

**Assessing the abundance and movement of marine birds during a range of tidal currents at
Cattle Point, San Juan Island**

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Ecology and Conservation of Marine Birds and Mammals

(Summer 2023)

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Abstract

Observational surveys are vital to ornithological studies. Often done by boat or plane, they can offer data on the behavior, ecology, and habitat use of marine birds. However, these methods can be challenging to use, expensive, and inaccessible. In this study, we propose a new shore-based method of surveying marine birds. We used a Fixed-Point Transect across Cattle Pass, San Juan Island, WA, a region with abundant bird populations and complex bathymetry. Over 6 days, we recorded the community composition, abundance and behavior of marine birds over all 8 tidal phases. We found that Gull and Cormorant abundance and behavior were likely not influenced by changes in tidal current speed in Cattle Pass. Alcid abundance, however, increased during fast flooding currents, with most birds either floating North with the current or flying South against it. These relationships can be explained by the preferred feeding habitats of these families: Gulls and Cormorants feed on larger prey in calmer, coastal waters, and Alcids feed on aggregations or smaller prey in fast-moving, turbulent waters. The Fixed-Point Transect offers a widely accessible and applicable survey method to collect data on marine birds who often act as sentinel species in their environment. Observations of bird behavior and movement are important in furthering our understanding of the marine ecosystem to help inform marine conservation efforts in the face of climate change.

Key Words:

San Juan Island, Gulls, Cormorants, Alcids, feeding behavior, movement patterns, tidal phase

Introduction

Marine bird surveys are typically conducted using aircraft or marine vessels, which are costly and not easily accessible. In the Salish Sea, these vessels are often used to conduct abundance, diversity, and behavioral surveys of marine birds. Bird surveys are used to collect data to assess the health of bird populations as well as the marine ecosystem since they are upper trophic level predators. Although shore-based methods are not typically used to collect data across the width of a channel, they are cheaper, more accessible, and easier to conduct than surveys via aircraft or marine vessels. Our study aimed to develop a shore-based marine bird survey method and determine what data can be accurately collected via this method. To do this, we selected a transect that spanned the width of Cattle Pass, San Juan as our study site.

Cattle Pass, a channel located between the Southernmost tip of San Juan Island and the Eastern side of Lopez Island, is known for its intense tidal currents due to the deep and narrow bathymetry of the pass. These tidal currents drive the movement of copepods and other small organisms (Zamon, 2002), and forage fish follow these prey aggregations to feed (Zamon, 2003). This phenomenon is known as the Tidal Coupling Hypothesis (Zamon, 2002, 2003). These aggregations of small prey in the water column create valuable feeding opportunities for both planktivorous and piscivorous marine birds.

Although the feeding activity of marine birds in Cattle Pass with respect to changes in tidal current speed has been well established, there is little data regarding the movement and behavior of marine birds in and out of Cattle Pass with respect to these changes. In this study, we used a Fixed-Point Transect survey method to observe and analyze the abundance and movement of marine birds in Cattle Pass over tidal current phases and the current speed they were observed

at. This data was then used to assess the effectiveness of our Fixed-Point Transect survey method across the broader context of ornithology and conservation.

Methods

The Fixed-Point Transect

We established a 1550 meter long fixed-point transect from the southernmost tip of Cattle Point ($48^{\circ}27'01.7''\text{N}$ $122^{\circ}57'47.5''\text{W}$) to the southernmost tip of Whale Rock ($48^{\circ}26'47.4''\text{N}$ $122^{\circ}56'35.1''\text{W}$). During each observational period, one person recorded all observations and used their naked eye to observe birds about 0-50 m offshore, one person used 10x25 mm binoculars to observe birds 100-700 m offshore, and one person used a Bushnell Spacemaster Scope to observe birds 700-1550 m offshore. All marine birds that crossed our fixed-point transect during an observational period were counted and identified at the family level. Direction and mode of movement for each bird was recorded; birds were recorded as either moving North or South; and as either flying or floating. Any bird that crossed our transect while on the water was counted as floating; regardless of whether they were swimming or not. Any marine vessel that crossed our transect was also recorded.

Field Surveys

Our study was conducted over 6 days from 8 August to 13 August, 2023. During each of the 6 days, 5, 30 min surveys were conducted. Each 30 min survey consisted of 3, 10 min intervals with a 1 min rest in between each 10 min interval. Start time, end time, and visual current observations were recorded and cross-referenced with published current speeds from NOAA's San Juan Channel, South Entrance (PUG1703), Depth: 75 ft Station (LAT/LON: 48.4610° N, 122.9520° W). Each 30 min survey was conducted during 1 of 8 tidal phases; fast

flood, 1st and 2nd slow flood, low and high slack, 1st and 2nd slow ebb, and fast ebb. Current speeds of 0-0.5 knots were considered slack, 0.6-2.0 knots were considered slow, and 2.6 knots and above were considered fast. From 8 August through 10 August, 5 surveys were conducted during the first high tide of the day. From 11 August through 13 August, 5 surveys were conducted during the first low tide of the day. The timing of these surveys allowed us to observe marine bird abundance and movement over a variety of current speeds.

Data Analysis

We compared the average number of birds in each family and in each of the four behavioral categories for five tidal phases: fast flood, slow flood, slack, slow ebb, and fast ebb currents. Standard deviations from these data points were also calculated and used to represent error in their respective graphs. We also compared the observed number of birds in each family in the four behavioral categories to the current speed of that survey period for each day. Finally, we compared the average observed number of birds in each family to the time of day they were observed.

Results

In this study, we identified three marine bird families that accounted for over 99% of birds that crossed our transect; Lariidae (Gulls), Phalacrocoracidae (Cormorants), and Alcidae (Alcids). Marine birds from the Gaviidae and Scolopacidae families were also identified, but infrequently and in limited numbers. These families were therefore not analyzed. Vessels were regularly recorded during study periods but showed no significant influence on marine bird abundance and behavior.

Lariidae Abundance and Movement Patterns

Gull abundance and movement behavior did not change significantly over different tidal current speeds (Fig 1). During a fast flood, an average of 185 gulls flew north (SD \pm 127), 90 floated north (SD \pm 77), 189 flew south (SD \pm 52) and 13 floated south (SD \pm 28). During a slow flood, an average of 181 gulls flew north (SD \pm 111), 7 floated north (SD \pm 8), 179 flew south (SD \pm 55), and 0 floated south (SD \pm 0). During slack, 210 gulls flew north (SD \pm 85), 31 floated north (SD \pm 58), 164 flew south (SD \pm 45), and 4 floated south (SD \pm 5). During a slow ebb, an average of 125 gulls flew north (SD \pm 75), 2 floated north (SD \pm 6), 141 flew south (SD \pm 33) and 5 floated south (SD \pm 7). During a fast ebb, an average of 228 gulls flew north (SD \pm 158), 0 floated north (SD \pm 0), 168 flew south (SD \pm 50) and 16 floated south (SD \pm 23). Overall, Gull abundance and movement does not seem to correlate with different tidal current speeds. Little correlation between Gull abundance and time of day was observed. (Fig 4).

Phalacrocoracidae Abundance and Movement Patterns

Cormorant abundance and movement patterns minimally changed across different tidal current speeds (Fig 2). During a fast flood, an average of 23 cormorants flew north (SD \pm 6), 4 floated north (SD \pm 5), 37 flew south (SD \pm 10) and 0 floated south (SD \pm 0). During a slow flood, an average of 28 cormorants flew north (SD \pm 10), 1 floated north (SD \pm 1), 31 flew south (SD \pm 5), and 0 floated south (SD \pm 0). During slack, 38 flew north (SD \pm 14), 1 floated north (SD \pm 1), 35 flew south (SD \pm 8), and 0 floated south (SD \pm 0). During a slow ebb, an average of 40 cormorants flew north (SD \pm 10), 0 floated north (SD \pm 0), 35 flew south (SD \pm 15) and 0 floated south (SD \pm 0). During a fast ebb, an average of 39 gulls flew north (SD \pm 19), 0 floated

north (SD \pm 0), 30 flew south (SD \pm 9) and 1 floated south (SD \pm 0). Cormorants mostly flew across the transect, rarely floating. Cormorant travel direction changed minimally at different tidal current speeds. Little relationship between cormorant abundance, method or direction of movement with tidal current speed was found. No major correlation between cormorant abundance and time of day was found (Fig 4).

Alcidae Abundance and Movement Patterns

Alcid abundance was highest during fast flood tidal phases, second highest during slow floods, and decreased in abundance from slack to fast ebb tides (Fig 3, 5). During a fast flood, an average of 25 alcids flew north (SD \pm 37), 237 floated north (SD \pm 147), 127 flew south (SD \pm 105) and 5 floated south (SD \pm 11). During a slow flood, an average of 13 alcids flew north (SD \pm 13), 43 floated north (SD \pm 31), 76 flew south (SD \pm 67), and 2 floated south (SD \pm 6). During slack, 24 alcids flew north (SD \pm 22), 24 floated north (SD \pm 26), 54 flew south (SD \pm 41), and 10 floated south (SD \pm 19). During a slow ebb, an average of 15 alcids flew north (SD \pm 23), 0 floated north (SD \pm 1), 39 flew south (SD \pm 40) and 15 floated south (SD \pm 18). During a fast ebb, an average of 15 alcids flew north (SD \pm 10), 1 floated north (SD \pm 1), 27 flew south (SD \pm 16) and 26 floated south (SD \pm 9). Alcids primarily floated across the transect during fast floods, and flew across the transect in all other tidal phases. During fast floods, most Alcids were observed floating North. During both fast and slow floods, most Alcids flew South, opposite of the tidal current. In all other tidal current phases, Alcids were seen flying South. No strong relationship was observed between alcid abundance and time of day (Fig 4).

Discussion

Gull and Cormorant abundance, movement method and direction were not observed to change in relation to changes in tidal current speed or direction. Alcids, however, were observed to change movement methods and direction with respect to tidal current phase and speed, especially in relation to flood tides. No confident pattern was observed between any of the three families and time of day.

Gull and Cormorant Abundance and Behavior

There are a number of different behaviors that could explain the difference between Gull, Cormorant, and Alcid behavior. Previous research describes the formation of feeding flocks of Gulls and Cormorants farther in and out of Cattle Pass (Cooper 2012; Gibbons 2013). Gulls are generalists, but often feed on fish near the surface of the water (Birds of the World). Cormorants are almost exclusively piscivores, feeding on deeper water fish and have been previously observed to not be strongly influenced by tidal currents (Birds of the World; Bravo and Castro 2005). Since both species prey on larger fish, in either surface or deep water, calmer water serves as better feeding grounds for these families, so they are less likely to feed in turbulent currents. As skilled flyers, they are likely flying through our transect to reach their preferred feeding sites. The feeding habits of both Gulls and Cormorants help explain why their abundance and movement patterns do not seem to be related to changes in tidal current.

Alcidae Abundance and Behaviour

Alcid abundance and movement patterns observed during our study differed from those of Gulls and Cormorants. Many Alcids feed on small prey like forage fish, plankton, and crustaceans. Considering their short, narrow wing shape, they are excellent swimmers, but are

not efficient flyers (Birds of the World). To ensure profitable dives, Alcids rely on aggregations of prey that occur in the turbulent waters of faster-moving current phases. Our findings are in line with the previously described Tidal Coupling Hypothesis (Zamon 2002, 2003), where faster tidal currents create aggregations of plankton, like copepods in the water column. These plankton attract schools of forage fish, which attract planktivorous and piscivorous marine birds, like Alcids. Our findings can be used alongside the Tidal Coupling Hypothesis to predict spatial and temporal distributions of Alcids and other pelagic predators.

The Fixed Point Transect Survey

In our study, there are many limitations we had to consider. Due to our short study period, we were only able to observe a limited variety of tidal conditions. Over the course of our study, the first low tide of the day always occurred in the morning, and the first high tide of the day always occurred in the afternoon. This makes it difficult to confidently discern between the abundance and movement relationships we observed and either tidal current or time of day. During the morning low tides, it was more difficult to count and identify birds since the sun was positioned behind the birds we were observing during sunrise. Since low tides only occurred in the morning during our study period, we were less confident in our abundance counts and identification during low tide surveys. Despite these limitations, our results still show strong relationships between marine bird abundance and movement patterns and tidal current phase.

Future studies should cover a wider range of tidal heights and current phases at a variety of times of day. With this, future studies will be able to more confidently attribute the changes in marine bird abundance and movement patterns to just one variable. Establishing multiple

transects throughout Cattle Pass might also increase confidence in patterns observed, since patterns observed would not be limited to one transect.

Conservation and Management of Marine Birds

The fixed-point transect survey is an effective shore-based technique for assessing marine bird abundance and movement. Despite limitations, we were able to confidently assess a variety of bird abundance and movement patterns. With this method, a wide variety of measurements can be made for marine bird populations. Relationships between marine bird abundance, movement patterns, and even individual behavior can be assessed in relation to variables such as time, current speed or tidal phase. The limitations we experienced using this method can be overcome by increasing the number of surveyors and conducting more surveys over a wider period of time. Using birds as an indicator of environmental change using cheaper, more accessible methods will be vital in understanding the impacts of our rapidly changing ocean.

It is important to understand marine bird abundance and movement patterns since marine birds serve as sentinel signal species. Marine bird population health is directly impacted by forage fish abundance, which are directly affected by plankton abundance, which serve as the basis of marine food webs. Marine birds can also reveal seasonal shifts in the climate through annual migrations. Unlike other marine animals, these birds are much easier to observe since they spend most of their time above the water. Therefore, marine bird population dynamics serve as an effective proxy for the health and abundance of the base of marine ecosystems, and can serve as signals of trends in marine ecosystems (Parrish and Zador 2003). By developing a less costly and more accessible method of bird monitoring, we can more regularly observe changes

not just in bird populations, but also marine ecosystem health overall, something notoriously difficult to do.

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Tables and Figures

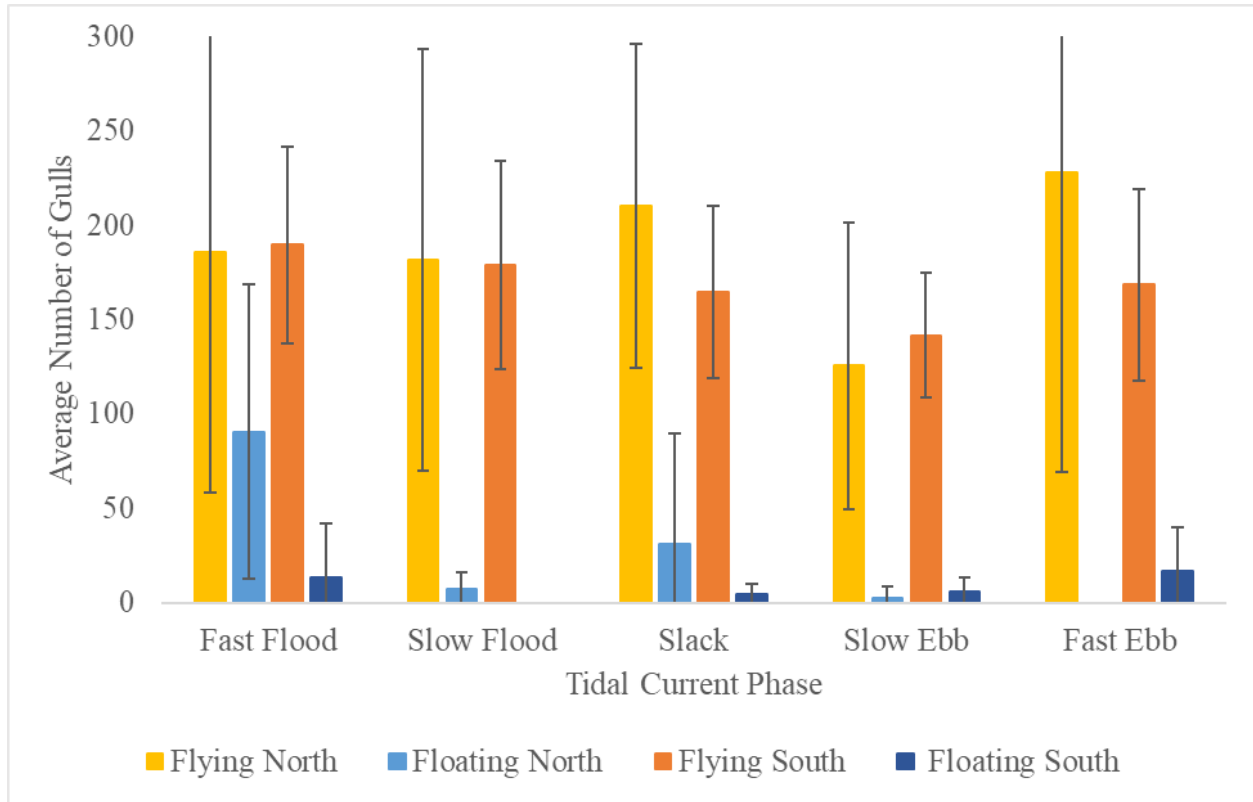


Figure 1. Gull abundance across five different tidal current speeds and directions (SD \pm 0-127). Little change in Gull abundance was observed across the different tidal current phases. Gulls mostly flew North and South regardless of tidal current condition.

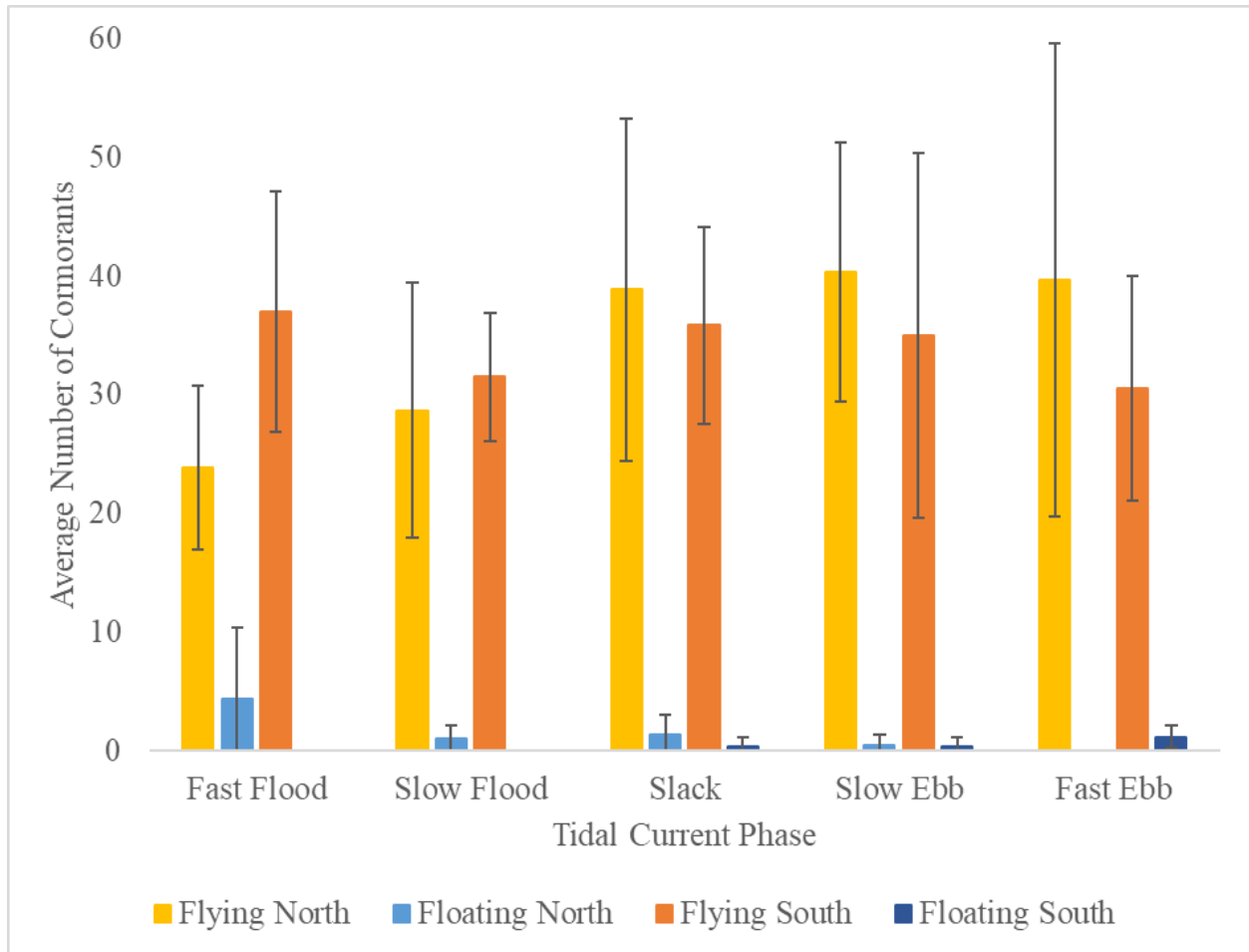


Figure 2. Cormorant abundance across five different tidal current speeds and directions (SD \pm 0-14). Cormorant abundance was constant over the different tidal phases, and were mostly flying North and South regardless of tidal current speed or direction.

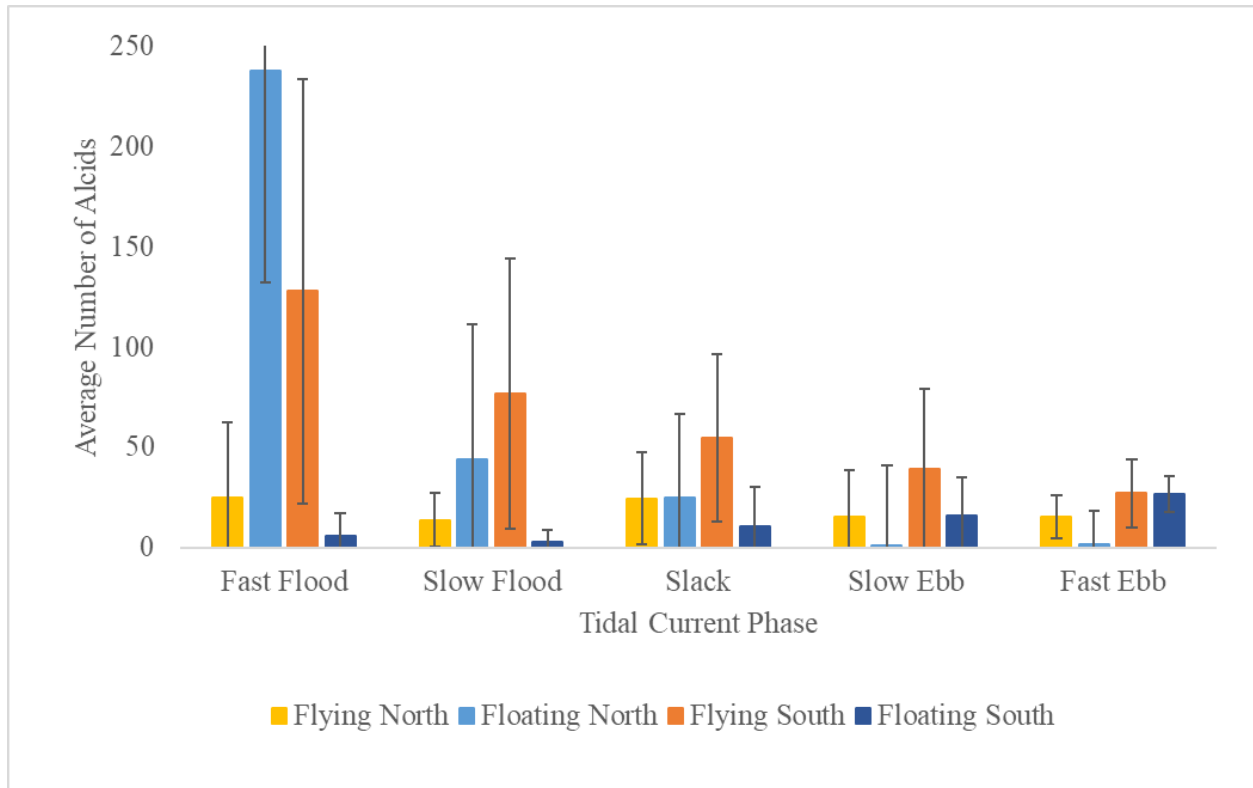


Figure 3. Alcids abundance across five different tidal current speeds and directions is shown (SD \pm 0-147). Alcids were most abundant during fast floods, in which they were mostly floating North with the current. Otherwise, they decreased in abundance from slow floods to fast ebbs, and predominantly South.

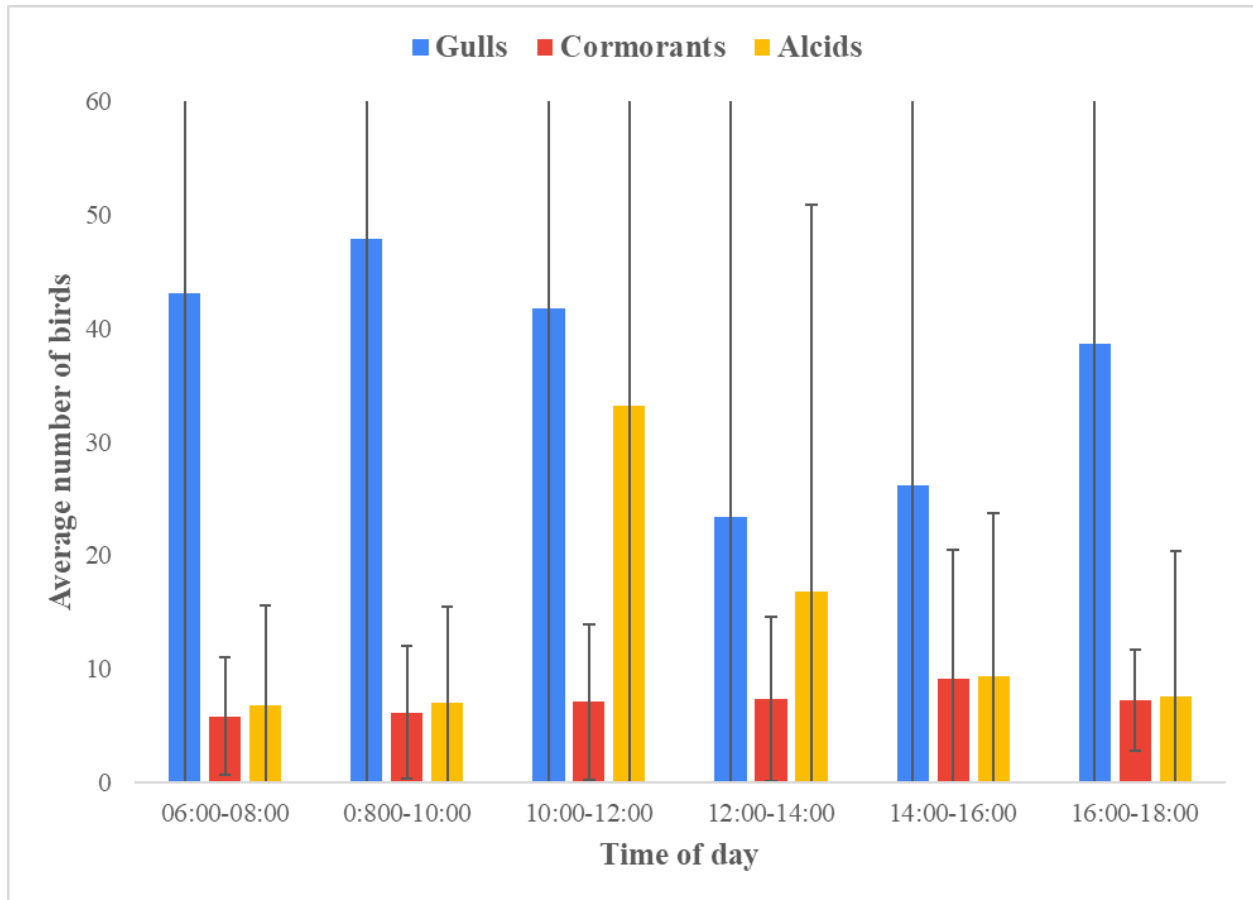


Figure 4. Average number of birds seen per approximate 2-hour time interval over 6 days (SD $\pm 4-75$). Gulls seem to be more abundant in the morning than in the afternoon and evening. Cormorant abundance does not seem to change between times of day. Alcids abundance seems to peak in the late morning and decrease in the afternoon and evening. Despite these observations, there is high variation, meaning that bird abundance was likely more correlated with changes in tidal current than changes in time of day.

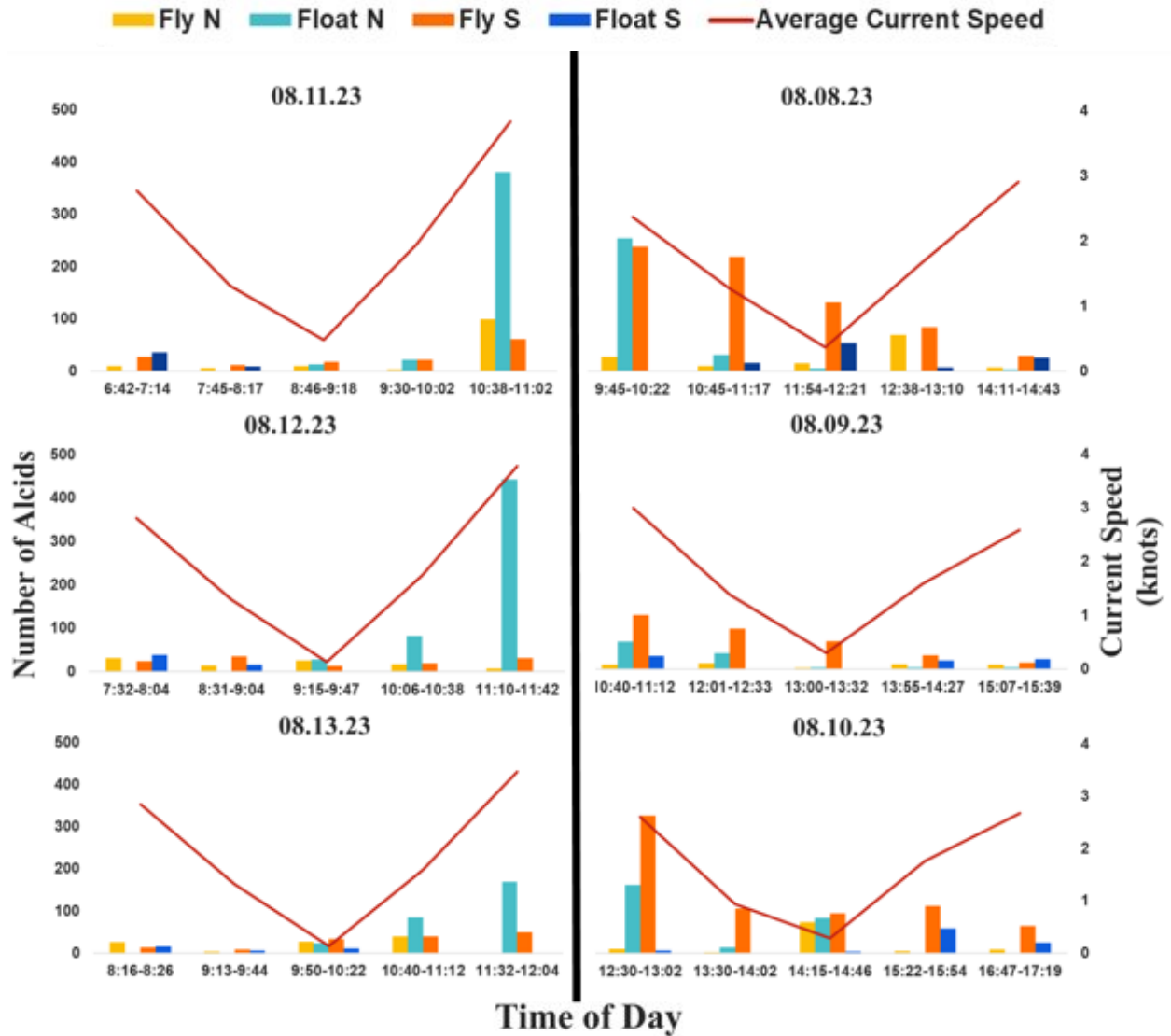


Figure 5. Abundance of Alcids during each survey are shown alongside both time of day and changes in current speed. Alcid abundance increases with increasing current speeds with flood tides, and remains low at low slack and ebbing currents (far left and right).