

**Analyzing Trends in Pigeon Guillemot (*Cepphus columba*) Abundance and Behavior Across
Time and Tide Height**

Lucy G. Kao^{1,2}

Jordan T. A. Votava^{1,2}

Ecology and Conservation of Marine Birds and Mammals

(Summer 2025)

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

²School of Aquatic and Fisheries Sciences, University of Washington, Seattle, WA 98195

Contact Information:

Lucy G. Kao

Jordan T. A. Votava

School of Aquatic and Fishery Sciences

School of Aquatic and Fishery Sciences

University of Washington

University of Washington

1122 NE Boat St.

1122 NE Boat St.

Seattle, WA 98105

Seattle, WA 98105

lucykao4@gmail.com

jordanvotava1@gmail.com

Authors contributed equally to this manuscript.

Abstract

Pigeon Guillemots (*Cepphus columba*) are widespread in the northern Pacific, occupying both natural and urban coastal habitats in the Salish Sea. Little research has addressed how abundance and behavior vary with habitat type, time-of-day, and tide height. For one week, we conducted systematic behavioral observations at a natural site and an urban site on San Juan Island. Abundance was consistently higher and more clumped at the natural site, indicating the higher-quality habitat. On the other hand, distributions of behavior were similar between sites, underlining the species' ability to adapt to environmental changes. Foraging activity peaked in the early morning at high tide at both sites, while other behaviors were found to have no correlation with time-of-day or tide height. Our findings confirm patterns in abundance and behavior that were previously demonstrated in other regions, and emphasize the importance of preserving natural habitat and continued monitoring for a prevalent species.

Keywords: Pigeon Guillemot, *Cepphus columba*, Salish Sea, urban adapters, abundance, behavior, habitat, time, tide height

Introduction

The Pigeon Guillemot (*Cepphus columba*) is a migratory bird that can be found throughout a large portion of the northern Pacific Ocean. In the Salish Sea, Pigeon Guillemots can be found year-round, but little research has been done on their behavior and time allocation outside of the breeding season (Ewins, P. J. 2020). The Salish Sea has an abundance of prey and optimal nesting habitat, allowing them to exist there year-round. Although natural nesting sites are plentiful on San Juan Island, there are at least two locations where Pigeon Guillemots have begun nesting in human-dominated landscapes—under the Friday Harbor Laboratories dock and

under the M-Dock in the Port of Friday Harbor. The perpetual presence of Pigeon Guillemots in the urban habitats of Friday Harbor Labs and Marina indicates that Pigeon Guillemots are urban adapters.

Urban adapters are able to maintain populations and tolerate the restrictions of living in an urban environment (Crocini et al. 2006). Pigeon Guillemots living in Friday Harbor forage, breed, and nest under docks that face constant human interference, yet they remain undisturbed. Although they may be able to survive in urban landscapes, their proximity to humans and limited access to undisturbed habitat may impact their abundance and behavior. Similarly, abiotic factors like time-of-day and tide height likely influence Pigeon Guillemot abundance and behavior as well.

While there have been findings to demonstrate the effects of time-of-day and tide height on Pigeon Guillemot abundance or behavioral patterns, there has been no published research for the San Juan Island populations. Time-of-day and tide height has been linked to certain Pigeon Guillemot and other alcid behaviors in British Columbia, specifically foraging and colony attendance (Vermeer, K., et al. 1993; Elliott, K. & Gaston, A., 2015). The west coast of San Juan Island is ideal habitat for Pigeon Guillemot nesting, yet the location of annual nesting colonies and response to factors such as time-of-day and tide height are unknown.

To fill in this research gap in the San Juan Islands, we focused our efforts on two main objectives. Our first objective was to assess differences in patterns of abundance and behaviors between natural and urban sites. Second, we determined if abundance and behaviors were influenced by time-of-day and tide height.

Methods

Preliminary surveys

To identify suitable study sites on San Juan Island, we conducted a preliminary survey by kayak in July 2025. Using eBird data, we knew that Pigeon Guillemots were reliably observed at the University of Washington's Friday Harbor Laboratories (FHL) dock and at the Friday Harbor Marina. To identify a natural nesting site, we kayaked from Andrews Bay to Deadman Bay. Guillemots were observed at San Juan County Park and Lime Kiln Point State Park. We selected San Juan County Park (Fig. 1a) due to its accessibility and clear view of nests. Between the two urban sites considered, we chose the FHL dock (Fig. 1b) as our second study site due to its accessibility and reliable presence of birds.

We deployed wildlife cameras at each site to document any trends in the timing of birds returning to land. At San Juan County Park (SJCP), the camera was placed above an observed nesting burrow, while the camera at the Friday Harbor Labs (FHL) dock was positioned in front of the nesting site. Previous observations of these nesting sites proved them to be inactive, so there were no chicks present at the time. The footage was downloaded each day from a distance, and timestamps were used to determine temporal patterns. At SJCP, birds were only detected in the camera during the early morning, whereas birds were detected in the camera more sporadically throughout the day at FHL. Based on this, we focused our observational efforts to be in the morning (07:00-11:00).

Behavioral observations

Between August 13, 2025 and August 18, 2025, we conducted direct observations on 3 separate days at each study site, for 6 total days or 24 total hours. Observations were between 07:00-11:00, and behavioral data was collected using focal animal sampling. At the start and end of each survey, we recorded the total number of birds present. Each sample lasted 2 minutes, with

behaviors recorded at 20-second intervals using binoculars and a spotting scope. An 8-minute break followed each sample, resulting in a 10-minute total cycle.

We placed behaviors into five categories: (1) Sitting in water (SIW), defined as a bird stationary with its head above water; (2) Sitting on land (SIL), defined as a stationary bird anywhere other than in the water; (3) Foraging (FOR), defined as scoping, actively diving, holding prey, or feeding; (4) Maintenance (MA), defined as preening, stretching, flapping, and bathing; and (5) Flying (FLY), defined as a bird in flight.

Data analyses

To determine the spatial dispersion of individuals, we calculated an aggregation index (AI) for each site. For each sample, we calculated the mean abundance of birds observed, and plotted abundance against time-of-day and tide height for each site to assess the strength of each. For behavior, we calculated the percentages of all behaviors within each site and Shannon Diversity Index values to determine the richness and evenness of displayed behaviors. To assess the association between behaviors and time-of-day, we plotted the average percentage of time allocated to each behavior. To assess the association between behaviors and tide height, we plotted the average percentage of time allocated to each behavior within each height bin. We recorded tide height (ft) based on data from NOAA. Tide height was binned into one-foot intervals for analysis. All graphs and statistical analyses were conducted in Microsoft Excel.

Results

Abundance

Sites varied with their spatial dispersion and average abundance. An aggregation index of 2.216 for San Juan County Park (SJCP) indicates an aggregated or clumped spatial distribution,

while an aggregation index of 0.839 for the Friday Harbor Labs (FHL) dock indicates a more uniform spatial distribution (Tab. 1). Average abundance of Pigeon Guillemots was greater at SJCP than at the FHL dock across all days (Fig. 2). SJCP had an average abundance of 9.83 individuals, ranging from 3 to 20 birds. FHL had an average abundance of 1.86 individuals, ranging from 0 to 6 birds.

In addition, abundance differed with time-of-day and tide height. At both sites, abundance was lower in the early morning, peaked between 08:30 and 10:00, and declined after 10:00 (Fig. 3). Abundance increased with tidal heights until mid-morning, when abundance began to drop while tide height continued increasing (Fig. 3).

Behavior

The frequency of observed behaviors was similar between the two sites. Most frequently observed behaviors for both sites were sitting-in-water (SIW), (SCJP = 44%; FHL = 48%) foraging (FOR) (SCJP = 23%; FHL = 24%), and sitting on land (SIL) (SCJP = 14%; FHL = 14%) (Tab. 1). Similar Shannon Diversity Index values of 1.42 for SJCP and 1.27 for FHL confirmed the similar evenness of behaviors between these sites (Tab. 1).

Time-of-Day

Observed behaviors varied with time-of-day, but the strength of the effect varied between behaviors. At both San Juan County Park (SJCP) and Friday Harbor Labs (FHL), the proportion of observed foraging (FOR) behaviors was highest in the early morning and declined across the observation period (Fig. 4). In the mid-morning, they engaged in distinct foraging bouts separated by non-foraging behaviors, but none of these bouts reached the frequency of foraging in the early morning. Sitting-on-land (SIL) had an opposite pattern to foraging, being lowest in the early

morning and increased while foraging decreased mid-morning (Fig. 4), followed by sporadic peaks and valleys. Maintenance (MA) (preening, bathing, and wing-flapping), sitting-in-water (SIW), and flying (FLY) showed no obvious association with time-of-day and occurred sporadically throughout the morning (Fig. 5).

Tide Height

The relationship between behavior and tide height varied between survey sites. At SJCP, foraging was observed throughout the tide heights, and only varied slightly (Fig. 6a). This was similar at FHL, with foraging occurring throughout the tide heights, however there was a higher percentage of observed foraging at a tide height between 5-6ft, suggesting a preference for this height at this location (Fig. 6b). Likewise, birds at FHL were only observed sitting-on-land when the tide height was between 5-6ft (Fig. 6a). However, at SJCP, no birds were observed sitting-on-land between 1-2ft and 5-6ft, while the highest percent of observations were at the 2-3ft range and decreased across 3-5ft (Fig. 6b).

Discussion

In this study we identified patterns in the abundance and behavior of Pigeon Guillemots, compared natural and urban sites, and assessed how time-of-day and tide height influenced these trends.

Our findings that individuals at San Juan County Park (SJCP) are spatially clumped, while those at the Friday Harbor Labs (FHL) dock are more uniformly dispersed can be attributed to rocky shorelines having numerous suitable nesting habitats than human-made structures, promoting stronger coloniality (Emms & Verbeek 1989). A greater abundance of birds at SJCP aligns with previous findings that natural sites are preferred by Pigeon Guillemots, likely due to

the higher availability and higher quality of suitable nesting habitat (Emms & Verbeek 1989; Pearson & Hamel 2013). Though we were observing a natural site, abundance at both sites were influenced by anthropogenic disturbances, such as vessels, loud noises, or sudden movements, and may have masked the natural differences between sites.

Our findings that the overall proportions of foraging (FOR), sitting-in-water (SIW), sitting-on-land (SIL), maintenance (MA), and flying (FLY) were similar between SJCP and FHL is consistent with previous knowledge of Pigeon Guillemots utilizing both natural and human-dominated environments without significantly altering their behavior (Buckner & Klinger 2020). This trend, confirmed by the similar Shannon Diversity index values, indicates that during the non-breeding season, Pigeon Guillemots likely allocate their time in similar ways, regardless of their use of natural or urban habitats.

Our findings that foraging (FOR) peaked highest in the early morning at both sites is consistent with previous studies in other regions that Pigeon Guillemot attendance and food delivery is concentrated during morning hours due to light conditions and prey availability (Vermeer et al. 1993). In periods of reduced foraging, there was an increase in observed time sitting-on-land (SIL). The alternating sequence observed between active foraging bouts and resting on land aligns with the pattern observed in many alcids that alternate energetically costly dives with periods of less costly activities to balance energy expenditure (Elliott & Gaston 2015).

Our findings that maintenance (MA) occurred throughout the morning without clear trends is expected, since Pigeon Guillemots, like other seabirds, require constant maintenance of plumage throughout the day for thermoregulation, waterproofing, and flight (Fauchet et al. 2021; Thorensen & Booth 1958). Similarly, our observations of sitting-in-water (SIW) and flying (FLY) occurring sporadically throughout the day is consistent with time-budget studies in other alcids

that demonstrate flying and resting on water to be more associated with foraging than specific times (Clowater 1994; Kato et al., 2003).

In parallel with time-of-day, maintenance (MA), sitting-in-water (SIW), and flying (FLY) do not correlate with tide height. Instead, these behaviors are more opportunistic and are likely more tied to foraging activity or fluctuations in energetic needs, rather than tide height (Vermeer et al., 1993). The birds at San Juan County Park consistently foraged across all tide heights, but showed a preference for sitting on land in the mid-tide heights (2-5 ft). The 2-5ft tide height range may have provided access to optimal resting areas, like the upper-intertidal rocks. At Friday Harbor Labs, the relationship between preference for both foraging and sitting on land at the 5-6 ft tide height can likely be attributed to energy saving. The breeding season can be very costly for many seabird species in the form of thermoregulation and prey deliverance to offspring (Tremblay et al. 2022). Since we were observing the birds in the weeks directly following their breeding season, they may have been prioritizing rest and feeding to make up for the high energy demands of the breeding season. Overall, tide height seemed to have different effects on behavior between the two sites.

There were a suite of other factors that could have influenced the results of our study. During our time at San Juan County Park, there were multiple instances of human disturbances and interactions with other species which flushed the birds from their resting place on land. Also, weather conditions and air temperature varied between the days that we collected data. These factors could have accounted for the slight variations in the time allocated to each behavior. It is also important to note that broad-scale factors like timing in the breeding season and prey availability could have accounted for our findings.

Our findings add to the growing literature surrounding Pigeon Guillemots, specifically filling in a research gap in the San Juan Islands. By documenting that local Pigeon Guillemot

populations peak in abundance during the early morning at high tide, we can confirm patterns previously observed in other regions (Vermeer, K., et al. 1993; Elliott, K. & Gaston, A., 2015). With a significantly greater amount of birds observed at the natural site, it is imperative to continue protecting the shorelines of San Juan Island that provide natural-occurring nesting habitat. In addition, their observed utilization of urbanized sites as well as natural sites, confirms their role as urban adapters. This flexibility allows them to exploit modified landscapes, making them more resilient to environmental changes (Pearson & Hamel, 2013). However, the closer proximity to human-dominated areas increases their vulnerability to threats, such as disturbance and pollution, including oil spills (Burger et al., 1992; Vermeer et al., 1993). Our study, therefore, created a baseline for future monitoring to detect changes in abundance or behavior in response to urbanization in order to ensure the year-round persistence of Pigeon Guillemots in the Salish Sea community.

Acknowledgements

Our work was made possible by Breck Tyler, Dr. Eric Anderson, and Meredith Dirkman, who provided us with their time, knowledge, and resources throughout the course of this study. We would also like to thank Dr. Amy Cook for her time and support in guiding our research. Thank you to the University of Washington's Friday Harbor Laboratories and San Juan County Park for allowing us to use their spaces to conduct our study. Finally, we would like to thank the Pigeon Guillemots for cooperating with us and allowing us to share their space.

Literature Cited

- Buckner, E., & Klinger, T. (2020). Spatial foraging patterns in Puget Sound Pigeon Guillemot (*Cephus columba*): an investigation using stable isotopes and community science. [University of Washington Libraries].
- Burger, A. E., Vermeer, K., Butler, R., & Morgan, K. (1992). The effects of oil pollution on seabirds off the west coast of Vancouver Island. Occasional Paper - Canada Wildlife Service.
- Clowater, J. S., & Burger, A. E. (1994). The diving behaviour of Pigeon Guillemots (*Cephus columba*) off southern Vancouver Island. *Canadian Journal of Zoology*, 72(5), 863–872.
- Elliott, K.H., Gaston, A.J. Diel vertical migration of prey and light availability constrain foraging in an Arctic seabird. *Mar Biol* 162, 1739–1748 (2015).
- Ewins, P. J. (2020). Pigeon Guillemot (*Cephus columba*), version 1.0. In *Birds of the World* (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.
- Fauchet, L., Cansse, T., & Arnould, J. P. Y. (2021). The importance of preening behaviour in the at-sea time budget of Australasian gannets. *Emu - Austral Ornithology*, 121(4), 348–353.
- Kato, A., Watanuki, Y., & Naito, Y. (2003). Foraging behaviour of chick-rearing rhinoceros auklets *Cerorhinca monocerata* at Teuri Island, Japan, determined by acceleration-depth recording micro data loggers. *Journal of Avian Biology*, 34(3), 282–287.
- Kuletz, K. (1983). Mechanisms and consequences of foraging behaviour in a population of breeding Pigeon Guillemots. Master's Thesis, Univ. California, Irvine.
- Pearson, S.F. and N.J. Hamel. 2013. Marine and terrestrial bird indicators for Puget Sound. Washington Department of Fish and Wildlife and Puget Sound Partnership, Olympia, WA, 55 pp

- Emms, S. K., Verbeek, N. A. M. (1989). Significance of the Pattern of Nest Distribution in the Pigeon Guillemot (*Cepphus columba*), *The Auk*, Volume 106, Issue 2, Pages 193–202.
- Thoresen, A. C. and E. S. Booth. (1958). Breeding activities of the Pigeon Guillemot *Cepphus columba columba* (Pallas). *Walla Walla Coll. Publ. Dept. Biol. Sci.* 23:1-36.
- Tremblay, F., Whelan, S., Choy, E. S., Hatch, S. A., Elliott, K. H. (2022). Resting costs too: the relative importance of active and resting energy expenditure in a sub-arctic seabird. *Journal of Experimental Biology*, 225 (4): jeb243548
- Vermeer, K., Morgan, K. H., & Smith, G. E. J. (1993). Colony Attendance of Pigeon Guillemots as Related to Tide Height and time-of-day. *Colonial Waterbirds*, 16(1), 1–8.

Tables

Table 1: Average percentage of total observed behaviors with the correlated aggregation index values to determine dispersion type and Shannon Diversity index values to determine the richness and evenness of behaviors within each site.

	SIW	FOR	SIL	MA	FLY	Aggregation Index	Shannon Diversity Index
SCJP	44%	23%	14%	13%	6%	2.216	1.42
FHL	48%	25%	14%	11%	3%	0.839	1.27

Figures

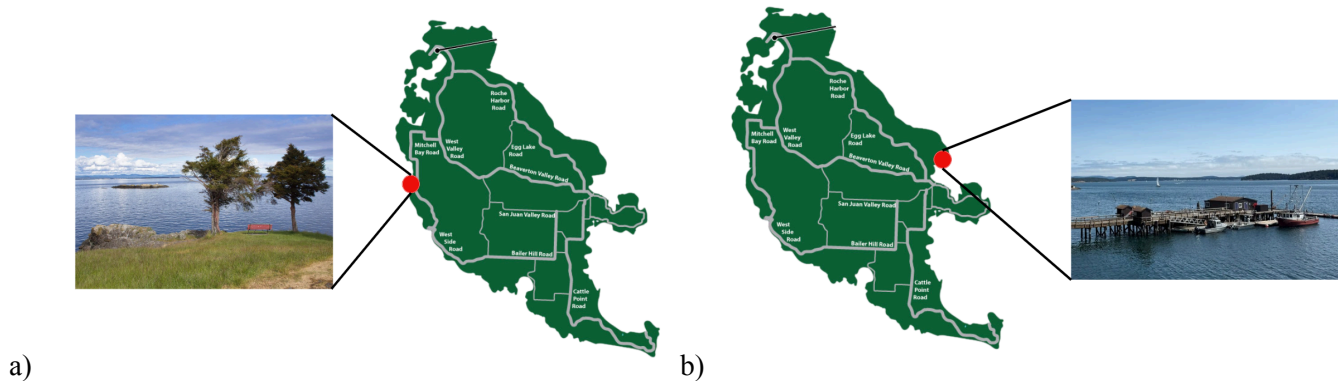


Figure 1: A map of San Juan Island with the two chosen survey sites denoted with red dots, (a) San Juan County Park and (b) Friday Harbor Laboratories Dock

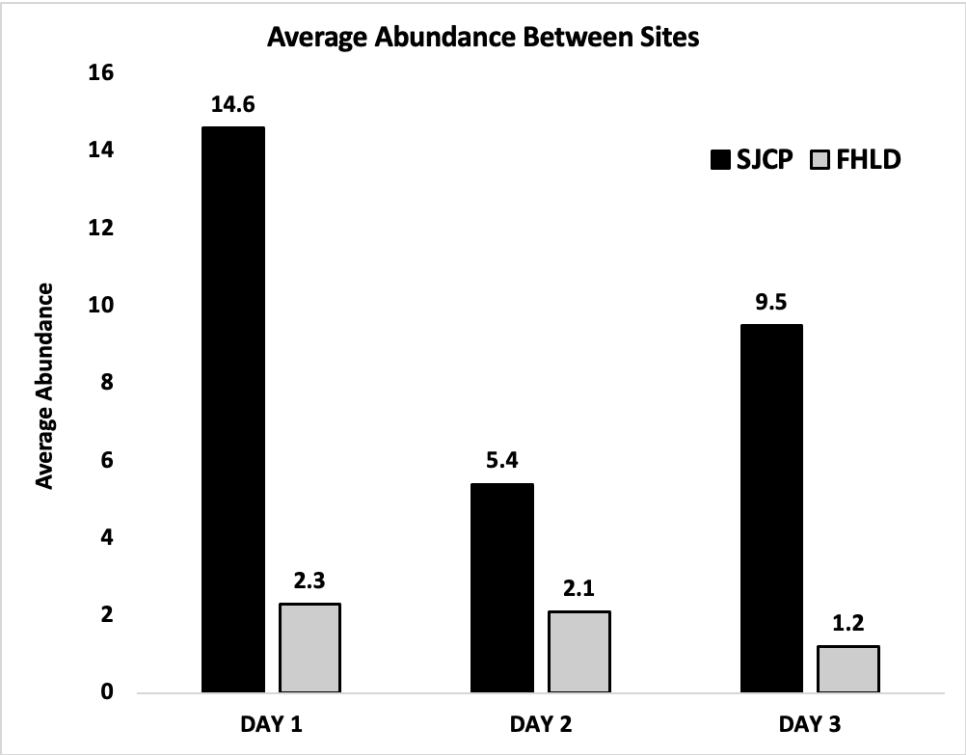
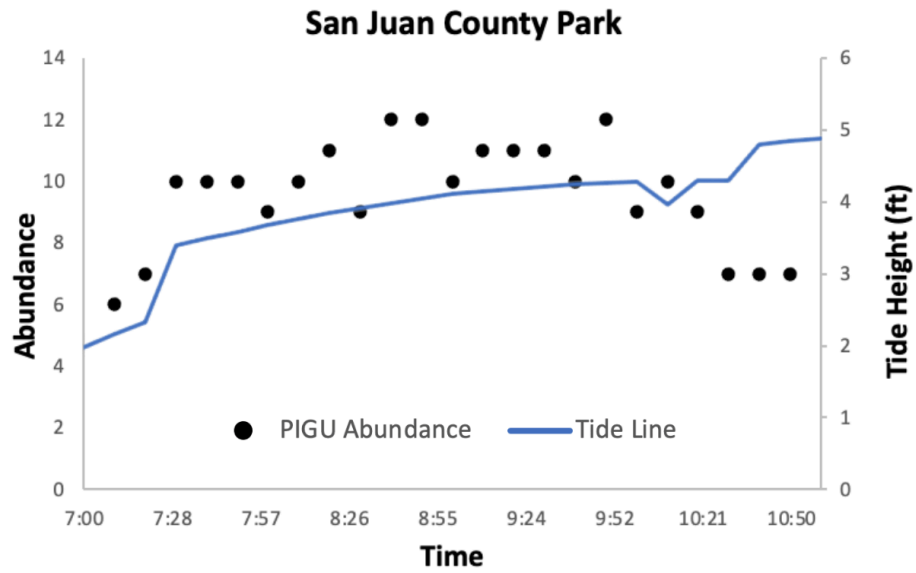
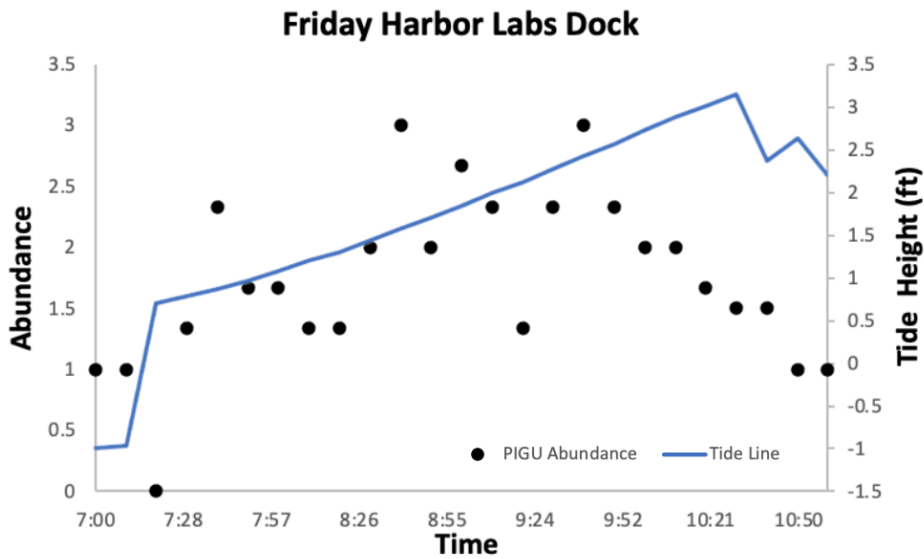


Figure 2: Average abundance of Pigeon Guillemots each day between San Juan County Park (SJCP) and Friday Harbor Labs (FHL) Dock

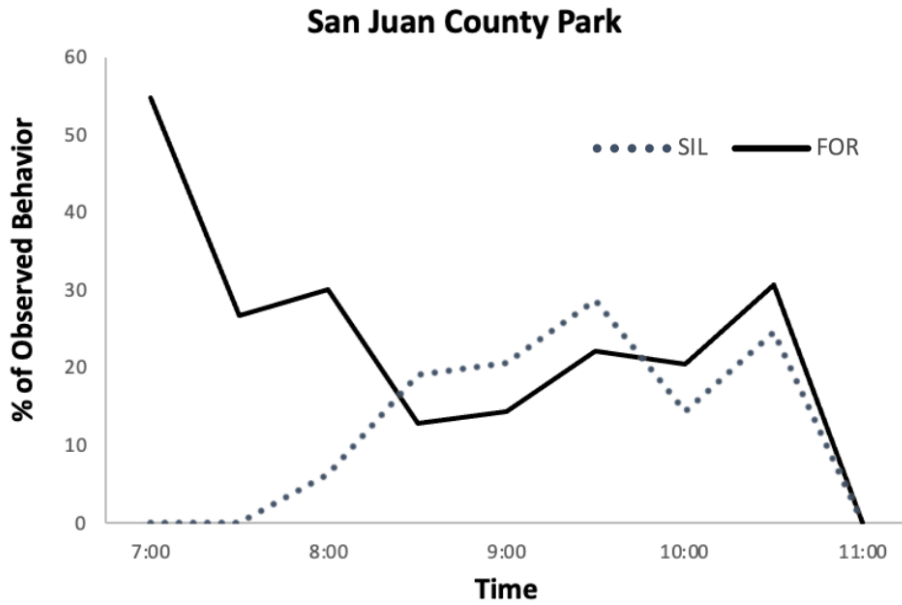


a)

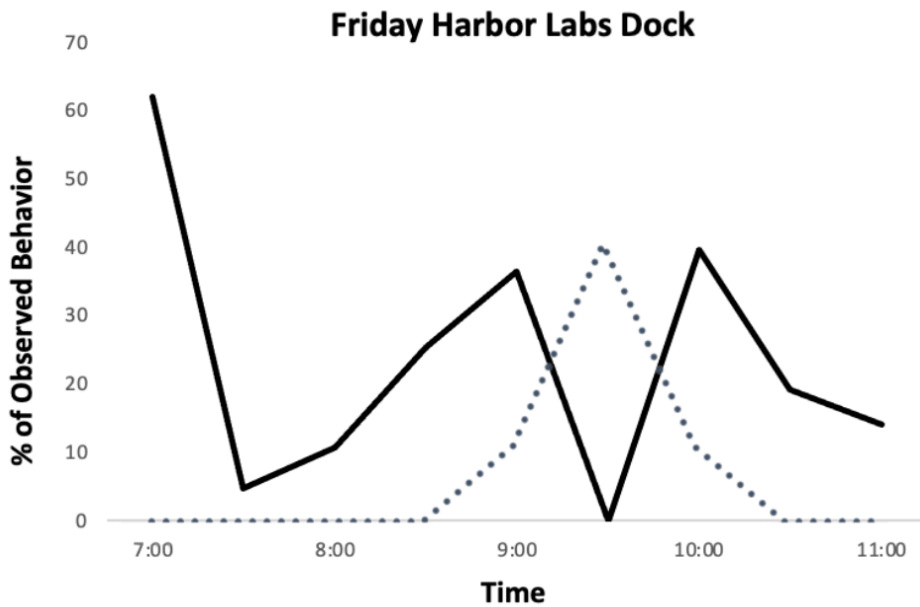


b)

Figure 3: Average abundance of Pigeon Guillemots as a function of time-of-day (primary y-axis) and tide height (secondary y-axis) at (a) San Juan County Park and (b) Friday Harbor Laboratories Dock

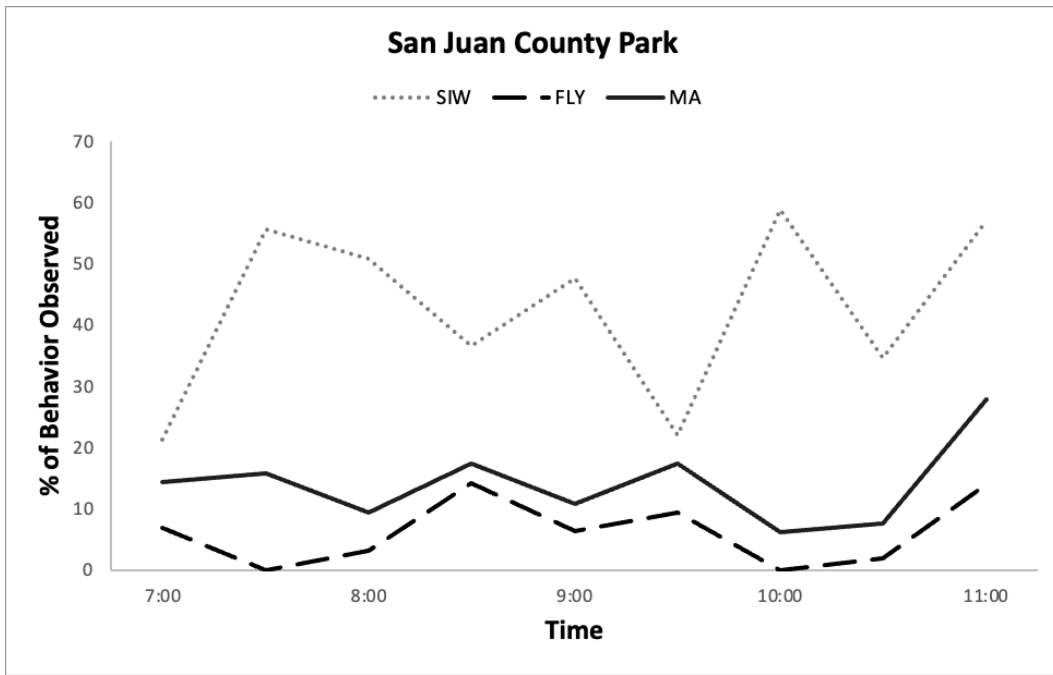


a)

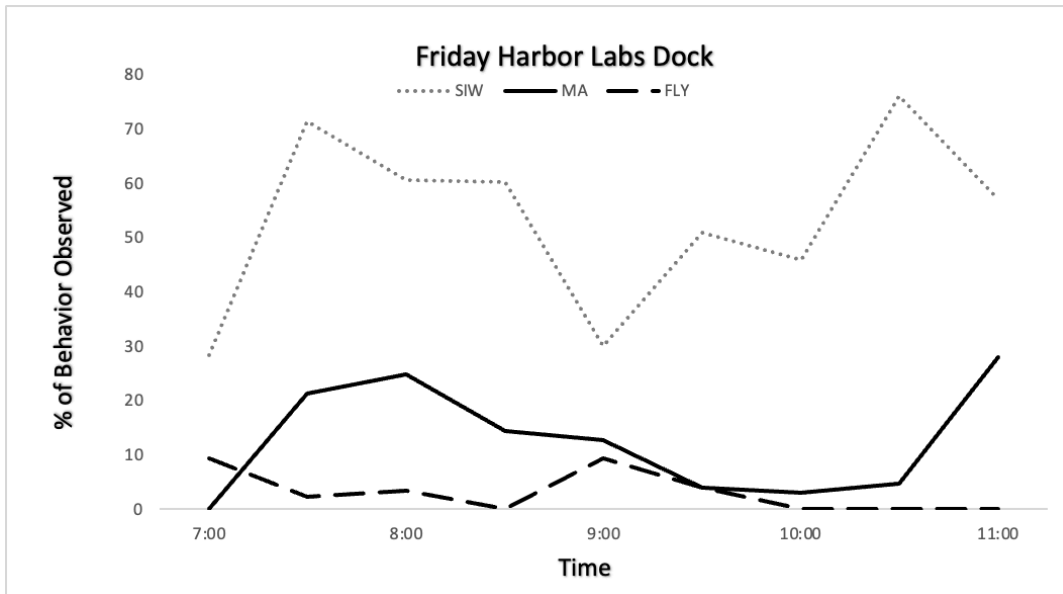


b)

Figure 4: Percentage of observed foraging (FOR) (diving, scoping, feeding) as a solid black line and sitting-on-land (SIL) as a dotted black line as a function of time-of-day between 07:00 and 11:00 at (a) San Juan County Park and (b) Friday Harbor Laboratories Dock.

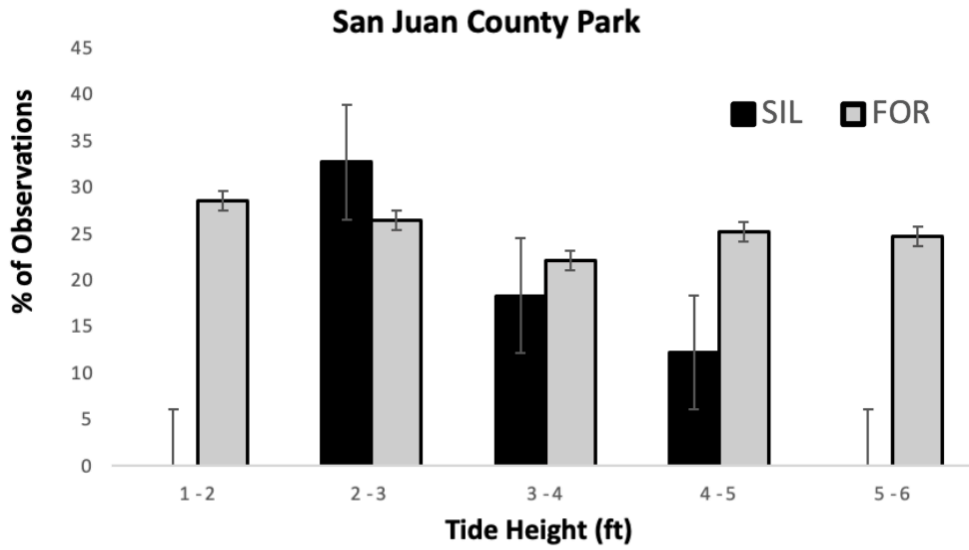


a)

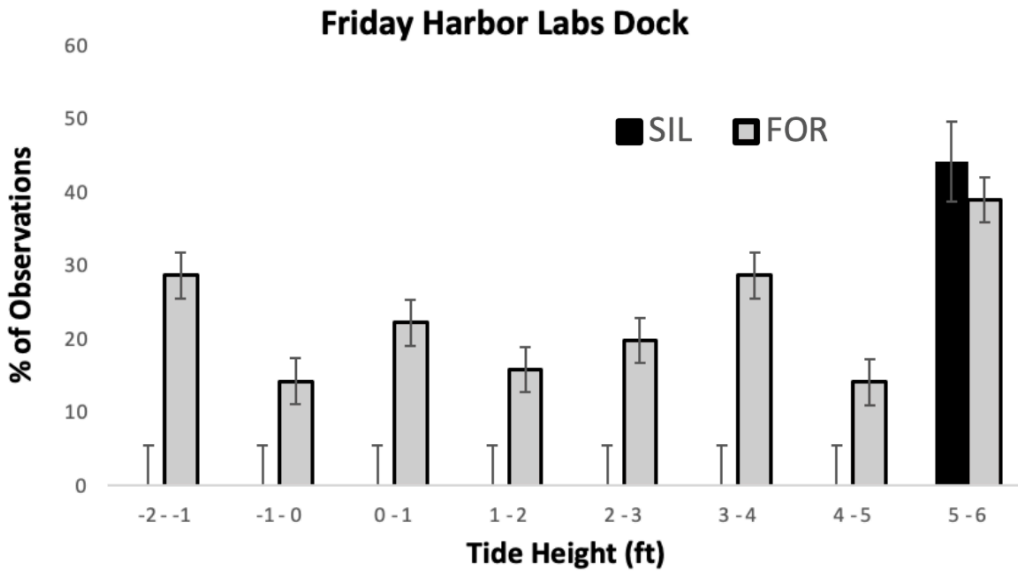


b)

Figure 5: Percent of time spent sitting in water, maintenance (preening, bathing, wing-flapping), and flying as a function of time-of-day between 07:00 and 11:00 at (a) San Juan County Park and (b) Friday Harbor Laboratories Dock.



a)



b)

Figure 6: Percent time spent foraging and sitting on land across tide heights at (a) San Juan County Park and (b) Friday Harbor Laboratories Dock.

