Investigating Harbor Seal (*Phoca vitulina*) haul-out abundance in relation to time of day at San Juan Island haul-out site

Sofia A. Denkovski[1]

Zoology Botany Program
Research in Marine Biology (FHL 470A)
Spring 2024

[1] Friday Harbor Laboratories, University of Washington, Friday Harbor, WA 98250

Contact information:
Sofia Denkovski
Department of Marine Biology
University of Washington, Seattle
1122 NE Boat St Box 355020
Seattle, WA 98115
sdenko@uw.edu

Keywords: harbor seal, haul-out, t-test, time of day, tide height

Abstract:

Harbor seals (*Phoca vitulina*) are an extremely widespread pinniped in the Pacific Ocean and play a vital role in the Salish Sea ecosystem. Haul-out behavior, where the individuals will temporarily leave the water and move onto rocks, islands, beaches, etc., is essential for most pinniped species in terms of thermoregulatory advantages, rest, reduced risk from predators, rearing pups, molting, etc. Although the behavior of seals at haul-out sites is well studied, significance between abundance and time of day have not been as investigated. This study tested whether harbor seal counts were significantly higher in the afternoon (3:00pm to 4:30pm) than in the morning (9:00am to 11:00am). Results showed that trends between high harbor seal count and morning time frames are significant. Trends from the data below also suggest that low tide events may facilitate high haul out abundance. The significance and trends found in this study imply potential impacts on the Salish Sea ecosystem due to harbor seals being a main prey source for mammal-eating Bigg's killer whales (*Orcinus orca*) and predators to Pacific herring (*Clupea pallasii)*, an essential forage fish threatened by climate change. Time of day could also imply higher risks of anthropogenic impacts in areas surrounding San Juan Island, as the channel adjacent to Goose Island is a high vessel-traffic area.

Introduction:

Harbor seals (*Phoca vitulina*) play a vital role in the Salish sea ecosystem (Jefferies et al., 2000). They are considered a recovered species following a massive decline in their populations in the mid-1900s due to commercial hunting, and now their populations are recovering making them a large contributor in the Salish Sea ecosystem (Jefferson et al., 2021). They are a main prey species for mammal-eating Bigg's killer whales (*Orcinus orca*) and are speculated to compete with the endangered Southern Resident killer whales because both species are adamant predators of Chinook salmon in the Salish Sea (Luxa, 2013; Shields et al., 2018). With harbor seal population size now returning to high levels the Salish Sea, there are large implications for organisms across the food web such as prey increase for Bigg's killer whales and decreases in salmon and other fish availability.

In the Pinniped family, a commonly observed behavior is "hauling-out", where harbor seals temporarily leave the water and move onto rocks, islands, beaches, etc. (Hamilton et al., 2014). Haul-out behavior is essential for most pinniped species in terms of thermoregulatory advantages, rest, reduced risk from predators, rearing pups, molting, etc. (Hamilton et al., 2014; London et al., 2012). Harbor seal haul-out abundance provides important information that can be used to understand multiple levels of ecosystem dynamics, from anthropogenic impacts to predator-prey relations. Although the behavior of seals at haul-out sites is well studied (Hamilton et al., 2014; Jefferson et al., 2021; London et al., 2012), significance between abundance and time of day have not been as investigated.

We aim to understand the significance of haul-outs during different times of the day and discuss the importance of these sites for the local harbor seal, an animal that plays an essential role in the inner workings of the Salish Sea's food web dynamics (Shields et al., 2018). This will be accomplished by comparing haul-out abundance to time of day as well as environmental factors such as tide height, air temperature, and weather. Our null hypothesis states that afternoon harbor seal abundance counts at the Goose Island haul-out site will not be significantly different from the morning counts. However, we aim to support our alternative hypothesis which states that harbor seal abundance counts will be significantly different in the afternoon time

frames (3:00pm to 4:30pm). We speculate that haul-out abundance will be higher in the afternoon due to warmer temperatures (thermoregulatory advantages).

Methods:

All research for this project was conducted near a harbor seal haul-out located in the Salish Sea ecosystem in Pacific coastal waters of Washington state. The haul-out site chosen for observation was Goose Island, a small nearshore island approximately 0.262 miles east of the Cattle Point peninsula of San Juan Island, WA; Figure 1, red star). This site was chosen based on recommendation by local marine mammal experts conducting year-round surveys of pinniped haul out sites around San Juan Island to understand population abundance (Jessica Farrer, personal communication). The location where observer data collection took place is shown in Figure 1 and represented by the red circle. This observation location was chosen for data collection as it was 1) the nearest accessible shoreline location (0.262 miles) to the haul-out site and 2) it was also clear of any physical obstruction blocking the view of animals at the haul-out site.

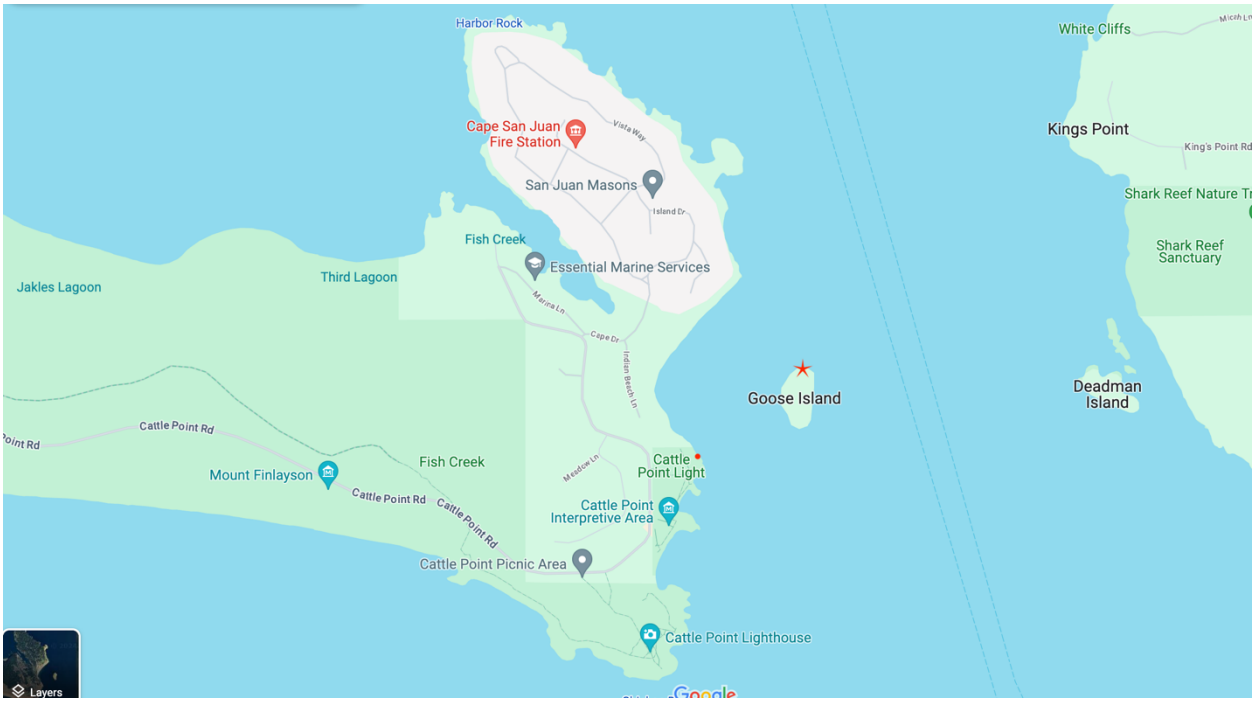

Figure 1: Cattle Point, SJI: Goose Island haul-out site (red star), and observers' location during survey time (red circle).

Field efforts conducted at this site resulted in a total of 20 observations of harbor seal abundance; 10 occurring during morning hours between 9:00am and 11:00am and 10 during afternoon hours between 3:00pm and 4:30pm. Seal abundance data (a count of visible, individual hauled-out seals) were collected using two complementary methods: 1) real-time counts using binoculars (Sky Genius/10x50/367ft@1000yrds/122M@1000M) and 2) digital photography (Nikon B500 Coolpix, lens length = 900 mm) for counts based on review of digital images. Upon arrival at the observation site, a team of two observers took approximately five minutes to count every seal visibly hauled-out at the Goose Island site through binoculars. One observer counted individuals through the binoculars while the other recorded data, then observer roles

were switched, and the haul-out site was re-counted. If an individual pops up in the site, i.e., completely hauls out in the middle of a count, they will not be included in the overall count number, unless they haul out in an area that has not been counted yet. Equipment needed includes binoculars, a camera, field notebook, and phone for weather/air temperature/time data. Data collection occurred between 04/27/24 and 05/24/24. The counts collected by each observer for each counting method were averaged and this value was recorded as the official count for that date/time/location/method. These individual observer counts were also used to calculate inter-observer variability. Photographic seal count data and binocular-based count data were combined for each observation session to create the final seal count data point to be used for analysis. Tide height data was collected using the online-accessible NOAA tides charts for Friday Harbor, WA.

The data will be visually presented using box plots, with # of seals counted on the y-axis and morning/afternoon counts at the Goose Island haul-out site on the x-axis. We will also visually display differences between tide height and morning/afternoon haul-out abundance using box plots. Three separate t-tests of equal variance will be performed to see whether haul-out abundance means are significantly different with morning vs. afternoon time frames, low vs. high tide heights, and warm vs. cool air temperature. We defined low tides as any tide at 0 ft or under (negative values) and high tide as anything above 0 ft (positive values). We define warm air temperature 13 degrees Celsius and above and cool air temperatures as 12 degrees Celsius and below. These values were chosen based off the variance of our specific data.

Results:

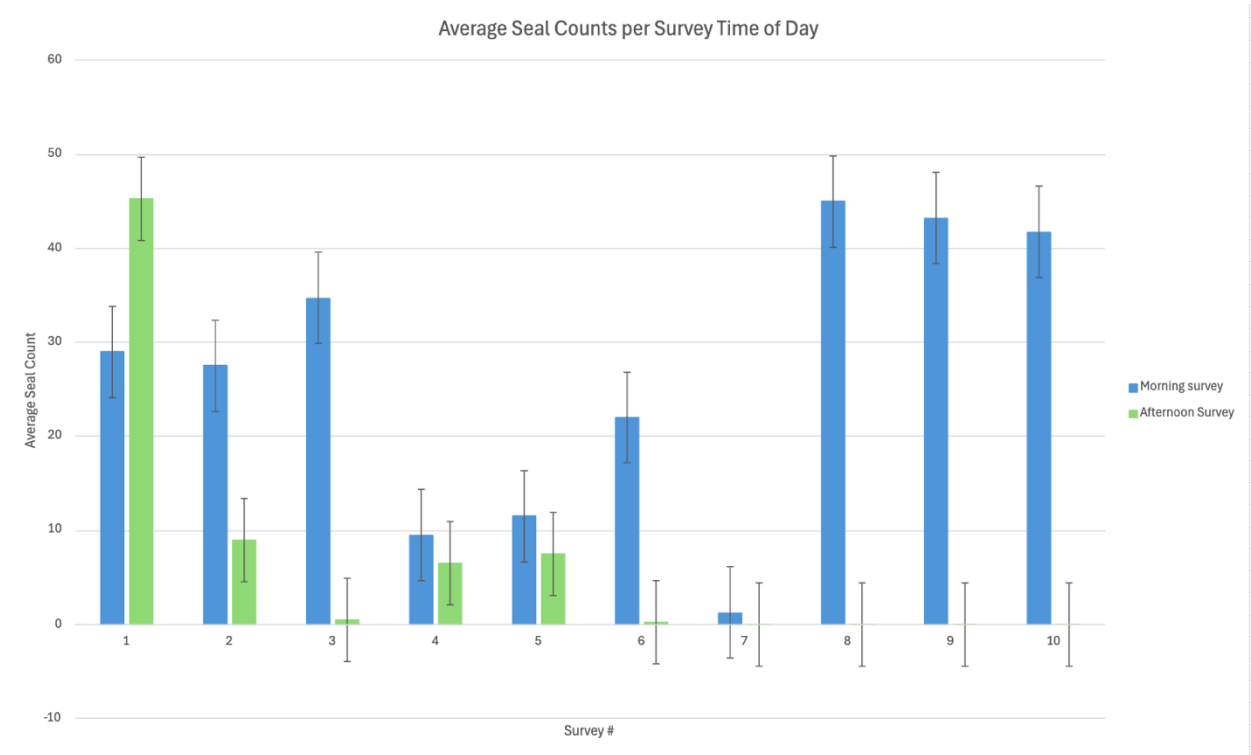

Figure 2: Averaged counts of hauled-out seals at Goose Island categorized by morning (9:00am to 11:00am) or afternoon (3:00pm to 4:30pm) survey.

Results showed that most morning (9:00am to 11:00am) survey counts at Goose Island had approximately 20 more hauled-out individuals than in the afternoon survey counts (3:00pm to 4:30pm) (Figure 2). For one morning survey the average number of seals ranged from 10 to 45 hauled-out individuals in comparison to a range of 0 to 9 individuals in the afternoon with an outlier of 45 individuals seen on one afternoon of data collection (Figure 2). The highest average haul-out abundance was seen in the morning on May 23rd, 2024, and in the afternoon on April 27th, 2024, with both surveys having approximately 45 individuals. The lowest haul-out abundance was observed on the afternoons of May 23rd and May 24th, 2024, with approximately 0 individuals (Figure 2). The total average haul-out count for morning surveys was approximately 28.33 individuals and the total average haul-out count for the afternoon surveys was approximately 6.89 individuals. An outlier in the usually high haul-out abundance during morning data collection was on the day of May 22nd, where a group of four Bigg's killer whales passed close to the haul-out site and all the seals flushed into the water (Figure 2).

A t-test of two-samples assuming equal variances was performed to evaluate the correlation between the time of day (morning vs. afternoon), and haul-out abundance at Goose Island. A significant difference between the means of the morning time frame and afternoon time frame was found, along with a positive interaction between the morning time frame and haul-out abundance as shown by p-value = 0.0038. Time of day for the afternoon time frame did not show a positive interaction with haul-out abundance.

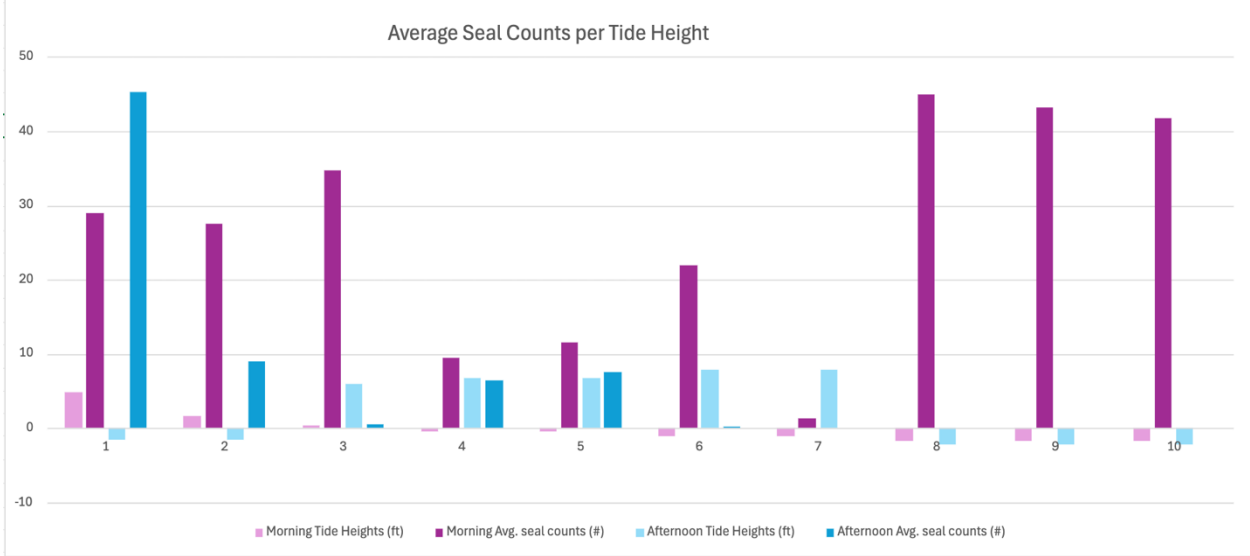

Figure 3: Averaged counts of hauled-out harbor seals at Goose Island compared by morning (9:00am to 11:00am) or afternoon (3:00pm to 4:30pm) survey and by tide height.

A t-test of two-samples assuming equal variances was performed to evaluate the correlation between the tide height (high vs. low) and haul-out abundance at Goose Island. Although the result was not significant (p-value = 0.2410), trends from our data showed the highest haul-out abundance counts during the lowest tides; for example, on May 23rd, the tide was at an extreme low at -1.71 ft and had the highest average number of individuals at approximately 45 (Figure 3). This day also had the highest variance in tide height and haul-out abundance as seen in Figures 3 and 5. The morning data collection was at approximately -1.71 ft with 45 individuals whereas the tide during the afternoon data collection on May 23rd was at

approximately 7.84 ft with 0 individuals (Figure 3). An outlier in this dataset included the last day of afternoon data collection on May 24th, 2024, where the lowest tide (-2.13 ft) yielded in the lowest haul-out count at 0 individuals (Figure 3). Tide height during different times of day showed to differ between the months of April, early May, and late May. The first rounds of data collection showed a high tide in the morning of May 3rd at 4.77 ft, meanwhile a low tide was seen in the afternoon of April 27th and 28th at -1.54 ft and -1.56 ft respectively. These data points are seen as outliers in the typical trends of time of day and haul-out abundance as shown in Figures 2 and 3.

A t-test of two-samples assuming equal variances was performed to evaluate the correlation between air temperature (warm vs. cool), and haul-out abundance at Goose Island. This test did not yield significant results (p-value = 0.0578), which indicates that the difference between the means of haul-out abundance in warm vs. cool air temperatures was not significant. The highest temperature observed was at 16 degrees Celsius at an afternoon survey, however only approximately 0.25 seals were counted. The lowest seal counts (0 individuals) were observed at 12 degrees Celsius, and the highest seal counts (43 – 45 individuals) were observed in 10 degrees Celsius – 12 degrees Celsius. Overall temperature over the course of the experiment can be found in Figure 4, however there was little variation to report.

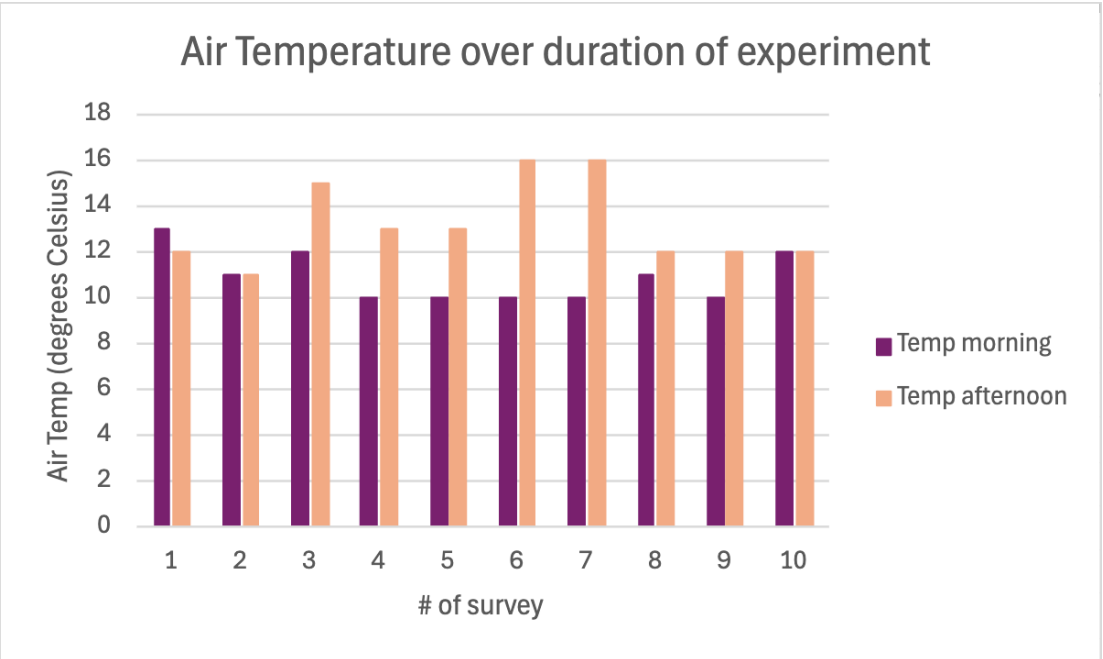

Figure 4: Air temperature per morning and afternoon surveys over the course of the observational study: 04/27/24 to 05/24/24

Discussion:

This study aimed to investigate whether time of day influenced haul-out abundance at a harbor seal haul-out site on Goose Island on the southeast side of San Juan Island. Our results showed a significant difference between the means of population abundance for the morning time and afternoon time frames, with a positive interaction between the morning time frame (9:00am – 11:00am) and haul-out abundance. Trends showed that a low tide height was also observed with high haul-out abundance. We reject our null hypothesis that haul-out abundance at

morning and afternoon time frames are not significantly different, however we also reject our alternative hypothesis which stated that the afternoon time frame would yield, on average, a significantly higher haul-out abundance than the morning time frame. We aim to discuss the driving factors and implications behind time of day and haul-out abundance, whether those are anthropogenic stress, environmental factors, predation, or otherwise. This data could help provide a baseline of knowledge for future scientists to conduct long-term surveys of local harbor seal populations. Exploring these factors and implications can expand on previous behavioral studies and start discussions on how the mechanics of haul-out abundance are affected by external factors.

Figure 5: High tide haul-out at Goose Island, on the northernmost point of the island, pebble beach substrate.

Figure 6: Low tide haul-out at Goose Island; spit that is uncovered by water at low tide located directly north of the high-tide beach haul-out (Figure 5).

We reject our alternative hypothesis that the afternoon time frame (3:00pm – 4:30pm) would yield, on average, a significantly higher haul-out abundance. This rejection is based on our findings of a significant difference between haul-out abundance means at morning and afternoon time frames coupled with a clear positive interaction between haul-out abundance and the morning time frame (Figure 2). During the afternoon time frame, data collection often coincided with high tide (Figure 3), which is speculated to be a cause for the observed trends of lower haul-out abundance in the afternoon time frame. Previous studies show that high haul-out abundance is typically correlated with low tide heights (Patterson & Acevedo-Gutiérrez, 2008; Reder et al., 2003; Schneider & Payne, 1983). This would explain why lowest haul-out abundance was observed at the highest tides. We speculate that the lack of space at Goose Island when the tide is high compared to when the tide is low (Figures 5 and 6) could create space competition between the seals. It also illustrates why, at this specific location, high tide results in lower haul-out abundance. Furthermore, harbor seals around San Juan Island, WA hunt primarily on Pacific herring (*Clupea pallasii*) (Lance & Jeffries, 2007). Due to the higher tide in the afternoon, it is likely that with the vertical expansion of the water column that the seals have more space to hunt as Pacific herring distribution ranges from shallow surface to deeper pelagic waters (Villalobos et al., 2020). As climate change continues to change the state of ecosystems and species around the planet, Pacific herring embryos are experiencing increases in mortality due to raised pCO2

levels in the ocean (Villalobos et al., 2020). The use of haul-out sites is extremely important for resting and thermoregulatory advantages (Hamilton et al., 2014; London et al., 2012), likely after extensive time spent foraging in the cold Salish Sea. To maintain the essential use of haul-out sites, harbor seals must be able to find enough food to take necessary rests. With Pacific herring embryos in danger, action must be taken to lower greenhouse gas emissions in the atmosphere so that this prey resource and its predator can continue to thrive.

Haul-out behavior allows seals to rest, molt, rear and nurse pups, avoid predation, and provides a thermoregulatory advantage (Hamilton et al., 2014; London et al., 2012). Due to its status as a protective behavior for harbor seals, anthropogenic or ecological disturbance can upset this activity and disrupt animal behavior which can lead to stress (Ruiz-Mar et al., 2022). Disturbance can cause physical changes in the individuals, such as a release of hormones like glucocorticoids, or cortisol (Ruiz-Mar et al., 2022). Long term effects of cortisol can lead to infertility, muscle/weight loss, reduced immunity, etc. (Ruiz-Mar et al., 2022). All these effects show that disturbances to haul-out sites have adverse side effects to harbor seals and could lead to reductions in total population. Cattle Pass is a fast-flowing channel of water that flows between Goose and Deadman Island, around Cattle Point and out into the Haro Strait (Figure 1). Past studies in this area have shown it to have high vessel traffic and for vessel traffic to be positively correlated with harbor seal disturbance (Carpenter et al., 2021; Johnson & Acevedo-Gutiérrez, 2007). Therefore, it is possible that these anthropogenic disturbances could induce stress to the major haul-out site observed at Goose Island. Our study showed that from the morning hours of 9:00am to 11:00am in the spring, Goose Island is a vital site of haul-out activity for approximately 30 harbor seals. For this area to remain without disturbance to haul-out behavior, future studies should investigate long term haul-out abundance at Goose Island to provide further evidence for a potential marine protected area or an expansion of the distance regulations put forth by the Be Whale Wise guidelines.

Natural disturbances such as predation were observed during this study. During data collection on May 22nd, 2024, a group of 4 mammal-eating (Bigg's) killer whales surfaced very close to the haul out site. These killer whales are known to prey on harbor seals, suggesting the ecological importance of the Goose Island haul-out site, not only for the seals but for their predators as well (Shields et al., 2018). Upon arrival of the killer whales on the scene all 20 of the harbor seals flushed into the shallow waters surrounding Goose Island. The disruption of the haul-out likely created a thermal disadvantage for the group of seals, as flushing into the cold waters due to a stress event can increase energy spending and thermal stress (Ruiz-Mar et al., 2022).

Although tide height showed clear trends within the data, such as with low tides yielding in high haul-out counts (Figure 3), the t-test results were not significant. However, the trends we observed were in correspondence to past studies that showed that low tide heights are typically associated with the highest haul-out abundance (Patterson & Acevedo-Gutiérrez, 2008; Reder et al., 2003; Schneider & Payne, 1983). Although we did not find significance between the means of abundance for low vs. high tides, the trends we observed, and the array of past evidence could suggest that low tide does provide the opportunity for increased haul-out abundance. There is clearly more space for individuals to haul-out at low tide at Goose Island (Figure 5), which creates less space competition and benefits all individuals. Similarly, an insignificant result was found for the t-test of high vs. low temperature, which could have been used to suggest a thermoregulatory advantage for morning or afternoon surveys; in the case of San Juan Island in

the spring, however, it seems the temperature is not variable enough to provide any real differences in haul-out abundance (Figure 4).

In this study a significant difference between the means of population abundance for the morning time and afternoon time frames, with a positive interaction between the morning time frame (9:00am – 11:00am) and haul-out abundance was observed. This finding was accompanied by positive trends of low tide and haul-out abundance as well. These findings could help researchers assess long term survey goals such as at the Whale Museum in Friday Harbor, WA. The San Juan County stranding network through the Whale Museum aims to take surveys of haul-out sites, therefore studies such as this one expands background knowledge of optimal timing to conduct long-term surveys. These findings provide insight on important time frames for harbor seal haul-out behavior, which is essential for rest, thermoregulatory function, low predation risk, etc. This shows that during optimal haul-out times, sites such as Goose Island should be protected so that haul-out behavior of local harbor seals are without anthropogenic disturbance.

References:

Carpenter, C. V., Ogle, C. E., & Weise, G. J. (2021). *Harbor seal (Phoca vitulina) behavior in response to vessel disturbance at Yellow Island and Goose Island, WA, USA*. 22.

Hamilton, C. D., Lydersen, C., Ims, R. A., & Kovacs, K. M. (2014). Haul-Out Behaviour of the World's Northernmost Population of Harbour Seals (Phoca vitulina) throughout the Year. *PLoS ONE*, *9*(1), e86055. https://doi.org/10.1371/journal.pone.0086055

Jefferson, T. A., Smultea, M. A., Ward, E. J., & Berejikian, B. (2021). Estimating the stock size of harbor seals (Phoca vitulina richardii) in the inland waters of Washington State using line-transect methods. *PLOS ONE*, *16*(6), e0241254. https://doi.org/10.1371/journal.pone.0241254

Jeffries, S.J.1, P.J. Gearin2, H.R. Huber2, D.L. Saul1, and D.A. Pruett1. 2000. Atlas of Seal and Sea Lion Haulout Sites in Washington. Washington Department of Fish and Wildlife, Wildlife Science Division, 600 Capitol Way North, Olympia WA. pp. 150.

Johnson, A., & Acevedo-Gutiérrez, A. (2007). Regulation compliance by vessels and disturbance of harbour seals (*Phoca vitulina*). *Canadian Journal of Zoology*, *85*(2), 290–294. https://doi.org/10.1139/Z06-213

Lance, M.M., and S.J. Jeffries. 2007. Temporal and spatial variability of harbor seal diet in the San Juan Island archipelago. Contract Report to SeaDoc Society Research Agreement No. K004431-25. Washington Department of Fish and Wildlife, Olympia WA. 21 pp.

London, J. M., Ver Hoef, J. M., Jeffries, S. J., Lance, M. M., & Boveng, P. L. (2012). Haul-Out Behavior of Harbor Seals (Phoca vitulina) in Hood Canal, Washington. *PLoS ONE*, *7*(6), e38180. https://doi.org/10.1371/journal.pone.0038180

Luxa, K. (2013). Food Habits of Harbor Seals (Phoca vitulina) in Two Estuaries in the Central Salish Sea. *Aquatic Mammals*, *39*(1), 10–22. https://doi.org/10.1578/AM.39.1.2013.10

Patterson, J., & Acevedo-Gutiérrez, A. (2008). Tidal Influence On the Haul-Out Behavior of Harbor Seals (Phoca vitulina) At A Site Available At All Tide Levels. *Northwestern Naturalist*, *89*(1), 17. https://doi.org/10.1898/1051-1733(2008)89[17:TIOTHB]2.0.CO;2

Reder, S., Lydersen, C., Arnold, W., & Kovacs, K. M. (2003). Haulout behaviour of High Arctic harbour seals (Phoca vitulina vitulina) in Svalbard, Norway. *Polar Biology*, *27*(1), 6–16. https://doi.org/10.1007/s00300-003-0557-1

Ruiz-Mar, M. G., Heckel, G., Solana-Arellano, E., Schramm, Y., Garcıa-Aguilar, M. C., & Arteaga, M. C. (2022). Human activities disturb haul out and nursing behavior of Pacific harbor seals at Punta Banda Estuary, Mexico. *PLOS ONE*, *17*(7), e0270129. https://doi.org/10.1371/journal. pone.0270129

Schneider, D. C., & Payne, P. M. (1983). Factors Affecting Haul-Out of Harbor Seals at a Site in Southeastern Massachusetts. *Journal of Mammalogy*, *64*(3), 518–520. https://doi.org/10.2307/1380370

Shields, M. W., Hysong-Shimazu, S., Shields, J. C., & Woodruff, J. (2018). Increased presence of mammal-eating killer whales in the Salish Sea with implications for predator-prey dynamics. *PeerJ*, *6*, e6062. https://doi.org/10.7717/peerj.6062

Villalobos, C., Love, B. A., & Olson, M. B. (2020). Ocean Acidification and Ocean Warming Effects on Pacific Herring (Clupea pallasi) Early Life Stages. *Frontiers in Marine Science*, *7*, 597899. https://doi.org/10.3389/fmars.2020.597899

University of Washington Libraries Non-Exclusive Distribution License

In order for the University of Libraries to reproduce, translate and distribute your submission worldwide your agreement to the following terms is necessary. Please take a moment to read the terms of this license, fill in the information requested, and sign and submit this license to the University Libraries.

By signing and submitting this license, you (the author(s) or copyright owner) grant to the University of Washington (UW) the non-exclusive right to reproduce, translate (as defined below), and/or distribute your submission (including the abstract) worldwide in print and electronic format and in any medium, including but not limited to, audio or video.

You agree that the UW may, without changing the content, translate the submission to any medium or format for the purpose of preservation.

You also agree that the UW may keep more than one copy of this submission for the purposes of security, backup and preservation.

You represent that the submission is your original work, and that you have the right to grant the rights contained in this license. You also represent that your submission does not, to the best of your knowledge, infringe upon anyone's copyright.

If the submission contains material for which you do not hold copyright, you represent that you have obtained the unrestricted permission of the copyright holder to grant UW the rights required by this license, and that such third-party owned material is clearly identified and acknowledged within the text or content of the submission.

The UW Libraries reserves the right to add or edit metadata for the purpose of access, clarification and/or preservation.

IF THE SUBMISSION IS BASED UPON WORK THAT HAS BEEN SPONSORED OR SUPPORTED BY AN AGENCY OR ORGANIZATION OTHER THAN THE UW, YOU REPRESENT THAT YOU HAVE FULFILLED ANY RIGHT OR REVIEW OR OTHER OBLIGATIONS REQUIRED BY SUCH CONTRACT OR AGREEMENT.

UW will clearly identify your name(s) as the author(s) or owner(s) of the submission, and will not make any alteration, other than allowed by this license, to this submission.

Licensor:

Investigating Harbor Seal (*Phoca vitulina*) haul-out abundance in relation to time of day at San Juan Island haul-out site

Title of work

Sofia A. Denkovski 05/28/2024

Signature Date

Sofia A. Denkovski

Printed Name