

**Harbor seal (*Phoca vitulina*) behavior in response to vessel disturbance at Yellow Island and Goose Island, WA, USA**

Courtney V. Carpenter<sup>1,2,3</sup>, Clare E. Ogle<sup>1,3</sup>, and Greta J. Weise<sup>1,3</sup>

Ecology and Conservation of Marine Birds and Mammals  
Summer 2021

<sup>1</sup>Friday Harbor Laboratories, University of Washington, Friday Harbor, WA 98250

<sup>2</sup>School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, 98105

<sup>3</sup>College of the Environment, University of Washington, Seattle, WA, 98105

*Contact Information:*

Courtney V. Carpenter  
School of Aquatic and Fishery Sciences  
University of Washington  
1122 NE Boat St.  
Seattle, WA 98105  
courtc17@uw.edu

Clare E. Ogle  
College of the Environment  
University of Washington  
1492 NE Boat St.  
Seattle, WA 98015  
cogle23@uw.edu

Greta J. Weise  
College of the Environment  
University of Washington  
1492 NE Boat St.  
Seattle, WA 98015  
gweise@uw.edu

**Authors contributed equally to this manuscript.**

## **Abstract**

The Salish Sea is an area with high vessel traffic, which can potentially cause negative shifts in the energetic budgets of many marine mammal species. This includes harbor seals, which use haul out sites to rest and rear their pups, and have been shown to exhibit increased vigilance and flushing in response to vessel disturbance. Therefore, vessel traffic in close proximity to harbor seal haul outs may be detrimental, especially when vessels are not in compliance with current regulations, such as the 91.4 m buffer zone set by the Marine Mammal Protection Act (MMPA). While the harbor seal population in the Salish Sea is believed to be at equilibrium, and is therefore not of great conservation concern, the management and protection of the species can set an important precedent for how other pinnipeds, both recovered and otherwise, are treated. To understand the impacts of vessel traffic on harbor seal behavior in the Salish Sea, we conducted a comparative study of harbor seal behavior in response to vessel disturbances at Yellow Island and Goose Island in the San Juan Islands, WA, USA. Tracking vessel traffic within 400 m of each haul out site, we monitored behavioral responses both during and after vessel disturbances and mapped the distribution of seals throughout our observational period. We found that, while vessel traffic differed at both sites, kayaks were the vessel type which most frequently came within the regulatory buffer zone. This is important considering kayaks also caused the most extreme behavioral responses observed. Additionally, while behavioral trends in response to vessel disturbances varied between sites, harbor seals show possible signs of habituation over time in comparison to previous studies as well as in areas of higher vessel traffic. These findings help contribute to the understanding of the impacts of vessel disturbance in the Salish Sea and may have important implications for management.

**Key words:** harbor seal, *Phoca vitulina*, vessel disturbance, behavior, Salish Sea, habituation

## Introduction

Harbor seals (*Phoca vitulina*) are a non-migratory pinniped species distributed throughout the northern hemisphere. They are the most common pinniped species in Washington State, breeding and feeding within the Salish Sea year-round (Jeffries et al. 2000). Harbor seals are considered a recovered species following their rebound from a significant reduction in population size in the mid-twentieth century (Jefferson et al. 2021). The current population within the Salish Sea is estimated to be at equilibrium at around 50,000 individuals (Ashley et al. 2020). In 1972, the Marine Mammal Protection Act (MMPA) granted protection for all marine mammals, regardless of conservation status (Roman et al. 2013). Specifically, a buffer zone of 100 yards, or 91.4 meters, was put in place to prevent human disturbance of marine mammals. Despite such regulations, violations regularly occur and cause disturbance for harbor seals (Johnson and Acevedo-Gutiérrez 2007).

Harbor seals can often be found hauled out on beaches and rocks for thermoregulation, resting, predator avoidance, and pupping (London et al. 2012). The percentage of seals found at haul out sites increases during breeding and molting seasons, which occur in the San Juan Islands from June through August (Jeffries et al. 2000; Cunningham et al. 2009). This increase of seals visibly hauled out coincides with peak tourism season, which sees an influx of private vessels traveling by known haul out sites (Johnson and Acevedo-Gutiérrez 2007). Past studies have shown that vessel disturbance can cause behavioral changes in seals, including increased vigilance and flushing from the haul out site back into the water (Suryan and Harvey 1999; Johnson and Acevedo-Gutiérrez 2007). As vessel traffic continues to increase globally and is expected to increase within the Salish Sea, it is important to fully understand the impact vessel

disturbance has on harbor seals to better manage the species and enforce regulations (Tournadre 2014; Seely et al. 2017).

We did a comparative study between two locations within the San Juan Islands to better understand vessel compliance and the impact of vessel disturbance on harbor seal behavior. The objectives of our study were to (i) determine if vessel disturbance differed between Yellow Island and Goose Island within the San Juan Islands, (ii) determine if behavior of harbor seals in response to vessel disturbance differed between the two sites, and (iii) determine which vessels caused the most disturbance. Based on previous visits to both locations, we predicted that there would be more vessel disturbance at Yellow Island and therefore the seals would exhibit more signs of habituation to vessel disturbance. We also predicted, given past findings, that kayaks and other non-motorized vessels would cause the highest disturbance at both locations (Henry and Hammill 2001; Johnson and Acevedo-Gutiérrez 2007; Cates and Acevedo-Gutiérrez 2017).

## **Methods**

### *Study sites*

We collected data from 10 August through 13 August 2021 at Yellow Island (48°35'29" N, 123°02'03" W) and Goose Island (48°27'29" N, 122°57'19" W), small islands located off of San Juan Island, WA, USA. These locations were chosen as they are known to have reliable harbor seal haul outs where we could view harbor seals with enough detail to allow for behavioral observations. At Yellow Island, observations of the west spit were made from a spot directly above a small dirt path approximately 200 m from the haul out. At Goose Island, observations were made from a rocky outcropping at the northern tip of the Cattle Point Interpretive Area directly across from Goose Island, approximately 400 m from the haul out. Two days were spent at each location, alternating between the two locations each day.

Observations began approximately three hours before low tide and were stopped approximately three hours after low tide. A total of six hours were spent at each location per day, with a total of 12 hours spent at each location over the four day period. Before beginning observations, a 15 minute buffer period was observed following setup to account for any immediate disturbance we may have caused. Each member of our team was assigned an observational role, which rotated each hour to counteract observer bias.

### *Vessel traffic*

To quantify vessel traffic, we tracked every vessel which entered within 400 m of the haul out sites. For each observed vessel we recorded vessel type and the times at which the vessel crossed specific distance thresholds. Vessel types included large motorized boats, small motorized boats, sailing boats, kayaks or other personal non-motorized vessels, and passenger vessels. It is important to note that a kayak group was considered a single vessel, regardless of the number of kayaks present, as the group generally moved as one unit. Passenger vessels were characterized as commercial vessels, generally used for tourism or travel. Distance of closest approach by each vessel was tracked by recording the time at which each vessel crossed within 400 m (i.e., entry into our observational zone), within 300 m, within 200 m, and within 100 m of the harbor seal haul out. Entry within 100 m was used to approximate compliance with the known buffer zone distance set by the MMPA. These distances were approximated visually by using known distances to specific landmarks surrounding each site. Additionally, the interval of time each vessel spent within its closest approach to the haul out site was recorded in order to match this data with behavioral data for the purpose of analysis. Following data collection, we analyzed vessel traffic using Microsoft Excel. We calculated both the mean number of vessels per day and the percent of each vessel type within the total number of vessels for both locations.

We also calculated the percent of total vessels and each vessel type entering within either 200 m or 100 m at their closest approach.

### *Behavioral sampling*

We used both interval and opportunistic scan sampling to measure harbor seal behavior throughout each six hour period of observation. Scan samples were performed using a Bushnell Spacemaster 15 x 45 spotting scope (Bushnell Corporation, Overland Park, Kansas, USA). We performed interval scan samples every 20 minutes, beginning immediately after our 15 minute buffer period. For each scan sample, the observer marked the time of scan and tallied the number of seals exhibiting each behavior including vigilance (i.e., head up, eyes open, scanning their surroundings), flushing (i.e., moving into the water), moving (e.g., shifting position or moving further up the shore), and other (e.g., resting, aggression, or other social behaviors). We performed opportunistic scans of behavior when a vessel entered within 200 m of the haul out site. For each opportunistic scan sample, the observer would begin their scan at the end of the haul out site closest to the disturbance. For opportunistic scans, time and disturbance type were also recorded. We took opportunistic control samples when no vessels were seen within 400 m of the haul out site, following the same scan protocol as above.

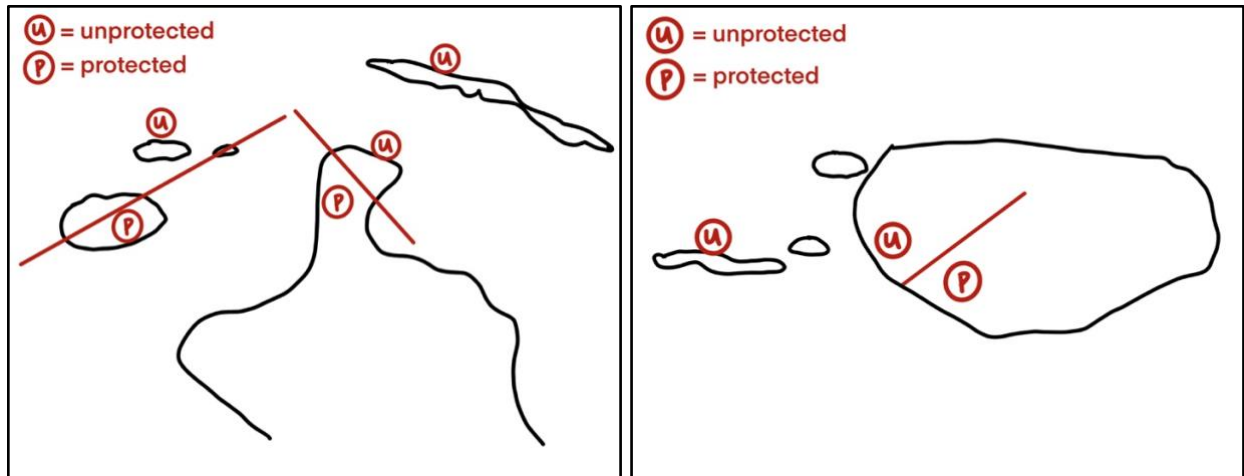
We analyzed the behavior data in Microsoft Excel, calculating the total number and percent of seals exhibiting each behavior during each scan. We combined this percent behavior data with vessels that entered within 200 m for each day. For each vessel, if there was an opportunistic or interval scan within one minute of the boat entering within 200 m, the behavior data for this scan were assigned to that vessel disturbance. The following two interval scans were also assigned to the same disturbance. This created the immediate disturbance response, response at next interval (1), and response at next interval (2) categories. We calculated an average and

standard deviation for each category from the recorded percentages across the two days of observations. This method was used for each vessel type at both locations. We performed statistical analysis for the immediate disturbance response of vigilance percentages. T-tests were performed to compare the average vigilance between sites for each vessel type. To account for the multiple statistical tests performed, we adjusted the p-values according to the Bonferroni correction and evaluated at  $p < 0.008$ .

### *Distribution mapping*

In addition to interval scan sampling, we mapped harbor seal distribution every 20 minutes at each haul out site. Mapping was performed using a Nikon Prostaff 3 16-48 x 60 P spotting scope (Nikon Corporation, Minato City, Tokyo, Japan). For each distribution map, the observer mapped the location of each individual seal on a standardized mapping sheet. The observer recorded individual classification of each seal within the categories of mother and pup, lone pup, lone adult, or swimming.

Following data collection, we denoted specific zones on the maps as areas that were protected and unprotected (Fig. 1). Unprotected zones were identified as areas closer to direct vessel disturbance and exposed to more wake disturbance. We analyzed the distribution of seals in Microsoft Excel and found the mean percentage of total seals in protected and unprotected areas for both locations. We divided each percentage within protected and unprotected areas proportionally into the four seal categories. Using the DaftLogic Distance Calculator, we approximated the total available protected habitat proportional to total available haul out habitat at Yellow Island and Goose Island to account for any differences between the two sites.

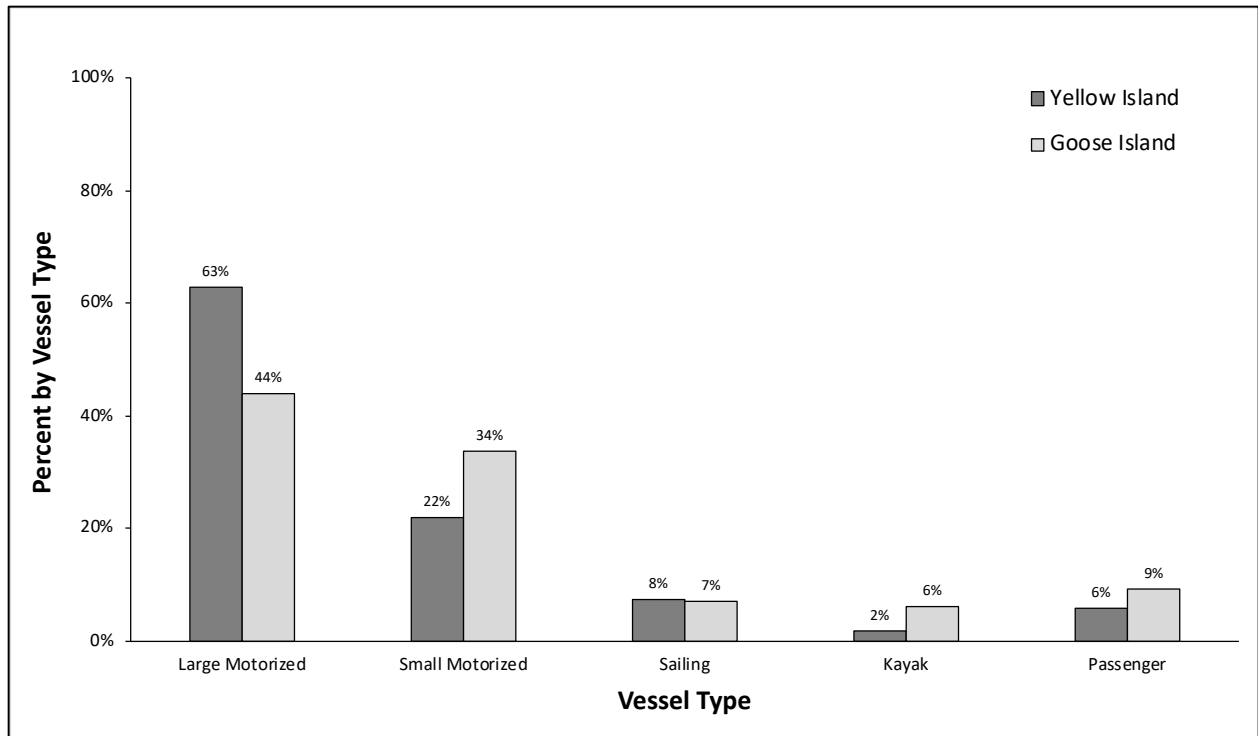


**Figure 1.** Maps of Yellow Island (left) and Goose Island (right). Lines indicate separation of unprotected versus protected zones. Unprotected zones are marked with u and protected zones are marked with p.

## Results

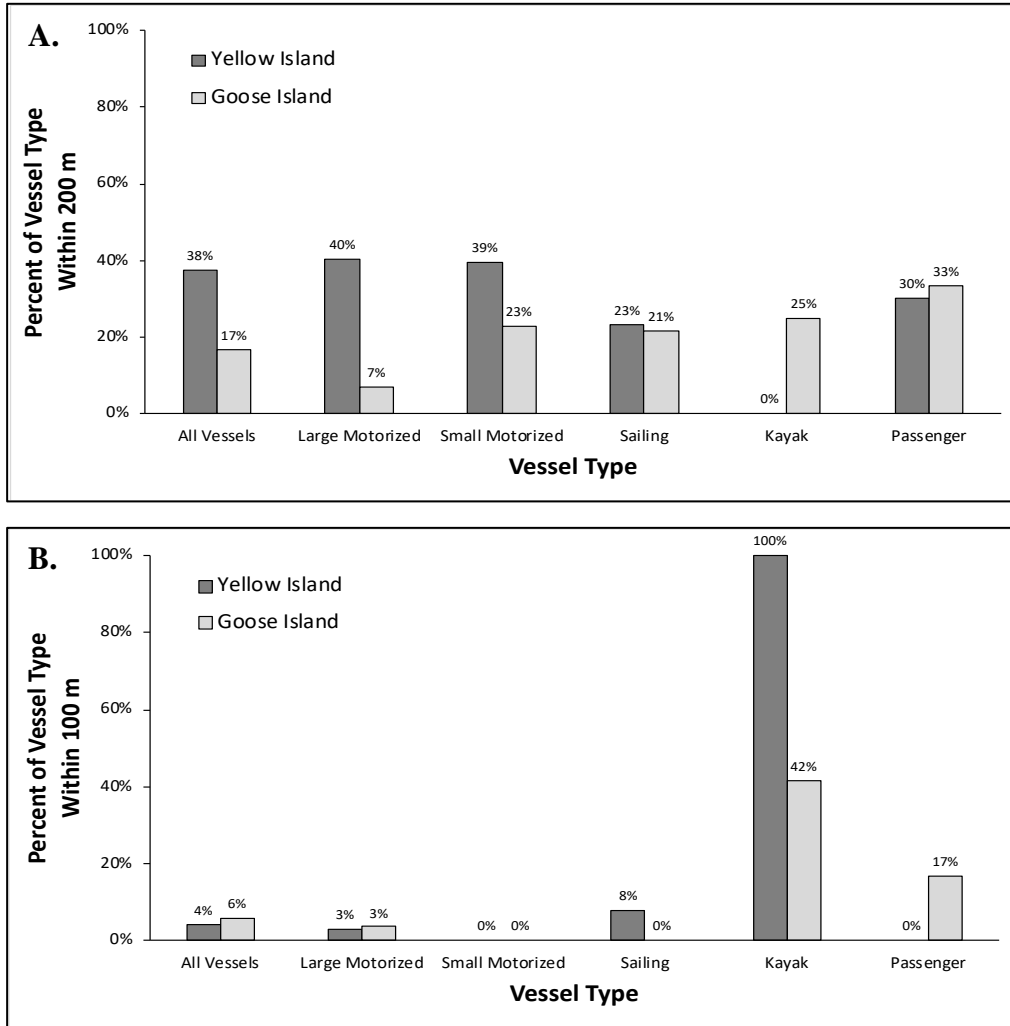
### *Vessel traffic*

Over the 12 hours of observations at each location, a total of 173 vessels at Yellow Island and a total of 196 vessels at Goose Island were observed within 400 m of the haul out sites. An average of  $14.4 \pm 5.7$  (mean  $\pm$  SD) vessels per hour were observed passing Yellow Island, while an average of  $16.3 \pm 5.6$  vessels per hour were observed at Goose Island. Large motorized boats were the most common vessel type at both locations, making up 63% ( $n = 173$ ) of vessels at Yellow Island and 44% ( $n = 196$ ) at Goose Island (Fig. 2). Small motorized boats were the second most common vessel type at both locations, making up 22% of vessels at Yellow Island and 34% at Goose Island (Fig. 2). Sailing boats, kayaks, and passenger vessels were less common, in total making up less than 30% of all vessels at both locations (Fig. 2).



**Figure 2.** Percent of each vessel type observed during total hours spent at Yellow Island (n = 173) and Goose Island (n = 196). Observations were made between 10 August and 13 August 2021, with two days spent at each location.

Analysis of vessel traffic found that 38% of vessels at Yellow Island and 17% of vessels at Goose Island passed within 200 m of the haul out sites at closest approach (Fig. 3A). Similar analysis performed for vessel traffic within 100 m at closest approach showed that, while a small percentage of total vessels entered within this distance of the haul out sites (4% at Yellow Island and 6% at Goose Island), 100% of kayaks (n = 3) at Yellow Island and 42% of kayaks (n = 12) at Goose Island entered within 100 m (Fig. 3B). Additionally, at Goose Island, 17% of passenger vessels (n = 18) entered within 100 m at closest approach (Fig. 3B).



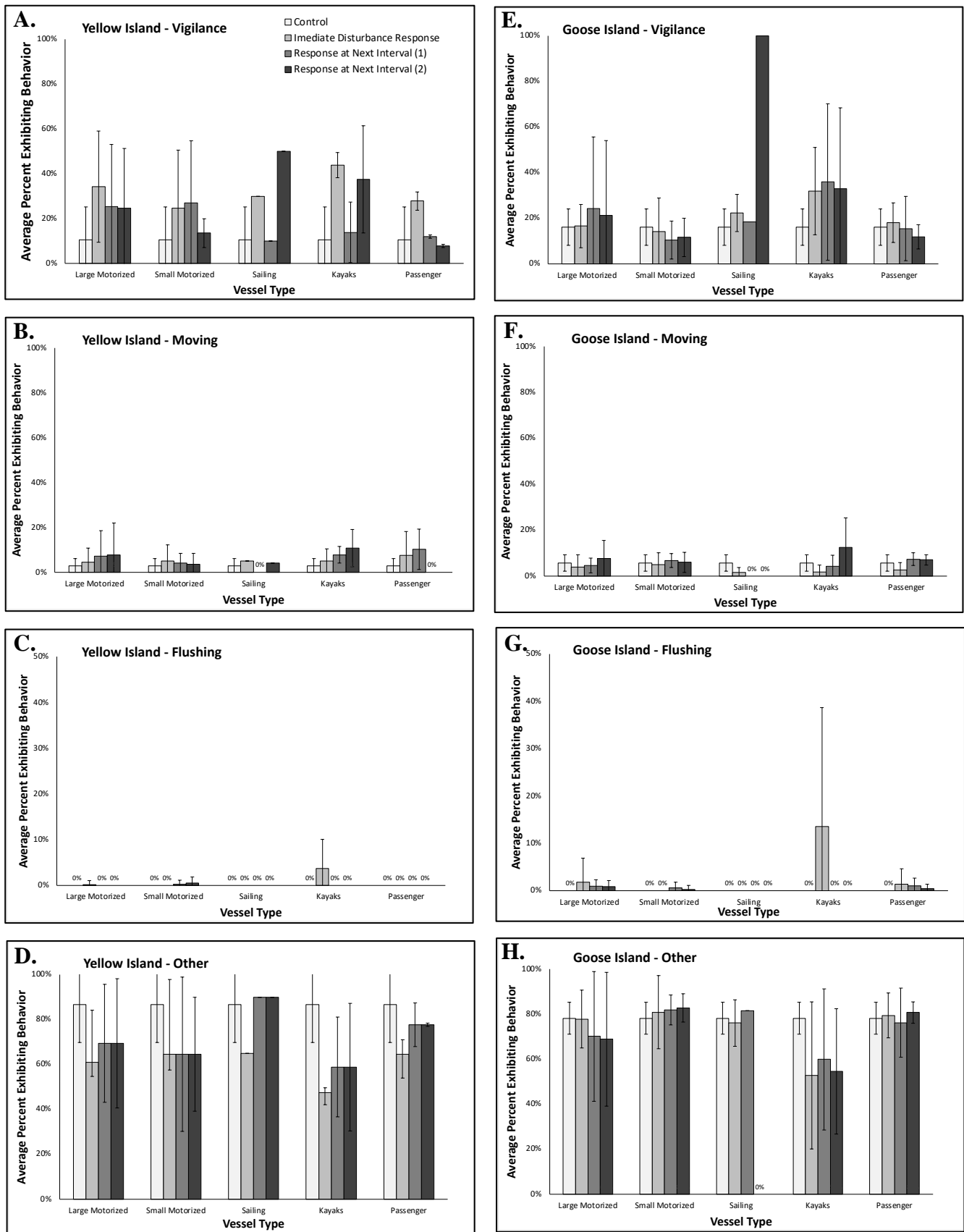
**Figure 3.** Percent of each vessel type observed within 200 m (A) and 100 m (B) at closest approach during total hours spent at Yellow Island and Goose Island. Observations were made between 10 August and 13 August 2021, with two days spent at each location.

### *Behavior*

At Yellow Island, there were several trends in the four measured behaviors. For vigilance, there was an increase in average percent vigilant during a disturbance compared to the control for all vessel types. When looking at the two intervals following the disturbance, we see a decrease in vigilance, returning back to a control level (Fig. 4A). Comparing vigilance behavior and other inactive behavior at Yellow Island, we see an increase in vigilance corresponding to a

decrease in other behaviors during a disturbance (Fig. 4A and D). Flushing behavior was rarely exhibited for any vessel type excluding kayaks, which had the highest average percent flushing at  $4\% \pm 6\%$  ( $n = 3$ ) (Fig. 4C and G). Moving at Yellow Island was variable with vessel type, with both increases and decreases during and after disturbances.

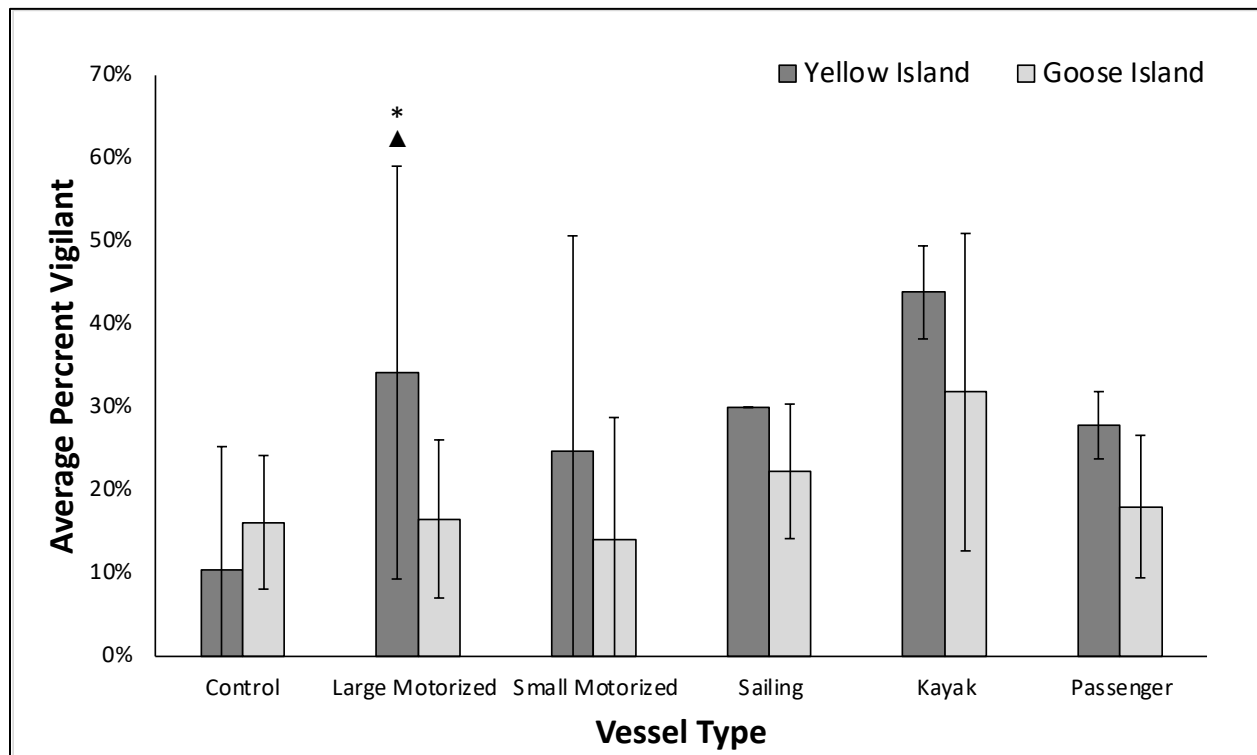
Goose Island had less clear trends in behavior. The average percent vigilant was variable both during and after disturbances, lacking a clear pattern. The other behaviors category was variable for all vessel types, except kayaks. During a kayak disturbance, there was a 25% decrease in other behaviors compared to the control, with both subsequent intervals fluctuating between 54-60% average percent exhibiting other behavior after the disturbance, compared to the control level of 78% ( $n = 8$ ) (Fig. 4H). Flushing behaviors were only exhibited during disturbance for kayaks ( $14\% \pm 25\%$ ,  $n = 6$ ), large motorized boats ( $2\% \pm 5\%$ ,  $n = 8$ ) and passenger vessels ( $1\% \pm 3\%$ ,  $n = 6$ ) (Fig. 4G). There was a consistent decrease in movement during disturbance for all vessel types relative to the control moving average, but movement after the disturbance was variable.



**Figure 4.** Average percent ( $\pm$  SD) of seals exhibiting vigilance (A and E), moving (B and F), flushing (C and G), and other (D and H) for each of the vessel types. For each disturbance, behavior was evaluated at a control, during disturbance and two intervals after the disturbance. The post disturbance scans were recorded as part of the continued interval scan. Graph C and D have a maximum of 50% on the y-axis.

## Vigilance

When comparing vigilance during disturbances at each location, trends emerged. The control average percent exhibiting vigilance was lower at Yellow Island ( $10\% \pm 15\%$ ,  $n = 8$ ) compared to Goose Island ( $16\% \pm 8\%$ ,  $n = 8$ ). For each vessel type the seals at Yellow Island exhibited higher vigilance on average than those at Goose Island (Fig. 5). Large motorized boats at Yellow Island elicited a significantly higher average percent vigilant than Goose Island ( $p = 0.007$ ). Large motorized boats at Yellow Island also elicited a significant increase in vigilance compared to the Yellow Island control level ( $p = 0.003$ ). Kayaks elicited the highest average percent vigilant at both locations with  $44\% \pm 6\%$  ( $n = 3$ ) at Yellow Island and  $32\% \pm 19\%$  ( $n = 6$ ) at Goose Island.

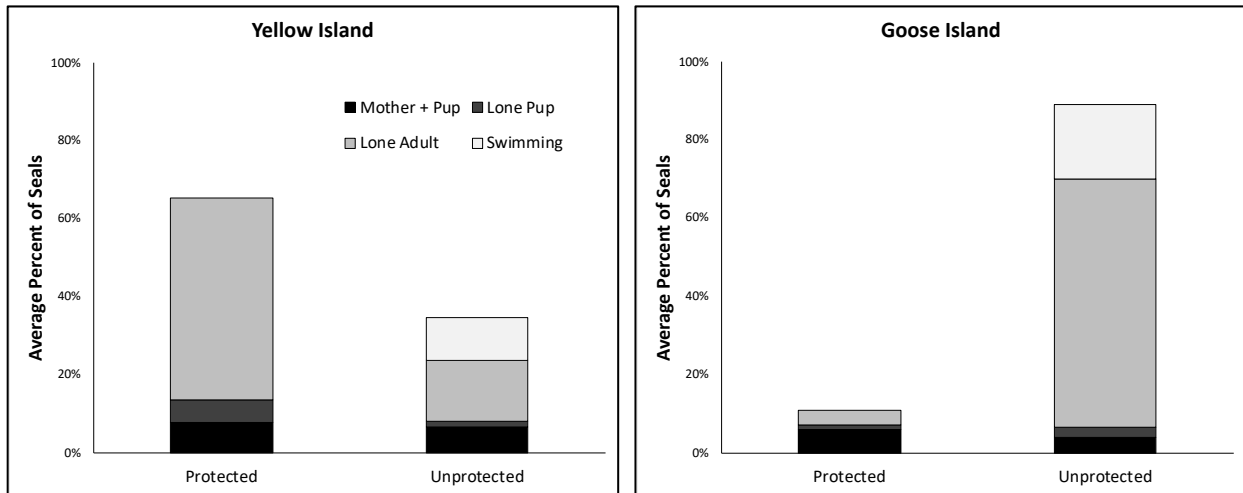


**Figure 5.** Average percent of observed seals displaying vigilance during a disturbance compared at Yellow Island and Goose Island per vessel type. ▲ Represents statistically significant difference between control value and vigilance response to vessel disturbance.

\* Represents statistically significant difference in vigilance response between sites.

## Distribution

The average percent of total seals within protected areas at Yellow Island was  $65.3\% \pm 11.7$ , ( $n = 38$ ), compared to only  $11\% \pm 7.4\%$  ( $n = 38$ ) at Goose Island (Fig. 1 and Fig. 6). The remainder of seals at both locations were found in unprotected areas. By breaking up each total percentage of seals into different categories based on seal type (mother and pup, lone pup, lone adult, and swimming), we looked at the proportion of each type in protected versus unprotected areas. Most seals at both locations were lone adults. There were no clear differences in the distribution of mother and pup pairs between protected and unprotected areas at either location. At Yellow Island, about  $79\% (\pm 34\% \text{ SD}, n = 25)$  of lone pups were located in protected areas compared to only  $30\% (\pm 37\% \text{ SD}, n = 24)$  at Goose Island (Fig. 6). We found that Yellow Island had more protected area proportional to total available haul out area than Goose Island. At Yellow Island, approximately 63% of the total available haul out area falls within protected zones. Goose Island has comparatively less area within protected zones, at only 20%.



**Figure 6.** The average percent of total observed harbor seals within protected and unprotected zones at Yellow Island and Goose Island. Each zone is divided into the proportion of each seal type (Mother + Pup, Lone Pup, Lone Adult, and Swimming) can be seen.

## **Discussion**

Together with past studies, our findings further clarify how vessel disturbance impacts harbor seals in the Salish Sea. Within the past two decades, vessel traffic in the Salish Sea appears to have increased. Despite this increase, we observed harbor seals displaying less extreme responses to vessel disturbance than in previous studies (Henry and Hammill 2001; Johnson and Acevedo-Gutiérrez 2007). We suggest that harbor seals within the Salish Sea have become more habituated to vessel presence and that this habituation could have negative implications. Kayaks appeared to be the main cause of extreme disturbance responses in our study. This finding is consistent with past studies, which found kayaks to be frequent violators of the 100-yard buffer zone set by the MMPA (Johnson and Acevedo-Gutiérrez 2007). Understanding the impacts of possible habituation of seals to vessel disturbance as well as non-compliance of vessels to current regulations is essential to improving both management and education moving forward.

### *Trends in vessel traffic*

During our 12 hours of observation at Yellow Island, we recorded a total of 173 vessels passing within 400 m of the west spit. This number becomes meaningful when comparing our study to a 2007 study done by Johnson and Acevedo-Gutiérrez, who recorded 187 vessels coming within 600 m of Yellow Island in approximately 115 hours of observation. Although accurate quantitative data regarding vessel trends within the Salish Sea are limited, through this comparison we can conclude that vessel traffic has increased substantially within the San Juan Islands over the past 14 years. This is consistent with relevant literature showing increases in vessel traffic globally and predicting similar increases within the Salish Sea (Olson et al. 2021). Looking at fine-scale differences in vessel traffic between our sites, we observed a higher

average number of vessels per hour at Goose Island compared to Yellow Island. A difference of approximately two vessels per hour indicates that, on average, Goose Island experiences approximately 24 more vessels within 400 m over a 12 hour period than Yellow Island. This result is the opposite of what we initially predicted and indicates that vessel traffic is somewhat higher at Goose Island overall. However, at Yellow Island we observed a higher percentage of total vessels passing within 200 m of the haul out site at their closest approach. These differences may become important when considering how harbor seals experience vessel traffic as a whole across different haul out locations. Additionally, it is important to note that our observations were conducted during the week, and therefore may not reflect the maximum number of vessels per hour passing each site during busier weekend vessel traffic.

Our results also allowed us to examine the compliance of various vessel types with the 91.4 m buffer zone outlined by the MMPA. Analysis of vessels passing within 100 m at closest approach was used to approximate this compliance and showed that, overall, a relatively low number of vessels come within the buffer zone. However, of those vessels that do, kayaks are the most common (Fig. 3). This result is supported by Johnson and Acevedo-Gutiérrez (2007), who found that 86% of kayaks passed within the buffer zone distance at Yellow Island. Specifically at Goose Island, passenger vessels, which were commonly whale watching boats, also came within this buffer zone distance. These results highlight the fact that vessels generally linked to tourism, and most notably kayaks, may regularly break regulation and can be important factors to consider when examining management efforts.

### *Trends of Behaviors*

Our prediction that harbor seals would be most vigilant for kayaks was proven true at both locations. At Yellow Island, the trend of increased vigilance during disturbance was

common across all vessel types and was paired with a decrease in other inactive behaviors, most commonly resting. This shift in behavior during disturbances may negatively impact their energetic budgets as it reduces time spent resting. Not all vessel types showed this trend in the following intervals, which may be due to the compounding effect of multiple disturbances occurring during the recovery intervals. Increased intervals following a disturbance may improve our understanding of recovery trends, or lack thereof, for all vessel types.

Across both sites, the average percentage of seals moving immediately following a disturbance lacks a clear trend. Through our observations, we witnessed movement being initiated by wake, boat disturbances, other seals, or seemingly no influence other than free will. Due to the variability in what caused movement and the relatively low levels in which we saw it occurring, it is difficult to draw conclusions on how boat disturbance directly affects movement. An increased sample size for opportunistic behavioral scans for each vessel category may help reveal trends in future studies. Our study saw kayaks initiate flushing events where 4% and 14% of seals flushed on average at Yellow Island and Goose Island respectively. Harbor seal sensitivity to kayaks is commonly recorded (Mathews et al. 2016). This is noteworthy considering no other vessel type initiated flushing at Yellow Island. Although we witnessed this sensitivity, our flushing observations are still relatively low compared to other harbor seal studies. A harbor seal study in Canada observed a flushing average of 86% when kayaks approached (Henry and Hammill 2001).

### *Habituation*

Based on both the trends in vessel traffic and response to disturbance we observed during our study, we believe that possible habituation to vessel disturbance has occurred within the harbor seal population in the Salish Sea and that this habituation may vary across haul out sites.

Past research has shown a positive correlation between vessel traffic and harbor seal disturbances (Johnson and Acevedo-Gutiérrez 2007). Based on this information, we would expect that the number of disturbances would have increased with increasing vessel traffic in the Salish Sea. However, we found that not only have disturbances not increased with increasing vessel traffic, but we also observed fewer extreme behavioral responses, such as flushing, in comparison to past studies (Henry and Hammill 2001; Johnson and Acevedo-Gutiérrez 2007). Therefore, we believe that harbor seals within the Salish Sea have become habituated to vessel disturbance.

Additionally, while we observed more vessels within 200 m at Yellow Island in comparison to Goose Island, the seals found at Yellow appear to have a more dramatic vigilance response to these disturbances. At Goose Island, we observed more vessels per hour, a lower increase in vigilance during vessel disturbance, and more harbor seals within unprotected areas. Harbor seals within the Salish Sea have been found to have moderate to high haul out site fidelity (Hardee 2008; Jefferson et al. 2021), and therefore it may be possible for differences in habituation to occur over time across haul out sites. Based on differences observed between the two sites, we believe that harbor seals at Goose Island may be somewhat more habituated to vessel disturbance than those at Yellow Island and that one possible mechanism of this habituation could be the higher control vigilance observed at Goose Island. We propose that there may be a tradeoff, where the harbor seals found at Goose Island remain slightly more vigilant during periods of no vessel disturbance and therefore are able to have a less extreme response to vessel disturbance when it occurs and can remain in unprotected areas as a result. This result is the opposite of what we had originally predicted based on initial observations of both locations. Additionally, this is only one possible explanation for the trends we observed,

and more long-term data is needed to more confidently determine whether habituation to vessel disturbance has occurred and whether this habituation may differ between sites.

While habituation to vessel disturbance may result in less flushing, and less energy expenditure during a disturbance as a result, habituation can also have several negative implications for harbor seals. These implications may include increased vulnerability to both vessel strikes and predation (Olson and Acevedo-Gutiérrez 2017). Therefore, habituation to vessel presence may be an important factor in properly managing vessel disturbance and the harbor seal population within the Salish Sea overall.

### *Implications for Management*

Understanding the habituation of harbor seals is important for the future of pinniped management. We saw 100% of kayaks at Yellow Island violate the 100 yard buffer zone protected by the MMPA. This is a 14.3% increase in non-compliance by kayaks at Yellow Island since 2007 (Johnson and Acevedo-Gutiérrez 2007). Our results showed that kayaks were the main vessel type to initiate flushing, one of the more energetically costly behaviors we observed (Suryan & Harvey 1999). Therefore, we suggest better education at kayak tour companies focusing on both what regulations are in place as well as the penalties for violating those regulations. Additionally, more signage should be put in areas that are known haul out sites such as Goose Island and especially at Yellow Island considering the access humans have to the site. Increased signage paired with consistent regulation wording across educational resources would be beneficial in increasing the general public's understanding of current regulations.

In addition to education, we observed the benefit of buoys acting as a visual aid to assist boats in determining the buffer zone. We saw most vessels staying beyond a buoy at Yellow Island, which is about 100 m from the haul out site. The buoy is dual purpose as it was installed

to warn boaters of a shallow reef in that region. We agree with Johnson and Acevedo-Gutiérrez's (2007) suggestion that implementing more buoys would decrease the number of boats coming within the buffer zone distance, which could lead to decreased disturbance. The goal of future management should be to educate the public, while also limiting their interactions with pinnipeds for the safety of both parties.

Harbor seals in the Salish Sea are not currently of high conservation concern, as their population is considered to be at equilibrium (Ashley et al. 2020). However, understanding their protection status as a recovered species sets an important standard for the treatment of pinnipeds as a whole. There are many pinniped species that are listed as Endangered, and the added stress of energetic budget shifts due to human disturbance may be less tolerable (Páez-Rosas et al. 2021). Additionally, harbor seals, regardless of conservation status, are still protected under the MMPA. Therefore, the non-compliance observed in our study highlights the need for better education on the regulations currently protecting pinniped species.

## **Acknowledgements**

We would like to thank Eric Anderson for his constant encouragement and guidance throughout this process. We would also like to thank W. Breck Tyler and Maria Kuruvilla for their support and knowledge. We appreciate the willingness of Friday Harbor Laboratories staff to provide resources necessary to conduct this study. Additionally, we would like to thank The Nature Conservancy for allowing us to conduct research at Yellow Island.

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