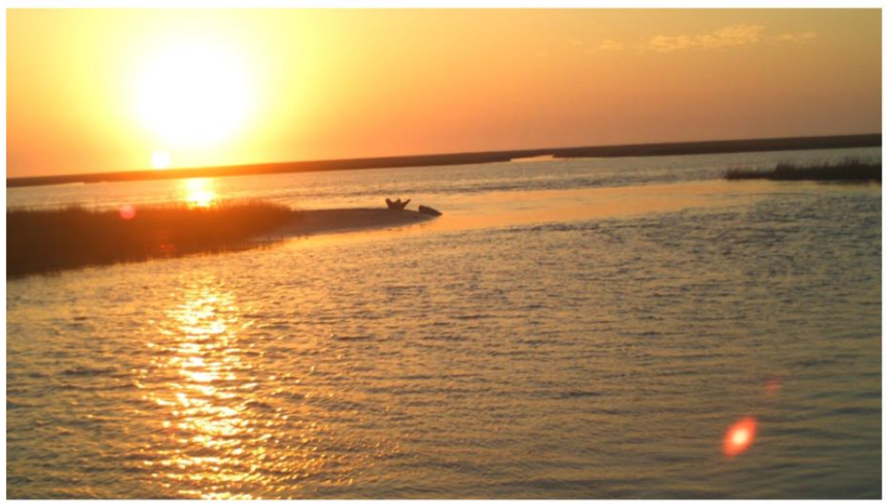
Pinniped Time-lapse Camera Surveys in Chesapeake Bay and Eastern Shore, Virginia

2022-2024

PROGRESS REPORT



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Harbor seals hauled out at the Eastern Shore, Virginia. Photo taken by CuddeLink L-series camera, operated by D. Poulton, D. Rees, and M. Guins, under National Marine Fisheries Service (NMFS) General Authorization permit #25811.

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Acronyms and Abbreviations

AIC	Akaike Information Criterion
ANOVA	analysis of variance
CBBT	Chesapeake Bay Bridge Tunnel
CNIC	Commander, Navy Installations Command
df	degrees of freedom
ES	Eastern Shore
°F	degrees Fahrenheit
ft.	foot or feet
GAM	Generalized Additive Model
HO	haul-out(s); hauled out
kts	knots
mi	miles
MP	megapixel
MMPA	Marine Mammal Protection Act
NAVFAC	Naval Facilities Engineering Systems Command
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OPAREA	Operating Area
U.S.	United States
USFF	U.S. Fleet Forces Command
VACAPES	Virginia Capes

1. Introduction

The western Atlantic harbor seal (*Phoca vitulina vitulina*) can be found in Greenland, eastern Canada and along the eastern United States (U.S.) coast with the southern-most extent to North Carolina (Jefferson et al., 2015; Pepper et al., 2024). The northwest Atlantic gray seal (*Halichoerus grypus atlantica*) can be found along Canada and the eastern U.S. from Labrador to New Jersey (Lesage & Hammill, 2001; Hayes et al., 2023). Both species are year-round coastal inhabitants in eastern Canada and New England, and occur seasonally in the mid-Atlantic region of the U.S. between the months of September and May (Hayes et al., 2023). Harbor seals generally exhibit a southward movement from the Bay of Fundy to southern New England; and for some as far south as North Carolina in the fall and winter months (Jacobs & Terhune, 2000; Rosenfeld et al., 1988; Whitman & Payne, 1990; Pepper et al., 2024). In the last decade, harbor seals have been documented seasonally in coastal Virginia from October through May, with gray seals occasionally observed in the winter months (Jones, 2024).

Accurate data on the distribution of pinniped species are needed to ensure proper documentation and analysis of impacts for compliance with the National Environmental Policy Act (NEPA) and Marine Mammal Protection Act (MMPA), and to establish effective protective measures during U.S. Navy training and testing activity planning. Harbor and gray seals, like all pinnipeds, are amphibious, spending time both hauled out on land and in the water. In general, the time they are in the water poses the greater potential for impact by Navy activities.

Since 2014, Navy biologists have been conducting surveys at known seal haul-out sites in Virginia. These surveys have provided a solid baseline of data on seasonal occurrence in Virginia, and an average abundance estimate of 150 individuals (Jones, 2024). These surveys have been limited by daylight, marine conditions, and weather, resulting in a paucity of information near sunrise/sunset and in adverse weather conditions (e.g., rain, high winds, and sea states greater than Beaufort 3), and at night.

For this project, time-lapse trail cameras were placed at two survey areas in southeastern Virginia in order to monitor all of the known haul-out sites in the region. Wildlife “trail” cameras are cost effective tools for collecting large amounts of data while limiting the impact to the animals as compared to traditional visual surveys (Koivuniemi et al., 2016; Wearn & Glover-Kapfer, 2019). Trail cameras are especially effective for monitoring wildlife in remote locations and sampling multiple sites for extended periods of time. The use of these cameras offer the ability to monitor haul-out sites in adverse marine and weather conditions with relatively low personnel demands.

Objectives for this study are to:

1) *improve the understanding of local haul-out patterns;*
2) *monitor seasonal patterns and the numbers of seals hauled out;*
3) *investigate any haul-out patterns in relation to environmental factors; and*
4) *investigate differences between vessel and drone-based surveys and time-lapse camera data collection.*

The data and results from these efforts will further improve the assessment of potential impacts from training and testing activities, installation construction (e.g., pile driving) and vessel-transiting activities as required under the MMPA and NEPA for Commander, U.S. Fleet Forces Command (USFF) and Commander, Navy Installations Command (CNIC) in the region. These data also provide important baseline information for the assessment of potential future impacts from climate change or anthropogenic activities.

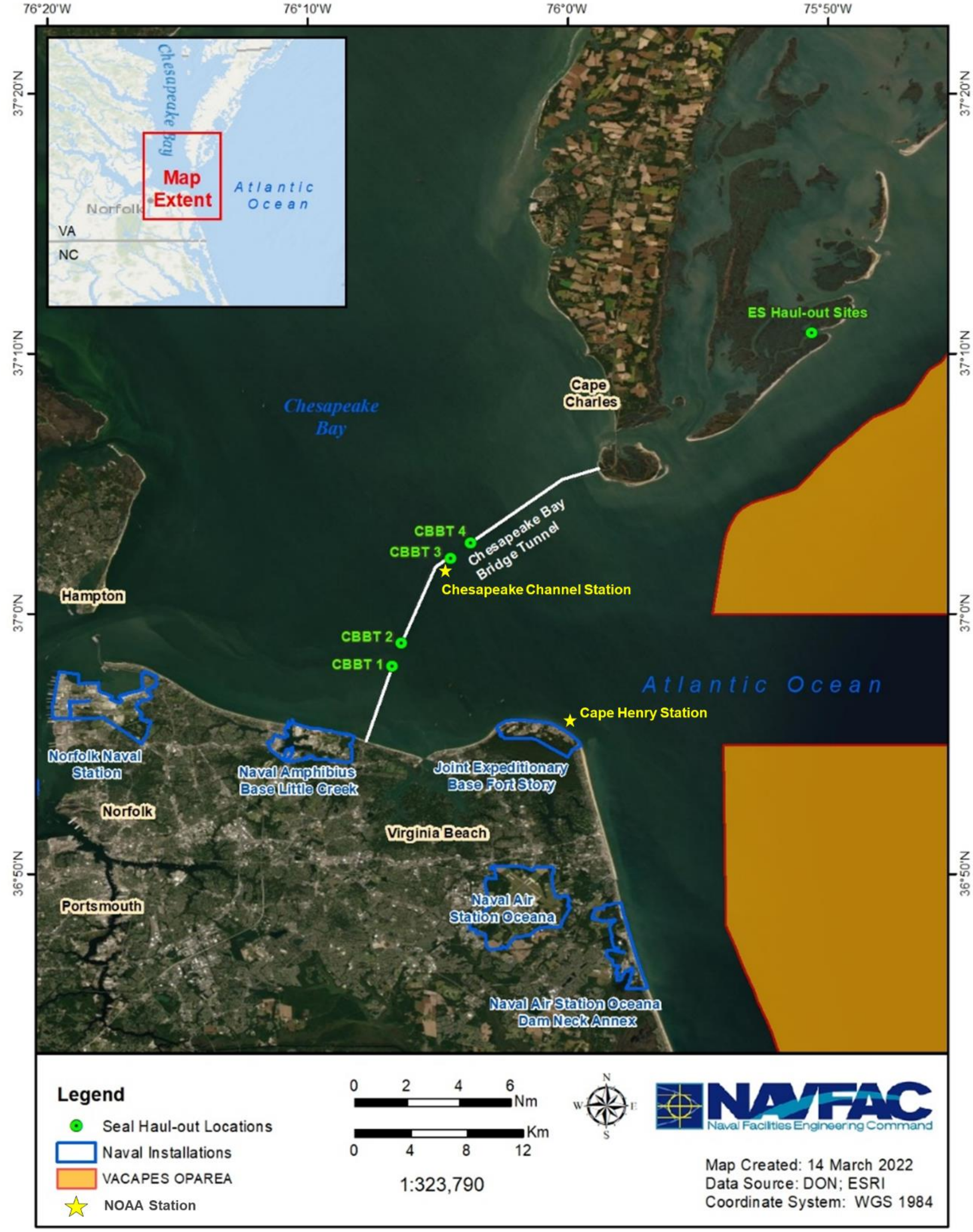
This report summarizes the time-lapse camera survey data collection in southeastern Virginia for all five field seasons from 2019-2024, and detail results from the 2022/2023 and 2023/2024 field seasons. For details from the first three seasons of data collection, see Rees et al. (2022) and Guins et al. (2023).

All survey effort for this report was conducted in accordance with National Marine Fisheries Service (NMFS) General Authorization permit #19826 from 2019 to 2021 and permit #25811 from 2021 to 2026.

2. Methods

2.1. Study Area

The study area shown in **Figure 1**, consists of two locations in southeastern Virginia where seals have been known to haul out for at least the last decade (Jones, 2024): 1) the southern region of the Eastern Shore (ES), and 2) in the lower Chesapeake Bay along the Chesapeake Bay Bridge Tunnel (CBBT). The distance between the two survey areas is approximately 17 miles (mi). Both survey areas are in close proximity [< 62 mi] 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.



CBBT = Chesapeake Bay Bridge Tunnel; ES = Eastern Shore; NOAA = National Oceanographic and Atmospheric Administration, OPAREA = Operating Area; VACAPES = Virginia Capes

Figure 1. Eastern Shore and Chesapeake Bay Bridge Tunnel haul-out locations and nearby U.S. Naval Installations

The Eastern Shore survey area contains several haul-out sites within close proximity to each other [< 2,400 feet (ft)] (**Figure 2**). Haul-out sites are designated with an alpha-numeric identifier (ID).

Haul-out sites are shown as blue lines and separated by white tick marks. Camera locations are shown as white markers.

Figure 2. Eastern Shore survey area haul-out sites and camera locations

At the CBBT survey area, seals haul out on the rock armor formations (locally referred to as "islands") (**Figure 3**) which protect the tunnels as they go beneath the water. There are four islands total, one at each end of the two tunnels. For this project, only two of the four islands (CBBT3 and CBBT4; **Figure 1**) were accessible to be monitored with trail cameras due to active tunnel construction (Chesapeake Tunnel Joint Venture, 2020; National Oceanic and Atmospheric Administration, 2024c) at CBBT1 and CBBT2. However, the Navy has been conducting surveys and monitoring all four islands since 2014 (Jones, 2024).

Photo by Virginia Aquarium & Marine Science Center Foundation

Figure 3. Aerial view of a Chesapeake Bay Bridge Tunnel haul-out site

2.2. Camera Models and Settings

Camera models were selected considering the accessibility of the survey area, the need for wireless capability, camera network linking, and photo quality. The ability to link to a wireless network in order to send photos via email was important for the Eastern Shore survey area, given the remoteness of the area. At the CBBT survey area, high photo quality was critical in order to capture seals at the distance from the camera installation locations to the haul-out sites (approximately 100-130 m or 328-427 ft). The following camera models were used in this study.

- **<u>CuddeLink Dual Cell Model G-5109</u>**. The CuddeLink G-Series Cell Home camera utilizes CuddeLink technology to create a wireless mesh network that allows communication between multiple CuddeLink cameras and the Home camera (i.e., camera network linking). Images from cameras within the mesh network are sent to the Home camera. From the Home camera, images from all the cameras in the mesh network are sent to a designated email, allowing images from multiple cameras to be sent using a single cellular data plan. Camera status reports were also sent daily to the designated email. These cameras were used at the Eastern Shore during all field seasons, and the CBBT survey area for the 2023/2024 season.
- **<u>CuddeLink Black Flash J-Series Model 1422 & LL-Series Model 3A</u>**. These are the remote cameras that link within the Home camera network. These CuddeLink cameras were used at the Eastern Shore during all field seasons, and the CBBT survey area for the 2023/2024 season.
- **<u>Stealth Cam DS4K</u>**. This is a standard trail camera with no cellular capabilities and the status of these cameras had to be checked and images retrieved by visiting the site. This model was selected for the high image resolution (16 megapixels (MPs) true and 30 MPs interpolated). Stealth cameras have been used for all field seasons and are only used at the CBBT survey area.

All cameras saved full resolution images to SD cards. Images sent via email from the CuddeLink cameras were low resolution images and were useful for monitoring camera activity, but only the high-resolution images from the SD cards were used for analysis.

All cameras had a time-lapse feature and were programmed to take an image every 15 minutes during daylight hours.

2.3. Camera Placement

Cameras were installed at the Eastern Shore survey area on 8-12-foot (ft.) pressure treated wooden posts approximately 65-160 ft. from each of the known haul-out sites. The elevated posts, shown in **Figure 4**, minimized vegetation interference and reduced the likelihood of cameras being flooded during extreme high tides or storms.

During the 2022/2023 and 2023/2024 seasons, nine CuddeLink cameras were installed at the Eastern Shore survey area to provide maximum coverage at all the known haul-out sites (**Figure 2**), rather than random placement. Cameras were angled to minimize water and sun glare as much as possible and were adjusted throughout the monitoring period. After photos were processed each year, adjustments were made for the next season, when the cameras were deployed, as needed.

Photo by D. Rees, NAVFAC Atlantic under NMFS General Authorization Permit #19826

Figure 4. Eastern Shore survey area with harbor seals hauled out and camera on the post to the right

At the CBBT survey area, during the 2022/2023 season, one Stealth camera was attached to a pressure treated wooden post, which was secured to the guardrail support overlooking the haul-out site, at CBBT3 and CBBT4 (**Figure 5**). During the 2023/2024 season, one Stealth and one CuddeLink camera was placed on each post facing the haul-out sites. The cameras were accessed from a maintenance road off the main bridge road.

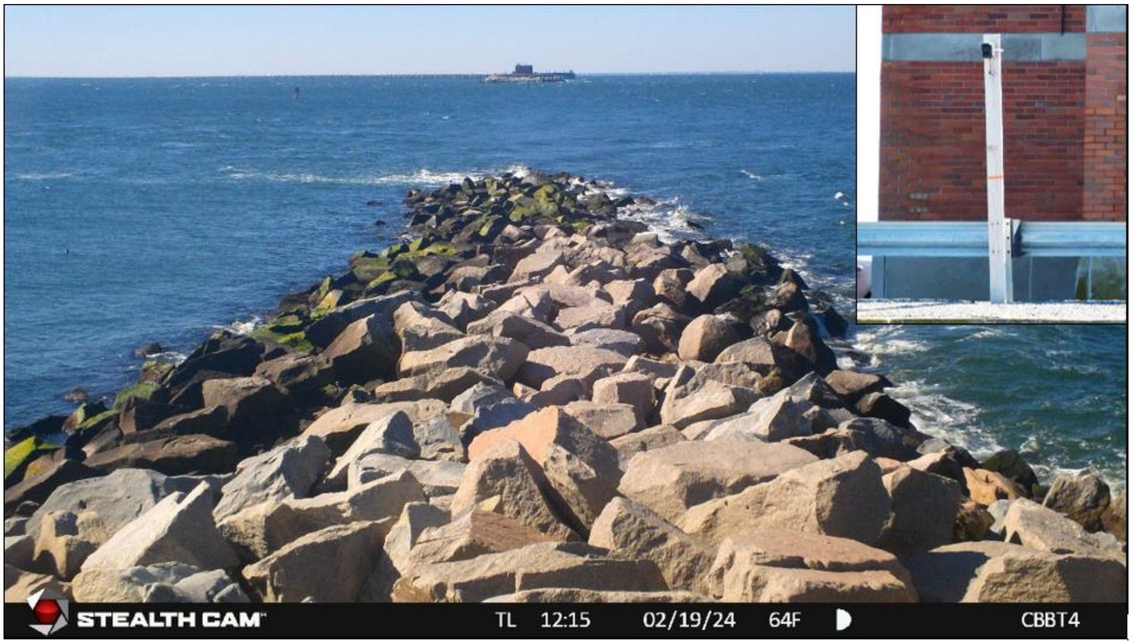


Photo taken under NMFS General Authorization Permit #25811

Figure 5. Camera view of CBBT4 with inset image of camera post attached to the guardrail

Cameras at both survey areas were generally checked monthly throughout the season to monitor the battery status, camera function, camera angle, to clean the lenses, and to replace the SD cards. Cameras at the Eastern Shore survey area were checked and SD cards retrieved in conjunction with the vessel surveys. Cameras at the CBBT survey area were accessed via the maintenance road.

2.4. Analytical Methods

2.4.1. Effort and Counts

In each season, an effort was made to install the cameras in October, at least a couple of weeks prior to estimated seal arrival (based on the first seal observations from previous seasons), and remove them after seal departure from the area in May. We defined seal occupancy season from the first observation in the fall to the last observation in the spring. Since images were collected prior to seal arrival and after departure, only images within the occupancy season were used in the data analysis.

Images were reviewed for the presence of seals that were either hauled out or in the water, as well as for the presence of vessels. A count is defined as the total number of seals or vessels recorded in an image. Seals emerging more than half a body length out of the water but clearly resting on the bottom of a sandbar, marsh bank, or rock were considered hauled out, similar to Jeffries, (2014).

The Timelapse Image Analysis system and the Timelapse2 program (Greenberg, 2024) was used to count, mark, and record the number of seals and vessels in each image. **Figure 6** shows a screenshot of the program analysis screen; on the right is a customizable data entry template, the yellow dots within the image appear once a seal is manually counted, and the magnifier feature allows the reviewer to zoom in on an area to get a better view. The Timelapse2 program includes built in features which simplify the visual examination, encoding, and recording of the data from each image. These features include a customizable data recording template, automatic extraction of image data (e.g. file name, date and time taken), automatic counting of marks as identified by the user developed template (e.g., harbor seal, gray seal, vessel), persistent marks, automated batch time correction, and image review tools (e.g. magnifier, play forward and reverse, pan/zoom tools, and image enhancement).

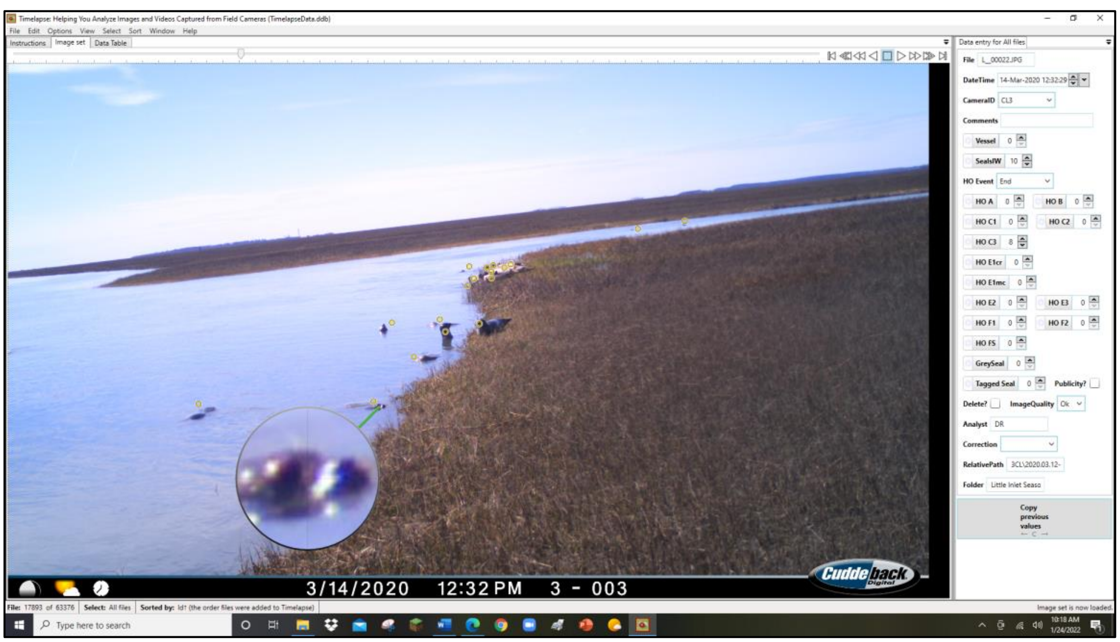


Photo taken under NMFS General Authorization Permit #19826

Figure 6. Screenshot of the Timelapse Image Analysis Workspace

At the Eastern Shore survey area, all vessels were counted regardless of proximity to the haul-out site, since any vessel that could be observed from the cameras had the potential to disturb the 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 as cameras only capture images once every 15 minutes. At the CBBT survey area, vessels were recorded if they were within about 980 ft from the haul-out site (the buoy marking the shipping lane was used as a cutoff). 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.

Some cameras at the Eastern Shore 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 which alternate camera(s) had a full or partial view of each site in the event the view from the primary camera was obstructed or a camera failed.

Camera failure was recorded and reported by day if there was a total failure in the ability to observe the haul-out sites. At the Eastern Shore survey area, if a camera failed (e.g., tilting from eagles perching on the cameras or high winds), images from a back-up were used for the counts so that each haul-out site was always covered. Effort was corrected for camera failure days when calculating the percentage of days that seals were hauled out or present. On occasion Stealth cameras captured images outside of the designated 15-minute time-lapse interval, these images were excluded from analyses regardless if there were seals in the image.

For data analysis, counts were averaged by the number of images with seals present to represent the relative presence of seals during each designated time frame (i.e., by month or season).

2.4.2. Temporal Data

Counts from the images were analyzed temporally to determine if there were patterns in haul-out activity by month and by hour after sunrise. The timestamp from each image was compared to the time of sunrise for each day to determine the number of hours after sunrise each haul-out event occurred. The time post-sunrise was then rounded to the nearest hour. All temporal data were reported in Eastern Standard or Eastern Daylight Time, depending on the date collected.

2.4.3. 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 tidal height (ft), air temperature (degrees Fahrenheit [°F]), and wind speed (knots [kts]). The seal counts were averaged to represent the relative presence of seals within the indicated environmental data range.

Environmental data were obtained from National Oceanic and Atmospheric Administration (NOAA) Tides and Currents, Chesapeake Channel station (station ID 8638901) (National Oceanic and Atmospheric Administration, 2024b) physically located at 37.032 N, 76.083 W (**Figure 1**). This station was chosen because it is within 15.5 mi of all the haul-out sites and would best represent average conditions across all the haul-out sites. Occasionally, there were dates where no meteorological data was available from station 8638901. To accommodate for the missing data, a nearby station, Cape Henry (station ID 8638999), physically located at 36.919 N, 76.001 W (National Oceanic and Atmospheric Administration, 2024a), was used as a proxy (**Figure 1**).

Tidal height provided by NOAA Tides and Currents stations use base elevation as a reference from which to estimate heights or depths. 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 (National Oceanic and Atmospheric Administration, 2024e). Air temperature and wind speed are recorded and averaged over an eight-minute period (National Oceanic and Atmospheric Administration, 2024d).

2.5. Statistical Analyses

Mean seal counts for each month and hours after sunrise were compared separately between all field seasons using a one-way analysis of variance (ANOVA) which compares the means in order to determine whether there is statistical evidence that the means are significantly different. The correlation between the number of seals hauled out and each environmental covariate (tidal height, wind speed, and air temperature) was tested with a Pearson's Correlation Test.

To test the effect of selected covariates (tidal height, wind speed, air temperature, month, and time after sunrise) on the number of seals that were hauled out, a Generalized Additive Model (GAM) was used because it allows for non-parametric relationships between the covariates. A GAM was chosen over a Generalized Linear Model because a GAM has no assumptions about the relationships between the predictor (hauled-out seals) and the covariates (tidal height, wind speed, air temperature, month, hours after sunrise). GAM's have also been noted to be a more effective method of modeling short term responses such as between seasons (Cheng & Gallinat, 2004).

Akaike Information Criterion (AIC) was used to determine the best fit model, meaning which covariates had the most influence on the number of seals that were hauled out. The model with the lowest AIC value and highest AIC weight were determined as the best fit model. Data across all five field seasons from 2019-2024 were tested together, but the two survey areas were tested separately due to the slight variations in environmental results between them. All statistical analyses were run using R software (R Core Team, 2024).

2.6. Vessel Survey and Drone Counts

During each field season, as a separate effort, vessel surveys were conducted at both the Eastern Shore and CBBT survey areas (Jones, 2024). In addition to vessel surveys, a drone was used to conduct counts at the Eastern Shore survey area when weather conditions permitted. Data from the differing survey methods at the same time and survey area allowed for a comparison of camera counts to vessel-based or drone based counts.

Since vessel presence from both the vessel surveys and the drone counts had the potential to disturb seals and cause them to flush (move from the haul-out to the water), the image captured by the time-lapse camera just before the vessel survey or drone count start time was used for comparison in the analysis.

If seals were hauled out on multiple sites within a survey area, counts were combined for that survey area for the comparison of camera counts to vessel-based or drone based counts.

2.7. Vessel Presence

At both survey sites, the number of vessels present in an image was counted to demonstrate the patterns of vessel activity on a monthly basis throughout the seal occupancy season. The number of vessels in an image will be referred to as “vessel counts”. To analyze the effect of vessel presence on the number of seals that were hauled out, instances where there were both a vessel recorded and hauled out seals in the same image were noted. Vessel counts were also averaged to represent the relative presence of vessels at any given time. These counts were not intended to provide a census of vessels in the area, but rather to provide relative vessel occurrence in each of the survey areas, and as a comparison between survey areas. To further analyze the effect of vessel presence on seal activity, instances where seals were hauled out before a vessel was recorded in an image, but not after the vessel, were considered a flushing event. **Figure 7** shows instances at both survey areas (Eastern Shore on the left; CBBT on the right) when there was more than one vessel in an image.

Photo taken under NMFS General Authorization Permit #19826

Figure 7. Examples of multiple vessels recorded at the Eastern Shore (left) and CBBT survey areas (right)

3. Results

3.1. Effort and Counts

Results presented here were summarized for data collection for five field seasons from 2019-2024, with additional analyses for the 2022/2023 and 2023/2024 seasons. For detailed analysis from the first three seasons of data collection, see Rees et al. (2022) and Guins et al. (2023).

Cameras were installed in October and removed in May to capture seal arrival to and departure from the survey areas, with the exception of the 2019/2020 field season (**Table 1**). Effort days represents the number of days cameras were deployed at the survey areas, regardless of functionality. Camera failure days sums the number of days that cameras were not operational at each survey site.

Table 1. Camera survey effort for each season

Season	Site	Install Date	Removal Date	Effort Days	Camera Failure Days	# of Images
2019/2020	ES	4 Nov	29 April	178	0	62,651
	CBBT3	7 Jan	28 April	113	0	5,788
	CBBT4				0	5,541
2020/2021	ES	28 Oct	28 May	213	0	76,397
	CBBT3	29 Oct	27 May	211	23	8,391
	CBBT4				0	7,968
2021/2022	ES	13 Oct	15 May	215	0	74,562
	CBBT3	20 Oct	11 May	204	42	7,636
	CBBT4				0	10,156
2022/2023	ES	21 Oct	29 May	221	0	77,775
	CBBT3	25 Oct	26 May	214	21	9,580
	CBBT4				71	6,039
2023/2024	ES	26 Oct	23 May	211	0	73,604
	CBBT3	21 Oct	22 May	215	0	7,600
	CBBT4				2	9,069

The seal occupancy season length is determined by the number of days between the first and last observation of a seal. The season length was calculated both by site and overall, combining data from both survey areas (**Table 2**). Since the Eastern Shore and CBBT survey areas are in relatively close proximity (approximately 17 mi apart), it is appropriate that the overall season length would represent the seal occupancy season for the region.

During the 2022/2023 season seals were recorded from October 22 to May 17 for a total season length of 199 days. During the 2023/2024 season seals were recorded from October 23 to May 9 for a total season length of 208 days.

Table 2. Seal occupancy for each season

Season	Site	First Seal	Last Seal	Season Length	
				By Site	Overall
2019/2020	ES	4 Nov	20 Apr	169	177
	CBBT	8 Jan	28 Apr	n/a[1]	
2020/2021	ES	30 Oct	25 May	208	208
	CBBT	30 Oct	22 May	205	
2021/2022	ES	15 Oct	28 Apr	196	199
	CBBT	20 Oct	1 May	194	
2022/2023	ES	22 Oct	17 May	208	208
	CBBT	25 Oct	23 Apr[2]	181	
2023/2024	ES	26 Oct	9 May	197	200
	CBBT	23 Oct	24 Apr	185	

[1] Season length is not available because cameras were not installed until 7 January, so this represents only a partial season at this site

Table 3 and **Table 4** summarize the haul-out data across years and locations. Haul-out average is reported as the average number of seals in each image where seals were observed as hauled out across the entire season. The number of days seals were hauled out is compared to the number of days seals were present, which includes observations of seals either hauled out or in the water. The season length used to determine the percentage of days seals were hauled out and present for the Eastern Shore survey area and the CBBT survey area is provided in the "by site" column in **Table 2**. The CBBT site data was used for both CBBT3 and CBBT4.

The lowest number of days with hauled out seals at the Eastern Shore was during the 2019/2020 season, and the following season (2020/2021) had the highest number of days with hauled out seals. The remaining three seasons alternated between being higher and lower from the previous season for the number of days with hauled out seals. The 2021/2022 season saw a decrease in the number of hauled out seals from the 2020/2021 season, followed by an increase in the 2022/2023 season, and another decrease in the 2023/2024 season. The number of days seals were present followed this same pattern (**Table 3**).

Table 3. Camera trap sightings summary at the Eastern Shore survey area

Season	HO Average	# Days HO	% of Days HO	# Days Present	% of Days Present
2019/2020	12	135	79.8	149	88.2
2020/2021	10	164	78.8	189	90.9
2021/2022	14	143	72.9	169	86.2
2022/2023	10	157	75.5	187	89.9
2023/2024	14	145	73.6	171	86.8

HO = haul/hauled out
Seals present = both seals hauled out and in the water

At the CBBT survey area, data can be compared between the two CBBT sites. For example, CBBT4 had higher haul-out averages than CBBT3 for the 2022/2023 and 2023/2024 seasons, which is consistent with the two previous seasons. The number of days seals were seen hauled out has been lower at CBBT3 for all seasons until the 2023/2024 season where it was higher (**Table 4**).

Table 4. Camera trap sightings summary at the CBBT survey area

Season	Site	HO Average	# Days HO	% of Days HO	# Days Present	% of Days Present
2019/2020	CBBT3	4	35	31.3	82	73.2
	CBBT4	4	48	42.9	62	55.4
2020/2021	CBBT3	5	39	21.4	94	51.6
	CBBT4	5	68	33.2	119	58.0
2021/2022	CBBT3	5	33	21.7	92	60.5
	CBBT4	7	84	43.3	112	57.7
2022/2023	CBBT3	5	73	45.6	145	90.6
	CBBT4	6	79	71.8	107	97.3
2023/2024	CBBT3	3	99	53.5	126	68.1
	CBBT4	8	67	36.6	115	62.8

HO = haul/hauled out
Seals present = both seals hauled out and in the water

When comparing the average number of hauled out seals between camera survey and vessel surveys at the Eastern Shore, the two have opposite trends of one another (**Figure 8**). The difference between the averages ranged from 2 seals (2021/2022) to 11 seals (2022/2023). During seasons where the average decreased from the previous season for vessel surveys, it increased for camera surveys. Similarly, when the average from vessel surveys increased, that of camera surveys decreased.

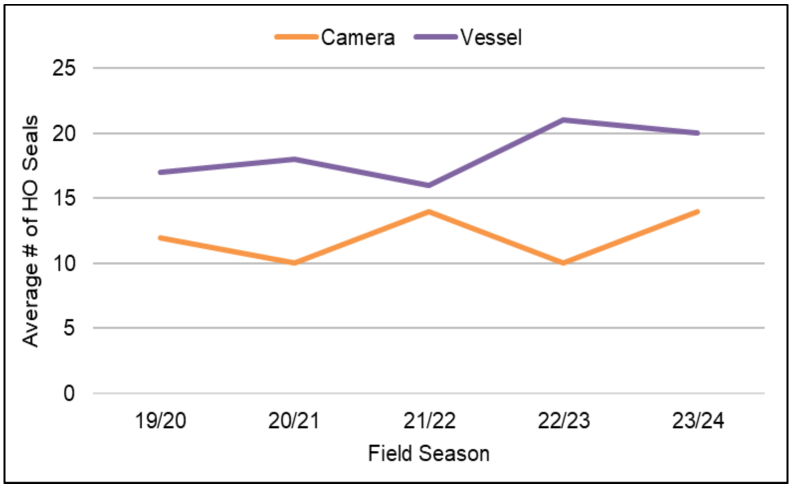


Figure 8. Average seal counts between survey methods at the Eastern Shore survey area

At the CBBT, the comparison of average number of seals hauled out between camera and vessel surveys was done separately for CBBT3 and CBBT4 (**Figure 9**). At CBBT3, the difference between the averages ranged from 3 seals (2023/2024) to no difference (2019/2020). Camera surveys observed an increase in the average number of seals between the 2019/2020 and 2020/2021 seasons, then remained constant until the most recent season where it decreased. The average number of seals during vessel surveys alternated between increasing and decreasing. The 2019/2020 season was the only season where the two survey methods obtained the same average. At CBBT4, the difference between the averages ranged from 3 seals (2019/2020) to no difference (2020/2021). The two survey methods follow the same pattern for when they increase or decrease between seasons.

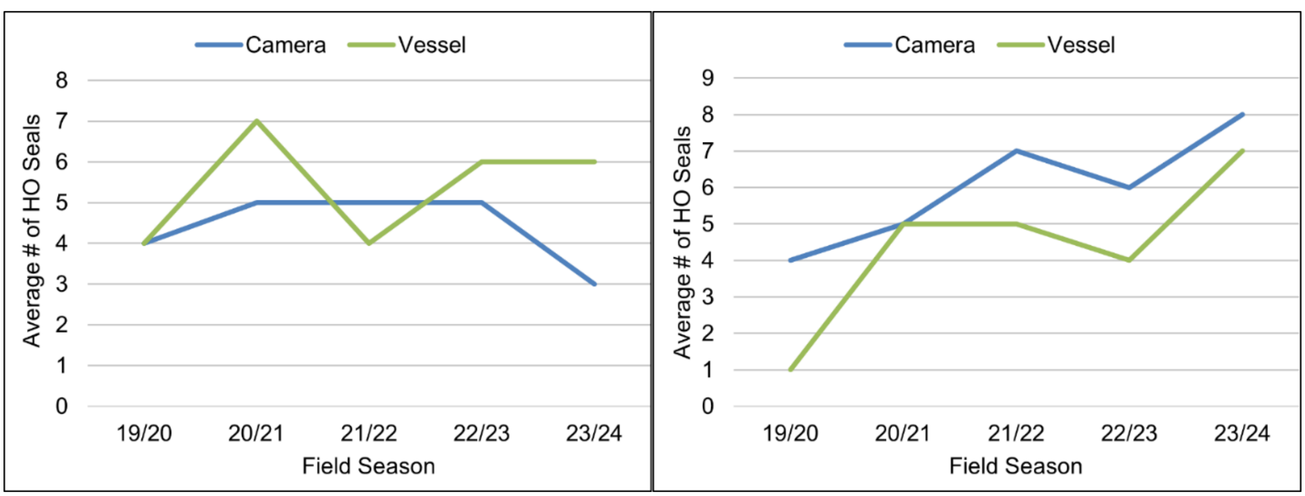


Figure 9. Average seal counts between survey methods at CBBT3 (left) and CBBT4 (right)

Camera failure during the 2022/2023 season resulted in no images collected at CBBT3 for a total of 21 days; and at CBBT4 for a total of 71 days. During the 2023/2024 season, two cameras were deployed at each site at the CBBT survey area, resulting in no days with missed images due to camera failure; however, cameras at CBBT4 were deployed a few days later than CBBT3 due to equipment issues. Since seals were observed at CBBT3 during those few days, this resulted in a loss of 2 days from the occupancy period for CBBT4.

Since the haul-out sites are photographed every 15-minutes, if a seal is hauled out for an hour, it would be counted 4 times in that hour. Therefore, the total seal counts in **Table 5** are not to be interpreted as total number of seals but are presented to provide relative haul-out use by survey area, and an index of haul-out activity across all five seasons (**Table 5**). The trend of the total count of seals has been increasing between seasons, except for the 2022/2023 season where it decreased (likely due to camera failure in that season). This pattern of general increase is evident at both the Eastern Shore and CBBT, as well as with the combined totals.

Table 5. Total seal haul-out count from (all images) for each season at both survey areas

Season	Eastern Shore	CBBT	Total
2019/2020	46,079	4,314	50,393
2020/2021	50,374	8,953	59,327
2021/2022	57,937	12,739	70,676
2022/2023	55,914	11,844	67,758
2023/2024	67,091	14,401	81,492

For the remainder of the report, seal haul-out counts are presented as average number of seals hauled out (the number of seals counted averaged over the number of images where seals were hauled out). Over the five seasons, seals have used eight different haul-out sites at the Eastern Shore (**Figure 2**). The maximum count of hauled-out seals from each haul-out site across each entire season is shown in **Table 6**, with the highest count for each season bolded.

The maximum count at the Eastern Shore was consistently in the low 70s until the 2022/2023 season where the maximum count decreased to 63 seals. This result was followed by an increase in the maximum count of 75 seals, during the 2023/2024 season. The specific haul-out site, where the maximum count of hauled-out seals was recorded, varied between seasons. Only in the 2021/2022 and 2022/2023 seasons was the maximum count on the same site (site A) in back-to-back seasons. However, the next season (2023/2024), there were never more than two seals hauled out on site A at any one time. At the CBBT survey area, only the first two seasons had the highest count of hauled-out seals at CBBT3. At CBBT4, the maximum count increased for the first three seasons but then began to decrease the last two seasons, though maximum counts at CBBT4 remained higher than at CBBT3. At CBBT3, the highest count increased between the first two seasons, remained the same for the second and third seasons, and then increased slightly for the last two seasons.

Table 6. Maximum seal haul-out count obtained at each haul-out site

Haul-out Site		Field Season				
		2019/2020	2020/2021	2021/2022	2022/2023	2023/2024
Eastern Shore	A	0	13	**73**	**63**	2
	B	0	35	1	45	17
	C1	19	15	26	12	18
	C3	27	22	26	41	38
	E1	**72**	47	64	46	**75**
	E2	37	**71**	54	55	74
	E3	28	9	17	34	36
	F	3	8	7	3	9
CBBT	CBBT3	**17**	**20**	20	21	22
	CBBT4	11	18	**29**	**26**	**25**

Note: The site with the highest count per season is bolded

During both the 2022/2023 and 2023/2024 seasons at the Eastern Shore survey area, haul-out site E2 had the highest average seal count (**Figure 10**), with 14 and 16 average seals, respectively. The average seal count obtained at E2 during the 2023/2024 season is the second highest average observed across all seasons. Haul-out sites A and B have not been consistently used across the seasons as no seals were observed on either site during the 2019/2020 season. Haul-out site F also consistently has lower numbers of seals hauled out compared to the other sites.

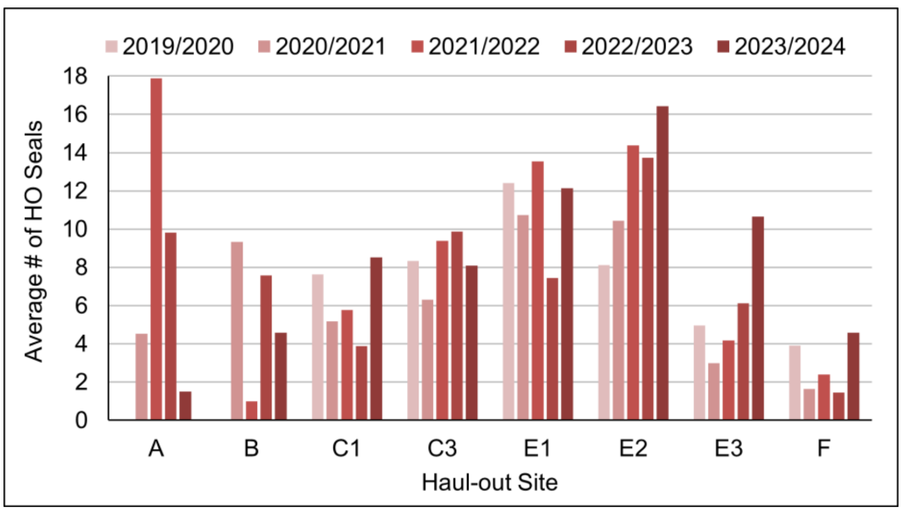


Figure 10. Average seal count at each haul-out site at the Eastern Shore survey area

During both the 2022/2023 and 2023/2024 seasons at the CBBT survey area, CBBT4 had a higher average seal count than CBBT3 (**Figure 11**), which is consistent with all but the first season. The average number of seals at CBBT3 has been declining for the past three seasons, whereas at CBBT4, the numbers have been fluctuating but show an overall increase from 2019-2024.

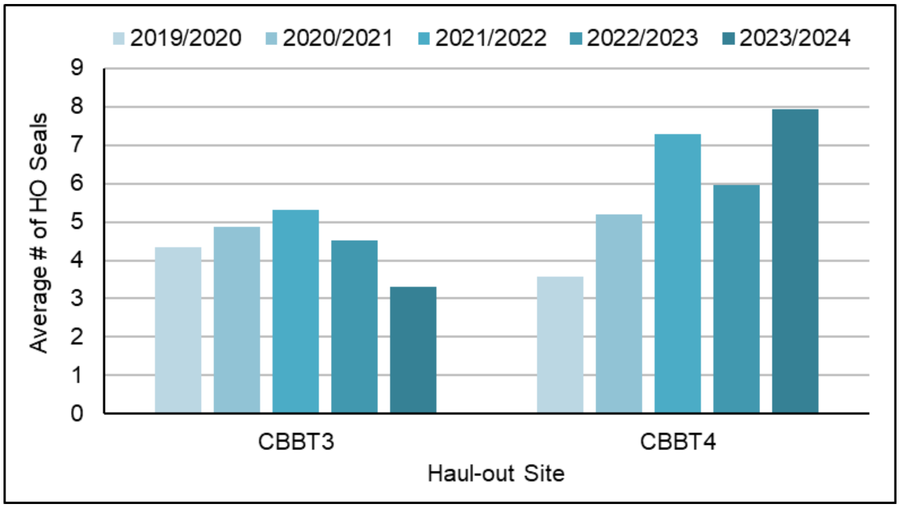


Figure 11. Average seal count at each haul-out site at the CBBT survey area

While the vast majority of the seals appeared to be harbor seals, gray seals (**Figure 12**) were positively identified in 21 different images during the 2022/2023 season and in 12 images during the 2023/2024 season (**Table 7**). Gray seals have only been observed in images between late November and mid-March, with the most observations being in December. During the 2022/2023 season gray seals were observed in November, December, January and February, but during the 2023/2024 season, gray seals were only observed in February and March. The 2022/2023 season is the only season where a gray seal has been observed in November.

Seals with flipper and satellite tags were also known to be present in the area when and where images were recorded based on data from the seal tagging effort at the Eastern Shore study area (Ampela et al., 2023). However, due to image quality, the tags were not easily detectable from the images in previous seasons, and none were recorded during the 2022/2023 or 2023/2024 seasons (**Table 7**).

Table 7. Number of images with gray or tagged seals

Season	Gray Seal Images	Tagged Seal Images
2019/2020	11	11
2020/2021	1	0
2021/2022	61	53
2022/2023	21	0
2023/2024	12	0

Photo taken under NMFS General Authorization Permit #19826

Figure 12. Gray seal (shown in the yellow box) on the Eastern Shore

3.1. Temporal Data

During the 2022/2023 and 2023/2024 seasons at the Eastern Shore, seals were recorded as present (either hauled out or in the water) from October to May (**Figure 13**). No seals were observed hauled out in the month of May during the 2023/2024 season, but a single seal was recorded in the water on three different days in May. The highest average seal count for the 2022/2023 season was in January, whereas during the 2023/2024 season, it was in February. The average quickly decreased after the month of March across all seasons. Results from a one-way ANOVA test showed that the average number of seals hauled out at the Eastern Shore varies significantly by month ($F = 4.187$, $p < 0.001$).

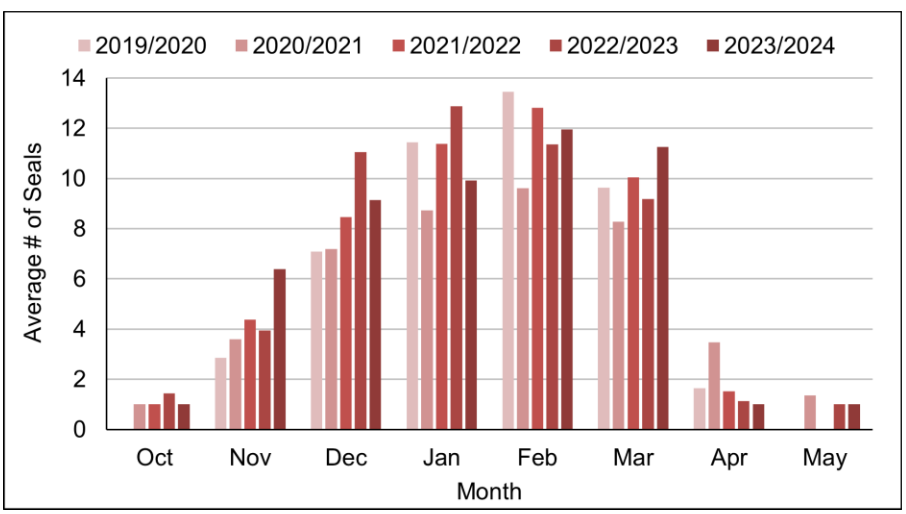
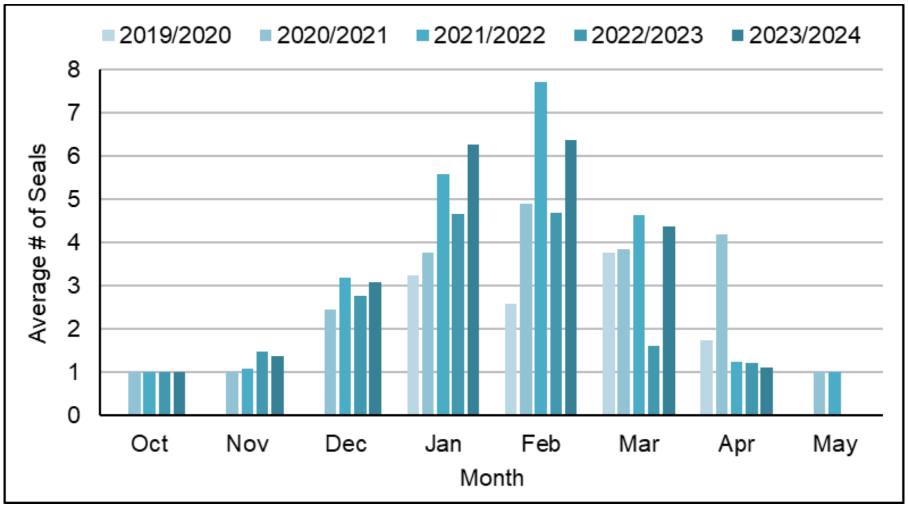


Figure 13. Average seal count by month at the Eastern Shore survey area

During the 2022/2023 and 2023/2024 seasons at the CBBT survey area, seals were recorded from October to April (**Figure 14**). The highest average counts were in February for all seasons except the first (2019/2020). During each season, the average decreased rapidly after March, except for the 2020/2021 season where the average in April was higher than March. Results from a one-way ANOVA test showed that the average number of seals at the CBBT varies significantly by month ($F = 8.254$, $p < 0.001$).



Note: Camera failure during seasons may affect these numbers, see Table 2

Figure 14. Average seal count by month at the CBBT survey area

Seals were observed hauled out on average, in higher numbers about 4 hours after sunrise during the 2022/2023 season and about 7 hours after sunrise during the 2023/2024 season. The 2022/2023 season increased and decreased on either side of its peak more rapidly than the 2023/2024 season. During the 2023/2024 season, the average slowly increased each hour after sunrise until reaching the peak, then decreased (**Figure 15**). Results from a one-way ANOVA test showed that the average number of hauled-out seals at the Eastern Shore was strongly associated with number of hours after sunrise ($F = 26.55$, $p < 0.001$).

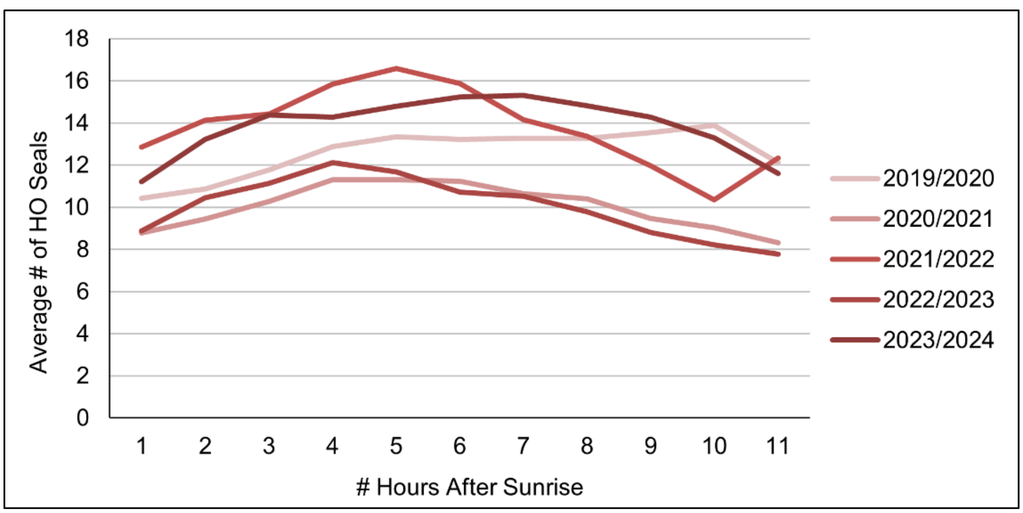


Figure 15. Average seal count by hour at the Eastern Shore survey area

During the 2022/2023 season at the CBBT survey area, the highest average number of seals hauled out was right around sunrise whereas during the 2023/2024 season, the highest was about 7 hours after sunrise (**Figure 16**). Results from a one-way ANOVA test showed that the average number of hauled-out seals at the CBBT varies significantly by the number of hours after sunrise ($F = 6.27$, $p < 0.001$).

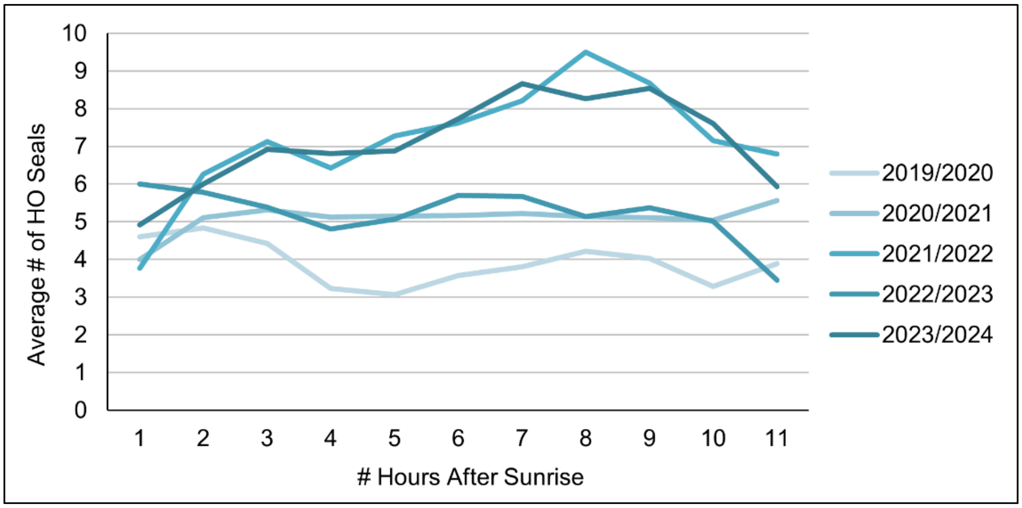


Figure 16. Average seal count by hour at the CBBT survey area

3.2. Environmental Data

3.2.1. Tidal Height

At the Eastern Shore during both the 2022/2023 and 2023/2024 seasons, approximately 30% of seals hauled out when the tide was between 2 and 3 ft, and 25% when the tide was between 1 and 2 ft. This is the opposite result of the prior season (2021/2022) where 34% of seals were hauled out between 1 and 2 ft, and 33% between 2 and 3 ft (**Figure 17**). Results of a Pearson's correlation test show that there was a significant negative correlation between the number of hauled-out seals and tidal height across all seasons ($r = -0.012$, $p < 0.001$).

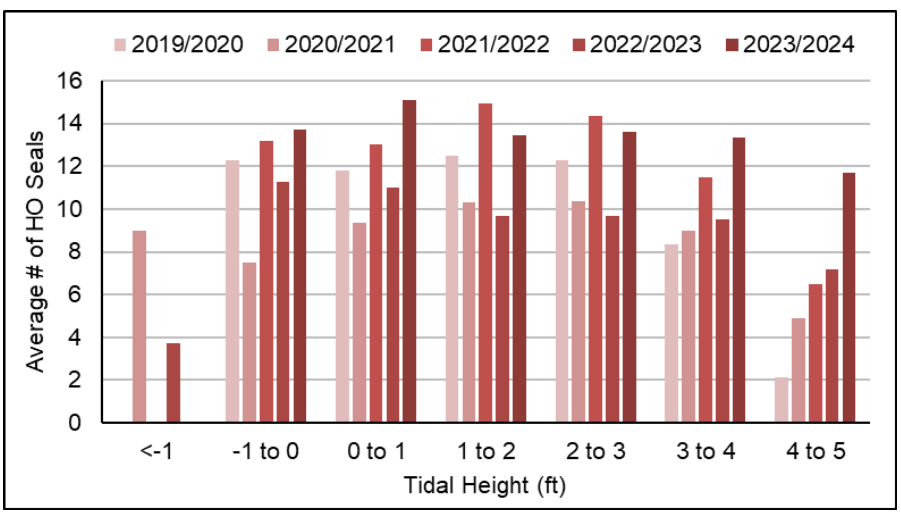


Figure 17. Average seal count by tidal height at the Eastern Shore survey area

At the CBBT during both the 2022/2023 and 2023/2024 seasons, the highest percentage of hauled-out seals was when the tide was between 2 and 3 ft (45% and 35%, respectively), though the 2023/2024 season percentage was lower. This is a different result of the 2021/2022 season where 43% of seals were hauled out between 0 and 1 ft (**Figure 18**). Results of a Pearson's correlation test show that the correlation between the number of hauled-out seals and tidal height was not significant ($p = 0.914$).

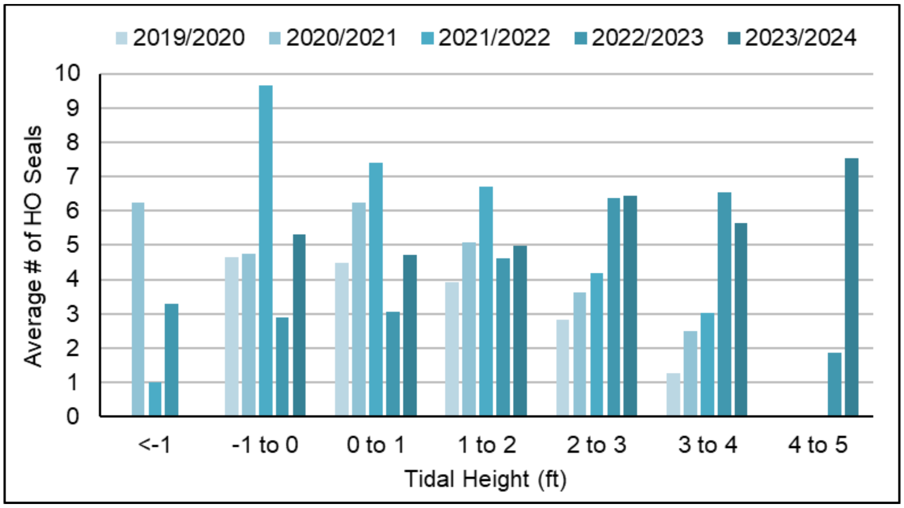


Figure 18. Average seal count by tidal height at the CBBT survey area

3.2.2. Wind Speed

At the Eastern Shore during both the 2022/2023 and 2023/2024 seasons, the highest percentage of hauled-out seals was when the wind speed was between 10 and 15 kts (34% and 33%, respectively). This is a similar result of the prior season (2021/2022) where 34% of seals were hauled out between 10 and 15 kts (**Figure 19**). Results of a Pearson's correlation test show there was a significant negative correlation between the number of hauled-out seals and wind speed ($r = -0.029$, $p < 0.001$).

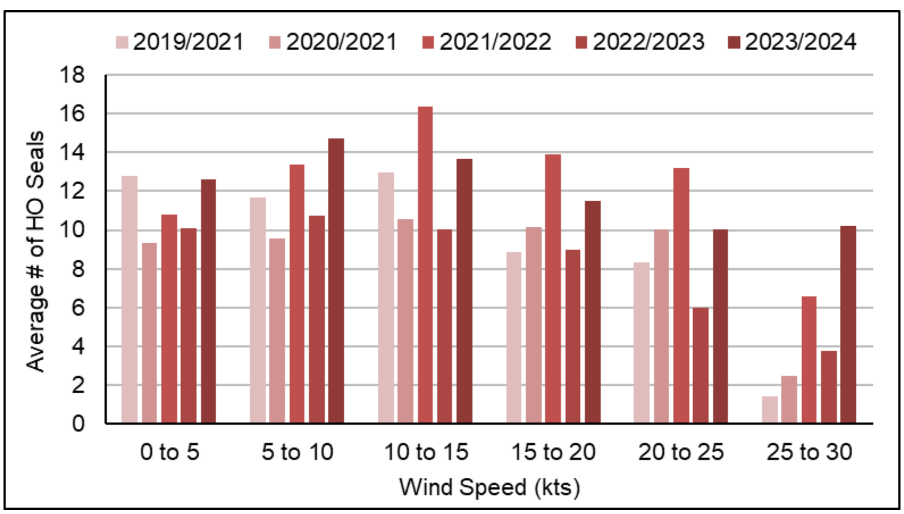


Figure 19. Average seal count by wind speed at the Eastern Shore survey area

At the CBBT during both the 2022/2023 and 2023/2024 seasons, the highest percentage of hauled-out seals was when the wind speed was between 5 and 10 kts (55% and 49%, respectively), though the 2023/2024 season percentage was lower. This is a similar result of the prior season (2021/2022) where 49% of seals were hauled out between 5 and 10 kts (**Figure 20**). Results of a Pearson's correlation test show there was a significant negative correlation between the number of hauled-out seals and wind speed (r = -0.151, p < 0.001).

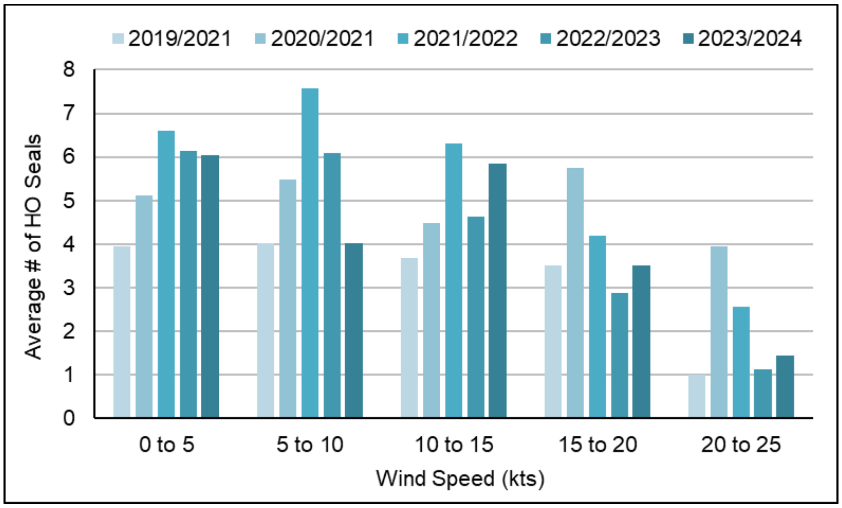


Figure 20. Average seal count by wind speed at the CBBT survey area

3.2.3. Air Temperature

At the Eastern Shore during the 2022/2023 season, the highest percentage of hauled-out seals occurred when the air temperature was between 45 and 55°F (49%), whereas during the 2023/2024 season, the highest percentage was between 35 and 45°F (47%). This is a different result compared to the prior season (2021/2022) where 35% of seals were hauled out between both 35 and 45 and 45 and 55°F (**Figure 21**). Results of a Pearson's correlation test show there was a significant negative correlation between the number of hauled-out seals and air temperature (r= -0.081, p <0.001).

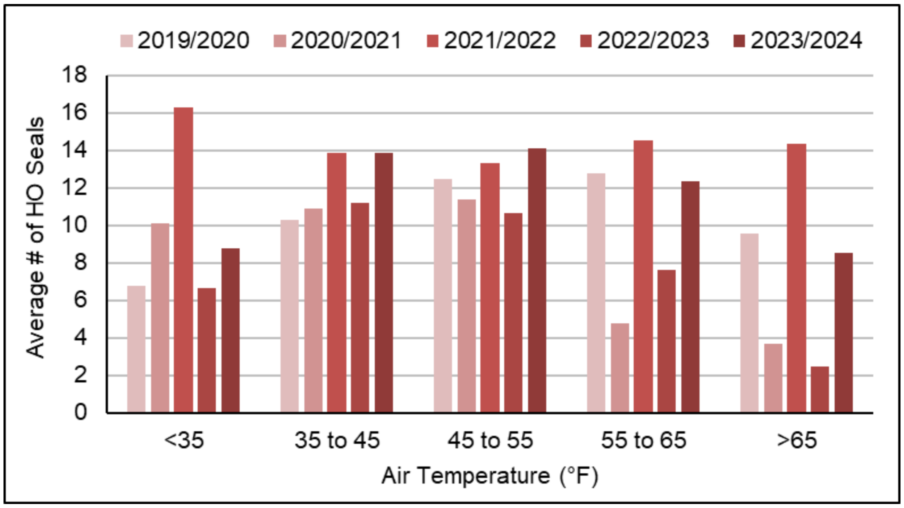


Figure 21. Average seal count by air temperature at the Eastern Shore survey area

At the CBBT during the 2022/2023 season, the highest percentage of hauled-out seals occurred when the air temperature was between 45 and 55°F (52%), whereas during the 2023/2024 season, the highest percentage was between 35 and 45°F (52%). The 2023/2024 season had similar results to the 2021/2022 season where the highest percentage was between 45 and 55°F (45%) (**Figure 22**). Results of a Pearson's correlation test show there was a significant negative correlation between the number of hauled-out seals and air temperature (r = -0.086, p<0.001).

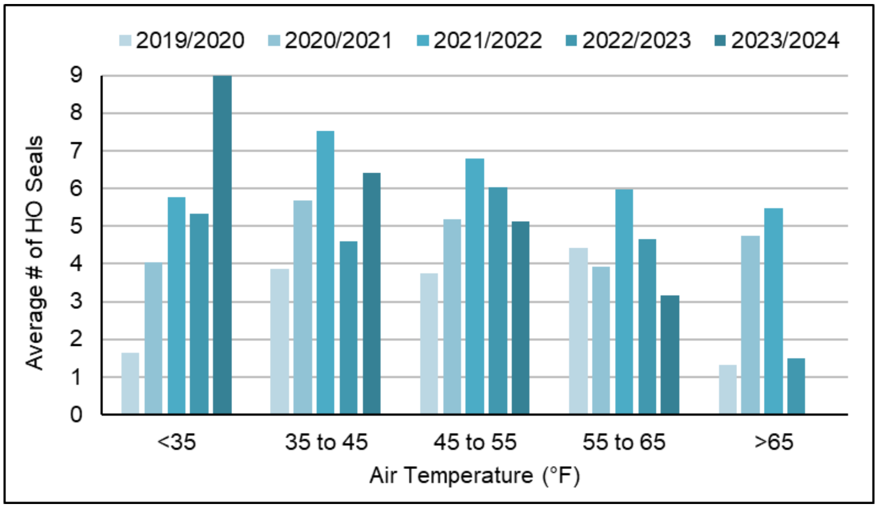


Figure 22. Average seal count by air temperature at the CBBT survey area

3.3. Statistical Analysis

Results from running a GAM for the Eastern Shore and CBBT survey areas showed that seal haul-out counts differed by all five covariates (**Table 8**). Both survey sites showed the highest variability in seal counts between months. Of the environmental covariates, air temperature had the highest variation at the Eastern Shore, while wind speed had the highest variation at the CBBT. AIC results showed the best model for seal haul-out counts at both the Eastern Shore and CBBT included all five covariates (delta-AIC = 0.00, AIC weight = 0.99; delta-AIC = 0.00, AIC weight = 1.00, respectively).

Table 8. GAM results comparing seal haul-out counts to tidal height, wind speed, air temperature, month, and time after sunrise at both survey areas

Covariate	Eastern Shore			CBBT		
	df	F Value	p-value	df	F Value	p-value
Tidal Height	8.35	30.63	<0.001	6.50	16.93	<0.001
Wind Speed	6.13	42.07	<0.001	6.50	138.65	<0.001
Air Temperature	8.67	99.45	<0.001	8.48	41.66	<0.001
Month	7	783.07	<0.001	7	551.18	<0.001
Time After Sunrise	17	40.25	<0.001	15	32.94	<0.001

df = degrees of freedom; GAM = Generalized Additive Model

3.4. Vessel Surveys and Drone Counts

Table 9 and **Table 10** present the data when comparing camera counts to vessel or drone counts at the Eastern Shore or CBBT survey areas. The number in the "Vessel Surveys" column represents the number of hauled-out seals recorded during the respective vessel/drone survey. The number in the "Camera Surveys" column represents the number of hauled-out seals recorded in images just prior to the time of the vessel/drone survey. The number in the "Difference" columns represent the difference in the number of hauled-out seals recorded between camera and vessel/drone counts. A positive value (indicated by a + symbol) in the "Difference" column means that a higher count was recorded from camera surveys and a negative value (indicated by a - symbol) means that a higher count was recorded from the vessel or drone surveys. Any row with a dash (-) in the "Drone Surveys" column for the Eastern Shore survey area indicates that no drone was flown on that date, likely due to high wind speed or precipitation.

For the 2022/2023 season at the Eastern Shore survey area, there were five instances where vessel and camera counts differed and three instances where drone counts and camera counts differed On average, when comparing camera counts to both vessel and drone counts, vessels had higher counts during this season (**Table 9**).

Table 9. Comparison of counts at the Eastern Shore during the 2022/2023 season

Vessel Survey Date	Vessel Surveys		Camera Surveys		Vessel Difference	Drone Difference
	Vessel	Drone	Before Vessel	Before Drone		
11/2/2022	0	0	0	0	0	0
11/18/2022	1	0	0	0	-1	0
12/2/2022	4	-	2	-	-2	-
12/14/2022	23	37	34	36	+11	-1
1/3/2023	0	0	0	0	0	0
1/24/2023	35	66	10	47	-25	-19
2/21/2023	16	25	11	18	-4	-7
2/28/2023	16	14	16	14	0	0
3/16/2023	0	0	0	0	0	0
				Average	**-2.33**	**-3.36**

- = the drone was not flown that survey

For the 2022/2023 season at the CBBT survey area, there were five instances of vessel and camera counts differing, but only one of those indicated a higher count from vessel surveys. Overall, the camera counts were slightly lower than vessel counts for seals at the CBBT survey area (**Table 10**).

Table 10. Comparison of counts at the CBBT during the 2022/2023 season

Vessel Survey Date	Vessel Surveys	Camera Surveys	Difference
11/2/2022	0	0	0
11/18/2022	0	0	0
12/2/2022	0	0	0
12/14/2022	0	0	0
1/3/2023	0	0	0
1/18/2023	15	6	-9
2/2/2023	0	1	+1
2/21/2023	9	11	+2
3/16/2023	1	2	+1
3/29/2023	1	2	+1
		Average	**-0.4**

For the 2023/2024 season at the Eastern Shore survey area, there were six instances where vessel observers and camera counts differed, and two instances of drone counts and camera counts differing. Cameras offered higher counts than the vessel surveys; however, drone counts were on average higher than the camera counts (**Table 11**).

Table 11. Comparison of counts at the Eastern Shore during the 2023/2024 season

Vessel Survey Date	Vessel Surveys		Camera Surveys		Vessel Difference	Drone Difference
	Vessel	Drone	Before Vessel	Before Drone		
11/2/2023	0	0	0	0	0	0
11/15/2023	2	1	2	1	0	0
12/1/2023	9	-	7	-	-2	-
12/12/2023	16	16	16	16	0	0
1/3/2024	0	0	0	0	0	0
1/22/2024	16	21	23	21	+7	0
2/8/2024	24	39	34	42	+10	+3
2/22/2024	0	36	38	33	+38	-3
3/4/2024	45	-	57	-	+12	-
3/26/2024	1	-	0	-	-1	-
				Average	**+6.4**	**0**

- = the drone was not flown that survey

For the 2023/2024 season at the CBBT survey area, there were five instances of vessel and camera counts differing, but only one of those indicated a higher count from vessel surveys. Upon averaging the differences for each vessel survey, there was no overall difference between vessel survey counts and camera counts (**Table 12**)**.**

Table 12. Comparison of counts at the CBBT during the 2023/2024 season

Vessel Survey Date	Vessel Surveys	Camera Surveys	Difference
11/3/2023	0	0	0
11/15/2023	0	0	0
12/4/2023	0	0	0
12/15/2023	0	7	+7
1/3/2024	6	9	+3
1/22/2024	34	19	-15
2/9/2024	0	1	+1
2/26/2024	0	0	0
3/12/2024	4	5	+1
		Average	**-0.33**

During four out of the five seasons, cameras had a higher average count than vessels at the Eastern Shore, the 2022/2023 season being the difference where vessels had a higher average count. Drone surveys had higher average counts in three out of the five seasons, the 2021/2022 season had a higher average camera count, and the 2023/2024 season had no difference between the two. At the CBBT the 2019/2020 season had no difference in counts between the two survey methods. The 2020/2021 and 2021/2022 seasons had higher average vessel counts, but the 2022/2023 and 2023/2024 seasons had higher camera counts. When averaging the results across all five seasons, cameras recorded more seals on average than vessels at both survey areas but recorded less on average than drones at the Eastern Shore survey area (**Table 13**).

Table 13. Overall average differences between survey methods for all seasons

Season	Eastern Shore		CBBT
	Vessel	Drone	
2019/2020	+1.72	-3.8	0
2020/2021	+1.4	-2.75	+0.08
2021/2022	+1.15	+3	+0.33
2022/2023	-2.33	-3.36	-0.4
2023/2024	+6.4	0	-0.33
Average	**+1.67**	**-1.38**	**+0.06**

+ Difference = higher camera survey count
- Difference = higher vessel/drone survey count

3.5. Vessel Presence

During the 2022/2023 season at the Eastern Shore survey area, vessels were counted on 28.8% of the survey days. The highest vessel presence for a single day was on 10 February, with an average of 1.34 vessels per image. During the 2023/2024 season, vessels were counted on 29.4% of the survey days. The highest vessel presence for a single day was 5 April, with an average of one vessel per image. October, November, and February are the only months during the 2022/2023 season where the average number of vessels was greater than one, meaning that the other months only had one vessel in an image at a time. October and March were the only months with a daily average greater than one during the 2023/2024 season (**Figure 23**).

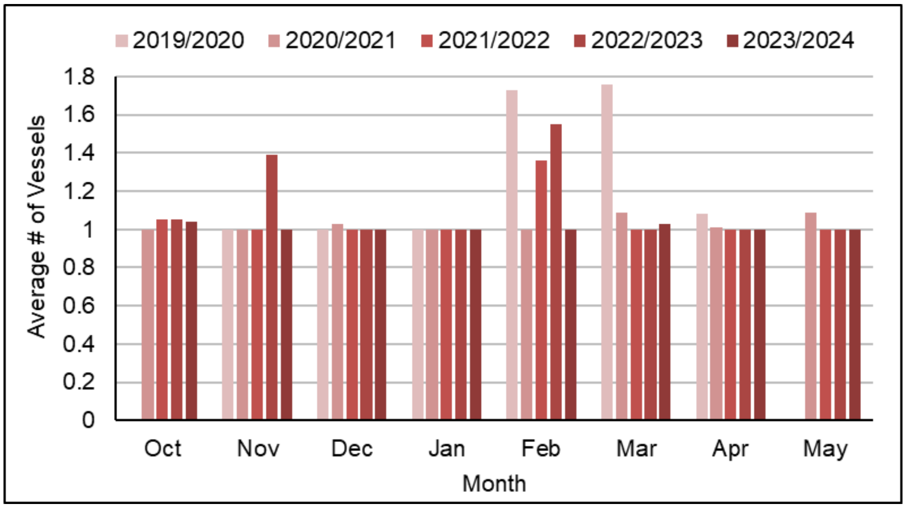


Figure 23. Average vessel count by month at the Eastern Shore survey area

During the 2022/2023 season at the CBBT survey area, vessels were counted in 51.4% of the survey days. The highest vessel presence in a single day was on 26 October, with an average of 2.2 vessels per image. During the 2023/2024 season, vessels were counted on 49.5% of the survey days. The highest vessel presence for a single day was 29 October, with an average of 3.5 vessels per image (**Figure 24**).

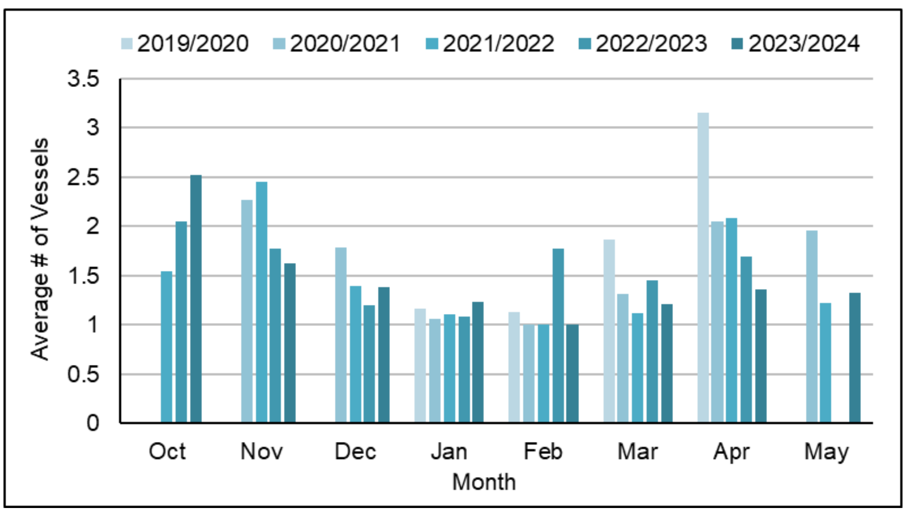


Figure 24. Average vessel count by month at the CBBT survey area

The number of images with both vessels and hauled-out seals are shown in **Table 14** to indicate the number of instances where seals tolerated vessels near the haul-out sites. During the 2022/2023 season at the Eastern Shore survey area, images with both hauled-out seals and vessels only increased by one from the previous season whereas the 2023/2024 season decreased to a single image. At the CBBT survey area, the 2022/2023 season remained consistent with the prior season with 100 images, but the 2023/2024 season increased by 44 images (**Table 14**).

Table 14. Number of images with vessels and hauled-out seals at both survey areas

Season	Vessels and HO Seals		HO Seals Only		Vessels Only	
	ES	CBBT	ES	CBBT	ES	CBBT
2019/2020	15	42	3935	1110	444	1104
2020/2021	4	201	5110	1761	267	2424
2021/2022	2	100	4176	1867	493	2014
2022/2023	3	100	5609	2206	315	1131
2023/2024	1	144	4936	2325	255	1930

HO = hauled out

Instances where vessels appeared to be the cause of seals flushing from a haul-out site are shown in **Table 15** through **Table 18.** The number of seals hauled out before and after vessel appearance is noted as well as the time between the flushing to the next recorded haul-out activity. For the Eastern Shore survey location, the haul-out site is also shown to indicate if subsequent haul-out activity occurred at the same location as the flush event.

In the 2022/2023 season, there were 27 instances of seals flushing after a vessel was present at the Eastern Shore (**Table 15**). The range of time for at least one seal to haul out was from 15 minutes to 21.5 hours, with an average of 5 hours. In 42.9% of the instances where seals flushed after the appearance of a vessel, subsequent haul-out activity was recorded at the same haul-out site. Since seals are not individually identified, there is no way to determine if the seals that hauled out after the flushing are the same or a new individual or group.

Table 15. Instances of seals flushing due to vessel presence at the Eastern Shore survey area during the 2022/2023 season

Flush		# of Vessels	# of Seals HO		Next HO		Time Till Next HO
Time	HO Site		Before	After	Time	HO Site	
11/15/22 8:57	E2	1	3	0	11/15/22 9:13	E1	12:16
11/23/22 14:27	E2	2	1	0	11/23/22 15:57	E2	1:30
11/29/22 11:33	C3	1	4	0	11/30/22 6:58	E1	19:25
12/2/22 7:57	E1/E2	1	15	1	12/2/22 8:12	E2	0:15
12/2/22 8:42	E2	1	3	0	12/2/22 11:43	E1	3:01
12/2/22 11:58	E1	1	1	0	12/2/22 12:13	E1	0:15
12/5/22 11:12	E2	1	15	0	12/5/22 15:43	E1	4:31
12/11/22 11:28	E1	1	8	0	12/11/22 11:43	E3	0:15
12/14/22 10:19	E3	1	3	0	12/14/22 12:34	C3	2:15
1/1/23 11:08	E2	1	41	0	1/1/23 11:23	E2	0:15
1/6/23 11:30	A	1	10	0	1/6/23 11:45	A	0:15
1/24/23 13:30	A	1	9	4	1/25/23 7:13	E2	17:43
2/7/23 10:02	A/C3	2	43	0	2/8/23 7:02	E1	21:00
2/8/23 10:02	A/B/C3/E1/E2	2	44	0	2/8/23 12:47	E1	2:45
2/8/23 13:58	E1/E2	1	2	0	2/8/23 14:58	E2	1:00
2/9/23 11:06	A/E1	2	29	0	2/10/23 7:09	A	20:05
2/10/23 10:58	C1/C3/E1/E2	1	28	0	2/10/23 17:43	E2	6:55
2/14/23 14:17	E1	2	22	0	2/14/23 16:47	E1	2:30
2/15/23 15:16	B/E1	2	30	0	2/15/23 16:47	E1	1:31
2/19/23 15:01	E1	1	5	1	2/19/23 16:47	E1	1:46
2/21/23 8:47	A/E1	1	15	0	2/21/23 9:32	E1	0:45
3/2/23 14:02	A/E1	1	9	1	3/2/23 14:17	E1	0:15
3/18/23 14:50	E2	1	12	11	3/18/23 15:05	E2	0:15
3/21/23 10:30	A	1	10	5	3/21/23 10:45	A	0:15
3/23/23 11:30	A/E1	1	27	0	3/23/23 11:48	E1	0:18
4/12/23 12:03	E1	1	1	0	4/12/23 13:03	E1	1:00
4/25/23 13:18	E1	1	1	0	4/26/23 10:48	E1	21:30

HO = haul-out or hauled out
Note: the time between haul outs is shown in hour: minute format

In the 2022/2023 season, there were 22 instances of seals flushing after a vessel was present at CBBT3 and 13 instances at CBBT4 (**Table 16**). The amount of time it took for at least one seal to haul out again after the flushing event ranged from 15 minutes to 103 hours, with an average of about 18 hours.

Table 16. Instances of seals flushing due to vessel presence at the CBBT survey area during the 2022/2023 season

HO Site	Time of Flush	# of Vessels	# of Seals HO		Time of Next HO	Time Till Next HO
			Before	After		
CBBT3	12/2/22 11:30	1	2	0	12/4/22 15:45	52:15
	12/14/22 09:00	1	1	0	12/14/22 15:45	6:45
	12/17/22 09:45	1	6	0	12/17/22 10:30	0:45
	12/17/22 12:15	1	1	0	12/17/22 15:30	4:15
	12/21/22 12:00	1	1	0	12/25/22 7:00	103:00
	12/27/22 10:00	1	3	0	12/28/22 7:00	9:00
	12/29/22 8:30	2	11	0	12/30/22 7:00	22:30
	12/30/22 7:15	1	8	6	1/1/23 10:00	50:45
	12/30/22 10:15	1	3	0	1/1/23 10:00	47:45
	1/2/23 10:00	1	10	0	1/4/23 10:15	48:15
	1/18/23 14:00	1	6	0	1/19/23 8:45	18:45
	1/29/23 8:00	1	4	2	1/29/23 8:45	0:45
	1/29/23 9:45	2	5	0	1/31/23 9:15	47:30
	2/14/23 11:15	1	2	1	2/15/23 6:45	19:30
	2/14/22 13:45	1	1	0	2/15/23 6:45	17:00
	2/19/23 11:30	1	13	11	2/19/23 11:45	0:15
	2/19/23 12:15	1	18	9	2/19/23 12:45	0:30
	2/19/23 14:30	1	8	0	2/20/23 12:15	21:45
	2/20/23 14:15	1	2	1	2/21/23 9:30	19:15
	3/6/23 11:45	1	1	0	3/7/23 8:15	20:30
	4/14/23 8:45	2	1	0	4:15/23 8:30	23:45
	4/15/23 8:45	1	1	0	4/17/23 12:00	51:15
CBBT4	12/29/22 12:45	1	3	1	12/29/22 13:00	0:15
	12/30/22 13:45	2	5	3	12/31/22 13:15	23:30
	1/2/23 9:00	1	11	5	1/2/23 9:15	0:15
	1/2/23 9:30	1	6	0	1/2/23 12:30	3:00
	1/30/23 12:15	1	10	1	1/30/23 12:30	0:15
	2/5/23 12:15	1	10	7	2/5/23 12:45	0:30
	2/5/23 14:00	1	8	7	2/5/23 14:15	0:15
	2/14/23 10:00	1	3	0	2/14/23 11:30	1:30
	2/15/23 11:15	1	12	0	2/25/23 11:30	0:15
	2/26/23 11:30	2	3	0	2/27/23 6:30	19:00
	3/5/23 13:00	1	6	4	3/5/23 13:30	0:30
	3/6/12 11:15	1	1	0	3/6/23 11:30	0:15
	3/16/23 8:15	1	1	0	3/26/23 8:30	0:15

HO = haul-out or hauled out; Note: the time between haul outs is shown in hour: minute format

In the 2023/2024 season, there were 20 instances of seals flushing after a vessel was present at the Eastern Shore (**Table 17**). The amount of time it took for at least one seal to haul out again ranged from 21 minutes to 19 hours, with an average of about 4 hours. In 56% of the instances where seals flushed from a vessel, the next time seals hauled out was on the same haul-out site.

Table 17. Instances of seals flushing due to vessel presence at the Eastern Shore survey area during the 2023/2024 season

Flush		# of Vessels	# of Seals HO		Next HO		Time Till Next HO
Time	HO Site		Before	After	Time	HO Site	
11/6/23 15:09	E2	1	1	0	11/6/24 15:30	E2	0:21
11/15/23 13:23	E2	1	2	0	11/15/23 16:30	E2	3:07
11/24/23 9:08	E2	1	9	0	11/24/23 14:15	E2	5:07
12/1/23 9:40	E1	1	8	1	12/1/23 10:39	E3	0:59
12/4/23 13:40	E2	1	25	0	12/5/23 07:15	E2	17:35
12/12/23 10:06	E2	1	16	0	12/12/23 17:14	E1	7:08
12/31/23 9:54	E2/C3	1	30	0	12/31/23 10:31	E2	0:37
1/22/24 15:08	E2	1	16	0	1/22/24 16:55	E1	1:47
1/23/24 14:35	E1/E2	1	43	0	1/23/24 14:57	E2	0:24
2/8/24 11:03	E1/E2/E3	1	35	0	2/8/24 15:14	E1	4:11
2/15/24 10:14	E2	1	45	0	2/15/24 10:59	E1	0:45
2/25/24 11:02	E1/E2	1	35	0	2/25/24 13:14	E1	2:12
2/27/24 11:29	E1	1	16	0	2/27/24 12:59	E2	1:30
3/4/24 9:32	E2	1	58	0	3/4/24 16:59	E2	7:27
3/16/24 12:17	E2	1	14	0	3/17/24 7:29	E1	19:13
3/17/24 11:10	E1	1	12	0	3/17/24 16:40	E1	5:30
3/26/24 14:02	E2	1	1	0	3/26/24 16:59	E1	2:57
3/30/24 14:10	E1	1	1	0	3/30/24 16:55	E1	2:45
4/4/24 6:55	E1	1	1	0	4/4/24 7:44	E1	0:49
4/14/24 11:20	E1	1	1	0	4/14/24 18:14	E1	6:54

HO = haul-out or hauled out
Note: the time between haul outs is shown in hour: minute format

In the 2023/2024 season, there were 34 instances of seals flushing after a vessel was present at CBBT3 and 20 instances at CBBT4 (**Table 18**). The amount of time it took for at least one seal to haul out again after seals flushed ranged from 15 minutes to 45 hours, with an average of about 7 hours.

Table 18. Instances of seals flushing due to vessel presence at the CBBT survey area during the 2023/2024 season

HO Site	Time of Flush	# of Vessels	# of Seals HO		Time of Next HO	Time Till Next HO
			Before	After		
CBBT3	11/16/23 17:30	1	3	0	11/17/23 8:45	13:15
	11/17/23 10:15	1	1	0	11/17/23 17:30	9:15
	11/19/23 16:15	1	1	0	11/19/23 17:15	1:00
	11/19/23 17:45	1	1	0	11/20/23 8:00	12:15
	11/24/23 8:45	1	1	0	11/24/23 9:45	1:00
	11/24/23 10:15	1	1	0	11/25/23 15:15	29:00
	11/30/23 15:15	2	1	0	12/1/23 7:45	16:30
	12/9/23 10:30	2	1	0	12/9/23 11:15	0:45
	12/9/23 12:15	1	4	3	12/9/23 12:45	0:30
	12/9/23 13:00	2	4	1	12/9/23 13:15	0:15
	12/9/23 13:30	1	2	1	12/9/23 13:45	0:15
	12/9/23 14:00	1	2	1	12/9/23 14:45	0:45
	12/9/23 15:00	1	2	0	12/9/23 17:45	2:45
	12/9/23 17:45	1	1	0	12/11/23 10:53	41:08
	12/12/23 6:03	1	1	0	12/13/23 12:18	18:15
	12/15/23 11:03	1	1	0	12/16/23 8:48	21:45
	12/16/23 9:03	1	1	0	12/16/23 12:33	3:30
	12/16/23 13:18	3	1	0	12/16/23 13:48	0:30
	12/16/23 14:03	1	1	0	12/18/23 10:33	45:15
	12/22/23 14:18	2	1	0	12/23/23 10:30	20:12
	12/23/23 10:45	1	1	0	12/23/23 11:00	0:15
	12/23/23 12:30	1	6	4	12/23/23 12:45	0:15
	12/23/23 13:15	1	5	1	12/23/23 15:00	2:45
	12/24/23 14:00	1	3	1	12/24/23 14:45	0:45
	12/24/23 15:00	1	4	2	12/25/23 8:15	17:15
	12/29/23 11:30	1	1	0	12/30/23 8:30	21:00
	12/31/23 12:00	1	2	1	12/31/23 12:15	0:15
	12/31/23 12:45	1	2	0	1/1/24 7:30	18:45
	12/31/23 17:00	1	1	0	12/31/23 17:30	0:30
	1/3/24 13:45	1	1	0	1/3/24 16:30	2:45
	1/18/24 11:45	1	11	9	1/18/24 12:00	0:15
	1/22/24 10:45	1	14	13	1/22/24 11:15	0:30
	2/18/24 14:24	1	2	0	2/18/24 16:39	3:15
	3/3/24 9:09	1	2	0	3/3/24 9:24	0:15

Table 18. Instances of seals flushing off the haul-out site due to vessel presence at the CBBT survey area during the 2023/2024 season (continued)

HO Site	Time of Flush	# of Vessels	# of Seals HO		Time of Next HO	Time Till Next HO
			Before	After		
CBBT4	12/4/23 8:27	1	1	0	12/5/23 17:12	32:45
	12/22/23 11:25	1	13	0	12/22/23 11:55	0:30
	12/22/23 12:10	1	3	0	12/22/23 14:25	2:15
	12/23/23 10:45	1	9	1	12/23/23 17:45	7:00
	12/24/23 14:00	2	2	0	12/24 23 15:30	1:30
	12/24/23 15:45	2	1	0	12/24/23 17:00	1:15
	12/25/23 12:15	1	5	1	12/25/23 12:30	0:30
	12/29/23 14:29	1	2	0	12/29/23 14:44	0:15
	12/29/23 14:59	2	2	1	12/29/23 15:14	0:15
	12/29/23 15:44	1	6	0	12/29/23 15:59	0:15
	12/31/23 14:44	1	17	16	12/31/23 14:59	0:15
	1/3/24 10:59	1	8	7	1/3/24 11:44	0:45
	1/3/24 13:44	1	3	0	1/3/24 15:44	2:00
	2/8/24 12:11	1	6	5	2/8/24 12:26	0:15
	3/3/24 11:14	1	10	7	3/3/24 14:44	3:30
	3/12/24 14:13	1	5	4	3/12/24 14:28	0:15
	3/13/24 8:28	1	5	4	3/13/24 10:58	2:30
	3/13/24 12:13	1	2	0	3/13/24 12:28	0:15
	3/13/24 14:58	1	4	3	3/13/24 16:28	2:30
	3/14/24 9:58	3	7	0	3/14/24 14:28	4:30

HO = haul-out or hauled out
Note: the time between haul outs is shown in hour: minute format

4. Discussion

Results from five seasons of effort show that time-lapse camera surveys are an effective means of collecting seal haul-out activity data. The data collected provides a clear visual record of events that would otherwise be difficult to capture in near real-time. In addition, these data continue to improve our understanding of localized seal haul-out activity, especially in relation to environmental factors and human disturbance.

The benefits demonstrated by this effort to use time-lapse camera counts for seal monitoring include:

- 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;
- the relatively low personnel demands to collect data;
- the low set-up cost; and
- the ability to collect data with limited disturbance to the seals.

While there are great benefits in using time-lapse cameras to collect data, there are limitations, including camera failure, limitations on image quality, and the intense labor effort to process the large volume of images. One challenge experienced this reporting period was the large number of camera failure days at the CBBT in the 2022/2023 seal occupancy season (**Table 1**), which resulted in inconsistent sampling effort and an incomplete dataset for that season. The unequal effort could potentially bias results depending on seal behavior during the camera failures, which could lead to inaccurate conclusions.

To reduce chances of camera failure following the 2022/2023 season, in 2023/2024 at the CBBT study area, the failed Stealth cameras were replaced and CuddeLink cellular cameras were installed as back-up cameras. The cellular capabilities of the CuddeLink cameras allowed us to monitor camera operation in near real time, and in the event of camera failure, we could quickly replace or repair the issue. However, the 20 MP resolution of the CuddeLink images was inferior to the Stealth images, and the photo resolution/quality for the distance to the haul-out sites at the CBBT3 haul-out site was not ideal. Therefore, for the 2023/2024 season, CuddeLink images from the CBBT were only used during periods of Stealth camera failure (a total of 42 days or 21% of images). The use of CuddeLink images resulted in a much lower camera failure rate (2 days or 1%), but due to the lower image resolution, there was lower confidence of the counts at CBBT3 on the days CuddeLink images were used, especially for seals that were hauled out amongst the rocks at the farthest point from the camera.

For the 2024/2025 season new Stealth Deceptor™ Max Cellular cameras were installed at the CBBT study area. This type of camera is operated with solar power and battery back-up, can be monitored regularly via cellular, and captures the higher resolution (40 MP) images needed at this location. Using the newer Stealth cameras should eliminate camera failure and image quality issues experienced in previous seasons.

Data was presented in the form of averages (number of seals recorded divided by the total number of images with seals recorded per designated time frame) rather than totals to better represent the relative presence of seals during each designated time frame. The total count was provided in **Table 5** for reference but is not to be interpreted as the total number of seals in the area but rather the total number of times a seal was recorded in an image across the entire field season. All other analyses of seal counts are in the form of averages by site, month, hours post-sunrise, or within the designated interval for the environmental data.

In most cases, images from the camera surveys were not of high enough quality to identify seals to species. Therefore, vessel surveys must be relied upon to provide the frequency of harbor versus gray seals occurring at each of the survey areas (Jones, 2024). There are a couple of exceptions to this at the Eastern Shore where the seals haul out within about 20 meters of the camera. At the Eastern Shore survey area, the ability to positively identify a gray seal has occurred at A, E1, E2, and C3, with most gray seal sightings at haul-out site C3. Due to the distance from the cameras to the tip of the rock islands at the CBBT survey area, gray or tagged seals are not able to be positively identified.

Seasonal patterns showed that seals generally hauled out in greater numbers in the months of January, February, and March (**Figure 13** and **Figure 14**). Both the Eastern Shore and CBBT survey areas had significant results from a one-way ANOVA test indicating that the average number of hauled out seals can be predicted by month. These results are similar to other studies monitoring seal presence in the western Atlantic. Seals in Massachusetts have been observed regularly October through May, with the number of seals rapidly declining in May (Schneider & Payne, 1983). Seal monitoring efforts in Narragansett Bay, Rhode Island have also observed seals arriving in November and departing in April, with peak numbers in March (Naval Undersea Warfare Center, 2024). Observers monitoring a seasonal haul-out site in southern New Jersey also found that seals were present from October to May (Toth, 2018). At the southernmost extent of their established range at Green Island in North Carolina, seals have been observed arriving later, in December, but still departing by May (Pepper et al., 2024). This site in North Carolina also records peak numbers of seals in February, similar to counts in Virginia.

In comparison to earlier vessel surveys, the camera surveys demonstrate that harbor seals consistently haul out at both the Eastern Shore and CBBT survey areas from October to May (**Table 2**, **Figure 13,** and **Figure 14**). This is an update to previous assumptions that seal occupancy ranged from November to April. While seals are in the area in very low numbers in October and May, the documentation of two additional months of seal occupancy is an important finding for monitoring changes in seal occupancy over time in Virginia.

Previous annual reports for this project presented the temporal data as time of day but after further investigation it was determined that an improved method for analyzing that data would be to compare counts to the number of hours after sunrise. This change was made because Daylight Savings Time alters what time sunrise is throughout the year and if the haul-out patterns of seals are affected by sunlight, then the data would not be entirely accurate. Seals are not aware of the concept of time of day and are rather on diel cycles from the sun/moon, so the data was normalized for this report to better represent this. When comparing the amount of time after sunrise to the amount of seals that were hauled out at the Eastern Shore, all seasons seemed to follow the same general pattern of increasing counts between four and seven hours post-sunrise, followed by a decrease in counts (**Figure 15)**. At the CBBT, there appeared to be a slight dip in counts around four hours after sunrise but an increase later in the afternoon (**Figure 16**). These patterns could be a result of the seals following the tidal cycle. Schneider & Payne (1983) compared seal counts in Massachusetts to time before and after low tide and found that seal counts increased leading up to low tide and decreased after the fact. One-way ANOVAs ran for data on both survey areas found that average seal counts significantly differed by time post-sunrise. However, at both survey areas, images taken near sunset or sunrise were darker and were therefore more difficult to count to obtain accurate counts of the seals. This could affect the accuracy of the counts taken around these times.

Harbor seal pupping occurs from April to June in the northwest Atlantic (Marine Mammals of Maine, 2024). In the early 1900s, harbor seal births were noted to occur along the shores of Maine, Massachusetts, New Hampshire, Rhode Island, and Connecticut (Allen, 1942), but surveys in 1978 and 1988 observed no pupping south of Maine (Temte et al., 1991). In 2021 pupping was observed near Long Island, New York (Schwach, 2021), and in April 2023, a harbor seal pupping event observed on camera at the Eastern Shore survey area. The April 2023 recording is the first documented seal pupping event in Virginia that we are aware of (Guins et al., in press). With seal pupping season in Maine starting in April, and seal occupancy season in Virginia extending through May, it is possible that pupping could shift to more southern locations. With more recent evidence of pupping occurring south of Maine, factors related to the effects of climate change, shifts in seal distribution, or the recolonization of areas of historical occurrence could be contributing to fluctuations in pupping behavior.

Monitoring trends in haul-out behavior in relation to environmental factors over time allows for the observation of potential adaptation to changing environmental conditions due to climate change. It also allows for the observation of what type of conditions are optimal for a seal to haul out. The influence of tidal height on haul-out activity is likely due to the availability of the haul-out sites during the tidal cycle. Schroeder (2000) noted that most seal haul-out activity along the western Atlantic coast is highly affected by the tidal cycle. During high tide at the Eastern Shore, most of the sites are under water, which is also true for haul-out sites in New Jersey and Massachusetts (Moll et al., 2017; Schneider & Payne 1983). There was a slightly negative correlation between the average number of seals hauled out and the tidal height at the Eastern Shore. At the CBBT, there was no significant relationship between average counts and tidal height.

Higher wind speeds may result in the air being cooler than what is optimal for hauled out seals for thermoregulatory requirements. The effect of wind speed on hauled-out harbor seals depends on the local topography, as some sites may be more sheltered or offer more protection from the wind (Granquist & Hauksson, 2016). Wind speed had a negative correlation with the average number of hauled-out seals at both the Eastern Shore and CBBT; however, the CBBT survey area had a lower negative correlation than the Eastern Shore. These results show that wind speed has a more drastic effect on seals hauled out at the CBBT, likely due to that area being more exposed to stronger wind gusts from the Chesapeake Bay and the potential for water spray/splashing from higher winds around the rocks where the seals haul out. This negative relationship with wind speed has also been observed at sites near New Jersey and Rhode Island (Moll et al., 2017; Norris, 2007).

Thermoregulation is very important to harbor seals and is managed by going in and out of the water as needed (Aarts et al., 2016; Godsell, 1988). Too high of an ambient temperature can cause thermal stress and overheating in hauled-out seals (Norris, 2007). Hansen & Lavigne, (1997) noted that at air temperatures higher than 86°F, cases of stress in adults and hyperthermia in juveniles increased. There was only one instance in the five seasons where a seal was hauled out at an air temperature higher than 86°F, which was on May 19, 2021, at an air temperature of 88.34°F. Both survey areas also showed a negative correlation between haul-out average and air temperature, which is similar to studies conducted in Rhode Island and Massachusetts (Norris, 2007; Schneider & Payne, 1983).

Results of the GAM for both the Eastern Shore and CBBT survey areas showed that variation in seal counts was statistically correlated with the five covariates (**Table 8**). Air temperature resulted in the highest level of variation between seal counts at the Eastern Shore whereas wind speed had the highest variation at the CBBT. As mentioned above, both air temperature and wind speed are factors in the thermoregulatory management by the seals and wind speed having more drastic effects on the seals at the CBBT, so these results are not shocking. Using AIC values to determine the best-fit model for the data allows us to see what combination of the covariates has the highest influence on the seal counts. The best fit model for the Eastern Shore survey area included all five covariates, meaning that the combination of tidal height, wind speed, air temperature, month and hours post-sunrise is the best predictor for the number of hauled-out seals at this survey area. Any models that excluded one or more of the variables resulted in a poorer fit. The best fit model for the CBBT survey area showed that the combination of tidal height, wind speed, air temperature, and month is the best predictive model of the number of hauled-out seals. Hours post-sunrise was not included in this model, potentially because around sunrise or sunset at the CBBT, it gets more difficult to see any seals that are hauled out on the rocks and therefore our counts may not be capturing all seals.

We relied upon observations during the vessel surveys and investigation of the haul-out area (looking for crawl patterns and trampled vegetation) to increase confidence that all haul-out sites remain in view of the cameras. If seals hauled out in a new area, not in view of the cameras, they would be missed. During image analysis, we are more confident in our ability to count every seal in each image at the Eastern Shore survey location, but at the CBBT, especially at CBBT3, the greater distance to the haul-out and the fact that seals haul out among the rocks, increases the chances for seals to be missed. For this reason, comparing camera counts to vessel and drone counts is of high importance.

A comparison of camera to vessel/ drone counts was conducted to determine if the counts yielded similar results and if camera counts continue to be a useful proxy for vessel counts (**Table 9** through **Table 12**)**.** Camera counts for in-water seals were not compared to that of vessel or drone surveys due to the vessel being in the area for a prolonged time whereas with cameras if a seal goes underwater at the time an image is taken, it will not be observed.

There were several important differences between camera and vessel counts:

1. Observation duration - Vessel count teams can observe haul-out areas over the entire survey period, during which three separate 2-minute counts are conducted at 10-minute intervals (Jones, 2024). Observations are still recorded outside of the designated count but are noted as "off-effort". Camera counts are conducted from a single snapshot once every 15 minutes from each camera but occur throughout the day from sunrise to sunset.
2. Weather/oceanographic limitations - Cameras are deployed constantly from season start to end, recording images regardless of weather conditions. However, there are instances, though rare, where rain or fog has obscured the view of the cameras. Vessel surveys are not conducted when there is a small craft advisory in effect or in sea states greater than Beaufort 3 for the safety of surveyors and are somewhat limited to specific tidal cycles because the Eastern Shore survey area is not accessible at very low tides.
3. Impact to seal behavior - Cameras do not appear to impact the behavior of the seals and therefore do not influence the counts, whereas vessel surveys often flush seals into the water. If seals are hauled out at locations where the animals are out of view of the observers before they fully flush (e.g., E3, C1 or the inside of E1), then vessel counts would have the potential to underestimate the seals hauled out. To help remedy the potential for underestimation, a drone was flown prior to vessel counts to get an unobstructed view of the seals. However, the use of the drone is weather dependent and not flown prior to every survey (Jones, 2024).
4. Species identification – Due to image quality and range to subject, seal species could usually not be positively determined from the camera surveys, whereas observers from vessel surveys could differentiate between harbor and gray seals using a large telephoto lens and/or binoculars.
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 can capture. Some cases of this were detected by the comparison of camera to vessel counts at the Eastern Shore 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 A, B, E1 (main channel side), E2, and E3 at the Eastern Shore survey area. At haul-out site A, we recorded one instance where the cameras missed a significant number of seals (**Table 9**).Camera perspectives could be changed, but 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 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 utilizes a digital single-lens reflex camera in 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 expected the counts here had the potential to be an underestimate from actual seal presence to a greater degree than at the Eastern Shore, but this was not clearly apparent from the comparison of vessel to camera survey results, which were very similar.

7. <u>Ability to observe behavior and document seals in the water</u> - Seals in the water during vessel counts were monitored continuously over the survey period, and seal movement could be observed and considered, whereas each camera took an image once every 15 minutes, resulting in only a single snapshot for review. 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.
8. <u>Potential for observer bias</u> – While drone and camera counts rely on data recordings and the ability to recheck counts, vessel surveys rely on observer counts which are conducted in real time from a moving vessel. In the case of flushing animals, this can greatly confound the ability to accurately count seals.

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 of locations where the cameras were missing hauled-out seals. 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 discussed above. For counting hauled-out seals, there were some cases where counts were higher from camera surveys while some were higher from vessel surveys. Those differences are likely due to observer error, or seals hauling out in areas outside of the camera view.

Results comparing the average number of hauled-out seals between camera surveys and vessel surveys at the Eastern Shore survey area were surprising as we noted opposite trends in all field seasons on 2021/2022 (**Figure 8**). Factors that may be contributing to these results are the large sample size of the camera counts versus vessel and drone surveys, or that vessel and drone counts rely on favorable weather and higher tides to access the haul-out survey location. Further investigation as to the reason is underway. From the analysis of vessel presence, fewer vessels were photographed at the Eastern Shore survey area than the CBBT survey area (**Figure 23** and **Figure 24**). This result is expected due to the remoteness of the Eastern Shore survey area compared to the popular fishing location at the CBBT. The peak in vessel presence at the Eastern Shore survey area in February during the 2019/2020, 2020/2021 and 2022/2023 seasons, were due to daily trips by the seal tagging team (Ampela et al., 2023) under NMFS Scientific Research Permit #21719. There was no tagging team present during the 2020/2021 season due to the COVID-19 pandemic travel restrictions or the 2023/2024 season due to the project concluding in early 2023. Most other occurrences of vessels at the Eastern Shore survey area were from the vessel surveys. The CBBT survey area saw higher vessel numbers 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 trend in vessel presence at the CBBT also coincides with the amount of popular saltwater fish that are in their peak seasons at that time. The months of October, November and May have the most fish species that are in their peak seasons and can be found around the CBBT, such as bluefish, black drum, flounder, gray trout, tautog, and striped bass (Virginia Marine Resources Commission, 2024).

The number of images with both hauled-out seals and vessels remained low at the Eastern Shore survey area, which coincides to the very limited vessel presence at that location (**Table 14**). There was no change at the CBBT survey area between the 2021/2022 and 2022/2023 season, but there was an increase of 144 images for the 2023/2024 season, which could indicate seals are becoming more tolerant of the presence of vessels at that location. However, in comparison to the number of images with seals and no vessels (n=2,325) and the number of images with vessels and no seals (n=1,930), 144 images with both seals and vessels seems quite low and would indicate seals prefer to haul out in the absence of vessels.

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 Eastern Shore would not support larger vessels due to the depth near the haul-out and the limitation of access to the area.

Seals at the Eastern Shore location may have become sensitive to the presence of vessels and associate it with tagging efforts that occurred in the spring of 2018, 2020, 2021, and 2023 (Ampela et al., 2023). Henry & Hammill, (2001) found that pursuit and capture of seals caused them not to haul out again while boats were present. The images captured at both survey areas 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 seem longer than it was (**Table 15** through **Table 18**). The average time it took for seals to haul out again at the Eastern Shore survey area remained relatively consistent between the 2022/2023 and 2023/2024 seasons. The higher number of instances where seals were flushed from a site during the 2022/2023 season is likely due to the increased tagging vessel presence (**Table 15**). On the contrary, the average time it took for seals to haul out again at the CBBT survey area decreased by over 50% between the 2022/2023 and 2023/2024 seasons. This data lines up with the result of having 44 more images with both vessels and seals during the 2023/2024 season (**Table 14**).

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, seals could be habituating to vessels that are not perceived as a threat, 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 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 100 ft 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 the vessel being recorded in an image, or a vessel could pass after seals flushed unrelated to the vessel.

5. Conclusion & Recommendations

This study demonstrates that time-lapse cameras are an effective method of collecting information on haul-out patterns of seals in Virginia. Benefits of time-lapse camera monitoring includes near continuous monitoring during daylight hours at the Eastern Shore and CBBT survey areas, and observational data are recorded and available for future analyses. These data are relatively inexpensive to obtain, provide 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 provides information critical to the development of effective protective measures during naval training and testing and other maritime activities, contributes to our understanding of seal occupancy in the region, provides more accurate information on the distribution of pinniped species, and provides data critical to understanding changes to the species distribution in relation to potential changes from anthropogenic activities or climate change. These data are invaluable to supporting future compliance with the MMPA, and proper documentation in NEPA analyses.

Recommended options for future data collection and analysis:

1. **Deploy infrared imaging cameras to collect images of haul-out activity at night**. Based on data from satellite telemetry tags deployed on seals in Virginia in 2018, 2020, and 2022, seals may be more likely to be hauled out between the hours of 04:00 and 12:00. Seals that haul out near the Outer Banks in North Carolina have also been noted to be hauled out overnight (M. Doshkov, personal communication, April 3, 2024). This data provides evidence that haul-out activity could be increased at night and seals in the population could be missed during daylight hours. This recommendation was added for the 2024/2025 season as 3 infrared cameras are currently deployed at the Eastern Shore survey area.
2. **Utilize automated image processing tools and artificial intelligence (AI) models (e.g., MegaDetector) for data collection**. Currently there are tools, which allow researchers to “auto-process” images in a 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. There have been preliminary analyses of using AI models for counting seals in time-lapse images, these should be further explored for future reports (Clarke, 2023; Robertson, 2023).
3. **Integrate tagging, drone and vessel data to obtain a more complete abundance estimate.** Combining all data sources can assist with the development of a more complete understanding of how seals are using haul-out sites in Virginia and potentially obtain a more accurate abundance estimate.
4. **Reduce image capture frequency or the number of images analyzed.** Analysis run by the University of St. Andrews indicated that results were similar on analysis run comparing the dataset for images taken every hour versus every 15 minutes (Thomas et al., 2024). The current method, analyzing images captured every 15 minutes is the most labor-intensive part of this project, so reducing the number of images that need to be analyzed would help mitigate this. Also, capturing images every hour versus every 15 minutes would not cause any issues when calculating abundance estimates in the future. It is possible to still record images every 15 minutes, but only analyze one image in an hour vice four.

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.

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