Pinniped Time-lapse Camera Surveys in Southern Chesapeake Bay and Eastern Shore, Virginia: 2019/2020

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Cover Photo Credit:

Harbor seals (*Phoca vitulina*) hauled out and in the water at the Eastern Shore, Virginia survey area. Cover photo taken by Stealth DS4K remote camera, operated by D. Poulton and D. Rees, under National Marine Fisheries Service (NMFS) General Authorization (GA) #19826.

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Acronyms and Abbreviations

CBBT	Chesapeake Bay Bridge Tunnel
ES	Eastern Shore
F°	degrees Fahrenheit
ft	foot or feet
GA	General Authorization for Scientific Research
HD	high-definition
HO	haul-out
hrs	hours
ID	identifier
km	kilometer(s)
kts	knots
LED	light emitting diode
MP	megapixel
m	meters
min	minutes
NMFS	National Marine Fisheries Service
NAVFAC	Naval Facilities Engineering Systems Command
NOAA	National Oceanic and Atmospheric Administration
OPAREA	Operating Area
U.S.	United States
VA	Virginia

1 Introduction and Objectives

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 region of the United States (U.S.) between September and May (Hayes et al. 2020). Harbor seals exhibit a general southward movement from the Bay of Fundy to southern New England and mid-Atlantic waters in autumn and early winter (Rosenfeld et al. 1988; Whitman and Payne 1990; Jacobs and Terhune 2000). In Virginia, harbor seals in the last several years, have been found to occur seasonally from November through April and gray seals are occasionally observed during the winter, but not on a consistent basis (Jones and Rees 2021). As climates change, populations at the edge of the species' distributional range are likely to be more affected (Blanchet et al. 2021).

Accurate data on the distribution of pinniped species are needed to ensure proper documentation in National Environmental Policy Act and Marine Mammal Protection Act analyses, and to prepare effective protective measures during naval training and testing activities. Harbor and gray seals, like all pinnipeds, are amphibious, spending time on land resting (i.e., hauled out) and in the water (Ampela et al. 2021). In general, the time they are in the water is where there is the greatest potential to be impacted by Navy activities.

Since 2014, Navy biologists have been conducting visual surveys at known seal haul-out locations in Virginia (Jones and Rees 2021). These surveys are currently limited to twice per month (by resources and study design), and survey scheduling is dependent on weather, daylight hours and marine conditions. These limitations have resulted in a paucity of information during certain times of the day (e.g. sunrise/sunset) and in adverse weather conditions (e.g. rain, high winds and sea states greater than Beaufort 3). This study builds on the current survey methods to include the use of camera traps (i.e. trail cameras) to survey for pinnipeds at the known haul-out areas.

Trail cameras (i.e., camera traps) are cost effective tools for collecting large amounts of data in a way that limits or eliminates impacts to the animals as compared to traditional visual surveys (Wearn and Glover-Kapfer 2019; Koivuniemi et al. 2016) and are especially effective for monitoring wildlife in remote locations. With the use of trail cameras, it is possible to simultaneously sample multiple haul-out areas for extended periods of time with relatively low personnel demands and limited disturbance to the seals.

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

Objectives for this study are to 1) improve the understanding of local, seasonal haul-out patterns, numbers of seals hauled out during daylight hours; 2) to investigate any haul-out patterns in relation to environmental factors; and 3) to investigate differences between vessel and time-lapse camera survey data collected. The data and results of this effort will further improve the assessment of potential impacts from Navy training and testing activities, installation construction (e.g. pile driving) and vessel-transiting activities as required under the Marine Mammal Protection Act and National Environmental Policy Act for Commander, U.S. Fleet Forces Command (USFF) and Commander, Navy Installations Command projects in Virginia. These data may also provide important baseline information for the assessment of potential future impacts from climate change or anthropogenic activities.

This report covers time-lapse camera survey data collection in southeastern Virginia from November 2019 to April 2020 (season 1). All work for this report was conducted in accordance with National Marine Fisheries Service (NMFS) General Authorization (GA) 19826.

2 Field Methods

2.1 Study Area

The study area consists of two locations in southeastern Virginia where seals have been known to haul out for the last decade (Jones and Rees 2021): 1) on the southeastern tip of the Eastern Shore (ES), and 2) in the lower Chesapeake Bay along the Chesapeake Bay Bridge Tunnel (CBBT) (**Figure 2-1**).

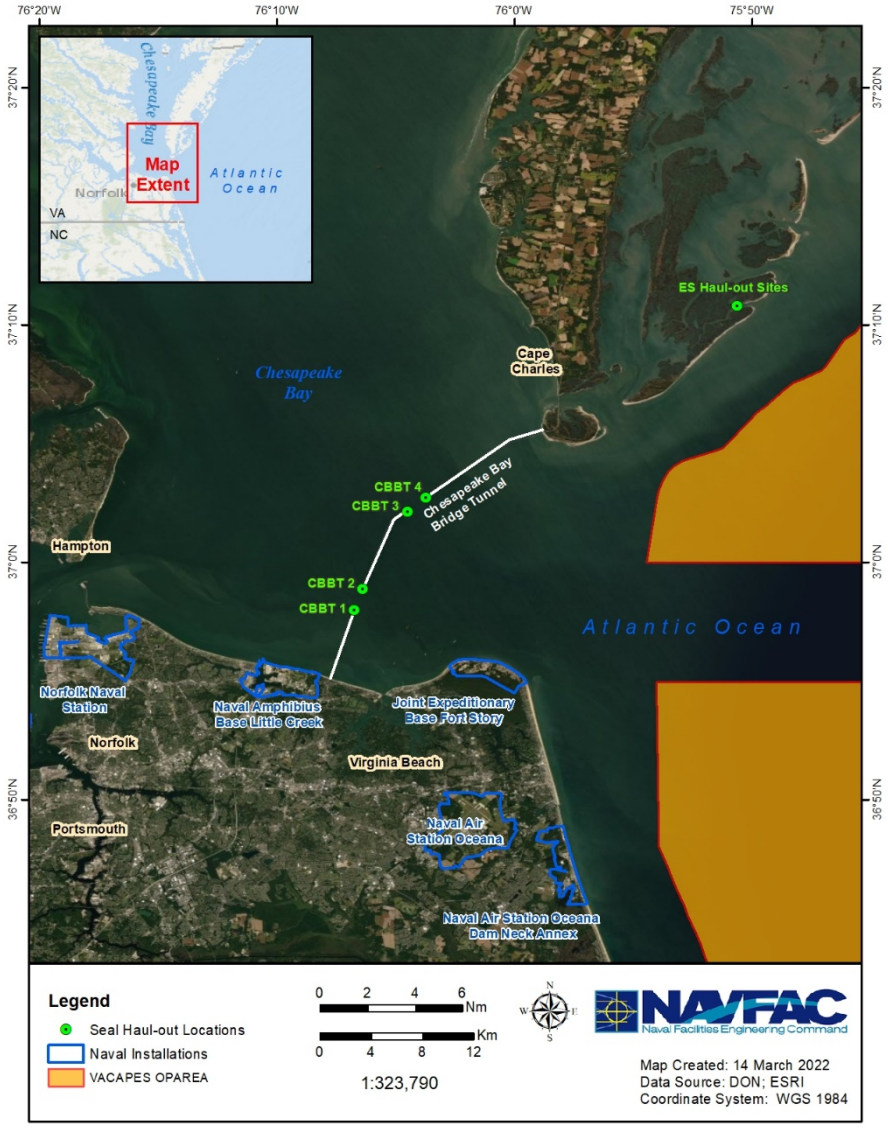

Figure 2-1. CBBT and ES haul-out locations and nearby U.S. naval installations. VACAPES OPAREA= Virginia Capes Range Complex Operating Area

The furthest distance between the two survey areas is approximately 27 km (31 nautical miles). Both survey areas are in close proximity (< 100 km) to several major 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) and the offshore Virginia Capes Operating Area (**Figure 2-1**).

The ES survey area contains several different haul-out sites within close proximity to each other [less than 2,400 feet (ft) or 732 meters (m)] (**Figure 2-2**). Haul-out sites are designated with a letter or with an alpha-numeric identifier (ID), with "A" being the first haul-out site recorded and "F" the most recent. Numbers are added if the seals establish a new haul-out site surrounding the same creek mouth. Haul-out site FS is designated as such because it is near F, but on a sandbar that is exposed only during very low tides.

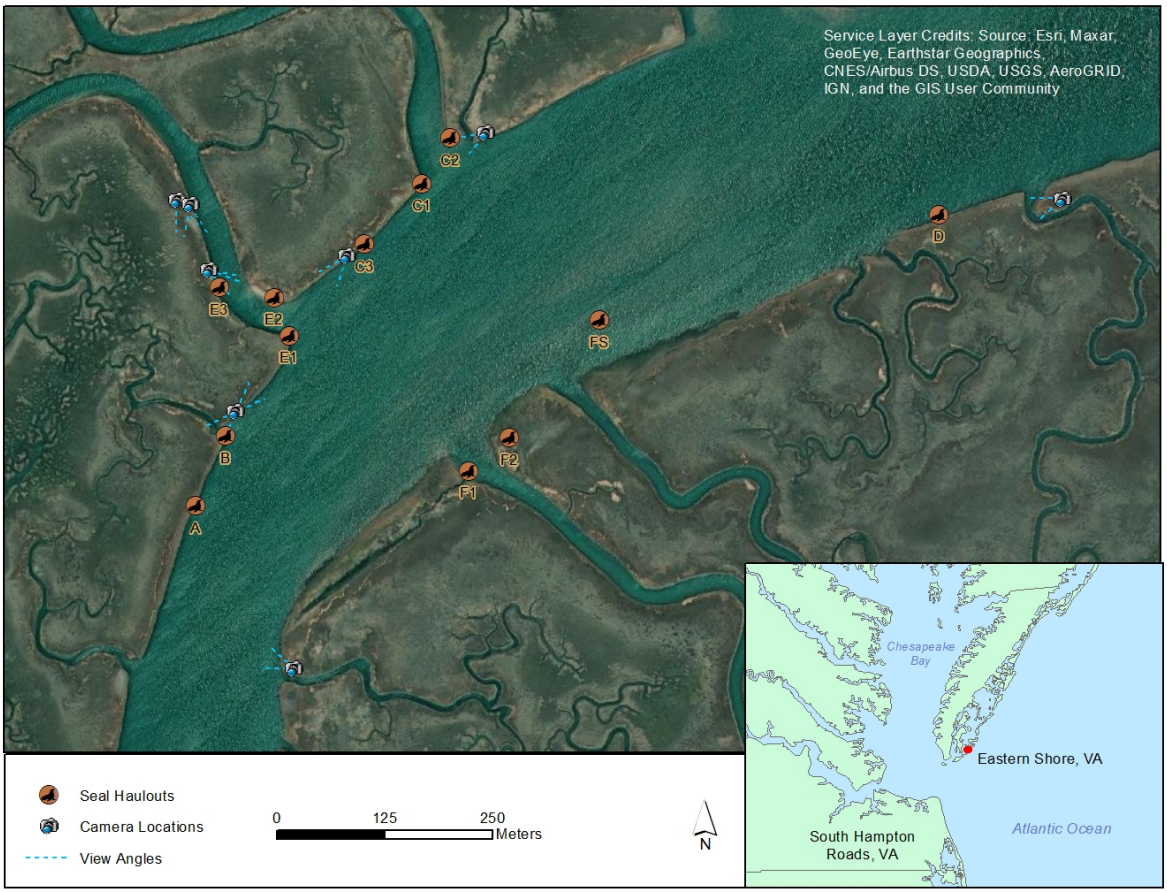

Figure 2-2. Seal haul-out and camera locations at the Eastern Shore survey area

The haul-out sites at the ES survey area are within an intertidal sandy ridge and salt marsh (*Sporobolus alterniflorus)* habitat (**Figure 2-3**).

Figure 2-3. Eastern Shore survey area with harbor seals hauled out with trail camera post to the right. Photo by D. Rees, NAVFAC Atlantic under NMFS GA Permit #19826

At the CBBT survey area, the haul-out sites are generally near the pointed tip of rock armor formations (locally referred to as "islands") (**Figure 2-4**), which protect the tunnels as they go beneath the water. For this study, only two of the four haul-out sites (CBBT3 and CBBT4) are monitored with the trail cameras (**Figure 2-1**). The CBBT1 and CBBT2 sites were not included in this study, because active tunnel construction occurred at those sites, which prevented our ability to install cameras. Of the four haul-out sites along the CBBT, CBBT3 and CBBT4 have historically had the highest haul-out activity, with the majority of sightings (84%) at CBBT3 and substantially fewer seals (<4% of total sightings) at CBBT1 and CBBT2 (Jones and Rees 2021). CBBT 1 and CBBT2 are being monitored for seal presence during construction activities (NOAA 2021c; Chesapeake Bay Joint Venture 2020) and by the Navy's haul-out vessel surveys (Jones and Rees, 2021).

Figure 2-4. Aerial view of a CBBT survey area. Photo by Virginia Aquarium & Marine Science Center Foundation.

2.2 Camera Models and Settings

Three different trail camera models were used in the first season (November 2019 to April 2020). Model selection was site specific and based on the need for wireless capability, camera network linking or photo quality. The ability to link to a wireless network in order to send photos remotely, and the ability to link cameras to a single wireless account was important for the ES survey area, given the remoteness of the area and close proximity of the haul-out sites to one another. At the CBBT survey area, high photo quality was critical in order to capture seals at the distance from the camera installation locations to the haul-out sites (approximately 100-130 m or 328-427 ft). All camera models selected had the time-lapse feature desired for our survey design.

1. Cuddeback Dual Cell Model K-5789. This camera is considered the "home" camera and utilizes CuddeLink technology to create a wireless mesh network that allows cameras to communicate by creating a camera-to-camera network. Each camera in the network is set to send images to the "home" camera. Using a CuddeLink Cell camera, images can be received from up to 15 remote cameras, then transmitted via cellular network to a designated email account.
2. CuddeLink Black Flash Model J-1422. This is a remote camera that links to other cameras in the wireless mesh network and transmits images wirelessly to the "home" camera.
3. Stealth Cam DS4K. This trail camera was the highest rated available for photo quality with a maximum 32 megapixel (MP) day resolution and 14.0 MP night resolution. This model was also selected for the no-glow infrared, light emitting diode flash, to minimize potential disturbance to seals from the camera flash in order to experiment with the feasibility of night images.

All cameras were programmed to take an image every 15 minutes during daylight hours. Cameras were not synced to each take an image at the same time. CuddeLink cameras were used exclusively at the ES survey area for the wireless and linking capability. Stealth cameras were used at the CBBT survey area because of the high MP rating to cover the distance from where the camera could be set up to where the seals haul out. Additionally, one Stealth camera was installed at the ES survey area alongside a CuddeLink camera and was programmed to record images day and night as a test to determine if seals could be observed from nighttime images and to determine if image quality was comparable.

2.3 Camera Placement

Cameras were installed at the Eastern Shore location on 8-12 foot pressure treated 2x4's approximately 20-50 m from each of the known haul-out sites (**Figure 2-3**). The elevated posts at this location minimized vegetation interference and reduced the likelihood of cameras being flooded during very high tides or storms. Ten cameras were installed at the ES survey area (nine CuddeLink and one Stealth). At this location, cameras were installed to provide maximum coverage at all of the known haul-out sites, rather than random placement (**Figure 2-2**). As much as possible, cameras were angled to minimize water and sun glare. At the ES, cameras were powered with solar panels and rechargeable batteries to minimize camera checks and avoid seal disturbance during the occupancy season. Camera status was monitored through a daily status report and the delivery of images to the project email which also minimized the need to check cameras and potentially disturb the seals.

At the CBBT, Stealth trail cameras were installed on a guardrail from an access road located approximately 100-130 m (328-427 ft) from each haul-out area (**Figure 2-5**). Camera placement was limited to the area off the bridge tunnel access roads at CBBT3 and CBBT4, and placed to maximize the view of the haul-out area. One camera was installed at each location.

Figure 2-5. Camera view of CBBT3 and image of camera installed on the guardrail (inset).

3 Analytical Methods

3.1 Image Review and Seal Counts

Images were reviewed for the presence of seals in the water or hauled out, and for the presence of vessels or other factors that appeared to disturb the seals [e.g. bald eagle (*Haliaeetus leucocephalus*) flying over the haul-out]. The Timelapse Image Analysis system, including the Timelapse2 program (Greenberg 2021a, 2021b), was used to count, mark and record the number of seals or vessels in each image (**Figure 3-1**). Timelapse2 includes built in features which simplify the visual examination and encoding the data from each image, including custom data recording template set-up, automatic extraction of image data (e.g. file name, date and time taken) persistent seal marking, automatic counting of marks as identified by the user developed template, automated image time correction (i.e. for daylight savings time changes), and image review tools (e.g. magnifier, play forward and reverse, pan/zoom tools, and image enhancement) (Greenberg 2021b).

For camera counts, animals emerging from the water more than half a body length or in water but clearly resting on the bottom or sandbar were considered as hauled out, similar to Jeffries (2014). During image review, the analyst also noted the start of a haul-out event and the end of a haul-out

event (defined as the last image seals were observed hauled out in a sequence of images). Because seals may haul out outside of daylight hours, it was also noted when seals were hauled out at sunrise or remained hauled out at sunset. If seals hauled out for only one image (i.e. did not remain on a haul out for a sequence of more than one image), this was also noted.

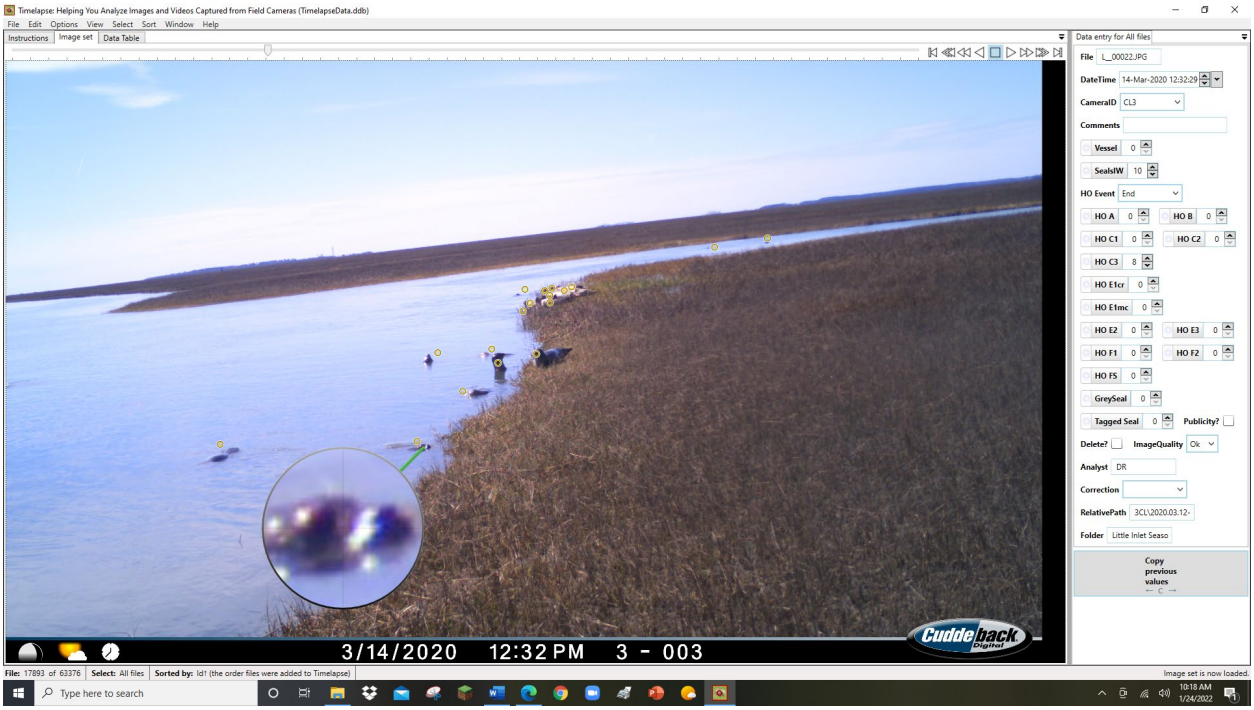

Figure 3-1. Screenshot of Timelapse Image Analysis workspace. Counted seals are marked by yellow circles, the magnifier feature is shown near front and the customizable data template at the right.

Some cameras at the ES survey area had a view of more than one haul-out site. To avoid counting the same seal from two different cameras, a key was created to designate the primary camera from which seals on each haul-out site should be counted. The key also indicated any alternate camera(s) that had a full or partial view of each site in the event the view from the main camera designated for that site was obstructed and the analyst needed to verify the count.

All cameras were programmed to take an image every 15 minutes (or 4 times per hour), so a single seal could be counted up to 4 times per hour. At the ES survey area, every vessel was counted regardless of proximity to haul-out site, since any vessel at that location that could be observed from the cameras had the potential to disturb seals. In some cases, this may have resulted in counting a vessel more than once if they could be seen from multiple cameras, but since the vessels seen at this survey area were generally not stationary, this potential was limited. At the CBBT survey area, vessels were recorded if they were within about 300 meters (984 ft) from the haul-out site; vessels beyond that distance (e.g. middle of the shipping channel) were not counted as they would not have the potential to disturb seals based on observations from vessel surveys at that site since 2014. Cameras at both CBBT sites had the potential to capture a vessel at least 4 times per hour and more often at the ES if multiple cameras captured the same vessel.

3.2 Haul-out Patterns

Counts from the images were analyzed temporally and in comparison to certain environmental factors to determine if there were patterns in haul-out behavior in relation to these factors.

3.2.1 Temporal Data

Each image taken has an associated time stamp as recorded by the cameras. In some instances, images were batch processed to correct for daylight savings time changes or time setting errors. All temporal data are reported in Eastern Standard or Eastern Daylight Time, depending on the date collected. For the temporal analysis, counts were totaled by month and binned in hour blocks (HH:00 to HH:59). Counts were further grouped by morning (AM, 06:00 to 11:59) and afternoon/evening (PM, 12:00 to 18:59) to determine if there was a difference in the numbers of seals hauled out in the morning versus afternoon/evening.

3.2.2 Environmental Data

Seal counts were compared to certain environmental factors to investigate if there were any haul-out patterns in relation to the selected factors. These include water levels, air temperature, and wind speed. For both the CBBT and ES survey areas, data were downloaded in one hour intervals and matched by hour to the image counts.

Environmental data were obtained for the data collection period (November 2019 – April 2020) from NOAA Tides and Currents, station ID 8638901 (NOAA 2021a), physically located at 37.032 N, 76.083 W. This station was chosen because it is within 25 km of all the haul-out sites, and of the available sensors/buoys recording data, it was the data collection station thought to best represent conditions at all of the haul-out sites. In general, water level provided by NOAA uses a base elevation as a reference from which to reckon heights or depths. Tidal datums are used as references to measure local water levels and should not be extended into areas having differing oceanographic characteristics without substantiating measurements (NOAA 2021b). Mean Lower Low Water was used and is defined by NOAA as the average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch (NOAA 2021b). Air temperature and wind speed are averaged over an eight-minute period (NOAA 2021d).

3.3 Vessel Survey Counts

For each field season, dedicated vessel surveys start in the fall (October/November) and end in the spring (April/May). See Jones and Rees 2021, for vessel survey protocols and methods. Camera counts were compared to vessel counts to determine if count results were similar.

Because vessel presence had the potential to disturb seals, causing them to move into the water (i.e. flush) and leave the haul-out site, the comparison for the number of seals on a haul-out site was based on the maximum seal count on the cameras one minute prior to survey vessel arrival to the maximum number of seals observed during the vessel surveys.

The maximum counts from each of the camera and vessel counts were then compared for any differences. Camera and vessel counts at the ES survey area for all haul-out sites were combined because the entire survey area is within the same vicinity. Counts at the CBBT were compared by site since the haul-out sites are several miles apart and not visible from each other from vessel or camera surveys.

4 Results

4.1 Effort and Sightings

For season 1 (November 2019 to April 2020), cameras were installed at the ES survey area on 4 November 2019. Access to install cameras at the CBBT was granted after the start of the seal occupancy season, on 7 January 2020. Cameras were removed at the end of the season from the ES survey area on 29 April 2020 and from the CBBT sites on 28 April 2020. Because seals are regularly present in Virginia from November through April (Jones and Rees 2021), the data presented in this report for the CBBT location constitutes an incomplete dataset for season 1 due to the installation not occurring until January.

As discussed in Section 3.1 Image Review and Seal Counts, cameras were programmed to take an image every 15 minutes. Though some cameras could capture the same seals on a haul-out site from a slightly different angle, the analyst used a key and count log to ensure each seal was counted from only one camera image.

Effort, total seals counted and percentage of days seals were present at the survey area (i.e., either hauled-out or in the water) are summarized in **Table 4-1**. Summing the ES and CBBT survey areas, there were a total of 291 camera recording days of effort. A total of 74,705 images were taken and a total of 55,819 seals counted (summing the individual counts from all images).

Table 4-1. Camera trap effort and sightings summary for the 2019/2020 season

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

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

An individual count is the number of seals counted from each image and haul-out site (as designated by the count key). Individual cameras were not synced to take an image at the same time, but only one count was taken per 15-minute period. Caution should be taken when interpreting total or summed seals counted, as an individual seal would be counted multiple times if they remained on the haul-out for longer than 15 minutes. For example, an individual seal resting on the haul-out for four hours would be counted four times each hour (once from each image taken), resulting in a total count of 16; likewise,

four seals on a haul-out for one hour would result in a total count of 16. Data presented on total or summed counts were not normalized for this report.

Total and summed counts are presented to provide an index of haul-out activity. This data is currently not appropriate to use for the analysis of population level. However, because survey effort was equal across the entire season for the ES survey area, these counts provide information on relative haul-out activity for the season. At the CBBT survey area, survey effort was equal for the last part of the season (January to April 2020) and provides information on relative haul-out activity for that time frame.

Unless otherwise indicated, total count, summed count or "seals present" refers to the combination of seals in the water and hauled out. Summed haul-out counts from all haul-out sites by survey area and month are shown in **Figure 4-1**. Seals were observed on the ES survey cameras from November to April, with peak haul-out numbers recorded in January and February (**Figure 4-1**). The difference between the mean counts across the months for the occupancy season was statistically significant ($F_{stat} = 2.34$, $p < 0.001$).

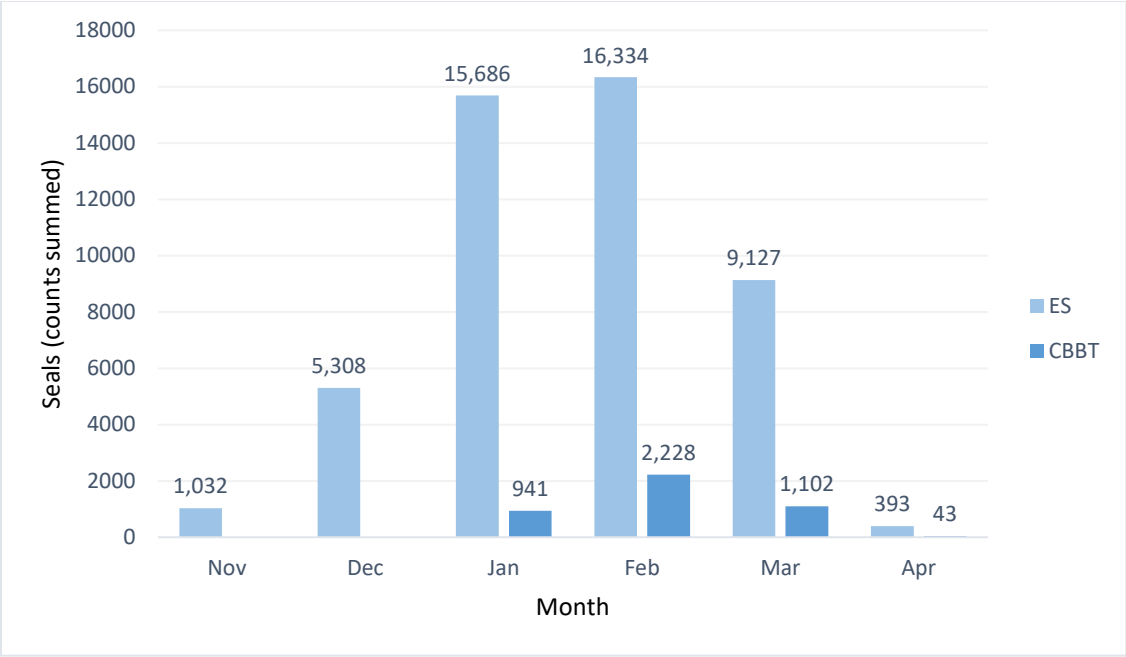

Figure 4-1. Seal haul-out counts (summed) by survey area and month

The maximum individual haul-out count is identified by seals in a single image or all seals hauled-out in the same 15-min period on different haul-out sites. The highest individual haul-out count for the ES survey area was 72 individual seals from a single image on 16 February 2020 (**Table 4-2**) on haul-out site E1. At the ES survey area, seals hauled out most frequently on site E1, with almost three times as many seals as any other haul-out site at the ES survey area (see **Table 4-2**). Haul-out sites F1, F2 and FS are new haul-out locations as of 2019, and were added because haul-out events occurred on three different occasions in the 2019/2020 season: 26 Nov 2019 early in the season, once after a tagging attempt on 2

March 2020, and once on 8 March 2020 (within five days of the last tagging attempt of the season). Since vessel counts started in 2016 we have not previously observed seals hauling out in this area, so it is unclear whether this will become a regular haul-out location or was only used during this season.

At the CBBT survey area seals were observed on the cameras from January to April, with the highest total count recorded in the month of February (**Figure 4-1**). The difference between the mean counts across the months for the occupancy season was statistically significant ($F_{stat} = 2.82$, $p < 0.001$). The temporal pattern presented for the 2019/2020 season at the CBBT only includes the months of January to April, and is incomplete due to late camera deployment. The highest individual seal count at the CBBT survey area was 17 seals on 5 February 2020 recorded at CBBT3 (**Table 4-2**).

Table 4-2. Maximum individual count, month of maximum individual count, and sum of all counts by haul-out site

Survey Location	Site	Maximum Individual Count (hauled-out)	Month of Maximum Individual Count	Seals Counted (hauled-out)
ES	A	0	N/A	0
	B	4	February	31
	C1	19	January	504
	C3	27	March	1,298
	D	0	N/A	0
	E1	72	February	31,017
	E2	37	January	10,796
	E3	28	March	3,904
	F1	10	March	336
	F2	2	March	5
	FS	4	March	16
CBBT	CBBT3	17	February	3,190
	CBBT4	11	February	2,500

Note: Seals counted (hauled-out) represents the sum of all hauled-out seals counted in all images for a given haul-out site, individual count is the count from a single image or 15-minute period

Camera resolution did not allow for 100% certainty of the seal species being counted in most cases. While the vast majority of the seals appeared to be harbor seals, there were five images where a gray seal was positively identified (e.g. **Figure 4-2**). Since surveys began in this area in 2014, very few gray seal have been sighted at these locations (Jones and Rees 2022).

Seals with flipper or satellite tags were also known to be present where images were being recorded based on data from the tagging report (Ampela et al. 2021), but due to image quality, the tags were not easily discernable. However there are a few instances (11 images) where a seal was positively determined to have either a satellite or flipper tag (or both).

Figure 4-2. Gray seal (front). Photo taken by Cuddeback remote camera under NMFS GA Permit #19826

4.2 Temporal - Counts by Time of Day

At the ES survey area, the CuddeLink cameras operate on an automatic daylight setting. To account for unequal effort (i.e., daylight start and end time changes throughout the year), only counts between 06:00 and 18:59 were included in this analysis (**Figure 4-3**).

From counts grouped by morning (AM, 06:00 to 11:59) and afternoon/evening (PM, 12:00 to 18:59), there was found to be no significant difference between the mean counts of hauled-out seals at the ES survey area for AM vs PM hours (t_{stat} = 0.42, p = 0.68) overall. When looking at the number of seals hauled out in the AM vs PM across months, there was no significant difference between mean counts for each of the months from November to April (**Figure 4-3**).

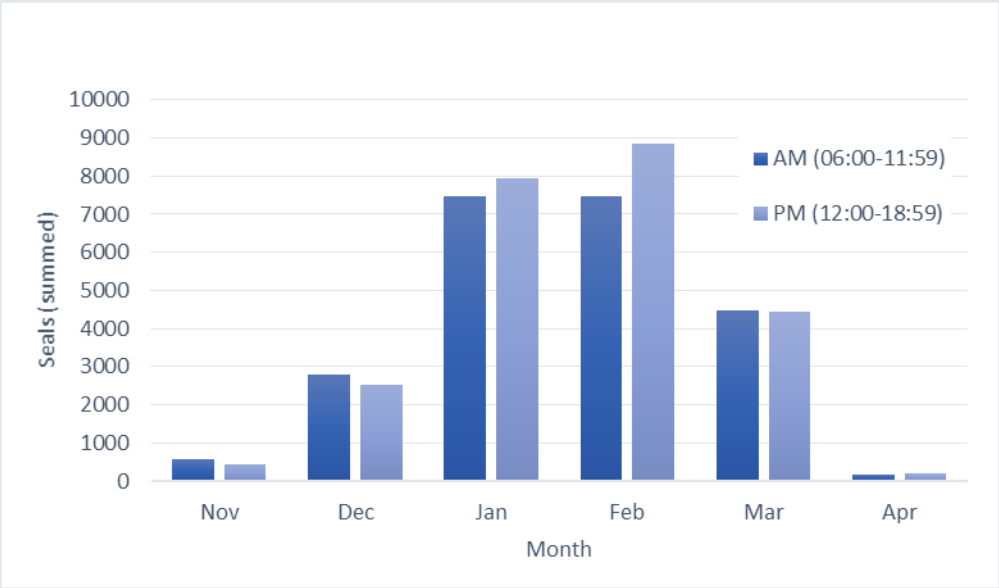

Figure 4-3. Seal haul-out counts (summed) by month and time of day at the ES survey area

For the CBBT survey area, cameras did not have an automatic daylight mode, so cameras were set to collect data from 06:00 to 18:00. Therefore, data collection at CBBT ended earlier than data collection at ES survey area when sunset was after 18:00. At the CBBT survey area, there was no significant difference between the mean counts for AM vs PM hours (t_{stat} = -0.24, p = 0.81) overall. When considering the number of seals hauled out in the AM vs PM across months, there was a significant difference (t_{stat} = -3.34, p = 0.008) between mean counts for the month of March only (**Figure 4-4**).

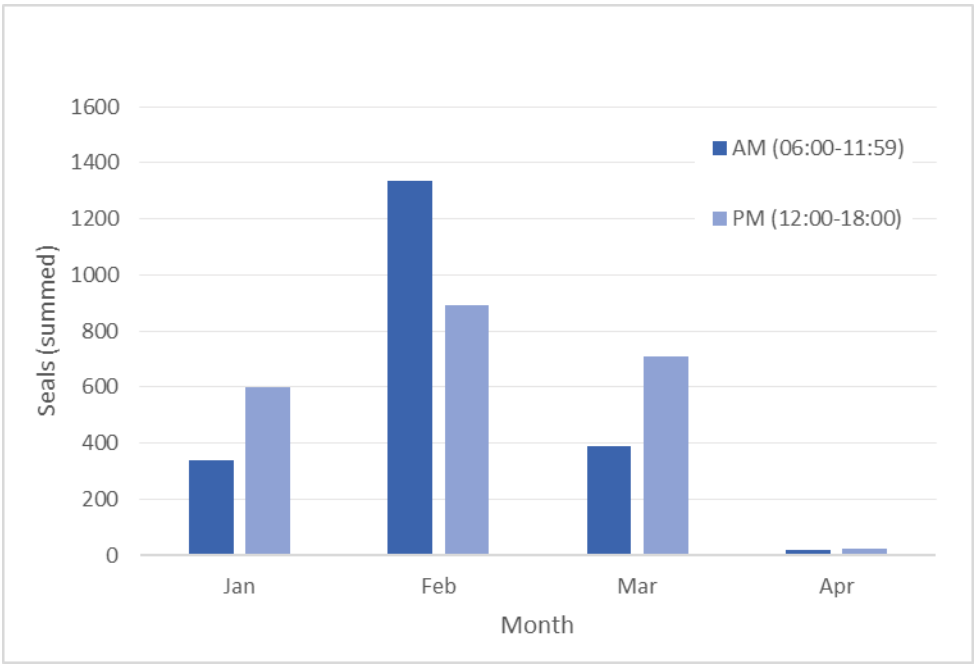

Figure 4-4. Seal haul-out counts (summed) by month and time of day at the CBBT survey area

At the ES survey area, a single Stealth camera recorded day and night images (over the full 24-hour cycle) to test if seals could be detected on images taken at night with the IR flash. In the nighttime images, seals were only detected on a small portion of haul-out site E3 due to the limited distance of detection (approximately 20 m or 66 ft). Night counts ranged from 0 to 6 seals, and seals were visible in 132 of 4,778 night images, on eight separate nights in January 2020 and one night in April 2020.

4.3 Environmental

4.3.1 Comparison of Haul-Out Counts to Water Levels

The range of water levels recorded at the ES during the survey period (November 2019 to April 2020) was -1.46 ft (foot) (-0.45 m) minimum and 5.63 ft (1.72 m) maximum. The range of water levels when seals were recorded on the haul-out sites was narrower at both sites. At the ES survey area, seals were hauled out when water levels were between -0.9 ft and 4.42 ft (0.27 to 1.35 m). The average water level for all counts of hauled-out seals at the ES survey area (irrespective of the number of seals) was 1.85 ft (0.56 m). At the CBBT survey area, water levels for the data collection timeframe (January to April 2020) ranged from -1.14 ft to 4.81 ft (-0.35 to 1.47 m), and the water level range for when seals were hauled out was slightly narrower (similar to the ES survey area) with a range of -1.0 ft to 3.79 ft. (-0.30 to 1.16 m) The average water level for when seals were hauled out was 1.30 ft (0.40 m).

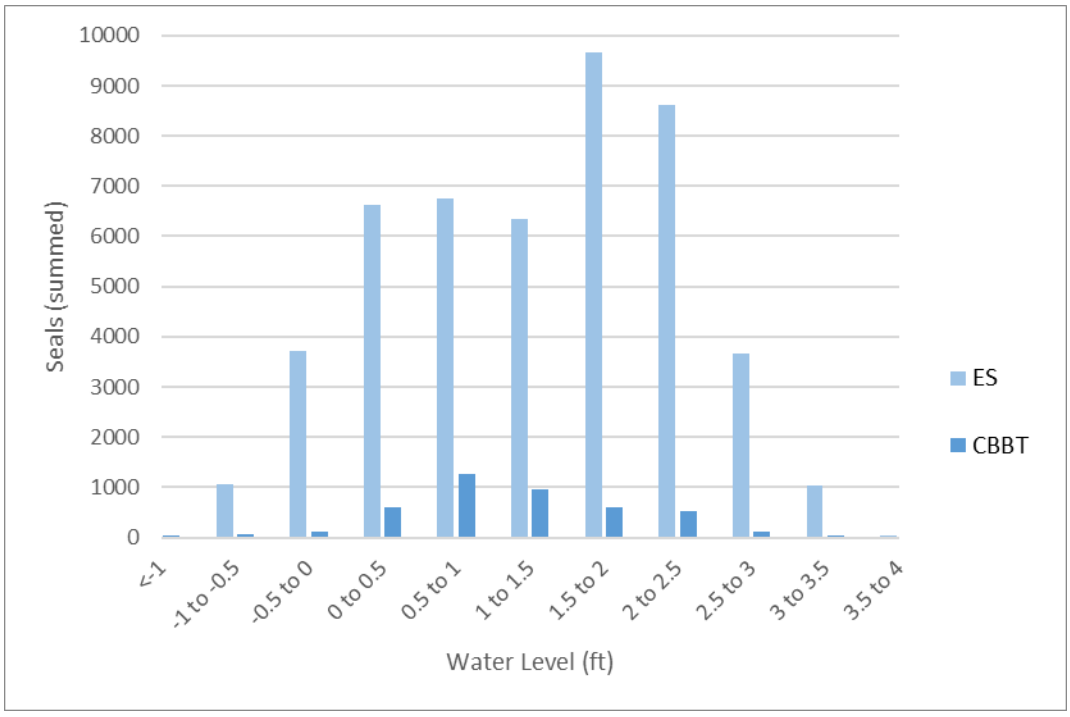

Figure 4-5. Seal haul-out counts (summed) by water level (ft) at the ES and CBBT survey areas

4.3.2 Comparison of Camera Counts to Wind Speed

Wind speed recordings for the camera data collection period (November 2019 to April 2020) at the ES survey area ranged from 0 to 35.57 knots (kts) [0-18.3 meters/second (m/s)]. At the ES survey area, the range of wind speeds when seals were recorded on the haul-out sites was 0 to 30.71 kts (0-15.8 m/s). The average wind speed for recorded seal haul-out events was 10 kts (5.1 m/s). **Figure 4-6** shows the distribution of wind speed to seal counts at the ES survey area. Wind speed recordings for the camera data collection period (January to April 2020) at the CBBT survey area ranged from 0 to 31.49 kts (0-16.2 m/s). The range of wind speeds when seals were recorded on the haul-out sites was 0 to 21.38 kts (0-11 m/s). The average wind speed for recorded seal haul-out events was 8.17 kts (4.2 m/s). **Figure 4-7** shows the distribution of wind speed to seal counts at the CBBT survey area.

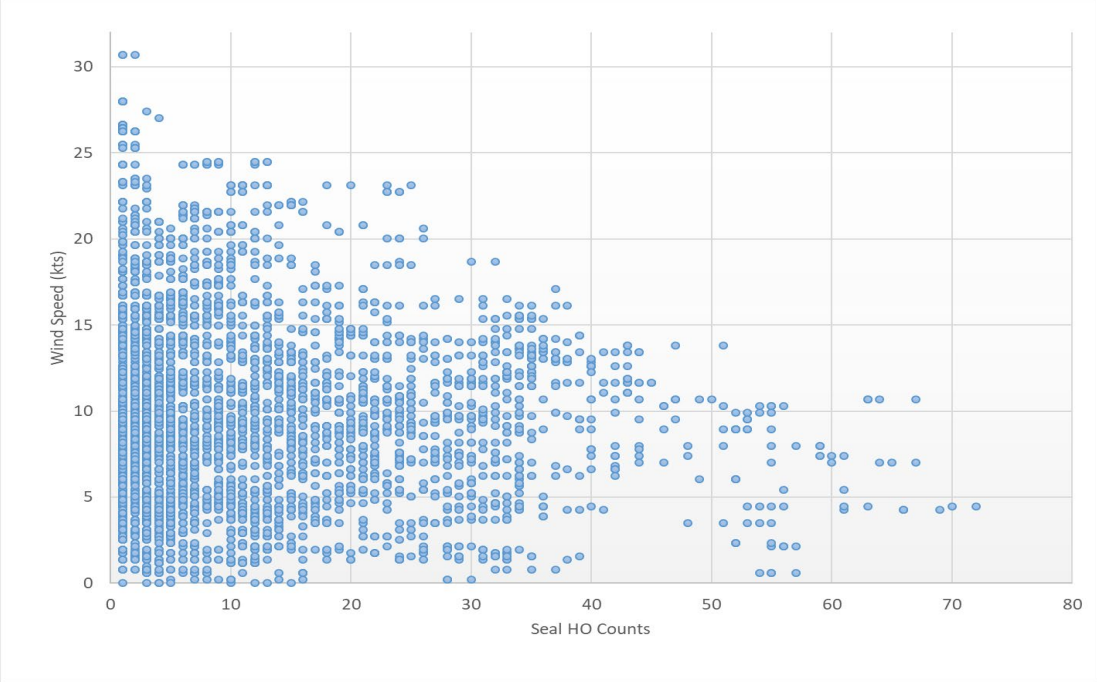

Figure 4-6. Seal haul-out counts from camera surveys compared to wind speed in knots (kts) at the ES survey area

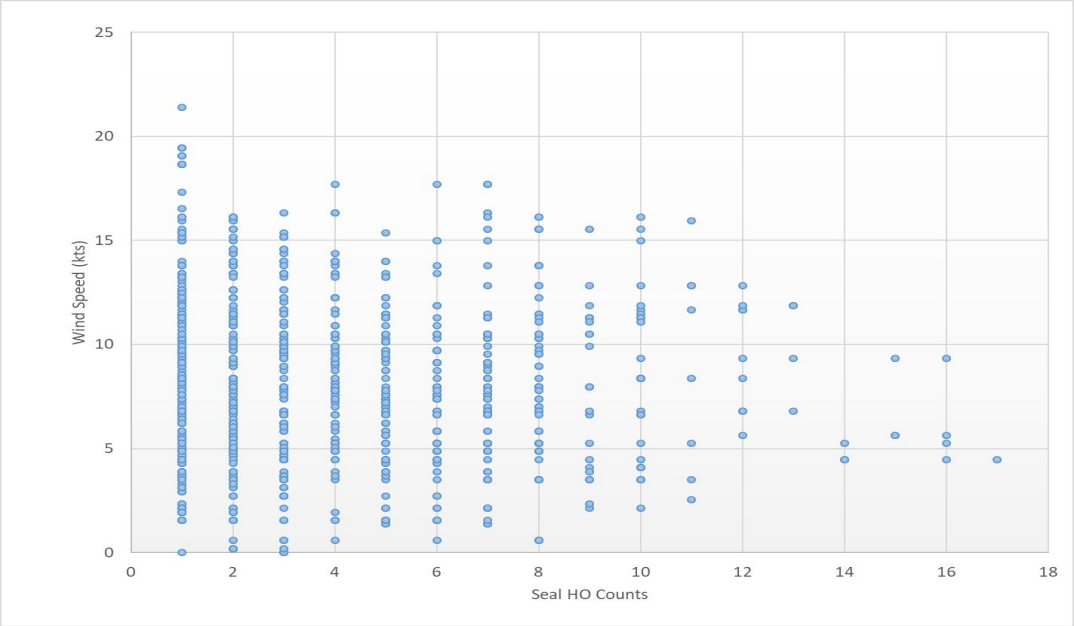

Figure 4-7. Seal haul-out counts from camera surveys compared to wind speed in knots (kts) at the CBBT survey area

4.3.3 Comparison of Camera Counts to Air Temperature

Air temperature recorded for the season (November 2019 through April 2020) ranged from 28.2 to 75.7 F° (-2.1 to 24.3 C°). The air temperatures recorded when seals were hauled out at the ES survey area ranged from 29.3 to 67.8 F° (-1.5 to 19.9 C°) and when seals were hauled out at the CBBT survey the range was 29.8 to 73.4 F° (-1.2 to 23 C°). The average air temperature recorded when seals were hauled out at ES survey area was 49.0 F° (9.5 C°) and 50.8 F° (10.4 C°) at the CBBT survey area.

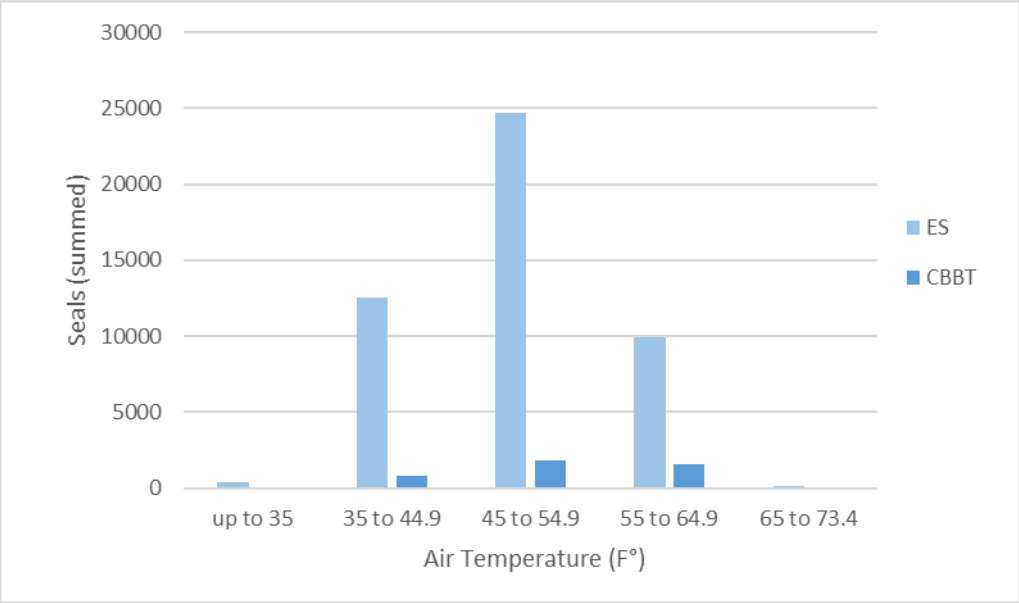

Figure 4-8. Seal haul-out counts (summed) by air temperature (F°) at the ES and CBBT survey areas

4.4 Comparison of Camera to Vessel Surveys

Camera counts were compared to vessel survey counts to determine if count results were similar and if camera counts could be a useful proxy for vessel counts. There are relatively few counts for comparison, because as noted earlier, vessel surveys are only scheduled every two weeks and are dependent on weather conditions.

The comparison of camera to vessel-based haul-out counts is presented in **Table 4-3** and **Table 4-4** for the ES and CBBT survey areas, respectively. The number of seals is the maximum seal count in the images one minute prior to survey vessel arrival, compared to the maximum number of seals observed during the vessel surveys. The one-minute time was to account for the potential for the presence of the survey vessel to flush hauled-out seals.

Overall there was a low sample size of vessel counts where seals were present for comparison to the camera counts. Only 6 of 12 vessel survey days at the ES had seals present and only 1 of 6 vessel survey days at the CBBT had seals present during the survey time window. There were no vessel surveys conducted at the CBBT survey area in February 2020.

A positive value in the Count Difference column indicated a higher count was recorded from camera surveys and a negative value indicated a higher count was recorded from the vessel surveys.

Table 4-3. Comparison of camera to vessel haul-out counts at the ES survey location

Date	Site	Seal HO Count Camera	Seal HO Count Vessel	Seal HO Count Difference	Seal IW Count Camera	Seal IW Count Vessel	Seal IW Count Difference
11/4/2019	ES	1	0	1	1	1	0
11/21/2019	ES	0	0	0	1	3	-2
12/4/2019	ES	31	22	9	0	12	-12
12/18/2019	ES	0	0	0	0	1	-1
1/7/2020	ES	0	0	0	1	9	-8
1/24/2020	ES	12	19	-7	4	15	-11
2/4/2020	ES	30	34	-4	4	5	-1
2/18/2020	ES	2	10	-8	4	2	2
3/12/2020	ES	29	27	2	4	3	1
3/26/2020	ES	0	0	0	1	2	-1
4/8/2020	ES	0	0	0	0	0	0
4/23/2020	ES	0	0	0	0	0	0
Average				**-0.58**			**-2.75**

HO=haul-out. IW=in water

Table 4-4. Comparison of camera to vessel counts at CBBT survey location

Date	Site	Seal HO Count Camera	Seal HO Count Vessel	Seal HO Count Difference	Seal IW Count Camera	Seal IW Count Vessel	Seal IW Count Difference
1/15/2020	CBBT3	0	0	0	3	7	-4
1/15/2020	CBBT4	0	0	0	0	2	-2
1/30/2020	CBBT 4	0	0	0	4	3	1
1/30/2020	CBBT 3	0	0	0	0	8	-8
3/11/2020	CBBT 4	2	2	0	0	3	-3
3/11/2020	CBBT 3	0	0	0	1	2	-1
3/26/2020	CBBT 3	0	0	0	0	0	0
3/26/2020	CBBT 4	0	0	0	0	1	-1
4/7/2020	CBBT 4	0	0	0	0	0	0
4/7/2020	CBBT 3	0	0	0	0	0	0
4/28/2020	CBBT 3	0	0	0	0	0	0
4/28/2020	CBBT 4	0	0	0	0	0	0
Average				0			-2

HO=haul-out. IW=in water

When comparing the two survey methods, several differences were noted between camera and vessel counts, including the date the first and last seal sightings were recorded (**Table 4-5)**. At the ES survey area, the camera survey documented both earlier sightings of seals at the start of the season and later departure at the end of the season. At the CBBT survey area, cameras were not installed until January so no comparison could be made for the start of the season. Similar to the ES survey area, cameras recorded a later last seal sighting (indicating the end of the seal occupancy season) than vessel surveys.

Table 4-5. Dates of first and last seal sighted by survey method

	ES First Survey	ES First Seal	ES Last Seal	ES Last Survey	CBBT First Survey	CBBT First Seal	CBBT Last Seal	CBBT Last Survey
Camera	4 Nov 2019	4 Nov 2019	22 Apr 2020	29 Apr 2020	7 Jan 2020*	8 Jan 2020	28 Apr 2020	28 Apr 2020
Vessel	4 Nov 2019	21 Nov 2019	26 Mar 2020	23 Apr 2020	14 Nov 2019	26 Nov 2019	26 Mar 2020	28 Apr 2020

*In season 1, cameras were installed after seal occupancy season began in November

At the ES survey area, over 12 survey days, the camera counts were slightly lower (as indicated by negative average values) than vessel survey counts for both hauled out and in water seals (**Table 4-3**). At the CBBT survey area, over six survey days, there was no difference in counts for hauled out seals and camera counts were slightly lower than vessel counts for in water seals. These results are not unexpected as vessel surveys conduct counts continuously for two minutes in an attempt to capture any seals that may have been underwater, and vessel surveys are on location for a duration of approximately 35 minutes, where time-lapse cameras take only a snapshot once every 15 minutes.

4.5 Vessel Presence

As indicated in Section 3.1 Image Review and Seal Counts, the same vessel could have been counted multiple times per hour; especially at the ES survey area, where the same vessel could have been counted from more than one camera. Data presented on vessel presence is intended to provide relative vessel occurrence in each of the survey areas, and as a comparison between survey areas.

Vessels were captured in 0.88% of all images taken at the ES survey area (444 images) and 19.40% of all images taken at the CBBT survey area (1,104 images). Vessels were photographed on 49 out of 178 of the survey days at the ES, and 54 out of 113 of the survey days at the CBBT. Most of the vessels recorded at the ES survey area were from research efforts, including survey vessels (surveys occurred approximately once every two weeks) and tagging vessels (daily presence from 23 to 26 February 2020 and 28 February to 9 March 2020) (**Figure 4-9**). At the ES, the highest vessel count for a single day was during tagging efforts on 2 March 2020 with 213 vessels captured in 110 images (**Figure 4-10**). At CBBT, the highest vessel count in a single day was on 5 April 2020 with 446 vessels captured in 74 photographs (**Figure 4-11**), which were all recreational fishing vessels.

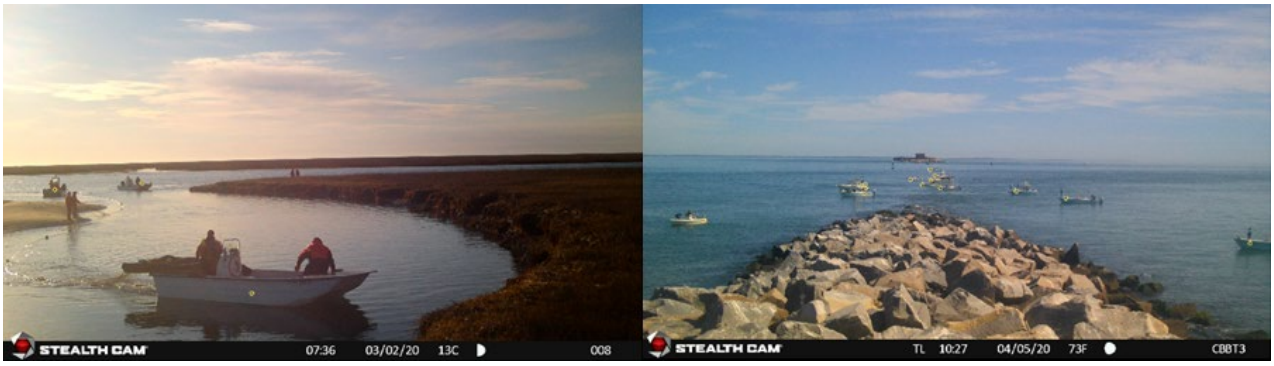

Figure 4-9. Examples of vessels recorded at the ES survey area (left) and CBBT survey area (right)

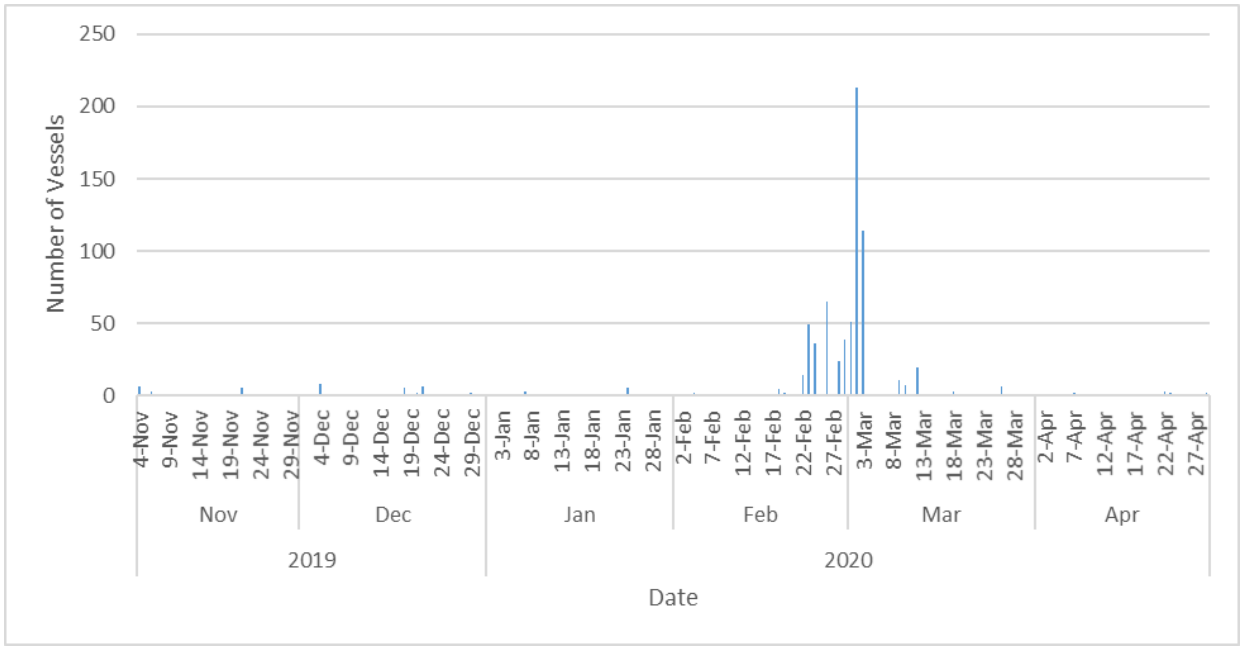

Figure 4-10. Total number of vessels counted by date at the ES survey area

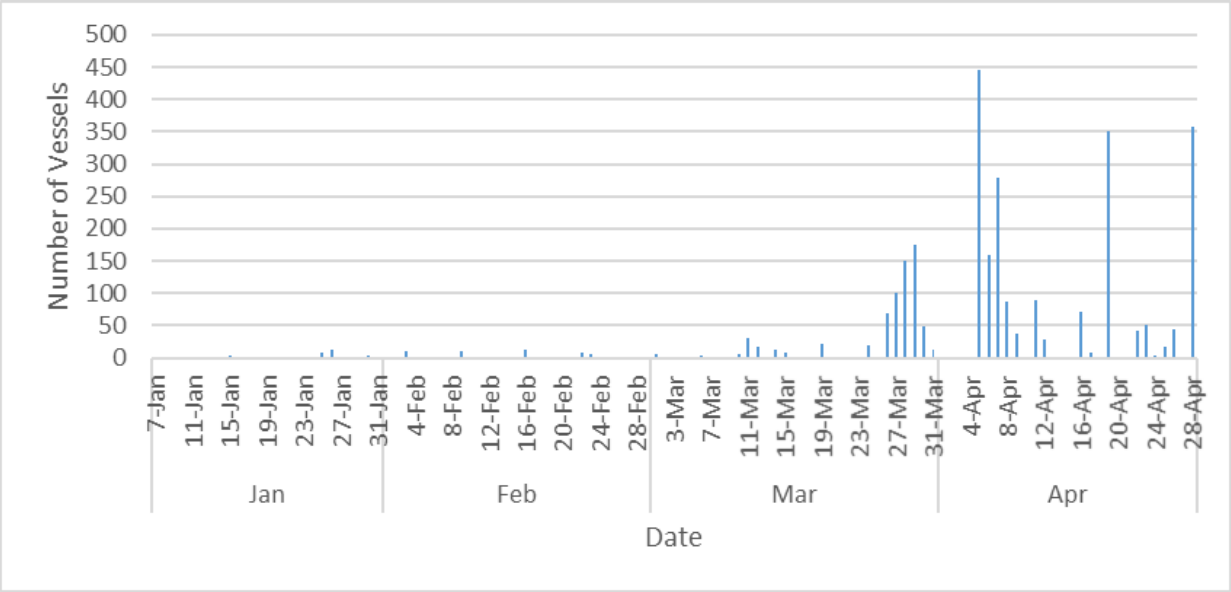

Figure 4-11. Total number of vessels counted by date at the CBBT survey area

Throughout the season, the most vessels were photographed from 11:00 to 11:59 at the ES and from 10:00 to 10:59 at CBBT (**Figure 4-12**). As stated previously for the ES, the same vessel could appear in multiple images every 15 minutes, but at the CBBT survey area, only one camera was used, so an individual vessel could have been captured a maximum of four times per hour at each haul-out site.

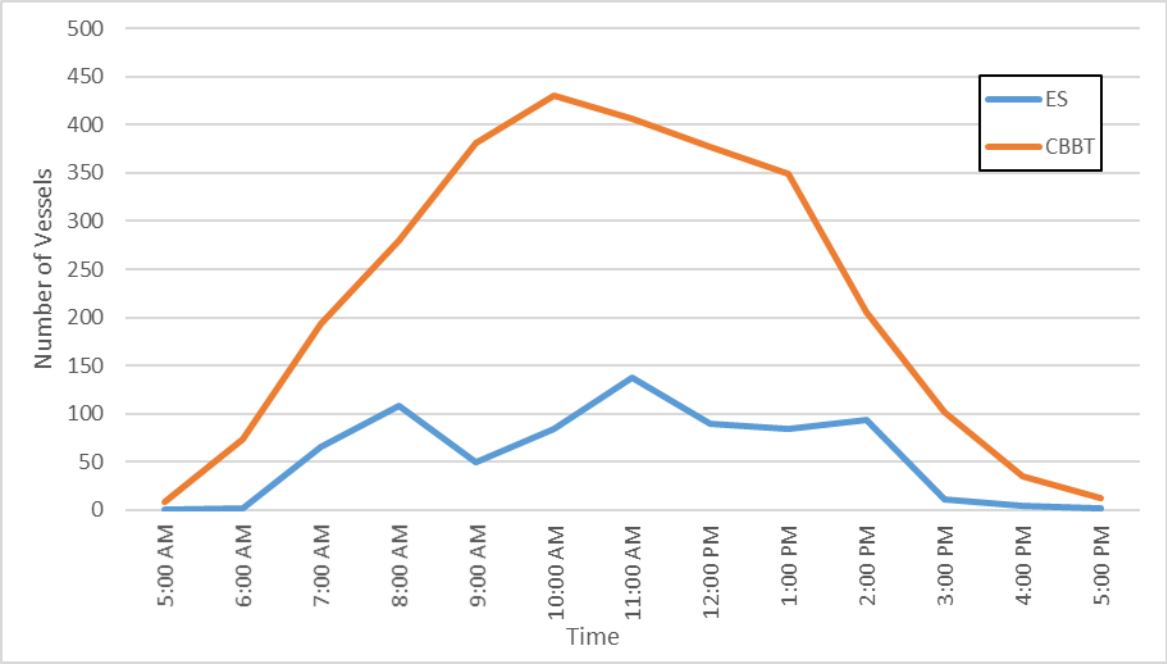

Figure 4-12. Total number of vessels photographed during each hour at the ES survey area (blue) and the CBBT survey area (orange)

There were 90 images with both vessels and seals present at the ES, with 44 images of vessels and seals hauled out and 59 images of vessels and seals in the water. There were 86 images with both vessels and seals present at CBBT, with 42 images of vessels and seals hauled out and 48 images with vessels and seals in the water.

While some images contained both vessels and seals, there were several instances where vessels appeared in the image and seals had flushed from the haul-out site. At CBBT, there were 16 instances where seals flushed after a vessel was present in an image. At the ES, there were 17 instances of seals flushing after a vessel was present. When seals left a haul-out, the time it took the seals to haul-out again varied. At ES, the amount of time it took for at least one seal to haul out again after seals flushed ranged from 15 minutes to 22.25 hours, with an average of 5.78 hours. At CBBT, the amount of time it took ranged from 15 minutes to 50.5 hours, with an average of 12 hours. **Table 4-6** and **Table 4-7** show instances where seals flushed after a vessel was present from ES and CBBT haul-out sites, respectively. The tables include the number of seals hauled out, the number of seals in the water, and the number of vessels present in 15 minute time intervals starting at 1 hour prior to seals flushing, and ending at 1 hour after seals flushed. The date and time of the next haul out after seals flushed is also recorded, along with a calculation of the time between the seals flushing and at least one seal hauling out again. The ES sites had multiple cameras in the same area, which allowed images to be taken more often than 15 minutes apart from different cameras. This also allowed multiple cameras to capture the same seal flush event. This was taken into account, and any duplicate entries from multiple cameras were combined.

Table 4-6. Instances of seals flushing after vessel presence at the ES survey area

Date and Time of Flush	Obsv Category	Time Before Flush				Flush	Time After Flush				Date and time of next HO	Time to HO After Flush (hrs)
		60 min	45 min	30 min	15 min		15 min	30 min	45 min	60 min		
12/4/2019 9:58	Seals HO	8	9	7	6	0	0	3	4	2	12/4/2019 10:28	0.50
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	0	1	1	1	1	0	0	0	0		
1/24/2020 9:18	Seals HO	0	2	5	6	0	1	0	4	3	1/24/2020 9:33	0.25
	Seals IW	2	0	4	3	4	0	2	2	3		
	Vessels	0	0	0	0	1	0	1	0	0		
1/24/2020 9:48	Seals HO	5	6	0	1	0	4	3	8	16	1/24/2020 10:03	0.25
	Seals IW	4	3	4	0	2	2	3	1	0		
	Vessels	0	0	1	0	1	0	0	0	0		
2/10/2020 14:57	Seals HO	0	0	0	46	0	0	0	0	0	2/10/2020 16:27	1.5
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	0	0	0	0	1	0	0	0	0		
2/18/2020 8:44	Seals HO	0	0	0	2	0	0	0	0	0	2/19/2020 6:59	22.25
	Seals IW	0	0	0	0	1	1	1	0	0		
	Vessels	0	0	0	0	1	0	0	0	0		
2/22/2020 7:29	Seals HO	0	0	0	1	0	0	0	1	5	2/22/2020 8:14	0.75
	Seals IW	0	1	4	2	4	0	3	4	0		
	Vessels	0	0	2	1	1	1	1	0	0		
2/23/2020 8:27	Seals HO	9	10	4	10	0	0	0	0	0	2/23/2020 9:42	1.25
	Seals IW	1	0	0	1	0	0	0	0	3		
	Vessels	0	0	0	0	2	2	0	0	0		
2/23/2020 14:00	Seals HO	18	22	26	22	0	0	0	0	0	2/24/2020 6:30	16.50
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	0	0	0	0	3	1	1	1	0		
2/24/2020 8:45	Seals HO	22	35	19	29	0	0	0	0	0	2/24/2020 10:00	1.25
	Seals IW	0	0	0	1	1	0	0	2	4		
	Vessels	0	0	2	0	2	1	3	1	0		
2/28/2020 11:15	Seals HO	0	0	5	17	0	0	0	0	0	2/28/2020 13:15	2.00
	Seals IW	0	0	1	1	0	2	0	0	0		
	Vessels	0	0	0	0	2	1	2	0	0		
2/29/2020 11:30	Seals HO	21	22	19	23	0	0	0	0	0	2/29/2020 12:45	1.25
	Seals IW	0	0	1	1	2	1	1	0	3		
	Vessels	0	0	0	0	1	1	1	1	2		
2/29/2020 13:00	Seals HO	0	0	0	1	0	0	0	0	0	3/1/2020 10:15	21.25
	Seals IW	1	0	3	1	0	0	2	1	1		
	Vessels	1	1	2	0	1	0	0	0	0		

Table 4-7. Instances of seals flushing after vessel presence at the ES survey area (continued)

Date and Time of Flush	Obsv Category	Time Before Flush				Flush	Time After Flush				Date and Time of Next HO	Time to HO After Flush (hrs)
		60 min	45 min	30 min	15 min		15 min	30 min	45 min	60 min		
3/1/2020 11:15	Seals HO	6	10	13	17	0	0	0	0	0	3/1/2020 12:30	1.25
	Seals IW	1	5	0	1	0	0	0	0	1		
	Vessels	0	0	0	0	2	2	2	2	2		
3/1/2020 13:00	Seals HO	0	0	9	19	0	0	0	0	0	3/2/2020 6:30	17.50
	Seals IW	0	1	2	0	0	0	0	1	2		
	Vessels	2	2	2	1	3	2	1	1	2		
3/2/2020 7:44	Seals HO	11	13	14	16	0	0	0	0	0	3/2/2020 10:44	3.00
	Seals IW	0	1	1	1	1	0	1	0	1		
	Vessels	0	0	0	0	2	2	2	2	0		
3/3/2020 7:44	Seals HO	32	32	0	34	0	0	0	0	0	3/3/2020 14:59	7.25
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	0	0	0	0	1	1	0	0	0		
3/9/2020 13:45	Seals HO	2	3	2	1	0	1	3	1	1	3/9/2020 14:00	0.25
	Seals IW	0	0	0	0	1	0	0	0	0		
	Vessels	0	0	0	0	1	0	0	0	0		

HO=haul out or hauled out, IW=in water, hrs=hours, min=minutes. Obsv=Observation

Table 4-8. Instances of seals flushing after vessel presence at CBBT survey area

Date and Time of Flush	Obsv Category	Time Before Flush				Flush	Time After Flush				Date and Time of Next HO	Time to HO After Flush (hrs)
		60 min	45 min	30 min	15 min		15 min	30 min	45 min	60 min		
1/18/2020 10:59	Seals HO	2	2	2	2	0	0	0	0	0	1/19/2020 7:29	20.50
	Seals IW	0	1	0	0	1	0	0	0	0		
	Vessels	0	0	0	0	1	0	0	0	0		
2/2/2020 11:28	Seals HO	4	5	3	2	0	1	0	0	0	2/2/2020 11:43	0.25
	Seals IW	1	1	0	0	0	0	0	0	1		
	Vessels	0	0	0	0	1	1	0	0	0		
2/3/2020 12:57	Seals HO	3	7	9	8	0	0	0	0	0	2/3/2020 16:42	3.75
	Seals IW	0	0	0	0	0	1	0	0	0		
	Vessels	0	0	0	0	1	1	1	1	2		

Table 4-9. Instances of seals flushing after vessel presence at CBBT survey area (continued)

Date and Time of Flush	Obsv Category	Time Before Flush				Flush	Time After Flush				Date and Time of Next HO	Time to HO After Flush (hrs)
		60 min	45 min	30 min	15 min		15 min	30 min	45 min	60 min		
2/8/2020 14:00	Seals HO	0	0	0	1	0	0	0	0	0	2/9/2020 11:45	21.75
	Seals IW	0	0	0	0	0	1	1	0	1		
	Vessels	0	0	0	1	0	0	0	0	0		
2/16/2020 11:14	Seals HO	1	2	1	1	0	0	0	0	0	2/17/2020 7:44	20.50
	Seals IW	1	2	0	1	0	0	1	2	1		
	Vessels	0	0	0	0	1	2	0	1	1		
2/23/2020 12:43	Seals HO	1	2	1	4	0	0	0	0	0	2/24/2020 10:13	21.50
	Seals IW	2	0	4	2	1	0	0	0	0		
	Vessels	0	1	0	0	1	0	0	1	0		
3/12/2020 12:59	Seals HO	0	0	0	1	0	0	0	0	1	3/12/2020 13:59	1.00
	Seals IW	0	0	0	0	1	0	0	0	0		
	Vessels	1	1	0	0	1	1	1	1	1		
3/12/2020 14:14	Seals HO	0	0	0	1	0	0	0	0	0	3/13/2020 6:44	16.50
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	1	1	1	1	2	2	0	0	0		
3/19/2020 14:58	Seals HO	2	3	2	2	0	1	2	1	2	3/19/2020 16:13	0.25
	Seals IW	1	0	0	0	0	0	0	0	0		
	Vessels	0	0	0	0	1	1	1	0	0		
3/26/2020 10:42	Seals HO	0	0	1	1	0	0	0	0	0	3/26/2020 13:27	2.75
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	1	1	1	1	2	1	1	1	2		
3/26/2020 13:42	Seals HO	0	0	0	1	0	0	1	1	1	3/26/2020 14:12	0.50
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	2	2	2	1	3	2	0	0	0		
3/28/2020 13:42	Seals HO	0	0	0	1	0	0	0	0	0	3/28/2020 17:42	4.00
	Seals IW	0	0	0	0	0	0	0	1	1		
	Vessels	4	4	4	3	4	4	4	4	3		
4/8/2020 13:26	Seals HO	1	1	1	1	0	0	0	0	0	4/9/2020 5:56	16.50
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	2	2	2	2	2	2	2	2	2		
4/17/2020 9:09	Seals HO	1	1	1	1	0	1	1	1	0	4/17/2020 9:24	0.25
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	1	1	1	1	0	0	0	0	0		

Table 4-10. Instances of seals flushing after vessel presence at CBBT survey area (continued)

Date and Time of Flush	Obsv Category	Time Before Flush				Flush	Time After Flush				Date and Time of Next HO	Time to HO After Flush (hrs)
		60 min	45 min	30 min	15 min		15 min	30 min	45 min	60 min		
4/24/2020 13:25	Seals HO	0	1	1	1	0	0	0	0	0	4/26/2020 15:55	50.50
	Seals IW	0	1	0	0	0	0	0	0	0		
	Vessels	0	0	0	1	1	0	1	0	0		
4/26/2020 16:25	Seals HO	0	0	1	2	0	0	0	0	0	Last Image of Seals HO	N/A
	Seals IW	0	0	0	0	0	0	0	0	0		
	Vessels	0	1	1	2	2	2	2	1	0		

HO=haul out or hauled out, IW=in water, hrs=hours, min=minutes. Obsv=observation

5 Discussion

The visual surveys (both shore and vessel-based), that have been conducted in southeastern Virginia since 2014 (Jones and Rees 2021) formed the foundation of this study. Results from this first season of camera survey effort shows that camera surveys can be an effective means of gathering a large amount of data on pinnipeds where they haul out (e.g. 55,814 seal observations in a single season), and at a relatively low cost. These data have great potential to improve our understanding of localized seal haul-out activity.

There were several benefits demonstrated by this first season of effort including:

- the ability to monitor the haul-out areas daily, at all times of daylight hours and even some limited ability to monitor at night
- the ability to monitor in adverse weather conditions
- the ability to simultaneously sample multiple haul-out areas for extended periods of time
- relatively low personnel demands to collect data
- relatively inexpensive equipment
- low up front cost and
- the ability to collect data with limited disturbance to the seals

As with the visual surveys, the camera surveys demonstrated that harbor seals consistently haul out and are present in the water at both the ES and CBBT survey areas from November to April. While the cameras cannot provide accurate counts for seals in the water, we feel confident that when cameras were placed to view the haul-out site, the time-lapse feature of the cameras allowed for observation of every haul-out event during daylight hours and when seals were within the detection range after daylight hours. A lack of sightings (i.e., counts), especially for seals in the water, does not indicate a lack of presence given the cameras only recorded images once every 15 min and seals in the water could

have been missed when diving or swimming out of the camera field of view. Likewise, if seals hauled out in an area not in view of the cameras they would have also been missed.

While images from the camera surveys were not of high enough quality to identify seals to species with 100% certainty in most cases, the vessel surveys can be relied upon to provide the frequency of harbor versus gray seals visiting the survey areas.

Analysis of the images showed the temporal and spatial preferences of seals during the 2019/2020 season. We found that seals hauled out in greater numbers in the months of January and February and we were able to document which specific haul-out sites at both the ES and CBBT survey areas were favored (as indicated by the highest counts) by the seals. These data will help to focus efforts during future studies (e.g. tagging attempts), and provide the ability to compare if site preferences persist from season to season in southeastern Virginia.

While this study was not designed to provide data on nighttime haul-out behavior, we did demonstrate that cameras at the ES study area could capture images of seals at night. However, seals had to be within close proximity (about 60 ft or 20 m) to the camera, and that image quality was greatly degraded at night. Haul-out behavior in relation to time of day is likely both seasonal and site specific. At Castro Rocks, San Francisco Bay, California, researchers found mean nighttime counts were significantly higher than daytime counts and hypothesized that pressure from human disturbance during the day was the cause (Grigg et al. 2002); while Norris (2007), recorded higher daytime counts in Providence, Rhode Island. For the Virginia survey areas, we believe tagging data will provide the best results of temporal pinniped behavior given the limitations of collecting camera data at night.

Analyzing environmental factors can help predict if seals will be hauled out or in the water during certain conditions. We found that seal haul-out counts are fairly even across the range of water levels at both survey areas. Seals were less likely to be hauled out when average wind speeds were higher than about 25 kts (**Figure 4-6**), and that seals were more likely to be hauled out at mid-range temperatures for the area (between 45 and 55 F° or approximately 7 to 13 C°).

Several environmental factors were considered for comparison, but were not included in this analysis including precipitation, tide cycle stage, and water temperature. These were not analyzed for reasons including lack of data availability (e.g. precipitation), complications in processing (e.g. tidal stage), and time constraints. This analysis may be developed in future reports as Navy needs dictate.

A comparison of camera to vessel counts was conducted to determine if the counts yielded similar results and if camera counts could be a useful proxy for vessel counts in the future, given the high cost, weather dependency, labor intensity, and the seal disturbance potential of vessel counts.

The main differences between camera and vessel counts are summarized as follows:

1. Observation duration - Vessel count teams are able to continuously observe haul-out areas over the entire survey period. During vessel counts, three separate 2-minute counts are conducted at 10-minute intervals (Jones and Rees 2021), and the area immediately surrounding the known haul-out locations is monitored continuously over about a 35 minute period. Observations are

still recorded outside of the counts, but are noted as "off-effort." Camera counts occur only once every 15 minutes from each camera, but occur throughout the daylight period.

2. Weather/tidal condition limitations - Cameras are deployed throughout the season and take images on a daily basis regardless of weather. Very infrequently, fog, rain or glare impacted the ability to detect seals from the camera. Vessel surveys generally are not conducted in adverse weather conditions, are somewhat limited to specific tidal cycles (e.g. at the ES survey area, the site is not accessible at very low tides), and safety is considered (e.g. surveys are not conducted when there is a small craft advisory in effect or in sea states greater than Beaufort 3).
3. Impact to seal behavior - Cameras do not appear to impact the behavior of the seals and therefore the cameras do not affect the counts, whereas vessel surveys often flush seals into the water. If seals are hauled out at locations (e.g. inside creek E) where the animals are out of view of the observers before they fully flush, then vessel counts would have the potential to underestimate the seals hauled out.
4. Species identification - Because of the image quality and range to subject, seal species could usually not be positively determined between harbor and gray seals from the camera surveys, whereas observers from vessel surveys could differentiate between the two species using a large telephoto lens and/or binocular to aid in species identification.
5. Observable area - With the ability to move the survey vessel to achieve a variety of views/perspectives of the haul-out sites, and with the use of binoculars; the vessel counts were able to cover a much larger area, investigate real time haul-out behavior and observe seals hauled out outside of the camera view. The counts from camera surveys have the potential to be underestimates because of the limited area that camera traps are able to capture. Some cases of this were detected by the comparison of camera to vessel counts at the ES survey area and some from the review of images, where seals were noted at the extreme edge of an image. This was noted especially at haul-out location E1 (main channel side), E2, E3 and A. Counts at E1 were improved on 23 February 2020, when repositioning the camera allowed analysts to see the entire haul-out site from the image. For locations E2, E3 and A, the lack of full coverage of certain haul-out sites by the cameras was corrected for season 2 (October 2020 to May 2021) by reconfiguring several camera locations and adding cameras where needed. Camera perspectives/survey area could be changed, but require a visit to the site.
6. Ability to observe obscured animals - At the CBBT survey area, seals have the potential to be obscured by rocks and the options for the adjusting camera angle are limited. In addition, the distance from the cameras to the haul-out does not allow for clear images of the seals at the CBBT. Image clarity could be improved by upgrading to a high-resolution time-lapse camera system, which utilize a digital single-lens reflex camera in a waterproof housing, at a cost of $3,500-$5,000 per camera system. Since we were aware that visibility is an issue at the CBBT survey area, we suspect the counts at the CBBT had the potential to be an underestimate from actual seal presence to a greater degree than at the ES, but this was not clearly apparent from the comparison of vessel to camera survey results, which were very similar. For season 2, the placement of cameras was modified as much as possible to maximize view (e.g. cameras elevated at the CBBT and to capture all the haul-out sites at the ES).
7. Ability to observe behavior and document seals in the water - Seals in the water during vessel counts were monitored continuously over about a 35 minute period, and seal movement could

be observed and considered in the vessel counts; whereas each camera took an image once every 15 minutes, resulting a snapshot for review, as opposed to the ability of continuous observation. In addition, cameras were deployed specifically to capture known haul-out sites and do not cover all the in water areas of the main channel and creeks. Vessel survey observers had a much broader perspective of the entire surrounding area.

Camera counts proved to be helpful in post-analysis to inform the vessel survey team as to how often and how many seals flushed prior to the vessel survey. Vessel surveys were helpful in alerting the camera survey team where cameras were missing hauled-out seals, e.g. haul-out site E2 was only partially visible from the cameras. While the small sample size of camera to vessel counts for comparison precludes a definitive conclusion, the available data seems to indicate that camera counts could be a proxy for vessel counts, with certain limitations.

For season 1, the arrival of seals in the ES area was prior to camera installation, as two seals were observed during installation of the cameras at ES on 4 November 2019. At the CBBT survey area, we did not get permission to install cameras until January 2020, and were likewise not able to capture first use of the CBBT haul-out sites. For season 2, (2020/2021) we were able to install cameras at both locations earlier (late October) and keep them installed later (May 2021). Our goal in the future will be to install cameras in mid-October and to keep cameras out for at least two weeks after last seal sighting by either images from the cameras that were transmitted via email, or sighted from vessel surveys, whichever is later.

From the analysis of vessel presence, fewer vessels were photographed at the ES survey area than the CBBT survey area, which was inversely related to seal counts at those survey areas. Vessel numbers were lowest at both survey areas at the start of the survey season into early February 2020. The ES survey area saw a peak of vessel numbers from the end of February into early March, which corresponded with daily trips by seal tagging team (Ampela et al. 2021). The CBBT survey area saw vessel numbers higher (especially recreational fishing vessels) from the end of March through the end of the survey season, corresponding with a lower number of seals as the weather got warmer and the seals started moving north (Ampela et al. 2021). The number of vessels present at the ES survey area was highly influenced by number tagging and survey vessels, while the CBBT was more influenced by the higher number of recreational fishing vessels, especially in the spring.

Both the number of seals and the number of vessels at the ES survey area were fairly evenly distributed throughout daylight hours, with the number of vessels peaking around 11:00 and the number of seals hauled out peaking around 12:00. At the CBBT survey area, the number of vessels peaked around 10:00 while the number of seals hauled out peaked around 8:00, decreased until 10:00, and then increased slightly until 16:00 before falling after that. During the survey period, the time of sunset ranged from 16:50 to 19:53, which means that especially during the winter when sunset was earlier, seals could have been missed in images as it got darker. Data from the tagging report found that the most seal haul-out events occurred between 14:00 and 19:00 (Ampela et al. 2021). This further implies that seals may tend to haul out as it gets closer to sunset, and therefore could have been missed in images. The decrease in seals hauled out from 08:00 to 10:00 at the CBBT could indicate that seals are avoiding times when more vessels are typically present.

Vessel usage for each of the sites varied. At CBBT, the rocky islands are a common fishing spot, so recreational vessels tend to anchor there for long periods of time in contrast to the ES where vessels were more likely to be from the survey team or from commercial crabbing or clamming operations that are moving though the area more quickly. Tagging vessels would stay in the ES survey area longer while staging for a tagging attempt. In Canada, seals were found to have more flight reactions when boats passed at a low speed and stayed in the area than when boats passed by at high speeds (Henry and Hammill 2001). Based on the camera surveys, the average amount of time it took for seals to haul out after flushing was about twice as long at the CBBT compared to the ES. This could have been caused by more vessels present, or by vessels staying anchored longer in the CBBT survey area. In addition, the environment could be an influence in flushing behavior since the habitat at the ES survey area is a restricted waterway with limited ingress/egress and the CBBT survey area is a rocky habitat with easy access to open water.

Larger vessels (e.g. container ships and military vessels) are known to pass by the CBBT survey area since it is located along a major shipping route for several ports in the Chesapeake Bay. These larger ships in the shipping channel were not counted as they are too far from the haul-out sites to cause disturbance. The ES would not support larger vessels due to the depth near the haul-out and the limitation of access to the area. At both survey areas, instances where seals flushed were only noted after smaller vessels were seen in the images, which is consistent with observations from haul-out surveys.

Many factors could have caused variance in the amount of time it took seals to haul out again after flushing. Vessels could have remained in the area, environmental factors such as wind speed could have changed, the amount of time seals had already been hauled out for, or the seals could have moved to a different haul-out location and stayed there even if a vessel left the previous haul-out area. The images captured were also limited to daylight hours, so if seals hauled out overnight after flushing from a vessel, the amount of time to the next haul-out event would have been less than was recorded by the survey cameras. The distance of the vessel from the seals hauled out could have also influence whether seals flushed or not. A study in Monterey Bay, California found that 74% of flushing occurred when the disturbance was less than 30 m from the seals (Osborn 1985). Our analysis was also limited by the 15 minute image capture intervals; a vessel could have passed without being captured in an image, and could have still caused seals to flush without being recorded.

Henry and Hammill (2001) found that pursuit and capture of seals caused them not to haul out again while boats were present. All but two of the instances of seals flushing after a vessel at the ES area occurred on dates where vessel surveys or seal tagging projects were occurring in the area. The seal-tagging project consisted of people traveling by boat to the site, and then attempting to capture seals in nets to place tags on them. We found that after this type of disturbance, seals would occasionally haul out again while the vessels were still in the area, but there were several haul-out sites in the area, allowing seals to haul out further away from the vessels and teams conducting research. The CBBT only had one instance of seals flushing after a vessel survey was conducted.

Since seals may haul out or leave the haul-out site outside of daylight hours when cameras were not able to record, it is not possible to accurately calculate haul-out duration from the camera trap images. While the analyst did record haul out start, haul out end, and when seals were on the haul-out at sunrise

or sunset; a haul out duration could be calculated for only daylight hours, when the haul out start and end both occurred during daylight hours on the same day. If haul out duration is an important value for future analyses, using tagging data to calculate would be more accurate.

6 Recommendations

The data collected from this effort provides important information required to assess potential impacts from U.S. Navy training and testing activities. Season 1 demonstrated the value of camera surveys and created the groundwork for the study to be improved upon for future seasons. Some improvements that have already been incorporated into season 2 (October 2020 to May 2021) include: improving camera placement to better observe the known haul-out sites, adding markers to distinguish between close proximity haul-out sites, and elevating camera platforms to improve visibility of the haul-out and reduce obstruction issues.

Other potential options to improve data collection and analysis in the future include:

1. Upgrading camera equipment would likely allow researchers to identify seals to species at the ES survey area and improve counts at the CBBT. The cameras currently being used, cost around $250 each, are adequate to provide minimum counts at both the ES and CBBT locations. However, with the long distance from camera to haul-out site at the CBBT, seals are more likely missed in the counts. Camera packages that would improve seal detectability are more complicated to operate and are estimated to cost in the range of about $3,000-$3,500 each, so there is a substantial increase in price to obtain cameras of the quality needed to improve both the ability to identify seals to species and detect tagged animals at the ES survey area, and improve the count of missed seals at the CBBT.
2. Automated image processing tools and artificial intelligence (i.e. AI) models (e.g. MegaDetector) may be developed in the future that could assist in counting seals from images. Currently there are tools, which allow researchers to “auto-process” images in limited setting, but none that have been successful with harbor seals. Since counting seals from the images is the most labor intensive part of this work, working with teams that are developing these models could pay dividends in future time savings.
3. 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 seals in the mid-Atlantic.
4. Integrate tagging data with camera data to develop a more complete understanding of how seals are using haul-out sites in Virginia.

As we continue to collect and analyze remote time-lapse camera data, improvements could provide an important supplement to what is being collected by the vessel survey and tagging teams, allowing researchers to answer questions about seals in Virginia that would not be possible without integrating the data.

7 Conclusions

This study demonstrated that time-lapse cameras were successful at collecting information on haul-out patterns of seals in Virginia and that camera data has the potential to provide near continuous monitoring data during daylight hours at the ES and CBBT survey areas. These data are relatively inexpensive to obtain, provide an excellent value in return on investment, and create a permanent record for monitoring seals in Virginia near the southern extent of their current range. The data collected by this effort will not only contribute to more accurate information on the distribution of pinniped species, but provide information critical to the development of effective protective measures during naval training and testing and other maritime activities. These data are also important to support future compliance with the Marine Mammal Protection Act, and proper documentation in National Environmental Policy Act analyses.

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