

**Comparative Behavioral and Diversity Studies of Shorebirds  
in Marine and Freshwater Habitats at San Juan Island**

Jamie Oman<sup>1,2,3</sup>

Jolee Thirtyacre<sup>1,2</sup>

A.J. Rossbach<sup>1,4,5</sup>

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

<sup>2</sup>School of Aquatic and Fisheries Sciences, University of Washington, Seattle, WA 98195

<sup>3</sup>Chemistry Department, University of Washington, Seattle, WA 98195

<sup>4</sup>Department of Biology, Middlebury College, Middlebury, VT 05753

<sup>5</sup>Department of Environmental Studies, Middlebury College, Middlebury, VT 05753

*Contact Information:*

Jamie Oman

[oman.jjm@gmail.com](mailto:oman.jjm@gmail.com)

Jolee Thirtyacre

[thirtyj@uw.edu](mailto:thirtyj@uw.edu)

A.J. Rossbach

[arossbach@middlebury.edu](mailto:arossbach@middlebury.edu)

**Authors contributed equally to this manuscript**

**Abstract:**

Shorebirds are found in marine and freshwater, and provide a variety of ecosystem functions. Our study took place on San Juan Island, Washington, USA where we observed sandpiper and plover species and how they interacted with the environment around them via diversity, substrate, and behavior scans. We used spotting scopes at a marine site at Argyle Lagoon and a freshwater site at Zylstra Lake. At these locations, morning and afternoon sessions provided temporal comparisons. We found that in correspondence with their hunting strategies and the ecological niches available, Greater Yellowlegs (*Tringa melanoleuca*) spent most of their time in water and Killdeer (*Charadrius vociferus*) were found on rocks at Argyle and vegetation at Zylstra Lake. Greater Yellowlegs fed more at Zylstra Lake but foraged equally between the two locations. We only observed Western Sandpipers (*Calidris mauri*) at Zylstra Lake, mainly along the shoreline in mud. The Western Sandpipers also spent the majority of their time foraging and feeding. These results indicate that prey availability and selection, and vegetation cover could play a role in substrate choice and behavior. We recommend that future studies consider seasonal changes in species diversity and environmental conditions, and how human disturbance may play a role in affecting shorebird natural life history.

**Keywords:** Greater Yellowlegs, Killdeer, Western Sandpiper, behavior, species diversity, marine, freshwater, San Juan Island

## **Introduction:**

Shorebirds are avifauna closely associated with coastal and inland waters (Gutiérrez et al. 2012). Species can be migratory or may occupy local areas year-round, choosing to use marine or freshwater when they are available (Martín et al. 2014). Current literature has provided little information on shorebird site selection between these two habitats. Differences in substrate use can provide key insights into their type of feeding and prey preference. Their hunting strategies, which can range from sitting and waiting along the water's edge to wading into water, make them favorable for visual studies compared to diving birds that frequently disappear underwater for foraging and feeding.

We focused on three prevalent shorebirds: two types of sandpiper, the Greater Yellowlegs (*Tringa melanoleuca*) and Western Sandpiper (*Calidris mauri*), and one species of plover, the Killdeer (*Charadrius vociferus*). These species' life histories differ in feeding strategy and prey preference. Greater Yellowlegs are wading birds that prefer shallow water to feed, but due to their long legs, are able to wade into deeper water (Bent 1927a). This allows them to feed on small fish and water insects that are unavailable to shallower waders (Bent 1927a). The Greater Yellowlegs is a migratory species living across the Americas (Bent 1927a, Buchanan 1988).

Western Sandpipers prefer to feed at the water's edge due to their small size (Bent 1927b). Because of this behavior, their feeding strategy involves skimming food off substrates (Bent 1927b). Specialized tongues coated in spines allow them to skim energy-rich biofilm and collections of microorganisms off surfaces (Canham et al. 2021). Like Yellowlegs, they are a migratory species (Bent 1927b).

Killdeer live in the widest range of habitats of any shorebird species in the Americas, including marine and freshwater areas, as well as locations altered by humans (Eberhart-Phillips 2017). They are sit-and-wait predators, using visual cues to hunt their prey rather than probing or skimming (Eberhart-Phillips 2017, Oklahoma Department of Wildlife Conservation). Killdeer feed on invertebrates and larvae found on various substrates (Oklahoma Department of Wildlife Conservation). The population that appears in the Salish Sea is a resident population (Bowles 1918).

Our location on San Juan Island provided the opportunity to better understand shorebird habitat preference when provided with both marine and freshwater locations. With a focus on these three species, we were able to observe how the species were using and selecting each of the habitats and its resources differently, focusing on species diversity, species frequency, substrate use, and behavior at each location.

### **Methods:**

Four days of data collection began on 8 August 2023. Two sites on San Juan Island, WA, USA included a marine habitat at Argyle Lagoon and a freshwater habitat at Zylstra Lake. We completed sessions in the morning (1000-1200 hrs) and afternoon (1330-1530 hrs). Roles were assigned to each group member for uniform measurements.

### *Study Areas*

We did behavior observations via focal sampling with a 20-60x zoom spotting scope. Diversity surveys across each shoreline were conducted with the same scope from left to right (Fig. 1). We used pre-existing markers for uniformity of scan boundaries and scope placement.

### *Parameters*

Substrate type and behavior were the two parameters of our study. We identified six substrates and six behaviors. We denoted sand as a dry substrate and mud as wet. Feeding was distinguished by actively dipping or pecking bills into a substrate. Foraging was actively wandering, including walking, looking at the ground, or wading. Inactivity occurred when the birds were alert, but not moving. Flying was determined by birds flushing or being in the air. Resting birds stood or laid down with their heads tucked back under a wing. Lastly, preening occurred when the birds actively cleaned, oiled, or ruffled their feathers.

### *Surveys*

We measured diversity by the total count of each species in the designated scan area and substrate used by each bird. We took diversity surveys every 20 minutes and six scans were done in each session. Ten minutes after each diversity survey, we did behavioral surveys. Behavior surveys consisted of logging a selected bird's behavior and the substrate it used for four minutes at 30 second intervals. There were six scans per session. We used a random number generator to select a shorebird when counting from left to right.

### *Analysis*

We conducted data analysis with Microsoft Excel and R programming software, using raw observation counts, means, and percents. We analyzed feeding and foraging data with analysis of covariance tests and a Tukey-Kramer test when appropriate.

### **Results:**

### *Diversity*

We identified three shorebird species at Argyle Lagoon. The Greater Yellowlegs comprised 44.9% of the birds present in the morning and 47.3% in the afternoon sessions. Killdeer accounted for 54.1% of the birds in the morning and 51.0% in the afternoon. We counted one individual of an unidentified sandpiper, which accounted for 1.0% of the shorebird diversity (Fig. 2).

At Zylstra Lake, we identified four shorebird species. Greater Yellowlegs were 21.4% of the shorebirds in the morning and 0.4% in the afternoon. Killdeer were 37.0% of the shorebirds in the morning and 39.6% in the afternoon. We only observed Western Sandpipers at Zylstra Lake. We found variance in Western Sandpiper presence between morning and afternoon with them comprising 40.1% and 60.0% of shorebirds respectively. We observed one unidentified Dowitcher at Zylstra lake, comprising 1.7% of shorebirds in the morning (Fig. 3).

### *Substrate Use*

At Argyle Lagoon, the highest number of Greater Yellowlegs substrate observations were in the water, followed by rocks (Fig. 4). We observed Greater Yellowlegs on four substrates at this location. The highest number of observations of Killdeer was on rocks at Argyle Lagoon, followed by mud. Killdeer used three substrates at this location.

At Zylstra Lake, most Greater Yellowlegs observations were in water, followed by mud (Fig. 5). They used two substrates at Zylstra Lake. The highest number of Killdeer observations at Zylstra Lake were on vegetation, followed by mud. Killdeer used five substrates at this location. We mainly observed Western Sandpipers on mud, followed by water. Western Sandpipers used two substrates at Zylstra Lake.

Killdeer were on rocks during 48.0% of our observations at Argyle Lagoon (Fig. 6). We observed Killdeer on sand 28.1% of the time and 37.5% of the time in vegetation at Zylstra Lake. Killdeer spent no time on rocks at Zylstra Lake since no rocks were present.

### *Behavior*

At Argyle Lagoon, Greater Yellowlegs spent the majority of their time foraging followed by resting, but did all six behaviors (Fig. 7). Killdeer at Argyle Lagoon were mainly foraging, followed by inactivity. Killdeer did four of the six behaviors.

At Zylstra Lake, Greater Yellowlegs performed two of the six behaviors: foraging and feeding (Fig. 8). For Killdeer, we observed five of the six behaviors, with foraging and inactivity being most prevalent. Western Sandpipers did three of the six behaviors, with most observations being foraging and feeding.

Of individuals that foraged, Greater Yellowlegs had a median time spent foraging of 55.5% for both Argyle Lagoon and Zylstra Lake (Fig. 9). We found the Killdeer's median time spent foraging was 55.5% at Argyle Lagoon and 66.6% at Zylstra Lake (Fig. 9). Of individuals we observed feeding, Greater Yellowlegs had a median time spent feeding of 22.2% at Argyle Lagoon and 38.8% at Zylstra Lake (Fig. 10). Killdeer had a median time spent feeding of 22.2% at Argyle lagoon and 17.0% at Zylstra Lake (Fig. 10). Greater Yellowlegs and Killdeer foraged equally between sites (ANCOVA,  $df=1$ ,  $F=0.1457$ ,  $p=0.706$ ). However, Greater Yellowlegs fed more at Zylstra Lake than at Argyle Lagoon (Tukey-Kramer,  $p=0.007$ ).

### **Discussion:**

This study demonstrates how different shorebird species partition ecological niches and behave in a way that is best suited to their life histories. Our findings suggest that sandpipers and plovers differ in their diversity, substrate use, and behavior at marine and freshwater locations.

### *Diversity*

We observed Western Sandpipers at Zylstra Lake but not Argyle Lagoon, most likely because of their group flushing behavior (Bent 1927b). Additionally, the stronger current at Argyle Lagoon may discourage them from foraging there. Killdeer and Greater Yellowlegs were present at both the marine and freshwater locations, however Great Yellowlegs were hardly recorded in the afternoon session at the lake whereas they were present throughout the day at Argyle Lagoon. Future observational studies with more study sites could show where these Greater Yellowlegs move to in the afternoon and could provide details on whether these birds are using spatial and temporal indicators at the sites. These indicators may relate to tidal cycles or time of day.

### *Substrate Use*

Life history of these species can explain the apparent trends we observed in substrate use. Greater Yellowlegs are wading birds and were counted in the water the most. In addition, Killdeer are sit-and-wait hunters, so their hunting strategy favors a different substrate (Eberhart-Phillips 2017). Killdeer were the only species observed in vegetation, and we only observed them in vegetation at Zylstra Lake (Figs. 4 and 5). Killdeer are found in a wide range of habitats, possibly explaining why they are the only species observed in vegetation (Sanzenbacher and Haig 2002). However, they spent different amounts of time in vegetation at these two sites,

(more time at Zylstra Lake than Argyle Lagoon). This may be explained by less-dense vegetation at the lagoon. Future substrate studies are needed to better understand the differences in Killdeer vegetation use and preference.

### *Behavior*

We observed Greater Yellowlegs doing more behaviors at Argyle Lagoon than at Zylstra Lake, while we observed Killdeer doing more behaviors at Zylstra Lake than at Argyle Lagoon (Figs. 7 and 8). These preliminary trends show that the species are using marine and freshwater habitats differently. Since Greater Yellowlegs are foraging equally between sites but feeding more at Zylstra Lake, it may indicate there is more prey available at Zylstra Lake or that the prey is less calorically dense, resulting in them feeding more to reach their energetic needs. A prey availability study would help understand these results.

### *Conservation and Management*

Apparent trends in diversity changing throughout the day and across sites imply a possible niche partitioning, and an active choice when selecting habitat. Shorebirds are often considered marine without a freshwater emphasis, but we must consider both habitats for the conservation and management of shorebirds.

Killdeer are a species of least concern but have had drastic population declines over the years (Sanzenbacher and Haig 2002). This is in part due to the human destruction of inland, freshwater habitats they occupy (Sanzenbacher and Haig 2002). To help protect this and other species from decline, a full-scope understanding of how they use both marine and freshwater habitats is critical. It is important to understand how the niches these birds occupy in different

locations impacts ecosystem functions so we have a better perception of the role shorebirds play in both fresh and marine water habitats.

### *Future Study Recommendations*

Based on our study, we recommend incorporating more survey days to collect further data. This includes longer scan times and, if proper equipment is provided, a night session. Comparing parameters across seasons and looking at how changing environmental conditions affect non-migratory and migratory species diversity, substrate use, and behavior is key to increasing our understanding of shorebirds.

Assessing the role of anthropogenic disturbance on sandpiper and plover habitat use would allow us to predict whether behaviors are natural or influenced by human presence. Argyle Lagoon is a public location with a boat launch, and has several residential areas nearby. In comparison, Zylstra Lake is a biological preserve with relatively few anthropogenic activities in the surrounding area. More research at these locations and the interactions between birds and humans can help future research studies and improve our understanding of ecological conservation of shorebirds.

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**Figures:**

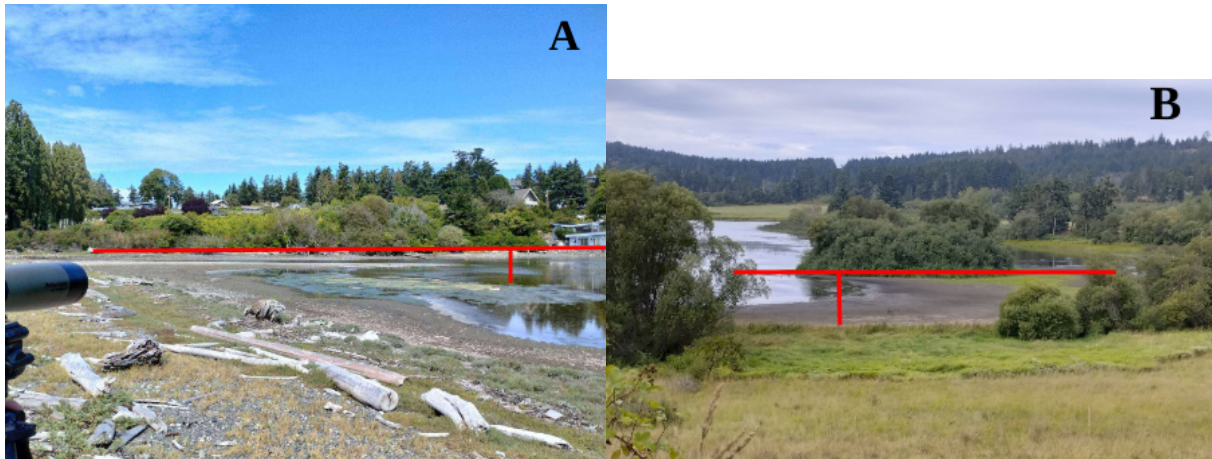


Figure 1: Study site locations used for shorebird surveys. The marine site was at Argyle Lagoon (A) and the freshwater site was at Zylstra Lake (B). Horizontal red marker denotes diversity scan range and vertical red marker denotes diversity scan width.

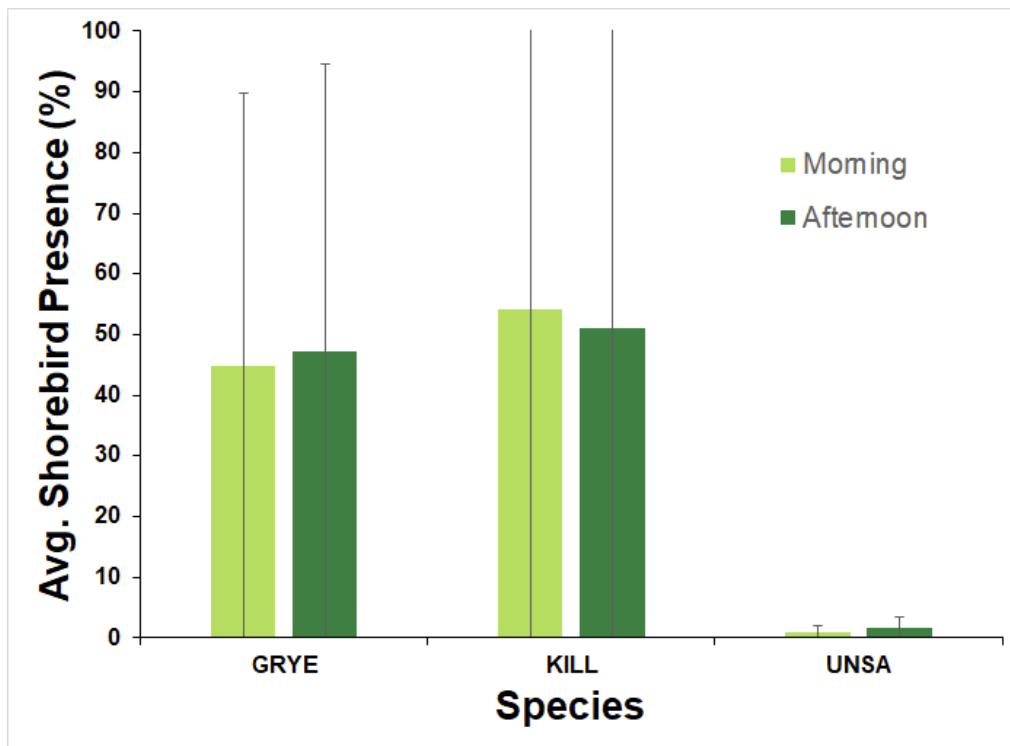


Figure 2: Average percent presence within shorebird population (+/- SD) by species at Argyle Lagoon, separated by time of day. GRYE is Greater Yellowlegs, KILL is Killdeer, and UNSA is unidentified Sandpiper. Data collected from diversity scans. Morning n=12. Afternoon n=12.

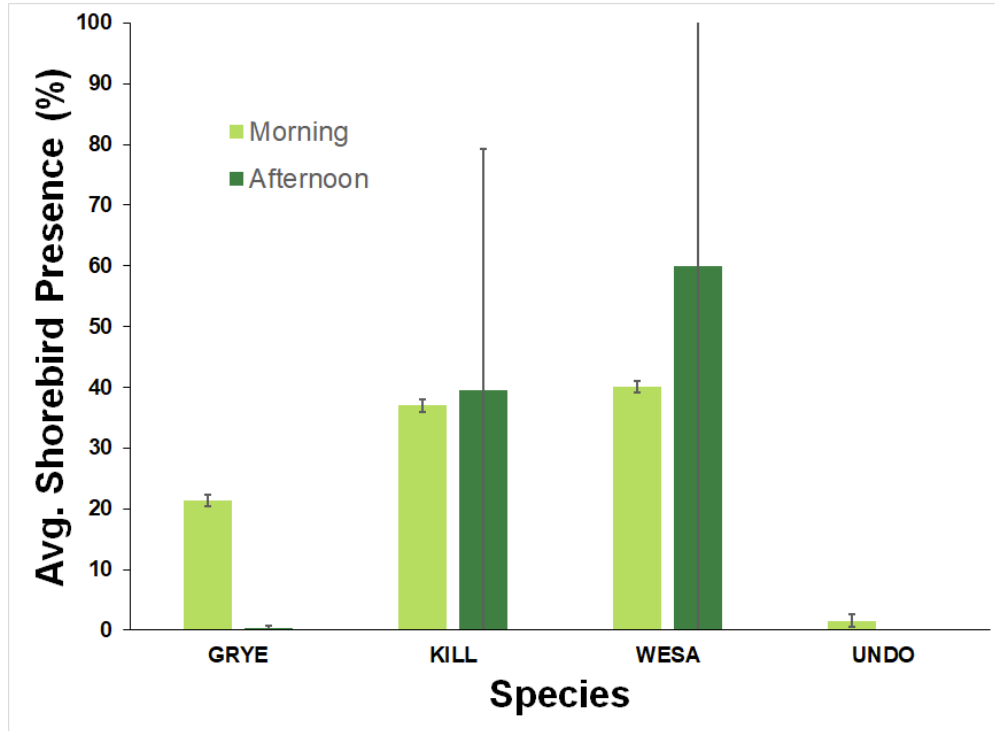


Figure 3: Average percent presence within shorebird population (+/- SD) by species at Zylstra Lake, separated by time of day. GRYE is Greater Yellowlegs, KILL is Killdeer, WESA is Western Sandpiper, and UNDO is unidentified Dowitcher. Data collected from diversity scans. Morning n=12. Afternoon n=12.

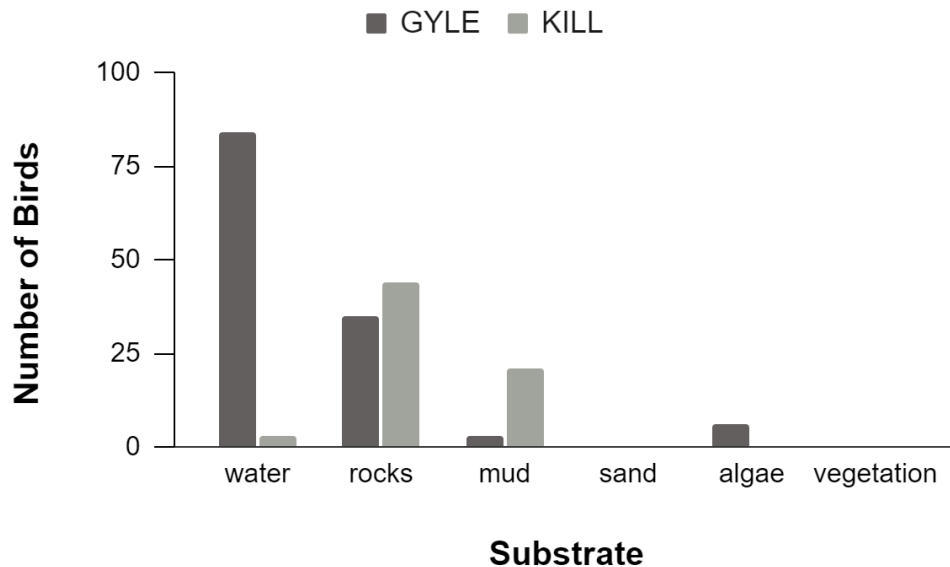


Figure 4: Number of bird observations by substrate type at Argyle Lagoon, separated by species. GYLE is Greater Yellowlegs, and KILL is Killdeer. Data is collected from focal behavior surveys. n=200.

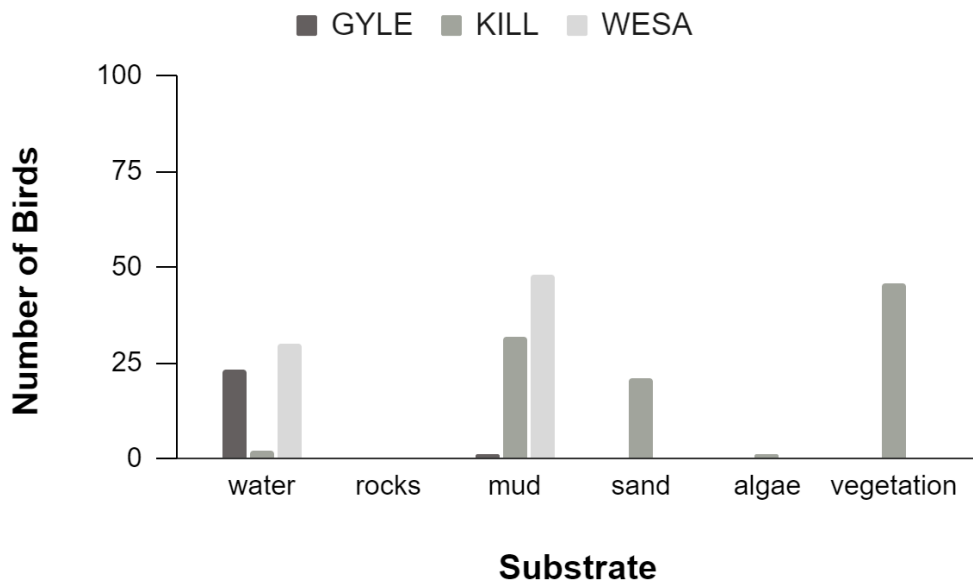


Figure 5: Number of bird observations by substrate type at Zylstra Lake, separated by species. GYLE is Greater Yellowlegs, KILL is Killdeer, and WESA is Western Sandpiper. Data is collected from focal behavior surveys. n=205.

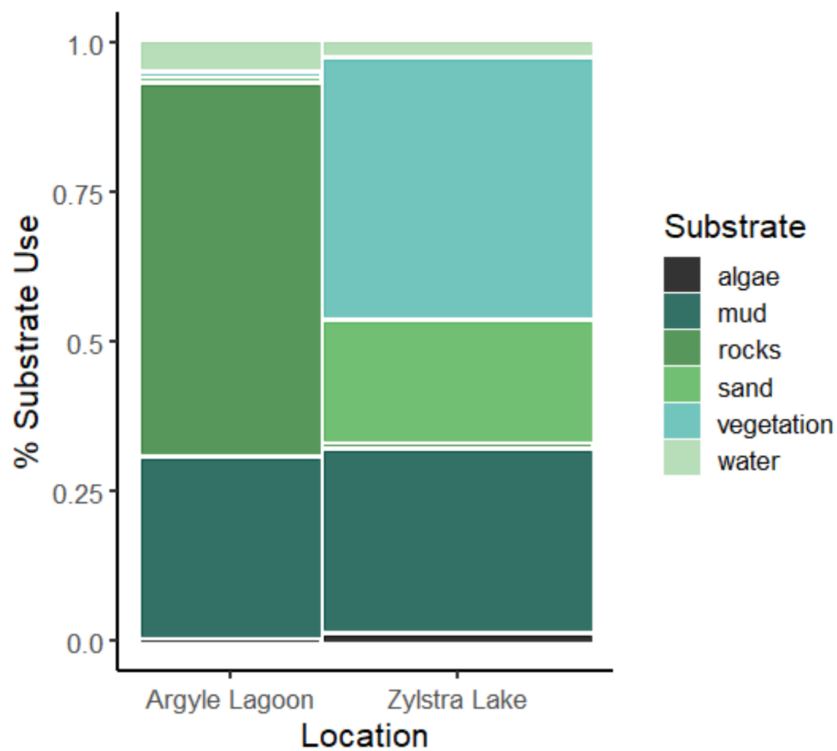


Figure 6: Killdeer percent substrate use by location. Data collected from density surveys. Argyle Lagoon n=25. Zylstra Lake n=32.

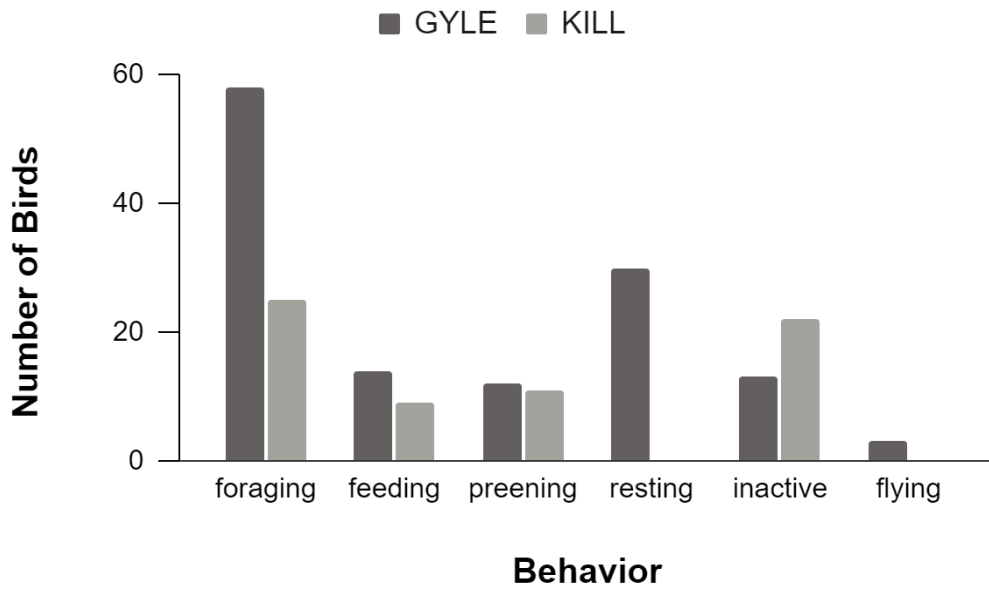


Figure 7: Number of bird observations by behavior at Argyle Lagoon, separated by species. GYLE is Greater Yellowlegs, and KILL is Killdeer. Data is collected from focal behavior surveys. n=204.

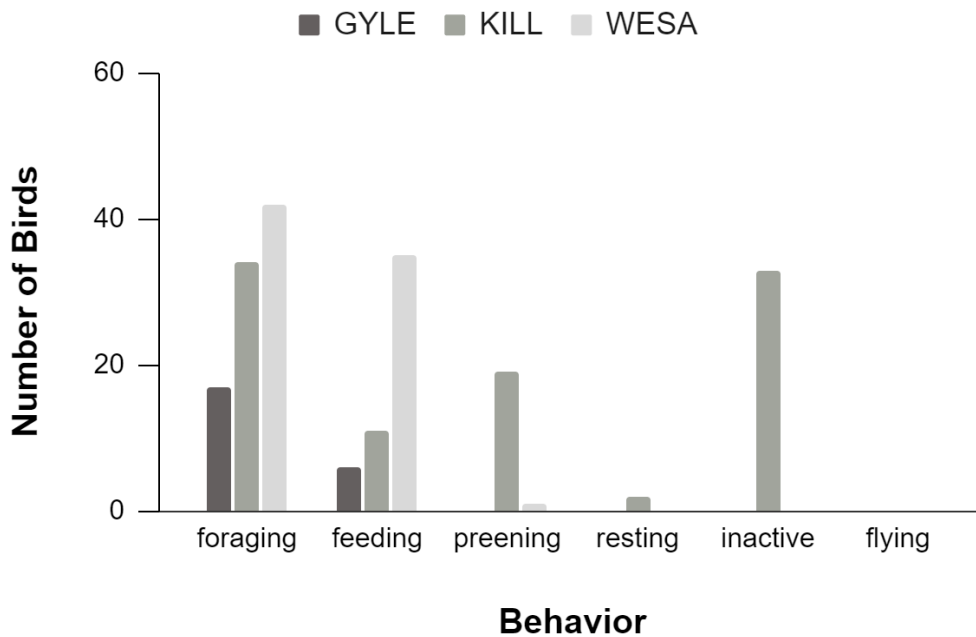


Figure 8: Number of bird observations by behavior at Zylstra Lake, separated by species. GYLE is Greater Yellowlegs, KILL is Killdeer, and WESA is Western Sandpiper. Data is collected from focal behavior surveys. n=211.

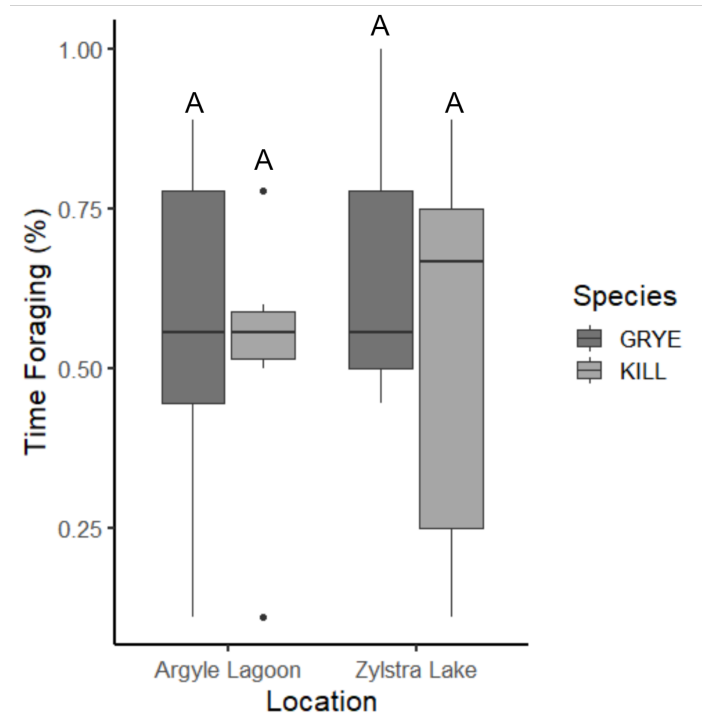


Figure 9: Percent time foraging by location for individuals with a percent time foraging above zero, separated by species. Data from focal behavior surveys. n=30. ANCOVA,  $df=1$ ,  $F=0.1457$ ,  $p=0.706$ .

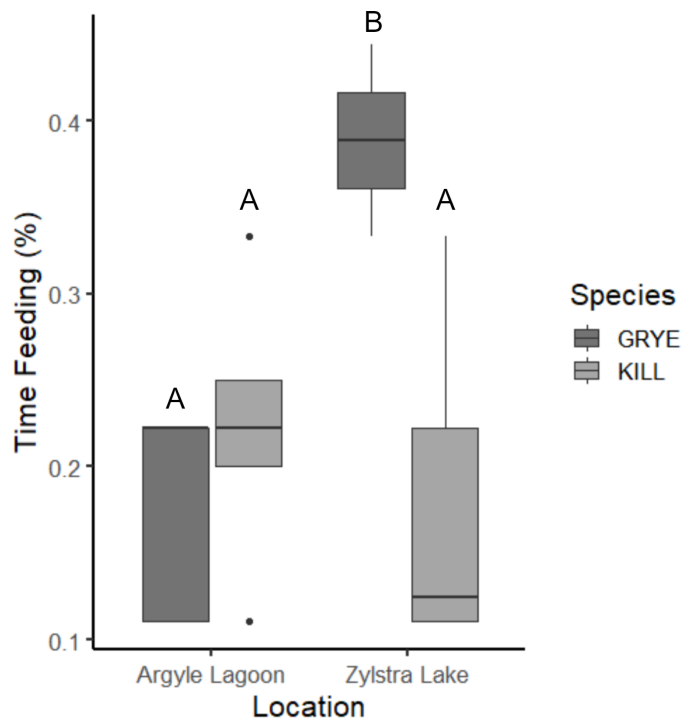


Figure 10: Percent time feeding by location for individuals with a percent time feeding above zero, separated by species. Data from focal behavior surveys. n=25. ANCOVA,  $df=1$ ,  $F=14.064$ ,  $p=0.001$ .