

**Foraging Behavior and Habitat Distribution of Seabirds on Fourth of  
July Beach and South Beach, San Juan Island**

**Erika Diane M. Merto**

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

Contact information

Erika Diane Merto

Primary email: [edmerto@uw.edu](mailto:edmerto@uw.edu)

Secondary email: [mertoerikadiane@gmail.com](mailto:mertoerikadiane@gmail.com)

**Abstract**

Seabirds play an important role in the ecosystem by being one of the top predators of the marine food chain, and also as bioindicators of environmental changes. Their ability to quickly respond to their surroundings can be useful in anticipating possible threats not only to the seabirds but also to areas where they congregate. This study aims to assess foraging behaviors and habitat distribution of four species groups; loons, ducks, grebes, and gulls, found at two representative beaches (Fourth of July Beach and South Beach). Marine bird surveys and habitat assessments were conducted to see which factors, mainly time of day, tide state, prey abundance, and weather, affect the number of foraging birds and their distribution. It was found that there were no significant differences in the numbers of foraging birds at any time of the day at Fourth of July Beach, while more birds were foraging in the early morning at South Beach. Marine birds were also observed to be scattered both nearshore and offshore on Fourth of July Beach, while the birds in South Beach preferred either nearshore (gulls and grebes) or offshore (loons and ducks). Our habitat assessments imply that prey abundance mostly influenced the patterns seen for foraging birds by time of day and their spatial distributions. Information in this study could be used as guidance for conservation and management, to further protect the seabirds and their preferred habitats.

## Introduction

Seabirds play a very important role in the ecosystem. They serve as top predators in the aquatic food webs and are good indicators of environmental changes (Rajpar, et al., 2018).

Different species of marine birds spend their time within and around shallow waters, and out to the open ocean finding food, shelter, and a place to breed (NOAA, 2021). Their exploitation of a wide range of habitat makes them a target for environmental research, as they quickly respond to any change in their surroundings, and can be easily spotted (Rajpar, et al., 2018).

San Juan Archipelago hosts a great number of seabird species due to its rich marine habitats. This area in the Pacific Northwest is composed of 172 islands, and receives large contributions from several bodies of water including multiple straits, the Pacific Ocean, and the Fraser River (Minney, 2018). These islands also lie within the Pacific Flyway, making it a good resting place for many migratory birds that are travelling to the south (or warmer areas), from Canada, for the winter (San Juan Safaris, 2018). A major island in the archipelago is San Juan Island, which is made up of beautiful beaches, lagoons, rocky shores, and many other habitats preferred by the seabirds. More than 200 species of beautiful marine birds are sighted near San Juan Island alone every year, making the island one of the best spots for birdwatching in the State of Washington (National Park Service, 2021).

Other than their immediate appealing colors and patterns, seabirds also possess different foraging strategies easily observed during birdwatching. Seabirds can either be plungers/divers, or surface foragers (Bowers, N., et al., 2000). Some examples of plungers/divers are ducks, grebes and loons. Ducks feed on bivalves, especially mollusks and clams, small crabs, worms,

and snails (All About Birds, 2019). Loons enjoy forage fish, but also feed on crustaceans, snails, and marine insects (All About Birds, 2019). Grebes' diet includes aquatic insects, worms, and crustaceans (All About Birds, 2019). Gulls on the other hand, are an example of a surface forager, and feed on forage fish, marine vegetation, and marine invertebrates (All About Birds, 2019). Although these birds have different foraging strategies, they often feed on the same prey species and share foraging habitats.

Several species of marine birds may be found near the same beach, yet are distributed differently due to their foraging strategies. Surface foragers, like the gulls, mostly feed on intertidal zones where they can easily locate their food without using so much energy (Irons, et al., 1986). In contrast, divers and plungers can be located nearshore as well as the open ocean to feed, where there are abundant food resources. Prey density, salinity, temperature, water transparency, and ocean depth affect marine bird's foraging behavior, as well as their distribution (Fraser, et al., 1996). Water status and ocean productivity are interconnected to the environmental performances of the seabirds, thus making them good bioindicators that could assist in conserving and managing marine protected areas (Rajpar, et al., 2018).

Understanding different foraging behaviors and habitat distribution of seabirds in a specific area can be used as a baseline to track what is happening around and beneath the waters. Even so, not many assessments are performed on seabirds found especially at places that were surveyed for conservation and management (Rajpar, et al., 2018). This study aims to assess connections between seabirds and their surrounding environment. The main objective of this study was to understand seabirds' foraging behavior and habitat distribution at two chosen study

areas, the Fourth of July Beach and South Beach, which are part of the American Camp (National Park). This research focused on four species of seabirds: loons, ducks, grebes, and gulls, as they are the most common marine birds seen on both study sites. Time of day (early morning, noon, and early evening) was one of the main factors examined to determine the effect on the number of foraging birds. Shore and benthic assessments were also carried out to determine the effects of habitat characteristics on the foraging habits of birds, and to identify preferred distribution and habitats. Additionally, the factors of prey availability and tide height were investigated.

## **Methods**

### ***Study area***

Fourth of July Beach (FJB) and South Beach (SB) on San Juan Island, Washington were chosen as study sites (**Figure 1**). A 500 meters by 1000 meters observational area was defined for each beach, and was divided into two zones, nearshore (within 200 m of shore) and offshore (200-1,000 m of shore). The zone boundaries were marked by manmade (e.g., existing moorings) and natural (e.g., rocks and driftwood piles) objects (**Figure 2**). At Fourth of July Beach, onshore markers were a rock located at 48°28.268' N, 123°0.400' W and wood piles located at 48°28.068' N, 123°0.156' W, the nearshore marker was a mooring, and the offshore marker was a small island located at 48°28.712' N, 123°0.007' W. At South Beach, onshore markers were a rock cliff located at 48°27.376' N, 123°0.455' W and wood piles located at 48°27.351' N, 123°0.071' W and the nearshore and offshore markers were existing moorings.

## **Data collection**

### ***Marine Birds Observations***

Marine bird surveys were conducted from land at the two beaches on 10/20/2021, 10/21/2021, 10/29/2021, 11/2/2021, and 11/3/2021. The observer stayed at a midpoint location marked  $48^{\circ}27.369'$  N and  $123^{\circ}0.261'$  W on South Beach and  $48^{\circ}28.165'$  N and  $123^{\circ}0.294'$  W on Fourth of July Beach. The observations took place three times a day: early morning, noon, and early evening, lasting two hours each. The early morning observation period began about 15-20 minutes after dawn, the noon observation period began around 11:30 am to 12:00 pm, and the beginning of the early evening observation period depended on the sunset time, making sure that the observation would finish within 15-20 minutes before sunset. Every 20 minutes, the observer switched between beaches, which gave two samples at both locations for each time of the day. These controls were implemented in order to maintain similar time and environmental conditions for both locations, thus reducing variability during data collection and for comparing beaches during data analysis. Each zone was scanned three to four times within the allotted time starting from offshore left, moving to nearshore left, to offshore right, then to nearshore right. Multiple scans were conducted to account for all diving birds.

The number of birds by species were recorded utilizing binoculars (Eagle Optic 8X42), and spotting telescope (Celestron 20-60X80). Whether the marine birds were feeding (F) or not feeding (N), if they were found nearshore or offshore, and the time they were spotted, were also recorded. In addition, sea and tide states were also monitored and recorded at the start and end of each 20-minute observation period. These data were gathered from the NOAA's (National

Oceanic and Atmospheric Administration) website for tide predictions at 9449828 Hanbury Point, San Juan Island, Washington. Hanbury Point was closer to both study sites so it was more preferred than the tide predictions at Friday Harbor (~30-minute difference).

To identify feeding or not feeding, spotted marine bird/s were observed for 30-60 seconds. Evidence of foraging included diving, food in the mouth, looking underwater and pecking on the ground. Birds observed only floating for more than a minute were considered not feeding. For gull species, flying higher and then very close to the water was considered evidence of feeding.

### ***Rest/Dive Durations***

Individual birds or groups of birds were observed periodically and the underwater duration and rest duration between dives were recorded. An iPhone XS Max was used as a timer for these observations. The bird species and the time (in seconds) for the rest and dive periods were recorded. These observations were made during all observation periods (early morning, noon, and early evening) and various tide heights.

### ***Habitat Characterization***

Both study areas were observed during days of data collection. Characteristics evident to plain sight were recorded; levels and types of disturbances, coastal make-up, and whether the beach was exposed or protected

Multiple habitat maps and scientific papers were analyzed to characterize habitat. These maps and papers were mostly gathered from scientists that had sampled the two study sites (G.

Greene, S. Wyllie-Echeverria). The two areas were compared to identify differences and similarities between their underwater environments.

South Beach and Fourth of July Beach were also sampled with a beach seine. At least three people, one timer/recorder and two people handling the net, conducted beach seining. The beach seine sampling followed a standard sampling method (M. Baker, pers. comm.). Beach seining began before first light (morning) or before last light (evening). Three repetitions moving from left to right along the beach and another three moving from right to left, each repetition lasting for two minutes were executed. Caught marine species were placed in a bucket and subsequently photographed and identified. The total number of caught prey were also recorded for each seine.

Lastly, stereo cameras were deployed at both study areas to collect prey type and density data. A camera was deployed on South Beach (within the observational area) on October 22, 2021, before first light, during a low tide. They were carried out from shore to a certain depth (chest depth of a tall person). The camera was then recovered two hours after dawn. More stereo cameras were deployed on both study locations (one within the observational area on Fourth of July, and one close to the observational area on South Beach) on November 20, 2021 at noon. They were deployed using the Friday Harbor Laboratories' small boats. The cameras were left underwater for about 20 hours and then recovered for data downloading and analysis. Images taken by the cameras were carefully scanned to identify captured available prey species.

### **Data analysis**

## ***Marine Bird Observation***

### ***Foraging Behavior***

For both study locations, the total number of seabirds (feeding and not feeding) for each visit was calculated, then averaged using the formulas:

$$\text{Average Density} = (\text{Total \# of birds for visit 1} + \text{Total \# of birds for visit 2}) / 2$$

$$\text{Average (F)} = (\text{Total \# of feeding birds for visit 1} + \text{Total \# of feeding birds for visit 2}) / 2$$

$$\text{Average (NF)} = (\text{Total \# of NF birds for visit 1} + \text{Total \# of NF birds for visit 2}) / 2$$

This data was analyzed using analysis of variance (ANOVA), to see if there was a significant difference in the numbers of birds feeding, and also the total number of birds at each location during early morning, noon, and early evening.

The effects of tide were also analyzed by looking at the tidal heights during each 20-minute observation period. Average tide height at each time of the day (early morning, noon, and early evening) was calculated. Data was analyzed using ANOVA.

### ***Rest/Dive Duration***

Average values for dive and rest durations were calculated for each species; loons, grebes, and ducks. The data was analyzed using ANOVA, to test for differences in averages and determine if these differences were statistically significant.

### ***Species Distribution***

Collected data was uploaded and analyzed in RStudio. Code to calculate density (number of birds/Area (km<sup>2</sup>)) of spotted seabirds for each zone, offshore and onshore at both locations, was created and applied. Box plots were created to explore each species distribution and which zone they likely prefer.

### ***Habitat Characterization***

Coastal or benthic characteristics of each study location were tabulated (e.g., exposed, protected). Prey caught by stereo cameras and beach seining were tabulated to see if both beaches have similar or different available prey for the observed foraging seabirds.

## **Results**

### ***Foraging Behavior***

Both beaches showed similar patterns with birds feeding most in the early morning, and feeding least at noon (**Figure 3**). The time-of-day effect for all birds combined was nearly significant (ANOVA,  $F(2,11) = 3.31$ ,  $p = 0.07$ ) for South Beach and not significant ( $F(2,11) = 1.10$ ,  $p = 0.37$ ) for Fourth of July Beach. Gulls were the species group that most affected the difference for South Beach. The number of foraging gulls in the early morning was significantly higher compared to noon and early evening ( $F(2,81) = 4.16$ ,  $p = 0.019$ ) (**Figure 4**). For the remaining species groups there were no statistically significant differences ( $p > 0.05$ ) (**Figure 4**).

Early morning had the lowest average tidal height of 3.4 feet, while noon had the highest average tidal height of 6.3 feet. Early evening's average tidal height was 5.5 feet (**Figure 5 and 7**). Early morning's average tide height was statistically lower than noon and early evening

(ANOVA,  $F(2,27) = 31.88, p < 0.001$ ). The number of foraging birds was negatively correlated ( $R = -0.54, p = 0.005$ ) with tide height at South Beach, but no correlation ( $R = -0.02, p = 0.92$ ) was found at Fourth of July (**Figure 6**).

### ***Rest/Dive Duration***

Loons rested (average of 15.2 seconds) and dove (average of 26.9 seconds) the longest, followed by grebes (rest = 12.2 seconds, dive = 18.9 seconds), and lastly, the ducks (rest = 8.4 seconds, dive = 18 seconds) (**Figure 8**). Average dive duration significantly differed among groups ( $F(2,6) = 11.44, p = 0.009$ ) whereas the differences between average rest duration was only marginally significant ( $F(2,6) = 4.53, p = 0.07$ ).

Dive duration differed significantly among species groups by time of day but rest duration did not (**Figure 9**). Loons had the lowest average dive duration in the early morning (20.8 seconds), and highest in the early evening (33.3 seconds) (ANOVA,  $F(2,53) = 6.33, p = 0.003$ ). Grebes had the lowest average dive duration during the early evening (16.5 seconds), and highest at noon (20.4 seconds) ( $F(2,60) = 2.97, p = 0.06$ ). Lastly, the ducks had the lowest average dive duration in the early morning (15.7 seconds), and highest at noon (19.5 seconds) ( $F(2,67) = 3.66, p = 0.03$ ). Average rest durations of all three species groups showed no significant difference ( $p > 0.05$ ) at any time of the day.

### ***Species Distribution***

Scoters were the most common seabird (based on number counted per square kilometer observed, i.e., density), with grebes in second place, and Pacific Loon in third place, for both

South Beach and Fourth of July Beach (**Figure 10**). Scoters were scattered both in the nearshore area (within 200-m of the beach) and in the offshore area (from 200-m to 1000-m of the beach) (i.e. There was no significant difference in density between the nearshore and offshore areas, T-test,  $p = 0.84$  for South Beach and  $p = 0.99$  for Fourth of July Beach) (**Figure 11**). Grebes were more common nearshore at South Beach (t-test,  $p = 0.03$ ), and scattered over both nearshore and offshore areas at Fourth of July Beach ( $p = 0.78$ ) (**Figure 11**). Pacific loons preferred nearshore at South Beach ( $p = 0.006$ ), and were scattered over both nearshore and offshore areas at Fourth of July Beach ( $p = 0.25$ ) (**Figure 11**). The result for Common loon was the exact opposite ( $p = 0.11$  on South Beach,  $p = 0.01$  on Fourth of July) of the Pacific loons stated above (**Figure 11**). Gulls preferred the nearshore area at both beaches ( $p = 0.00001$  on South Beach,  $p = 0.005$  on Fourth of July) (**Figure 11**).

### ***Habitat Characterization***

Fourth of July Beach is a protected beach within Griffin Bay whereas South Beach is exposed to the open water at the eastern end of the Strait of Juan de Fuca. Both beaches are made up of sand and gravel. Many kelps and seagrasses washed ashore at both beaches in our fall observation period, though on Fourth of July, many opened shells also were spotted at the beach. The benthic habitat of both sites differed slightly. Though both were composed of soft substrates (mud, sand, gravel), Fourth of July Beach had ulva and seagrass beds offshore and nearshore, while seagrass beds on South Beach were only found farther offshore (beyond the observational boundary located 1-km offshore). Levels of disturbances for South Beach were higher compared to Fourth of July. During days of data collection, it was observed that more tourists and locals

visited South Beach. There were numerous fishing boats and other aquatic vessels that sailed all around the area, throughout the day (**Table 1**).

Fourth of July Beach was found to have more species and more abundant prey than South Beach (**Table 2**). Crab, sculpin, sand lance, and shrimp species were observed by beach seine and/or stereo camera at both beaches. Among the four species groups, at Fourth of July Beach, crabs were more abundant (average of 22.5 vs. 0.17 crabs per seine) as were shrimp (average of 6.8 vs. 0.17 shrimp per seine), while sand lance were more abundant on South Beach (average of 10 vs. 0.33 per seine). Both beaches have an almost similar sculpin abundance (average of 7.2 on Fourth of July vs. 6.7 on South Beach, per seine). Two species were observed only at Fourth of July Beach, rainbow perch (average of 2.3 per seine) and needlefish (average of per seine). In addition, Fourth of July Beach also hosts different species of annelid, insects, mites, bivalves, and crustaceans, while South Beach lacks bivalve and annelid species (Klinger, T., et al., 2006).

## **Discussion**

Fourth of July Beach and South Beach are both exquisitely healthy habitats for seabirds. They serve as homes for similar lists of marine bird species. However, according to the combined feeding and non-feeding number of birds, more birds were observed at Fourth of July Beach compared to South Beach (**Figure 3**). Also, Fourth of July Beach showed no significant difference in the number of foraging birds at any time of the day (**Figure 3**). Its rich benthic habitat that hosts abundant prey species can help explain this pattern. Fourth of July's underwater environment is composed of prey that can be present throughout the day, like the bivalves. In comparison at South Beach, foraging birds are mostly dependent on forage fish which are

typically active in the early morning and early evening (Holland, et al., 2020). Zooplankton that forage fish feed on emerge at dawn and dusk (Holland, et al., 2020). This dependence, and enough light to feed underwater, makes early morning the best time for birds to forage in South Beach, which aligns perfectly with the result acquired (**Figure 7**). Average tide height also was lowest in early morning compared to noon and early evening (**Figure 7**). Since gulls prefer to feed in the intertidal, it explains why there are more gulls foraging in the morning (Irons, et al., 1986). Most diving birds prefer low tide because they do not have to spend so much energy on diving deeper to find food (Calle, et al., 2016). Between both sites, South Beach is a very exposed area, not only to human disturbances but also to a lot of wind and wave actions. Even so, the number of foraging birds were not significantly affected by this kind of natural disturbances, because seabirds have waterproof feathers and have the ability to float on big waves (Botting, 2017).

Most of the observed species groups were found scattered in the nearshore and offshore areas of Fourth of July Beach, including gulls. However, on South Beach gulls were highly likely to be spotted nearshore (**Figure 11**). Prey availability and the difference in number of birds seen in both locations can impact these results. On South Beach, the observed foraging birds are mostly dependent on the forage fish. This is why they will often be spotted in areas where prey aggregate. Forage fish can either be offshore or nearshore, since they follow where their food is mostly abundant; zooplankton (Holland, et al., 2020). Forage fish aggregation attracts the feeding birds on South Beach. Though, grebes preferred to stay more nearshore on South Beach which could be because of its smaller size, and to reduce the amount of energy needed (Calle, et al., 2016). On the other hand, Fourth of July Beach has a higher abundance of available prey

underwater. Birds in that area can feed nearshore and offshore because of the extensive amount of eelgrass beds underneath which hosts a great amount of available prey including bivalves, crustaceans, annelids, and insects. Another striking observation on both beaches was that feeding seabirds frequently followed the glassy surface (**Figure 12**). That is because the water beneath it is rich with nutrients, as well as possible prey, concentrated by upwelling (Endean, 2010).

Dive durations were longest for loons (**Figure 8**). Among the diving birds observed, loons are the largest. They are also less buoyant due to dense bones and heavier body, which makes them better at diving (Bradford, 2016). Nevertheless, the difference in diving duration patterns throughout the day between the three species groups remains worth investigating. It could be because different groups target different prey, tide effects, time effects, and bird size. This would be a great subject for future research.

Some study limitations may affect the data collected. Marine bird observations are hard to execute with bad weather conditions (rain, strong wind, and waves). This factor also limited one day of observation (no early evening sample) because a whole day of good weather is required to complete a full survey. Another caveat that could interfere with the result is the unexpected presence of fishing vessels and feeding mammals. On one occasion, a passing fishing boat attracted gulls away from the study beach. These kinds of events are hard to avoid during observation, so conducting more days of data gathering can decrease the effects of these variables on the study. Lastly, the asynchronous diving of observed birds can affect the data. Birds can easily be missed during zone observation because they are underwater. It would be helpful to do multiple area examinations or have multiple observers to track individual birds and

thereby account for this possible error. All efforts to reduce inaccuracy were implemented to strengthen the conclusions of this research.

This study showed evidence on the interconnectedness between marine birds and their surroundings. Ocean makeup, water physics, and prey density all impact the seabirds' occurrence. It was concluded that bird congregation marks important and rich habitats. Time of day, prey abundance, tide state, and upwelling areas affect seabird distribution and foraging. Places like Fourth of July and South Beach are home for marine birds which should be protected for sustainable use by marine birds. Observations of bird behaviors and distribution can help inform decisions about how to control restrictions into places where seabirds are found to reduce levels of disturbances. Long term data replicating this study can show trends in the number of foraging birds (either declining or improving) that could indicate changes in ocean conditions. Monitoring seabirds is helpful in conservation and management of the marine protected areas. Safety of these birds should be ensured as they serve a major role in all aquatic ecosystems.

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Tables and Figures

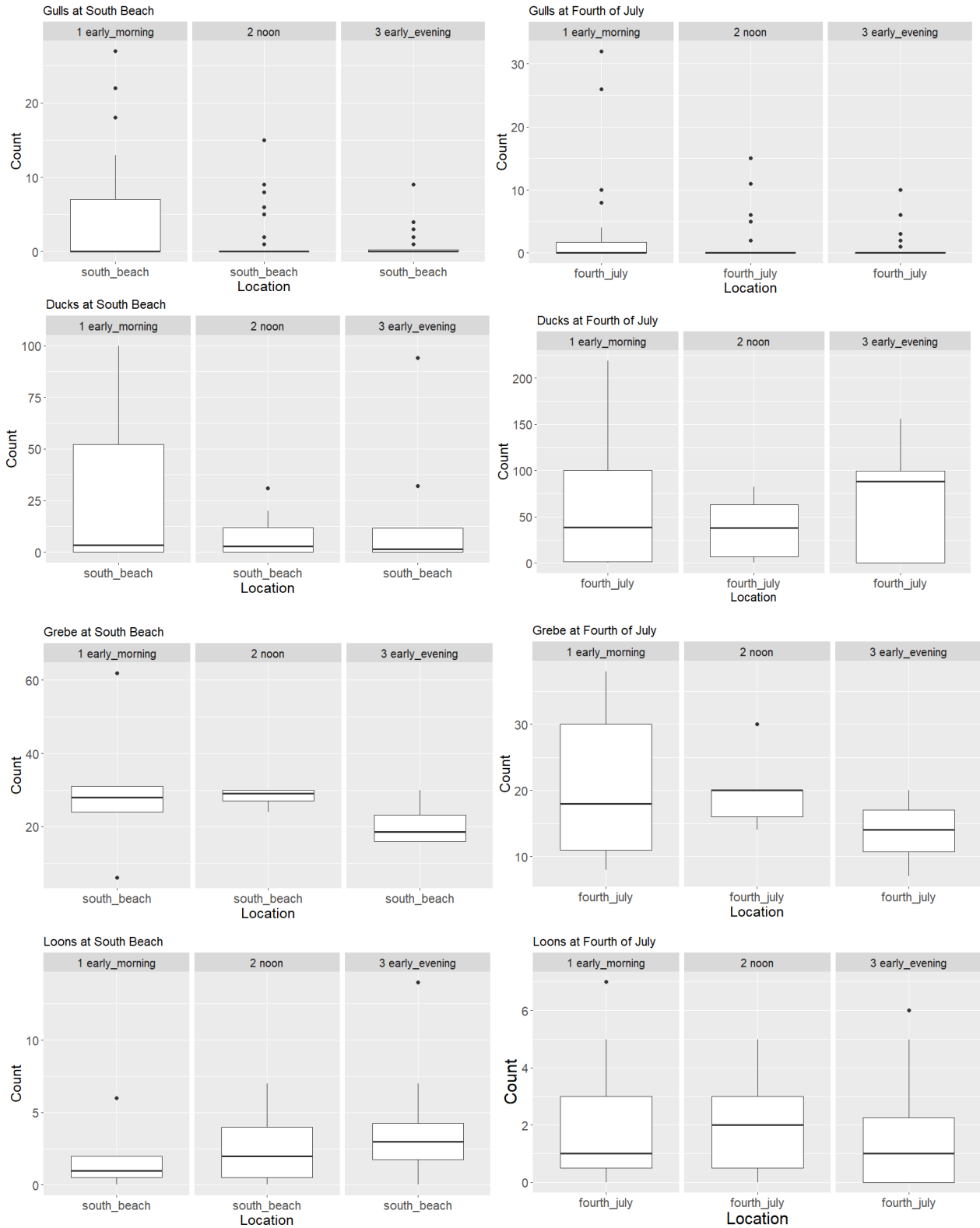


**Figure 1:** *Study Sites.* Fourth of July Beach and South Beach are part of the American National Park.

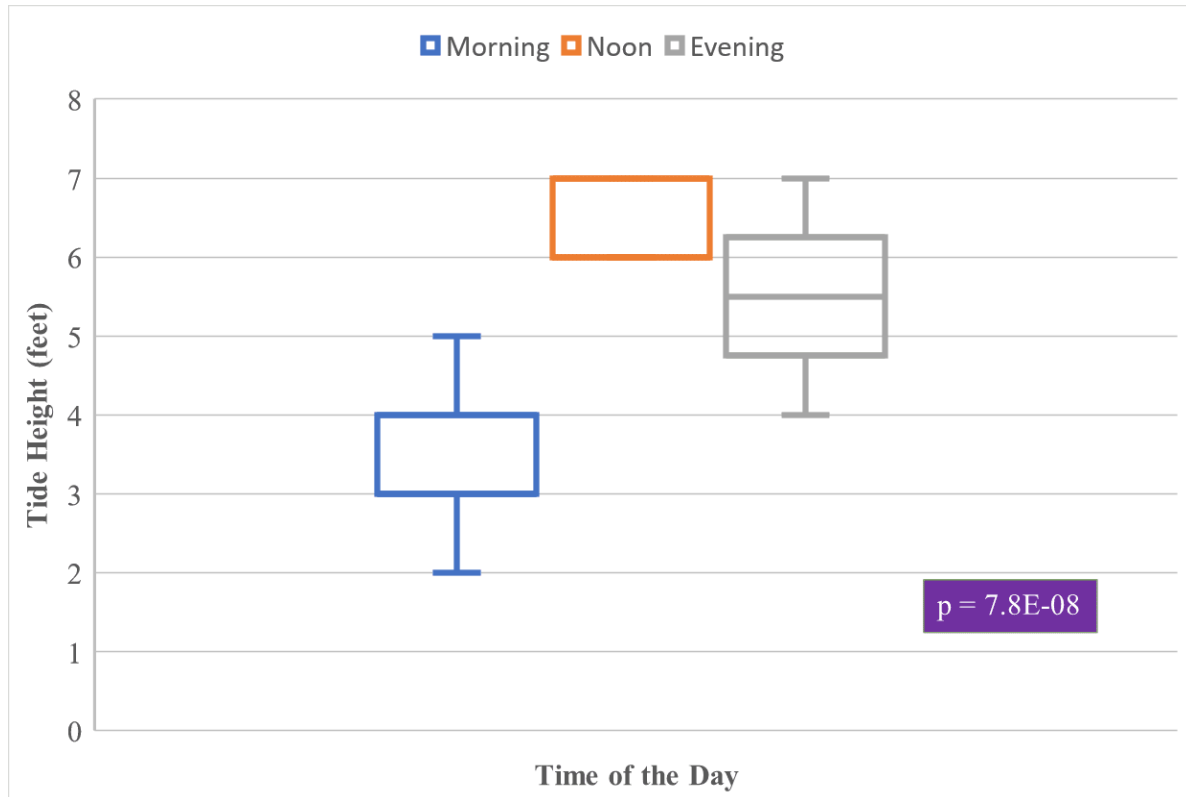


**Figure 2:** *Area markers.* Manmade and natural onshore markers for both sites. Bedrock and woodpile were used on Fourth of July. Shore indent and a cliff were used for South Beach. Markers were 500 meters apart.

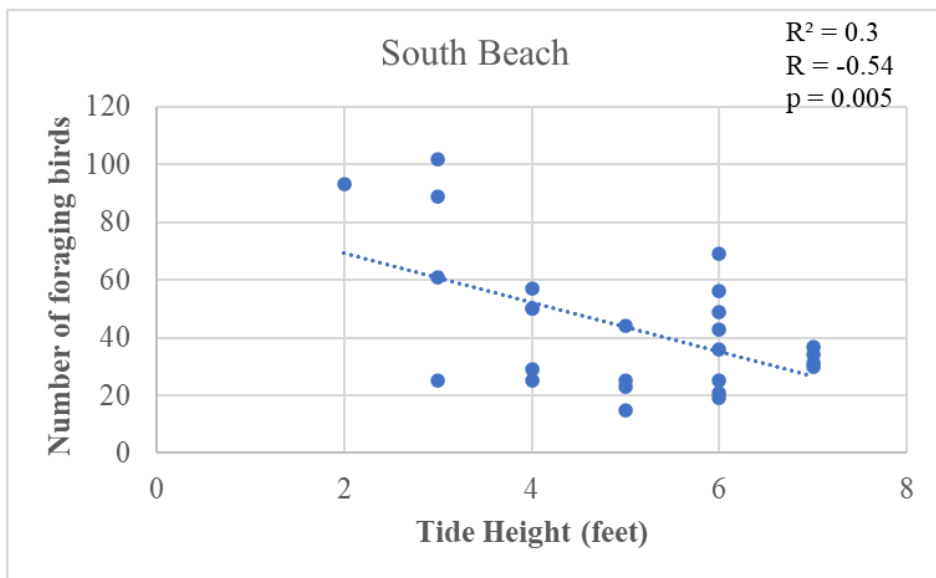
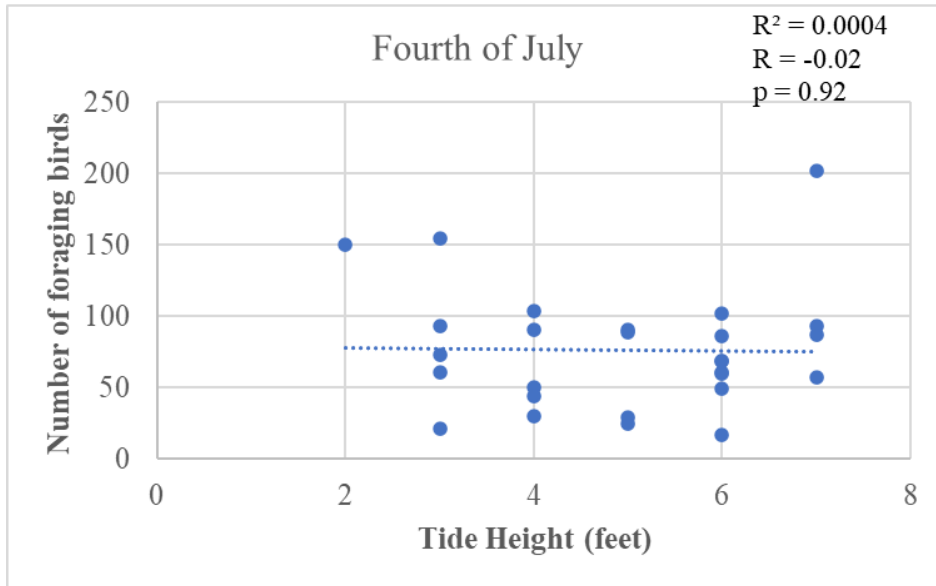




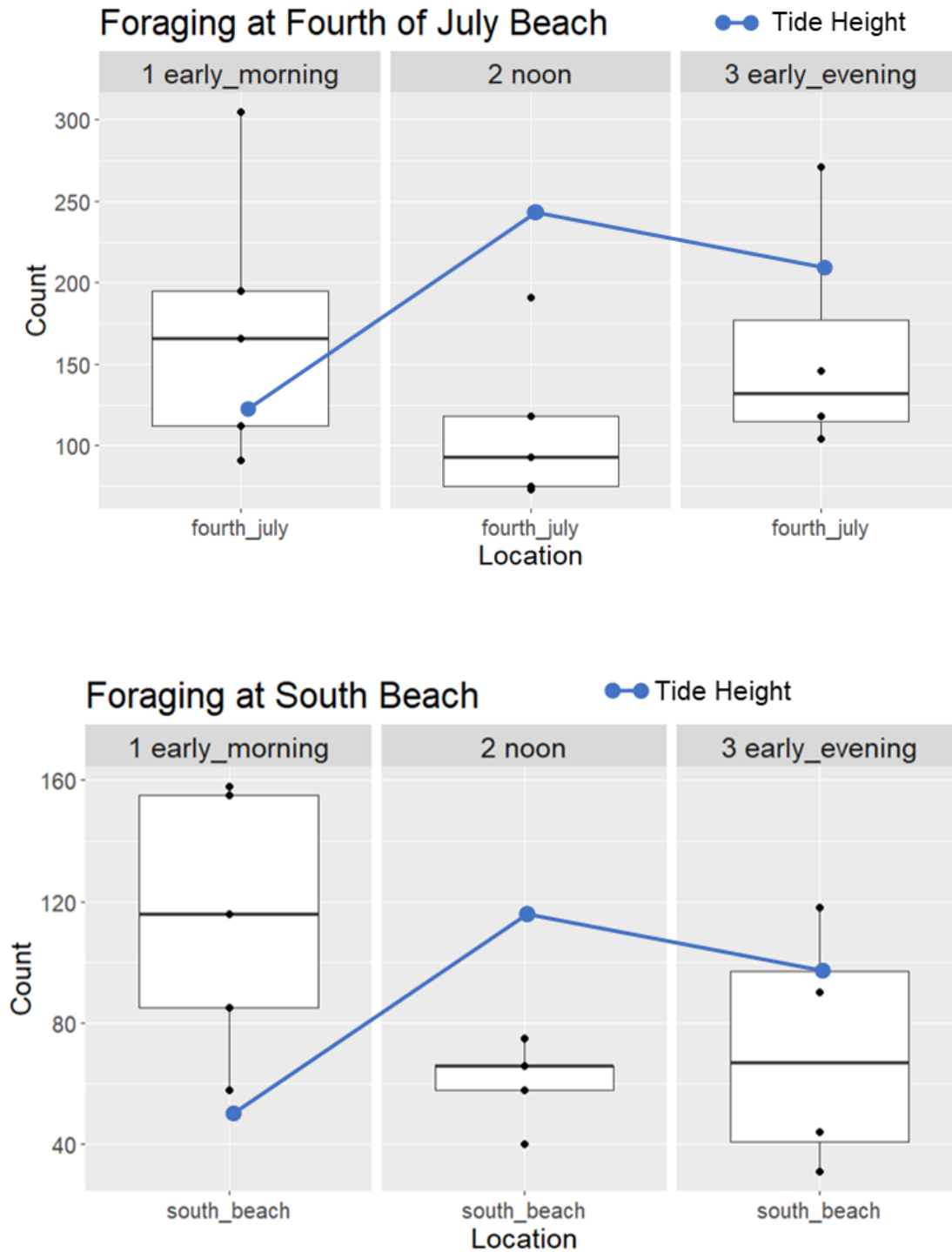
**Figure 4:** Foraging by species group. Number of foraging birds (count, y-axis) for four species group; gulls duck, grebes, and loon, at different times of the day. Left figures were for South beach, and right represents species found on Fourth of July Beach.



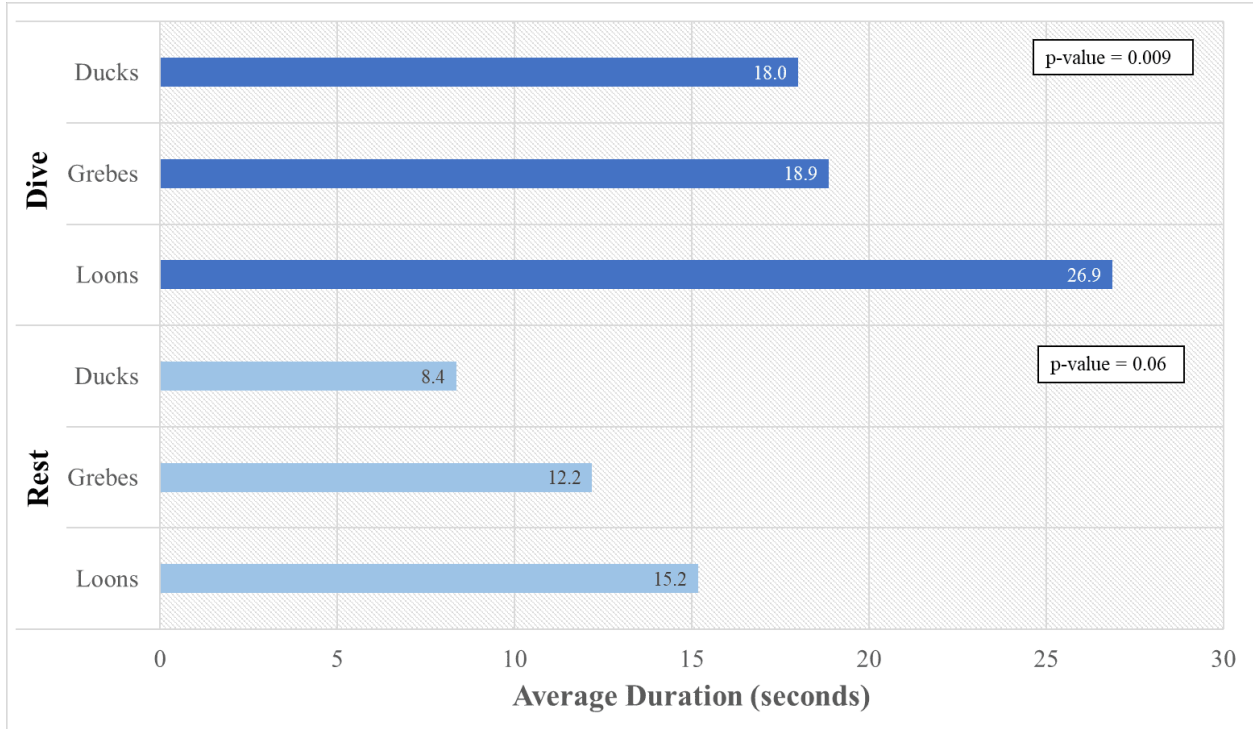
**Figure 5: Tide Height.** Average tide height (feet) in the y-axis at different time of day; early morning-blue, noon-orange, and early evening-gray (x-axis).



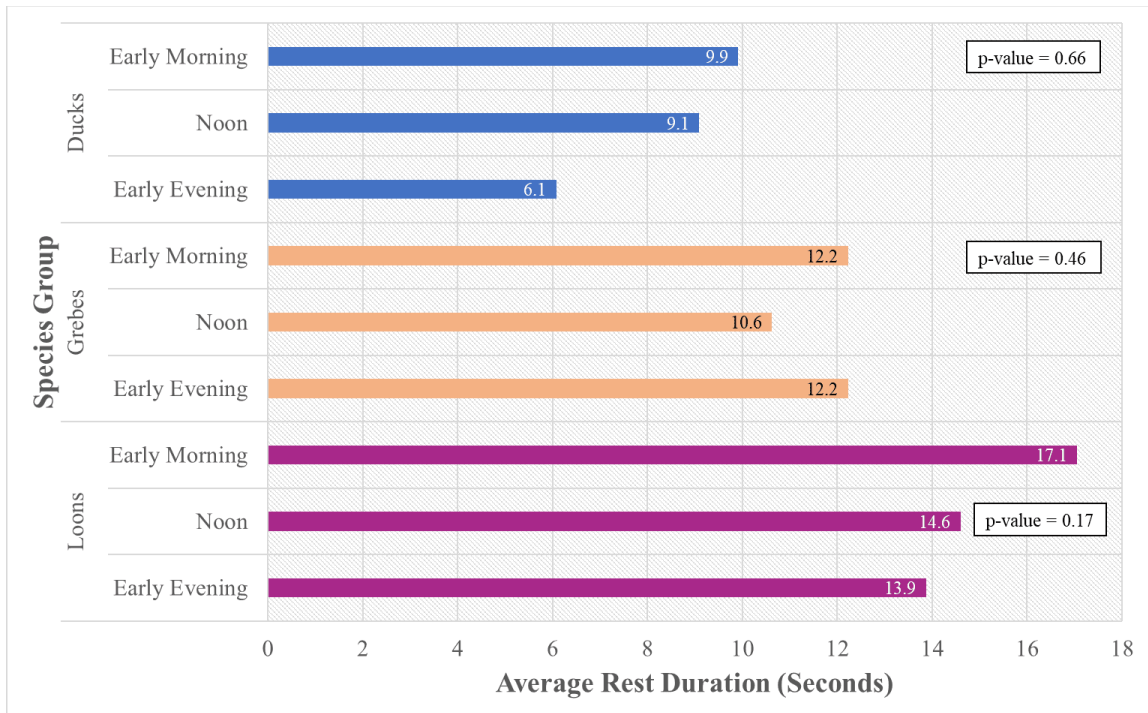
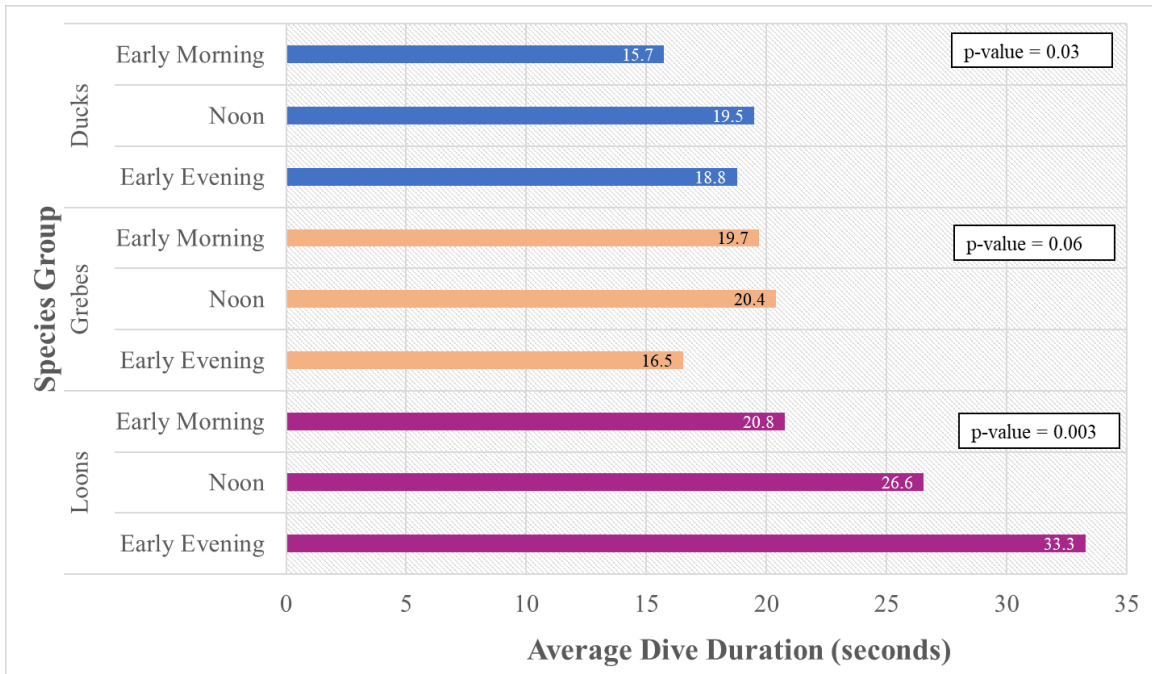
**Figure 6: Tide Height.** Number of foraging birds versus tide height (feet) for both study sites; Fourth of July and South Beach.



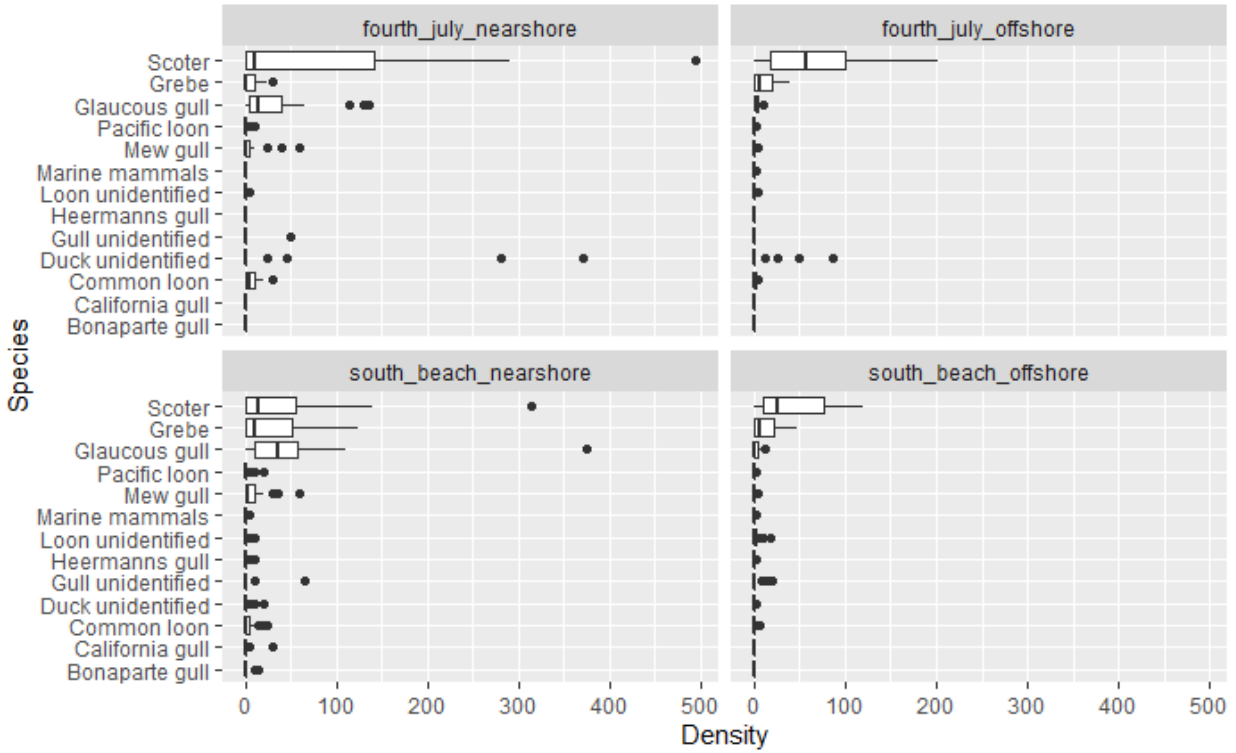
**Figure 7: Tide height.** Lowest average tide height in the early morning, when observed number of foraging birds are the highest. Noon has the highest average tide height when number of foraging birds are lowest.



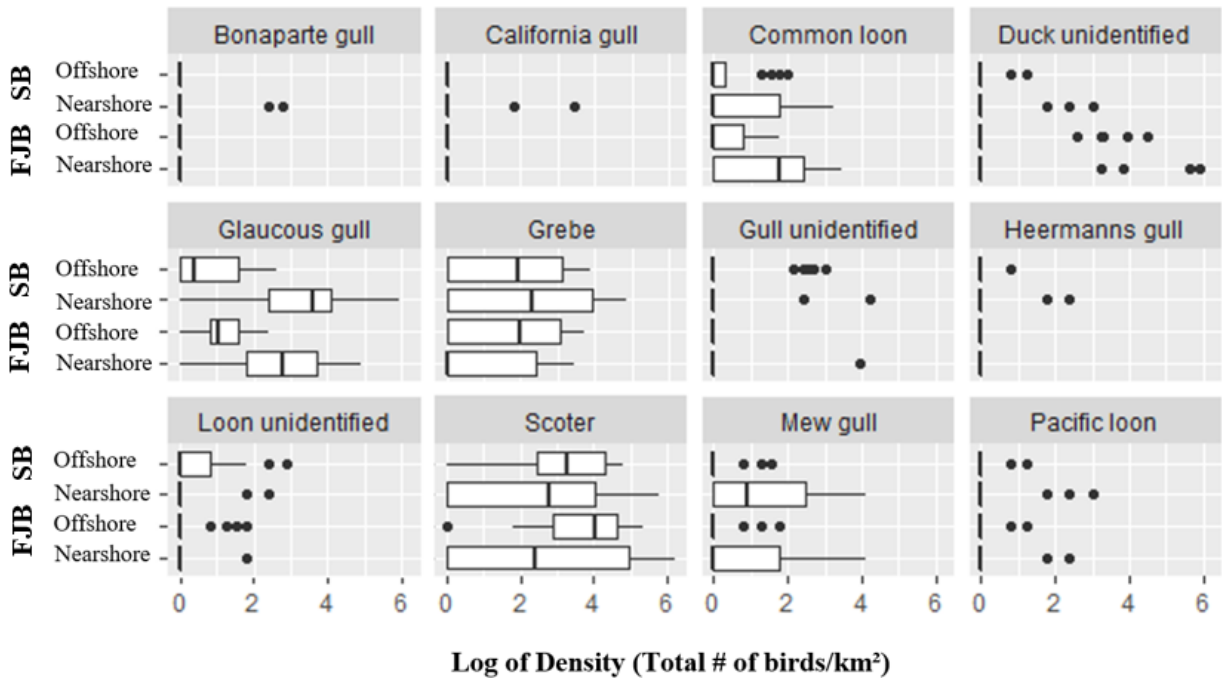
**Figure 8:** *Dive/rest durations.* The average dive/rest durations (x-axis) for grebes, ducks, and loons.



**Figure 9: Dive/rest durations.** The average dive (top)/rest (bottom) durations for each species group; grebes, ducks, and loons, at different times of the day (early morning, noon, and early evening).



**Figure 10: Habitat Distribution.** Ranked density of each individual species of birds found nearshore (left) and offshore (right) on both study sites; Fourth of July (top) and South Beach (bottom).



**Figure 11: Habitat Distribution Preferred zones of each individual species on both sites.** Note: x-axis is  $\log^*(\text{density})$  instead of density to clearly show distribution.

**Table 1: Habitat Characteristics.** Similar and different characteristics of both study sites; South Beach and Fourth of July Beach.

Characteristics	South Beach	Fourth of July
Level of Disturbances (boats/tourists/local)	high	moderate
Coastal Features	Fine sand+gravel, kelps, eelgrass	Fine sand+gravel, ulva, eelgrass, shells
Benthic Habitat	Sand+gravel, eelgrass	Mud, eelgrass beds, Ulva
Habitat for forage fish spawn	●	●
Exposed	●	
Protected		●

**Table 2: Prey abundance.** List of available prey on both study sites. \* - represents the abundance of prey on each study site. \* - almost none, \*\* - few, \*\*\* - abundant, \*\*\*\* - very abundant.

Prey	South Beach	Fourth of July
Crabs	* ●	**** ●
Sculpins	*** ●	*** ●
Sand lances	*** ●	* ●
Shrimp	* ●	*** ●
Rainbow Perch	⊗	** ●
Needlefish	⊗	* ●
Mollusks	* ●	**** ●
Insects	** ●	*** ●



**Figure 12:** *Glassy surface water - upwelling.* Image on top shows aggregation of different species of birds in Fourth of July, following the glassy surface water. Image at the bottom (different day) shows group of gulls feeding also on a glassy surface water.