

**Tidal Current Speed and Bird Abundance: an investigation into bird behavior  
patterns in the San Juan Channel**

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**Abstract:**

Seabird abundance in the San Juan Channel is affected by variations in tidal current speed and direction. In this paper we investigate the abundance and community structure of seabirds in a tidally active transect of San Juan Channel. Using a variation of the strip-transect vessel survey method, we observed the abundance of birds in a 200 m wide strip between Turn Rock and Shaw Island. We divided tidal current into five different categories, and conducted 36 transects, recording the number of birds observed during each tidal current category. Our results suggest that the presence of birds in San Juan Channel correlates with changes in tidal current speed and direction. We observed a greater number of birds during periods of fast current, and fewer birds during slack and slow ebbs. When focusing our analysis on gulls and alcids, we discovered that while alcids prefer fast floods, gulls prefer fast ebbs. Finally, we observed that Rhinoceros Auklets and Common Murres have similar tidal current speed and direction preference. These surveys demonstrate the importance of the variation in current speed and direction on marine bird behavior in the San Juan Channel.

**Key Words:**

San Juan Channel, Salish Sea, seabird abundance, marine birds, alcids, gulls, tidal cycle, currents, Turn Rock, Shaw Island, San Juan Island, ship-based survey

**Introduction:**

Seabird abundance and distribution in the coastal waters of the Salish Sea are known to be affected by tidal fluctuations. The Salish Sea is comprised of a labyrinth of inland coastal waters. Interspersed in this water system are dozens of islands divided by deep, cold channels of seawater. One of these channels is the San Juan Channel, which

divides San Juan Island from Shaw and Lopez Islands. The topography of the region, paired with the depth of these channels, makes for a highly active tidal system. The tidal activity in this region concentrates nutrients and prey that in turn regulate seabird abundance (Holm and Burger 2002).

The Salish Sea is home to a wide variety of seabirds. These seabirds are mostly high trophic level piscivores, therefore their distribution is regulated by concentrations of forage fish, which are in turn regulated by concentrations of plankton. Plankton distribution, and therefore planktivorous fish concentrations, is highly regulated by tidal currents, but few scientific studies have been conducted on this front (Zamon 2000). Predator prey dynamics are often considered the core of ecology. Knowledge of low trophic level prey can inform predictions of abundance and distribution of higher trophic level predators. Studies have found correlations between plankton aggregation and flood tides, as high current speeds concentrate the planktonic organisms and promote nutrient mixing (Zamon 2000). Ebb tides also promote productivity in a similar fashion, but the effects of ebb tide productivity can occur in different locations (Spatz 2007).

Research on abundance and distribution of seabirds in the Salish Sea is important for understanding population dynamics of these animals and informing conservation decisions. In 2009, a compilation of several studies found that between 1978 and 2005, 14 of 37 marine bird species in the Salish Sea experienced population declines, with 10 of those species declining by over 50% (Bower 2009). Seabirds are considered indicator species of marine processes as their high trophic level status makes them susceptible to habitat degradation and decreasing prey availability (Vilchis 2012). These declines, therefore, could be indicative of ecosystem level problems.

Our study investigated the effect of tidal current speed and direction on bird abundance in the Turn Rock region of the San Juan Channel. This is important because the region has strong tidal influence, has received little previous study, and our study surveyed a cross-channel transect, as compared to previous along-channel transect surveys that have been conducted. Specifically, we determined the abundance of flying versus swimming birds at different tidal current speeds and directions. We compared abundance of gulls and alcids at different tidal current speeds and direction, and also compared abundance of Rhinoceros Auklets (*Cerorhinca monocerata*) and Common Murres (*Uria aalge*) at these tidal currents. By comparing bird abundance during differing tidal current speeds, we determined those current speeds that are preferentially selected by birds in the Turn Rock region of the San Juan Channel.

### **Methods:**

This study was conducted in the San Juan Channel, between Turn Rock and the southern tip of Shaw Island (Fig. 1). We chose this location because of its complex bathymetry and strong tidal currents.

We determined seabird abundance using shipboard surveys, with a modified strip-transect method. We conducted 36 surveys from 9-17 August 2012. The platform for all of our surveys was a fiberglass runabout called the Bufflehead. Our transect was between 48° 32.207 latitude, 122° 57.823 longitude and 48° 32.738 latitude, 122° 57.042 longitude. For each survey, we designated a driver, a recorder, and two observers (Fig. 2). The observers chose the side of the boat that afforded the best observation conditions based on sun glare and sea state. One observer watched forward, the other aft, working

together to survey the transect. We recorded the number of birds seen per transect, their species, and whether they were swimming or flying. The driver maintained a straight course and a speed of 5 knots, albeit at times navigating through tidal rips, around rafts of debris, and avoiding other boat traffic. Each transect took an average of eight minutes.

Our surveys covered a wide variety of tidal phases. We obtained tidal current speed from the Turn Rock Station (Mobile Geographics 2012), and divided current speed into five categories as follows: fast ebb (-1.7 to -1.1 kts), slow ebb (-1 to -0.4 kts), slack (-0.3 to 0.3 kts), slow flood (0.4 to 0.9kts), and fast floods (1 to 1.5 kts). Positive numbers represent flooding current speeds, and negative numbers represent ebbing current speeds. In total we have between five and nine samples in each current speed category.

After preliminary data analysis we chose to combine birds into three categories: gulls, alcids and others. We also elected to do most of our tidal analysis with swimming birds as they were most directly affected by tidal current speed. We choose to analyze flying birds because they could inform us of tidal preference. For the purpose of our analysis, statistical significance within means was assessed as no overlap between 95% confidence intervals. We chose to discard a data point that proved to be a major outlier. This point occurred during an ebb tide when we observed a raft of over 100 birds floating through our transect, apparently riding the tide out of the channel. We did not observe these birds foraging, and they passed through our transect quickly.

## **Results**

Throughout our study we counted a total of 872 birds of 14 different species (Fig. 3), of which 61% were flying and 39% were swimming. Gulls accounted for 29% of the

total, alcids accounted for 67% and 4% was comprised of other birds such as cormorants and ducks. The most common species were Rhinoceros Auklets (*C. monocerata*) with a mean of 11.5 birds per transect, Common Murres (*U. aalge*) with a mean of 3.4 birds per transect, Glaucous-winged Gulls (*Larus glaucescens*) with a mean of 2.2 birds per transect, and Heermann's Gulls (*Larus heermanni*) with a mean of 1.8 birds per transect.

Abundance of both swimming and flying birds varied with tidal current speed and direction (Fig. 4). Swimming bird abundance was highest at fast flood, followed by slow flood, with intermediate abundance at fast ebb and low abundance at slack and slow ebb currents; the only statistically significant difference was between fast flood and slack tides. In contrast flying birds were most prevalent at slack tides, followed by floods and were least abundant during ebbs. At slack tides, the number of swimming birds was significantly lower than the number of flying birds.

The relationship between swimming bird abundance and tidal currents differed between alcids and gulls (Fig. 5). We saw highest abundance of alcids during flood tides, intermediate numbers at fast ebbs, and lowest abundance during slow ebb and slack tides; the difference between the average number of swimming alcids at slow ebbs as compared to those at fast floods was significant. Gulls were most prevalent during high ebbs tides, and relatively rare at the other tidal stages, with significance between the number of gulls at fast ebbs and the number of gulls at slack and fast flood tides. Overall, alcid and gull patterns were similar during ebb and slack tides, but show distinct differences during flood tides, with a statistically significant difference at fast floods. Clearly, the large percentage alcids in our total bird count obscured this difference in the previous figure.

Finally, Rhinoceros Auklets and Common Murres used the study region in a similar capacity (Fig. 6). Rhinoceros Auklets were most abundant at flood tides and had low numbers during other tidal stages. There was significance between the abundance of Rhinoceros Auklets at slow ebbs and flood tides. Common Murres showed similar trends, but exhibited a higher preference for fast ebb tides. During fast ebb tides Common Murre abundance was comparable to their abundance at flood tides.

### **Discussion:**

This study found that tidal current speed has significant impact on bird abundance in the Turn Rock region of the San Juan Channel. The discrepancy we found between birds flying and birds swimming at slack tides suggests that during slack tides fewer birds are directly using the environment, and are rather bypassing it for other regions perhaps with higher concentrations of prey. This is consistent with previous studies that have found that fast flood tides in this region concentrate plankton in inland waters, thereby concentrating forage fish and birds (Zamon 2000). These studies have also shown that the minimal water movements associated with slack tides allow planktonic organisms to disperse (Zamon 2000). Our findings indicate an apparent increase in the number of birds using the transect during fast ebb tides compared with slow ebb and slack tides, this is not consistent with studies conducted on the north side of Cattle Pass by Zamon (2000) and Eisenlord (2011). However, our findings were comparable to bird abundance at fast ebbs seen in a study conducted by Spatz (2007) to the south of Cattle Pass. The discrepancies in previous studies conducted in Cattle Pass may be due to the bathymetric variations in the region. A shallow sill in Cattle Pass separates the San Juan Channel from the Strait of

Juan de Fuca. This sill may be responsible for differing plankton aggregations seen at ebb and flood tides. Unlike Cattle Pass, our transect lacks a cross channel sill and this bathymetric difference may be responsible for the higher number of birds observed at ebb tides.

The difference between swimming gull and alcid abundance suggests that preference may be due to feeding strategy. According to a study by Holm and Burger (2002), diving piscivorous birds such as Common Murres and Rhinoceros Auklets prefer deep regions with high current speeds to forage in. Our results are consistent with Holm and Burger's findings in this respect. The fact that gulls are significantly less likely to use the region during fast floods is likely due to prey location and availability in the water column. Ebb tides may promote nutrient mixing that increases the feeding profitability for gulls. Similar surveys conducted in Cattle Pass also observed that gulls preferred ebbing currents (Palmer 2012). As diving alcids are capable of foraging in deeper waters than the surface feeding gulls, it is likely that at fast ebbs, prey inaccessible to the surface feeding gulls was available to the diving birds. However during fast ebb tides more prey may be available to the surface feeding gulls than at other times. Further investigations must be conducted to fully understand this trend.

Our study also found that Common Murres and Rhinoceros Auklets exhibit similar abundance patterns based upon tidal current speed and direction. This pattern once again is supported by these birds' feeding type, as prey availability is best in this region for both species during flood tides. While Common Murres show very similar trends at most tidal current speeds and directions, they are more abundant at times of high

ebb currents than Rhinoceros Auklets. This could have important conservation implications as the species has been in recent local decline.

Seabirds have long been considered indicators of change in marine ecosystems. Seabirds are high trophic level species, and are thereby impacted by lower trophic levels processes. These birds are also particularly susceptible to anthropogenic disturbances such as fishery impacts, boat traffic and pollutants (Parsons et al. 2009). Marine birds are exposed to harsh conditions when at sea, and are therefore sensitive to further stressors. Local bird populations have experienced recent severe declines in the Salish Sea. Common Murres are one of the species most impacted, with population declines of greater than 80% between 1985 and 2007 (Bower 2009). Given the indicator status of these species, population declines may imply ecosystem level problems. Knowledge of tidal preferences for Common Murres can inform protection efforts. Understanding feeding and behavioral patterns in these birds can assist in holistic conservation efforts that support the health of the entire bioregion. By comparing bird abundance with tidal current speed and direction we can begin to understand the vast cascade that affect birds in the Salish Sea, and thereby the entire bioregion.

The time-pressured nature of this study precluded the opportunity to assess other potential players that may impact bird abundance in this region. With more time, we would have assessed the impact of tide height on bird abundance in our transect. However based entirely upon preliminary raw data, tide height appeared to play less of a role in bird abundance in our transects than current speed and direction. Also, we did not consider the impact of diurnal changes on bird behavior. Diurnal changes are generally thought to play less of a role in seabird behavior than tidal currents (Holm and Berger

2002). However, we observed some diurnal patterns in our research. For example we observed Rhinoceros Auklets provisioning in the evening, and at no other time of day. This seemed to have little correlation with changes in tides, and rather depended on time of day. Further research might inquire into how bird abundances and behavior varies with both tidal and diurnal variations.

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**Figures and Tables:**



Figure 1: San Juan archipelago with transect region circled. Transect is indicated with red line.

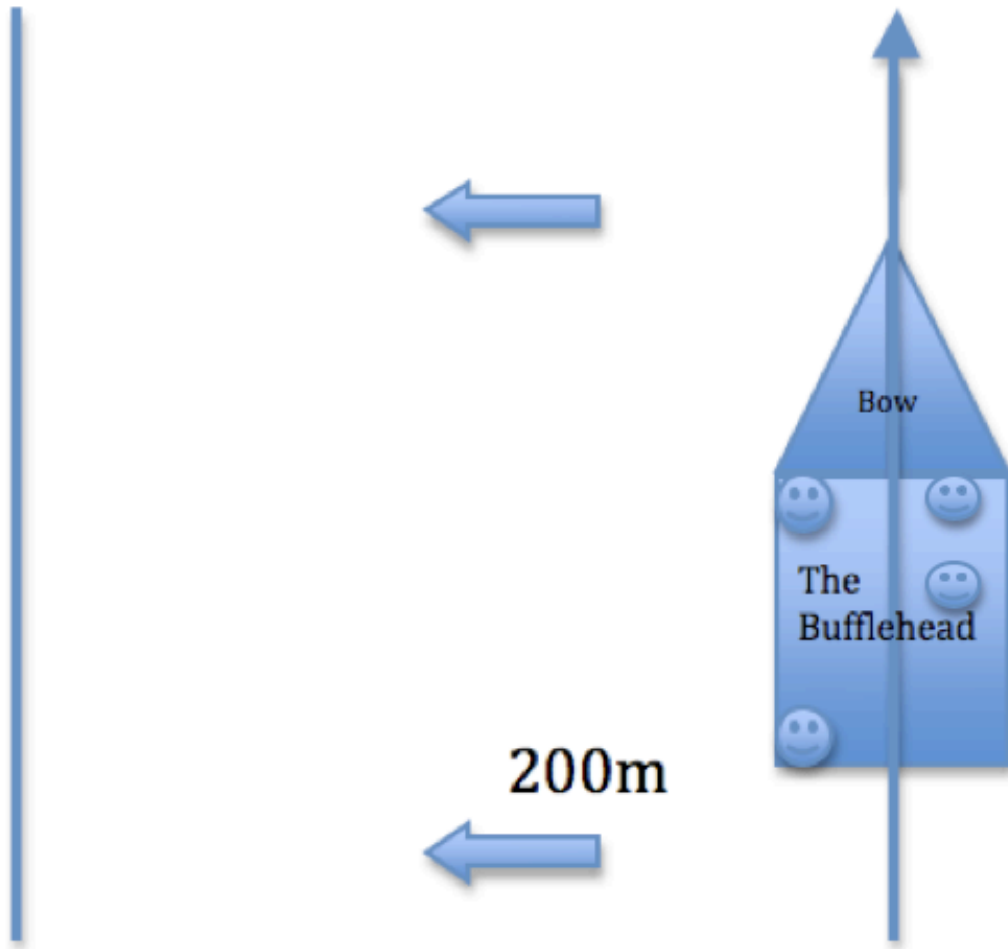


Figure 2: Diagram of shipboard survey transect with 200 m transect distance off one side of the boat.

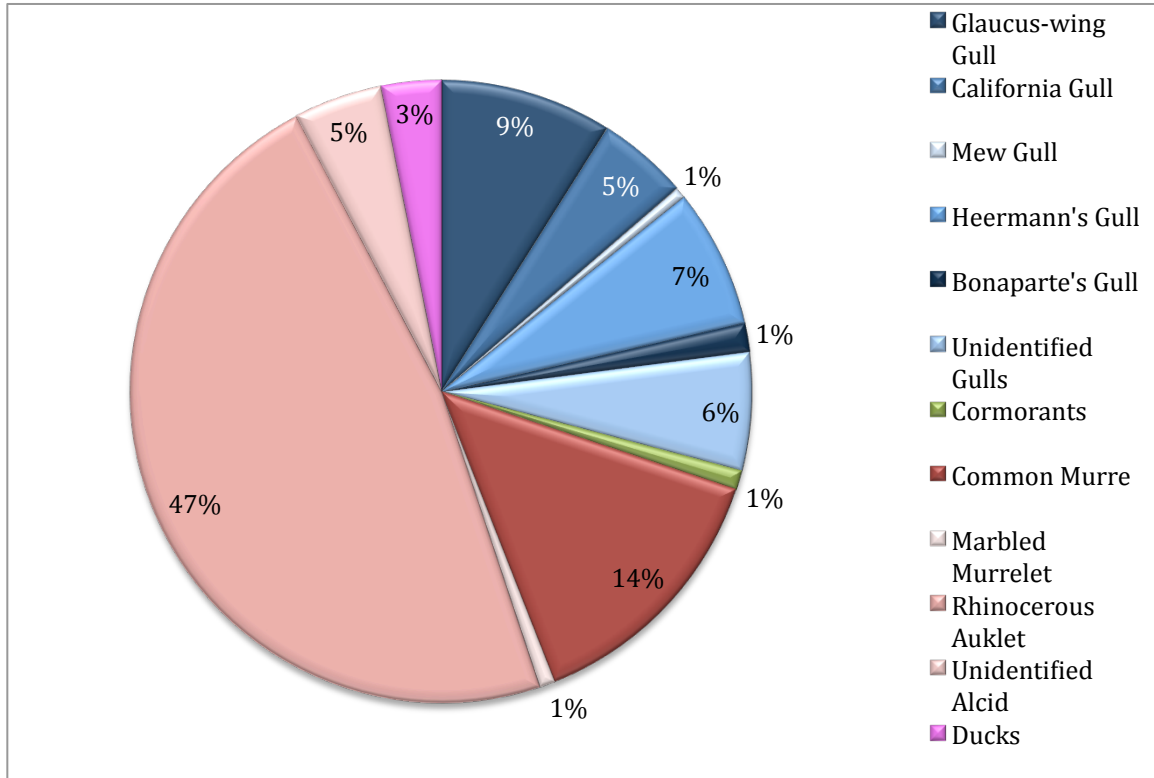


Figure 3: All bird species identified during survey period, with alcids depicted in shades of red and gulls depicted in shade of blue.

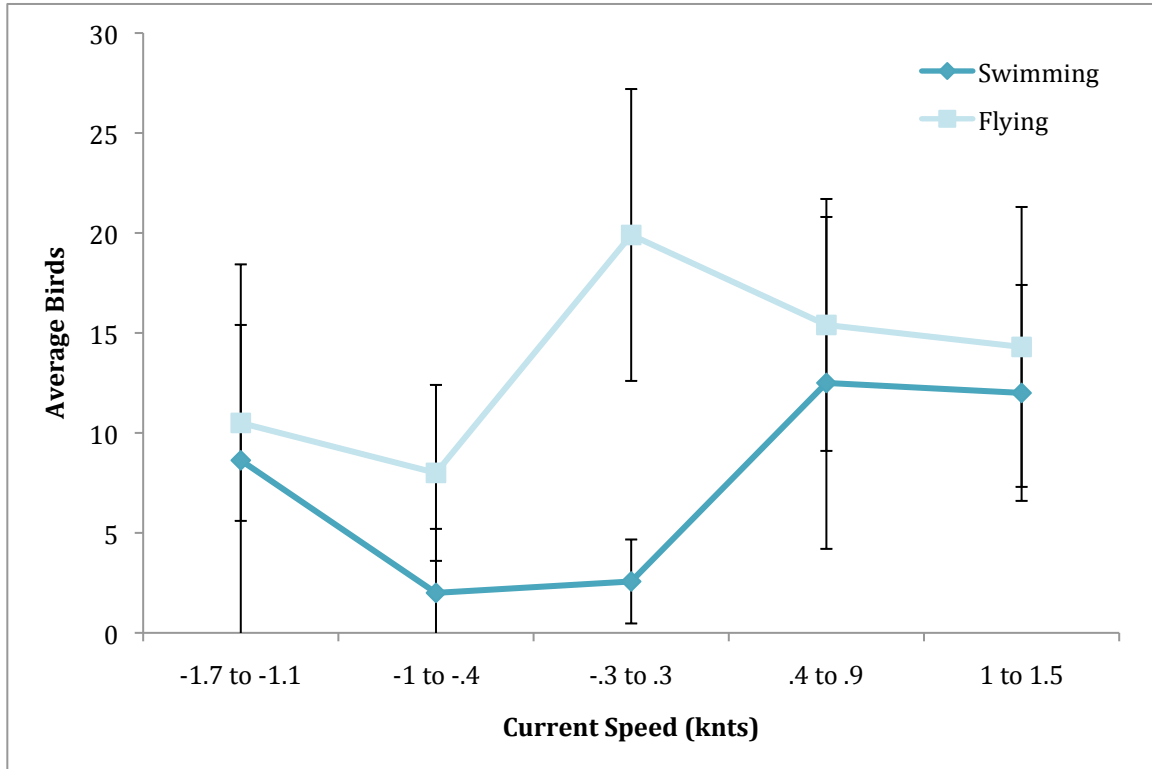


Figure 4: Mean number (with 95% confidence intervals) of birds observed flying versus swimming during fast ebb, slow ebb, slack, slow flood and fast flood during survey period.

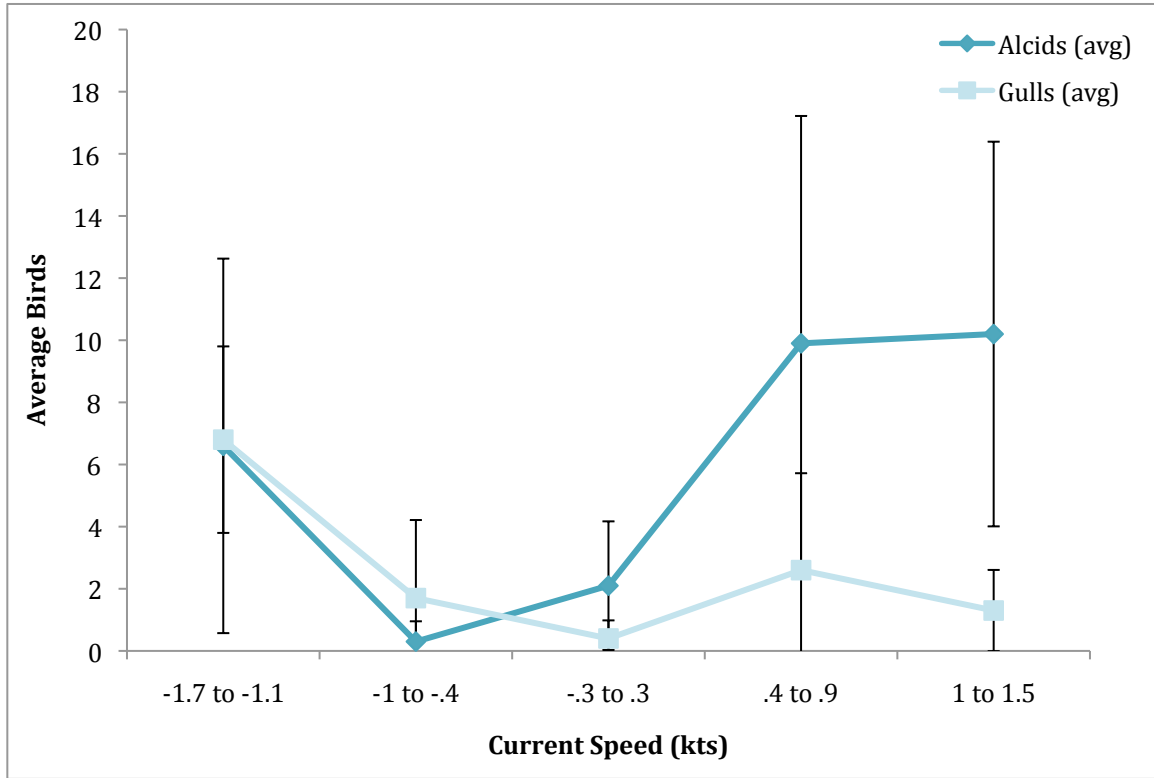


Figure 5: Mean number (with 95% confidence intervals) of gulls and alcids swimming at different current speeds throughout survey period.

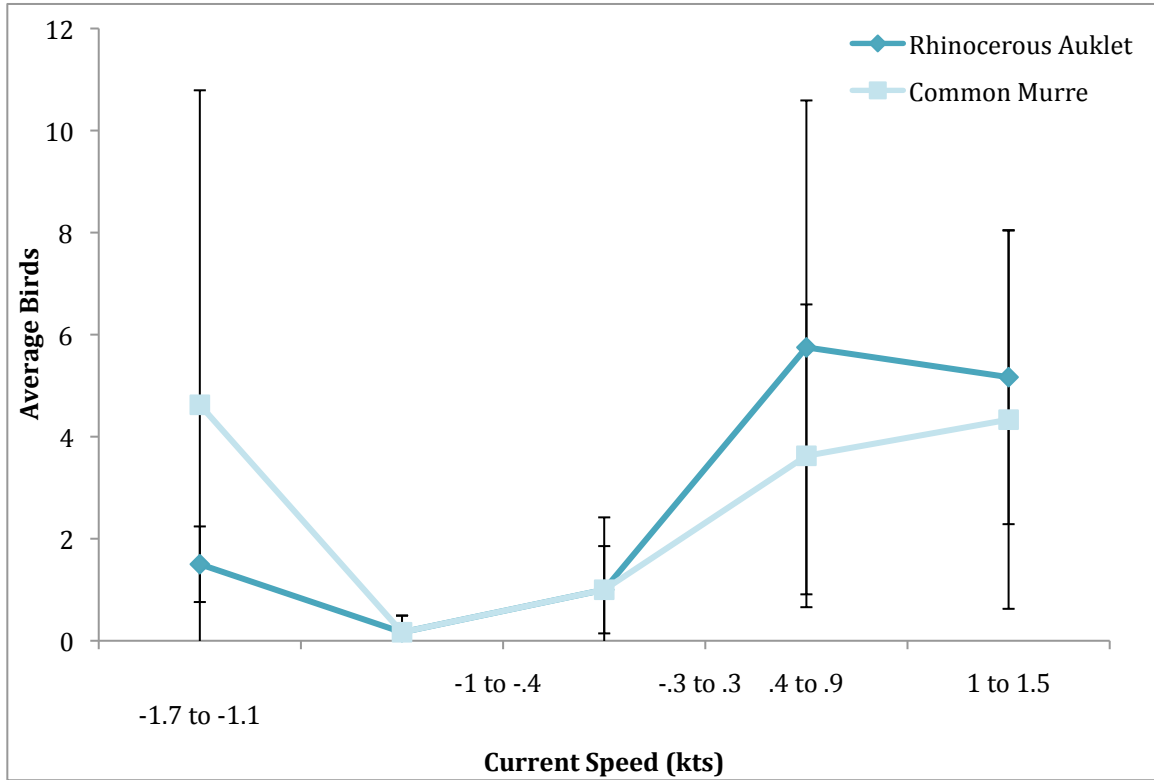


Figure 6: Mean number (with 95% confidence intervals) of Rhinoceros Auklets compared with Common Murres at different tidal speeds.