Pinniped Time-lapse Camera Surveys

Southern Chesapeake Bay and Eastern Shore, Virginia: 2019-2022

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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

ANOVA	Analysis of Variance
C°	degrees Celsius
CBBT	Chesapeake Bay Bridge Tunnel
deg	Degrees
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
IW	in water
km	kilometer(s)
kts	knots
LED	light emitting diode
Max	Maximum
MP	megapixel
m	meters
min	minutes
NMFS	National Marine Fisheries Service
NAVFAC	Naval Facilities Engineering Systems Command
NOAA	National Oceanic and Atmospheric Administration
OBIS-SEAMAP	Ocean Biodiversity Information System Spatial Ecological Analysis of Megavertebrate Populations
OPAREA	Operating Area
U.S.	United States
USFF	U.S. Fleet Forces Command
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 the months of 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 the last decade, harbor seals have been found to occur seasonally in Virginia from October through May, and gray seals are occasionally observed during the winter but not on a consistent basis (Jones and Rees 2023), and stranding's have been increasing in Virginia for the last two decades (Swingle et al. 2014).

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 U.S. Navy training and testing activities. Harbor and gray seals, like all pinnipeds, are amphibious, spending time on land resting (hauled out) and in the water. 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 vessel-based surveys, at known seal haul-out sites in Virginia and have provided a solid baseline of data on seasonal seal occurrence in Virginia including an estimated average seasonal abundance of 198 individuals from mark-recapture efforts and data on site fidelity from photo-identification data (Jones and Rees 2023). However, vessel based surveys are currently limited by resources and study design to twice per month, 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., near sunrise/sunset) and in adverse weather conditions (e.g. rain, high winds and sea states greater than Beaufort 3).

Trail cameras 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 to operate in a time-lapse mode to take photographs at a set time interval. 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 1) to improve the understanding of local and seasonal haul-out patterns, and the 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-based surveys and time-lapse camera data collection. The data and results of these efforts will further improve the assessment of potential impacts from the Navy including 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 in the region. These data may also provide important baseline information for the assessment of potential future impacts from climate change or other anthropogenic activities.

This report covers time-lapse camera survey data collection in southeastern Virginia for the 2019/2020, 2020/2021, and 2021/2022 seasons. All work for this report as well as the vessel-based surveys was conducted in accordance with NMFS GA #19826 from 2019 to 2021 and #25811 from 2021 to 2026.

2 Field Methods

2.1 Study Area

The study area shown in **Figure 2-1**, consists of two locations in southeastern Virginia where seals have been known to haul-out for the last decade (Jones and Rees 2023): 1) on the southeastern tip of the Eastern Shore (ES), and 2) in the lower Chesapeake Bay along the Chesapeake Bay Bridge Tunnel (CBBT). 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.

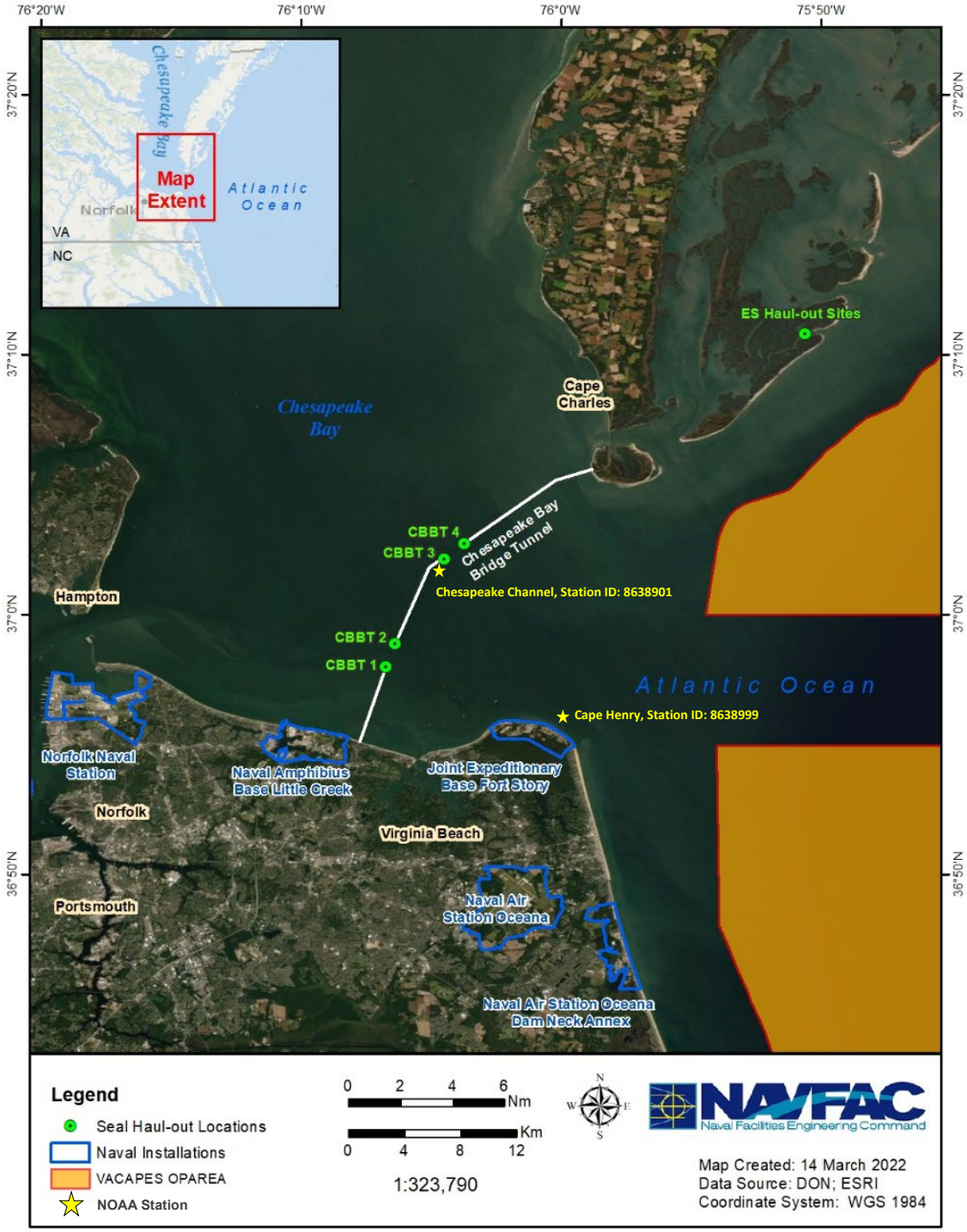

Figure 2-1. ES and CBBT haul-out sites and nearby U.S. naval installations. VACAPES OPAREA = Virginia Capes Range Complex Operating Area, NOAA = National Oceanographic and Atmospheric Administration

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 an alpha-numeric identifier (ID), with alphabetic designations added if seals establish a new haul-out site (generally near a new creek mouth), and a numeric identifier is added when a new haul-out site is established in close proximity to an existing haul-out site.

Figure 2-2. Seal haul-out sites at the ES survey area

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

At the CBBT survey area, seals haul-out on the rock armor (locally referred to as “islands”) (**Figure 2-4**) which protect the tunnels as they go beneath the water. There are four of these islands, one at each end of the two tunnels. The Navy vessel surveys have been systematically monitoring all four of the haul-out sites since 2014. For this study, only two of the four haul-out sites (CBBT3 and CBBT4; **Figure 2-1**) were accessible to be monitored with the trail cameras. The CBBT1 and CBBT2 haul-out sites were not included in this study because active tunnel construction (NOAA 2021c; Chesapeake Bay Joint Venture 2020) prevented access and the installation of cameras at those locations. CBBT 1 and CBBT2 are currently monitored for seal presence by the Navy’s haul-out vessel surveys (Jones and Rees, 2023) and during construction activities (NOAA 2021c; Chesapeake Bay Joint Venture 2020).

Figure 2-4. Aerial view of a CBBT haul-out site. Photo by Virginia Aquarium & Marine Science Center Foundation

2.2 Camera Models and Settings

Three different trail camera models were used in this study. Model selection was site specific and based on the need for wireless capability and camera network linking (for remote sites), or image quality (for sites where cameras had to be placed at a distance from the haul-out site) (see **Section, 2.3 Camera Placement**). The ability to link to a wireless network in order to send photographs 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 image quality was critical in order to capture seals at greater distances 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 image quality with a maximum 32 megapixel (MP) day resolution and 14 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; however, they were not synced to take images simultaneously. CuddeLink cameras were used exclusively at the ES survey area and Stealth cameras were used at the CBBT survey area. Additionally, one Stealth camera was installed at the ES survey area during the 2019/2020 season 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 ES survey area on 8-12 ft pressure treated 2x4s approximately 20-50 m from each of the known haul-out sites. The elevated posts at this location minimized vegetation interference and reduced the likelihood of cameras being flooded during very high tides or storms. At the CBBT survey area, cameras were attached directly to the guardrail supports overlooking the haul-out areas in the 2019/2020 season (**Figure 2-5**), and in subsequent seasons were elevated using pressure treated 2x4s attached to the guardrail supports (**Figure 2-6**).

Figure 2-5. Camera view of CBBT3 and image of camera installed on the guardrail (inset) during the 2019/2020 season

Figure 2-6. Image of camera installed on elevated 2x4 wooden post for the 2020/2021 and 2021/2022 seasons. Photo by D. Jones, Naval Facilities Engineering Systems Command Atlantic

During the 2019/2020 season, ten cameras were installed at the ES survey area (nine CuddeLink and one Stealth), and during the 2020/2021 and 2021/2022 seasons nine CuddeLink cameras were installed. At the ES survey area, cameras were installed to provide maximum coverage at all of the known haul-out sites, rather than random placement. Cameras were angled to minimize water and sun glare as much as possible, and were adjusted throughout the monitoring period as needed. Cameras were checked throughout the season to check the battery percentage, camera function, that camera angle was maintained, and to switch the SD cards.

The camera locations between the three seasons are shown in (**Figure 2-7)**. Placement corrections were made as needed between and throughout the seasons to maximize the visibility of the haul-out areas. For the 2020/2021 season, the home camera was renamed from camera 1 (CL1) to camera 10 (CL10), camera 2 (CL2) was added to the same post as camera 10 facing in opposite directions, and camera 5 (CL5), camera 7 (CL7), and camera 8 (CL8) were moved to new locations.

As a result of the close proximity of seal haul-out sites to the cameras at the ES, cameras were powered with solar panels and rechargeable batteries to minimize the need for camera checks to avoid seal disturbance during the occupancy season. Camera status was monitored through a daily status report and the delivery of images via email eliminating the need to check cameras, potentially disturbing hauled out seals.

At the CBBT survey area, Stealth trail cameras were accessed from a maintenance road located approximately 100-130 m (328-427 ft) from each haul-out area. Since the entire haul-out site was visible, only one camera was needed at each CBBT haul-out site.

Figure 2-7. Seal camera locations at the ES survey area across the three seasons

3 Analytical Methods

3.1 Effort and Counts

Cameras were installed at each of the haul-out areas in the fall (October/November) and removed in the spring (April/May), except for the 2019/2020 season at the CBBT survey area where cameras were not installed until January 2020. An effort was made to install the cameras prior to seal arrival and remove them after seal departure from the area. Data was analyzed within the occupancy season, from the date the first seal is recorded to the date the last seal is recorded.

At the ES survey area, camera failure was generally the result of the cameras tilting so that the haul-out site was no longer in view (e.g., from eagles perching on the cameras). When this occurred, a different camera with the same haul-out area in view was used. At the CBBT survey area, camera failure was the result of mechanical failure or the camera tilting, and there is no overlap between haul-out sites, so when there was camera failure, data were not available for that haul-out site.

Images were reviewed for the presence of seals in the water or hauled out, and vessels. The Timelapse Image Analysis system and the Timelapse2 program (Greenberg 2021a, 2021b), was used to count, mark and record the number of seals or vessels (**Figure 3-1**). The Timelapse2 program includes built in features which simplify the visual examination, encoding, and recording 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 batch time correction, and image review tools (e.g. magnifier, play forward and reverse, pan/zoom tools, and image enhancement) (Greenberg 2021b). For the counts, animals emerging from the water more than half a body length or in water but clearly resting on the bottom of a sandbar were considered as hauled out, similar to Jeffries (2014).

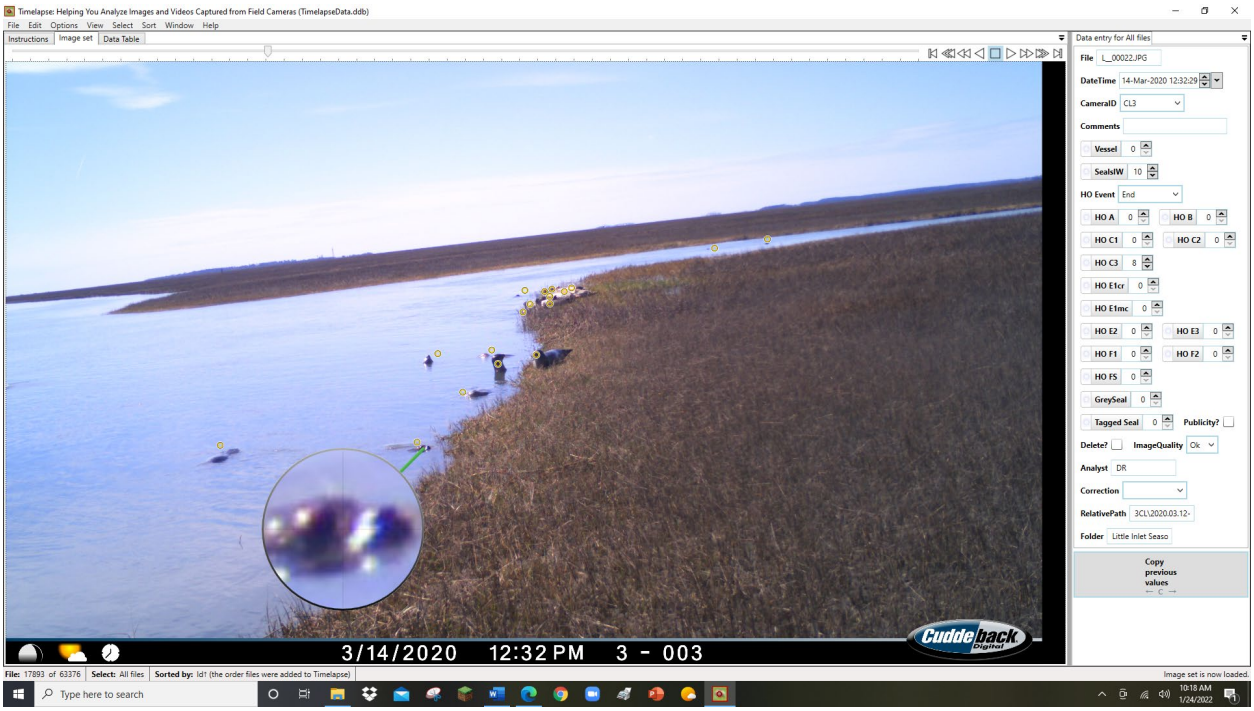

Figure 3-1. Screenshot of the Timelapse Image Analysis workspace. Counted seals are marked by yellow circles, the magnifier feature is shown near the front and the customizable data template at the right

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, or a camera became inoperable and the analyst needed to use a different camera to count from.

Each camera was programmed to take an image every 15 minutes to monitor the presence of the seals and to be able to detect changes in haul-out activity over time. Cameras were not synced to take images at the same time, but only one count was taken at each haul-out site per 15-minute period. At the ES survey area, every vessel was counted regardless of proximity to the haul-out site, since any vessel 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 transiting through, this potential was limited. At the CBBT survey area, vessels were recorded if they were within about 300 m (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 our vessel surveys at that site since 2014. Cameras at both CBBT sites had the potential to capture a vessel up to 4 times per hour and more often at the ES if multiple cameras captured the same vessel. Therefore, the number of vessels was averaged by month for each season by dividing the total number of vessels counted by the number of images where vessels were recorded.

3.2 Temporal Data

Counts from the images were analyzed temporally to determine if there were patterns in haul-out activity by time of day. Each image has a time stamp as recorded by the cameras. In some instances, images were corrected for daylight savings time changes or time setting errors using the Timelapse2 program. 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).

3.3 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 included verified water level, air temperature, wind speed, and wind direction. 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 from NOAA Tides and Currents, station, Chesapeake Channel (station ID 8638901) (NOAA 2021a), physically located at 37.032 N, 76.083 W (**Figure 2-1**). 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. For the 2019/2020 season there were a few instances where there was no meteorological data collected from station 8638901. This occurred on 6, 8, and 10 November 2019, 16 and 18-20 December 2019, and 19, 21, and 27 February 2020. For the 2020/2021 season, there was no meteorological data from station 8638901 on 9 January 2021 and from 19 April -18 May 2021. During the 2021/2022 season, there was no meteorological data for 14-15 March 2022 and 9 May 2022. To accommodate for the missing data, a nearby station, Cape Henry (station ID 8638999), physically located at 36.558 N, 76.040 W, was used (**Figure 2-1**).

Water level provided by NOAA tides and currents stations use a base elevation as a reference from which to reckon heights or depths. Verified 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, wind speed, and wind direction are averaged over an eight-minute period (NOAA 2021d).

3.4 Vessel Survey Counts

In each field season dedicated vessel surveys were conducted in the same survey areas as the camera surveys (see Jones and Rees 2023), allowing for a comparison of camera counts to vessel counts to determine if count results were comparable across these survey methods.

Since vessel presence had the potential to disturb seals and cause them to flush (move from the haul-out to the water), the comparison for the number of seals on a haul-out site was based on the maximum seal count from the cameras one minute prior to survey vessel arrival, to the maximum number of seals observed during the vessel surveys. Camera and vessel counts at the ES survey area for all haul-out sites were combined because the sites are all within the same proximity and the maximum count by the vessel survey is based on the maximum count at the survey area. Counts at the CBBT were compared by haul-out site since they are spatially separated, some by several miles, and seals at the CBBT sites are not visible from one haul-out site to another.

4 Results

4.1 Effort and Counts

The total number of camera recording days (total days less camera failure days), total images captured, and the date the first and last seals were seen (seal occupancy season) are shown by season in **Table 4-1** for the ES survey area and **Table 4-2** for the CBBT survey area.

Table 4-1. Camera trap effort summary for the ES survey area during the occupancy season

Season	Camera Recording Days	Images Captured	First Seal Recorded	Last Seal Recorded
2019/2020[1]	169	59,679	4 Nov	20 Apr
2020/2021	208	75,120	30 Oct	25 May
2021/2022	193	69,125	15 Oct	28 Apr

ES=Eastern Shore. Cameras were removed early during the 2019/2020 season.

Table 4-2. Camera trap effort summary for the CBBT survey area during the occupancy season

Season	Camera Recording Days	Images Captured	First Seal Recorded	Last Seal Recorded
2019/2020	112	11,309	8 Jan[1]	28 Apr
2020/2021	187	22,053	30 Oct	22 May
2021/2022	153	19,278	20 Oct	1 May

CBBT=Chesapeake Bay Bridge Tunnel. For 2019/2020

[1]In 2019/2020 cameras were not installed at the start of the occupancy season

At the ES survey area, in each instance of camera failure, there was another camera that had the haul-out site in view, so the secondary camera was used for counts until the primary camera failure was corrected. The result was no camera failure days in any season for the ES survey area. At the CBBT survey area there were only 87 camera recording days in the 2019/2020 season because cameras were not installed until January. There were no camera failure days for that season at the CBBT. During the 2020/2021 season, the camera did not collect images at CBBT3 for 17 days in November 2020 and one day in December 2020 as the result of the camera tilting and the haul-out area not being visible from the images. During the 2021/2022 season at the CBBT survey area, there were no images collected at CBBT3 for 15 days in January 2022, 15 days in February 2022, 10 days in March 2022, one day in April 2022 and one day in May 2022 due to camera mechanical failure.

Since the haul-out sites are photographed every 15-minutes, a hauled-out seal would be counted up to four times per hour. Total count occurrences are not to be interpreted as total number of seals at a site, but are presented to provide relative haul-out use by site, and an index of haul-out activity.

Seal haul-out count occurrences at the ES survey area totaled 48,784 during the 2019/2020 season, 54,066 during the 2020/2021 season, and 60,963 during the 2021/2022 season. At the CBBT survey area there were 5,690 seal haul-out count occurrences during the 2019/2020 season, 10,555 during the 2020/2021 season, and 14,144 during the 2021/2022 season. To account for unequal effort (e.g., camera failure days), seal haul-out counts were averaged (number of seals hauled out divided by the number of images with seals hauled out) and the sightings summaries for all three seasons are shown in **Table 4-3** for the ES survey area and in **Table 4-4** for the CBBT survey area (seals present = either hauled out or in the water).

Table 4-3. Camera trap sightings summary for the ES survey area during the occupancy season

Season	Haul-out Average	Days Seals Hauled out	% of Days Hauled out	Days Seals Present	% of Days Present
2019/2020	9.78	135	75.8	149	83.7
2020/2021	7.65	164	76.9	189	88.2
2021/2022	10.21	143	67.7	173	81.9

ES=Eastern Shore, Seals present=seals hauled out or in the water.

Table 4-4. Camera trap sightings summary for the CBBT survey area during the occupancy season

Season	Haul-out Average	Days Seals Hauled out	% of Days Hauled out	Days Seals Present	% of Days Present
2019/2020	3.88	63	55.8	92	81.4
2020/2021	5.08	80	37.9	139	65.9
2021/2022	6.82	94	46.1	146	71.6

CBBT=Chesapeake Bay Bridge Tunnel. Seals present=seals hauled out or in the water.

Seal count averages (number of seals hauled out and in the water divided by the number of images with seals) by season and month for the ES survey area are shown in **Figure 4-1**. Seals were observed at the ES survey area during the 2019/2020 season from November to April, with peak values in February. During the 2020/2021 season, seals were observed from October to May, with peak values in February. During the 2021/2022 season, seals were observed from October to April, with peak values in February.

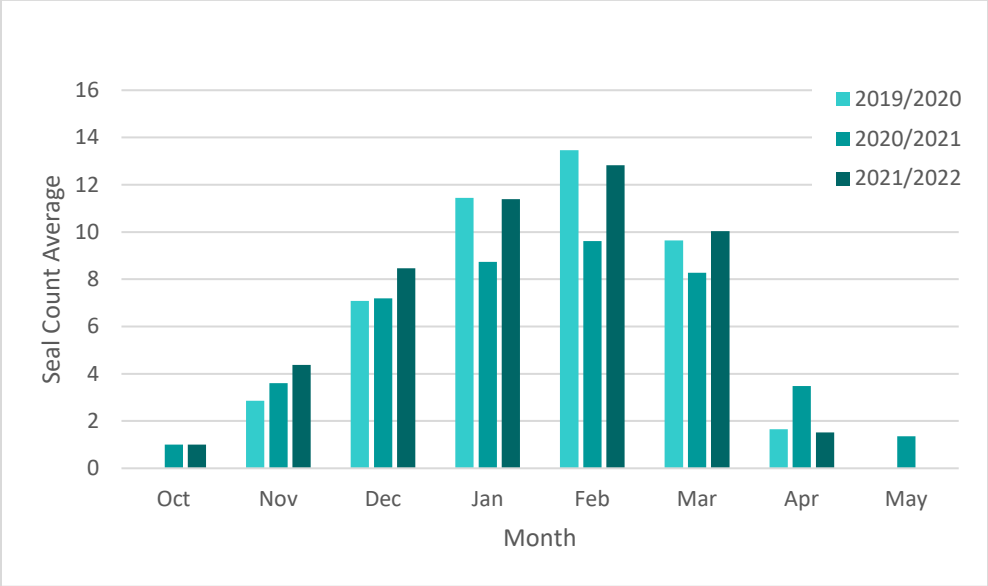

Figure 4-1. Average seals counted by month at the ES survey area

Seal count average by season and month for the CBBT survey area are shown in **Figure 4-2.** At the CBBT survey area, there are no data for October, November, or December in the 2019/2020 season as we did not get permission to install cameras until January 2020. Seals were observed at the CBBT survey area during the 2019/2020 season from January to April, with peak values in March. During the 2020/2021 season, seals were observed from October to May, with peak values in February. During the 2021/2022 season, seals were observed from October to May, with peak values in February.

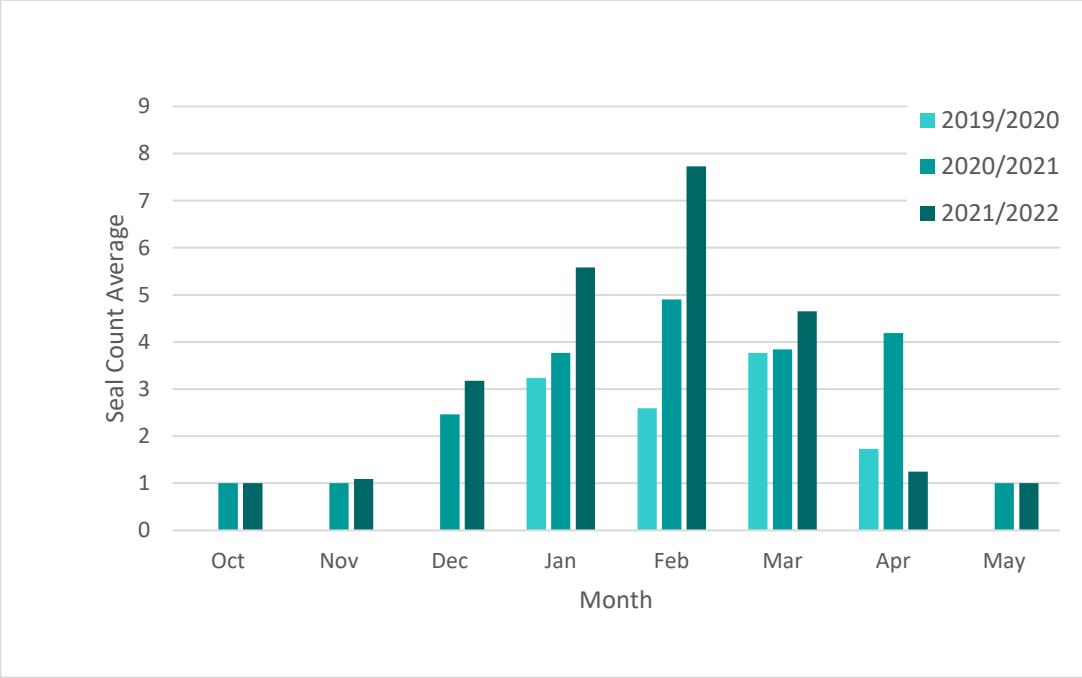

Figure 4-2. Average seals counted by month at the CBBT survey area

An ANOVA statistical test was completed to determine the statistical significance, or lack thereof, for the mean number of seals hauled out per month of the occupancy season for each season at each survey area (**Table 4-5**). At all survey areas, during all seasons, the mean counts between the months of occupancy were statistically significant.

Table 4-5. ANOVA test results comparing mean numbers of seals hauled-out per month of the occupancy season

Survey Area	ES		CBBT	
	F_{stat}	*p*-value	F_{stat}	*p*-value
2019/2020	184.7	< 0.001	103.3	< 0.001
2020/2021	242.2	< 0.001	160.8	< 0.001
2021/2022	335.5	< 0.001	318.1	< 0.001

ES=Eastern Shore, CBBT=Chesapeake Bay Bridge Tunnel

The maximum seal count (hauled out or in the water) by month and season are shown for each survey area in **Figure 4-3** for the ES survey area and in **Figure 4-4** for the CBBT survey area.

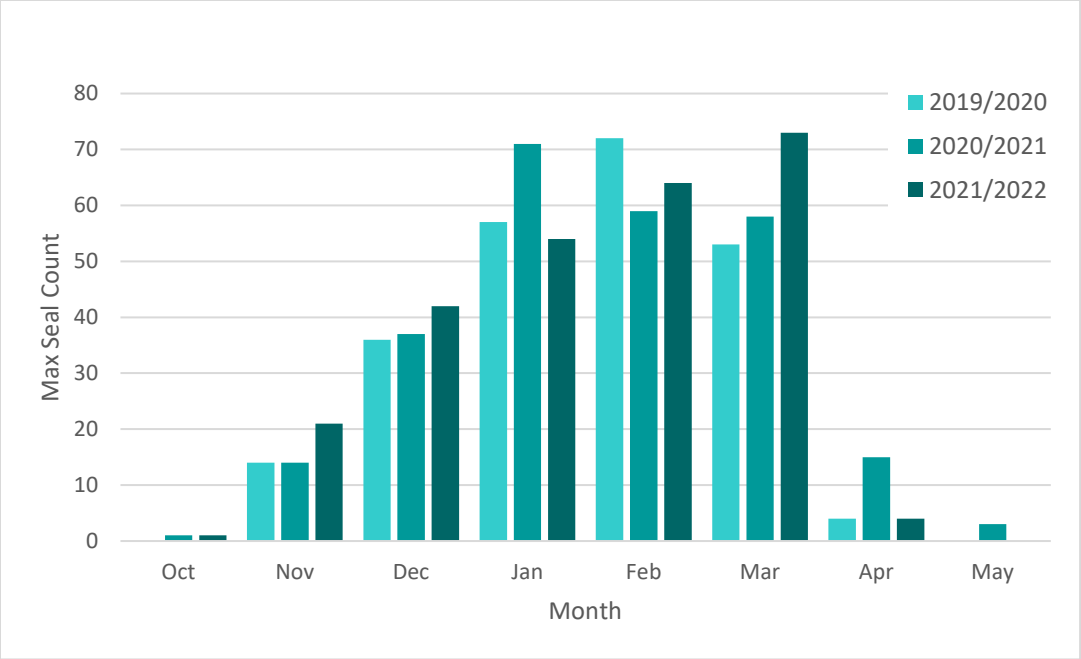

Figure 4-3. Maximum seal count by month at the ES survey area

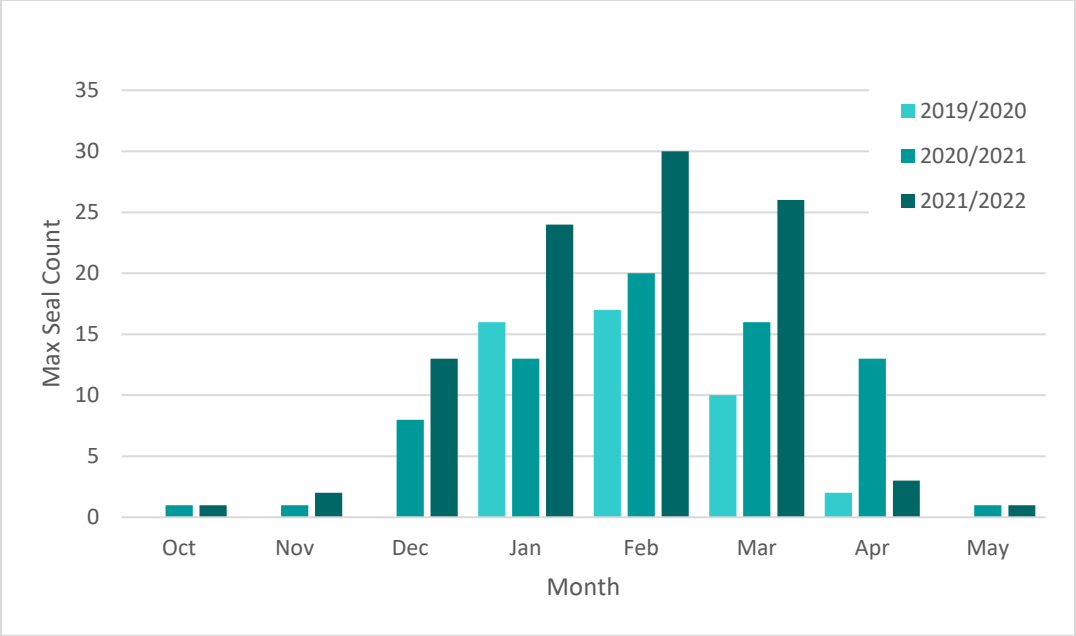

Figure 4-4. Maximum seal count by month at the CBBT survey area

The maximum number of seals hauled out by haul-out site for each survey area and season are shown in **Table 4-6**. This was determined for each haul-out site by all the seals in a single image or all seals hauled out in the same 15-min period on different haul-out sites.

Table 4-6. Maximum seals hauled out by haul-out site for each survey area and season

Season	ES								CBBT	
	A	B	C1	C3	E1	E2	E3	F	CBBT3	CBBT4
2019/2020	0	0	19	27	72	37	28	10	17	11
2020/2021	13	35	15	22	46	71	9	8	20	18
2021/2022	73	1	26	36	64	54	17	7	20	29

ES=Eastern Shore, CBBT=Chesapeake Bay Bridge Tunnel

At the ES survey area, during the 2019/2020 season, the highest individual haul-out count (maximum) was 72 seals on 16 February 2020 on haul-out site E1. Due to cameras during the 2019/2020 season not having a full view of the haul-out site E2, the total and highest counts may not be representative of actual seal presence in that area during that season. During the 2020/2021 season, the highest individual haul-out count for the ES survey area was 71 seals from a single image on 27 January 2021 on haul-out site E2. During the 2021/2022 season, the highest individual haul-out count for the ES survey area was 73 seals from a single image on 3 March 2022 on haul-out site A. Haul-out site D was not used by seals during any of the three seasons (D. Jones, pers. comm., May 23, 2023). Haul-out site F was a new haul-out site as of 2019 and at this point still has a fairly low level of usage (three days during the 2019/2020 season, seven days during the 2020/2021 season, and five days during the 2021/2022 season).

At the CBBT survey area, during the 2019/2020 season, the highest individual seal count at the CBBT survey area was 17 seals on 22 January 2020 recorded at CBBT3. During the 2020/2021 season, the highest individual seal count at the CBBT survey area was 20 seals on 6 February 2021 recorded at CBBT3. During the 2021/2022 season, the highest individual seal count at the CBBT survey area was 29 seals on 21 February 2022 recorded at CBBT4. The total number of days when seals were recorded at each haul-out site is shown in (**Table 4-7**). At the ES survey area, seals hauled out most frequently on site E1 during the 2019/2020 season, and on E2 during the 2020/2021 and 2021/2022 seasons. During all three seasons at the CBBT survey area, seals were recorded hauled out most frequently at CBBT4 (**Table 4-7**).

Table 4-7. Number of days when seals were recorded at each haul-out site

Season	ES								CBBT	
	A	B	C1	C3	E1	E2	E3	F	CBBT3	CBBT4
2019/2020	0	0	4	14	104	88	39	3	28	32
2020/2021	27	24	4	51	94	136	6	7	39	68
2021/2022	31	1	15	27	92	104	6	5	33	84

ES=Eastern Shore, CBBT=Chesapeake Bay Bridge Tunnel

Total seal haul-out counts for each haul-out site at each survey area and season are shown in **Figure 4-5** for the ES survey area and in **Figure 4-6** for the CBBT survey area. Total count occurrences are not to be interpreted as total number of seals at a site, but are presented to provide relative haul-out use by site, and an index of haul-out activity.

Figure 4-5. Total seal haul-out counts by haul-out site at the ES survey area

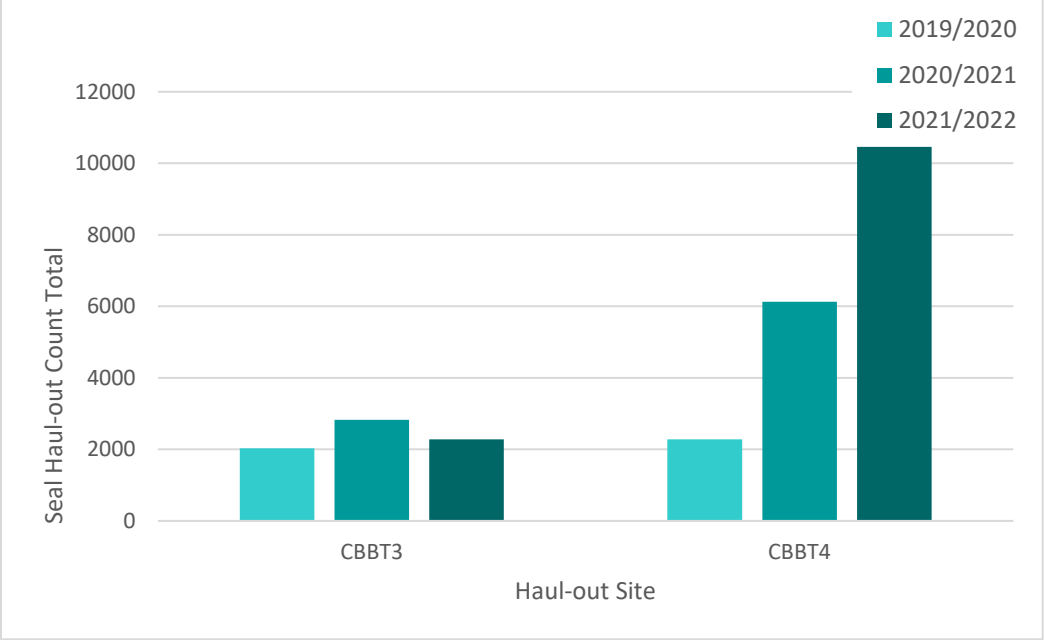

Figure 4-6. Total seal haul-out counts by haul-out site at the CBBT survey area

Seal count average (number of seals hauled out by number of images with hauled out seals) by haul-out site and season are shown in **Figure 4-7** for the ES survey area and in **Figure 4-8** for the CBBT survey area. Cameras at the ES survey area were positioned to cover the haul-out site area, but had to be adjusted in the 2019/2020 season as we did not have a full view of haul-out sites A, B, and E2. At the CBBT survey area, the entirety of the haul-out site was visible in the cameras field of view.

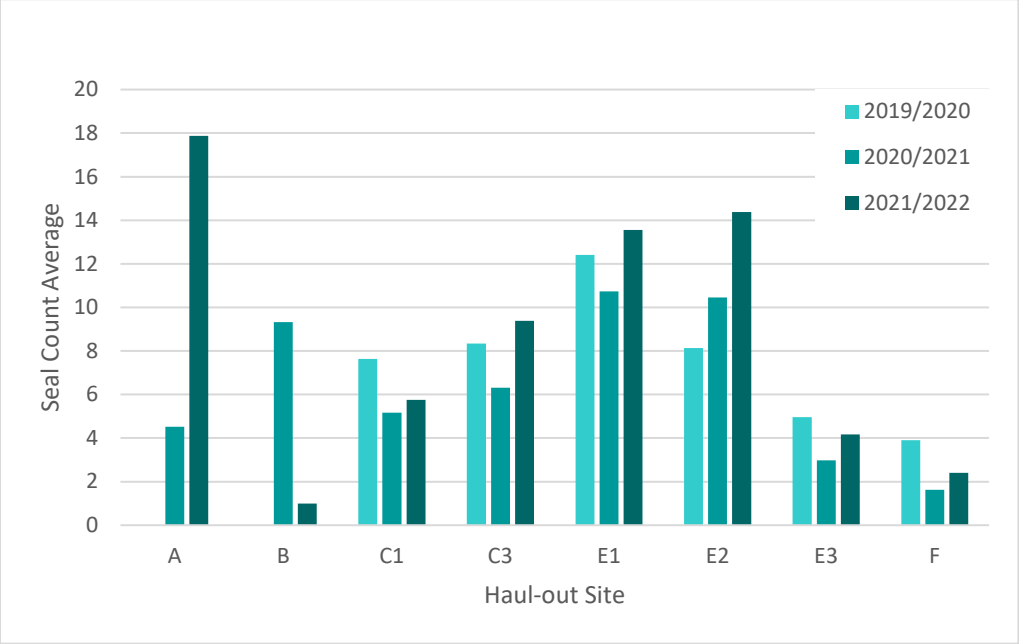

Figure 4-7. Average seal haul-out counts by haul-out site at the ES survey area

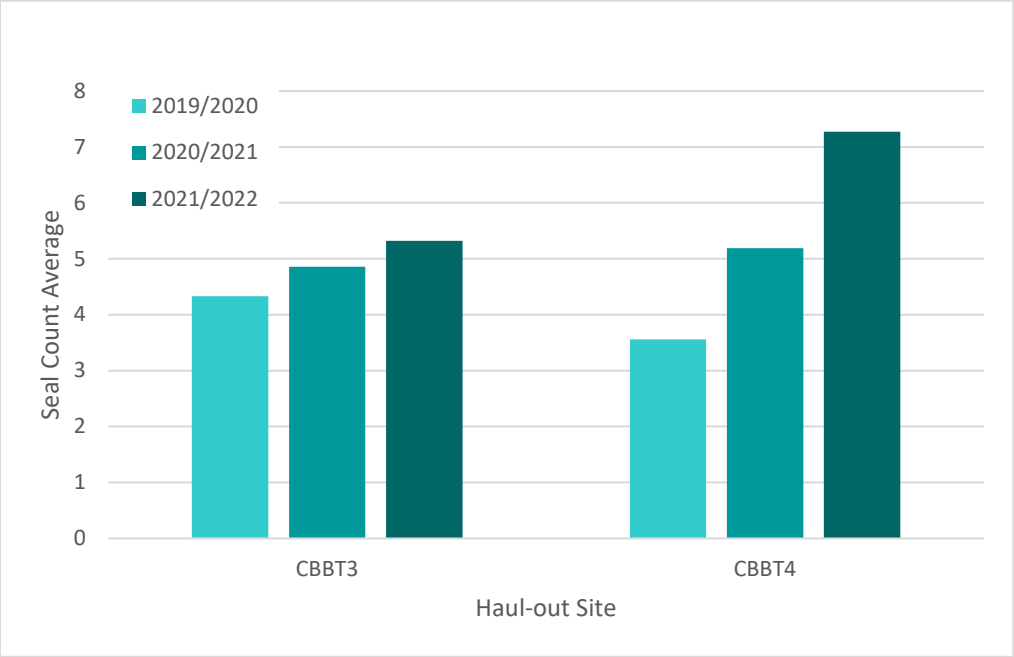

Figure 4-8. Average seal haul-out counts by haul-out site at the CBBT survey area

An ANOVA statistical test was also completed to determine the statistical significance, or lack thereof, for the differences in individual haul-out site use, by comparing the mean number of seals hauled out at each site during the occupancy season, by season and survey area (**Table 4-8**). In all seasons, the mean counts between the haul-out sites at each survey area were statistically significant. It is important to note that there were missing images from the CBBT3 due to camera failure during the 2020/2021 and 2021/2022 seasons as well as the delayed installation of cameras at the CBBT survey area during the 2019/2020 season which may have influenced these results.

Table 4-8. ANOVA test results comparing mean numbers of seals hauled-out at each haul-out site during the occupancy season

Survey Area	ES		CBBT	
	F_{stat}	*p*-value	F_{stat}	*p*-value
2019/2020	474.3	< 0.001	5.1	.0243
2020/2021	614.9	< 0.001	188.7	< 0.001
2021/2022	335.5	< 0.001	300.5	< 0.001

ES=Eastern Shore, CBBT=Chesapeake Bay Bridge Tunnel

Camera resolution and distance to most of the haul-out site did not allow for 100% certainty in identifying the species being counted in most cases. While the vast majority of the seals appeared to be harbor seals, gray seals (**Figure 4-9**) were positively identified on two survey days during the 2019/2020 season, one day during the 2020/2021 season, and on eleven days during the 2021/2022 season.

Seals with flipper and satellite tags were also known to be present when, and where images were recorded based on data from the seal tagging effort in the ES Study Area (Ampela et al. 2021), however, due to image quality, the tags were not easily detectable from the images. There were several instances (11 images during the 2019/2020 season, none during the 2020/2021 season and 53 during the 2021/2022 season) where a seal was positively determined to have either a satellite tag, flipper tag, or both. Seals with flipper or satellite tags were only detected at the ES survey area. Though tagging data indicated visits to the CBBT survey area, the distance from cameras to the haul-out, make it nearly impossible to detect the presence of a flipper or satellite tag.

Figure 4-9. Gray seal (front). Photo taken by Cuddeback remote camera under NMFS GA Permit #19826

4.2 Comparison of Haul-out Counts to Time of Day

At the ES survey area, the CuddeLink cameras operated on an automatic daylight setting. During the survey periods for all three seasons, the time of sunrise ranged from 05:41 to 07:19, and sunset ranged from 16:40 to 20:20. While the data shows there were very few seals hauled out during the early and late hours, as it got darker, the images became harder to get an accurate count or the camera was not recording due to the automatic daylight setting.

At the ES survey area during the 2019/2020 season, 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 infrared 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 15 seals, and seals were visible in 199 of 4,778 night images, on 17 different nights from January to April 2020.

A comparison of the total seal haul-out counts by time of day for the ES survey area are shown in **Figure 4-10,** with the dotted line representing the average sunset/sunrise time over the entire season. 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.

A comparison of the total seal haul-out counts by time of day for the CBBT survey area are shown in **Figure 4-11,** with the dotted line representing the average sunset/sunrise time over the entire season.

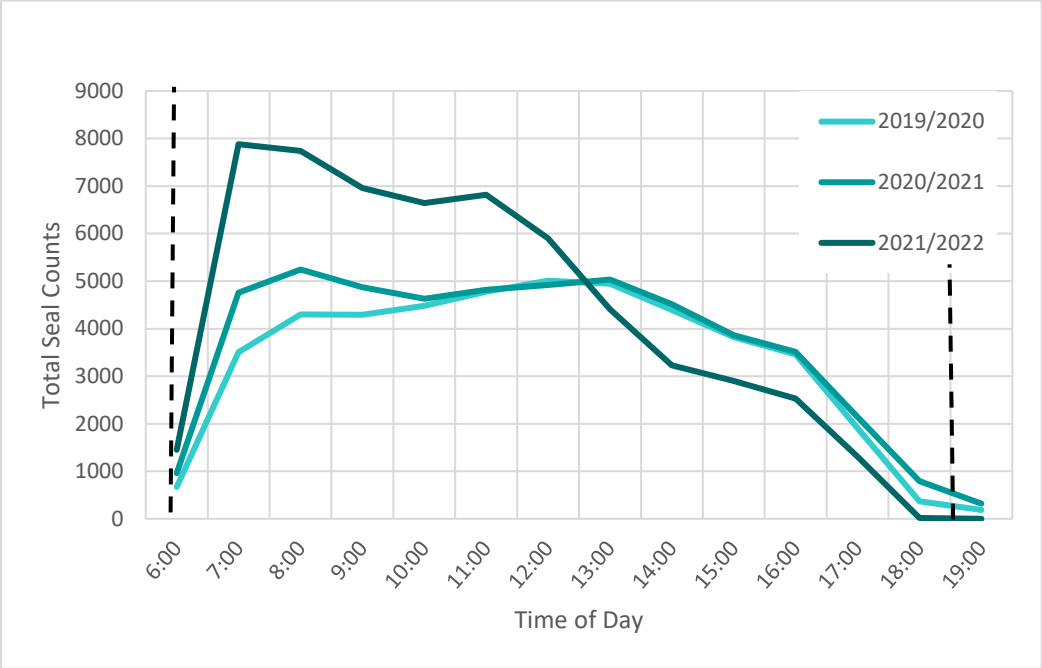

Figure 4-10. Total seal haul-out counts by time of day at the ES survey area

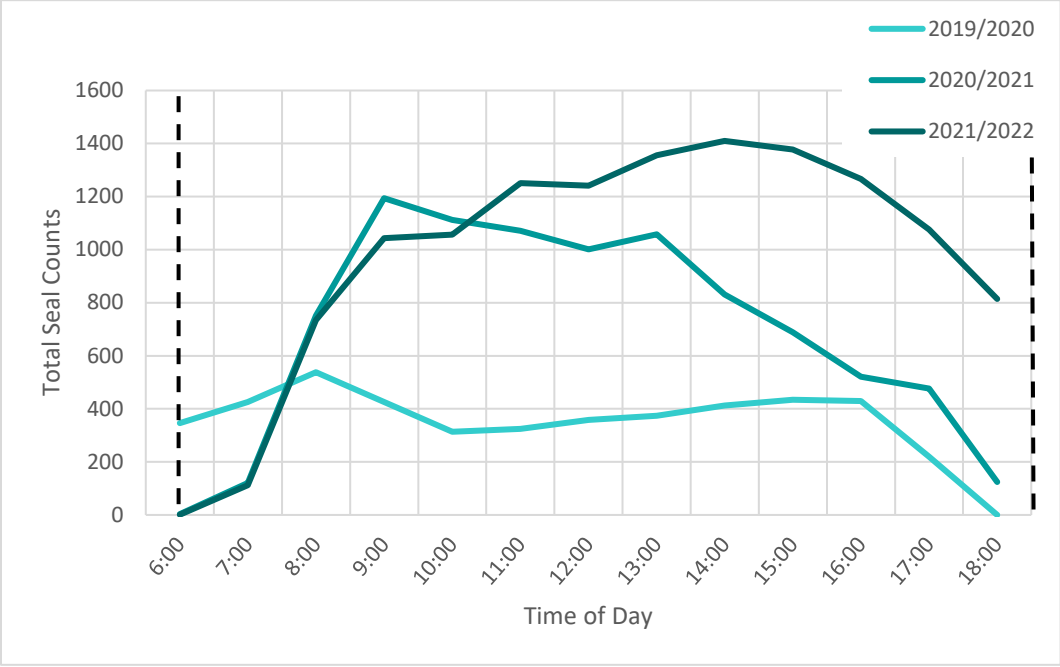

Figure 4-11. Total seal haul-out counts by time of day at the CBBT survey area

4.3 Comparison of Haul-out Counts to Environmental Data

4.3.1 Comparison of Haul-out Counts to Water Levels

Water levels recorded during 2019/2020, 2020/2021, and 2021/2022 seasons are shown for the ES survey area in **Figure 4-12** and for the CBBT survey area in **Figure 4-13**.

At the ES survey area for the 2019/2020 season, water levels ranged from -1.46 ft to 5.63 ft (-0.45 to 1.72 m), and the water level range for when seals were hauled out was slightly narrower with a range of -0.9 ft to 4.19 ft (0.28 to 1.28 m), The average water level for all counts was 1.84 ft (0.56 m). The range for the 2020/2021 season was -1.06 ft (-0.324 m) to 4.78 ft (1.46 m), and seals were hauled out when water levels were between -1.06 ft and 4.74 ft (-0.32 m and 1.45 m). The average water level for all counts was 1.77 ft (0.54 m). The range for the 2021/2022 season was -1.11 ft (-0.36 m) to 6.46 ft (1.97 m), and seals were hauled out when water levels were between -0.96 ft and 4.46 ft (-0.29 m and 1.36 m). The average water level for all counts was 1.67 ft (0.51 m) (**Figure 4-12**).

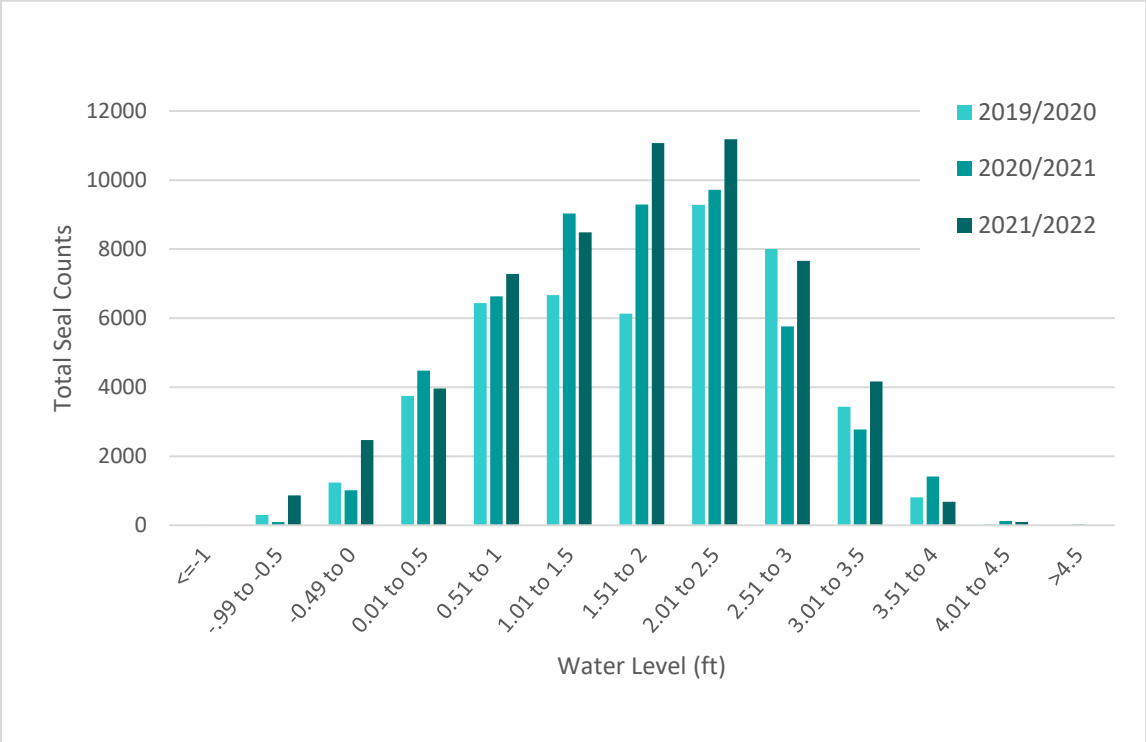

Figure 4-12. Total seal haul-out counts by water level (ft) for the ES survey area

At the CBBT survey area for the 2019/2020 season, water levels 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). The range for the 2020/2021 season was -1.06 ft (-0.32 m) to 4.78 ft (1.46 m), and seals were hauled out when water levels were between -1.06 ft and 3.66 ft (-0.32 m and 1.11 m). The average water level for all counts was 1.81 ft (0.55 m). The range for the 2021/2022 season was -1.11 ft (-0.36 m) to 6.46 ft (1.97 m), and seals were hauled out when water levels were between -1.11 ft and 3.51 ft (-0.36 m and 1.07 m). The average water level for all counts was 1.87 ft (0.57 m) (**Figure 4-13**).

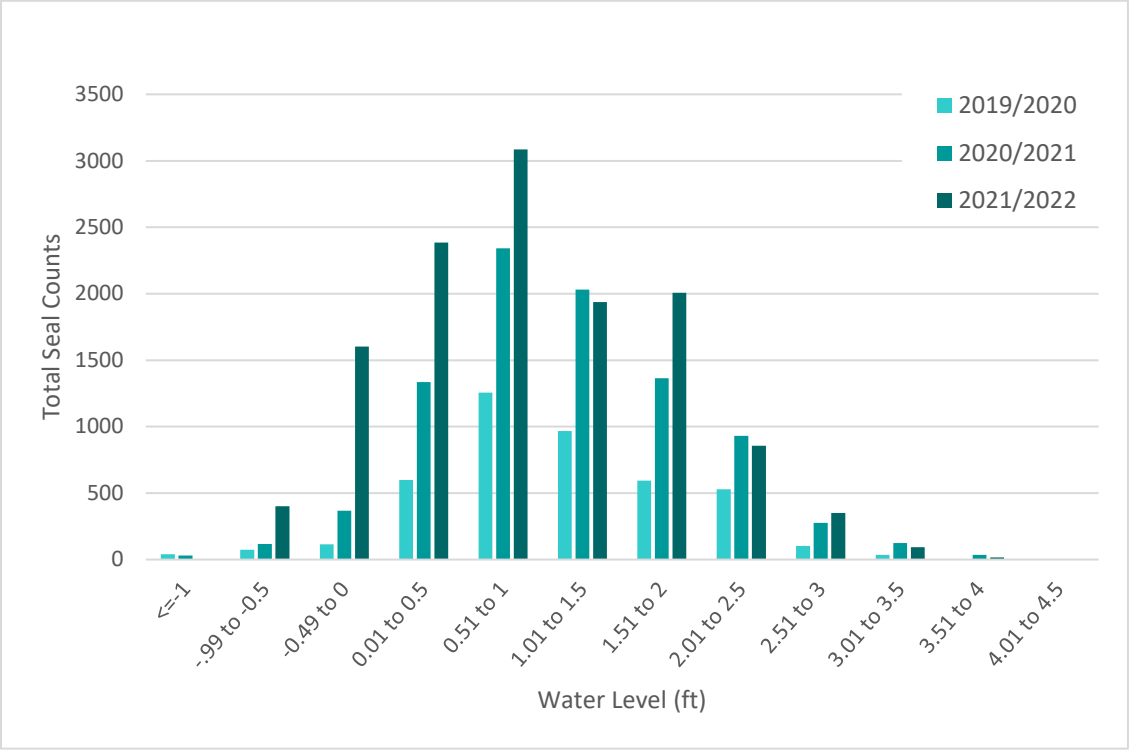

Figure 4-13. Total seal haul-out counts by water level (ft) for the CBBT survey area

4.3.2 Comparison of Haul-out Counts to Wind Speed

Wind speed recordings for the ES survey area are shown in **Figure 4-14**. During the 2019/2020 season, wind speed ranged from 0 to 35.57 knots (kts) [0 to 18.3 meters/second (m/s)]. The range of wind speeds when seals were recorded on the haul-out sites was 0 to 30.71 kts (0 to 15.8 m/s), with an average speed of 10 kts (5.1 m/s). Wind speed recordings for the 2020/2021 season ranged from 0 to 38.49 knots (kts) (0 to 14.8 m/s.) The range of wind speeds when seals were recorded on the haul-out sites was 0 to 31.49 kts (0 to 16.2 m/s), with an average speed of 12.97 kts (6.59 m/s). Wind speed recordings during the 2021/2022 season ranged from 0.19 to 39.27 kts (0.1 to 20.2 m/s). The range of wind speeds when seals were recorded on the haul-out sites was 0.19 to 27.21 kts (0.1 to 14 m/s), with an average speed of 6.35 kts (12.33 m/s).

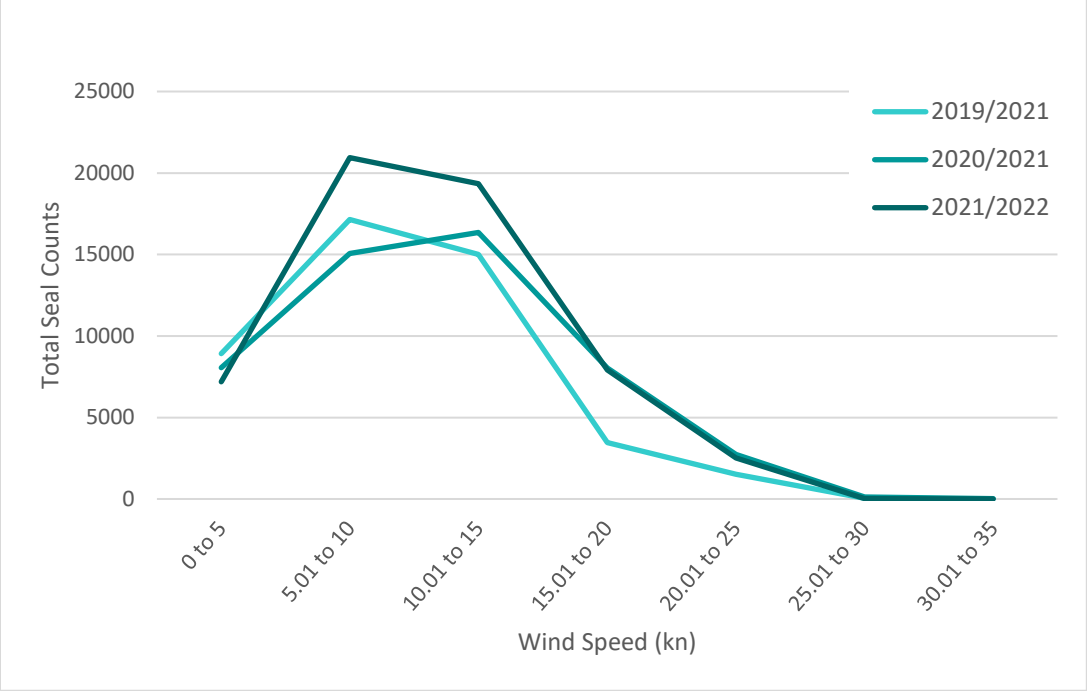

Figure 4-14. Total seal haul-out counts by wind speed in knots (kts) at the ES survey area

Wind speed recordings for the CBBT survey area are in **Figure 4-15.** Wind speed recordings during the 2019/2020 season ranged from 0 to 31.49 kts (0 to 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 to 11 m/s), with an average of 8.17 kts (4.2 m/s). Wind speed during the 2020/2021 season ranged from 0 to 34.79 kts (0 to 17.9 m/s). The range of wind speeds when seals were recorded on the haul-out sites was 0 to 29.16 kts (0 to 12.3 m/s), with an average of 8.55 kts (4.4 m/s). Wind speed recordings for the 2021/2022 season ranged from 0 to 39.27 kts (0 to 20.2 m/s). The range of wind speeds when seals were recorded on the haul-out sites was 0.19 to 27.21 kts (0.1 to 14 m/s), with an average of 9.6 kts (4.94 m/s).

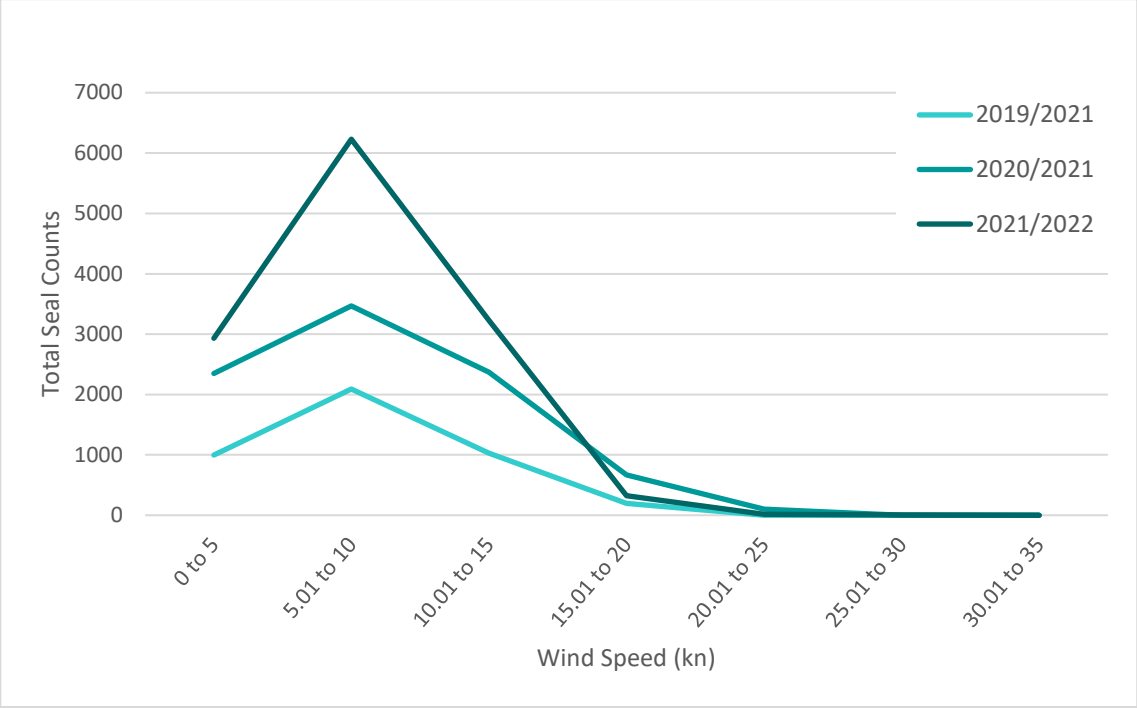

Figure 4-15. Total seal haul-out counts by wind speed in knots (kts) at the CBBT survey area

4.3.3 Comparison of Haul-out Counts to Wind Direction

Wind direction recordings for the ES survey area are shown in **Figure 4-16**. Wind direction recordings during the 2019/2020 season ranged from 0 to 360 deg. 0 and 360 degrees (deg) are north, 90 degrees is east, 180 degrees is south, and 270 degrees is west. The range of wind direction when seals were recorded on the haul-out sites was 2 to 359 deg, with an average of 195.4 deg. Wind direction during the 2020/2021 season ranged from 0 to 360 deg. The range of wind direction when seals were recorded on the haul-out sites was 1 to 360 deg, with an average of 194.72 deg. Wind direction recordings for the 2021/2022 season ranged from 0 to 360 deg. The range of wind direction when seals were recorded on the haul-out sites was 0 to 359 deg with an average of 186.6 deg.

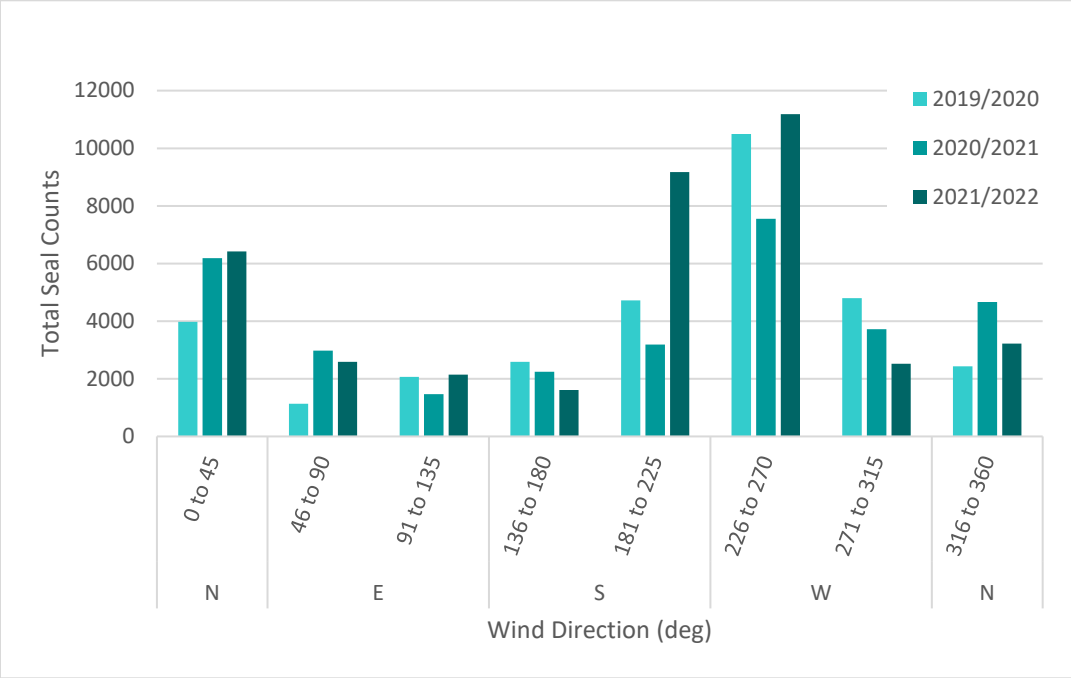

Figure 4-16. Total seal haul-out counts by wind direction in degrees (deg) at the ES survey area

Wind direction recordings for the CBBT survey area are in **Figure 4-17**. Wind direction recordings during the 2019/2020 season ranged from 0 to 360 deg. The range of wind direction when seals were recorded on the haul-out sites was 2 to 359 deg, with an average of 188.9 deg. Wind direction during the 2020/2021 season ranged from 0 to 360 deg. The range of wind direction when seals were recorded on the haul-out sites was 3 to 358 deg, with an average of 186.8 deg. Wind direction recordings for the 2021/2022 season ranged from 0 to 360 deg. The range of wind direction when seals were recorded on the haul-out sites was 4 to 360 deg with an average of 173 deg.

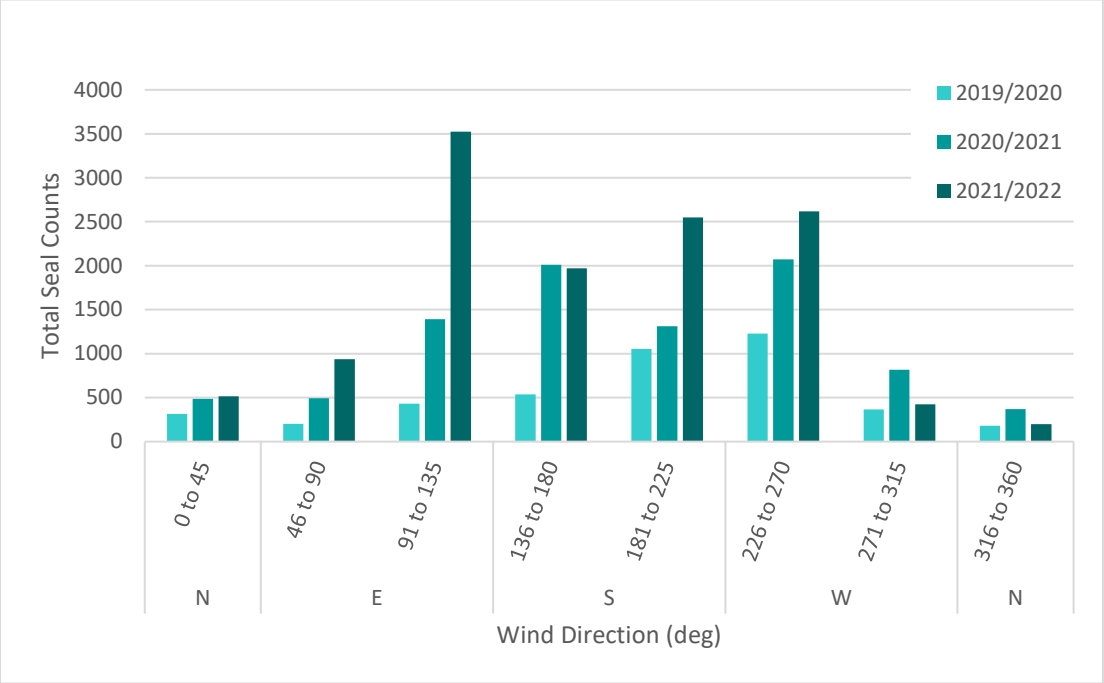

Figure 4-17. Total seal haul-out counts by wind direction in degrees (deg) at the CBBT survey area

4.3.4 Comparison of Haul-out Counts to Air Temperature

Air temperature recorded for the ES survey area is shown in **Figure 4-18**. During the 2019/2020 season, air temperature ranged from 28.2 to 75.7 F° (-2.1 to 24.3 C°). The air temperatures recorded when seals were hauled out ranged from 29.3 to 70.5 F° (-1.5 to 21.4 C°) with the average temperature of 49.0 F° (9.5 C°). During the 2020/2021 season, air temperature ranged from 27.1 to 88.3 F° (-2.7 to 31.3 C°). The air temperatures recorded when seals were hauled out ranged from 27.5 to 88.3 F° (-2.5 to 31.3 C°) with the average temperature of 52.7 F° (11.6 C°). During the 2021/2022 season, air temperature ranged from 25.0 to 81.9 F° (-3.9 to 27.7 C°). The air temperatures recorded when seals were hauled out ranged from 26.6 to 81.9F° (-3.0 to 27.7 C°) with the average temperature of 49.71 F° (9.84 C°).

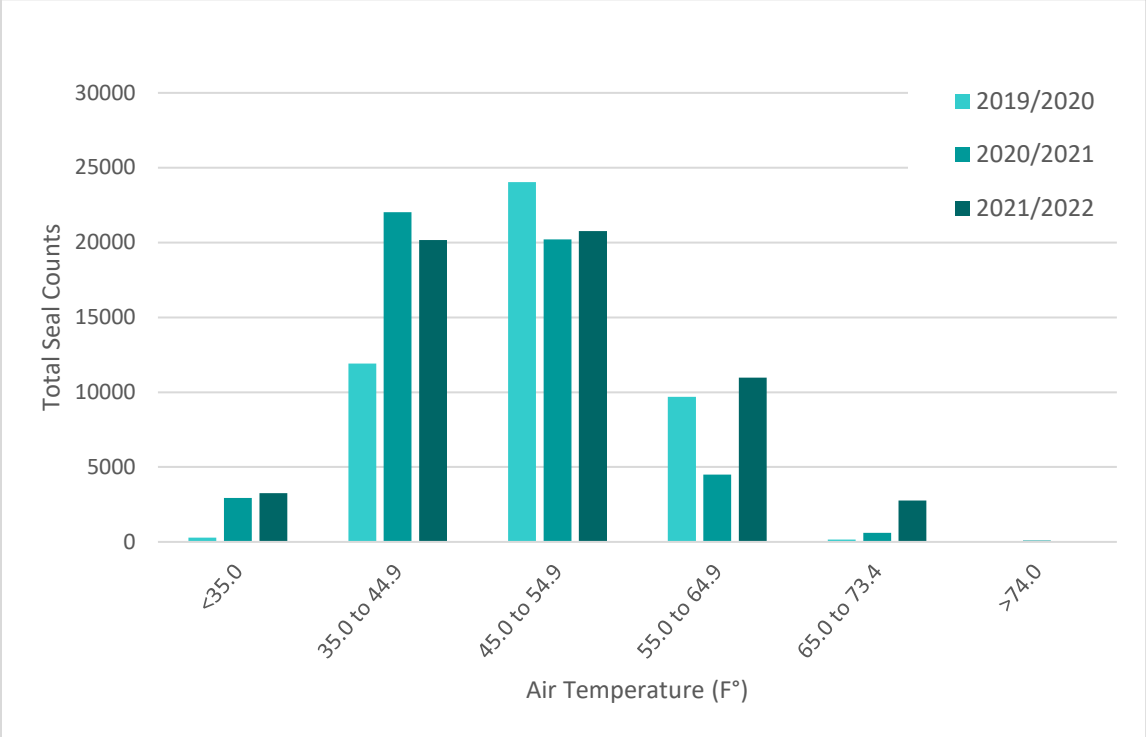

Figure 4-18. Total seal haul-out counts by air temperature (F°) for the ES survey area

Air temperature recorded for the CBBT survey area are shown in **Figure 4-19.** During the 2019/2020 season, air temperature ranged from 28.2 to 73.4 F° (-2.1 to 23.0 C°). The air temperatures recorded when seals were hauled out ranged from 29.8 to 73.4 F° (-1.2 to 23.0 C°) with the average temperature of 50.8 F° (10.4 C°). During the 2020/2021 season, air temperature ranged from 27.1 to 88.3 F° (-2.7 to 31.3 C°). The air temperatures recorded when seals were hauled out ranged from 27.9 to 84.9 F° (-2.3 to 29.4 C°) with the average temperature of 48.9 F° (9.4 C°). During the 2021/2022 season, air temperature ranged from 24.4 to 81.7 F° (-4.2 to 27.6 C°). The air temperatures recorded when seals were hauled out ranged from 29.7 to 76.5 F° (-1.3 to 24.7 C°) with the average temperature of 49.4 F° (9.65 C°).

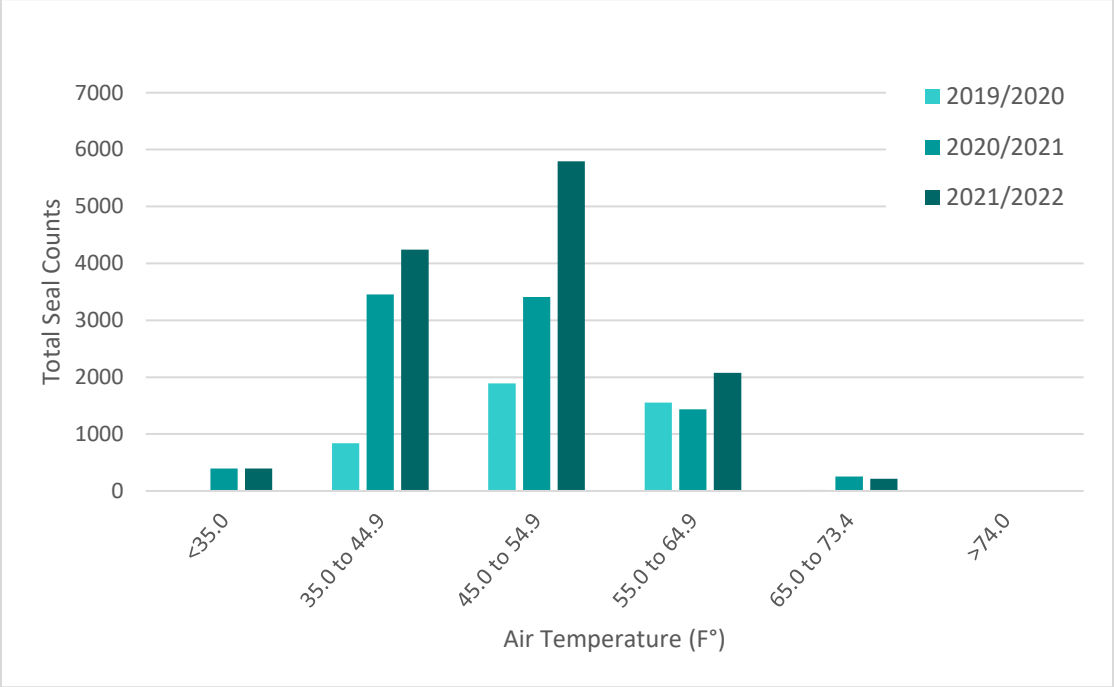

Figure 4-19. Total seal haul-out counts by air temperature (F°) for the CBBT survey area

4.4 Comparison of Camera to Vessel Survey Counts

Camera survey counts were compared to vessel survey counts to determine if 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 4-9** for the ES survey area and **Table 4-10** for the CBBT survey area for the 2019/2020 season. The 2020/2021 season comparison data is represented in **Table 4-11** and **Table 4-12,** and 2021/2022 season data is represented in **Table 4-13** and **Table 4-14**. 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 difference was used to account for the potential for the presence of the survey vessel to flush hauled out seals. 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.

Overall for the 2019/2020 season, 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.

Over 12 survey days at the ES survey area during the 2019/2020 season, the camera counts were lower (as indicated by a negative average value) than vessel survey counts for in water seals and higher for hauled out seals (as indicated by a positive average value) (**Table 4-9**). 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 (**Table 4-10**). Higher counts from the vessel surveys for in-water seals 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.

Table 4-9. Comparison of camera to vessel counts at the ES survey area for the 2019/2020 season

Date	Seal HO Count Camera	Seal HO Count Vessel	Seal HO Count Difference	Seal IW Count Camera	Seal IW Count Vessel	Seal IW Count Difference
11/21/2019	0	0	0	1	3	-2
12/4/2019	29	22	7	0	12	-12
12/18/2019	0	0	0	0	1	-1
1/7/2020	0	0	0	0	9	-9
1/24/2020	12	19	-7	2	15	-13
2/4/2020	28	34	-6	0	5	-5
2/18/2020	8	12	-2	2	2	0
3/12/2020	54	27	27	5	3	2
3/26/2020	0	0	0	0	2	-2
4/8/2020	0	0	0	0	0	0
4/23/2020	0	0	0	0	0	0
Average			**1.72**			**-3.8**

HO=haul-out, IW=in water

Table 4-10. Comparison of camera to vessel counts at CBBT survey area for the 2019/2020 season

Date	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	0	0	0	3	9	-6
1/30/2020	0	0	0	4	11	-7
3/11/2020	2	2	0	1	5	-4
3/26/2020	0	0	0	0	1	-1
4/7/2020	0	0	0	0	0	0
4/28/2020	0	0	0	0	0	0
Average			**0**			**-3**

HO=haul-out, IW=in water

For the 2020/2021 season, only 9 of 15 vessel survey days at the ES had seals present and only 7 of 13 vessel survey days at the CBBT had seals present during the survey time window.

Over 15 survey days at the ES survey area during the 2020/2021 season, the camera counts were lower than vessel survey counts for in water seals and slightly higher for hauled out seals (**Table 4-11**)**.** At the CBBT survey area, over 13 survey days, camera counts were lower than vessel counts for in water seals and higher for hauled out seals (**Table 4-12**). There were some dates at CBBT3 where vessel surveys were conducted but no images were taken at the survey site due to the camera being tilted and the haul-out area not being visible, so those data points were not included in the comparison.

Table 4-11. Comparison of camera to vessel counts at the ES survey area for the 2020/2021 season

Date	Seal HO Count Camera	Seal HO Count Vessel	Seal HO Count Difference	Seal IW Count Camera	Seal IW Count Vessel	Seal IW Count Difference
11/4/2020	0	0	0	0	0	0
11/20/2020	0	0	0	0	3	-2
12/4/2020	16	16	0	0	3	-3
12/21/2020	23	31	-8	0	0	0
1/5/2021	19	7	12	1	7	-6
1/22/2021	20	27	-7	1	11	-10
2/4/2021	54	44	10	0	0	0
2/17/2021	0	0	0	0	8	-8
3/2/2021	23	31	-8	1	7	-6
3/17/2021	0	0	0	1	6	-5
3/29/2021	0	0	0	0	4	-4
4/7/2021	3	0	3	0	1	-1
4/28/2021	1	1	0	0	0	0
5/4/2021	0	0	0	0	0	0
5/14/2021	0	0	0	0	0	0
Average			**0.13**			**-3**

HO=haul-out, IW=in water

Table 4-12. Comparison of camera to vessel counts at CBBT survey area for the 2020/2021 season

Date	Seal HO Count Camera	Seal HO Count Vessel	Seal HO Count Difference	Seal IW Count Camera	Seal IW Count Vessel	Seal IW Count Difference
11/4/2020	0	0	0	0	0	0
11/20/2020	0	0	0	0	0	0
12/3/2020	0	0	0	0	1	-1
12/30/2020	0	0	0	0	10	-10
1/11/2021	7	8	-1	1	17	-16
1/25/2021	22	17	5	0	21	-21
2/9/2021	0	0	0	0	14	-14
2/24/2021	20	22	-2	1	16	-15
3/9/2021	4	2	2	0	9	-9
3/25/2021	4	7	-3	0	4	-4
4/6/2021	0	0	0	0	4	-4
4/27/2021	0	0	0	0	1	-1
5/14/2021	0	0	0	0	0	0
Average			**0.08**			**-7.3**

HO=haul-out, IW=in water

For the 2021/2022 season, only 6 of 13 vessel survey days at the ES had seals present and only 5 of 12 vessel survey days at the CBBT had seals present during the survey time window.

Over 13 survey days at the ES survey area during the 2020/2021 season, the camera counts were lower for in water seals and higher for hauled out seals (**Table 4-13).** At the CBBT survey area, over 12 survey days, counts were slightly higher for hauled out seals and lower than vessel counts for in water seals (**Table 4-14**). There were some dates at CBBT 3 where vessel surveys were conducted but no images were taken at the survey site due to camera failure, so those dates were not included in the comparison.

Table 4-13. Comparison of camera to vessel counts at the ES survey area for the 2021/2022 season

Date	Seal HO Count Camera	Seal HO Count Vessel	Seal HO Count Difference	Seal IW Count Camera	Seal IW Count Vessel	Seal IW Count Difference
11/2/2021	0	0	0	0	0	0
11/17/2021	0	0	0	0	0	0
12/1/2021	0	1	-1	1	4	-3
12/16/2021	31	19	12	3	4	-1
1/6/2022	0	0	0	0	9	-9
1/19/2022	42	43	-1	0	2	-2
2/3/2022	22	21	1	1	13	-12
2/23/2022	0	0	0	0	9	-9
3/11/2022	0	0	0	0	4	-4
3/22/2022	3	4	-1	0	5	-5
4/5/2022	3	0	3	0	1	-1
4/20/2022	0	0	0	0	0	0
5/6/2022	0	0	0	0	0	0
Average			**1**			**-3.54**

HO=haul-out, IW=in water

Table 4-14. Comparison of camera to vessel counts at CBBT survey area for the 2021/2022 season

Date	Seal HO Count Camera	Seal HO Count Vessel	Seal HO Count Difference	Seal IW Count Camera	Seal IW Count Vessel	Seal IW Count Difference
11/2/2021	0	0	0	0	0	0
11/17/2021	0	0	0	0	1	-1
12/1/2021	1	1	0	0	1	-1
12/28/2021	0	0	0	0	9	-9
1/13/2022	15	11	4	0	13	-13
1/24/2022	8	0	8	0	4	-4
2/3/2022	4	6	-2	0	5	-5
3/1/2022	2	11	-9	1	15	-14
3/14/2022	3	0	3	0	4	-4
3/30/2022	0	0	0	0	4	-4
4/13/2022	0	0	0	0	1	-1
4/25/2022	0	0	0	0	0	0
Average			**0.33**			**-4.67**

HO=haul-out, IW=in water

The differences in the percentage of days that seals were recorded between the vessel and camera surveys are shown in **Table 4-15** for the ES survey and in **Table 4-16** for the CBBT survey area. The days seals were hauled out at the CBBT survey area during the 2020/2021 season was the only instance where camera surveys recorded a lower percentage of days with seals hauled out than vessel surveys.

Table 4-15. Comparison of percentages seals present and seals hauled out between vessel and camera surveys at the ES survey area

	Camera Surveys		Vessel Surveys	
Season	**% Days Seals Hauled out**	**% Days Seals Present**	**% Days Seals Hauled out**	**% Days Seals Present**
2019/2020	75.8	83.7	45.5	81.8
2020/2021	76.9	88.2	46.6	80.0
2021/2022	67.7	81.9	38.5	69.2

ES=Eastern Shore, Seals present=seals hauled out or in the water

Table 4-16. Comparison of percentages seals present and seals hauled out between vessel and camera surveys at the CBBT survey area

	Camera Surveys		Vessel Surveys	
Season	**% Days Seals Hauled out**	**% Days Seals Present**	**% Days Seals Hauled out**	**% Days Seals Present**
2019/2020	55.8	81.4	45.5	81.8
2020/2021	37.9	65.9	46.6	80.0
2021/2022	46.1	71.6	38.5	69.2

CBBT=Chesapeake Bay Bridge Tunnel, Seals present=seals hauled out or in the water

4.5 Vessel Presence

As discussed in **Section 3.1 Effort and Image Counts**, the same vessel could have been counted multiple times per hour; up to four times per hour at the CBBT survey area, and even more at the ES survey area, where there are multiple cameras in the same survey area. Data presented on vessel presence is not intended to provide a census of vessels in the area, rather relative vessel occurrence in each of the survey areas, and as a comparison between survey areas. Examples of images with multiple vessels for both the ES and CBBT locations are shown in **Figure 4-20.**

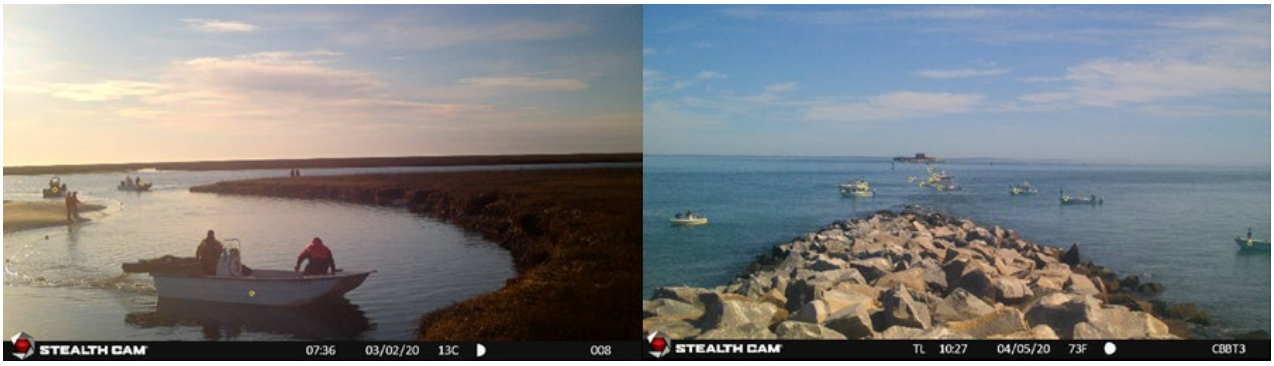

Figure 4-20. Examples of vessels recorded at the ES survey area (left) and CBBT survey area (right)

Total vessel counts by month and season for the ES survey area are shown in **Figure 4-21** and for the CBBT survey area in **Figure 4-22**. During the 2019/2020 season, vessels were captured in 0.7% 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 survey area. Vessels were photographed on 54 out of 113 of the survey days at the CBBT survey area. 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). The remainder of the vessels were recreational or commercial waterman. At the ES, the highest vessel presence for a single day was during seal tagging efforts on 2 March 2020 with vessels captured in 110 images (**Figure 4-21**). At CBBT, the highest vessel presence in a single day was on 5 April 2020 with vessels captured in 74 images (**Figure 4-22**), which were all recreational fishing vessels.

During the 2020/2021 season, vessels were captured in 0.35% of all images taken at the ES survey area (267 images) and 10.93% of all images taken at the CBBT survey area (2,424 images). Vessels were photographed on 72 out of 212 of the survey days at the ES survey area. Vessels were photographed on 112 out of 211 of the survey days at the CBBT survey area. Most of the vessels recorded at the ES survey area were from research efforts, including survey vessels. There were no tagging vessels during this year. The remainder of the vessels were recreational or commercial waterman. At the ES survey area, the highest vessel presence for a single day was on 20 Nov 2020 with vessels captured in 31 images (**Figure 4-21**). At CBBT, the highest vessel presence in a single day was on 15 May 2021 with vessels captured in 53 images (**Figure 4-22**).

During the 2021/2022 season, vessels were captured in 0.65% of all images taken at the ES survey area (501 images) and 10.2% of all images taken at the CBBT survey area (2014 images). Vessels were photographed on 78 out of 211 of the survey days at the ES survey area. Vessels were photographed on 112 out of 204 of the survey days at the CBBT survey area. Most of the vessels recorded at the ES survey area were from research efforts, including survey vessels and tagging vessels (daily presence from 6 to 16 February 2022). The remainder of the vessels were recreational or commercial waterman. At the ES survey area, the highest vessel presence for a single day was during tagging efforts on 12 February 2022 with vessels captured in 82 images (**Figure 4-21**). At CBBT, the highest vessel presence in a single day

was on 21 November 2021 with vessels captured in 83 images (**Figure 4-22**) which were all recreational fishing vessels.

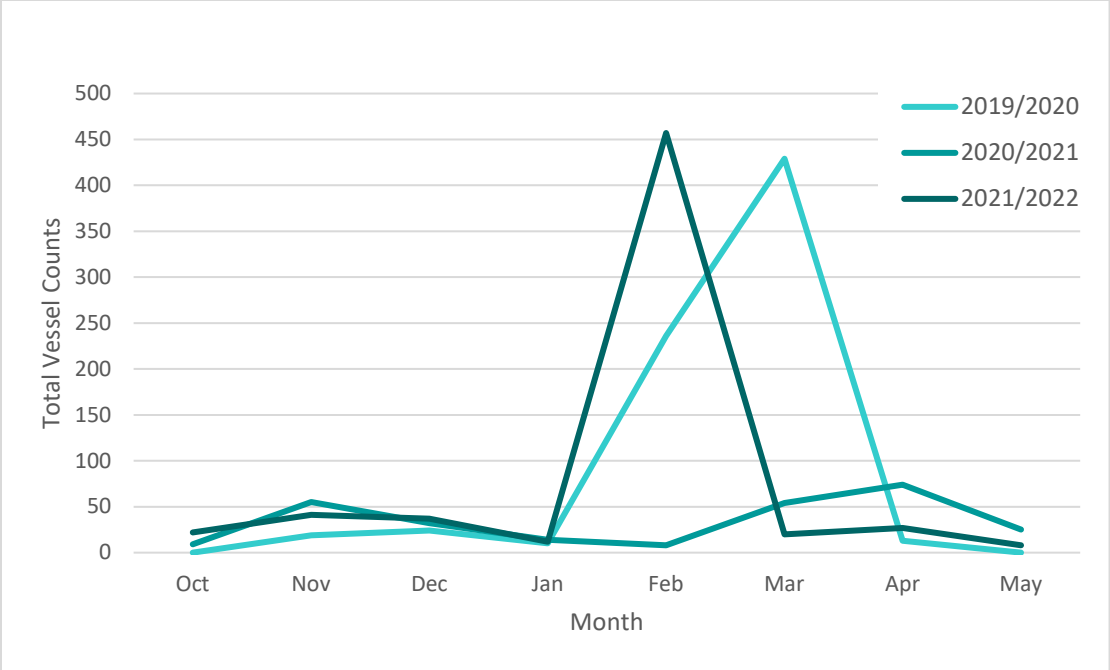

Figure 4-21. Total vessel counts by month at the ES survey area

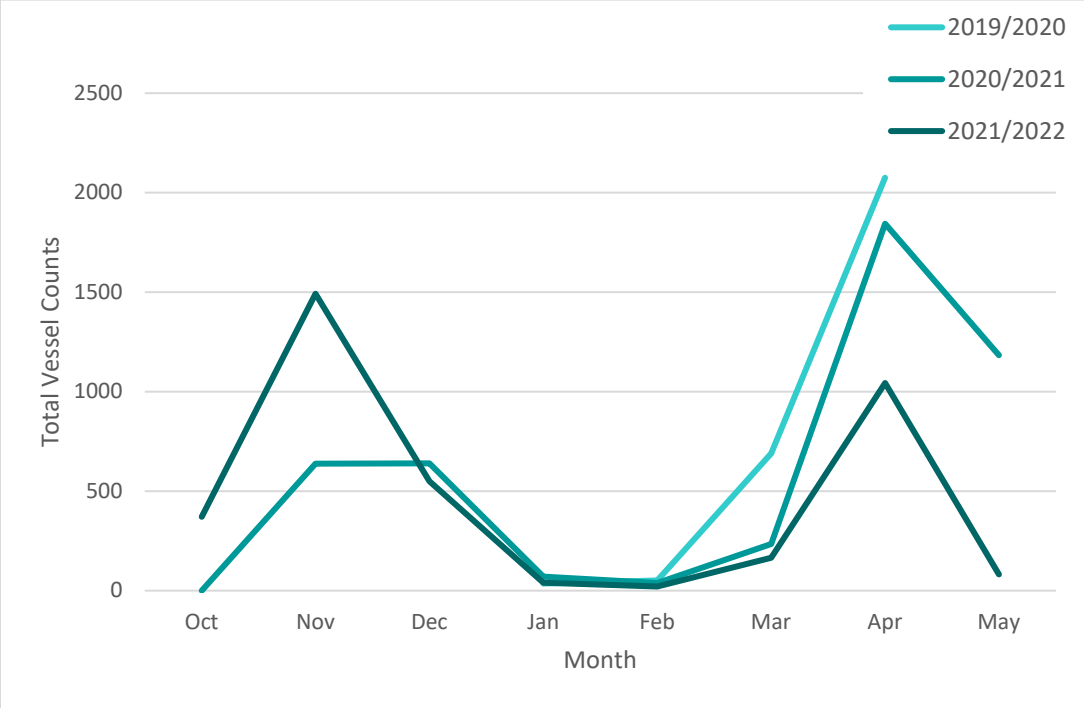

Figure 4-22. Total vessel counts by month at the CBBT survey area

Total vessel count compared to time of day for the ES survey area is shown in **Figure 4-23.** The majority of vessels were photographed from 11:00 to 11:59 during the 2019/2020 season, from 10:00 to 11:59 during the 2020/2021 season, and from 13:00 to 15:00 during the 2021/2022 season.

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 4-23. Total vessel counts by time of day at the ES survey area

Total vessel counts compared to time of day for the CBBT survey area are shown in **Figure 4-24.** The majority of vessels were photographed from 10:00 to 10:59 during the 2019/2020 season, 11:00 to 11:59 during the 2020/2021 season, and 12:00 to 12:59 during the 2021/2022 season.

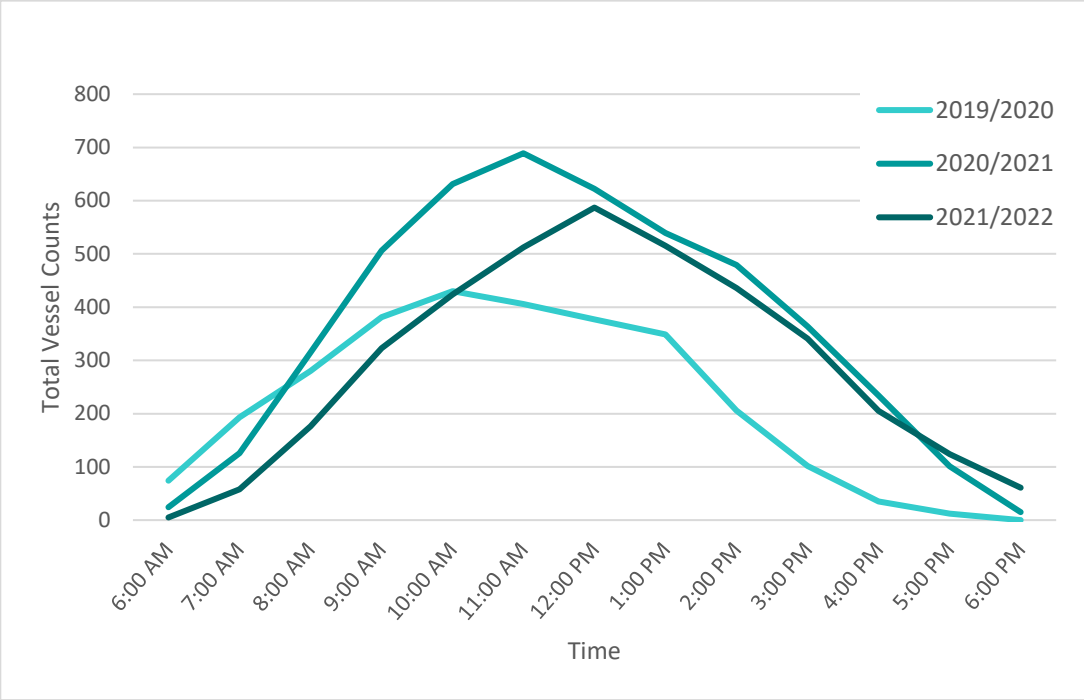

Figure 4-24. Total vessel counts by time of day at the CBBT survey area

The number of images where both vessels and seals were present are shown in **Table 4-17** for each season for both the ES and CBBT survey areas**.**

Table 4-17. Number of images with vessels and seals at the ES and CBBT survey areas

Season	Images with Vessels and Seals HO		Images with Vessels and Seals IW	
	ES	CBBT	ES	CBBT
2019/2020	15	42	60	48
2020/2021	4	201	12	95
2021/2022	2	100	16	66

HO=haul-out, IW=in water

Instances where seals flushed after a vessel was present from ES and CBBT haul-out sites are shown in **Table 4-18** through **Table 4-24.** These tables include the number of seals hauled out, the number of seals in the water, and the number of vessels present in the images before and after the flush. 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. The images captured were 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.

For the 2019/2020 season at the ES, there were 21 instances of seals flushing after a vessel was present. At the CBBT, there were 18 instances where seals flushed after a vessel was present in an image. 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 21.15 hours, with an average of 4.10 hours. At the CBBT, the amount of time it took ranged from 15 minutes to 50.3 hours, with an average of 9.40 hours.

For the 2020/2021 season at the ES, there were 6 instances of seals flushing after a vessel was present. At the CBBT, there were 79 instances where seals flushed after a vessel was present in an image. 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 27.15 hours, with an average of 6.34 hours. At the CBBT, the amount of time it took ranged from 15 minutes to 193.59 hours, with an average of 13.71 hours.

For the 2021/2022 season at the ES, there were 15 instances of seals flushing after a vessel was present. At the CBBT, there were 35 instances where seals flushed after a vessel was present in an image. 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 22.31 hours, with an average of 12.59 hours. At the CBBT, the amount of time it took ranged from 15 minutes to 67.45 hours, with an average of 14.37 hours.

Table 4-18. Instances of seals flushing after vessel presence at ES survey area

Season	Camera	Flush	Vessels		Seals IW		Seals HO		Next HO	Time to next HO
			Before	After	Before	After	Before	After		
2019/2020	CL1	2/29/20 11:30	0	1	1	2	23	0	2/29/20 12:45	1:15:00
		2/29/20 13:00	0	1	1	0	1	0	3/1/20 10:15	21:15:00
		3/1/20 11:15	0	2	1	0	17	0	3/1/20 12:30	1:15:00
		3/1/20 13:01	1	3	0	0	19	0	3/2/20 6:24	17:23:00
		3/9/20 13:57	0	1	0	1	1	0	3/9/20 14:03	0:06:00
	CL2	12/4/19 9:28	1	1	0	0	9	7	12/4/19 9:43	0:15:00
		12/4/19 9:43	1	1	0	0	7	6	12/4/19 10:28	0:45:00
		12/4/19 9:58	1	1	0	0	6	0	12/4/19 10:28	0:30:00
	CL3	2/22/20 7:29	1	1	2	4	1	0	2/22/20 8:14	0:45:00
		2/23/20 7:59	2	2	1	0	16	15	2/23/20 8:12	0:13:00
		2/23/20 8:29	2	2	0	0	18	0	2/23/20 9:44	1:15:00
		2/23/20 13:59	0	3	0	0	22	0	2/24/20 6:27	16:28:00
		2/24/20 8:14	0	2	0	2	28	19	2/24/20 8:29	0:15:00
		2/24/20 8:44	0	2	1	1	21	0	2/24/20 10:00	1:16:00
		2/28/20 11:14	0	2	1	0	17	0	2/28/20 13:14	2:00:00
		3/2/20 7:44	0	2	1	1	16	0	3/2/20 10:44	3:00:00
		3/3/20 7:44	0	1	0	0	34	0	3/3/20 15:29	7:45:00
	CL8	1/24/20 9:48	0	1	0	2	1	0	1/24/20 10:03	0:15:00
		2/23/20 8:27	0	2	1	0	12	0	2/23/20 9:44	1:17:00
		2/24/20 8:42	0	3	0	6	10	0	2/24/20 10:00	0:15:00
		3/3/20 7:48	0	3	0	0	6	0	3/3/20 15:29	1:17:00
2020/2021	CL2	3/13/21 7:16	0	1	0	0	2	0	3/13/21 11:10	3:54:08
		3/14/21 13:31	0	1	0	0	4	0	3/14/21 17:25	3:54:08
	CL4	3/2/21 13:53	0	1	0	0	13	1	3/3/21 6:54	17:01:00
	CL5	12/30/20 10:42	0	1	1	0	6	0	12/30/20 17:12	6:30:00
		1/5/21 14:57	0	1	1	0	14	0	1/6/21 7:30	16:33:50
		3/14/21 13:25	0	1	0	0	12	0	3/14/21 17:25	4:00:00
		3/24/21 7:25	0	1	2	0	29	0	3/24/21 7:55	00:30:00
		4/17/21 6:55	0	1	0	0	1	0	S4/17/21 8:10	1:15:00

Table 4-19. Instances of seals flushing after vessel presence at ES survey area cont.

Season	Camera	Flush	Vessels		Seals IW		Seals HO		Next HO	Time to next HO
			Before	After	Before	After	Before	After		
2019/2020	CL1	2/29/20 11:30	0	1	1	2	23	0	2/29/20 12:45	1:15:00
		2/29/20 13:00	0	1	1	0	1	0	3/1/20 10:15	21:15:00
		3/1/20 11:15	0	2	1	0	17	0	3/1/20 12:30	1:15:00
		3/1/20 13:01	1	3	0	0	19	0	3/2/20 6:24	17:23:00
		3/9/20 13:57	0	1	0	1	1	0	3/9/20 14:03	0:06:00
	CL2	12/4/19 9:28	1	1	0	0	9	7	12/4/19 9:43	0:15:00
		12/4/19 9:43	1	1	0	0	7	6	12/4/19 10:28	0:45:00
		12/4/19 9:58	1	1	0	0	6	0	12/4/19 10:28	0:30:00
	CL3	2/22/20 7:29	1	1	2	4	1	0	2/22/20 8:14	0:45:00
		2/23/20 7:59	2	2	1	0	16	15	2/23/20 8:12	0:13:00
		2/23/20 8:29	2	2	0	0	18	0	2/23/20 9:44	1:15:00
		2/23/20 13:59	0	3	0	0	22	0	2/24/20 6:27	16:28:00
		2/24/20 8:14	0	2	0	2	28	19	2/24/20 8:29	0:15:00
		2/24/20 8:44	0	2	1	1	21	0	2/24/20 10:00	1:16:00
		2/28/20 11:14	0	2	1	0	17	0	2/28/20 13:14	2:00:00
		3/2/20 7:44	0	2	1	1	16	0	3/2/20 10:44	3:00:00
		3/3/20 7:44	0	1	0	0	34	0	3/3/20 15:29	7:45:00
	CL8	1/24/20 9:48	0	1	0	2	1	0	1/24/20 10:03	0:15:00
		2/23/20 8:27	0	2	1	0	12	0	2/23/20 9:44	1:17:00
		2/24/20 8:42	0	3	0	6	10	0	2/24/20 10:00	0:15:00
		3/3/20 7:48	0	3	0	0	6	0	3/3/20 15:29	1:17:00
2020/2021	CL2	3/13/21 7:16	0	1	0	0	2	0	3/13/21 11:10	3:54:08
		3/14/21 13:31	0	1	0	0	4	0	3/14/21 17:25	3:54:08
	CL4	3/2/21 13:53	0	1	0	0	13	1	3/3/21 6:54	17:01:00
	CL5	12/30/20 10:42	0	1	1	0	6	0	12/30/20 17:12	6:30:00
		1/5/21 14:57	0	1	1	0	14	0	1/6/21 7:30	16:33:50
		3/14/21 13:25	0	1	0	0	12	0	3/14/21 17:25	4:00:00
		3/24/21 7:25	0	1	2	0	29	0	3/24/21 7:55	00:30:00
		4/17/21 6:55	0	1	0	0	1	0	S4/17/21 8:10	1:15:00

Table 4-20. Instances of seals flushing after vessel presence at ES survey area cont.

Season	Camera	Flush	Vessels		Seals IW		Seals HO		Next HO	Time to next HO
			Before	After	Before	After	Before	After		
2020/2021	CL8	2/4/21 16:10	0	1	0	0	31	0	2/4/21 17:25	1:15:00
		2/6/21 15:10	0	1	0	0	17	0	2/6/21 17:40	2:30:00
		3/4/21 16:25	0	1	0	0	56	0	3/5/21 6:39	9:14:00
		3/11/21 12:55	0	1	0	0	6	0	3/11/21 15:25	14:30:00
		4/5/21 11:25	0	1	0	2	13	7	3/22/21 11:55	00:30:00
		4/15/21 9:10	0	1	0	0	1	0	4/16/21 12:25	27:15:00
		4/19/21 8:40	0	1	0	0	1	0	4/19/21 8:53	0:13:42
		5/1/21 16:25	0	1	0	1	2	0	5/1/21 17:25	1:00:00
	CL10	3/20/21 9:55	0	1	0	1	4	1	3/20/21 12:55	3:00:00
		4/3/21 8:10	0	1	0	0	9	0	4/3/21 11:10	3:00:00
2021/2022	CL2	2/8/22 13:05	0	2	0	0	11	0	2/8/22 16:59	3:54:12
	CL3	3/19/22 11:03	0	1	0	2	13	0	3/19/22 11:18	0:15:00
		4/8/22 10:48	0	1	0	0	2	0	4/8/22 12:03	1:14:58
	CL4	2/7/22 13:04	0	2	0	0	11	0	2/8/22 6:59	17:54:58
		2/15/22 8:19	0	2	0	0	22	0	2/16/22 6:50	22:31:10
	CL5	12/16/21 9:59	1	1	0	0	7	0	12/17/21 6:59	20:59:42
		1/24/22 11:59	0	1	1	0	28	0	1/25/22 7:13	19:13:52
		2/8/22 12:59	0	2	0	4	16	0	2/8/22 16:59	4:00:00
		2/10/22 9:59	0	1	0	0	5	0	2/11/22 6:44	20:44:38
		2/12/22 11:44	0	1	0	0	17	0	2/13/22 7:14	19:29:16
	CL7	1/1/22 11:34	0	1	0	0	2	0	1/1/22 15:14	3:39:56
	CL8	12/17/21 11:28	0	1	0	1	18	0	12/17/21 12:13	0:45:00
		2/7/22 12:59	0	1	0	1	43	0	2/8/22 6:59	18:00:04
		2/9/22 14:14	0	1	0	0	7	0	2/10/22 6:50	16:35:54
		2/12/22 11:44	0	1	0	0	27	0	2/13/22 7:14	19:29:40

Table 4-21. Instances of seals flushing after vessel presence at the CBBT survey area

Season	Camera	Flush	Vessels		Seals IW		Seals HO		Next HO	Time to next HO
			Before	After	Before	After	Before	After		
2019/2020	CBBT 3	1/18/20 10:59	0	1	0	1	2	0	1/19/20 7:29	20:30:00
		1/26/20 13:58	0	2	1	1	9	1	1/26/20 14:13	0:15:00
		1/26/20 14:58	0	1	0	0	2	1	1/26/20 15:28	0:30:00
		2/2/20 11:28	0	1	0	0	2	0	2/2/20 11:43	0:15:00
		2/3/20 12:57	0	1	0	0	8	0	2/3/20 16:42	3:45:00
		2/16/20 11:14	0	1	1	0	1	0	2/17/20 7:44	20:30:00
		2/23/20 12:43	0	1	2	1	4	0	2/24/20 10:14	21:31:00
		4/24/20 13:25	1	1	0	0	1	0	4/26/20 15:55	50:30:00
		4/26/20 16:25	2	2	0	0	2	0	n/a	
	CBBT 4	3/12/20 12:59	0	1	0	1	1	0	3/12/20 13:59	1:00:00
		3/12/20 14:14	1	2	0	0	1	0	3/13/20 6:44	16:30:00
		3/19/20 12:43	0	1	0	0	3	2	3/19/20 12:58	0:15:00
		3/19/20 14:58	0	1	0	0	2	0	3/19/20 15:13	0:15:00
		3/26/20 10:42	1	2	0	0	1	0	3/26/20 13:27	2:45:00
		3/26/20 13:42	1	3	0	0	1	0	3/26/20 14:12	0:30:00
		3/27/20 13:57	1	2	0	0	3	2	3/27/20 14:12	0:15:00
		3/28/20 13:42	3	4	0	0	1	0	3/28/20 17:42	4:00:00
		4/8/20 13:26	2	2	0	0	1	0	4/9/20 5:56	16:30:00
2020/2021	CBBT 3	12/12/20 13:14	5	5	0	0	1	0	12/13/20 11:44	22:29:54
		12/23/20 9:43	0	1	0	0	5	0	12/24/20 8:43	22:59:54
		1/11/21 13:26	0	1	0	0	9	0	1/11/21 13:41	0:15:00
		1/11/21 13:56	1	2	0	0	2	1	1/11/21 14:11	0:15:00
		1/11/21 14:26	0	1	0	0	6	2	1/11/21 14:41	0:15:00
		1/11/21 16:41	0	1	0	0	4	0	1/12/21 8:41	15:59:56
		1/13/21 12:56	0	1	0	1	9	8	1/13/21 13:11	0:15:00
		1/13/21 13:11	1	1	1	1	8	7	1/13/21 13:26	0:15:00
		1/13/21 14:26	0	1	0	0	6	0	1/15/21 11:11	44:44:49
		1/25/21 11:45	0	1	0	0	11	3	1/25/21 12:00	0:15:00
		2/6/21 14:43	0	1	2	1	3	0	2/6/21 14:58	0:15:00
		2/24/21 11:12	0	1	0	0	7	1	2/24/21 11:27	0:15:00
		2/24/21 13:58	0	1	0	0	4	2	3/3/21 7:41	161:43:23
		2/24/21 14:12	1	1	0	0	2	0	3/3/21 7:41	161:29:20
		3/9/21 10:55	2	1	0	0	2	1	3/10/21 7:55	20:59:55
		3/9/21 11:10	1	1	0	0	1	0	3/10/21 7:55	20:44:55
	CBBT 4	12/20/20 16:43	0	1	0	0	2	0	12/23/20 8:13	63:29:40
		1/8/21 9:56	0	1	0	0	10	8	1/8/21 10:11	0:15:00
		1/8/21 11:11	0	1	0	0	6	4	1/11/21 10:25	71:14:38
		1/11/21 10:40	0	1	0	0	1	0	1/11/21 16:55	6:14:58
		1/13/21 13:10	0	1	2	1	7	6	1/13/21 13:25	0:14:59
		1/25/21 11:15	0	1	0	0	9	0	1/27/21 8:14	44:59:46

Table 4-22. Instances of seals flushing after vessel presence at the CBBT survey area cont.

Season	Camera	Flush	Vessels		Seals IW		Seals HO		Next HO	Time to next HO
			Before	After	Before	After	Before	After		
2020/2021	CBBT 4	2/26/21 11:56	1	1	0	0	15	0	2/27/21 17:40	29:44:51
		2/28/21 10:55	0	1	3	0	4	3	2/28/21 11:25	0:29:59
		2/28/21 15:55	0	1	1	1	7	0	3/1/21 7:55	15:59:55
		3/3/21 11:55	0	1	0	2	12	10	3/3/21 12:10	0:15:00
		3/9/21 10:24	0	1	0	0	5	0	3/9/21 11:39	1:15:00
		3/9/21 14:09	0	1	1	0	4	3	3/9/21 14:24	0:15:00
		3/10/21 12:09	0	1	0	1	9	1	3/10/21 12:24	0:15:00
		3/14/21 10:39	0	1	0	0	2	0	3/14/21 10:54	0:15:00
		3/14/21 11:20	1	1	0	0	1	0	3/14/21 11:24	0:04:00
		3/14/21 12:39	1	1	0	1	4	0	3/16/21 8:01	43:22:06
		3/25/21 11:44	2	1	0	0	8	6	3/25/21 11:59	0:15:00
		3/25/21 11:59	1	3	0	1	6	4	3/25/21 12:14	0:15:00
		3/25/21 13:29	1	1	0	1	7	4	3/25/21 13:44	0:15:00
		3/25/21 13:44	1	1	1	1	4	3	3/25/21 13:59	0:15:00
		3/25/21 14:14	1	1	0	0	4	3	3/25/21 14:29	0:15:00
		3/27/21 10:44	2	3	0	2	1	0	3/27/21 11:29	0:45:00
		3/30/21 10:14	2	1	0	2	2	0	3/30/21 10:44	0:30:00
		3/30/21 11:29	1	2	0	0	2	1	3/30/21 11:44	0:15:00
		3/30/21 12:59	1	1	0	1	4	1	3/30/21 13:14	0:15:00
		3/30/21 13:59	1	1	0	0	4	3	3/30/21 14:14	0:15:00
		3/30/21 16:14	0	1	0	0	7	0	3/30/21 16:44	0:30:00
		4/3/21 14:59	1	1	0	0	3	2	4/3/21 15:14	0:14:59
		4/3/21 17:59	1	1	0	0	11	10	4/3/21 18:14	0:15:00
		4/3/21 18:14	1	1	0	0	10	9	4/3/21 18:29	0:15:00
		4/3/21 18:44	1	1	0	0	11	10	4/4/21 11:43	16:59:56
		4/4/21 13:13	1	1	0	0	9	8	4/4/21 13:28	0:15:00
		4/4/21 13:28	1	1	0	0	8	6	4/4/21 13:43	0:14:59
		4/4/21 13:58	1	2	0	0	8	0	4/4/21 14:13	0:15:00
		4/4/21 14:58	1	2	0	0	8	6	4/4/21 15:13	0:15:00
		4/4/21 15:13	2	2	0	0	6	3	4/4/21 15:28	0:15:00
		4/4/21 15:58	2	1	0	0	11	10	4/4/21 16:13	0:15:00
		4/4/21 17:28	1	1	0	0	13	12	4/4/21 17:43	0:15:00
		4/5/21 13:43	1	1	0	0	6	4	4/5/21 14:43	1:00:00
		4/5/21 13:58	1	2	0	1	4	0	4/5/21 14:43	0:45:00
		4/6/21 8:28	2	2	0	1	1	0	4/6/21 9:13	0:45:00
		4/6/21 9:43	1	1	1	0	2	0	4/6/21 13:28	3:44:59
		4/6/21 14:43	1	1	0	0	6	4	4/6/21 14:58	0:15:00
		4/6/21 15:13	1	1	0	3	6	0	4/6/21 15:28	0:15:00
		4/6/21 15:43	1	1	0	1	1	0	4/6/21 15:58	0:15:00
		4/6/21 16:04	1	1	2	3	2	0	4/6/21 16:13	0:09:18
		4/6/21 16:28	1	1	0	0	2	0	4/6/21 17:13	0:45:00
		4/7/21 10:13	2	2	0	0	8	7	4/7/21 10:28	0:14:59
		4/7/21 10:43	2	3	0	0	8	7	4/7/21 10:58	0:15:00

Table 4-23. Instances of seals flushing after vessel presence at the CBBT survey area cont.

Season	Camera	Flush	Vessels		Seals IW		Seals HO		Next HO	Time to next HO
			Before	After	Before	After	Before	After		
2020/2021	CBBT 4	4/7/21 11:13	2	2	0	0	7	6	4/7/21 11:28	0:15:00
		4/7/21 11:58	1	1	0	0	7	4	4/7/21 12:13	0:15:00
		4/7/21 12:13	1	1	0	0	4	2	4/7/21 12:28	0:15:00
		4/7/21 12:43	2	2	1	0	4	0	4/8/21 9:58	21:14:55
		4/10/21 10:28	3	2	1	2	6	5	4/10/21 10:43	0:15:00
		4/10/21 10:58	2	3	0	0	5	4	4/10/21 11:13	0:15:00
		4/10/21 11:43	0	4	0	0	2	1	4/10/21 11:58	0:14:59
		4/10/21 12:13	3	4	1	0	2	0	4/11/21 16:43	28:29:54
		4/17/21 10:27	1	1	1	0	2	1	4/17/21 10:42	0:15:00
		4/17/21 10:57	2	4	0	0	2	1	4/17/21 11:12	0:15:00
		4/17/21 12:42	4	3	0	0	1	0	4/17/21 16:27	3:44:59
		4/18/21 11:12	6	5	0	0	1	0	4/20/21 11:42	48:29:49
		4/20/21 11:57	2	3	0	0	1	0	4/20/21 13:42	1:45:00
		4/20/21 14:12	3	1	0	0	1	0	4/28/21 16:11	193:59:17
2021/2022	CBBT 3	12/1/21 11:15	3	2	0	0	1	0	12/1/21 12:15	1:00:00
		12/1/21 12:30	1	2	0	0	1	0	12/1/21 13:00	0:30:00
		12/1/21 13:15	2	2	0	0	1	0	12/1/21 15:00	1:45:00
		12/13/21 12:01	0	1	0	0	8	0	12/13/21 12:16	0:15:00
		12/28/21 9:14	0	1	1	0	1	0	12/28/21 17:44	8:30:00
		12/31/21 14:29	0	1	0	3	11	9	12/31/21 14:44	0:15:00
		12/31/21 14:59	1	1	2	3	9	7	12/31/21 15:14	0:15:00
		12/31/21 15:14	1	1	3	1	7	6	12/31/21 15:29	0:15:00
		12/31/21 15:29	1	1	1	2	6	4	12/31/21 15:44	0:15:00
		12/31/21 16:14	2	1	3	3	4	0	12/31/21 16:44	0:30:00
		1/9/22 12:43	1	1	0	0	3	0	1/12/22 8:28	67:45:00
	CBBT 4	12/10/21 16:45	1	1	0	0	1	0	12/10/21 17:30	0:45:00
		12/10/21 18:15	1	1	0	0	2	0	12/15/21 16:30	118:15:00
		12/15/21 16:45	0	1	0	0	1	0	12/18/21 18:00	73:15:00
		12/26/21 16:44	0	1	0	0	1	0	12/26/21 16:59	0:15:00
		12/31/21 18:14	0	1	0	1	3	0	1/1/22 10:58	16:44:00
		1/24/22 13:56	0	1	1	1	5	4	1/24/22 14:11	0:15:00
		2/27/22 11:59	0	1	0	2	17	12	2/27/22 12:14	0:15:00
		3/1/22 10:14	1	1	2	4	7	6	3/1/22 10:29	0:15:00
		3/2/22 18:16	0	1	1	1	10	9	3/2/22 18:29	0:13:00
		3/5/22 12:43	0	1	2	0	5	0	3/5/22 12:58	0:15:00
		3/11/22 11:28	0	1	0	0	6	5	3/11/22 11:43	0:15:00
		3/11/22 11:43	1	1	0	1	5	2	3/11/22 11:58	0:15:00
		3/14/22 12:28	1	2	0	0	3	1	3/14/22 12:43	0:15:00
		3/14/22 13:28	2	1	0	0	1	0	3/14/22 15:43	2:15:00

Table 4-24. Instances of seals flushing after vessel presence at the CBBT survey area cont.

Season	Camera	Flush	Vessels		Seals IW		Seals HO		Next HO	Time to next HO
			Before	After	Before	After	Before	After		
2021/2022	CBBT 4	3/15/22 17:58	1	1	0	0	8	7	3/15/22 18:13	0:15:00
		3/18/22 13:27	2	2	0	1	6	2	3/18/22 13:42	0:15:00
		3/18/22 13:57	2	2	0	0	4	3	3/18/22 14:12	0:15:00
		3/18/22 14:27	1	2	0	1	6	0	3/20/22 14:42	48:15:00
		3/21/22 14:42	0	1	1	0	1	0	3/23/22 11:45	45:03:00
		3/23/22 13:00	0	1	0	0	2	0	3/23/22 15:15	2:15:00
		3/25/22 16:45	0	1	0	0	3	0	3/25/22 17:00	0:15:00
		3/25/22 18:45	0	1	0	1	2	1	3/27/22 9:15	38:30:00
		4/8/22 18:30	1	1	0	0	2	0	4/11/22 18:30	72:00:00
		4/13/22 13:44	1	2	0	0	1	0	4/13/22 14:59	1:15:00

5 Discussion

The visual surveys (both shore and vessel-based), that have been conducted in southeastern Virginia since 2014 (Jones and Rees 2023) formed the foundation of this study. Results from three seasons of effort show that camera surveys can be an effective means of gathering a large amount of data which has great potential to improve our understanding of localized seal haul-out activity.

There were several benefits demonstrated by this camera survey effort over vessel surveys 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 at both the ES and CBBT survey areas from November to April (**Figure 4-1** and **Figure 4-2**). 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 or count occurrences, especially for seals in the water, does not indicate a lack of presence given the cameras only recorded images once every 15 minutes 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 generally of high enough quality to identify seals to species in most cases, the vessel surveys can be relied upon to provide the frequency of harbor versus gray seals occurring in each of the survey areas.

Analysis of the images showed a clear spatial patterns of seals hauled out in Virginia. We were able to document which specific haul-out sites at both the ES and CBBT survey areas were favored by the seals as indicated by the maximum counts (**Table 4-6**) and highest number of days seals were recorded at each haul-out site (**Table 4-7**). These data will help to focus efforts during future studies (e.g., seal tagging attempts), and provide the ability to compare if site preferences persist from season to season in southeastern Virginia.

During the first season, we likely missed seals, especially at the ES survey area at haul-out sites A, B, and E2 due to the cameras not having a full view of the haul-out sites, which was remedied in the 2020/2021 season. The counts at haul-out site A increased over the three seasons with the highest usage recorded in the 2021/2022 season. The haul-out site with the highest total count overall was on E1 during the 2019/2020 season (**Figure 4-5**). The data for haul-out sites A, B and E2 may not be as reliable during the 2019/2020 season, due to the likelihood that we missed a portion of the seals that hauled out at that site.

Analysis of the total seal haul-out count at each haul-out site at the ES survey area showed that seals preferred haul-out sites E1 and E2 compared to the other sites. Seal counts per haul-out site at the CBBT survey area are better represented as averages (**Figure 4-8**) to account for camera failure days, and the potential bias from unequal effort. Average seal haul-out count data was conducted by dividing the total count of hauled out seals by the total number of images with hauled out seals present.

At the CBBT survey area during the 2020/2021 season, there was camera failure due to the camera being tilted from heavy winds and the haul-out site being out of view. This was corrected for in the following seasons by applying zip-ties to the cameras onto the 2x4 post. During the 2021/2022 season there was also camera failure due to camera malfunction. For the 2023/2024 season, we plan to add the cellular linked and solar power Cuddelink cameras at the CBBT survey area, to have the ability to monitor the cameras remotely and reduce the opportunity for multiple day camera malfunctions.

Seasonal patterns were documented in that seals hauled out in greater numbers in the months of January, February, and March (**Figure 4-1** and **Figure 4-2**). Temporal patterns were documented in that seals hauled-out in greater numbers at the ES survey area between the hours of 07:00 and 08:00 during the 2019/2020 season, 07:30 and 08:30 during the 2020/2021 season, and 13:00 and 14:00 during the 2021/2022 season (**Figure 4-10**). Temporal patterns were documented in that seals hauled-out in greater numbers at the CBBT survey area between the hours of 07:30 and 08:30 during the 2019/2020 season, 08:30 and 09:30 during the 2020/2021 season, and 13:30 and 14:30 during the 2021/2022 season (**Figure 4-11**). While this study was not designed to provide data on nighttime haul-out behavior, we did demonstrate in the 2019/2020 season 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 image quality was greatly degraded at night. Haul-out behavior in relation to time of day is likely both seasonal and site specific. According to Ampela et al. 2023, of the seals that were tagged in Virginia, the probability of haul-out was greatest between 04:00 and 12:00. At Castro Rocks in 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 that in the future, tagging data will provide the best results of nighttime pinniped behavior given the limitations of collecting images at night.

Analyzing environmental factors can help predict if seals will be hauled out or in the water during certain conditions. We found that seals prefer to haul-out when the water level is between 1.0 and 2.5 ft high at the ES survey area (**Figure 4-12**) and between 0.5 and 2 ft at the CBBT survey area (**Figure 4-13**). Seals were less likely to be hauled out when average wind speeds were higher than about 20 kts at both the ES and CBBT survey areas (**Figure 4-14** and **Figure 4-15**). The seals were more likely to haul-out when the wind direction was between 201 (SSW) and 250 (WSW) degrees at the ES survey area and 101 (E) and 150 (SSE) degrees at the CBBT survey area (**Figure 4-16** and **Figure 4-17**). Seals were more likely to be hauled out at mid-range temperatures for the area (between 35 and 55 F° or approximately 2 to 13 C°) (**Figure 4-18** and **Figure 4-19**).

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 (**Table 4-18** through **Table 4-24**)**.**

There were several important differences between camera and vessel counts:

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 (Rees et al. 2016, Jones et al. 2018, Jones and Rees 2020, 2021, 2022), and the area immediately surrounding the known haul-out sites 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 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. A drone was used prior to some vessel counts to get an unobstructed view of the seals before they flushed to help remedy the potential for underestimation, however the drone is weather dependent and not flown prior to every survey (Jones and Rees 2023).

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 binoculars 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 underestimated 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 site E1 (main channel side), E2, E3 and A. Coverage at E1 was improved on 23 February 2020, when repositioning the camera allowed analysts to see the entire haul-out site from the image. For haul-out sites E2, E3 and A, the lack of full coverage by the cameras was corrected for the 2020/2021 season by reconfiguring several camera locations and adding cameras where needed. Camera perspectives/survey area could be changed, but require a visit to the site, and in some cases the lack of coverage was not detected until the images were processed at the end of the season.
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. 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 the 2020/2021 season, 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 in only a single moment (image) 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.

When the drone was not available, 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 during the 2019/2020 season. 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.

The difference between camera and vessel counts varied across the seasons, but the vessel surveys consistently counted more seals in the water than the camera surveys. For counting hauled out seals, there were some cases where counts where higher from camera surveys and some were higher from vessel surveys, and those differences are likely due to observer error, or seals hauling out in areas outside of the camera view.

For the 2019/2020 season, 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 the 2020/2021 and 2021/2022 seasons we were able to install cameras at both locations earlier (late October) and keep them installed later (May). Our goal in the future will be to continue 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 (**Figure 4-21** and **Figure 4-22**). Vessel numbers were lowest at both survey areas at the start of the survey season into early February. The ES survey area saw a peak of vessel numbers from the end of February into early March during the 2019/2020 season and at the beginning of February during the 2021/2022 season, which corresponded with daily trips by the seal tagging team (Ampela et al. 2023) under National Marine Fisheries Service Scientific Research Permit #21719. There was no tagging team present during the 2020/2021 season due to the COVID-19 pandemic travel restrictions. The CBBT survey area saw higher vessel numbers (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. 2023). The number of vessels present at the ES survey area was highly influenced by the number of tagging and survey vessels, while the CBBT was more influenced by the higher number of recreational fishing vessels, especially in the spring.

During the 2019/2020 season at the ES survey area, the number of vessels peaked around 08:00, 11:00, and slightly at 14:00 (**Figure 4-23**) and the number of seals hauled out peaked around 13:00 (**Figure 4-10**). At the CBBT survey area, the number of vessels peaked around 10:00 and slightly at 13:00 (**Figure 4-24**) while the number of seals hauled out peaked around 08:00 and 16:00 (**Figure 4-11**). During the 2020/2021 season at the ES survey area, the number of vessels peaked around 11:00 and the number of seals hauled out peaked around 08:00 and 13:00. At the CBBT survey area, the number of vessels peaked around 11:00 while the number of seals hauled out peaked around 09:00, slightly increased around 13:00, but then decreased for the rest of the day. During the 2021/2022 season at the ES survey area, the number of vessels peaked around 08:00, 11:00, and 14:00 while the number of seals hauled out peaked around 07:00 and slightly at 11:00. At the CBBT survey area, the number of vessels peaked around 12:00 while the number of seals hauled out peaked slightly around 09:00 and 11:30 with the largest numbers around 14:00 before decreasing for the rest of the day.

During the survey periods, the time of sunrise ranged from 05:41 to 07:19, and the time of sunset ranged from 16:40 to 20:20 during the three seasons, which means that especially during the winter when sunset was earlier, seals could have been missed in images as it got darker. Seals could have also been missed at the CBBT survey area when sunset was later since the cameras were only set to record images through 18:00. Data from the tagging report found that the most seal haul-out events occurred between 04:00 and 12:00 (Ampela et al. 2023). This further implies that seals may tend to haul-out before sunrise, and therefore could have been missed in images.

The number of images with vessels and seals present decreased across seasons for the ES survey area with 15.77% of images in the 2019/2020 season, 5.32% in the 2020/2021 season, and 3.39% in the 2021/2022 season (**Table 4-17**).This could be due to the tagging activities that occurred in this survey area. Seals may have become sensitized to the presence of vessels and associated it with tagging efforts that started in the 2019/2020 season, which involved capturing seals. Although the number of images with vessels and seals present decreased across seasons, the number of instances of flushing after vessel presence did not increase across seasons. There were 21 instances during the 2019/2020 season, 6 instances during 2020/2021, and 15 instances during the 2021/2022 season. The fewer instances during the 2020/2021 season could have been because no tagging efforts occurred during that season, reducing the presence of vessels to cause seals to flush. The average time for seals to return to a haul-out after flushing also increased across seasons with an average of 4.10 hours for the 2019/2020 season, 5.38 hours for the 2020/2021 season, and 12.59 hours for the 2021/2022 season. Seals could be increasing the time to haul out again to avoid further interactions with the tagging team. In addition to tagging efforts, local nature cruises have started offering visits to the ES haul-out area, but the frequency of those vessel visits are unknown.

The number of images with vessels and seals present at the CBBT remained more similar across seasons with 7.79% for the 2019/2020 season, 10.60% for the 2020/2021 season, and 7.10% for the 2021/2022 season (**Table 4-17**). The presence and activities of vessels likely remained more similar at this survey area since tagging efforts did not occur here. The instances of seals flushing after vessel presence varied across seasons with 18 instances during the 2019/2020 season, 79 instances during the 2020/2021 season, and 35 instances during the 2021/2022 season. The amount of time to haul out again after flushing also increased like it did at the ES with an average of 9.40 hours for the 2019/2020 season, 13.71 hours for the 2020/2021 season, and 14.37 hours for the 2021/2022 season.

Larger vessels (e.g. container ships and military vessels) are known to transit within the CBBT survey area since major shipping routes for several ports in the Chesapeake Bay overlap with the survey area. These larger ships in the shipping channel were not counted as they are too far from the haul-out sites to cause disturbance, which has been verified by the vessel survey observers. 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 differences 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 or direction 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 site 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 influenced 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 and caused seals to flush without being recorded in an image.

Henry and Hammill (2001) found that pursuit and capture of seals caused them not to haul-out again while boats were present. For vessel survey between the years of 2019 and 2023, there were 19 instances of seals flushing during a vessel survey at the ES survey area. This data is not including days where vessels were out for the seal-tagging project, which often resulted in the seals flushing as well. 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.

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. If haul-out duration is an important value for future analyses, using tagging data to calculate this 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. The 2019/2020 season demonstrated the value of camera surveys and created the groundwork for the study to be improved upon for future seasons. Some improvements that have been incorporated into the 2020/2021 and 2021/2022 seasons 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 (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. Integrate tagging data with camera data to develop a more complete understanding of how seals are using haul-out sites in Virginia.
4. Implement further quantitative analysis to better understand the density and abundance of seals in the area.
5. Analyze haul-out patterns in comparison to tidal cycle.

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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