Marine Species Monitoring for the U.S. Navy's Atlantic Fleet Training and Testing (AFTT) – 2021 Annual Report

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Three young male North Atlantic right whales (*Eubalaena glacialis*) socializing off Virginia Beach; photographed by Mark Cotter (HDR, Inc.), taken under National Marine Fisheries Service Scientific Research Permit No. 21482, issued to Dan Engelhaupt (HDR, Inc.)

Cuvier's beaked whale (*Ziphius cavirostris*) during a satellite tag deployment off Cape Hatteras; photographed by Will Cioffi (Southall Environmental Associates), taken under National Marine Fisheries Service Scientific Research Permit No. 19903, issued to Andy Read, (Duke University)

A group of humpback whales (*Megaptera novaeangliae*) engage in cooperative bubble-net feeding on the U.S. Navy's VACAPES range offshore of Virginia; photographed by Todd Pusser, taken under National Marine Fisheries Service Scientific Research Permit No. 16239, issued to Dan Engelhaupt (HDR, Inc.)

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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
LT	lookout team
M3R	Marine Mammal Monitoring on Navy Ranges
m	meter(s)
MAHWC	Mid-Atlantic Humpback Whale Photo-ID Catalog
MFAS	mid-frequency active sonar
MINEX	Mine-neutralization Exercise
MMC	Marine Mammal Commission
MMO	marine mammal observer
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
USS	U.S. Ship
USWTR	Undersea Warfare Training Range
VACAPES	Virginia Capes
VAQF	Virginia Aquarium Foundation

SECTION 1 – INTRODUCTION

This report contains a summary of marine species monitoring (MSM) activities funded by the United States (U.S.) Navy within the Atlantic Fleet Training and Testing (AFTT) study area during 2021. 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 of this report provides a summary of progress and results for each project, with additional details available in individual technical reports linked directly from the corresponding subsection.

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 (OPAREA) 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 occur.

In order to authorize the incidental taking of marine mammals under the MMPA, the National Marine Fisheries Service (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 nearly $46 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). This 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.

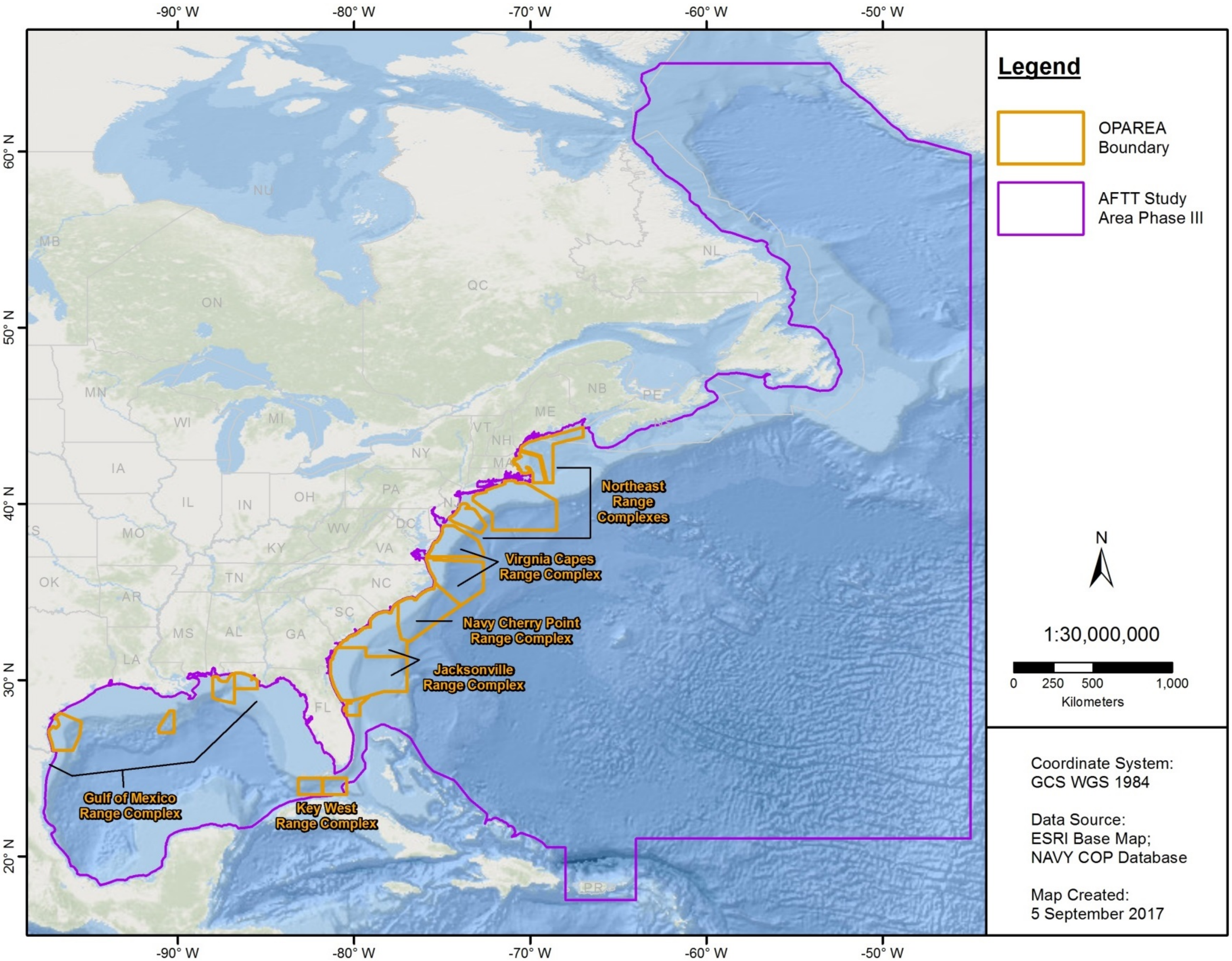

Figure 1. Atlantic Fleet Training and Testing study area.

Table 1. Annual funding for the U.S. Navy's Marine Species Monitoring Program in the Atlantic Fleet Training and Testing study area (formerly AFAST and East Coast/Gulf of Mexico Range Complexes) during Fiscal Years 2009–2021.

Fiscal Year (01 October–30 September)	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
2021	$4,610,000
Total	**$45,864,000**

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 and Technology as well as Research and 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 U.S. Navy developed the Strategic Planning Process (DoN 2013) 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 ICMP 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 U.S. Navy MSM activities in the AFTT study area in 2021 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 2021, 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 2022 and beyond, improve understanding of the occurrence and distribution of marine mammals and sea turtles in the AFTT study area, and improve understanding of their exposure and response to sonar and explosives training and testing activities.

Appendix A summarizes U.S. Navy MSM investments in the Atlantic for 2021 and projects continuing in 2022. Additional details regarding these projects as well as data, reports, and publications can be accessed through the U.S. Navy's marine species monitoring web portal as they become available.

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 (PAM) 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-term study areas now primarily serve to support more recent projects involving tagging and tracking 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, 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 from exposure to training and testing activities.

2.1 Occurrence, Distribution, Population, and Social Structure

Small vessel-based monitoring in 2021 incorporated multi-disciplinary methods, including photo-identification (photo-ID), biopsy sampling, unmanned aerial vehicle observations, and tagging. While PAM 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, with effort being directed more towards species-specific studies and broader ecological analyses. A summary of accomplishments and results from visual and PAM 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 (BRS; **Section 2.3.1**), Duke University continued photo-ID fieldwork in the Cape Hatteras study area during 2021 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 2021).

Digital photographs were obtained from five species, with most taken of Cuvier's beaked whales (*Ziphius cavirostris*) and short-finned pilot whales (*Globicephala macrorhynchus*), the two primary focal species of the Atlantic (BRS). The other cetacean species for which photographs were taken include the sperm whale (*Physeter macrocephalus*), Atlantic spotted dolphin (*Stenella frontalis*), 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 numbers of photo-ID images collected for species in the Cape Hatteras study area in 2021.

Species	Common Name	Number of Sightings	Number of Photo-ID Images
Globicephalus macrorhynchus	Short-finned pilot whale	21	676
Physeter macrocephalus	Sperm whale	6	391
Stenella frontalis	Atlantic spotted dolphin	1	61
Tursiops truncatus	Bottlenose dolphin	23	90
Ziphius cavirostris	Cuvier's beaked whale	127	17,241
Total		**178**	**18,459**

Images of 86 newly identified animals were added to existing photo-ID catalogs of Cuvier's beaked whales, short-finned pilot whales, Atlantic spotted dolphins, and common bottlenose dolphins. Twenty-four new photo-ID matches (18 of Cuvier's beaked whales and 6 of short-finned pilot whales) were made within these two respective catalogs from surveys conducted in 2021. To date, photo-ID catalogs for 11 species have been assembled for the Cape Hatteras area, spanning multiple AFTT MSM projects, with more than 2,000 distinct individuals and 582 individuals re-sighted across all species (**Table 3**).

Table 3. Summary of all images collected during fieldwork in the Cape Hatteras study area in 2021 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
Balaenoptera physalus	0	0	1	0	0
Delphinus delphis	0	0	46	0	1
Globicephalus macrorhynchus	676	28	1,339	6	469
Grampus griseus	0	0	46	0	6
Kogia sp.	0	0	1	0	0
Megaptera novaeangliae	0	0	2	0	0
Physeter macrocephalus	391	0	28	0	1
Stenella clymene	0	0	3	0	0
Stenella frontalis	61	1	25	0	0
Tursiops truncatus	90	11	360	0	19
Ziphius cavirostris	17,241	38	234	18	86
Total	**18,459**	**78**	**2,085**	**24**	**583**

Short-finned Pilot Whales

Totals of 28 new identifications and 6 new re-sights were added to the short-finned pilot whale catalog in 2021 (**Table 3**). The current re-sight rate of short-finned pilot whales is 35 percent, unchanged from the rate documented in 2020. More than 200 short-finned pilot whales have been seen on three or more occasions, and 14 animals have been re-sighted more than six times. Most of the pilot whales that have been sighted the most frequently have either been satellite-tagged or biopsied, and out of the more than 100 that have been biopsied between 2006 and 2021, 95 have been genetically sexed (69 males; 26 females).

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 5 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 with 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. Duke University researchers compared short-finned pilot whales in the Norfolk catalog to the Hatteras catalog, which contains 1,339 individuals. Three new matches were made between the two areas, adding to the 40 previous matches; one animal that had been previously matched between the two areas was re-sighted in Norfolk in 2021. Therefore, 15 percent (43 of 280) of pilot whales observed in the Norfolk Canyon region have also been photographed in the Cape Hatteras area. Comparing the two catalogs provides additional long-term re-sighting information; 13 of the pilot whales were seen in Cape Hatteras from 2007 to 2009, but not observed again until they were photographed in the Norfolk Canyon.

The cross-catalog comparisons also provide interesting information on patterns of social associations. For example, individuals *M-015* and *M-016* were first seen in Cape Hatteras in June 2015, then were re-sighted together in Norfolk in June 2016, and finally were sighted a third time together in Cape Hatteras in October 2017. *M-001*, *M-002*, and *M-003* were in the same group in Cape Hatteras in June 2014 and re-sighted together in Norfolk Canyon in October 2015. *M-026* and *M-046* (matches made during this reporting period) were seen together in October 2013 off Cape Hatteras and re-sighted in the same group in June 2021 off Norfolk. These long-term associations confirm the strong social bonds in this strongly matrifocal species.

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	134
1 to 2	49
2 to 3	46
3 to 4	57
4 to 5	71
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	**469**

Cuvier's Beaked Whales

Thirty-eight new identifications were added to the Cuvier's beaked whale photo-ID catalog during 2021, and 18 new re-sights were made (both within and between years) (**Table 3**). The current re-sight rate for Cuvier's beaked whales in the Cape Hatteras area is up to 36 percent, compared to previous re-sight rates of 35 percent in 2020, 30 percent in 2019, and 24 percent in 2018. To date, 56 of the 86 (65 percent) matched Cuvier's beaked whales have been seen across multiple years, and 28 of those have been re-sighted more than 3 years after the initial observation. 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

Sixteen Cuvier's beaked whales were tagged in 2021 as part of the BRS project, and four of those individuals were matched to the photo-ID catalog. Of the four whales tagged in 2021:

- *ZcTag124* was photographed in 2014 and 2018 before being satellite-tagged in July 2021.
- *ZcTag114* was initially observed in May of 2018 and then tagged in June 2021.
- *ZcTag118* was photographed in 2017 and 2018 and was satellite-tagged in July 2021.
- *ZcTag112* was first observed in August 2019 and was satellite tagged; it was re-sighted in June 2021, and then re-sighted again later in June 2021 when it was satellite-tagged a second time (**Figure 2**).

As part of this project, there have been four Cuvier's beaked whales in the Cape Hatteras study area that have been satellite-tagged multiple times. In all cases, the initial satellite tag and its hardware had been shed and the tag site healed prior to the second transmitter being deployed.

In addition to taking photographs of the dorsal fin and body scarring, used for photo-ID, Duke University 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 less than 50 percent of the body length of the other individual surfacing in proximity; McSweeney et al. 2007). Researchers in Hawaiʻi (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.

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
Sub-adult	Male	Teeth beginning to erupt
Sub-adult	Female	None at present time
Unknown	Unknown	No photograph of head, or photograph of head but no erupted teeth/minimal scarring

Figure 2. Photographs of Cuvier's beaked whale individual *ZcTag096* during satellite-tagging in Cape Hatteras in August 2019 (top), re-sighting in June 2021 (middle), and re-sighting and satellite-tagging a second time in June 2021 (bottom).

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 they are adult males. Many of these non-classified whales are likely adult or sub-adult females or sub-adult males.

Duke University is planning to contribute their sighting history data for Cuvier's beaked whales to a meta-analysis project coordinated by Erin Falcone and Greg Schorr of MarEcoTel. This is a project funded by the ONR; it is a collaborative project involving multiple scientists with the goal of comparing vital rates of Cuvier's beaked whales across distinct populations that are exposed to varying degrees of military sonar. 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, in some cases, sex. Estimation of vital rates for each population will require age- and sex-linked life-history data from a large sample of individual animals; therefore, it is important to have adequate samples of photo-ID data from each region. The Cape Hatteras photo-ID catalog is the largest in this dataset and will be an extremely important contribution to this comparative analysis.

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 (*Grampus griseus*), 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 5 days after tagging in 2014. Most re-sightings have been of satellite-tagged short-finned pilot whales and Cuvier's beaked whales.

Satellite Tagging

To date, 80 satellite tags have been deployed on 79 short-finned pilot whales off Cape Hatteras, and 31 of these (39 percent) have been re-sighted. Most of these re-sightings occurred within the same field season but 11 (35 percent) have been re-sighted across multiple years after being tagged. Eighty-six satellite tags have been deployed on 84 Cuvier's beaked whales from 2014 through 2021. 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.

One notable resighting of a satellite-tagged short-finned pilot whale occurred when *GmTag176*, an individual that was tagged in May 2017 and then re-sighted in October 2020, showed the tag and all hardware had been shed with only two well-healed scars remaining at the tag location. Images were provided to Joe Day, a student from Savannah State University, who completed a research project documenting the long-term effects of satellite tags deployed on short-finned pilot whales. Mr. Day presented his findings at the annual meeting of the Association for the Sciences of Limnology and Oceanography in 2021.

For more information regarding this study, refer to the annual progress report for this project (Waples and Read 2022).

2.1.1.2 Jacksonville Vessel Surveys

In 2021, vessel surveys were conducted off the coast of Florida within the Jacksonville (JAX) OPAREA and the Jacksonville Shallow Water Training Range (JSWTR). Similar to the previous section of this report that focused on the Cape Hatteras, North Carolina, study area, these surveys are an extension of the baseline monitoring program that began in 2007 in Onslow Bay, North Carolina, before it expanded to include U.S. Navy range areas off Florida, North Carolina, and Virginia. The surveys are the latest in a multi-institutional monitoring project intended to provide information regarding species composition, population identity, density, and baseline behavior of marine mammals and sea turtles present in U.S. Navy range complexes along the U.S. Atlantic Coast.

In the Onslow Bay study area, 6 years of monitoring yielded a comprehensive picture of the density, distribution, and abundance of marine mammals and sea turtles and provided new insights into residency patterns among pelagic delphinids in this region (Read et al. 2014), with dedicated survey effort at this site concluding in 2013. In Cape Hatteras, more than 8 years of surveys have provided information on the complex patterns of distribution and diversity of the marine mammals and sea turtles in this highly productive area—serving as a robust baseline for ongoing tagging and behavioral response projects (see **Section 2.3**). More than 9 years of monitoring in the JAX OPAREA have provided similar information regarding the density and distribution of marine mammals and sea turtles (Foley et al. 2019).

More recently, vessel-based visual surveys were conducted in April, May, and December 2021 to assist with the implementation of the Marine Mammal Monitoring on Navy Ranges (M3R) system in conjunction with the Naval Undersea Warfare Center, Division Newport M3R team (see **Section 2.1.2.4**). The following summary describes vessel monitoring activities, including photo-ID, satellite tagging, and biopsy sampling at the Jacksonville study area in 2021. This vessel-based component assisted the passive acoustic M3R system by validating species in real-time based on detections made by the hydrophone array.

Table 6. Vessel survey effort within the Jacksonville study area in 2021.

Date	Beaufort Sea State	Distance surveyed (kilometers)	Survey Time (hours:minutes)	At Sea Time (hours:minutes)
09-April-2021	2–5	85.1	6:38	11:37
12-April-2021	4–6	67.3	5:10	10:25
14-April-2021	2–4	52.5	3:54	8:58
16-April-2021	2–3	94.9	6:50	11:55
16-April-2021	1–4	141.0	7:32	12:03
20-May-2021	2	486.1	10:25	11:59
21-May-2021	2–5	137.5	11:04	24:00
22-May-2021	2–4	126.9	9:52	24:00
23-May-2021	2–3	225.9	10:54	24:00
24-May-2021	2–4	513.2	10:40	24:00
25-May-2021	2	643.1	4:11	14:50
06-December-2021	1–3	114.7	6:14	14:20
07-December-2021	2–4	407.9	9:42	24:00
08-December-2021	2–4	268.0	10:42	24:00
09-December-2021	3–4	407.8	9:48	24:00

The study area within the JAX OPAREA is 5,786 square kilometers, surrounding the JSWTR, which is approximately 1,700 square kilometers in area. The study area straddles the continental shelf break, including part of the Blake Plateau, and includes both shelf and pelagic waters. Seven vessel days of surveys were conducted on both the Research Vessel (R/V) *Richard T. Barber* and R/V *Shearwater*, along with an additional 8 days of surveys during transit on the *Shearwater* **(Table 6, Figure 3)**.

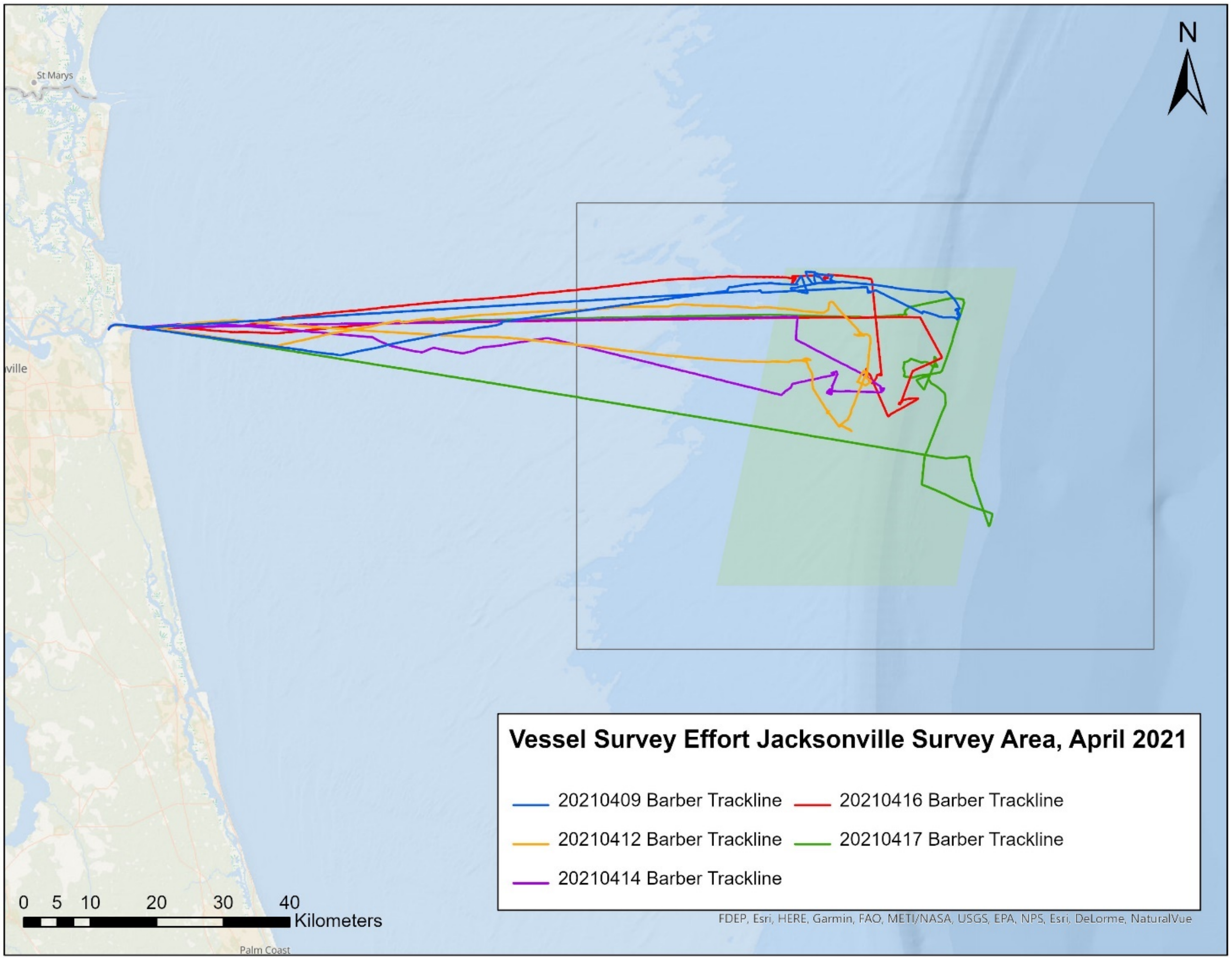

Figure 3. Select example of vessel survey effort (April 2021) in the JAX OPAREA and JSWTR. The gray rectangle is the JAX study area, and the green shaded parallelogram encompasses the JSWTR.

Eighty-five cetacean sightings were recorded, and most (92.9 precent) comprised two species: Atlantic spotted dolphins (*n*=41) and common bottlenose dolphins (*n*=38). There were also three sightings of Risso's dolphins, two sightings of rough-toothed dolphins (*Steno bredanensis*), and, finally, one sighting of a dolphin group that was not identified to species. Eight sightings of 8 sea turtles were composed of 7 loggerhead sea turtles (*Caretta caretta*) and 1 unidentified hard-shell turtle. Consistent with observations in previous years, Atlantic spotted dolphins were restricted to shallow shelf waters, while common bottlenose and rough-toothed dolphins were found both on the shelf and offshore of the continental shelf break (**Figure 4**).

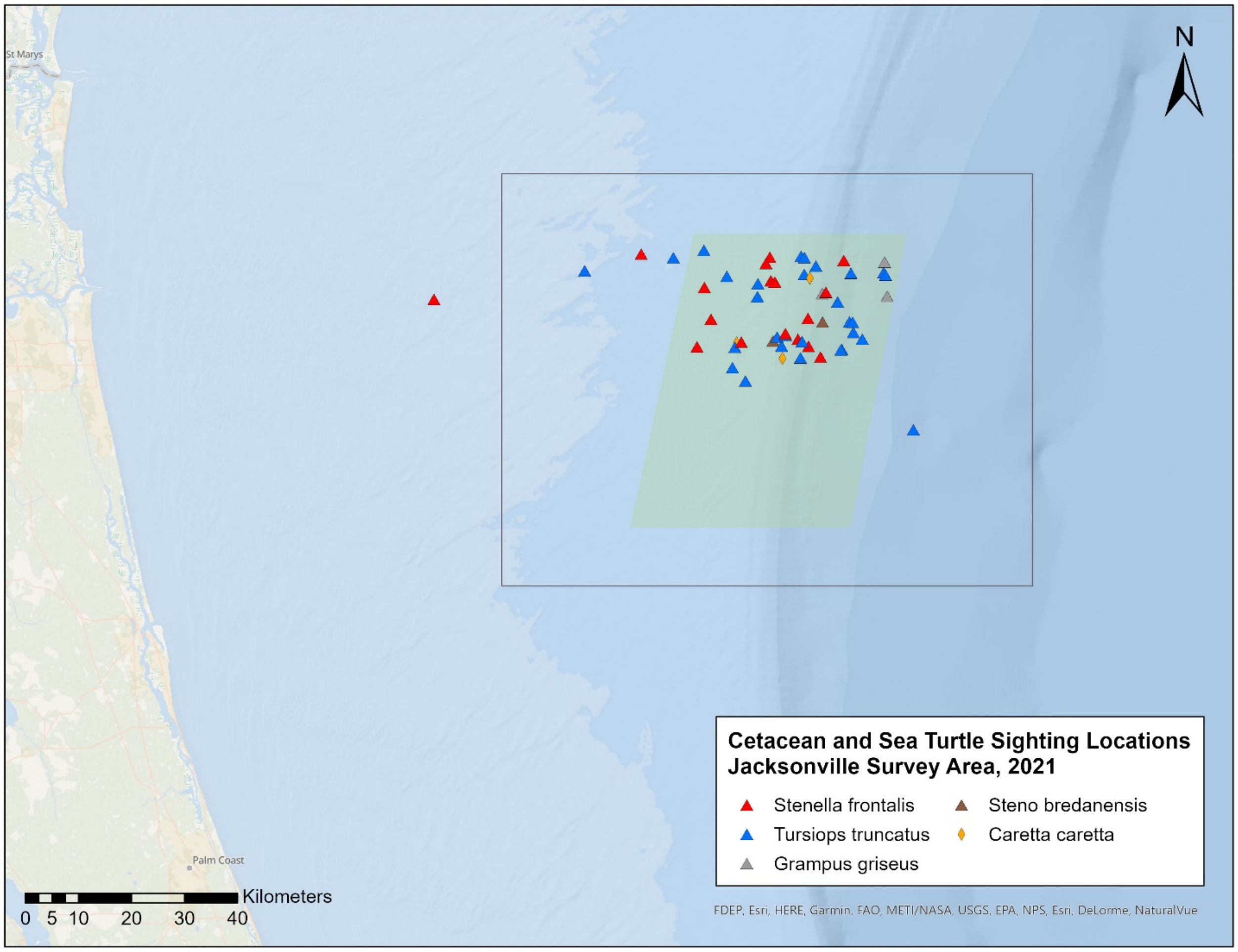

Figure 4. Distribution of cetacean and sea turtle sightings recorded in 2021. The gray rectangle is the JAX study area, and the green shaded parallelogram encompasses the JSWTR.

Satellite tagging and remote biopsy-sampling activities were also conducted in 2021. Two satellite tags were deployed, both on rough-toothed dolphins on 16 and 17 April 2021. The first tag, "Sbr001" transmitted for 6 days, showing the individual traveling out of the Jacksonville survey area and continuing north along the shelf break (**Figure 5**). Tag "Sbr002" transmitted for less than 5 hours.

Thirteen total biopsy samples were collected; 12 samples were obtained from bottlenose dolphins and 1 sample came from an Atlantic spotted dolphin. Voucher specimens of these samples are archived at the Duke University Marine Laboratory in Beaufort, North Carolina. Researchers investigated genetic variation between the coastal and pelagic ecotypes of bottlenose dolphins that occupy distinct habitats and engage in different patterns of diving behavior.

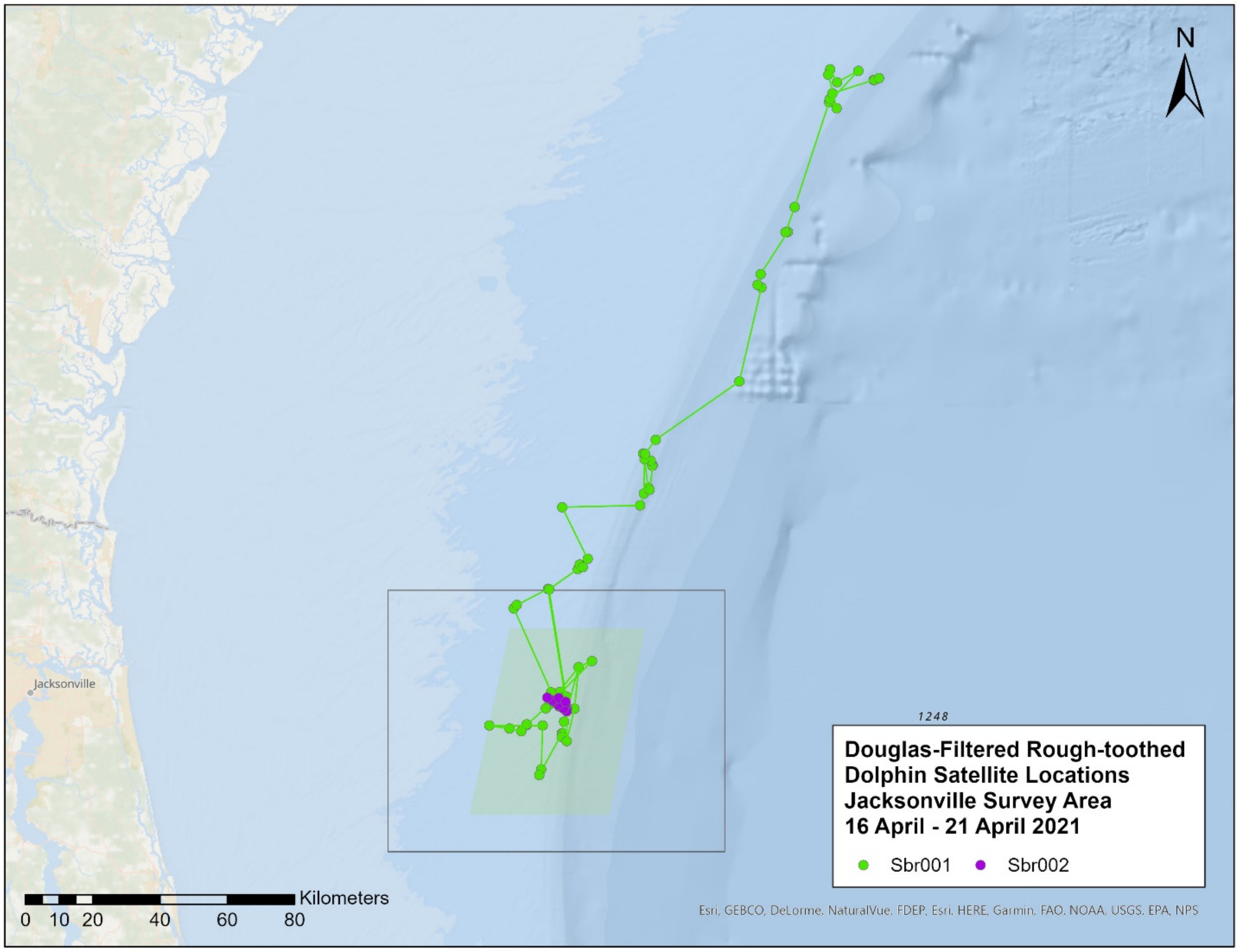

Figure 5. Locations of the two satellite-tagged rough-toothed dolphins in the Jacksonville survey area in 2021.

To improve understanding of population structures in and between these groups, genome-wide genetic variation was investigated using restriction site associated DNA sequencing. A total of 96 samples was available from bottlenose dolphins in coastal and pelagic waters of the Northwest Atlantic from North Carolina to Florida. Analysis of 14,783 single-nucleotide polymorphisms revealed at least three genetically differentiated populations through both Bayesian clustering analysis and Discriminate Analysis of Principal Components. These results suggest the existence of a coastal population along North Carolina's Outer Banks (*n*=32); a pelagic population off the continental shelf break from North Carolina to Jacksonville, Florida (*n*= 38); and a shelf population off Jacksonville, Florida (*n*=26).

For additional details and information on this study, please refer to the annual progress report for this project (Alvarez et al. 2022).

2.1.1.3 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 (SARs) 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 (den Heyer et al. 2021, 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). NOAA SARs now 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 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.

For the 2020/2021 field season, systematic vessel-based counts of all seal species were conducted at two different survey areas (**Figure 6**): 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. Haul-out surveys started in the fall (November) and ended in the spring (May) to ensure the documentation of seal arrival and departure for the 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). An unmanned aircraft system (i.e., drone) was also used at the Eastern Shore survey area to help improve count data collected during vessel-based point counts. 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 2016–2021 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 that tagged seals spent ashore (Huber et al. 2001; Thompson et al. 1997).

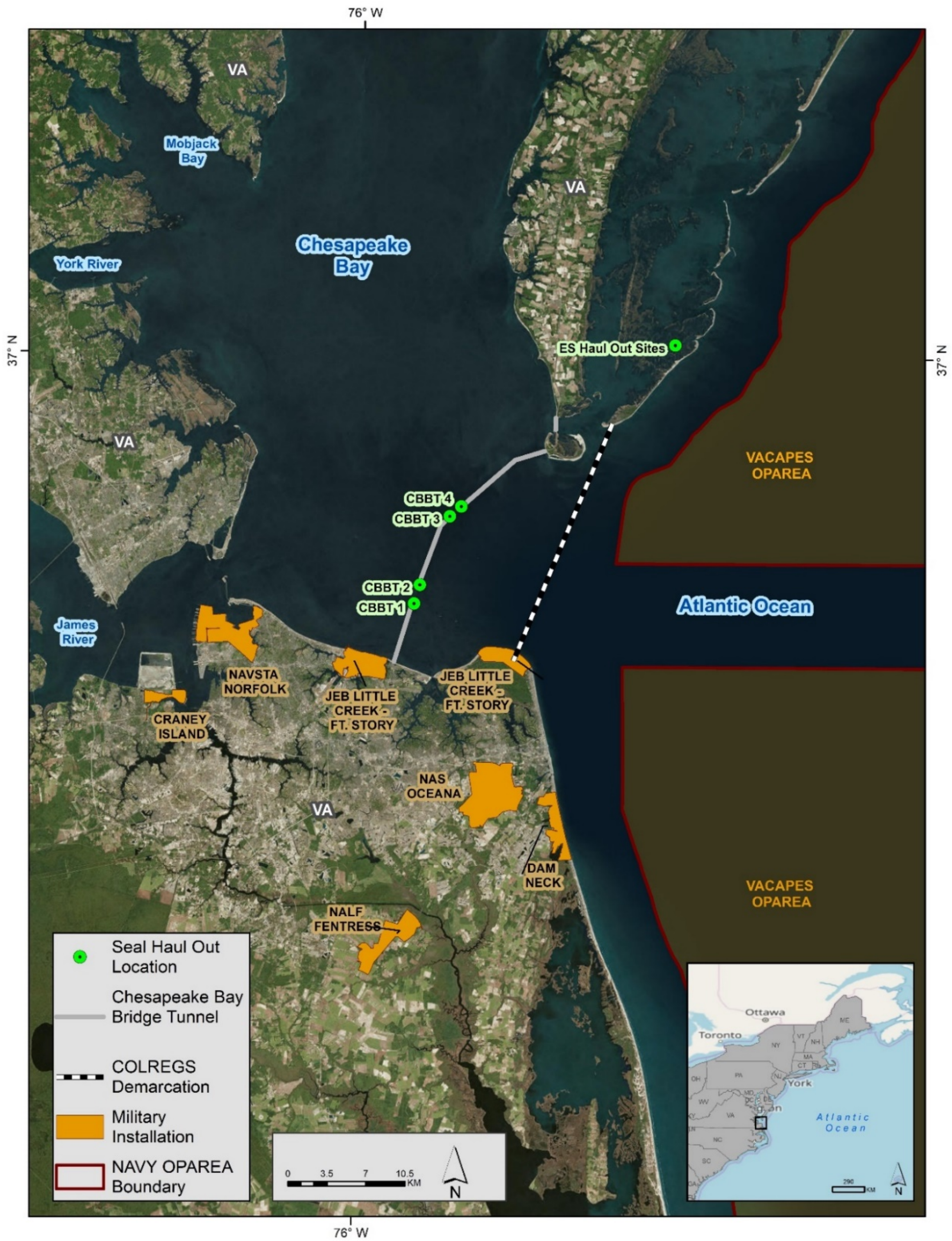

Figure 6. CBBT and Eastern Shore haul-out locations and their proximity to U.S. Naval installations. COLREGS = collision regulations; OPAREA = Operating Area; VACAPES= Virginia Capes Range Complex.

Haul-out Count Results

For the 2020/2021 field season at the CBBT survey area, 13 survey days were completed between 4 November 2020 and 14 May 2021. Overall, a total (combined in-water and hauled out) of 137 seals were sighted across the four CBBT haul-out locations, with more seals (n=75) observed at CBBT 3. Seals were observed on 11 of the 13 (84.6 percent) survey days. The total daily number of seals counted per survey day ranged from 0-32 seals, with the highest counts recorded in January. For the Eastern Shore survey area, 13 survey days were completed between 4 November 2020 and 14 May 2021. Seals were observed on 12 of the 13 (92.3 percent) survey days, with a total of 219 seal sightings recorded for the season. The total daily number of seals counted ranged from 0-44 individuals per survey day, with the highest counts recorded from December to March. Seals were observed hauled out at four of the five main haul-out sites.

As of the end of the 2020/2021 field season, a total of 110 survey days have been conducted across seven field seasons (2014-2021) at the CBBT survey area. Seals have been consistently recorded from mid-November to April. For the Eastern Shore survey area, a total of 58 survey days have been conducted across five field seasons (2016-2021) and seals have been recorded from early November to early April. The majority of seals observed at both survey areas were harbor seals. Gray seals have been occasionally sighted during the winter at both survey areas, although not on a consistent annual basis. For the CBBT, gray seal sightings were recorded for the 2014/2015 (n=1), 2015/2016 (n=2), and 2020/2021 (n=1) field seasons. For the Eastern Shore, gray seal sightings were recorded for the 2017/2018 (n=1), 2018/2019 (n=2), 2019/2020 (n=1), and 2020/2021 (n=4) field seasons.

Since the start of the study in 2014, there has been a fluctuation in seal presence for the CBBT survey area, with an increasing trend in average and maximum seal count from 2014-2018, followed by a decrease from 2018 to 2020 (**Table 7**). For the 2020/2021 season, seal presence appeared to rebound with an increase in average seal count as well as maximum seal count for a single survey day. A similar fluctuation in seal presence was observed for the Eastern Shore survey area, with an increase in average seal count from 2016 to 2018 and again for the 2019 to 2021 field seasons (**Table 8**). Some of the lowest total, maximum, and average seal counts for the CBBT and Eastern Shore survey areas were reported for the 2018 to 2020 seasons. In addition, there was a statistically significant difference (F_{stat}=2.90, p=0.013) between the average seal counts across the seven field seasons (2014 to 2021) for the CBBT survey area. The drop in maximum and average seal count for the 2018 to 2020 seasons for the Eastern Shore survey area was not as substantial compared to the CBBT for these seasons, and the difference between average seal counts across five field seasons (2016 to 2021) was not statistically different (F_{stat}=0.50, p=0.73).

Table 7. Seasonal survey effort (number of survey days), 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
2020–2021	11	137	12	32

Table 8. Seasonal survey effort (number of survey days), 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
2020–2021	12	219	18	44

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

For the 2020/2021 field season, 56 harbor seals were uniquely identified; 35 (63 percent) were new individuals to the catalog and 21 (38 percent) were re-sightings of individuals that were identified from previous field seasons (**Figure 7**). After reviewing all images from the 2015 to 2021 seasons, 155 harbor seals and 1 gray seal were uniquely identified. Of the 155 individuals, 88 (57 percent) were observed only once and 67 (43 percent) were determined to be present in the study area on more than one occasion across the six 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 (34 percent) sighted at only the Eastern Shore survey area. Twelve harbor seals 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.

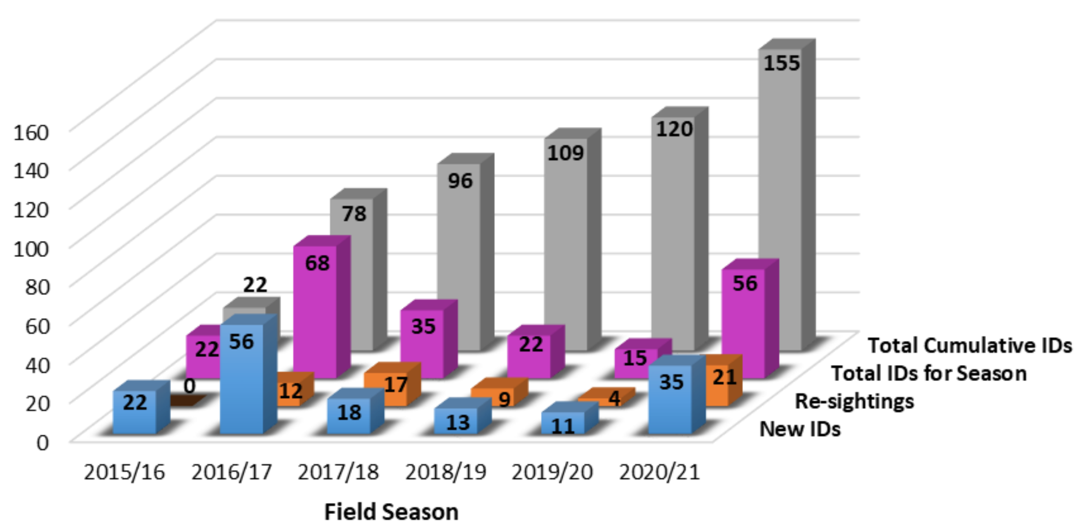

Figure 7. Harbor seal identifications over six field seasons (2015–2021). The purple bars indicate the total number of IDs for a season, orange bars indicate the number of re-sightings, i.e., those IDs that were seen in previous seasons, and blue bars indicate the number of new IDs added to the catalog. The gray bars indicate the total number of cumulative unique IDs.

A population abundance for harbor seals was estimated for the study area using mark-recapture data and the Lincoln-Peterson model. A total of 183 individuals were estimated as the average abundance across all six seasons (2015–2021). Abundance estimates were also calculated for each field season from 2015 to 2021 using the mark-recapture data as well as from 2016 to 2021 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 8**). 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 245 (95% CI: 39.42–450.77) individual harbor seals (**Figure 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 of Virginia may be relatively stable.

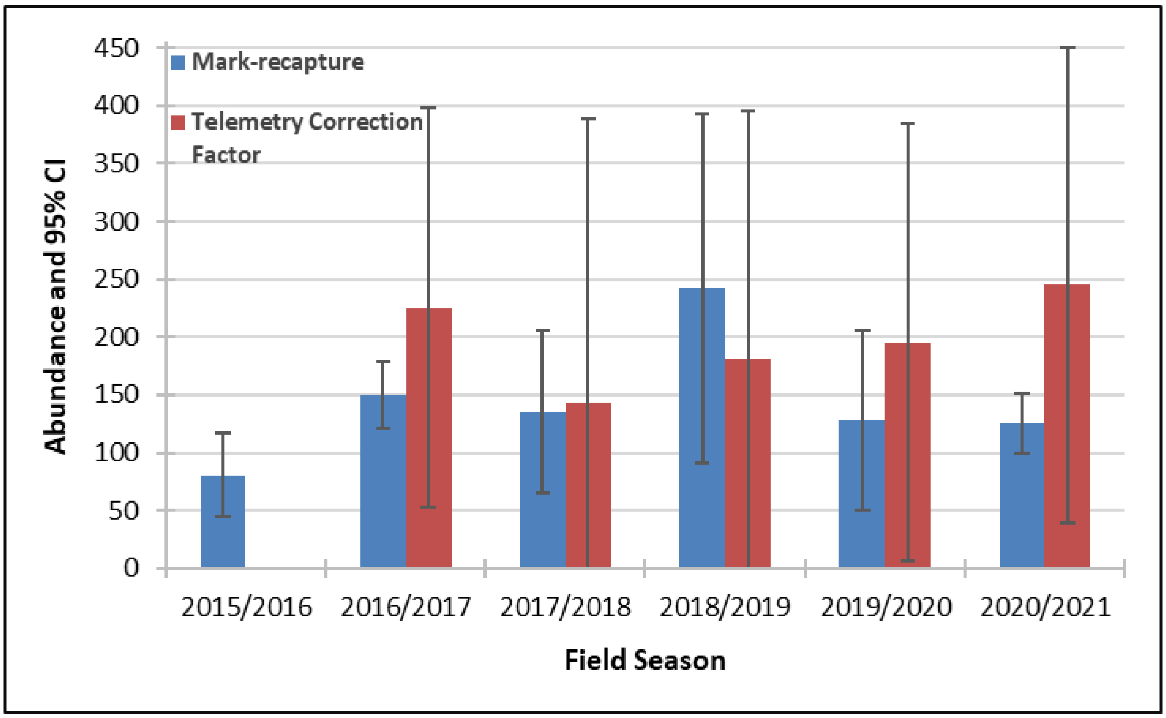

Figure 8. Total abundance estimates and 95% confidence intervals (CIs) for the CBBT and Eastern Shore survey areas combined calculated from the mark-recapture (blue bars) and telemetry correction factor (red bars) approaches for the 2015–2021 field seasons. There is no 2015/2016 estimate for the telemetry correction factor approach because surveys at the Eastern Shore did not start until the 2016/2017 season.

Haul-out counts and photo-ID data collection have continued for the 2021/2022 field season at both the CBBT and Eastern Shore survey areas. For more information on the Virginia seal haul-out count visual surveys, please see the annual progress report (Jones and Rees 2022), and visit the project profile page.

Time-lapse Camera Monitoring

The visual survey haul-out counts discussed above are currently limited to twice per month, and survey scheduling is dependent on weather, daylight hours and marine conditions. These limitations have resulted in a paucity of information during certain times of the day (e.g., sunrise/sunset) and in adverse weather conditions (e.g., rain, high winds, and sea states greater than Beaufort 3). Camera traps have proven effective for monitoring wildlife in remote locations and are cost effective tools for collecting large amounts of data in a way that limits or eliminates impacts to the animals as compared to traditional visual surveys (Wearn and Glover-Kapfer 2019; Koivuniemi et al. 2016). With the use of trail cameras, it is possible to simultaneously sample multiple haul-out areas for extended periods of time with relatively low personnel demands and limited disturbance to the seals independently of many of the typical limitations associated with visual surveys.

Camera trap surveys consist of one or multiple cameras that are set up to capture animals in, or moving through an area. Camera traps can either be set to take a photograph when motion is detected, or can be set to operate in a time-lapse mode to take photos during a set time frame. For this project, camera traps were placed at multiple locations covering most of the known haul-out sites at two survey areas in southeastern Virginia and were operated in time-lapse mode.

Objectives for this study are to 1) improve the understanding of local, seasonal haul-out patterns and the numbers of seals hauled out during daylight hours; 2) to investigate any haul-out patterns in relation to environmental factors; and 3) to determine any differences between vessel and time-lapse camera survey data collected. The data and results from this effort will further improve the assessment of potential impacts from Navy training and testing activities, installation construction (e.g., pile driving) and vessel-transiting. These data may also prove important baseline information to assessing the impacts of future climate change.

Twelve trail cameras have been installed at seven Virginia locations at the CBBT and Eastern shore haul-out sites. Three different models of camera were selected based on site-specific needs, including wireless capability, network linking, and photo quality. Each camera records images throughout the local seal occupancy season from November through April. Cameras are placed to provide maximum coverage of the known haul-out locations at the Eastern Shore area, and the two highest use areas of the CBBT. Images are recorded during daylight hours at a frequency of every 15 minutes.

Images are reviewed for the presence of seals in the water or hauled out, and for the presence of vessels or other factors that appeared to disturb the seals [e.g., bald eagle (*Haliaeetus leucocephalus*) flying over the haul-out]. The Timelapse Image Analysis system, including the Timelapse2 program (Greenberg 2021a, 2021b), is used to count, mark and record the number of seals or vessels in each image (**Figure 9**). Timelapse2 includes built in features which simplify the visual examination and encoding of the data from each image, including custom data recording template set-up, automatic extraction of image data (e.g., file name, date, and time taken) persistent seal marking, automatic counting of marks as identified by the user developed template, automated image time correction (i.e., for daylight savings time changes), and image review tools (Greenberg 2021b).

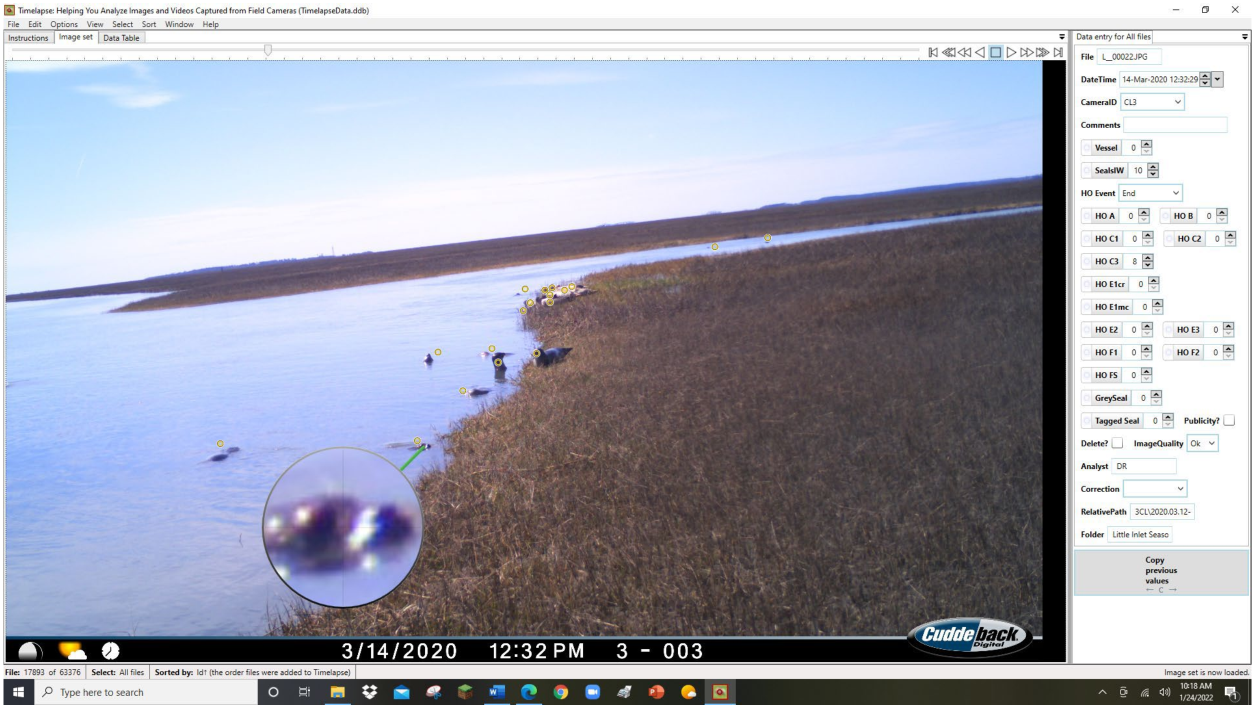

Figure 9. Screenshot of Timelapse Image Analysis workspace. Counted seals are marked by yellow circles, the magnifier feature is shown near front and the customizable data template at the right.

Over 74,000 images were collected and analyzed for the 2019/2020 season. Effort, total seals counted and percentage of days seals were present at the survey area (i.e., either hauled-out or in the water) are summarized in **Table 9**. Seals were observed on the ES survey cameras from November to April, with peak haul-out numbers recorded in January and February., and at the CBBT survey area from January to April, with the highest total count recorded in the month of February (**Figure 10**).

Table 9. Camera trap effort and sightings summary for the 2019/2020 season

Location	Camera Recording Days	Images	Seals Counted	Days Seals Hauled-out	% of Days Hauled-out	Days Seals Present[a]	% of Days Present
ES	178	63,376	50,129	138	77.5	150	84.3
CBBT	113	11,329	5,690	63	55.8	92	81.4
Total	**291**	**74,705**	**55,819**				

Key: ES=Eastern Shore, CBBT=Chesapeake Bay Bridge Tunnel.
[a] Seals present=seals hauled-out or in the water.

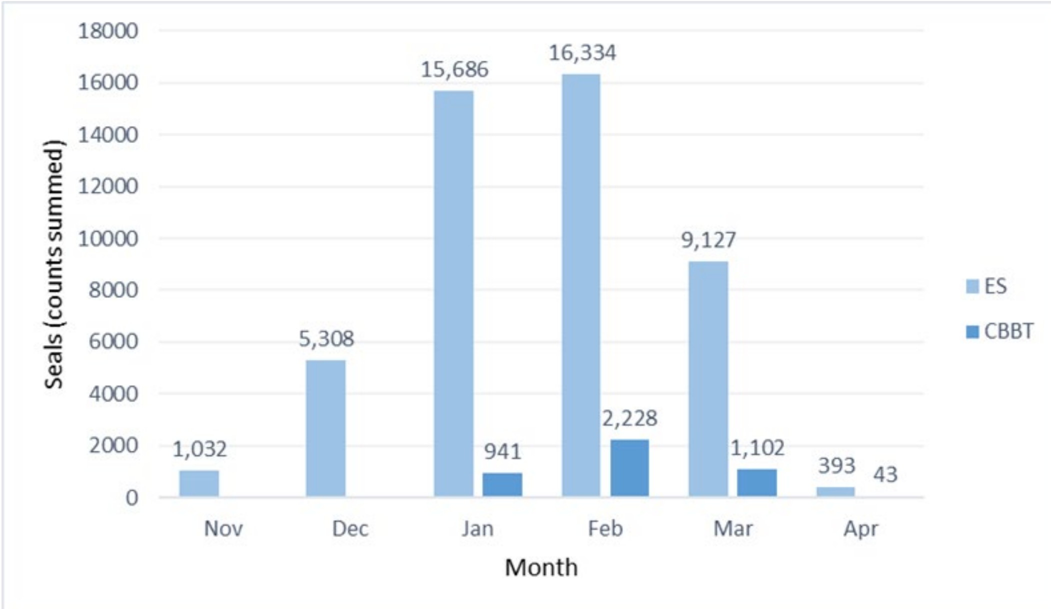

Figure 10. Monthly summed haul-out counts across all cameras at the ES and CBBT locations for the 2019/20 season.

Analyzing environmental factors can help predict if seals will be hauled out or in the water during certain conditions. It was found that seal haul-out counts are fairly even across the range of tide levels at both survey areas. Seals were less likely to be hauled out when average wind speeds were higher than about 25 knots, and seals were more likely to be hauled out at mid-range temperatures for the area (between 45 and 55° Fahrenheit or approximately 7 to 13° Celsius). Several environmental factors were considered for comparison, but were not included in this analysis, including precipitation, tide cycle stage, and water temperature. These were not analyzed for reasons that include lack of data availability (e.g., precipitation), complications in processing (e.g., tidal stage), and time constraints. This analysis may be developed in future.

A comparison of counts from cameras to vessel surveys was conducted to determine if the counts yielded similar results and if camera counts could be a useful proxy for vessel counts in the future, given the high cost, weather dependency, labor intensity, and the seal disturbance potential of vessel counts. Several differences were identified including observation duration (continuous for vessel surveys), impact to behavior (seals often flush into the water in response to approaching vessels), and better ability to observe obscured animals and behavior from vessel surveys.

For more information on the Virginia seal camera trap work including details of analyses conducted, please see the annual progress report (Rees et al., 2022), and visit the project profile page.

2.1.1.4 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 2 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) has been leading the development of a collaborative, integrative platform for the MAHWC that provides a broad-scale and high-quality tool that can be used 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. 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 U.S. have increased substantially in the past few years. To integrate data from a multitude of sources more effectively, both current and historical, a streamlined process for submissions, management, and access is necessary. Additionally, 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 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.

During 2020 and 2021, the catalog underwent substantial restructuring of its programming to take advantage of automated uploading procedures that were developed for other catalogs on the OBIS-SEAMAP platform. While the automated system reduced the workload for curators, it required changing key fields and re-linking data and images previously submitted to the catalog. Additionally, curator instructions and protocols required updating and testing. The catalog is available to collaborators but has yet to be moved from the beta-testing stage because of the work required to take advantage of enhancements for future curation.

The MAHWC remains 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 of the Marine Biological Association of the United Kingdom*. The rollout of the final catalog is currently slated for spring 2022.

2.1.2 Passive Acoustic Methods

Passive acoustic monitoring (PAM) 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. Additionally, the M3R 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 MSM and interactions with training and testing activities.

All current and past deployments of PAM devices—including High-frequency Acoustic Recording Packages (HARPs); Slocum G3 ocean gliders; Marine Autonomous Recording Units (MARUs); Autonomous Multichannel Acoustic Recorders (AMARs); Ecological Acoustic Recorders (EARs); automated click detectors (CPODs); and, most recently, autonomous real-time acoustic detection buoys—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 (**Figure 11**). Deployments ended at the Onslow Bay site in 2013, Jacksonville in 2019, and Cape Hatteras in 2020. The final deployment at the Norfolk Canyon location is scheduled to be retrieved in summer 2022. 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 2021, single-channel HARP data were collected at the Norfolk Canyon site and Scripps Institution of Oceanography conducted basic analyses and produced technical reports covering deployments from 2019 to 2020 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).

Deployment details for each site are shown in **Table 10** through **Table 12**. 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.

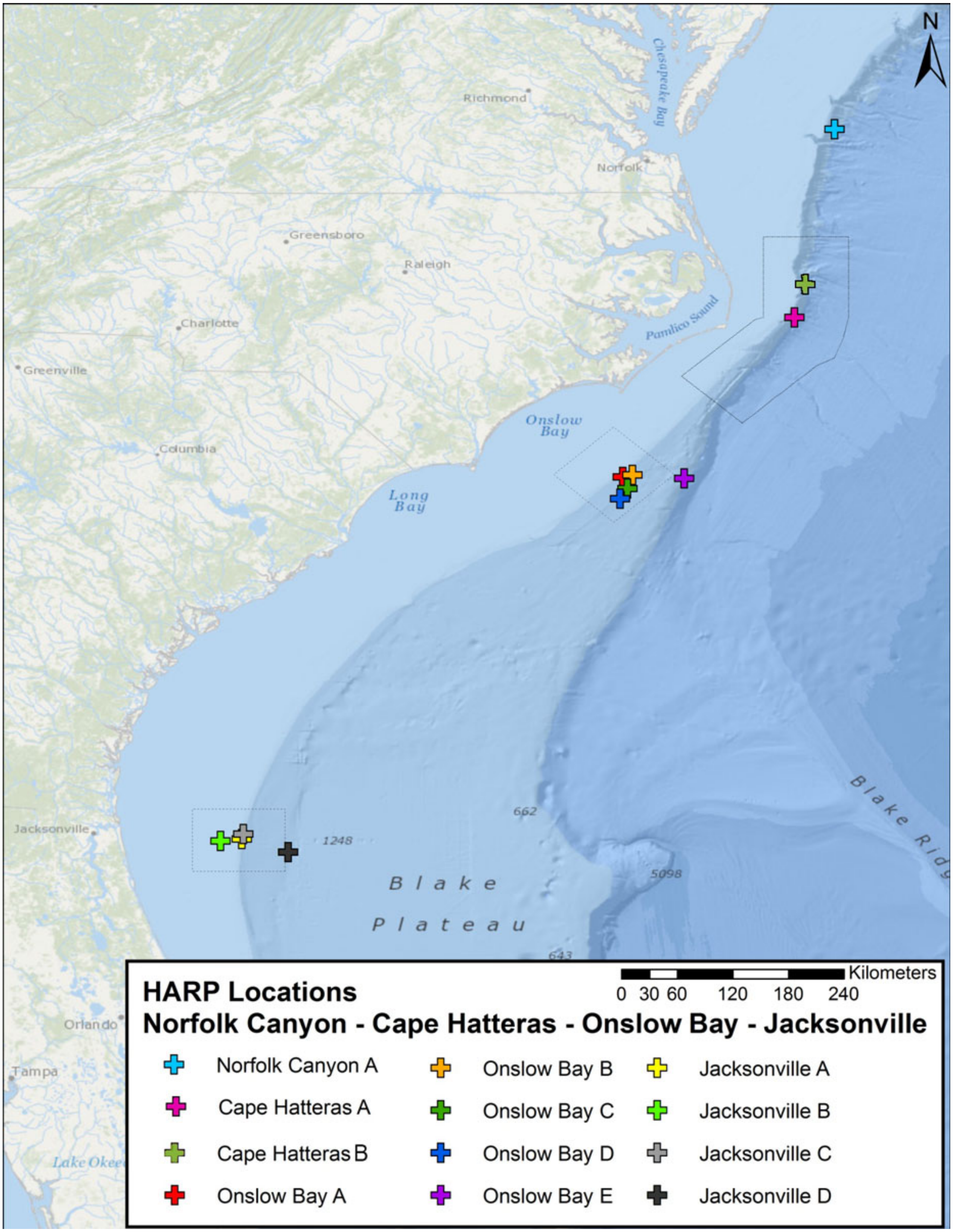

Figure 11. Location of HARP deployment sites in Norfolk Canyon, Cape Hatteras, Onslow Bay, and JAX.

Table 10. All HARP deployments in JAX, 2014–2021.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude (°N)	Longitude (°W)	Depth (m)	Sampling Rate (kHz)	Duty Cycle
11D	23-Aug-14	02-Jul-15	23-Aug-14	22-May-15	30.1506	79.7700	806	200	continuous
12D	02-Jul-15	26-Apr-16	03-Jul-15	04-Nov-15	30.1489	79.7711	800	200	continuous
13D	26-Apr-16	25-Jun-17	26-Apr-16	25-Jun-17	30.1518	79.7702	736	200	continuous
14D	25-Jun-17	26-Jun-18	25-Jun-17	26-Jun-18	30.1527	79.7699	740	200	continuous
15D	26-Jun-18	15-Jun-19	26-Jun-18	15-Jun-19	30.1522	79.7710	740	200	continuous
16D	15-Jun-19	14-Jun-21	15-Jun-19	30-Jun-20	30.155	79.771	735	200	continuous

Key: °N = degrees North; °W = degrees West; kHz = kilohertz; m = meter(s).

Table 11. 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 (kHz)	Duty Cycle
01A	19-Jun-14	07-Apr-15	19-Jun-14	05-Apr-15	37.1662	74.4669	982	200	continuous
02A	30-Apr-16	30-Jun-17	30-Apr-16	28-Jun-17	37.1652	74.4666	968	200	continuous
03A	29-Jun-17	02-Jun-18	29-Jun-17	02-Jun-18	37.1674	74.4663	950	200	continuous
04A	02-Jun-18	19-May-19	02-Jun-18	18-May-19	37.1645	74.4659	1,050	200	continuous
05A	19-May-19	01-Mar-21	19-May-19	8-May-20	37.1645	74.4659	1,050	200	continuous
06A	29-Jun-21	N/A	29-Jun-21	N/A	37.1645	74.4659	1,050	200	continuous

Key: °N = degrees North; °W = degrees West; kHz = kilohertz; m = meter(s); N/A = not available.

Table 12. 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 (kHz)	Duty Cycle
02A	09-Oct-12	29-May-13	09-Oct-12	09-May-13	35.3406	74.8559	970	200	continuous
03A	29-May-13	08-May-14	29-May-13	15-Mar-14	35.3444	74.8521	970	200	continuous
04A	08-May-14	06-Apr-15	09-May-14	11-Dec-14	35.3467	74.8480	850	200	continuous
05A	06-Apr-15	29-Apr-16	07-Apr-15	29-Jan-16	35.3421	74.8572	980	200	continuous
06A	29-Apr-16	09-May-17	29-Apr-16	06-Feb-17	35.3057	74.8776	1,020	200	continuous
HAT_B_01_01	09-May-17	25-Oct-17	09-May-17	25-Oct-17	35.5837	74.7492	1,118	200	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	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	continuous
HAT_B_02_02_C4	28-Jun-17	Lost-at-sea	28-Jun-17	N/A	35.5793	74.7569	1,040	200	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	continuous
HAT_B_03_01	25-Oct-17	01-Jun-18	25-Oct-17	01-Jun-18	35.5835	74.7431	1,117	200	continuous
HAT_B_04_01	01-Jun-18	13-Dec-18	01-Jun-18	13-Dec-18	35.5897	74.7476	1,350	200	continuous
HAT_B_04_02_C4	01-Jun-18	13-Dec-18	N/A	N/A	35.5851	74.7515	1,175	200	continuous
HAT_B_04_03_C4	01-Jun-18	13-Dec-18	01-Jun-18	13-Dec-18	35.5905	74.7628	1,078	200	continuous
HAT_B_05_01	13-Dec-18	18-May-19	14-Dec-18	18-May-19	35.5897	74.7476	1,350	200	continuous
HAT_B_06_01	18-May19	24-Oct-19	18-May-19	24-Sep-19	35.5844	74.7479	1,120	200	continuous
HAT_B_05_02_C4	17-May-19	24-Oct-19	17-May-19	N/A	35.5805	-74.7455	1,217	200	continuous
HAT_B_05_03_C4	17-May-19	24-Oct-19	17-May-19	N/A	35.5848	-74.7415	1,227	200	continuous
HAT_B_07_01	24-Oct-19	01-Mar-21	25-Oct-19	29-Oct-20	35.5826	-74.7501	1,100	200	continuous

Key: °N = degrees North; °W = degrees West; m = meter(s); kHz=kilohertz; m=meter(s); N/A=not available.

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 to 2019, in coordination with the Bureau of Ocean Energy Management. 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 to 2019. The focus of the 2021 efforts were to refine species occurrence analyses, including extensive work to improve the classification algorithms for odontocetes; applying frameworks to assess impacts of anthropogenic noise on the acoustic ecology and acoustic behavior of protected species; and finalizing and publishing work on new acoustic metrics to describe species occurrence and diversity.

Work conducted in 2021 was aimed at advancing the analytical components for these key objectives:

- Continuing to improve tools for 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 13, Figure 12**). 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. See Van Parijs et al. 2021 for details.

Table 13. 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	1,000
Nantucket Canyon (NC)	April 2015	June 2019	977
Babylon Canyon (BC)	April 2016	May 2019	1,000
Wilmington Canyon (WC)	April 2016	May 2019	1,000
Norfolk Canyon (NFC)	April 2016	May 2019	1,000
Hatteras (HAT)	April 2016	May 2019	1,100
Gulf Stream (GS)	April 2016	June 2019	954
Blake Plateau (BP)	April 2016	May 2019	945
Blake Spur (BS)	April 2016	June 2019	1,005
Jacksonville (JAX)	April 2016	June 2019	750

Key: m = meter(s)

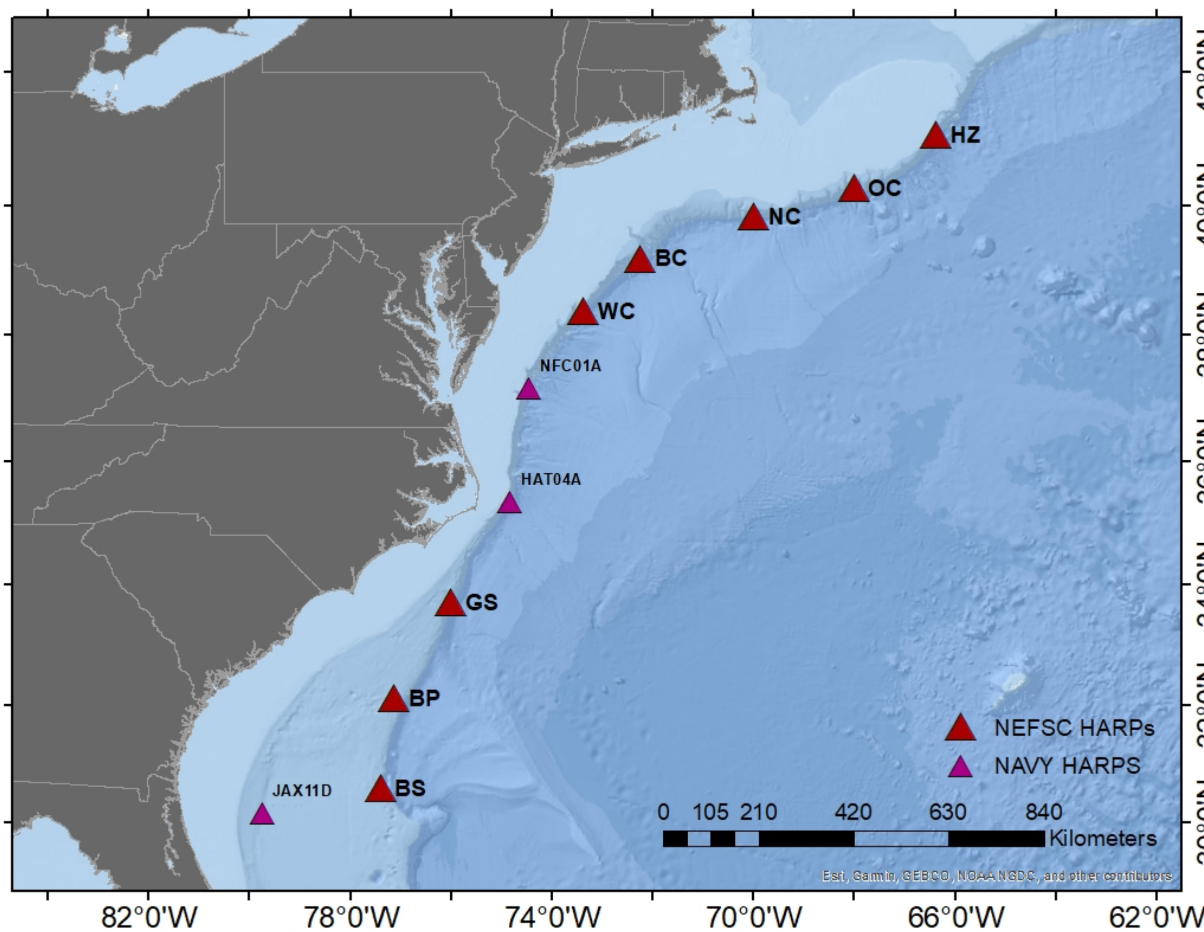

Figure 12. HARP deployment sites for data collected from 2015 through 2019.

Improving automated classification for beaked whales

The volume of data generated from the 11 recording sites during 2015 to 2019 presented a challenge for classification of beaked whales to the species level as it requires expertise and time to manually label echolocation clicks. The purpose of this effort was to design a system to streamline and automate the process of detecting and classifying beaked whale echolocation clicks using deep-learning neural networks. The classification pipeline consisted of multiple steps targeted to efficiently detect beaked whales, often rare to detect when other species dominate the soundscape. The steps included 1) a generic detector to detect clicks above a received level threshold; 2) a discrimination phase to remove dominant non-beaked whale detections; 3) an unsupervised learning to derive clusters of distinct clicks types based on similarities in the spectral shape; and 4) a trained deep neural network to classify clusters of echolocation clicks based on spectral shape, inter-click interval, and click duration.

Assessing effects of anthropogenic noise on beaked whale vocal activity

The goal for this component of the project is to refine a statistical approach to investigate the potential impacts of mid-frequency active (MFA) sonar on beaked whale acoustic activity in the Western North Atlantic. The analyses include data for 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 focus on the Navy HARP sites, as presence of MFA sonar is higher there than on the WAT sites.

Assessing the prevalence of seismic survey noise along the eastern seaboard

The goal for this component of the project is to describe and quantify the extent to which seismic airgun activity is detected along US shelf-break waters, and consider these results within the context of potential impacts on baleen whale acoustic ecology. Work on this component of the project in 2021 was two-fold. First, analyses of airgun prevalence were completed for 11 HARP sites, including both WAT and Navy sites, recording from 2016 to 2017. The resulting data were then used to localize all events in which corresponding airgun signals were detected across four or more hydrophones. The initial presence of airguns was automatically detected using a matched filter detector, where the time series was filtered with a 10^{th} order Butterworth bandpass filter between 25 and 200 Hz. A cross-correlation was computed on the filtered time series; when a correlation coefficient reached a threshold of $2*10^{-6}$ above the median, a trained analyst manually verified the detections (Rafter et al. 2020). A second trained analyst reviewed the entire dataset, to identify periods with gaps in airgun activity that could be used to match signals across multiple hydrophones. Custom-written Matlab code was used to align gaps in airgun activity and estimate the bearing to the signals via time-of-arrival differences between hydrophones. Putative locations with corresponding localization errors were plotted to assess ocean basin-wide sources for airgun signals detected along the US eastern seaboard.

Novel broad-scale approach to assessing acoustic niche and anthropogenic contributors, and assessing the utility of new acoustic metrics

The goal for this component of the project is to develop and apply new techniques for visualization and rapid extraction of soundscape information from large acoustic datasets. For the former objective, in 2021 the following manuscript was published in Marine Policy: *Weiss SG, Cholewiak D, Frasier KE, Trickey JS, Baumann-Pickering SM, Hildebrand JA, Van Parijs SM. 2021. Monitoring the acoustic ecology of the shelf break of Georges Bank, Northwestern Atlantic Ocean: New approaches to visualizing complex acoustic data. Mar Pol.*

130:104570. This manuscript includes the summary results and data visualization from the deployment of three HARPs in 2015-2016, which were presented in Van Parijs et al., 2020.

Towards the goal of assessing the utility of acoustic metrics for the rapid soundscape assessment in long-term datasets, an approach to apply a suite of acoustic metrics was pursued, using supervised machine learning, to assess the presence and species richness (SR) of baleen whales at two sites in the western North Atlantic: the Heezen Canyon HARP dataset (2018 to 2019), and a MARU recorder deployed at Nantucket Shoals (2016 to 2018).

Details on the results from this work in 2021 can be found in Van Parijs et al. 2022.

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

The Rice's whale (*Balaenoptera ricei*; formerly Gulf of Mexico (GOM Bryde's whale) is estimated to have a population size of 51 individuals in U.S. waters (Garrison et al. 2021) and was listed as endangered under the ESA in 2019 (84 FR 15446, 87 FR 8981). The majority of modern sightings occur in waters between the 100 to 400 m water depths in an area near the De Soto Canyon off northwestern Florida (Soldevilla et al. 2017; Rosel et al. 2021). This primary distribution area is defined as the Rice's whale core habitat (Rosel and Garrison 2022). Occurrence patterns from one year of long-term PAM and two summer and fall visual surveys during 2018 and 2019 indicate the whales are found year-round within the core 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 Science Center (SEFSC) and Scripps Institution of Oceanography have been collaboratively deploying long-term PAM stations throughout the GOM since 2010 to monitor the impacts of the Deepwater Horizon oil spill and subsequent restoration activities on cetaceans. HARPs deployed at the De Soto Canyon (DC) site in the core Rice's whale habitat have been continuously recording ambient noise and other acoustic events in the 10 Hz to 100 kHz frequency range, and 8 years of near-continuous recordings (2010 to 2018) were the focus of 2019 to 2021 analyses to better understand Rice's whale seasonal and interannual occurrence patterns. In 2019 to 2020, the focus of this project was on developing automated detectors for Rice's whale calls and analyzing 8 years of near-continuous HARP recordings to establish complete occurrence time-series for understanding seasonal and interannual trends and for future habitat modeling and density estimation. In 2021, the project focus expanded to deploy a sparse array of 17 PAM units concurrent with the one long-term HARP to cover the Rice's whale core habitat (**Figure 13**) and provide the necessary data to understand seasonal distribution and density.

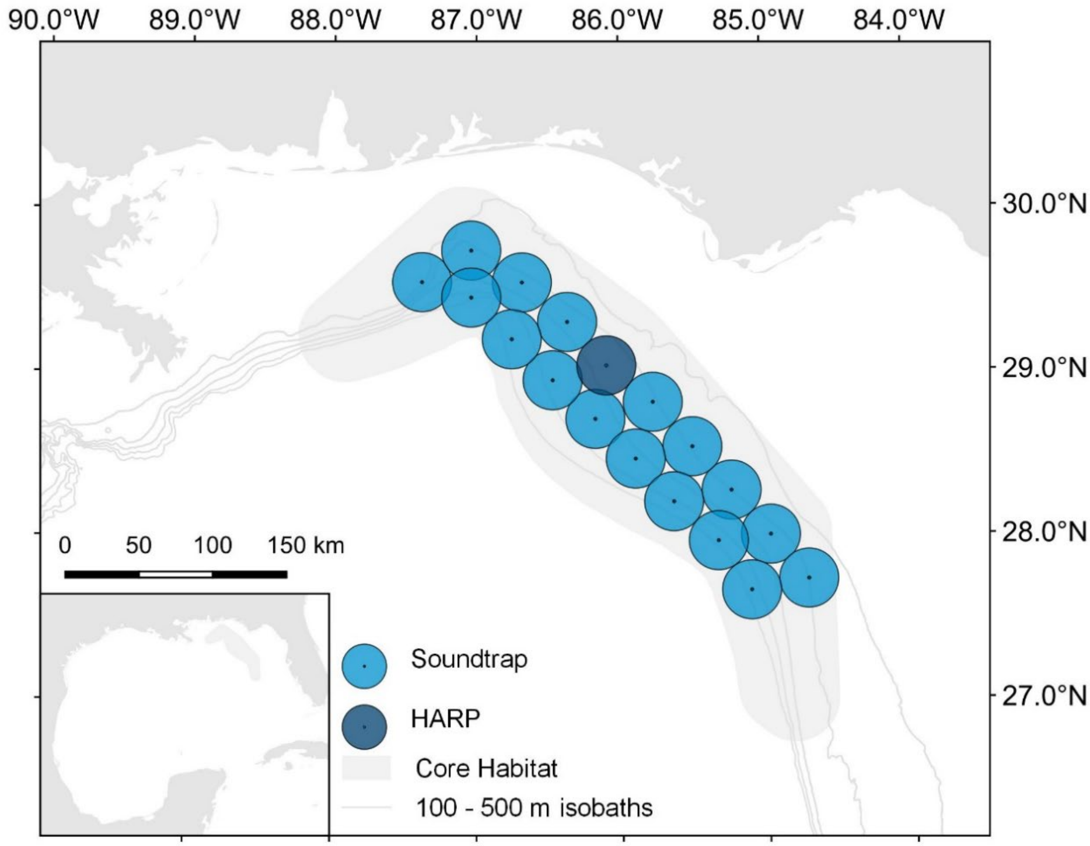

Figure 13. Historic long-term PAM station in the Rice's whale core habitat since 2010 (HARP) and 2021–2022 PAM stations (SoundTraps). The NMFS core habitat of Rice's whales is indicated the long-term De Soto Canyon (DC) HARP site, where Rice's whale calls have previously been detected, is being deployed concurrent with the SoundTrap array under a NRDA Deepwater Horizon restoration project.

During 2021, work focused on 1) preparing a manuscript to submit for peer-review describing the seasonal and interannual occurrence patterns from 8 years of DC HARP data and 2) implementing the new field data collection project. The draft manuscript describes the automated detectors for long-moan and downsweep-sequence call types and the resulting occurrence time-series from the eight years of DC HARP data, which show year-round occurrence of both Rice's whale call types, with decreased call detections during late winter and early spring in some years. The high percentage of time Rice'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. This temporally rich time series will be available for comparison with the spatially rich data from the new 2021 to 2022 field project and will improve interpretation of habitat use. To improve management of human-based activities in the core habitat of these endangered whales, further research is needed to understand and predict seasonal and interannual movement patterns and the factors driving this variation.

In May 2021, the new field project was implemented with 17 SoundTrap ST500 STD moorings deployed concurrent with the long-term DC HARP, in two lines of 9 PAM units each, to nearly completely cover the core habitat for approximately one year to improve understanding of seasonal and interannual movement patterns and habitat use (**Figure 13**). The SoundTrap ST500 STDs are calibrated long-term recorders capable of continuously recording underwater sound in the 20 Hz to 48 kHz frequency range, including Rice's whale calls and ambient noise, for up to 6 months. SEFSC deployed 14 autonomous passive acoustic recording instruments in the northeastern habitat of the Rice's whale in May 2021, and recovered them and redeployed 17 instruments in November 2021. The instruments each recorded for a median of 4.5 months, with most recordings ending in September 2021. SEFSC will service the 17 moorings again in March to April 2022, and will recover the instruments in August 2022, yielding 12 to 15 months of near-continuous recordings across sites. The concurrently deployed DC HARP will have three deployments spanning this period: 1) August 2020 to August 2021; 2) August 2021 to July 2022; and 3) July 2022 to July 2023. Data from the first HARP deployment have been recovered, yielding 3.5 months of concurrent data from 1 May to 23 August 2021.

During 2021–2022, data analyses were begun on the SoundTrap recordings (May to September 2021) as well as the concurrently deployed DC HARP recordings (May to August 2021). Automated spectrogram cross-correlation detectors for the downsweep-sequence and long-moan calls, developed under the 2019 work, were run on all recordings. Given the critically endangered status of this species, automated detector thresholds are intentionally set to minimize missed detections at the cost of increased false positive detections, and a subsequent manual validation step is conducted to remove false positive detections. This semi-automated process is both more efficient and consistent than a complete manual detection process and more accurate than a fully automated process. Across the 15 moorings deployed during the May to September period, there were a total of 1,867 days of effort recorded, a total of 365,997 Rice's whale long-moan calls detected, and a total of 58,130 Rice's whale downsweep sequences detected. The validation process has been completed for long-moan calls from 12 of the 15 moorings, yielding a total of 141,931 true long-moan call detections out of 217,816 auto-detections validated to date. During the May to September 2022 period, true detections of Rice's whale long-moans occurred at all 12 of the manually validated sites, ranging from 27 to 38,375 calls per site. Higher numbers of detections occurred at the inshore sites. Manual validation results indicate false detection rates for the long-moan detector vary by site and over time within sites, with higher false-positive rates at offshore sites compared to inshore sites. Across the 12 validated sites, the daily occurrence of Rice's whale long-moan calls varied by site as well, with calls present on 7 to 95 percent of days per site over the May to September 2022 period.

Planned work for the remainder of the project includes completing validation and statistical analyses from the first deployment, completing field work and conducting analyses on the second deployment, and conducting field work and analyses for the third deployment. The manual validation process will be completed for long-moans on data from the remaining 3 sites and for downsweep sequences at all sites, and the detectors will be run and validated on the SoundTrap data from the second and third deployment cycles, and on the concurrent DC HARP data collected from September 2021 to July 2022. Additionally, ambient noise analyses, monthly occurrence mapping, and evaluation of diel and seasonal changes in call occurrence and ambient noise impacts on call detection will be conducted.

Additional details on the work conducted over the past year is available in Soldevilla et al. 2022.

2.1.2.4 Marine Mammal Monitoring on Navy Ranges (M3R)

The Marine Mammal Monitoring on Navy Ranges (M3R) program began in 2000, with the development of a system to use the bottom-mounted hydrophones of the U.S. Navy's test and training ranges to detect, classify, localize and monitor marine mammals in real-time by listening for their vocalizations. Each of the ranges has 100-200+ widely spaced hydrophones, and the systems consist of rack-mounted computer nodes and monitoring displays connected with Gigabit networks. The M3R system is currently installed at the Atlantic Undersea Test and Evaluation Center (AUTEC), the Southern California Tactical Training Range (SCTTR), the Pacific Missile Range Facility (PMRF), the Jacksonville Shallow Water Training Range (JSWTR), and the Canadian Forces Maritime Experimental and Test Ranges (CFMETR) Nanoose range. The M3R program collects continuous archive data and periodic recordings from each of these ranges and uses these data, along with field tests, for collaborative studies on marine mammal behavior, distribution, abundance, foraging, habitat use; for understanding the effects of Navy activities and the long-term health of the populations; and for the development of detection, classification, localization, and density estimation algorithms.

The M3R system was installed at the JSWTR in December 2019 and initially connected to 126 hydrophones installed on the northern half of the range at the time. The M3R team conducted three species verification trials in 2021 in collaboration with Duke University and HDR, Inc.: April 9 to 17, May 20 to 24, and December 7 to 11 (see **Section 2.1.1.2**). During these trials M3R personnel used the system PAM displays to look for species of interest, and vector the on-water team to the locations of the animals via satellite phone text messages. Upon finding the animals, the vessel survey crew verified the species, collected behavioral and environmental data, photos for photo-ID catalogs, biopsy samples, and potentially also deploy satellite telemetry tags on individuals. The focal species for these efforts are:

1. Short-finned pilot whales (*Globicephala macrorhynchus)*
2. Bottlenose dolphins (*Tursiops truncatus*)
3. Atlantic spotted dolphins (*Stenella frontalis*)
4. Risso's dolphin (*Grampus griseus*)
5. Rough-toothed dolphins (*Steno bredanensis*)

During the three field sessions conducted in 2021, four of the five focal species were acoustically identified by M3R and visually verified by the on-water team (all but pilot whales). Satellite tags were placed on two rough-toothed dolphins, and numerous biopsy samples were collected. **Table 14 to Table 16** summarize the M3R findings from these three field trials.

Table 14. April 2021 field effort: species acoustically identified with the M3R system at JSWTR.

Species			# Acoustic Detections Logged	# Acoustic Detections Directed	# Acoustic Detections Visually Verified	# Biopsies	# of Tags
ID	Common Name	Scientific Name					
Tt	Bottlenose dolphin	*Tursiops truncatus*	4	4	4	4	0
Sf	Atlantic spotted dolphin	*Stenella frontalis*	5	5	5	1	0
Sb	Rough-toothed dolphin	*Steno bredanensis*	1	1	1	0	1
Uz	Unidentified beaked whale	*Ziphiidae* sp.	1	0	0	0	0
UD	Unidentified dolphin	*Delphinidae* sp.	43	3	1	0	0
LF	Unknown low frequency	NA	2	2	0	0	0

Table 15. May 2021 field effort: species acoustically identified with the M3R system at JSWTR.

Species			# Acoustic Detections Logged	# Acoustic Detections Directed	# Acoustic Detections Visually Verified	# Biopsies	# of Tags
ID	Common Name	Scientific Name					
Tt	Bottlenose dolphin	*Tursiops truncatus*	10	10	10	5	0
Sf	Atlantic spotted dolphin	*Stenella frontalis*	7	7	7	1	0
Gg	Risso's dolphin	*Grampus griseus*	2	2	2	0	0
UD	Unidentified dolphin	*Delphinidae* sp.	64	8	0	0	0

Table 16. December 2021 field effort: species acoustically identified with the M3R system at JSWTR.

Species			# Acoustic Detections Logged	# Acoustic Detections Directed	# Acoustic Detections Visually Verified	# Biopsies	# of Tags
ID	Common Name	Scientific Name					
Sb	Rough-toothed dolphin	*Steno bredanensis*	3	0	0	0	0
Tt	Bottlenose dolphin	*Tursiops truncatus*	3	3	3 (4)	2	0
Sf	Atlantic spotted dolphin	*Stenella frontalis*	2	2	2	0	0
UD	Unidentified dolphin	*Delphinidae* sp.	22	2	0	0	0

2.1.2.5 Autonomous Real-time Detection Buoy

An autonomous real-time reporting passive acoustic detection buoy was deployed by Woods Hole Oceanographic Institute off the coast of Cape Hatteras, North Carolina in December 2020 (**Figure 14**). The buoy has the ability to detect and classify whale vocalizations using a digital acoustic monitoring instrument (DMON) and sophisticated analysis software to listen for whales and send notifications and data to researchers in near-real time.

Figure 14. DMON buoy deployed off the coast of Cape Hatteras North Carolina.

Sensor data from the buoy is relayed to shore and posted on the project's publicly accessible website at Robots4Whales. The DMON is programmed with the Low-frequency Detection and Classification System (Baumgartner and Mussoline 2011; Baumgartner et al. 2013) and is capable of detecting humpback, fin, sei and North Atlantic right whales. Detection data are transmitted in near real time to shore where they are reviewed daily by trained personnel, and the results 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 detected (**Figure 15**). NARW were also relatively commonly detected from December through February. Technical issues with the Iridium communications equipment prevented data from being transmitted from March into April, and the buoy had to be retrieved for servicing at the end of May. It was redeployed in late October 2021.

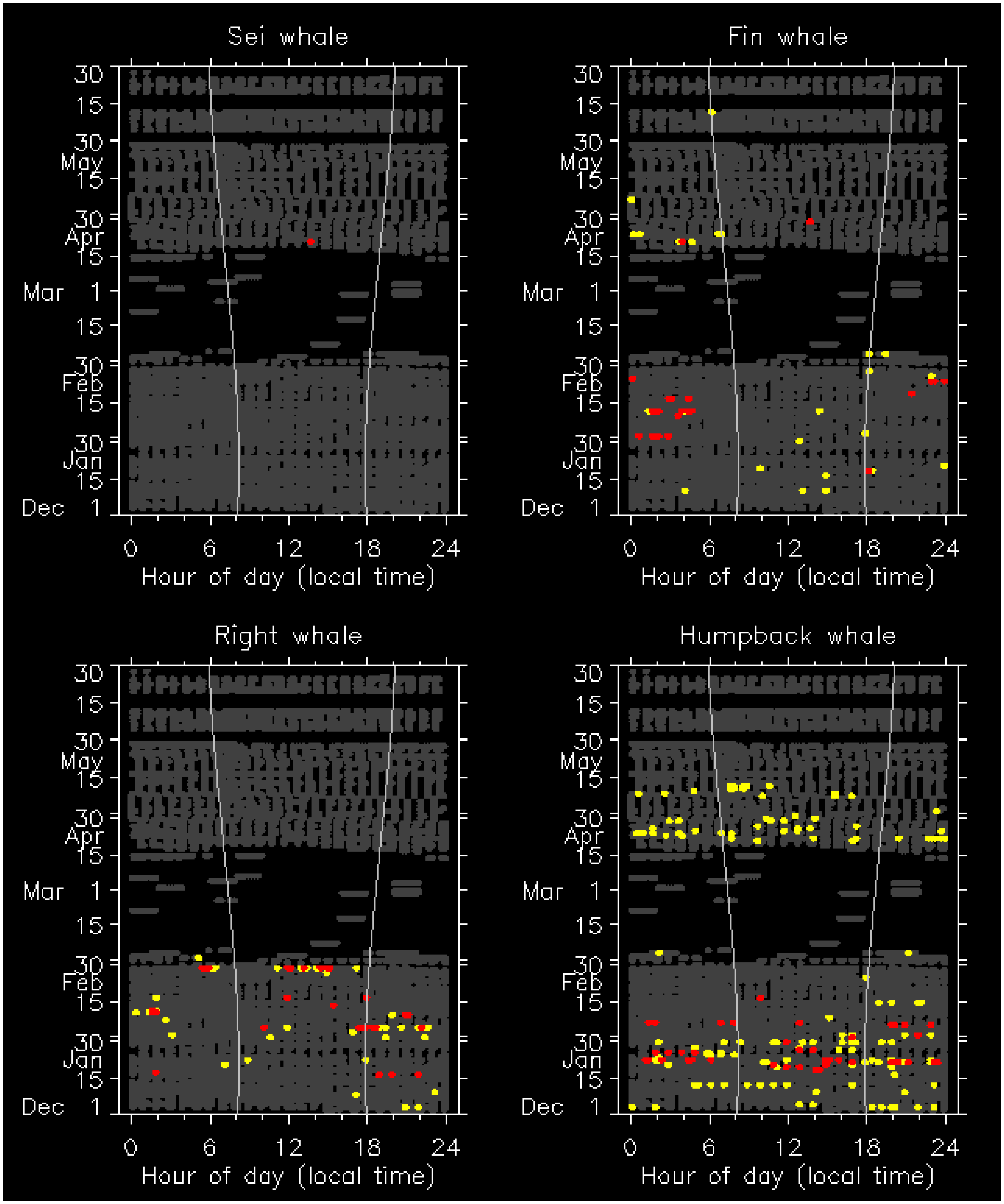

Figure 15. Diel plot showing detections (yellow = possible, red = confirmed) of baleen whales from December 2020 through May 2021.

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 2021, tagging activities were conducted off the coast of Cape Hatteras in association with the Atlantic BRS (**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). The 2020 study year 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) can be collected using photo-ID techniques (see **Section 2.1.1.1** of this report).

During June through September 2021, the fifth 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—a controlled exposure experiment (CEE) studying cetacean reaction to military sonar—is a collaborative effort between Duke University, Southall Environmental Associates, and the University of St. Andrews. The goal of this study was to deploy satellite tags prior to scheduled CEEs on the primary species: Cuvier's beaked whale (highest priority) and short-finned pilot whale (second priority). 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 by 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, 16 satellite tags were deployed, all on Cuvier's beaked whales (**Table 17**). The Douglas-filtered ARGOS locations and pseudo-tracks for all satellite-tagged Cuvier's beaked whales during the 2021 field season are shown in **Figure 16**. **Figure 17** through **Figure 19** show selected examples of all filtered positions for the entire satellite-tag deployment periods for Cuvier's beaked whales *ZcTag113*, *ZcTag119*, and *ZcTag123*, respectively. The figures also indicate the start and end locations of the respective CEEs conducted while the tag was transmitting on the animal.

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 (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 17. Summary of satellite tag deployments during Atlantic BRS field efforts in 2021.

Species/Tag ID	Deployment Date	Tag Duration (days)	Deployment Latitude (°N)	Deployment Longitude (°W)
ZcTag112	29-June-2021	31	35.5471	74.7080
ZcTag113	29-June-2021	67	35.5470	74.7038
ZcTag114	29-June-2021	76	35.5318	74.7181
ZcTag115	05-July-2021	26	35.4441	74.7325
ZcTag116	05-July-2021	57	35.4416	74.7438
ZcTag117	05-July-2021	58	35.4373	74.7327
ZcTag118	06-July-2021	66	35.4262	74.6778
ZcTag119	06-July-2021	72	35.4264	74.6656
ZcTag120	06-July-2021	70	35.4190	74.5990
ZcTag121	06-July-2021	60	35.4206	74.6145
ZcTag122	27-July-2021	79	35.6263	74.7552
ZcTag123	27-July-2021	71	35.6101	74.7645
ZcTag124	27-July-2021	42	35.5580	74.7641
ZcTag125	12-September-2021	68	35.5870	74.6807
ZcTag126	14-September-2021	62	35.4883	74.7432
ZcTag127	14-September-2021	5	35.4842	74.7461

Key: °N = degrees north; °W = degrees west; Zc = *Ziphius cavirostris* (Cuvier's beaked whale)

One DTAG was deployed on a Cuvier's beaked whale during the 2021 field effort on 15 July (**Table 18**). DTAG deployments in 2021 were limited by tag failures, including several units that were sent back to the manufacturer for repairs or full replacement. The single successful deployment was a long-duration attachment, and would have resulted in more than 20 hours of baseline data, including information that could potentially be used to assess diurnal behavior, which is not yet available for Cuvier's beaked whales in the Cape Hatteras study area. However, the tag did not release from the animal when programmed, and the team was fortunate to even relocate the tag for recovery. Modifications were implemented to overcome past very high frequency (VHF) limitations, which resulted in the location and retrieval of the tag, but enough time had elapsed that the tag's onboard battery had failed, and no data were obtained from the deployment.

Table 18. DTAG deployments for Cuvier's beaked whales during Atlantic BRS field efforts in 2021.

Species/Tag ID	Deployment Date	Deployment Latitude (°N)	Deployment Longitude (°W)	Baseline or CEE Number	Tag Duration	Recovered?
Zc21_196a	15-July-2021	35.6140	74.5850	Baseline	20+ hours	Yes[a]

Key: °N = degrees north; °W = degrees west; CEE = controlled exposure experiment; Zc = *Ziphius cavirostris* (Cuvier's beaked whale)

[a] Tag was recovered, but a battery malfunction resulted in no data being obtained

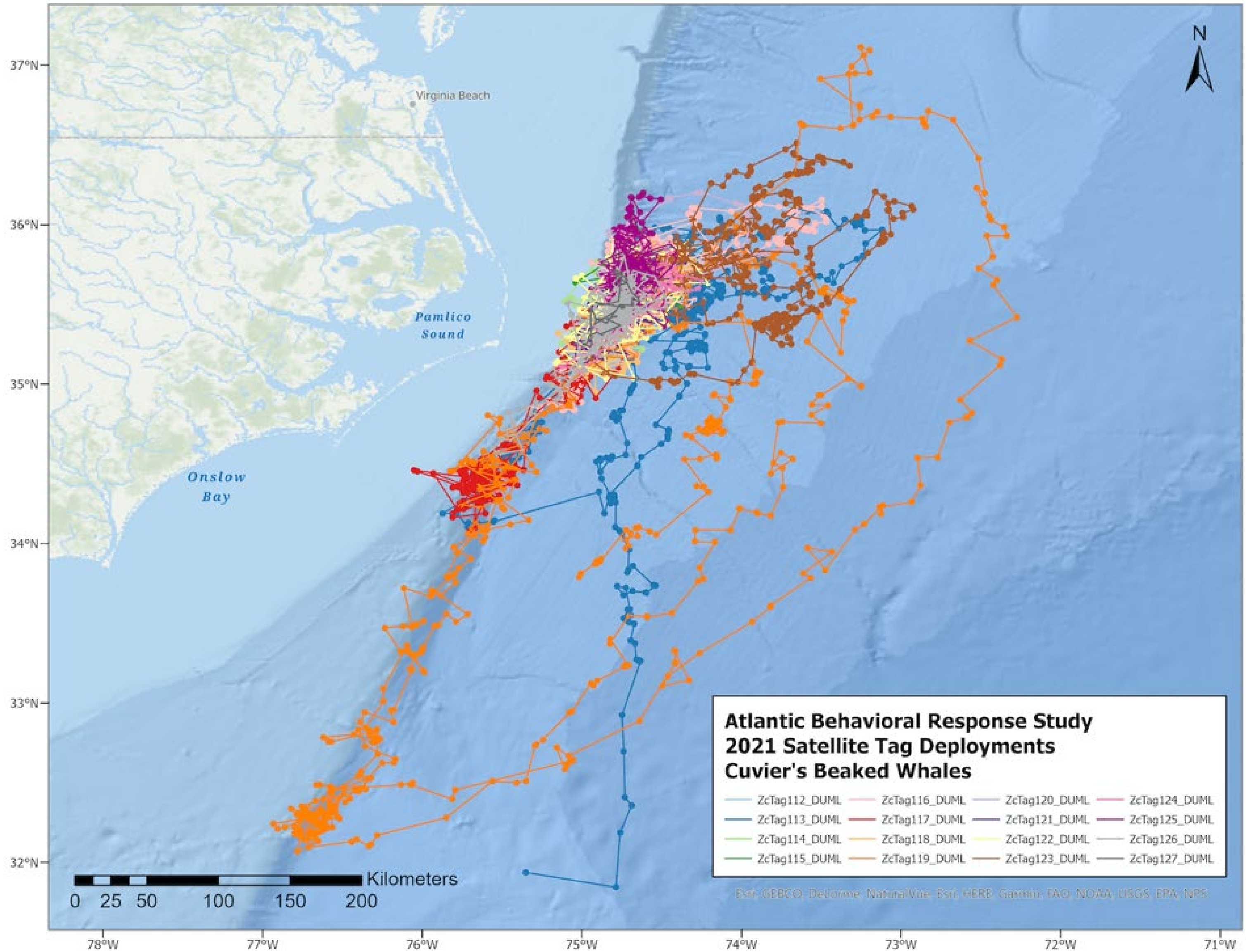

Figure 16. Douglas-filtered ARGOS positions and tracklines for all 16 Cuvier's beaked whale satellite-tag deployments in 2021.

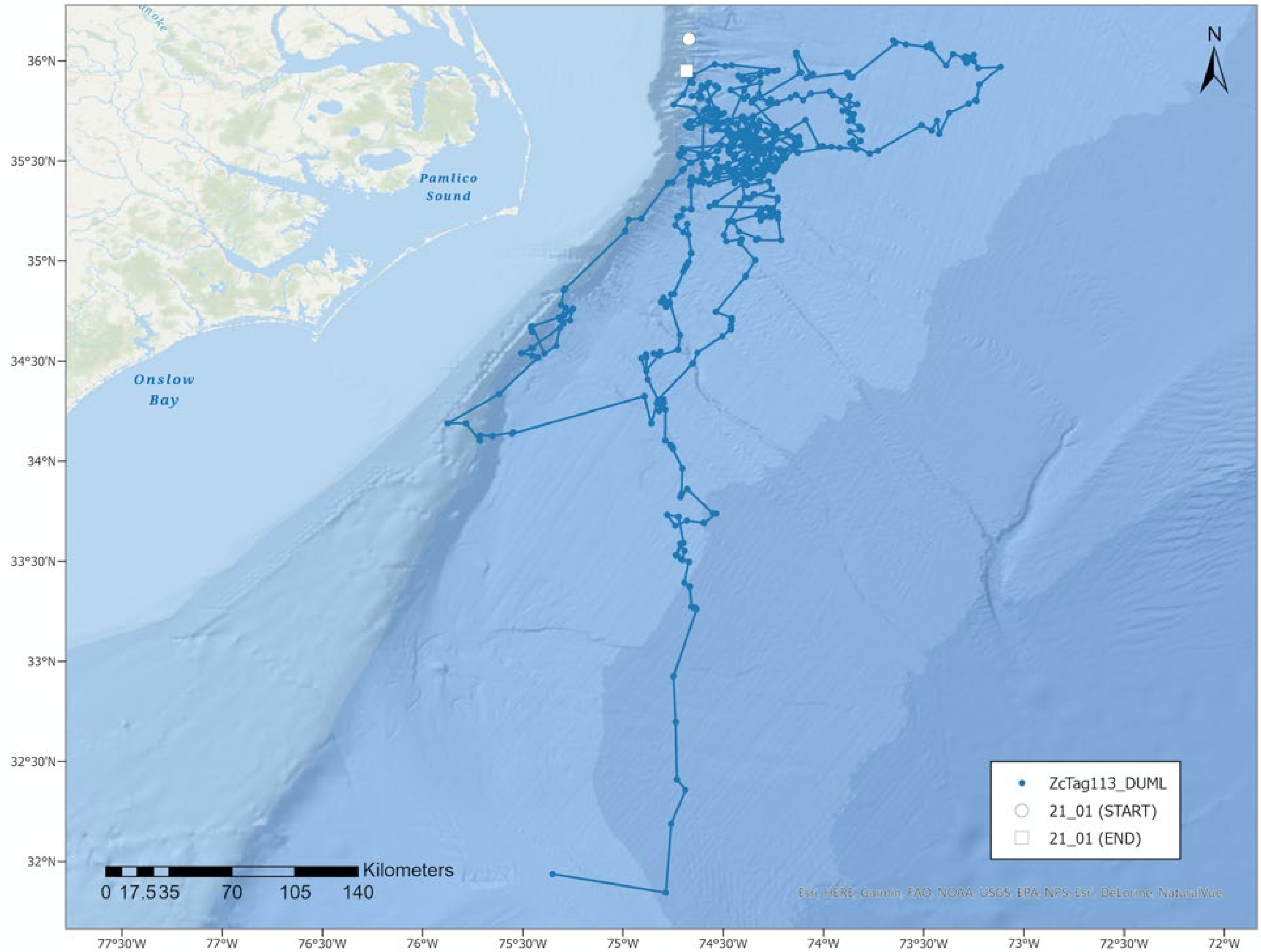

Figure 17. Douglas-filtered ARGOS positions and trackline for entire track of *ZcTag113*, showing positions of the CEE (white circle and square) conducted while the tag was deployed (tag duration *n*=67 days).

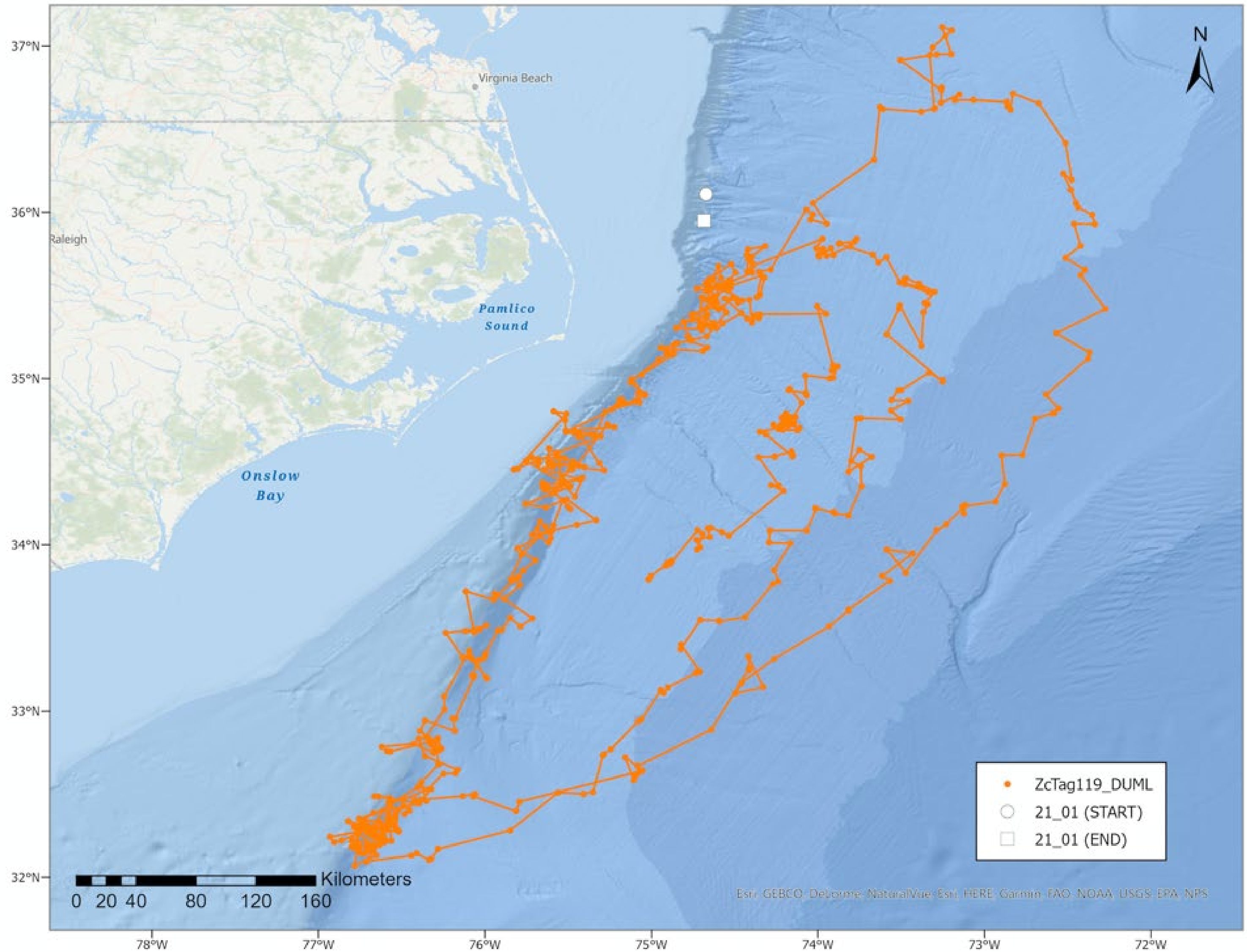

Figure 18. Douglas-filtered ARGOS positions and trackline for entire track of *ZcTag119*, showing positions of the CEE (white circle and square) conducted while the tag was deployed (tag duration *n*=72 days).

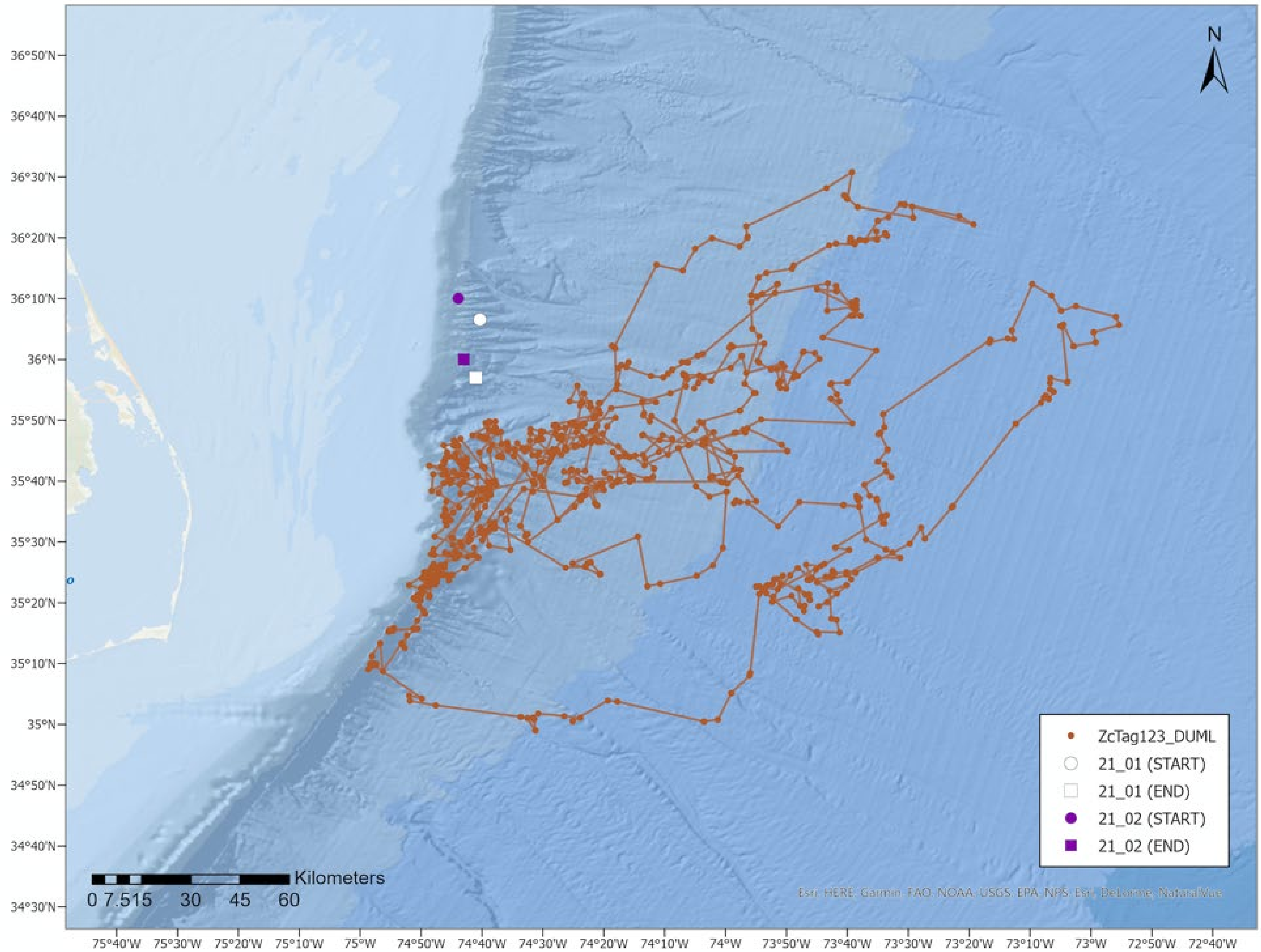

Figure 19. Douglas-filtered ARGOS positions and trackline for entire track of *ZcTag123*, showing positions of two CEEs (white and purple circles and squares) conducted while the tag was deployed (tag duration *n*=72 days).

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.

The humpback whale field season off Virginia Beach runs from approximately the end of October through March, typically concentrated between December and February, with a smaller number of sightings occurring outside this timeframe. Since this project's inception in 2015, there have been seven annual field seasons, beginning with collection of basic baseline information using photo–ID, focal follow, and biopsy sampling methods (Aschettino et al. 2015). Subsequently the project has evolved to include deployment of satellite-linked telemetry and Digital Acoustic Recording Tags (DTAGs), collaboration with researchers from Duke University to examine behavioral response of humpbacks to large vessels (see **Section 2.3.2**), photogrammetry using small Unmanned Aerial Systems (sUAS), and most recently an expansion into the mid-shelf region with addition of other baleen whale species including fin whales (*Balaenoptera physalus*) and North Atlantic right whales (*Eubalaena glacialis*) (Aschettino et al. 2016, 2017, 2018, 2019, 2020b, 2021).

Survey Effort

Twenty-three vessel surveys were conducted between 19 November 2020 and 27 March 2021. Thirteen of these surveys were considered nearshore surveys, nine surveys were defined as mid-shelf, and one additional survey was conducted off Massachusetts as a follow-up to collect data from a satellite tagged North Atlantic right whale (*Eubalaena glacialis*). Over 193 hours of survey effort were completed and 3,213 kilometers of trackline were covered (**Figure 20**). The 2021/2022 season began on 14 November 2021 and is still underway at the time of this report.

Sightings

Excluding one sighting each of a humpback whale and North Atlantic right whale from the additional Massachusetts survey, there were 41 baleen whale sightings, including 28 humpback whale sightings composed of 41 individuals, 8 fin whale (*Balaenoptera physalus*) sightings composed of 13 individuals, and 4 North Atlantic right whale sightings composed of 7 individuals recorded during the 2020/2021 survey season (**Figure 20**). Sightings of non-target species (i.e., common bottlenose dolphins) were also recorded but are not presented here.

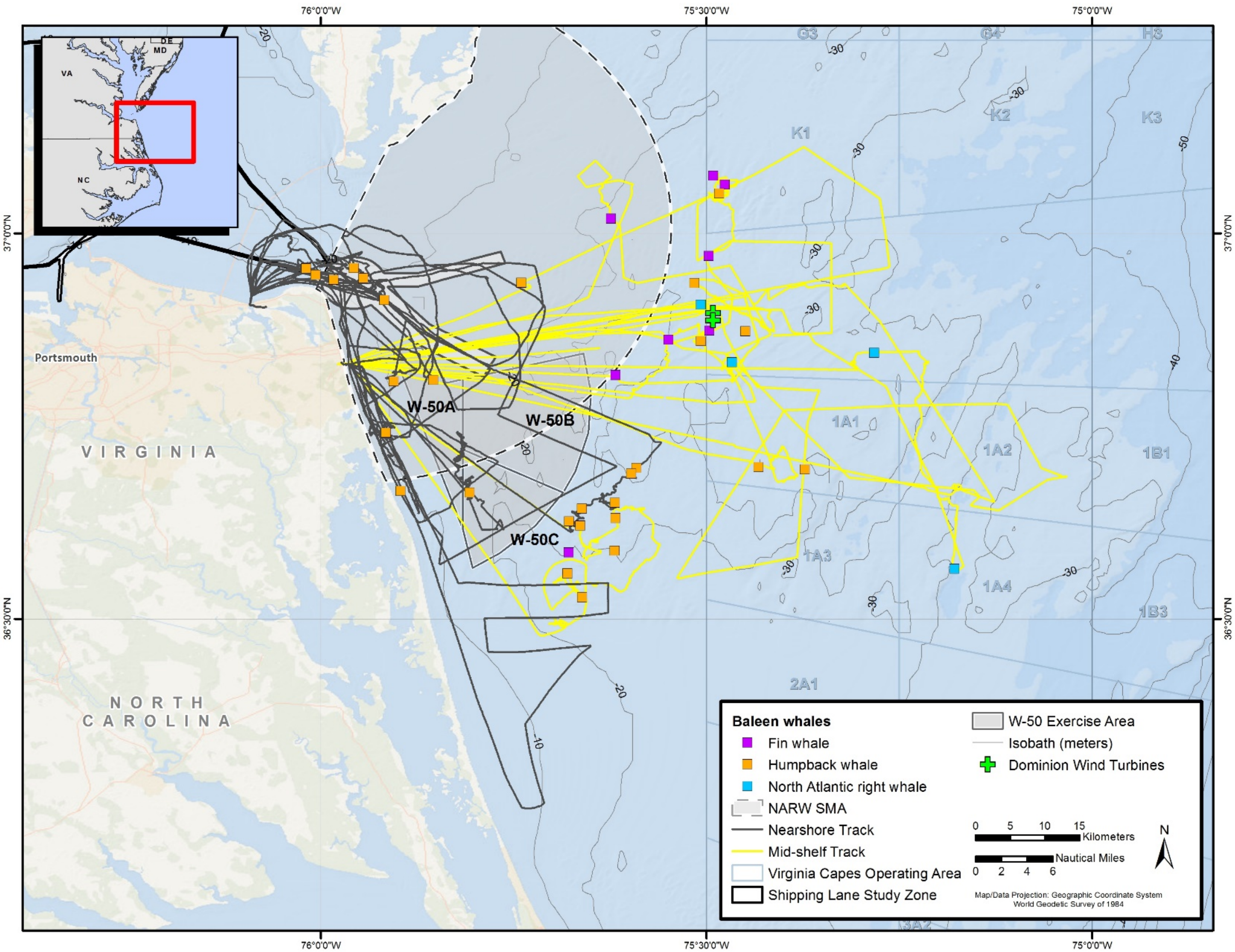

Figure 20. Nearshore survey tracks (gray) and mid-shelf survey tracks (yellow) with locations of all humpback (*n*=28), fin (*n*=8), and North Atlantic right whale (*n*=4) sightings for the 2020/2021 field season.

Photo-identification

The 28 sightings of humpback whales included 41 total individuals and resulted in 26 unique humpback whales identified using dorsal fin and fluke images for the season. An additional 5 humpback whales were also seen during the Outer Continental Shelf Break Cetacean Study (see **Section 2.2.3**) surveys in April 2021 and are included in catalog results. Of the 31 unique humpback whales seen during the 2020/2021 season, 16 (51.6 percent) were categorized as juveniles based on their estimated size, 9 (29.0 percent) were classified as sub-adults/adults; 5 (16.1 percent) were classified as adults; and for the first time since the projects inception, a single calf was observed (3.2 percent). Six (19.4 percent) of the 31 individuals were re-sights to HDR, Inc.'s catalog; 2 individuals had not been seen since the 2014/2015 season (HDRVAMn003 and HDRVAMn025), 1 individual had not been seen since an out-of-season observation in July 2018 (HDRVA123), and the other 3 individuals had been seen during the previous 2019/2020 season (HDRVAMn172, HDRVAMn174, and HDRVAMn179). The remaining 25 whales were new individuals added to HDR, Inc.'s growing catalog, which, to date, has 207 unique humpback whales (inclusive of identifications added from the Outer Continental Shelf Break Cetacean Study (see **Section 2.2.3**) (**Figure 21**). Only 4 of the 31 (12.9 percent) humpback whales were seen on more than one occasion during the 2020/2021 field season, which is a lower proportion than in all previous seasons (42.9 percent during 2019/2020; 44.7 percent during 2018/2019; 21.9 during 2017/2018; and 69.5 percent during 2016/2017).

Beginning in December 2018 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, as well as 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 ultra-high-definition 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 (data from December 2018 through June 2020). Each of these whales has a unique identification in the HDR, Inc. 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 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. Following the methodology described in Dawson et al. (2017), HDR, Inc. recently retrofitted the DJI Phantom 4 Pro V2.0 and installed a custom LiDAR (Light Detection and Ranging) altimeter. This upgrade increases the precision (to within 5 cm) and consistency of the sUAS altimetry measurements to minimize possible error in measured animal lengths. The photogrammetry techniques remain the same, however, with greater accuracy than the stock DJI barometer. To continue collecting consistent imagery data with exact altimetry measurements, as well as transitioning to a DoD-compliant platform following 2020 National Defense Authorization Act restrictions, HDR, Inc. is acquiring a new American-made drone with improved capabilities such as a LiDAR sensor, longer flight times, and a higher resolution camera.

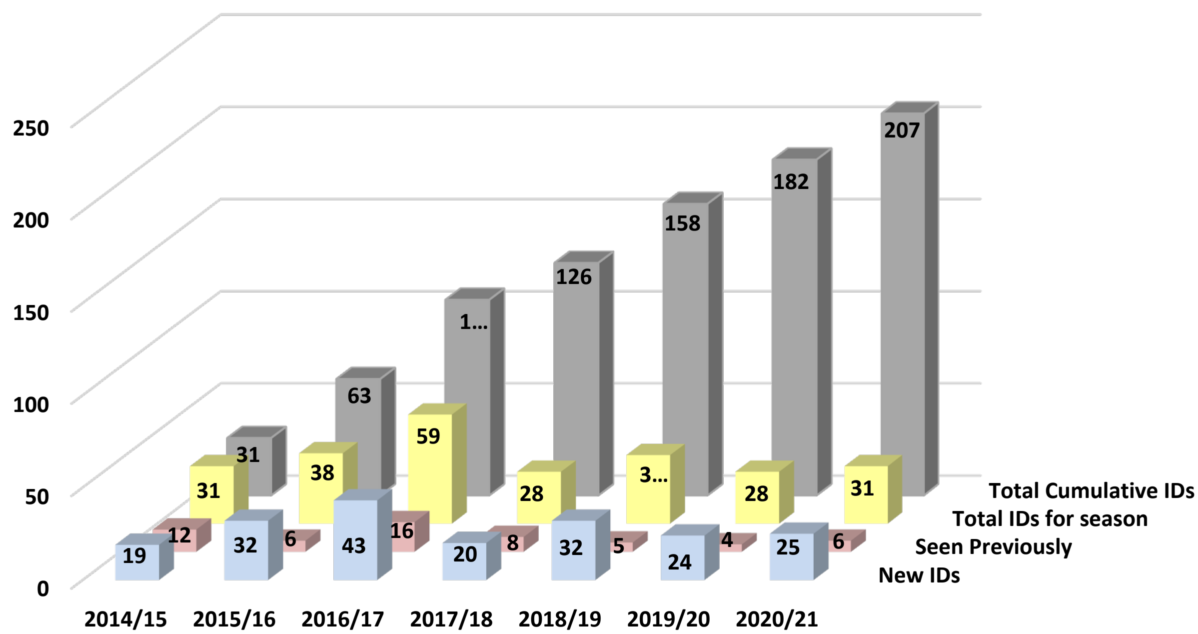

Figure 21. Humpback whale identifications over seven seasons in the Virginia study area: yellow bars = yellow bars = total number of IDs for the season; red bars = number of those IDs that were seen in previously seasons; blue bars = number of new IDs added to the catalog; gray bars = total number of cumulative unique IDs.

Biopsy Samples

Six biopsy samples were collected from humpback whales during the 2020/2021 season and are awaiting analysis along with samples collected during the previous field season. Thirty-one samples (29 humpback and 2 fin whale samples) from 2014 to 2016 were 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 were 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 show roughly equal sex ratios of humpback whales (32 ♂ and 31♀) and a skewed gender ratio of 6:1 (males vs female) for fin whales (Bérubé and Palsbøll 2022). Genetic matching to the larger North Atlantic humpback whale catalog of more than 9,200 individuals showed that a total of 18 HDR, Inc. samples matched to samples collected elsewhere along the eastern US eastern. There were no duplicate humpback whale samples in the HDR, Inc. dataset. All samples matched 100 percent on all loci genotyped in both samples in each pair (i.e., no mismatching genotypes were detected). A single pair of duplicate samples was detected between two HDR, Inc. fin whale samples; however, none of the HDR, Inc. fin whale samples matched to the 1,789 samples contained in the North Atlantic fin whale genetic archive (Bérubé and Palsbøll 2022).

Tagging

In total, 11 Argos-linked satellite tags were deployed on baleen whales during the 2020/2021 season. Seven tags were deployed on humpback whales: 3 SPOT-6, 2 SPLASH10-292, and 2 SPLASH10-F (**Table 19**). Two SPLASH10-F tags were deployed on fin whales (**Table 20**), and 2 SPLASH10-F tags were deployed on North Atlantic right whales (**Table 21**). Humpback tags transmitted between 6.7 and 45.9 days (mean=16.1 days), fin whale tags transmitted 1.3 and 8.1 days (mean=4.7 days), and North Atlantic right whale tags transmitted 1.8 and 16.7 days (mean=9.3 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 22** through **Figure 24**). Humpback *HDRVAMn202*, who was tagged in the mid-shelf region, traveled over 1,300 km in the 11-day deployment, moving primarily southward in an apparent migration to breeding grounds (**Figure 22**). Humpback *HDVAMn174*, whose tag lasted for the longest deployment of any humpback whale to-date, spent approximately 40-days in the primary nearshore study area before moving south (**Figure 23**). Although the fin whale tag durations were relatively brief, both individuals stayed close to their initial tagging locations, and 90 percent of their filtered Argos locations occurred within the Virginia Capes Range Complex (VACAPES) OPAREA (**Figure 24**). The 2 yearling North Atlantic right whales showed different movement patterns, with 1 individual moving south over the short tag duration and the other traveling over 1,600 km to the north along the coast, eventually ending up off Massachusetts, inside Cape Cod Bay with the last location occurring outside of Boston Harbor (**Figure 25**).

Table 19. Satellite-tag deployments on humpback whales during the 2020/2021 field season.

Animal ID	Estimated Age Class	Tag Type	Argos ID	Deployment Date	Last Transmission Date	Tag Duration (Days)
HDRVAMn193	Juvenile	SPOT-6	174075	13-Dec-2020	28-Dec-2020	15.1
HDRVAMn172	Sub-Adult/ Adult	SPLASH10-292	183913	27-Dec-2020	08-Jan-2021	11.3
HDRVAMn196	Sub-Adult/ Adult	SPOT-6	94797	27-Dec-2020	09-Jan-2021	13.1
HDRVAMn174	Juvenile	SPOT-6	174746	05-Jan-2021	20-Feb-2021	45.9
HDRVAMn202	Adult	SPLASH10-292	179198	13-Jan-2021	24-Jan-2021	11.1
HDRVAMn204	Juvenile	SPLASH10-F	183929	24-Jan-2021	31-Jan-2021	6.7
HDRVAMn003	Adult	SPLASH10-F	208686	25-Jan-2021	04-Feb-2021	9.7

Table 20. Satellite-tag deployments on fin whales during the 2020/2021 field season.

Animal ID	Estimated Age Class	Tag Type	Argos ID	Deployment Date	Last Transmission Date	Tag Duration (Days)
HDRVABp030	Adult	SPLASH10-F	178209	11-Jan-21	13-Jan-21	1.3
HDRVABp097	Adult	SPLASH10-F	183932	06-Feb-21	14-Feb-21	8.1

Table 21. Satellite-tag deployments on North Atlantic right whales during the 2020/2021 field season.

Animal ID	Estimated Age Class	Tag Type	Argos ID	Deployment Date	Last Transmission Date	Tag Duration (Days)
Calf of 2642	Yearling	SPLASH10-F	183933	03-Mar-21	20-Mar-21	16.7
Calf of 1612	Yearling	SPLASH10-F	183930	08-Mar-21	10-Mar-21	1.8

Eight of the 11 satellite tags recorded information on dive depth and duration in addition to the Argos capabilities (**Table 22**). Four humpback whale tags record a total of 4,119 dives. Mean dive depth ranged from 15.7 to 30.5 m with a maximum dive depth of 243 m by one individual. Mean dive durations ranged from 2.47 to 3.8 minutes. Two fin whale tags recorded a total of 515 dives. Mean dive depth ranged from 14.2 to 16.3 m, and mean dive durations ranged from 3.7 to 5.5 minutes. Two North Atlantic right whale tags recorded a total of 2,360 dives. Mean dive depths ranged from 19.3 to 23.1 m, and mean dive durations ranged from 6.02 to 6.58 minutes.

Table 22. Summary of dive data collected from all tagged baleen whales during the 2020/2021 season.

Animal ID	Species	Argos ID	No. Dives Logged	Mean Dive Depth (m)	Max Dive Depth (m)	Mean Dive Duration (mm:ss)	Max Dive Duration (mm:ss)
HDRVAMn172	Humpback whale	183913	1,535	17.6	31.0	03:31	14:01
HDRVAMn202	Humpback whale	179198	1,045	30.5	243	03:48	13:47
HDRVAMn204	Humpback whale	183929	244	15.7	28.0	02:28	04:23
HDRVAMn003	Humpback whale	208686	1,295	20.2	31.0	02:57	07:43
HDRVABp030	Fin whale	178209	140	16.3	24.0	05:32	12:15
HDRVABp097	Fin whale	183932	375	14.2	37.0	03:39	08:33
Calf of 2642	North Atlantic right whale	183933	2,250	19.3	66.0	06:01	20:35
Calf of 1612	North Atlantic right whale	183930	110	23.1	39.0	06:42	13:55

Key: Max = Maximum; m = meter(s); mm:ss = minutes:seconds

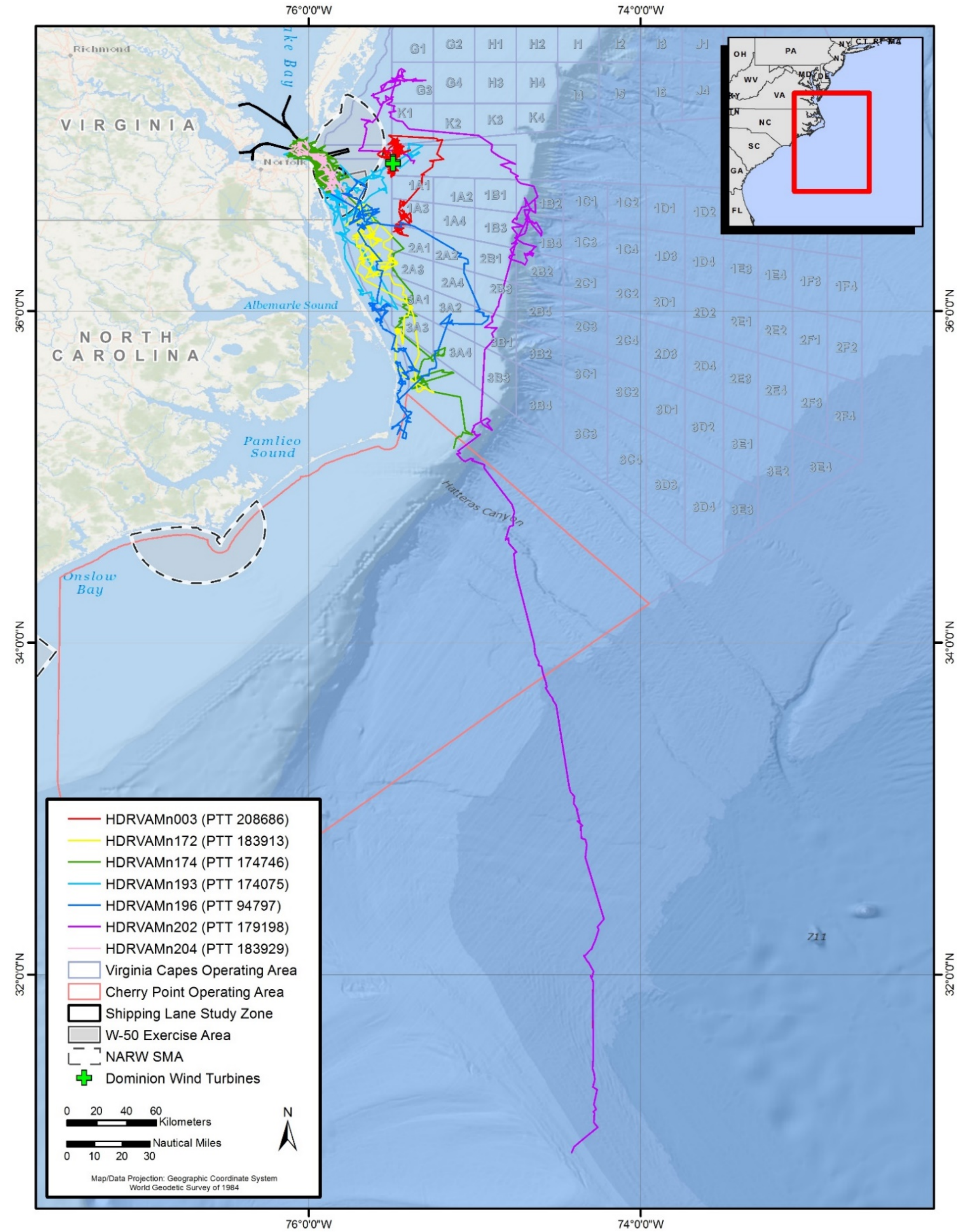

Figure 22. Argos trackline for all humpback whales (*n*=7) tagged during the 2020/2021 field season.

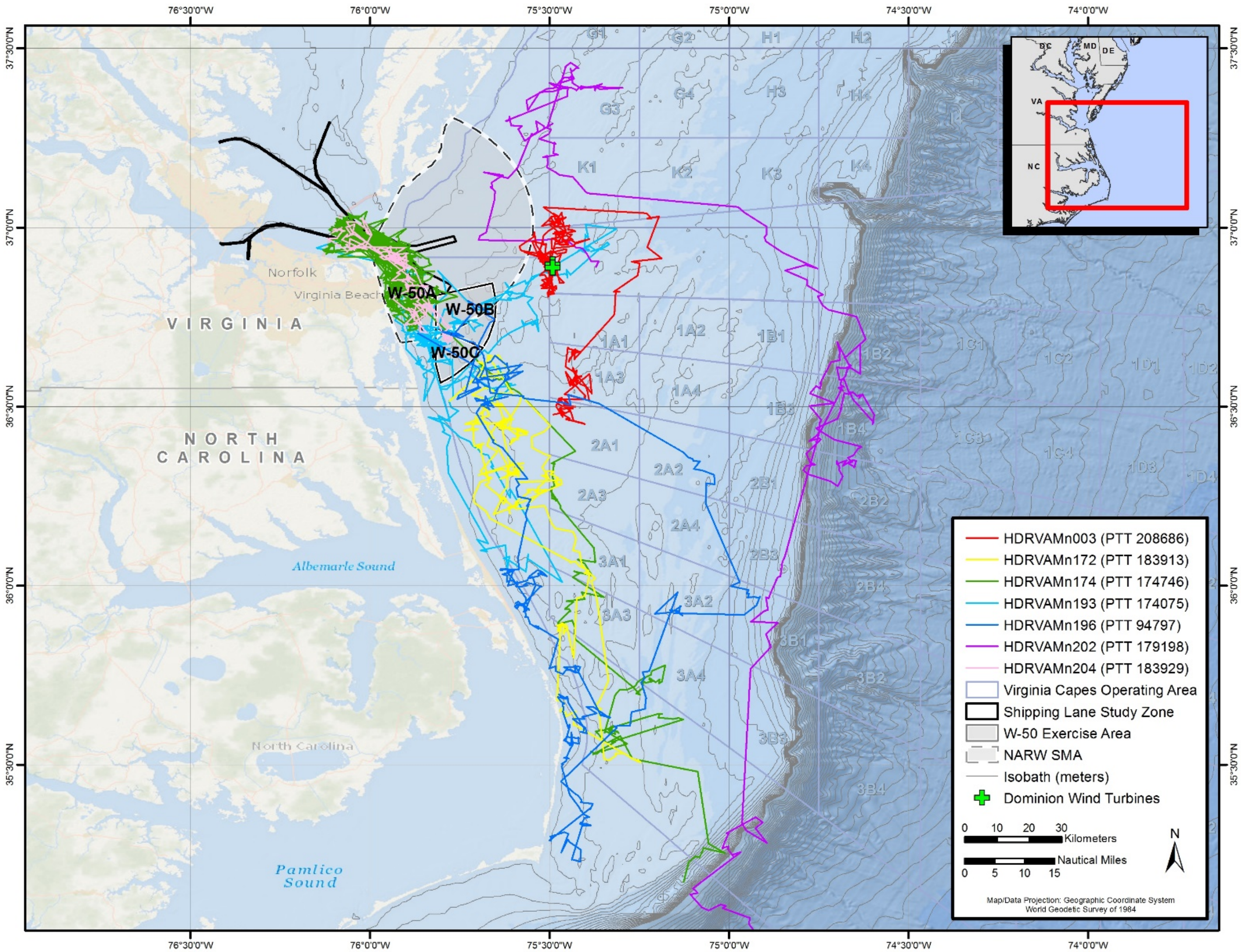

Figure 23. Zoomed-in Argos trackline for all humpback whales (*n*=7) tagged during the 2020/2021 field season.

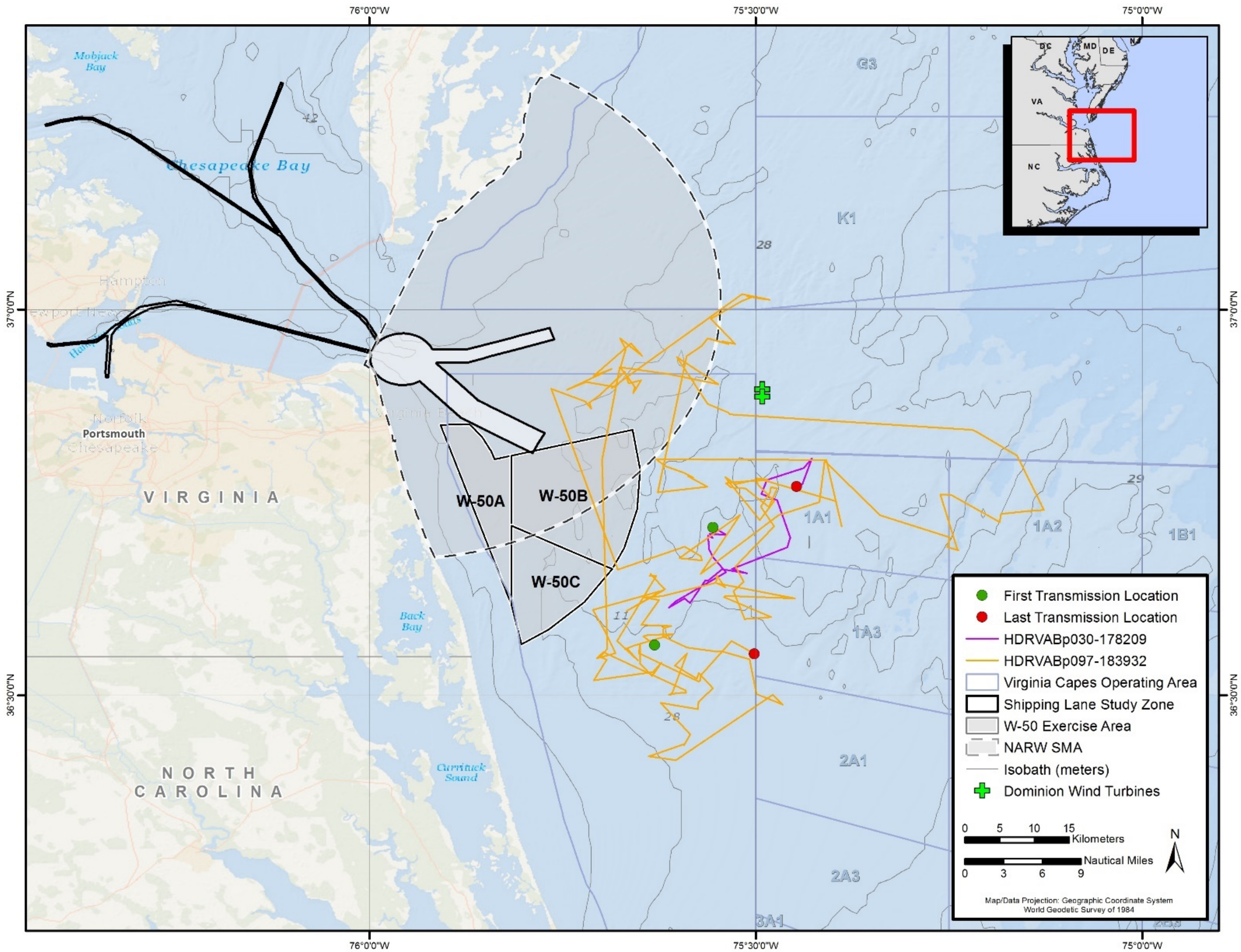

Figure 24. Argos locations and trackline of all satellite-tagged fin whales (*n*=2) tagged during the 2020/2021 field season.

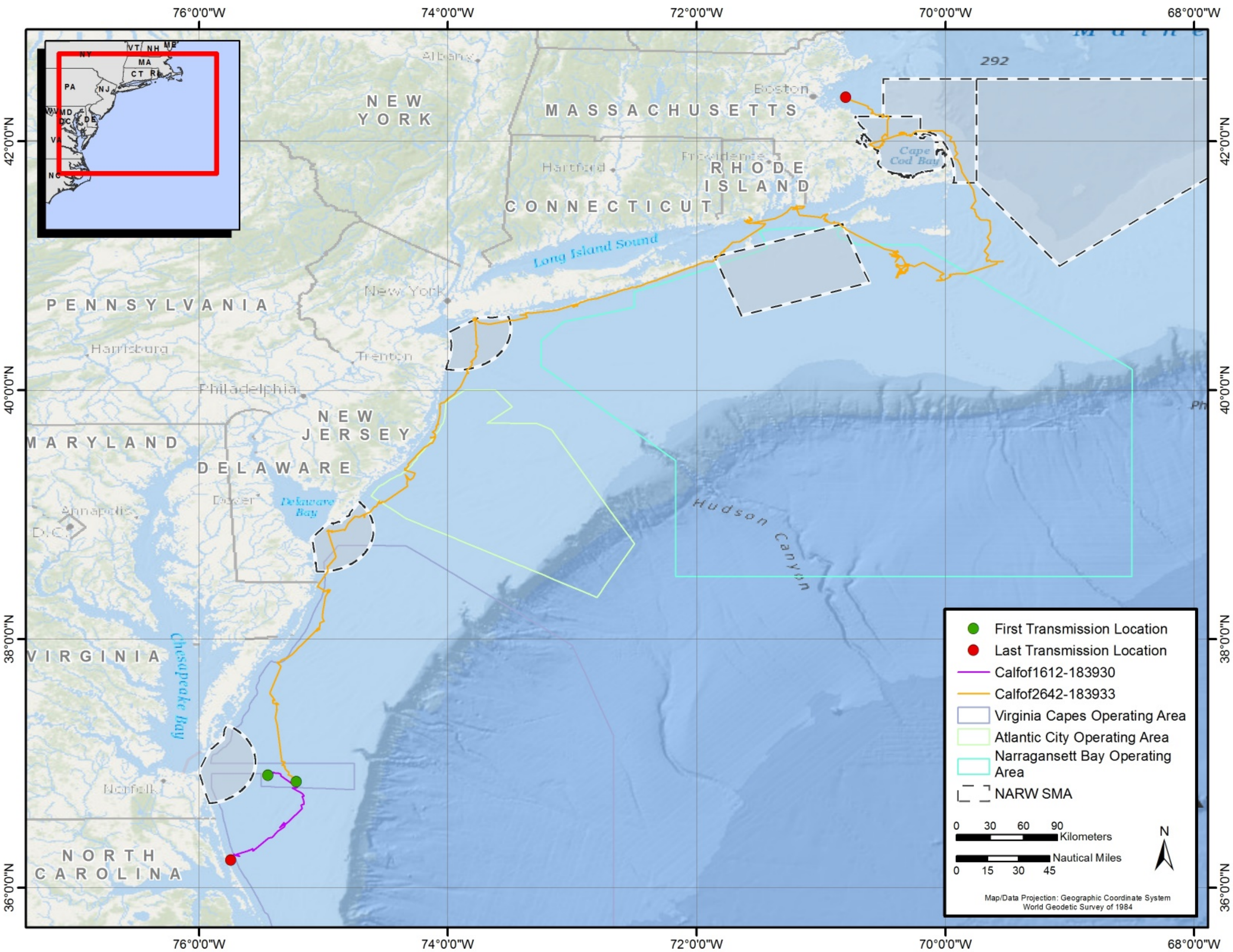

Figure 25. Argos locations and trackline of all satellite-tagged North Atlantic right whales (*n*=2) tagged during the 2020/2021 field season.

In January 2019, Duke University researchers initiated a concurrent tagging project on whales around the shipping lanes in the Chesapeake Bay study area. This study continued into the 2020/2021 field season. 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**. In November 2020, HDR, Inc. also incorporated the use of DTAGs into their existing project. The goal was to deploy tags on individuals in the mid-shelf region to learn more about their foraging and fine scale dive behavior in these areas. In total, 4 DTAGs were deployed on baleen whales during the 2020/2021 season (**Table 23**). Two tags were deployed on humpback whales, which generated 313 and 583 minutes of recordings, respectively. Neither of these individuals was satellite tagged. Two DTAGs were also deployed on the satellite-tagged North Atlantic right whales, which produced 255 and 960 (estimated) minutes of recordings. These data are still being analyzed, however dive-depth profiles for all individuals are shown below (**Figure 26** and **Figure 27**).

Table 23. DTAG deployments on humpback and North Atlantic right whales during the 2020/2021 field season.

Animal ID	Species	DTAG # / Deployment ID	Deployment (GMT)	Depth at Tagging (m)	Tag off Animal (GMT)	Tag Duration (mins)
HDRVAMn190	Humpback	321 / mn20_324[a]	2020-Nov-19 15:29	14	2020-Nov-19 20:42	313
HDRVAMn208	Humpback	321 / mn21_037[a]	2021-Feb-06 16:15	19	2021-Feb-07 01:58	583
Calf of 2642	North Atlantic right whale	313 / eg21_062[a]	2021-Mar-03 17:02	30	2021-Mar-03 21:15	255
Calf of 1612	North Atlantic right whale	313 / eg21_067[a]	2021-Mar-08 21:56	23	2021-Mar-09 20:30[a]	960[a]

Key: DTAG = Digital Acoustic Recording Tag; ID = Identification; GMAT = Greenwich Mean Astronomical Time; m = meter(s); min = minute(s)
[a] Research team was not present during tag release; the tag-off time and tag duration are estimated

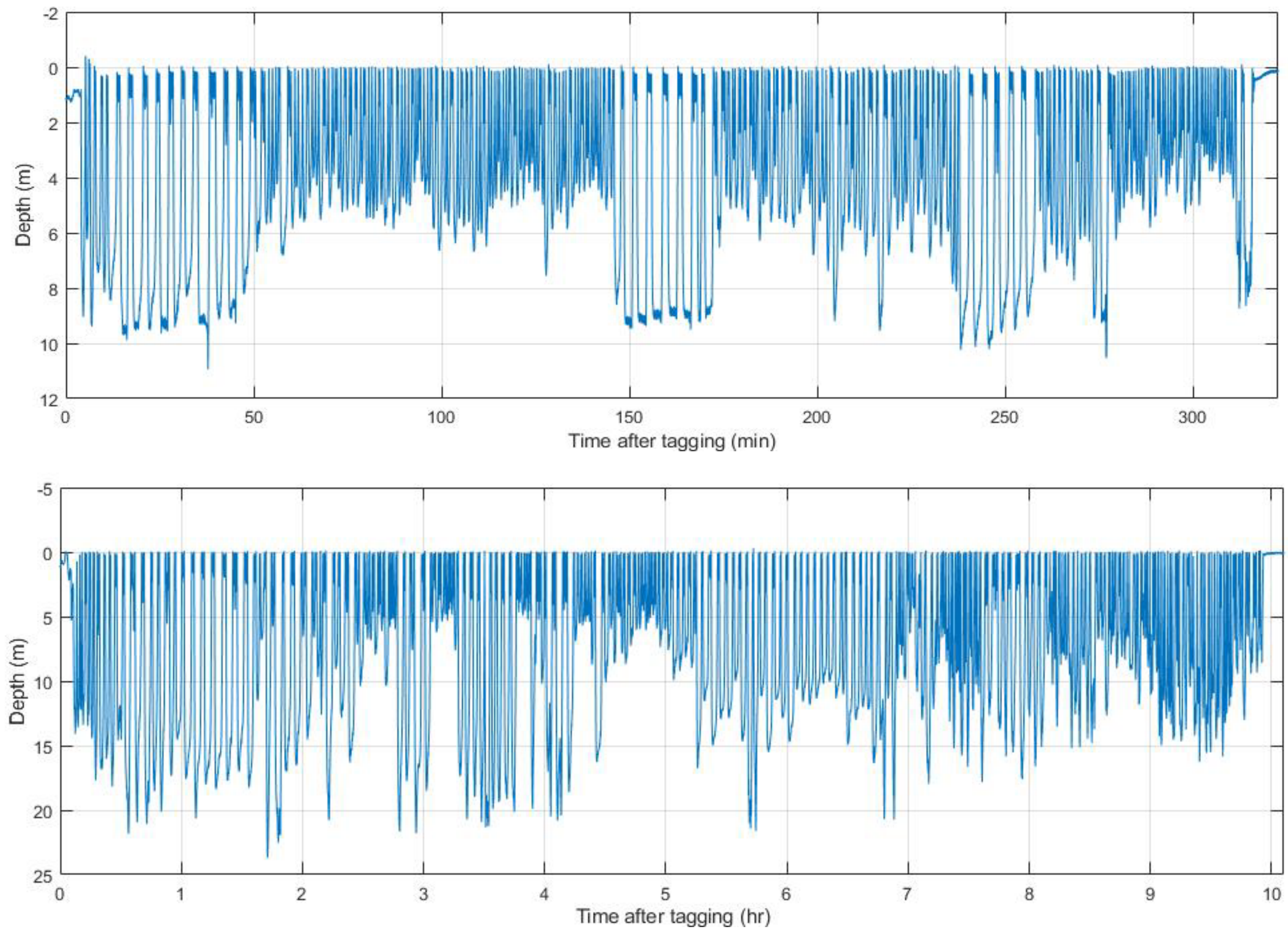

Figure 26. Dive profile for humpback whales, DTAG *mn20_324a* (top) and DTAG *mn21_037a* (bottom).

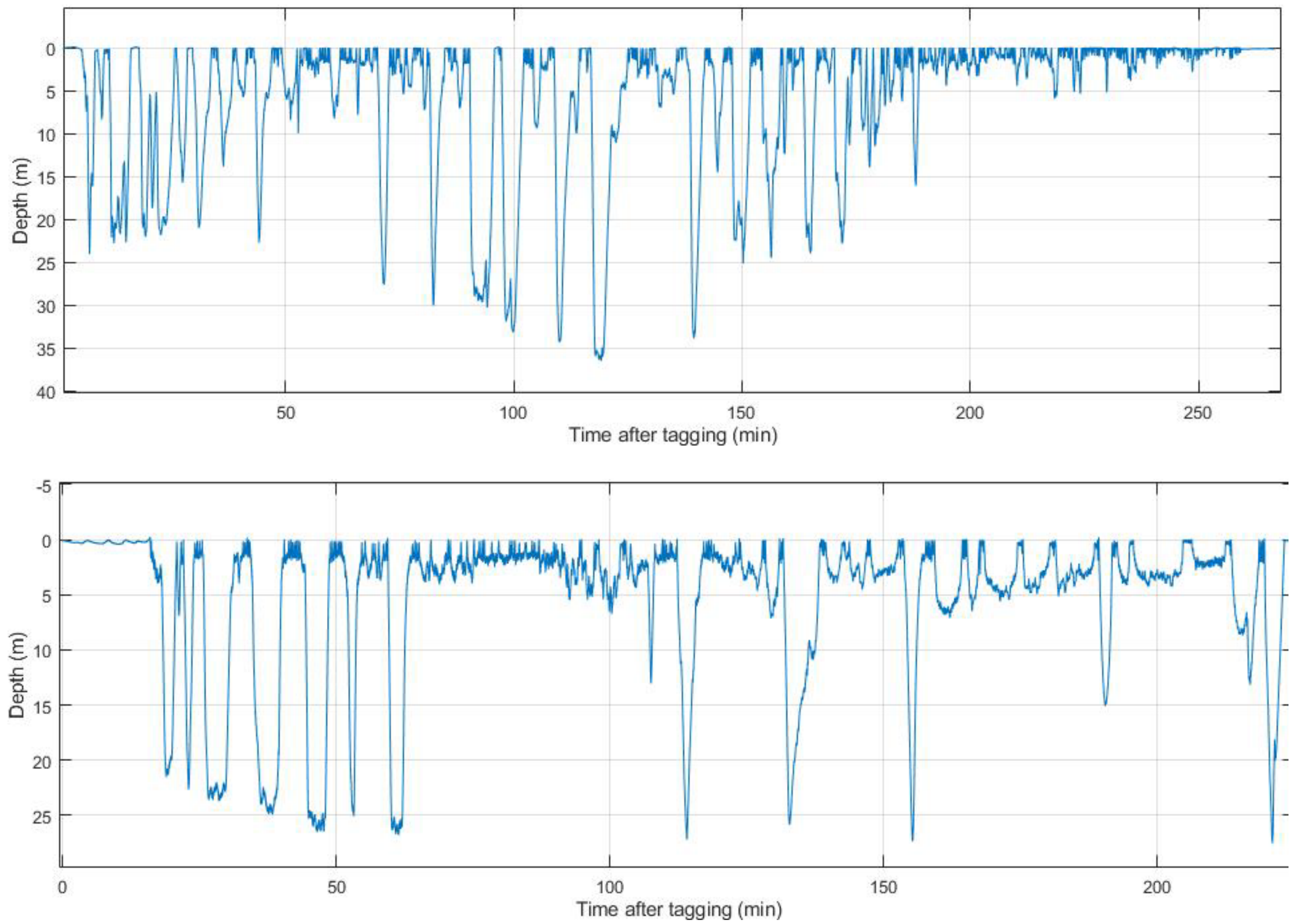

Figure 27. Dive profile for North Atlantic right whales, DTAG *eg21_062a* (top) and DTAG *eg21_067a* (bottom).

Discussion

Data analyses for this study are ongoing. Results to-date indicate some site fidelity to the study area for individuals over a period of days and some returning to the area in subsequent seasons. A high level of occurrence within the shipping channels continues to be prevalent for animals utilizing the nearshore waters; these are important high-use areas for both the U.S. Navy and commercial traffic. Further effort into the mid-shelf region has shown that another subset of animals is also spending time in or near the W-50 MINEX zone and the broader offshore 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 10 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 remains ongoing.

In previous years juveniles made up approximately three-quarters of the humpback whales seen, which is consistent with historic stranding and observational data collected in this area (e.g., Swingle et al. 1993, Wiley et al. 1995). As this project has evolved and more effort has been spent in the mid-shelf area, sightings of sub-adult and adult-sized humpback whales have increased. The number of within-season re-sightings of these larger whales tend to be fewer, suggesting that they may be passing through the area rather than remaining in the 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 3 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. 2022).

2.2.3 VACAPES Outer Continental Shelf Break Cetacean Study

Since 2012, HDR, Inc. 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 s (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, Engelhaupt et al. 2018, Engelhaupt et al. 2019, Engelhaupt et al. 2020a, Engelhaupt et al. 2021). 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 2021 field season are summarized below and detailed in Engelhaupt et al. 2022.

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. HDR, Inc. conducted 9 offshore vessel surveys during 2021 covering 2,840 km of trackline.

Totals of 125 marine mammal sightings and 18 sea turtle sightings were recorded during vessel surveys in 2021 (**Figure 28**). Nine cetacean taxa were identified (in order of decreasing frequency): pilot whale (*Globicephala* sp.) (*n*=29), common bottlenose dolphin (*n*=28), common dolphin (*n*=13), fin whale (*n*=12), sperm whale (*n*=12), Atlantic spotted dolphin (*n*=6), humpback whale (n=6), Risso's dolphin (*n*=5), blue whale (*n*=1), and short-finned pilot whale (*n*= 1). In addition, there were 12 sightings of unconfirmed species: unidentified dolphin (*n*=10), unidentified large whale (*n*=1), and unidentified *Mesoplodon* beaked whale (*n*=1). Two sea turtle taxa were identified: loggerhead turtle (*n*=16) and leatherback turtle (*n*=2). Given the study's focus on priority species that do not include pilot whales, the overlapping range of both short-finned and long-finned pilot whales (*Globicephala melas*) in the study area, and the challenge of identifying the genus *Globicephala* down to species from a distance, most pilot whale groups were classed as unidentified pilot whales.

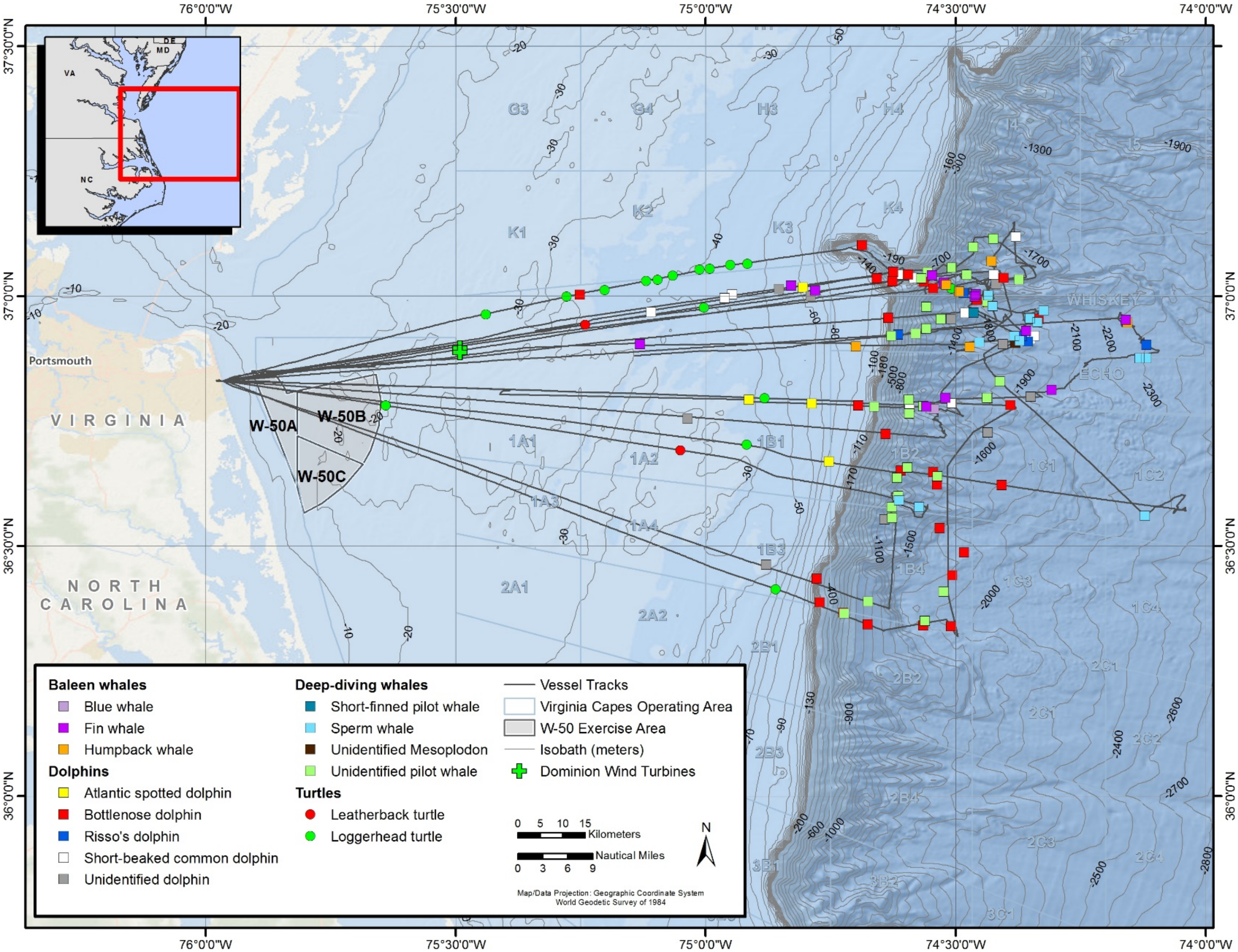

Figure 28. All tracklines and sightings of marine species for field work conducted in 2021.

Sightings of deep-diving species including sperm whales and pilot whales were concentrated past the shelf break and into deeper offshore waters during 2021 surveys. Baleen whales were encountered both over the shelf and past the shelf break as during previous years of this study, but similar to 2019 and 2020, the majority of baleen whale sightings were past the shelf break. This is in contrast to where baleen whale sightings occurred during surveys in 2016 through 2018. Dolphin species were sighted throughout the core study and transit areas, and only a single loggerhead sea turtle was sighted in deep water past the shelf break.

Photo-ID

Photo-ID images were collected during 52 of the 125 marine mammal sightings. Baleen and sperm whale images were added to HDR, Inc.'s existing catalogs, which now contain 207 humpback whales (**Section 2.2.2**), 101 fin whales, 12 North Atlantic right whales, 10 minke whales (*Balaenoptera acutorostrata*), 2 sei whales (*Balaenoptera borealis*), 3 blue whales (*Balaenoptera musculus*), 111 sperm whales, 8 Sowerby's beaked whales (*Mesoplodon bidens*), 3 Cuvier's beaked whales, and 1 True's beaked whale (*Mesoplodon mirus*). Of the 101 identified fin whales, 14 (13.8 percent) have been re-sighted; 9 (8.9 percent) of them during different years ranging from 248 to 1,801 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 111 identified sperm whales (12.6 percent) were sighted on more than one day, ranging from 9 to 1,402 days between first and last sightings. Four sperm whales photographed in 2021 were sighted previously in this study, 2 first documented in June 2017 and 2 during August 2018. Photo-ID images of the blue whale were sent to Mingan Island Cetacean Study colleagues, who attempted to match it to their North Atlantic blue whale catalog but found no match. The humpback whale photographs were added to HDR, Inc.'s humpback whale catalog, which is summarized in that project's report (Aschettino et al. 2022 and **Section 2.2.2**). Pilot whale photos that are collected have been shared with Duke University; the year 2020 and 2021 season images were processed and added an additional 50 individuals to the Norfolk catalog, including 3 new matches to the Cape Hatteras catalog (see Waples and Read 2021, 2022)and **Section 2.1.1.1** of this report). The updated total of matches between Virginia and North Carolina is now more than 15 percent (43 of 280).

Biopsy Samples

Three biopsies were collected from sperm whales, which are currently being processed at Oregon State University. One biopsy was collected from a blue whale, which is being stored for processing at a later date.

Tagging

Five satellite tags were deployed on sperm whales in 2021; 4 SPLASH-10 and 1 SPOT-6 (**Table 24**). Tag duration ranged from 0.2 to 58.2 days (mean=19.0). Maximum distance from initial tagging location ranged from 94 to 628 km (mean=293.6), and mean distance from tagging locations for each tagged individual ranged from 35 to 361 km (mean=158.2). Maximum dive depth ranged from 512 to 2,127 m, and maximum dive duration ranged from 54 to 91 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. Although 1 of the 5 sperm whale tags did not provide useable locations after filtering, movements of the 4 tagged sperm whales that did transmit valid locations varied. Two individuals remained within the VACAPES OPAREA for the duration of the tag transmissions, while the third moved a greater distance to the northeast, still along the continental shelf edge and slope, through the Atlantic City and Narragansett Bay OPAREAs. The fourth moved south into the Cherry Point OPAREA waters before traveling farther east and northeast to a distance greater than 700 km from shore (**Figure 29**).

One blue whale was tagged with a SPLASH-10 tag, with a duration of 9.6 days (**Table 24**). Locations from the tagged blue whale show movement through multiple VACAPES OPAREA boxes, moving in a loop from where it was tagged south of Norfolk Canyon, approximately 100 km from shore to approximately 170 km from shore (**Figure 30**). All locations were within the OPAREA, distance traveled from tagging location averaged 36.5 km, and the maximum distance from tagging location was 73.0 km. Maximum dive depth was 185 m, and maximum dive duration was 11.7 min.

Table 24. Satellite tag deployments for all species during 2021.

Animal ID	Species	Tag Type	Deployment Date	Last Transmission Date	Tag Duration (Days)
HDRVABm003	Blue whale	SPLASH10-F	10-Mar-2021	20-Mar-2021	9.6
HDRVAPm096	Sperm whale	SPLASH10-292B	18-Apr-2021	23-Apr-2021	4.7
HDRVAPm099	Sperm whale	SPLASH10-292B	01-Jun-2021	08-Jun-2021	6.4
HDRVAPm100	Sperm whale	SPLASH10-292B	01-Jun-2021	02-Jun-2021	0.2
HDRVAPm101	Sperm whale	SPOT-6	01-Jun-2021	30-Jul-2021	58.2
HDRVAPm113	Sperm whale	SPLASH10-292B	24-Oct-2021	19-Nov-2021	25.7

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, as well as ESA-listed baleen whales in this high-use U.S. Navy training and testing activity area. As the study has continued, coverage has been adapted to better describe the occurrence of the species most at risk of long-term consequences from potential anthropogenic interactions. The satellite tagging of a blue whale during 2021 has added unique insight to the movements of this ESA-listed species, supporting the previously published records of sightings off Virginia (Engelhaupt et al. 2020b). Movement and dive data for both fin and sperm whales have shown similarities and variability within and between individuals of each species and have continued to further inform researchers' current understanding of site fidelity and habitat use. Providing a more detailed understanding of both fine- and medium-scale foraging ecology of sperm and beaked whales will be the priority in 2022 and beyond, with the planned addition of fine-scale DTAG deployments on these deep-diving species. Although photo-ID 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. With every new survey conducted and each tag deployed on multiple species across seasons, the research team continues to develop the current 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. 2022).

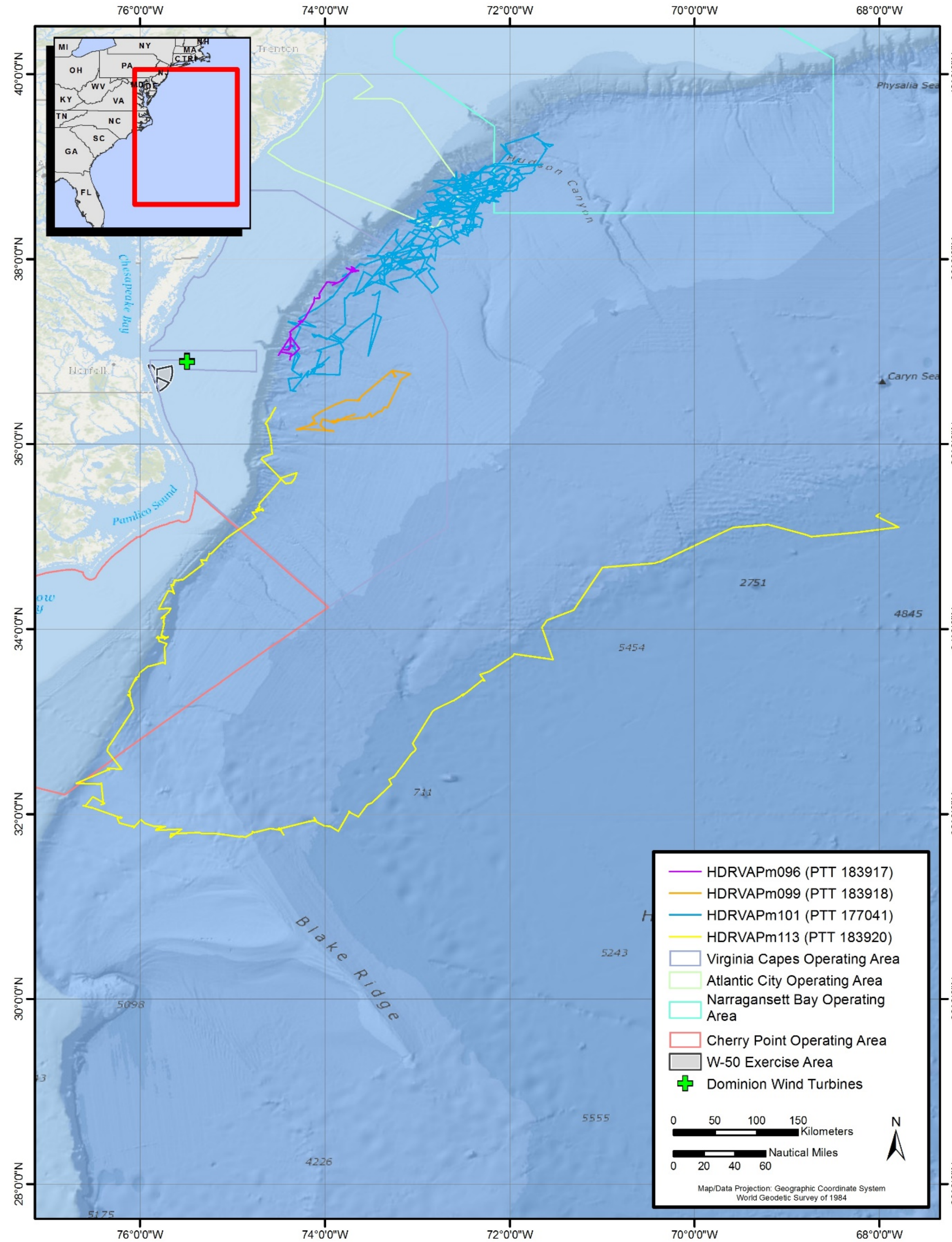

Figure 29. Tag tracks of all sperm whales tagged during 2021.

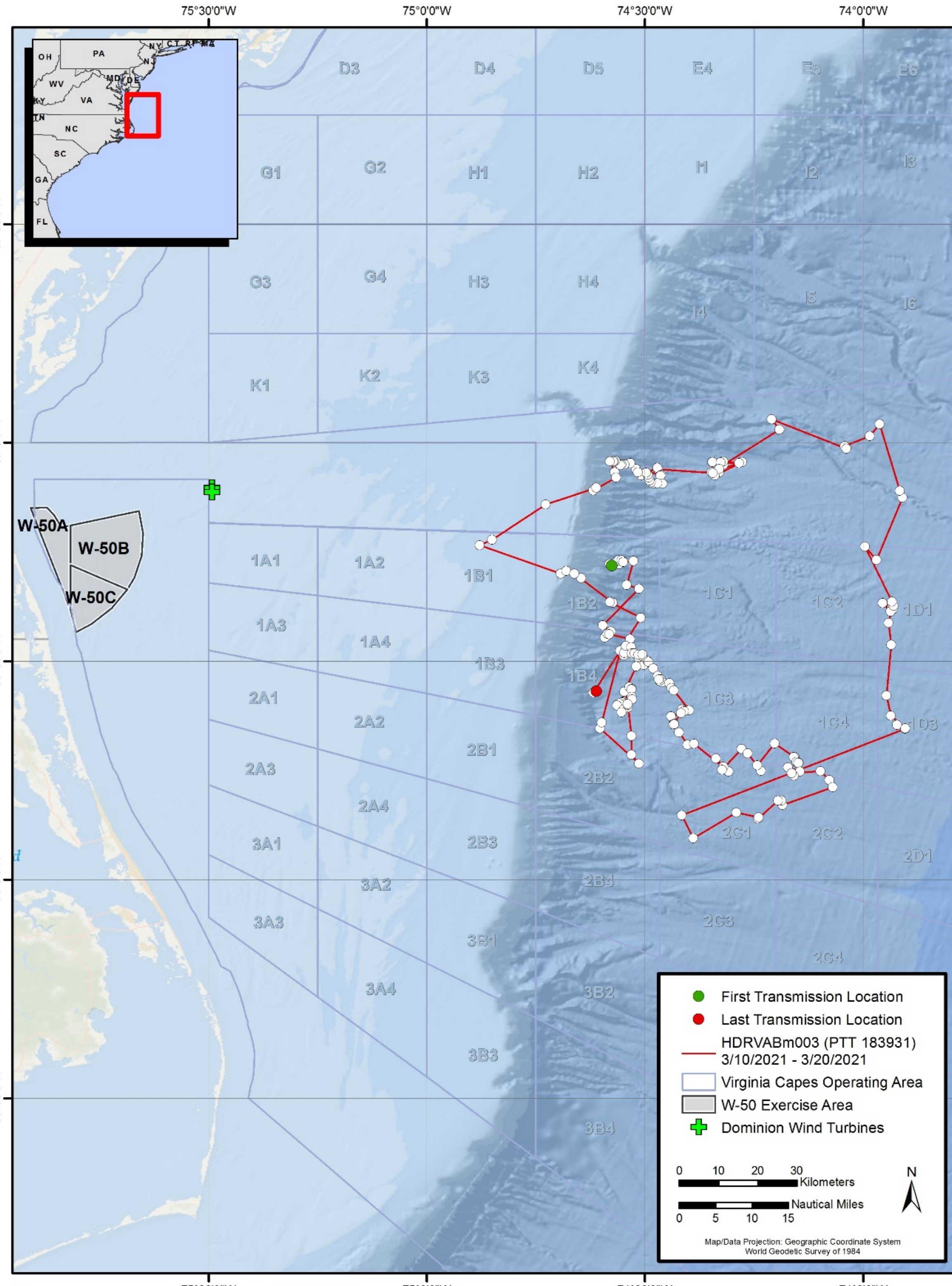

Figure 30. Filtered locations (white dots) and track of blue whale *HDRVABm003* over 9.6 days.

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). Harbor seals are year-round inhabitants of the coastal waters of eastern Canada and Maine (Katona et al. 1993), and occur seasonally along the coasts from southern New England to Virginia from September through late May (Hayes et al. 2021). 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 to a few gray seals are occasionally observed during the winter, but not on a consistent basis (Jones and Rees 2022).

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 2.1.1.3**). Results from these surveys indicate that seals arrive in the area in fall and depart in spring (Jones and Rees 2022). 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 U.S. 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 studies (haul out counts and photo-ID) are useful for estimating the minimum number of animals present on land at various times of the year and local abundance, 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 telemetry tags to better understand seals' residency time in Virginia waters, their local habitat utilization patterns, and their migratory destinations in 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 2022). 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 three small flat-bottomed vessels with outboard motors, and brought onshore after being secured in the capture net.

Vinyl AllflexTM livestock ear tags are attached to the seal's left and right hind flipper webbing. These flipper 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 is 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 are glued directly to the seals' fur on the head or shoulder area (depending on the size of the animal) using DevconTM 20845 High Strength 5-Minute Epoxy. The tags are 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.

A total of nine harbor seals were captured and tagged in 2018 and 2020 (**Table 25**). No seals were tagged in 2019 due to a number of environmental and logistical factors, and fieldwork was not conducted in 2021 due to the COVID-19 pandemic. Over 11 months of telemetry data composed of more than 12,700 individual records from these tagged seals has been uploaded to the Animal Telemetry Network data assembly center (ATN DAC). Tag data included the animals' horizontal and vertical (i.e., depth) position, location class, and sensor type. Detailed metadata is also available, including taxonomic information, attribute definitions, data quality and processing steps, and spatial bounds of the data.

For more information and details on the previous tagging and data analysis, please refer to the 2019-2020 annual progress report for this project (Ampela et al. 2021).

Table 25. Summary of seals tagged in 2018 and 2020.

Date Tagged	Animal ID	Sat Tag PTT #	Date of Last Transmission	VEMCO Tag #	Length (cm)	Girth (cm)	Weight (kg)	Sex	Estimated Age
04-Feb-18	1801	166450	23-May-18	15249	102	80	29.0	Male	Juvenile†
04-Feb-18	1802	166449	29-Jun-18	N/A	153	118	90.4	Male	Adult
04-Feb-18	1803	166451	06-May-18	15251	129	99	58.8	Female	Juvenile†
04-Feb-18	1804	166452	26-May-18	15252	143	119	74.8	Female	Juvenile†
06-Feb-18	1805	166453	09-Apr-18	15253	121	97	49.8	Female	Adult
06-Feb-18	1806	173502	22-Jun-18	N/A	149	116	82.2	Female	Adult
06-Feb-18	1807	173503	26-Apr-18	15250	93	77	24.8	Female	YOY‡
26-Feb-20	2001	177411	12-July-20	N/A	95	80	26.1	Female	Juvenile
02-Mar-20	2002	177410	10-Jun-20	N/A	130	88	47.0	Male	Juvenile

Key: †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.

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 continues to 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 and tagging procedures) and analyses have resulted in recent peer-reviewed publications.

A novel sensitivity analysis using simulated deployments indicated that too few Kemp's ridley turtles were tagged with satellite transmitters to identify all possible home-range areas in Chesapeake Bay. Researchers used simulation to create animal deployments of equal duration to address biases (differing lengths of deployments and time between locations) in home-range analyses and boost the information available from relatively short deployments (DiMatteo et al. 2021). Combined home ranges from simulated deployments identified important areas for these animals in the southwestern portions of Chesapeake Bay and in the nearshore areas of the bay north to the middle of the bay. These areas represent opportunities for managers to mitigate impacts from boating, dredging, military activities, and fishing, and could inform critical habitat designations under the ESA. Telemetry data for loggerheads have been previously analyzed to estimate local home range and assess foraging behavior (see Barco et al. 2017).

Habitat suitability models for Kemp's ridley and loggerhead turtles were created to inform conservation efforts in the region and explore the extent of overlap between their distributions (DiMatteo et al. 2022). Boosted regression tree models were created for each species using presence-only animal locations, predicting suitable habitat within Chesapeake Bay. Habitat for Kemp's ridley turtles was predicted in shallow, coastal areas of the southern bay as well as in brackish areas of rivers. Loggerhead turtle habitat was predicted to extend farther north than Kemp's ridley habitat and was generally found in deeper areas of the middle bay. There is some evidence that these two species are partitioning habitat. Any conservation measures adopted to conserve marine turtles in Chesapeake Bay should consider the habitat of both species holistically to avoid shifting impacts from one species to another.

2.3 Behavioral Response

2.3.1 Atlantic Behavioral Response Study

The Atlantic BRS was initially conceived following extensive planning discussions with researchers and U.S. Navy personnel to transition experimental methods previously developed under the Southern California BRS, funded primarily by the U.S. Navy's Living Marine Resources program, as well as ONR. For the past 5 years, a research collaboration of scientists from Duke University, Southall Environmental Associates, and the University of St. Andrews has conducted strategic tag deployments and 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 U.S. Navy surface vessels (e.g., SQS-53C-equipped combat vessels) and experimental sound sources simulating these systems. The primary focus of this summary is accomplishments from the 2021 field season and response analyses largely conducted on data collected from 2017 to 2020 (Southall et al. 2018, 2019, 2020, and 2021), as detailed analyses of the 2021 field data are still ongoing. All figures included in this synopsis, as well as the complete collection for all CEEs, are available for viewing on the project's 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 to 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 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 U.S. 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 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 2021 annual progress report (Southall et al. 2022).

2.3.1.1 Field Effort

The 2021 Atlantic BRS field effort was modeled after the successful 2020 approach of having the field portion occur during a single extended timeframe beginning in July and extending through October. Historically, field effort would commence in May of a given year and be split into multiple sessions. Field effort for 2021 occurred from 15 June through 29 September. Several logistical and personnel adaptations that began during the 2020 effort because of the COVID-19 pandemic remained in effect. Considerable advanced planning and coordination within the field team and with U.S. Navy sponsors was critical to the success of the project and resulted in two well-coordinated and successful CEEs with operational U.S. Navy vessels.

This was the second year of the project that included the use of Duke University Marine Laboratory's newly acquired research vessel, R/V *Shearwater*, a 19.9-meter fast catamaran that proved useful as a high-vantage observational platform for searching for and tracking tagged animals. The R/V *Shearwater* also housed the simulated MFAS sound source. When conditions allowed, the R/V *Richard T. Barber* was also used for tag deployments, remote biopsy sampling, and efforts to re-sight focal animals.

Overall, 16 satellite tags were deployed, all on Cuvier's beaked whales, 1 of the 2 focal species of the Atlantic BRS (along with short-finned pilot whales). Please refer to **Section 2.2.1** of this report for more details on the tagging component of this project. One DTAG was deployed on a Cuvier's beaked whale, but no data were collected from this deployment due to a malfunction of the tag release, ultimately leading to battery failure by the time the tag was recovered. Two CEE sequences were conducted in 2021 (**Table 26**), both of which were successful, complete, full-scale, operational Navy SQS/53C MFAS CEEs coordinated with separate U.S. Navy warships (U.S. Ship [USS] *Farragut* and USS *Delbert D. Black*). The 2 operational CEEs were conducted with 5 (3 during CEE #2021_01 and 2 during CEE #2021_02) of the tagged Cuvier's beaked whales as the focal animals. While not the focal whales, 11 total other tagged Cuvier's beaked whales were in the vicinity during the simulated CEE events and described as "incidental whales." These individuals were roughly 50 and 80 nautical miles, respectively, away from the first and second CEEs. Observers in the field reported a lack of clear behavioral avoidance in focal whales during and following the CEE; this is in line with observations from previous experiments.

Accomplishments:

- Successful deployment of 16 satellite tags (all on Cuvier's beaked whales).
- Two successful CEEs with operational U.S. Navy vessel, full-scale 53C MFAS. Both were conducted at or near Cuvier's beaked whale target received levels (RL) (140 decibels root mean square) specified for 2021.
- Continued success with new research platform R/V *Shearwater* included in the Atlantic BRS field effort. High success locating and tracking animals, including successful tracking overnight for both satellite-transmitting and DTAG sensors, and an extensive and remarkable DTAG recovery despite the tag's failure.
- Successful deployment, tracking, and recovery of a long-duration (20-plus hour) DTAG on priority Cuvier's beaked whale individual, which included a long-sought-after overnight baseline deployment. Unfortunately, no data were obtained from this tag and because of tag malfunction, it did not release from the animal when planned.
- Sustained efforts to relocate satellite-tagged animals in the field using goniometer detections, increasing the 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, evaluate social interactions, and collect a large number of remote biopsy samples.
- Sustained high-quality satellite-transmitting tag dive data due to earlier progress in tag deployment strategies to reduce/eliminate gaps in satellite-tag data and improve temporal resolution on diving and behavioral data.
- Successful collection of continuous dive data for 2-week periods, strategically covering CEE periods, as designed. The field team continued to see long duration (up to 79 days) function of tags, potentially because of improved batteries in the SPLASH tag.

Assessment of field approach:

- Sustained success using advance planning and support as well as close coordination among members of the research team and the U.S. Navy Fleet Forces Command team. Coordination between research and operational vessels both from land and at-sea was also successful, and given the challenges faced during an ongoing pandemic, the success was a testament to the adaptability and determination of the field team.
- Very good conditions occurred during several windows with workable weather in July and August when tags were deployed. Overall, weather conditions were suboptimal for most of the days during the field effort, including both days that CEEs were conducted.
- Continued success by the team in locating and tagging Cuvier's beaked whales, to the point where no second-priority short-finned pilot whales were tagged in 2021.
- Limited DTAG deployments due to tag failures, including a number that were sent back for repairs or replacement and a long-duration (20-plus hour) baseline tag, which would have been useful for assessing diurnal behavior previously unavailable for this location, that did not successfully deploy, was barely recovered, and was rendered entirely unusable by battery failure. Modifications to overcome previous VHF limitations were the only reason the tag was recovered; unfortunately, no data were collected from the tag.

The full 2021 annual progress report for this project (Southall et al. 2022) 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, and 4) dive records for satellite tagged whales during CEEs. Select examples of some of these figures for CEE #2021_01 can be seen in **Figure 31** through **Figure 33.**

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 to both quantify behavior and behavioral response to MFAS as well as depict and understand these data. The 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 27** demonstrate progress and ongoing new directions. Collaborators with the Centre for Research into Ecological and Environmental Modelling 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 26. Controlled exposure experiments conducted during 2021 Atlantic BRS field efforts.

CEE ID	Date	CEE Type	Focal Whales	CEE Duration (minutes)	Start CEE Source Latitude (°N)	Start CEE Source Longitude (°W)
#2021_01	30-July-2020	Operational MFAS (USS *Farragut*)	ZcTag122; ZcTag123; ZcTag124	60	36.102	74.672
#2021_02	25-September-2020	Operational MFAS (USS *Delbert D. Black*)	ZcTag125; ZcTag126	60	35.950	74.449

Key: °N = degrees north; °W = degrees west; CEE = controlled exposure experiment; MFAS = mid-frequency active sonar; Zc = Cuvier’s beaked whale

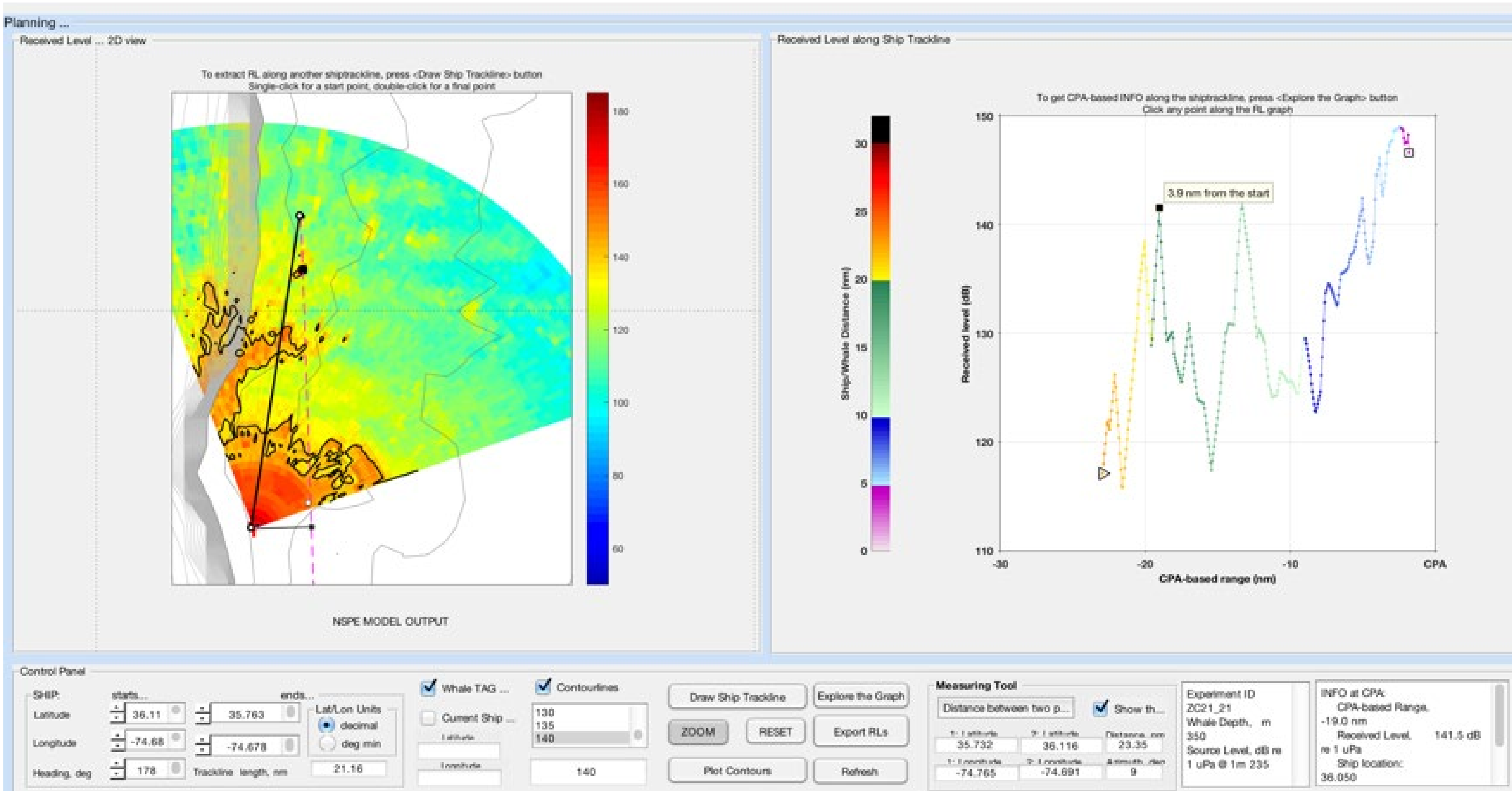

Figure 31. Received level model prediction at 10-meter depth for focal Cuvier's beaked whales *ZcTag122* and *ZcTag124* based on interpolated position and USS *Farragut* end positions during Atlantic BRS CEE #2021_01. Modeled received level at this depth and estimated position was 141.5 decibels.

NOTE: This RL model prediction plot was generated using the Naval Postgraduate School sound propagation tool in the field to estimate RLs for animals at known/estimated tag location (T) with a MFAS source positioned at a strategic location (small white circle in left plot). The 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.

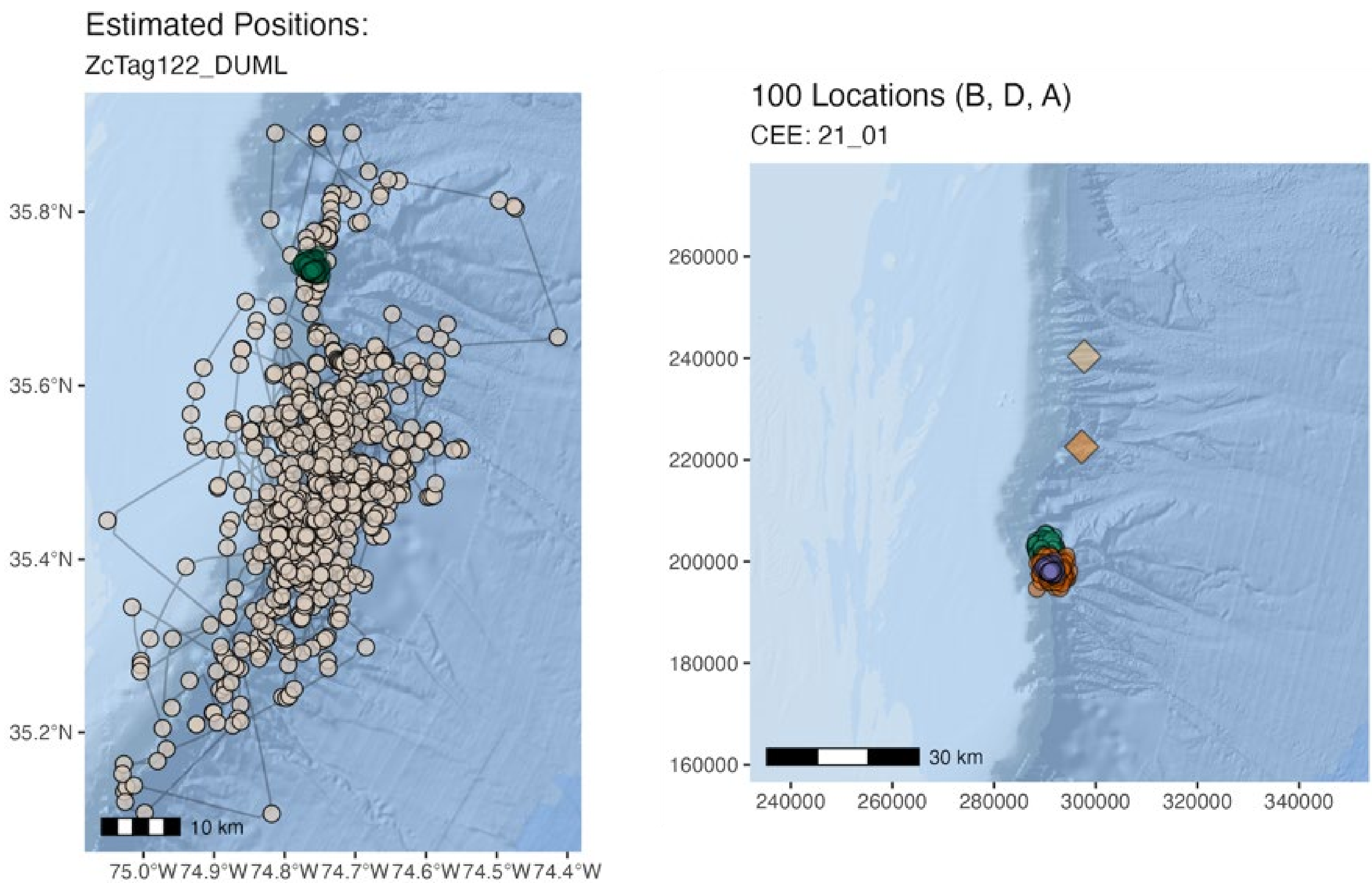

Figure 32. Estimated surface positions for focal whale *ZcTag122* before, during, and after Atlantic BRS CEE #2021_01.

NOTE: This plot has two panels for the individual specific to this CEE. The left panel shows modeled animal locations from both Douglas ARGOS filtered tracks with the location along the entire track (in green circles) and positions during the respective CEE indicated with track imputations indicated along this track (red dots). The 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).

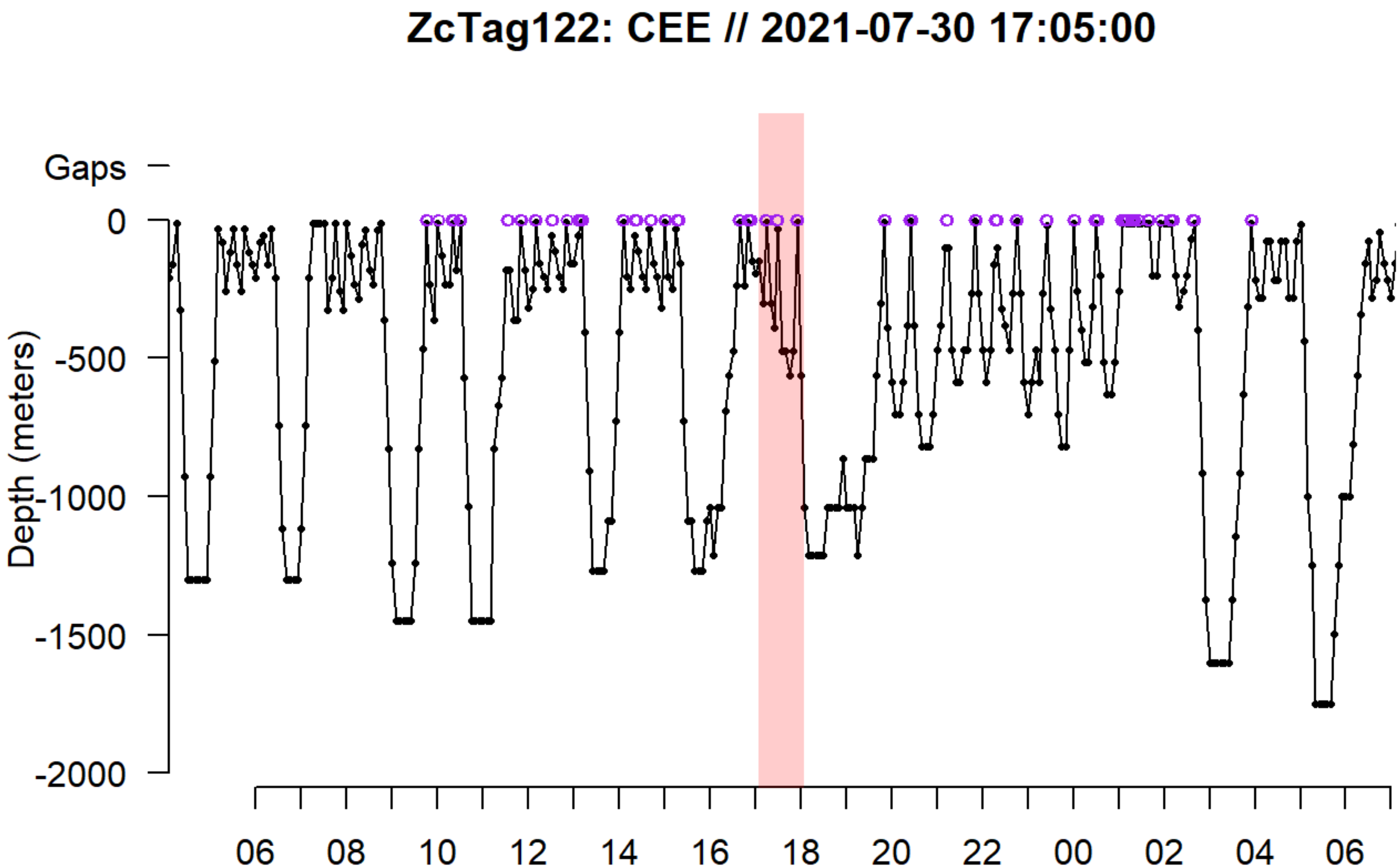

Figure 33. Available dive data for focal Cuvier's beaked whale *ZcTag122* before, during, and after Atlantic-BRS CEE #2021_01. The pink bar shows the time of simulated MFAS transmission.

NOTE: This plot illustrates dive data for days during which CEEs occurred. Time (in Greenwich Mean Time, which is +4 hours from Eastern Daylight Time during CEE periods) is indicated on the X-axis, with depth indicated on the Y-axis. CEE periods are indicated as pink bars.

Table 27. 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 University)	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 University)	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 University)	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 University)	Published: *Journal of Experimental Biology 223: No. 18, jeb222109 (2020)*
Methodology-Technology	Continuous-time discrete-state modeling for deep whale dives.	Hewitt (Duke University)	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 University)	Published: *Marine Ecology Press Series 660: 203–216 (2021)*
Baseline Behavior	Adult male Cuvier's beaked whales (*Ziphius cavirostris*) engage in prolonged bouts of synchronous diving	Cioffi (Duke University)	Published: *Marine Mammal Science 37(3): 1085-1100 (2021)*
Baseline Behavior	More than metronomes: variation in diving behaviour of Cuvier's beaked whales (*Ziphius cavirostris*)	Quick (Duke University)	In review

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

2.3.1.3 Overall Assessment and Recommendations for 2022 Effort

Despite the challenges presented surrounding the ongoing COVID-19 pandemic, the Atlantic BRS research team was extremely successful in deploying 16 satellite tags (all deployed on highest-priority Cuvier's beaked whales) and coordinating with the U.S. Navy to successfully complete two operational MFAS CEEs. The following summarizes the accomplishments and general assessments for the 2021 field effort:

- Sustained effort, patience, and adaptability was required to conduct field operations successfully during a pandemic.
- Successfully deployed a large number (*n*=16) of tags on many high-priority Cuvier's beaked whales and collected tens of thousands of hours of movement and diving behavior. No secondary priority pilot whales were tagged due to the success with beaked whales.
- Successfully coordinated two complete (and as-designed) CEEs with U.S. Navy vessels. These events evolved flawlessly due to extensive, sustained coordination and effort with U.S. Navy personnel working with vessels ahead of their deployment and close, real-time communication of time and locations of possible coordination using shore-based personnel from both the Atlantic BRS and U.S. Navy teams. There were multiple focal whales present during both CEEs, with RLs spanning the entirety of the target range, including a CEE with the USS *Farragut* that represents the largest number (*n*=12) of Cuvier's beaked whales ever tagged during a known U.S. Navy sonar-exposure event. Requested data from U.S. Navy vessels were provided in a complete, timely, and unclassified manner.
- Maintained target RLs for Cuvier's beaked whales at 110 to 140 decibels based on the assessment of results and indications of quite strong responses to simulated MFAS from previous years at the upper range of these levels. Target levels were achieved again with real vessels at realistic operational ranges (10 to 40 nautical miles), as intended, with focal and non-focal Cuvier's beaked whales. Some, but not all, exposed whales showed clear changes in movement and diving patterns, similar to those observed with simulated MFAS sources at closer range (2 to 3 nautical miles), based on field observations and initial analyses of data collected.
- Maintained satellite tag deployment settings as refined in 2019 and 2020 with very positive results. Many of the 2021 tags achieved greater duration deployments for returning ARGOS position data in addition to 2 weeks of focused, high-resolution, continuous time-series dive 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 photographs, obtain biopsy samples, and locate other individuals for tagging attempts. These are essential in evaluating MFAS exposure on social interactions and group composition.

Recommendations for 2022 include:

- With five successful field seasons of tagging and CEEs (in which tag types, settings, and experimental approaches have been adapted and improved) in the exceptionally productive study site off Cape Hatteras completed, it is recommended that field operations cease for the current phase of the Atlantic BRS experiment following the completion of the 2022 campaign.
- No changes should be made to methodological or field approaches, but efforts should be focused on ensuring a single, high-sample-size, closely coordinated CEE to be conducted with a U.S. Navy vessel in acceptable weather conditions to allow appropriate animal tracking and further attempts to deploy high-resolution tags. As discussed with Fleet Forces Command colleagues, this will require advance coordination and planning for multiple ship opportunities to select a single

event. A slight reduction in total field time is envisaged; however, retaining enough effort for multiple tag deployment windows to enable this adaptive, selective approach is anticipated.

- The combination of satellite tags (with series settings for Cuvier's beaked whales) and DTAG deployments should be maintained, with additional effort to simultaneously deploy DTAGs within groups with satellite-tagged individuals. Even further advance testing of DTAGs for all sensors should be conducted ahead of deployments given battery and multiple sensor failures during both the 2020 and 2021 deployments.
- Field efforts to locate tagged animals with validated locations using goniometer detections, visual observations, and photo-ID should be maintained before and after CEEs, as successfully done with the increased effort in 2021.
- The 2022 field season should serve as the analyses and publication completion period for the current effort. Some of the reduced field cost inherent in the above recommendation could be applied to expand analytical and writing time.
- Given the interest and intent to test continuously active sonar signals in CEEs using the Atlantic-BRS field and methodological teams and approaches, initial planning and coordination should occur in 2022, with field operations pivoting to continuously active sonar signals in 2023 and beyond.

Please refer to the annual progress report for detailed information on 2021 fieldwork, preliminary results from 2017 to 2020, and ongoing analyses (Southall et al. 2022).

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 U.S. 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 156 humpback whale strandings have occurred along the U.S. East Coast, causing NMFS to declare an unusual mortality event for humpback whales in 2017 (still ongoing as of February 2022). 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; more than 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 2016/2017 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 mid-2021, Hampton Roads (Virginia) was the sixth busiest port in the U.S. and Baltimore (Maryland) was the sixteenth busiest port in the U.S. Both ports are reached via the shipping lanes that pass through the mouth of 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 be 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 may 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 Gulf of Maine sub-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 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/non-foraging) 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 collected information regarding the acoustic profile of the nearby large vessels, including the RLs 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 facilitating 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 used 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 were shared with researchers from HDR, Inc. and contributed to regional catalogs. Biopsy samples were contributed to the sample collection curated by HDR, Inc. Efforts were made to coordinate DTAG deployments with individuals previously tagged with longer-term satellite-linked tags 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 tags simultaneously.

Table 28. Vessel survey effort during suction-cup tagging in the Virginia Beach shipping lanes study area in 2021.

Date	Beaufort Sea State	Distance Surveyed (kilometers)	Survey Time (hours:minutes)	At-sea Time (hours:minutes)
11-January-2021	1–2	63.6	6:49	7:24
12-January-2021	2–3	44.8	6:29	7:19
13-January-2021	1–4	110.6	7:37	9:07
14-January-2021	2–4	116.7	6:10	6:35
19-January-2021	2–4	38.5	3:25	4:03
21-January-2021	2	42.0	2:07	2:54
22-January-2021	2–4	40.7	3:15	3:42
25-January-2021	1–3	72.4	7:21	8:02
26-January-2021	3	N/A	2:01	2:21

Key: N/A = not applicable

Table 29. Humpback whale sightings during suction-cup tagging in the Virginia Beach shipping lanes study area in 2021.

Date	Time (UTC)	Latitude (°N)	Longitude (°W)	Group Size	Tags Deployed
11-January-2021	14:32	36.9613	76.0197	1	–
12-January-2021	14:07	36.9604	76.0271	1	mn21_012a
13-January-2021	13:57	36.9652	76.0326	1	–
13-January-2021	18:31	36.8313	75.5415	2	–
13-January-2021	20:35	36.7830	75.4981	1	–
13-January-2021	21:04	36.7978	75.6753	1	–
14-January-2021	15:27	36.9809	75.9928	1	–
19-January-2021	14:31	36.9030	75.9204	1	–
19-January-2021	14:56	36.9288	75.9449	1	–
21-January-2021	21:19	36.9665	76.0347	1	–
22-January-2021	15:43	36.9682	75.9420	1	–
25-January-2021	14:17	36.9779	76.0556	1	–
25-January-2021	18:50	36.9512	75.9423	1	–
25-January-2021	18:56	36.9450	75.9465	1	mn21_025a
26-January-2021	N/A	N/A	N/A	1	–

Key: N/A = not applicable; °N = degrees north; UTC = Coordinated Universal Time; °W = degrees west

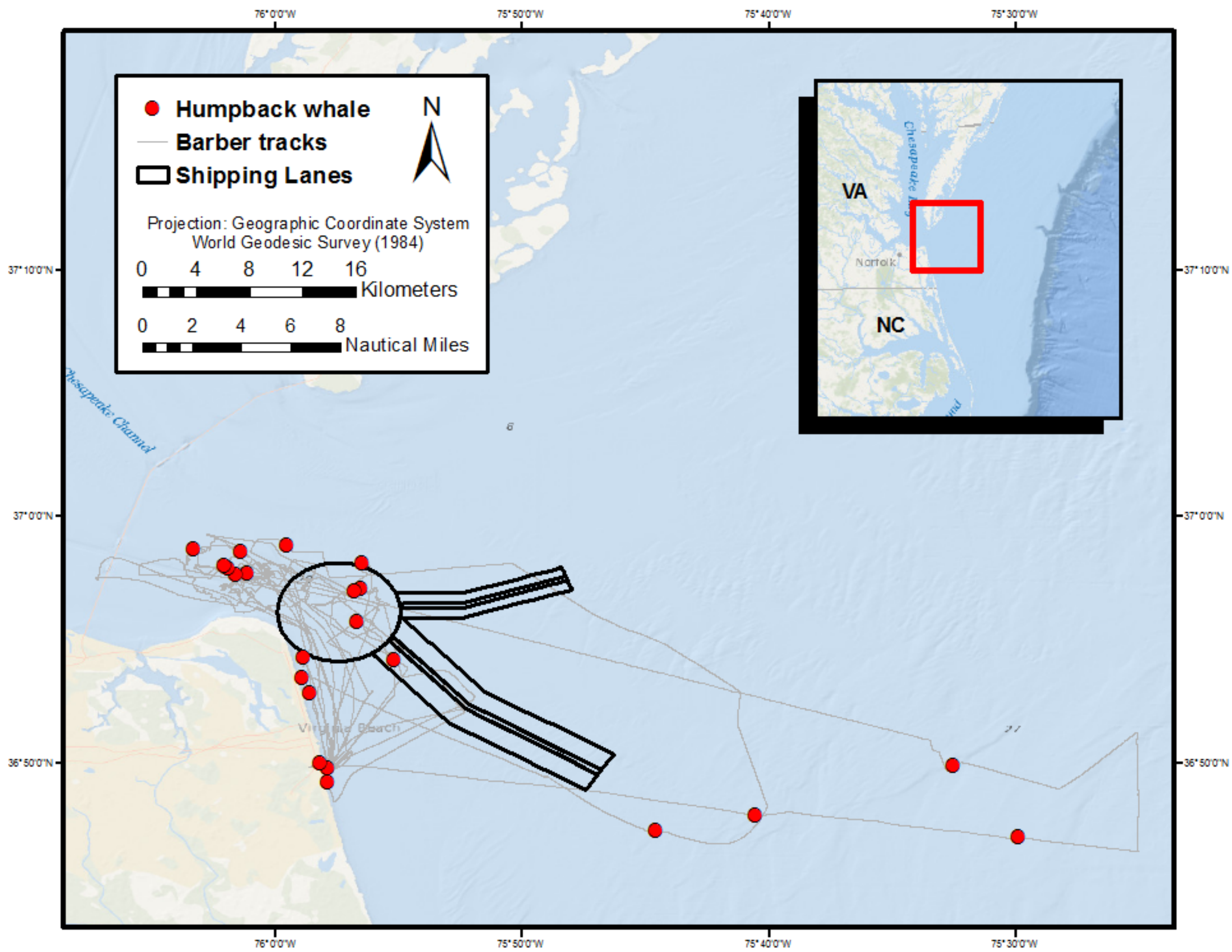

Figure 34. Survey tracks and locations of all humpback whale sightings during suction-cup tagging effort in the Virginia Beach shipping lanes study area in 2021.

Nine days of suction-cup tagging effort were conducted in the Virginia Beach shipping lanes during the 2021 season, totaling 529.3 kilometers during 51.5 hours of survey effort (**Table 28**). Surveys were conducted in Beaufort Sea States ranging from 1 to 4.

Humpback whales were sighted on 15 occasions, totaling 16 whales (**Table 29, Figure 34**). Single animals were the most common (14 of 15 sightings), followed by one sighting of a pair; no whales were observed in groups larger than two animals.

Two DTAGs were deployed (**Table 30, Figure 35**), both on animals that were already carrying satellite-transmitting tags deployed by HDR, Inc. One of these deployments (*mn21_012a*) was nearly 26 hours long, marking the longest DTAG deployment on a humpback whale in this area. The tagged whale foraged nearly continuously while the tag was attached, except for a brief period overnight (**Figure 36**). Deployment *mn21_025a* lasted just over 6 hours; this whale engaged in some foraging behavior, but only during the night (**Figure 37**).

Both animals tagged in 2021 exhibited clear lunges. *Mn21_012a*, the 26-hour duration tag, had the most foraging lunges (*n*=370) of any animal tagged to date in this area. Lunges were recorded during most hours of the day and night (**Figure 38**), with 202 of the lunges occurring at night (55 percent). The deepest lunge was at 24.3 meters for this animal, with an average of 10.2 meters. Lunges were relatively horizontal, with pitches ranging from -30° (head down) to +18° (head up) and roll ranging from -35° (left) to +24° (right). *Mn21_025a* had 44 total lunges. These lunges were shallower, with an average of 5.7 meters and a maximum of 12.9 meters. They also had more variation in pitch, with a range of -55 to +58 degrees, but roll was similar at -32 to +4 degrees. All lunges from *mn21_025a* occurred at night (**Figure 39**).

Table 30. Suction-cup tag deployments on humpback whales in the Virginia Beach shipping lanes study area in 2021.

Date	Time (UTC)	Latitude (°N)	Longitude (°W)	Tag Type	Tag ID	Duration (hours:minutes)
12-January-21	15:05	36.9852	75.0404	DTAG	mn21_012a	25:56
25-January-21	20:02	36.9516	75.9329	DTAG	mn21_025a	6:11

Key: N/A = not applicable; °N = degrees north; UTC = Coordinated Universal Time; °W = degrees west

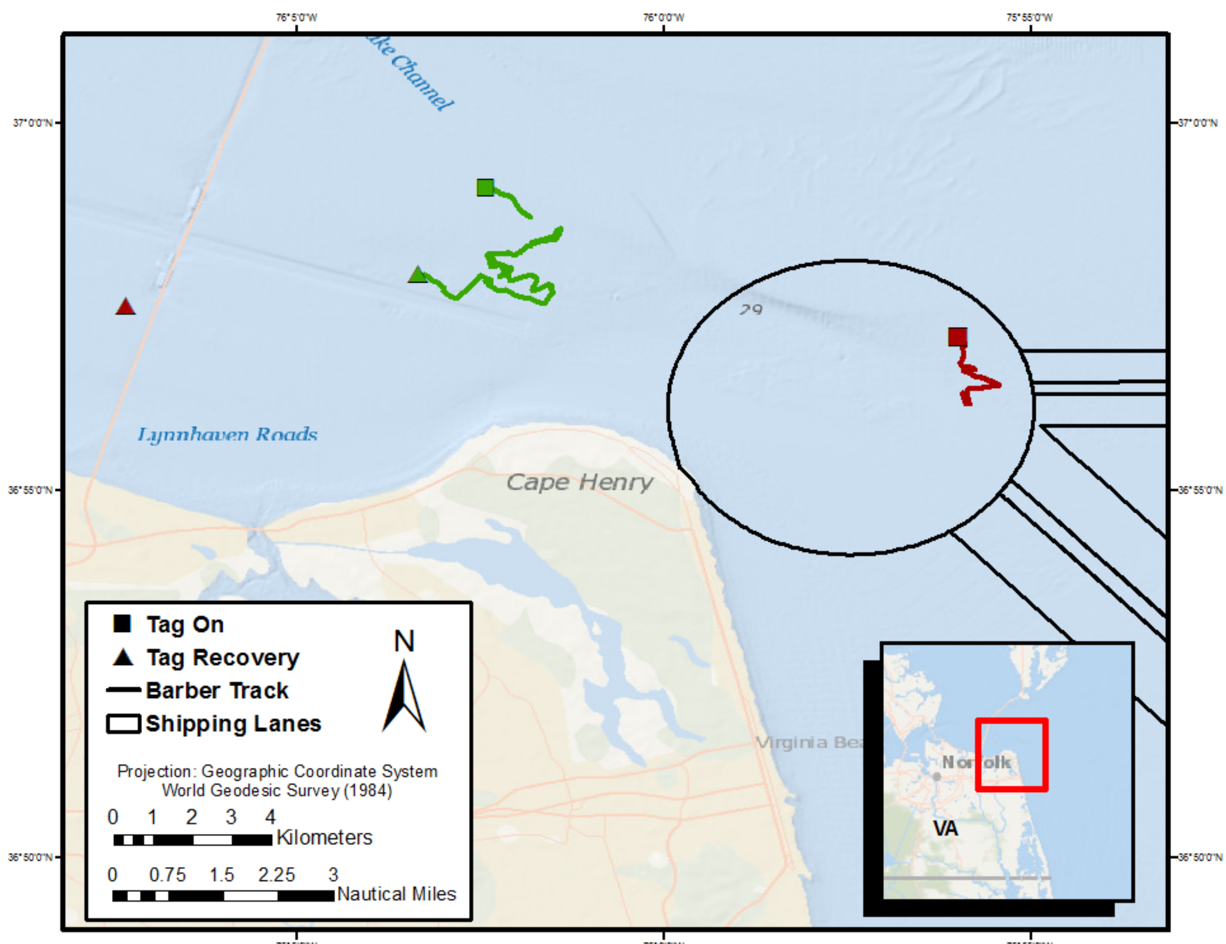

Figure 35. Tagging and tag recovery locations for two DTAG deployments in the Virginia Beach shipping lanes study area in 2021. The green- and red-colored lines represent the R/V *Barber*'s track during the focal follow of the animal.

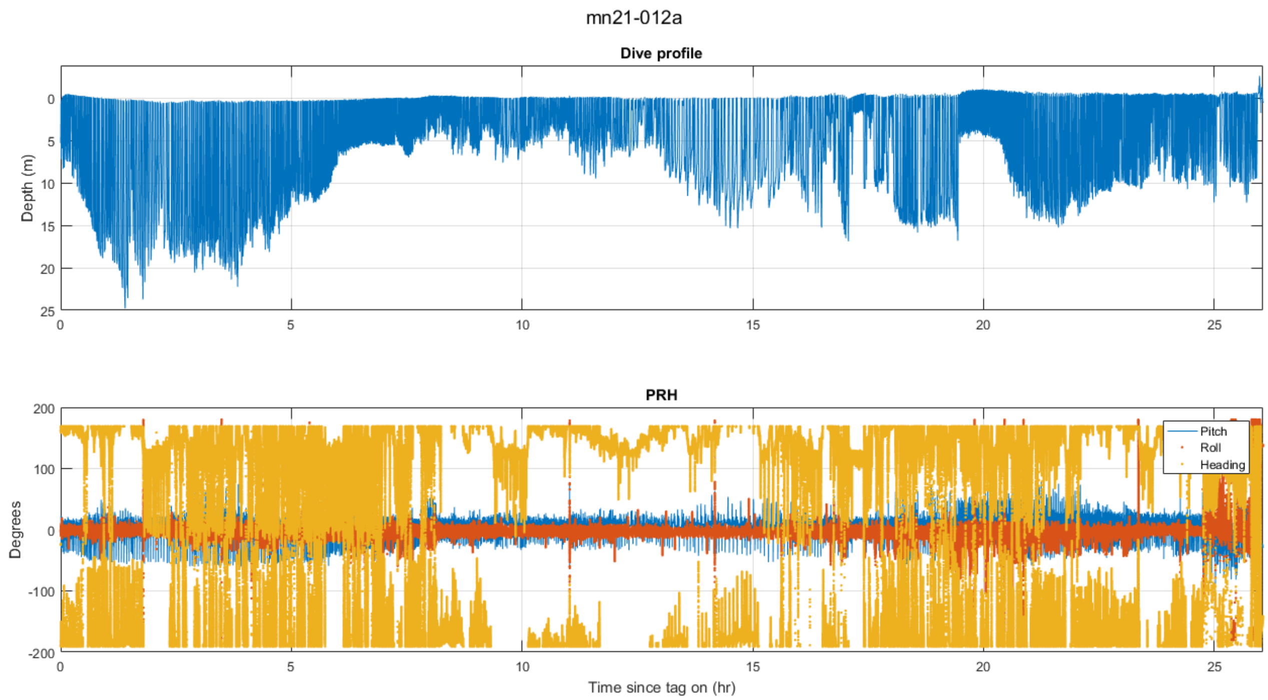

Figure 36. Dive-depth profile (top) and accelerometry metrics (bottom: pitch = blue, roll = orange, and heading = yellow) for tagged animal *mn21_012a*.

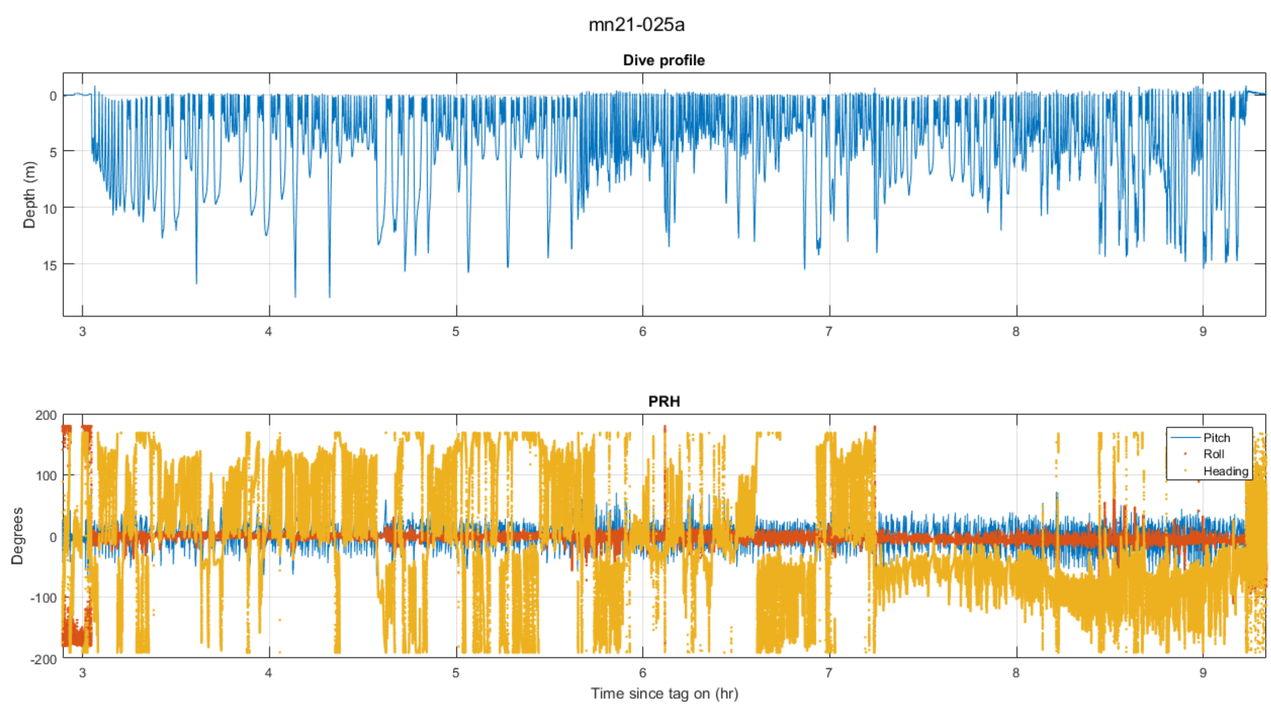

Figure 37. Dive-depth profile (top) and accelerometry metrics (bottom; pitch = blue, roll = orange, and heading = yellow) for tagged animal *mn21_025a*.

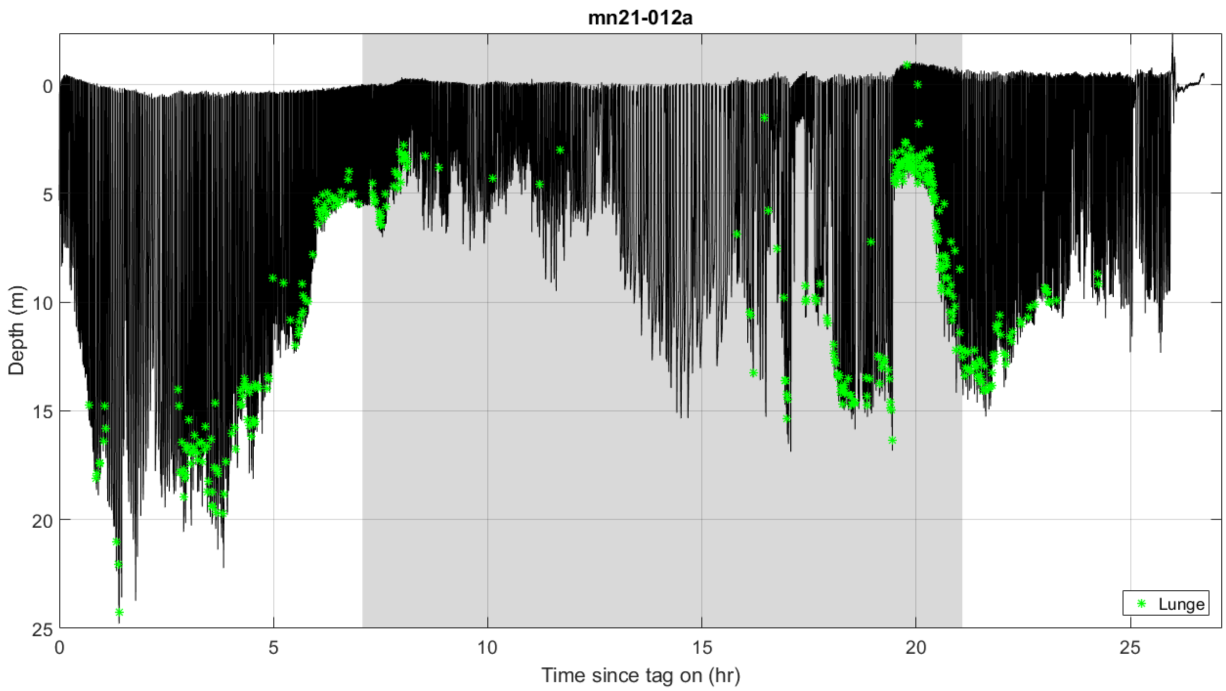

Figure 38. Dive profile for mn21_012a with lunges overlaid (green stars). The shaded area indicates nighttime hours.

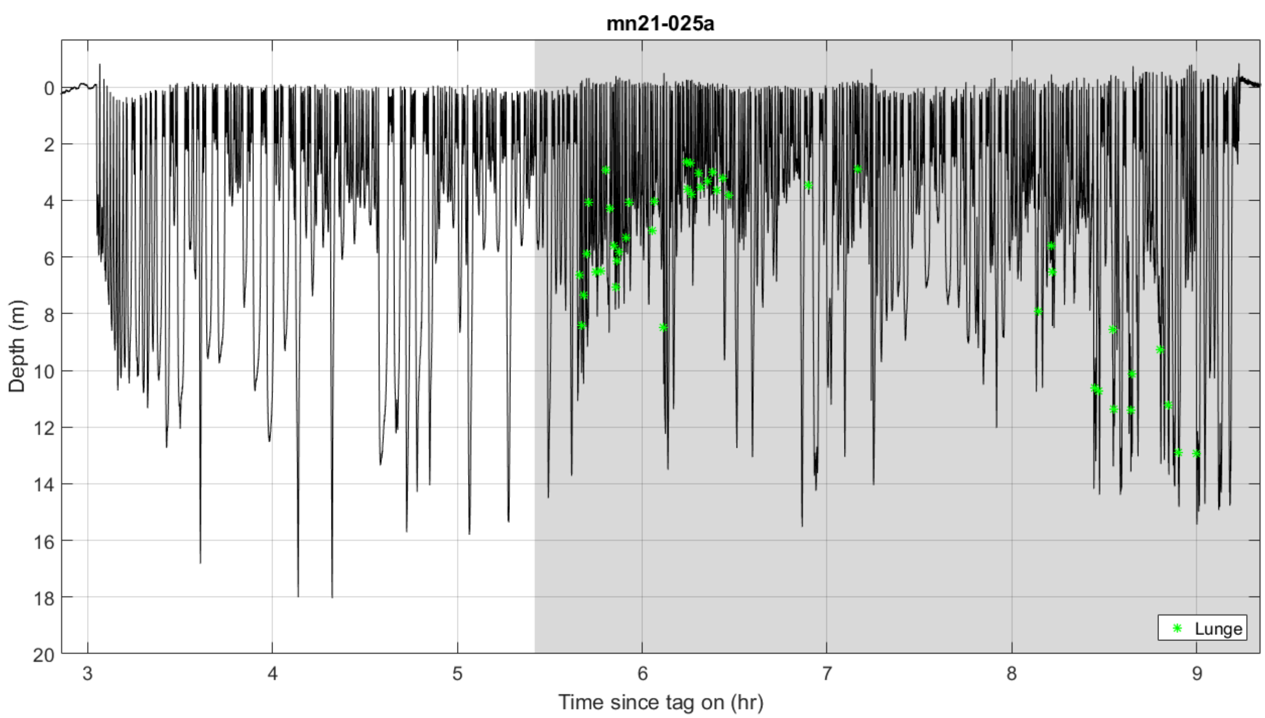

Figure 39. Dive profile for mn21_025a with lunges overlaid (green stars). The shaded area indicates nighttime hours.

Efforts in 2021 built upon previous years of tagging effort by deploying two additional DTAGs on already-satellite-tagged animals. Both tags recorded nighttime data, which will allow researchers to determine diel patterns in foraging as well as ship-approach risk. Both animals foraged extensively, highlighting the importance of this area as a winter feeding ground. As cessation of foraging is often considered a response to disturbance, identifying the presence and frequency of foraging events contributes to the understanding of humpbacks' responses to ships. Future work will combine the lunge data from these DTAGs with the synoptic satellite-tag locations collected by HDR, Inc. and available high-resolution bathymetry data to determine whether animals are foraging at the seafloor or in the water column, as well as their exact foraging locations relative to the shipping lanes.

During the 2021 season, researchers focused their analysis on acoustic audits of ship records and comparing the RL of sound on the tags with the ship's known distance to the animal. This preliminary analysis showed a weak linear relationship. The plan is to continue to refine this regression, adding data from more animals and changing variables, such as the frequency band in which the ship noise was calculated, to attempt to increase predictive power. The addition of other variables to the model is also expected, such as the ship's speed and type. If the ship's distance can be predicted with accuracy from the RL, then researchers can estimate ship distances from parts of the tag record without focal follows.

The 2021 season saw the development and addition of several analytical tools, including:

- Continued refinement of foraging lunge detection from accelerometry data streams and flow noise.
- Acoustically detecting ship approaches on tag records.

Future analytical tools currently being developed, include:

- Deconstructing high-resolution accelerometer and magnetometer data into biologically meaningful movement metrics, such as turning rates and overall body acceleration.
- Refining the ship distance/received level regression to increase predictive power.

Fieldwork is currently being conducted during the 2022 season (January through March) to increase the number of tagged whales with ship approaches for analyses. The research team will continue to prioritize coordination with HDR, Inc. to deploy DTAGs on whales equipped with satellite tags. This allows extending tag deployment durations and deploying overnight tags. Additionally, 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 2021 annual progress report (Shearer et al. 2022).

2.4 Sturgeon Monitoring

2.4.1 Atlantic and Shortnose Sturgeon Monitoring in the Lower Kennebec River

This telemetry monitoring study was initiated in May 2021 to collect year-round occurrence data for Atlantic and shortnose sturgeon in the lower Kennebec River (at Bath Iron Works) and also to collect data during recurrent Naval activities. This study will also implement monitoring stations offshore of Popham Beach to capture coastal movements of sturgeon and other species, including white sharks. This area encompasses a curtain between Fox-Seguin Islands and the JackKnife Ledge Dredge Disposal area. Additionally, an additional 55 total Atlantic and shortnose sturgeon will be tagged in the Kennebec River to increase the population of tagged fish.

Project objectives are: 1) monitor sturgeon activity in the proximity of Bath Iron Works; 2) Document coastal movements of fish offshore from Popham Beach: sturgeon, striped bass, white sharks, and highly migratory species; 3) Monitoring year-round presence and migration of Atlantic sturgeon in the lower Kennebec River; 4) Monitoring year-round presence and migration of shortnose sturgeon in the lower Kennebec River; and 5) add additional acoustically tagged species to the Kennebec River system. Collaborators on this project include State of Maine Department of Marine Resources, University of Maine, U.S. Geological Survey, Portsmouth Navy Yard, and University of Maryland Center for Environmental Science.

In May 2021, eight telemetry stations were deployed in the river, and six were deployed offshore. Atlantic sturgeon, shortnose sturgeon, and striped bass were detected on river stations. Both species of sturgeon, striped bass, white sharks, and Atlantic bluefin tuna were detected offshore, with several unknown tag IDs still pending. Twelve stations were deployed in the river in October 2021, with downloads expected in May 2022. Also, tagging of 55 total Atlantic and shortnose sturgeon is expected to occur in 2022.

2.4.2 Distribution of Gulf Sturgeon in the Panama City Testing Range

Gulf sturgeon were ESA listed as threatened in 1991. From spring to fall, adults undergo a prolonged period of fasting in the river before transiting to marine foraging areas, which are linked to reproductive success and key to the recovery of this species. Improving the limited understanding of marine habitat requirements is emphasized in the Gulf Sturgeon Recovery Plan, which highlights the need for multi-year tracking studies and will also assist in the Biological Assessment required under Section 7 of the ESA. The U.S. Naval Surface Warfare Center Panama City Division Testing Range overlaps extensively with Gulf sturgeon critical habitat as well as adjacent areas where Gulf sturgeon are believed to occur, and information on the spatial temporal patterns of habitat use is needed.

In October 2021, 53 Gulf sturgeon were captured via gillnetting directed by side-scan sonar in the lower Choctawhatchee River. All Gulf sturgeon were measured and weighed. A small tissue sample from the caudal fin was fixed in 95 percent ethanol for subsequent genetic assignment to be conducted by the University of Southern Mississippi. Gulf sturgeon that did not already have a passive integrated transponder received a 12-millimeter, 134.2-kHz passive integrated transponder tag, implanted at the left base of the dorsal fin. Fifty Gulf sturgeon received acoustic transmitters (VEMCO Ltd. V-16-6H) that were surgically implanted according to previously developed protocols (Fox et al. 2000). A gonadal biopsy was also collected from all individuals that received transmitters to assign sex and stage of maturity using developed criteria (Van Eenennaam et al. 1996).

Immediately after the sampling effort for Gulf sturgeon, building and deploying the acoustic receiver array began in the GOM. Upon completion, this array covers an area of approximately 145 km of shoreline between Cape San Blas and Santa Rosa Island, Florida, extending 40 km offshore (**Figure 40**). On 14 and 15 October, eight receiver stations were deployed bracketing Destin Pass as well as seven inshore receivers between Destin Pass and St. Andrew's Bay to monitor telemetered Gulf sturgeon as they entered the GOM. Time restraints and supply chain issues delayed the deployment of the remaining 61 receivers in the GOM until December.

Collaborations with NOAA's Panama City Laboratory and the U.S. Fish and Wildlife Service's Panama City Field Office were formed and strengthened in the beginning stages of this project and will be vital assets going forward.

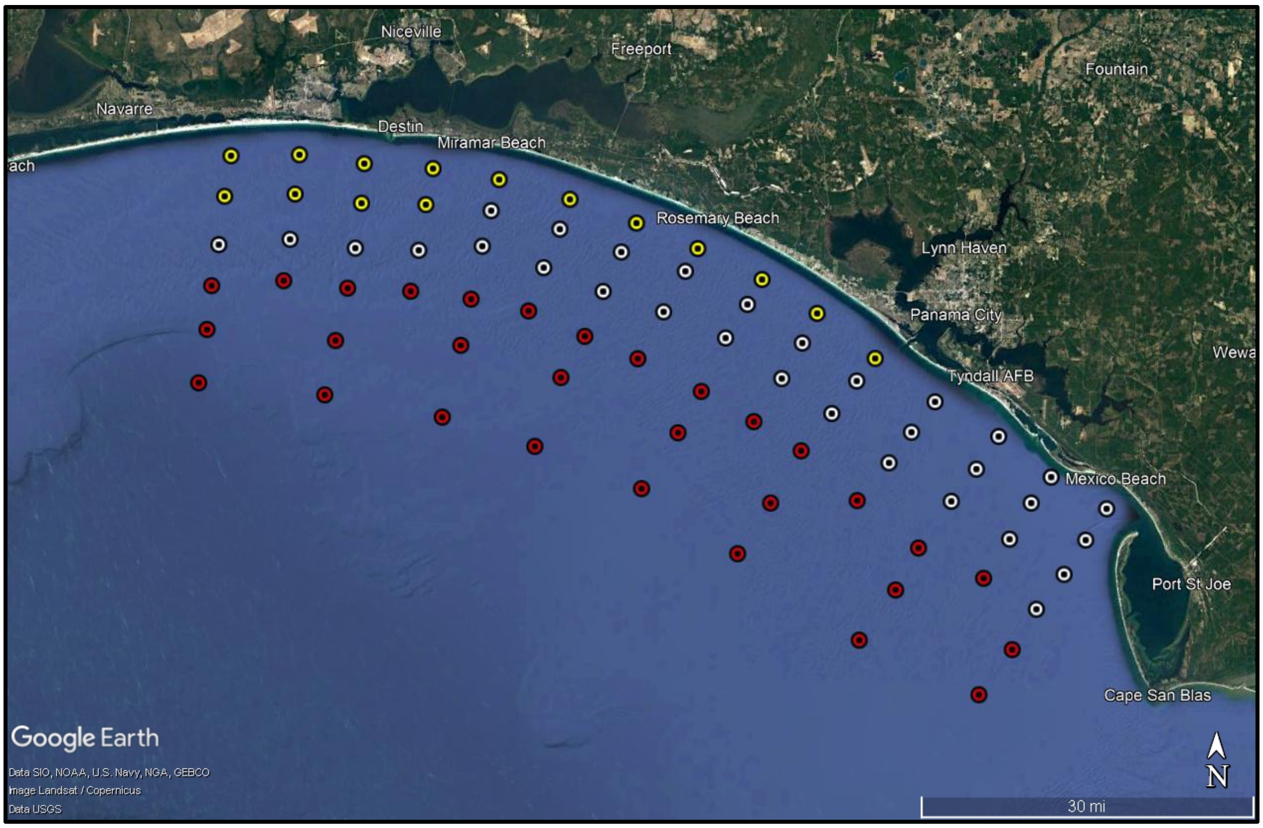

Figure 40. Deployment locations of the passive acoustic receivers to monitor for Gulf sturgeon in the U.S. Naval Surface Warfare Center Panama City Division Testing Range. Yellow = TX receivers deployed in October 2021, White = TX receivers deployed in December 2021, and Red = AR receivers deployed in December 2021.

2.5 Lookout Effectiveness Analysis

The U.S. Navy undertakes monitoring and mitigation for marine mammals during training and testing activities as part of procedures designed to minimize risk to these animals. One component of this mitigation is the shipboard lookouts (LOs), who are part of the standard operating procedure that ships use to detect objects (including marine mammals and other animals) around the ship during operations. As well as dedicated lookouts, detections of marine mammals may also be made by other members of the ship's crew such as officers on the bridge or sonar technicians (although in the latter case visual confirmation is required). Collectively, these personnel are referred to as the "lookout team" (LT).

From 2010 to 2019, the U.S. Navy conducted a lookout effectiveness study to assess the effectiveness of lookouts in detecting marine mammals during at-sea training events. As part of this study, experienced civilian marine mammal observers (MMOs) followed a systematic protocol to collect data, including sightings and environmental conditions, which were then pooled across multiple embark events for analysis. The primary goal of this project was to determine how effective the LTs are at detecting marine mammals before they enter a defined set of mitigation ranges (200, 500, and 1,000 yards). This was achieved by undertaking a set of at-sea trials where LT observations could be compared with those made by the MMOs stationed on board U.S. Navy ships training with mid-frequency active sonar. This setup enabled a secondary aim of determining how LT effectiveness compared with that of MMO teams.

A total of 27 data collection embarks were conducted from both cruiser and destroyer class ships, generating 716 sighting "trials" of marine mammals for analysis. A comprehensive analysis was conducted, which included development of new analytical methods that allow estimation of the probability of animals approaching the vessel within a specified mitigation range without being detected (probability of remaining undetected [PrU]). These methods include a model for the surfacing pattern of animal pods, and for the range-dependent probability of detecting a pod each time it surfaces. The methods are also flexible in allowing for various patterns of animal surfacing and various experimental configurations (in terms of communication between MMO and LT platforms and whether repeat surfacings of the same pod are recorded).

The data were analyzed in four groups according to similarity in surfacing pattern: rorquals (i.e., large baleen whales), sperm whales, small cetaceans in small schools (six or less), and small cetaceans in large schools (more than six). Overall, the probability of small cetaceans, particularly in small groups, remaining undetected was higher than for large cetaceans for both LT and MMO. In addition, the probability of each of the groups analyzed remaining undetected by the LT was higher than the MMOs at all three ranges. Please see Oedekoven and Thomas (2022) for complete details of the analysis methods and results as well as data collection protocols.

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APPENDIX A

SUMMARY OF MONITORING PROJECTS IN THE ATLANTIC FOR 2021–2022

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Appendix A: Summary of Monitoring Investments in the Atlantic for 2021–2022

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, DTAGs, satellite tags **Performing Organizations**: Duke University, Southall Environmental Associates, University of St. Andrews, Bridger Associates, Calvin College, HDR Inc. **Timeline**: 2017–2022 **Funding**: FY16 – $35K, FY17 – $1.25M, FY18 – $1.4M, FY19 – $1.4M, FY20 – $1.3M, FY21 – $1.25M	• Evaluate behavioral responses by marine mammals exposed to Navy training and testing activities	**Field work ongoing – anticipate completion in 2022** • Technical progress reports available – 2017–2021 • Tagging data available through Animal Telemetry Network • Multiple peer-reviewed publications • 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, Bridger Consulting, HDR Inc. **Timeline**: Ongoing since 2013, transitioned to Atlantic 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** • Technical progress reports available – 2013–2018 • Tagging field work transitioned to Atlantic BRS in 2017 • Tagging data available through Animal Telemetry Network • Multiple peer-reviewed publications

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, FY21 – $430K	• 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 – 2016–2021 • Sperm whale diving and feeding ecology focus beginning 2021 • 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 and movements in the Mid-Atlantic region. *Previous* - Assess behavior in coastal waters of the Southeast calving grounds, including rates of travel, dive behavior, rates of sound production, mother/calf interactions; **Methods**: Autonomous near real-time PAM, DTAGs, satellite-linked tags, UAS 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, FY21 – $200K	• 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 2014–2017 • Multiple peer-reviewed publications available • 2018 – shift focus to occurrence in Mid-Atlantic • 2018–20 autonomous PAM glider deployments in Mid-Atlantic • 2020 deployed fixed auto-reporting PAM buoy off Cape Hatteras • Opportunistic visual monitoring, satellite-linked tagging, and DTAG deployments in Mid-Atlantic beginning 2021

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, FY21 – $320K	• 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 – 2014–2021 • Peer-reviewed publication • Vessel response component added winter of 2019 • Tagging data available through Animal Telemetry Network • Primary focus shifting to continued photo-ID in 2022
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**: 2018–2022 **Funding**: FY19 – $95K, FY20 – $75K, FY21 – $80K	• 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** • Technical progress reports available – 2019–2021
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, FY21 – $79K	• 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 resumed – anticipate completion in 2022** • Technical progress report available – 2017–2020 • Field work resumed winter 2022 • 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, photo-ID **Performing Organizations**: NAVFAC Atlantic, The Nature Conservancy, HDR Inc. **Timeline**: 2015–2022 **Funding**: FY15 – $52K, FY16 – $57K, FY17 – $7K, FY18 – $29K, FY19 – $62K, FY20 – $40K, FY21 – $50K	• 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 – 2016–2021 • Time-lapse camera traps incorporated in 2020
Title: Time-lapse Camera Surveys of Pinnipeds in Southeastern Virginia **Location:** Lower Chesapeake Bay and Virginia Eastern Shore **Objectives:** Document seasonal occurrence, habitat use, and haul-out patterns of seals **Methods:** Remote time-lapse camera traps, photo-ID **Performing Organizations**: NAVFAC Atlantic, The Nature Conservancy **Timeline:** 2019–2022 **Funding:** FY19 - $15k, FY20 – $18K, FY21 – $11K	• 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	**Data collection and analysis ongoing** • 2019–2020 technical progress reports available

Project Description	Intermediate Scientific Objectives	Status
Title: Occurrence of Rice's Whales in the Gulf of Mexico [1] **Location**: Northeastern Gulf of Mexico **Objectives**: Assess seasonal and occurrence of Rice's whales in the Northeastern Gulf of Mexico **Methods**: PAM **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	**Data collection and analysis ongoing** • Technical progress reports available – 2019–2021 • 2020 data collection delayed due to COVID-19 pandemic • Data collection anticipated to be complete by December 2022
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, FY21 – $124K	• 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	**Field work ongoing** • Field work resumed in 2021 • Transitioned from small vessel baseline surveys • Current focus on photo-ID, tagging, and M3R species verification support

[1] Funded by Naval Sea Systems Command

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 complete in 2022** • Technical progress report series available • Multiple peer-reviewed publications available • Data contributed to broad scale collaborative ecological analysis efforts • Data archiving at NCEI initiated
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, FY21 – $150K	• 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 – 2019–2021 • Multiple peer-reviewed publications available

Project Description	Intermediate Scientific Objectives	Status
Title: Atlantic Marine Assessment Program for Protected Species (AMAPPS) **Location:** Northwest Atlantic (Maine to Florida) **Objectives:** Assess the abundance, distribution, ecology, and behavior of marine mammals, sea turtles, and seabirds throughout the U.S. Atlantic **Methods:** Visual surveys, passive acoustic monitoring, tagging **Performing Organizations:** NOAA Fisheries Northeast and Southeast Fishery Science Centers **Timeline:** 2010–present **Funding:** $250K annually	• 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	**Ongoing** • AMAPPS I – 2010–2014 • AMAPPS II – 2015–2019 • AMAPPS III – 2020–2024
Title: Marine Mammal Monitoring on Navy Ranges (M3R) [2] **Location**: Jacksonville USWTR **Objectives**: TBD **Methods**: Passive acoustic monitoring **Performing Organizations**: NUWC Newport **Timeline**: 2020–TBD **Funding**: FY21 – $180K	• 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	**2021 New start** • Data collection and species verification tests initiated in 2021
Title: Gulf of Mexico Sturgeon Monitoring [3] **Location**: NSWC Panama City Testing Range **Objectives**: Assess Gulf Sturgeon distribution and habitat use **Methods**: Acoustic tagging **Performing Organizations**: University of Delaware, Delaware State University **Timeline**: 2021–TBD	• Assess the occurrence and distribution of Threatened and Endangered species in Navy range complexes and in specific training and testing areas • Establish the baseline habitat uses and movement patterns of threatened and Endangered species where Navy training and testing activities occur	**2021 New start** • Field work initiated in October 2021

[2] Joint-funded by U.S. Fleet Forces and Naval Sea Systems Command

[3] Funded by Naval Sea Systems Command

Project Description	Intermediate Scientific Objectives	Status
Title: Lower Kennebec River Sturgeon Monitoring **Location**: Bath Iron Works and Lower Kennebec River **Objectives**: Assess Atlantic and shortnose sturgeon distribution and habitat use **Methods**: Acoustic tagging **Performing Organizations**: NUWC Newport, Maine Department of Natural Resources, U.S. Geological Survey, PSNY, University of Maryland **Timeline**: 2021–TBD	• Assess the occurrence and distribution of Threatened and Endangered species in Navy range complexes and in specific training and testing areas • Establish the baseline habitat uses and movement patterns of threatened and Endangered species where Navy training and testing activities occur	**2021 New start** • Field work initiated in May 2021

Key: DTAG = digital acoustic tag; FY = Fiscal Year; BRS = behavioral response study; VACAPES = Virginia Capes; PAM = passive acoustic monitoring; UAS = Unmanned Aerial Systems; photo-ID = photo identification; NAVFAC = Naval Facilities Engineering Systems Command; USWTR = Undersea Warfare Training Range; M3R = Marine Mammal Monitoring on Navy Ranges; NOAA = National Oceanic and Atmospheric Administration; NMFS = National Marine Fisheries Service; NUWC = Naval Undersea Warfare Center; PSNY = Portsmouth Navy Yard; TBD = to be determined

APPENDIX B

RECENT PUBLICATIONS AND PRESENTATIONS RESULTING FROM AFTT-RELATED MONITORING INVESTMENTS

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

Cioffi, W.R., N.J. Quick, H.J. Foley, D.M. Waples, Z.T. Swaim, J.M. Shearer, D.L. Webster, A.S. Friedlaender, B.L. Southall, R.W. Baird, D.P Nowacek, and A.J. Read. 2021. Adult male Cuvier's beaked whales (*Ziphius cavirostris*) engage in prolonged bouts of synchronous diving. *Marine Mammal Science* 37(3):1085–1100.

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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

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