Mid-Atlantic Nearshore and Mid-Shelf Baleen Whale Monitoring, Virginia Beach, Virginia: 2022/23 Annual Progress Report

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Prepared by

Jessica Aschettino[1], Dan Engelhaupt[1], and Amy Engelhaupt[2]

[1] HDR
Virginia Beach, Virginia

[2] Amy Engelhaupt Consulting
Virginia Beach, Virginia

Submitted by:

Virginia Beach, VA

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A group of North Atlantic right whales (*Eubalaena glacialis*) engage in surface active behavior off Virginia Beach, Virginia. Cover photograph collected from drone by Jessica Aschettino, taken under National Marine Fisheries Service Scientific Research Permit No. 21482, issued to Dan Engelhaupt, HDR.

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Acronyms and Abbreviations

BSS	Beaufort sea state
CATS	Customized Animal Tracking Solution
CLS	Collection & Location by Satellite
CMARI	Clearwater Marine Aquarium Research Institute
CTD	conductivity, temperature, and depth
DMA	Dynamic Management Area
DTAG	Digital Acoustic Recording Tag
ESA	Endangered Species Act
GMT	Greenwich Mean Time
GPS	Global Positioning System
ID	identifier
km	kilometer(s)
LiDAR	Light Detection and Ranging
LIMPET	Low Impact Minimally Percutaneous External-electronics Transmitter
m	meter(s)
min	minute(s)
MINEX	Mine Neutralization Exercise
mm:ss	minutes:seconds
NAVFAC	Naval Facilities Engineering Systems Command
NEFSC	Northeast Fisheries Science Center
nm	nautical mile(s)
OPAREA	Operating Area
photo-ID	photo-identification
SAG	surface active group
SMA	Seasonal Management Area
SPOT	Smart Position and Temperature

UME	Unusual Mortality Event
U.S.	United States
VACAPES	Virginia Capes Operating Area
VHF	very-high frequency

1. Introduction and Background

Since January 2015, HDR Inc. has been monitoring humpback whales (*Megaptera novaeangliae*) to assess their occurrence, habitat use, and behavior within and near United States (U.S.) Navy training and testing areas off Virginia via the Mid-Atlantic Humpback Whale Monitoring Project (Aschettino et al. 2016, 2017, 2018, 2019, 2021, 2022a, 2023) (**Table 1**). Vessel surveys focused on photo-identification (photo-ID), biopsy sampling, tagging using medium-resolution satellite tags and high-resolution suction-cup tags, and using a small drone for length and body condition assessments. These baseline data are critical for assessing the potential for disturbance to humpback whales within this part of the mid-Atlantic.

Although humpback whales were the focal species for this study, data on other high-priority baleen whale species were also collected opportunistically. Relatively little information exists on how other species of baleen whales, including endangered North Atlantic right (*Eubalaena glacialis*) and fin (*Balaenoptera physalus*) whales, use the central Mid-Atlantic waters of the Atlantic Fleet Training and Testing area. Passive acoustic monitoring results from autonomous gliders and Marine Autonomous Recording Units confirm that humpback, fin, sei (*Balaenoptera borealis*), minke (*Balaenoptera acutorostrata*), and North Atlantic right whales regularly use the continental shelf waters off the coasts of Virginia and North Carolina (Stanistreet et al. 2016, Salisbury et al. 2018, Baumgartner 2019). Acoustic detections are supported by visual sighting data collected by the Atlantic Marine Assessment Program for Protected Species aerial and vessel surveys (NEFSC and SEFSC 2012, 2013) as well as previously funded U.S. Navy aerial and vessel surveys (Mallette et al. 2018, Cotter 2019).

Fin whales, considered a strategic stock given their Endangered Species Act (ESA) status, appear to show a reliable pattern of occurrence near the continental shelf break throughout the Virginia Capes Operating Area (VACAPES OPAREA) (Hayes et al. 2023, Mallette et al. 2018). Satellite-monitored tags deployed on fin whales in the region by researchers from HDR Inc. between 2016 and 2021 show both localized and extensive movements over all areas of the continental shelf (A. Engelhaupt et al. 2017, 2018, 2019; Aschettino et al. 2018, 2021, 2022a). Confirmed sightings of critically endangered North Atlantic right whales off Virginia have also increased as coverage during the Mid-Atlantic Humpback Whale Project surveys extended farther from the coastline in recent years (Aschettino et al. 2022a, 2023). Movements of satellite-tagged North Atlantic right whales show extensive use of the mid-shelf region both north and south of the primary study area (Aschettino et al. 2022a, 2023; D. Engelhaupt et al. 2022). Although sightings of blue whales (*Balaenoptera musculus)* off Virginia are infrequent, they have now been documented during HDR Inc. surveys in 2018 (A. Engelhaupt et al. 2019; D.T. Engelhaupt et al. 2020), 2019 (Cotter 2019; D.T. Engelhaupt et al. 2020), 2021 (A. Engelhaupt et al. 2022), and 2022 (A. Engelhaupt et al. 2023). Argos location data from satellite-tagged blue whales showed at least some movements through shallower continental shelf waters (Lesage et al. 2017, A. Engelhaupt et al. 2022, Aschettino et al. 2022b).

Building upon the long-term dataset established through the ongoing monitoring of humpback whales, the Mid-Atlantic Nearshore and Mid-Shelf Baleen Whale Monitoring Project expanded the previous study area to encompass mid-shelf waters to approximately 75 kilometers (km)

from shore, where the diversity of baleen whale species increases. The goals of this study are to assist the U.S. Navy and regulatory agencies by addressing the following questions:

- What is the baseline ecology and behavior of baleen whales (including North Atlantic right, fin, humpback, sei, minke, and blue whales) within the study area?
- Do individual whales exhibit site fidelity within specific regions of the U.S. Navy OPAREAs over periods of weeks, months, years?
- What is the seasonal extent of baleen whale movements within and around U.S. Navy OPAREAs?
- Do baleen whales spend significant time within or primarily move through areas of U.S. Navy live-fire or anti-submarine warfare training events?
- Are baleen whale movement patterns affected by U.S. Navy training exercises?
- Are baleen whales likely to be exposed to significant sound levels produced by vessel traffic and/or military training exercises using active sonar?

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. Nine field seasons have been dedicated to addressing the above objectives (**Table 1**), starting with collection of basic baseline information using photo-ID, focal-follow, and biopsy-sampling methods. Subsequently, the project evolved to include deployment of satellite-linked telemetry tags, Digital Acoustic Recording Tags (DTAGs), and Customized Animal Tracking Solutions (CATS) tags; collaboration with researchers from Duke University to examine behavioral response of humpbacks to large vessels (Shearer et al. 2020); photogrammetry using a drone; and, most recently, an expansion into the mid-shelf region with the additional focus of other baleen whale species, including fin and North Atlantic right whales. This report will therefore present details for both the nearshore and mid-shelf effort during the 2022/23 season.

2. Executive Summary

Twenty-four vessel surveys were completed during the 2022/23 field season. Five of these surveys were considered nearshore, and 19 were defined as mid-shelf. In total, 49 baleen whale sightings, including 33 sightings of humpback whales composed of 48 individuals, 9 sightings of North Atlantic right whales composed of 36 individuals, and 7 sightings of fin whales composed of 13 individuals, occurred during the 2022/23 field season. There were 8 aerial surveys completed during the 2022/23 field season. In total, there were 12 sightings of baleen whales, including 6 North Atlantic right whale sightings composed of 18 individuals, 3 fin whale sightings composed of 4 individuals, and 3 humpback whale sightings composed of 3 individuals. There was also a single sighting of 9 individual sperm whales (*Physeter macrocephalus*) on the aerial survey that extended out to deep waters past the shelf break in association with an offshore vessel survey (see A. Engelhaupt et al. 2024). Two satellite tags were deployed on humpback whales, two CATS tags were deployed on North Atlantic right whales, and two CATS tags were deployed on humpback whales. One biopsy sample was also collected from a tagged humpback whale (**Table 1**).

Table 1. Summary of field seasons and objectives since initiation of project in 2014.

Season	Begin	End	Objectives	Biopsy samples	Satellite tags deployed Mn / Bp / Eg	Suction cup tags deployed	Report
1 (2014/15[a])	31-Dec-2014	15-May-2015	Collect baseline information	12	-	—	Aschettino et al. 2015; A. Engelhaupt et al. 2015
2 (2015/16)	01-Dec-2015	09-May-2016	Collect baseline information and deploy telemetry tags	11	9 / 0 / 0	—	Aschettino et al. 2016
3 (2016/17)	01-Nov-2016	21-Mar-2017	Collect baseline information and deploy telemetry tags	29	26 / 0 / 0	—	Aschettino et al. 2017
4 (2017/18)	01-Oct-2017	01-Mar-2018	Collect baseline information and deploy telemetry tags, expand spatial extent of coverage	3	6 / 2 / 0	—	Aschettino et al. 2018
5 (2018/19)	12-Nov-2018	20-May-2019	Collect baseline information and deploy telemetry tags, collaborate on behavioral response of humpbacks to large vessels (Shearer et al. 2019, 2020)	9	10 / 0 / 0	—	Aschettino et al. 2019; Aschettino et al. 2020a
6 (2019/20)	21-Dec-2019	27-Mar-2020	Collect baseline information, deploy telemetry tags, photogrammetry using a drone, collaborate on behavioral response of humpbacks to large vessels (Shearer et al. 2021)	7	9 / 1 / 0	—	Aschettino et al. 2021
7 (2020/21)	19-Nov-2020	27-Mar-2021	Collect baseline information, deploy telemetry and acoustic tags, photogrammetry using a drone, expansion to mid-shelf region with addition of other baleen whale species, collaborate on behavioral response of humpbacks to large vessel project (Shearer et al. 2022)	6	7 / 2 / 2	4	Aschettino et al. 2022a
8 (2021/22)	14-Nov-2021	15-Mar-2022	Collect baseline information, deploy telemetry and acoustic tags, photogrammetry using a drone, continued expansion to mid-shelf region with addition of other baleen whale species, collaborate on behavioral response of humpbacks to large vessel project (Shearer et al. 2023)	7	9 / 0 / 1	2	Aschettino et al. 2023
9 (2022/23)	21-Nov-2022	06-Mar-2023	Collect baseline information, deploy telemetry and acoustic tags, photogrammetry using a drone, continued expansion to mid-shelf region with addition of other baleen whale species, collaborate on behavioral response of humpbacks to large vessel project (Shearer et al. 2024)	1	2 / 0 / 0	4	Current and Aschettino et al. 2024

[a] Additional humpback whale sighting information from coastal line-transect surveys for bottlenose dolphins (*Tursiops truncatus*) conducted from 2012 through 2015 (see A. Engelhaupt et al. 2016) was also incorporated into these analyses

Key: Mn = Humpback whale (*Megaptera novaeangliae*); Bp = Fin whale (*Balaenoptera physalus*); Eg = North Atlantic right whale (*Eubalaena glacialis*)

3. Methods

3.1 Vessel surveys

The study area for this project includes waters within and around the mouth of Chesapeake Bay; the W-50 Mine Neutralization Exercise (MINEX) region off Virginia Beach; and, beginning with the 2020/21 field season, the mid-shelf region of the VACAPES OPAREA (**Figure 1**). Two primary areas of interest within the nearshore study area are U.S. Navy training areas and commercial shipping lanes. Inbound and outbound shipping lanes are defined by the Traffic Separation Scheme. Initially, the "shipping lane study area" was defined by the Traffic Separation Scheme within the mouth of Chesapeake Bay (**Figure 1**). However, as tag locations showed movements outside the defined area but within shipping channels, the area was extended using multiple nautical charts and datasets. This includes using the following guidelines: the Traffic Separation Scheme; Coastal Maintained Channels in U.S. Waters (U.S. Army Corps of Engineers); and Shipping Fairways, Lanes, and Zones for U.S. Waters (National Oceanic and Atmospheric Administration). The U.S. Navy training areas include portions of the W-50 MINEX range. Within the mid-shelf study area, the Dominion Wind Energy Area, where two wind turbines are currently installed, is also an area of interest (**Figure 1**).

Local availability of researchers allowed survey effort to be flexible and take advantage of limited winter weather windows to maximize the ability to achieve project objectives. Optimal weather conditions include good visibility and a Beaufort sea state (BSS) of 3 or lower. Once a survey was underway, if BSS reached 4 to 5, or visibility was reduced to less than 1 nautical mile (nm) because of rain, fog, or snow, the survey was typically aborted, and the vessel returned to port. Efforts were coordinated with the W-50 MINEX range, so the research vessel had clearance to operate when training was not being conducted. Because of frequent range closures and limited weather windows, it was not always possible to conduct surveys within the W-50 MINEX range.

The primary survey vessel for nearshore effort during the 2022/23 season was the 7.6-meter (m), fiberglass boat *Nauticstar* (**Figure 2**). Surveys using this vessel departed from Marina Shores, located in Lynnhaven Inlet, Virginia Beach. While working within the mid-shelf area, surveys primarily used the 15.2-m fishing vessel *Waverunner* (**Figure 3**), but also the 11.0-m fishing vessel *Smoke Show* and 16.5-m fishing vessel *Game On*. Surveys using these vessels departed from the Virginia Beach Fishing Center or the Rudee Inlet Station Marina, both located within Rudee Inlet. Given the focus on the mid-shelf with the intent to locate North Atlantic right whales, more mid-shelf surveys were conducted than nearshore surveys. When working within the mid-shelf region, the vessel would often coordinate with concurrent aerial surveys being conducted in Virginia and North Carolina by HDR Inc., Clearwater Marine Aquarium Research Institute (CMARI), and Azura Consulting LLC in order to respond to any sightings of North Atlantic right whales.

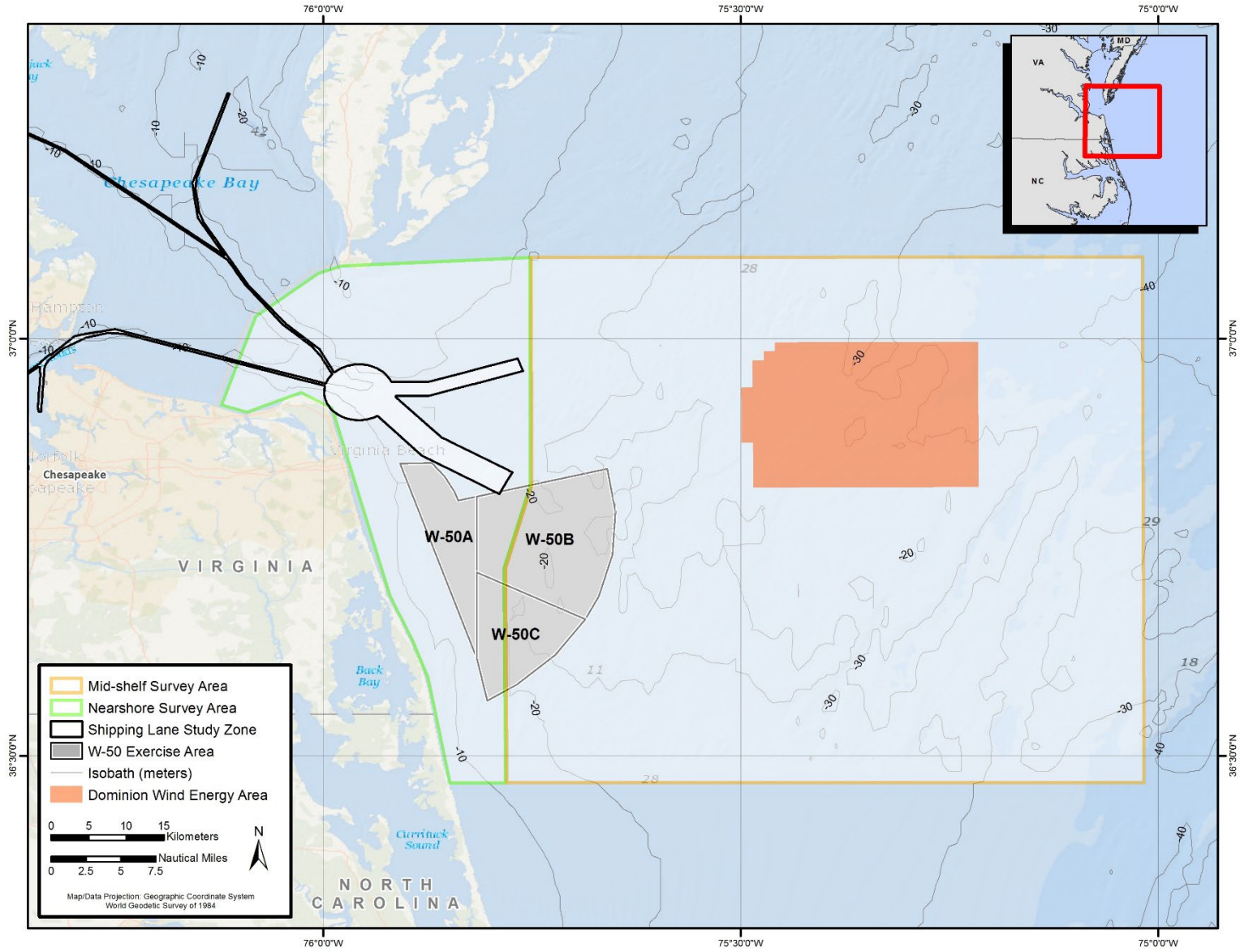

Figure 1. Map of the nearshore and mid-shelf study area, which includes waters within and around the mouth of Chesapeake Bay shipping lanes, the W-50 MINEX region off Virginia Beach, and the Dominion Wind Energy Area.

Figure 2. Nearshore survey vessel used during the 2022/23 season, 7.6-m *Nauticstar*.

Figure 3. Primary mid-shelf survey vessel, 15.2-m *Waverunner*.

The crew typically consisted of three or four qualified marine mammal scientists, with one also serving as the vessel operator when working from the nearshore vessel. Survey efforts typically begin when the local whale-watch operations and other mariners first start reporting humpback sightings. Once departed from the inlet, the vessel would transit to areas where baleen whales were previously seen or reported. If no whales were located within these areas, the vessel would expand the search into waters farther offshore, north, or south of the primary study area (see **Figure 1**). Survey data were collected on an Apple® iPad using COMPASS (see Richlen et al. 2019), a U.S. Navy-funded, marine mammal survey software platform. Sightings of non-target species within the survey area (i.e., bottlenose dolphins [*Tursiops truncatus*]) were not always recorded and are not presented in this report.

3.2 Aerial Surveys

To better assist the tag boat in locating target species, aerial surveys were periodically flown by researchers from HDR Inc. and Naval Facilities Engineering Systems Command (NAVFAC) Atlantic in association with the vessel surveys. A set of tracklines was established to cover the primary study area (**Figure 4**). Tracklines ran from shore out to 45 nm; tracklines from one aerial survey extended out to 70 nm in association with an offshore survey (A. Engelhaupt et al. 2024); however, given that survey coverage also occurred over the mid-shelf area, effort and sightings are reported within this report. Other researchers also had intermittent coverage in this study area, including CMARI and Azura Consulting LLC (Whitt 2023) (**Figure 4**), and HDR researchers leveraged sightings from the aerial platforms whenever possible.

Survey flights conducted by HDR Inc. originated from Signature Flight Support at Norfolk International Airport in Norfolk, Virginia. All flights were flown by Technology Service Corporation (Plymouth, Massachusetts) in a Cessna 337 Skymaster with two pilots and two observers (positioned at the left and right windows in the rear seats of the aircraft). Surveys were flown at 305-m altitude and 100-knot (185 km/hour) speed. Observers continuously scanned the trackline and used an inclinometer to obtain a vertical angle to a sighting when a detection was made within the observer's field of view. Survey data were collected on an Apple® iPad using COMPASS (Richlen et al. 2019). Photographs were taken of all baleen whale sightings when feasible and were used to substantiate species and individual identifications.

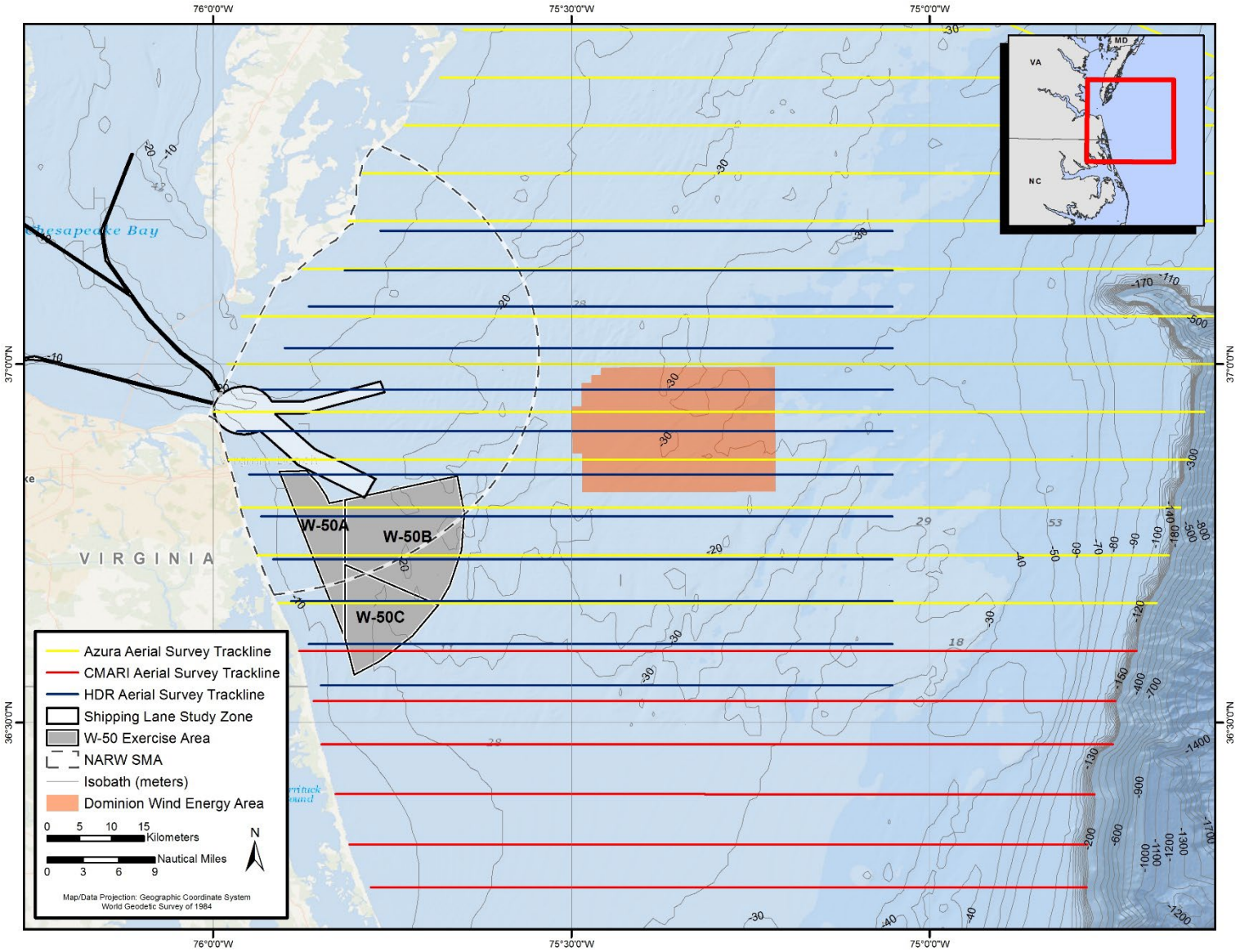

Figure 4. Aerial tracklines for HDR Inc. (blue), CMARI (red), and Azura Consulting LLC (yellow).

3.3 Photo-ID

Photographs of humpback, right, and fin whales were collected using a digital single-lens reflex camera (Canon 7D, 7D Mark II, or 1DX Mark II) or mirrorless camera (Canon R5) with a telephoto lens (Canon 100- to 400-millimeter or Canon 100- to 500-millimeter). Photographs were post-processed using ACDSee (Versions 7–9) by cropping the best image of each individual whale's dorsal fin (left and right), callosity pattern (for North Atlantic right whales), and tail flukes (when obtained).

Photographs were assembled into a project catalog managed by HDR Inc. in which each new humpback or fin whale was assigned a unique identifier (ID) using the naming convention "HDRVA," followed by the two-letter abbreviation for the scientific name of the species, followed by a numerical sequence of three numbers (e.g., HDRVABp001). Each whale was compared with every other cataloged whale before receiving a new ID. Given the small population size of North Atlantic right whales (fewer than 400) and the publicly accessible online catalog, the official catalog identifications were used rather than the conventional HDR Inc. naming mechanism for other species. Details from humpback whale photo-ID efforts are included in Aschettino et al. (2024b); details from the fin whale and North Atlantic right whale photo-ID efforts are presented in this report.

When sightings of North Atlantic right whales were made in the field, the drone was launched to record overhead videos of all individuals, and the resulting stills were used to compare with an onboard catalog of known reproductive females. If within cell-phone range, photographs of the individual North Atlantic right whales were also shared with Katie Jackson (Florida Fish and Wildlife Service) for identification assistance. If not within cell-phone range, images would be sent to Katie Jackson as well as others at the Northeast Fisheries Science Center (NEFSC) and New England Aquarium once back within range. Sightings of North Atlantic right whales were also reported to NEFSC, added to Whale Map, and shared with the U.S. Coast Guard, U.S. Navy, and other researchers within the area for awareness. At the end of the 2022/23 field season, all photographs and drone data collected from North Atlantic right whales were submitted to the New England Aquarium for incorporation into the North Atlantic Right Whale Catalog. Fin whale photographs were added to HDR Inc.'s fin whale catalog, and will be added to Happywhale and compared to catalog photographs from other regions that have been shared with HDR Inc.

The use of a drone was incorporated into the field effort beginning in the 2018/19 field season. A DJI Phantom 4 Pro V2.0 was used to collect morphometric data, assess overall body condition, and identify any potential entanglements. In the field, live video was also used to assist the research team during tagging attempts to maximize successful deployments. 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. Following the methodology described in Dawson et al. (2017), the DJI Phantom 4 Pro V2.0 was retrofitted with a custom Light Detection and Ranging (LiDAR) altimeter (Lightware SF11) in 2020. This upgrade increases precision (to within 5 centimeters) and consistency of the drone altimetry measurements to minimize possible errors in estimated

animal lengths. HDR Inc. used open-source software developed by researchers at Duke University (Torres and Bierlich 2020) to calculate whale lengths (see Aschettino et al. 2024b).

3.4 Biopsy Sampling

Biopsy samples were collected using either a crossbow or biopsy rifle. Finn Larsen-designed crossbow bolts outfitted with 25-millimeter, ethanol-sterilized, stainless steel tips were projected by a 68-kilogram pull Barnett recurve crossbow (Barnett Outdoors, LLC, Tarpon Springs, Florida). Alternatively, a Paxarms biopsy rifle (Paxarms New Zealand Ltd., Cheviot, New Zealand) fired 6- by 20-millimeter sterilized dart tips propelled by .22 caliber blank cartridges.

Samples were post-processed by sectioning the skin into three equal-sized pieces. One-third of the skin was placed in a cryovial and frozen (-40 degrees Celsius) for future stable isotope analysis, one-third was placed in a cryovial with a dimethylsulfate and sodium chloride solution in preparation for analysis by University of Groningen, and one-third was frozen (-40 degrees Celsius) for archival storage for the Southeast Fisheries Science Center. Blubber from the samples was wrapped in foil and frozen (-40 degrees Celsius) for archiving for the Southeast Fisheries Science Center. Stable isotope analysis and gender determination was performed on a portion of samples at the end of the 2016/17 field season (see Waples 2017). At the end of the 2018/19 field season, all humpback whale samples were sent to the University of Groningen for processing, where they analyzed 63 humpback whale and 8 fin whale samples collected since the project's inception, and matched them to the larger archive of more than 9,200 North Atlantic humpback whale and more than 1,700 fin whale samples (Bérubé and Palsbøll 2022). At the end of the 2022/23 field season, samples from 2019/20 through 2022/23 field seasons were sent to the University of Groningen to be processed.

3.5 Satellite Tagging

Satellite tagging has been a primary component of the project since the 2015/16 field season. Initially, Wildlife Computers (Redmond, Washington) Smart Position and Temperature (SPOT6) Argos satellite-linked tags in the Type-A (Andrews et al. 2019) Low Impact Minimally Percutaneous External-electronics Transmitter (LIMPET) configuration (Andrews et al. 2008) were used. SPLASH10-F-333 and SPLASH10-292B tags, which collect dive depth data in addition to location, were incorporated into the project in subsequent seasons. The SPLASH10-F tags use Fastloc® Global Positioning System (GPS) technology; they were initially intended to be deployed during windows of opportunity during which Duke University researchers might also be within the area and could potentially "double-tag" whales using DTAGs (see Shearer and Read 2020; Shearer et al. 2021). Tags were remotely deployed using a DAN-INJECT JM25 pneumatic projector. The LIMPET tags use two 6.8-centimeter, surgical-grade, titanium darts with six backwards-facing petals to attach tags to or just below the dorsal fin (**Figure 5**).

Figure 5. LIMPET SPLASH10-F tag on a humpback whale immediately after deployment.

Given existing information about attachment durations of LIMPET tags on humpback whales, maximum tag attachment duration was expected to be on the order of days to weeks. Therefore, tags were programmed to maximize the number of transmissions and locations received rather than to extend battery life. Based on satellite availability within the area, tags were programmed to transmit for between 18 and 22 hours per day with an unlimited number of transmissions for the SPOT6 tag, and 1,100 transmissions per day for the SPLASH10-F tag. A Collection & Location by Satellite (CLS) goniometer was also used as a mobile receiving station to maximize the amount of data (i.e., tag messages) collected that may otherwise be missed by the satellites.

In order to constitute a “dive” for the Wildlife Computers-generated behavior and time-series data outputs of the SPLASH10-F tags, a definition was established for humpback whales in which a submergence needed to be both deeper than 2 m and longer than 120 seconds to be classified as a dive. Locations of tagged individuals were approximated by the Argos system using the Kalman filtering location algorithm (Argos User’s Manual © 2007–2015 CLS), and unrealistic locations (i.e., on land) were manually removed using tools provided within Movebank.

Biopsy samples were collected from some tagged whales using the protocols described previously; conductivity, temperature, and depth (CTD) casts were typically taken following a tag deployment.

3.6 Suction-cup Tagging

Suction-cup tagging was added to the project for the 2020/21 season using DTAGs (Johnson and Tyack 2003) within the mid-shelf and/or MINEX region of the study area. CATS tags were incorporated for the 2022/23 season. Both types of digital tags are deployed using a hand-held

carbon fiber pole and must be retrieved for data recovery. Version 3 DTAGs were equipped with hydrophones and pressure sensors as well as a three-axis accelerometer and magnetometer. The audio-sampling rate was set to 120 kilohertz for baleen whales, and programmed release time was set according to conditions and logistics to facilitate the best opportunity for tag retrieval. The customized CATS tag contains a 4K high-resolution video camera in addition to the diary that records accelerometer, magnetometer, gyroscope, and pressure data as well as a single hydrophone. Both types of tags contain a very-high frequency (VHF) transmitter that allows recovery using Communications Specialists, Inc. R-1000 VHF receivers with hand-held Yagi antennas to direct the vessel to the tag location after release from the animal. The CATS tag also includes a SPOT-6 satellite tag to support recovery.

Tag calibration and data visualization following recovery of all tags was completed using a suite of tools found on animaltags.org and using MATLAB. CATS tag calibration steps are outlined in Cade et al. (2021).

4. Results

4.1 Nearshore and Mid-shelf Vessel Surveys

The first survey for the 2022/23 field season occurred on 21 November 2022, and the last survey occurred on 06 March 2023. In total, 24 vessel surveys were conducted, covering 3,379 km of trackline with more than 185 hours of effort (**Table 2; Figure 6**). Five of these surveys were considered nearshore (**Figure 7**), and 19 surveys were defined as mid-shelf (**Figure 8**). In total, 49 baleen whale sightings, including 33 humpback whale sightings composed of 48 individuals, 9 North Atlantic right whale sightings composed of 36 individuals, and 7 fin whale sightings composed of 13 individuals, occurred during the 2022/23 field season (**Figure 6**; **Table 2**).

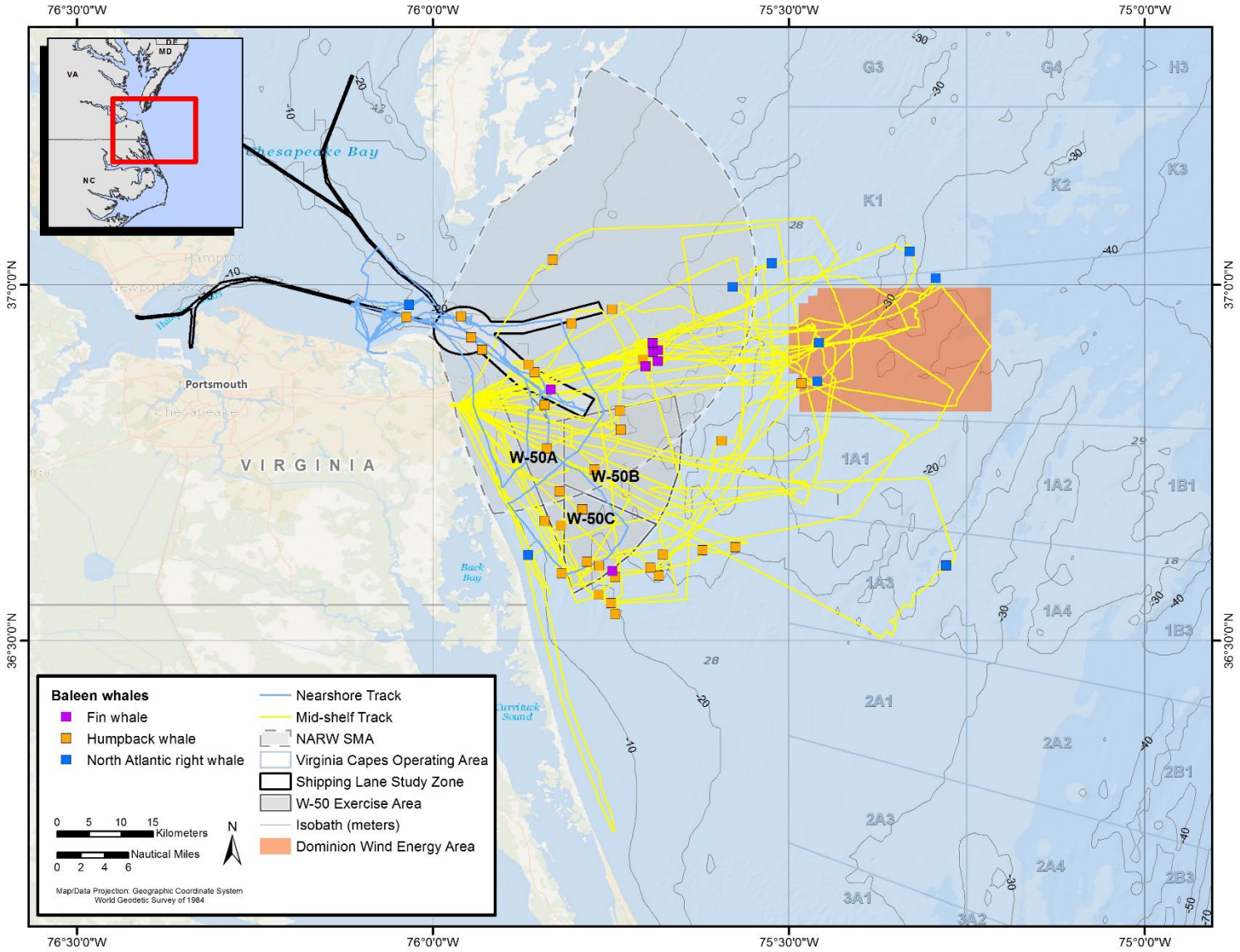

Figure 6. Nearshore (blue) and mid-shelf (yellow) survey tracks, with locations of all humpback (*n*=33), fin (*n*=7), and North Atlantic right (*n*=9) whale sightings for the 2022/23 field season.

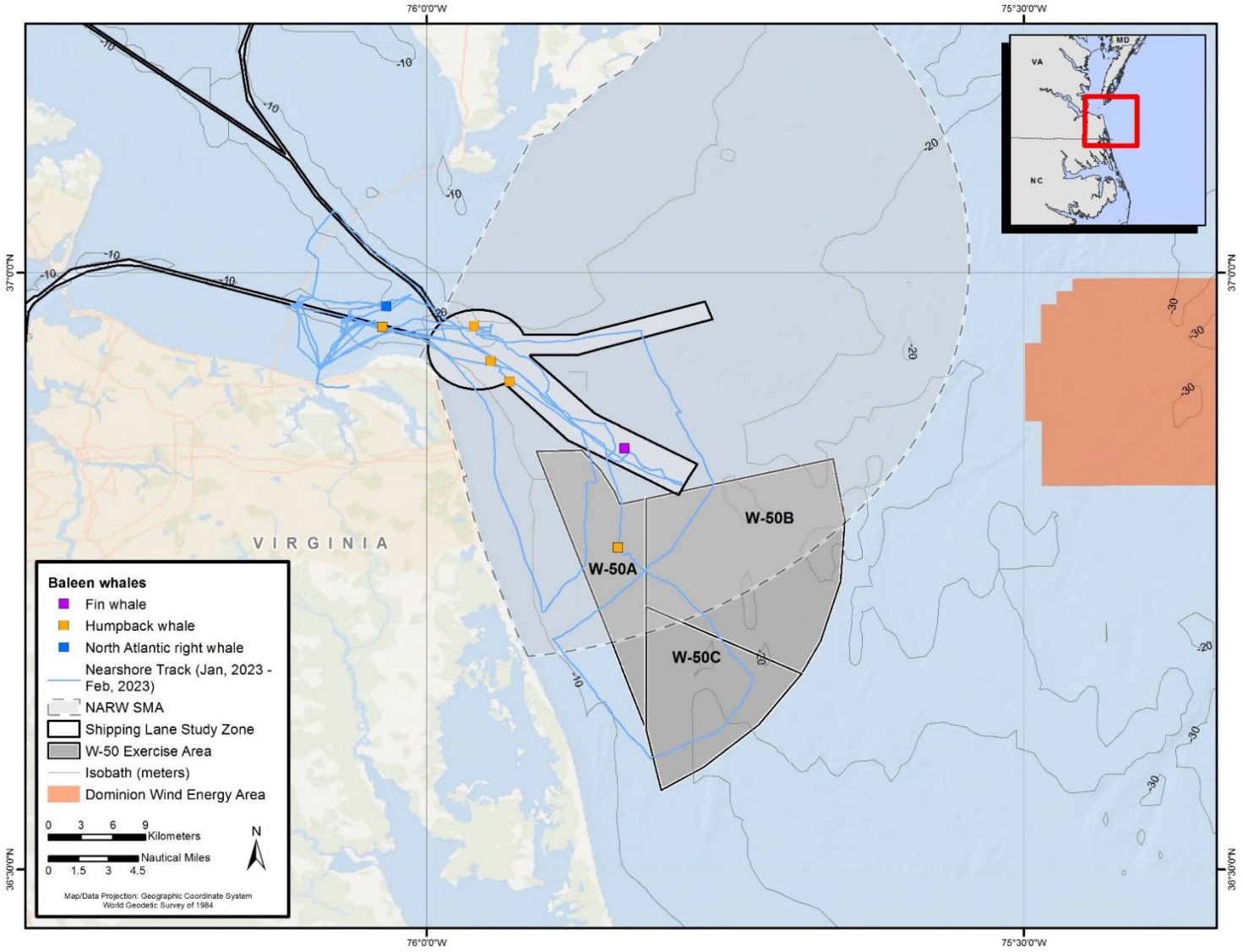

Figure 7. Nearshore survey tracks (blue), with locations of all humpback (*n*=5), fin (*n*=1), and North Atlantic right (*n*=1) whale sightings for the 2022/23 field season.

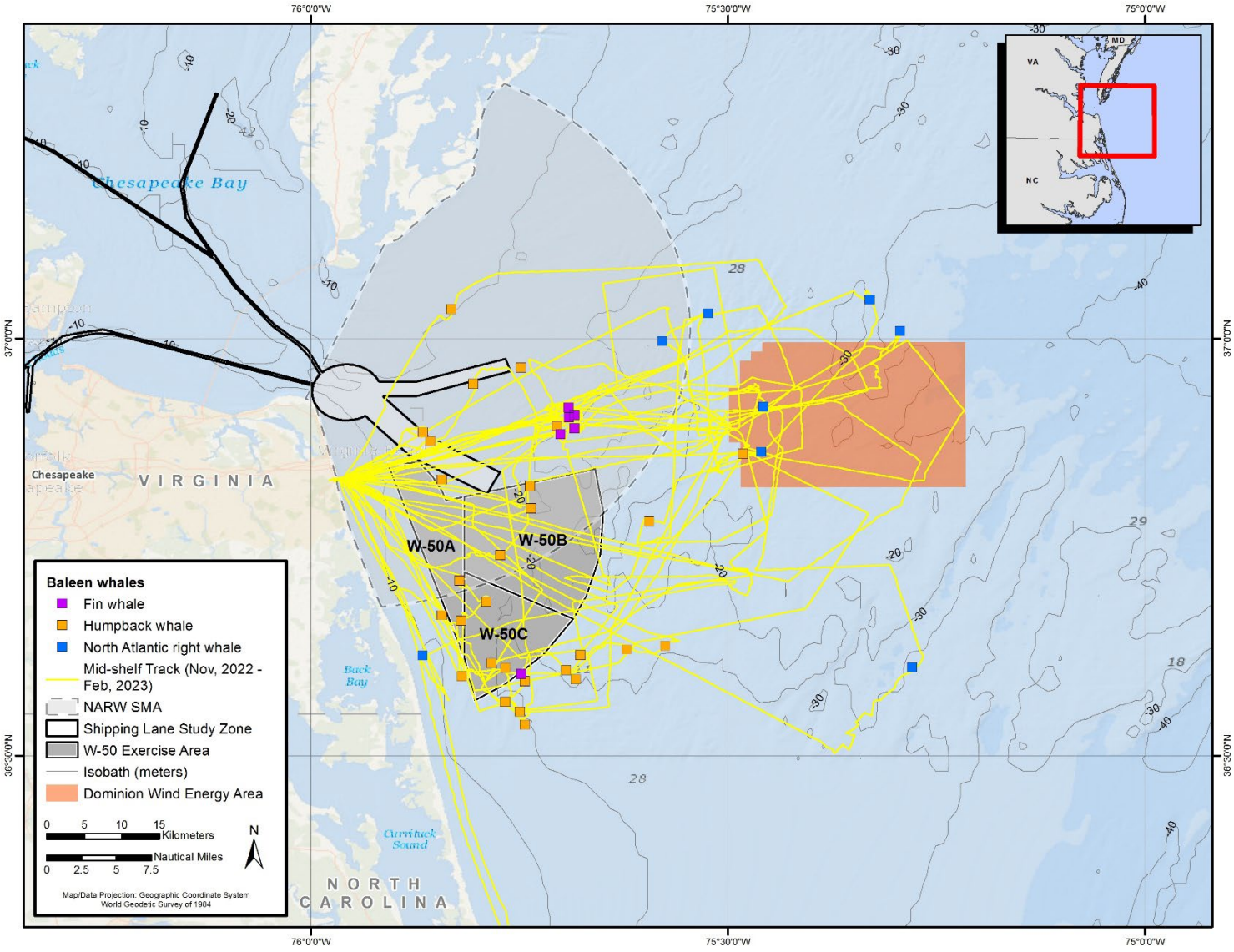

Figure 8. Mid-shelf survey tracks (yellow), with locations of all humpback (*n*=28), fin (*n*=6), and North Atlantic right (*n*=8) whale sightings for the 2022/23 field season.

Table 2. Summary of nearshore and mid-shelf vessel survey efforts off Virginia Beach, Virginia, for the 2022/23 field season.

Date	Survey type	Survey time (min)	Distance surveyed (km)	# sightings Mn	# individuals Mn	# sightings Bp	# individuals Bp	# sightings Eg	# individuals Eg
21-Nov-22	Mid-shelf	543	146	2	4	0	0	0	0
22-Nov-22	Mid-shelf	579	164	4	7	0	0	1	2
23-Nov-22	Mid-shelf	254	140	0	0	0	0	0	0
02-Dec-22	Mid-shelf	471	151	5	8	0	0	0	0
28-Dec-22	Mid-shelf	449	176	1	1	0	0	0	0
30-Dec-22	Mid-shelf	476	108	6	9	1	1	0	0
02-Jan-23	Mid-shelf	489	165	0	0	1	3	0	0
07-Jan-23	Nearshore	423	149	1	1	0	0	0	0
10-Jan-23	Mid-shelf	582	96	4	5	0	0	0	0
11-Jan-23	Mid-shelf	418	88	1	1	2	3	0	0
18-Jan-23	Nearshore	378	99	0	0	0	0	1	1
19-Jan-23	Nearshore	184	56	0	0	0	0	0	0
24-Jan-23	Mid-shelf	537	164	1	2	1	1	1	7[a]
29-Jan-23	Mid-shelf	615	171	1	1	1	4	1	7
30-Jan-23	Mid-shelf	521	174	1	2	0	0	1	8
02-Feb-23	Nearshore	360	88	3	4	1	1	0	0
07-Feb-23	Mid-shelf	557	149	0	0	0	0	2	8
08-Feb-23	Nearshore	344	52	1	1	0	0	0	0
14-Feb-23	Mid-shelf	440	156	0	0	0	0	0	0
19-Feb-23	Mid-shelf	511	200	1	1	0	0	0	0
21-Feb-23	Mid-shelf	488	195	1	1	0	0	0	0
26-Feb-23	Mid-shelf	573	178	0	0	0	0	1	1
05-Mar-23	Mid-shelf	475	145	0	0	0	0	1	2
06-Mar-23	Mid-shelf	464	169	0	0	0	0	0	0
Totals	—	**11,131**	**3,379**	**33**	**48**	**7**	**13**	**9**	**36**

Key: min = minute(s); Bp = *Balaenoptera physalus* (fin whale); Eg = *Eubalaena glacialis* (right whale); Mn = *Megaptera novaeangliae* (humpback whale)
[a] Includes 1 individual seen and photographed by HDR Inc.'s aerial survey team working concurrently with the vessel team

4.2 Aerial Survey Results

Eight aerial surveys were flown during the 2022/23 field season, covering 7,484 km of trackline with more than 43 hours of survey effort (**Table 3, Figure 9**). The first aerial survey occurred on 22 November 2022, and the last survey occurred on 20 March 2023. In total, there were 12 sightings of baleen whales, including 6 North Atlantic right whale sightings composed of 18 individuals, 3 fin whale sightings composed of 4 individuals, and 3 humpback whale sightings composed of 3 individuals. There was also a single sighting of 9 individual sperm whales on an aerial survey that extended out to deep waters past the shelf break in association with an offshore vessel survey (see A. Engelhaupt et al. 2024). Dolphins, including bottlenose, common (*Delphinus delphis*), and Risso's (*Grampus griseus*), as well as a great white shark (*Carcharodon carcharias*), were also observed during aerial surveys but are not reported here.

Table 3. Summary of aerial survey efforts off Virginia Beach, Virginia, for the 2022/23 field season.

Date	Survey time (min)	Distance surveyed (km)	# sightings Eg	# individuals Eg	# sightings Bp	# individuals Bp	# sightings Mn	# individuals Mn	# sightings Pm	# individuals Pm
22-Nov-22	314	844	1	2	0	0	0	0	0	0
28-Dec-22	356	1065	0	0	0	0	1	1	0	0
24-Jan-23	279	827	2	6	1	1	1	1	0	0
07-Feb-23	361	853	2	8	0	0	0	0	0	0
21-Feb-23	304	903	0	0	0	0	0	0	0	0
05-Mar-23	350	808	1	2	1	2	0	0	0	0
06-Mar-23	337	1024	0	0	0	0	1	1	0	0
20-Mar-23	327	1160	0	0	1	1	0	0	1	9
Totals	**2,628**	**7,484**	**6**	**18**	**3**	**4**	**3**	**3**	**1**	**9**

Key: min = minute(s); Bp = *Balaenoptera physalus* (fin whale); Eg = *Eubalaena glacialis* (right whale); Mn = *Megaptera novaeangliae* (humpback whale); Pm = *Physeter macrocephalus* (sperm whale)

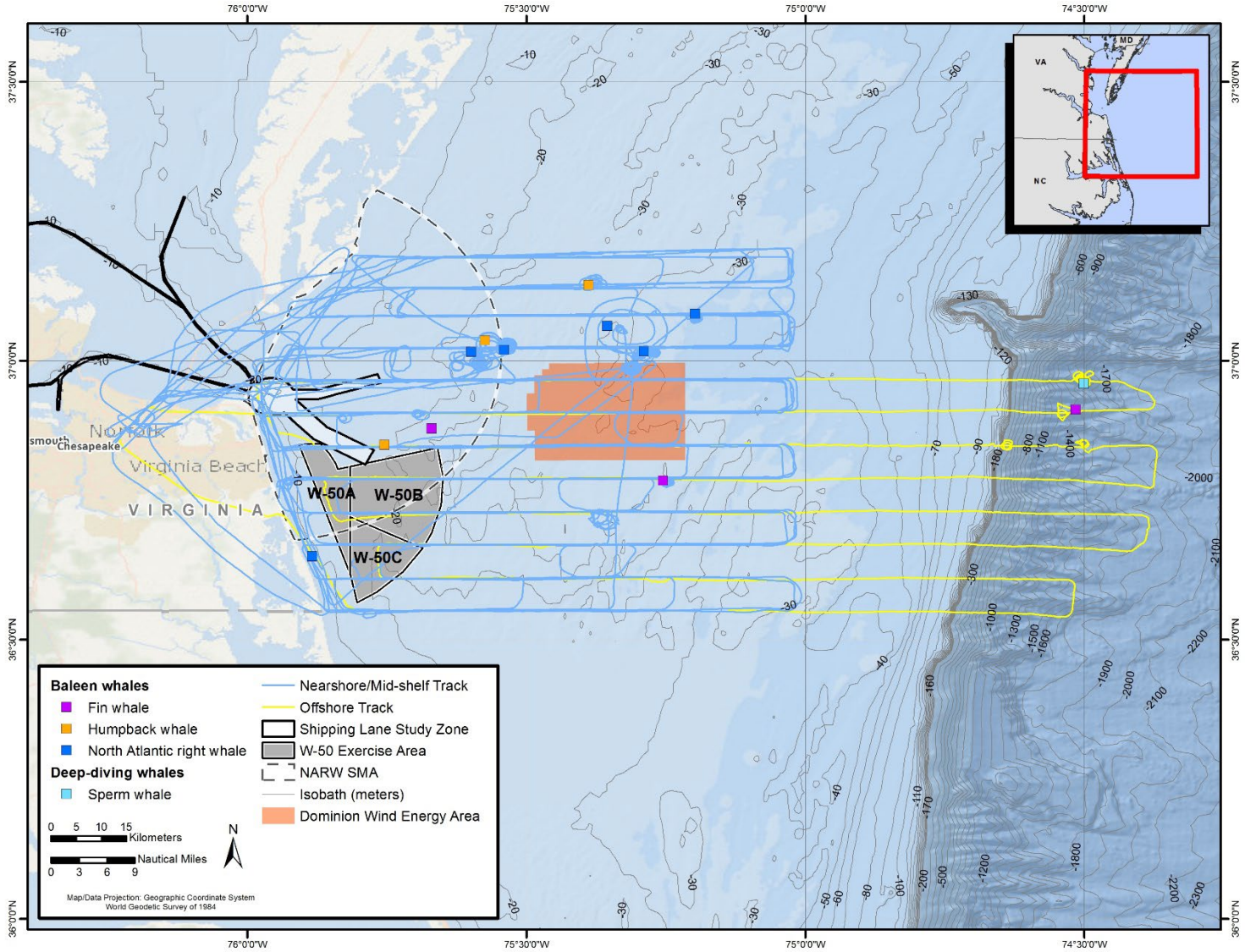

Figure 9. Aerial survey tracks (blue and yellow), with locations of all North Atlantic right (*n*=6), fin (*n*=3), humpback (*n*=3), and sperm whale (*n*=1) sightings for the 2022/23 field season.

4.3 Photo-ID Results

The 33 sightings of humpback whales during the 2022/23 field season included 48 total individuals and resulted in 36 unique humpback whales identified using dorsal fin and fluke images. An additional humpback whale was also seen during the VACAPES Offshore Cetacean Study surveys in March 2023 (Engelhaupt et al. 2024). Details of humpback whale photo-ID effort and results from drone photogrammetry are presented in Aschettino et al. (2024b).

Seven sightings of fin whales were recorded during nearshore and mid-shelf vessel surveys between December 2022 and February 2023, composed of 13 total individuals. Useable photographs were collected of 10 of those sighted individuals (**Table 4)**. Two were the same individual, HDRVABp010, photographed on 02 and 29 January 2023, making a total of nine unique individuals identified from vessel photographs. An additional individual, HDRVABp116, sighted only during aerial surveys, is also shown in **Table 4**. Including that individual, three identified fin whales were new additions to the catalog, which now contains 118 individuals (see Engelhaupt et al. 2024 for further details). The other seven IDs had previous sightings, some dating as far back as 2016. Days between first and last sighting ranged from 722 to 2,530 days (nearly 7 years); the year of first sighting for each is also shown in **Table 4**.

The 36 North Atlantic right whales observed during surveys resulted in 27 unique individuals identified during the 2022/23 field season (**Table 5**) and included all age classes and both sexes. Four individuals were observed on two different days, and three individuals were observed on three different days. One juvenile male, #4523/Beaker, was seen previously within the study area during 2021 in addition to being observed on three different days during the 2022/23 field season; the number of days between first and last sighting for this individual was 755. With the exception of adult female #2605/Smoke, who was first seen with another adult female, #3503/Caterpillar, in November 2022 then re-sighted with her new calf in March 2023, all other re-sighted North Atlantic right whales were parts of larger groupings of six to nine individuals engaged in either social or milling behavior. These larger groupings were observed within the study area between 24 January and 09 February 2023, indicating that larger groups of North Atlantic right whales were persistent within the study area for at a least a 2-week period. Also noteworthy is that of the nine sightings, only two occurred within the North Atlantic right whale Seasonal Management Area (SMA) (**Figure 5**), where vessels larger than 65 feet are required to slow down to speeds of 10 knots or less from November through April.

Table 4. Summary of photo-identified fin whales observed during the 2022/23 field season.

Animal ID	Estimated age class	Sex	Group size	Behavior	Sighting date	Survey type/ sighting #	Sighting latitude (°N)	Sighting longitude (°W)	Year of initial catalog record
HDRVABp010	Sub-adult/adult	Unknown	3	Feed	02-Jan-23	Midshelf_s1	36.9055	75.6906	2016
HDRVABp034	Sub-adult/adult	Unknown	3	Feed	02-Jan-23	Midshelf_s1	36.9055	75.6906	2017
HDRVABp009	Sub-adult/adult	Unknown	2	Feed	11-Jan-23	Midshelf_s1	36.9175	75.6913	2016
HDRVABp114	Sub-adult/adult	Unknown	2	Feed	11-Jan-23	Midshelf_s1	36.9175	75.6913	2023
HDRVABp027	Sub-adult/adult	Male	1	Feed	11-Jan-23	Midshelf_s2	36.9084	75.6839	2017
HDRVABp010	Sub-adult/adult	Unknown	4	Mill	29-Jan-23	Midshelf_s1	36.8925	75.6840	2016
HDRVABp092	Sub-adult/adult	Unknown	4	Mill	29-Jan-23	Midshelf_s1	36.8925	75.6840	2021
HDRVABp093	Sub-adult/adult	Unknown	4	Mill	29-Jan-23	Midshelf_s1	36.8925	75.6840	2021
HDRVABp097	Sub-adult/adult	Unknown	4	Mill	29-Jan-23	Midshelf_s1	36.8925	75.6840	2021
HDRVABp115	Sub-adult/adult	Unknown	1	Mill	02-Feb-23	Nearshore_s3	36.8527	75.8344	2023
HDRVABp116	Sub-adult/adult	Unknown	2	Travel	05-Mar-23	Aerial_s2	36.7850	75.2552	2023

Key: ID = identifier; °N = degrees North; °W = degrees West

Table 5. Summary of photo-identified North Atlantic right whales from all platforms during the 2022/23 field season.

Animal ID/ name	Age class	Sex	Group size	Behavior	Sighting date	Survey type/ sighting #	Sighting latitude (°N)	Sighting longitude (°W)	Unique sighting days
#2605	Adult	Female	2	Travel	22-Nov-2022	Aerial_s1	36.6492	75.8839	2
#2605	Adult	Female	2	Travel	22-Nov-2022	Midshelf_s5	36.6201	75.8662	2
#3503	Adult	Female	2	Travel	22-Nov-2022	Aerial_s1	36.6492	75.8839	1
#3503	Adult	Female	2	Travel	22-Nov-2022	Midshelf_s5	36.6201	75.8662	1
2022Calfof#2753	Yearling	Unknown	1	Travel	18-Jan-2023	Nearshore_s1	36.9719	76.0335	1
#1934	Adult	Female	1	Travel	24-Jan-2023	Aerial_s1	37.0838	75.1981	1
#3640	Adult	Male	6	Social/SAG	24-Jan-2023	Aerial_s4	37.0173	75.2895	1
#3810	Adult	Male	6	Social/SAG	24-Jan-2023	Aerial_s4	37.0173	75.2895	3
#3810	Adult	Male	6	Social/SAG	24-Jan-2023	Vessel_s2	37.0091	75.2938	3
#4610	Juvenile	Female	6	Social/SAG	24-Jan-2023	Aerial_s4	37.0173	75.2895	1
#4610	Juvenile	Female	6	Social/SAG	24-Jan-2023	Vessel_s2	37.0091	75.2938	1
#3120	Adult	Male	6	Social/SAG	24-Jan-2023	Aerial_s4	37.0173	75.2895	2
#3120	Adult	Male	6	Social/SAG	24-Jan-2023	Vessel_s2	37.0091	75.2938	2
#3701	Adult	Male	6	Social/SAG	24-Jan-2023	Aerial_s4	37.0173	75.2895	3
#3701	Adult	Male	6	Social/SAG	24-Jan-2023	Vessel_s2	37.0091	75.2938	3
#4612	Juvenile	Female	6	Social/SAG	24-Jan-2023	Aerial_s4	37.0173	75.2895	1
#4612	Juvenile	Female	6	Social/SAG	24-Jan-2023	Vessel_s2	37.0091	75.2938	1
#4523	Juvenile	Male	7	Social/SAG	29-Jan-2023	Midshelf_s3	36.8642	75.4600	3
#3810	Adult	Male	7	Social/SAG	29-Jan-2023	Midshelf_s3	36.8642	75.4600	3
#3701	Adult	Male	7	Social/SAG	29-Jan-2023	Midshelf_s3	36.8642	75.4600	3
#4540	Adult	Female	7	Social/SAG	29-Jan-2023	Midshelf_s3	36.8642	75.4600	1
#3541	Adult	Male	7	Social/SAG	29-Jan-2023	Midshelf_s3	36.8642	75.4600	1
#3301	Adult	Male	7	Social/SAG	29-Jan-2023	Midshelf_s3	36.8642	75.4600	1
#3579	Adult	Male	7	Social/SAG	29-Jan-2023	Midshelf_s3	36.8642	75.4600	1
#4523	Juvenile	Male	9	Mill	30-Jan-2023	Mishelf_s2	36.9039	75.4579	3
#3810	Adult	Male	9	Mill	30-Jan-2023	Midshelf_s2	36.9039	75.4579	3

Animal ID/ name	Age class	Sex	Group size	Behavior	Sighting date	Survey type/ sighting #	Sighting latitude (°N)	Sighting longitude (°W)	Unique sighting days
#3120	Adult	Male	9	Mill	30-Jan-2023	Midshelf_s2	36.9039	75.4579	2
#3701	Adult	Male	9	Mill	30-Jan-2023	Midshelf_2	36.9039	75.4579	3
#3460	Adult	Male	9	Mill	30-Jan-2023	Midshelf_s2	36.9039	75.4579	1
#4991	Juvenile	Female	9	Mill	30-Jan-2023	Midshelf_s2	36.9039	75.4579	1
#4457	Juvenile	Male	9	Mill	30-Jan-2023	Midshelf_s2	36.9039	75.4579	1
#4020	Adult	Female	9	Mill	30-Jan-2023	Midshelf_s2	36.9039	75.4579	1
#4130	Adult	Male	9	Mill	30-Jan-2023	Midshelf_s2	36.9039	75.4579	1
#4523	Juvenile	Male	7	Social/SAG	07-Feb-2023	Midshelf_s2	37.0302	75.5308	3
#4991	Juvenile	Female	6	Social/SAG	07-Feb-2023	Aerial_s3	37.0161	75.5994	2
#4991	Juvenile	Female	7	Social/SAG	07-Feb-2023	Midshelf_s2	37.0302	75.5308	2
#4130	Adult	Male	6	Social/SAG	07-Feb-2023	Aerial_s3	37.0161	75.5994	2
#4130	Adult	Male	7	Social/SAG	07-Feb-2023	Midshelf_s2	37.0302	75.5308	2
#4191	Adult	Female	2	Mill	07-Feb-2023	Aerial_s1	37.0197	75.5406	1
#4191	Adult	Female	1	Mill	07-Feb-2023	Midshelf_s1	37.0302	75.5240	1
#4720	Juvenile	Unknown	6	Social/SAG	07-Feb-2023	Aerial_s3	37.0161	75.5994	1
#4720	Juvenile	Unknown	7	Social/SAG	07-Feb-2023	Midshelf_s2	36.9968	75.5787	1
#3845	Adult	Male	6	Social/SAG	07-Feb-2023	Aerial_s3	37.0161	75.5994	1
#3845	Adult	Male	7	Social/SAG	07-Feb-2023	Midshelf_s2	36.9968	75.5787	1
#4330	Adult	Male	2	Mill	07-Feb-2023	Aerial_s1	37.0197	75.5406	1
#4330	Adult	Male	6	Social/SAG	07-Feb-2023	Aerial_s3	37.0161	75.5994	1
#4330	Adult	Male	7	Social/SAG	07-Feb-2023	Midshelf_s2	36.9968	75.5787	1
#3997	Adult	Male	6	Social / SAG	07-Feb-2023	Aerial_s3	37.0161	75.5994	1
#3997	Adult	Male	7	Social / SAG	07-Feb-2023	Midshelf_s2	36.9968	75.5787	1
#1423	Adult	Unknown	1	Travel	26-Feb-2023	Midshelf_s1	36.6057	75.2792	1
#2605	Adult	Female	2	Mill	05-Mar-2023	Aerial_s1	37.0622	75.3556	2
#2605	Adult	Female	2	Travel	05-Mar-2023	Midshelf_s1	37.0432	75.3302	2

Animal ID/ name	Age class	Sex	Group size	Behavior	Sighting date	Survey type/ sighting #	Sighting latitude (°N)	Sighting longitude (°W)	Unique sighting days
2022calfof#2605	Calf	Unknown	2	Mill	05-Mar-2023	Aerial_s1	37.0622	75.3556	1
2022calfof#2605	Calf	Unknown	2	Travel	05-Mar-2023	Midshelf_s1	37.0432	75.3302	1

Key: ID = identifier; °N = degrees North; SAG = surface active group; °W = degrees West

4.4 Biopsy Results

One biopsy sample was collected from tagged humpback whale HDRVAMn268 during the 2022/23 field season and is awaiting analyses, along with samples collected during the 2019/20 and 2020/21 field seasons.

Thirty-one samples (29 humpback and 2 fin whales) from 2014 to 2016 were previously processed for stable-isotope analyses ($\delta^{13}C$ and $\delta^{15}N$) (Waples 2017). Sixty-three humpback samples and eight fin whale samples (inclusive of the samples analyzed for stable isotopes) have been provided to the University of Groningen for genetic analysis, with humpback samples being integrated into a larger North Atlantic humpback whale population study. Gender results from the full set of samples show roughly equal sex ratios of humpback whales (32 males and 31 females) and a skewed gender ratio of fin whales (6 males and 1 female) (Bérubé and Palsbøll 2022). Genetic matching to the larger North Atlantic Humpback Whale Catalog, which contains more than 9,200 individuals, showed that 18 samples matched to samples collected elsewhere along the eastern U.S., and no duplicate humpback whale samples occurred 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).

4.5 Satellite Tagging Results

Two Argos-linked satellite tags were deployed on humpback whales during the 2022/23 field season: one SPOT6 tag and one SPLASH10-F tag (**Table 6**; **Figures 10** through **13**). The tags transmitted 14.3 and 5.0 days, respectively.

Table 6. Satellite-tag deployments on humpback whales during the 2022/23 field season.

Animal ID	Estimated age class	Tag type	Argos ID	Deployment latitude (°N)	Deployment longitude (°W)	Deployment date	Last trans-mission date	Tag duration (days)
HDRVA Mn268	Sub-adult	SPOT6	233709	36.5904	75.7434	30-Dec-22	13-Jan-23	14.3
HDRVA Mn278	Juvenile	SPLASH 10-333F	201573	36.9524	76.0673	08-Feb-23	13-Feb-23	5.0

Key: ID = identifier; °N = degrees North; °W = degrees West

The two whales tagged during the 2022/23 field season showed varied movement patterns. Sub-adult-sized humpback whale HDRVAMn268 was tagged just outside the MINEX area and close to the Virginia-North Carolina border (**Figure 11**), and just over 2 weeks of location data were collected. This individual initially moved south after tagging, with locations between 0 and 12 nm from shore and moving 44 nm from the initial tagging location, just north of Oregon Inlet. After 11 days, HDRVAMn268 worked back to the north and into the primary study area, with locations in and around shipping channels at the mouth of Chesapeake Bay. This individual was re-sighted by the field team on 10 January 2024, and a CATS tag was deployed (see

Section 3.6). Several days later, this individual moved northeastward before the tag stopped transmitting on 14 January 2024, 27 nm from shore within the VACAPES OPAREA.

Juvenile humpback whale HDRVAMn278 was tagged at the mouth of Chesapeake Bay within the boundaries of the shipping lane study area (**Figure 12**). This individual was simultaneously double-tagged with a SPLASH10-F tag and CATS tag. At the time of tagging, Duke University was also working within the area, conducting prey mapping from the research vessel *Shearwater*. This individual spent the entire 5 days either at the mouth of Chesapeake Bay or inside the bay, with locations as far west as the Hampton Roads Bridge Tunnel.

Figure 13 shows a zoomed-in view of both humpback whale tag locations during the 2022/23 field season, focused on the nearshore study zone. As in previous years, a number of locations occurred within and around the shipping channels as well as at the mouth of Chesapeake Bay; however, given that only two tags were deployed, the impact from this figure is not as profound as during seasons when a higher number of tags were deployed. As in some previous seasons (e.g., Aschettino et al. 2018, 2020b, 2021), Argos locations also occurred west of the Chesapeake Bay Bridge Tunnel. Locations were also reported to the east, west, and south of the North Atlantic right whale SMA, where vessel speed restrictions are in place seasonally.

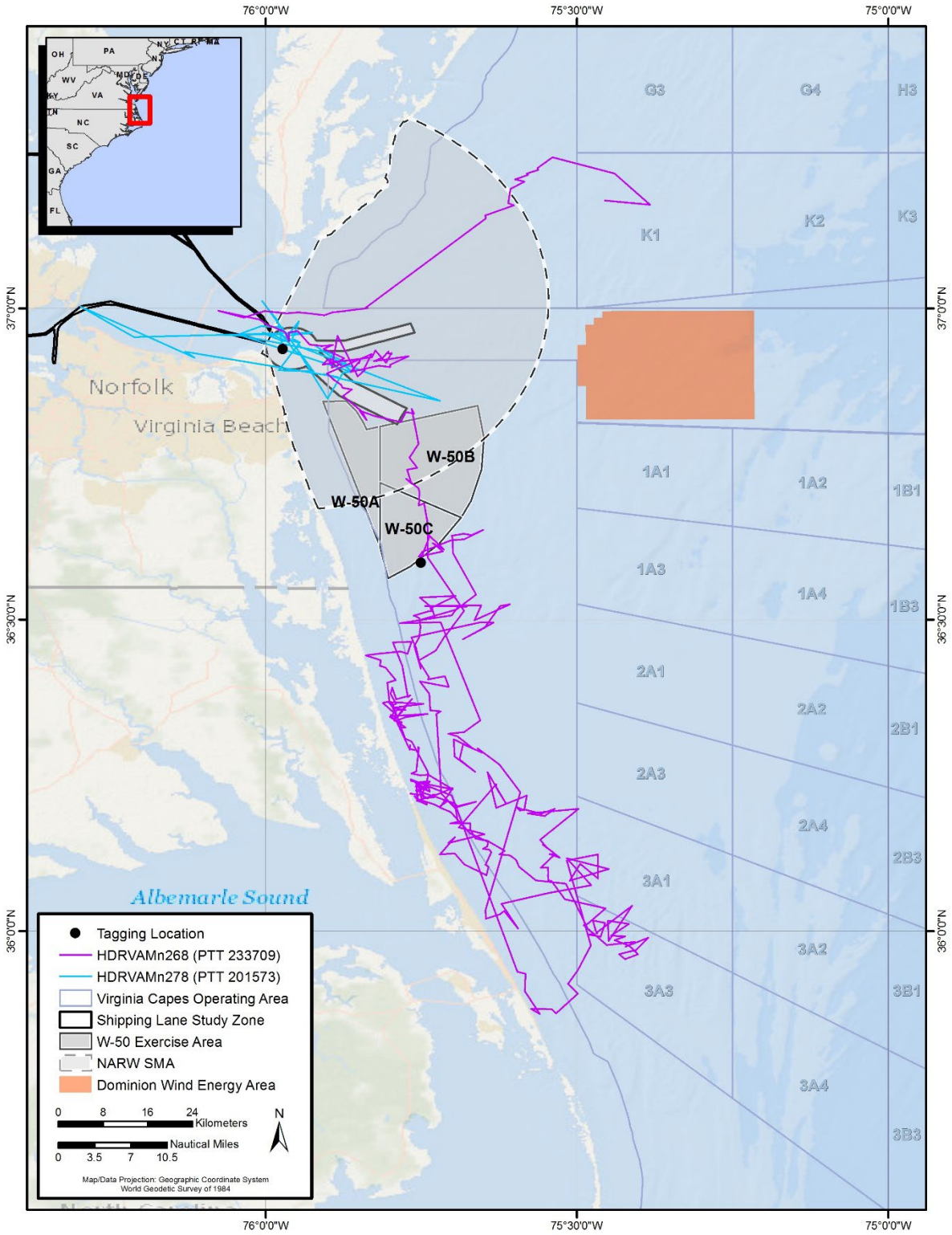

Figure 10. Argos tracks for all humpback whales tagged (*n*=2) during the 2022/23 field season.

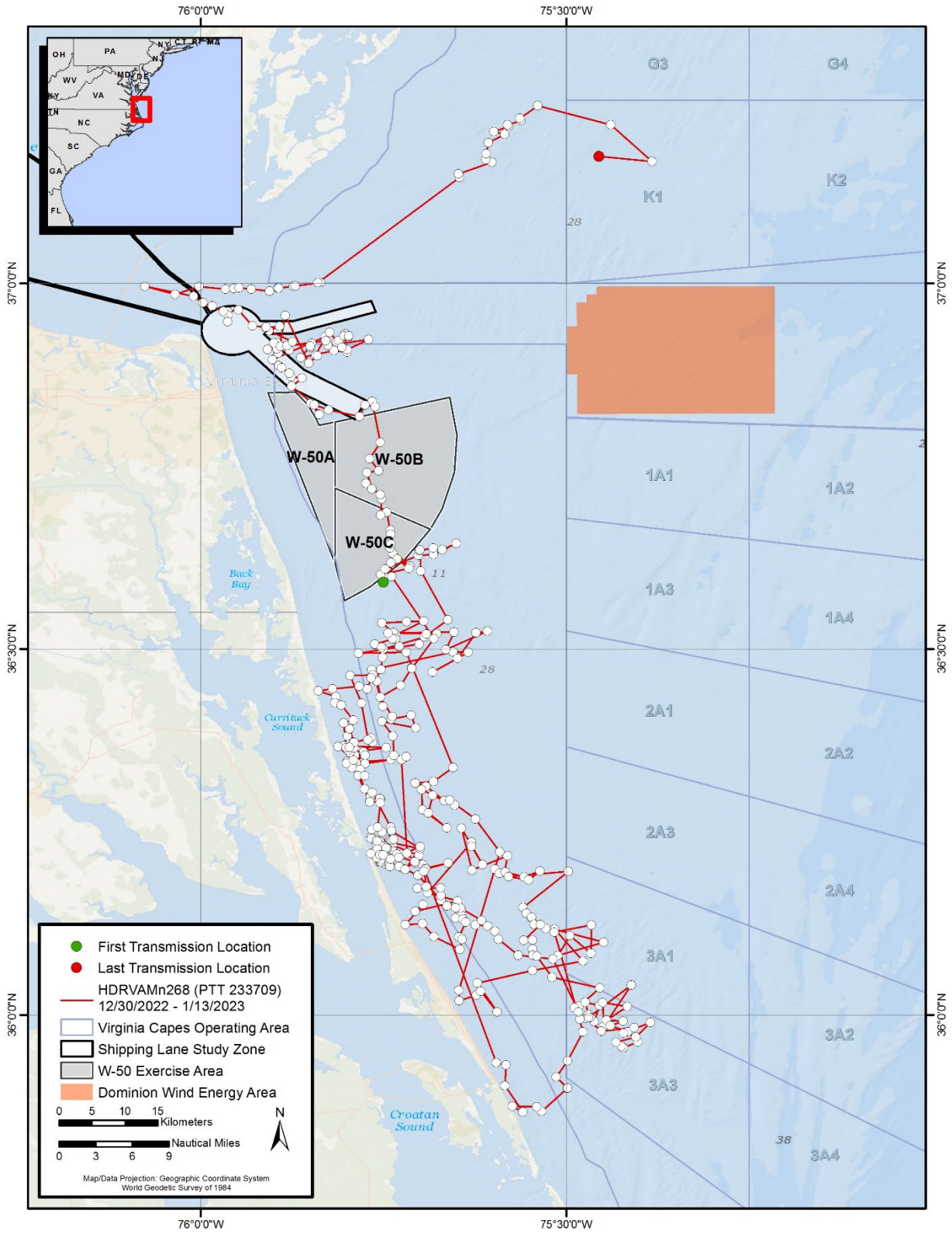

Figure 11. Filtered locations (white dots) and trackline of humpback whale HDRVAMn268, tagged on 30 December 2022, over 14.3 days of tag-attachment duration.

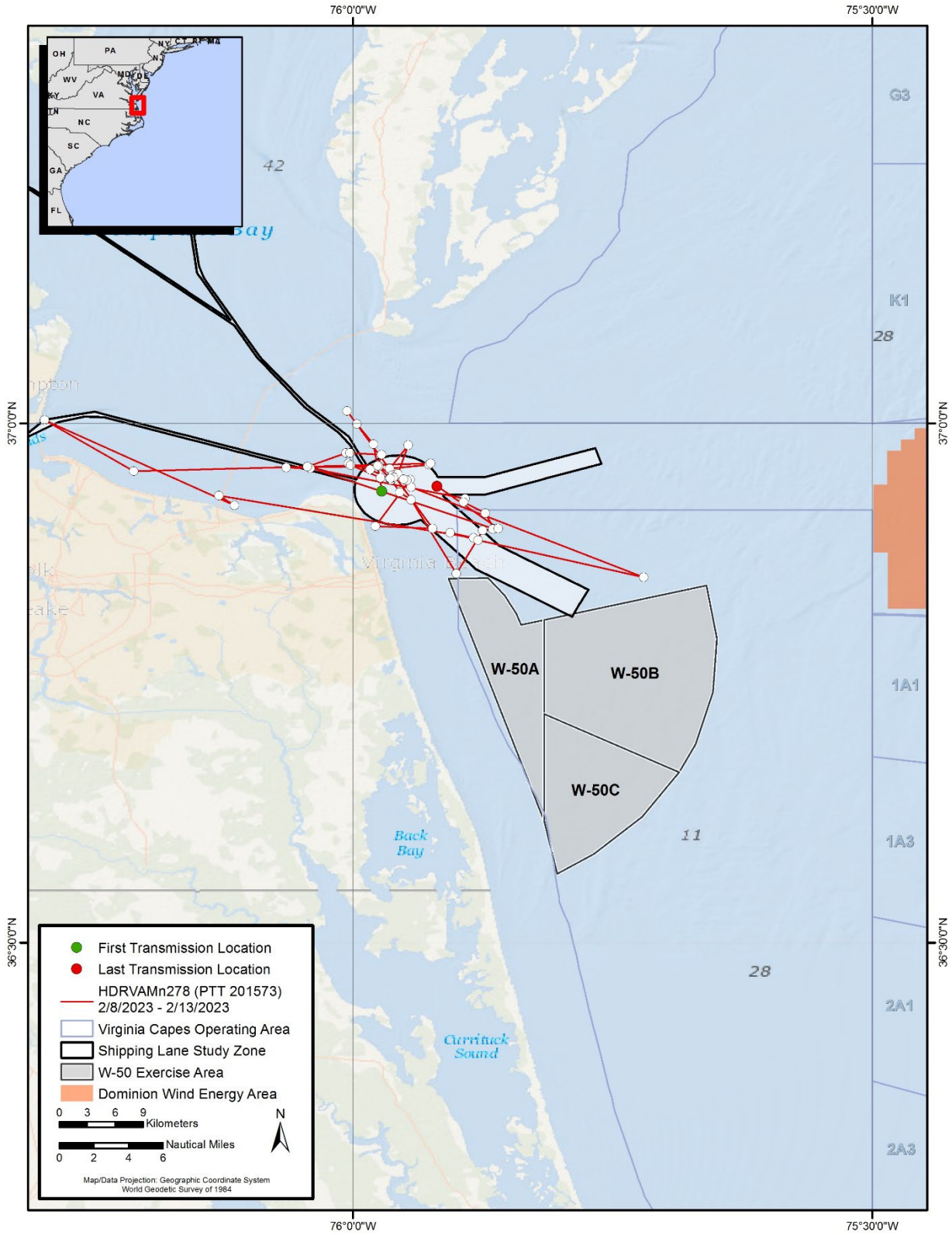

Figure 12. Filtered locations (white dots) and trackline of humpback whale HDRVAMn278, tagged on 08 February 2023, over 5 days of tag-attachment duration.

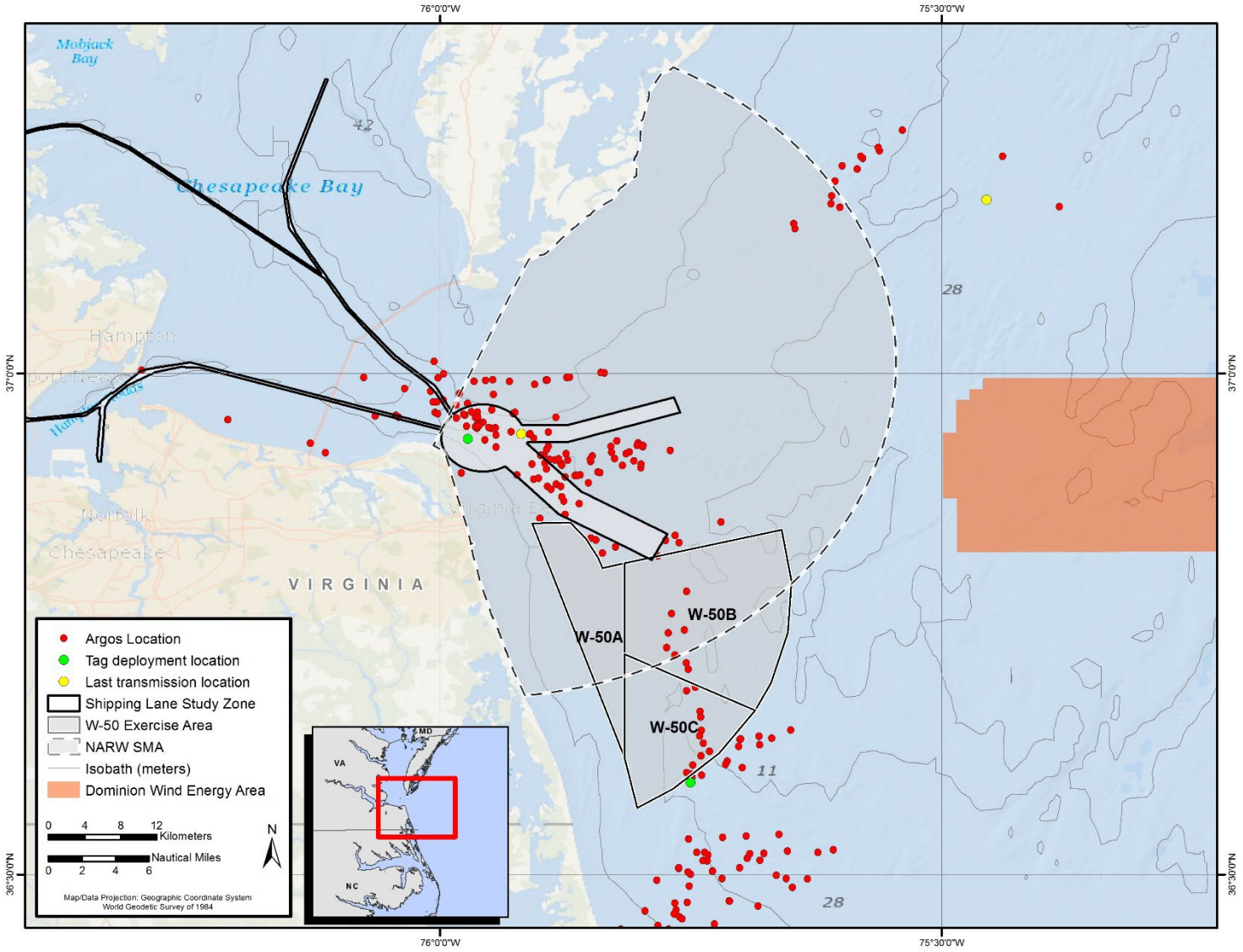

Figure 13. Filtered locations of all humpback whale Argos locations within the immediate vicinity of shipping channels at the mouth of Chesapeake Bay from tag deployments (*n*=2) during the 2022/23 field season.

Maximum straight-line distance from the initial tagging location ranged from 29.6 to 82.6 km (mean = 56.2 km) (**Table 7**). The percentage of locations occurring within the shipping channel study area ranged from 4.9 to 49.0 percent (mean = 27.0 percent) (**Table 7**). The percentage of locations within VACAPES ranged from 15.62 to 57.9 percent (mean = 36.8 percent) (**Table 7**).

Table 7. Summary of results from satellite-tag data for humpback whales tagged during the 2022/23 field season.

Animal ID	# locations post filtering	Percent within shipping channels	Percent within VACAPES	Maximum distance from initial location (km)	Mean distance from initial location (km)
HDRVAMn268	428	4.9	57.9	82.6	39.2
HDRVAMn278	51	49	15.7	29.6	6.7

Key: ID = identifier

One satellite tag on a humpback whale recorded data on dive depth and duration in addition to the Argos capabilities (**Table 8**). This tag recorded a total of 405 dives. Mean dive depth was 17.6 m, with a maximum dive depth of 31.0 m. Mean dive durations ranged from 2.7 to 3.1 min.

Table 8. Summary of dive depth and duration data collected from tagged humpback whale during the 2022/23 field season.

Animal ID	# dives logged	Mean dive depth (m)	Maximum dive depth (m)	Mean dive duration (mm:ss)	Maximum dive duration (mm:ss)
HDRVAMn278	405	17.6	31.0	2:43	4:49

Key: ID = identifier; mm:ss = minutes:seconds

The dive duration of humpback whale HDRVAMn278, tagged during the 2022/23 field season, was similar to humpbacks tagged during the previous three seasons; during the 2019/20 field season (*n*=11,708 dives), mean dive durations ranged from 2.4 to 3.9 min; during the 2020/21 field season (*n*=4,119 dives), mean dive duration ranged from 2.5 to 3.8 min; and during the 2021/22 field season (n=4,519 dives), mean dive duration ranged from 2.7 to 3.1 min. Mean dive depths were also similar to whales tagged during previous seasons: mean dive depth of 12.6 to 16.3 m in 2019/20, 15.7 to 30.5 m in 2020/21, and 13.9 to 17.6 m in 2021/22. Dives for humpback whales tagged during the 2018/19 field season were shorter, ranging from 1.8 to 3.0 min (Aschettino et al. 2020a), and shallower, ranging from 8.6 to 14.6 m, which may be a result of a smaller dataset (*n*=230 dives) or different foraging strategies.

4.6 Suction-cup Tagging Results

Four CATS suction-cup tags were deployed during the 2022/23 field season, two on humpback whales and two on North Atlantic right whales (**Table 9**). The 22 November 2023 right whale tag (eg220110-01) collected more than 10 hours of three-dimensional movement, acoustic, and video data. **Figure 14** shows the location data and **Figure 15** shows the dive profile for eg220110-01. **Table 10** summarizes the dive statistics calculated using the find-dive MATLAB script from the toolbox posted to the animaltags.org site, with a dive-depth definition of 2 m, then manually sorting to include dives longer than 2 min. A preliminary audit for vocalizations was completed, but none were detected. Totals of 66 dives and 65 surfacing bouts were recorded

during the tags' deployment. Maximum dive depth ranged from 2.0 to 13.1 m (mean = 5.04 m). Dive duration ranged from 2.0 to 8.78 min (mean = 3.76 min) (**Table 10**).

Table 9. CATS deployments on baleen whales during the 2022/23 field season.

Animal ID	Species	#/Deployment ID	Tag type	Deployment (GMT)	Depth at tagging (m)	Tag off animal (GMT)	Tag duration (minutes)
Eg #2605/ "Smoke"	North Atlantic right whale	eg221122-01	CATS	2022-Nov-22 21:05	11.3	2022-Nov-23 07:31	626
HDRVAMn268	Humpback whale	mn230110-01	CATS	2023-Jan-10 19:41	20.7	2023-Jan-11 11:06	864
Eg #3810	North Atlantic right whale	eg230129-01	CATS	2023-Jan-29 19:16	29.3	2023-Jan-29 19:39	23
HDRVAMn278	Humpback whale	mn230208-01	CATS	2023-Feb-08 17:04	18.9	2023-Feb-08 23:01	357

Key: ID = identifier; GMT = Greenwich Mean Time

Table 10. Summary of dive depth and duration data collected from CATS Tag eg221122-01.

Deployment ID	# dives logged	Mean dive depth (m)	Maximum dive depth (m)	Mean dive duration (mm:ss)	Maximum dive duration (mm:ss)
Eg221122-01	66	5.04	13.1	3:46	8:47

Key: ID = identifier; mm:ss = minutes:seconds

Figures 16 and **17** show the dive profiles of mn230110-01 and eg230129-01, which collected data for 14 hours and 23 minutes, respectively. Tag eg230129-01 came off during surface-active behaviors between two individual whales. Files containing the depth data for mn230208-01 were incomplete and are awaiting engineer help from the CATS team for conversion. Further analysis of all tag data is underway.

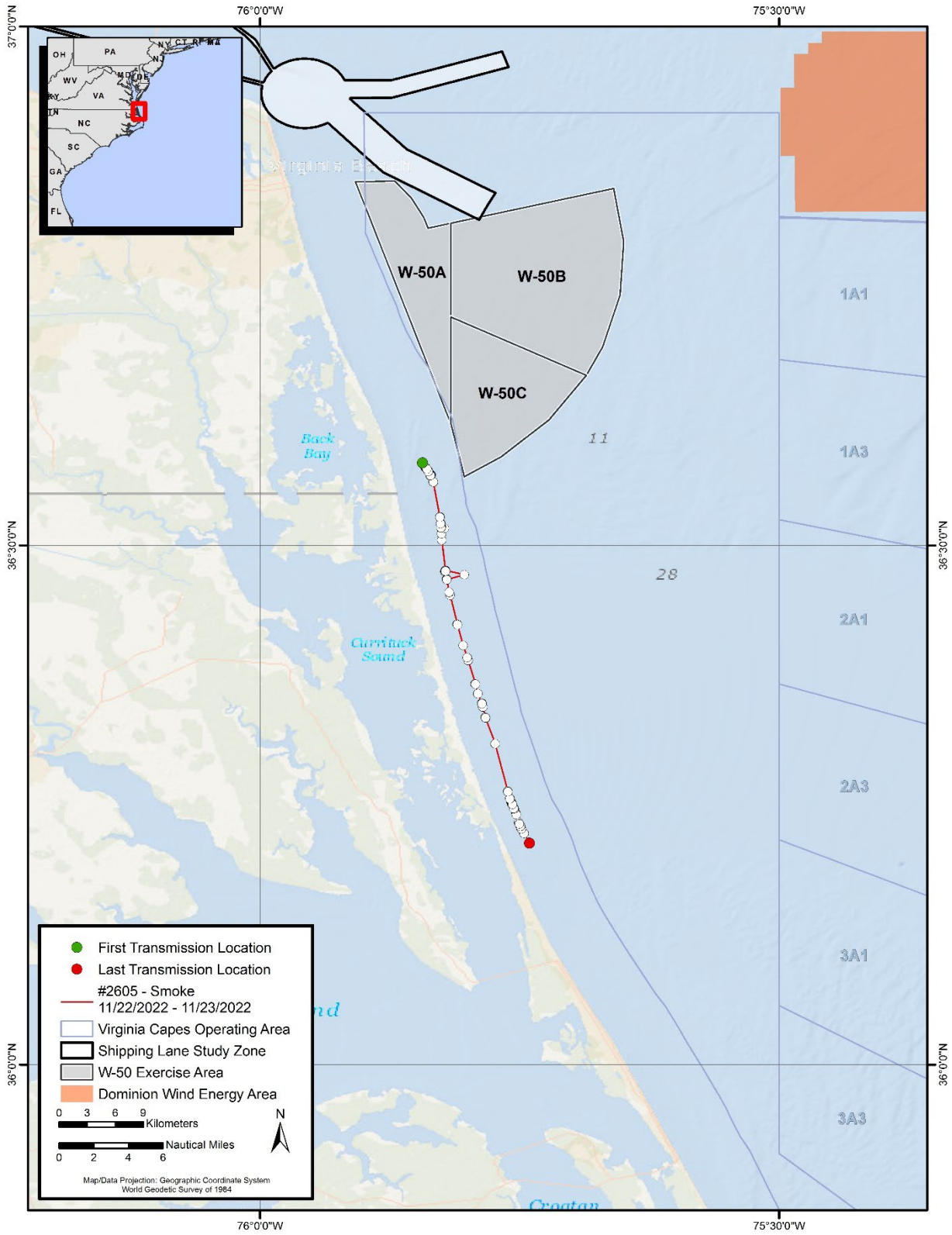

Figure 14. Filtered locations (white dots) and trackline of North Atlantic right whale #2605/"Smoke," tagged on 22 November 2022 over a 10-hour, suction-cup, tag-attachment duration.

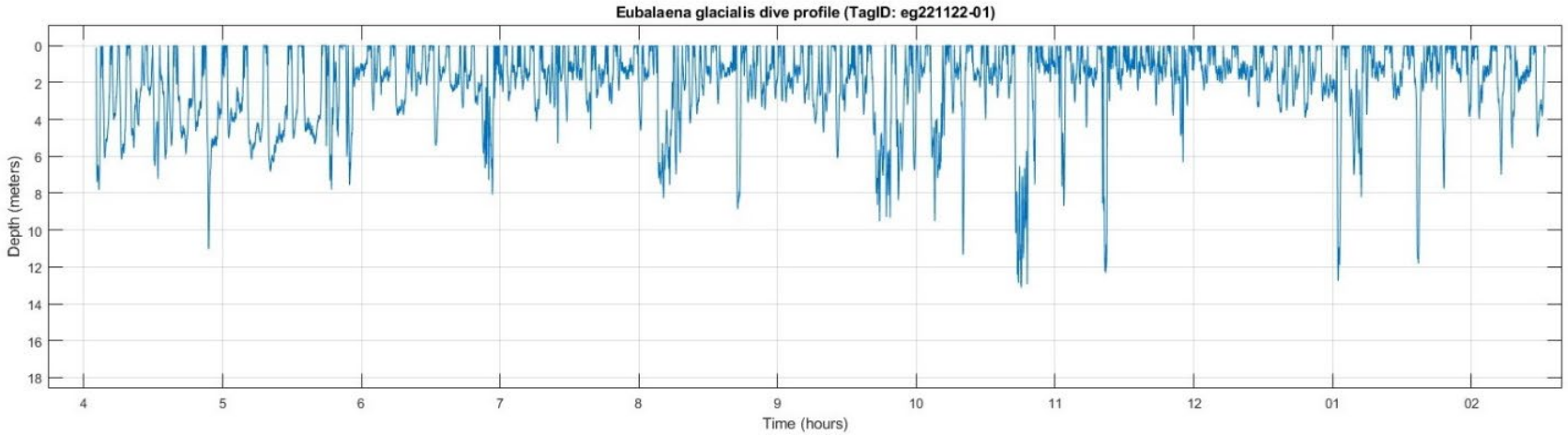

Figure 15. Dive-depth profile (in meters) for NARW #2605/"Smoke" (CATS eg221122-01).

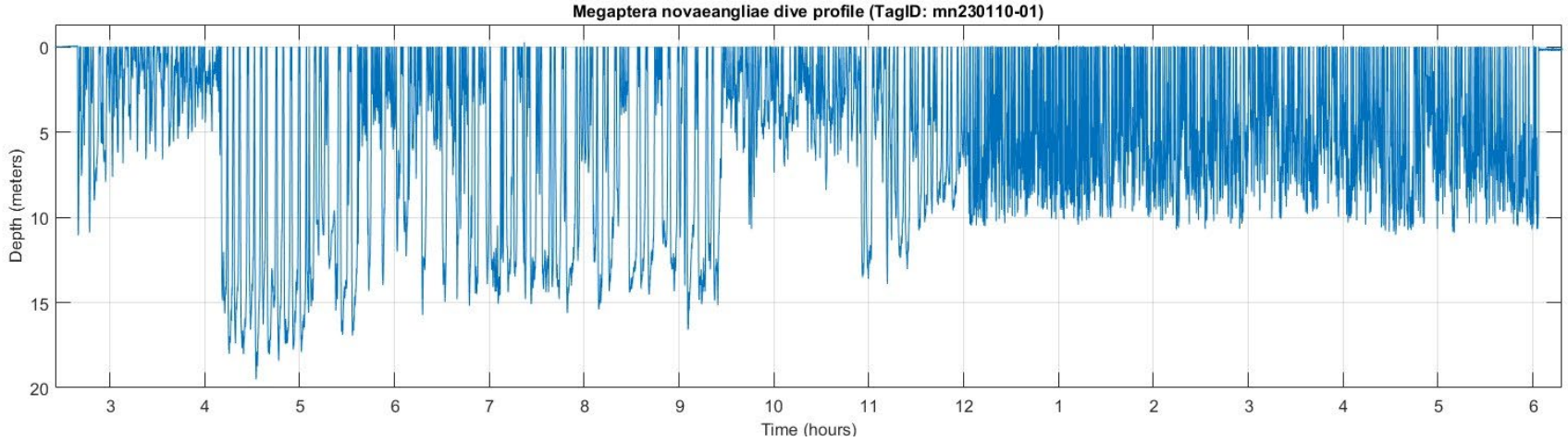

Figure 16. Dive-depth profile (in meters) for humpback HDRVAMn268 (CATS mn230110-01).

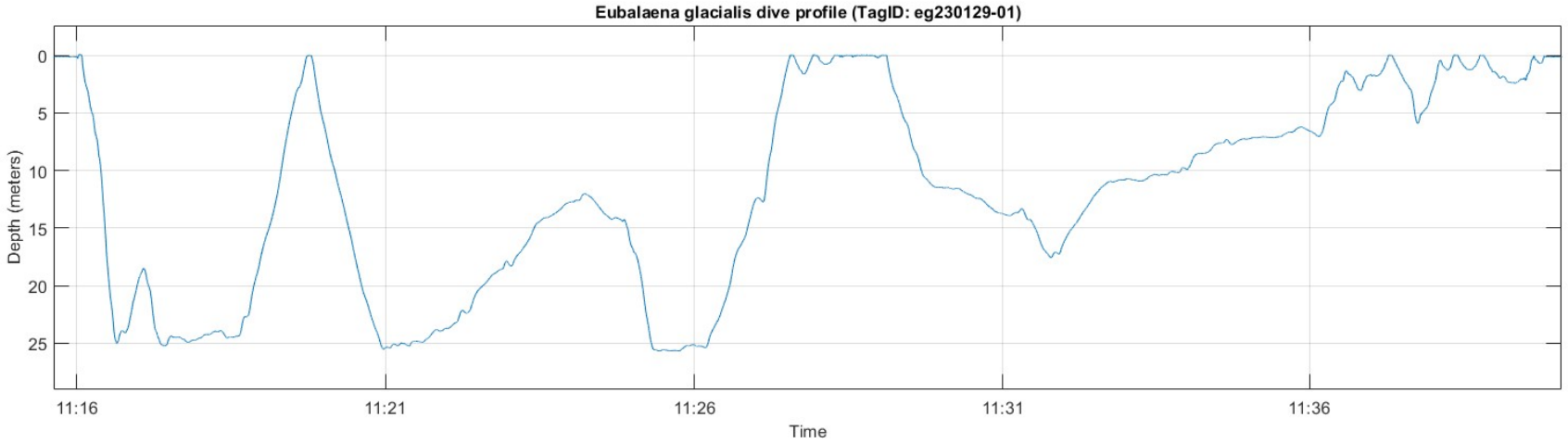

Figure 17. Dive-depth profile (in meters) for NARW #3810 (CATS eg230129-01).

5. Discussion

Continued analysis of data from this multi-year project are ongoing; however, each season of data helps build a more comprehensive picture of how baleen whales use the waters within and around the mouth of Chesapeake Bay and the surrounding area. Shipping channels, U.S. Navy training and OPAREAs, and wind energy development areas all overlap with the habitat that these whales use seasonally. Results continue to show a high level of occurrence within areas that are heavily used by the U.S. Navy; commercial shipping, recreational, and commercial fishing vessels; and future wind energy areas. These findings are supported by information collected during the past 9 years of this study, including photo-IDs, focal follows, and satellite-tagging results.

Interactions with vessels, both large and small, are a significant cause for concern for humpbacks as well as endangered fin and North Atlantic right whales within the study area. In April 2017, the National Marine Fisheries Service declared an Unusual Mortality Event (UME) for humpback whales within the Atlantic Ocean, from Maine to Florida, based on elevated mortalities of this species since January 2016. As of November 2023, 212 humpback whales are included in this UME, and 59 (27.8 percent) of those have occurred along the shore or in waters off the coast of Virginia or North Carolina (NOAA 2023a). Given this designation, a group of subject matter experts, the UME working group, aim to further investigate what is causing or contributing to the increased number of deaths of humpback whales within this area. Although the UME investigation process is ongoing, of the approximately 90 whales that were examined, an estimated 40 percent showed evidence of human interaction via vessel strike or entanglement. While the UME working group will look at humpback whales of all age classes, approximately two-thirds of the humpback whales identified during the 9 years of survey effort on this project appear to be juveniles (Aschettino et al. 2024) that are spending more time within the study area than larger animals, presumed to be adults, and may be at greater risk for injury. Sightings of sub-adult-sized humpback whales are highest early in the field season or farther from shore within the mid-shelf region, and those individuals are often re-sighted less frequently, suggesting that sightings early in the season may be whales passing through the area rather than whales remaining within the nearshore study area for longer durations. The large percentage of juveniles observed in this study matches both historic stranding (e.g., Wiley et al. 1995) and observational (e.g., Swingle et al. 1993) data for the area.

A UME for North Atlantic right whales was also declared in 2017, with 123 instances of mortality, serious injury, and morbidity, primarily from rope entanglements and vessel strikes as of February 2024 (NOAA 2024). The first vessel-related death of a North Atlantic right whale in 2023 was reported in Virginia Beach, and highlights the potential for serious injuries and fatalities within this area. In a statement released by NOAA regarding the results of the necropsy, it states that “the whale suffered a catastrophic blunt force traumatic injury, impacting a large portion of the vertebral column. The injuries, consistent with vessel strike, included multiple vertebral fractures and separations that would have resulted in death shortly after the injury” (NOAA 2023b).

The large number of sightings of individual North Atlantic right whales during the 2022/23 field season may partially be a result of the increased survey effort within the area and in association

with aerial survey support, although the presence of relatively large groups has not previously been observed here. The persistence of individuals to remain within the same general area over the course of up to 14 days suggests these individuals are not simply passing through, and are at an increased risk of vessel strike and other anthropogenic activities within the area.

With eight seasons of satellite-tag deployments completed, trends are emerging, as is the variability among individuals and between years. The mouth of Chesapeake Bay, and shipping lanes in particular, continues to be an area heavily used by humpback whales seasonally. From November through April, a ship-speed reduction rule is in effect at the mouth of Chesapeake Bay as part of the SMA set up to protect ESA-listed North Atlantic right whales, with added benefits to other species of whales that also use this area. These speed restrictions require all vessels 65 feet (19.8 m) or longer to travel at 10 knots (18.5 km/hour) or less. A proposed rule to extend these restrictions to smaller vessels within a wider area is currently under review, with a decision expected by early 2024.

The SMA within this study area begins at the mouth of Chesapeake Bay and extends outwards 37 km from shore; however, sightings of North Atlantic right whale groups outside the SMA during the 2022/23 season highlight that these boundaries do not offer protection to whales when they are outside these limits. The socializing and milling behavior observed by many of these aggregations may put these individuals at increased risk for vessel strikes while they spend more time at the surface and may be distracted while engaging with other whales. Dynamic Management Areas (DMAs) are created when three or more North Atlantic right whales are observed together. For a period of 15 days after a grouping is detected, NOAA uses these DMAs to notify vessel operators of the presence of right whales in a given area and to urge mariners to reduce speed to 10 knots or less when traveling through these areas. These are voluntary requirements, however, and therefore do not guarantee additional protection to whales using those areas. Argos locations from tagged humpback whales have also shown that the SMA boundaries do not necessarily protect all large whales using the area (**Figure 13**).

Portions of Chesapeake Bay, west of the Chesapeake Bay Bridge Tunnel, were not used by any tagged humpback whales during the 2015/16, 2017/18, 2020/21, or 2021/22 field seasons; used sparsely during the 2018/19 and 2022/23 field seasons; but used heavily during the 2016/17 and 2019/20 field seasons. Short-term distributional shifts related to oceanographic conditions may have caused prey to become concentrated farther into Chesapeake Bay during the 2016/17 and 2019/20 field seasons, resulting in an increased presence of humpback whales within that area. The presence of humpback whales west of the Chesapeake Bay Bridge Tunnel raises additional concerns given the high traffic within that area, increased vessel speeds allowed outside the SMA boundaries, and extent of marine-based training occurring out of Joint Expeditionary Base Little Creek. Future analyses should explore year-to-year differences in oceanographic conditions to help better understand the factors that may contribute to these findings.

Efforts for the 2023/24 field season will continue to focus on pushing farther into mid-shelf waters as well as continuing humpback photo-ID and body-condition assessment efforts within nearshore waters. During the 2023/24 field season, the study team will also continue to deploy DTAGs and CATS tags on baleen whales, with a focus on the W-50 MINEX and mid-shelf areas. This will allow the team to continue to better detail fine-scale movement, dive patterns,

and foraging behavior as well as record acoustic activity to add to the existing medium-duration dataset.

The numbers of sightings of humpback, fin, and North Atlantic right whales, as well as the level of interaction between whales and vessel traffic detailed to date, support previous recommendations to continue this study using the same techniques to better understand movement patterns and habitat use. Continued photo-ID efforts will build a more complete picture of inter-annual site fidelity to this region. The inclusion of SPLASH10-F tags with Fastloc® GPS technology, capable of providing high-resolution data logging, will provide superior quality with respect to accuracy of locations. Coupled with the use of DTAGs and CATS tags, which can examine the three-dimensional movements of baleen whales within and around high-traffic shipping channels, the entirety of these data will provide a better understanding of the occurrence and behavior of large whales within this area and further support future mid-Atlantic behavioral response studies.

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