Pigeon Guillemot Nesting Behavior on San Juan Island, Washington

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NSF REU-Blinks Program

Summer 2022

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Keywords: Cepphus columba, Pigeon Guillemot, nesting behavior, provisioning

Abstract

Pigeon Guillemots (*Cepphus columba*) are seabirds native to the west coast of North America and forage on the sea floor for benthic fish. The variety in their nesting sites makes them prime subjects for studying the effects that urbanization has on their nesting behavior and provisioning. We asked; how does nesting behavior differ between dock and cliff nesters and how does the presence of humans affect the duration of adults delivering fish to their chicks? We used behavioral observations to record the types of fish being brought to the nest, approaches to the nest and where the bird spent most of their time at the sites. For eight weeks, we surveyed two field sites on San Juan Island, Washington, where we watched two cliff nests and one dock nest. To determine how human presence affects length of delivery, we ran two trials: a control in which there was no human presence near the nesting site, and an experimental in which we placed one of the researchers below the nest. We recorded time in seconds that the bird sat in the water with the fish in its mouth before entering the nest. Between the control and experimental of the cliff nesters, we found that the delivery time for the experimental trial was significantly higher than the control ($p < .0001$). The dock nesters also showed relatively high delivery duration. There were also qualitative differences in the approaches to the nests at the two sites, including approach behavior and the prevalence of incomplete deliveries when a bird abandoned the fish in the presence of high levels of humans. The results of this experiment provided an interesting insight into how human activity may influence Pigeon Guillemot behavior and provides a foundation for future studies to expand the sample size and examine other aspects of this influence. Future experiments to build on this data could explore the difference in survival rate of chicks between sites, which could show us a direct relationship between urbanization and the decrease of population of the Pigeon Guillemot in the San Juan Islands.

Introduction

Cepphus columba, also known as Pigeon Guillemots, nest on the North American shores from California to Alaska. Most adults, recognizable by their black bodies, white patch on their wings and their dark red feet, forage 0.2 to 0.7 km from their nesting colonies (Thoresen and Booth 1958, Drent 1965, Follett and Ainley 1976, Oakley 1981, Kuletz 1983, Nelson 1987). While hunting for benthic fish, they dive down to the seabed usually foraging on rocky substrate (Duffy et al. 1987, Johnsgard 1987). As piscivores, the Pigeon Guillemots eat fish species including gunnel, sculpins, pricklebacks and less commonly eat invertebrates like Redrock crab and shrimp (Oakley 1981, Kuletz 1983, Sanger 1987a). In Washington, fish are only brought to the surface in 16% of dives as most of their meals are eaten underneath the water's surface (Thoresen 1989). Adults use their tongue to trap fish to the upper beak and surface with it to feed to their chicks in nests (Bedard 1969a).

Pigeon Guillemots nest primarily in crevices of natural cliffs along the coastline. They also nest in a variety of other places such as tree roots, soil burrows and wharfs (Ewins et al. 1993). These nest sites are typically positioned at least 30m above the water mark to avoid predation from raccoons (Vermeer et al. 1993d) and garter snakes (Emms and Morgan 1989). This does not rule out the predation of eggs by the Northwestern Crow (Bent 1919, Emms and Verbeek 1989, Vermeer t al. 1993d), Glaucous-winged Gull (Emms and Morgan 1989), and the Bald Eagle (Vermeer et al. 1989a). Despite the ~~constant~~ predation threat, Pigeon Guillemots will reuse nests from previous years (Drent 1965) starting around March (Ainley and Boekelheide 1990). They are excavated by the females who will push out disruptive rocks to create a nest for the eggs using soil, sand, and loose stones (Ewins 2020).

Pigeon Guillemot eggs are laid in the month of May and into the early weeks of June (Drent et al. 1964, Aitchison 1972, Osborne 1972, Ainley and Boekelheide 1990, Vermeer et al. 1993d). After the eggs are laid, the two adults will equally share the incubating without leaving the eggs for more than 5 to 15 minutes (Drent et. al. 1965). Drent et. al. (1965) found that the first eggs laid hatch at a rate of 32.0 +/- 1.1 days while the second laid eggs hatch after 29.8 +/- 1.4 days. Adult Pigeon Guillemots will begin to feed chicks within 24 hours of hatching (). They do this by capturing fish in their beak, rising to surface with the fish and then flying to the nest. As chicks grow, adults will leave the prey at the entrance for the chicks to eat and then quickly return to the water to resume their hunting or rest. Bishop (2016) found in a study conducted in the Puget Sound that the percentages of delivered prey were 57.6% gunnel or prickleback, 25.6% sculpin and 16.5% other or unknown prey. These fish deliveries are done by both adults throughout the day and in British Columbia an average of 0.8 to 1.9 fish per hour were delivered per nest (Drent 1965, Aitchinson 1972), which also can give an indicator to researchers of how many chicks are in the nest. During their deliveries, Pigeon Guillemots will often sit on the surface of the water with the fish in its mouth for a period before beginning its flight to the nest.

A need for research on how human recreation impacts wildlife is needed more now than ever, as more people enjoy the outdoors. In the case of sea birds, research has been done on the effects that watercraft vessels have on nesting. Research has found that in Black Guillemot species, heavy human activity increases flushing (Ronconi and Clair 2002) and lowers reproductive success (Cairns 1980).

Behavior analysis research has been used to gain insight into a variety of animals and offers a direct window into the health of a species. Nesting behavior is particularly important in assessing the well-being of a species. Pigeon Guillemots are a key subject to study when

assessing the effect of humans on their environment as they reside throughout the West coast in areas of varying levels of anthropogenic activity. This experiment will look at the differences in the time budgeting of the urban, dock nesting Pigeon Guillemots compared to the natural, cliff nesting ones. As well as, assessing whether human presence near the colony causes a delay in the time of fish deliveries. We used the hypothetico-deductive method, to ensure that my experiment does not experience bias (Platt 1964). Using this method, we created multiple hypotheses for each question.

Hypotheses

1. Human presence prolongs the time that the Pigeon Guillemot sits with a fish in mouth before delivering to the nest because the human is perceived as a predator invading the nesting area.
2. Human presence is negligible in terms of the interference and the length of the pause correlates to the length of the preceding dive.
3. There is no additional time taken for the delivery when a human is present due to the habituation of Pigeon Guillemots on San Juan Island.

Methods and Materials

Data Collection

We made observational recordings at three different sites throughout eight weeks using binoculars with the magnification of 8x42. These sites have been observed over the past few years for Pigeon Guillemot activity by Dr. Amy Cook. San Juan County Park, Port of Friday Harbor Marina and Friday Harbor Labs dock were chosen due to the obvious signs of Pigeon

Guillemot nesting in addition to a large amount of bird activity. These three had varying levels of human activity: boat commotion, human-wildlife interaction, and man-made structures.

The Friday Harbor Marina, located on the East side of San Juan Island, docks 500 boats, is the site of whale watching and fishing excursions and is the docking point for the WSDOT ferry. Our observations were done on the Spring Street landing dock, which was an advantageous spot to watch the area to the right of the ferry dock and look towards to marina. Underneath the Port of Friday Harbor man-made structure (48.537237, -123.015529) we observed 3 pairs nesting, which allowed us to monitor nesting behaviors in the area (Figure 1). The Friday Harbor Labs dock is a docking point for a trawling boat, a sailboat, and various smaller boats of seven meters or less. It has a substantially smaller amount of boat traffic compared to the Friday Harbor port, yet it is regularly used by researchers. Recreation also takes place along the dock, so there is human activity throughout the day. The human activity peaks in the afternoon but is much lower in the mornings and evenings. In addition to the dock offering a wide observational view of the harbor, the under part of the wharf is host to 3 Pigeon Guillemot nests (48.545323, -123.012252) (Figure 2). In San Juan County Park observations are done from a beach that faces "Park Bay" (48.543339, -123.160853) (Fig 3). It sits below a campsite and is relatively quiet with little human activity. There are kayakers and recreationists who will depart and return to the beach. On the far end of the beach are rocky cliffs that face the ocean; within these cliffs are two nests that have been observed.

Monitoring the Birds' Use of the Seascape

At both sites, the area observed varied in terms of vessel traffic and other human activities, depth, patterns of currents and wave action, and shoreline type. We divided each observation area into several sections to allow us to monitor how the guillemots used the

different sections (Figure 1 and 2). During the two-hour observation bouts, a scan sample was taken approximately every ten minutes to document which sections birds were in, what type of behavior they were engaged in, and how many birds there were in each section.

Behavior Sampling

This experiment analyzed the behaviors of Pigeon Guillemots behavior through scan sampling, focal sampling, and behavior sampling. To focus on provisioning, the specific instances of adults delivering fish to the young in nests also referred to as "fish deliveries" throughout this paper, we used behavior sampling. These fish deliveries can happen quickly and are important for the development of chicks and crucial for the overall understanding of behavior in the colony. The methods of focal and scan sampling often miss the rare occurrences of behavior (like fish deliveries) and are not deemed the best method for focused behavioral experiments (Martin and Bateson 2007).

Fish deliveries started the week of June 26th, 2022 at San Juan County Park. At this site, we began manually recording the place and time of delivery, where the fish was retrieved, the time that the fish waits in the water with the fish, the nest site that is delivered to and the type of fish caught. A timer was begun when a bird landed in the water of Park Bay with a fish in its mouth and when it entered the nest, the timer was stopped. This was repeated each time a bird had a fish in its mouth and recorded in seconds. Provisioning at the Friday Harbor Laboratories dock began the week of July 12th, 2022. The same methods were applied at this site but started two weeks later.

To observe the effect that human presence has on the fish delivery time at the San Juan County Park field site, an experiment was designed that measured the effect of the beachgoers, kayaks, and swimmers that regularly use the beach and cove. This experiment measured the time

of delivery by watching how long the bird sat with a fish in its mouth before delivering to the nest; this was called the "pre-delivery pause". Each day that observations were made at San Juan County Park, a researcher sat on the outskirts of "One Tree Cove" for ten minutes. When a Pigeon Guillemot landed in "Park Bay" the researcher moved into the nesting area and sit 15 m away from the two nests. The approach remains the same with no alarming movements or sounds. The researcher remained there, unmoving for 10 minutes. To ensure we did not cause irreparable damage to the nesting site there were preventative measures taken. We followed the Cornell Lab's Nestwatch Code of Conduct in our observations of the nests. At all times there was 15m distance in between researcher and nest. We sat for only ten minutes imitating the amount of time that a beachgoer or swimmer may be in the area. When sitting on the rocks, we avoided pointing binoculars at nest site as that has been proven to alert crows of where the nest site is. Additionally, when non-associated humans were within the vicinity of the nesters, data was taken on that instance instead of us interrupting the birds another time. Finally, we allowed at least five deliveries to take place before the experimental trial was conducted.

We observed a behavior performed by the Pigeon Guillemots near nesting sites that we termed "incomplete deliveries". This behavior was characterized by adults attempting to enter the nest with a fish in their mouth, but then return to the water with the fish in mouth. They then were seen without the fish in their mouth after a few minutes. We concluded that these data points were outliers and were not included in the averages of the pre-delivery pauses. They were included as observational data and their importance is explained in the analysis.

Another behavior that was observed was the "screaming" behavior. See example in Image 2. This behavior has been categorized as a warning sound among Pigeon Guillemots, as

birds often make it when there are predators nearby individuals or near the nest. These behaviors were noted for observational analysis.

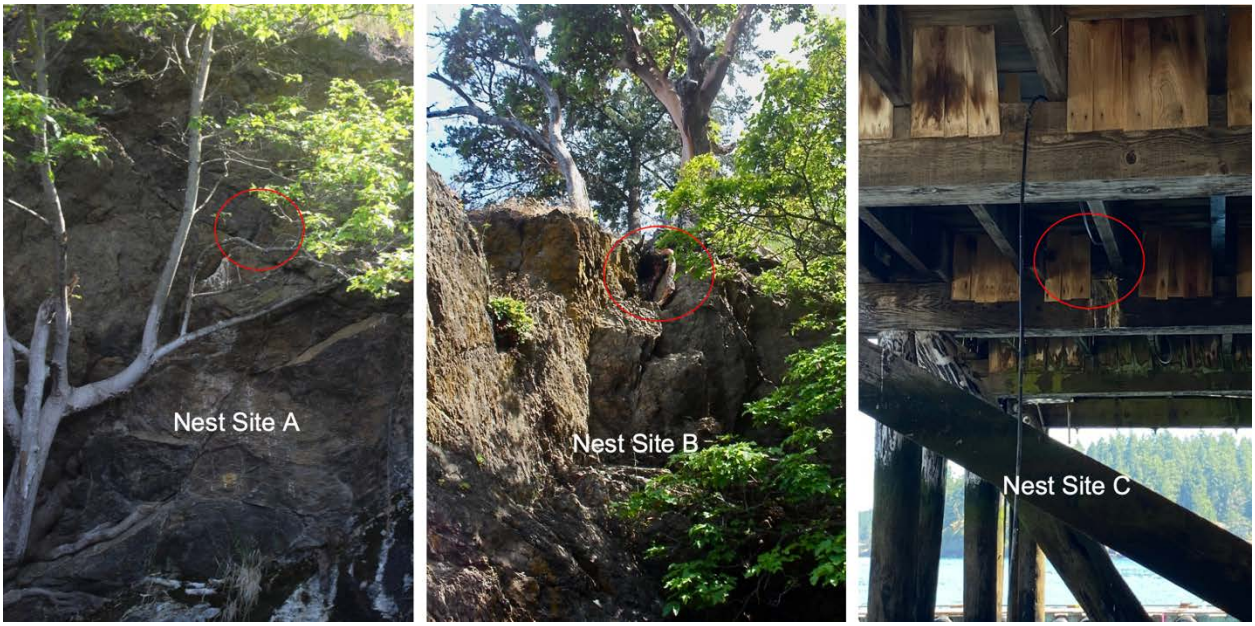

Image 1. The three nest sites. Nest A and Nest B in Park Bay, San Juan County Park. Nest C in Friday Harbor Laboratories.

Image 2. An image of screaming behavior by Pigeon Guillemot.

Figure 1. Map of Friday Harbor Laboratory.

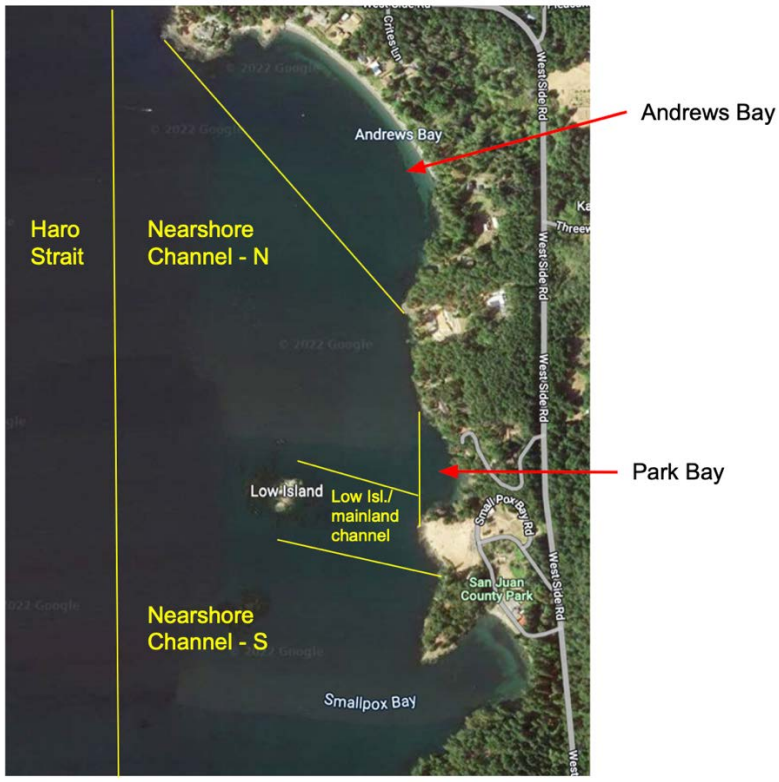

Figure 2. Map of San Juan County Park. Observations were conducted at Park Bay within San Juan County Park. This paper uses these names interchangeably.

Statistical Analysis

Following data collection, a t-test was performed on the pre-delivery pause duration data comparing the Park Bay control and the Park Bay experimental. An ANOVA test was also performed on the three trials “Park Bay control”, “Park Bay experimental” and “Friday Harbor Laboratories”.

Results

Natural history of Pigeon Guillemots at Friday Harbor Laboratories and San Juan County Park

We collected a variety of data on the Pigeon Guillemots in their nesting habitats. Since our data was observationally based, to get a better understanding of their behavior we investigated how the birds used the two field sites. By using scan sampling, we documented the section of the site that each of the individual Pigeon Guillemots were located every ten minutes. From this we could find the percentages of time that the birds spent in each section of the site. Figure 3 shows that Pigeon Guillemots at the Friday Harbor Laboratories site spent more than 30 percent in “FHL Cove”, spent less than 30% in “Mid-Harbor” and more than 20% of their time “Under Dive Locker Wharf”. See figure 1 for specific areas.

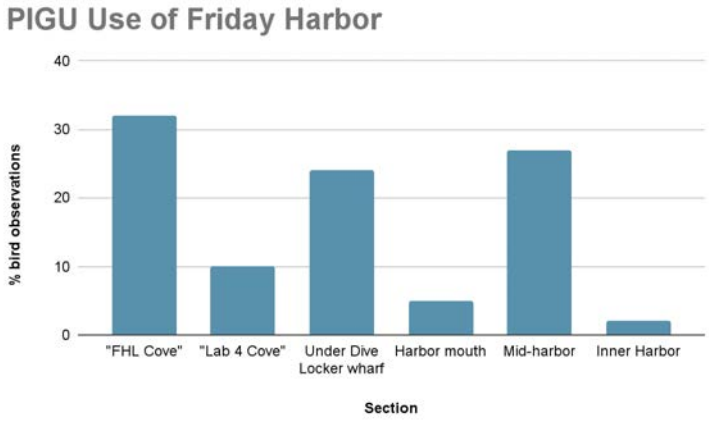

Figure 3. Percentage of observations of Pigeon Guillemot in each section at the Friday Harbor Site; based on observations made from the FHL Dock.

For San Juan County Park birds spent most of the time in “Andrews Bay” and “Park Bay”, each at over 40 percent (Figure 4).

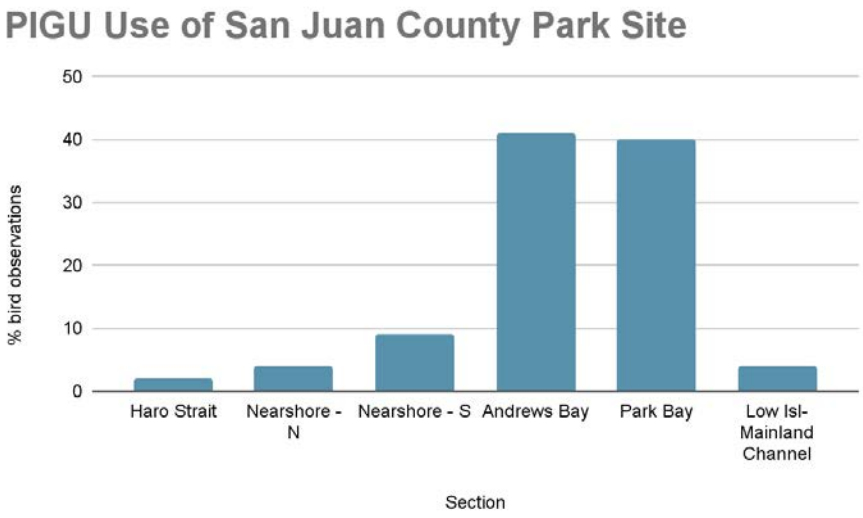

Figure 4. Percentage of observations of Pigeon Guillemot in each section at the San Juan County Park site.

Analysis of the duration of delivery times for provisioning

At the San Juan County Park site, the first observed deliveries of fish to Nest Site A and to Nest Site B were on June 29, 2022. The last observed delivery at these sites were August 1, 2022. At the FHL dock site, the first observed delivery to Nest Site C was on July 13, 2022. The last observed delivery to this nest site was on August 5, 2022. There were a couple of delivery attempts the next day but, in all cases, the bird eventually swallowed the fish.

Between San Juan County Park and Friday Harbor Laboratories a total of 160 fish deliveries were recorded. 103 of those deliveries we recorded pre-delivery pause times at San Juan County Park and 40 of those we recorded pre-delivery pause times at Friday Harbor Laboratories. Figure 5 shows each of these deliveries as a function of time separated by experimental and control trials and field site.

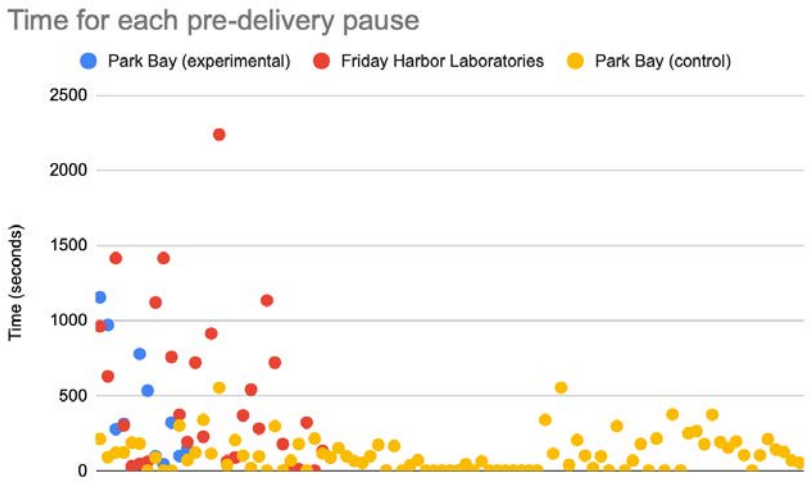

Figure 5. At each of the respective sites, the average time in seconds the bird spent sitting in the water with the fish in mouth before delivering to nest. This includes the incomplete deliveries and spans all of the data collected. (n=143)

The first observed deliveries of fish at San Juan County Park site were on June 29, 2022. The last observed delivery at these sites were August 1, 2022. The first observed delivery at the

FHL dock site was on July 13, 2022. The last observed delivery to this nest site was on August 5, 2022. Therefore, we paired down our data to the first three weeks of deliveries at each site to ensure that we were comparing similar time frames (Figure 6). In case the timing of the provisioning affected the number of deliveries or enhanced experience in delivery. The data shown in both Figure 5 and Figure 6 include incomplete deliveries.

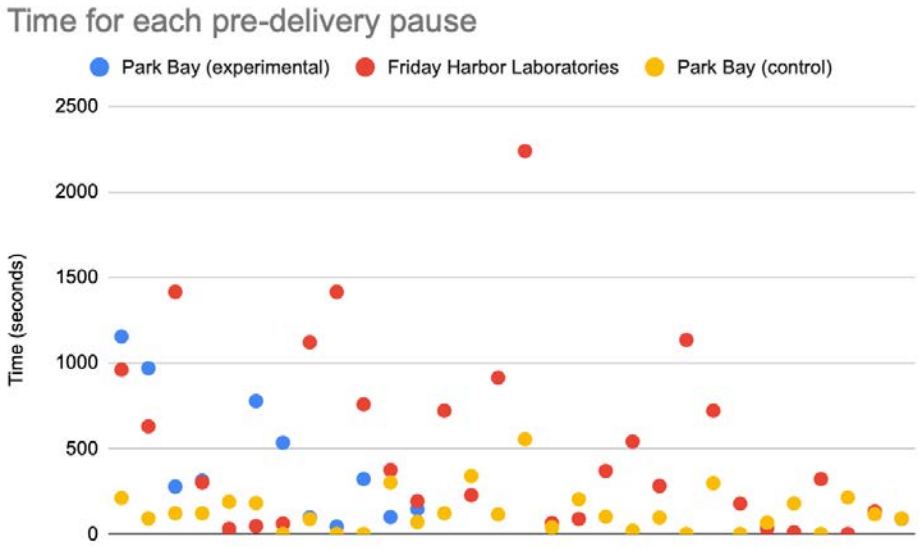

Figure 6. The time in seconds the bird spent sitting in the water with the fish in mouth. San Juan County Park data is paired down to the first two weeks of deliveries to match the collected data at Friday Harbor Laboratories. This includes the incomplete deliveries.

Figure 7 shows the average time that the Pigeon Guillemot sits with fish at "Park Bay Control", the control with no human or predator activity (n=86), "Park Bay Experimental" which is where we introduced predator activity (n=12) and "Friday Harbor Lab" wharf (n=35). San Juan County Park control trial had an average of 94.2 second, San Juan County Park experimental trial had an average of 393.3 seconds, and Friday Harbor Laboratories had an average of 301.7 seconds. San Juan County Park control data range is three weeks (6/29/22 to 7/20/22). This data excludes incomplete deliveries at Friday Harbor Laboratories because we

measured the delivery time and in these instances the fish were dropped and not delivered to the nests. These incomplete deliveries averaged 1006.0 seconds until the bird was no longer seen with the fish in mouth (n=5). We used a T-test to compare the control and experimental at San Juan County Park, we got a significant value for p was less than 0.0001. We also ran an ANOVA test on the three samples which found significance between “Park Bay control” and “Park Bay experimental” with a P < .0001 and “Park Bay control” and “Friday Harbor Laboratories” also with a P < .0001. However, when comparing “Park Bay experimental” and “Friday Harbor Laboratories” was found to be nonsignificant with a P value of 0.27.

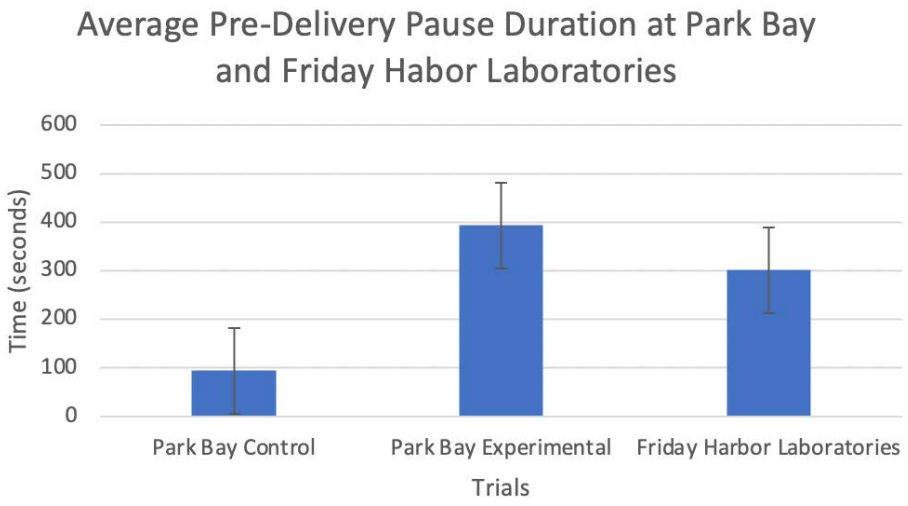

Figure 7. Park Bay Control (n=86), Park Bay Experimental (n=12), Friday Harbor Laboratories (n=35). T-test ran for Park Bay Park Bay Control and Park Bay Experimental. t =-5.95, df= 96, and p < .0001. T-test ran for Park Bay Experimental and Friday Harbor Laboratories. t=0.74, df=16.88, and p =0.27

Additionally, we split the San Juan County Park into nest site A and B to determine if there was a difference between the two nesting sites in pre-delivery pause durations. For this we removed the experimental trials to just test control. This test was found to produce a significant difference with a p value lower than 0.05.

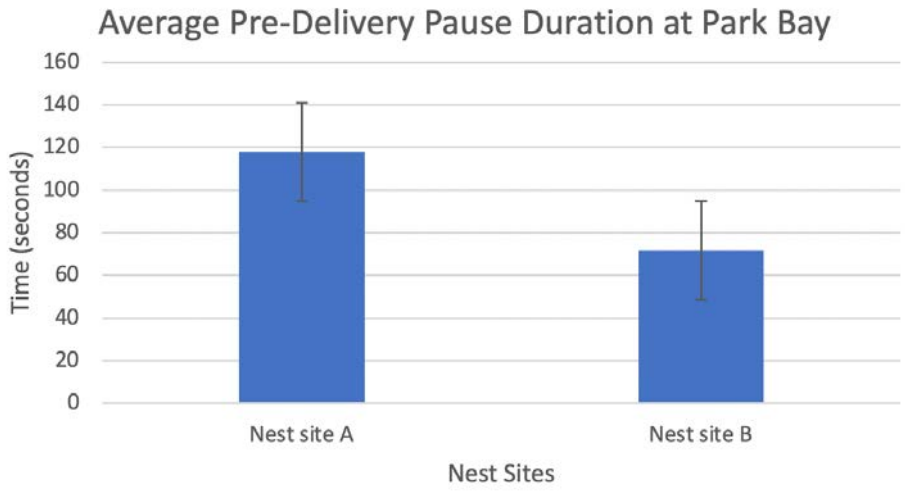

Figure 8. Average of nest site A is 118.0 seconds (n=43 deliveries), Average of nest site B is 71.8 seconds (n=48 deliveries). The t value is 2.16, df = 79.01, p = 0.0461.

Analysis of types of fish brought back to nest

Because of their wide range diet, Pigeon Guillemots have been identified to be indicators of health within a habitat (Bishop 2016). While looking at the behavior of the birds during provisioning, we observed the quantity and variety of the fish that the birds were returning to the nest. Out of 171 total fish deliveries at the two sites, 48 were gunnels or pricklebacks, 17 were crescent gunnels and were distinguished because of their easily identifiable shade, 74 were sculpins, 30 were unidentified.

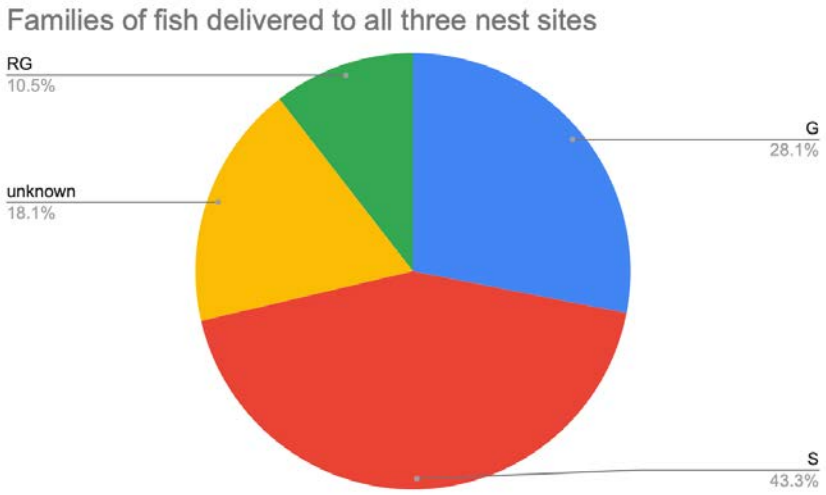

Figure 9. The percentage of fish delivered at all sites by species of fish. The different categorizations are gunnel and prickleback (G), crescent gunnel (RG), sculpins (S), and unknown which were unidentified fish. (N=171)

We categorized the families of fish brought back by field site. At San Juan County Park, out of 128 deliveries, 11 were unidentified, 35 were sculpins, 80 were gunnels and pricklebacks.

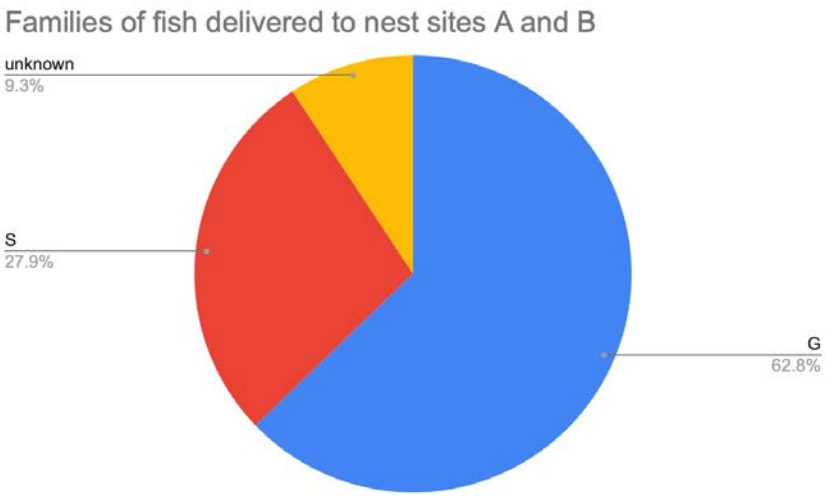

Figure 10. The percentage of fish delivered to San Juan County Park nesting sites. The different categorizations are Gunnel and prickleback (G) which includes Saddleback Gunnel, sculpins (S), and unknown which were unidentified fish.(N=128)

At Friday Harbor Laboratories, out of 43 deliveries (this number does include the incomplete deliveries because they were intending to deliver the fish), 7 were gunnels and pricklebacks, 6 were crescent gunnels, 9 were unknown and 21 were Sculpins (Figure 11).

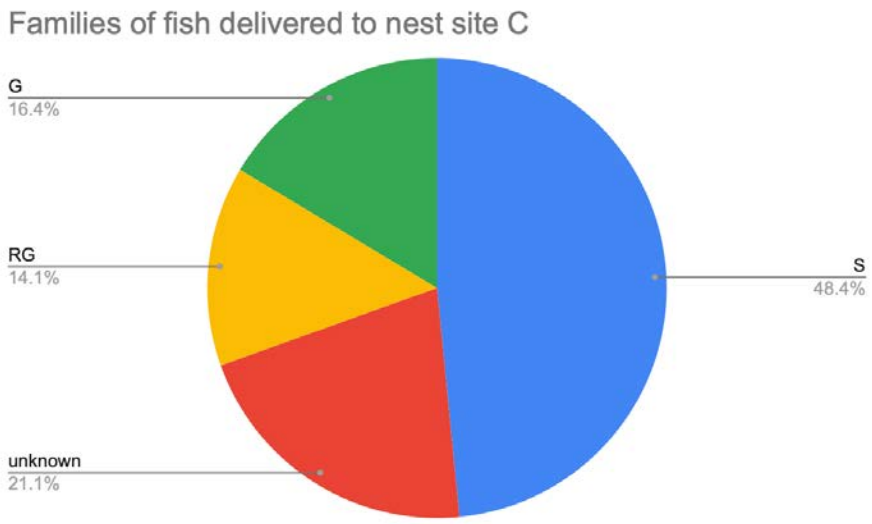

Figure 11. The percentage of fish delivered to Friday Harbor Laboratories nesting site. Gunnel and prickleback (G), sculpins (S), and unknown which were unidentified fish. (N=43)

Qualitative observation on the differences between Friday Harbor Laboratories and San Juan County Park nesting sites

We observed distinct behaviors at the two sites due to the differences in nesting sites. At Friday Harbor Laboratories, as the tide changes, so does the proximity of the nest to the water surface, and it also changes key points of access for the nest. The nest is underneath the wharf, tucked behind some wooden planks. The Pigeon Guillemots jump or land on wooden diagonal beams that are part of the structure. They then fly into the nest from these diagonal beams. During high tide the wooden beams are covered by water and offer no place to land, additionally at extremely low tide the birds are not able to just hop onto it, they must fly onto it.

In addition to this, birds at Friday Harbor Laboratories would often attempt to enter the nest and fail. This failure is defined as a bird who intentionally tried to get into the nest, and either hit the wooden board or slipped on the board while landing. Often the birds were unable to get into the nest the first time and had to try again. This was observed, 11 times out of the 43

deliveries; accounting for 25.6% of all the deliveries observed at Friday Harbor Laboratories. While there were no instances of this behavior witnessed at San Juan County Park.

Finally, the number of screaming behaviors witnessed at the San Juan County Park was much higher than the screams heard at Friday Harbor Laboratories. When a predator (human, crow, eagle, heron, otter) was near to the Pigeon Guillemots or their nest they would immediately emit at least one scream. Often this would be the only scream if it were a crow or eagle passing by. However, if a human or heron were near the nest for a prolonged period the birds would scream intermittently for minutes. This would also attract other Pigeon Guillemots to join them on the water, where they would scream together. Regarding the screams that resulted due to a predator's proximity to nest, except for crows, we never observed potential predators any closer than 30 meters from the nest. Crows would occasionally perch on the cliffs within 1 to 2 meters of a nest site. However, at Friday Harbor Laboratories, humans would get much closer to the nest than at San Juan County Park and the birds would not react. Additionally, birds would swim close to the dock when there were humans present. Some getting within 5 meters and even hopping onto the dock while there was human activity. There were a few times when screams were heard at FHL: when scuba divers entered the water underneath the wharf, and when a third bird would join a couple.

Discussion

By studying how Pigeon Guillemots have adapted to live within urban areas and continue to thrive in natural ones, we have gained important information into how humans can continue to coexist with them. As we continue to make alterations to natural habitats for animals, we must also learn how these changes impacts their habitats. This research has showed that Pigeon Guillemots will alter some aspects of their nesting behavior because of human activity,

highlighting the impact humans have even though they are commonly known to live in highly populated areas.

This data shows that in areas of low urbanization and human activity, Pigeon Guillemots will extend the amount of time that they wait in the water before delivering a fish when there is a predator near the nesting site; 8 out of 12 times the predators were human. The pre-delivery pause time increases by more than four times when a human is introduced. The more time that the birds spend on each individual delivery, there are fewer deliveries in a day that they can carry out.

When comparing San Juan County Park (a lower human activity area) to Friday Harbor Laboratories (a higher one), the one with more human activity the average of the pre-delivery pause was three times as longer than the control of the lower human activity area. Pigeon Guillemots took much more time to deliver at Friday Harbor Laboratories, displaying that in higher human areas they are more cautious with their delivery. However, the FHL pre-delivery pause average was lower than the experimental at San Juan County Park. This could show that even though Friday Harbor Laboratories is affected by the level of human presence, they are also still more acclimated to it than the birds who do not encounter human interactions at the same quantity. The comparison between Friday Harbor Laboratories and San Juan County Park was insignificant, therefore it would require more data to make a full conclusion.

There may be room for error in this experiment surrounding the identification of individual birds. The Pigeon Guillemots we studied looked very similar, with no unique markings or tags to distinguish them. Therefore, when they were delivering, we did not know which was which. Figure 8 separates the Park Bay data into the two nests; this splits the individuals up from 4 to 2 for each bar graph. Here we have a significant difference from nest A

to nest B, displaying that there is a change in one nest behavior to another. An alternative explanation may be differences in the experience of the pairs we observed. More experienced birds may take less time to deliver a fish or may be less perturbed by human activity.

In addition to this we saw six incomplete deliveries at FHL. This shows a higher rate of birds abandoning the prey altogether and ceasing their delivery because they were too disturbed. Cairns discusses the implications of human visits to a Black Guillemot nest too often can lead to the abandonment of a nest (Cairns 1980). There is a possibility that this could be an early sign of the Pigeon Guillemots at Friday Harbor Laboratories abandoning their nest. There was also the case when they completed six deliveries, then the bird landed in the nest with the seventh fish, it stayed for a minute then returned to the water with the fish. This was not the result of disturbance by human activity but most likely because the chicks were no longer feeding.

In an experiment done by Ronconi and Clair, Black Guillemots flushed depending on the boats approach distance, usually flushing when the vessel was within 260m (Ronconi and Clair 2002). This flushing response also increases in habitats with less cover provided (Bratton 1990, Pierce et al. 1993). In a study by Cairns (Cairns 1980), Black Guillemot nests were visited within 15m either once every four days, (lightly disturbed zone) and daily (heavily disturbed zone). Reproductive success in the Black Guillemots that were part of the heavily disturbed zone was much lower than the reproductive success in the less disturbed zone (Cairns 1980).

Regarding general group behavior of the Pigeon Guillemot, we observed that they would often spend time in a group of three. This recalled species of birds that within the couples have a third bird that serves as the “helper” bird. In these cases, there is often a new adult that is helping the adults with provisioning and other activities (). Although Pigeon Guillemots are not known to cooperatively breed, there was a possibility that there was a third bird delivering to the nests.

This individual may be a juvenile from a recent clutch and lack the experience that the other adults have. Alternatively, a third individual may be from a neighboring nest site somewhere in the harbor (including a possible failed nest under the FHL dock), similar to what has been seen in Common Murres (Birkhead and Nettleship, 1984). This third bird could explain the difference in times between individual birds and therefore affect the total averaged time at each of the sites. Although, this was observed at both field sites, so therefore it may have affected both equally.

A possible error with the methodology was the identification of fish. As Pigeon Guillemots quickly surface with a fish and can disappear quickly, making it difficult to observe fish. In future studies, using a high-powered camera will present a more accurate identification of the fish caught. Another error that we had was that at San Juan County Park, 10 of the 12 experimental trials were conducted on adults delivering to nest site A, only two of the experimental trials were done on the adults delivering to nest site B. This was something that we could not have anticipated as we could not tell which birds were delivering to which nest while they were sitting in the water, but it may have impacted our result as we were mostly measuring the response of the adults at nest site A. My sample size was also extremely small with only three Pigeon Guillemot nests. This study could be broadened to a larger group of nests and be repeated to gain a more substantial amount of data and observations for these birds.

It is essential to study the behavior of animals and especially Pigeon Guillemots as they can be easily linked to human interactions and can be used as indicator species for the habitat. This is especially important with climate change. Pigeon Guillemots provision within two kilometers of their nests due to the proximity of their prey; they can feed their chick efficiently because of this closeness. In the case of birds that must fly further into the ocean to catch prey, they use the regurgitation method to feed their chicks. This is more effective than carrying the

fish outside of their crop, which increases the possibility of losing the fish or attracting competition. Warming temperatures of water forces fish, crabs, and other invertebrate prey into deeper water (Spares et. al. 2012) causing piscivores, like the Pigeon Guillemot, to increase the distances at which they hunt. For birds without the ability to feed their young using methods, such as regurgitation, this could prove deadly. With the rapidity of climate change, there will not be time to adapt to these changes. It will force Pigeon Guillemots to change nesting sites to areas like bird preserves and islands farther away from the shore.

Future studies that would be important for furthering the research of Pigeon Guillemots on San Juan Island include looking at the timing of hatching eggs and the survival rates of chicks at both sites. The San Juan County Park eggs hatched a month earlier than the Friday Harbor eggs; looking into seeing if this is a pattern would be important for studying the health of reproduction. As eggs are laid later in the year, chicks are more susceptible to colder temperatures at a younger age than normal. Also monitoring the number of chicks that survive to adulthood at the two different sites would give us an even better idea as to whether humans are impacting reproduction of Pigeon Guillemots.

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