Haul-out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay and Eastern Shore, Virginia: 2021/2022 Annual Progress Report

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Cover Photo Credit:

Harbor seals (*Phoca vitulina*) and a gray seal (*Halichoerus grypus atlantica*) hauled out at a survey site on the Eastern Shore, Virginia. Cover photo taken by Danielle Jones, Naval Facilities Engineering Systems Command Atlantic, under NMFS General Authorization Permit #19826.

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Acronyms and Abbreviations

ANOVA	analysis of variance
BSS	Beaufort sea state
CBBT	Chesapeake Bay Bridge Tunnel
CI	Confidence Interval
DWR	Virginia Department of Wildlife Resources
°F	degrees Fahrenheit
ft	foot or feet
GA	General Authorization for Scientific Research
Hg	Gray seal (*Halichoerus grypus atlantica)*
ID	Identification or identifier
km	kilometer(s)
kts	knots
m	meter(s)
MLLW	Mean lower low water
mm	millimeter(s)
NAVFAC LANT	Naval Facilities Engineering Systems Command Atlantic
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
Photo-ID	Photo identification
Pv	Harbor seal (*Phoca vitulina)*
SAR	Stock Assessment Report
TNC	The Nature Conservancy
U.S.	United States
UAS	Unmanned aircraft systems
UME	Unusual mortality event
USFF	United States Fleet Forces Command

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1. Introduction and Background

Harbor seals (*Phoca vitulina*) are one of the world's most widely distributed pinniped species and are found in temperate to polar coastal waters of the northern hemisphere (Jefferson et al. 2015). Gray seals (*Halichoerus grypus atlantica*) are widely distributed over the continental shelf in cold temperate and sub-polar North Atlantic waters (Lesage and Hammill 2001). Both species are year-round coastal inhabitants in eastern Canada and New England, and occur seasonally in the mid-Atlantic United States (U.S.) between September and May (Hayes et al. 2022). Individuals of both species move to northern areas for mating and pupping in the spring and summer, and return to southerly areas in the fall and winter. Harbor seals generally exhibit a southward movement from Maine and eastern Canada to southern New England and through the mid-Atlantic beginning in the fall (DeAngelis 2023; Rosenfeld et al. 1988).

Until 2018, National Oceanic and Atmospheric Administration (NOAA) Stock Assessment Reports (SARs) indicated that the gray seal and harbor seal populations range from Labrador to New Jersey; with scattered sightings and strandings reported as far south as North Carolina for gray seals and Florida for harbor seals (Hayes et al. 2018). Other researchers have reported that harbor and gray seal distribution along the U.S. Atlantic coast appears to be expanding or shifting (den Heyer et al. 2021; DiGiovianni et al. 2011; Johnston et al. 2015; DiGiovianni et al. 2018). In Virginia, reports from local anglers, Chesapeake Bay Bridge Tunnel (CBBT) staff, and the Virginia Aquarium & Marine Science Center indicated that seals have been using the CBBT rock armor or "islands" to haul out on for more than a decade. Additionally, pinniped stranding numbers have generally increased in Virginia since the early 1990s, with 2020 being a lower than average stranding year (Costidis et al. 2021). The range expansion of the harbor seal is not necessarily indicative of an increasing population; recent population trends and abundance estimates suggest the population is stable (Hayes et al. 2022; Sigourney et al. 2021). Rather, it may be due to rapid growth of gray seal populations in Canada (e.g., Sable Island) and now the Northeastern U.S. (den Heyer et al. 2021; Wood et al. 2022), which could be causing the displacement of harbor seals at haul-out sites due to physical interference or competitive exclusion (Cammen et al. 2018; Pace et al. 2019; Wood et al. 2019). Substantial increases in gray seal populations in Canada and the United Kingdom have been known to negatively impact harbor seal abundance in those areas (Bowen et al. 2003; Thompson et al. 2019).

Within the last decade, harbor seals have been observed returning seasonally, from fall to spring, to haul-out (resting) locations in coastal Virginia, and gray seals are occasionally observed during the winter, but not on a consistent basis (Ampela et al. 2023; Jones and Rees 2022). More recently, NOAA SARs indicate the southern extent for the harbor seal population range is now North Carolina. However, the geographic range for the gray seal population remains the same (Hayes et al. 2022).

Since this project's commencement, there have been eight dedicated field seasons of research from 2014-2022. During this time, we have expanded the study to include partnerships with The Nature Conservancy (TNC) and the Virginia Department of Wildlife Resources (DWR), as well as Contractor support from HDR, Inc., which allowed for an increase in survey area coverage beginning in 2016.

The goal of this study is to document the presence and abundance of seals in Virginia and to gain an increased understanding of the seasonal occurrence, habitat use and haul-out patterns of seals near several important U.S. Navy installations, training and testing areas, and vessel transit routes. This report discusses the survey results for the 2021/2022 field season as well as the analyses conducted using data from all eight field seasons.

Primary objectives of this project include:

- *assessing occurrence, movement, and haul-out patterns adjacent to Navy training and testing areas;*
- *the use of photo-identification methods to identify and compare individuals and assess site fidelity among haul-out site locations in the study area; and*
- *the use of mark-recapture, telemetry correction factor, and modeling methods to estimate local population size.*

This work is part of the United States Fleet Forces Command (USFF) marine species monitoring program and is conducted in accordance with National Marine Fisheries Service (NMFS) General Authorizations (GA) 19826 and 25811. The data collected under this effort is being used to analyze and estimate potential impacts that U.S. Navy training and testing, installation construction (e.g. pile driving), and vessel-transiting activities may have on pinniped species and to develop mitigation options if appropriate.

2. Methods

2.1 Study Area

The study area consists of two general survey locations in southeastern Virginia (**Figure 1**): 1) in the lower Chesapeake Bay along the Chesapeake Bay Bridge Tunnel (CBBT) – from 2014 to present, and 2) on the southern tip of the Eastern Shore – from 2016 to present. The CBBT survey area is comprised of four haul-out sites (referred to as CBBT 1, CBBT 2, CBBT 3, and CBBT 4) along the bridge tunnel that span approximately 10 kilometers (km) from the most southern site (CBBT 1) to the most northern site (CBBT 4). The haul-out sites are on rock armor formations (commonly referred to as “islands”), which are intended to protect the tunnels as they go beneath the water (**Figure 2**).

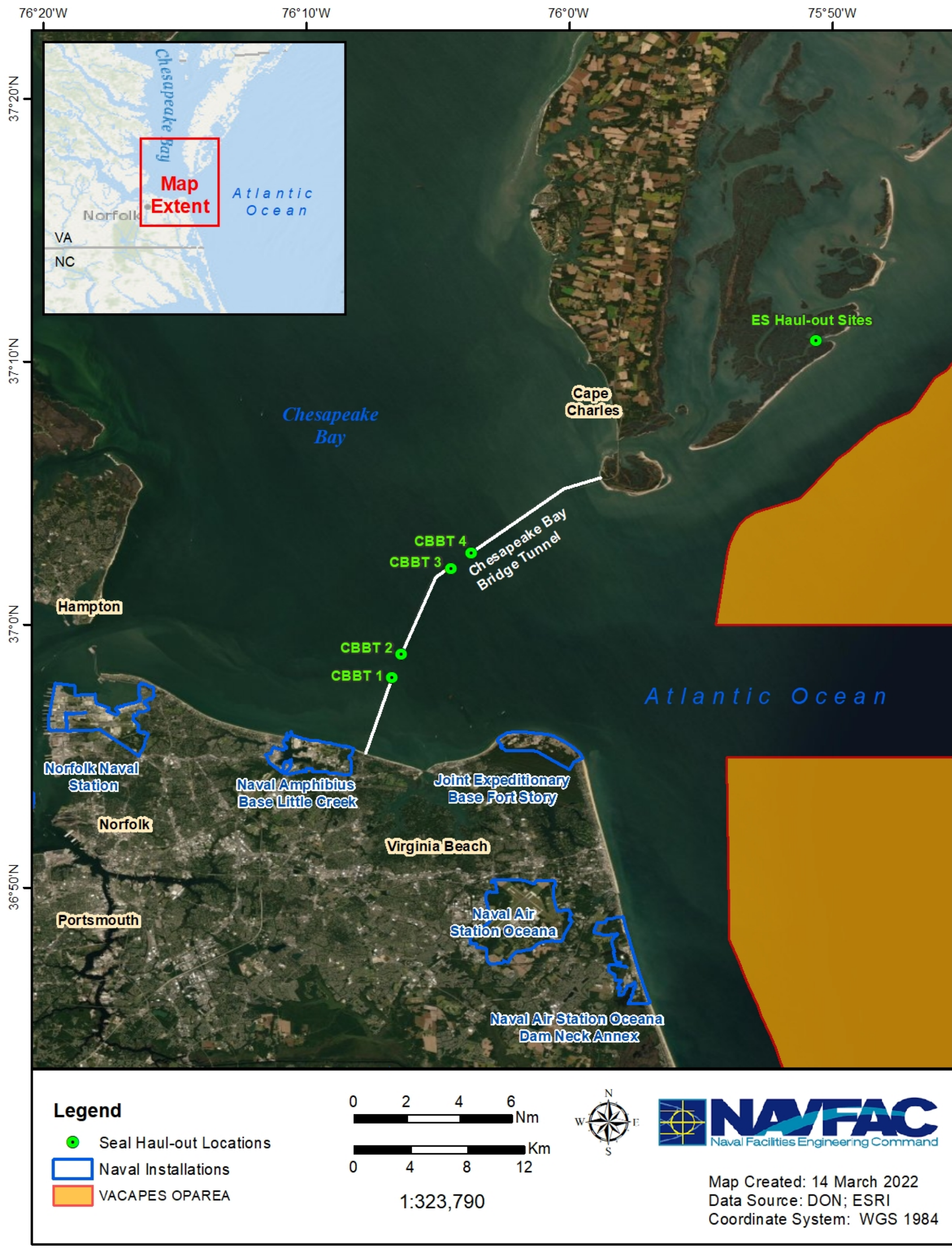

Figure 1. CBBT and Eastern Shore (ES) haul-out locations and their proximity to U.S. Naval Installations. OPAREA = Operating Area; VACAPES= Virginia Capes Range Complex.

Figure 2. Aerial view of a CBBT haul-out site. Seals generally haul out on the tip of the rock armor farthest from the road. Photo by Virginia Aquarium & Marine Science Center Foundation

The survey area on the Eastern Shore of Virginia was added to the project in the fall of 2016 in collaboration with TNC. The Eastern Shore survey area has several haul-out sites (about five main locations: A, B, C, D, and E) where seals have been observed (**Figure 3**). The haul-out sites are within a tidal salt marsh habitat, and are mainly comprised of mud banks with vegetation (**Figure 4**).

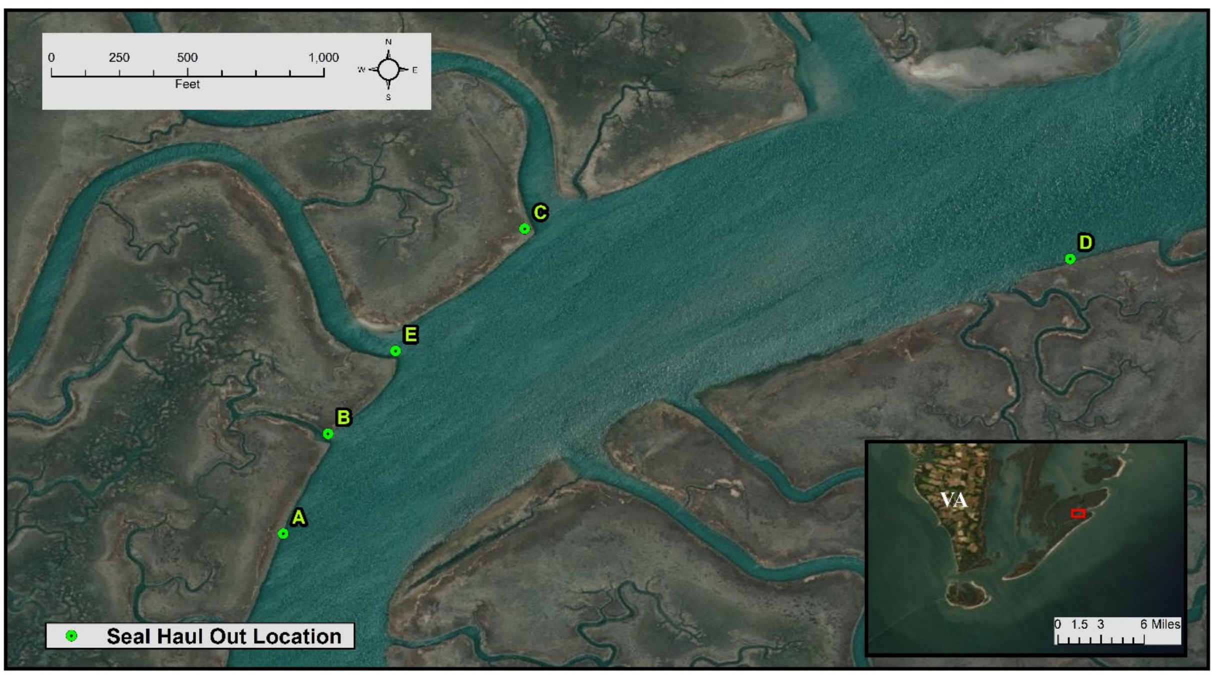

Figure 3. The five main seal haul-out locations on the Eastern Shore of Virginia

Figure 4. Eastern Shore survey area with harbor seals hauled out on a mud bank. Photo by Danielle Jones, NAVFAC Atlantic under NMFS GA Permit #19826

The straight line distance from the northernmost (i.e., the closest) CBBT haul-out site, CBBT 4, to the Eastern Shore survey area is approximately 27 km. Both survey areas are in close proximity (<100 km) to several major U.S. Navy installations (e.g., Norfolk Naval Station, Naval Amphibious Base-Little Creek, Joint Expeditionary Base-Fort Story, Naval Air Station Oceana, and Naval Air Station Oceana Dam Neck Annex) (**Figure 1**).

2.2 Survey Protocol

For each field season, dedicated seal haul-out surveys started in the fall (October/November) and ended in the spring (April/May). Based on sightings/stranding data, seals generally begin to arrive in Virginia in November, and depart the area by May, at the latest. Therefore, we started surveys in the fall, at least two weeks prior to previously recorded presence for that time period. We ended the surveys in the spring, conducting at least one additional survey at each survey area after the first recorded absence of seals. This allowed for the documentation of the arrival and departure time period for the season.

For the 2021/2022 field season, systematic vessel-based counts were conducted with support from HDR, Inc. for the CBBT survey area and with TNC for the Eastern Shore survey area. The vessel surveys at the CBBT survey area were conducted using a 27-foot (ft) fiberglass hybrid-foam-collar boat or a 30-ft center console Sea Hunt boat, and the vessel surveys at the Eastern Shore survey area were conducted using a 19, 23, or 24-ft Carolina skiff (**Figure 5**). The survey crew consisted of one or two marine mammal observers, one data recorder, and one boat captain.

Figure 5. Observers used a Carolina skiff (vessel) for the Eastern Shore haul-out counts. Photo by NAVFAC Atlantic

We aimed to conduct vessel surveys at the CBBT and Eastern Shore survey areas at least two times per month during the field season. The number of survey days were dependent on weather, tides, and staff/survey vessel availability. Surveys were not conducted at either of the CBBT or Eastern Shore survey areas during inclement weather such as precipitation or high winds. Vessel-based counts at the CBBT and Eastern Shore survey areas were not conducted in Beaufort sea states higher than 3. With vessel access to the Eastern Shore survey area being restricted by tides, we were only able to conduct surveys during tidal heights of 0.1 ft (Mean Lower Low Water [MLLW]) or higher at that location.

Seals were recorded at each haul-out site using point sampling techniques (Raposa and Dapp 2009). The survey period consisted of three separate 2-minute counts (10 minutes apart) at each site to account for seals moving between the water and the haul-out sites or diving during a previous count. Counts were conducted using hand held binoculars (Fujinon 7x50 MTRC-SX or Canon 10x30 IS II Image Stabilizer). During each sampling period, the data recorder documented the survey start and end times, each count start time, the number of seals present, the species present, photo numbers, standardized animal behaviors and the presence of vessels at the site. The best estimate of seals in the water and hauled out was recorded separately during each count. For analysis purposes, the best total estimate (i.e., the highest count from all three counts) for the overall number of seals sighted (both in the water and hauled out) was used, consistent with similar studies by Grellier et al. (1996) and Pauli and Terhune (1987). Unless otherwise specified, seal count data should be interpreted as the best total estimate of seals present during the survey period.

During the 8-minute between-count breaks, one of the observers obtained images of the seals. A master photo capturing all of the seals on a haul-out was taken, along with photos of individual seals. A digital single-lens reflect camera (Nikon D90 or D7100) with a zoom lens (ranging in size from 70-600 millimeter [mm]) was used to capture photos. A 1.4x TC-1401 teleconverter was occasionally used to increase focal length of the lens and increase photo quality. Image frame numbers were recorded in order to be used later for photo-identification (photo-ID). Multiple photos of different views (head/neck region, dorsal, lateral, and ventral) of each seal were taken when possible in order to obtain quality photos of pelage (fur) patterns.

In the 2018/2019 season, we added the use of an unmanned aircraft system (UAS), i.e., drone, for the Eastern Shore survey area to help improve count data collected during vessel-based point counts. Depending on the haul-out site at this survey area, animals may be obscured to observers during vessel-based counts by creek banks, marsh vegetation and other animals, especially as the number of animals present in the survey area increases throughout the winter. The UAS provides a better visual perspective from which to capture photos and video as it allows for visual detection of all animals on a haul-out site during point counts (animals are less likely to be obscured if viewed from above), which should increase the accuracy of counts.

The UAS, a DJI Matrice 300 quadrocopter with a Zenmuse X5 camera and Olympus 14-44mm zoom lens, was piloted by a certified UAS operator from TNC. The UAS was launched from the marsh or survey vessel, which was either idle on the water or anchored on a marsh bank, at about 800 meters (m) away from the haul-out survey area. The UAS was flown at an altitude of 60-120 m above ground level and at least 100 m away from a haul-out site. One UAS flight was comparable to a 2-minute count, since the UAS hovered over the haul-out sites and the camera was able to capture the same survey area as the observer team during a count. The UAS was only used in good weather conditions (e.g., no precipitation and winds less than 15 knots [kts]). For surveys where weather conditions were favorable, a count using the UAS was conducted by the pilot first followed by a vessel-based count by the observers. The animal count from the UAS footage was recorded after the vessel-based count in order to prevent bias in the data. For analysis purposes, the number of seals recorded during a drone count was compared to the counts recorded by the observers during the vessel surveys and considered for determining the best total estimate of the overall number of seals sighted (both in the water and hauled out) during a survey.

Environmental data were recorded prior to the start of each survey at each of the haul-out sites and later downloaded from the National Oceanic and Atmospheric Association's (NOAA) Tides & Currents page (https://tidesandcurrents.noaa.gov/). Data were collected on the following environmental variables: air temperature (˚F), water temperature (˚F), wind speed (kts), wind direction (cardinal and degrees), wind gusts (kts), visibility, tidal height (ft) (MLLW), Beaufort sea state (BSS), glare (%), and cloud cover (%).

Similar to previous field seasons, environmental data, with the exception of visibility, BSS, cloud cover, and glare were acquired from several NOAA weather stations for the 2021/2022 season. For the CBBT survey area, environmental data (with the exception of water temperature) were collected from NOAA weather station (ID 8638901) - CBBT, Chesapeake Channel, located at 37.032 N, 76.083 W. Water temperature for the CBBT survey area was collected from NOAA weather station (ID 8632200) - Kiptopeke, Virginia, located at 37.165 N, 75.988 W, due to the water sensor from the CBBT, Chesapeake Channel station being disabled. Looking at the average monthly water temperatures for the previous field seasons (2014-2017), the averages at the Kiptopeke station differed by only 1-2 degrees compared to the CBBT, Chesapeake Channel station, and so data was representative of the CBBT survey area. For the Eastern

Shore survey area, environmental data were collected from the Kiptopeke and CBBT, Chesapeake Channel stations as well as NOAA weather station (ID 8631874) - Smith Island (Coast Guard Station), Virginia (via https://tides4fishing.com), located at 37.117 N, 75.917 W. Environmental data may be used to investigate relationships between seal presence and environmental variables in future reports.

2.3 Photo Identification (Photo-ID)

Upon returning from the field, images were cropped and graded based on photographic quality and distinctiveness of the pelage pattern (**Table 1**). Image criteria was based on image grading methods used by Balmer et al. (2008) and Forcada and Aguilar (2000). In order to standardize methods for photo-ID across similar projects, and attempt to uniquely identify more individual seals, the photo-ID criteria (see below) was updated after the 2015/2016 progress report (Rees et al. 2016). All photos have been reassessed using these new criteria, and consequently images from the 2014/2015 field season were not included as they did not meet the quality standards of the updated methods. Therefore, individuals from this study were not identified until the 2015/2016 field season. In addition, images were obtained for the years 2010-2015 from Brian Lockwood, Jet Ski Fishing & Adventures. Many seals in these mostly earlier images have been matched to individuals identified in this study, providing valuable historical occurrence and site fidelity information. The Lockwood photos were not utilized in our analyses, as they were not collected under similar standardized survey protocols.

The photographic quality rating (Q1-Q4) focused on clarity, image resolution, glare/lighting, distortion, angle of the animal from the camera, the posture of the animal, and the proportion of the animal's body captured within the image. A Q1 signified an excellent photo fully suitable for manual or computer aided photo identification, whereas, a Q4 represented a photo with a quality too poor to reliably conduct photo-ID using either computer software or through manual matching. The distinctiveness rating (D1-D3) focused on the distinctiveness of pelage patterns and/or unique markings/scarring of an animal.

Table 1. Image criteria and grading for photo identification

Image Grade	Criteria
Quality	
Q1	Excellent photo, sharp focus, no glare, animal perpendicular to camera, majority (>/= 75% of) of side of seal captured, and/or fully wet pelage
Q2	Good photo, minimal glare, minor bending of animal, 50-75% of seal captured, and/or mostly wet pelage
Q3	Marginal photo, mediocre focus, moderate glare and bending of animal, 25-50% of seal captured, and/or partially dry pelage
Q4	Poor photo, limited focus, substantial glare, shading, or bending, <25% of animal captured, and/or fully dry pelage
Distinctiveness	
D1	Very distinct, large and numerous marks, visible scars, and/or 3+ very characteristic marks apparent even in poor quality photos
D2	Moderately distinct, 1-2 characteristic marks or some, but limited, distinctive patterning
D3	Indistinct, uniform pelage and no distinct markings

Using the quality and distinctiveness grades for images, a catalog of uniquely identified seals was compiled. Photos with a Q1-Q3 grade, along with a distinctiveness grade of D1-D2, were given a unique ID number (e.g., CB001) and added to a Microsoft Excel catalog and seal ID database for the study area. The resulting uniquely identified individuals were used to determine population abundance of harbor seals within the study area (Section 2.4.2 [Abundance Estimation]). For each photo included in the catalog, standardized descriptions were applied for pelage color patterns (i.e., color phase), which allowed for greater ease in manual matching by creating documented categories of images from which to match. The color phases in which the photos were categorized were the following: light (light background with no to a few/faint spots), intermediate (light background with dark spots), dark (dark background with many light-colored spots/rings), light/intermediate (seal pelage with two distinct light and intermediate color phases), and dark/light (seal pelage with two distinct light and dark color phases).

Fields included within the database are survey date, location, original photo image name, unique seal ID, file name, species, quality rating, distinctiveness rating, aspect (portion of seal's body that was captured), color phase, notable markings, and additional comments. The catalog allows for the sorting and processing of seal photos in order to compare and identify individual seals, using visual matching, for the mark-recapture portion of the study. Photos were reviewed through the use of this catalog and captured (i.e., marked) and re-captured (i.e., re-sighted) seals were identified and recorded in the seal identification database. Movement of some of the identified seals has been observed between the CBBT and Eastern Shore survey areas. Therefore, mark-recapture data from both survey areas were included to estimate a minimum population size for the region.

2.4 Analytical Methods

2.4.1 Analysis of Seal Presence

Mean seal count was compared between the eight field seasons (2014/2015, 2015/2016, 2016/2017, 2017/2018, 2018/2019, 2019/2020, 2020/2021, and 2021/2022) for the CBBT survey area using a one-way analysis of variance (ANOVA). Mean seal count was also compared between the six field seasons (2016/2017, 2017/2018, 2018/2019, 2019/2020, 2020/2021, and 2021/2022) for the Eastern Shore survey area using a one-way ANOVA. If a significant difference (p-value ≤ 0.05) was found between the mean seal counts for the CBBT and Eastern Shore survey areas, then a Tukey/Kramer multiple comparison test was performed in order to see which of the mean counts across the individual field seasons were significantly different from each other. Determining the differences between the respective seasonal mean counts was done by calculating the critical value of Q (Q_{cv}) as well as the Q statistic (Q_{stat}) for each possible pairwise comparison of the mean counts. The Q statistic was compared to the critical value for each pair of mean counts; if the Q statistic was larger than the critical value, the mean counts for the two separate seasons were statistically different.

2.4.2 Abundance Estimation

To estimate the population abundance (N) of harbor seals for the study area, including both the CBBT and Eastern Shore survey areas, we used two different approaches. For the first approach, we used the mark-recapture data from the photo-ID portion of the study to fit a Lincoln-Petersen mark-resight model (see Section 2.4.2.1 [Mark-recapture Approach]). We also experimented with using the seal count data and developing a correction factor from the satellite telemetry data from the 2018, 2020, and 2022 seal tagging efforts on the Eastern Shore (refer to Ampela et al. 2023 for more information on the pinniped tagging project) to produce abundance estimates (see Section 2.4.2.2 [Telemetry Correction Factor Approach]). Seasonal abundance estimates were produced using both approaches. The abundance estimates produced from the telemetry correction factor approach were compared to the respective seasonal abundances estimated using the Lincoln-Petersen mark-resight model.

2.4.2.1 Mark-recapture Approach

The Lincoln-Petersen mark-resight model was fit for each individual season (2015/2016, 2016/2017, 2017/2018, 2018/2019, 2019/2020, 2020/2021, and 2021/2022), as well as for the seven seasons combined.

The Lincoln-Petersen mark-resight model was selected based on the protocol for the photo-ID portion of the study, as this model assumes 1) a closed population (i.e., no recruitment [birth or immigration] or losses [death or emigration] during the study period), 2) all individuals have the same probability of being caught, 3) capture and marking do not impact catchability, 4) samples are random, 5) marks are not lost between sampling events, and 6) all marks are correctly recorded and reported when recovered in sample two.

$N = ((m_1 * n_2)/m_2)$, where

m_1= total # of marked animals/captures;
n_2= total # of marked/unmarked animals;
and m_2= # of total re-sightings/re-captures

In this study, m_1 was the total number of marked (i.e., uniquely identified) seals with an ID number (e.g., CB001) in the seal catalog. Only identified seals with a quality grade of Q1-Q3 and a distinctiveness grade of D1 and D2 were used in order to not violate the model's assumption that all individuals have the same probability of being caught. A distinctiveness grade of D3, as previously discussed in Section 2.3 (Photo Identification [Photo-ID]), represented seals with uniform pelage and no distinct markings. Therefore, the probability of "capturing" or identifying seals given a D3 in comparison to those with unique markings (grades of D1 or D2) would be far lower, and thus not equal. For the purpose of this study, we interpreted n_2 as meaning that all catchable animals are marked, therefore m_1 and n_2 are equal. The number of times each uniquely identified seal was re-captured, i.e. re-sighted, is represented as m_2. Due to the small sample size, all re-sightings were counted, as opposed to just one re-sighting per individual.

2.4.2.2 Telemetry Correction Factor Approach

Seal count data for the 2016-2022 field seasons from the CBBT and Eastern Shore vessel-based surveys were combined with satellite telemetry data on harbor seal activity in Virginia waters to produce individual abundance estimates for the 2016/2017, 2017/2018, 2018/2019, 2019/2020, 2020/2021, and 2021/2022 seasons. The 2016/2017 season was the first season where counts were made at both the CBBT and Eastern Shore survey areas. This approach for abundance estimation was based on methods used by Huber et al. (2001) and Thompson et al. (1997).

The haul-out data from harbor seals tagged at the Eastern Shore survey area in 2018 (n=7), 2020 (n=2), and 2022 (n=5) were analyzed for the pinniped tracking study for southeastern Virginia (Ampela et al. 2023). All of the deployed satellite tags were equipped with wet/dry switches, which reported the percentage of time the seal spent dry (i.e., hauled out) per hour. Histogram data representing the percentage of time an animal spent dry per hour during daylight hours and while in Virginia waters were used to calculate a correction factor that accounted for seals in the water during haul-out surveys, and therefore, potentially not accounted for by observers. The correction factor to account for seals in the water is the reciprocal of the proportion of time that tagged harbor seals spent ashore at haul-out sites.

Absolute abundance was estimated from the equation: $N = 2n/h$, where

N = total abundance of seals in the study area;
n = mean seal count during a field season;
and h = mean proportion of time seals were hauled out during the sampling period

Estimates of n for the 2016/2017, 2017/2018, 2018/2019, 2019/2020, 2020/2021, and 2021/2022 field seasons were based on counts made during "in season" survey days (refer to

Section 3.2 [Seal Presence Analysis Results] for a definition of "in season") at the CBBT and Eastern Shore survey areas. Tagged seals have been recorded at both survey areas within a season from both telemetry and photo-ID data (Ampela et al. 2023; Jones and Rees 2022). Therefore, counts for the two survey areas were combined to produce a total mean count for each season for the entire study area. Count data was also combined in order to increase the sample size for this analysis even though this could result in some individuals being counted more than once if movement between survey areas occurred within a season.

Telemetry data from the time period that tagged seals spent in Virginia waters were used to estimate the proportion of time spent ashore (h). Because the number of seals tagged and tracked during the 2017/2018, 2019/2020, and 2021/2022 field seasons was low, activity data from all tagged seals in both seasons were combined and a mean proportion of time spent ashore was calculated. Thus, it was assumed that activity did not vary among years, which allowed for h to be applied to the mean counts for the 2016-2022 field seasons.

3. Results

3.1 Haul-out Counts: 2021/2022 Field Season

Haul-out counts commenced in November 2021 for the eighth field season at the CBBT survey area. Counts were conducted over the course of 12 survey days between 2 November 2021 and 25 April 2022 (**Table 2**). Once seals were sighted in the survey area, animals were recorded on a consistent basis (10 out of 12 [83.3%] survey days) until departure. Overall, a total (combined in water and hauled out) of 98 seals were sighted across the four CBBT haul-out locations for the season (**Table 2)**. Historically, seals have been observed more at CBBT 3 than the other CBBT haul-out sites. However, slightly more seals were sighted at CBBT 4 than CBBT 3 this season compared to previous seasons. Of the 98 seals sighted, 44 (45%) were recorded at CBBT 3 and 50 (51%) were recorded at CBBT 4. The total daily number of seals counted ranged from 0-25 seals per survey day. Only harbor seals were identified at the CBBT during this season.

Table 2. Summary of the number of seals sighted for the 2021/2022 field season for the CBBT survey area

Date	Number of Individuals Pv	Number of Individuals Hg
2-Nov-21	0	0
17-Nov-21	1	0
1-Dec-21	2	0
28-Dec-21	9	0
13-Jan-22	19	0
24-Jan-22	15	0
3-Feb-22	14	0
1-Mar-22	25	0
14-Mar-22	8	0
30-Mar-22	4	0
13-Apr-22	1	0
25-Apr-22	0	0
Total	**98**	**0**

Key: Pv = *Phoca vitulina* (harbor seal)*;* Hg = *Halichoerus grypus atlantica* (gray seal)

Haul-out counts commenced in November 2021 for the sixth field season at the Eastern Shore survey area. Counts were conducted over the course of 13 survey days, between 2 November 2021 and 6 May 2022 (**Table 3**). Once seals were sighted in the survey area, animals were recorded on a consistent basis (9 out of 13 [69.2%] survey days) until departure. Seals were observed hauled out at two of the five main haul-out sites, C and E (**Figure 3**); and seals did not appear to establish any new haul-out sites. Over the entire season, a total (combined in water and hauled out) of 143 seals were sighted (**Table 3**). The total daily number of seals counted ranged from 0-45 individuals per survey day. The majority of seals observed were identified as harbor seals; one gray seal was sighted off effort after the survey on 16 December 2021 had concluded.

Table 3. Summary of the number of seals sighted for the 2021/2022 field season at the Eastern Shore survey area

Date	Number of Individuals Pv	Number of Individuals Hg
2-Nov-21	0	0
17-Nov-21	0*	0
1-Dec-21	4	0
16-Dec-21	20	0**
6-Jan-22	9	0
19-Jan-22	45	0
3-Feb-22	38	0
23-Feb-22	9	0
11-Mar-22	4	0
22-Mar-22	9	0
5-Apr-22	5	0
20-Apr-22	0	0
6-May-22	0	0
Total	**143**	**0**

* 2 harbor seals sighted off effort while between counts
** A gray seal was sighted after survey concluded
Key: Pv = *Phoca vitulina* (harbor seal); Hg = *Halichoerus grypus atlantica* (gray seal)

The UAS (i.e., drone) was used to conduct seven counts during the 2021/2022 season, specifically from December 2021 to April 2022 **(Table 4)**. The UAS was unable to be used during several surveys throughout the season due to high winds and limited availability of UAS operator. A higher seal count was recorded from the UAS during two of the seven survey days; the difference between the counts from the UAS compared to the counts recorded by an observer was five seals or less for these two survey days. The observer recorded more seals (differential ranged from 3-9 animals) from the vessel-based counts compared to the UAS counts during four of the seven survey days. There was no significant difference between the mean counts for the UAS compared to the observer ($t_{stat} = -0.38$, $p = 0.71$).

Table 4. Comparison of counts recorded from the UAS and observer during vessel-based surveys for the 2021/2022 season at the Eastern Shore survey area

Date	Seal Count from UAS	Seal Count from Observer
1-Dec-21	1	4
6-Jan-22	2	9
3-Feb-22	38	33
23-Feb-22	2	9
22-Mar-22	0	9
5-Apr-22	5	2
20-Apr-22	0	0

3.2 Seal Presence Analysis Results

3.2.1 CBBT Survey Area

A total of 122 survey days have been conducted across eight field seasons (see Section 2.4.1 [Analysis of Seal Presence]) at the CBBT survey area. Seals have been consistently recorded from mid-November to early April across field seasons (**Figure 6**). Most sightings (79.1%) occurred at the CBBT 3 haul-out site during the eight field seasons combined followed by 17.4% of sightings at CBBT 4 and 3.5% for CBBT 1 and 2 combined. These percentages should be interpreted with caution due to the variation in survey effort across field seasons at the CBBT survey area.

Once seals arrived in the CBBT survey area, animals were recorded on a consistent basis (96 out of 107 [89.7%] survey days) until departure. Based on this and similar observations for the Eastern Shore survey area, we termed the number of survey days between and including the first and last seal observation as "in season" survey effort and included only "in season" data in our analyses for both survey areas (unless otherwise specified). Over eight field seasons, there has been a fluctuation in seal presence for the CBBT survey area. The total count (sum of all the seals sighted in a season) and maximum count for a single survey day in a season increased over the first four field seasons (**Table 5**). However, a drop in total and maximum seal count occurred for the 2018/2019 and 2019/2020 field seasons. The average number of seals observed per survey day also increased across the first four field seasons, but decreased to eight and then five seals for the 2018/2019 and 2019/2020 field seasons, respectively. For the 2020/2021 season, seal presence appeared to rebound with an increase in average seal count as well as maximum seal count for a single survey day. A slight decrease in these summary statistics was observed for the 2021/2022 season.

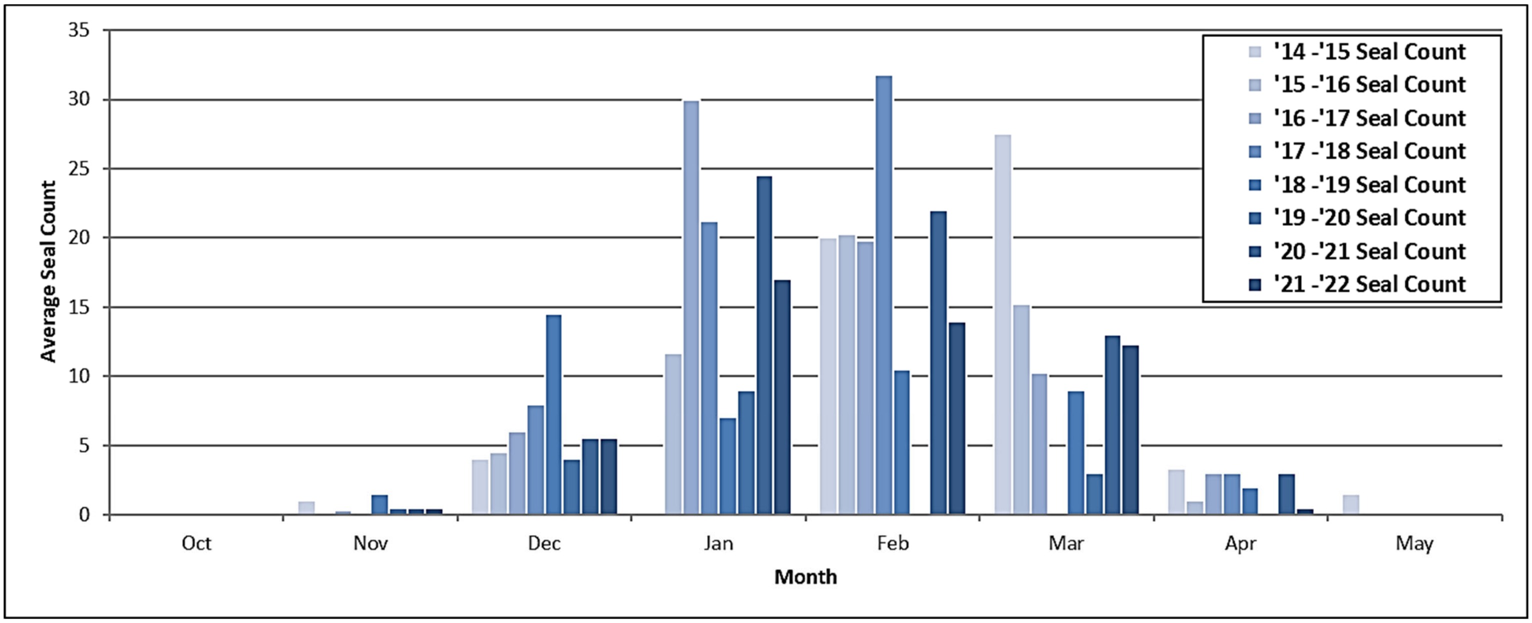

Figure 6. Average seal count by month using "in season" effort for the CBBT survey area. Surveys were only conducted in October for the 2015-2017 seasons and in May for the 2014-2016 and 2021/2022 seasons. Surveys were not conducted in January 2015, March 2018, or February 2020.

The difference between the mean counts across the eight field seasons was statistically significant (F_{stat}=2.75, p=0.012), with the Tukey/Kramer test results (Q_{cv}=4.36 for df=91) indicating that the mean counts for the 2017/2018 and 2018/2019 seasons (Q_{stat}=4.64) as well as the 2017/2018 and 2019/2020 seasons (Q_{stat}=4.83) were statistically different. This between-season comparison, however, does not take into account the sampling bias for some of the field seasons. For example, values (e.g., average and maximum count) for the 2017/2018 season appear to be much higher than the other seasons, which may be due to a change in sampling methodology (counts being vessel-based instead of land-based). In addition, there was inconsistent survey effort across months for the 2017/2018 season as well as the 2019/2020 season (e.g., no surveys in March 2018 and February 2020, and concentrated survey effort in January-February 2018).

Table 5. "In season" survey effort (number of survey days), total seal count (best estimate), effort-normalized average (number of seals observed per survey day), and maximum seal count on a single survey day at the CBBT survey area

Field Season	"In Season" Survey Effort (days)	Seal Counts		
		Total	Average	Maximum
2014-2015	11	113	10	33
2015-2016	14	187	13	39
2016-2017	22	308	14	40
2017-2018*	15	340	23	45
2018-2019	10	82	8	17
2019-2020	6	29	5	9
2020-2021	11	137	12	32
2021-2022	10	98	10	25

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

3.2.2 Eastern Shore Survey Area

A total of 71 surveys have been conducted across six field seasons at the Eastern Shore survey area. Seals have been recorded from early November to early April (**Figure 7**).

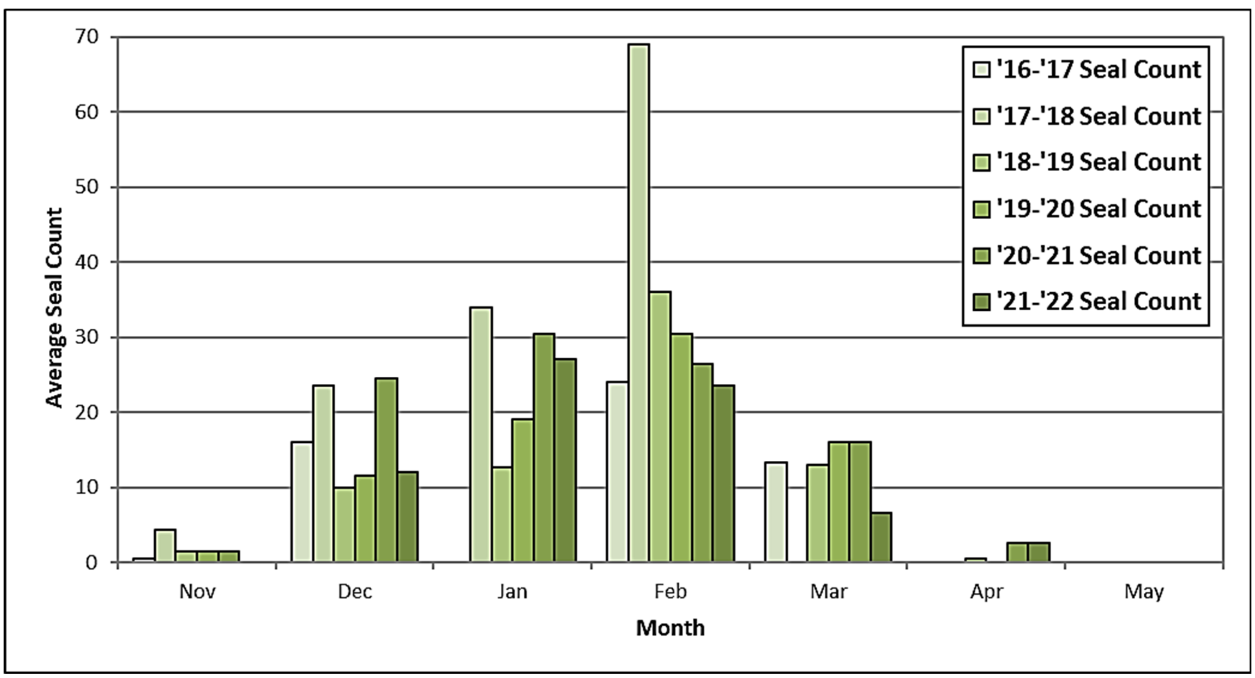

Figure 7. Average seal count by month using "in season" effort for the Eastern Shore survey area. No surveys were conducted in October for all six seasons. May surveys were only conducted during the 2020-2022 seasons. Surveys were not conducted in January 2017 and from March to April 2018. One survey was conducted in February 2018.

Similar to the CBBT, animals were recorded on a consistent basis (56 out of 61 [91.8%] survey days) once they arrived at the Eastern Shore survey area until departure. Over six field seasons, there has been a fluctuation in seal presence, similar to what was observed for the CBBT survey area. The total count and maximum count for a single survey increased over the first two field seasons and again for the 2020-2022 field seasons (**Table 6**). The average number of seals observed per survey day also increased over the first two field seasons, but decreased to 15 seals for the 2018/2019 season. Average seal count has fluctuated slightly since the 2019/2020 season. The difference between the mean counts across the six field seasons was not statistically significant (F_{stat}=0.43, p=0.82). This between-season comparison, however, does not take into account the sampling bias for the 2016-2018 seasons. There was inconsistent survey effort across months (e.g., no surveys conducted in January 2017 and March-April 2018) for the first two seasons.

Table 6. "In season" survey effort (number of survey days), total seal count (best estimate), effort-normalized average (number of seals observed per survey day), and maximum seal count on a single survey day at the Eastern Shore survey area

Field Season	"In Season" Survey Effort (days)	Seal Counts		
		Total	Average	Maximum
2016-2017	7	105	15	24
2017-2018	8	197	25	69
2018-2019	11	160	15	66
2019-2020	9	157	17	39
2020-2021	12	219	18	44
2021-2022	9	143	16	45

3.3 Photo Identification

For the 2021/2022 field season, 45 harbor seals were uniquely identified based upon image grading criteria (**Table 1, Table A-1**). The last images used for photo-ID analysis were collected on 5 April 2022. None of the images collected on 13 April 2022 (the last day of sightings for the 2021/2022 season) met the quality standards for the study. Of the 45 harbor seals, 15 (33%) were new individuals to the catalog and 30 (67%) were re-sightings of individuals that were identified from previous field seasons (**Figure 8)**. The highest number of individual re-sights (n=30) were recorded for this season compared to previous field seasons. Identified harbor seals were sighted at the CBBT and Eastern Shore survey areas, with 25 seals sighted at only the CBBT survey area and 17 seals sighted at only the Eastern Shore survey area (**Table A-1)**. Three seals (CB053, CB066, CB216) were sighted at both the CBBT and Eastern Shore survey areas during the season. In addition, four (CB020, CB091, CB150, and CB154) of the 35 identified seals sighted at the CBBT survey area were also sighted at the Eastern Shore survey area during previous field seasons. Only one gray seal sighting (off effort) was recorded during the 2021/2022 field season. The animal was sighted in the water at the Eastern Shore survey area on 16 December 2021. The gray seal could not be given a unique ID based on the study's image grading criteria.

After reviewing all images from the 2015-2022 field seasons, 170 harbor seals and 1 gray seal have been uniquely identified (**Table A-1, Figure 8**) based upon image grading criteria. As previously mentioned, images from the 2014/2015 season did not meet the quality standards for the study. The 2019/2020 field season marked the first time a gray seal (CB168) could be uniquely identified (Jones and Rees 2021) and added to the catalog. This animal was sighted at the Eastern Shore survey area in February 2020.

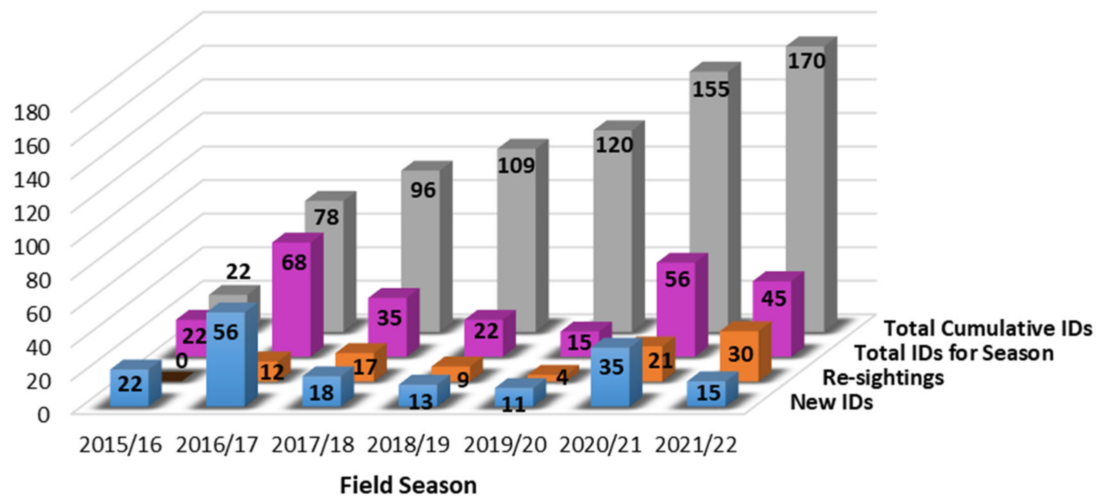

Figure 8. Harbor seal identifications over seven field seasons (2015-2022). The purple bars indicate the total number of IDs for a season, orange bars indicate the number of re-sightings, i.e., those IDs that were seen in previous seasons, and blue bars indicate the number of new IDs added to the catalog. The gray bars indicate the total number of cumulative unique IDs.

Of the 170 uniquely identified harbor seals, 88 (52%) were observed only once and 82 (48%) were determined to be present in the study area on more than one occasion from 2015-2022. In an individual season, the minimum number of sightings of a uniquely identified seal was one; the maximum number of sightings of a uniquely identified seal was nine (CB069) during the 2016/2017 field season.

Between December 2015 and April 2022, the minimum number of days for an identifiable re-sighting (or re-capture) of an individual was 5 days (CB121, 15 March 2017 and the last sighting being on 21 March 2017) and the maximum number of days was 2,295 days (CB053, 9 December 2015 and the last sighting being on 22 March 2022), which is about 6 years and 3.5 months. Across the study period, 52 individuals were observed on two survey days and 30 individuals were observed on three or more survey days, with the maximum number of encounters being 16 for one individual (CB053).

Photo-ID data from seven field seasons have provided additional information pertaining to habitat use patterns and site fidelity for harbor seals. Some seals have been sighted across multiple seasons. Of the 82 individuals identified to be present on more than one occasion, 17 were re-sighted within one season, 50 were sighted across two different field seasons, five (e.g., CB062) were sighted across three different field seasons, eight were sighted across four different field seasons (CB006 and CB047), and one seal was sighted across five (CB047) and six (CB053) different field seasons. For example, CB047 was first sighted on 26 February 2016 and then resighted multiple times (e.g., on 24 February 2021) during the 2016-2022 seasons (**Figure 9)**.

Not only have individual seals been sighted on more than one occasion whether that is within a season or across seasons, but some individuals have been sighted and re-sighted together. For example, CB046 and CB047 were first sighted together at the same haul-out site (CBBT 3) on 26 February 2016 and then re-sighted together on multiple survey days at that same haul-out site, with the last re-sighting of them recorded on 13 January 2022, which amounts to a 2,148-day span (about 6 years) between sightings.

The majority of identified seals (n=95) have been sighted at only the CBBT survey area, with some (n=59) being sighted at only the Eastern Shore survey area. Surveys have been conducted at the CBBT for more seasons compared to the Eastern Shore, which may account for this difference in number of identified seals across survey areas. The remaining 16 identified seals have been sighted at both survey areas on separate survey days. Five seals (CB053, CB066, CB121, CB206, and CB216) were sighted at both survey areas during the same season, whereas, the other 11 seals (e.g., CB020) were sighted at each survey area across different seasons.

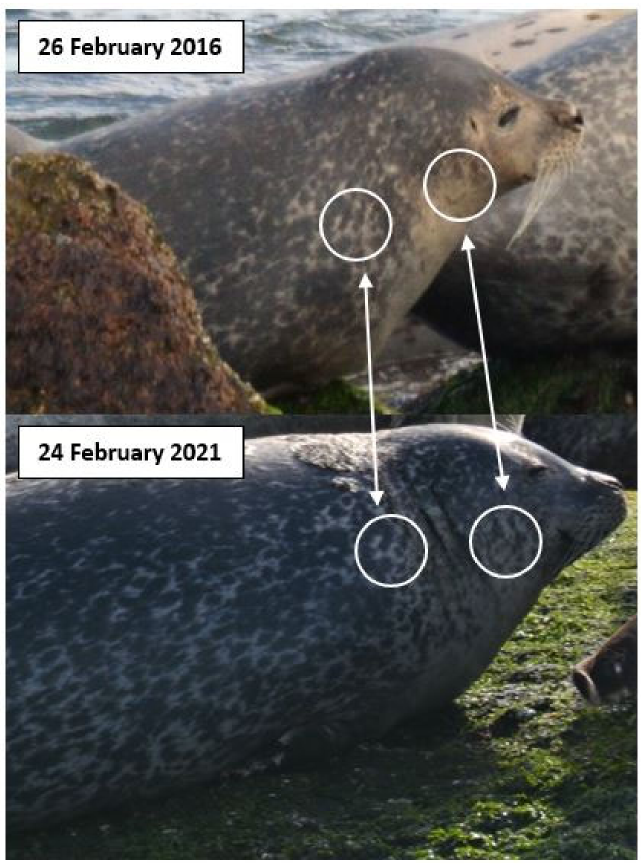

Figure 9. Harbor seal, CB047, sighted on 26 February 2016 at the CBBT 3 haul-out site (above) and re-sighted on 24 February 2021 at CBBT 4 (below). Photo by NAVFAC Atlantic under NMFS GA Permit #19826

3.4 Abundance Estimates

The abundance estimates and 95% confidence intervals (CI) calculated from the Lincoln-Peterson model for the 2015-2022 field seasons ranged from 81 (95% CI: 44.14-117.19) to 242 (95% CI: 91.35-392.65) individual harbor seals (**Figure 10**). As previously mentioned in Section 3.3 (Photo Identification), uniquely identified harbor seals were sighted at the CBBT and Eastern Shore survey areas, therefore, capture and re-capture data across both survey areas were used for the abundance estimate calculations. Abundance estimates show a fluctuation across seasons. There was an overall increase from the 2015/2016 to 2018/2019 field seasons, with the exception of the 2017/2018 season, in which a decrease in abundance (N=135 individuals) was observed. Abundance decreased after the 2018/2019 season, but seemed to remain relatively stable from the 2019/2020 to 2021/2022 seasons, with an estimated 128 and 135 individuals, respectively. The lowest abundance estimate (81 individuals) occurred during the 2015/2016 field season; however, it should be noted that this season had a low number of captures (n=22), which was most likely due to a lower amount of survey effort and not a large enough zoom lens (≤400 mm) given the distance from the observer to the seals. In addition, surveys were only conducted at the CBBT during this season, which means that a smaller closed population (in terms of area) was used for this abundance estimate, whereas, a larger closed population (in terms of area) was used for the other six seasons' abundance estimates since capture and re-capture data were used from both the CBBT and Eastern Shore survey areas. The 2018/2019 season had the highest estimate of 242 individuals, however, the 95% CI for this season's estimate is larger compared to the other seasons, indicating that this estimate may not be the most accurate representation of the number of individuals utilizing both survey areas for this season. This may be due to the low proportion of re-captures (n=2) compared to the number of captures (n=22) that were recorded for a single season. A regression analysis was conducted for the seasonal abundance estimates to see if there is a potential population trend for the study area. Results indicated that the slope was not statistically significant (p=0.72), therefore, there does not appear to be a trend in the seasonal abundance of the local population.

With the abundance showing a fluctuation across seasons, especially from 2015-2019 and no discernable trend, a mean abundance estimate was calculated. The abundance estimate for all seven seasons (2015/2016, 2016/2017, 2017/2018, 2018/2019, 2019/2020, 2020/2021, and 2021/2022) yielded an estimate of 198 individuals (95% CI: 193.44-202.45). Given the CI, this estimate may be a reliable representation of the number of harbor seals using both the CBBT and Eastern Shore survey areas.

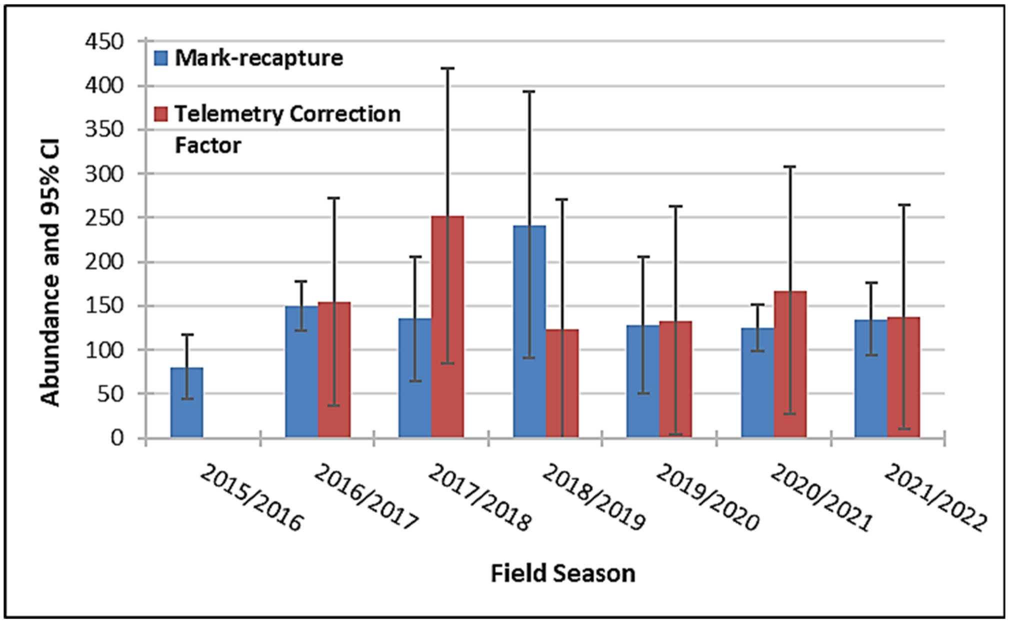

Figure 10. Total abundance estimates and 95% confidence intervals (CIs) for the CBBT and Eastern Shore survey areas combined calculated from the mark-recapture (blue bars) and telemetry correction factor (red bars) approaches for the 2015-2022 field seasons. There is no 2015/2016 estimate for the telemetry correction factor approach because surveys at the Eastern Shore did not start until the 2016/2017 season.

Count data for both the CBBT and Eastern Shore survey areas were combined to produce a total mean count for each season from 2016-2022. Mean counts for each season are presented in (**Table 7**); values ranged from 11.4 (SE=3.1) to 23.3 (SE=3.4). The 2017/2018 season had the highest mean seal count for the study area, and this was also reflected in the mean counts that were calculated for the CBBT and Eastern Shore survey areas for this season (see Section 3.2 [Seal Presence Analysis Results]). Mean count showed a fluctuation across seasons, which could be due to a fluctuation in seal presence across seasons or the unequal survey effort across seasons (e.g., there were a total of 15 "in season" survey days for the 2019/2020 season compared to a total of 23 "in season" survey days for the 2020/2021 season). Based on the 2018, 2020, and 2022 tagging data, harbor seals were found to spend a mean proportion time (*h*) of 0.18 daylight hours on land (i.e., hauled out) while in Virginia waters.

Table 7. Mean haul-out counts of harbor seals at the CBBT and Eastern Shore survey areas for the 2016-2022 field seasons and the resulting abundance estimates calculated for each seasons using the telemetry correction factor approach. SE= standard error. CI= confidence interval

Field Season	Mean Count (SE)	Estimated Abundance	95% CI for Abundance
2016-2017	14.2 (2.1)	154	36.02 - 272.46
2017-2018	23.3 (3.4)	252	84.46 - 420.34
2018-2019	11.4 (3.1)	124	0 - 270.66
2019-2020	12.3 (3.2)	134	4.55 - 262.60
2020-2021	15.5 (2.8)	168	26.96 - 308.32
2021-2022	12.7 (2.8)	137	10.85 - 263.90

From the equation in Section 2.4.2.2 (Telemetry Correction Factor Approach), and using the mean proportion of time that tagged seals spent ashore (h=0.18), the abundance estimates for the 2016-2022 seasons ranged from 124 (95% CI: 0-270.66) to 252 (95% CI: 84.46 - 420.34) individual harbor seals (**Table 7, Figure 10**). Similar to the abundance estimates calculated from the Lincoln-Peterson model (presented above), the abundance estimates calculated using the telemetry correction factor showed a fluctuation across seasons. However, estimates were slightly higher in comparison for most of the seasons. The 2018/2019 season had the lowest abundance estimate of 124 individuals, whereas the abundance estimate calculated for this season using the Lincoln-Peterson model was 242 individuals. The 2017/2018 season had the highest abundance estimate of 245 individuals, whereas the abundance estimate calculated for this season using the Lincoln-Peterson model was 135 individuals. A regression analysis was also conducted for the seasonal abundance estimates to see if there is a potential population trend based on this approach. Similar to the results for the Lincoln-Peterson model-based estimates, there appears to be no trend in the seasonal abundance of the local population (p=0.47). With the addition of the 2022 tagging data and a refined mean proportion of time that tagged seals spent hauled out, abundance estimates slightly decreased compared to the 2016-2021 seasonal abundance estimates that were produced using only the 2018 and 2020 tagging data (Jones and Rees 2022). However, the 95% CI values for all of these seasonal abundance estimates were still very large, especially when comparing them to the CIs for the estimates that were calculated from the Lincoln-Peterson model and one (for the 2018/2019 season) contained a value of zero for the lower end of the CI. With the abundance estimates produced from this approach also showing a fluctuation across seasons and no discernable trend, a mean abundance estimate was calculated. The abundance estimate for the 2016-2022 seasons yielded an estimate of 166 individuals (95% CI: 19.56-311.91). These extreme 95% CI values indicate that these estimates may not be the most accurate representation of the number of individuals utilizing both survey areas in each season. This may be due to the low sample size for counts across seasons (for this particular abundance estimation approach) as well as for the low number of tagged harbor seals (n=14), with which the proportion of time seals were hauled out was produced from. Increasing the number of counts conducted at each survey area in a season as well as the number of tagged harbor seals may improve abundance estimation using this experimental approach (Thompson et al. 1997).

4. Discussion

The results from this study to date indicate that seals, specifically harbor seals, regularly occur in southeastern Virginia from the fall to the spring. Harbor seals have been consistently recorded at the CBBT and Eastern Shore survey areas from November to April. This finding is reflected in the count data collected across eight field seasons. Since the start of the study in 2014, there has been a fluctuation in seal presence for the CBBT survey area, with an increasing trend in average and maximum seal count from 2014 to 2018, followed by a decrease from 2018 to 2020. For the 2020/2021 season, seal presence appeared to rebound with an increase in average seal count as well as maximum seal count for a single survey day. A slight decrease in these summary statistics was observed for the 2021/2022 season. A similar fluctuation in seal presence was observed for the Eastern Shore survey area, with an increase in average and maximum seal count from 2016 to 2018 and again for the 2019 to 2022 field seasons.

Some of the lowest total, maximum, and average seal counts for the CBBT and Eastern Shore survey areas were reported for the 2018 to 2020 as well as 2021/2022 seasons. In addition, there was a statistically significant difference between the average seal counts across the eight field seasons for the CBBT survey area. The drop in maximum and average seal count for the 2018 to 2020 as well as 2021/2022 seasons for the Eastern Shore survey area was not as substantial compared to the CBBT survey area for these seasons, and the difference between average seal counts across the six field seasons (2016-2022) for this survey area was not statistically different.

The observed fluctuation in seal presence for maximum and average seal count as well as overall seal sightings may be due to several factors such as sampling bias in survey effort, two unusual mortality events (UMEs) along the U.S. east coast during the study, seasonal differences (e.g., pupping season) in haul-out behavior, and/or environmental conditions.

For both the CBBT and Eastern Shore survey areas, the number of “in season” survey days conducted has varied each season and has varied by month within a season. Caution needs to be taken when comparing these numbers across seasons and when drawing conclusions due to a change in sampling methodology (e.g., vessel-based counts vs. land-based counts) for the CBBT survey area and variable survey effort across the 2014-2022 seasons for both survey areas, leading to sampling bias. In addition, the incorporation of the UAS with the vessel-based counts on the Eastern Shore may help to improve counts, especially if seals frequently exhibit movement from the haul-out site into the water as vessels approach closer to the haul-out locations for counts and photographs. This in turn could improve the analysis of the local population to see if there is an increasing or decreasing trend in numbers over the course of this study.

A Northeast U.S. Pinniped UME was declared from 2018 to 2020 based on elevated harbor and gray seal stranding numbers (mainly across Maine, New Hampshire, and Massachusetts) as well as seals testing positive for pathogens such as phocine distemper virus and avian influenza virus. Clinical signs were observed in seals that stranded as far south as Virginia, therefore, the UME encompassed all seal strandings from Maine to Virginia (NOAA 2020). Three harbor seals captured and tagged on the Eastern Shore during the 2017/2018 field season tested positive for the avian influenza virus (Costidis et al. 2019). This UME is no longer active and the closure of it is currently pending (NOAA 2022). However, another Northeast U.S. Pinniped UME was declared in 2022 based on elevated numbers of sick harbor and gray seals that were testing positive for avian influenza along the Maine coast; this UME remains active (NOAA 2023). Several of the harbor seals tagged at the Eastern Shore survey area from 2018-2022 displayed northward movements to Maine in the spring (Ampela et al. 2023). Therefore, both of these UMEs could be a potential reason for the observed fluctuation in count numbers across the study area from 2018 to 2022.

The lower seal counts recorded for the 2018 to 2020 as well as 2021/2022 seasons could also be a result of harbor seals spending less time hauled out and more time at sea, resting or foraging, during surveys. Russel et al. (2015) found that outside of the molting and pupping seasons, the amount of time that harbor seals spend hauled out is reduced and variable, resulting at more time spent at sea. The probabilities of resting on land were estimated to be about 0.10-0.33 for harbor seals that were satellite tagged in Britain (Russel et al. 2015). Harbor seals migrate to Virginia in the fall from New England after the molting and pupping seasons. Similar to the probabilities reported by Russel et al. (2015), harbor seals tagged in 2018, 2020 and 2022 were found to spend a mean proportion of 0.18 of daylight hours resting on land (i.e., hauled out) while in Virginia.

Environmental conditions are other potential factors affecting seal occurrence and haul-out behavior in Virginia waters for the previous field seasons. Results from initial data exploration of "in season" seal count for the CBBT survey area for the 2014-2018 field seasons indicated that the arrival and departure of seals at the CBBT survey area might coincide with changes in oceanographic and environmental conditions, such as water temperature (Jones et al., 2018). These analyses were not conducted using the 2018-2022 seal count data due to sampling bias, since vessel surveys at the CBBT and Eastern Shore survey areas were required to be conducted in ideal weather and marine conditions (e.g., low winds and wave height). However, looking at the water temperatures recorded at a NOAA station in the vicinity of the CBBT survey area, average water temperatures during the peak months (January-March) of the 2019/2020 and 2021/2022 seasons were slightly more mild compared to previous seasons as well as the 2020/2021 season. Therefore, this could have potentially accounted for the lower seal counts recorded for the 2019/2020 and 2021/2022 seasons.

Another potential factor to be considered in the future is the construction activity for the CBBT expansion project. Construction, including pile driving, has been taking place since 2017 at CBBT 1 and 2, where few seals (about 3.5% of total sightings) have been observed in previous seasons. Looking at the months where certain in-water activities related to construction were conducted, especially once construction takes place at CBBT 3 and 4, and if that overlaps with the timeframe that seals are present in the study area, will aid in determining if construction activity may be influencing seal occurrence.

More surveys for both the CBBT and Eastern Shore survey areas must be conducted in order to investigate whether or not there is a potential increase or decrease in seal occurrence in the region and before drawing firm conclusions as to what may be the factor(s) for the observed fluctuation in the number of seals present in the study area.

An ongoing, complimentary project is investigating seal occurrence and haul-out behavior using time-lapse remote cameras throughout the study area (Guins et al. 2023). Cameras were placed at multiple haul-out locations at both the CBBT and Eastern Shore survey areas for simultaneous sampling, which will aid in accounting for sampling bias in both methodology and inconsistent survey effort. Results from the study indicate that remote cameras are a valuable addition to vessel survey effort, with the benefits of frequent data sampling throughout the day and in most weather conditions, thereby providing a more robust investigation. The camera surveys demonstrated that harbor seals were present in the study area from fall to spring, with peak numbers from January-March, similar to the haul-out survey results presented in this report. Seals also appeared to haul out more during certain environmental conditions, e.g., at wind speeds less than 20 kts and air temperatures below 56 °F. Refer to Guins et al. (2023) for more information on the pinniped time-lapse camera project.

Prior to this pinniped haul-out study, there was no seasonal population abundance estimate for harbor seals in southeastern Virginia. For this study, a population abundance was estimated for the lower Chesapeake Bay and coastal Virginia waters using mark-recapture data. A total of 198 individuals were estimated as the average seasonal abundance across all seven seasons (2015-2022). Abundance estimates were also calculated for each annual field season from 2015-2022 using the mark-recapture data as well as from 2016-2022 using a telemetry correction factor approach incorporating seal count and satellite tagging data. Abundance estimates produced from the mark-recapture data ranged from 81 individuals (2015/2016 season) to 242 individuals (2018/2019 season), whereas the estimates calculated using the telemetry correction factor were slightly higher in comparison for most seasons and ranged from 124 individuals (2018/2019 season) to 252 individuals (2017/2018 season). However, the margin of error (i.e. 95% CI values) was larger for the abundance estimates produced using the telemetry correction factor approach. This is potentially due to a small sample size for count and telemetry data.

A fluctuation in abundance estimates occurred across seasons for both approaches. Based on the number of counts conducted within a season for the study area (small sample size compared to the amount of count data used by Huber et al. (2001) and Thompson et al. (1997)), the telemetry correction factor approach may not be an appropriate method to use for abundance estimation for this region. If additional tagging and tracking efforts are planned for future field seasons (Ampela et al. 2023), a more robust approach involving a generalized linear mixed model framework to estimate seasonal absolute abundance using haul-out counts and information from satellite telemetry data may be possible (Sharples et al. 2009). Inferences about population trends in the region cannot be accurately made due to this fluctuation in abundance across seasons as well as the observed decrease in maximum and average seal count for the 2018-2020 as well as 2021/2022 seasons at both survey areas. Regression analysis results indicate that there is not a statistically significant trend in population abundance. Therefore, there is reason to believe that the population of animals utilizing the lower Chesapeake Bay and Eastern Shore, Virginia may be relatively stable. The harbor seal population in Maine is also considered stable due to the minor changes in abundance that were observed between 2012 and 2018 (Hayes et al. 2022; Sigourney et al. 2021). It is difficult to draw further conclusions until additional data is collected and a more robust dataset (for the mark-recapture and haul-out and camera survey data) is developed that will allow us to determine if the population is, in fact, stable and/or if harbor seal site fidelity at this southeastern Virginia study area is potentially increasing.

Since this study began in 2014, the NOAA SAR for harbor seals of the Western North Atlantic stock has been updated and now states that harbor seals are generally found in the coastal waters of Canada and Maine throughout the year (Katona et al. 1993) and occur seasonally (from September through late May) from New England south to Virginia (Hayes et al. 2022; Jones and Rees 2022; Schneider and Payne 1983; Schroeder 2000). Results from this study document that a small population does occur seasonally within southeastern Virginia, and contributed towards the geographic range for harbor seals of the Western North Atlantic stock being updated in the NOAA SAR (Hayes et al. 2022).

Both the harbor and gray seal previously formed large colonies (prior to subsistence hunts and government-supported bounties) from Labrador, Canada to Cape Hatteras, North Carolina (Johnston et al. 2015). The observed fluctuation in seal count numbers across the study period as well as the Virginia abundance estimates calculated for this study reflect claims made by Johnston et al. (2015), who believe that harbor seals are now beginning to re-occupy substantial portions of their previous range. Several researchers report that harbor and gray seal distribution along the U.S. Atlantic coast appears to be expanding or shifting (den Heyer et al. 2021; DiGiovianni et al. 2011; Johnston et al. 2015; DiGiovianni et al. 2018), which could explain the fluctuation observed in seal occurrence at the CBBT and Eastern Shore survey areas since this study began in 2014. A large southward shift in pup production had occurred by 2016, with more than 90% of production occurring south of the Gulf of St. Lawrence in Canada, and some parts of the Gulf of Maine have seen as much as a 26% increase in gray seal populations (den Heyer et al. 2021; Wood et al. 2019 and 2022). An increase in gray seal pupping (Wood et al. 2019 and 2022) and overall, abundance, in the Northeastern U.S. (Pace et al. 2019) could create interspecific competition for the two species, whether that is for habitat and/or prey resources, thus leading to changes in species distribution. In some areas of the Northeast U.S. coast where gray and harbor seals overlap such as southeastern Massachusetts, harbor seal counts have declined since 2009, and gray seals appear to have displaced harbor seals from some haul-out locations that they formerly used (Pace et al. 2019). Recent trends in sighting data for New York indicate that the Western New York Bight harbor seal population may eventually experience displacement by the influx of gray seals, which would result in more of a southern expansion of harbor seals along the east coast (Sieswerda and Kopelman 2018).

Although the majority of seals observed within the study area have been harbor seals, occasional sightings of gray seals have been recorded at both the CBBT and Eastern Shore survey areas between December and March. Gray seal sightings have not been recorded consecutively between field seasons for each survey area since the start of the study; therefore, we cannot say with any certainty that this species regularly occurs in southeastern Virginia or if this species is starting to expand its distribution farther south.

Based on the photo-ID analysis, results indicate that some harbor seals are returning to the same southerly haul-out locations in Virginia across multiple seasons. Photo-ID conducted via visual matching for the 2015-2022 field seasons has shown that some individuals (82 out of 170 uniquely identified seals) sighted at the study area have been re-sighted within a season and across seasons, indicating at least some degree of site fidelity within the lower Chesapeake Bay and coastal Virginia waters. For example, 10 identified seals have now been sighted across four or more seasons since 2015. Identifiable re-sightings across the study period have spanned as far as about 33 to 75 months, and some of these identified harbor seals have utilized the CBBT haul-out sites for longer than our study period (based on images taken in years prior to 2014 and provided by B. Lockwood). Based on these contributed citizen photographs, we have been able to determine that some of the individuals (CB004, CB005, CB006, CB056, and CB057) have been occurring seasonally in the region since 2011 and 2012. These findings further prove that this region serves as an important resource for harbor seals by providing regular, seasonal haul-out sites for these animals within the lower Chesapeake Bay and Eastern Shore, Virginia.

Using photo-ID, we have also been able to gather more information on movement and habitat preference within the region. More than half of the identified harbor seals (56%) have been sighted at only the CBBT survey area, with some (35%) being sighted at only the Eastern Shore survey area. However, 16 individuals were re-sighted at both survey areas on separate survey days within a season and across seasons. These results indicate that harbor seals make localized movements throughout the region during their seasonal occupancy and that while some seals may be utilizing a particular haul-out site within a given season, others may utilize multiple haul-out sites within a season. The pinniped tracking study for southeastern Virginia confirms that seals make localized movements throughout the region (Ampela et al. 2021 and 2023). Nine of the 14 harbor seals captured and tagged at haul-out sites from the Eastern Shore survey area in February 2018, February-March 2020, and February 2022 displayed movements between the Eastern Shore and CBBT survey areas.

5. Conclusions and Recommendations

Our research continues to document a regular, seasonal presence of harbor seals and occasional sightings of gray seals within the lower Chesapeake Bay and Eastern Shore, Virginia. Patterns of seasonal residency and a baseline for population abundance for harbor seals within the region are beginning to emerge. However, more research is necessary to determine the level of site fidelity and whether or not harbor seal abundance is potentially increasing, decreasing, or is stable within the study area, and as to what may be the factors for the observed fluctuation in abundance. Data will continue to be collected and examined for any emerging patterns of habitat utilization and residency time, as well as population trends, which will help the Navy with ongoing environmental compliance and conservation efforts.

While the study provides an essential basis towards determining the occurrence and habitat use of harbor and gray seals within the lower Chesapeake Bay and coastal waters of Virginia, recommendations to enhance the project are below:

1. **Experiment with using satellite telemetry data for abundance estimation**. Fourteen harbor seals were successfully tagged within the study area in February 2018, February-March 2020, and February 2022 with satellite tags. The satellite telemetry data for the tagged seals is available on MoveBank.org as well as the Animal Telemetry Network. The final report summarizing tagging efforts for the 2021/2022 season as well as analysis results from the 2018-2022 seasons has been completed (Ampela et al. 2023). The additional data from this study will provide a more robust suite of information pertaining to the distribution, migratory routes, haul-out patterns, and diving behavior of seals in this area, as well as provide a baseline for behavioral response studies in the future. If additional tagging and tracking efforts are planned for future field seasons along the U.S. east coast, especially Virginia, the modeling framework developed by Sharples

et al. (2009) could be applied to the count and satellite telemetry data, to potentially improve abundance estimation efforts for the region.

2. **Investigate the use of improved automated photo identification tools and seal recognition software.** The use of the Extract Compare software was previously investigated in partnership with Naval Undersea Warfare Center, Division Newport and was determined to be ineffective for this project. However, new computer-assisted pattern and facial recognition software (e.g., Hotspotter, Seal Codex, or SealNet) have been developed and improved upon to assist in seal pelage pattern and facial recognition and matching individuals (Birenbaum et al. 2022; Langley et al. 2021), which in the future may be used to enhance the photographic mark-recapture potential of the study. Automated matching may improve the frequency of matches as well asimprove photo-matching time and abundance estimation.

3. **Submit data to OBIS-SEAMAP**. Documentation of seal presence for Virginia is currently lacking in sightings databases and the published literature. We are in the process of adding these data to OBIS-SEAMAP, which will allow the data to be archived and accessible for use by future researchers and promote collaboration with organizations in order to augment our understanding of the distribution and the ecology of pinnipeds in the Mid-Atlantic.

4. **Integrate remote time-lapse camera data with the haul-out survey analysis.** The use of time-lapse remote camera surveys provides additional and near continuous monitoring data during daylight hours at the Eastern Shore and CBBT survey areas. These data are an important supplement to what is being collected by the vessel survey team, providing a much larger sample size for the count estimates. The integration of the data from these projects will likely allow us to better assess seal presence and abundance in Virginia.

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A

Sightings History Tables

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Table A-1. Sighting history (by number of days seen per season) of uniquely identified harbor and gray seals at the Chesapeake Bay Bridge Tunnel (CBBT) and Eastern Shore (ES): December 2015-April 2022

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals											
CB004		1	1					CBBT 3	2	2	1
CB005	1	3	2					CBBT 3	6	3	3
CB006	1	3	2			3		CBBT 3	9	4	3
CB017	1	1						CBBT 3	2	2	1
CB020	1	1	1				1	CBBT 3 & ES	4	4	1
CB021	1				1			CBBT 3 & ES	2	2	1
CB022		3	1			1	1	CBBT 3/4	6	4	3
CB023	1	2						CBBT 3	3	2	2
CB035	2							CBBT 3	2	1	2
CB036	1	1						CBBT 3	2	2	1
CB037	1							CBBT 3	1	1	1
CB038	2							CBBT 4	2	1	2
CB041	1							CBBT 3	1	1	1
CB042	1							CBBT 4	1	1	1
CB043	1							CBBT 4	1	1	1
CB044	1	1						CBBT 3/4	2	2	1
CB045	1	1						CBBT 3	2	2	1
CB046	1	1				2	2	CBBT 3	6	4	2
CB047	2	1		1		3	4	CBBT 3/4	11	5	4
CB048	1	1						CBBT 3	2	2	1
CB051	1							CBBT 3	1	1	1

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals (continued)											
CB053	4	2	2	1		1	6	CBBT 1/3 & ES	16	6	6
CB056				1	1	1		CBBT 3	3	3	1
CB057		1	1					CBBT 3 & ES	2	2	1
CB062	1		1	1			1	CBBT 3/4	4	4	1
CB064	1						1	CBBT 3/4	2	2	1
CB066		1				1	4	CBBT 3 & ES	6	3	4
CB067		1						CBBT 3	1	1	1
CB069		9	1					CBBT 3/4	10	2	9
CB071		4						CBBT 3	4	1	4
CB072		1						CBBT 3	1	1	1
CB073		1						CBBT 3	1	1	1
CB074		1						CBBT 3	1	1	1
CB076		1				2	1	CBBT 3/4	4	3	2
CB078		1						CBBT 3	1	1	1
CB079		1						CBBT 3	1	1	1
CB080		1				1		CBBT 3 & ES	2	2	1
CB081		1						CBBT 3	1	1	1
CB083		2	1					CBBT 3	3	2	2
CB084		1						CBBT 3	1	1	1
CB085		2						CBBT 3	2	1	2
CB086		3				1		CBBT 3 & ES	4	2	3

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals (continued)											
CB087		1	1					CBBT 3 & ES	2	2	1
CB088		1						CBBT 3	1	1	1
CB089		1						CBBT 3	1	1	1
CB090		2		1		1	1	CBBT 3/4	5	4	2
CB091		1					1	CBBT 3 & ES	2	2	1
CB092		2						CBBT 3	2	1	2
CB095		1						CBBT 3	1	1	1
CB096		1				1		CBBT 3	2	2	1
CB097		1						CBBT 3	1	1	1
CB098		1		1				CBBT 3	2	2	1
CB099		1	1					CBBT 3	2	2	1
CB100		3	2					CBBT 3	5	2	3
CB101		1		2				CBBT 3/4	3	2	2
CB102		1						CBBT 3	1	1	1
CB103		1						ES	1	1	1
CB104		2	2			1		ES	5	3	2
CB105		1						ES	1	1	1
CB106		1		1		2	2	ES	6	4	2
CB107		1						ES	1	1	1
CB110		1						CBBT 3	1	1	1
CB111		1						CBBT 3	1	1	1

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals (continued)											
CB112		1		1				CBBT 3 & ES	2	2	1
CB113		1						ES	1	1	1
CB114		1	1					ES	2	2	1
CB115		1						ES	1	1	1
CB116		2						ES	2	1	2
CB117		1						ES	1	1	1
CB118		1						CBBT 3	1	1	1
CB119		1						CBBT 3	1	1	1
CB120		1		1				CBBT 3 & ES	2	2	1
CB121		2						CBBT 3 & ES	2	1	2
CB122		1						ES	1	1	1
CB123		1	1					ES	2	2	1
CB124		1						ES	1	1	1
CB125		1						ES	1	1	1
CB126		1	1					ES	2	2	1
CB127		1				1		ES	2	2	1
CB128*			1					ES	1	1	1
CB129			1				1	ES	2	2	1
CB130			1					CBBT 3	1	1	1
CB132			1			3		CBBT 3/4	4	2	3
CB133			1					CBBT 3	1	1	1

*CB128 found stranded/dead at the Eastern Shore survey area on 9 April 2019

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals (continued)											
CB134			1					CBBT 3	1	1	1
CB135			1					CBBT 3	1	1	1
CB136			1					CBBT 3	1	1	1
CB137			1					CBBT 3	1	1	1
CB138			1					ES	1	1	1
CB139			1			1		ES	2	2	1
CB140			1					ES	1	1	1
CB141			1					ES	1	1	1
CB143			1					ES	1	1	1
CB144			1					ES	1	1	1
CB145			1					ES	1	1	1
CB146			1					ES	1	1	1
CB147			1					ES	1	1	1
CB148				1				ES	1	1	1
CB149				1				ES	1	1	1
CB150				1	1	2	1	CBBT 3 & ES	5	4	2
CB151				1				CBBT 3	1	1	1
CB152				1				CBBT 3	1	1	1
CB153				1				CBBT 3	1	1	1
CB154				2			1	CBBT 4 & ES	3	2	2
CB156				1				ES	1	1	1

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals (continued)											
CB157				1	1			ES	2	2	1
CB158				1			1	ES	2	2	1
CB159				1				ES	1	1	1
CB160				1				CBBT 2	1	1	1
CB161					2			ES	2	1	2
CB162					1		1	ES	2	2	1
CB163					1	1		ES	2	2	1
CB164					1		1	ES	2	2	1
CB165					1			ES	1	1	1
CB166					1			ES	1	1	1
CB167					1			ES	1	1	1
CB169					1			ES	1	1	1
CB170					2	1		ES	3	2	2
CB171					1	1		CBBT 4	2	2	1
CB172					1			CBBT 4	1	1	1
CB173						3		CBBT 3	3	1	3
CB174						2		ES	2	1	2
CB175						1		ES	1	1	1
CB176						2		ES	2	1	2
CB177						2	1	CBBT 3/4	3	2	2
CB178						2		CBBT 3/4	2	1	2

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals (continued)											
CB179						3	1	CBBT 3/4	4	2	3
CB180						1	1	CBBT 3	2	2	1
CB181						1		ES	1	1	1
CB182						2	1	CBBT 3	3	2	2
CB183						1	1	CBBT 3/4	2	2	1
CB184						2		CBBT 3	2	1	2
CB185						1		CBBT 3	1	1	1
CB186						1	1	CBBT 3/4	2	2	1
CB187						2	2	CBBT 3/4	4	2	2
CB188						1		CBBT 3	1	1	1
CB189						1		CBBT 3	1	1	1
CB190						1		CBBT 3	1	1	1
CB191						1		CBBT 3	1	1	1
CB192						1		CBBT 3	1	1	1
CB193						1	1	ES	2	2	1
CB194						1		ES	1	1	1
CB195						1		CBBT 4	1	1	1
CB196						2		CBBT 3	2	1	2
CB197						1	1	ES	2	2	1
CB198						1	1	CBBT 4	2	2	1
CB199						2		CBBT 4	2	1	2

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals (continued)											
CB200						1		CBBT 3	1	1	1
CB201						1	1	ES	2	2	1
CB202						1		ES	1	1	1
CB203						1	1	CBBT 4	2	2	1
CB204						1		CBBT 2	1	1	1
CB205						1		CBBT 2	1	1	1
CB206						2		CBBT 4 & ES	2	1	2
CB207						1		ES	1	1	1
CB208							1	CBBT 3	1	1	1
CB209							1	CBBT 3	1	1	1
CB210							1	CBBT 4	1	1	1
CB211							1	ES	1	1	1
CB212							1	ES	1	1	1
CB213							1	CBBT 4	1	1	1
CB214							1	CBBT 2	1	1	1
CB215							1	ES	1	1	1
CB216							2	CBBT 4 & ES	2	1	2
CB217							1	CBBT 4	1	1	1
CB218							1	CBBT 2	1	1	1
CB219							1	ES	1	1	1

NAVFAC Catalogue ID	Season 2 Dec 2015-Mar 2016	Season 3 Dec 2016-Apr 2017	Season 4 Nov 2017-Feb 2018	Season 5 Dec 2018-Mar 2019	Season 6 Dec 2019-Mar 2020	Season 7 Dec 2020-Apr 2021	Season 8 Nov 2021-Apr 2022	Location	Total No. Days Seen	Total No. Seasons Seen	Max No. Days Seen within a Season
Harbor Seals											
CB220							1	ES	1	1	1
CB221							1	ES	1	1	1
CB222							1	ES	1	1	1
Totals	**28**	**98**	**40**	**24**	**17**	**80**	**60**				
Gray Seals											
CB168					1			ES	1	1	1