Final Report

Seal Tagging and Tracking in Virginia: 2018–2022

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Cover Photo Credits:

Top photo: Harbor seals (*Phoca vitulina*) resting ("hauled out") on a salt marsh on the Eastern Shore of Virginia in February 2018. Photograph taken by D. Rees, Naval Facilities Engineering Systems Command Atlantic, under National Marine Fisheries Service General Authorization #19826-03.

Middle photo: Post-tagging release of a juvenile male harbor seal instrumented with a GPS-enabled SPLASH tag at the Eastern Shore of Virginia in February 2022. Photograph taken by D. Rees, Naval Facilities Engineering Systems Command Atlantic, under National Marine Fisheries Service Scientific Research Permit #21719.

Bottom photo: A tagged harbor seal swimming off the coast of Virginia. Photograph taken by Write Coast Photography.

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Acronyms and Abbreviations

%	percent
°C	degrees Celsius
a-LoCoH	adaptive local convex hull
AI	Avian Influenza
Argos	Advanced Research and Global Observation Satellite
CBBT	Chesapeake Bay Bridge and Tunnel
CBC	Complete Blood Count
cm	centimeter(s)
COLREGS	collision regulation(s)
DMSO	dimethyl sulfoxide
GPS	Global Positioning System
ID	identification
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
LoCoH	local convex hull
m	meter(s)
MAX	maximum
MIN	minimum
MMPA	Marine Mammal Protection Act
N/A	not applicable
Navy	U.S. Navy
NEFSC	Northeast Fisheries Science Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
Obs.	observation(s)
OPAREA	Operating Area
PBM	peripheral blood mononuclear cell(s)
PDV	phocine distemper virus
PTT	platform transmitter terminal
SD	standard deviation
SEFSC	Southeast Fisheries Science Center
SPOT	satellite-tracked position-only

U.S.	United States
VA	Virginia
VACAPES	Virginia Capes Range Complex
VAQS	Virginia Aquarium Stranding Response Program
VTM	viral transport medium
YOY	Young of the year

1. Introduction

Following the enactment of the Marine Mammal Protection Act (MMPA) in the United States (U.S.), and as amended (16 United States Code § 1361 14 et seq.), harbor seal (*Phoca vitulina*) numbers rebounded in the northwest Atlantic Ocean (Sigourney et al. 2022). Harbor seals are now year-round inhabitants in coastal Maine and occur seasonally in southern New England and the mid-Atlantic U.S. between September and May (Hayes et al. 2022). Individuals move to northern areas for mating and pupping in the spring and summer and return to southerly areas in the fall and winter. During the last decade, harbor seals have been observed returning seasonally to haul-out (resting) locations in coastal Virginia, and gray seals (*Halichoerus grypus*) are occasionally observed there as well (Jones and Rees 2022). Harbor seals' range in the northwest Atlantic is now considered to extend as far south as Cape Hatteras, North Carolina seasonally (September to May) (Hayes et al. 2022). This population is thought to be relatively stable despite pressures from white shark predation, mortality from disease, and competition with gray seals (Sigourney et al. 2022).

The U.S. Navy (Navy) regularly engages in training, testing, and in-water construction activities in coastal Virginia and the Chesapeake Bay (**Figure 1**) in order to maintain Fleet readiness and the structural integrity of military installations. The lower Chesapeake Bay and coastal areas of Virginia comprise one of the busiest hubs of naval activity on the East coast and hosts numerous pierside facilities, installations, vessel, shipyards, and in-water training ranges. Seals seasonally inhabiting and transiting through these areas could be impacted by the use of active sonar and explosives, vessel traffic and movement, dredging, pile driving, and other military and non-military activities. Since 2013, the Navy has conducted regional harbor seal studies in order to assess the potential impacts on these animals from Navy activities, mitigate potentially harmful interactions, and obtain appropriate authorizations to maintain environmental compliance.

1.1 Project Background

Navy biologists have been researching seal occurrence in and around the Chesapeake Bay since 2013 and conducting systematic haul-out counts in the region since 2014 (Jones and Rees 2022). Results from these surveys indicate that seals arrive in the area annually each fall and depart in the spring. However, our understanding of seal movements, habitat use, haul-out patterns, and dive behavior, both in Virginia waters and along the Eastern Seaboard, is still very limited. In order to assess potential impacts to seals from Navy activities, it is important to better understand seal distribution and behavior in these areas.

Since 2017, the Navy has undertaken telemetry (tagging) studies in order to characterize seals' at-sea movements, habitat use, dive behavior, and the environmental variables that may influence their distribution and haul-out patterns. Satellite-tracked tags were deployed on seven harbor seals in 2018, two harbor seals in 2020, and on another five harbor seals in 2022, for a total of 14 tags deployed to date as part of this study. No tags were deployed in 2019 or 2021. Detailed results from previous tagging efforts are presented in Ampela et al. (2019, 2021). In this report we present key results from the 2018 and 2020 tags, detailed methods and results from the 2022 tagging efforts, and where appropriate, cumulative analyses of all 14 satellite-tracked tags deployed to date.

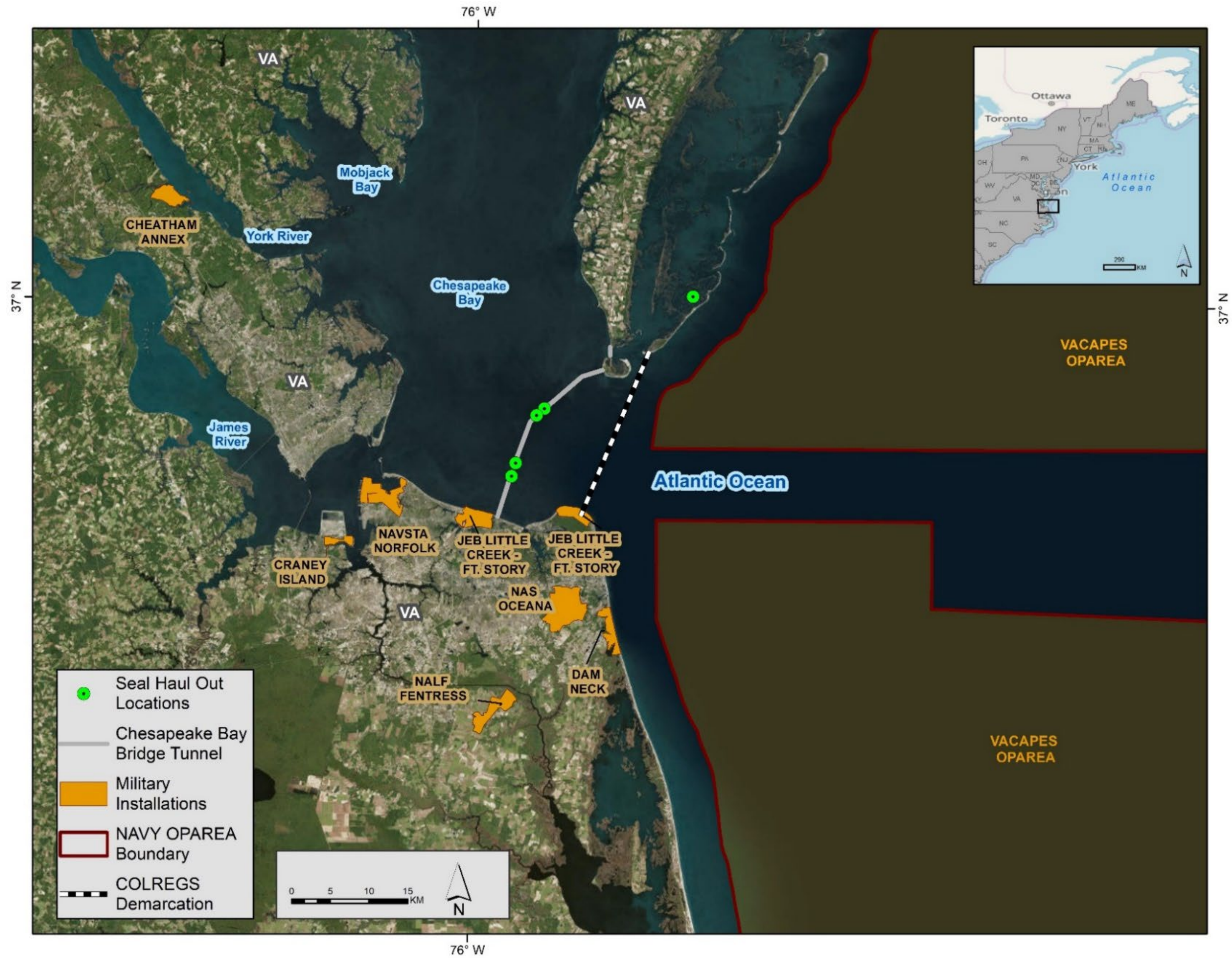

Figure 1. Chesapeake Bay and coastal Virginia waters, including known seal haul-out sites, and the Virginia Capes Range Complex (VACAPES). COLREGS = collision regulations; OPAREA = Operating Area.

1.2 Key Results from 2018 and 2020 Tag Deployments

In February 2018, seven harbor seals were captured and instrumented with satellite-tracked tags. Of these, six were satellite-tracked position-only (SPOT) tags and one was a depth-sensing SPLASH tag (all tags were manufactured by Wildlife Computers, Redmond, Washington). SPOT tags recorded information about the animal's horizontal movements, amount of time hauled out, and ambient temperature. SPLASH tags recorded information about dive depth and duration in addition to the data collected by the SPOT tags. Five of the seven seals tagged in 2018 were also instrumented with VEMCO tags, which were designed to be acoustically detected on a receiver array[1]. In February/March 2020, another two harbor seals were captured and instrumented with depth-sensing SPLASH tags with Fastloc® capabilities (i.e., Global Positioning System (GPS)-enabled). Summary information for all seven seals tagged in 2018 and 2020 is shown in **Table 1**.

Table 1. Summary of seals tagged in 2018 and 2020.

Date Tagged	Seal ID	Satellite Tag PTT #	Tag Type	Date of Last Transmission	VEMCO Tag #	Length (cm)	Girth (cm)	Weight (kg)	Sex	Estimated Age
2/4/18	1801	166450	SPOT (location-only)	5/23/18	15249	102	80	29.0	Male	Juvenile†
2/4/18	1802	166449	SPLASH (Depth-sensing)	6/29/18	N/A**	153	118	90.4	Male	Adult
2/4/18	1803	166451	SPOT (location-only)	5/6/18	15251	129	99	58.8	Female	Juvenile†
2/4/18	1804	166452	SPOT (location-only)	5/26/18	15252	143	119	74.8	Female	Adult
2/6/18	1805	166453	SPOT (location-only)	4/9/18	15253	121	97	49.8	Female	Juvenile†
2/6/18	1806	173502	SPOT (location-only)	6/22/18	N/A	149	116	82.2	Female	Adult
2/8/18	1807	173503	SPOT (location-only)	4/26/18	15250***	93	77	24.9	Female	YOY‡
2/26/20	2001	177411	GPS-enabled SPLASH (depth- sensing)	7/12/20	N/A	95	80	26.1	Female	Juvenile†
3/2/20	2002	177410	GPS-enabled SPLASH (depth- sensing)	6/10/20	N/A	130	83	47.0	Male	Juvenile†

**Seal 1802 was initially instrumented with VEMCO Tag #15250 on 04 February, but that tag was later dislodged when he was (unintentionally) recaptured on 06 February; ***VEMCO Tag #15250 was retrieved and deployed on seal 1807 on 08 February. No acoustic "pings" were detected during the time the VEMCO tag was attached to seal 1802; therefore, the data presented only include results from seal 1807; †Juvenile = 2–4 years old; ‡YOY = Young of the year, up to 1.5 years old. cm = centimeters; ID = identification; kg = kilogram(s); N/A = not applicable; PTT = platform transmitter terminal; SPOT = satellite-tracked position-only.

All nine platform transmitter terminal (PTTs) recorded 12,704 Advanced Research and Global Observation Satellite (Argos)/GPS locations over a total of 949 tracking days between 4 February 2018 and 12 July 2020. Data was transmitted on 93 percent (%) of tracking days. The mean number of tracking days was 105 (standard deviation [SD]±28.3 days; range 61–204

[1] A total of 591 detections (mean 68.87 detections, SD±22.55) from the five VEMCO-tagged harbor seals were recorded between February and April 2018; see Ampela et al. (2019) for array configuration and other details.

days). Six of these animals traveled as far north as coastal Maine during their respective tag deployment periods. While tagged seals were in Virginia waters, satellite tag data showed that haul-out sites on the Eastern Shore and Chesapeake Bay Bridge Tunnel (CBBT) Islands most likely functioned as a central resting location between foraging trips, and seals traveled to the Chesapeake Bay or to offshore waters east of the Bay from these sites. An adaptive local convex hull (a-LoCoH) habitat-use analysis showed that seals spent a cumulative 450 days in Virginia waters, and on 83 of these days (19%), satellite tags reported locations within the Navy's Virginia Capes Range Complex (VACAPES) Operating Area (OPAREA).

The average and maximum dive depths recorded by the SPLASH tags deployed in 2018 and 2020 (n=3) were consistent with those observed for harbor seals in other regions and ocean basins (Tollit et al. 1998; Frost et al. 2001; Eguchi and Harvey 2005). The mean depth recorded for all three seals (1802, 2001, and 2002) was 13.93 meters (m) (SD±11.73). While in Virginia waters, both seals tagged in 2020 had mean dive depths of 8-9 m. Dive depths increased in April for seal 2001, corresponding to when the seal traveled northward (maximum dive depth was 50.67 m in April 2020). A similar pattern of increased dive depth was observed for seal 2002, which also showed an increase in dive depth for the month of April 2020 (maximum dive depth was 54.16 m); this individual typically remained at dive depths <40 m for almost the entire tag deployment period. The male seal tagged with a SPLASH tag in 2018 remained in Virginia waters through early April at dive depths of <30 m, and close to the capture site, but deeper dives (104 and 118 m) were recorded off southern Long Island, New York, in early April 2018, and Penobscot Bay, Maine, in late May 2018, respectively (Ampela et al. 2019).

1.3 2022 Study Objectives

The primary goals of the 2022 tagging work were to increase our understanding of harbor seals' residency time in Virginia waters and in the VACAPES OPAREA, their local habitat utilization, haul-out behavior, and seasonal movement patterns. All tags deployed in 2022 employed Fastloc® technology, which provides location accuracy of up to 20 m, allowing for robust conclusions about habitat use in and near Navy training areas. Information gathered from these tags builds on the data collected in 2018 and 2020 and will provide valuable baseline data needed to assess potential impacts to seals from Navy activities in Virginia waters and along the Eastern Seaboard.

2. Methods

2.1 Field Methods

2.1.1 Captures

The capture site was located on the Eastern Shore of Virginia, where harbor seals are regularly observed hauling out between fall and spring. The Eastern Shore haul-out area has several discrete haul-out sites (centered around five discrete haul-out locations) within a tidal salt marsh habitat (**Figure 2**). The capture site is characterized by mud banks covered with vegetation and the five discrete haul-outs are clustered within a <1 square kilometer (km^2) area (Jones and Rees 2022; **Figure 2**). Seals were captured using a modified seine net deployed in-water adjacent to a haul-out site, following methods outlined in Ampela et al. (2019) (**Figure 3**). The net was brought onto land following deployment, and any seals caught were evaluated by the health assessment team as a candidate for tagging or recommended release. If deemed necessary by team, seals were in some cases removed from the capture net with a hoop net and secured onto a vessel for transport to land prior to heath assessment. Once the health assessment team confirmed that a seal was a candidate for tagging[2] it was then removed from the seine net and placed in a sock net for holding, prior to its transfer to the restraint board (**Figure 4**) for tagging and biological sampling. A team member was assigned to each seal for monitoring during the holding period.

[2] Seals were determined to be candidates for tagging based on health and behavioral criteria, including respiration characteristics, body condition, body posture, and presence/absence of wounds (see **Appendix A**).

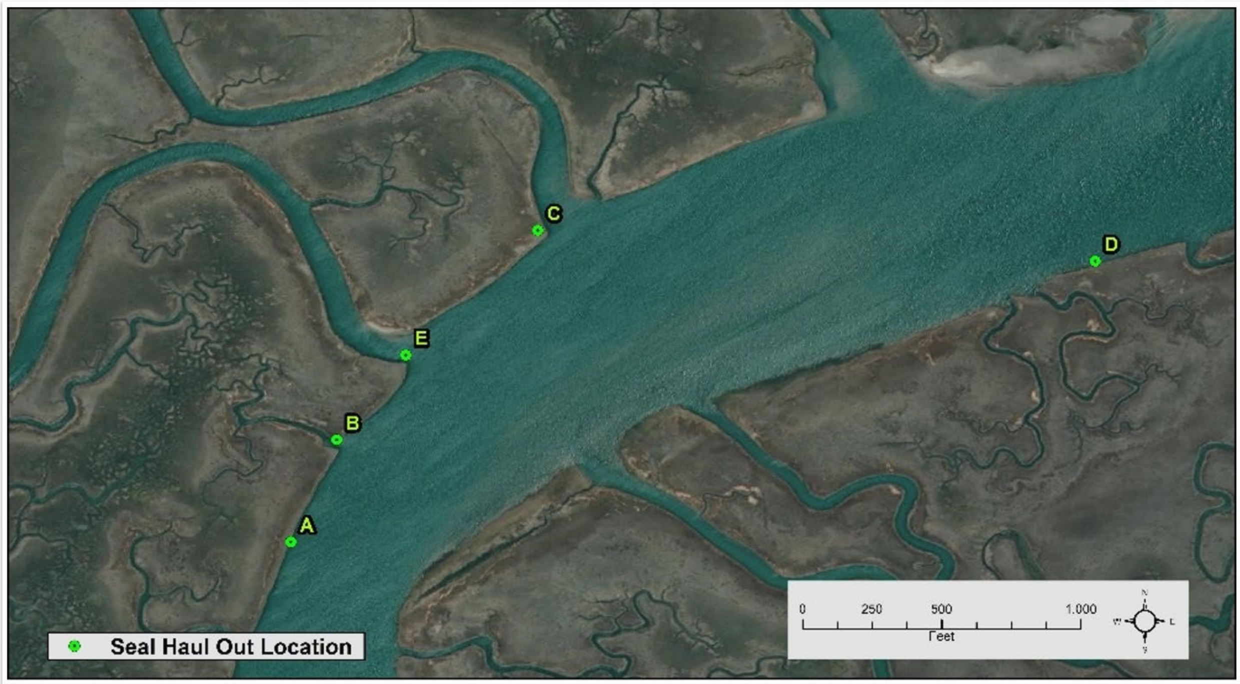

Figure 2. Aerial photo of five established seal haul-out locations (denoted A, B, C, D, and E) on the Eastern Shore of Virginia. Source: Jones and Rees 2022.

2.1.2 2022 Tagging

Tagging location and methods were the same as those outlined in Ampela et al. (2019, 2021). Seals were instrumented with flipper tags and satellite tags. Colored (orange[3]), flexible, vinyl Allflex™ livestock ear tags were attached to the seal's left hind flipper webbing. These flipper tags feature unique identifiers specific to this study and are used for purposes of individual identification if recovered or resighted, as they potentially stay attached for multiple years. Each seal was also instrumented with a GPS-enabled, non-depth sensing satellite tag (SPLASH10-BF). These tags are data-archiving, satellite-transmitting tags designed for tracking fine- and broad-scale horizontal movements and are equipped with temperature and wet/dry sensors. Satellite tags were glued directly to the seals' fur on the head or shoulder area (depending on the size of the animal) using Devcon™ 20845 High Strength 5-Minute Epoxy. Satellite tags were positioned on the animal's back or neck to maximize data transmission, since data are only transmitted to the Argos network when the tag antenna is above the water surface. Since the tags are affixed to the surface of the pelage/fur, the tags fall off during the annual molt in July, following the May-June breeding season.

[3] Orange flipper tags were deployed in 2022 and light blue tags were deployed in 2018 and 2020.

Figure 3. The capture team monitoring the deployed net (indicated by red arrows) for seal activity. Photograph by D. Rees, Naval Facilities Engineering Systems Command, Atlantic, taken under National Marine Fisheries Service Permit #21719.

Figure 4. Post-tagging release of seal 2260, a juvenile male. Photograph by D. Rees, Naval Facilities Engineering Systems Command Atlantic, taken under National Marine Fisheries Service Permit #21719.

2.1.3 Biological Sampling

A series of biological samples was collected from each tagged seal (**Table 2; Appendix A**). Samples were either processed and sent immediately to the requesting lab upon return from the capture site, or after the field sampling event had concluded. Morphometric measurements were also collected, and photographs were taken of ventral, lateral, and frontal views (see **Appendix A** for example data sheets). Any wounds or abnormalities were also photographed. During capture and tagging procedures each seal was monitored for respiration and heart rate; quality of breaths (open mouth breathing, wheezing); body condition (emaciated, thin, normal/robust); attitude (alert, lethargic, non-responsive); presence of eye and ear exudate, and whether the animal was shivering. When possible, vital rates were obtained both before and after tagging (pre-release). Information recorded during the capture and sampling events included 1) time the net was set; 2) time seal was removed from net; 3) time biological sampling began, and 4) time the animal was released. All capture and sampling activities were conducted in accordance with the National Marine Fisheries Service (NMFS) Scientific Research Permit #21719.

Table 2. Biological sample type, purpose, and receiving laboratory.

Sample Type	Sample Purpose	Requesting Researcher[4]	Storage Medium
Swab - Rectal	Virology - PDV	NOAA NMFS	Frozen -80
Serum	Virology - AI	NOAA NMFS	Frozen -80
Whole Blood	Virology - PDV	NOAA NMFS	Frozen -80
Fur	Stable Isotope	Louisiana State University	Room Temp
Whisker	Stable Isotope	Louisiana State University	Room Temp
Whole Blood	Stable Isotope	Louisiana State University	Frozen -80
Blubber	Diet Analysis	NOAA NEFSC	Frozen -20
Skin	Genetics	University of Maine	Room Temp
Swab - Nasal	Virology - AI	Tufts University	VTM, Frozen -80
Swab - Conjunctival	Virology - AI	Tufts University	VTM, Frozen -80
Swab - Rectal	Virology - AI	Tufts University	VTM, Frozen -80
Serum	Virology - AI	Tufts University	Frozen -80
Whole Blood	Contaminants	University of Connecticut	Room Temp
Serum	Cytokine Analysis	University of Connecticut	Frozen -80
Whole Blood	CBC	IDEXX	IDEXX
Serum	Chemistry	IDEXX	IDEXX
Whole Blood	Archive	VAQS	Frozen -80
Serum	Archive	VAQS	Frozen -80
Skin	Genetics	NOAA SEFSC	DMSO

KEY: AI = Avian Influenza; CBC = Complete Blood Count; DMSO = dimethyl sulfoxide; NEFSC = Northeast Fisheries Science Center; NMFS = National Marine Fisheries Service; NOAA = National Oceanic and Atmospheric Administration; PBM = peripheral blood mononuclear cell; PDV = phocine distemper virus; SEFSC = Southeast Fisheries Science Center; VAQS = Virginia Aquarium Stranding Response Program; VTM = viral transport medium.

2.2 Data Analysis Methods

2.2.1 Satellite Tag Data Processing

Data returned from the PTTs associated with each satellite (SPLASH) tag included information about the animals' haul-out behavior, short- and long-distance horizontal movements (with location accuracies of up to 20 m), and recorded temperature. SPLASH tags were Fastloc® enabled, meaning that the tags acquired positions every few minutes using GPS. The Fastloc® feature allowed fine-scale movement tracking and more precise identification of haul-out locations. Data were summarized and compressed for transmission to the Argos satellite network when the animal surfaced. All satellite transmitters were programmed to collect continuous location and sensor (i.e., wet/dry and temperature) data. Satellite tag return data were used to investigate seals' use of marine and coastal habitat, and to create maps of their transits and haul-out locations. SPLASH tags recorded time in GMT, which was converted to EST/EDT by subtracting four or five hours, as appropriate.

[4] Requesting researchers and laboratories are conducting a number of ongoing health, genetics, and diet studies which are independent of this tagging study.

2.2.2 In-water Temperature

In-water temperature (°C) thresholds for the five SPLASH tags deployed in 2022 were explored using time-series plots and summary statistics. Because the relationship between harbor seal in-water behavior and water temperature at depth was of primary interest in this study, temperature data analysis was restricted to in-water values and haul-out (i.e., in-air) temperatures were not included in the analysis. In order to ensure that temperature thresholds were representative of in-water activity only, any temperature data that corresponded with a 'haul out' code was filtered out from the temperature data. The resulting in-water temperature thresholds were cross-checked via comparison with maximum in-water temperatures recorded by regional National Oceanic and Atmospheric Administration (NOAA) data buoys, (https://www.ndbc.noaa.gov/).

2.2.3 Haul-out Behavior

In order to investigate temporal patterns in seals' haul-out behavior while in Virginia waters, probability density plots of time seals spent hauled out (dry) were generated for the five tags deployed in 2022 using wet/dry sensor data. The tags were programmed to register haul-out events as follows:

- If the wet/dry sensor on a tag is dry for at least 30 seconds in one minute, the tag is considered dry.
- If the tag records five minutes of consecutive dry cycles, it will register a haul-out event.
- If at any time during those cycles the tag is wet for 45 seconds or more, the cycle stops and the tag is not considered hauled-out.

2.2.4 Location Data

Location data from PTTs were filtered and managed using the Argos-system, a data management system by Woods Hole Group, a CLS Company (https://argos-system.cls.fr/argos-cwi2/login.html). The Douglas Argos Filter Algorithm was used in Argos-system to remove implausible locations (Douglas et al. 2012) (**Appendix B**). Location data obtained from these tags included position quality codes for each position transmitted. Argos location codes three, two, one and Fastloc® GPS positions were included in the post-filter analysis, as these codes are considered high quality (see **Appendix B**). All post-filter locations were loaded into an ArcMap 10.8.1 project for map generation.

2.2.5 Habitat Use

Resulting location data were used to conduct a habitat-use analysis for all tagged seals. A LoCoH approach was chosen to determine areas of highest habitat utilization, as this method performs well when considering spaces that change abruptly with barriers that can be identified as ecological determinants, such as nearshore estuarine and ocean environments (Getz et al. 2007). The LoCoH home range analysis was conducted using the R package from Lyons et al. (2013) (https://tlocoh.r-forge.r-project.org/). The location data used for this analysis included Fastloc® GPS positions and Argos quality positions that were filtered through the Douglas Argos Filter Algorithm to remove implausible locations (Douglas et al. 2012) (**Appendix B**). Location codes that did not have an accuracy measurement (i.e., those that did not have Argos location codes of codes three, two, or one, or have Fastloc® GPS positions) were excluded from this data set.

Isopleths were calculated from spatial utilization distributions to predict the 50% and 95% likelihood of an animal traversing a given area (Calenge 2006). The resulting isopleths were used to create maps of each animal's home range (defined as the 95% isopleth) and core habitat (defined as the 50% isopleth), and isopleths for each seal were overlaid to create relative habitat use maps that highlight areas utilized by multiple seals.

In Virginia waters, seal "trips" were defined as being *inshore* (within the Chesapeake Bay) if after leaving the haul-out site, the animal crossed the U.S. collision regulation (COLREGS) lines of demarcation and went into the Bay. Seal trips were defined as being *offshore* if the track destination (i.e., the point where the animal changed direction and returned to the Eastern Shore capture site) was outside of the COLREGS line and was greater than or equal to 10 km from the capture site[5] (see **Figure 1**).

[5] This distance threshold was determined post-hoc during data exploration. The ArcGIS Line Statistics tool was used to identify the distance from the capture location in which seal track density was relatively high (>200 km of track line per 5 × 5 km grid).

3. Results

3.1 Summary of Tagged Animals

Five harbor seals were captured and instrumented with satellite-tracked tags and flipper tags from 7–15 February 2022. One was an adult female, and the others were juvenile males. All five seals were instrumented with GPS-enabled, non-depth sensing satellite tags (SPLASH10-BF). **Table 3** summarizes individual harbor seal and deployment information for all five tags.

Table 3. Individual harbor seals tagged in 2022 and summary of satellite tag deployments.

Seal ID	Satellite Tag PTT #	Length (cm)	Girth (cm)	Weight (kg)	Sex	Estimated Age	Date Tagged	Date Left VA	Tag Last Transmission	Tracking Days	Total Distance Traveled (km)	Distance Traveled in VA Waters (km)
2260	178255	119.0	85	40.6	Male	Juvenile	2/7/22	3/4/22	6/8/22	121	4,049	1,432
2261	178256	155.0	116	102.0	Female	Adult	2/8/22	3/3/22	6/17/22	129	3,864	539
2262	178257	146.0	114	81.0	Male	Juvenile	2/9/22	3/10/22	7/18/22	159	3,017	511
2263	178258	115.5	85	38.0	Male	Juvenile	2/15/22	4/10/22	6/4/22	109	4,575	1,959
2264	177412	121.5	89.5	47.1	Male	Juvenile	2/15/22	3/22/22	5/25/22	99	2,880	748

cm = centimeter(s); ID = identification; kg = kilogram(s); km = kilometer(s); PTT = platform transmitter terminal; VA = Virginia.

3.2 In-water Temperature

3.2.1 2022 Tags

In-water temperature data recorded by the five seal tags deployed in 2022 are shown in **Figure 5** and **Table 4**.

Table 4. Monthly in-water temperature statistics for seals tagged in 2022 (n=5).

Year	Seal ID	Month	Mean	Max	Min	Median	SD	Number of Obs
In-water Temperature (°C)								
2022	2260	February	6.51	8.40	5.60	6.40	0.91	7
2022	2260	March	8.32	13.4	3.80	8.25	3.60	6
2022	2260	April	6.62	7.90	5.50	6.40	0.95	6
2022	2260	May	11.19	17.50	8.90	9.95	2.75	12
2022	2260	June	11.53	12.70	10.50	11.40	1.11	3
2022	2261	February	6.06	8.3	3.80	6.35	1.42	10
2022	2261	March	6.22	7.90	1.50	6.70	1.66	13
2022	2261	April	7.17	8.50	6.10	7.10	0.82	13
2022	2261	May	9.48	11.70	6.90	10.00	1.47	24
2022	2261	June	14.23	15.80	13.50	13.70	0.91	7
2022	2262	February	7.26	9.80	5.50	7.00	1.23	9
2022	2262	March	8.14	12.20	4.90	7.40	2.67	13

Year	Seal ID	Month	Mean	Max	Min	Median	SD	Number of Obs
2022	2262	April	5.58	7.10	4.20	5.80	1.15	5
2022	2262	May	11.23	20.10	6.60	9.10	6.05	4
2022	2262	June	12.28	18.30	10.60	11.60	2.15	11
2022	2262	July	15.63	20.70	12.70	14.30	3.19	6
2022	2263	February	6.74	9.50	4.70	6.50	1.64	8
2022	2263	March	8.83	11.20	7.00	8.55	1.23	18
2022	2263	April	10.42	16.30	7.50	10.35	2.05	20
2022	2263	May	9.27	17.30	6.20	8.30	2.84	15
2022	2263	June	9.3	9.30	9.30	9.30	0.00	1
2022	2264	February	6.6	9.50	5.00	5.95	2.05	4
2022	2264	March	7.6	10.20	3.50	8.20	2.25	9
2022	2264	April	6.52	7.50	5.60	6.50	0.70	5
2022	2264	May	9.7	14.70	7.40	9.40	1.85	11

°C = degrees Celsius; ID = identification; Max = maximum; Min = minimum; Obs. = observation(s); SD = Standard deviation.

The mean in-water temperature recorded by the five 2022 tags while seals were in Virginia waters was 8.95 degrees Celsius (°C) (SD±3.01). Mean in-water temperatures recorded by the tags increased slightly over the respective deployment periods, with the lowest temperature recorded in March by seal 2261 (**Figure 5**). The maximum in-water temperature recorded was 20.10°C (seal 2262 in May 2022) (**Table 4**).

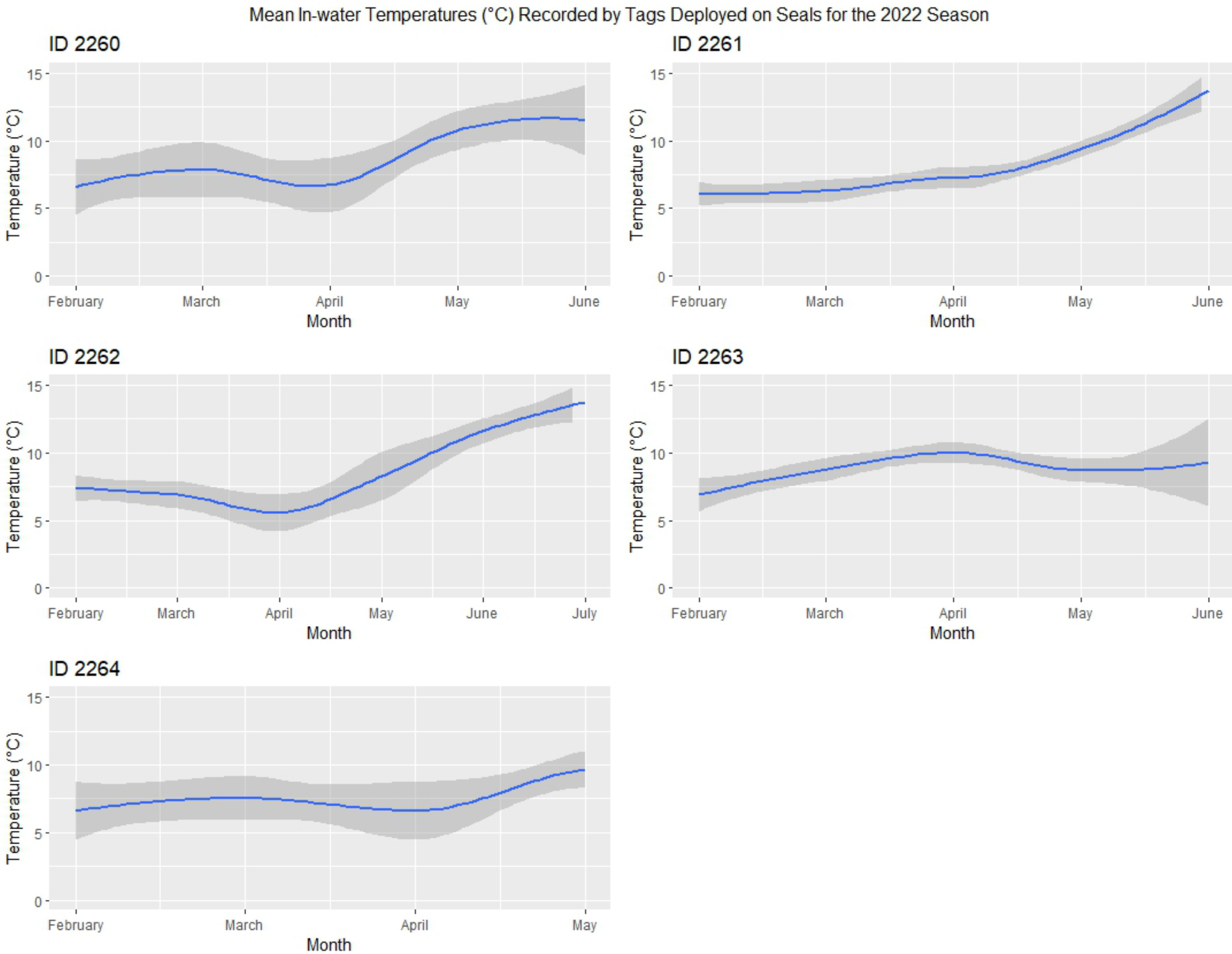

Figure 5. In-water temperature (°C) values and averages for each harbor seal tagged in 2022, over the entire duration of the tag reporting periods. Blue line represents mean temperature; gray shading represents the range of temperatures recorded. ID = identification.

3.3 Haul-out Behavior

Haul-out locations for the five seals tagged in 2022, as defined by GPS-enabled satellite tags (location accuracy up to 20 m), are shown in **Figure 6**. Haul-out locations for seals tagged in 2020, also instrumented with GPS-enabled tags, are also shown for comparison. (Tags deployed in 2018 were not GPS-enabled, and therefore had different data resolution with respect to haul-out sites and are therefore not shown in **Figure 6**). Results showed a strong overlap in haul-out locations in subsequent years, indicating that tagged seals are using established haul-out sites over time. Exceptions were sites in coastal New Jersey, which were used by tagged seals on the northbound migration in 2022 but not in 2020, and in Cape Cod Bay, which were used by tagged seals on the northbound migration in 2020 but not in 2022. Specifically, seal 2263 hauled out in coastal New Jersey during the northbound migration in March 2022. Seal 2002 (tagged in 2020) departed Virginia waters in mid-March 2020 and the next haul-out locations were reported in Cape Cod Bay from March 19 through early May 2020.

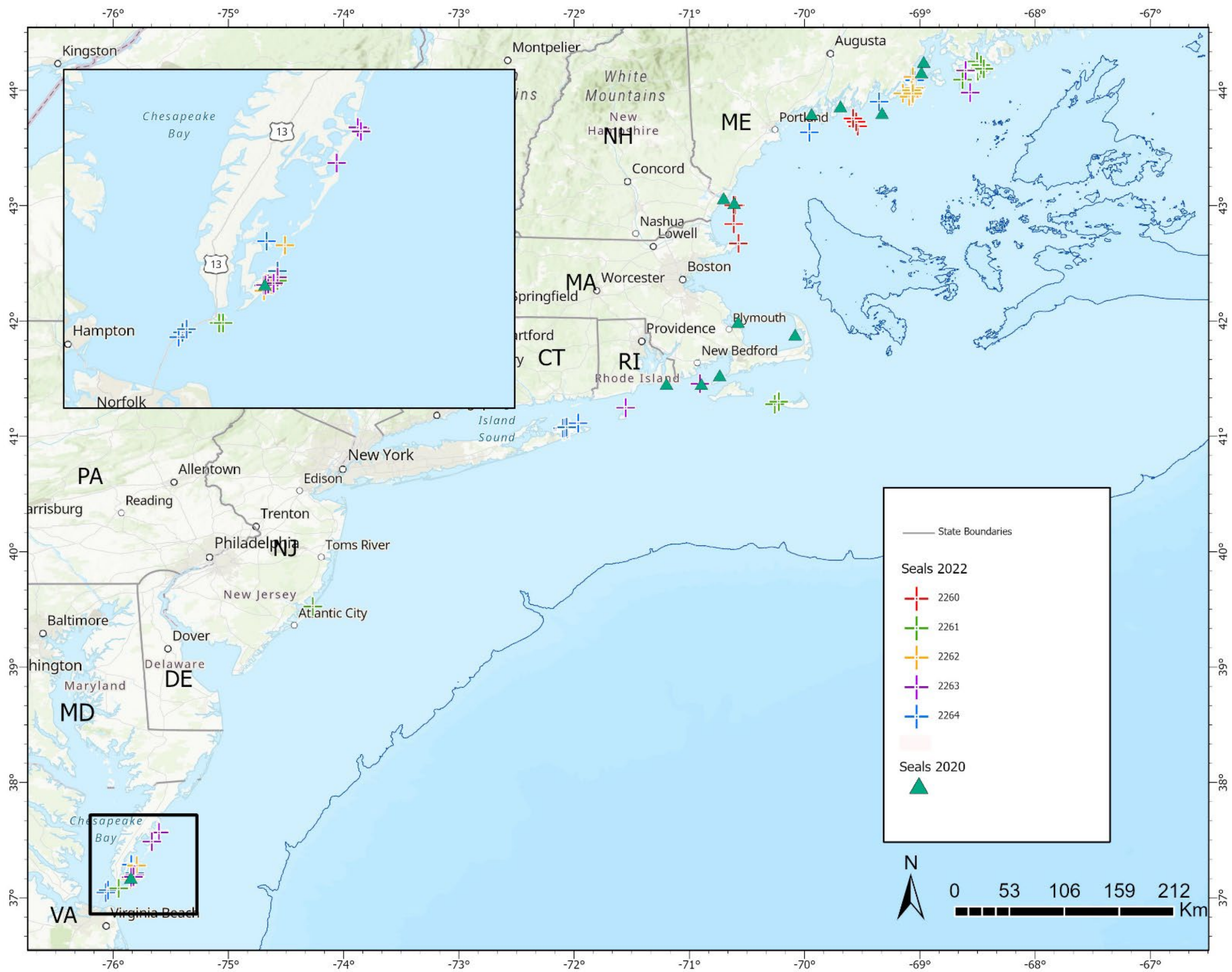

Figure 6. Haul-out locations for the five seals tagged in 2022, as compared to the two seals tagged in 2020. Haul-out areas are based on Fastloc® GPS locations classified as "hauled out." OPAREA = Operating Area; VACAPES = Virginia Capes Range Complex. (Haul-out locations from 2018 tags are not shown as these were not GPS-enabled.)

3.3.1 Temporal Haul-Out Patterns

Monthly haul-out probabilities (Virginia waters only) with respect to time of day for each of the seals tagged in 2022 are shown in **Figures 7** through **11.** Pooled monthly haul-out probabilities for all five tagged seals while in Virginia waters in February and March are shown in **Figure 12**. April was not included in the pooled monthly haul-out data due to only one seal being in Virginia waters in April. Tagged seals showed roughly similar temporal haul-out patterns while in Virginia waters (February—April timeframe) with the majority most likely to haul out between 04:00 and 12:00 local time. An exception was seal 2262 in March, which was most likely to haul out between 12:00 and 17:00. All but one tagged seal departed Virginia waters in March; seal 2263 departed on 10 April (**Figure 10**). This seal showed a distinct bimodal temporal haul-out pattern, with peaks at 09:00 and 20:00 in February and March, and peaks at 08:00 and 16:00 in April (**Figure 10**).

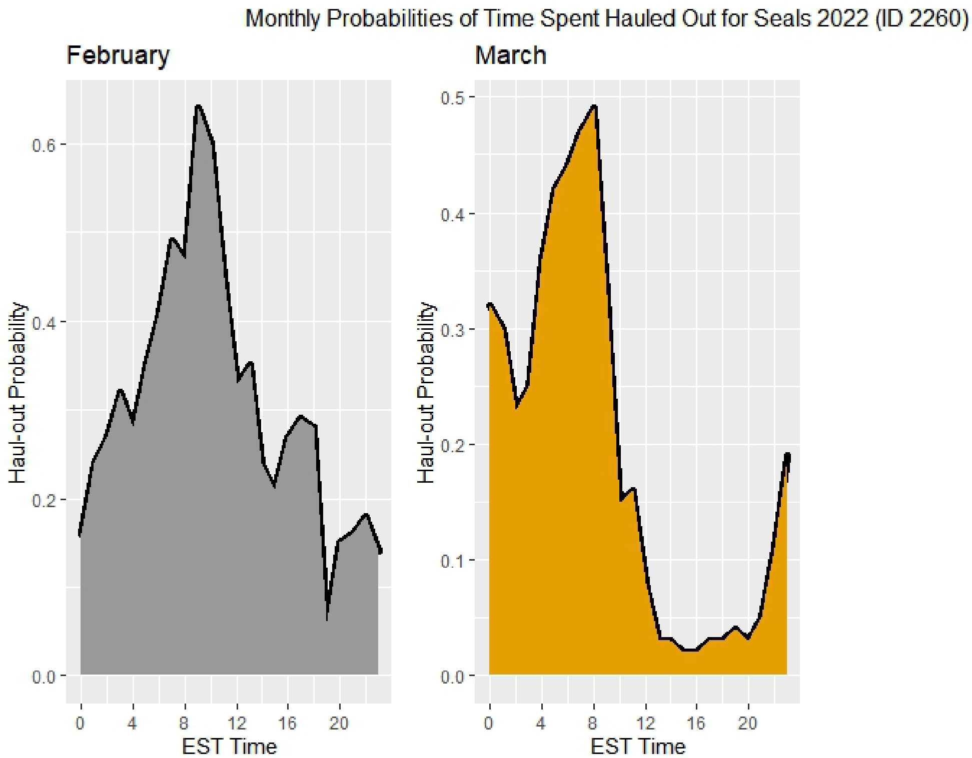

Figure 7. Monthly probability densities of time spent hauled out for Seal 2260 while in Virginia waters. Hour-of-day (x-axis) is local 24-hour time.

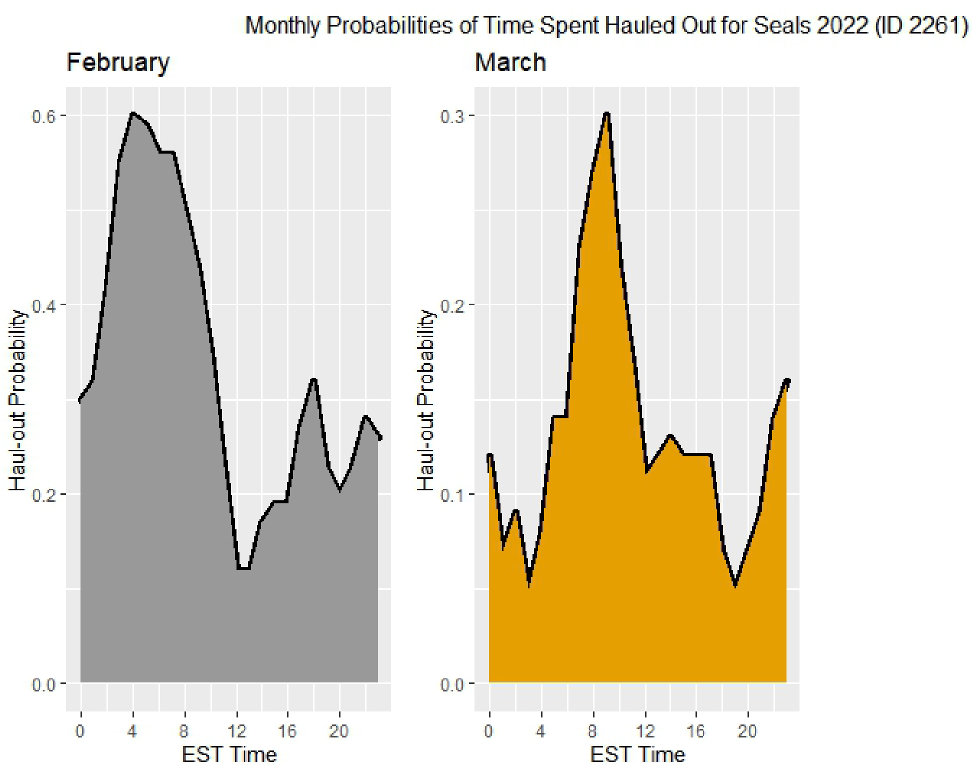

Figure 8. Monthly probability densities of time spent hauled out for Seal 2261 while in Virginia waters. Hour-of-day (x-axis) is local 24-hour time.

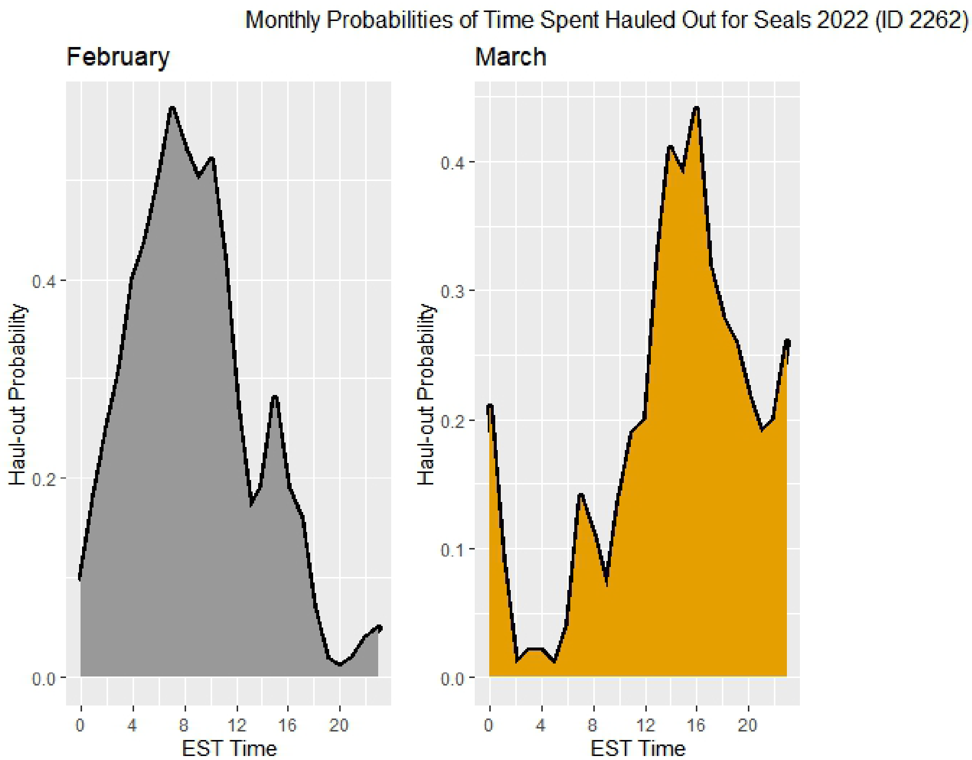

Figure 9. Monthly probability densities of time spent hauled out for Seal 2262 while in Virginia waters. Hour-of-day (x-axis) is local 24-hour time.

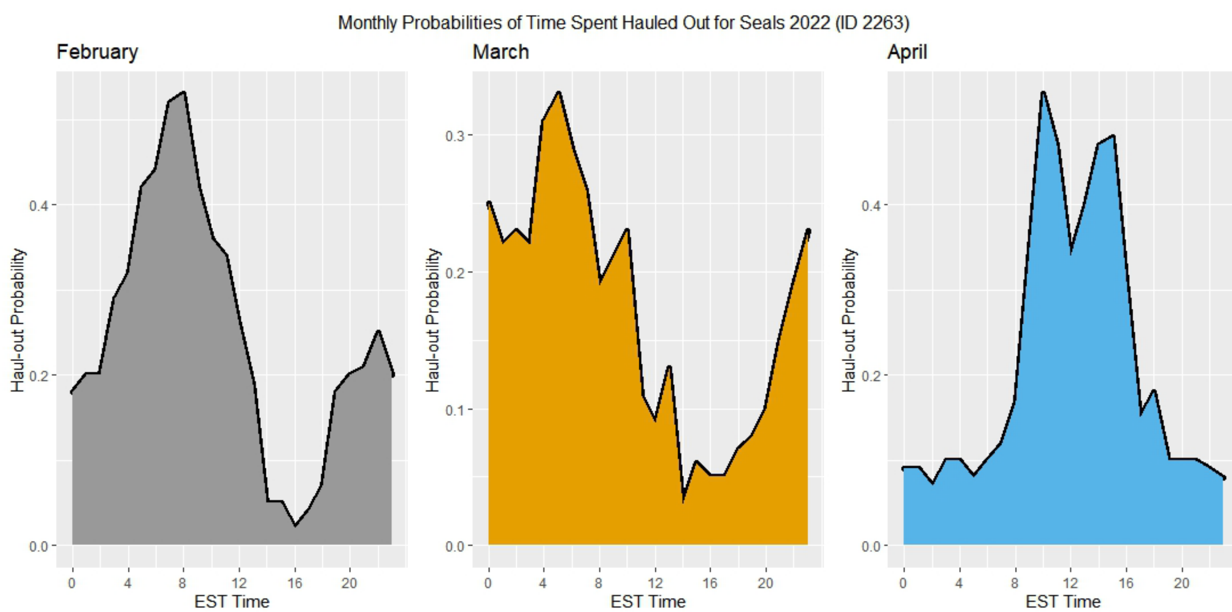

Figure 10. Monthly probability densities of time spent hauled out for Seal 2263 while in Virginia waters. Hour-of-day (x-axis) is local 24-hour time.

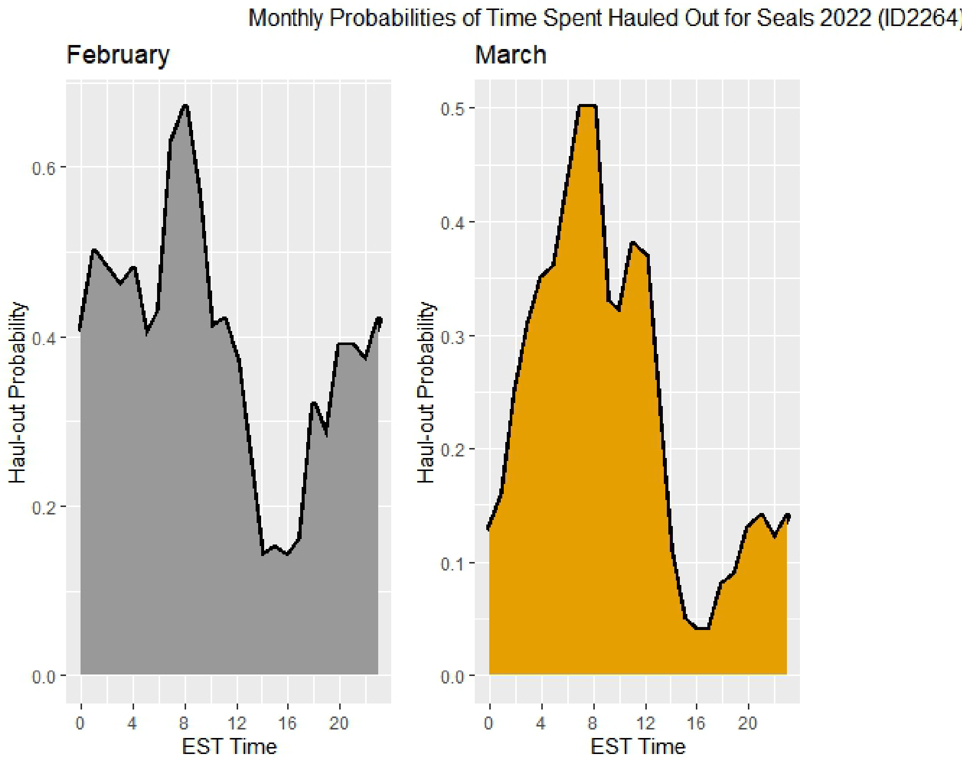

Figure 11. Monthly probability densities of time spent hauled out for Seal 2264 while in Virginia waters. Hour-of-day (x-axis) is local 24-hour time.

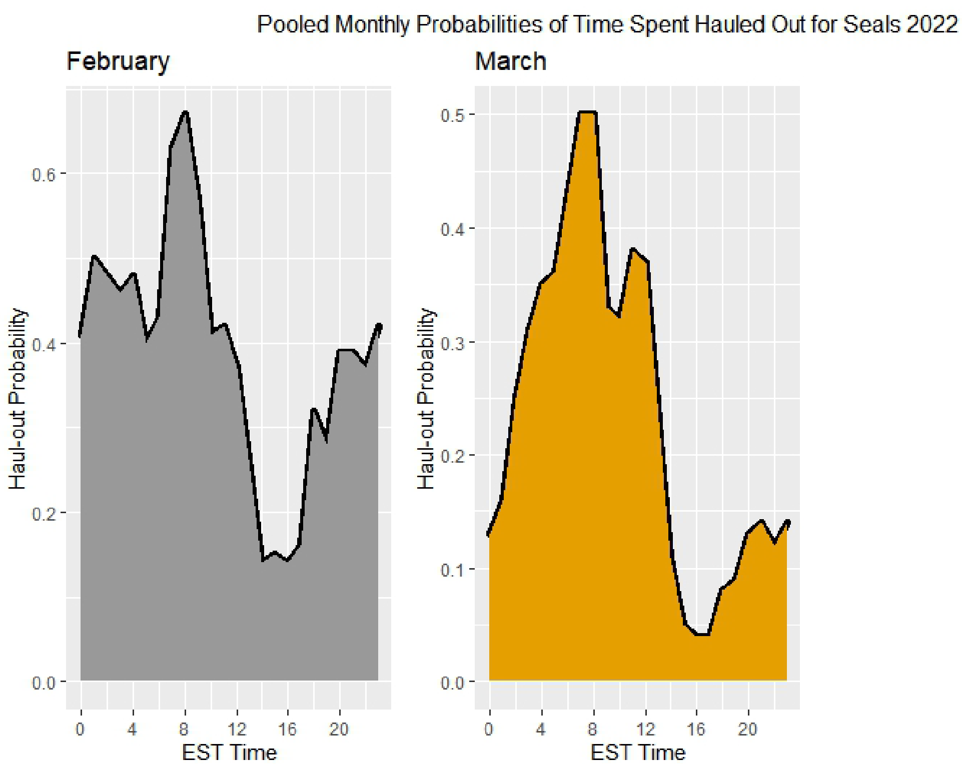

Figure 12. Pooled monthly probability densities of time spent hauled out for all seals tagged in 2022 (n=5) while in Virginia waters. Hour-of-day (x-axis) is local 24-hour time.

3.4 Location Data

3.4.1 2022 Tags

The five PTTs deployed in 2022 recorded 16,850 raw locations. Seal tracks were created using filtered Argos locations with the Douglas Argos-Filter Algorithm (**Figures 13** through **17**). These five GPS-enabled tags recorded 174 locations where seals were classified as “hauled-out”, 44 (25%) of which were on the Eastern Shore, close to the capture site (**Figure 6**). Haul-out locations were also identified on the CBBT Islands and Fisherman’s Island. The remainder of haul-out locations were recorded in coastal areas and islands in New Jersey, New York, Rhode Island, or further north, including Cape Cod Bay, Massachusetts, and coastal Maine.

The five tags pooled together reported a total of 617 tracking days (defined as the number of days from 24 hours post-deployment to last transmission for each tag) from 7 February through 18 July 2022. Quality location code data was transmitted on 610 of 617 tracking days (99% of transmission days). The average number of days spent in Virginia waters was 37 days, with a range of 23 days to 54 days. The average length of time the 2022 tagged seals were tracked for was 123 days, with 30% of that time spent in Virginia waters. The last tagged seal to leave Virginia waters headed north on 10 April 2022; all other tagged seals departed Virginia waters in March. All seals tracked northward along the Eastern Seaboard, stopping at haul-out sites in coastal New Jersey, New York, Rhode Island, Massachusetts, and New Hampshire, traveling as far north as coastal Maine during the tag reporting periods **(Figure 6**).

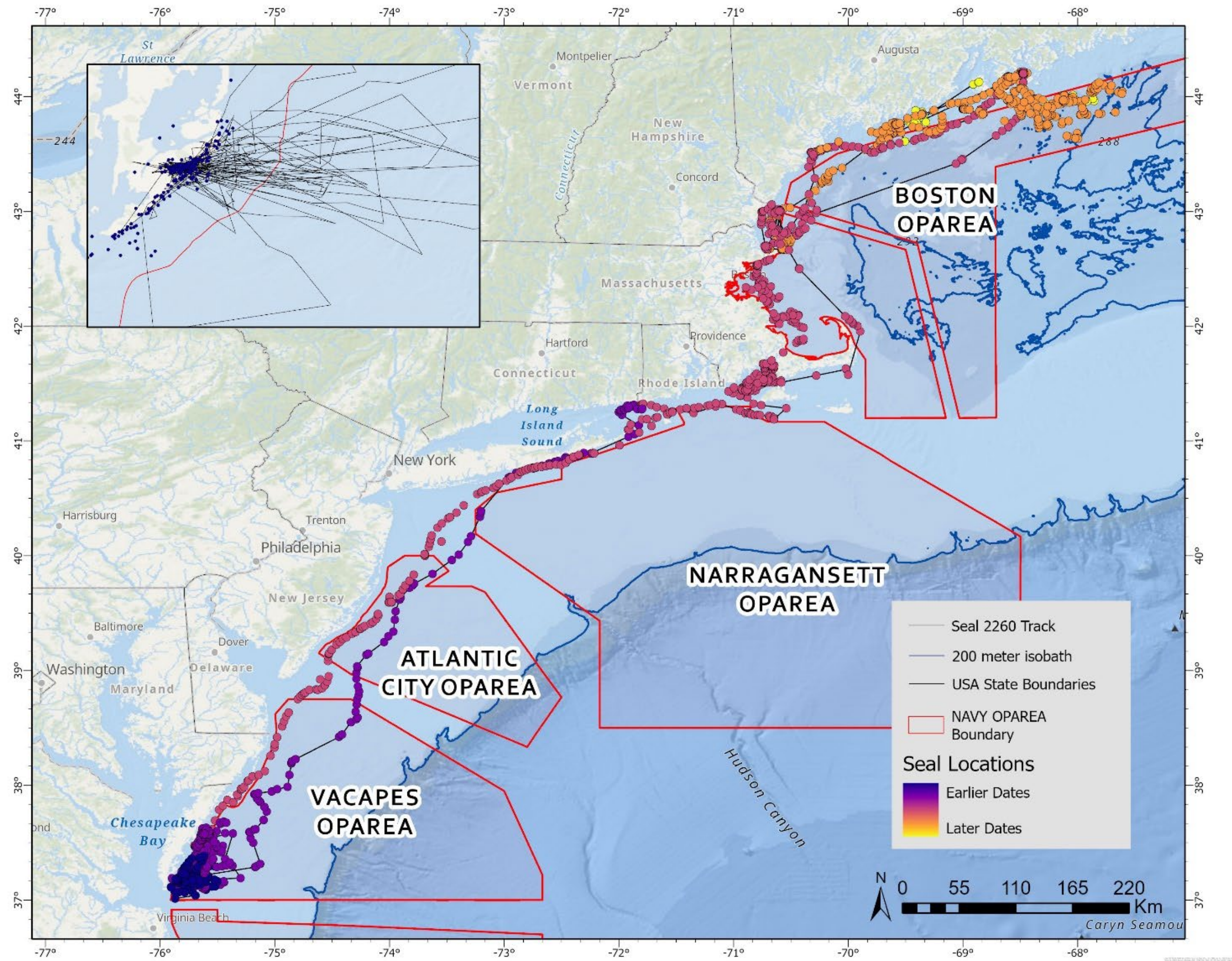

Figure 13. Reconstructed track of seal 2260 (tag duration 7 February through 8 June 2022) in relation to Navy operating areas (OPAREA). VACAPES = Virginia Capes Range Complex.

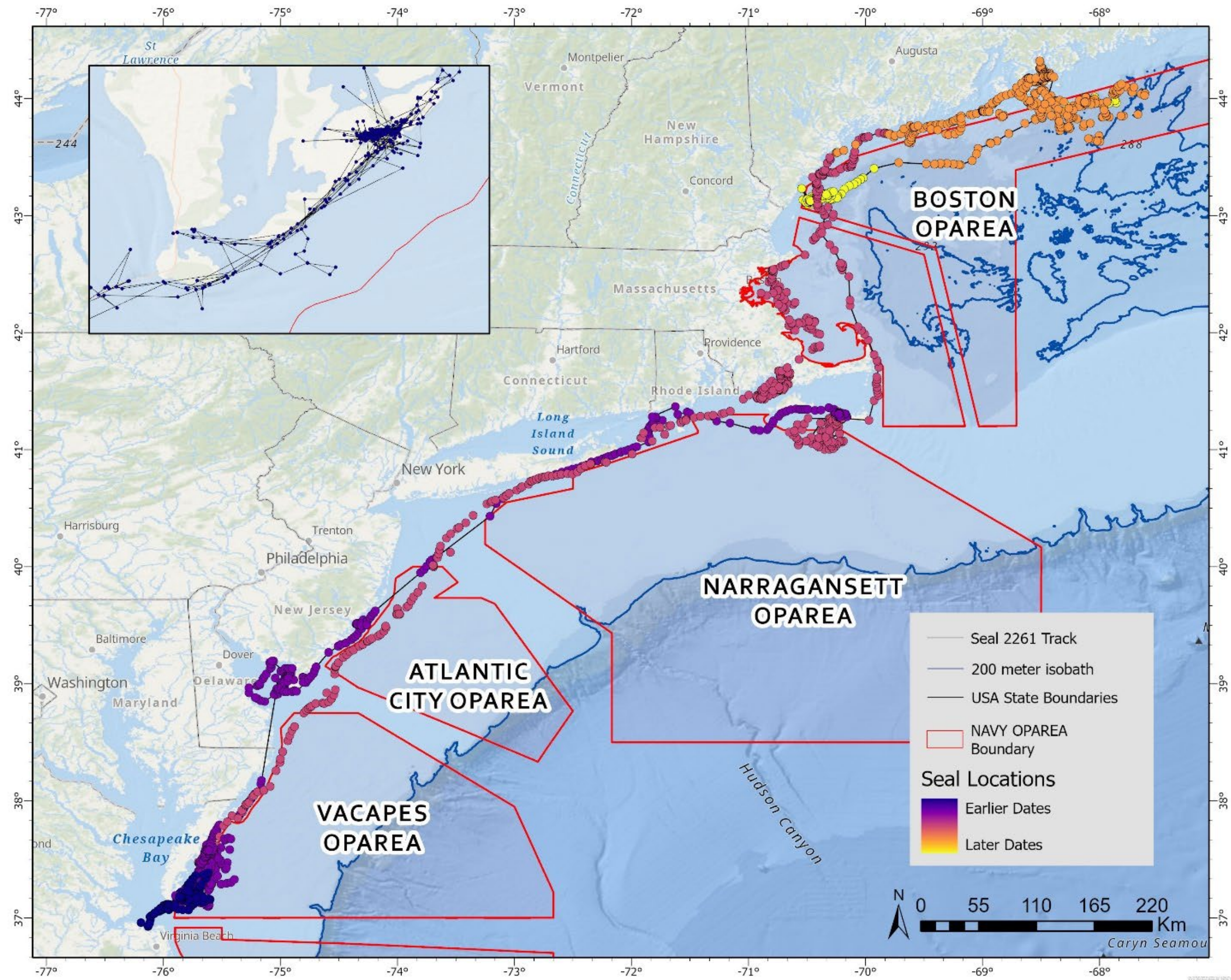

Figure 14. Reconstructed track of seal 2261 (tag duration 8 February through 17 June 2022) in relation to Navy operating areas (OPAREA). VACAPES = Virginia Capes Range Complex.

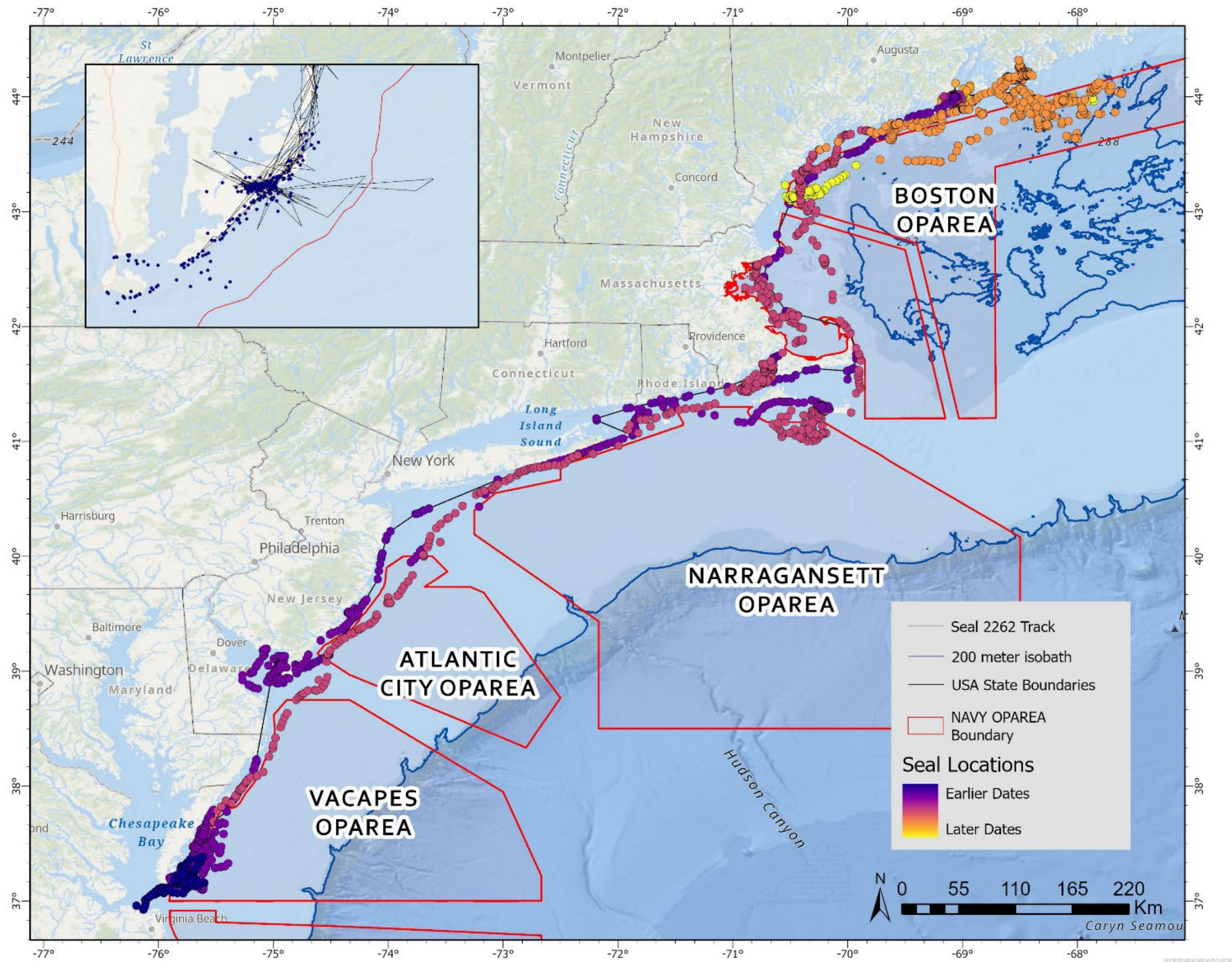

Figure 15. Reconstructed track of seal 2262 (tag duration 9 February through 18 July 2022) in relation to Navy operating areas (OPAREA). VACAPES = Virginia Capes Range Complex.

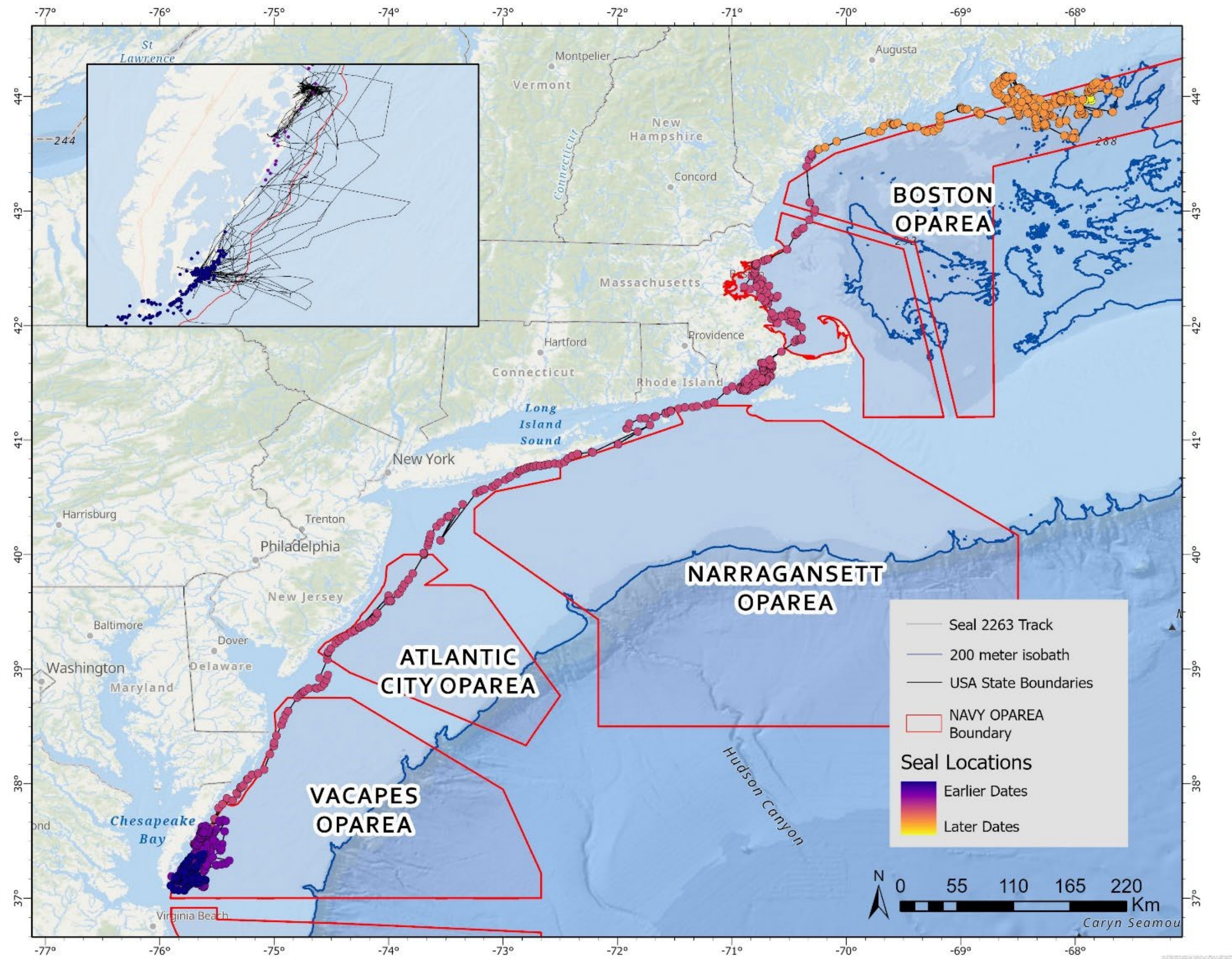

Figure 16. Reconstructed track of seal 2263 (tag duration 15 February through 4 June 2022) in relation to Navy operating areas (OPAREA). VACAPES = Virginia Capes Range Complex.

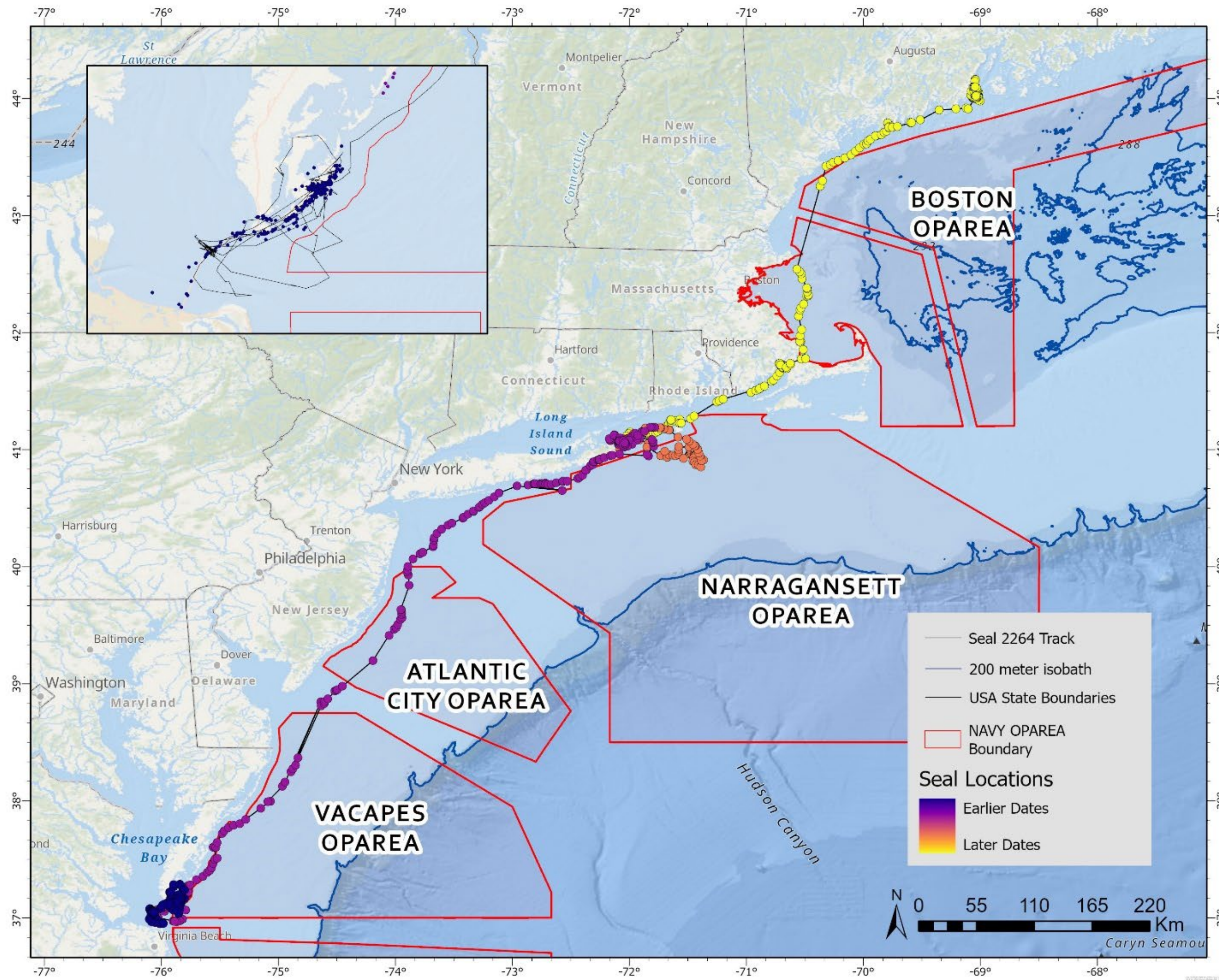

Figure 17. Reconstructed track of seal 2264 (tag duration 15 February through 25 May 2022) in relation to Navy operating areas (OPAREA). VACAPES = Virginia Capes Range Complex.

3.4.2 2018, 2020, and 2022 Tags

All 14 tags (seven in 2018, two in 2020, and five in 2022) recorded 29,554 Argos/GPS locations. Seal tracks were created using Douglas-filtered Argos locations and, for the two tags deployed in 2020 and five tags deployed in 2022, using GPS locations[6] (**Figures 18** and **19**[7]). All 14 tags recorded a total of 1,566 tracking days (defined as the number of days from 24 hours post-deployment to last transmission for each tag) between 4 February 2018 and 18 July 2022. Data was transmitted on 95% of tracking days. The mean number of tracking days was 112 (SD±26.88 days; range 62–159 days). All 14 seals were captured at the same Eastern Shore

[6] In 2018, six location-only SPOT tags and one depth-sensing SPLASH tag were deployed; in 2020, two GPS-enabled depth-sensing SPLASH tags were deployed.

[7] The use of straight lines to depict seals' movements assumes a direct path from one recorded location to the next. In some cases, due to limited data resolution, reconstructed tracks may appear to extend over land masses, when in reality it can be assumed that the seal travelled in the water to the next recorded location.

location, and 11 of these animals traveled as far north as coastal Maine during their respective tag deployment periods. One tag stopped transmitting data while the animal was still in Virginia waters. Two seals only traveled as far north as southern New England before their tags stopped transmitting data.

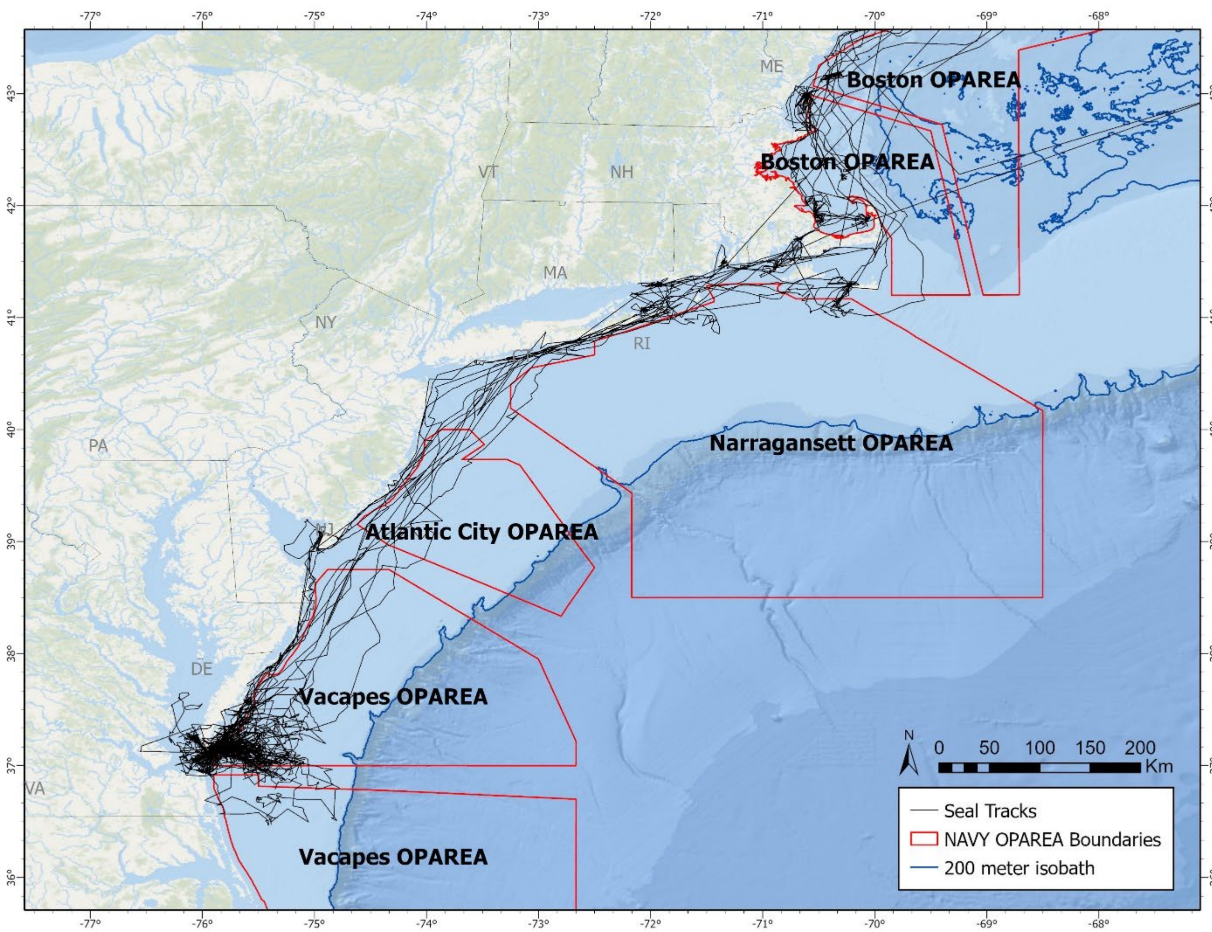

Figure 18. Reconstructed tracks of all 14 seals tagged in coastal Virginia from 2018 through 2022 (maximum tag duration = 160 days) in relation to Navy operating areas (OPAREAs). VACAPES = Virginia Capes Range Complex.

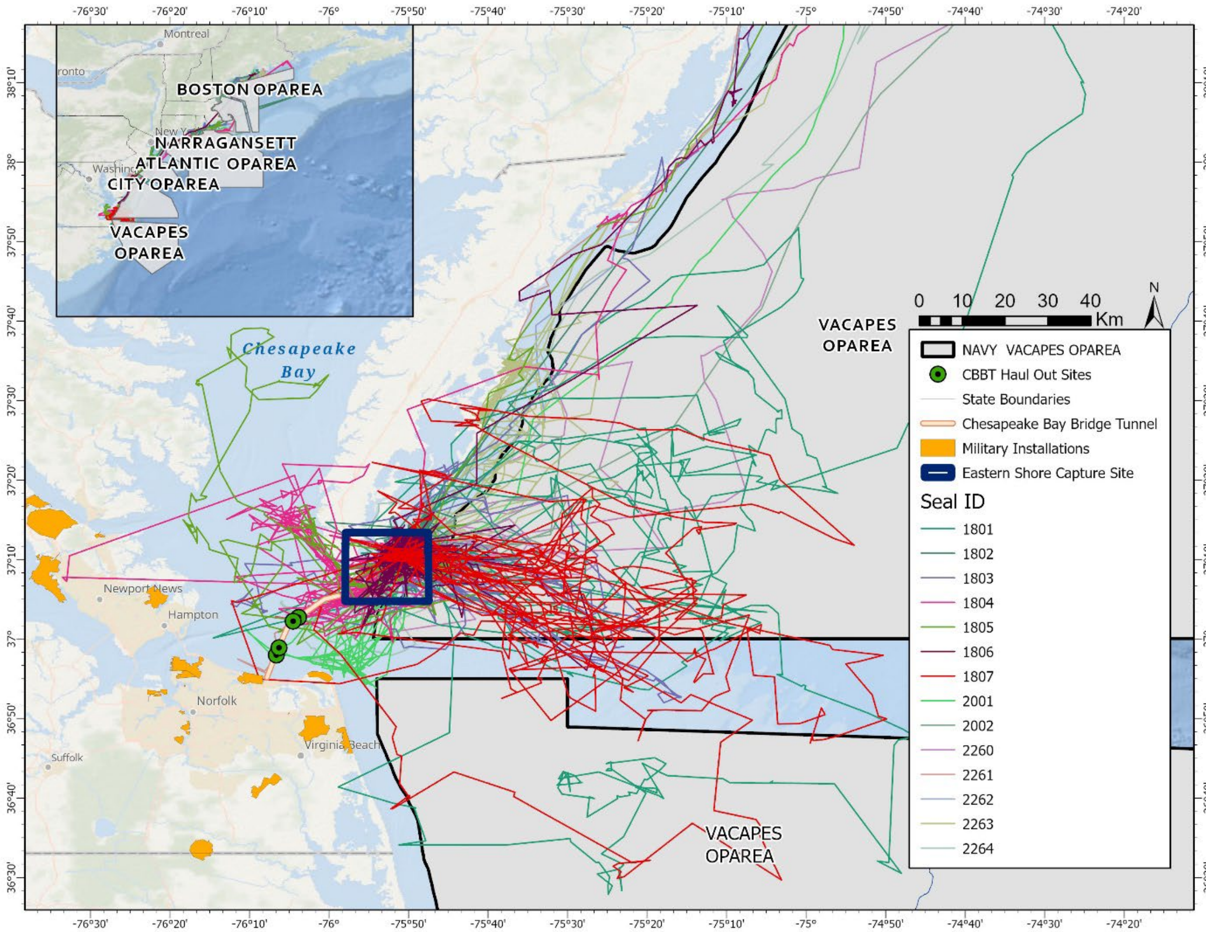

Figure 19. Reconstructed tracks of all 14 tagged seals in relation to the Virginia Capes Range Complex (VACAPES) Operating Area (OPAREA). CBBT = Chesapeake Bay Bridge and Tunnel; ID = identification.

3.5 Habitat Use

3.5.1 2022 Tags

Habitat use for the five seals tagged in 2022 was analyzed for the entire time each tag signaled using likelihood predictions generated by the LoCoH analysis. Seal 2260 had a 95% use area of 1,327 km^2 and a 50% use area of 4.54 km^2, the largest area used by the 2022 tagged animals. Seal 2262 had the smallest area use, with a 95% use area of 62 km^2 and a 50% use area of 1 km^2. Each of the seals tagged in 2022 utilized Virginia waters differently, as shown in **Figures 20** through **24**. Cumulatively, all five seals tagged in 2022 had a 95% habitat-use isopleth and 50% isopleth (core habitat) that extended as far north as coastal Maine (**Figure 25**). Seal 2260 had a 95% chance of using the waters off the Eastern Shore, with much of that time spent in the VACAPES OPAREA. For seal 2261, in contrast, the 95% isopleth included the coastal waters (within 3 nautical miles of shore) of Virginia and the mouth of Chesapeake Bay. Seal 2262 was more often located near the Eastern Shore capture site, while seal 2263 had 95% isopleth use across a wide area of the Eastern Shore and offshore (more than 10 nautical miles) in the VACAPES OPAREA. Seal 2264 had 95% isopleth use similar to seal 2260, concentrating on the back bays of the Eastern Shore capture site and the mouth of the Chesapeake Bay. The 2022 tagged animals utilized the nearshore waters (between three and ten nautical miles) more often, which resulted in a smaller area of use for the 2022 tagged animals when compared to the 95% and 50% isopleth use of the 2020 animals. Note that seals' use of coastal areas as haul-out habitat results in several instances where the 95% isopleths extend over land.

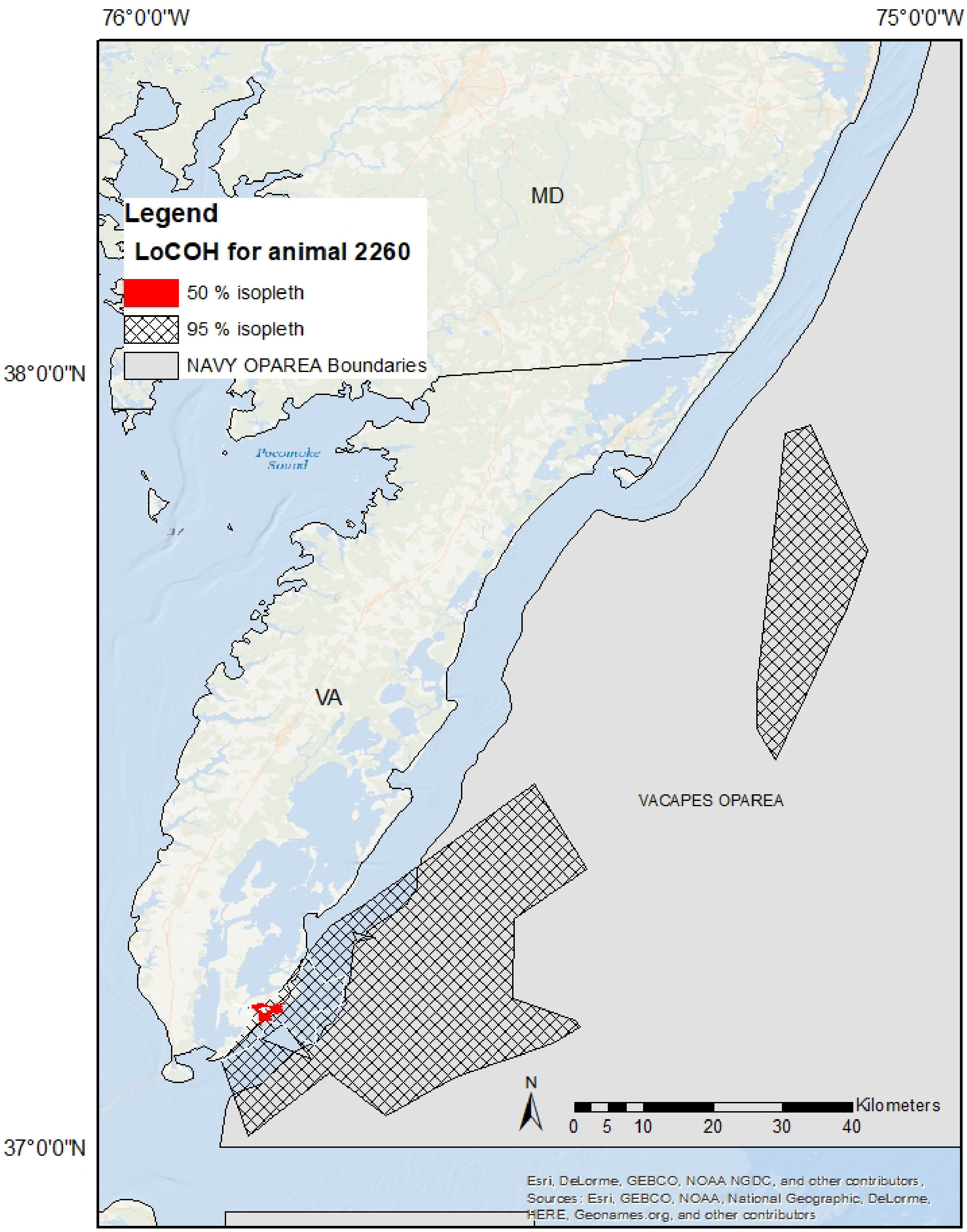

Figure 20. Habitat use map for seal 2260 (tag duration = 7 February through 8 June 2022) in relation to the Virginia Capes Range Complex (VACAPES) Operating Area (OPAREA). Red areas represent the 50 percent isopleth; hashmarked lined areas represent the 95 percent isopleth.

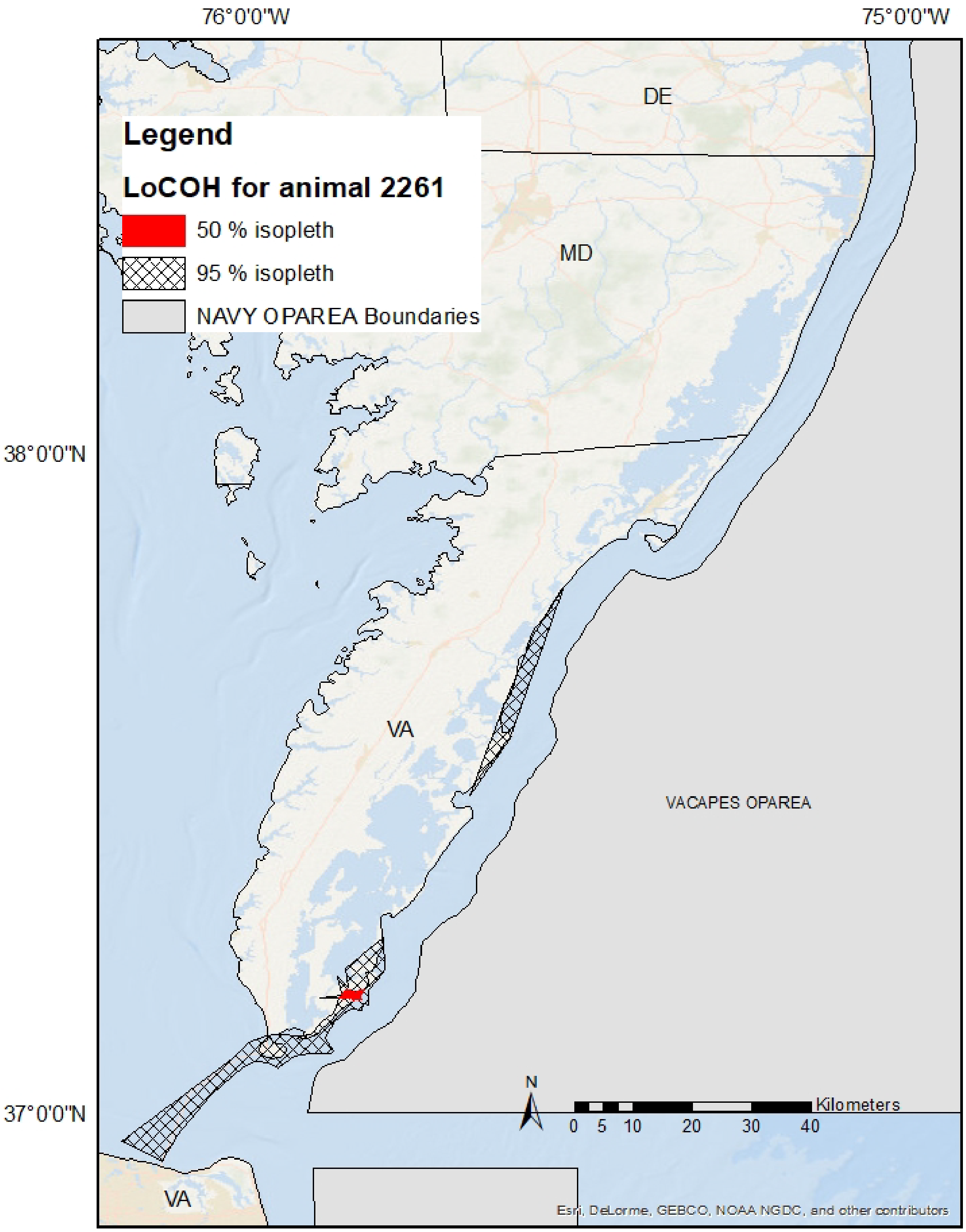

Figure 21. Habitat use map for seal 2261 (tag duration = 8 February through 17 June 2022) in relation to the Virginia Capes Range Complex (VACAPES) Operating Area (OPAREA). Red areas represent the 50 percent isopleth; hashmarked areas represent the 95 percent isopleth.

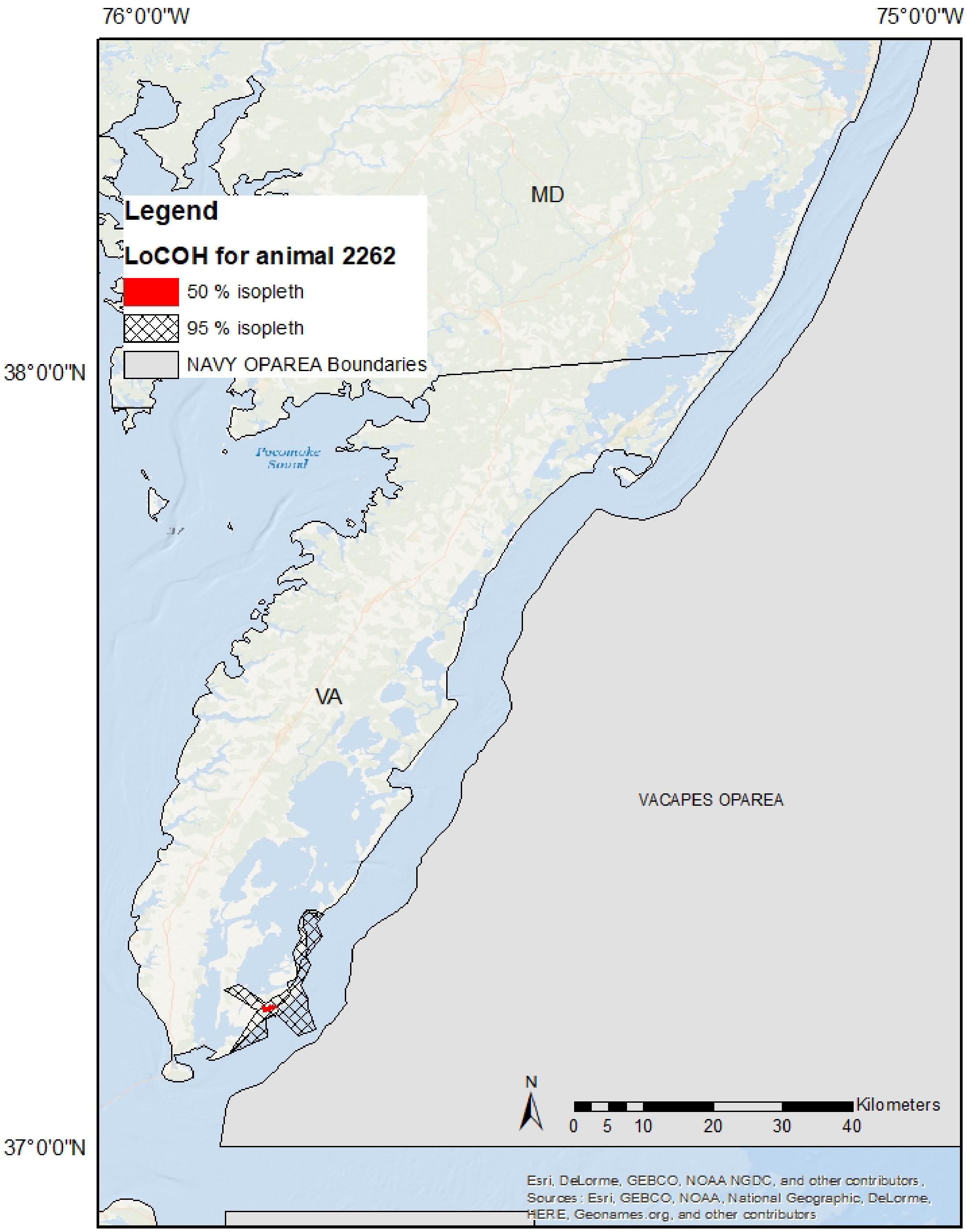

Figure 22. Habitat use map for seal 2262 (tag duration = 9 February through 18 July 2022) in relation to the Virginia Capes Range Complex (VACAPES) Operating Area (OPAREA). Red areas represent the 50 percent isopleth; hashmarked areas represent the 95 percent isopleth.

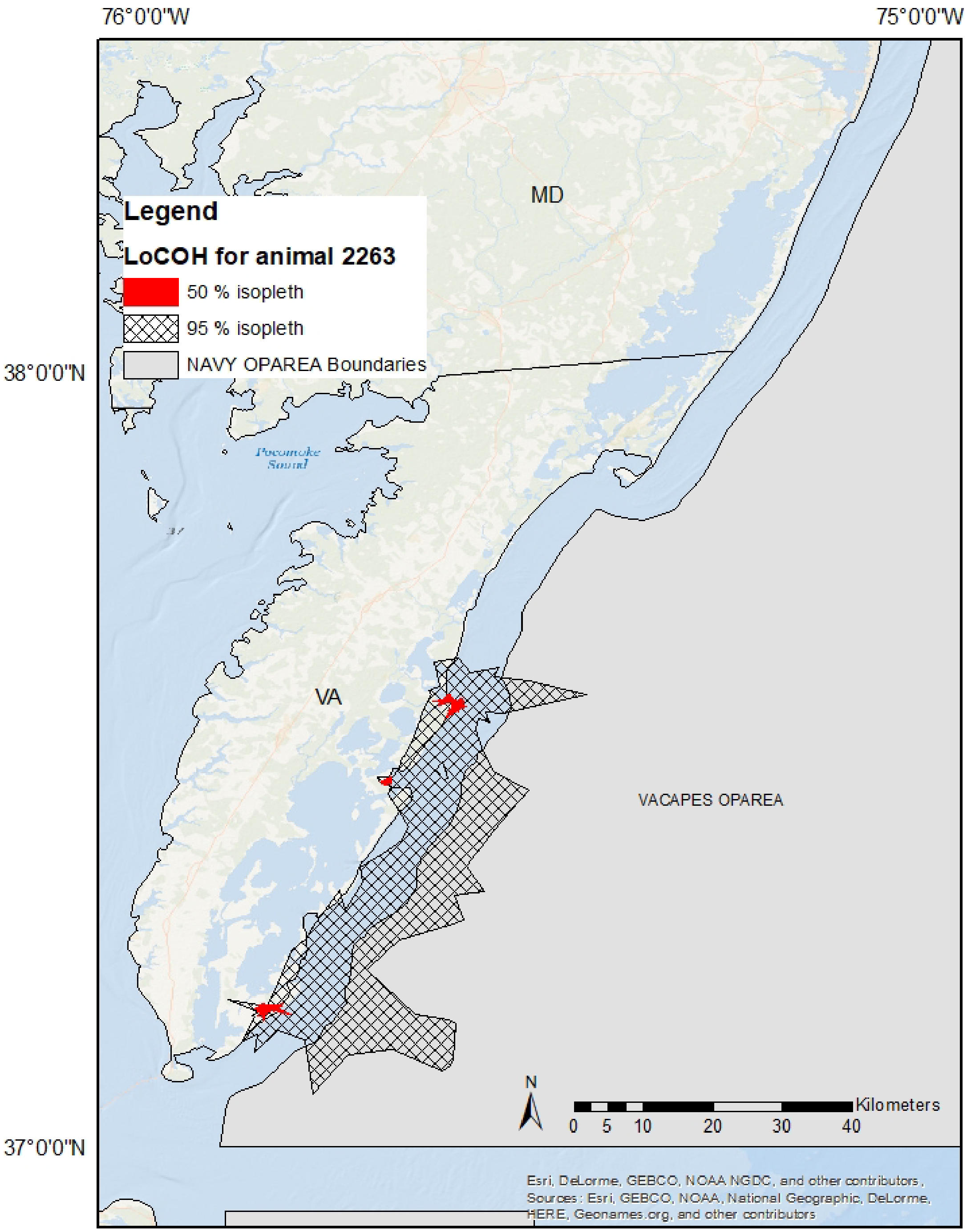

Figure 23. Habitat use map for seal 2263 (tag duration = 15 February through 4 June 2022) in relation to the Virginia Capes Range Complex (VACAPES) Operating Area (OPAREA). Red areas represent the 50 percent isopleth; hashmarked areas represent the 95 percent isopleth.

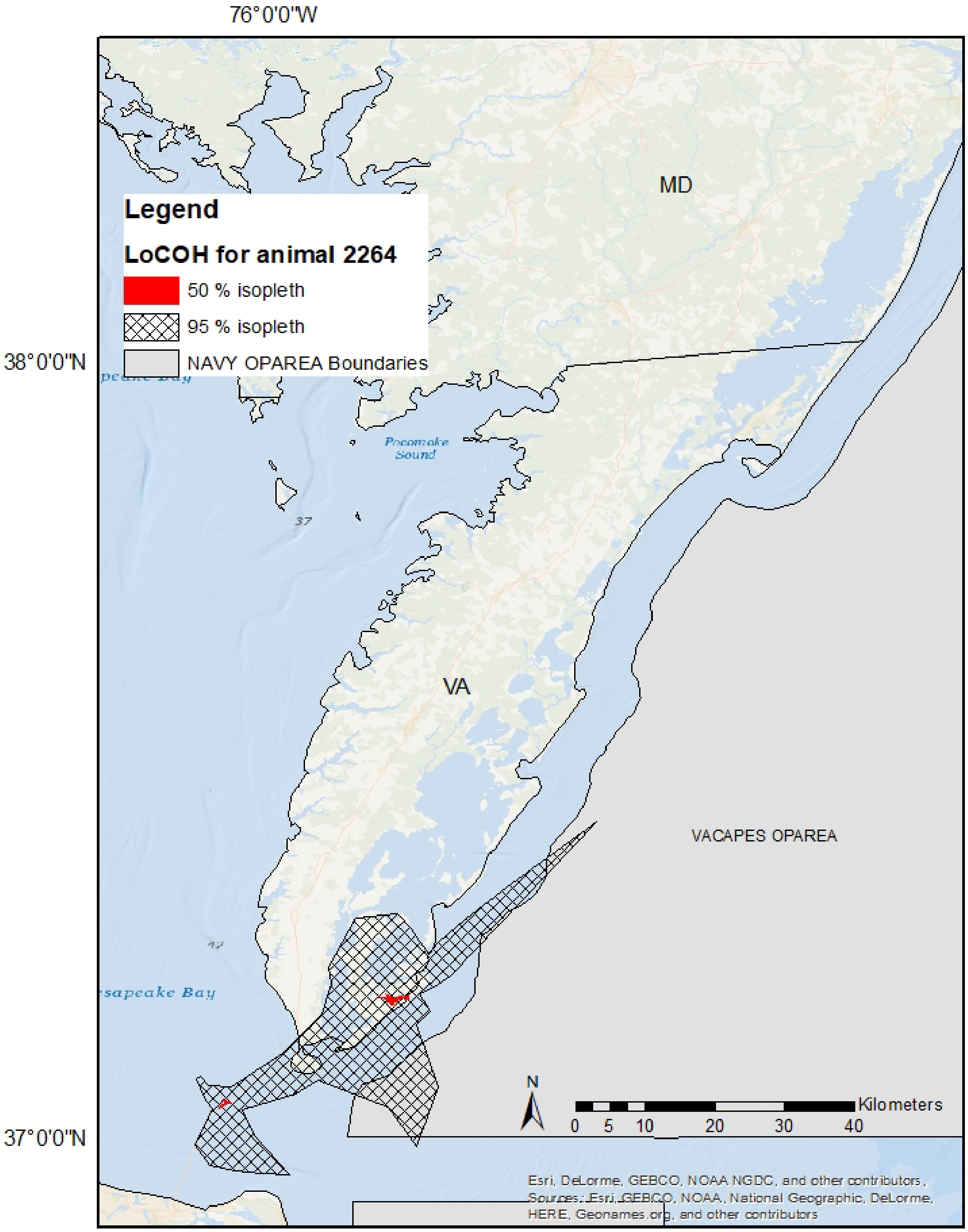

Figure 24. Habitat use map for seal 2264 (tag duration = 15 February through 25 May 2022) in relation to the Virginia Capes Range Complex (VACAPES) Operating Area (OPAREA). Red areas represent the 50 percent isopleth; hashmarked areas represent the 95 percent isopleth.

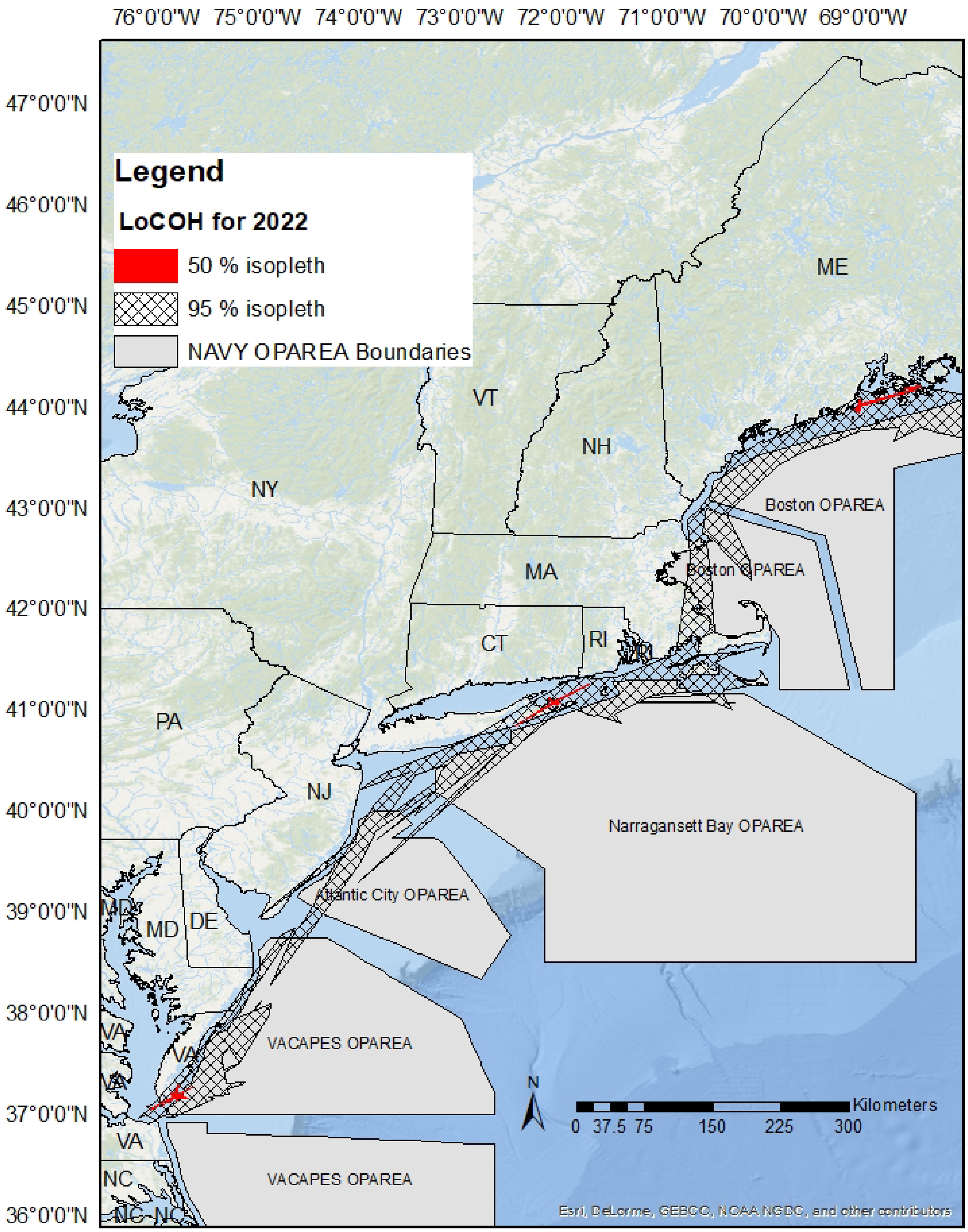

Figure 25. Habitat use map for seals tagged in 2022 (maximum tag duration = 160 days) in relation to Navy operating areas along the Eastern Seaboard. Red areas represent the 50 percent isopleth; hashmarked areas represent the 95 percent isopleth. OPAREA = Operating Area; Virginia Capes Range Complex (VACAPES).

3.5.2 2018, 2020, and 2022 Tags

Cumulative habitat use using likelihood predictions generated by the LoCoH analysis for all 14 seals tagged in 2018, 2020, and 2022 is shown in **Figures 26** and **27**. Based on the 95% isopleth intersection polygon, the 95% habitat-use isopleth extended into the eastern half of each OPAREA from VACAPES to Boston (**Figure 26**). In Virginia waters, tagged seals utilized both the Chesapeake Bay and offshore waters, although individual seals used this habitat differently (**Table 5**). All fourteen tagged seals had core habitat (i.e.,50% likelihood) near the Eastern Shore capture site, as well as farther north along the Eastern Shore near Hog Island and Parramore Island (**Figure 27**). Only a very small portion of the cumulative 50% isopleths, representing the seals home range/core habitat, overlapped with the VACAPES OPAREA (**Figure 27**). Tagged seals had a 95% likelihood of being in the lower Chesapeake Bay and utilizing the waters around the mouth of Chesapeake Bay. The 95% isopleths did overlap with the VACAPES OPAREA (**Figure 27**), with a concentration at the western edge (closest to the coast) of the northern half of the VACAPES OPAREA. The 95% isopleths also extended to the southern half of the VACAPES OPAREA offshore of North Carolina (**Figures 26** and **27**). Overall, seals spent a cumulative 669 days in Virginia waters, and on 158 of these days (24%) satellite tags reported locations within the VACAPES OPAREA. Note that seals' use of coastal areas as haul-out habitat results in several instances where the 95% isopleths extend over land.

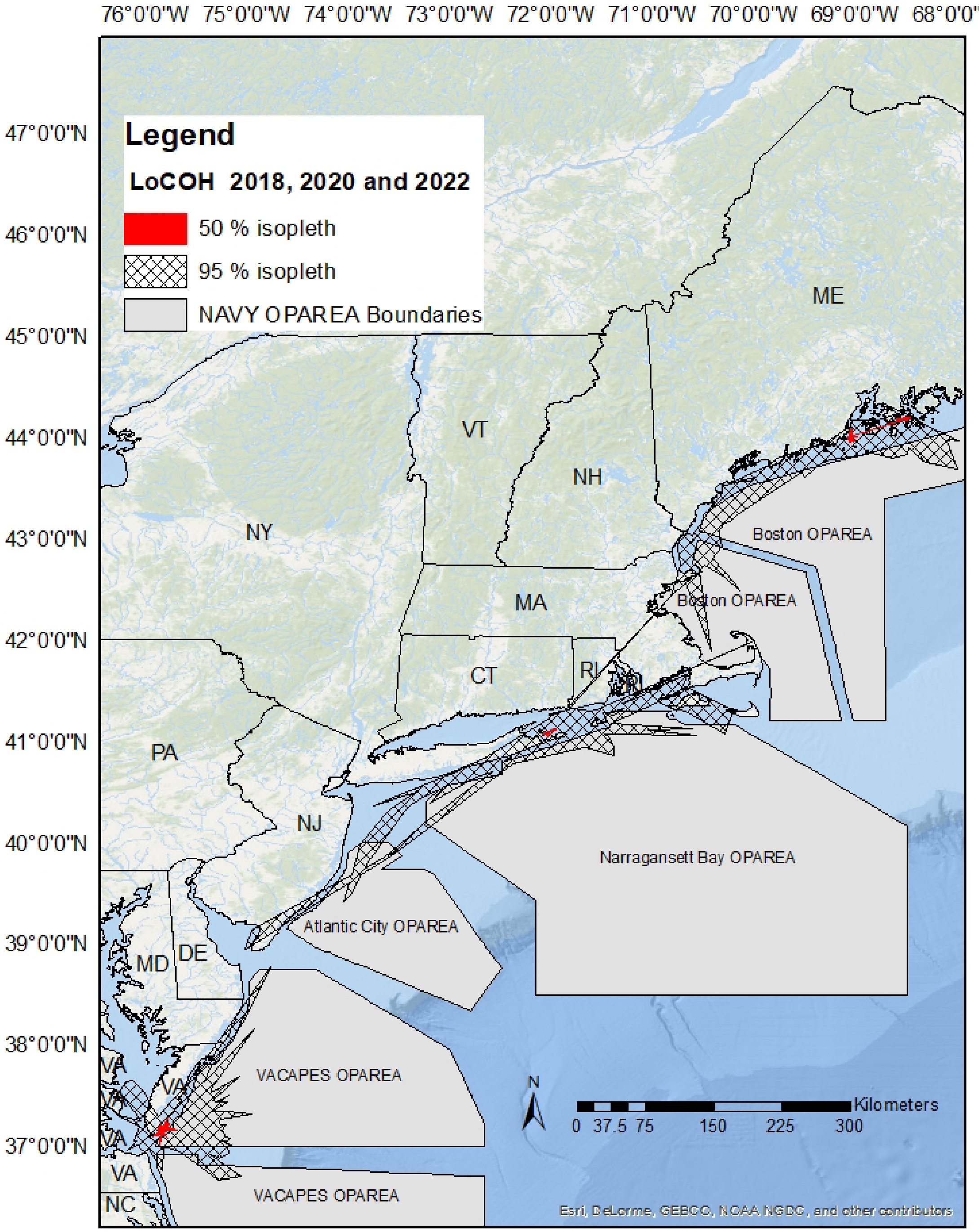

Figure 26. Habitat use map for all 14 harbor seals tagged in relation to Navy operating areas (OPAREA) along the Eastern Seaboard (maximum tag duration = 160 days). Red areas represent the 50 percent isopleth; hashmarked areas represent the 95 percent isopleth. OPAREA = Operating Area; Virginia Capes Range Complex (VACAPES).

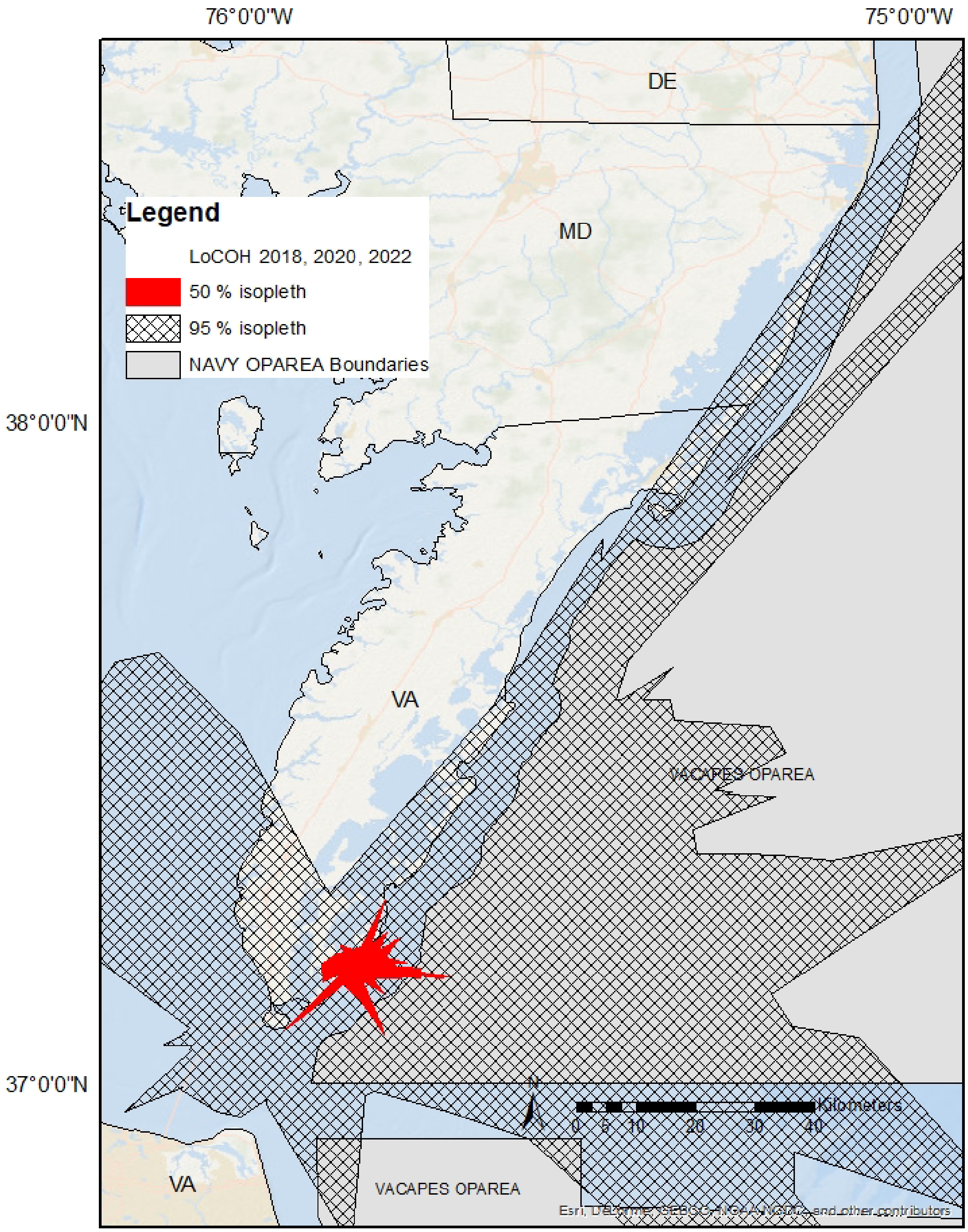

Figure 27. The cumulative habitat-use isopleths for all 14 tagged harbor seals in Virginia waters in relation to the VACAPES OPAREA. Red areas represent the 50 percent isopleth; hashmarked areas represent the 95 percent isopleth; OPAREA = Operating area; VACAPES = Virginia Capes Range Complex.

Consistent with habitat use patterns displayed by seals tagged on the Eastern Shore in previous years, the five seals tagged in 2022 showed distinct individual differences in their use of the coastal environment while in Virginia waters. Each seal made between 5 and 17 trips to and from the capture site during the time that the satellite tag was transmitting in Virginia waters (**Table 5**). These trips extended from 8 to 232 km away from the capture site and lasted from three hours to 6 days. Individual seals used offshore vs. estuarine waters differently (**Table 5**). Three seals (2260, 2262, and 2263) never made trips into the Chesapeake Bay (Figures 5, 7 and 8, respectively), while one seal (2261) stayed within Atlantic coastal waters and the lower Chesapeake Bay, but never visited offshore waters (**Figure 13**).

Table 3. Distance, duration, and number of all trips to and from the capture site made by all 14 tagged seals while in Virginia waters (trips were defined as travel >10 kilometers away from capture site).

Seal ID	MIN Travel Distance (km)	MAX Travel Distance (km)	MIN Travel Time (hours)	MAX Travel Time (hours)	Total Trips	Trips in Bay	Trips Offshore
2022							
2260	22	164	11	70	17	0	17
2261	21	92	12	78	5	5	0
2262	27	60	16	76	5	0	5
2263	8	232	3	88	15	0	15
2264	17	137	44	137	6	5	1
2020							
2001	21	115	12	70	11	5	6
2002	12	139	8	96	6	0	6
2018							
1801	27	88	9	340	7	1	6
1802	20	30	12	22	3	0	3
1803	13	61	1	86	8	1	7
1804	20	61	13	136	13	13	0
1805	13	60	13	133	6	5	1
1806	17	43	8	28	6	0	6
1807	34	104	38	166	13	0	13

Note: ID = identification; km = kilometers, MAX = maximum; MIN = minimum.

3.6 Health Assessments

As noted above, a full suite of blood and biological samples was collected from each tagged seal (**Table 2**). The complete blood count and chemistry panel results for all five tagged seals were within normal range for pinnipeds according to values published in Dierauf and Gulland (2001). Heart rates for each seal were monitored throughout the capture period and were within normal range. Evaluation of biological samples collected in 2022 is ongoing as part of a separate project (Northwest Atlantic Pinniped Health Assessments) which is a collaborative effort between regional laboratories and the Northeast Fisheries Science Center.

4. Discussion

This work is a continuation of seal tagging efforts in coastal Virginia first undertaken in 2017. Although findings are limited to the 14 individual seals tagged in this study to date, these data provide preliminary insight into the habitat use patterns and haul-out behavior of harbor seals in and near Navy training areas and installations in coastal Virginia, and along the Eastern Seaboard. All capture and tagging activities were performed under NMFS Scientific Research Permit #21719.

Seals tagged in 2022 showed a broadly similar spatial extent of seasonal movements as seals tagged in previous years (Ampela et al. 2019, 2021). In all three years, tagged seals traveled as far north as coastal Maine, and used similar haul-out areas in coastal New York and New England. For the majority of tagged seals, the haul-out sites in New York and southern New England appeared to be stop-overs during the northward migration. In Virginia waters, tagged seals utilized both the Chesapeake Bay and offshore waters (although individual seals used these areas differently, consistent with results from previous years), and exhibited site fidelity to the haul-out locations on the Eastern Shore and CBBT Islands. Habitat use analysis of all 14 seals included in this study indicated that the areas most heavily utilized by tagged seals in Virginia waters were near the Eastern Shore capture site, and farther north along the Eastern Shore. None of the cumulative 50% isopleths (i.e., core habitat) for tagged seals overlapped with the VACAPES OPAREA. Off New York and New England, the 50% isopleths for tagged seals were located on eastern Long Island and coastal Maine.

The 14 harbor seals tagged to date as part of this study represent a variety of age classes (defined as young of the year, juvenile, and adult) and overall have an even sex ratio (7:7). Phocid seals use coastal and marine habitats differently depending on age, sex, and breeding status (Breed et al. 2006, 2009, 2011). While the sample size from this study is still too small to understand how these factors may influence harbor seals' habitat use in and near areas of interest to the Navy, the information gathered to date has already improved our understanding of the demography of harbor seal movements along the Eastern Seaboard. Results from this study have demonstrated that adult harbor seals make long-distance seasonal movements through the mid-Atlantic and Gulf of Maine. Prior to this and other similar tagging studies, it was believed that the majority of seals moving into southern New England and mid-Atlantic waters were subadults and juveniles (Hayes et al. 2022). Based on morphometric measurements, nine of the 14 seals tagged during this study were estimated to be juveniles, one was estimated to be a young-of-the-year (YOY) pup, and four were estimated to be adults. Seven of the nine tagged juveniles reported locations in coastal Maine after moving northward from Virginia. The tags attached to the other two juveniles stopped reporting locations in southern New England, and the tag attached to the YOY stopped reporting while the animal was still in Virginia waters.

Harbor seal populations around the world are generally considered to be non-migratory, staying within approximately 50 km of their natal area (Bjørge et al. 1995; Frost et al. 1996; Swain et al. 1996; Ogilvie et al. 2009; Ross et al. 2013; NOAA Fisheries 2022). However, results from this and other tagging studies in the U.S. have documented regular, long-distance (>900 km) seasonal movements (Womble and Gende 2013), which could reasonably be viewed as migratory behavior. The near-extirpation, and subsequent (relatively recent) reintroduction, of pinnipeds in U.S. waters following the enactment of the MMPA in 1972, may play a role in the seasonal movement patterns of tagged harbor seals. That is, observed movements of seals such as those tagged in this study could represent a gradual recolonization of previous habitat (e.g., Wood et al. 2011) and/or exploration of new, suitable habitat, versus a true migratory pattern. If this is the case, then long-distance movements of these seals would be expected to diminish over time and for harbor seals to remain closer to their natal areas, possibly establishing pupping sites further south along the Eastern Seaboard. The influence of climate change on oceanographic conditions and prey distribution is also likely to drive the distribution and habitat use of Atlantic harbor seals. In addition, it should be noted that individual differences play a significant role in the habitat use and seasonal movements of phocid seals, as shown in this and other studies (e.g., LeBoeuf et al. 2000; Breed et al. 2009; Womble and Gende 2013), and therefore not all members of a population may be expected to migrate regardless of the factors outlined above. Understanding the various anthropogenic and ecological drivers of harbor seals' seasonal movements is therefore quite challenging and currently beyond the scope of this study.

5. Summary and Future Work

Additional tag deployments are planned for early 2023 at the same capture location. Future capture efforts will involve use of a modified seine net, similar to that used in previous years, in order to maximize the probability of capture success. Findings from this study will inform methods for future capture efforts at this location, with the goal of increasing the number of seal tags deployed. Up to 16 seals will be instrumented with a combination of GPS-enabled location-only and depth-sensing tags, with a focus on gathering detailed dive data to inform Navy analyses of anthropogenic sound on seals at varying depths in the water column and in offshore versus inshore habitats. Results from this work will further our understanding of harbor seals' movement patterns, dive behavior, and habitat use in relation to Navy training areas and installations in the mid-Atlantic and New England, allowing for more accurate assessments of the potential impacts on these animals from Navy activities. We note that a separate but related Navy-funded study is currently being conducted in coastal Rhode Island adjacent to the Narragansett Bay OPAREA to investigate the behavioral responses of harbor and gray seals to Navy training and testing activities (DeAngelis et al. 2022).

This project was a collaborative effort among a variety of organizations, and biological samples taken from captured seals were shared with a number of researchers who are investigating the health, diet, and genetic structure of harbor seals in the northwest Atlantic. These data can be used to help monitor population-level health status, particularly in the context of recent Unusual Mortality Events for the harbor and gray seal North Atlantic stocks, and in support of NOAA's Marine Mammal Health and Stranding Response program. Understanding the distribution and abundance, habitat use, survivorship, and health status of these seal populations can eventually provide the foundation for a range-wide ecosystem-based analysis. The results from this study have already contributed important new information about the fine-scale movements of harbor seals near the southern extent of their current range, as well as information about their long-range seasonal movements along the Eastern Seaboard. Future work will build on these findings and add to our knowledge of this relatively understudied population of harbor seals in U.S. waters.

6. Acknowledgements

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7. Literature Cited

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A

Appendix A
Sample Data Sheets

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Animal Information

NAVFAC ATLANTIC PINNIPED TAGGING 2022: Animal Information Datasheet

ANIMAL INFORMATION

Field #: NAVFAC2022___ ___ Date: ___________ Species: □ Harbor □ Grey Seal

Animal Sex: __________ Animal Sentinel:___________ GPS WP:______________

GPS Coordinates (where tagged): ______________°N, ________________°W

Team Lead:________ Data Recorder:__________ Restrainers: (H)_____(R)_____

HOLDING TIMES

Time Net Set:___________________

Time Out of Net:________________

Monitoring Time:_______________

Time Sampling Start:_____________

Time Epoxy Start: 1:_______ 2: ______

Time Lidocaine admin :_____________

Target Release Time (45min):________

Actual Release Time:______________

Total Time Sampled: ______________

MORPHOMETRICS

Weight with Net (Kg):________ Weight of Net:_______ Animal Weight:_______

Straight Length (cm):_________ Axillary Girth (cm):__________

TAGGING & SAMPLING

PRIORITY 1A: Sat Tag
Tagger:____________
PTT:
____
Time start mixing:_____
Time warm:__________
Time Hard:___________
☐ Tape removed

PRIORITY 1B: Flipper Tag
Tagger:_____________
Flipper Tag ID:
____
Flipper Tag Color:_____
☐ Left biopsy collected

Initial Heart Rate: ______________

PRIORITY 2: Bloods
Sampler:_____________
Bleed Site:
☐ Ex. intravertabral
☐ Hind flipper
Time: __________
#Sticks: (1-3):________
☐ Lg Lavender
☐ Red/Yellow
☐ Red/Black
☐ Green
☐ White
☐ Sm Lavender
☐ Other:___________

PRIORITY 3A: Swabs
Sampler:_____________
☐ Nasal L—VTM
☐ Nasal R—DRY
☐ Conjuctiva L-VTM
☐ Conjuctiva R-DRY
☐ Rectal VTM
☐ Rectal Dry

PRIORITY 3B: Other
Sampler:_____________
☐ Blubber sample
☐ Hair
☐ Whisker

PHOTOS

☐ Left Head- ☐ Right Head
☐ Sat Tag Num ☐ Sat Tag on Seal
☐ Flipper Tags ☐ Full body

Photo #:

NOTES:________________________
____
____
____
____
____
____
____
____

Date Data Entered:________________ **Entered By:**____________________ **Updated: 2/6/2022**

Environmental Conditions

Page ____ of ____

NAVFAC-Atlantic Pinniped Tagging 2022
Environmental Conditions
Location: Little Inlet

Date (ddmmyyyy)	Data Recorder	Start Time	End Time	Set #	Cloud Cover	Visibility	Beaufort Sea State	Tidal Height (ft)	Tidal State	Wind Speed (mph)	Wind Gusts (mph)	Wind Direction	Air Temp (°F)	Water Temp (°F)

COMMENTS

ENVIRONMENTAL KEY

Visibility		**Beaufort Sea State**					
1	Good (clear conditions, >10 km)	0	Glassy calm	3	Scattered whitecaps	6	All whitecaps
2	Moderate (partly obscured, 1.5-10 km	1	Light ripple	4	Small waves, frequent whitecaps	7	Breaking waves, spindrift
3	Bad (fully obscured, <1.5 km)	2	Small wavelets	5	Moderate waves, many whitecaps		

Net Log

Page 1 of ____

NAVFAC-Atlantic Pinniped Tagging 2022- Little Inlet

Date (ddmmyyyy)	Set Time	Haul Out Location	Set #	Seals 0 =No 1= Yes	# other species (Pv, Pg, Cc) Taken	# Pv Taken	# Caught	# Escap.	# Sampled	SI/Mort. 0 = No 1 = Yes	Notes / Photo numbers

COMMENTS

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B

Appendix B
Argos Filter Algorithm Parameters

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The Douglas Argos-Filter algorithm (DAF) offers three filtering methods of increasing complexity: (i) the 'maximum redundant distance' filter (MRD), which simply retains locations based on spatial redundancy between consecutive locations; (ii) the 'distance angle rate' filter (DAR), which retains spatially redundant locations and locations that pass movement rate and turning angle tests; and (iii) the 'hybrid' filter (HYB), which optimally combines the MRD and DAR results by extracting DAR outcomes only during migration periods and combines them with all MRD outcomes. When a user applies the DAF in Movebank, a new attribute called 'algorithm marked outlier' is added to the data set and the value 'true' is assigned to all filtered locations. The outlier attribute can be entirely removed at any time, and the DAF reapplied using a different method or different thresholds. Any filtering decision can be manually overruled on a case-by-case basis using tabular- and map-based interfaces. User-defined parameters and corresponding values applied in this analysis are listed in **Table B-1** and further described **Table B-2**.

Standard-quality animal tracking locations (Argos classes 3, 2 and 1) have larger errors than those reported in Argos manuals (Douglas et al. 2012). They are based on levels of accuracy: location class (LC) LC-3 with a stated error of less than 150 m, LC-2 with error of 150–350 m, LC-1 with error of 350–1000 m (Costa et al. 2010).[8] See KEEP_LC in **Table B-2**.

Table B-1. Douglas Advanced Research and Global Observation Satellite (Argos) Filter Algorithm parameters used to remove implausible locations.

Parameter	Value
filter method	best hybrid
keep_lc	3
maxredun	5
offset by one sec.	1
Filter Method	0
Keep last	0
skiploc	0
minrate	5000
r_only	1
ratecoef	25
xmigrate	1
xoverrun	50
xdirect	50
xangle	50
xpercent	50
testp_0a	0
testp_bz	1
best of day filter	0

From: Douglas et al. (2012).

[8] Costa, D.P., Robinson, P.W., Arnould, J.P.Y., Harrison, A-L., Simmons, S.E., et al. 2010. Accuracy of ARGOS Locations of Pinnipeds at-Sea Estimated Using Fastloc GPS. PLoS ONE 5(1):e8677. doi:10.1371/journal.pone.0008677

Table B-2. Supplemental Table. Annotated descriptions of the required and optional user-defined parameters for the Douglas Argos-Filter Algorithm.

Parameters required by all filters (MRD, DAR and HYB)

MAXREDUN (units=km; default=10): Near-consecutive locations within this distance threshold will be retained. Prescribe a larger value (e.g., 15–30) if results are to be interpreted at continental scales because larger location errors are tolerable, and more locations will be retained to inform temporal interpretations. Prescribe a smaller value (e.g., 2–5) if results are to be interpreted at local scales because overall location accuracy of the retained locations will be greater, however higher proportions of acceptable locations will be excluded.

KEEP_LC (categorical range Z, B, A, 0, 1, 2, 3; default=1): Locations with an Argos location class (LC) better or equal to the prescribed value are always retained. A primary goal of the Douglas Argos-Filter (DAF) is to improve the collective accuracy of low-quality Argos locations (classes 0, A, B and Z). Since average accuracy of the Argos standard-quality LC 1 is already greater or equivalent to most post-filtered low-quality LCs, prescribing the default value for KEEP_LC (=1) is a logical choice. Indeed, LC 1 locations do possess a broad error distribution, and if KEEP_LC=2 is applied, the DAF will exclude many of the more erroneous LC 1 locations but often at the expense of excluding a high proportion of useful LC 1 locations.

Optional parameters for the MRD filter

KEEPLAST (enabled, disabled; default=disabled): When enabled, the last location for each animal is unconditionally retained. Last locations are important for ascertaining an animal's final destination but often of low quality due to PTT age. If KEEPLAST is enabled, the user should manually validate each animal's last location.

SKIPLOC (enabled, disabled; default=disabled): The MRD filter evaluates triplets of consecutive locations, A→B→C. If the middle location (B) is rejected, should it be considered again as the first location of the next triplet B→C→D, or should it be 'skipped' so the next triplet is C→D→E? SKIPLOC=disabled is a more liberal filtering choice and will retain more locations than SKIPLOC=enabled.

Parameters required by the DAR filter

MINRATE (units=km/hr; default=50): Maximum sustained rate of movement over a period of several hours, including enhanced velocities due to assisting winds or currents. Values of at least 80-120 are appropriate for birds; lower values risk excluding in-flight locations. Values ranging 5-15 are typical for marine and terrestrial animals. Modest errors among plausible locations can sometimes inflate tracking velocities, so MINRATE should be prescribed somewhat liberally.

RATECOEF (unitless; default=25): A scaling coefficient within a synthetically constructed equation that controls the threshold for evaluating the internal turning angle formed by 3 consecutive locations. Empirically, the equation was designed such that RATECOEF values ranging from 10–40 will afford reasonable filtering outcomes. Prescribe a lower RATECOEF (i.e., 10) for animals thought to move in very circuitous patterns, or a higher value (i.e., 40) for animals thought to adhere to highly directional movement.

R_ONLY (enabled, disabled; default=disabled): If enabled, then the turning angle test within the DAR filter is disabled. Enabling R_ONLY might be justified for animals that are known to frequently alternate between two locales, such as repeatedly visiting a foraging area and returning to a nest site. Beware that such 'out and back' behavior emulates the classic signature of inaccurate Argos locations, so if R_ONLY is enabled, it is incumbent on the user to critically review the filtered results and manually differentiate between real and erroneous 'out and back' movement patterns.

Parameters required by the HYB filter

XMIGRATE (scaling factor; default=2): Controls whether a movement between two consecutive locations that were retained by the MRD filter (the MRD origin and MRD destination locations) is considered a migration event. If length of the MRD movement is greater than XMIGRATE × MAXREDUN, then the MRD movement is considered a migration event and all temporally intervening locations that passed the DAR filter (DAR locations) will be evaluated (individually) for membership in the HYB output based on the 6 parameters below.

XOVERRUN (scaling factor; default=1.5): If distance from the MRD origin location to the intervening DAR location is greater than the MRD movement length plus XOVERRUN × MAXREDUN, then the DAR location is not included in the HYB output. This test attempts to prohibit an animal from 'overshooting' the MRD destination.

XDIRECT (units=degrees; default=20): One of three directionality tests. If the difference between the departure azimuth to the intervening DAR location and the departure azimuth to the MRD destination is greater than XDIRECT, the test is failed.

XANGLE (units=degrees; default=150): One of three directionality tests. If the internal turning angle formed by the MRD origin, the intervening DAR location, and the MRD destination is less than XANGLE, the test is failed.

XPERCENT (units=percent; default=20): One of three directionality tests. If the distance to travel from the MRD origin to the MRD destination via the intervening DAR location is greater by XPERCENT or more than the MRD vector length, the test is failed.

TESTP_0A (range 1–3; default=2): If the intervening DAR location is Argos LC 0 or LC A, then TESTP_0A of the three directionality tests (above) must be passed for membership in the HYB output.

TESTP_BZ (range 1–3; default=3): If the intervening DAR location is LC B or LC Z, then TESTP_BZ of the three directionality tests (above) must be passed for membership in the HYB output.

Optional parameters for creating a 'Best of Day' subset

PICKDAY (enabled, disabled; default=disabled): When enabled, the highest-quality post-filtering location per GMT day will be selected for membership in the 'Best of Day' subset.

MINOFFH (units=hours; default=8): Used for selecting 'Best of Day' locations based on PTT duty cycles rather than GMT days. Only relevant if PICKDAY is disabled. MINOFFH can be any value that is larger than the longest duty cycle on-period and slightly less than the shortest duty cycle off-period. If any duty cycle on-period is greater than 12 hours, then PICKDAY must be used.

RANKMETH (categorical options 1, 2, or 3; default=1): Establishes the rank order of metrics that are used to pick the highest quality location per GMT day (or per duty cycle). The Argos LC is always used as the highest ranked criteria. In the event of a tie, other variables from the Argos DIAG data are considered, specifically the number of messages collected during the satellite overpass (NBMES) and the IQX and IQY variables which provide information about the PTT's frequency stability. Option #1 uses LC, IQX, IQY, and NBMES; Option #2 uses LC, IQX, NBMES, and IQY; and Option #3 uses LC and NBMES.