

# **The Effects of Marine Protected Areas on Seabird Species Composition and Abundance**

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## **Abstract**

Seabirds are highly mobile animals that are being impacted by climate change and other anthropogenic factors. Protection and conservation of seabirds is needed as populations are declining globally. However, given their wide ranges it is difficult to determine sites of protection and the efficacy of marine protected areas, which are locations that limit human activity. The purpose of this study was to determine if there was a relationship between seabird abundance and species composition relative to the protection of two marine lagoons on San Juan Island, Washington. Additionally, prey abundance and species composition were tested relative to protection at the same two marine lagoons. Data was collected by performing abundance and species surveys of each lagoon. Core samples of the sediment surrounding the lagoons were also processed to collect data on abundance and groups of invertebrate prey. The marine lagoon with a designated protection status yielded a higher abundance and species diversity than that of the unprotected lagoon. There were no significant findings in the prey survey. Future studies are recommended to enhance data and further determine the ability of marine protected areas to provide seabirds with proper refuge.

## **Introduction**

The tidal activity of the Salish Sea creates an environment that is rich in seabird species as mass amounts of water flood through the Strait of Georgia and into the Haro Strait (Yang et al. 2021). This creates nutrient rich waters due to mixing that allow for seabirds to thrive. The nutrient rich water of the Salish Sea also makes for a commercially and recreationally busy environment. The busy environment of the Salish Sea contributes to the anthropogenic stressors that factor into the decline of seabirds. Globally, seabird species are declining and many species are in risk of extinction as a result of climate change and other anthropogenic stressors (Senzaki et al. 2019). For this reason, it is pertinent that there are designated areas of protection or marine protected areas to provide refuge for seabirds. Marine protected areas are designated sites of protection in our oceans that are designed to allow for ecosystem recovery, climate change mitigation, and provide refuge to vulnerable species (Gonçalves 2023).

Seabirds can be used as an important tool in marine protected area site selection as they are critical marine top predators as they can act as indicator species of their environments (Lascelles et al. 2012). Indicator species are animals or plants that can be used to draw conclusions and make inferences about the state of the environment and thus the organisms living in it. Abundance counts are a good ways to measure the health of indicator species as they are easy to perform and trends can be drawn from them (Parsons et al. 2008). However, given the highly mobile nature of birds, it is hard to determine the effectiveness and the locations of marine protected areas (Ronconi et al. 2012). Further research and surveys need to be done in order to fill this data gap. More specifically, the commercial and ecological significance of the Salish Sea makes it vital to monitor and protect seabird species as they can be used as indicators of not only the conditions of their environments but also fisheries stocks (Einoder 2009).

This study focused on two marine lagoons on San Juan Island, Washington with different designations of protection to identify whether established areas of protection offer better refuge and prey availability than non-protected areas do. Additionally, core samples were taken at each site to determine if there was a correlation between prey and site protection. We hypothesized that the protected areas of our study would have a larger total number of birds as well as more

species diversity than the unprotected site would. We also hypothesized that there would be a higher abundance and species diversity of prey at the protected lagoon.

## Methods

### *Study Sites*

This study was conducted from May 20 - May 24 with two additional collection days on May 3 and May 16 at two marine lagoons on San Juan Island, Washington. The protected study site was Argyle Lagoon which is a 0.05 km<sup>2</sup> body of water (Figure 1) within a University of Washington biological reserve and an established marine protected area. The unprotected study site was Third Lagoon which is 0.01 km<sup>2</sup> (Figure 2). Areas of the lagoons were found using DaftLogic Area Calculator Tool. Both sites are marine lagoons surrounded by salt marsh with similar vegetation, experience little to no wave action from nearby beaches, and have muddy sediments in the lagoons and on the surrounding shore. However, Argyle Lagoon has constant water flow via Argyle Creek and is significantly larger than Third Lagoon. While the two sites differ in water movement and size, Argyle and Third Lagoon were the two most similar sites on San Juan Island while still varying in levels of protection which is why these sites were chosen for this study.



**Figure 1:** Map of Argyle Lagoon Marine Preserve. Area = 0.05 km<sup>2</sup>. Vantage point marked by star.



**Figure 2:** Map of Third Lagoon. Area = 0.01 km<sup>2</sup>. Vantage point marked by star.

Old Town Lagoon was a third site that was visited for three days of data collection. However, Third Lagoon was a more comparable site to Argyle Lagoon, so the remainder of the experiment was done at Third Lagoon and Argyle Lagoon. Data from the three collection days at Old Town lagoon will be presented in figures 3 and 4 but was not the focus of this project.

#### *Data Collection*

Abundance and species count of birds and invertebrates were done at both sites in the morning and afternoon mainly using Vortex Diamondback HD binoculars with 10x42 magnification. A Celestron Ultima 80 spotting scope was used when birds were on the other side of the lagoons and extra magnification was needed to identify bird species. At both sites, an initial survey was done from a vantage point (Figures 1 and 2) as not to flush the bird. For both the initial and final surveys scans of the entire lagoon and the surrounding shore were done from left to right. As birds were spotted, they were identified and counted. Birds were counted if they were in the lagoon or on the shore surrounding the lagoon. The duration of the survey was variable but ended once all birds in the lagoon had been counted and identified. If birds could not be identified, they were added to the category “unknown species.” A 10-minute interval followed the initial survey, which allowed birds to leave or enter the lagoon in hope that birds would not be recounted. A final survey was taken after the 10-minute interval with the same procedure as the initial survey. Data from the surveys was initially written in a field notebook but then was transferred to a spreadsheet in Google Sheets. Bird abundance counts were averaged within their respective species as to minimize any recounting errors.

After the final survey, core samples were taken at 6 random locations around each lagoon using a 2 mm mesh sieve to remove sediment from the sample. To do the core samples, a portion of sediment was removed from the water’s edge using a metal shovel. The core sample did not exceed 5 centimeters in depth as the longest beak of local shorebird species (greater yellowlegs) does not typically exceed 5 centimeters. The sediment was put into a mesh sieve and was

strained in the water to isolate only large items and invertebrates. Once sediment was removed, organisms and their amount were noted. Organisms were put into groups such as worm, snail, bivalve, crab, anemone, bubble snail, amphipod, and beetle.

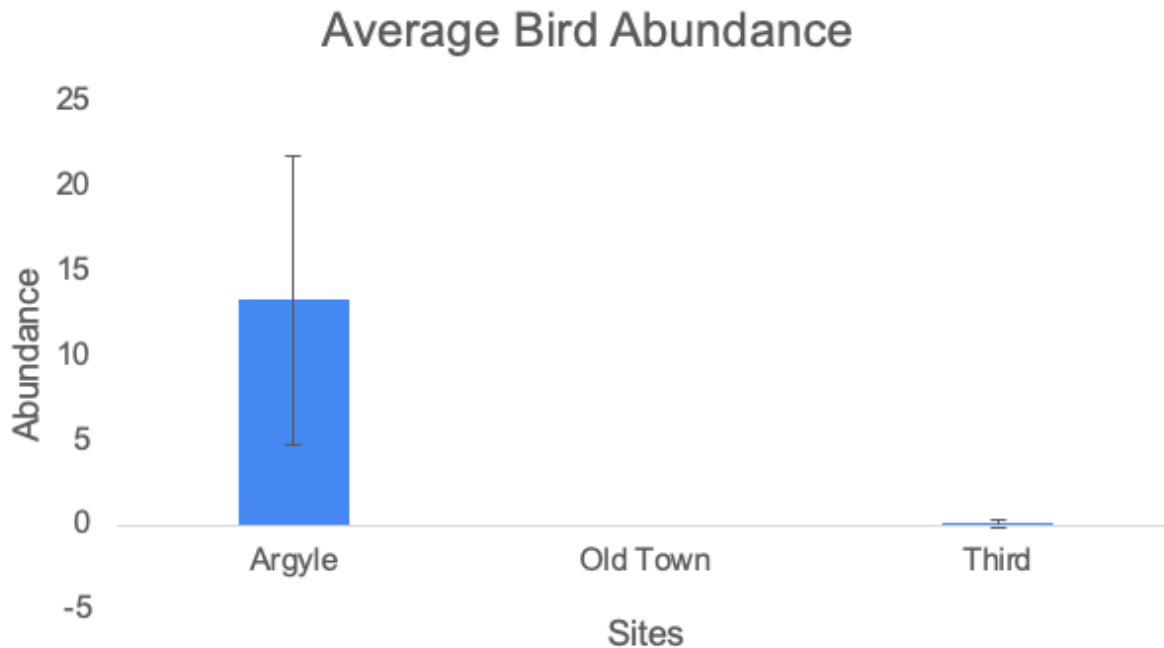
### Data Analysis

Bird and prey data were entered into two separate Google Sheets spreadsheets. The bird data set included counts of specific species seen during each survey, a count of the total number of species seen during each survey, and a total abundance of all birds seen in the lagoons during each survey. Prey data was entered into a similar spreadsheet but was not species specific as identification was difficult to do in the field. To make figures and test for significance, data was transferred from Google Sheets to Excel. Data was tested for significance in Excel using a one-sided t-test assuming unequal variance. The t-test compared bird abundance, bird species count, prey abundance, and prey groups count between sites for a total of four tests.

## Results

### Bird Abundance

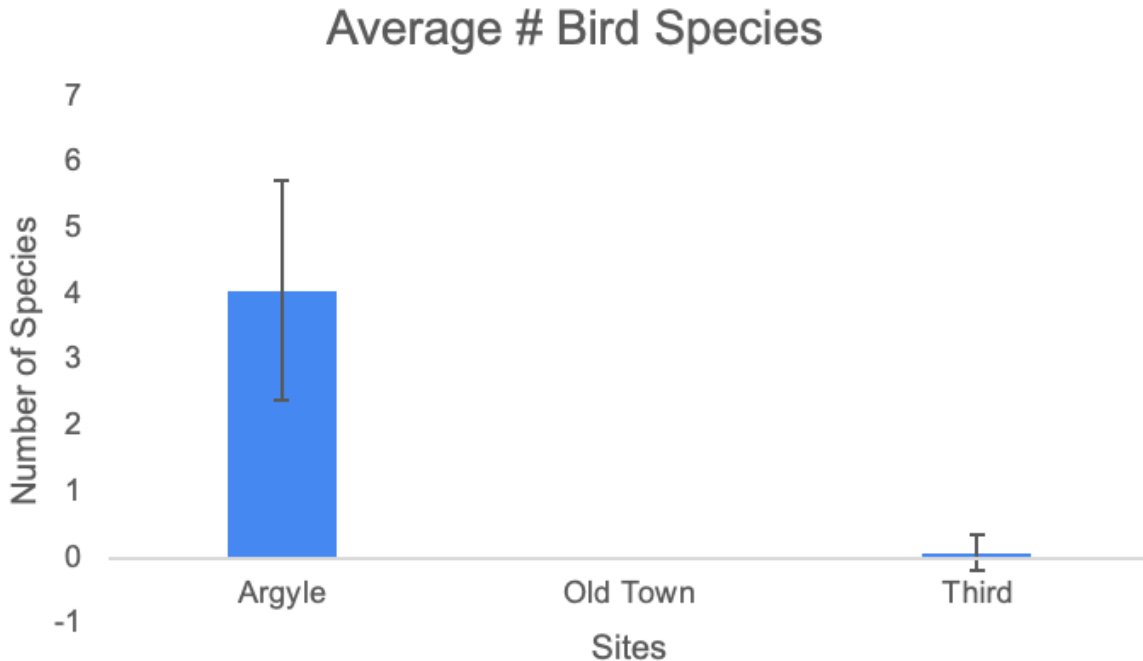
The total counts of birds taken during each survey were averaged for their respective lagoons. Argyle Lagoon had the highest abundance between the unprotected and protected marine lagoons with an average of 13.4 birds and a standard deviation of  $\pm 8.88$  (Figure 3). The number of birds seen at each survey at Argyle Lagoon ranged from 2 to 37. No birds were seen at Old Town Lagoon. There was an average of 0.07 birds seen at Third Lagoon with a SD of  $\pm 0.27$  as there was only one bird sighting for the duration of data collection. The hypothesis that protected areas will have a higher abundance of birds compared to non-protected areas is supported by a significant p-value (one tailed t-test,  $t = 6.76$ ,  $p < 0.05$ ).



**Figure 3:** Abundance of birds averaged  $\pm$  SD across all surveys.

### Bird Species Composition

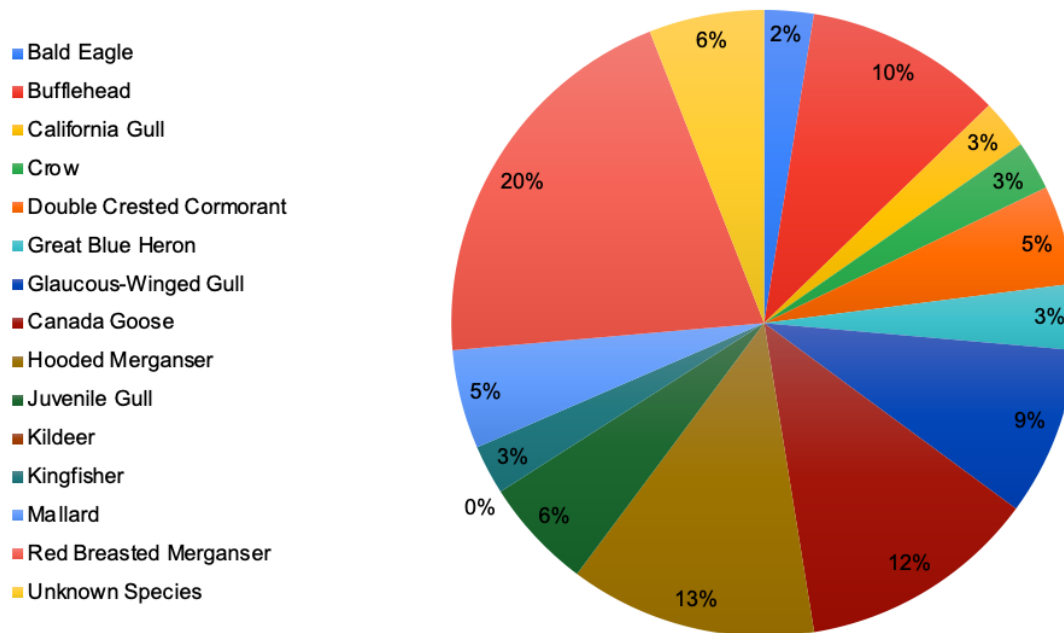
The number of species seen during each survey were averaged across the duration of the project to find that Argyle Lagoon had the greatest number of different species at a given point. Argyle Lagoon had an average of 4.05 species with a SD of  $\pm 1.67$  while Old Town Lagoon had an average of 0 species with an SD of  $\pm 0$ . Third Lagoon had an average of 0.07 species with a SD of  $\pm 0.27$  (Figure 4). This finding was supported by a significant p-value (one tailed t-test,  $t = 10.68$ ,  $p < 0.05$ ). The significant finding that fewer diverse species occupy unprotected lagoons aligns with our original hypothesis.



**Figure 4:** Average number of bird species  $\pm$  SD present at a given time

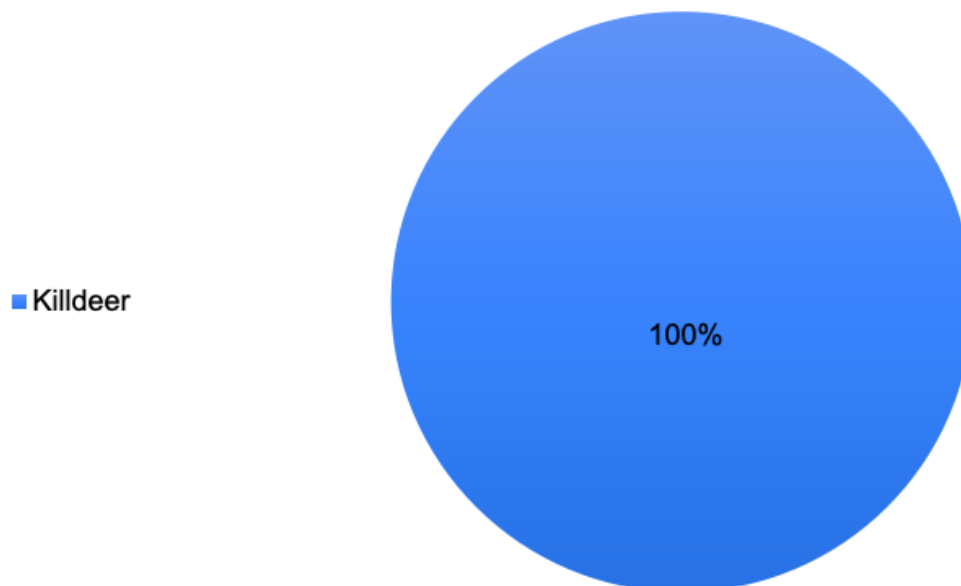
In addition to finding that Argyle Lagoon had the most diverse species at a given time, the species composition of birds at each site was also observed (Figure 5). The number of birds in each species category were averaged and then made into a pie chart to create a species composition profile of Argyle Lagoon. Red breasted mergansers, hooded mergansers, and Canada geese respectively made up the three most prevalent species we observed in Argyle Lagoon. A pie chart of species composition was also made for Third Lagoon. Killdeer was the only species of bird found at Third Lagoon (Figure 6).

## Seabird Composition at Argyle Lagoon



**Figure 5:** Species composition of birds at Argyle Lagoon.

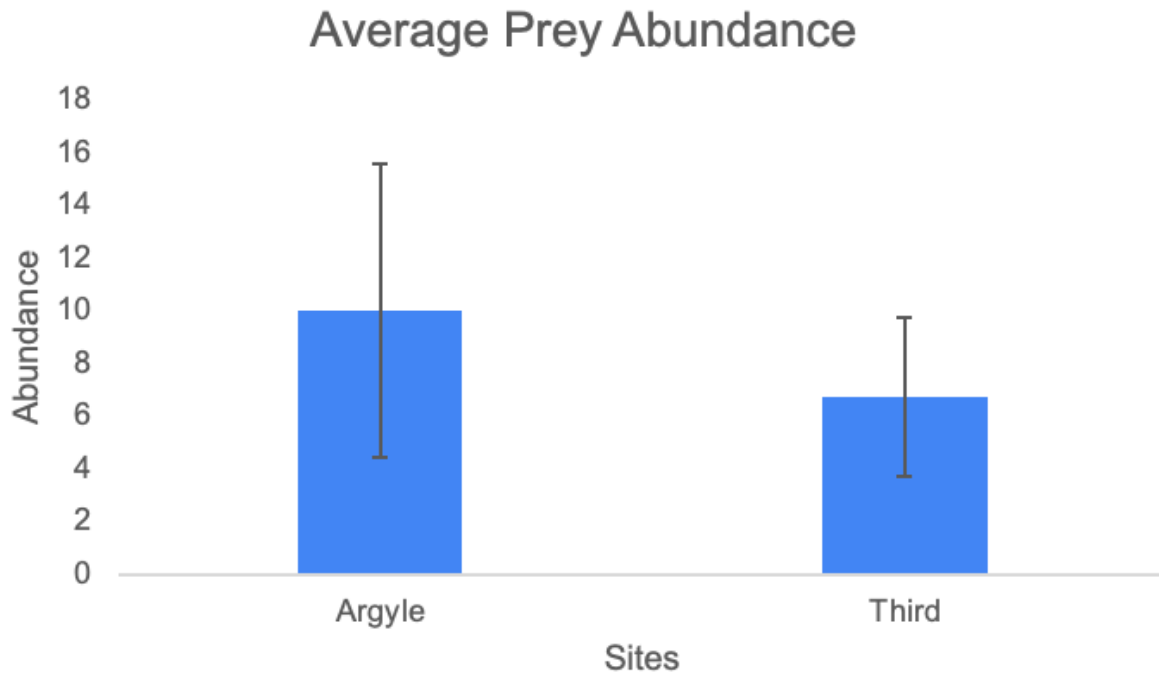
## Seabird Composition at Third Lagoon



**Figure 6:** Species composition of birds at Third Lagoon.

*Prey Abundance*

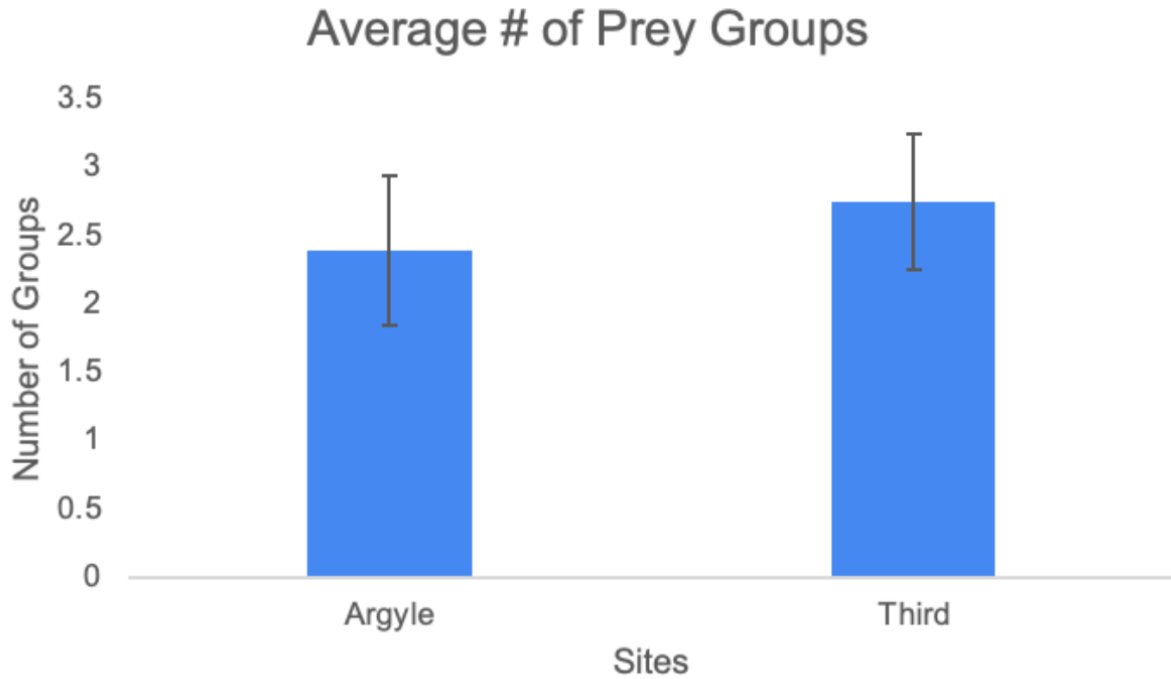
Prey abundance was measured by taking core samples of the sediment surrounding the lagoons and sieving it through mesh. Prey abundance surveys showed a trend that Argyle Lagoon yielded the highest abundance of marine invertebrate prey with 2.8 diverse species (Figure 7). At Argyle Lagoon there was an average of 10 invertebrates total with a SD of  $\pm 5.57$  in the 6 core samples that were taken per day. 6 core samples were taken daily, and the number of invertebrates found in each sample were added. At Third Lagoon there was an average of 6.75 invertebrates with a SD of  $\pm 2.99$ . The data shows a trend towards higher prey abundance in protected areas than in unprotected areas which aligned with our hypothesis. This trend was however not statistically supported (one tailed t-test,  $t = 1.02$ ,  $p > 0.05$ ).



**Figure 7:** Average abundance of prey between Argyle and Third Lagoon  $\pm$  SD.

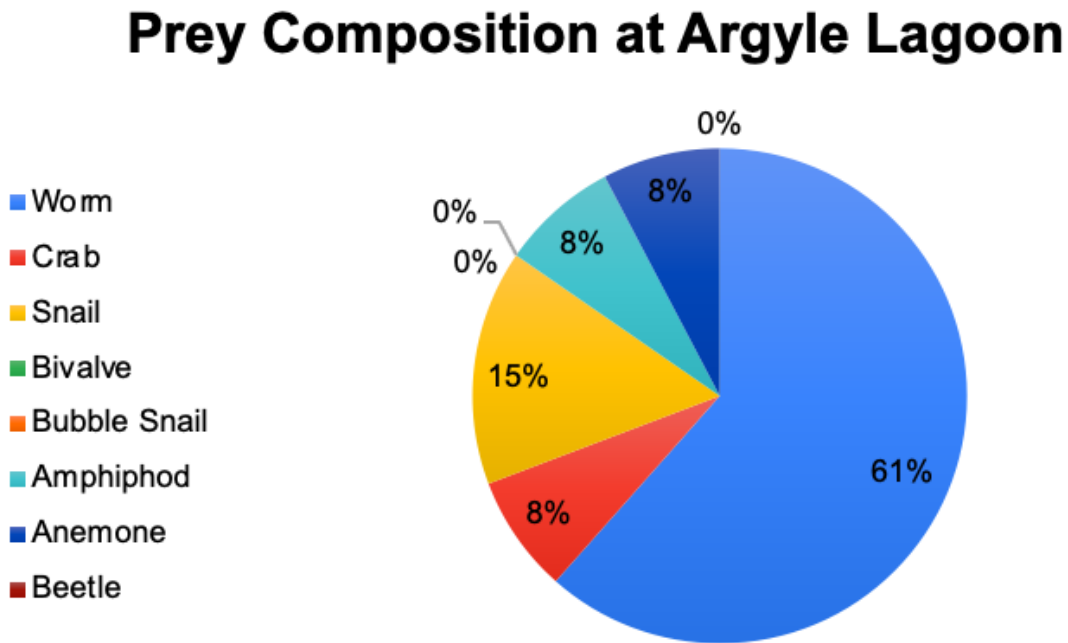
#### *Prey Group Composition*

In addition to abundance of prey, prey was also categorized into groups based on their morphology (Figure 8). Third Lagoon had the largest number of diverse species of prey at an average of 2.75 with an SD of 0.5. Argyle Lagoon had an average of 2.4 prey groups across the core samples with a SD of  $\pm 0.54$ . This trend was not statistically supported and needs more data to draw any conclusions on whether there is a higher diversity of species composition at unprotected areas than protected areas (one tailed t-test,  $t = -1$ ,  $p > 0.05$ ).



**Figure 8:** Average number of prey groups from core samples  $\pm$  SD.

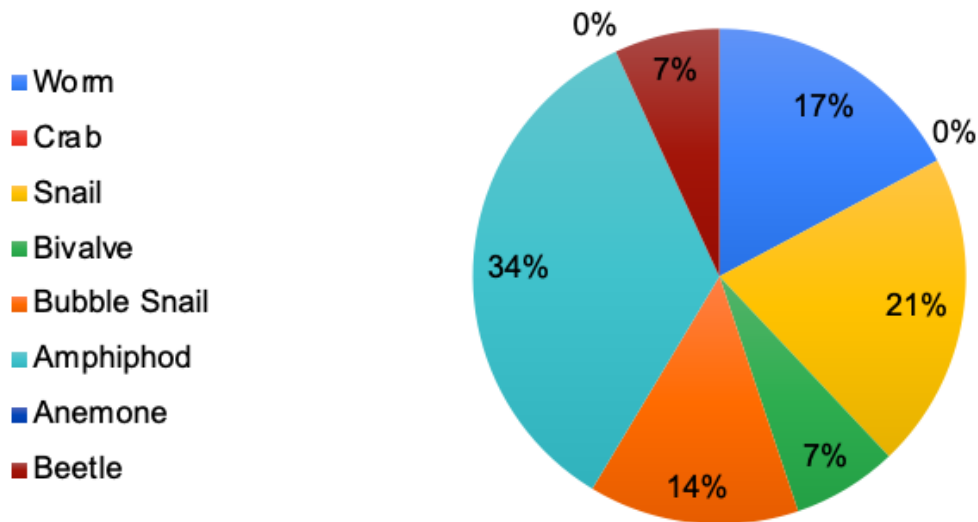
At Argyle Lagoon the most abundant prey group found in the core samples were worms which made up 61%, followed by snails which made up 15%. Crabs, amphipods, and anemones each made up 8% of the total composition, making up 24% in total (Figure 9).



**Figure 9:** Composition of prey groups at Argyle Lagoon.

At Third Lagoon the most abundant prey group found in the core samples were amphipods which made up 34%, followed by snails which made up 21%. Worms made up the third largest group at 17% (Figure 10).

## Prey Composition at Third Lagoon



**Figure 10:** Composition of prey groups at Third Lagoon.

## Discussion

### *Bird Abundance and Species Composition*

Argyle Lagoon had the highest abundance of birds while Third Lagoon had only one bird sighting and Old Town Lagoon had no bird sightings during the dates of our data collection. This finding was supported by a significant p-value which indicates that there was correlation between the abundance of birds and the protection of study sites. However, this correlation may not be entirely due to the protection designation of Argyle Lagoon but could be due to another variable entirely. Argyle Lagoon has an area that is roughly 5 times larger than that of Third Lagoon, meaning it would be able to accommodate more birds which could be a factor in why more birds were observed at Argyle Lagoon than Third Lagoon. The lack of birds in Third Lagoon could also be an indication that water quality is poor or that there is not sufficient prey available. Seabirds have been used in the past as early warning indicators of pollution and other environmental phenomena (Burger and Gochfeld 2004), as could be the case at Third Lagoon.

In addition to the spatial differences in both Argyle and Third Lagoon, there are hydrodynamic differences in both lagoons. In Argyle Lagoon, there is constant flow of water via Argyle Creek. During high tide, Argyle Lagoon fills with water from the creek and floods out during low tide (University of Washington). This helps to maintain constant water circulation within the lagoon. In Third Lagoon, water is stagnant with the only exchange of water occurring

during extremely high tides. The stagnant water in Third Lagoon likely does not garner many nutrients whereas in Argyle Lagoon, the constant flow of water from the creek brings in new nutrients. The flow of nutrients allows for more productive growth of seaweeds and in turn other marine organisms which may serve as prey for seabirds (Crossley et al. 2002). In future studies, it would be advisable to compare lagoons with more comparable hydrodynamic processes and sizes to be able to better assess the value of marine protected areas for seabirds. Additionally, future studies with longer time allowances should look more closely at seasonal behaviors that could be aided by marine protected areas such as roosting, rearing young, and feeding (Camphuysen et al. 2012). These behaviors may be more susceptible to stressors both anthropogenic and environmental; in which case, marine protected areas may prove more effective.

### *Prey Abundance and Species Composition*

Prey abundance and species composition differed widely between the two lagoons. Argyle Lagoon had far more worms than Third Lagoon, likely because of the differing sediment types. The sediment in and surrounding Third Lagoon was densely packed mud and clay, with a lot of organic material and low oxygen content. Argyle Lagoon had better oxygenated sediment as it was looser grains of sandy mud. The differences in sediment are probably a factor in the variable prey groups that we saw at Argyle vs. Third Lagoon. These factors affect the available food for invertebrates which could explain why we see the difference in species makeup at both sites which has been supported in past experiments by Wieking and Kröncke (2005). The lack of water flow at Third Lagoon limits the amount of oxygen in the water and reduces the rate of primary production occurring which in turn decreases infaunal populations as there are fewer nutrients cycling (Mendonça et al. 2007). Given Third Lagoon receives minimal water exchange with the Salish Sea, it is probably a lower salinity environment than Argyle Lagoon as it has more freshwater input via rainwater and runoff. The lower salinity environment creates a brackish environment that may not be able to sustain the same marine invertebrates that Argyle can.

Third Lagoon had more diverse species of prey found in the sediment than Argyle Lagoon, which did not align with the stated hypothesis that protected areas would offer a more diverse composition of prey groups. This finding, however, was not statistically supported. This was unexpected as Argyle Lagoon is larger and has better water flow which may create a more habitable environment and thus have higher species diversity (Palardy and Witman 2011). Additionally, in a study by Péron et al. (2013) a higher diversity of prey species were found in protected areas. However, Third Lagoon yielded a higher species diversity. While the protection levels of the lagoons may influence the diversity of prey, it could also be due to more site-specific factors and/or sampling error. The sediment type may influence the difference in species composition as the sediment at Argyle was looser while the sediment at Third was densely packed. This trend could be better supported by a larger sample size as there was a small sample size for each lagoon. Sampling error could also have influenced the results, as a coring device was not used but rather a metal shovel. A coring device could have better standardized samples and made them more comparable to one another.

### *Conclusions*

More research is needed on the efficacy of marine protected areas for seabirds as they are crucial to marine food webs and serve as indicator species of their environments. Seabirds

can help to determine where marine protected areas should be placed as top marine predators. Further research and data should be applied to this project as the time scale in which data was collected was short and more time would allow for more concrete conclusions to be drawn.

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