Haul-out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay and Eastern Shore, Virginia: 2018/2019 Annual Progress Report

Prepared by

Danielle V. Jones and Deanna R. Rees

Naval Facilities Engineering Command Atlantic
Norfolk, Virginia

March 5, 2020

Suggested Citation:

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

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 by Naval Facilities Engineering Command, Atlantic. Photo taken by Danielle Jones, Naval Facilities Engineering Command Atlantic, under NMFS General Authorization Permit #19826.

This project is funded by United States Fleet Forces Command and carried out by Naval Facilities Engineering Command Atlantic as part of the U.S. Navy's marine species monitoring program

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Acronyms and Abbreviations

BSS	Beaufort sea state
CBBT	Chesapeake Bay Bridge Tunnel
CI	Confidence Interval
°F	degrees Fahrenheit
ft	feet
GA	General Authorization for Scientific Research
Hg	Gray seal (*Halichoerus grypus atlantica)*
km	kilometer(s)
kts	knots
m	meter(s)
min	minute
MLLW	Mean lower low water
mm	millimeter(s)
MMPA	Marine Mammal Protection Act
NAVFAC LANT	Naval Facilities Engineering 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
VDGIF	Virginia Department of Game and Inland Fisheries

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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).

There has been some debate in recent years about the southern range extent for harbor and gray seal stocks in the Western North Atlantic. Until 2018, National Oceanic and Atmospheric Administration (NOAA) Stock Assessment Reports (SARs) indicated that the gray seal and harbor seal populations range from New Jersey to Labrador; 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, report that harbor and gray seal distribution along the United States (U.S.) Atlantic coast appears to be expanding or shifting (DiGiovianni et al. 2011; Johnston et al. 2015; DiGiovianni et al. 2018). This range expansion, especially in the case of the harbor seal, may be due to rapid growth of gray seal populations in Canada and now the Northeastern U.S. (Cammen et al. 2018; Wood et al. 2019). 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, mentioned above, remains the same (Hayes et al. 2019; NOAA NMFS-NEFSC 2019).

In Virginia, reports from local anglers and Chesapeake Bay Bridge Tunnel (CBBT) staff (B. Lockwood and B. Biegel pers. comm.) indicated that seals have been using the CBBT rock armor or "islands" to haul out on for many years in increasing numbers. Additionally, annual pinniped stranding numbers have increased in Virginia since the early 1990s (Costidis et al. 2019).

In order to verify the distribution of seals in southern Virginia, biologists from Naval Facilities Engineering Command, Atlantic (NAVFAC LANT) have been investigating seal presence in Virginia since 2014. Since this project's commencement, there have been five dedicated field seasons of research from 2014-2019 and we have expanded the study to include partnerships with HDR, Inc., The Nature Conservancy (TNC), and the Virginia Department of Game and Inland Fisheries (VDGIF). With these partnerships, we were able to increase survey area coverage beginning in 2016. Harbor seals have been consistently recorded from fall to spring, mainly November to April. Gray seals have been occasionally sighted during the winter, but not on a consistent annual basis.

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, testing and training areas, and vessel transit routes. This report discusses the survey results for the 2018/2019 field season as well as the analyses conducted using data from all five field seasons.

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 Authorization (GA) 19826. The data collected under this effort is being used to

analyze and estimate potential impacts that U.S. Navy training and testing, installation construction (pile driving), and vessel-transiting activities may have on pinniped species and to develop mitigation options if appropriate.

Primary objectives of this project include:

- *assessing occurrence, movement, and haul-out patterns adjacent to Navy testing and training 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 methods to estimate local population size.*

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 14 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**).

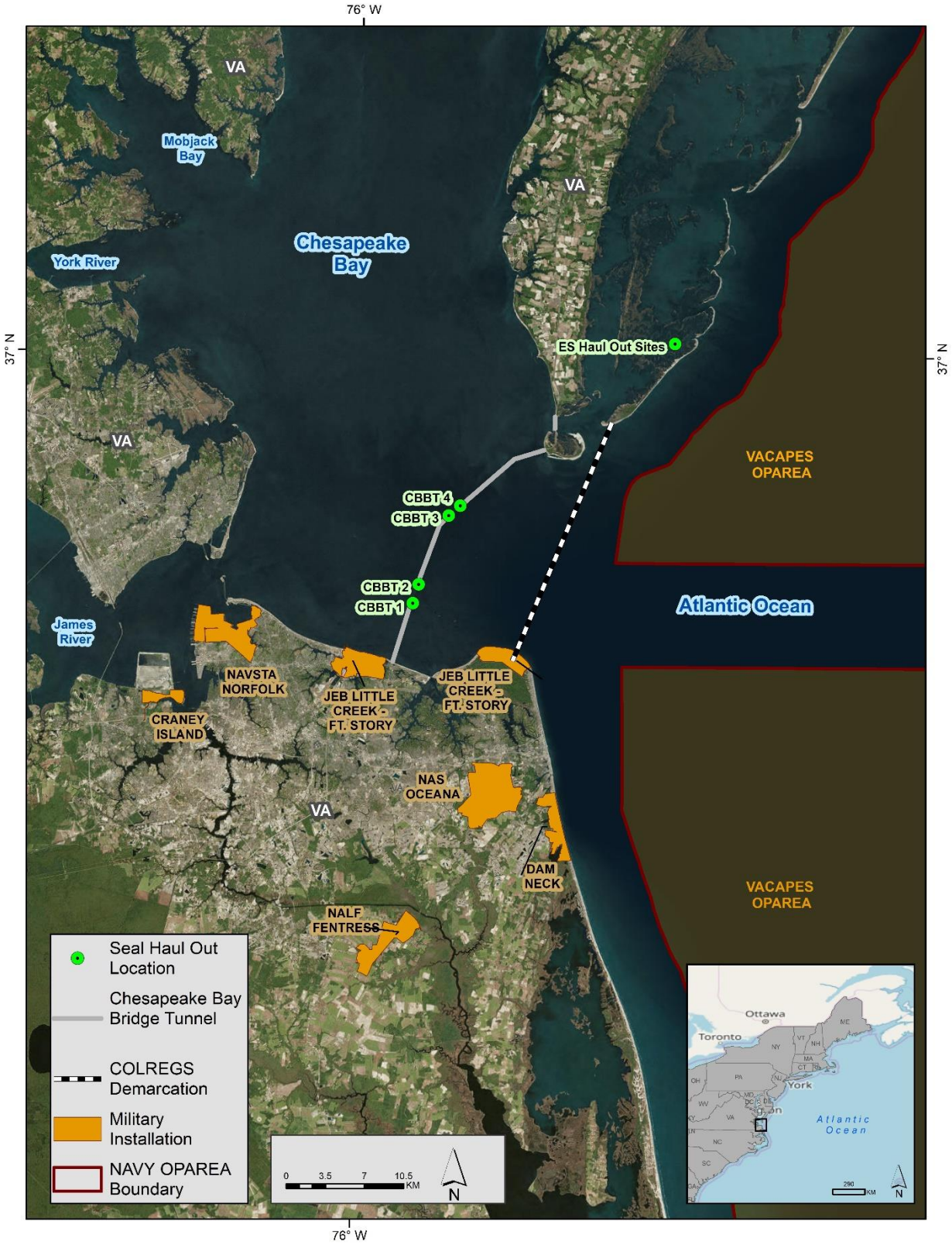

Figure 1. CBBT and Eastern Shore (ES) haul-out locations and their proximity to U.S. Naval Installations. COLREGS = collision regulations; OPAREA = Operating Area; VACAPES= Virginia Capes Range Complex.

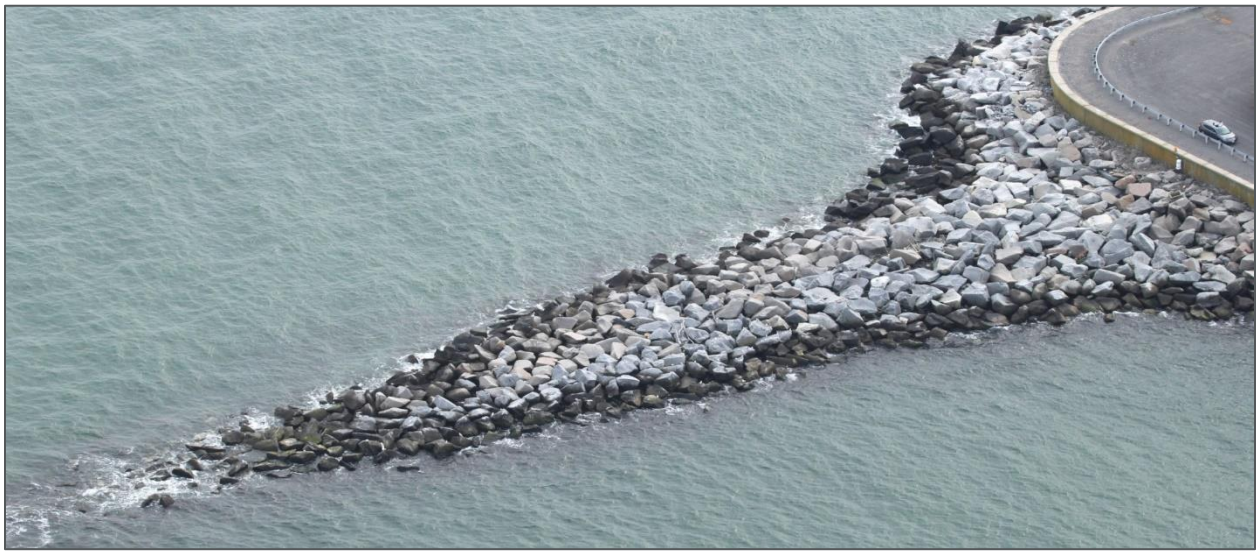

Figure 2. Aerial view of a CBBT haul-out site. Seals generally haul-out on the tip of the rock armor farthest from the road. Photo by Virginia Aquarium & Marine Science Center Foundation

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) where seals have been observed. The haul-out sites are within a tidal salt marsh habitat, and are mainly comprised of mud banks with vegetation (**Figure 3**).

Figure 3. 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 distance from the northernmost (i.e., the closest) CBBT haul-out site, CBBT 4, to the Eastern Shore survey area is approximately 25 kilometers (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 survey at each survey area after no seals were sighted. This allowed for the documentation of the arrival and departure time frame for the season.

For the 2018/2019 field season, systematic vessel-based counts were conducted in collaboration with VDGIF and 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-ft fiberglass hybrid-foam-collar boat, owned and operated by HDR, Inc., or an 18-ft Parker, owned and operated by VDGIF. The vessel surveys at the Eastern Shore survey area were conducted using a 19, 23, or 24-foot (ft) Carolina skiff (**Figure 4**). The survey crew consisted of one or two marine mammal observers, one data recorder, and one boat captain.

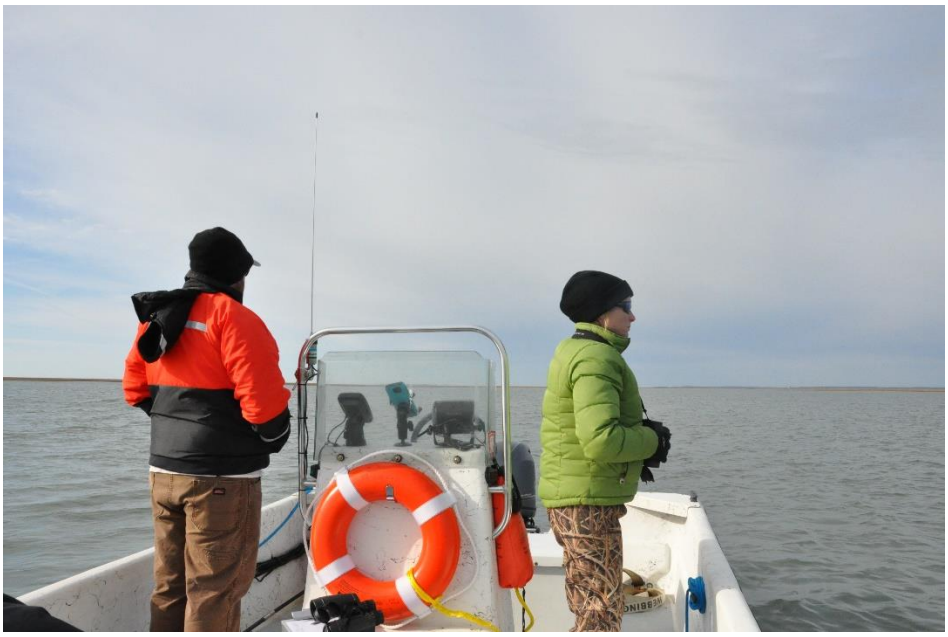

Figure 4. Observers used a Carolina skiff (vessel) for the Eastern Shore haul-out counts. Photo by NAVFAC Atlantic

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 rain and snow. 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 0.01 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). Three separate 2-minute counts (10 minutes apart) were conducted at each site to account for seals moving between the water and the haul-out sites. 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 start and end times, 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 across each of the three two-minute counts, 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. A 1.4x TC-1401 teleconverter was often 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 (neck region, dorsal, lateral, ventral) of each seal were taken when possible in order to obtain quality photos of pelage (fur) patterns.

For 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. The UAS, a DJI Inspire 1 Pro quadrocopter with a Zenmuse X5 camera and Olympus 14-44mm zoom lens, was used and 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 a haul-out site. 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 when there were a high number of animals hauled out, approximately 30 or more animals hauled out, and only in good weather conditions (e.g., no precipitation and winds less than 15 knots (kts)). Depending on the haul-out site at this survey area, animals may be obscured by 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 to capture photos and video from 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 haul-out counts. In addition to improving counts at the known haul-out sites, the UAS was occasionally used to survey a broader area to investigate whether or not seals established any new haul-out sites.

Environmental data were recorded prior to the start of each survey at each of the haul-out sites and also 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, wind direction (cardinal and degrees), wind gusts (kts), visibility, tidal height (ft) (MLLW), Beaufort Sea state (BSS), glare (%), and cloud cover (%).

For the 2018/2019 season, environmental data, with the exception of visibility, BSS, cloud cover, and glare were acquired from several NOAA weather stations. 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 CBBT, Chesapeake Channel and Kiptopeke stations from October through December 2018. Beginning in January 2019, environmental data were collected from the Kiptopeke station 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 will likely 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, collected images were cropped and graded based on photographic quality and distinctiveness of the pelage pattern. 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 was updated (see below) after the 2015/2016 progress report (Rees et al. 2016). All photos have been reassessed using these new criteria, and 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 individuals in these images have been matched to individuals identified in this study, providing valuable historical occurrence information. The Lockwood photos were not utilized in our analyses as they were not collected under similar 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 (sharp focus, no glare, minimum angling of seal to camera, and majority [≥ 75%] of seal captured). Q1 photos were generally a perpendicular shot showing an entire side of the animal, with fully wet pelage. A Q2 represented a good photo (minimal glare, minor bending/obstructions, and 50-75% of seal

captured, with mostly wet pelage) and, although not perfect, was suitable for both manual and computer aided photo-ID. A Q3 represented a marginal photo; images may have been suitable for photo-ID, but problems were persistent (mediocre focus, moderate glare, bending, obstruction, and only 25-50% of seal captured). A seal that scored a Q3 generally had partially dry pelage or other obstructions that interfered with pattern visibility. A Q4 represented a photo with a quality too poor to reliably conduct photo-ID using either computer software or through manual matching (limited focus, substantial glare, shading, or bending, <25% of animal captured, and/or fully dry pelage).

The photographic distinctiveness rating (D1-D3) focused on the distinctiveness of pelage patterns and/or unique markings/scarring of an animal. A score of D1 represented an individual with very distinct patterns (large and numerous marks, visible scars, and/or 3+ very characteristic marks apparent even in poor quality photos). A D2 score represented 1-2 characteristic marks or some, but limited, distinctive patterning. A D3 represented seals with a uniform pelage and no distinct markings.

Using the quality and distinctiveness grades for images, a catalogue 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 catalogue and seal ID database. The results of the grading were used to determine population abundance of harbor seals within the study area (Section 2.4.2 [Abundance Estimation]). For each photo selected for inclusion in the catalogue, standardized descriptions were applied for pelage color patterns (i.e., color phase), which allowed for greater ease in manual matching by creating 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), dark/light (seal pelage with two distinct light and dark color phases).

Fields included within the database were: 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 catalogue allowed 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 catalogue and captured 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 surveys 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 five field seasons (2014/2015, 2015/2016, 2016/2017, 2017/2018, and 2018/2019) for the CBBT survey area using a one-way analysis of variance. Mean seal count was also compared between the three field seasons (2016/2017,

2017/2018, and 2018/2019) for the Eastern Shore survey area using a one-way analysis of variance. 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.

2.4.2 Abundance Estimation

To estimate the population abundance (N) of harbor seals utilizing the CBBT and Eastern Shore survey areas, we used the mark-recapture data from the photo-ID portion of the study and fitted a Lincoln-Petersen mark-resight model. The Lincoln-Petersen mark-resight 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.

$$N = ((m_1 * n_2)/m_2), \text{ where}$$

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 catalogue. 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. For m_2, this was the number of times each uniquely identified seal was re-sighted. As a result of the small sample size, all re-sightings were counted, as opposed to just one re-sighting per individual.

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

3. Results

3.1 Haul-out Counts: 2018/2019 Field Season

Haul-out counts commenced in November 2018 for the fifth field season at the CBBT survey area. Counts were conducted over the course of 11 survey days between 18 November 2018 and 24 April 2019 (**Table**). Once seals were sighted in the survey area, animals were recorded on a consistent basis (10 out of 11 [90.9%] survey days) until departure. A best total estimate (combined in water and hauled out) of 82 seal sightings was recorded across the four CBBT haul-out locations (**Table)**. Seals were observed more at CBBT 3 than the other CBBT haul-out sites, similar to previous field seasons. Of the estimated 82 seal sightings, 54 (65.9%) were recorded at CBBT 3. The total number of seals counted per survey day ranged from 0-17 seals. The harbor seal was the only pinniped species that was observed at the CBBT survey area during this field season.

Table 1. Summary of the number of seals sighted for the 2018/2019 field season for the CBBT survey area

Date	Number of Individuals Pv	Number of Individuals Hg
18-Nov-18	1	0
30-Nov-18	2	0
13-Dec-18	13	0
19-Dec-18	16	0
4-Jan-19	7	0
1-Feb-19	11	0
21-Feb-19	10	0
7-Mar-19	17	0
28-Mar-19	1	0
9-Apr-19	4	0
24-Apr-19	0	0
Total	**82**	**0**

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

Haul-out counts commenced in November 2018 for the third field season at the Eastern Shore survey area. Counts were conducted over the course of 13 survey days, between 1 November 2018 and 22 April 2019 (**Table**). Once seals were sighted in the survey area, animals were recorded on a consistent basis (11 out of 13 [84.6%] survey days) until departure. Seals were observed at four of the five main haul-out sites; and seals did not appear to establish any new haul-out sites. Over the entire season, a best total estimate (combined in water and hauled out) of 160 seal sightings were recorded (**Table**). The total number of seals counted ranged from 0-66 seals per survey day. The majority of seals observed were identified as harbor seals; one gray seal was observed on 28 January 2019 and 5 February 2019. The UAS was used to conduct only one count during the 2018/2019 season, specifically during the 5 February 2019

survey, which resulted in a total number of 66 seals sighted. The total number of seals sighted during the boat-based counts for this survey resulted in a similar count of 61 seals.

Table 2. Summary of the number of seals sighted for the 2018/2019 field season at the Eastern Shore survey area

Date	Number of Individuals Pv	Number of Individuals Hg
1-Nov-18	0	0
19-Nov-18	3	0
7-Dec-18	15	0
27-Dec-18	5	0
17-Jan-19	6	0
22-Jan-19	4	0
28-Jan-19	27	1
5-Feb-19	65	1
28-Feb-19	6	0
8-Mar-19	20	0
28-Mar-19	6	0
9-Apr-19	1	0
22-Apr-19	0	0
Total	**158**	**2**

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

3.2 Seal Presence Analysis Results

A total of 88 survey days have been conducted across five 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 5**). Most sightings (85.8%) occurred at the CBBT 3 haul-out site during all five field seasons. This percentage should be interpreted with caution due to the variation in survey effort across field seasons at the CBBT survey area.

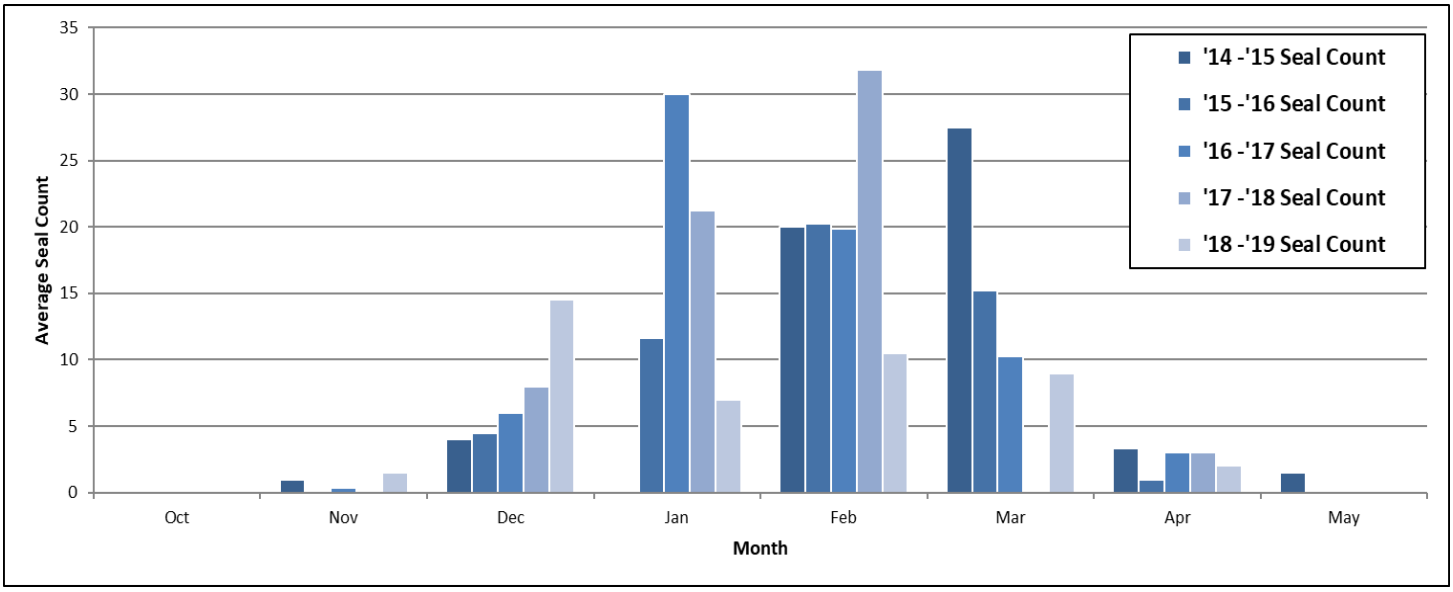

Figure 5. Average seal count by month using "in season" effort for the CBBT survey area. Surveys were not conducted in January 2015 or March 2018.

Once seals arrived in the CBBT survey area, animals were recorded on a fairly consistent basis (69 out of 88 [78.4%] survey days) until departure. Based on this, we termed the number of survey days between and including the first and last seal observation as "in season" survey effort and used this in our analyses. The number of seals observed appeared to be increasing over the first four field seasons; given the increase in total count and maximum count for a single survey (**Table**). However, a drop in total and maximum seal count occurred for the 2018/2019 field season. The average number of seals observed per "in season" survey day also increased across the first four field seasons, but decreased to eight seals for the 2018/2019 field season. The difference between the mean counts across the five field seasons was statistically significant (F_{stat} = 3.076, p = 0.022), with the Tukey/Kramer test results (Q_{cv}=3.95 for df=67) indicating that the mean counts for the 2017/2018 and 2018/2019 seasons were statistically different (Q_{stat}= 4.37). This between-season comparison, however, does not take into account the sampling bias for the 2017/2018 season. Values (e.g., average and max count) for the fourth 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) and unequal survey effort across months (e.g., no surveys in March and concentrated survey effort in January and February) for that season.

Table 3. "In season" survey effort, total seal count (best estimate), max seal count on a single survey day, and effort-normalized average (number of seals observed per "in season" survey day) at the CBBT survey area

Field Season	"In Season" Survey Days	Total Count	Average Count	Max Count
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

A total of 31 surveys have been conducted across three field seasons at the Eastern Shore survey area. Seals have been recorded from early November to early April **(Figure 6).**

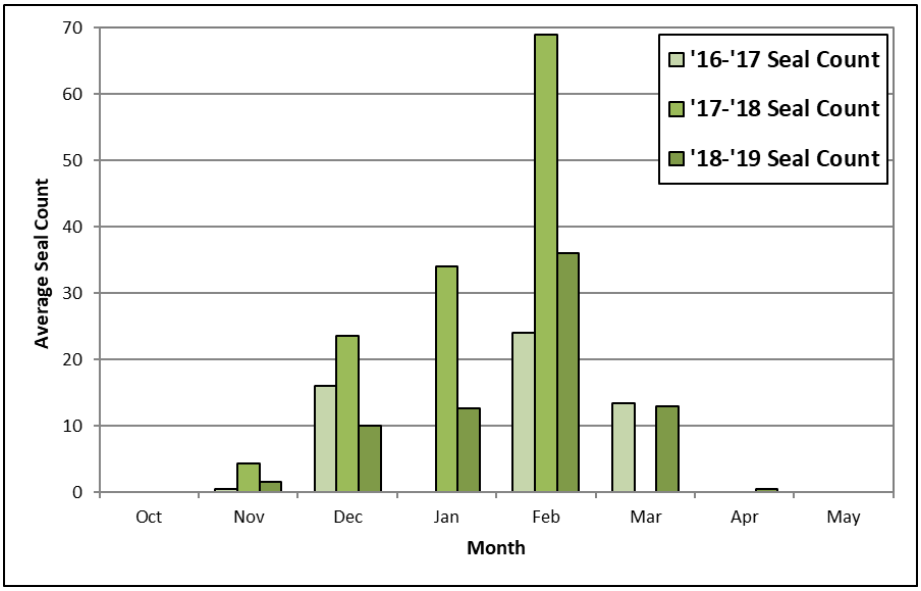

Figure 6. Average seal count by month using "in season" effort for the Eastern Shore survey area. Surveys were not conducted in January 2017 and from March to April 2018.

Once seals arrived in the Eastern Shore survey area, animals were recorded on a fairly consistent basis (26 out of 31 [83.9%] survey days) until departure. Based on this, we termed the number of survey days between and including the first and last seal observation as "in season" survey effort and used this in our analyses. Over three field seasons, the number of seals observed does appear to fluctuate. The total count and maximum count for a single survey increased over the first two field seasons, however, both total and maximum count for a single survey were lower for the 2018/2019 field season (**Table**). The average number of seals observed per "in season" survey day also increased over the first two field seasons, but decreased to 15 seals for the 2018/2019 season. The difference between the mean counts

across the three field seasons was not statistically significant (F_{stat} = 3.422, p = 0.437). This between-season comparison, however, does not take into account the sampling bias for the 2016-2018 seasons. There was unequal survey effort across months (e.g., no surveys conducted in January 2017 and March-April 2018) for the first two seasons.

Table 4. "In season" survey effort, total seal count (best estimate), max seal count on a single survey day, and effort-normalized average (number of seals observed per "in season" survey day) at the Eastern Shore survey area

Field Season	"In Season" Survey Days	Total Count	Average Count	Max Count
2016-2017	7	105	15	24
2017-2018	8	197	25	69
2018-2019	11	160	15	66

3.3 Photo Identification

For the 2018/2019 field season, 21 harbor seals were uniquely identified based upon image grading criteria. Of the 21 harbor seals, 12 (57.1%) were new individuals to the catalogue and nine (42.9%) were re-sightings of individuals that were identified from previous field seasons. Identified seals were sighted at the CBBT and Eastern Shore survey areas, with 10 seals sighted at only the CBBT survey area and 11 seals sighted at only the Eastern Shore survey area. However, three of the 11 identified seals sighted at the Eastern Shore survey area were also sighted at the CBBT survey area in previous field seasons (**Table A-1**).

After reviewing all images from the 2015/2016, 2016/2017, 2017/2018, and 2018/2019 field seasons, 112 harbor seals were uniquely identified (**Table A-1**) based upon image grading criteria. Gray seals (n=5) could not be uniquely identified by collected images based on the image grading criteria for quality; images were too poor of quality. As previously mentioned, images from the 2014/2015 season did not meet the quality standards for the study. The last images used for photo-ID analysis were collected on 8 March 2019. None of the images collected on 9 April 2019 (the last day of sightings for the 2018/2019 season) met the quality standards for the study.

Of the 112 uniquely identified harbor seals, 72 (64.3%) were observed only once and 40 (35.7%) were determined to be present in the study area on more than one occasion across the four field seasons. 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 March 2019, 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 1,105 days (CB062, 12 February 2016 and the last sighting being on 21 February 2019). Across the study period, 25 individuals were observed on two survey days and 15 individuals were observed on three or more survey days, with the maximum number of encounters being 10 (CB069).

Photo-ID data from four 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 40 individuals identified to be present on more than one occasion, 10 were re-sighted within one season, 24 were sighted across two different field seasons, five (e.g., CB062) were sighted across three different field seasons and one (CB053) was sighted across four different field seasons. For example, CB005 was first captured on 26 February 2016 and then re-captured multiple times during the 2016-2018 seasons, with the last re-capture on 6 February 2018 (**Figure)**. 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, CB004, CB006, CB083, and CB099 were sighted all together at the same haul-out site (CBBT 3) on 25 January 2017 and then re-sighted together at that same haul-out site on 14 February 2018, which amounts to a 385-day span between sightings.

For the 2015/2016 field season, surveys were only conducted at the CBBT; therefore, individual seals were identified only at the CBBT survey area. Beginning in the 2016/2017 field season , surveys were conducted at the CBBT and Eastern Shore survey areas; therefore, individual seals were identified from both survey areas. The majority of identified seals (n=71) have been sighted at only the CBBT survey area, with some (n=34) being sighted at only the Eastern Shore survey area. However, seven identified seals (CB020, CB053, CB057, CB087, CB112, CB120, and CB121) have been sighted at both survey areas on separate survey days. Two seals, CB053 and CB121, were sighted at both survey areas during the same season, whereas, the other seals (e.g., CB020) were sighted at each survey area across different seasons.

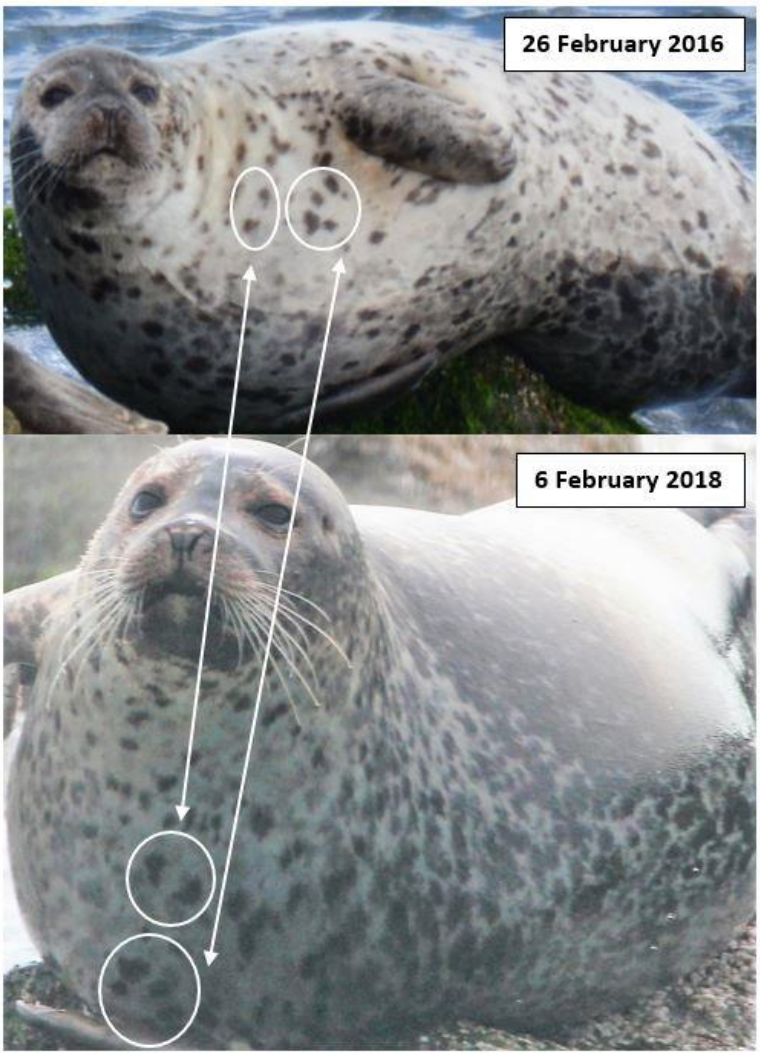

Figure 7. Harbor seal, CB005, captured on 26 February 2016 at the CBBT 3 haul-out site (above) and re-captured on 6 February 2018 at CBBT 3 (below). Photo by NAVFAC Atlantic under NMFS GA Permit #19826

3.4 Abundance Estimates

The abundance estimates calculated from the Lincoln-Peterson model for the 2015-2019 field seasons ranged from 88 (95% CI: 47.67-128.66) to 221 (95% CI: 83.61-357.40) individual harbor seals (**Figure**). 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. The lowest abundance estimate (88 individuals) occurred during the 2015/2016 field season; however, it should be noted that this season had a low number of captures (n=23), which was most likely due to a lower amount of survey effort and not a large enough zoom lens (≤ 400 mm) for photo-ID. 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 three seasons' abundance estimates since capture and re-capture data were used from both the CBBT and Eastern Shore survey areas. Overall, abundance estimates did 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= 125 individuals) was observed. The 2018/2019 season had the highest estimate of 221 individuals, however, the 95% confidence interval (CI) for this season's estimate is larger (83.61-357.40) 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 number of captures (n=21) and re-captures (n=2) that were recorded for this 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 = 0.16), therefore, the population does not appear to be increasing or decreasing, and may be stable.

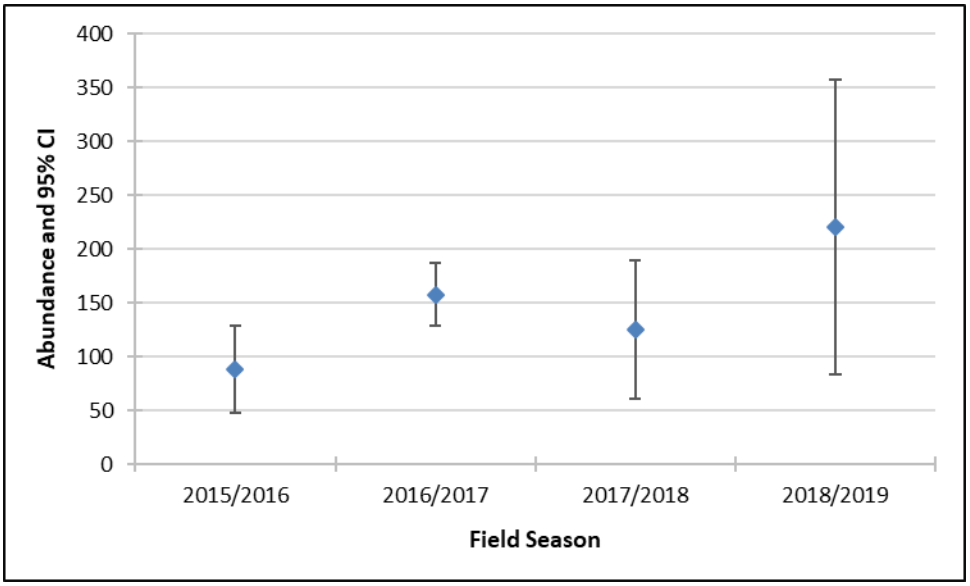

Figure 8. Total abundance estimates (blue diamonds) and 95% confidence intervals (CIs) for the CBBT and Eastern Shore survey areas combined during each of the field seasons: 2015/2016, 2016/2017, 2017/2018, and 2018/2019.

With the abundance showing a fluctuation across seasons and no discernable trend, a mean abundance estimate was calculated. The abundance estimate for all four seasons (2015/2016, 2016/2017, 2017/2018, and 2018/2019) yielded an estimate of 159 individuals (95% CI: 148.61-168.96). Given the CI, this estimate may be a fairly reliable representation of the number of harbor seals using both the CBBT and Eastern Shore survey areas.

4. Discussion

The results from this study to date indicate that seals regularly occur in southeastern Virginia from the fall to the spring. Furthermore, count data collected from the first four field seasons showed an increase in seal presence from the 2014/2015 season through the 2017/2018 season; with the majority of the observations comprising harbor seals. This increase in numbers is very apparent for the CBBT study area; with maximum seal count for a single survey day and average seal count per “in season” survey day increasing from 2014 to 2018. A similar increasing trend for maximum seal count for a single survey day and average seal count per “in season” survey day was observed for the Eastern Shore survey area from 2016 to 2018. However, a decrease in both maximum and average seal count occurred at the CBBT and Eastern Shore survey areas for the 2018/2019 field season. The lowest total, maximum, and average seal counts for the CBBT survey area were reported for this season since the start of the study in 2014. In addition, there was a statistically significant difference between the average seal counts across the five field seasons for the CBBT survey area. The drop in maximum and average seal count for the 2018/2019 season for the Eastern Shore survey area was not as substantial compared to the CBBT survey area for this season, and the difference between average seal counts across the three field seasons (2016-2019) was not statistically different.

The observed decrease in maximum and average seal count as well as overall seal sightings for the 2018/2019 season may be due to sampling bias in survey effort and/or an unusual mortality event (UME). 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 (vessel-based counts vs. land-based counts) for the CBBT survey area and variable survey effort from the 2014-2019 seasons for both survey areas, leading to sampling bias. In 2018, a Northeast U.S. Pinniped UME was declared, 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 have been observed in seals that stranded as far south as Virginia, therefore, the UME encompasses all seal strandings from Maine to Virginia (NOAA 2019). 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). 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 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.

Although the majority of seals observed 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; 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.

Harbor seals were consistently recorded in the CBBT and Eastern Shore survey areas from November to April. Results from initial data exploration of “in-season” seal count for the CBBT survey area for the 2014-2018 field seasons indicated that seal occurrence at the CBBT survey area may vary based on oceanographic and environmental conditions. Previous correlation and regression analyses indicated that arrival and departure of seals at the CBBT survey area may coincide with changes in water temperature and tidal height (Jones et al., 2018). These analyses were not conducted using the 2018/2019 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). With vessel surveys being highly dependent on weather and boating conditions, data collection is limited. A separate, complimentary pilot project is currently underway investigating the use of remote cameras at both the CBBT and Eastern Shore survey areas to overcome sampling bias in both sampling methodology and unequal survey effort. Preliminary data indicate that remote cameras are a viable addition to vessel survey effort with the benefits of visual site monitoring in most weather conditions and at all times of the day. With remote cameras, we are finding that it will be possible to simultaneously sample multiple haul-out sites for extended periods of time with relatively low personnel demands. Because data is collected so frequently (every 5-15 minutes), a more robust investigation of seal presence and haul-out behavior in relation to time of day, weather, and tidal cycles will be able to be conducted.

Prior to this 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-re-capture data. A total of 159 individuals were estimated as the average seasonal abundance across all four seasons (2015-2019). Abundance estimates were also calculated for each annual field season, with an abundance of 88 individuals for the 2015/2016 season, increasing to 221 individuals for the 2018/2019 season, with the exception of the 2017/2018 season, in which abundance decreased to 125 individuals. Inferences about population trends in the region cannot be accurately made due to this fluctuation in abundance across seasons as well as the recently observed decrease in maximum and average seal count 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. It is difficult to draw further conclusions with this limited data. Our aim is to develop a more robust dataset that will allow us to determine if the population is, in fact, stable or if the overall population is potentially increasing and/or harbor seal site fidelity at this southeastern Virginia study area is 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 (Rees et al. 2016; NOAA NMFS-NEFSC 2019; Schneider and Payne 1983; Schroeder 2000). Results from this study document that a small population does occur seasonally within southeastern Virginia. This study’s results also contributed towards the updated geographic range for harbor seals of the Western North Atlantic stock in the 2019 draft NOAA SAR.

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 increasing trend observed in average seal count from 2014-2018 and 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 original range. Several researchers report that harbor and gray seal distribution along the U.S. Atlantic coast appears to be expanding or shifting (DiGiovianni et al. 2011; Johnston et al. 2015; DiGiovianni et al. 2018), which could explain the potential increase in seal occurrence at the CBBT and Eastern Shore survey areas since 2014. An increase in gray seal pupping (Wood et al. 2019) and overall, abundance, in the Northeastern U.S. could create interspecific competition for the two species, whether that is for habitat and/or prey resources, thus leading to changes in species distribution. 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 a southern expansion of harbor seals along the east coast (Sieswerda and Kopelman 2018).

Based on the photo-ID analysis, harbor seals may not only be expanding their distribution farther south, but some individuals are returning to the same southerly haul-out locations across multiple seasons. Photo-ID conducted via visual matching for the 2015 to 2019 field seasons has shown that individual harbor seals (40 out of 112 uniquely identified seals) sighted at the CBBT and Eastern Shore study areas 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 some individuals, identifiable re-sightings across the study period have spanned approximately three years. In addition, some of the identified harbor seals have been utilizing the CBBT haul-out sites for longer than our study period captures. Based on 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 supports a series of regular, seasonal haul-out sites for harbor seals within the lower Chesapeake Bay and Eastern Shore, Virginia.

Through the use of photo-ID, we have also been able to gather more information on movement and habitat preference within the region. The majority of identified harbor seals (63%) have been sighted at only the CBBT survey area, with some (30%) being sighted at only the Eastern Shore survey area. However, seven individuals were re-sighted at both survey areas on separate survey days within a season and across seasons. These results indicate the potential for harbor seals to make localized movements throughout the region during their seasonal occupancy and that while some seals may be utilizing a particular haul-out site within a given season, others may utilize multiple haul-out sites within a season. A pinniped tracking study for southeastern Virginia reinforces the concept of localized seasonal movements within the region (Ampela et al. 2019). Five of the seven harbor seals captured at a haul-out site from the Eastern Shore survey area in February 2018 and equipped with satellite tags 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 increasing within the study area. 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. **Expand satellite-monitored tagging effort**. Seven harbor seals were successfully tagged within the Study Area in February 2018 with both satellite and acoustic tags. The satellite data for the tagged seals is available on Movebank.org, and the final report on the 2017/2018 season was completed in March 2019. Satellite tags were not deployed on harbor seals during the 2018/2019 field season. Tagging efforts for the 2019/2020 field season are in the planning phase and field work is scheduled for February- March 2020. Data from this study will better demonstrate the occurrence, migratory routes, and behavior of seals in this area, as well as provide a baseline for behavioral response studies in the future.

2. **Continue the use of unmanned aircraft systems (UAS).** The use of UAS will allow biologists to survey on the Eastern Shore to access inaccessible barrier islands for additional haul-outs and possibly improve count and photographic data collected. UAS imaging systems provide a permanent visual record; allow for visual detection of all animals on the haul-out during point counts (animals are less likely to be obscured if viewed from above), which should increase the accuracy of haul-out counts; and improve the identification of species and ability to detect previously captured/tagged/marked animals.

3. **Consider using automated photo identification tools.** 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 tools are being developed to assist in seal pelage pattern recognition and matching individuals (e.g. Hotspotter), 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 and improve photo-matching time.

4. **Submit data to OBIS-SEAMAP**. Documentation of seal presence for Virginia is currently lacking in sightings databases and the published literature. Adding these data to OBIS-SEAMAP will allow them to be archived and accessible for use by future researchers and helps us to connect with those who we would collaborate with to

augment our understanding of the distribution and the ecology of pinnipeds in the Mid-Atlantic.

5. **Continue to collect and analyze remote camera data.** The use of remote cameras is being evaluated to provide additional data needed at the Eastern Shore and CBBT survey areas. The initial deployment in January and February 2019 sampled two of the five known Eastern Shore haul-out sites. Data are currently being processed and preliminary results for those locations (e.g., time spent hauled out and haul-out behavior in relation to time of day, tidal phase and wind speed) will be available by the end of February 2020. New remote cameras were deployed in November 2019 at all five known haul-out sites on the Eastern Shore and a camera was deployed at the CBBT 3 haul-out site in January 2020. These data will be used to investigate what influence weather, tides, and time of day may have on seal presence in the region. A separate report detailing the remote camera project will be available in late 2020.

6. Acknowledgements

This project is funded by USFF and was undertaken by members of the NAVFAC LANT Marine Resources Group as part of the U.S. Navy's marine species monitoring program.

We would like to acknowledge all of the individuals that have contributed to this effort, beginning in 2014. We would like to thank Andrea Bogomolni at Woods Hole Oceanographic Institute, Lisa Sette at the Center for Coastal Studies, and Len Thomas at the University of St. Andrews. The initial advice and feedback of these individuals helped to get this project up and running.

We would especially like to acknowledge Ruth Boettcher and Jeremy Tarwater from VDGIF, who have been coordinating the CBBT vessel surveys with us since 2017, as well as Alex Wilke and Zak Poulton from TNC, who have been coordinating the Eastern Shore surveys with us since 2016. Ruth and Jeremy have graciously volunteered their time and resources to support the CBBT vessel surveys since the CBBT expansion project started. We would also like to thank HDR, Inc., who started providing additional support for the CBBT vessel surveys in November 2018. The CBBT surveys would not be possible without the continued support from VDGIF and HDR, Inc. The Eastern Shore surveys would not be possible without Alex and Zak's tremendous support and interest in the project. They have helped us expand our overall study area, which in turn has greatly improved the amount of information we have for harbor seals in southeastern Virginia.

We would also like to thank the CBBT authority, specifically Chief Spencer, Brent Beagle and the numerous escorts that have accompanied us on our land-based counts in previous field seasons at the CBBT haul-out sites. And, thank you to Brian Lockwood for providing numerous photographs of harbor seals over multiple years to assist in our study.

Thank you to Laura Busch, from USFF, for the valuable feedback and continued support for this project. We would also like to thank from USFF, Amy Farak and Ryan Schultz, for their helpful feedback during the review of this report. From NAVFAC LANT, we would like to thank Joel Bell,

Cara Hotchkin, Jackie Bort Thornton, Carter Watterson, and Jaime Gormley for field work assistance and valuable feedback. From NAVFAC Pacific, we would like to especially thank Brittany Bartlett for all of the assistance she provided with field work, data analysis, and report preparation for previous field seasons when she worked with us on this project at NAVFAC LANT. From Ecology and Environment, Inc., we would like to thank Gwen Lockhart for field work assistance and valuable feedback. In addition, a special thanks to our Pinniped Team counterparts at the Naval Undersea Warfare Center, Division Newport, especially Dr. Jason Krumholz for a plethora of statistical knowledge and feedback. We greatly appreciate your partnership and guidance throughout the span of this project.

7. References

Ampela, K., M. DeAngelis, R. DiGiovanni, Jr., and G. Lockhart. 2019. Seal Tagging and Tracking in Virginia, 2017-2018. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-8006, Task Order 17F4058, issued to HDR, Inc., Virginia Beach, Virginia. December 2018. Accessible via https://www.navymarinespeciesmonitoring.us/index.php/download_file/view/1953/.

Balmer, B.C., Wells, R.S., Nowacek, S.M., Nowacek, D.P., Schwacke, L.H., Mclellan, W. A., Scharf, F.S., Rowles,T.K., Hansen, L.J., Spradlin, T. R., and D.A. Pabst. 2008. Seasonal abundance and distribution patterns of common bottlenose dolphins (*Tursiops truncates*) near St. Joseph Bay, Florida, USA. *Journal of Cetacean Research and Management*, 10(2): 157-167.

Cammen, K. M., T.F. Schultz, W. Don Bowen, M.O. Hammill, W.B. Puryear, J. Runstadler, F.W. Wenzel, S.A. Wood, S., and M. Kinnison. 2018. Genomic signatures of population bottleneck and recovery in Northwest Atlantic pinnipeds. *Ecology and Evolution*, 8(13): 6599-6614.

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

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

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

Forcada, J. and A. Aguilar. 2000. Use of photographic identification in capture-recapture studies of Mediterranean Monk seals. *Marine Mammal Science*, 16(4): 767-793.

Grellier, K., Thompson, P. M., and H.M. Corpe. 1996. The effect of weather conditions on harbour seal (Phoca vitulina) haulout behaviour in the Moray Firth, northeast Scotland. *Canadian Journal of Zoology, 74*(10), 1806-1811.

Hayes S. A., Josephson E., Maze-Foley K., Rosel P. E., Byrd B., Chavez-Rosales S., Col T. V. N., Engleby L., Garrison L. P., Hatch J., Henry A., Horstman S. C., Litz J., Lyssikatos M. C., Mullin K. D., Orphanides C., Pace R. M., Palka D. L., Soldevilla M., and F. W.

Wenzel. 2018. TM 245 US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2017. NOAA Tech Memo NMFS NE-245; 371 p.

Hayes S. A., Josephson E., Maze-Foley K., Rosel P.E., Byrd B., Chavez-Rosales S., Col T.V.N, Garrison L.P., Hatch J., Henry A., Horstman S.C., Litz J., Lyssikatos M.C., Mullin K.D., Orphanides C., Pace R.M., Palka D.L., Powell, J., and F. W. Wenzel. 2019. TM 258 US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2018. NOAA Tech Memo NMFS NE-258; 306 p.

Jefferson, T. A., Webber, M. A., and R. L. Pitman. 2015. Marine Mammals of the World: A Comprehensive Guide to Their Identification, Second Edition. Academic Press, San Diego, CA

Johnston, D.W., Frungillo J., Smith A., Moore K., Sharp B., Schuh J., and A. Read. 2015. Trends in Stranding and By-Catch Rates of Gray and Harbor Seals along the Northeastern Coast of the United States: Evidence of Divergence in the Abundance of Two Sympatric Phocid Species? PLoS ONE 10(7): e0131660. doi:10.1371/journal.pone.0131660

Jones D.V., Rees, D.R., and B.A. Bartlett. 2018. *Haul-out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay and Eastern Shore, Virginia: 2017/2018 Annual Progress Report. Final Report*. Prepared for U.S. Fleet Forces Command, Norfolk, Virginia. 21 December 2018.

Katona, S. K., V. Rough, and D. T. Richardson. 1993. A field guide to whales, porpoises, and seals from Cape Cod to Newfoundland. Smithsonian Institution Press: Washington, DC, 316 pp.

Lesage, V. and M. O. Hammill. 2001. The status of the Grey Seal, *Halichoerus grypus*, in the Northwest Atlantic. *Canadian Field-Naturalist*, 115(4): 653-662.

NOAA. 2019. 2018-2019 Pinniped Unusual Mortality Event along the Northeast Coast. Retrieved from https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-life-distress/2018-2019-pinniped-unusual-mortality-event-along as accessed on January 7, 2020.

NOAA NMFS-NEFSC. 2019. DRAFT US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2019. Retrieved from https://www.fisheries.noaa.gov/national/marine-mammal-protection/draft-marine-mammal-stock-assessment-reports as accessed on January 7, 2020.

Pauli, B. and J. Terhune.1987. Meteorological influences on harbour seal haul-out. *Aquatic Mammals, 13*(3), 114-118.

Raposa, K.B. and R.M. Dapp. 2009. A Protocol for Long-Term Monitoring of Harbor Seals (*Phoca vitulina concolor*) in Narragansett Bay, Rhode Island. Technical Report Series 2009:2; 48 p.

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

Schneider, D.C. and P.M. Payne. 1983. Factors affecting haul-out of harbor seals at a site in southeastern Massachusetts. *Journal of Mammalogy*, 64(3), 518-520.

Schroeder, C.L. 2000. Population status and distribution of the harbor seal in Rhode Island waters. M.S. thesis. University of Rhode Island, Kingston, RI. 197 pp.

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

Waring, G.T., R.A. DiGiovanni Jr, E. Josephson, S. Wood, and J.R. Gilbert. 2015. 2012 population estimate for the harbor seal (Phoca vitulina concolor) in New England waters. NOAA Tech. Memo. NMFS NE-235. 15 pp.

Wood, S.A., Murray, K.T., Josephson, E., and J. Gilbert. 2019. Rates of increase in gray seal (*Halichoerus grypus atlantica*) pupping at recolonized sites in the United States, 1988-2019. *Journal of Mammalogy,* gyz184.

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A

Sightings History Tables

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Table A-1. Sighting history (days/month) of uniquely identified harbor seals at the Chesapeake Bay Bridge Tunnel (CBBT) and Eastern Shore (ES): December 2015-March 2019

NAVFAC Catalogue ID (Harbor Seals)	2015	2016			2016	2017				2017		2018		2018	2019			Location	Total No. Days Seen	Total No. Season Seen
	Season 2 (2015-2016)				Season 3 (2016-2017)					Season 4 (2017-2018)				Season 5 (2018-2019)						
	December	January	February	March	December	January	February	March	April	November	December	January	February	December	January	February	March			
CB004						1							1					CBBT 3	2	2
CB005			1		1	2						1	1					CBBT 3	6	3
CB006				1		2	1					1	1					CBBT 3	6	3
CB020		1						1					1					CBBT 3 & ES	3	3
CB021		1																CBBT 3	1	1
CB022					1	2							1					CBBT 3	4	2
CB023			1			2												CBBT 3	3	2
CB034		1																CBBT 3	1	1
CB035		1	1															CBBT 3	2	1
CB036		1				1												CBBT 3	2	2
CB037		1																CBBT 3	1	1
CB038			2															CBBT 4	2	1
CB040			1			1												CBBT 3	2	2
CB041			1															CBBT 3	1	1
CB042			1															CBBT 4	1	1
CB043			1															CBBT 4	1	1
CB044			1			1												CBBT 4/3	2	2
CB045			1			1												CBBT 3	2	2
CB046			1			1												CBBT 3	2	2
CB047			1	1					1							1		CBBT 3/4	4	3
CB048			1			1												CBBT 3	2	2
CB051				1														CBBT 3	1	1
CB053	1	1		2				2		1	1			1				CBBT 1/3 & ES	9	4
CB056														1				CBBT 3	1	1

NAVFAC Catalogue ID (Harbor Seals)	2015	2016			2016	2017				2017		2018		2018	2019			Location	Total No. Days Seen	Total No. Season Seen
	Season 2 (2015-2016)				Season 3 (2016-2017)					Season 4 (2017-2018)				Season 5 (2018-2019)						
	December	January	February	March	December	January	February	March	April	November	December	January	February	December	January	February	March			
CB057							1				1							CBBT 3 & ES	2	2
CB062			1									1				1		CBBT 4/3	3	3
CB064			1															CBBT 3	1	1
CB066					1													CBBT 3	1	1
CB067					1													CBBT 3	1	1
CB069						3	5	1				1						CBBT 4/3	10	2
CB070						1												CBBT 3	1	1
CB071						2	1											CBBT 3	3	1
CB072						1												CBBT 3	1	1
CB073						1												CBBT 3	1	1
CB074						1												CBBT 3	1	1
CB076						1												CBBT 3	1	1
CB078						1												CBBT 3	1	1
CB079						1												CBBT 3	1	1
CB080						1												CBBT 3	1	1
CB081						1												CBBT 3	1	1
CB083						2							1					CBBT 3	3	2
CB084						1												CBBT 3	1	1
CB085						1		1										CBBT 3	2	1
CB086						2		1										CBBT 3	3	1
CB087						1					1							CBBT 3 & ES	2	2
CB088						1												CBBT 3	1	1
CB089						1												CBBT 3	1	1
CB090						2												CBBT 3	2	1

NAVFAC Catalogue ID (Harbor Seals)	2015	2016			2016	2017				2017		2018		2018	2019			Location	Total No. Days Seen	Total No. Season Seen
	Season 2 (2015-2016)				Season 3 (2016-2017)					Season 4 (2017-2018)				Season 5 (2018-2019)						
	December	January	February	March	December	January	February	March	April	November	December	January	February	December	January	February	March			
CB091						1												CBBT 3	1	1
CB092						1		1										CBBT 3	2	1
CB094						1												CBBT 3	1	1
CB095						1												CBBT 3	1	1
CB096						1												CBBT 3	1	1
CB097						1												CBBT 3	1	1
CB098						1								1				CBBT 3	2	2
CB099						1							1					CBBT 3	2	2
CB100							2		1				2					CBBT 3	5	2
CB101							1									1	1	CBBT 3/4	3	2
CB102							1											CBBT 3	1	1
CB103							1											ES	1	1
CB104							2			1			1					ES	4	2
CB105							1											ES	1	1
CB106							1							1				ES	2	2
CB107							1											ES	1	1
CB110							1											CBBT 3	1	1
CB111							1											CBBT 3	1	1
CB112							1							1				CBBT 3 & ES	2	2
CB113							1											ES	1	1
CB114							1				1							ES	2	2
CB115							1											ES	1	1
CB116							1	1										ES	2	1
CB117							1											ES	1	1

NAVFAC Catalogue ID (Harbor Seals)	2015	2016			2016	2017				2017		2018		2018	2019			Location	Total No. Days Seen	Total No. Season Seen
	Season 2 (2015-2016)				Season 3 (2016-2017)					Season 4 (2017-2018)				Season 5 (2018-2019)						
	December	January	February	March	December	January	February	March	April	November	December	January	February	December	January	February	March			
CB118								1										CBBT 3	1	1
CB119								1										CBBT 3	1	1
CB120								1								1		CBBT 3 & ES	2	2
CB121								2										CBBT 3 & ES	2	1
CB122								1										ES	1	1
CB123								1				1						ES	2	2
CB124								1										ES	1	1
CB125								1										ES	1	1
CB126								1					1					ES	2	2
CB127								1										ES	1	1
CB128*												1						ES	1	1
CB129												1						ES	1	1
CB130												1						CBBT 3	1	1
CB132													1					CBBT 3	1	1
CB133													1					CBBT 3	1	1
CB134													1					CBBT 3	1	1
CB135													1					CBBT 3	1	1
CB136													1					CBBT 3	1	1
CB137													1					CBBT 3	1	1
CB138													1					ES	1	1
CB139													1					ES	1	1
CB140													1					ES	1	1
CB141													1					ES	1	1
CB143													1					ES	1	1

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

NAVFAC Catalogue ID (Harbor Seals)	2015	2016			2016	2017				2017		2018		2018	2019			Location	Total No. Days Seen	Total No. Season Seen
	Season 2 (2015-2016)				Season 3 (2016-2017)					Season 4 (2017-2018)				Season 5 (2018-2019)						
	December	January	February	March	December	January	February	March	April	November	December	January	February	December	January	February	March			
CB144													1					ES	1	1
CB145													1					ES	1	1
CB146													1					ES	1	1
CB147													1					ES	1	1
CB148														1				ES	1	1
CB149														1				ES	1	1
CB150														1				CBBT 3	1	1
CB152														1				CBBT 3	1	1
CB153														1				CBBT 3	1	1
CB154															1		1	ES	2	1
CB155																1		CBBT 3	1	1
CB156																1		ES	1	1
CB157																1		ES	1	1
CB158																1		ES	1	1
CB159																1		ES	1	1
CB160																1		CBBT 2	1	1