy season from November through April (Jones and Rees 2020). Images were recorded during daylight hours, at a frequency of every 15 minutes. Cameras were placed to provide maximum coverage of the known haul-out locations at the Eastern Shore survey area, and the two highest use CBBT islands, CBBT 4 and CBBT 3. The number of seals hauled out and in the water were recorded from each haul-out event, and these data will be compared to local environmental variables.

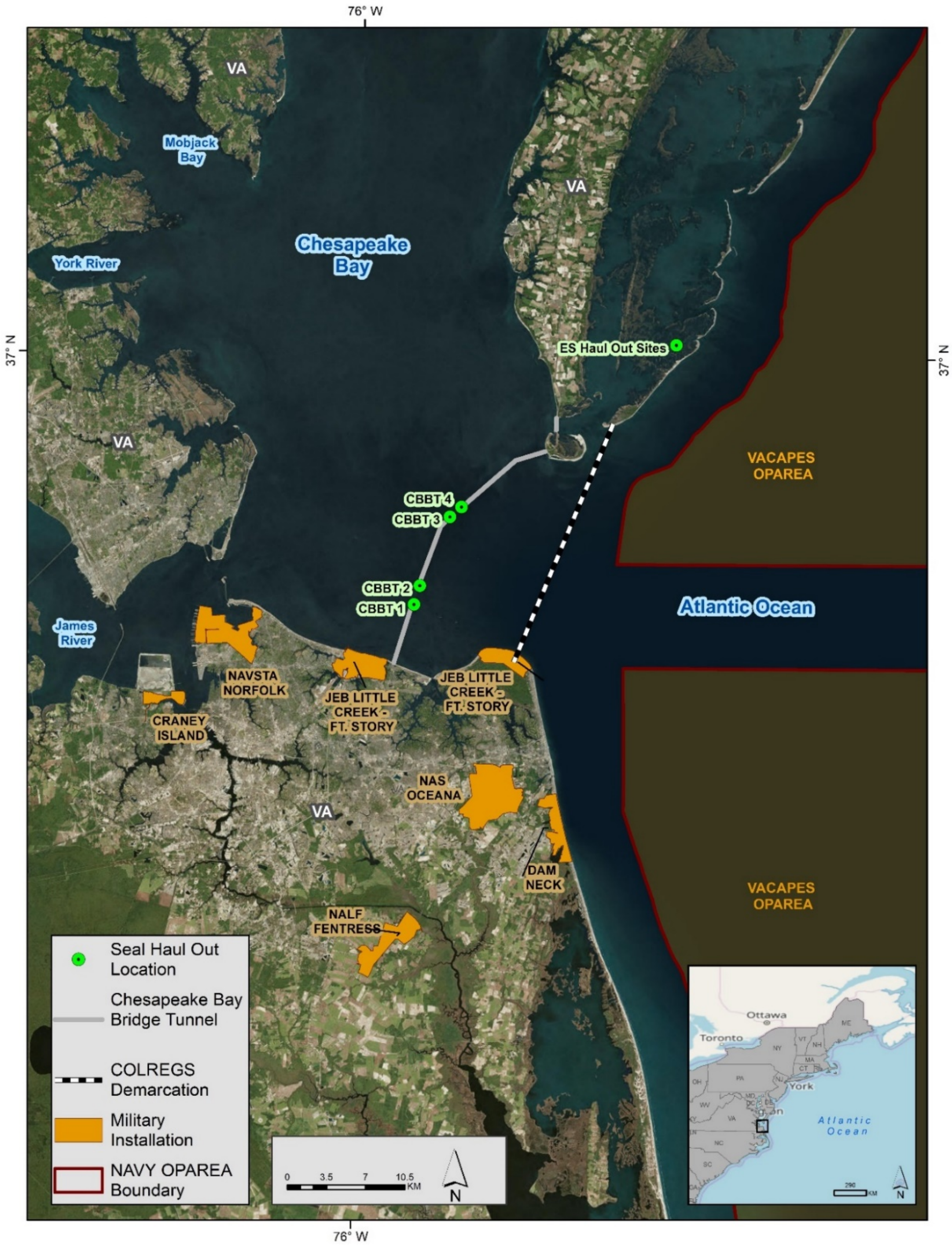

Figure 4. CBBT and Eastern Shore haul-out locations and their proximity to U.S. Naval installations. COLREGS = collision regulations; OPAREA = Operating Area; VACAPES= Virginia Capes Range Complex.

Haul-out Count Results

CBBT

For the sixth field season of the study, nine survey days were completed at the CBBT survey area between 14 November 2019 and 28 April 2020. A best total estimate (combined in-water and hauled out) of 29 seal sightings was recorded across the four CBBT haul-out locations for the season. Seals were observed on 6 of the 9 (66.7 percent) survey days. The total daily number of seals counted per survey day ranged from 0-9 seals, with the highest counts recorded in January.

A total of 97 survey days were conducted across six field seasons (2014–2020) at the CBBT survey area. Seals have been consistently recorded from mid-November to April, with most sightings (85.5 percent) recorded at the CBBT 3 haul-out site. The majority of seals observed were harbor seals with gray seals occasionally sighted during the winter. One gray seal was seen during the 2014/2015 season, and two gray seal sightings were recorded during the 2015/2016 season. Once seals arrived, animals were recorded on a fairly consistent basis (75 out of 97 survey days [77.3 percent]) until departure. Based on this, the number of survey days between and including the first and last seal observation were termed as "in-season" survey effort, and subsequently used this in the analyses. The number of seals observed appeared to be increasing over the first four field seasons; given the increase in maximum count for a single survey day and average number of seals observed per "in season" survey day. However, a drop in both max and average count occurred for the 2018/2019 and 2019/2020 seasons (**Table 6**). The difference between the mean counts across the six field seasons was statistically significant (F_{stat}= 3.43, p= 0.008), with the Tukey/Kramer test results (Q_{cv}= 4.13 for df= 72) indicating that the mean counts for the 2017/2018 and 2018/2019 seasons (Q_{stat}= 4.52) as well as the 2017/2018 and 2019/2020 seasons (Q_{stat}= 4.71) were statistically different.

Table 6. Seasonal survey effort, total seal count (best estimate), maximum seal count for a single survey, and effort-normalized average seal count (number of seals observed per "in season survey" day) for the CBBT survey area.

Field Season	"In-Season" Survey Effort	Seal Counts		
		Total	Average	Maximum
2014–2015	11	113	10	33
2015–2016	14	187	13	39
2016–2017	22	308	14	40
2017–2018*	15	340	23	45
2018–2019	10	82	8	17
2019–2020	6	29	5	9

* Surveys for the CBBT survey area switched from land-based to vessel-based

Eastern Shore

For the Eastern Shore survey area, haul-out counts commenced in November 2019 for the fourth field season. Twelve survey days were completed between 4 November 2019 and 23 April 2020. Seals were observed on 9 of the 12 (75 percent) survey days, with a best total estimate of 157 seal sightings. The total daily number of seals counted ranged from 0-39 individuals per survey day, with the highest counts recorded from January to March.

A total of 43 survey days have been conducted across four field seasons at the Eastern Shore survey area. Seals have been recorded from early November to early April. The majority of seals observed were harbor seals, but gray seals have been sighted during the past three field seasons. One gray seal was sighted during the 2017/2018 season, two gray seal sightings were recorded during the 2018/2019 season, and one gray seal was sighted during the 2019/2020 season. Once seals arrived, animals were recorded on a fairly consistent basis (35 out of 43 [81.4 percent] survey days) until departure. Based on this, the number of survey days between and including the first and last seal observation were termed as "in-season" survey effort, and subsequently used this in the analyses. Over four field seasons, the number of seals observed appears to fluctuate. The number of seals observed increased over the first two field seasons; given the increase in maximum count for a single survey day and average number of seals observed per "in season" survey day. As with the CBBT survey area, a drop in both max and average count occurred for the 2018/2019 season (**Table 7**). However, the average count slightly increased to 17 seals for the 2019/2020 season. The difference between the mean counts across the four field seasons was not statistically significant (F_{stat}= 0.64, p= 0.60).

Table 7. Seasonal survey effort, total seal count (best estimate), maximum seal count for a single survey, and effort-normalized average seal count (number of seals observed per "in season survey" day) for the Eastern Shore survey area.

Field Season	"In-Season" Survey Effort	Seal Counts		
		Total	Average	Maximum
2016–2017	7	105	15	24
2017–2018	8	197	25	69
2018–2019	11	160	15	66
2019–2020	9	157	17	39

Photo-ID and Abundance Estimation Results: CBBT and Eastern Shore Combined

The 2019/2020 field season marked the first time a gray seal (CB168) could be uniquely identified due to the collection of quality images of the animal's distinctive pelage pattern. The gray seal was sighted during one Eastern Shore survey on 18 February 2020. Prior to the 2019/2020 season, gray seals (n= 5) could not be uniquely identified by collected images based on the image grading criteria for quality; images were too poor of quality. After reviewing all images of harbor seals from the 2015-2020 seasons, 121 harbor seals were uniquely identified. Of the 121 individuals, 75 (62 percent) were observed only once and 46 (38 percent) were determined to be present in the study area on more than one occasion across the 5 field seasons, indicating at least some degree of seasonal site fidelity in the lower Chesapeake Bay and coastal Virginia waters. More than half of the identified harbor seals (58 percent) have been sighted at only the CBBT survey area, with a smaller percentage (36 percent) sighted at only the Eastern Shore survey area. Eight individuals were re-sighted at both survey areas on separate survey days within a season and across seasons. These results indicate that harbor seals make localized movements throughout the region during their seasonal occupancy and that while some seals may be utilizing a particular haul-out site within a given season, others may utilize multiple haul-out sites within a season.

A population abundance for harbor seals was estimated for the study area using mark-re-capture data and the Lincoln-Peterson model. A total of 170 individuals were estimated as the average abundance across all five seasons (2015–2020). Abundance estimates were also calculated for each field season from 2015–2020 using the mark-recapture data as well as from 2016–2020 using a telemetry correction factor approach that incorporated seal count and satellite telemetry data (Ampela et al. 2021; Huber et al. 2001; Thompson et al. 1997). Abundance estimates produced from the mark-recapture data ranged from 81 (95% CI: 44.14–117.19) to 242 (95% CI: 91.35–392.65) individual harbor seals (**Figure 5**).

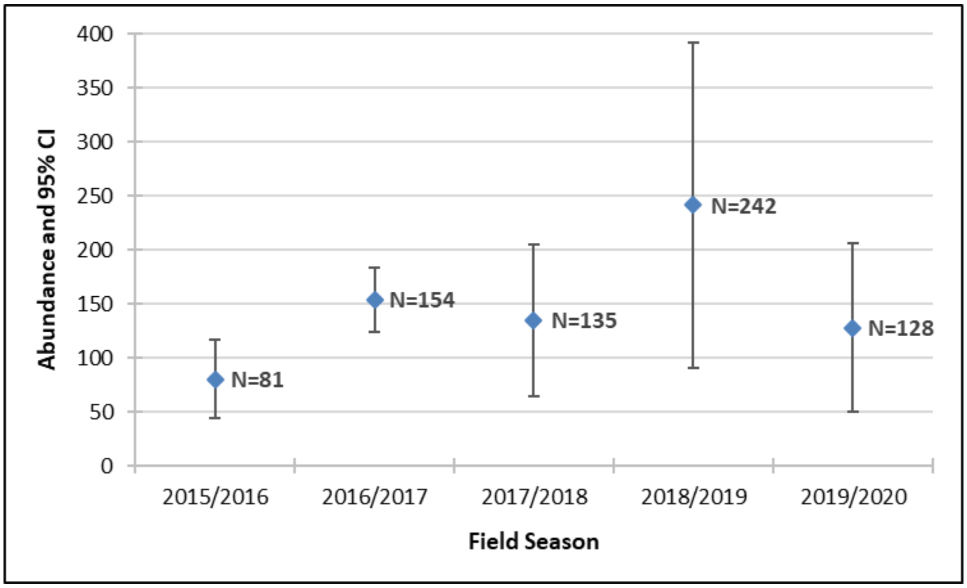

Figure 5. Total abundance estimates (blue diamonds) and 95% confidence intervals (CIs) for the CBBT and Eastern Shore survey areas combined during each of the field seasons: 2015/2016, 2016/2017, 2017/2018, 2018/2019, and 2019/2020.

The estimates calculated using the telemetry correction factor were slightly higher in comparison for most seasons and ranged from 143 (95% CI: 0–388.05) to 226 (95% CI: 52.67–398.35) individual harbor seals (**Table 8**). The margin of error was larger for the abundance estimates produced using the telemetry correction factor approach; potentially due to small sample sizes for both count and telemetry data for this type of calculation. A fluctuation in abundance estimates occurred across seasons for both approaches and regression analysis results indicate there is not a statistically significant trend in population abundance. Therefore, there is reason to believe that the population of animals utilizing the lower Chesapeake Bay and Eastern Shore, Virginia may be relatively stable.

Table 8. Mean haul-out counts of harbor seals at the CBBT and Eastern Shore survey areas for the 2016-2020 field seasons, the mean proportion of time spent ashore (*h*) by tagged harbor seals, and the resulting abundance estimates for each season. SE= standard error. CI= confidence interval.

Field Season	Mean Count (SE)	Proportion Time Ashore	Estimated Abundance	95% CI for Abundance
2016–2017	14.2 (2.1)	0.13	226	52.67 - 398.35
2017–2018	23.3 (3.4)	0.13	143	0 - 388.05
2018-2019	11.4 (3.1)	0.13	181	0 - 395.72
2019-2020	12.3 (3.2)	0.13	195	6.65 - 383.94

Time-lapse Camera Monitoring Progress and Results

During the 2019/2020 season, over 85,000 images were collected from 12 cameras (two cameras at the CBBT and 10 cameras on the Eastern Shore). Photo processing is underway using Timelapse2 computer software and a progress report is scheduled to be available summer 2021.

Summary

This research continues to document a regular, seasonal presence of harbor seals and occasional sightings of gray seals within the lower Chesapeake Bay and Eastern Shore, Virginia from November to April. Patterns of seasonal residency and a baseline for population abundance for harbor seals within the region have now been documented. Reports of harbor and gray seal distribution along the U.S. Atlantic coast potentially expanding or shifting (DiGiovianni et al. 2011; Johnston et al. 2015; DiGiovianni et al. 2018) could explain the fluctuation observed in seal occurrence at the CBBT and Eastern Shore survey areas since 2014. An increase in gray seal pupping (Wood et al. 2019) and overall, abundance, in the Northeastern U.S. (Pace et al. 2019) could create interspecific competition for the two species and thus, potentially resulting in a mortaliore southern expansion of harbor seals along the east coast (Sieswerda and Kopelman 2018). The observed decrease in seal occurrence for the study area for the 2018-2020 seasons may be due to several factors such as the ongoing Northeast U.S. Pinniped Unusual Mortality Event that was declared in 2018 (NOAA 2020), seasonal differences in haul-out behavior (Russel et al. 2015), and/or environmental conditions. However, more research is necessary to determine the level of site fidelity and whether harbor seal abundance is increasing, decreasing, or stable within the study area. Haul-out counts, camera trap monitoring, and photo-ID data collection have continued for the 2020/2021 field season at both the CBBT and Eastern Shore survey areas. Data will continue to be examined for any emerging patterns of habitat utilization and residency time, as well as population trends, which will help the Navy with ongoing environmental compliance and conservation efforts.

For more information on the Virginia seal haul-out study, please see the annual progress report (Jones and Rees 2021), and visit the project profile page.

2.1.1.3 Mid-Atlantic Humpback Whale Catalog

Humpback whales (*Megaptera novaeangliae*) are the most common mysticete in the nearshore waters off the coast of Virginia (Mallette et al. 2017). Evidence of seasonal use, foraging, and site fidelity from photo-ID efforts suggest the mid-Atlantic provides important seasonal habitat for humpback whales (Swingle et al. 1993, Wiley et al. 1995, Barco et al. 2002). Barco et al. (2002) suggested that some individual humpback whales overwinter in the mid-Atlantic, and that this region may serve as a supplemental winter feeding ground. Over the last two decades, the Virginia Aquarium Foundation (VAQF) has conducted photo-ID studies of humpback whales off the coast of Virginia and North Carolina and currently curates the Mid-Atlantic Humpback Whale Catalog (MAHWC).

VAQF has been developing a collaborative, integrative platform for the MAHWC that provides a broad-scale and high-quality scientific product that can answer questions to inform the U.S. Navy and other stakeholders of the identity, residency, site fidelity, and seasonal habitat use of humpback whales in the mid-Atlantic and southeastern U.S. training areas. This project contributes to the overall community effort to help monitor the West Indies Distinct Population Segment and complements existing U.S. Navy MSM efforts (Mid-Atlantic Humpback Whale Monitoring, Mid-Atlantic Continental Shelf Break Cetacean Study, and Aerial Survey Baseline Monitoring).

The overarching goal of this project is to facilitate exchange of information among researchers who have been involved in humpback whale photo-ID efforts over the last 40 years in the North Atlantic. These efforts can also serve to support assessment of human impacts (e.g., injuries from entanglement or watercraft), body condition, and behavior (e.g., foraging). Longitudinal mark-recapture data can also serve as a non-invasive mechanism to investigate and detect changes in patterns of humpback whale occurrence, inter-annual variation, and changes in distribution and phenology over time. Survey effort and opportunistic sightings of humpback whales in the mid-Atlantic and southeastern United States have increased substantially in the past few years. To integrate data from a multitude of sources more effectively, both current and historic, a streamlined process for submissions, management, and access is necessary. In addition, simplifying and standardizing submissions from the mid-Atlantic to the broader regional and North Atlantic catalogs is essential to the efficiency of information exchange between regions. A broad data-sharing agreement was developed in order to facilitate the exchange of sighting and individual life-history information among contributors rather than requesting permission for each individual match, as is often the case with other catalogs.

The MAHWC is hosted on the Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP; Halpin et al. 2009), a web-based biogeographic database for marine megafauna. It provides tools for mapping and visualizing species sighting data on a global scale. Currently, OBIS-SEAMAP hosts multiple other photo-ID catalogs (e.g., Mid-Atlantic Bottlenose Dolphin Catalog, Pacific Islands Photo-Identification Network) and provides a user-friendly interface and efficient tools for comparison of collections.

In 2020, the catalog has undergone substantial restructuring in the programming in order to take advantage of automated uploading procedures that were developed for other catalogs on the OBIS platform. While the automated system reduces the workload for future curators, it has required changing key fields and re-linking data and images previously submitted to the catalog. In addition, curator instructions and protocols have required updating and testing. The catalog is available to collaborators but has not moved from the beta-testing stage because of the work required to take advantage of enhancements for future curation.

The MAHWC is in the final stage of development (see Mallete and Barco 2017, 2019; Mallette et al. 2018 for more detail on project development), and data from the catalog have been included in a manuscript authored by Danielle Brown (Rutgers University) with several MAHWC collaborators as authors. The manuscript is currently in review in the peer-reviewed scientific journal *Marine Mammal Science*. The rollout of the final catalog is currently slated for the spring of 2021.

2.1.2 Passive Acoustic Methods

Passive acoustic monitoring has been a significant component of the U.S. Navy's MSM program in the Atlantic since it began in 2007. Although initially used primarily to collect baseline data on the occurrence of various species, more recently statistical methods have been developed to begin examining potential changes in vocalization behaviors that could represent responses to training and testing activities. In addition, the Marine Mammal Monitoring on Navy Ranges program has been leveraging permanent, fixed acoustic training ranges to develop a suite of tools and techniques and support various projects addressing specific questions related to marine species monitoring and interactions with training and testing activities.

All current and past deployments of PAM devices including High-frequency Acoustic Recording Packages (HARPs), Marine Autonomous Recording Units, Autonomous Multichannel Acoustic Recorders, Ecological Acoustic Recorders, and automated click detectors, can be explored, along with accompanying metadata and links to analyses and reports, through a data viewer on the U.S. Navy's MSM program web portal.

2.1.2.1 High-frequency Acoustic Recording Packages

Duke University and Scripps Institution of Oceanography began deploying High-frequency Acoustic Recording Packages (HARPs) as part of the original multi-disciplinary monitoring effort for Onslow Bay in 2007, which was later expanded to the JAX OPAREA in 2009, Cape Hatteras in 2012, and Norfolk Canyon in 2014. All HARPs deployed were in compact mooring configurations with the hydrophones suspended approximately 20 m above the seafloor (**Figure 6**). Each HARP was calibrated in the laboratory to provide quantitative analysis of the received sound field. Representative data loggers and hydrophones were also calibrated at the Navy's TRANSDEC facility to verify the laboratory calibrations (Wiggins and Hildebrand 2007). Deployments ended at the Onslow Bay site in 2013 but have continued at the other locations (**Figure 7**). The primary objective of deployments at all locations has been to determine species distributions and document spatiotemporal patterns of cetaceans throughout areas of interest. During 2020, single-channel HARP data were collected at the Norfolk Canyon, Cape Hatteras, and JAX sites over a bandwidth from 10 Hertz up to 200 kHz.

Deployment details and links to available analyses from all previous HARP deployments can be found through the HARP data explorer on the U.S. Navy's MSM program web portal.

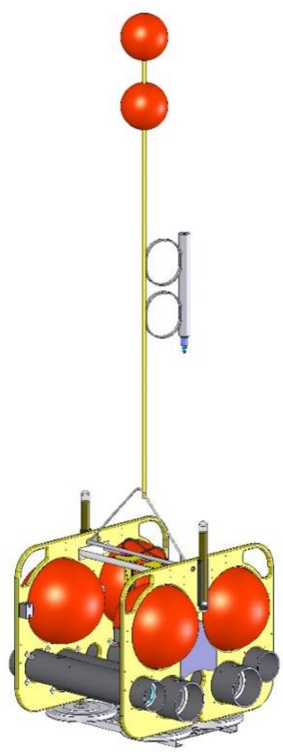

Figure 6. Standard seafloor-mounted High-frequency Acoustic Recording Package configuration.

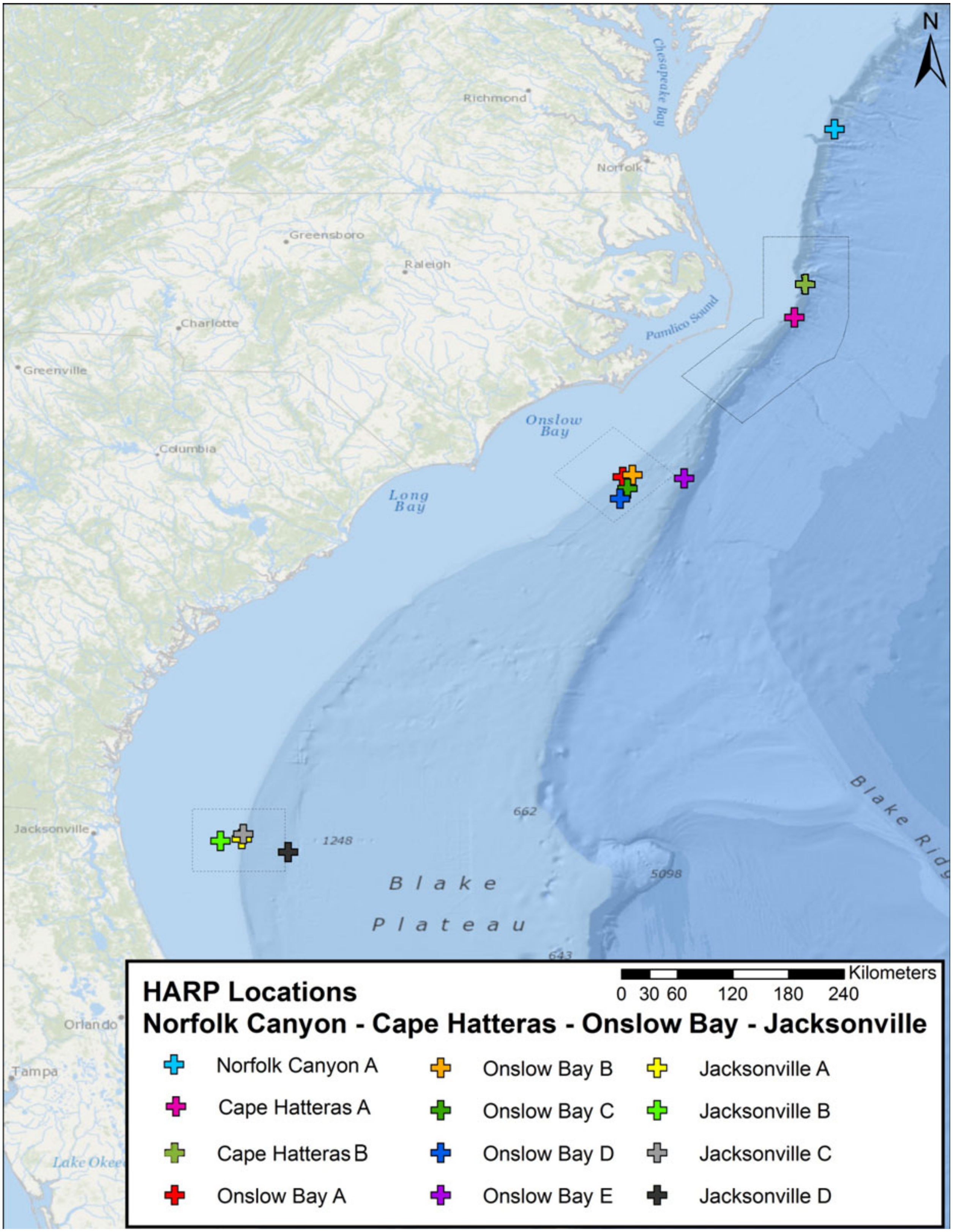

Figure 7. Location of HARP deployment sites in Norfolk Canyon, Cape Hatteras, Onslow Bay, and JAX.

Jacksonville Data Collection (Table 9)

The HARP deployed at Site D in the JAX OPAREA 15 June 2019 has not been recovered due to the COVID-19 epidemic. This is the last deployment planned for the JAX site.

Norfolk Canyon Data Collection (Table 10)

NFC05A initially deployed on 19 May 2019 at Site A near Norfolk Canyon at a depth of 1050 m was recovered on 1 March 2021. Recovery of this unit was significantly delayed due to the COVID-19 epidemic and a replacement was not able to be redeployed immediately. The Norfolk Canyon Site A unit is tentatively planned to be redeployed in Spring of 2021.

Cape Hatteras Data Collection (Table 11)

HAT_B_07_01 initially deployed on 24 October 2019 at Site A near Norfolk Canyon at a depth of 1100 m was recovered on 1 March 2021. Recovery of this unit was significantly delayed due to the COVID-19 epidemic. This was the last HARP deployment planned for the Cape Hatteras study area.

Table 9. All HARP deployments in JAX, 2014-2021, with currently deployed instrument highlighted in blue.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude (°N)	Longitude (°W)	Depth (m)	Sampling Rate	Duty Cycle
11D	23-Aug-14	02-Jul-15	23-Aug-14	22-May-15	30.1506	79.7700	806	200 kHz	continuous
12D	02-Jul-15	26-Apr-16	03-Jul-15	04-Nov-15	30.1489	79.7711	800	200 kHz	continuous
13D	26-Apr-16	25-Jun-17	26-Apr-16	25-Jun-17	30.1518	79.7702	736	200 kHz	continuous
14D	25-Jun-17	26-Jun-18	25-Jun-17	26-Jun-18	30.1527	79.7699	740	200 kHz	continuous
15D	26-Jun-18	15-Jun-19	26-Jun-18	15-Jun-19	30.1522	79.7710	740	200 kHz	continuous
16D	15-Jun-19	N/A	15-Jun-19	N/A	30.155	79.771	735	200 kHz	continuous

Key: kHz = kilohertz; m = meter(s); N/A = not applicable.

Table 10. All HARP deployments at Norfolk Canyon site, 2014-2021.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude (°N)	Longitude (°W)	Depth (m)	Sampling Rate	Duty Cycle
01A	19-Jun-14	07-Apr-15	19-Jun-14	05-Apr-15	37.1662	74.4669	982	200 kHz	continuous
02A	30-Apr-16	30-Jun-17	30-Apr-16	28-Jun-17	37.1652	74.4666	968	200 kHz	continuous
03A	29-Jun-17	2-Jun-18	29-Jun-17	2-Jun-18	37.1674	74.4663	950	200 kHz	continuous
04A	02-Jun-18	19-May-19	02-Jun-18	18-May-19	37.1645	74.4659	1050	200 kHz	continuous
05A	19-May-19	1-Mar-21	19-May-19	N/A	37.1645	74.4659	1050	200 kHz	continuous

Key: kHz = kilohertz, m = meter(s), N/A = not available.

Table 11. All HARP deployments at the Cape Hatteras site, 2012-2021.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude (°N)	Longitude (°W)	Depth (m)	Sampling Rate	Duty Cycle
02A	09-Oct-12	29-May-13	09-Oct-12	09-May-13	35.3406	74.8559	970	200 kHz	continuous
03A	29-May-13	08-May-14	29-May-13	15-Mar-14	35.3444	74.8521	970	200 kHz	continuous
04A	08-May-14	06-Apr-15	09-May-14	11-Dec-14	35.3467	74.8480	850	200 kHz	continuous
05A	06-Apr-15	29-Apr-16	07-Apr-15	29-Jan-16	35.3421	74.8572	980	200 kHz	continuous
06A	29-Apr-16	09-May-17	29-Apr-16	06-Feb-17	35.3057	74.8776	1,020	200 kHz	continuous
HAT_B_01_01	09-May-17	25-Oct-17	09-May-17	25-Oct-17	35.5837	74.7492	1,118	200 kHz	continuous
HAT_B_01_02_C4	09-May-17	28-Jun-17	09-May-17	28-Jun-17	35.5797	74.7559	1,111	200 kHz	continuous
HAT_B_01_03_C4	09-May-17	28-Jun-17	09-May-17	28-Jun-17	35.5865	74.7560	1,095	200 kHz	continuous
HAT_B_02_02_C4	28-Jun-17	Lost-at-sea	28-Jun-17	N/A	35.5793	74.7569	1,040	200 kHz	continuous
HAT_B_02_03_C4	28-Jun-17	25-Oct-17	28-Jun-17	25-Oct-17	35.5861	74.7558	1,190	200 kHz	continuous
HAT_B_03_01	25-Oct-17	1-Jun-18	25-Oct-17	1-Jun-18	35.5835	74.7431	1,117	200 kHz	continuous
HAT_B_04_01	01-Jun-18	13-Dec-18	01-Jun-18	13-Dec-18	35.5897	74.7476	1350	200 kHz	continuous
HAT_B_04_02_C4	01-Jun-18	13-Dec-18	N/A	N/A	35.5851	74.7515	1175	200 kHz	continuous
HAT_B_04_03_C4	01-Jun-18	13-Dec-18	01-Jun-18	13-Dec-18	35.5905	74.7628	1078	200 kHz	continuous
HAT_B_05_01	13-Dec-18	18-May-19	14-Dec-18	18-May-19	35.5897	74.7476	1350	200 kHz	continuous
HAT_B_06_01	18-May19	24-Oct-19	18-May-19	24-Sep-19	35.5844	74.7479	1120	200kHz	continuous
HAT_B_05_02_C4	17-May-19	24-Oct-19	17-May-19	N/A	35.5805	-74.7455	1217	200kHz	continuous
HAT_B_05_03_C4	17-May-19	24-Oct-19	17-May-19	N/A	35.5848	-74.7415	1227	200kHz	continuous
HAT_B_07_01	24-Oct-19	1-Mar-21	25-Oct-19	29-Oct-20	35.5826	-74.7501	1100	200kHz	continuous

Key: kHz=kilohertz; m=meter(s); N/A=not available.

During 2020 Scripps Institution of Oceanography conducted basic analyses and produced technical reports covering deployments from 2017–2019 at Norfolk Canyon Site A, Cape Hatteras Site B, and JAX Site D. These technical reports are available through the HARP metadata explorer. All data from previous and current deployments is being contributed to a broad collaborative analysis of North Atlantic shelf break species (see **Section 2.1.2.2**). For more information on the HARP program, refer to the primary literature publications using data from previous HARP deployments (Stanistreet et al. 2016, Davis et al. 2017, Hodge et al. 2018).

2.1.2.2 Occurrence and Acoustic Ecology of North Atlantic Shelf-Break Species

Acoustically sensitive species such as beaked whales inhabit the North Atlantic shelf break region; while all ESA listed baleen whales, such as the North Atlantic right whale (NARW) (*Eubalaena glacialis*), fin (*Balaenoptera physalus*), blue (*Balaenoptera musculus*), and sei whales (*Balaenoptera borealis*), are known to use this area to different extents. To better understand patterns in species distribution and vocal activity, NOAA's Northeast Fisheries Science Center and Scripps Institution of Oceanography collaboratively deployed long-term high-frequency acoustic recording packages (HARPs) at eight sites along the western North Atlantic shelf break. This work was conducted from 2015–2019, in coordination with the Bureau of Ocean Energy Management (BOEM). Likewise, the U.S. Navy has been monitoring the shelf break region at 3 to 4 sites since 2007. Together these combined efforts bring the total to 11 recording sites spanning the U.S. eastern seaboard, from New England to Georgia.

Data from earlier HARP recorders have been analyzed in multiple previous studies (e.g., Davis et al. 2017; Stanistreet et al. 2017, 2018). This project focuses on analyses of more recent datasets collected from 2015–2019. The focus of efforts in 2020 were to refine species occurrence analyses, including completing analyses of baleen whale occurrence and working to improve the classification algorithms for odontocetes; exploring new acoustic metrics to describe species diversity; and developing frameworks to assess impacts of anthropogenic noise on the acoustic ecology and acoustic behavior of protected species.

Work conducted in 2020 was aimed at advancing the analytical components for these key objectives:

- Assessing the seasonal and spatial occurrence of baleen whales
- Improving automated classification for beaked whales
- Assessing effects of anthropogenic noise on beaked whale vocal activity
- Assessing the prevalence of seismic survey noise along the eastern seaboard
- Novel broad-scale approach to assessing acoustic niche and anthropogenic contributors, and assessing the utility of new acoustic metrics

Continuous passive acoustic recordings have been collected along the Atlantic continental shelf break of the United States at eleven sites beginning as early as 2015 by both Northeast Fisheries Science Center and the U.S. Navy. The sites deployed starting in 2015 include Heezen Canyon, Oceanographer Canyon, Nantucket Canyon (3 northernmost sites), and Norfolk Canyon, Hatteras, and JAX (U.S. Navy deployments). These were expanded in 2016 to include Wilmington Canyon & Babylon Canyon north of Cape Hatteras, and Gulf Stream, Blake Plateau and Blake Spur south of Cape Hatteras. (**Table 12, Figure 8**). Each HARP was programmed to record continuously at a sampling rate of 200 kHz with 16-bit quantization, providing an effective recording bandwidth from 0.01–100 kHz. Further details of HARP design are described in Wiggins and Hildebrand, 2007.

Preliminary analyses conducted in 2019 focused on data collected from 2015 through 2017 at eight sites along the continental shelf break. Acoustic niche results from these analyses are presented in Van Parijs et al. (2020) and will be incorporated into the broader ecological analyses to be conducted once the remaining data from

2017 through 2019 is processed. Progress made during 2020 included analyses of the 2017–2018 datasets for all species as well as mid-frequency active sonar (MFAS), assessing the seasonal and spatial occurrence of baleen whales, improving automated classification for beaked whales, and assessing effects of anthropogenic noise on beaked whale vocal activity.

The Low-Frequency Detection and Classification System was used to identify and distinguish species-specific vocalizations and extract the presence of five mysticete species: blue, fin, humpback, NARW, and sei whales. The high-frequency acoustic data sets were used to extract the presence of echolocation clicks from six beaked whale species: Blainville's beaked whales (*Mesoplodon densirostris*), Cuvier's beaked whale, Gervais'/True's beaked whale (*Mesoplodon europaeus/Mesoplodon mirus* respectively), Northern bottlenose whales (*Hyperoodon ampullatus*), and Sowerby's beaked whale (*Mesoplodon bidens*), as well as sperm whales, Kogia spp., and a grouping of at least 12 delphinid species known to occur in the region. The HARP data was also examined for the presence of four types of anthropogenic noise: broadband ship sounds, airguns, explosions, and echosounders.

Automatic detection of MFA sonar was implemented using a modified version of the *silbido* detection system (Roch et al., 2011) designed for characterizing toothed whale whistles. The algorithm identifies peaks in time-frequency distributions (e.g., spectrogram) and determines which peaks should be linked into a graph structure based on heuristic rules that include examining the trajectory of existing peaks, tracking intersections between time-frequency trajectories, and allowing for brief signal drop-outs or interfering signals. Parameters in *silbido* were adjusted to detect tonal contours ⩾ 2 kHz (in data decimated to a 10 kHz sample rate) with a signal-to-noise ratio ⩾ 5 dB and contour durations > 200 ms with a frequency resolution of 100 Hz.

Table 12. HARP deployment sites and recording details for data analyzed from 2015 through 2019.

Site	Recording Start Date	Recording End Date	Recorder Depth (m)
Heezen Canyon (HZ)	June 2015	May 2019	845
Oceanographer Canyon (OC)	April 2015	May 2019	1000
Nantucket Canyon (NC)	April 2015	June 2019	977
Babylon Canyon (BC)	April 2016	May 2019	1000
Wilmington Canyon (WC)	April 2016	May 2019	1000
Norfolk Canyon (NFC)	April 2016	May 2019	1000
Hatteras (HAT)	April 2016	May 2019	1100
Gulf Stream (GS)	April 2016	June 2019	954
Blake Plateau (BP)	April 2016	May 2019	945
Blake Spur (BS)	April 2016	June 2019	1005
Jacksonville (JAX)	April 2016	June 2019	750

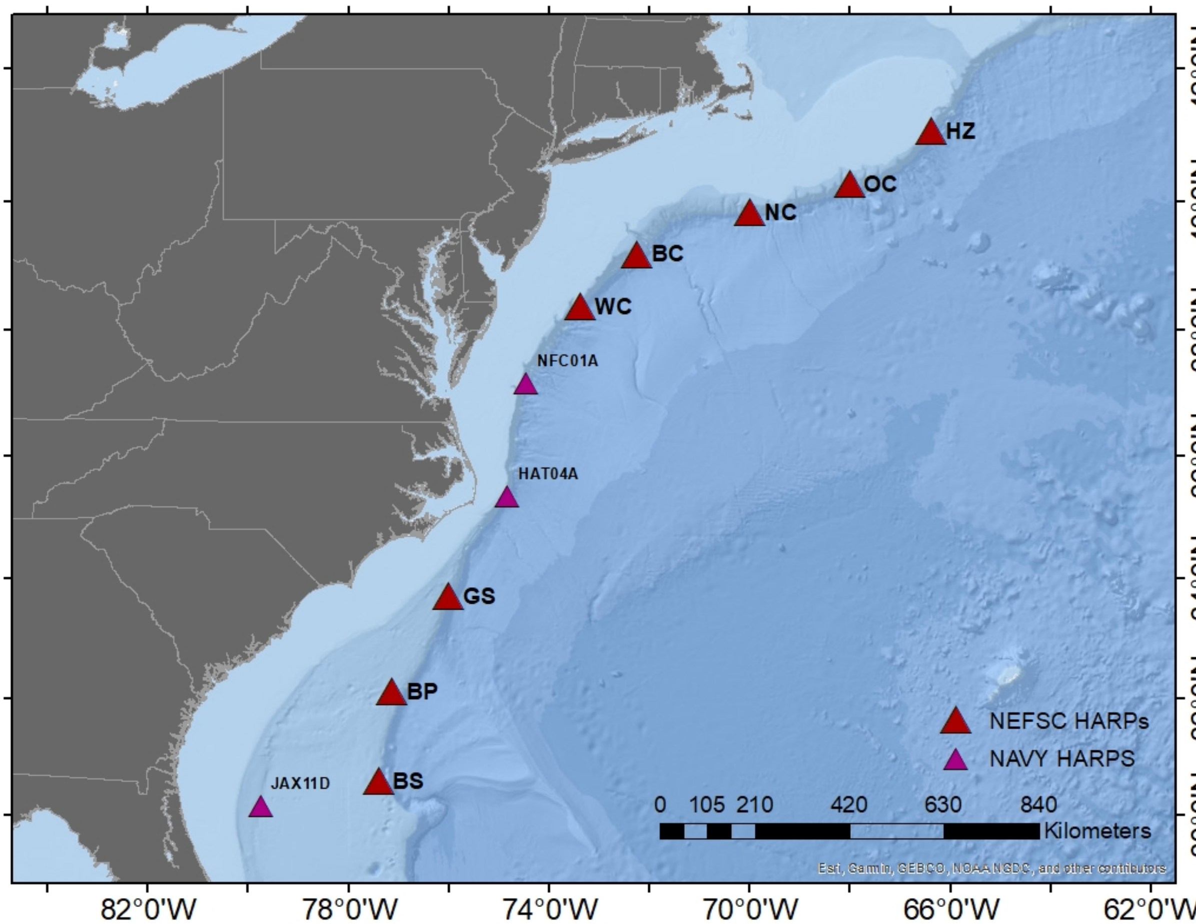

Figure 8. HARP deployment sites for data collected from 2015 through 2019.

A significant focus of the work conducted in 2020 was to expand the analysis of automatic identification of beaked whales to click-level and subsequently develop a statistical approach to investigate the potential impacts of MFAS in the Western North Atlantic. The goal is to refine existing data of several species of beaked whales for acoustic behavioral response to sonar operations in areas with varying naval activity. The relationship between MFA sonar and the acoustic behavior of beaked whales is complex and requires the inclusion of natural temporal and spatial variability in click densities, e.g., caused by species or population-level seasonality, habitat preference, the behavioral context of echolocating, and individual variability. For this part of the project, analyses have focused largely on the Navy HARP sites, as presence of MFA sonar is higher there than on the other sites.

Details on the progress made in 2020 can be found in Van Parijs et al. 2021.

2.1.2.3 Bryde's Whale Occurrence in the Northeastern Gulf of Mexico

The Gulf of Mexico (GOM) Bryde's whale (*Balaenoptera edeni*) is estimated to have a population size of 33 individuals in U.S. waters (Hayes et al. 2018) and was listed as endangered under the ESA in 2019 (84 FR 15446). The majority of modern sightings occur in waters between the 100–400 m water depths in an area near the De Soto Canyon off northwestern Florida (Soldevilla et al. 2017). Occurrence patterns from one year of long-term passive acoustic monitoring and two recent summer and fall surveys indicate the whales are found year-round within this primary habitat, but also suggest there may be seasonal movements throughout, and potentially out of, this area. High densities of anthropogenic activities occur throughout the GOM, including oil and gas exploration and extraction, fisheries, shipping, and military activities; several of these activities overlap with the whales' primary habitat. Understanding seasonal distribution and density will improve understanding of potential impact of human activities in the core habitat and assist in developing effective mitigation measures as needed.

The Southeast Fisheries and Science Center and Scripps Institution of Oceanography have been collaboratively deploying long-term passive acoustic monitoring stations at five GOM sites since 2010 to monitor the impacts of the Deepwater Horizon oil spill and subsequent restoration activities on cetaceans (Figure 9). HARPs deployed at the five sites, including the De Soto Canyon (DC) HARP in the primary GOM Bryde's whale habitat, have been continuously recording ambient noise and other acoustic events in the 10 Hz to 100 kHz frequency range, and these 8-year near-continuous recordings (2010–2018) are available for analysis to better understand distribution and density trends of GOM Bryde's whales. The focus of this project in 2019 was on developing automated GOM Bryde's whale call detectors, characterizing ambient noise levels, and running and validating the detectors on data from the DC HARP in the core habitat collected between October 2010 and July 2011, and the focus for 2020 was to complete the validation of automated detections on data through June 2018 to establish complete occurrence time-series for understanding seasonal and interannual trends and for future habitat modeling and density estimation. An additional goal for 2020 was to begin a new data collection study with greater spatial coverage to improve the understanding of seasonal movement patterns within the GOM Bryde's whale core habitat.

During 2020, work focused on validating the automated detections of long-moan calls and downsweep pulse sequences from the remaining nine deployments out to June 2018, and results are being prepared in a manuscript to submit for peer-review. Over the eight years of data collected at the De Soto Canyon site from 2010–2018, a total of 625,911 GOM Bryde's whale long-moan call detections were manually validated, yielding 439,052 true call detections, and a total of 115,729 GOM Bryde's whale downsweep pulse sequence detections were manually validated, yielding 13,369 true call detections. Manual validation results indicate average false detection rates per deployment of the two automated detectors were 32 percent (range: 17–60 precent) for long-moan detections and 89 percent (range: 74–98 percent) for downsweep pulse sequence detections; all false detections, repeat call detections, and detections labeled as potentially true calls were removed from further analyses during the manual validation process. True detections of both GOM Bryde's whale long-moan and downsweep pulse sequence call types were detected in all seasons and all years at the De Soto Canyon HARP site.

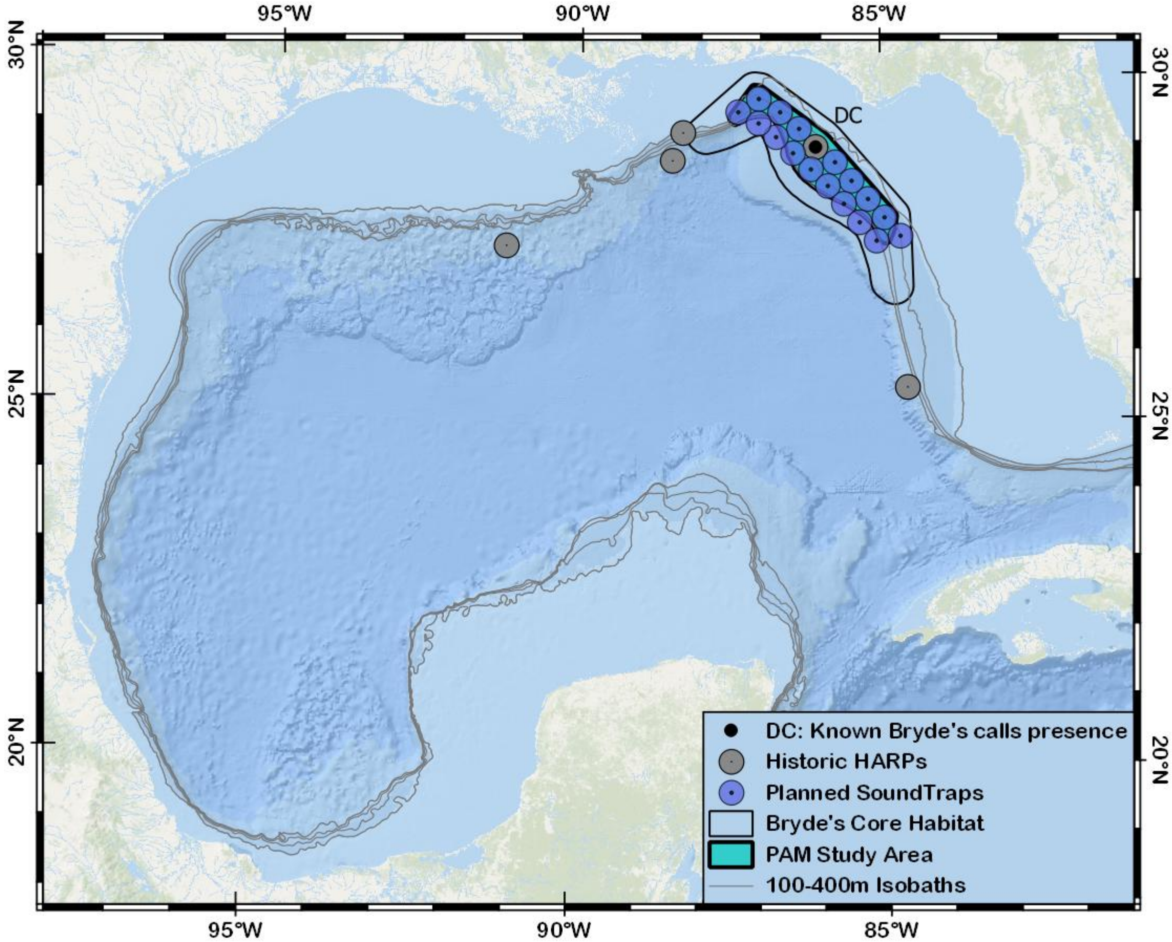

Figure 9. Historic long-term passive acoustic monitoring stations in the Gulf of Mexico since 2010 (HARPs) and planned 2021 passive acoustic monitoring stations (SoundTraps). The NMFS core habitat of Gulf of Mexico Bryde's whales is indicated, including the De Soto Canyon (DC) site, where Gulf of Mexico Bryde's whale calls have previously been detected.

GOM Bryde's whale long-moan calls were detected on nearly all days of each deployment at the De Soto Canyon HARP site over the eight-year period, with calls present during an average of 95 percent of days with recordings per deployment (range: 79–99 percent of days), as well as for a substantial portion of the time throughout days with an average of 66 percent of recording hours containing long-moan calls (range: 33–86 percent of hours) per deployment. This region of the GOM is quieter than other areas in the GOM (Wiggins et al. 2016) and detection distances of these calls may be large; preliminary localization work indicates 20 km is common while instances with detection distances to at least 70 km have occurred. The core habitat is approximately 350 km long by 75 km wide and the HARP site is near the middle of the habitat so a substantial portion of the habitat may be sampled under some oceanographic and ambient noise conditions. In addition to the typical long-moan calls found in the northeastern Gulf, western long-moan variants were detected during some deployments, with western calls present on an average of 5.6 precent of recording days per deployment (range: 0–18 percent of days), and western calls present during an average of 0.8 percent of recording hours per deployment (range: 0–2.9 percent of hours). Preliminary analyses suggest interannual and seasonal variability in daily long-moan call detection rates with lower daily long-moan call detection rates in some years (2010, 2012, 2013) compared to other years with higher daily call detection rates (2011, 2018), and lower daily call detection rates in some months (late winter/early spring) with higher rates in other months (fall). Preliminary analyses also indicate increased hourly call detection rates in late afternoon to early evening. Final statistical evaluations of the significance of this variation will be included in the manuscript for peer-review.

GOM Bryde's whale downsweep pulse sequence calls were detected an order of magnitude less frequently than long-moan calls at the De Soto Canyon HARP site over the eight-year period, with calls present during an average of 24 percent of days with recordings per deployment (range: 9–40 percent of days), and an average of 5.2 percent of recording hours had downsweep pulse sequence detections present (range: 1.5–9.2 percent of hours) per deployment. Preliminary analyses suggest inter-annual and intra-annual variability in daily downsweep pulse sequence call detection rates with lower daily downsweep pulse sequence call detection rates in some years (2010, 2015) compared to other years with higher daily call detection rates (2011, 2018), and lower daily call detection rates in some months (August and late winter/early spring) with higher rates in other months (July and fall months). Preliminary analyses also indicate increased hourly downsweep pulse sequence call detection rates in late afternoon to early evening. Final statistical evaluations of the significance of this variation will be included in the manuscript for peer-review.

The high percentage of time GOM Bryde's whale calls are present throughout this 8-year period strongly supports the definition of this area as their core habitat, as based on sightings from visual surveys of the northern Gulf primarily conducted during summer and fall months. Seasonal and interannual variation in call detection rates described here may reflect 1) variation in ambient noise conditions or sound propagation conditions that impact detection ranges of the calls, and hence the HARP sampling area, 2) variation in call behavior, and 3) variation in spatio-temporal distribution and density of whales throughout the core habitat related to oceanographic variation.

A final goal for work during 2020 was to begin a new project to better understand the observed intra-annual variability in GOM Bryde's whale call occurrence with respect to the entire core habitat, by expanding passive acoustic monitoring to an additional 17 sites that should completely cover the core habitat. The study aims to provide further information to interpret the changes seen at the De Soto Canyon HARP site over 8 years and to understand how call density varies seasonally throughout the core habitat. The project will deploy 17 SoundTrap ST500 STD units concurrent with the long-term DC HARP in two lines of 9 PAM units each to cover the core habitat nearly completely, for two six-month deployments. All equipment for the PAM moorings has been purchased and is ready to deploy. However, vessel schedule cancellations, high vessel demand, and travel restrictions and limitations due to the COVID-19 pandemic have delayed the deployment of these moorings over the last year with the project currently delayed by one year due to these challenges. Vessel time is scheduled on NOAA's R/V *Gordon Gunter* to deploy the SoundTrap moorings in summer 2021, for subsequent retrieval and redeployment in October 2021, and final recovery in May 2022. Data analyses of the recordings from the 17 SoundTraps as well as the concurrently deployed DC HARP data are planned upon retrieval of the first deployment, anticipated for November 2021.

Additional details on the work conducted over the past year is available in Soldevilla et al. 2021.

2.1.2.4 Autonomous Glider Deployments

Two autonomous Slocum G3 gliders equipped with digital acoustic monitoring (or DMON) instruments and near real-time reporting capabilities were deployed and operated in the mid-Atlantic Bight to the north and south of Cape Hatteras, North Carolina, in late January and early February 2020, respectively, to potentially detect right whales in the Virginia/North Carolina region during the migration period (**Figure 10** and **Figure 11**). The gliders were programmed to survey pre-determined cross-shelf transects by traveling between specified waypoints from roughly the 20 m isobath eastward to the shelf break as local currents allowed, but also could be remotely piloted in the event mechanical or environmental factors required intervention for course deviation.

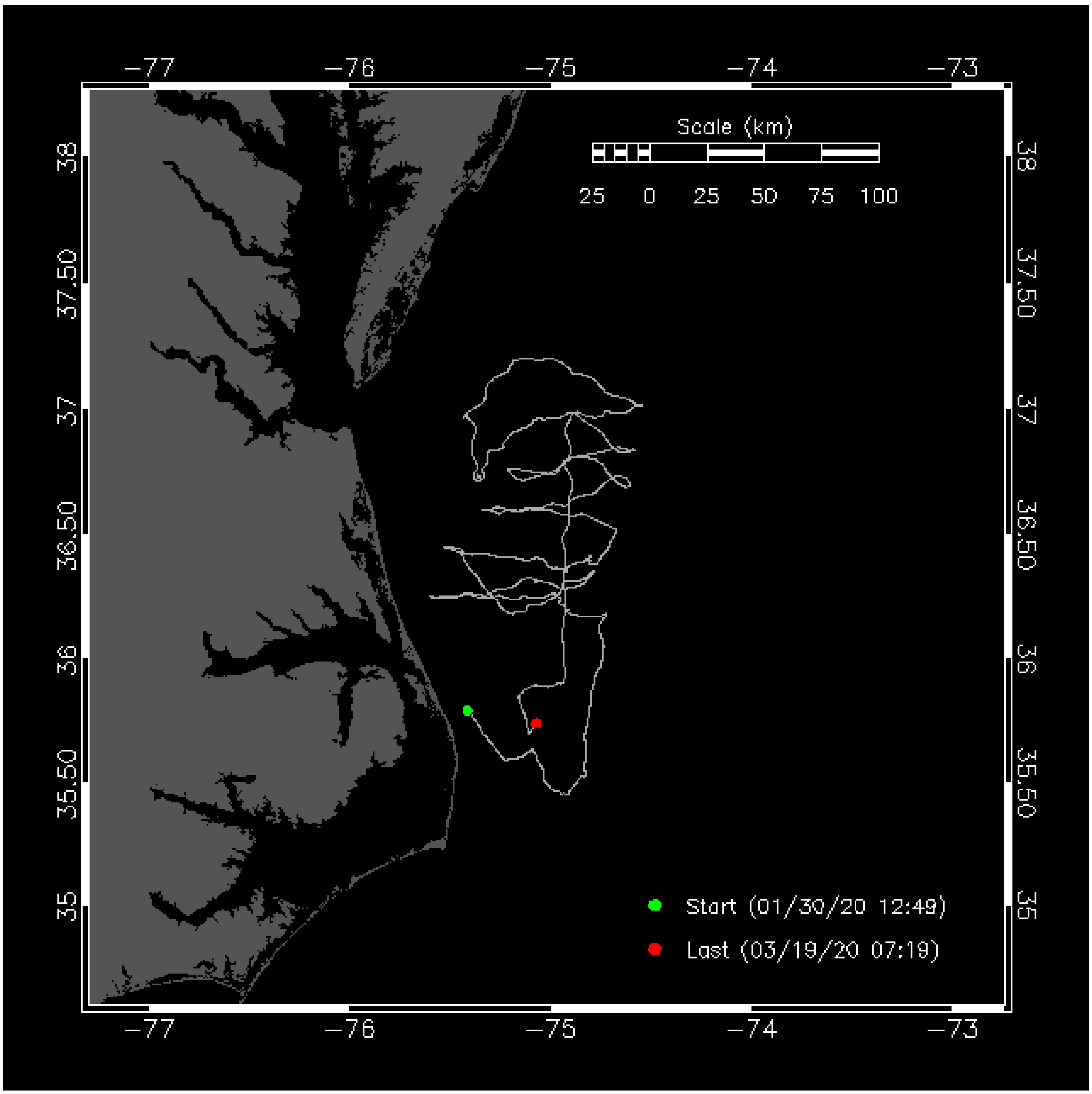

Figure 10. Map showing the trackline of the Slocum G3 glider deployed to the north of Cape Hatteras, North Carolina in January 2020.

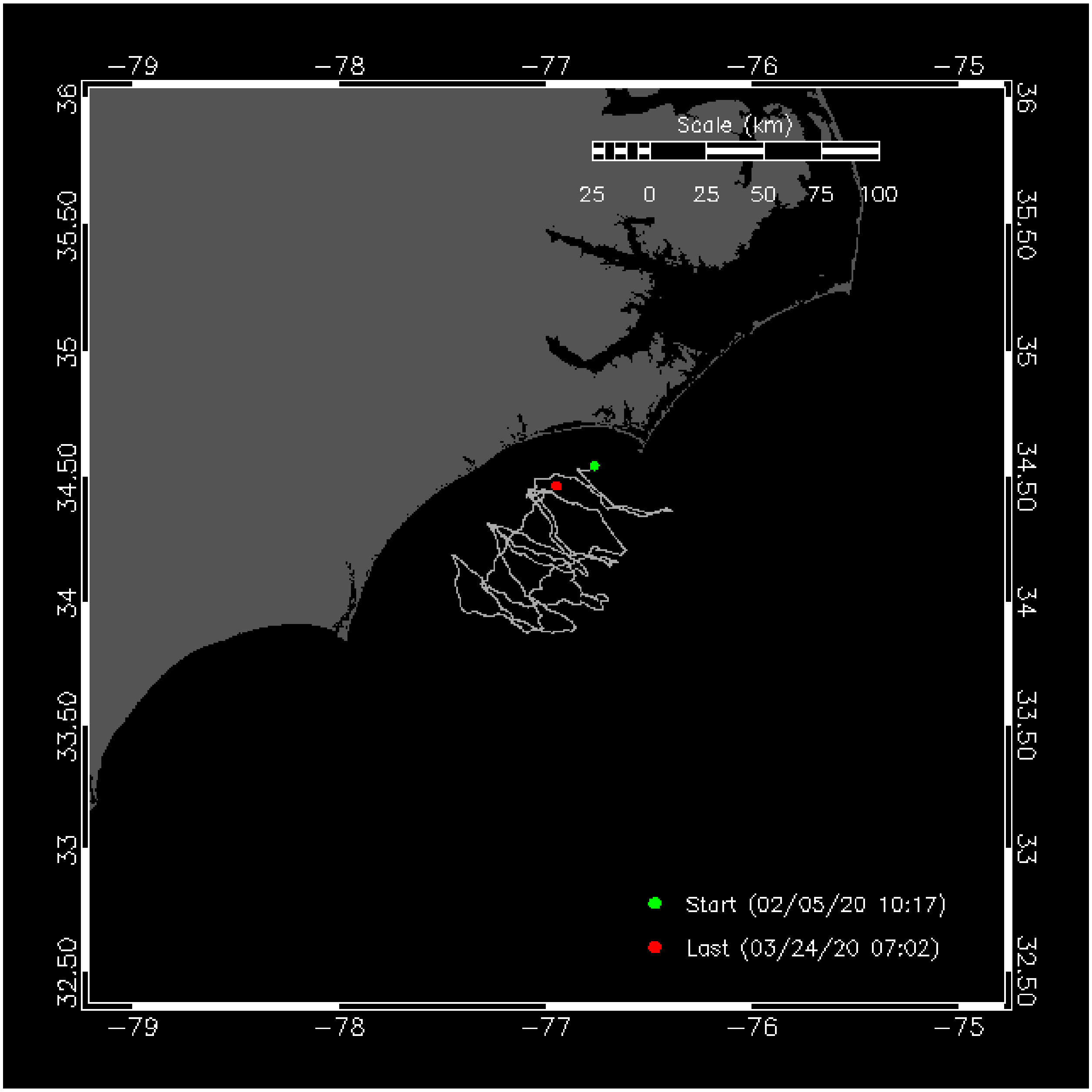

Figure 11. Map showing the trackline of the Slocum G3 glider deployed to the south of Cape Hatteras, North Carolina in February 2020.

Both gliders were deployed within one day of each other in late January 2019, and although winter storms tended to move the glider deployed to the north of Cape Hatteras off the pre-determined survey track, the instrument generally was able to stay in the study area and traverse across the shelf successfully. The glider deployed to the south of Cape Hatteras needed remote pilot intervention to avoid being caught in the powerful Gulf Stream currents. The maneuvers were successful, but the glider repeatedly made contact with the sea floor, which filled its nose cone with sediment, effectively disabling the acoustic altimeter housed in the nose.

The principal investigators successfully intercepted the instrument at sea in early February to clean the nose cone, and the unit was redeployed and able to complete the modified survey plan.

Sensor data from the gliders were relayed to shore every two hours and posted on the project's publically accessible website at Robots4Whales. Pressure, temperature, conductivity (to derive salinity measurements), chlorophyll fluorescence, and turbidity metrics were transmitted in near real time. The temperature and salinity observations clearly demonstrated the two environments in which the gliders were deployed, with the area north of Cape Hatteras much cooler and fresher, reflecting currents originating to the north along with the influence of cold slope waters sourced from north of the Gulf Stream wall. The area to the south of Cape Hatteras was much warmer and saltier, reflecting the strong influence from the Gulf Stream and coastal waters originating to the south. The digital acoustic monitoring instrument was programmed with the Low-frequency Detection and Classification System (Baumgartner and Mussoline 2011, Baumgartner et al. 2013) and is capable of detecting humpback, fin, and sei whales in addition to NARWs (**Figure 12**). Detection data were transmitted in near real time to shore where they were reviewed daily by trained personnel, and the results were posted on the project website, distributed to interested parties by automated email messages, and made available for display in the Whale Alert App.

Of the four baleen whale species monitored, humpback whales were the most commonly recorded on the northern glider. Fin whale detections were also fairly common, while sei whales were detected on a single occasion (**Figure 12**). There were three days with possible NARW calls, but no detections that fit the analysis protocol for "detected".

The southern glider had no detections or possible detections of sei or North Atlantic right whales on any day. Fin whales were detected on a single occasion, with several other "possible detections", but detections of humpbacks were the only detections classified as "detected" with high confidence (**Figure 13**). Both gliders were recovered in mid-March 2020, earlier than anticipated, due to general disruptions and travel restrictions caused by the beginning of the COVID-19 pandemic.

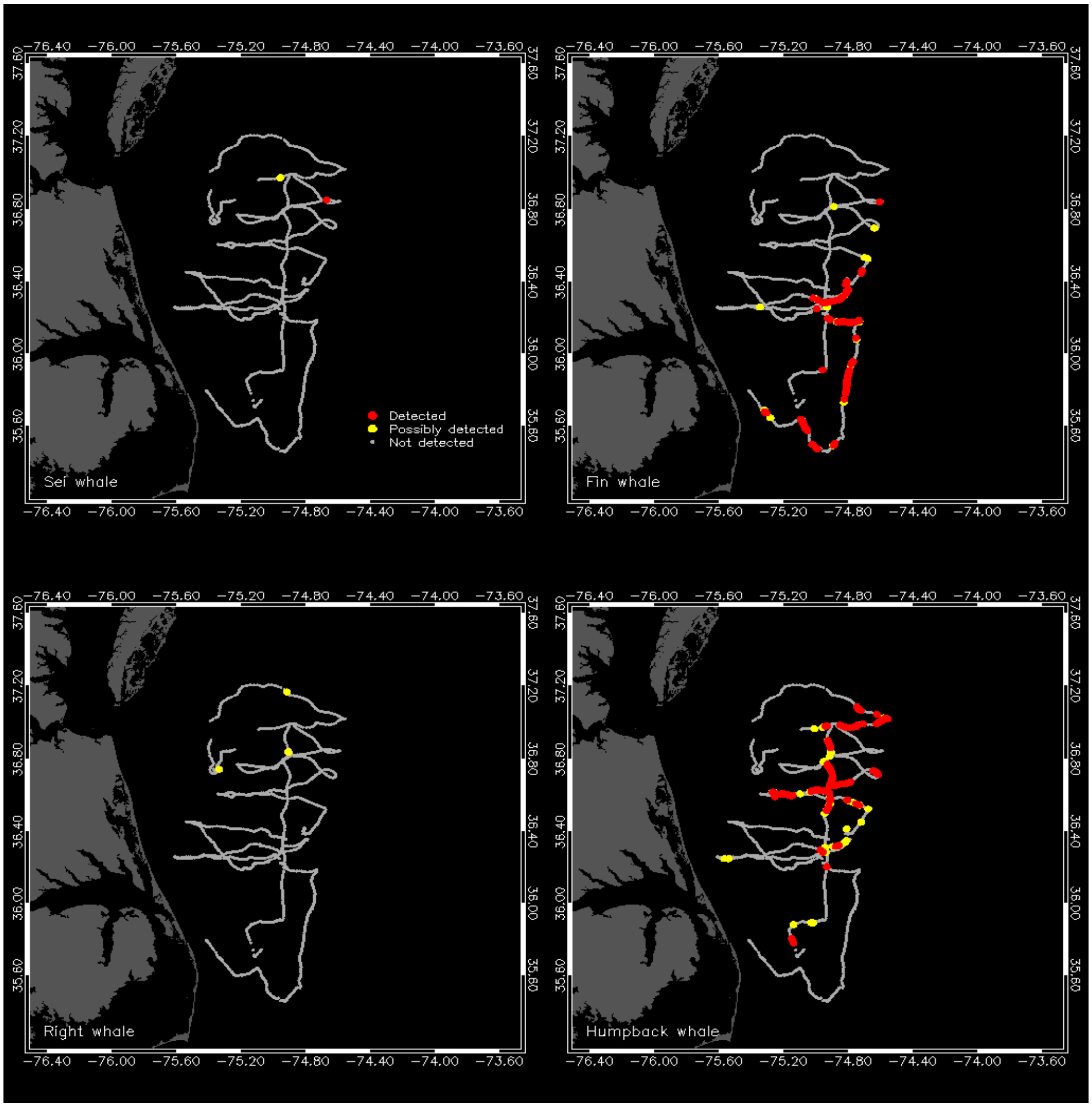

Figure 12. Near real-time acoustic detections from the northern Slocum G3 glider. Clockwise from the upper left are sei whales, fin whales, humpback whales, and North Atlantic right whales.

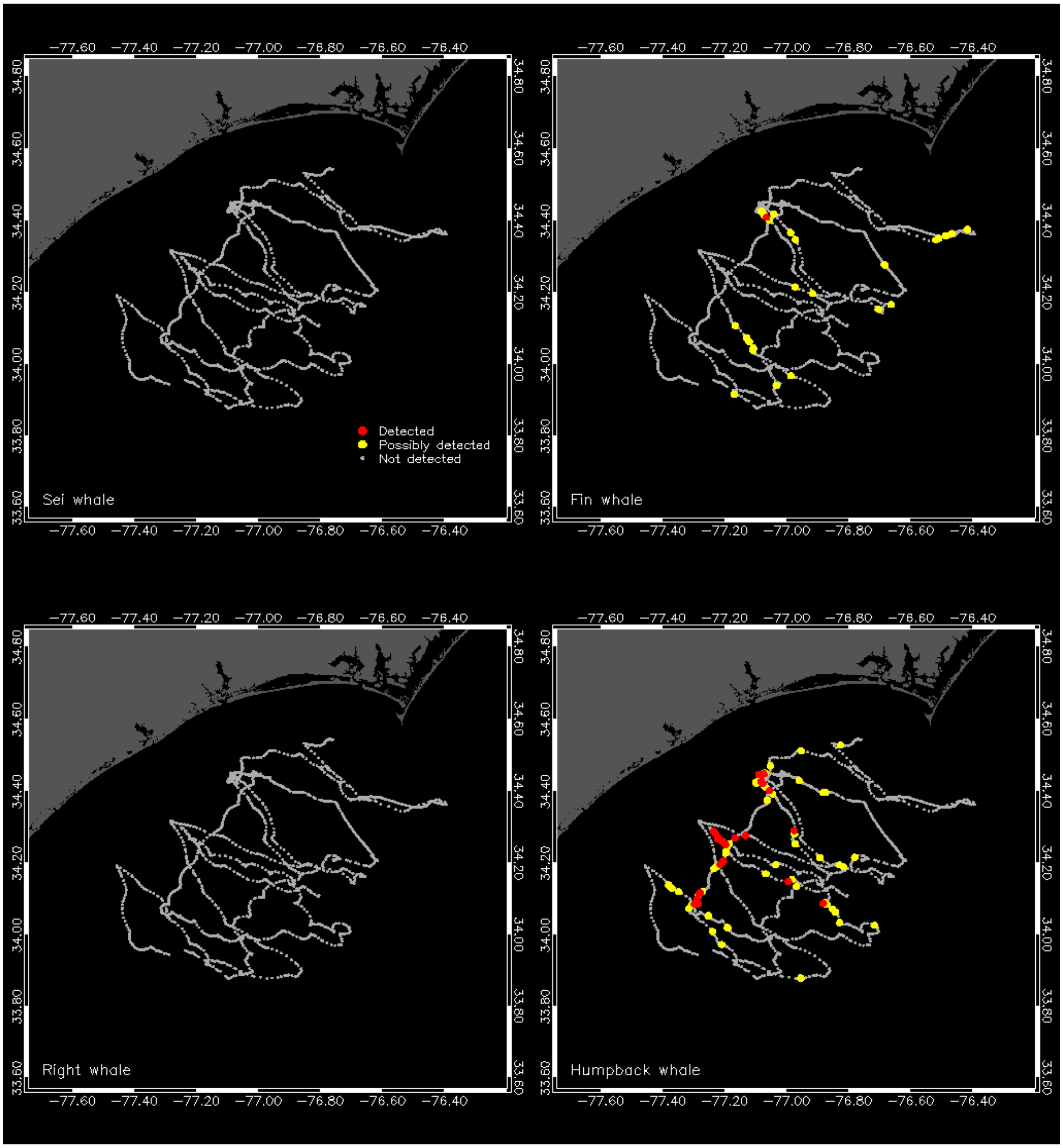

Figure 13. Near real-time acoustic detections from the Slocum G3 glider deployed to the south of Cape Hatteras, North Carolina.

2.2 Tagging Studies

During the reporting period, the U.S. Navy supported tagging fieldwork and associated analyses for odontocetes (**Sections 2.2.1 and 2.2.3**), baleen whales (**Sections 2.2.2 and 2.2.3**), pinnipeds (**Section 2.2.4**), and sea turtles (**Section 2.2.5**), in support of AFTT monitoring requirements.

2.2.1 Tagging of Deep-Diving Odontocete Cetaceans

In 2020, tagging activities were conducted off the coast of Cape Hatteras in association with the Atlantic BRS study (**Section 2.3**). These deployments built on the Deep Divers project that began in 2014 to develop a more robust picture of the medium-term movement patterns of deep-diving and other odontocete cetaceans off North Carolina. While the primary focus has been on Cuvier's beaked whales and short-finned pilot whales, a number of other species were tagged during the first 3 years of the Deep Divers project (Baird et al. 2015, 2016, 2017; Foley et al. 2017; Thorne et al. 2017). 2020 constituted the seventh year of tagging with a continued focus on the distribution and ecology of Cuvier's beaked whales and short-finned pilot whales. Satellite tagging has provided information on the spatial use and diving behavior of deep diving odontocetes over the medium term (weeks to months) (Baird et al. 2018). Shorter-term dive data (i.e., hours to days) can be collected using digital acoustic tags (DTAGs), and longer-term movement information (i.e., months to years) using photo-ID techniques (see **Section 2.1.1.1** of this report).

During May–August 2020, the fourth year of field effort was completed in support of the Atlantic BRS (**Section 2.3**). Satellite-tag deployments were conducted by researchers from Bridger Consulting Group in coordination with the Atlantic-BRS team aboard Duke University vessels. The Atlantic-BRS is a collaborative effort between Duke University, Southall Environmental Associates, and the University of St. Andrews—a Controlled Exposure Experiment (CEE) studying cetacean reaction to military sonar. The goal of this study was to deploy satellite tags prior to scheduled CEEs on the primary species, Cuvier's beaked whale and short-finned pilot whale. Given the CEEs and their potential influence on fine-scale movements and diving behavior, this section summarizes the satellite tag data, focusing on large-scale spatial use of tagged individuals as well as diving behavior prior to the CEEs. Detailed analyses of fine-scale movements and diving behavior in relation to the CEEs are summarized in **Section 2.3.1.2**.

Overall, 15 satellite tags were deployed—14 on Cuvier's beaked whales and one on a short-finned pilot whale (**Table 13**). The Douglas-filtered ARGOS locations and pseudo-tracks for all satellite-tagged Cuvier's beaked whales and short-finned pilot whales during the 2020 field season are shown in **Figure 14** and **Figure 15**, respectively. **Figure 16** (for Cuvier's beaked whale "ZcTag098") and **Figure 17** (for Cuvier's beaked whale "ZcTag107") show examples of all filtered location positions for the entire satellite-tag deployment periods for those given individuals. The figures also indicate the start and end locations of the respective CEEs conducted while the tag was transmitting on the animal. The tagged animals in the figures were exposed to three and two CEEs each, respectively.

A variety of analyses have been conducted (and are continuing) incorporating the satellite tag data spanning many years resulting in peer-reviewed publications on topics such as aerobic dive limits in (Quick et al. 2020), residency and movement patterns (Foley et al. 2021), and synchronous diving behavior of Cuvier's beaked whales (Cioffi et al. 2021). The results of these studies provide an important ecological and behavioral baseline to support assessment of behavioral responses and potential consequences to individuals, stocks, and populations.

Table 13. Summary of satellite tag deployments during Atlantic-BRS field efforts in 2020.

Species[1]/Tag ID	Deployment Date	Tag Duration (days)	Deployment Latitude (°N)	Deployment Longitude (°W)
ZcTag098	14-Jul-20	41	35.7686	74.7544
ZcTag099	17-Jul-20	19	35.6848	74.7443
ZcTag100	17-Jul-20	29	35.6473	74.7391
ZcTag101	07-Aug-20	66	35.5377	74.7551
ZcTag102	07-Aug-20	29	35.5230	74.7632
ZcTag103	08-Aug-20	32	35.4963	74.7512
ZcTag104[2]	08-Aug-20	0	35.4963	74.7295
ZcTag105	08-Aug-20	69	35.4937	74.7226
ZcTag106	08-Aug-20	64	35.4895	74.7523
ZcTag107	09-Aug-20	68	35.6507	74.7451
ZcTag108	09-Aug-20	56	35.6558	74.7350
ZcTag109	10-Aug-20	55	35.5216	74.7244
ZcTag110	10-Aug-20	85	35.5112	74.7304
ZcTag111	10-Aug-20	69	35.4990	74.7544
GmTag223	14-Jul-20	68	35.7703	74.7084

[1] Zc = *Ziphius cavirostris* (Cuvier's beaked whale); Gm = *Globicephala macrorhynchus* (short-finned pilot whale)

[2] Tag failed on deployment

Two DTAGs were deployed on Cuvier's beaked whales during the 2020 field effort (**Table 14**). The first was deployed on 18 August on an individual ("Zc20_231a") within a group in which another whale was being simultaneously tracked with a satellite-transmitting tag, with the intention of tracking the individual overnight for a long-duration deployment prior to a CEE on the following day. The field team successfully tracked the whale through the night from the Research Vessel (R/V) *Shearwater* and prepared for a CEE the following day, although it was ultimately conducted after the tag had detached. This tag offered great promise for insight into baseline (no known exposure), fine-scale, overnight behavioral data, including insight regarding behavioral synchrony with the satellite tagged whale. Unfortunately, multiple failures were experienced with the movement and acoustic sensors and no usable data were able to be recovered despite extensive effort. Fortunately, another DTAG was deployed on a Cuvier's beaked whale ("Zc20_232a") and the animal was tracked during a pre-exposure baseline period, following which CEE #2020_03 was conducted with the simulated MFAS source.

Table 14. DTAG deployments for Cuvier's beaked whales during Atlantic-BRS field efforts in 2020.

Species[1]/Tag ID	Deployment Date	Deployment Latitude (°N)	Deployment Longitude (°W)	Baseline or CEE Number	Tag Duration	Recovered?
Zc20_231a	18-Aug-20	35.5250	74.6270	Baseline	23 hours	Yes
Zc20_232a[2]	19-Aug-20	35.5450	74.7047	CEE #2020-03	6 hours	Yes

[1] Zc = *Ziphius cavirostris* (Cuvier's beaked whale)

[2] In group with satellite tagged Zc108 during CEE #2020-03

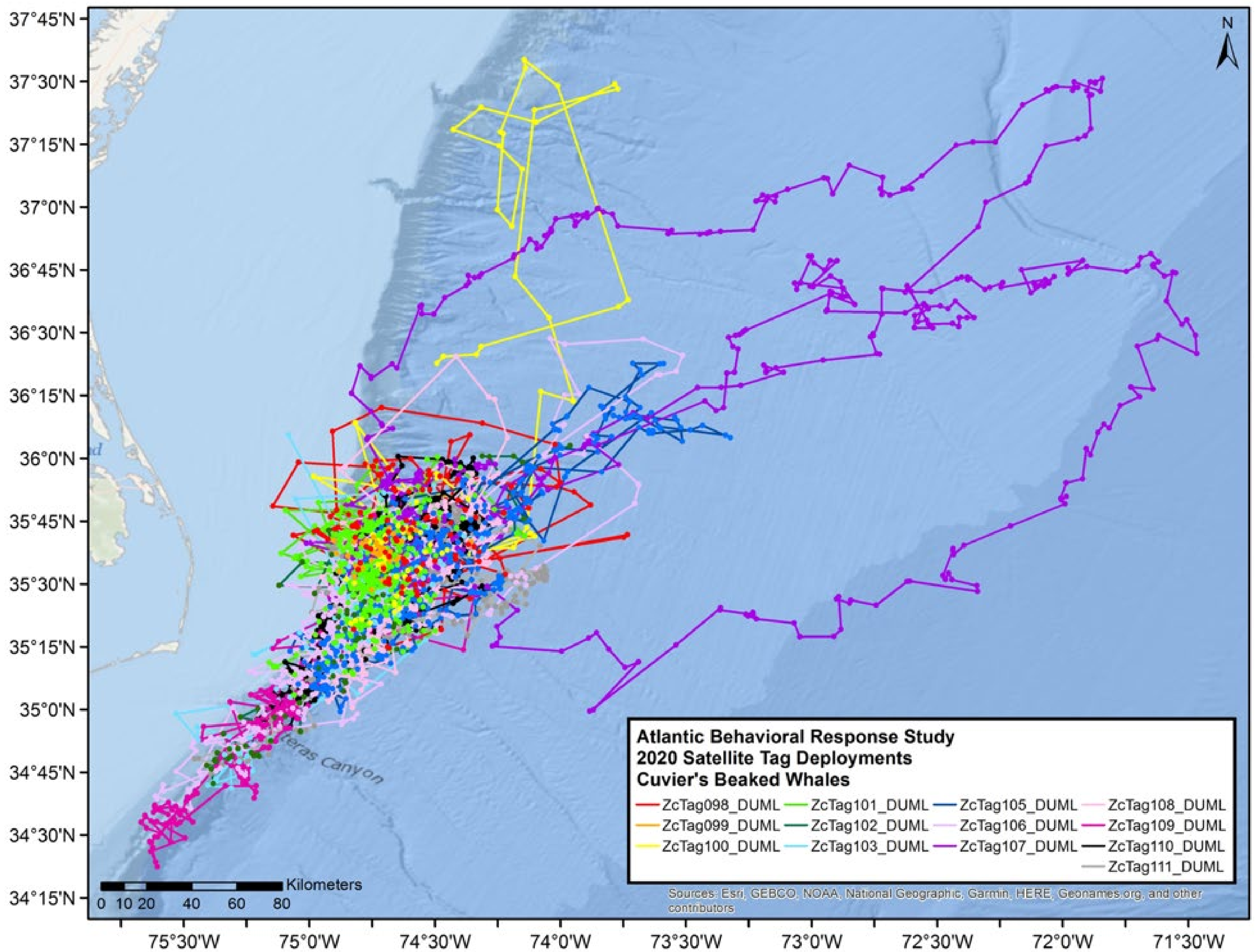

Figure 14. Douglas-filtered ARGOS positions and trackline for all 14 Cuvier's beaked whale satellite tag deployments in 2020.

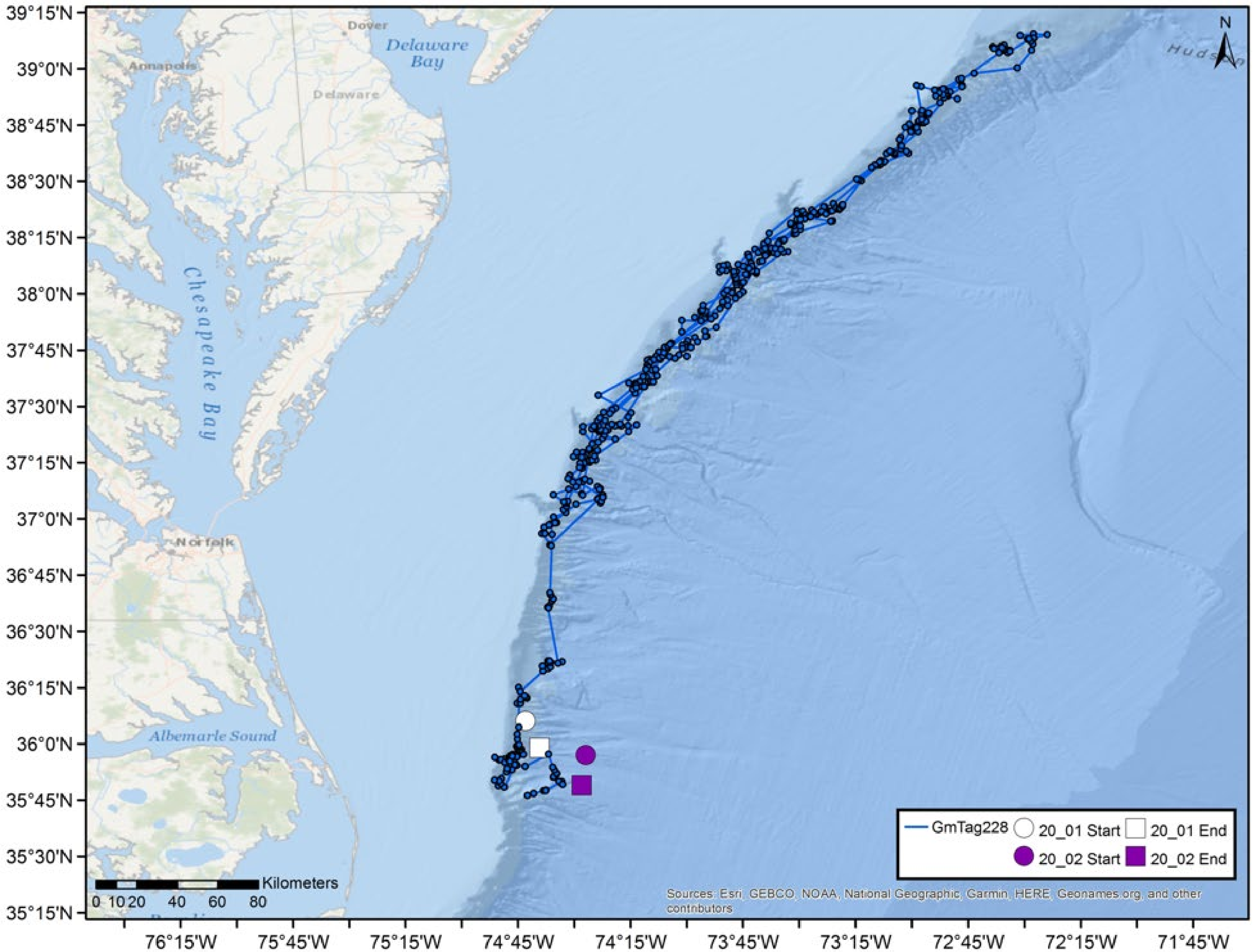

Figure 15. Douglas-filtered ARGOS positions and trackline for the single short-finned pilot whale ("GmTag228") satellite-tagged in 2020 and showing positions of two CEEs conducted while the tag was deployed.

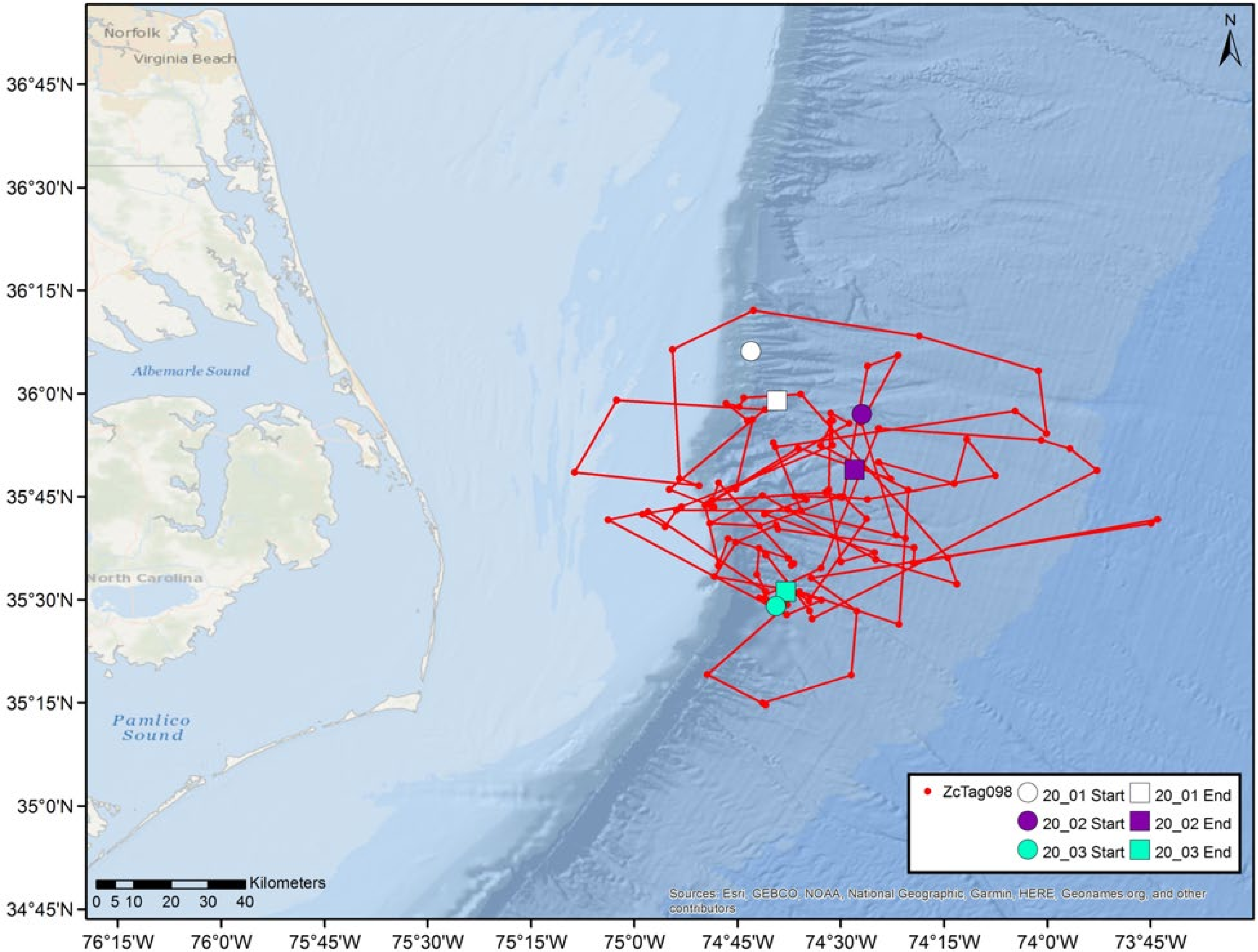

Figure 16. Douglas-filtered ARGOS positions and trackline for entire track of "ZcTag098," showing positions of three CEEs conducted while the tag was deployed.

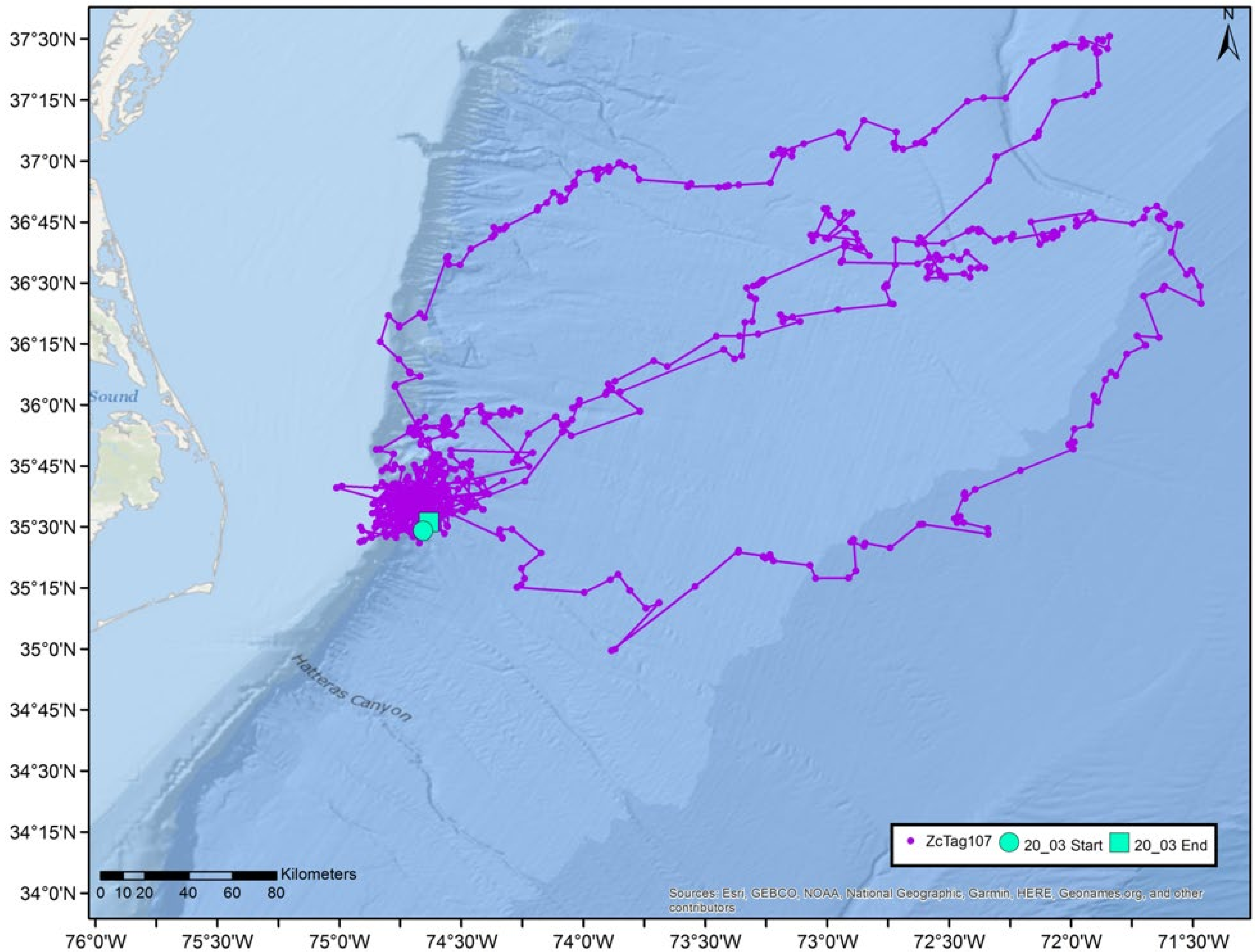

Figure 17. Douglas-filtered ARGOS positions and trackline for entire track of "ZcTag107," showing positions of CEE conducted while the tag was deployed.

2.2.2 Mid-Atlantic Humpback Whale Monitoring

During the winter, humpback whales migrate to the West Indies from feeding grounds in the Gulf of Maine, the Gulf of St. Lawrence, Newfoundland/Labrador, western Greenland, Iceland, and Norway (Katona and Beard 1990, Christensen et al. 1992, Palsbøll et al 1997). However, some whales overwinter in the mid-Atlantic region, which may serve as a supplemental feeding ground (Barco et al. 2002). Information on the movements of individuals within this region, particularly in U.S. Navy training ranges and high-traffic areas in the Chesapeake Bay and mid-Atlantic coastal waters, has historically been limited (see Swingle et al. 1993, Wiley et al. 1995, Barco et al. 2002).

Since January 2015, HDR Inc. has been monitoring humpback whales to assess their occurrence, habitat use, and behavior in and near U.S. Navy training and testing areas off Virginia. These baseline data are critical for assessing the potential for disturbance to humpback whales in this portion of the mid-Atlantic. Although humpback whales are the target of this study, data on other high-priority baleen whale species are collected when possible.

Dedicated surveys began in January 2015 when vessel and aerial surveys were conducted in conjunction with photo-ID, focal-follow, and biopsy-sampling techniques to obtain baseline data on humpback whales in the region (Aschettino et al. 2015). Data from that field season also included humpback whale sightings recorded during concurrent line-transect surveys in December 2014 (Engelhaupt et al. 2016). The 2015/16 field season (December 2015–May 2016) consisted only of nearshore vessel surveys to collect biopsy samples of humpback whales, as well as photo-ID and focal-follow data from humpback whales and other high-priority baleen whale species, particularly in U.S. Navy training areas (e.g., W-50 Mine-neutralization Exercise [MINEX] zone) and shipping channels (Aschettino et al. 2016). Wildlife Computers (Redmond, Washington) Smart Position and Temperature (SPOT)-6 Argos-linked satellite tags were deployed during that field season to better understand the movement patterns of humpback whales off Virginia Beach, specifically in areas of high shipping traffic and live-fire exercises. Research efforts since the 2016/17 field season have included the use of nearshore vessel surveys to collect photo-ID data and biopsy samples and to deploy both SPOT-6 and SPLASH10-F Fastloc® Global Positioning System (GPS) tags (Aschettino et al. 2017, 2018, 2019, 2020b). The 2018/19 and 2019/20 seasons also included collaboration with Duke University examining the response of humpbacks to approaching ships (see **Section 3.2.2**).

Survey Effort

HDR conducted 15 nearshore vessel surveys for humpback whales between 21 December 2019 and 27 March 2020. Over 99 hours of survey effort were completed and 1,382 kilometers (km) of trackline were covered (**Figure 18**). The 2020/21 season began on 19 November 2020 and is still underway at the time of this report.

Sightings

A total of 44 sightings of humpback whales was recorded during the 2019/20 survey season. Additional baleen whale sightings included two minke whale sightings (*Balaenoptera acutorostrata*) and one fin whale (**Figure 18**). Thirty (63.8 percent) of the 47 total large whale sightings were in the shipping lanes, although HDR's survey effort for the 2019/20 season focused largely on this area due to a multi-tagging collaboration effort with Duke University. Sightings of non-target species (i.e., common bottlenose dolphins) were also recorded but are not presented here.

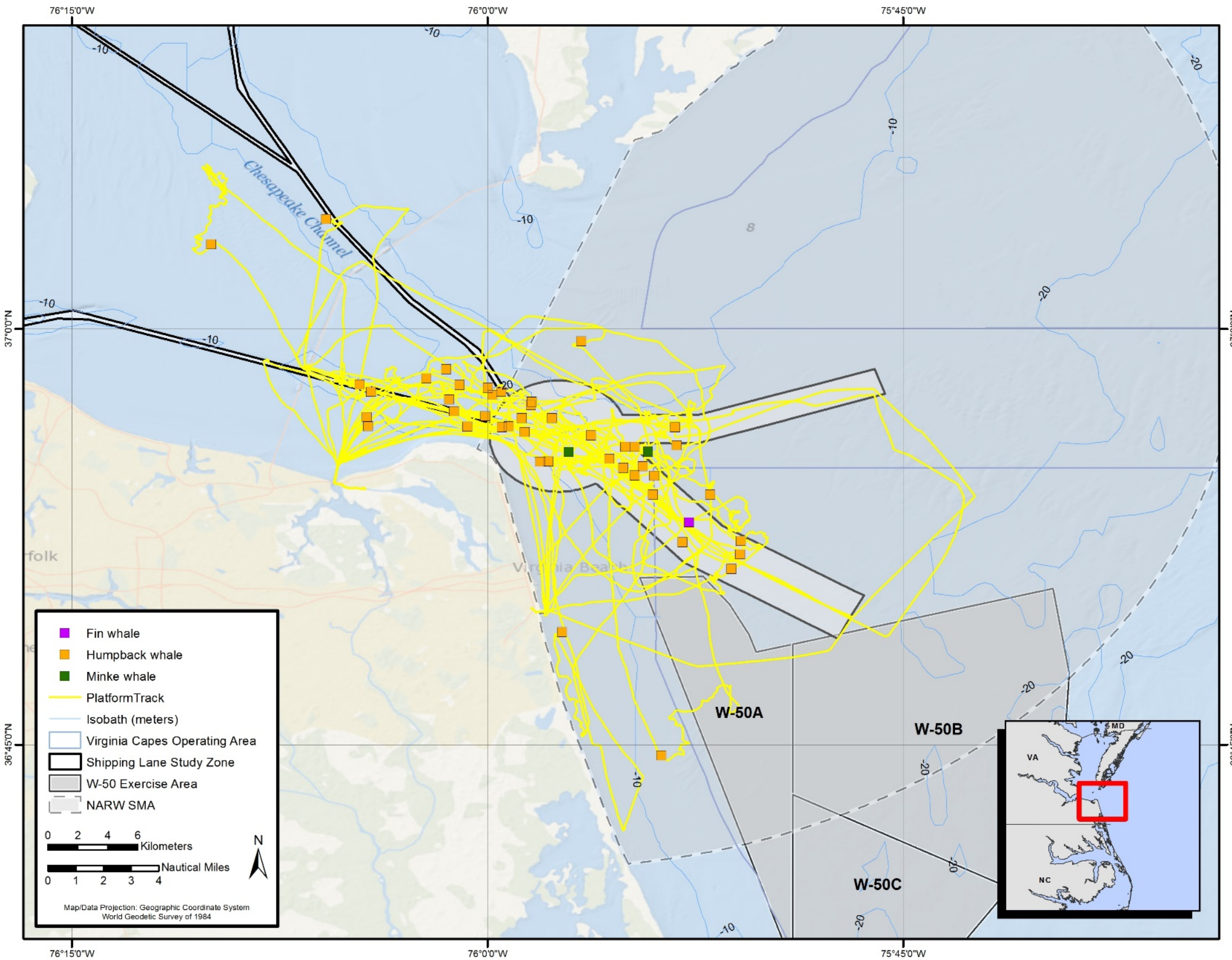

Figure 18. Nearshore survey tracks and locations of all humpback (*n*=44), minke (*n*=2), and fin (*n*=1) whale sightings for the 2019/20 field season.

Photo-identification

The 44 sightings of humpback whales included 60 total individuals and resulted in 28 unique humpback whales identified using dorsal fin and fluke images for the season. Fifteen (53.6 percent) of those unique whales were categorized as juveniles based on their estimated size and the remaining 13 (46.4 percent) were categorized as sub-adults or adults. Only four (14.3 percent) of the 28 individuals were re-sights to HDR's catalog; three individuals had been seen in four of the last five seasons (HDRVAMn007, HDRVAMn021, and HDRVAMn064) and one individual had been seen in three of the last five seasons (HDRVAMn093). The remaining 24 whales were new individuals added to HDR's growing catalog, which, to date, has 182 unique humpback whales (inclusive of identifications added from the Outer Continental Shelf Break Cetacean Study (see **Section 2.2.3**) (**Figure 19**). Twelve of the 28 (42.9 percent) humpback whales were seen on more than one occasion during the 2019/20 field season, which is similar to the previous season (44.7 percent), greater than the 2017/18 season (21.9 percent), and fewer than the 2016/17 season (69.5 percent).

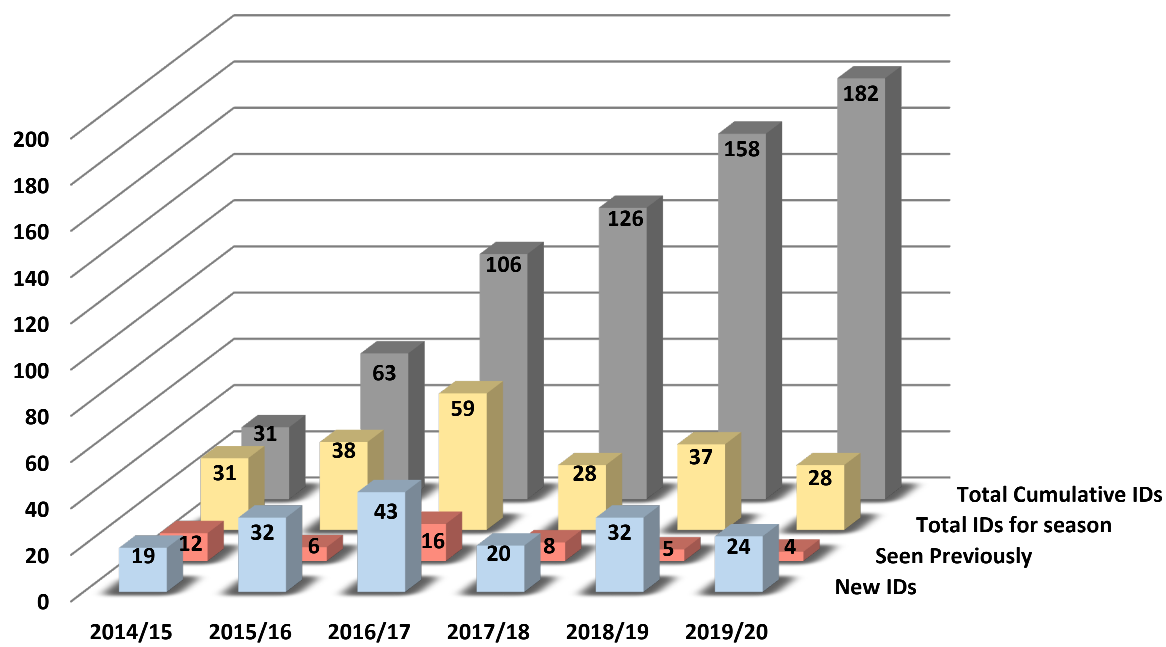

Figure 19. Humpback whale identifications over six seasons with the yellow bars indicating the total number of IDs for the season, red bars indicating the number of those IDs that were seen in previously seasons, and blue bars indicating the number of new IDs added to the catalog. Gray bars indicate the total number of cumulative unique IDs.

Between December 2018 and June 2020 drone video was collected on numerous humpback whales. In the field, live video was used to assist the research team in assessing overall body condition and during tagging attempts to maximize successful deployments. A DJI Phantom 4 Pro V2.0 was used to collect morphometric data. Data were typically collected at flight heights between 15 and 30 m, depending on the behavior of the focal animal during the time of the encounter. The drone collected 4K UHD video at 30 frames per second. Measurements were made from data using altitude values from the drone's stock barometer, although some error is expected with this method. Open-source software developed by researchers at Duke University (Torres and Bierlich 2020) was used to calculate lengths of 30 individual humpback whales. Each of these whales has a unique ID in the HDR humpback catalog and had previously been assigned an age-class based on subjective size assessments from the research vessel platform. The measured humpbacks ranged in size from 6.9 to 10.1 meters (m) in total length, with a mean value of 8.5 m and a median length of 8.6 m. All whales that measured 9.8 m or greater (*n*=6) had been classified as sub-adults or adults in the field. All but one of the whales that measured 8.7 m or less (*n*=17) had been classified as juveniles in the field. Whales that ranged from 8.7 to 9.6 m (*n*=7) were classified as either juvenile (*n*=2), juvenile/sub-adult (*n*=1), sub-adult (*n*=3), or sub-adult/adult (*n*=1) in the field. To continue collecting consistent imagery data with exact altimetry measurements, as well as transitioning to a DoD-compliant platform following recent 2020 National Defense Authorization Act restrictions, HDR is acquiring a new American-made sUAS with improved capabilities such as a LiDAR sensors, longer flight times, and a higher resolution camera.

Biopsy Samples

Seven biopsy samples were collected from humpback whales during the 2019/20 season and are awaiting analysis along with samples collected during the previous field seasons. Thirty-one samples (29 humpback and two fin whale samples) from 2014 to 2016 were also processed for stable-isotope analysis. The stable-isotope signatures for all samples were comparable to those reported for other regions of the North Atlantic (Waples 2017). There were significant differences in both $\delta^{13}C$ and $\delta^{15}N$ values between the humpback and fin whales in the study area. The humpback whales were slightly more depleted in carbon and had significantly higher $\delta^{15}N$ signatures than the fin whales. The humpback whales had a mean $\delta^{15}N$ value of 14.6 (standard error [*SE*]=0.9) compared to the fin whales' value of 10.5 (*SE*=0.0).

Given a difference in $\delta^{15}N$ values between the two species, it is likely that the humpback whales are feeding at a higher trophic level than the fin whales in this area (Waples 2017). Genetic analyses identified 14 female and 15 male humpback whales from these samples. There were no significant differences in $\delta^{13}C$ values between male and female humpback whales, but females did have significantly lower $\delta^{15}N$ values than males, indicating that the diets of the two sexes may differ in this area (Waples 2017). These biopsy samples have also been provided to the University of Groningen in the Netherlands for genetic analysis and integration into a larger North Atlantic humpback whale population study. Gender results have been provided and have shown roughly equal sex ratios of humpback whales (32 ♂ and 31♀) and a skewed gender ratio of 6:1 (males vs female) for fin. Genetic matching to the larger North Atlantic humpback whale catalog will take place in early 2021 and results should be available by the summer of 2021.

Tagging

Nine SPLASH10-F Argos-linked satellite tags were deployed on humpback whales during the 2019/20 field season and one SPLASH10 tag was deployed on a fin whale (**Table 15**). The tags transmitted between 2.7 and 39.9 days (mean=12.7 days). Whales tagged during this field season showed varied movement patterns, with some exclusively spending time in the primary study area and others moving out of the study area and farther offshore or to the north or south (**Figure 20**). Two individuals, HDRVAMn186 and HDRVAMn187 moved well into the Chesapeake Bay and in the case of HDRVAMn187, spent 24 days in this area moving as far as 74 km into the Bay during the nearly 40-day deployment (**Figure 21**). The fin whale, HDRVABp086, was tagged just north of the W-50 MINEX region and spent some time in the primary study zone before working north and into the mouth of the Delaware Bay before looping offshore and back off the eastern shore of Virginia (**Figure 22**).

Table 15. Satellite-tag deployments on humpback whales during the 2018/2019 field season.

Animal ID	Estimated Age Class	Tag Type	Argos ID	Deployment Date	Last Transmission Date	Tag Duration (Days)
HDRVAMn093	Juvenile	SPLASH10-F	173232	28-Dec-19	31-Dec-19	2.7
HDRVAMn166	Juvenile	SPLASH10-F	178208	28-Dec-19	05-Jan-20	7.6
HDRVAMn172	Sub-Adult/Adult	SPLASH10-F	177052	15-Jan-20	24-Jan-20	8.4
HDRVAMn173	Juvenile	SPLASH10-F	177053	03-Feb-20	13-Feb-20	9.5
HDRVAMn175	Juvenile	SPLASH10-F	179197	03-Feb-20	18-Feb-20	14.8
HDRVAMn177	Juvenile	SPLASH10-F	180779	08-Feb-20	19-Feb-20	10.8
HDRVAMn184	Juvenile	SPLASH10-F	180778	18-Feb-20	27-Feb-20	8.7
HDRVAMn187	Juvenile	SPLASH10-F	180780	01-Mar-20	12-Mar-20	10.6
HDRVAMn186	Juvenile	SPLASH10-F	180781	04-Mar-20	13-Apr-20	39.9
HDRVABp086	Sub-Adult/Adult	SPLASH10	177047	08-Feb-20	23-Feb-20	14.7

In January 2019, Duke University researchers initiated a concurrent tagging project on whales around the shipping lanes in the Chesapeake Bay study area. High-resolution DTAGs were deployed on overwintering humpback whales to better understand the factors that influence their responses to approaching vessels. More information about this project can be found in **Section 2.3.2**.

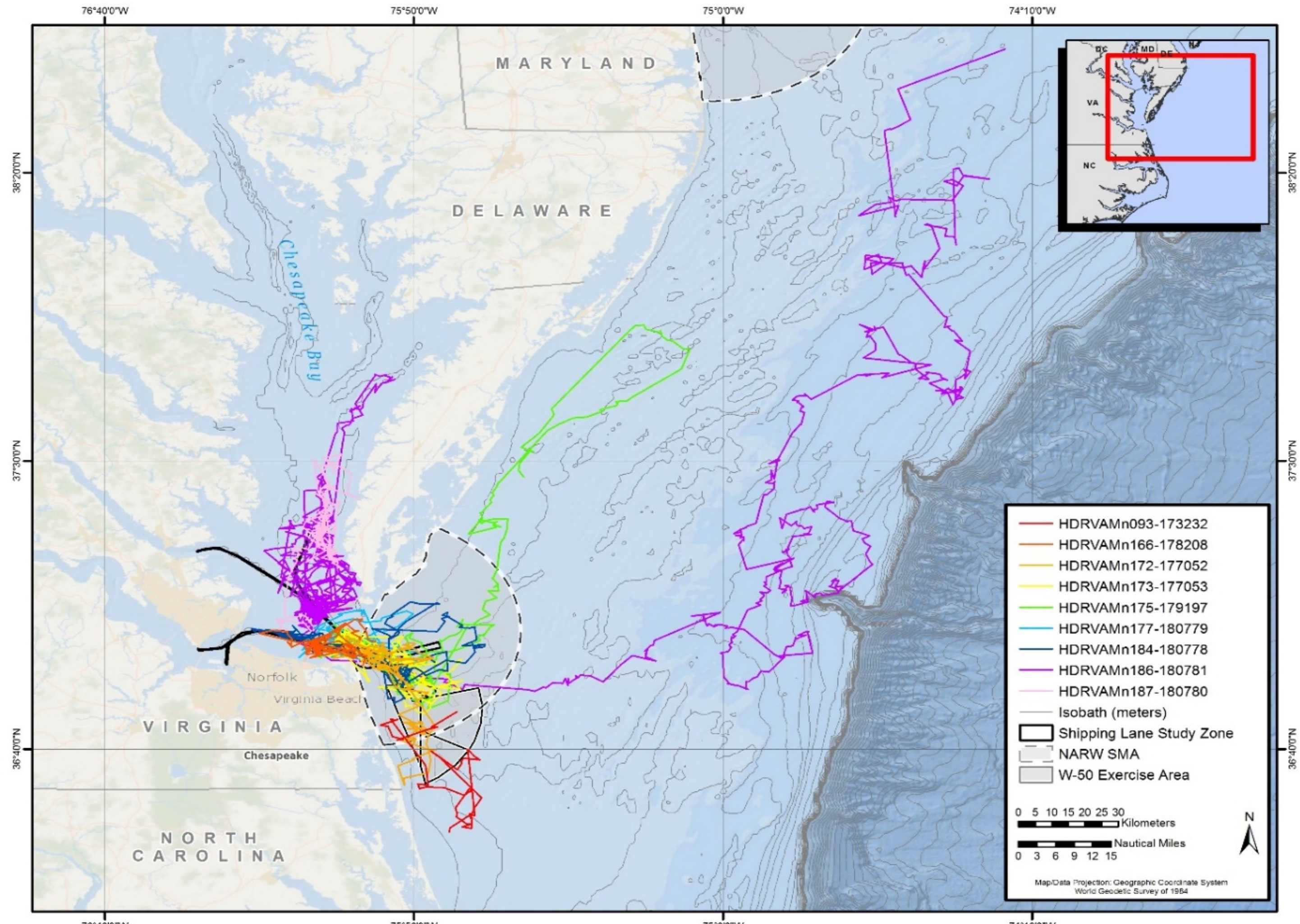

Figure 20. Argos trackline for all humpback whales (*n*=9) tagged during the 2019/20 field season.

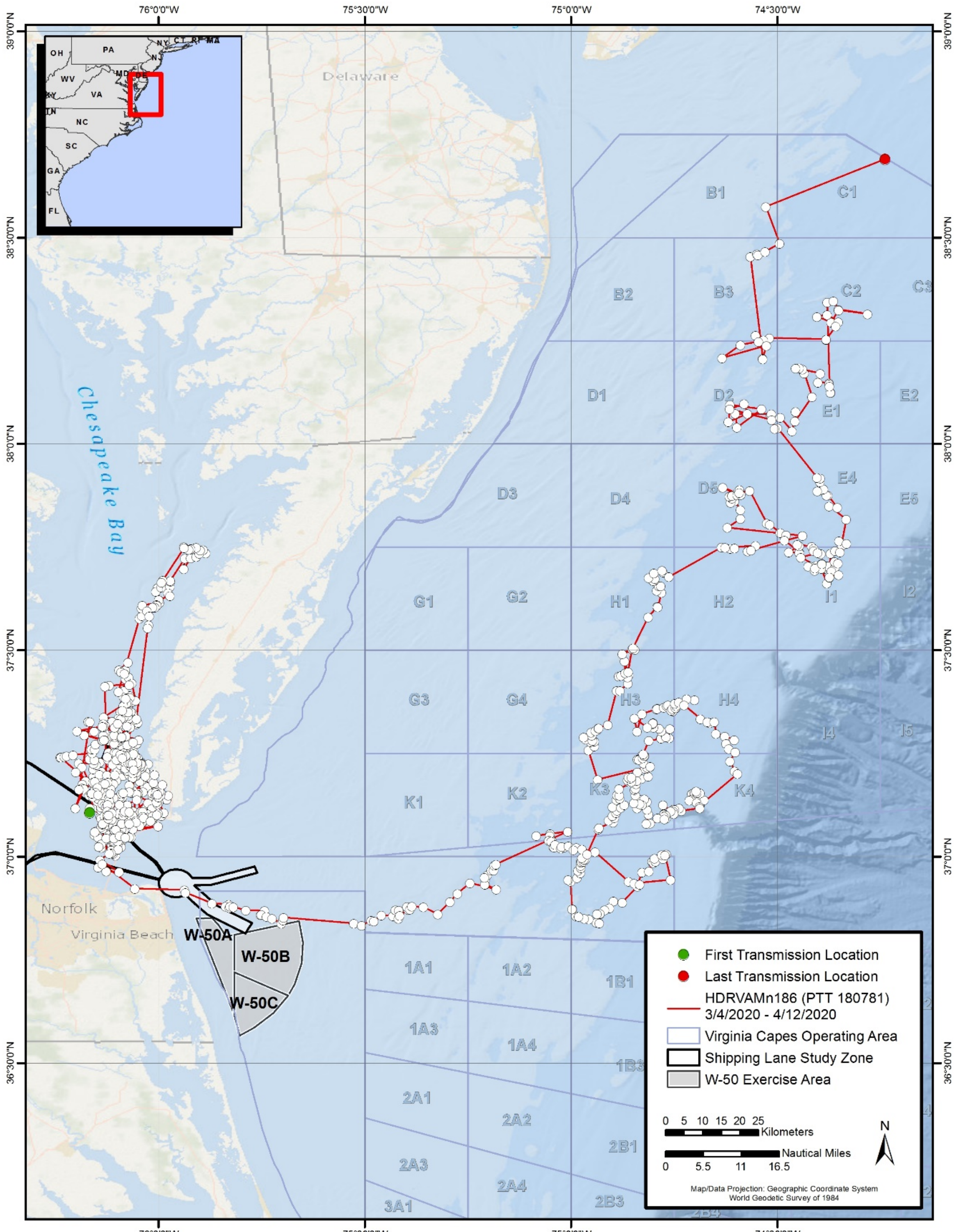

Figure 21. Argos locations and trackline of satellite-tagged humpback whale (HDRVAMn186) 04 March–12 April (39.9 days).

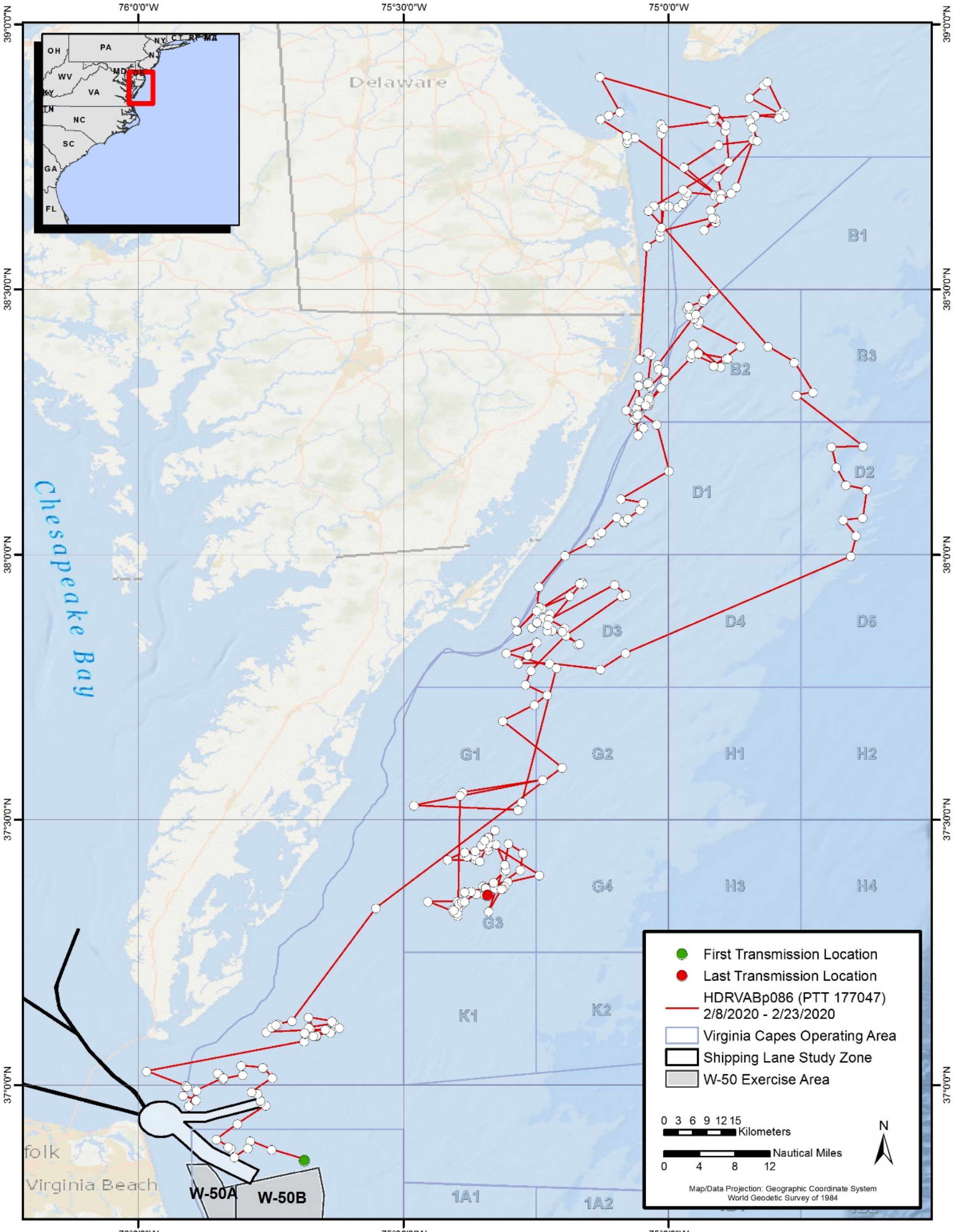

Figure 22. Argos locations and trackline of satellite-tagged fin whale (HDRVABp086) 08–23 February 2020 (14.7 days).

Results

Data analyses for this study are ongoing. Results to-date indicate some site fidelity to the study area for individuals during a season and a high level of occurrence within the shipping channels, which are important high-use areas for both the U.S. Navy and commercial traffic. A smaller number of animals are also spending time in or near the W-50 MINEX zone and the broader offshore Virginia Capes Range Complex (VACAPES) OPAREA, where they are presumably within the hearing range of underwater detonation training exercises. Vessel interactions in the study area are still a concern for humpback whales. Nearly ten percent of the individual humpback whales in the catalog have scars or injuries indicative of propeller or vessel strikes or from line entanglements. Throughout this study, individual humpback whales have been observed with boat injuries or have been found dead with evidence of vessel interactions being the likely cause. In April 2017, NMFS declared an Unusual Mortality Event for humpback whales in the Atlantic from Maine to North Carolina based on elevated mortalities of this species since January 2016. Some of the whales examined thus far have exhibited evidence of pre-mortem vessel strike, but the Unusual Mortality Event investigation process is ongoing.

Approximately three-quarters of the humpback whales seen throughout this project appear to be juveniles, which is consistent with historic stranding and observational data collected in this area (e.g., Swingle et al. 1993, Wiley et al. 1995). Sightings of sub-adult-sized humpback whales have been highest early in the field seasons and in waters farther from shore. They typically are not re-sighted during a field season, suggesting that these whales may be passing through the area rather than remaining in the primary study area for long durations. Because the juveniles are spending more time in the study area than larger animals, they may be at greater risk for injury (Aschettino et al. 2018). A manuscript with details from the first three years of effort was published in a special issue on the “Impacts of Shipping on Marine Fauna” in *Frontiers in Marine Science* (Aschettino et al. 2020a).

For more information on this study, refer to the annual progress report for this project (Aschettino et al. 2021).

2.2.3 VACAPES Outer Continental Shelf Break Cetacean Study

HDR has collaborated with the U.S. Navy to conduct marine mammal surveys near Naval Station Norfolk, Joint Expeditionary Bases-Little Creek and Fort Story, and Naval Air Station Oceana Dam Neck Annex, and within the W-50 MINEX zone since 2012 (Engelhaupt et al. 2016). However, limited survey effort has previously occurred farther offshore of the Virginia coast—in the VACAPES OPAREA near the continental shelf break. Therefore, there are limited data and information on how offshore species, including beaked whales, endangered fin and sperm whales, and other large baleen whales utilize the deeper waters of this region. Vessel surveys for the VACAPES Outer Continental Shelf Cetacean Study were initially conducted from April 2015 through June 2016 in association with the Mid-Atlantic Humpback Whale Monitoring project (Aschettino et al. 2016) and became a dedicated study in July 2016 (Engelhaupt et al. 2017), followed by a second dedicated year of surveys through all of 2017 (Engelhaupt et al. 2018), third year through all of 2018 (Engelhaupt et al. 2019a), and fourth year for 2019 (Engelhaupt et al. 2020a). The goal of this study is to determine the seasonal occurrence, movement patterns, site fidelity, behavior, and ecology of cetaceans in VACAPES OPAREA offshore waters. During the vessel surveys, researchers utilize a combination of techniques including focal follows, photo-ID, biopsy sampling, unmanned aircraft systems, and satellite-linked telemetry tags. Activities conducted during the 2020 field season are summarized below and detailed in Engelhaupt et al. 2021.

Survey Summary

The study area is located approximately 90 to 160 km off the Virginia coast, encompasses Norfolk and Washington Canyons, and ranges in depth from less than 100 m to over 2,000 m. Although surveys were limited in 2020 due to COVID-19 pandemic restrictions and weather conditions, HDR conducted seven offshore vessel surveys covering 2,263 km of trackline.

Totals of 140 marine mammal sightings and 8 sea turtle sightings were recorded during vessel surveys (**Figure 23**). Ten cetacean taxa were identified (in order of decreasing frequency): unidentified pilot whale (*Globicephala* sp.) (*n*=54), common bottlenose dolphin (*n*=28), common dolphin (*n*=15), Risso's dolphin (*n*=8), fin whale (*n*=7), sperm whale (*n*=3), Atlantic spotted dolphin (*n*=2), short-finned pilot whale (*n*= 2), Cuvier's beaked whale (*n*=2), True's beaked whale (*n*=1), and minke whale (*n*=1). In addition, there were 17 sightings of unconfirmed species: unidentified dolphin (*n*=13), unidentified medium whale (*n*=2), unidentified cetacean (*n*=1), and unidentified beaked whale (*n*=2). Two sea turtle taxa were identified: loggerhead turtle (*Caretta caretta*) (*n*=6) and leatherback turtle (*Dermochelys coriacea*) (*n*=1), with one unconfirmed species: unidentified hardshell turtle (*n*=1). Given the study's focus on priority species that do not include pilot whales, combined with the challenge of identifying the genus *Globicephala* down to species from a distance, most pilot whale groups were classed as unidentified pilot whales.

As expected, sightings of deep-diving species, including sperm whales, pilot whales, and beaked whales, were concentrated near and offshore of the continental shelf-break and in the Norfolk Canyon area. Baleen whale sightings were recorded both over and offshore of the shelf, although again, a greater proportion occurred offshore in 2020 and 2019 compared to 2018. Coverage during 2020 continued to include more time in waters deeper than 1,500 m than in preceding seasons, focusing on locating priority deep-diving sperm whales and beaked whales for tagging efforts. Dolphin species were sighted throughout the core study and transit areas, and sea turtles were only sighted over the shelf. Marine mammal sightings in U.S. Navy ranges in and around the Norfolk Canyon were frequent, showing the potential for overlap between these species and U.S. Navy training activities, as well as recreational and commercial fishing activities.

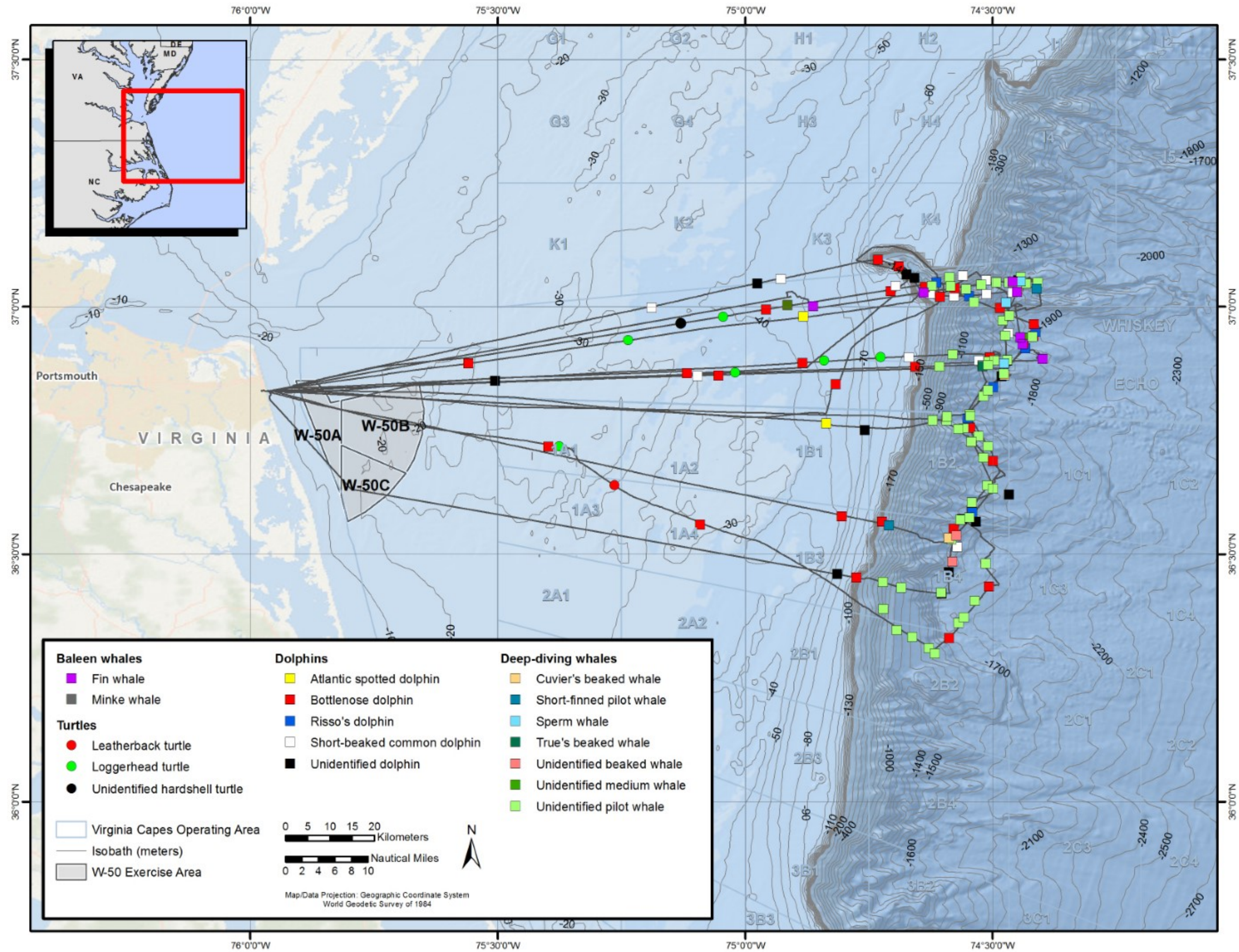

Figure 23. All tracklines and sightings of marine species for field work conducted in 2020.

Photo-ID

Photo-ID images were collected during 38 of the 140 marine mammal sightings. Baleen, sperm, and beaked whale images were added to HDR's existing catalogs, which now contain 89 fin whales, 10 minke whales, 6 North Atlantic right whales, 2 sei whales, 95 sperm whales, 8 Sowerby's beaked whales, 3 Cuvier's beaked whales, and 1 True's beaked whale. Of the 89 identified fin whales, 13 (14.6 percent) have been re-sighted; 7 (7.9 percent) of them during different years ranging from 247 to 352 days between first and last sightings. Locations of all re-sighted fin whales were over the continental shelf inshore of the 100-m depth contour. Fourteen of the 95 identified sperm whales (14.7 percent) were sighted on more than one day, ranging from 9 to 1,062 days between sightings. All 14 re-sighted sperm whales were photographed at least once within or offshore of Norfolk Canyon; 7 of those 12 were in those waters for all documented sightings. Two individuals were re-sighted more than 15 km to the south of initial sighting, which was east of Norfolk Canyon. The whales were together during both sightings, 719 days apart. The minke whale photographed was not sufficiently marked to be identifiable, so was not added to the minke catalog, and the two Cuvier's beaked whale IDs did not match the previous sighting in the catalog. Pilot whale photos that are collected have been shared with Duke University, and although 2020 data have not yet been processed, an individual that was seen in the study area in 2019 was matched to a sighting 4 years prior (see Waples and Read 2021 and **Section 2.1.1.1** of this report). In a comparison to the Cape Hatteras catalog, Waples and Read found an additional 16 individuals that matched between areas, increasing the total to 40 matches between Virginia and North Carolina.

Biopsy Samples

Four biopsies were collected from sperm whales, which are currently being processed at Oregon State University.

Tagging

Three SPLASH-10 satellite tags were deployed on sperm whales in 2020 (**Table 16**). Tag duration ranged from 7.1 to 20.5 days (mean=12.4). Maximum distance from initial tagging location ranged from 170 to 322 km (mean=222.3), and mean distance from tagging locations for each tagged individual ranged from 69 to 160 km (mean=99.4). Maximum dive depth ranged from 1,311 to 1,823 m, and maximum dive duration ranged from 56 to 73 minutes.

Locations from satellite-tagged sperm whales showed movements through multiple U.S. Navy OPAREAS, mostly along the continental shelf break and beyond the slope. Movements varied, with two individuals showing all locations within the VACAPES OPAREA (e.g., **Figure 24**), and the third moving a greater distance to the northeast, still along the continental shelf edge and slope through the Atlantic City and Narragansett Bay OPAREAs. As in 2019, none of the 2020 tagged whales moved south to the Cherry Point OPAREA waters as some individuals had done in previous years.

Table 16. Satellite tag deployments on sperm whales during 2020.

Animal ID	Tag Type	Deployment Date	Last Transmission Date	Tag Duration (Days)
HDRVAPm036	SPLASH-10	13-May-20	23-May-20	9.6
HDRVAPm090	SPLASH-10	13-May-20	21-May-20	7.1
HDRVAPm091	SPLASH-10	13-May-20	03-Jun-20	20.5

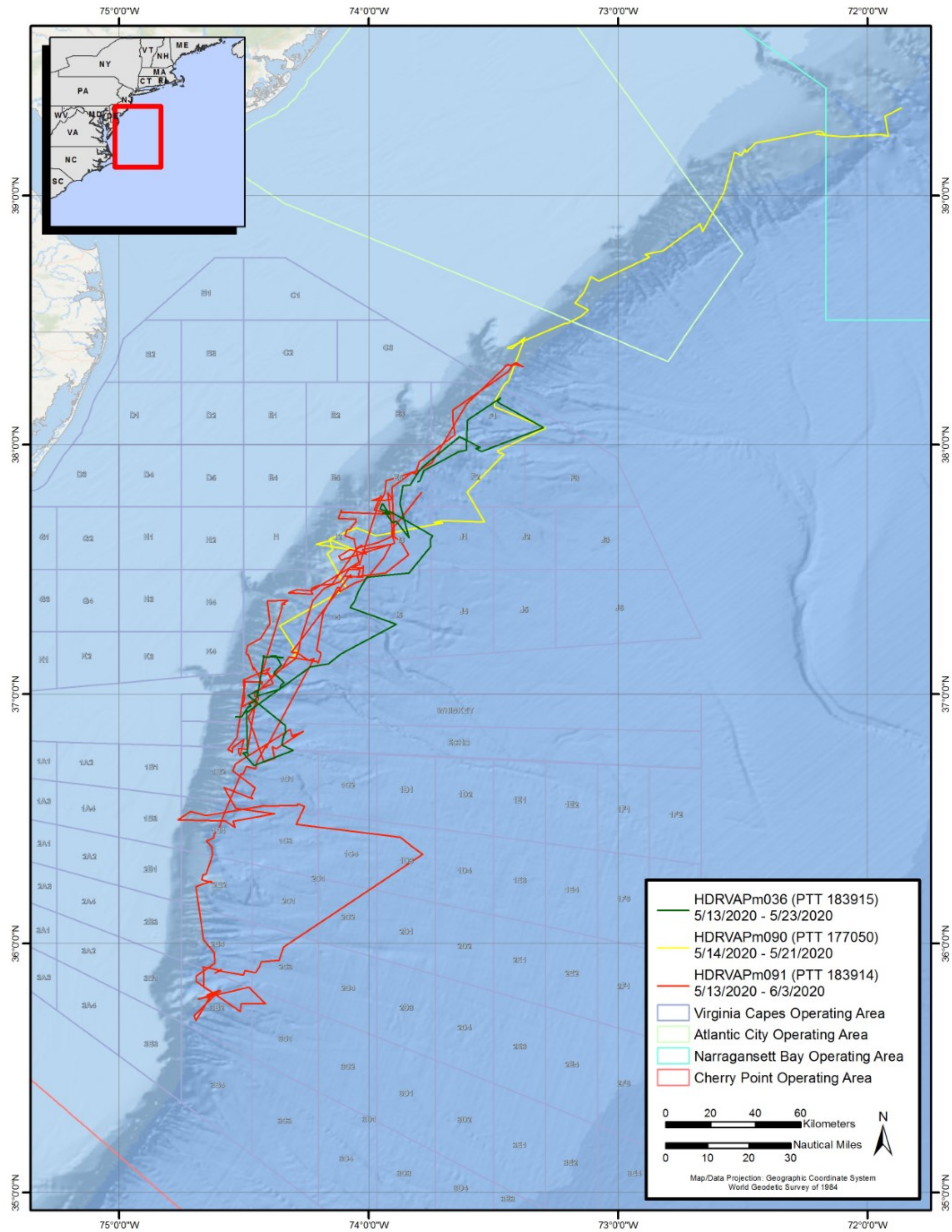

Figure 24. Tag tracks of all sperm whales tagged during 2020.

Fieldwork and data-analysis efforts for this project are ongoing and continue to yield positive progress. Survey results show a high diversity of marine mammal species, including deep-diving sperm whales and Cuvier's, True's, and Sowerby's beaked whales, in this high-use U.S. Navy training and testing activity area. A manuscript describing the ESA-listed blue whale sightings off Virginia in 2018 and 2019 was published in *Marine Biodiversity Records* in May of 2020 (Engelhaupt et al. 2020b). A continuation of detailed analysis of movement and dive data for both fin and sperm whales has shown similarities and variability within and between individuals of each species. The dive data from the first satellite-monitored location & dive-behavior tag to be deployed on a Sowerby's beaked whale has provided valuable insight with respect to the behavior of this highly cryptic species that is potentially at higher risk from anthropogenic activities. Further analysis of these data has been presented at the World Marine Mammal Conference in 2019 (Engelhaupt et al. 2019b) and a manuscript is in final preparation with plans to submit for publication in spring of 2021. Providing a more detailed understanding of both fine- and medium-scale foraging ecology of sperm and beaked whales will be the priority in 2021 and beyond, with the planned addition of fine-scale DTAG deployments on these deep-diving species. Although photo-ID is a technique that requires a multi-year commitment to accumulate sufficient data to produce meaningful contributions towards understanding site-fidelity and ultimately population consequences, the steady increase of matches of fin whales on the continental shelf across years provides evidence of site-fidelity displayed by an ESA-listed species whose movements were previously poorly understood in this region. The importance of the Norfolk Canyon and surrounding waters to ESA-listed sperm whales has become evident through individual re-sightings, group structure (including those with calves), tagged whale movements, and dive behavior. Additional effort is now focused on comparing HDR's photo-ID catalogs to existing catalogs in the Atlantic across several species. With every new survey conducted and each tag deployed on multiple species across seasons, we expand our knowledge of marine mammal and sea turtle occurrence and habitat use within this important U.S. Navy training range.

For more information on this study, refer to the annual progress report for this project (Engelhaupt et al. 2021).

2.2.4 Pinniped Tagging and Tracking in Virginia

Since the passage of the MMPA in the U.S. in 1972, and as amended (16 United States Code § 1361 14 et seq.), the harbor seal population has grown in the Northwest Atlantic Ocean (Hayes et al. 2019). The harbor seal is a year-round coastal inhabitant in eastern Canada and New England, and occurs seasonally in the mid-Atlantic United States between September and May (Hayes et al. 2019). Harbor seals in the mid-Atlantic region undertake seasonal migrations to northern areas for pupping and mating in the spring and summer, and return to more southerly areas in the fall and winter (Ampela et al. 2021; Hayes et al. 2019). Within the last decade, harbor seals have been observed returning seasonally to haul-out (resting) locations in coastal Virginia, and one or two gray seals occasionally are observed there as well (Jones et al. 2018).

The Navy regularly engages in training, testing, and in-water construction activities in coastal Virginia and the Chesapeake Bay (**Figure 25**) in order to maintain Fleet readiness and structural integrity of military installations. The lower Chesapeake Bay and coastal areas of Virginia overlap with one of the busiest hubs of naval activity on the East Coast and host numerous pierside facilities, installations, vessel, shipyards, and in-water training ranges. Seals seasonally inhabiting and transiting through these areas could be impacted by the use of active sonars and explosives, vessel traffic and movement, dredging, pile driving, and other activities.

Navy biologists have been researching seal occurrence in and around the Chesapeake Bay since 2013. Systematic counts have been conducted since 2014, and time-lapse trail cameras have recorded counts since 2019 (see **Section 2.1.1.2**). Results from these surveys indicate that seals arrive in the area in the fall and depart in the spring (Jones and Rees 2021). However, understanding of seal movements, habitat use, haul-out patterns, and dive behavior in Virginia waters is still extremely limited. In order to assess the potential impacts on seals from Navy activities, mitigate potentially harmful interactions, and obtain appropriate authorizations to maintain environmental compliance, it is important to have a better understanding of seal distribution and behavior in these areas. Although visual haul-out studies are useful for estimating the minimum number of animals present on land at various times of the year, tagging studies are needed to characterize seals' at-sea movements, habitat use, and dive behavior, as well as the environmental variables that may influence their distribution patterns.

The goal of the Pinniped Tagging and Tracking study is to use satellite tags to better understand seals' residency time in Virginia waters, their local habitat utilization patterns, and their migratory destinations in the spring. The information gathered from this effort will provide valuable baseline data needed for the future assessment of harbor seal movements and site fidelity along the U.S. Eastern Seaboard.

The capture site is located on the Eastern Shore of Virginia, where seals haul out between fall and spring. The Eastern Shore haul-out area has several discrete haul-out sites (five main locations within the marsh, which can further be broken down into a total of nine smaller sites) where seals have been observed (Jones and Rees 2021). These sites are located in a tidal salt marsh consisting of muddy banks and vegetation, which is subject to tidal influx. Seal captures followed a similar protocol as described by Jeffries et al. (1993). Seals are captured in the water adjacent to haul-out site(s) using a seine net and 3 small flat-bottomed vessels with outboard motors, and brought onshore after being secured the capture net.

Allflex™ livestock ear tags were attached to the seal's left and right hind flipper webbing. These tags feature unique identifiers specific to this study and are used for purposes of individual identification if resighted as they potentially stay attached for multiple years. Each seal was also instrumented with a GPS-enabled depth-sensing satellite tag (SPLASH10-F manufactured by Wildlife Computers, Inc., Redmond, Washington) which provide location accuracy of up to 20 m, designed for tracking fine-scale horizontal movements as well as vertical (dive) movements. Satellite tags were glued directly to the seals' fur on the head or shoulder area (depending on the size of the animal) using Devcon™ 20845 High Strength 5-Minute Epoxy. The tags were designed to fall off during the annual molt in July, following the May-June breeding season. A suite of biological samples was also collected from each animal in accordance with the National Marine Fisheries Service Scientific Research Permit number 21719.

Seven harbor seals were captured and tagged during the 2018 field season; due to a number of environmental and logistical factors, no seals were tagged in 2019 (Ampela et al. 2021). In late February/early March 2020, two additional harbor seals were captured and instrumented with satellite-tracked tags and flipper tags. Each satellite tag successfully transmitted data for over 3 months. The satellite tag attached to seal 2001, a juvenile female, stayed on for approximately one month longer than the tag attached to the other seal 2002, a juvenile male (**Table 17**). The 2020 tag data was analyzed for seal movements, habitat use, haul-out patterns, and dive behavior. A cumulative analysis was also performed for all nine tags deployed in 2018 and 2020 (**Table 18**).

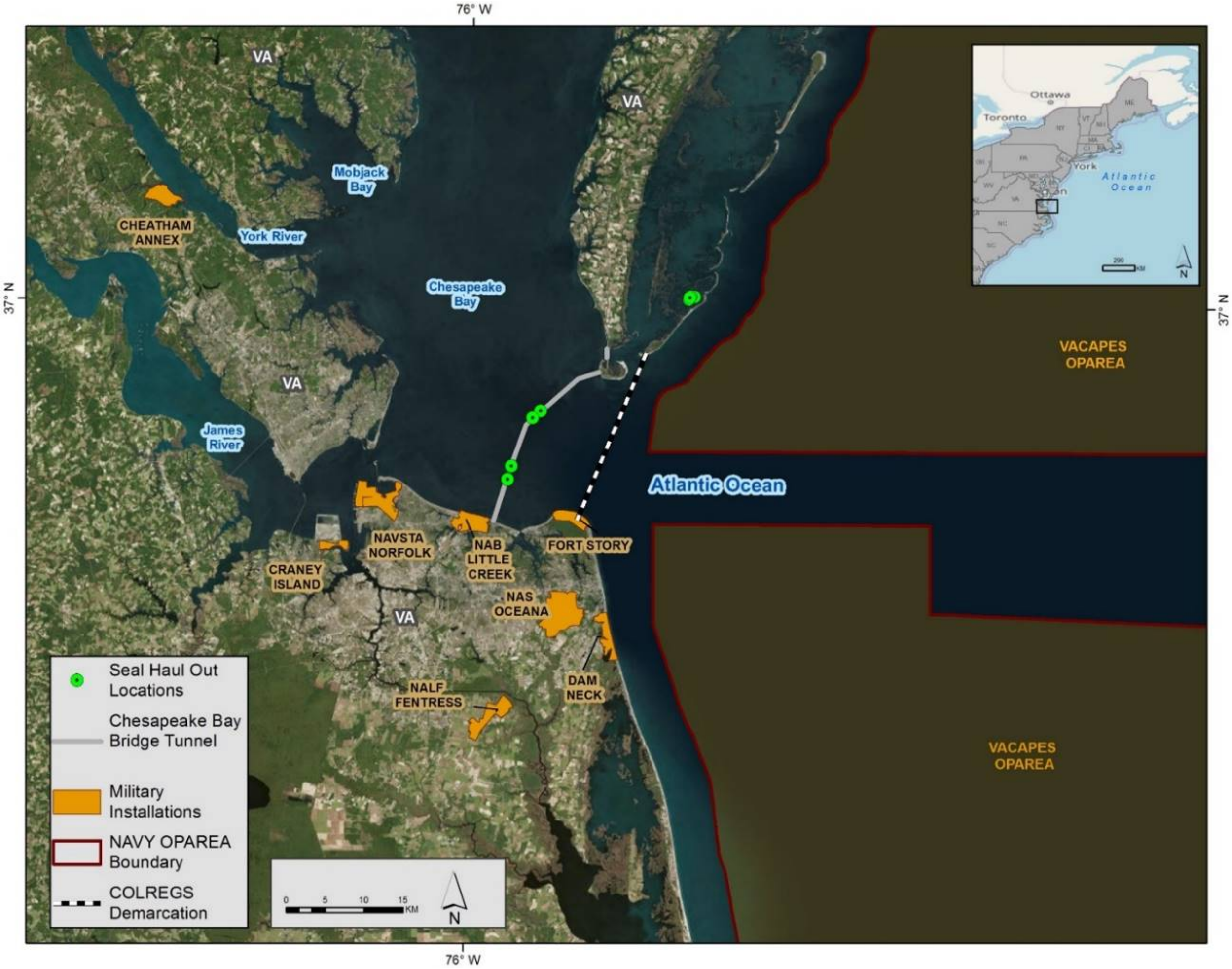

Figure 25. Seal haul-out locations in lower Chesapeake Bay and coastal Virginia, showing the Virginia Capes Range Complex (VACAPES) and sonar training areas.

Table 17. 2020 and summary of tag deployments.

Animal ID	Sat Tag PTT #	Length (cm)	Girth (cm)	Weight (kg)	Age (est.) and sex	Tag Start Date	Date Left VA	Tag End Date	Tracking Days	Distance Traveled (km)	Distance Traveled in VA Waters
2001	177411	95	80	26.1	Juv. Female	26-Feb-20	31-Mar-20	12-July-20	137	7,572	1,897
2002	177410	130	88	47.0	Juv. Male	2-Mar-20	20-Mar-20	10-Jun-20	99	5,743	1,039

PTT = platform transmitter terminal; cm = centimeters; kg = kilogram(s); est. = estimated; VA = Virginia; km = kilometer(s); km2 = square kilometer(s); % = percent; juv. = juvenile.

Table 18. Summary of seals tagged in 2018.

Date Tagged	Animal ID	Sat Tag PTT #	Date of Last Transmission	VEMCO Tag #	Length (cm)	Girth (cm)	Weight (kg)	Sex	Estimated Age
4-Feb-18	1801	166450	23-May-18	15249	102	80	29.0	Male	Juvenile†
4-Feb-18	1802	166449*	29-Jun-18	N/A**	153	118	90.4	Male	Adult
4-Feb-18	1803	166451	6-May-18	15251	129	99	58.8	Female	Juvenile†
4-Feb-18	1804	166452	26-May-18	15252	143	119	74.8	Female	Juvenile†
6-Feb-18	1805	166453	9-Apr-18	15253	121	97	49.8	Female	Adult
6-Feb-18	1806	173502	22-Jun-18	N/A	149	116	82.2	Female	Adult
6-Feb-18	1807	173503	26-Apr-18	15250***	93	77	24.8	Female	YOY‡

*One depth-sensing SPLASH tag was deployed on seal 1802. All other seals were instrumented with location-only SPOT tags; **Seal 1802 was also initially instrumented with VEMCO Tag #15250 on 04 February, but that tag was later dislodged when he was (unintentionally) recaptured on 06 February; ***VEMCO Tag #15250 was retrieved and deployed on seal 1807 on 08 February. No acoustic "pings" were detected during the time the VEMCO tag was attached to seal 1802; therefore, the data presented only include results from seal 1807; †Juvenile = 2–4 years old; ‡YOY = Young of the year, up to 1.5 years old. cm = centimeters; kg = kilometer(s); PTT = platform transmitter terminal.

Both seals tagged in 2020 spent at least 22 days in Virginia waters following tag deployments and returned regularly to the capture site while in the region, but utilized the coastal environment differently. Seal 2002, a juvenile male, used the offshore environment almost exclusively, whereas seal 2001, a juvenile female, spent time both in the Bay and the offshore environment. Both individuals departed Virginia in late March 2020 and tracked northward along the eastern seaboard, traveling as far north as coastal Maine during the tag reporting periods, stopping at haul-out sites in coastal Rhode Island, Massachusetts, and New Hampshire (**Figures 26 and 27**).

Filtered location data were used to generate utilization distributions and calculate 50% and 95% isopleths for all tagged seal (Calenge 2006). Four seals had a 95% habitat-use isopleth that extended as far north as the coast of Maine, and two additional seals had a 95% likelihood of occurring off the coast of Connecticut, Rhode Island, and Massachusetts. In Virginia waters, tagged seals utilized both the Chesapeake Bay and offshore waters, but the area that was utilized most heavily was near the Eastern Shore capture site (**Figure 28**). The analysis shows that at least one seal had a 95% likelihood of being in the lower Chesapeake Bay. Five seals had a 95% likelihood of being around the CBBT Islands, and up to five seals had a 95% likelihood of being near Fisherman's Island. Overall, the nine tagged seals spent a cumulative 450 days in Virginia waters, and on 83 of these days (19%) satellite tags reported locations within the VACAPES OPAREA.

Haul-out patterns were analyzed with respect temporal and environmental factors. Haul-out locations for the two seals tagged in 2020 are shown in **Figure 29**. Monthly haul-out probabilities with respect to time of day for the two seals were roughly similar for the months of March–June. Seal 2001 varied its haul-out times in February and July. Reviewing haul-out patterns for all nine tagged seals in 2018 and 2020, a bimodal haul-out pattern was observed in June, which was mainly attributable to two seals (1802 and 1806) tagged in 2018. While in Virginia waters, seals were as likely to haul out on a high tide as a low tide. In terms of total time spent hauled out, examination of diurnal/nocturnal haul-out patterns revealed that seals tagged in 2018 and 2020 were nearly equally likely to haul out during nighttime hours as daylight hours. Additionally, tagged seals were most likely to haul out in Virginia when water temperatures were in the 6°–11°C range and when air temperatures were in the 4°–13°C range.

For more information and additional analysis, please refer to the 2019–2020 annual progress report for this project (Ampela et al. 2021).

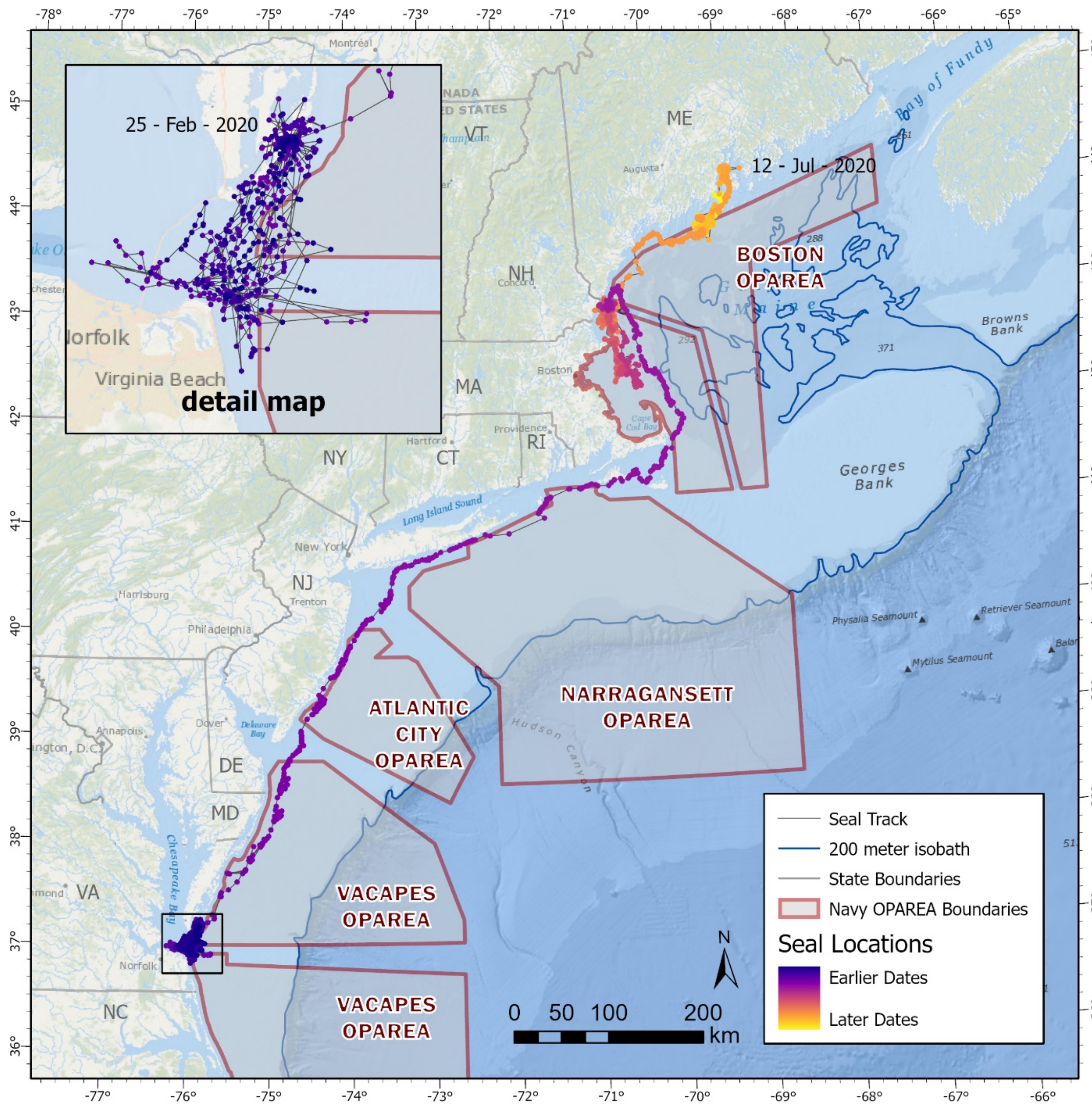

Figure 26. Reconstructed track of seal 2001, a juvenile female harbor seal (tag duration 27 February through 11 July 2020) in relation to Navy operating areas.

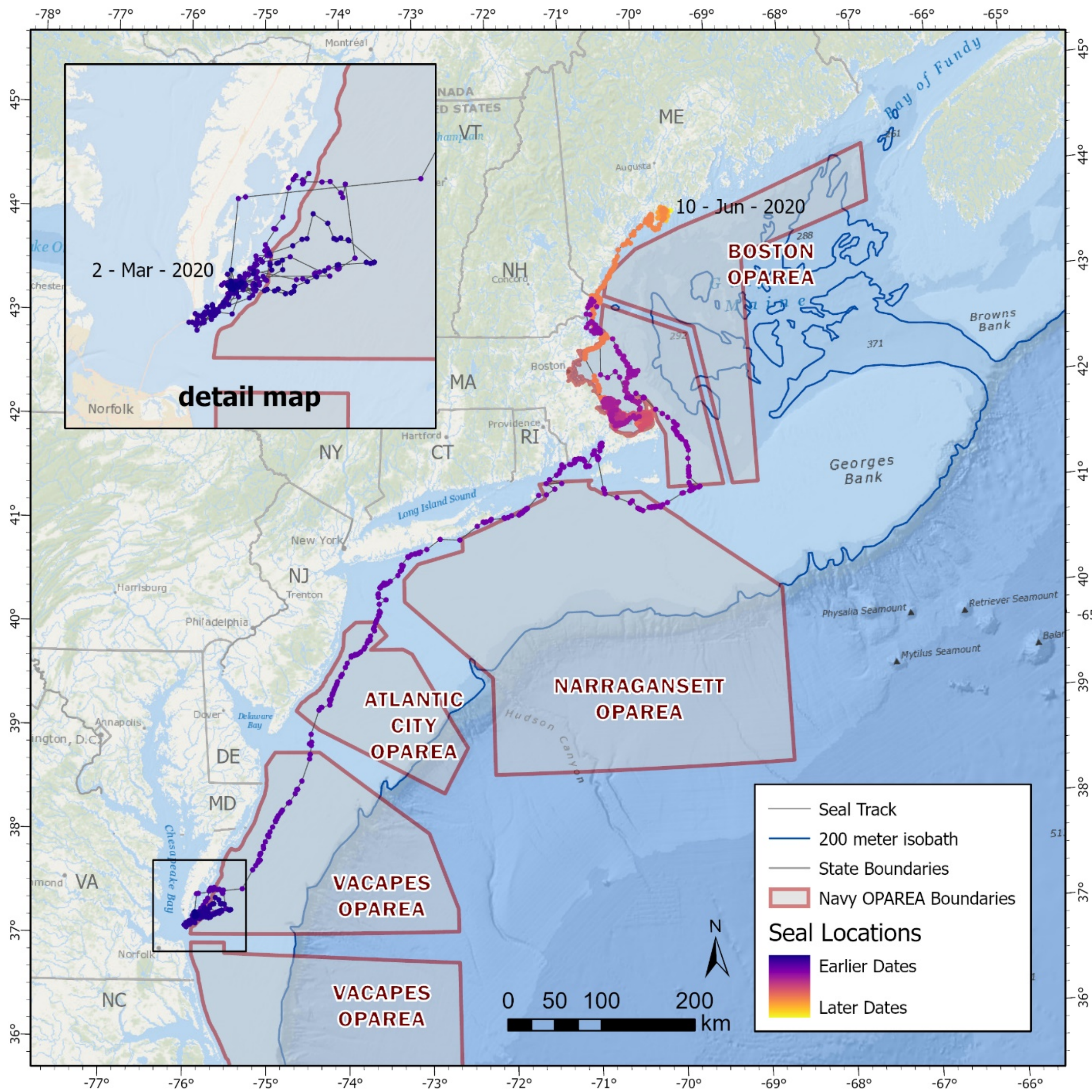

Figure 27. Reconstructed track of seal 2002 (tag duration 3 March through 10 June 2020) in relation to Navy operating areas.

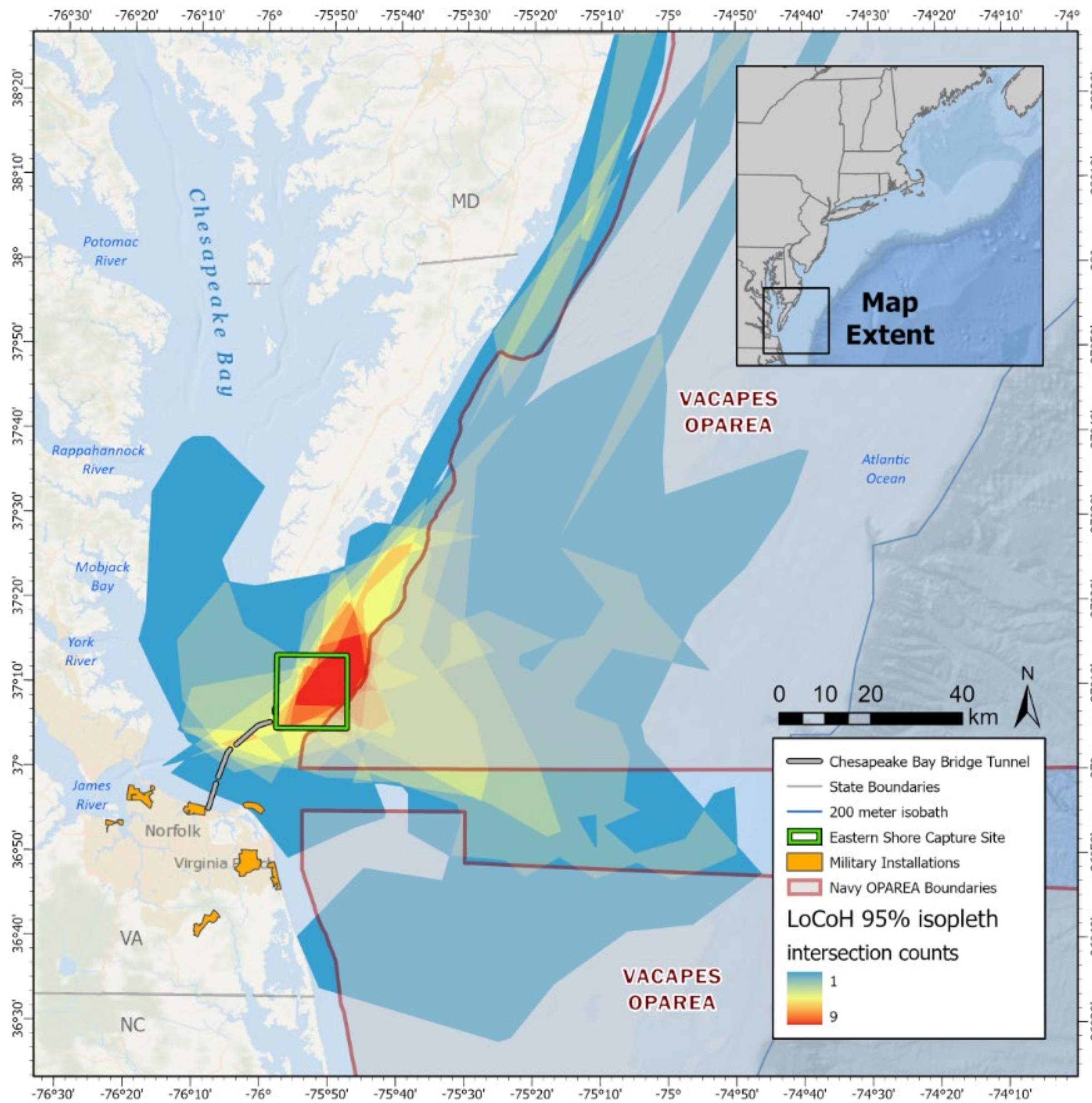

Figure 28. The intersection of all nine harbor seals' 95 percent habitat-use isopleths (local convex hull). Colors represent the number of overlaid individual isopleths, with cool colors indicating lower counts and warmer colors indicating high counts.

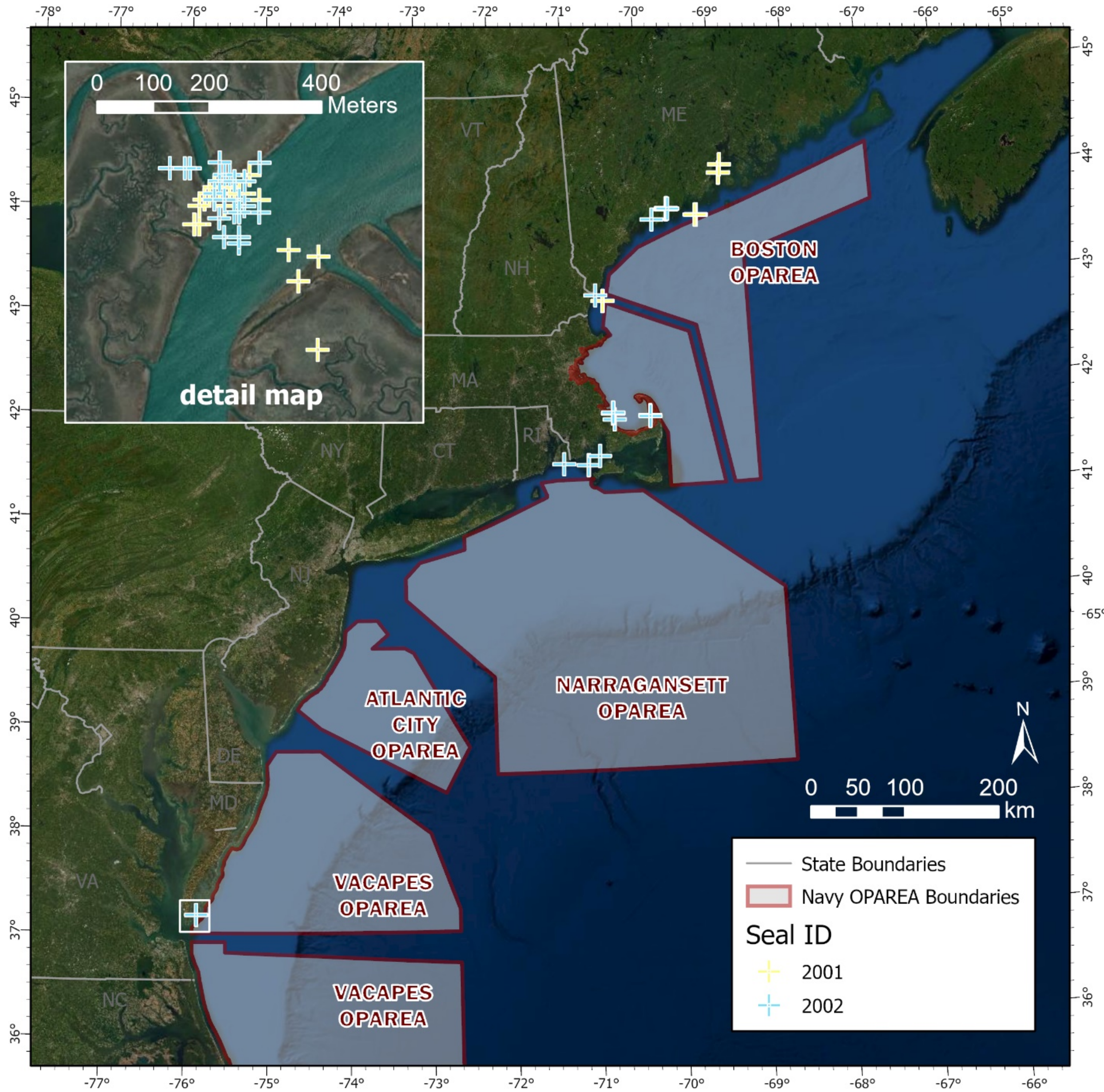

Figure 29. Haul-out locations for the two seals tagged in 2020. Haul-out areas are based on Fastloc® GPS locations classified as "hauled out."

2.2.5 Sea Turtle Tagging—Chesapeake Bay and Coastal Virginia

Researchers from the Virginia Aquarium & Marine Science Center and Naval Facilities Engineering Command Atlantic collaborated on a project to tag and track sea turtles in lower Chesapeake Bay and coastal Virginia waters from 2013 to 2018. The goal of this project was to assess the occurrence, habitat use, and foraging behavior of loggerhead, green (*Chelonia mydas*), and Kemp's ridley (*Lepidochelys kempii*) turtles in this region. Research methods included the use of satellite telemetry to characterize broad-scale movement patterns and the use of both satellite- and acoustic-telemetry data to characterize the occurrence of turtles in specific areas of interest to the U.S. Navy. This dataset will assist the U.S. Navy in identifying seasonal areas where cheloniid sea turtles are likely to occur in order to support environmental planning and compliance efforts.

A total of 141 turtles was released with satellite-transmitter or VEMCO acoustic tags (51 satellite, 90 acoustic) from 2013 through 2018 (See Barco et al. (2017) and Barco et al. (2018) for details of how turtles were acquired as well as tagging procedures). Telemetry data for loggerheads have been previously analyzed to estimate local home range and assess foraging behavior (see Barco et al. 2017), as well as a home range and preliminary foraging analysis for Kemp's ridley turtles (manuscript accepted for publication in *Marine Biology Research* in February 2021). Additional analyses to develop both state-space switching and habitat models for both loggerhead and Kemp's ridley turtles in the Chesapeake Bay have been finalized and the manuscript is currently in preparation for expected publication in 2021. For more details on the final results of this project, please see the cumulative technical report that was completed in August 2020 (DiMatteo et al. 2020).

2.3 Behavioral Response

2.3.1 Atlantic Behavioral Response Study

The Atlantic Behavioral Response Study (Atlantic-BRS) was initiated following extensive planning discussions with researchers and U.S. Navy personnel to transition experimental methods previously developed under the Southern California Behavioral Response Study (SOCAL-BRS), funded primarily by the U.S. Navy's Living Marine Resources program, as well as ONR. For the past four years, a research collaboration of scientists from Duke University, Southall Environmental Associates, and the University of St. Andrews has conducted strategic tag deployments and Controlled Exposure Experiments (CEEs) on Cuvier's beaked whales and pilot whales off Cape Hatteras, North Carolina. This collaboration has had unprecedented success in tagging high-priority beaked whales and conducting CEEs with both operational mid-frequency active sonar (MFAS) systems from Navy surface vessels (e.g., SQS-53C-equipped combat vessels) as well as experimental sound sources simulating these systems. The primary focus is on accomplishments from the adapted 2020 field season and response analyses largely conducted on data collected from 2017 to 2019 (Southall et al. 2018, 2019, 2020), as detailed analyses of the 2020 field data are still ongoing. All figures included in this synopsis, as well as the complete collection for all CEEs are openly available for viewing at project GitHub.

Most previous studies have either used short-term, high-resolution acoustic tag sensors to measure fine-scale behavior in response to calibrated metrics of experimental noise exposure, or coarser-scale, longer-term measurements of movement and diving behavior associated with incidental exposures during sonar training operations. This study is unique in bringing both approaches together and building on previous experience with both tag types for focal species within the same area. Specifically, the overall design involves expanding the temporal and spatial scales of previous BRS efforts by combining short-term, high-resolution DTAGs providing short-term (hours) but very high-resolution movement and calibrated acoustic data, and satellite-linked, time-depth recording tags providing much longer-term (weeks-months) data on movement and increasingly better resolution dive data, simultaneously deployed on multiple individuals of focal species in the same CEEs.

The overall research objective is to provide direct, quantitative measurements of marine mammal behavior before, during, and after known exposures to MFAS signals in order to better describe behavioral response probability in relation to key exposure variables (e.g., received sound level, proximity, animal behavioral state). These measurements will have direct implications for, and contributions to, more informed assessments of the probability and magnitude of potential behavioral responses of these species. Results will be directly applicable to the Navy in meeting their mandated requirements to understand the impacts of training and testing activities on protected species, as well as to regulatory agencies in evaluating potential responses within regulatory contexts.

Several key categories of behavioral responses are being evaluated, including potential avoidance of sound sources that influence habitat usage, changes in foraging behavior, and changes in social behavior. While the overall experimental approach using CEEs and comparing exposure among conditions before, during, and after noise exposure is not uncommon, several methodological parameters (e.g., tag types and configuration settings, nominal target exposure levels) differ slightly among species given known variability in their life history, baseline behavior, and presumed (from previous observations and studies in other areas) sensitivity to noise exposure. As in previous studies, explicit monitoring and mitigation protocols have been established and followed in conducting CEEs in order to meet experimental objectives and ensure compliance with both permit authorizations and ethical standards. Further, experimental objectives, field work accomplishments, and planned effort are regularly communicated transparently to interested stakeholders through periodic compliance reporting, progress updates, and presentations and discussions in scientific and general audience fora.

Full details of the experimental design, analytic approach, and field logistics can be found in the 2020 annual progress report (Southall et al. 2021).

2.3.1.1 Field Effort

The Atlantic-BRS field effort in 2020 was impacted considerably by the effects of the COVID-19 global pandemic. Several logistical and personnel adaptations necessitated by travel restrictions and workplace protocols resulted in one long, extended field season from 6 July through 30 September. Despite these challenges, the field season was successfully completed and no fundamental changes or compromises to experimental design were necessary. This was also the first year of the project that included the use of Duke Marine Lab's newly acquired research vessel, R/V *Shearwater*, a 19.9-m fast catamaran that proved useful as a high-vantage observational platform for searching for and tracking tagged animals.

Overall, 15 satellite tags were deployed on focal species (14 on Cuvier's beaked whales, and 1 on a short-finned pilot whale). Please refer to **Section 2.2.1** of this report for more details on the tagging component of this project. Three CEE sequences were conducted in 2020 (**Table 19**), two of which were successful, complete, operational Navy SQS/53C MFAS CEEs coordinated with separate U.S. Navy warships (USS *Cole* and USS *Laboon*). A third CEE was conducted with the experimental simulated MFAS source. The two operational CEEs were conducted with three of the tagged Cuvier's beaked whales and the single short-finned pilot whale, and the simulated event was conducted with one DTAG and one satellite-tagged Cuvier's beaked whales as the focal animals. While not the focal whales, three other tagged Cuvier's beaked whales were in the vicinity during the simulated CEE event.

Accomplishments:

- Successful deployment of 15 of satellite tags (14 beaked whales; 1 pilot whale).
- Two successful CEEs with operational U.S. Navy vessel, full-scale 53C MFAS. Both were conducted at or near beaked whale target RLs (140 decibels root mean square) specified for 2020.
- One successful CEE with simulated MFAS conducted at or near target beaked whale levels for focal animals; CEE conducted with large sample size (*n*=12) of beaked whales.
- Successful integration of new research platform R/V *Shearwater* into Atlantic-BRS field effort. Highly successful in locating and tracking animals, including successful tracking overnight for both satellite-transmitting and DTAG sensors.
- Successful deployment, tracking, and recovery of both a moderate-duration (6-hour) and long-duration (23-hour) DTAG on priority beaked whale individuals, both in social groups with other known and satellite-transmitting tagged individuals. Unfortunately, not all data were obtained due to tag failures.
- Sustained efforts to relocate satellite-tagged animals in the field using goniometer detections, increasing chances of subsequent tag deployments, improving animal pseudotracks by providing high confidence surface locations, and resulting in many photo-ID re-sights (see **Section 2.1.1.1**)

to evaluate group composition and social interactions. Explicit and novel quantitative metrics for integrating various levels of confidence/quality of detections into modeled track imputations for movement models.

- Additional observations of potential social group responses in beaked whales with individuals with known sighting history in same social group subsequently sighted apart following CEE.
- Sustained high-quality satellite-transmitting tag dive data thanks to earlier progress in tag deployment strategies to reduce/eliminate gaps in satellite-tag data and to improve temporal resolution on diving and behavioral data. Successfully collected continuous dive data for two-week periods, strategically covering CEE periods, as designed. Observations of longer than previous overall function of tags in reporting ARGOS positions, potentially as a result of improved batteries in SPLASH tag.

Assessment of field approach:

- Extremely positive developments in planning, coordination, and execution of Navy vessel CEEs. This also required considerable adaptation and effort on the Navy side. Lessons learned are that operational MFAS source CEEs can be successfully accomplished with advance planning and support and close coordination among members of the research team and the Navy team present on land communicating with respective research and Navy vessels at sea in real time. At-sea coordination between research and operational vessels was also successfully coordinated.
- Very good conditions occurred during several windows with workable weather at least for re-sight detections for several stretches in July and August. However, major storms were also experienced in the area during this period and into September. Overall, weather conditions were less favorable in 2020 than in any previous field season.
- Both DTAG deployments were limited partially or entirely by tag failures. A long-duration (23-hour) baseline tag that would have provided very useful in assessing diurnal behavior previously unavailable for this location was rendered entirely unusable by pressure sensor and hydrophone failures. A programed shorter (within-day) DTAG yielded useful dive and acoustic data during a CEE, but sensor issues with heading data precluded some analytical assessments. Modifications to overcome previous VHF limitations seemed to be effective in tracking, but these sensor failures unfortunately rendered the data recovered compromised.

The full 2020 annual progress report for this project (Southall et al. 2021) includes a complete synthesis of each CEE conducted with standardized tables and figures for each. These include: (1) metadata summaries, (2) planning RL modeling (where applicable), (3) modeled positions from satellite-tag locations for individuals exposed during each CEE using several methods, (4) dive records for satellite tagged whales during CEEs, and (5) DTAG quick-look summaries for applicable CEEs. Select examples of some of these figures for CEE #2020_01 can be seen in **Figures 30** through **32**.

Table 19. CEEs conducted during 2020 Atlantic-BRS field efforts.

CEE ID	Date	CEE Type	Focal whales	CEE duration (minutes)	Start CEE source latitude (°N)	Start CEE source longitude (°W)
#2020_01	15-May-19	Operational MFAS (USS *Cole*)	ZcTag98; GmTag228	60	36.102	74.718
#2020_02	07-Jun-19	Operational MFAS (USS *Laboon*)	ZcTag99; ZcTag100	60	35.950	74.449
#2020_03	06-Aug-19	Simulated MFAS	Zc20_232a & ZcTag108 (same social group) [ZcTag98, ZcTag105, ZcTag110 in vicinity]	30	35.484	74.657

Key: CEE = controlled exposure experiment; MFAS = mid-frequency active sonar; Zc = Cuvier's beaked whale; Gm = short-finned pilot whale

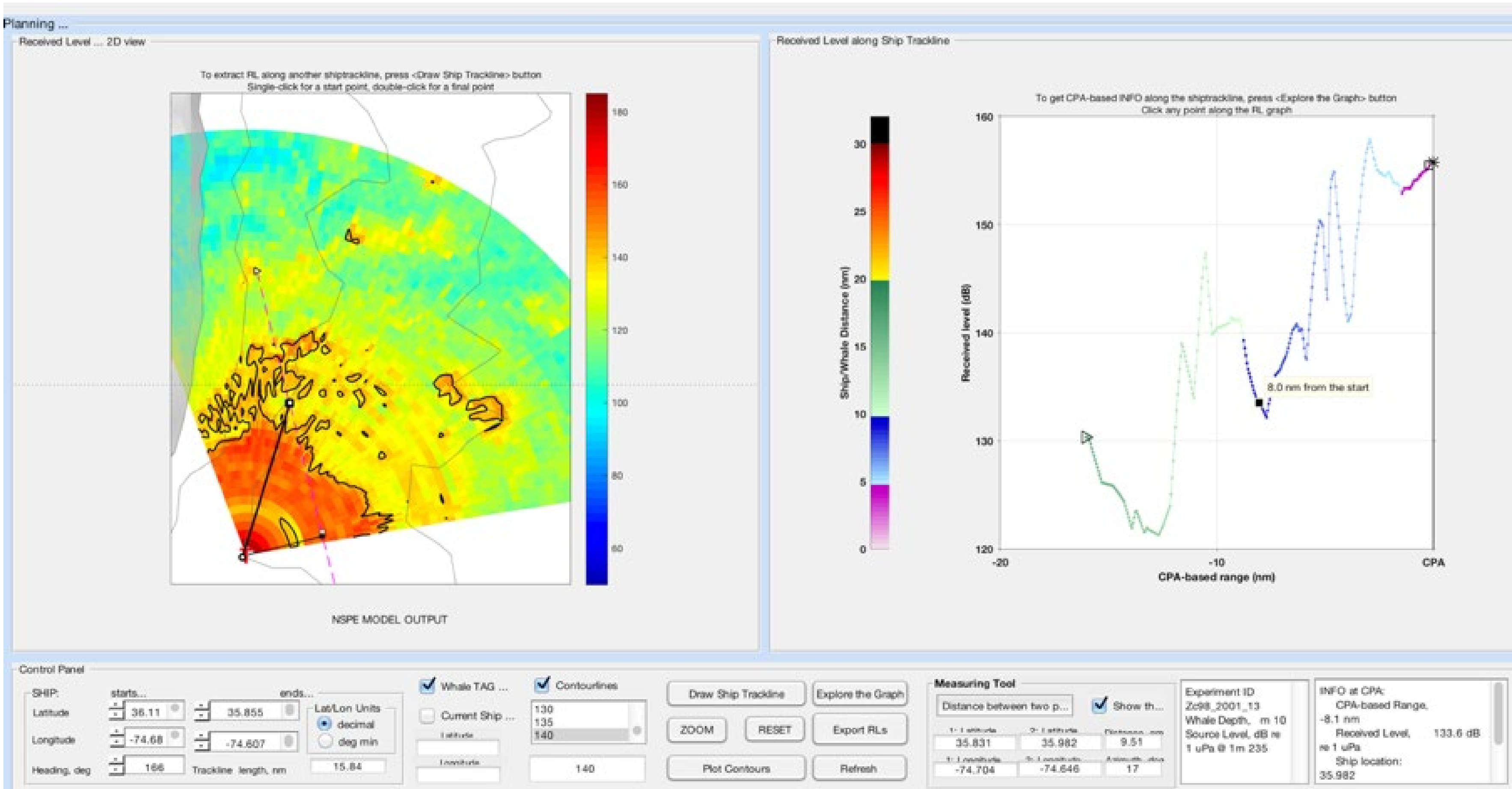

Figure 30. Received level model prediction at 10-m depth for focal beaked whale “ZcTag98” based on interpolated position and USS *Cole* end position during Atlantic-BRS CEE #2020_01. Modeled RL at this depth and estimated position was 133.6 decibels.

NOTE: This RL model prediction plot was generated using the Naval Postgraduate School sound propagation tool used in the field to estimate received levels for animals at known/estimated tag location (T) with a MFAS source positioned at a strategic location (small white circle in left plot). Right panel shows modeled RLs at different positions along tracks – selected points here correspond to the estimated position based on an interpolation of surface locations from focal follow observations. Model runs are shown for different focal animals (where appropriate) and different animal depths in the water column, based on species and location differences.

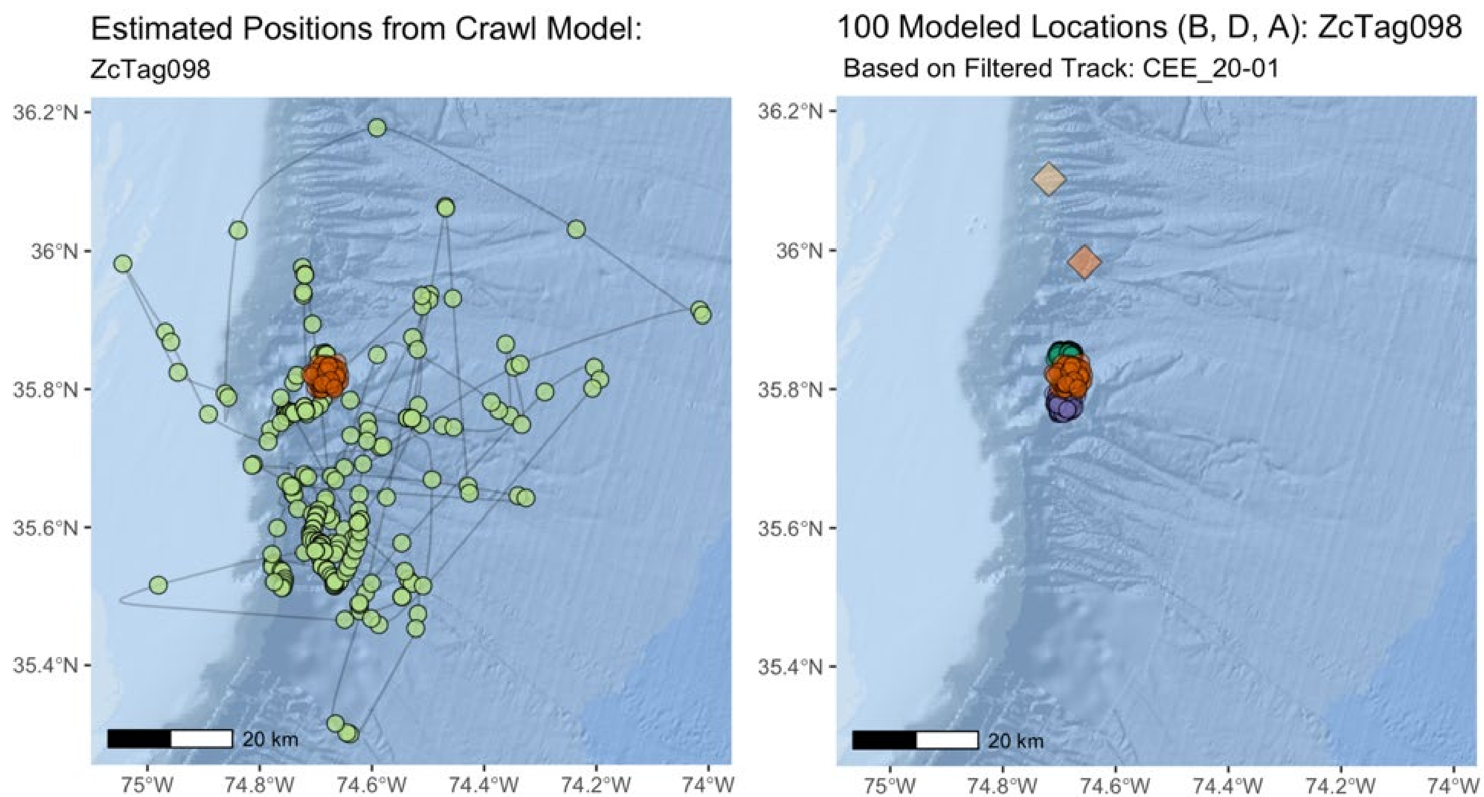

Figure 31. Estimated surface positions for focal whale "ZcTag98" before, during, and after Atlantic-BRS CEE #2020_01.

NOTE: This plot has two panels for the individual specific to this CEE. Left panel shows modeled animal locations from both Douglas ARGOS filtered tracks with the location along the entire track (in green circles) with positions during the respective CEE indicated with track imputations indicated along this track shown as red dots. Right panel shows modeled locations from 100 imputed tracks based upon the simple Douglas ARGOS filtered track corrected with surface locations to better account for spatial error in the underlying data. Locations of the MFAS sound source are shown as diamonds, with pale orange representing locations at the start of CEEs and darker orange indicating ending locations. The 100 positions for each imputed track are shown 1 hour before CEEs (green dots), at the start of CEEs (red dots), and 1 hour after CEEs (purple dots).

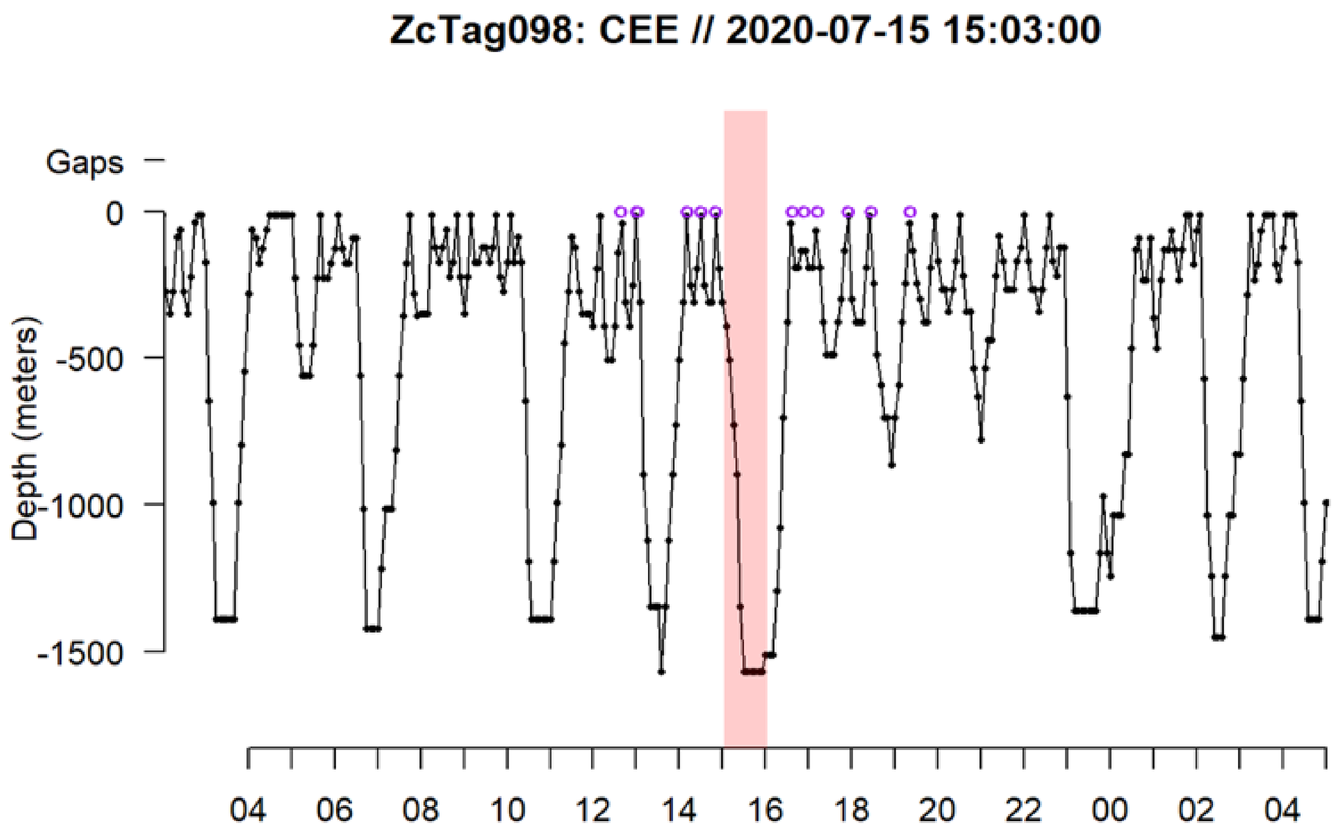

Figure 32. Available dive data for focal beaked whale "ZcTag98" before, during, and after Atlantic-BRS CEE #2020_01. The pink bar shows the time of simulated MFAS transmission.

NOTE: This plot illustrates dive data for days during which CEEs occurred. Time (in GMT, which is +4 hours from EDT during CEE periods) is indicated on the x-axis, with depth indicated on the y-axis). CEE periods are indicated as pink bars. Figures are provided for each animal for periods spanning 12-hour periods occurring before and after each CEE (shown here); figures showing 24 hours before and after each CEE (are available at the link provided).

2.3.1.2 Analytical Developments, Results, Publications and Presentations

The Atlantic-BRS team has continued to develop a wide range of analytical and data-visualization methods in order to both quantify behavior and behavioral response to MFAS and to depict and understand these data. Some of the analytical progress includes major development in data visualization through a concerted effort led by Dr. Rob Schick, with the direct engagement and support of several undergraduate students at Duke University. This effort, focused initially on the processed 2019 satellite-transmitting data and CEE data as a test case, is important in multiple ways. First, it uses cutting-edge data-visualization methods to systematically integrate and depict large data sets. **Figure 33** is a visualization of the entirety of the 2019 satellite-transmitting tag data and shows the temporal extent of the tags, while **Figure 34** shows the spatial distribution of all the data. This not only provides a common understanding of the existing data and how they relate to one another as a starting foundation for baseline and response analyses, it also provides an easily accessible and visually understandable portal into complex movement and diving data for project managers and others interested in the Atlantic-BRS. Further, by working directly with capable and motivated students, the project is both simultaneously being substantially in-kind supported and serving as a means of teaching and enabling the next generation of researchers in methods used in these kinds of applied research projects addressing real-world conservation and management issues.

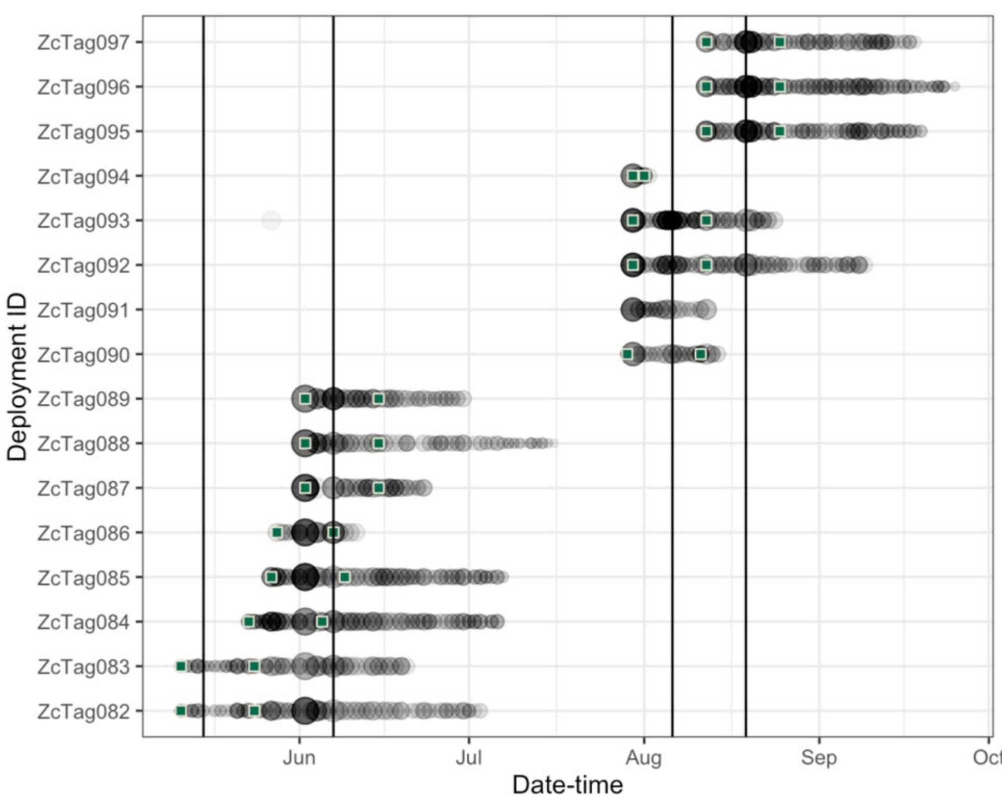

Figure 33. Longevity of individual Cuvier's beaked whale tags. Gray circles denote daily observed x,y locations (from satellite, goniometer, and focal-follow data); larger circles correspond to more observations. Green squares correspond to the first and last observation of depth data from the series data stream. Note that both ZcTag091 and ZcTag094 had pressure sensor failures. Dark vertical lines correspond to the four CEE days.

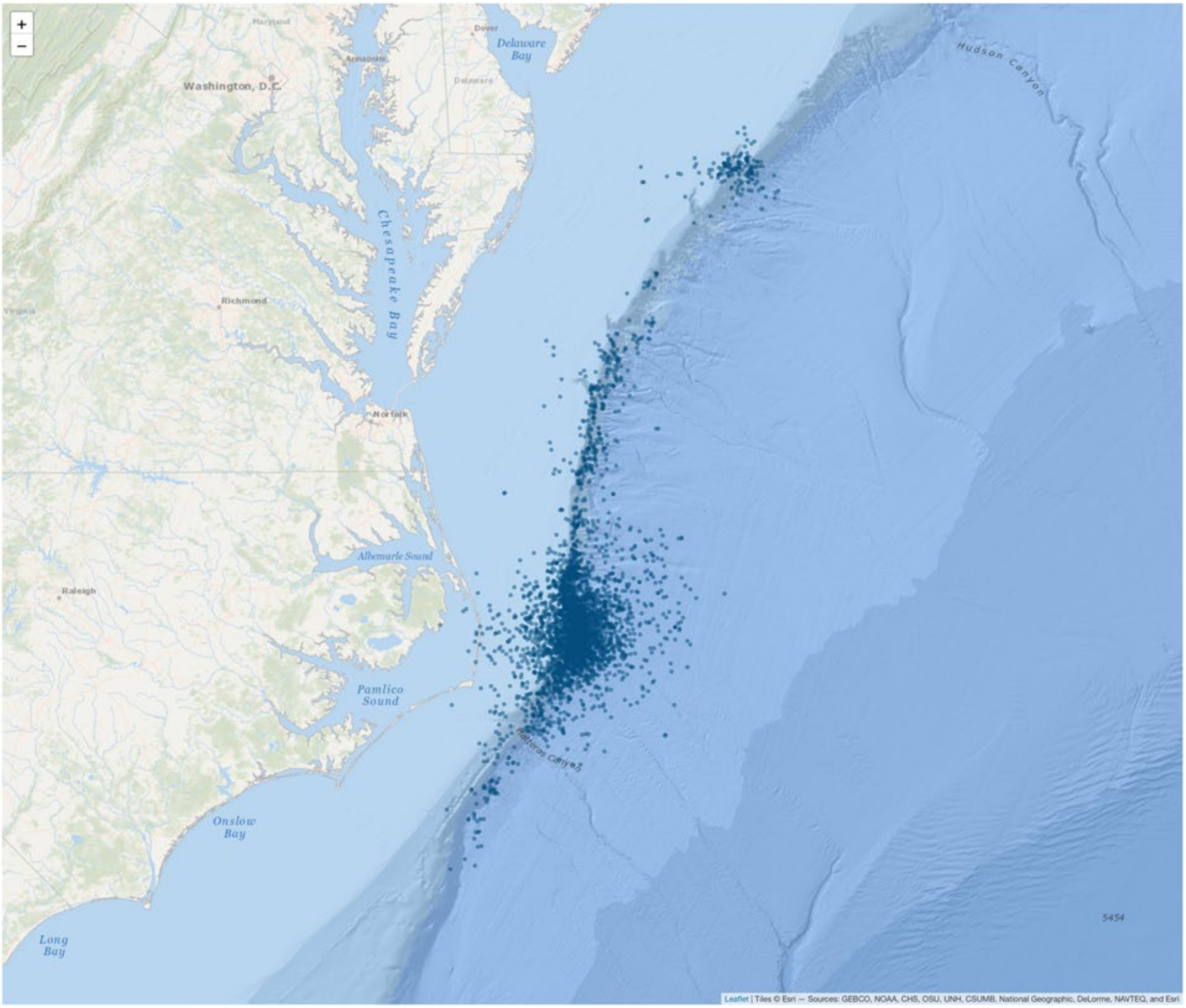

Figure 34. Distribution of all satellite tag location data collected during the 2019 field effort.

The Atlantic-BRS team has continued to expend considerable effort and make progress in processing field data, applying and developing new methods, and integrating data across years in synthesis assessments of baseline behavior and, increasingly, response. Several recent and ongoing publications listed in **Table 20** demonstrate progress and ongoing new directions. Collaborators with CREEM at the University of St. Andrews are leading a number of these efforts, both in directly funded aspects of the Atlantic-BRS and through overlapping interest and collaboration with the ONR-funded Double Mocha effort.

Table 20. Atlantic-BRS publications, and manuscripts in review or advanced stages of preparation.

Category	Nominal Title/Subject	Lead Author (Institution)	Status
Baseline Behavior	Diving Behavior of Cuvier's Beaked Whales (*Ziphius cavirostris*) off Cape Hatteras, North Carolina	Shearer (Duke)	Published: *Royal Society Open Science 6: Issue 2 (2019)*
Methodology-Technology	Mind the gap—Optimizing satellite tag settings for time series analysis of foraging dives in Cuvier's beaked whales (*Ziphius cavirostris*)	Quick (Duke)	Published: *Animal Biotelemetry 7: article 5 (2019)*
Methodology-Technology	Accounting for Positional Uncertainty When Modeling Received Levels for Tagged Cetaceans Exposed to Sonar	Schick (Duke)	Published: *Aquatic Mammals 45(6): 675–690 (2019)*
Baseline Behavior	Extreme diving in mammals: first estimates of behavioural aerobic dive limits in Cuvier's beaked whales	Quick (Duke)	Published: *Journal of Experimental Biology 223: No. 18, jeb222109 (2020)*
Methodology-Technology	Continuous-time discrete-state modeling for deep whale dives.	Hewitt (Duke)	Published: *Journal of Agricultural, Biological, and Environmental Statistics (2021)*
Baseline Behavior	Residency and movement patterns of Cuvier's beaked whales (*Ziphius cavirostris*) off Cape Hatteras, North Carolina, USA	Foley (Duke)	Published: *Marine Ecology Press Series 660: 203–216 (2021)*
Baseline Behavior	Extreme Synchrony in Diving Behaviour of Cuvier's Beaked Whales (*Ziphius cavirostris*) off Cape Hatteras, North Carolina.	Cioffi (Duke)	Final Review
Baseline Behavior	More than metronomes: variation in diving behaviour of Cuvier's Beaked Whales (*Ziphius cavirostris*)	Quick (Duke)	In Review

Category	Nominal Title/Subject	Lead Author (Institution)	Status
Baseline Behavior	Shallow night intervals in *Ziphius cavirostris*	Cioffi (Duke)	In Preparation
Baseline Physiology	Baseline variation of steroid hormones in short-finned pilot whales (*Globicephala macrorhynchus*)	Wisse (Duke)	In Preparation
Baseline Behavior	Possible orientation behaviour in *Ziphiu*s	Quick (Duke)	In Preparation
Methodology-Technology	Continuous time series data programming regime	Cioffi (Duke)	In Preparation
Methodology-Technology	Estimating RLs and horizontal avoidance with dynamic covariates in exposed animals	Schick (Duke)	In Preparation
Methodology-Technology	Detecting changes in foraging behavior in Cuvier's beaked whales exposed to sonar using coarse resolution data	Glennie (St. Andrews)	In Preparation
Methodology-Technology	Monte Carlo testing to identify behavioral responses to exposure using satellite tag data	Hewitt (Duke)	In Preparation
CEE Exposure-Response	Meta-analysis of context of beaked whale response to sonar exposure	Quick (Duke)	In Preparation
CEE Exposure-Response	Behavioral responses of Cuvier's beaked whales to simulated mid-frequency active military sonar off Cape Hatteras, NC	Southall (SEA; Duke)	In Preparation
Disturbance Exposure-Response	Measuring stress responses in short-finned pilot whale biopsies: are field methods confounding our data?	Wisse (Duke)	In Preparation

2.3.1.3 Overall Assessment and Recommendations for 2021 Effort

Despite the challenges presented surrounding the COVID-19 pandemic, the Atlantic-BRS research team was extremely successful in deploying satellite tags (*n*=15, including 14 highest-priority beaked whales) and coordinating with the U.S. Navy to successfully complete two operational MFAS CEEs. The following are a summary of the accomplishments and some general assessments for the 2020 field effort:

- Developing and successfully implementing adaptive, thorough protocols in order to field research teams and safely achieve comparable field results as in previous years during a pandemic was a major accomplishment.
- Despite the challenges with the pandemic and less than ideal weather for much of the field period, the team again managed to deploy various types of tags on many high-priority beaked whales and collect tens of thousands of hours of movement and diving behavior and movement.
- Successfully coordinated two complete (and as-designed) CEEs with Navy vessels, a major accomplishment after none were achieved in 2019. This was especially notable in that due to the pandemic the team was unable to place liaison riders aboard vessels to coordinate their operations before and during CEEs. There were multiple focal whales during both CEEs, with RLs spanning the entirely of the target range, given that vessels went precisely to requested locations and tracks. Requested data from Navy vessels was provided in a complete, timely, and unclassified manner.
- In one instance, where many (*n*=12) beaked whales were tagged and a potential Navy vessel for coordination was ultimately unavailable, the simulated MFAS source was used successfully.
- Field efforts in 2020 were the first to utilize the R/V *Shearwater* as a research platform. It served as an excellent platform for visual observation, tag tracking, MFAS source, and small-vessel base of operations.
- There were two very promising DTAG deployments, and both tags were successfully tracked through their full programed deployment and relatively easily recovered. However, various sensor failures limited or rendered the data obtained entirely useless. One of these tags stayed on overnight and had the promise of collecting the first such fine-scale diurnal baseline behavioral data, but none were obtained due to sensor and hydrophone failures. The second was notably deployed on a beaked whale that was in the same social group with a satellite-tagged beaked whale, enabling us to fully achieve the multi-scale design of this experiment within a MFAS CEE for the highest-priority species for the second time. Data from this tag were more complete although aberrant heading data from sensor issues will preclude analysis of possible orienting responses as observed in other CEEs.
- Maintained target RLs for beaked whales at 140 decibels based on assessment of results and indications of quite strong responses to simulated MFAS from previous years at these levels. These target levels were achieved for the first time with real vessels at realistic operational ranges (10 to 15-nautical miles), as intended, on two occasions in three focal beaked whales. Each whale showed clear changes in movement and diving patterns, similar to those observed with simulated MFAS sources at closer ranges (2- to 3-nautical mile. While additional samples are needed at these target RLs, these are invaluable data points with important insight in some of the potential range-dependent behavioral responses being evaluated.

- Maintained satellite tag deployment settings as refined in 2019 with very positive results. Notably, some of the more recently obtained tags achieved greater duration deployments for returning ARGOS position data.
- Continued efforts to apply and improve methods of receiving and signals from satellite tags using ARGOS goniometer remained essential in tracking and relocating tagged individuals many times to obtain photos, biopsy samples, and locate other individuals for tagging attempts. These are essential in evaluating MFAS exposure on social interactions and group composition.

Recommendations for 2021 include:

- Retaining the approach taken in 2020 with a single, extended field effort over the entire summer period, as opposed to a spring and later summer/fall effort, focusing effort before and during available Navy vessel coordination periods, and timed relative to optimal weather windows.
- The highest field priority is to obtain additional operational Navy-vessel CEEs for target RLs similar to those evoking strong responses in simulated MFAS CEEs. Based on the observed responses in some focal beaked whales in 2019 to both simulated and real MFAS, no further escalation in target RLs is recommended.
- Beaked whales should be maintained as a high priority species for tagging and CEEs, as conditions allow. Where possible, as recommended in 2019, additional deployments of tags of both types on multiple individuals within the same species group should be tagged. Repeat sightings to confirm surface locations, obtain satellite-tag data, and obtain photo-ID should be sustained.
- Navy ship coordination was extremely well done in 2020, despite the mentioned challenges. We recommend similar close, regular communication and configuration between the field team and Navy personnel communicating with vessels.
- Given the highly productive and efficient experience with the R/V *Shearwater* and unique (to this project) ability to track animals overnight, the team will strive to utilize this platform during CEE periods.

Please refer to the annual progress report for detailed information on 2020 fieldwork, preliminary results from 2017 to 2019, and ongoing analyses (Southall et al. 2021).

2.3.2 Assessment of Behavioral Response of Humpback Whales to Vessel Traffic

In the western North Atlantic, humpback whales feed in high-latitude summer foraging grounds off the east coast of the United States and Canada before migrating to Caribbean breeding grounds in winter (Katona and Beard 1990, Barco et al. 2002, Stevick et al. 2006). Since the early 1990s, juvenile humpback whales have been documented feeding in winter in coastal waters of the mid-Atlantic states (Swingle et al. 1993). The abundance of humpback whales in the North Atlantic is increasing (Stevick et al. 2003), but there are high levels of mortality in mid-Atlantic states (Wiley et al. 1995). Since January 2016, more than 147 humpback whale strandings have occurred along the U.S. East Coast, causing NMFS to declare an unusual mortality event for humpback whales in 2017. One-third of these strandings occurred in the mid-Atlantic, and although only roughly half of the whales were able to be examined post-mortem at all, over half of those that were examined showed evidence of anthropogenic mortality (ship strikes or entanglement).

The U.S. Navy has supported research on humpback whales near Virginia Beach since 2014 as part of the Mid-Atlantic Humpback Whale Monitoring Project. Satellite-tracking data from this project show that the distribution of these animals overlaps significantly with shipping channels (Aschettino et al. 2020b). One live and three dead whales with evidence of ship strikes were observed in the 2016/17 field season. Given the unusual mortality event, the large number of ship-related injuries, and the high spatial overlap with shipping channels, it is essential to understand the behavior of these animals around ships at the entrance of Chesapeake Bay.

Humpback whales in Virginia Beach are constantly exposed to ships. As recently as 2017, Hampton Roads (Virginia) was the ninth busiest port in the U.S. and Baltimore (Maryland) was the fourteenth busiest. Both ports are reached via the shipping lanes that pass through the mouth of the Chesapeake Bay at Virginia Beach, making these shipping lanes extraordinarily busy. This frequent exposure to ships could cause animals to become habituated to ship approaches and, therefore, perhaps less responsive. Habituation to vessel traffic has been documented by baleen whales in Cape Cod (Watkins 1986). However, some types of abrupt, startling sounds may lead to sensitization, or an increased sensitivity to the noise (Götz and Janik 2011). Humpback whales remain in the Virginia Beach area for days to months, and have been re-sighted over multiple years (Aschettino et al. 2021). This suggests that the disturbance from repeated ship exposures is not causing long-term displacement but may put the whales at heightened risk of being struck, given multiple encounters. Theoretically, animals are more likely to remain in good foraging areas even if they are risky, because the potential to be gained from productive foraging outweighs the heightened risk (Christiansen and Lusseau 2014). Therefore, responses may be short-lived and subtle, and require fine-scale sampling to detect. Understanding the behavior of these animals around ships is critical to developing measures to reduce the risk of ship-strike mortality and promote the recovery of this population.

In other areas, humpback whales have low responses to anthropogenic sound such as sonar, especially when compared with other species (Sivle et al. 2015, Wensveen et al. 2017). Recent work in Virginia Beach indicates that these whales do not respond to startling sounds (V. Janik, University of St. Andrews, pers. comm.) Other researchers have suggested that, when whales are engaged in feeding behavior, they are less responsive to approaching ships (Laist et al. 2001), although there is also evidence that foraging behavior is disrupted by approaching ships (Blair et al. 2016) or sonar use (Sivle et al. 2016). Therefore, these whales provide a unique opportunity to study state-dependent risk of ship-strike injury and disturbance in a high-mortality area. Understanding the behavioral context in which they are most likely to both encounter and respond to ships can inform ways to change human behavior to lower the likelihood of detrimental encounters. Determining when and how these whales respond to ships can help with management directives to prevent ship strikes, improving animal welfare and human safety as well as lessening the mortality occurrence of a recovering population.

The objective of this work is to build upon the ongoing Mid-Atlantic Humpback Whale project (section 2.2.2) by deploying high resolution digital acoustic tags (DTAGs) to measure humpback whale responses to close ship approaches. The following questions are being addressed:

1. *Do humpback whales respond to ship approaches, and if so, which behavioral or movement parameters change?*
2. *Which aspects of a ship approach (including the ship's acoustic and behavioral characteristics) elicit which types of responses?*
3. *Does the behavioral context of the animal (foraging/nonforaging) affect the probability of responding to a ship approach?*

DTAGs were deployed on humpback whales in conjunction with focal follows. These tags provide the opportunity to study the whales' three-dimensional movement and reactions to the sound of vessel approaches. The acoustic recorders on the DTAGs also collect information on the acoustic profile of the nearby large vessels, including the received levels of sound at the animal and the frequency characteristics of the ship noise. Kinematic parameters recorded by the tag are used to categorize animal behavioral states (foraging, traveling, other) and measure direct avoidance responses. At each surfacing during the focal follows, behavioral state, distance and bearing, and estimated distance to the nearest ship were recorded. The DTAGs were programmed to record either for 4 to 6 hours per day, or set for an overnight attachment before detaching, allowing for multiple ship approaches per animal, and facilitated collection of synoptic behavioral observations. The aim was to deploy a single tag each day, unless a tag detached from the whale early.

Automatic Identification System data were utilized to collect additional information on vessels, including size, speed, and course of the focal vessel and other ships in the area. Photo-ID images of the focal whale and its associates during the focal follow and biopsy samples were also collected. Photo-ID images will be shared with colleagues from HDR and contributed to regional catalogs. Biopsy samples will be contributed to the sample collection curated by HDR. Efforts were made to coordinate DTAG deployments with individuals previously tagged with longer-term satellite-linked tags (SPOT or SPLASH) to provide days to weeks of movement and behavior data, providing additional context for the high-resolution, short-term DTAG deployments. Ideally, individuals would carry both types of tag simultaneously.

Ten days of suction-cup tagging effort were conducted in the Virginia Beach shipping lanes during the 2020 season, totaling 640 km during 60 hours of survey effort (**Table 21**). Surveys were conducted in Beaufort Sea States ranging from 1 to 4. Humpback whales were sighted on 19 occasions, totaling 25 whales (**Table 22, Figure 35**). Single animals were the most common (14 of 19 sightings), followed by pairs, and no whales were observed in groups larger than three animals. Six DTAGs were deployed (**Table 23, Figure 36**), including two on animals that were carrying satellite-transmitting tags deployed by HDR Inc. One of these deployments (mn20_040a) was 25.5 hours long, marking the first overnight DTAG deployment on a humpback whale in this area. Deployment mn20_053a was also satellite-tagged by HDR and was programmed as an overnight tag. This animal was tagged in the shipping lanes, but soon after tagging, travelled east offshore.

Table 21. Vessel survey effort during suction-cup tagging in the Virginia Beach shipping lanes study area in 2020.

Date	Beaufort Sea State	Distance surveyed (km)	Survey Time (hrs:min)	At Sea Time (hrs:min)
15-January-2020	1–2	67.3	8:54	9:17
03-February-2020	1–2	74.8	8:29	9:11
04-February-2020	2	68.9	6:07	6:57
08-February-2020	2–3	44.2	4:18	5:07
09-February-2020	2	103.7	8:39	9:16
10-February-2020	2–4	35.1	3:10	4:16
22-February-2020	2	40.8	3:56	4:21
23-February-2020	2	109.8	7:51	9:16
24-February-2020	1–3	72.3	6:49	7:30
25-February-2020	3–4	22.0	1:31	2:06

Table 22. Humpback whale sightings during suction-cup tagging in the Virginia Beach shipping lanes study area in 2020.

Date	Time (UTC)	Latitude (°N)	Longitude (°W)	Group Size	Tags Deployed
15-January-2020	14:40	36.8642	75.8778	2	mn20_015a
03-February-2020	14:55	36.9094	75.8853	1	mn20_034a
03-February-2020	21:18	36.9660	75.9649	1	–
04-February-2020	14:49	36.9571	76.0107	1	–
04-February-2020	17:39	36.9561	76.0119	2	–
04-February-2020	19:09	36.9666	76.0211	1	–
08-February-2020	18:40	36.9383	75.9313	1	–
08-February-2020	19:42	36.9312	75.9138	1	–
08-February-2020	20:20	36.9227	75.8969	1	–
09-February-2020	14:16	36.9687	76.0481	1	mn20_040a
09-February-2020	18:29	36.9108	75.9291	1	mn20_040b
10-February-2020	14:07	36.9580	75.0853	1	mn20_040a[1]
22-February-2020	15:28	36.8601	75.8529	1	mn20_066a
23-February-2020	15:45	37.0426	75.7553	2	–
23-February-2020	17:09	37.0163	75.7263	1	mn20_015a
24-February-2020	14:46	36.9343	75.9342	1	–
24-February-2020	15:24	36.9518	75.9612	1	–
25-February-2020	17:22	36.9195	75.9623	3	–
25-February-2020	17:58	36.9074	75.9210	2	–

[1]Tag remained deployed overnight and was retrieved at this time.

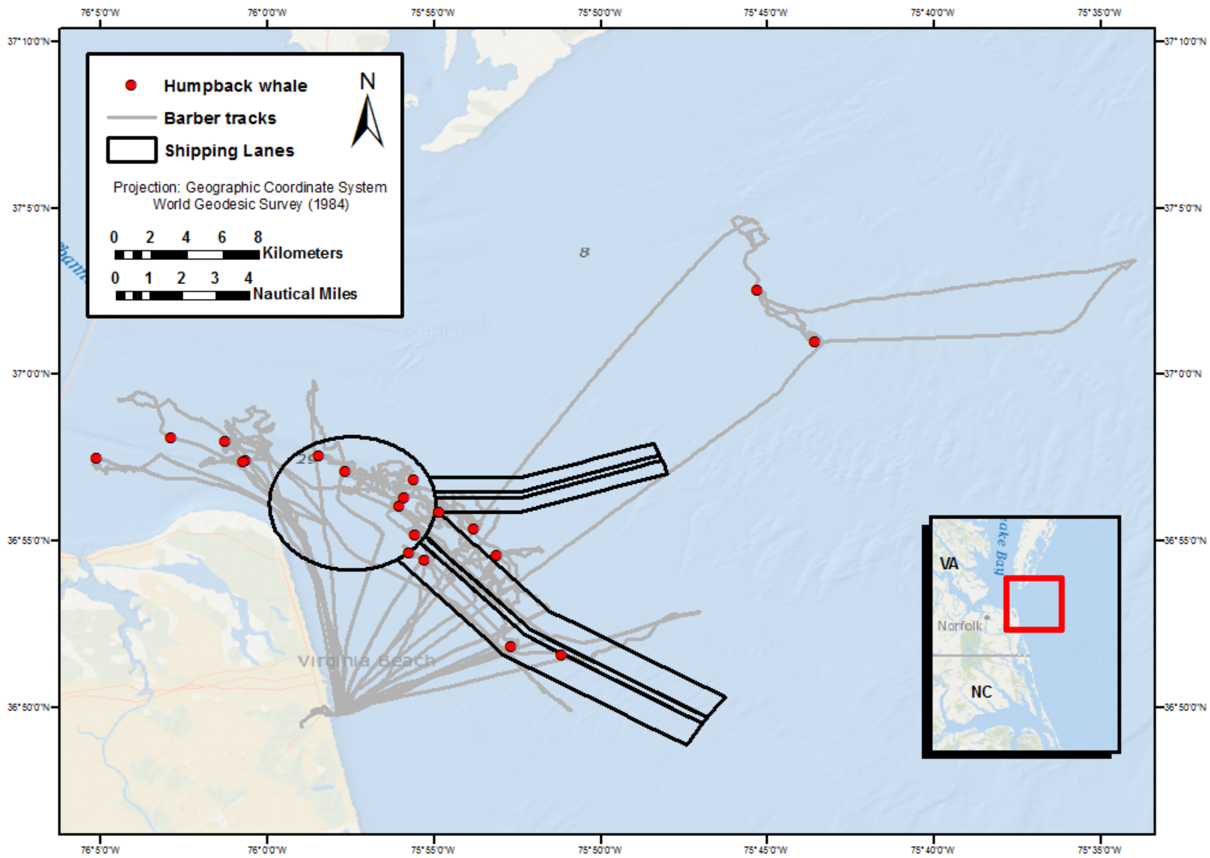

Figure 35. Survey tracks and locations of all sightings during humpback whale suction-cup tagging effort in the Virginia Beach shipping lanes study area in 2020.

Table 23. Suction-cup tag deployments on humpback whales in the Virginia Beach shipping lanes study area in 2020.

Date	Time (UTC)	Latitude (°N)	Longitude (°W)	Tag Type	Tag ID	Duration (hrs:min)
15-Jan-20	15:52	36.8853	75.8848	DTAG	mn20_015a	7:39
03-Feb-20	16:00	36.8915	75.8759	DTAG	mn20_034a	4:37
09-Feb-20	14:26	36.9754	76.0521	DTAG	mn20_040a	25:33
09-Feb-20	18:55	36.8989	75.9161	DTAG	mn20_040b	2:05
22-Feb-20	16:03	36.8616	75.8336	DTAG	mn20_053a	6:58
23-Feb-20	18:09	37.0242	75.7320	DTAG	mn20_054a	3:05

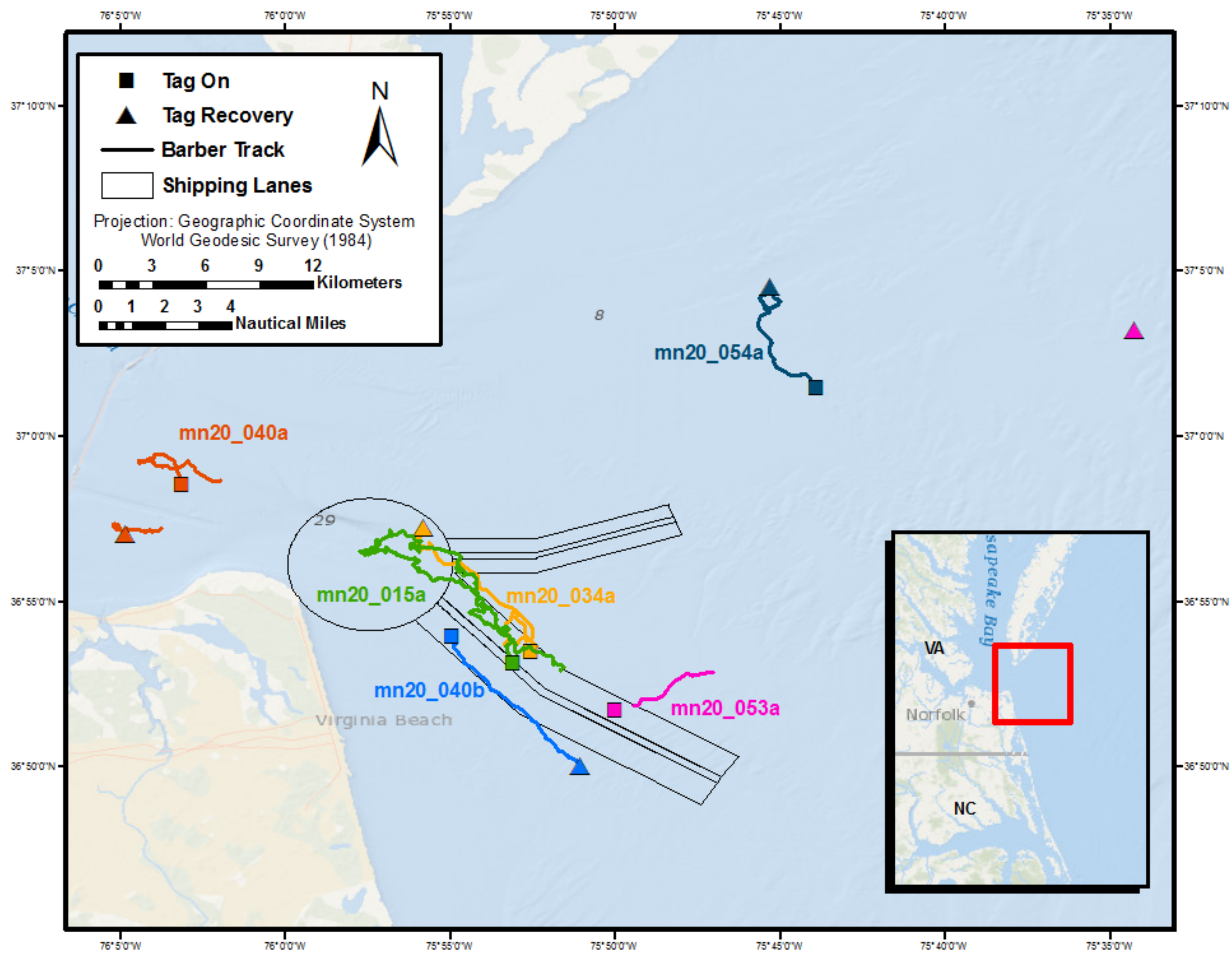

Figure 36. Tagging and tag recovery locations for all six DTAG deployments in the Virginia Beach shipping lanes study area in 2020. Each colored line represents the R/V *Barber*'s track during the focal follow of the animal.

Five tags were deployed in or near the shipping lanes; one tag was deployed offshore (mn20_054a). Mn20_015a remained in the shipping lanes for the entirety of the deployment and spent most of its time foraging. Mn20_034a covered nearly the same track as mn20_015a but showed little foraging. Instead, this animal vocalized for 3.2 hours of the deployment. A biopsy was not successfully obtained from this animal, so its sex is not known. Deployment mn20_040a, which lasted 25.5 hours, showed clear lunges throughout the daytime hours, with reduced foraging effort at night.

Mn20_040b was exhibiting unusual logging behavior at the time of tagging. The tag was only attached by two suction cups, complicating analysis of the accelerometry. The animal's dives were very shallow, with unusually slow ascents and no clear evidence of foraging. There were several recreational and commercial whale-watching boats in the area during the deployment. Given its unusual behavior, the field team watched closely for evidence of entanglement, but no gear was apparent. Deployment mn20_053a was also satellite tagged by HDR and was programmed as an overnight tag. This animal was tagged in the shipping lanes, but soon after tagging, travelled east offshore. The focal follow was discontinued due to worsening offshore conditions and the tag was recovered the following morning approximately 20 nautical miles offshore after having released from the animal 7 hours into the deployment. After 3 hours of deployment, the animal breached several times on the tag and the acceleration data become unstable after this point, likely caused by one or more suction cups becoming dislodged. Mn20_054a was tagged offshore and showed several foraging attempts.

Focal-follow data were collected throughout most of the tag deployment durations. Each animal's distance and bearing from the known position of the research vessel were used to determine the animal's position during the follows. AIS data were obtained from the VesselFinder database and used to determine the locations of all large ships during focal follows. **Figure 37** provides an example of the combined focal follow locations data along with vessel tracks obtained from AIS.

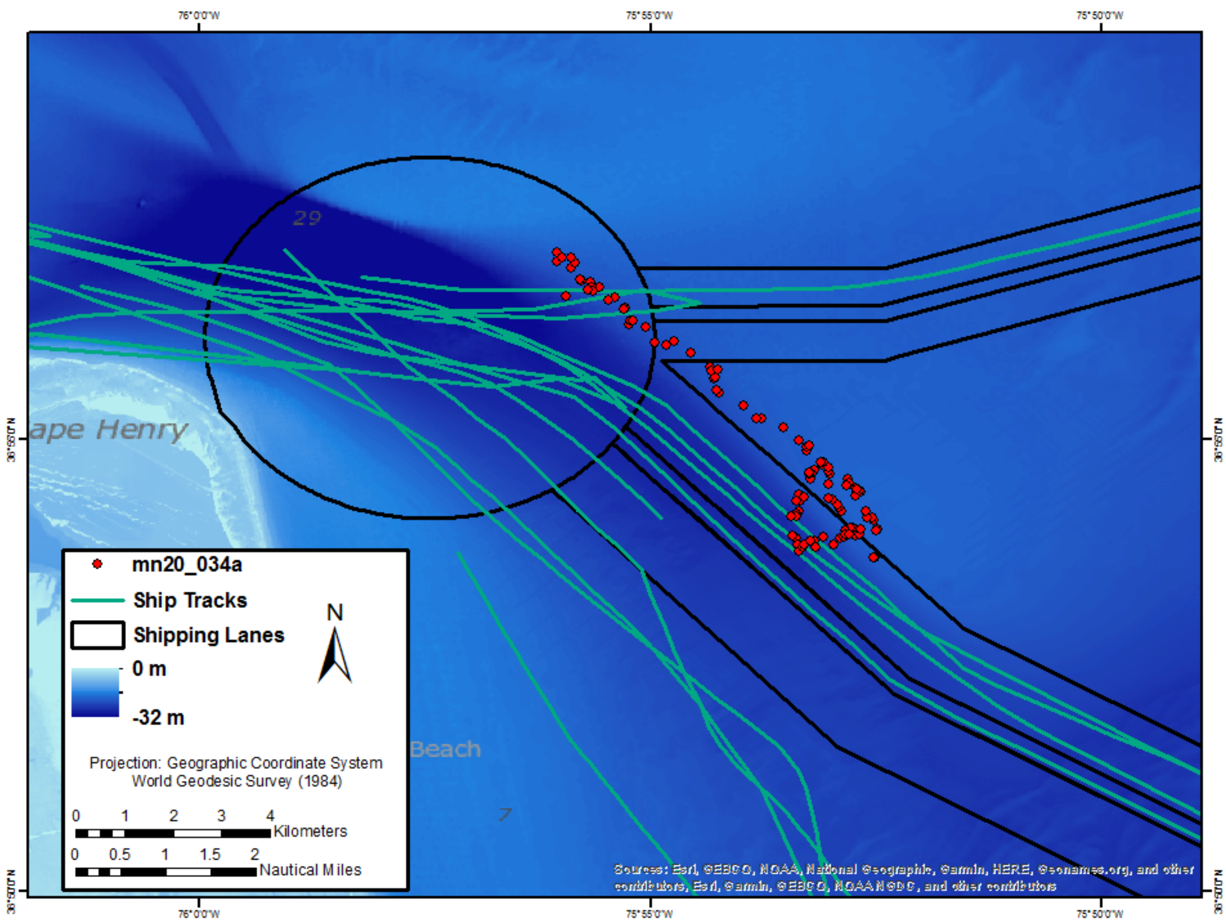

Figure 37. Whale positions (red circles) and ship tracks (green lines) for deployment mn20_034a. Whale positions are derived from the focal follow distance and bearing and the Barber's GPS track. Ship positions were obtained from the VesselFinder AIS service. Ship locations included are those that overlap in time with any point on the tag record. Proximity or crossing tracks does not indicate that the ship and animal were in the same location at the same time.

Of the six DTAG deployments, only three individuals had encounters in time and space with ships, limiting our ability to conduct extensive analysis of the response to ship approaches at this time. However, many of the animals displayed evidence of foraging, and the analysis this year focused on identifying and describing those foraging events. As cessation of foraging is often considered a response to disturbance, identifying the presence and frequency of foraging events will add another variable to our analysis of ship responses. Four of the six tagged individuals exhibited clear lunges and rolling lunges. **Figure 38** is an example of the dive profile from one individual indicating lunges and rolling lunges across a 24hr tag deployment.

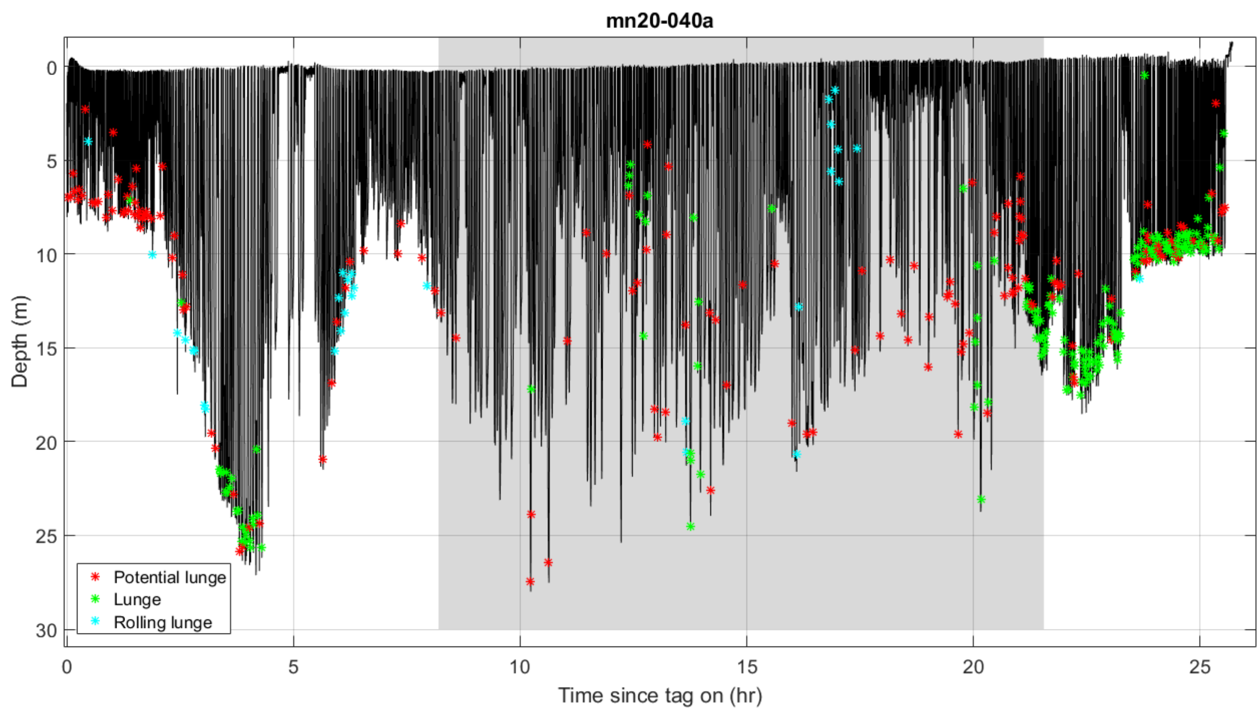

Figure 38. Dive profile for mn20_040a with lunges overlaid. Shaded area indicates nighttime hours.

Fieldwork is currently being conducted during the 2021 season (January–March) to increase the number of tagged whales with ship approaches for analysis. We will continue to prioritize coordination with HDR Inc., to deploy DTAGs on whales equipped with satellite tags. This allows us to extend tag deployment durations and deploy overnight tags. In addition, double-tagging animals improves the accuracy of location estimates for whales in the vessel response project (particularly when tags have been deployed overnight and focal follows are not possible), and provides fine-scale information on the diving behavior of satellite-tagged whales. Both projects will contribute to ongoing efforts to understand the behavior of juvenile humpback whales in the Virginia Beach area and to better understand risk factors and develop potential mitigation measures for ship strikes.

For more information on this project and details of the analyses, please refer to the 2020 annual progress report (Shearer et al. 2021).

This page intentionally left blank.

SECTION 3 – REFERENCES

Ampela, K., J. Bort, M. DeAngelis, R. DiGiovanni, Jr., A. DiMatteo, and D. Rees. 2021. Seal Tagging and Tracking in Virginia: 2019-2020. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Order 19F4147, issued to HDR, Inc., Virginia Beach, Virginia. February 2021.

Aschettino, J., A. Engelhaupt, and D. Engelhaupt. 2015. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, VA: Annual Progress Report. Final Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-10-3011, Task Order 054, issued to HDR Inc., Virginia Beach, Virginia. 29 June 2015.

Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, and M. Richlen. 2016. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, VA: Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract Nos. N62470-10-D-3011, Task Order 54 and N62470-15-8006, Task Order 13, issued to HDR Inc., Virginia Beach, Virginia. 01 March 2016.

Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, and M. Richlen. 2017. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, Virginia: 2016/17 Annual Progress Report. Final Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract N62470-15-8006, Task Order 33, issued to HDR Inc., Virginia Beach, Virginia. 31 August 2017.

Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, and M. Richlen. 2018. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, Virginia: 2017/18 Annual Progress Report. Final Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract N62470-15-8006, Task Order F4013, issued to HDR Inc., Virginia Beach, Virginia. July 2018.

Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, M. Richlen, and M. Cotter. 2019. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, Virginia: 2018/19 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract N62470-15-8006, Task Order F4013, issued to HDR Inc., Virginia Beach, Virginia. July 2019.

Aschettino J.M., D.T. Engelhaupt, A.G. Engelhaupt, A. DiMatteo, T. Pusser, M.F. Richlen, and J.T. Bell. 2020a. Satellite telemetry reveals spatial overlap between vessel high-traffic areas and humpback whales (*Megaptera novaeangliae*) near the mouth of the Chesapeake Bay. *Frontiers in Marine Science* 7: 121. doi: 10.3389/fmars.2020.00121.

Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, M. Richlen, and M. Cotter. 2020b. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, Virginia: 2019/20 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract N62470-15-8006, Task Order 19F4005, issued to HDR Inc., Virginia Beach, Virginia. February 2020.

Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, M. Richlen, and M. Cotter. 2021. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, Virginia: 2020/21 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract N62470-15-8006, Task Order 19F4005, issued to HDR Inc., Virginia Beach, Virginia. March 2021.

Baird, R.W. 2016. *The Lives of Hawai'i's Dolphins and Whales: Natural History and Conservation.* University of Hawai'i' Press, Honolulu, Hawai'i. (beaked whale section on pp 181–198.)

Baird, R.W., D.L. Webster, Z. Swaim, H.J. Foley, D.B. Anderson, and A.J. Read. 2015. *Spatial Use by Cuvier's Beaked Whales, Short-finned Pilot Whales, Common Bottlenose Dolphins, and Short-beaked Common Dolphins, Satellite Tagged off Cape Hatteras, North Carolina, in 2014.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N6247010-D-3011, Task Orders 14 and 21, issued to HDR Inc., Virginia Beach, Virginia. 17 July 2015.

Baird, R.W., D.L. Webster, Z. Swaim, H.J. Foley, D.B. Anderson, and A.J. Read. 2016. *Spatial Use by Odontocetes Satellite Tagged off Cape Hatteras, North Carolina in 2015.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract Nos. N62470-10-3011, Task Order 57 and N62470-15-8006, Task Order 07, issued to HDR Inc., Virginia Beach, Virginia. 17 February 2016.

Baird, R.W., D.L. Webster, Z.T. Swaim, H.J. Foley, D.B. Anderson, and A.J. Read. 2017. *Spatial Use by Odontocetes Satellite Tagged off Cape Hatteras, North Carolina: 2016 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 28, issued to HDR Inc., Virginia Beach, Virginia. August 2017.

Baird, R.W., D.L. Webster, Z.T. Swaim, H.J. Foley, D.B. Anderson, and A.J. Read. 2018. *Spatial Use by Cuvier's Beaked Whales and Short-finned Pilot Whales Satellite Tagged off North Carolina in 2017*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 50, issued to HDR Inc., Virginia Beach, Virginia. March 2018.

Barco, S.G., W.A. McLellan, J.M. Allen, R.A. Asmutis-Silvia, R. Mallon-Day, E.M. Meagher, D.A. Pabst, J. Robbins, R.E. Seton, W.M. Swingle, M.T. Weinrich, and P.J. Clapham. 2002. Population identity of humpback whales (*Megaptera novaeangliae*) in the waters of the US mid-Atlantic states. *Journal of Cetacean Research and Management* 4: 135–141.

Barco, S.G., S.A. Rose, G.G. Lockhart, and A.D. DiMatteo. 2017. *Turtle Tagging and Tracking in Chesapeake Bay and Coastal Waters of Virginia: 2016 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 27, issued to HDR Inc., Virginia Beach, Virginia. June 2017.

Barco, S.G., S.A. Rose, G.G. Lockhart, and A.D. DiMatteo. 2018. *Kemp's Ridley and Green Turtle Tagging and Tracking in Chesapeake Bay and Coastal Waters of Virginia: 2017 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command

Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 27, issued to HDR Inc., Virginia Beach, Virginia. June 2018.

Baumgartner, M.F. and S.E. Mussoline. 2011. A generalized baleen whale call detection and classification system. *Journal of the Acoustical Society of America* 129: 2889–2902.

Baumgartner, M.F., D.M. Fratantoni, T.P. Hurst, M.W. Brown, T.V.N. Cole, S.M. Van Parijs, and M. Johnson. 2013. Real-time reporting of baleen whale passive acoustic detections from ocean gliders. *Journal of the Acoustical Society of America* 134: 1814–1823.

Blair, H.B., N.D. Merchant, A.S. Friedlaender, D.N. Wiley, and S.E. Parks. 2016. Evidence for ship noise impacts on humpback whale foraging behaviour. *Biology Letters* 12: 20160005.

Calenge, C. 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. *Ecological Modelling* 197(3-4):516–519.

Cammen, K.M., T.F. Schultz, W.D. Bowen, M.O. Hammill, W.B. Puryear, J. Runstadler, F.W. Wenzel, S.A. Wood, and M. Kinnison. 2018. Genomic signatures of population bottleneck and recovery in Northwest Atlantic pinnipeds. *Ecology and Evolution* 8: 6599–6614.

Christiansen, F., and D. Lusseau. 2014. Understanding the ecological effects of whale-watching on cetaceans. In J. Higham, L. Bejder, & R. Williams (Eds.), Whale-watching: Sustainable Tourism and Ecological Management (p. 177-192). Cambridge University Press, Cambridge, UK.

Christensen, I., T. Haug and N. Øien. 1992. Seasonal distribution, exploitation and present abundance of stocks of large baleen whales (Mysticeti) and sperm whales (*Physeter macrocephalus*) in Norwegian and adjacent waters. *ICES Journal of Marine Science* 49: 341–355.

Coomber, F., A. Moulins, P. Tepsich and M. Rosso. 2016. Sexing free-ranging adult Cuvier's beaked whales (*Ziphius cavirostris*) using natural marking thresholds and pigmentation patterns. *Journal of Mammalogy* 97: 879–890.

Costidis, A.M., W.M. Swingle, S.G. Barco, E.B. Bates, S.D. Mallette, S.A. Rose, and A.L. Epple. 2019. *Virginia Sea Turtle and Marine Mammal Standing Network 2018 Grant Report*. Final Report to the Virginia Coastal Zone Management Program, NOAA CZM Grant NA17NOS4190152, Task 49. VAQF Scientific Report 2019-01, Virginia Beach, VA, 57 pp.

Davis, G.E., M.F. Baumgartner, J.M. Bonnell, J. Bell, C. Berchok, J. Bort Thornton, S. Brault, G. Buchanan, R.A. Charif, D. Cholewiak, C.W. Clark, P. Corkeron, J. Delarue, K. Dudzinski, L. Hatch, J. Hildebrand, L. Hodge, H. Klinck, S. Kraus, B. Martin, D.K. Mellinger, H. Moors-Murphy, S. Nieukirk, D.P. Nowacek, S. Parks, A.J. Read, A.N. Rice, D. Risch, A. Širović, M. Soldevilla, K. Stafford, J.E. Stanistreet, E. Summers, S. Todd, A. Warde, and S.M. Van Parijs. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales (*Eubalaena glacialis*) from 2004 to 2014. *Scientific Reports* 7: 13460.

DiGiovanni, R.A., Jr., S.A. Wood, G.T. Waring, A. Chaillet, and E. Josephson. 2011. Trends in harbor and gray seal counts and habitat use at southern New England and Long Island index sites. Poster presented at the Society for Marine Mammalogy, Tampa, Florida USA, October 2011.

DiGiovanni, R.A., Jr., A. DePerte, H. Winslow, and K. Durham. 2018. Gray seals (*Halichoerus grypus*) and harbor seals (*Phoca vitulina*) in the endless winter. Presented at the Northwest Atlantic Seal Research Consortium Meeting, New Bedford, Massachusetts USA, April 27, 2018.

DiMatteo, A., S. Barco, and G. Lockhart. 2020. *Loggerhead and Kemp's Ridley Sea Turtle Habitat Models for the Chesapeake Bay.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Orders 17F4031, 19F4026, and 20F4039, issued to HDR, Inc., Virginia Beach, Virginia. August 2020.

DoN (Department of the Navy). 2010a. *U.S. Navy Marine Mammal Research Program Overview*. U.S. Navy, Chief of Naval Operations Environmental Readiness Division, Washington, D.C.

DoN (Department of the Navy). 2010b. *United States Navy Integrated Comprehensive Monitoring Program. 2010 update*. U.S. Navy, Chief of Naval Operations Environmental Readiness Division, Washington, D.C.

DoN (Department of the Navy). 2013. *U.S. Navy Strategic Planning Process for Marine Species Monitoring*. U.S. Navy, Chief of Naval Operations Environmental Readiness Division, Washington, D.C.

Engelhaupt, A., J. Aschettino, T.A. Jefferson, D. Engelhaupt, and M. Richlen. 2016. *Occurrence, Distribution, and Density of Marine Mammals Near Naval Station Norfolk and Virginia Beach, Virginia: 2016 Final Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-10-3011, Task Orders 03 and 043, issued to HDR Inc., Virginia Beach, Virginia. 12 October 2016.

Engelhaupt, A., J.M. Aschettino, and D. Engelhaupt. 2017. *VACAPES Outer Continental Shelf Cetacean Study, Virginia Beach, Virginia: 2016/17 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract Nos. N62470-10-3011, Task Orders 03 and 54, and N62470-15-D-8006, Task Order 35, issued to HDR Inc., Virginia Beach, Virginia. 31 August 2017.

Engelhaupt, A., J.M. Aschettino, and D. Engelhaupt. 2018. *VACAPES Outer Continental Shelf Cetacean Study, Virginia Beach, Virginia: 2017 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract Nos. N62470-10-3011, Task Orders 03 and 54, and N62470-15-8006, Task Order 35, issued to HDR Inc., Virginia Beach, Virginia. May 2018.

Engelhaupt, A., J.M. Aschettino, D. Engelhaupt, A. DiMatteo, M. Richlen, and M. Cotter. 2019a. *VACAPES Outer Continental Shelf Cetacean Study, Virginia Beach, Virginia: 2018 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Order 18F4082, issued to HDR Inc., Virginia Beach, Virginia. July 2019.

Engelhaupt, D., A. Engelhaupt, J. Aschettino, and J. Bell. 2019b. Diving behavior and movements of a Sowerby's beaked whale tagged near Norfolk Canyon. Oral presentation, World Marine Mammal Conference. 9–12 December 2019. Barcelona, Spain.

Engelhaupt, A., J.M. Aschettino, D. Engelhaupt, M. Richlen, and M. Cotter. 2020a. *VACAPES Outer Continental Shelf Cetacean Study, Virginia Beach, Virginia: 2019 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Orders 18F4082 and 19F4068, issued to HDR Inc., Virginia Beach, Virginia. February 2020.

Engelhaupt, D.E, T. Pusser, J.M. Aschettino, A.G. Engelhaupt, M.P. Cotter, M.F. Richlen, and J.T. Bell. 2020b. Blue whale (*Balaenoptera musculus*) sightings off the coast of Virginia. *Marine Biodiversity Records* 13: 6.

Engelhaupt, A., J.M. Aschettino, D. Engelhaupt, M. Richlen, and M. Cotter. 2021. *VACAPES Outer Continental Shelf Cetacean Study, Virginia Beach, Virginia: 2020 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Order 19F4068, issued to HDR Inc., Virginia Beach, Virginia. February 2021.

Falcone, E.A., G.S. Schorr, A.B. Douglas, J. Calambokidis, E. Henderson, M.F. McKenna, J. Hildebrand, and D. Moretti. 2009. Sighting characteristics and photo-identification of Cuvier's beaked whales (*Ziphius cavirostris*) near San Clemente Island, California: a key area for beaked whales and the military? *Marine Biology* 156: 2631–2640.

Foley, H.J., D.M. Waples, Z.T. Swaim, and A.J. Read. 2017. *Deep Divers and Satellite Tagging Project in the Virginia Capes OPAREA–Cape Hatteras, North Carolina: 2016 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 07, issued to HDR Inc., Virginia Beach, Virginia. August 2017.

Götz, T. and V.M. Janik. 2011. Repeated elicitation of the acoustic startle reflex leads to sensitisation in subsequent avoidance behaviour and induces fear conditioning. *BMC Neuroscience* 12: 30.

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird and sea turtle distributions. *Oceanography* 22: 104–115.

Hayes, S.A., E. Josephson, K. Maze-Foley, and P.E. Rosel, eds. 2018. *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2017.* NOAA Technical Memorandum NMFS-NE-245. National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts. June 2018.

Hayes, S.A., E. Josephson, K. Maze-Foley, and P.E. Rosel, eds. 2019. *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2018.* NOAA Technical Memorandum NMFS-NE-258. National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts. June 2019.

Hayes S.A., E. Josephson, K. Maze-Foley, and P.E. Rosel. 2020. *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2020.* NOAA Technical Memorandum NMFS-NE-264. National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts. July 2021.

Hodge, L.E.W., S. Baumann-Pickering, J.A. Hildebrand, J.T. Bell, E.W. Cummings, H.J. Foley, R.J. McAlarney, W.A. McLellan, D.A. Pabst, Z.T. Swaim, D.M. Waples, and A.J. Read. 2018. Heard but not seen: Occurrence of *Kogia* spp. along the western North Atlantic shelf break. *Marine Mammal Science* 34: 1141–1153.

Huber, H.R., S.J. Jeffries, R.F. Brown, R.L. DeLong, and G. Van Blaricom. 2001. Correcting aerial survey counts of harbor seals in Washington and Oregon. *Marine Mammal Science* 17(2): 276-293.

Jeffries, S.J., R.F. Brown, and J.T. Harvey. 1993. Techniques for capturing, handling and marking harbour seals. *Aquatic Mammals* 19(1): 21–25.

Johnston, D.W., J. Frungillo, A. Smith, K. Moore, B. Sharp, J. Schuh, and A. Read. 2015. Trends in stranding and by-catch rates of gray and harbor seals along the northeastern coast of the United States: Evidence of divergence in the abundance of two sympatric phocid species? *PLoS ONE* 10(7): e0131660.

Jones, D.V. and D.R. Rees. 2021. *Haul-out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay and Eastern Shore, Virginia: 2019/2020 Annual Progress Report.* Final Report. Prepared for U.S. Fleet Forces Command, Norfolk, Virginia. February 2021.

Jones, D.V. and D.R. Rees. 2020. *Haul-out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay and Eastern Shore, Virginia: 2018/2019 Annual Progress Report. Final Report.* Prepared for U.S. Fleet Forces Command, Norfolk, Virginia. 5 March 2020.

Katona, S.K. and J.A. Beard. 1990. Population size, migrations, and feeding aggregations of the humpback whale (*Megaptera novaeangliae*) in the western North Atlantic Ocean. *Reports of the International Whaling Commission, Special Issue* 12: 295–306.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet, and M. Podesta. 2001. Collisions between ships and whales. *Marine Mammal Science* 17(1): 35–75.

Mallette, S.D. and S. Barco. 2017. *Development of a Web-based Mid-Atlantic Humpback Whale Catalog: 2016 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Order 27, issued to HDR Inc., Virginia Beach, Virginia. June 2017.

Mallette, S.D. and S.G. Barco. 2019. *Mid-Atlantic & Southeast Humpback Whale Photo-ID Catalog: 2018 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Order 18F4032, issued to HDR Inc., Virginia Beach, Virginia. June 2019.

Mallette, S.D., R.J. McAlarney, G.G. Lockhart, E.W. Cummings, D.A. Pabst, W.A. McLellan, and S.G. Barco. 2017. *Aerial Survey Baseline Monitoring in the Continental Shelf Region of the VACAPES OPAREA: 2016 Annual Progress Report. Final Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 05, issued to HDR Inc., Virginia Beach, Virginia. October 2017.

Mallette, S.D., N.H. Mathies, and S. Barco. 2018. *Development of a Web-based Mid-Atlantic Humpback Whale Catalog: 2017 Annual Progress Report. Final Report.* Prepared for U.S. Fleet Forces

Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Order 27, issued to HDR Inc., Virginia Beach, Virginia. March 2018.

McSweeney, D.J., R.W. Baird and S. Mahaffy. 2007. Site fidelity, associations, and movements of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales off the island of Hawai'i. *Marine Mammal Science* 23: 666–687.

National Marine Fisheries Service (NMFS). 2018a. Letter of Authorization for Navy Training Exercises Conducted in the Atlantic Fleet Training and Testing Study Area. Period November 14, 2018, through November 13, 2023. Issued November 14, 2018.

National Marine Fisheries Service (NMFS). 2018b. Biological Opinion and Conference Opinion on Atlantic Fleet Training and Testing Activities (2018-2023) FPR-2018-9259. Period November 14, 2018, through November 13, 2023. Issued November 14, 2018.

National Marine Fisheries Service (NMFS). 2019. Letter of Authorization for Navy Training Exercises Conducted in the Atlantic Fleet Training and Testing Study Area. Period December 23, 2019, through November 13, 2025.

NOAA. 2020. 2018-2020 Pinniped Unusual Mortality Event along the Northeast Coast. Retrieved from https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/2018-2020-pinniped-unusual-mortality-event-along. Accessed on December 2, 2020.

Pace, R.M, Josephson, E., Wood S.A., Murray, K., and G. Waring. 2019. Trends and Patterns of Seal Abundance at Haul-out Sites in a Gray Seal Recolonization Zone. NOAA Technical Memorandum NMFS-NE-251; 23 p.

Palsbøll, P.J., J. Allen, M. Bérubé, P. Clapham, T. Feddersen, P. Hammond, R. Hudson, H. Jørgensen, S. Katona, A.H. Larsen, F. Larsen, J. Lien, D. Mattila, J. Sigurjónsson, R. Sears, T. Smith, R. Sponer, P. Stevick, and N. Øien. 1997. Genetic tagging of humpback whales. *Nature* 388: 767–769.

Rees, D.R., D.V. Jones, and B.A. Bartlett. 2016. *Haul-out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay, Virginia: 2015/16 Annual Progress Report. Final Report*. Prepared for U.S. Fleet Forces Command, Norfolk, Virginia. 15 November 2016.

Richlen, M., M. Davis, M. Cooper, and P. Hille. 2019. *COMPASS – A Survey Toolkit for Marine Species Data Collection: 2018 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 015, issued to HDR, Inc., Virginia Beach, Virginia. 28 February 2019.

Russel, D.J.F., B.T. McClintock, J. Matthiopoulous, P.M Thompson, D. Thompson, P.S. Hammond, E.L. Jones, M.L. MacKenzie, S. Moss, and B.J. McConnel. 2015. Intrinsic and extrinsic drivers of activity budgets in sympatric grey and harbour seals. Oikos, 124: 1462-1472.

Shearer, J.M., Z.T. Swaim, H.J. Foley, and A.J. Read. 2021. *Behavioral Responses of Humpback Whales to Approaching Ships in Virginia Beach, Virginia: 2020 Annual Progress Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract N62470-15-8006, Task Order 20F4011, and Contract N62470-20-D-0016, Task Order 21F4005 issued to HDR Inc., Virginia Beach, Virginia. February 2021.

Sieswerda, P. and A. Kopelman. 2018. Monitoring harbor seal displacement by grey seals in the Western New York Bight. Presented at the Northwest Atlantic Seal Research Consortium Meeting, New Bedford, Massachusetts USA, April 27, 2018

Širović, A., H. Basset, S.C. Johnson, S.M. Wiggins and J.A. Hildebrand. 2014. Bryde's whale calls recorded in the Gulf of Mexico. *Marine Mammal Science* 30(1): 399–409.

Sivle, L.D., P.H. Kvadsheim, C. Curé, S. Isojunno, P.J. Wensveen, F-P.A. Lam, and P.J. Miller. 2015. Severity of expert-identified behavioural responses of humpback whale, minke whale, and northern bottlenose whale to naval sonar. *Aquatic Mammals* 41(4): 469–502.

Sivle, L.D., P.J. Wensveen, P.H. Kvadsheim, F-P.A. Lam, F. Visser, C. Curé, C.M. Harris, P.L. Tyack, and P.O. Miller. 2016. Naval sonar disrupts foraging in humpback whales. *Marine Ecology Progress Series* 562: 211–220.

Soldevilla, M.S., J.A. Hildebrand, K.E. Frasier, L.A. Dias, A. Martinez, K.D. Mullin, P.E. Rosel, and L.P. Garrison. 2014. Spatial distribution and dive behavior of Gulf of Mexico Bryde's whales: potential risk of vessel strikes and fisheries interactions. *Endangered Species Research* 32: 533–550.

Soldevilla, M.S., A.J. Debich, and L.M. Garrison. 2020. Historical Occurrence of Gulf of Mexico Bryde's Whale Calls at De Soto Canyon 2010-2013. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006.

Southall, B.L., R. Baird, M. Bowers, W. Cioffi, C. Harris, J. Joseph, N. Quick, T. Margolina, D. Nowacek, A. Read, R. Schick, J. Shearer, and D. Webster. 2018. *Atlantic Behavioral Response Study (BRS) 2017 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 50, issued to HDR Inc., Virginia Beach, Virginia. July 2018.

Southall, B.L, R.W. Baird, M. Bowers, W. Cioffi, C. Harris, J. Joseph, N. Quick, T. Margolina, D. Nowacek, A. Read, R. Schick, and D.L. Webster. 2019. *Atlantic Behavioral Response Study (BRS): 2018 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 18F4036, issued to HDR Inc., Virginia Beach, Virginia. July 2019.

Southall, B.L., M. Bowers, W. Cioffi, H. Foley, C. Harris, J. Joseph, N. Quick, T. Margolina, D. Nowacek, A.J. Read, R. Schick, Z.T. Swaim, D.M. Waples, and D.L. Webster. 2020. *Atlantic Behavioral Response Study (BRS): 2019 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 19F4029, issued to HDR Inc., Virginia Beach, Virginia. May 2020.

Southall, B.L, W. Cioffi, H. Foley, C. Harris, J. Joseph, N. Quick, T. Margolina, M. McKenna, D. Nowacek, A.J. Read, R. Schick, Z.T. Swaim, D.M. Waples, D.L. Webster, and J. Wisse. 2021. *Atlantic Behavioral Response Study (BRS): 2020 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 20F4029, issued to HDR Inc., Virginia Beach, Virginia. January 2021.

Stanistreet, J.E., D.P. Nowacek, A. Read, S. Baumann-Pickering, H.B. Moors-Murphy, and S.M. Van Parijs. 2016. Effects of duty-cycled passive acoustic recordings on detecting the presence of beaked whales in the northwest Atlantic. *Journal of the Acoustical Society of America* 140(1): EL31–EL37.

Stanistreet, J.E., D.P. Nowacek, S. Baumann-Pickering, J.T. Bell, D.M. Cholewiak, J.A. Hildebrand, L.E.W. Hodge, H.B. Moors-Murphy, S.M. Van Parijs, and A.J. Read. 2017. Using passive acoustic monitoring to document the distribution of beaked whale species in the western North Atlantic Ocean. *Canadian Journal of Fisheries and Aquatic Sciences* 74: 2098–2109.

Stanistreet, J.E., D.P. Nowacek, J.T. Bell, D.M. Cholewiak, J.A. Hildebrand, L.E.W. Hodge, S.M. Van Parijs, and A.J. Read. 2018. Spatial and seasonal patterns in acoustic detections of sperm whales Physeter macrocephalus along the continental slope in the western North Atlantic Ocean. *Endangered Species Research* 35: 1–13.

Stevick, P.T., J. Allen, P.J. Clapham, N. Friday, S.K. Katona, F. Larsen, J. Lien, D.K. Mattila, P.J. Palsbøll, J. Sigurjónsson, T.D. Smith, N. Øien, and P.S. Hammond. 2003. North Atlantic humpback whale abundance and rate of increase four decades after protection from whaling. *Marine Ecology Progress Series* 258: 263–273.

Stevick, P.T., J. Allen, P.J. Clapham, S.K. Katona, F. Larsen, J. Lien, D.K. Mattila, P.J. Palsbøll, R. Sears, J. Sigurjónsson, T.D. Smith, G. Vikingsson, N. Øien, and P.S. Hammond. 2006. Population spatial structuring on the feeding grounds in North Atlantic humpback whales (*Megaptera novaeangliae*). *Journal of Zoology* 270: 244–255.

Swingle, W.M., S.G. Barco, T.D. Pitchford, W.A. McLellan, and D.A. Pabst. 1993. Appearance of juvenile humpback whales feeding in the nearshore waters of Virginia. *Marine Mammal Science* 9:309–315.

Thompson, P.M., Tollit, D.J., Wood, D., Corpe, H.M., Hammon, P.S., and A. Mackay. 1997. Estimating harbour seal abundance and status in an estuarine habitat in north-east Scotland. *Journal of Applied Ecology* 34, 43-52.

Thorne, L.H., H.J. Foley, R.W. Baird, D.L. Webster, Z.T. Swaim, and A.J. Read. 2017. Movement and foraging behavior of short-finned pilot whales in the Mid-Atlantic Bight: Importance of bathymetric features and implications for management. *Marine Ecology Progress Series* 584: 245–257.

Torres, W.I. and K.C. Bierlich. 2020. MorphoMetriX: a photogrammetric measurement GUI for morphometric analysis of megafauna. *Journal of Open Source Software* 5(45): 1825.

Waples, D. 2017. Stable Isotope Analysis of Humpback and Fin Whales off Virginia Beach, Virginia. Appendix A in Aschettino, J.M., D. Engelhaupt, A. Engelhaupt, and M. Richlen. 2017. *Mid-Atlantic Humpback Whale Monitoring, Virginia Beach, Virginia: 2016/17 Annual Progress Report. Final*

Report. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract N62470-15-8006, Task Order 33, issued to HDR Inc., Virginia Beach, Virginia. August 2017.

Waples, D.M. and A.J. Read. 2020. *Photo-Identification Analyses in the Cape Hatteras Study Area: 2019 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract Nos. N62470-15-D-8006, Task Order 19F4026 issued to HDR Inc., Virginia Beach, Virginia. April 2020.

Waples, D.M. and A.J. Read. 2021. *Photo-Identification Analyses in the Cape Hatteras Study Area: 2020 Annual Progress Report*. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 19F4026 issued to HDR Inc., Virginia Beach, Virginia. February 2021.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. *Marine Mammal Science* 2: 251–262.

Wensveen, P.J., P.H. Kvadsheim, F-P.A. Lam, A.M. von Benda-Beckmann, L.D. Sivle, F. Visser, C. Curé, P.L. Tyack, and P.J.O. Miller. 2017. Lack of behavioural responses of humpback whales (*Megaptera novaeangliae*) indicate limited effectiveness of sonar mitigation. *Journal of Experimental Biology* 220: 4150–4161.

Wiggins, S.M. and Hildebrand, J.A. 2007. High-frequency Acoustic Recording Package (HARP) for broad-band, long-term marine mammal monitoring. Pp. 551–557 in: *International Symposium on Underwater Technology 2007; International Workshop on Scientific Use of Submarine Cables & Related Technologies 2007; 17–20 April, 2007, IIS Conference Hall "Haicot," Komaba Research Campus, The Univeristy [sic] of Tokyo, Tokyo, Japan; Underwater Technology 2007, UT 07, SSC '07.* IEEE Xplore, Piscataway, New Jersey.

Wiley, D.N., R.A. Asmutis, T.D. Pitchford, and D.P. Gannon. 1995. Stranding and mortality of humpback whales, *Megaptera novaeangliae*, in the mid-Atlantic and southeast United States, 1985-1992. *Fishery Bulletin* 93: 196–205.

Wood, S.A, K.T. Murray, E. Josephson, and J. Gilbert. 2019. Rates of increase in gray seal (*Halichoerus grypus atlantica*) pupping at recolonized sites in the United States, 1988–2019. *Journal of Mammalogy* 101(1): 121–128.

APPENDIX A

SUMMARY OF MONITORING PROJECTS IN THE ATLANTIC FOR 2021

Appendix A: Summary of Monitoring Investments in the Atlantic for 2021

Project Description	Intermediate Scientific Objectives	Status
Title: Atlantic Behavioral Response Study **Location**: Cape Hatteras **Objectives**: Assess behavioral response of beaked and pilot whales to mid-frequency tactical sonar **Methods**: Controlled exposure experiments **Performing Organizations**: Duke University, Woods Hole Oceanographic Institution, Cascadia Research Collective, Southall Environmental Associates, University of St. Andrews, HDR Inc. **Timeline**: Ongoing since 2017 **Funding**: FY16 – $35K, FY17 – $1.25M, FY18 – $1.4M, FY19 – $1.4M, FY20 - $1.3M	• Evaluate behavioral responses by marine mammals exposed to Navy training and testing activities	**Field work ongoing** • Technical progress reports available – 2017–2020 • Tagging data available through Animal Telemetry Network • Multiple peer-reviewed publications available • Multiple manuscripts in prep or review
Title: Occurrence, Ecology, and Behavior of Deep Diving Odontocetes **Location**: Cape Hatteras **Objectives**: Establish behavioral baseline and foraging ecology. Assess behavioral response to acoustic stimuli and Navy training activities **Methods**: Visual surveys, biopsy sampling, DTAGs, satellite-linked tags **Performing Organizations**: Duke University, Cascadia Research Collective, Bridger Consulting **Timeline**: Ongoing since 2013, transition to BRS in 2017 **Funding**: FY12 – $275K, FY13 – $250K, FY14 – $510K, FY15 – $520K, FY16 – $420K	• Determine what populations of marine mammals are exposed to Navy training and testing activities • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur • Evaluate behavioral responses by marine mammals exposed to Navy training and testing activities	**Field work ongoing** • Tagging field work continues in support of Atlantic BRS • Funding transitioned under Atlantic BRS in 2017 • Technical progress reports available – 2013–2018 • Tagging data available through Animal Telemetry Network • Multiple peer-reviewed publications available

Project Description	Intermediate Scientific Objectives	Status
Title: Mid-Atlantic Offshore Cetacean Study (VACAPES) **Location**: VACAPES Range Complex **Objectives**: Assess occurrence, habitat use, and baseline behavior of cetaceans in the mid-Atlantic region **Methods**: Visual surveys, focal follow observational methods, photo-ID, biopsy sampling, satellite-linked tags, high-resolution dive tags **Performing Organizations**: HDR, Inc., Kimora Solutions **Timeline**: Ongoing since 2015 **Funding**: FY15 – $75K, FY16 – $645K, FY17 – $0, FY18 – $321K, FY19 – $357K, FY20 – $371K	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline habitat uses and movement patterns of marine mammals where Navy training and testing activities occur • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur	**Field work ongoing** • Technical progress reports available – 2016–2020 • Focus on sperm whale diving and feeding ecology in 2020–21 • Tagging data available through Animal Telemetry Network
Title: North Atlantic Right Whale Monitoring **Location**: Mid-Atlantic and Southeast calving grounds **Objectives**: *Current* - Assess seasonal distribution in the Mid-Atlantic region. *Previous* - Assess behavior of right whales in coastal waters of the Southeast calving grounds, including rates of travel of individuals, dive behavior, and rates of sound production; **Methods**: Autonomous underwater gliders and fixed buoy equipped with passive acoustic monitoring capabilities and near real-time reporting. DTAGs, satellite-linked tags, and focal follow observational methods; **Performing Organizations**: Woods Hole Oceanographic Institution, Duke University, Syracuse University, HDR, Inc **Timeline**: Ongoing since 2014 **Funding**: FY13 – $335K, FY14 – $390K, FY15 – $505K, FY16 – $390K, FY17 – $278K, FY18 – $268K, FY19 – $214K, FY20 – $365K	• Establish the baseline habitat uses and movement patterns of marine mammals where Navy training and testing activities occur • Establish the baseline vocalization behavior of marine mammals and sea turtles where Navy training and testing activities occur • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur	**Fieldwork ongoing** • DTAG deployments on SE calving grounds 2014-17 • Multiple peer-reviewed publications available • 2018 – shift focus to occurrence in Mid-Atlantic • 2018–20 autonomous glider deployments in Mid-Atlantic • 2020 deployed fixed auto-reporting PAM buoy off Cape Hatteras with coordinated opportunistic field work

Project Description	Intermediate Scientific Objectives	Status
Title: Mid-Atlantic Humpback Whale Monitoring **Location**: VACAPES Range Complex **Objectives**: Assess occurrence, habitat use, and baseline behavior of humpback whales in the mid-Atlantic region **Methods**: Focal follow observational methods, photo-ID, biopsy sampling, satellite-linked tags **Performing Organizations**: HDR, Inc., Kimora Solutions **Timeline**: Ongoing since 2015 **Funding**: FY14 – $320K, FY15 – $260K, FY16 – $370K, FY17 – $325K, FY18 – $0, FY19 – $250K, FY20 – $157K	• Establish the baseline habitat uses and movement patterns of marine mammals where Navy training and testing activities occur • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur	**Fieldwork ongoing** • Technical progress reports available – 2014–20 • Peer-reviewed publication • Vessel response component added winter of 2018–19 • Tagging data available through Animal Telemetry Network
Title: Behavioral Response of Humpback Whales to Vessel Traffic **Location**: Chesapeake Bay and Nearshore Mid-Atlantic **Objectives**: Understand the behavioral response of humpback whales to approaching vessels in the shipping channels at the mouth of the Chesapeake Bay. **Methods**: Dtags, satellite-linked tags, and focal follow observational methods **Performing Organizations**: Duke University, HDR Inc. **Timeline**: 2018–2021 **Funding**: FY19 – $95K, FY20 – $75K	• Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur • Evaluate behavioral responses of marine mammals exposed to Navy training and testing activities	**Fieldwork ongoing** • Pilot project - February 2019 • Technical progress reports available – 2019–2020
Title: Mid-Atlantic Humpback Whale Catalog **Location**: Northwest Atlantic **Objectives**: Establish a centralized collaborative humpback whale photo-id catalog for the mid-Atlantic and southeast regions to support management and environmental planning **Methods**: Photo-ID **Performing Organizations**: Organizations: Virginia Aquarium & Marine Science Center Foundation, Duke University **Timeline**: 2017–2020 **Funding**: FY16 – $106K, FY17 – $74K, FY18 - $75K	• Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur	**Finalized in 2020** • Stakeholder workshop report available • Technical progress reports available – 2016–2019 • Online catalog application available through OBIS-SEAMAP

Project Description	Intermediate Scientific Objectives	Status
Title: Lower Chesapeake Bay Sea Turtle Tagging and Tracking **Location**: Lower Chesapeake Bay **Objectives**: Assess occurrence and behavior of loggerhead, green, and Kemp's ridley sea turtles in the Hampton Roads region of Chesapeake Bay and coastal Atlantic Ocean **Methods**: Tagging - satellite, GPS, and acoustic telemetry **Performing Organizations**: Virginia Aquarium and Marine Science Center Foundation, NAVFAC Atlantic, CheloniData LLC **Timeline**: 2013–2020 **Funding**: FY13 – $180K, FY14 – $195K, FY15 – $70K, FY16 – $183K, FY17 – $103K, FY18 – $0, FY19 - $28K, FY20 - $20K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to Navy training and testing activities	**Fieldwork complete** • Tagging field work complete in 2019 • Technical progress reports available – 2013–2018 • Loggerhead analysis complete • Final Kemp's Ridley analysis underway • Multiple peer-reviewed publications available • Tagging data available through Animal Telemetry Network
Title: Pinniped Tagging and Tracking in Virginia **Location**: Lower Chesapeake Bay (Hampton Roads) **Objectives**: Document habitat use, movement and haul-out patterns of seals in the Hampton Roads region of Chesapeake Bay and coastal Atlantic Ocean **Methods**: Photo-ID, tagging **Performing Organizations**: NAVFAC Atlantic, Naval Undersea Warfare Center, The Nature Conservancy, Atlantic Marine Conservation Society, Virginia Aquarium & Marine Science Center Foundation, HDR Inc. **Timeline**: 2017–2022 **Funding**: FY16 – $40K, FY17 – $164K, FY18 – $46K, FY19 – $468K, FY20 – $200K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to Navy training and testing activities	**Fieldwork on hold** • Technical progress report available – 2017–19 • Field work postponed until winter 2021–22 due to COVID-19 pandemic • Tagging data available through Animal Telemetry Network

Project Description	Intermediate Scientific Objectives	Status
Title: [Haul Out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay, Virginia] **Location**: Chesapeake Bay **Objectives**: Document seasonal occurrence, habitat use, and haul-out patterns of seals **Methods**: Visual surveys, remote camera traps, photo-ID **Performing Organizations**: NAVFAC Atlantic **Timeline**: 2015–2022 **Funding**: FY15 – $52K, FY16 – $57K, FY17 – $7K, FY18 – $29K, FY19 – $62K, FY20 – $40K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**Fieldwork ongoing** • Technical progress reports available – 2016–2020 • Time-lapse camera traps incorporated in 2020
Title: Occurrence of Bryde's Whales (Rice's whale) in the Gulf of Mexico **Location**: Northeastern Gulf of Mexico **Objectives**: Assess seasonal and occurrence of Bryde's whales in the Northeastern Gulf of Mexico **Methods**: Passive acoustic monitoring **Performing Organizations**: NOAA-NMFS Southeast Fisheries Science Center **Timeline**: 2019–2022 **Funding**: FY18 – $78K, FY19 – $395K, FY20 – $250K	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline vocalization behavior of marine mammals where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to Navy training and testing activities	**Analysis ongoing, data collection on hold** • Technical progress reports available – 2019–2020 • 2020 data collection delayed due to COVID-19 pandemic
Title: Jacksonville Vessel Surveys and Tagging **Location**: Jacksonville Range Complex (USWTR) **Objectives**: Assess occurrence, habitat associations, and stock structure of marine mammals and sea turtles in key areas of Navy range complexes **Methods**: Vessel visual surveys, satellite-linked tags, biopsy sampling, photo-ID **Performing Organizations**: Duke University, HDR, Inc. **Timeline**: 2020-2022 **Funding**: FY18 – $261K, FY19 – $62K, FY20 – $97K	• Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Determine what populations of marine mammals are exposed to Navy training and testing activities • Evaluate trends in distribution and abundance of populations that are regularly exposed to Navy training and testing activities	**On hold** • Field work postponed until 2021 due to COVID-19 pandemic • Transitioned from small vessel baseline surveys • Focus on photo ID, tagging, and M3R species verification support

Project Description	Intermediate Scientific Objectives	Status
Title: Baseline Monitoring for Marine Mammals in the East Coast Range Complexes – Passive Acoustics **Location**: Virginia Capes, Cherry Point, and Jacksonville Range Complexes **Objectives**: Assess occurrence, habitat associations, density, stock structure, and vocal activity of marine mammals in key areas of Navy range complexes **Methods**: Passive acoustic monitoring **Performing Organizations**: Duke University, Scripps Institute of Oceanography **Timeline**: 2007–2022 **Funding**: FY13 – $780K, FY14 – $800K, FY15 – $680K, FY16 – $596K, FY17 – $426K, FY18 – $299K, FY19 – $303K, FY20 – $231K	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline vocalization behavior of marine mammals where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to Navy training and testing activities	**HARP deployments ongoing** • Current focus – Norfolk Canyon, Hatteras, Jacksonville • Technical progress report series available • Multiple peer-reviewed publications available • End data collection at JAX and Hatteras in 2020 • End data collection at Norfolk Canyon in 2022
Title: Acoustic Ecology of Northwest Atlantic Shelf Break Species and Effects of Anthropogenic Noise Impacts **Location**: Northwest Atlantic **Objectives**: Assess seasonal and spatial, acoustic niches, and anthropogenic drivers of distribution throughout the Northwest Atlantic shelf break region **Methods**: Passive acoustic monitoring **Performing Organizations**: NOAA-NMFS Northeast Fisheries Science Center **Timeline**: 2019–2022 **Funding**: FY18 – $143k, FY19 – $145K, FY20 – $145K	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline vocalization behavior of marine mammals where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to Navy training and testing activities	**Analysis ongoing** • Technical progress reports available – 2019–2020
Title: Marine Mammal Monitoring on Navy Ranges (M3R) **Location**: Jacksonville USWTR **Objectives**: TBD **Methods**: Passive acoustic monitoring **Performing Organizations**: NUWC Newport **Timeline**: 2020–TBD **Funding**: TBD	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline vocalization behavior of marine mammals where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to Navy training and testing activities	**New start - on hold** • Data collection and species verification tests delayed due to COVID-19 pandemic

APPENDIX B

RECENT PUBLICATIONS AND PRESENTATIONS RESULTING FROM AFTT-RELATED MONITORING INVESTMENTS

Appendix B: Recent Publications and Presentations Resulting from AFTT-related Monitoring Investments

Aschettino, J.M., D.T. Engelhaupt, A.G. Engelhaupt, A. DiMatteo, T. Pusser, M.F. Richlen, and J.T. Bell. 2020. Satellite telemetry reveals spatial overlap between vessel high-traffic areas and humpback whales (*Megaptera novaeangliae*) near the mouth of the Chesapeake Bay. *Frontiers in Marine Science* 7: 121.

Davis, G.E., M.F. Baumgartner, P.J. Corkeron, J. Bell, C. Berchok, J.M. Bonnell, J. Bort-Thorton, S. Brault, G.A. Buchanon, D.M. Cholewiak, C.W. Clark, J. Delarue, L.T. Hatch, H. Klinck, S.D. Kraus, B. Martin, D.K. Mellinger, H. Moors-Murphy, S. Nieukirk, D.P. Nowacek, S.E. parks, D. Parry, N. Pegg, A.J. Read, A.N. Rice, D. Risch, A. Scott, M.S. Soldevilla, K.M. Stafford, J.E. Stanistreet, E. Summers, S. Todd, S.M. VanParijs. 2020. Exploring movement patterns and changing distributions of baleen whales in the western North Atlantic using a decade of passive acoustic data. Global Change Biology 26: 9.

DiMatteo, A., Lockhart, G., and S.G. Barco. 2021. All Kemp's ridley turtles (*Lepidochelys kempii*) are created equal: normalizing utilization distributions in an important estuarine foraging area. *Marine Biology Research* (In press).

Engelhaupt, D.E, T. Pusser, J.M. Aschettino, A.G. Engelhaupt, M.P. Cotter, M.F. Richlen, and J.T. Bell. 2020. Blue whale (*Balaenoptera musculus*) sightings off the coast of Virginia. *Marine Biodiversity Records* 13: 6.

Foley, H.J., K. Pacifici, R.W. Baird, D.L. Webster, Z.T. Swaim, A.J. Read. 2021. Residency and movement patterns of Cuvier's beaked whales *Ziphius Cavirostris* off Cape Hatteras, North Carolina, USA. Marine Ecology Progress Series 660: 203–216

Quick, N.J., W.R. Cioffi, J.M. Shearer, A. Fahlman, and A. Read. 2020. Extreme diving in mammals: first estimates of behavioural aerobic dive limits in Cuvier's beaked whales. Journal of Experimental Biology. (2020) 225.

Publications and presentations from previous years also are available in the reading room of the U.S. Navy's Marine Species Monitoring Program website:

http://www.navymarinespeciesmonitoring.us/reading-room/publications