

**Effects of Boating Disturbance on Seabird Abundance
and Flushing Behavior in the San Juan Islands**

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Abstract

Boating traffic can disturb and negatively affect normal behaviors of marine birds, including foraging. Surveys of seabirds were performed on two vessel routes with different types of boat traffic in the San Juan Islands, Washington. Comparisons of data showed that birds were more abundant on the route taken by the Centennial vessel in the San Juan Channel than on the route taken by the Klahowya vessel in the Washington State Ferries' San Juan Interisland route. Seabird species were non-uniformly distributed both between the two vessel routes and within each vessel route. My study was unable to find a correlation between seabird abundance and tidal state, contrary to established literature. Data on flushing behavior suggest that response to disturbance is variable between species, locations, and vessels causing the disturbance.

Keywords

Marine birds, boat traffic, boat disturbance, flushing behavior, gulls, alcids, seabird abundance, seabird distribution, San Juan Islands, Washington State Ferries

Introduction

Disturbances caused by boat traffic are known to negatively affect aquatic birds. High levels of disturbance can alter seabird foraging behavior. The amount of time spent in feeding areas may be significantly reduced, or birds may abandon certain foraging sites altogether (Kahl 1991). Flying, diving, or swimming away from high-density boating areas also causes seabirds to expend more energy. Disturbed individuals would then need to forage more often in order to offset the energy loss (Asplund 2000). Potential long term impacts of these effects include changes in reproductive success and population size (Carney and Sydeman 1999).

Factors of vessel traffic may affect the strength of seabirds' responses to disturbance. Faster-moving vessels produce a stronger disturbance response in aquatic birds. Higher boat speeds cause both an increase in the rate of seabird flushing and in the distance that the birds flushed (Bellefleur et al. 2009). Predictability and randomness is a factor of vessel traffic which may explain variation in seabird response, but this topic has yet to be addressed thoroughly. Currently, it appears that unpredictable traffic (i.e. that of recreational boating) may augment the potential for a disturbance event, relative to consistent vessel traffic like that of commercial shipping (Schwemmer et al. 2011).

The main objective of my study was to further examine the effects of boat traffic on marine birds. I established three foci for the study. First, surveys of seabird abundance and distribution in two routes with dissimilar vessel traffic were compared. Second, the effects of tidal state on abundance were examined. Third, data on flushing behavior in marine birds was analyzed and compared with previous research on the topic.

Methods

Study area

Surveys of seabirds were conducted on two routes taken by vessels in the San Juan Islands region of Washington. Eight surveys were completed onboard the Washington State Ferries vessel Klahowya from 7-16 August 2014. The ferry travelled between terminals at San Juan Island (Friday Harbor), Orcas Island, Shaw Island, and Lopez Island. The routes between departing and arriving terminals constituted a transect (Fig. 1). Four surveys were completed onboard the University of Washington research vessel Centennial on 31 July and 15 August 2014. These surveys occurred in the San Juan Channel, east of San Juan Island. The transect zones were predetermined. For

analyses of bird densities, the Centennial route was broken into two categories, northern transect zones 1-3 and southern transect zones 4-6 (Fig. 2). I considered the Klahowya route to be an area with less random vessel traffic (i.e. the ferry runs the same route every day during the summer), compared to the relative randomness of traffic in the Centennial route.

Field surveys

Three species of gulls (Heerman's gull, *Larus heermani*; glaucous-winged gull, *Larus glaucescens*; and California gull, *Larus californicus*) and three species of alcids (rhinoceros auklets, *Cerorhinca monocerata*; pigeon guillemots, *Cepphus columba*; and common murre, *Uria aalge*) served as subjects for my study.

Surveys were conducted in slightly different manners on each vessel. On the Centennial, only birds that came within 200 m of the vessel were recorded. No data on behavior was collected. On the Klahowya, the 200 m range was maintained. Each seabird observed was recorded for abundance analyses. Swimming birds within 100 m of the ferry were noted for whether or not they flushed. The 100 m range allows for a better comparison of flushing behavior with the results of a similar study by Baldock and Barber (2012), who utilized a 100 m range for their research.

Results

Seabird Abundance

Seabird populations and compositions differed between the Centennial and Klahowya routes. Total bird density on the ferry route was 16.05 ± 4.07 birds/km². Bird density on the Centennial route was four times greater, at 64.79 ± 11.75 birds/km². The contribution of each species to the total population varied between the routes. California

gulls and rhinoceros auklets were the most prevalent in the ferry route (Fig. 3). In the Centennial route, rhinoceros auklets dominated, comprising about 70% of all observed individuals, while glaucous-winged gulls were the most prevalent gull species (Fig. 4).

Non-random distribution patterns within both vessel routes were observed. Most of the studied species exhibited preferences for certain ferry transects while tending to avoid others (Fig. 5). Similar patterns of non-uniform distribution were observed across individual transects in the Centennial route (Fig. 6).

The density of each seabird species varied across the survey areas (Fig. 7). Glaucous-winged gulls, rhinoceros auklets, and common murrelets were observed in greater numbers in the southern Centennial areas, while pigeon guillemots were recorded more frequently in the northern ferry area. Heerman's gulls and California gulls were more clustered towards intermediate locations.

Tidal State

Neither gull abundance nor alcid abundance data showed an association with tidal state. The two bird groups did not exhibit a strong relationship with positive or negative current speeds, which would have denoted a preference for either flood tides or ebb tides (Figs. 8 and 9). The seabird groups also showed no strong association with higher or lower current speeds (Figs. 10 and 11).

Flushing Behavior

Alcids exhibited a higher tendency to flush than gulls (Fig. 12). Combined, the three gull species flushed roughly 41% of the time. This result agrees very well with the 41% flushing probability found in a similar study done by Baldock and Barber (2012) in

the San Juan Islands. The three combined alcid species flushed about 61% of the time, a result significantly departed from the 28% value recorded by Baldock and Barber (2012).

Within bird families, there was slight variation among species (Fig. 13).

California gulls flushed at similar rates when encountering the Klahowya vessel.

Heerman's gulls flushed much less often in such instances. Alcids demonstrated less variation in terms of flushing probabilities. Rhinoceros auklets and common murrelets both showed higher rates of flushing behavior. The results suggest that pigeon guillemots may flush at lower rates than the two other alcids.

The data indicates that the rate of flushing behavior in alcids, but not gulls, varies by transect (Fig. 14). For gulls, the probability of flushing is similar across the four ferry transects, with a slight possibility that flushing rates may be higher in the Orcas-Shaw transect. The probability of alcids flushing was about 80% in the two Lopez Island transects, while it was roughly 45% in the two Orcas Island transects.

For all studied marine birds in the eight Klahowya surveys, ferry traffic caused about 50% of marine birds to flush. This datum is an intermediate value when compared to flushing rates caused by other vessel types (Fig. 15). Based on data found by Baldock and Barber (2012), high-speed motorboats caused birds to flush 62% of the time. Slower motorboats and sailboats instigated flushing rates of 32% and 6%, respectively.

Discussion

Seabird Abundance

Significantly more seabirds per unit area were observed during the Centennial surveys than during the Klahowya ferry surveys. My data suggests that marine birds as a whole tend to avoid the areas with consistent, non-random ferry traffic in favor of areas

with less-predictable vessel traffic. This finding opposes the early literature on the subject of boat traffic predictability (Schwemmer et al. 2011).

Within both vessel routes, the abundance of marine birds varied by transect. For most species, the density of seabirds in each transect zone was dissimilar. The data signifies that marine birds tend to be heterogeneously distributed within the two survey areas. Unlike differences between the Centennial and Klahowya abundance data, such an observation cannot be adequately explained by randomness or predictability of boat traffic. Further research on the regularity of vessel traffic, while accounting for other possible variables, is needed to better understand its effect on seabird behavior.

Other factors must be responsible for variations in bird density within each vessel route. This notion suggests that these factors may also account for variations between the two vessel routes. Factors may include the features of the waterways in which my surveys took place. Much of the ferry route runs through narrower and shallower waters, especially north and east of Shaw Island. Centennial zones 1-3 are located in the wider, deeper waterways of the northern San Juan Channel, and zones 4-6 are situated in very deep and wide-open waters. My results suggest that certain species favor one of these habitat types over the other. Glaucous-winged gulls and common murrelets were observed more in the deeper, wider regions of the San Juan Channel, and pigeon guillemots were more numerous in the thinner, narrower areas of the Klahowya route. The importance of habitat features in determining seabird abundance is stressed here. For research looking at vessel traffic's effects on marine birds, habitat features must be taken into account.

Tidal State

The most unexpected results of my research were that of tidal effects on seabird density. My data showed no signs that either gull or alcid abundance were correlated with tide direction (ebb vs. flood) or current speed (fast vs. slow). The apparent lack of a relationship between the variables directly contradicts what has been well established in primary literature. Studies in the San Juan Islands have found strong linkages between seabird abundance and tidal state (Eisenlord 2011). Birds aggregate in locations where prey availability and foraging ability is optimal, and both elements are highly dependent on tidal oscillations (Zamon 2000). My inconclusive tidal data is most likely due to the methods of recording and analysis. For the surveys, birds exhibiting all behaviors were included. Thus, many birds (e.g. flying birds) were not using the site at which they were observed for necessary tasks such as feeding. Such instances do not accurately reflect seabirds' dependence on tides. Also, my data arranged all six studied species into two groups, gulls and alcids. This method does not account for interspecies variation in tidal preferences. Focusing solely on foraging birds for the individual species would likely produce a clearer picture of the association between tides and marine bird abundance.

Flushing Behavior

My data on flushing behavior in gulls and alcids differed from the results compiled by Baldock and Barber (2012), who did not break down flushing data for individual species. Their data showed that gulls flushed 50% more often than alcids, while my ferry survey results showed that alcids flushed 50% more often than gulls. However, our studies' subject pools were not the same. Baldock and Barber included mew gulls but not pigeon guillemots for their research, and this seemingly small discrepancy could affect the overall data. Other studies have suggested interspecies

variation in responses to similar forms of disturbance (Rodgers Jr. and Smith 1995). The inclusion or exclusion of certain species from our two studies, therefore, may explain the major differences observed when comparing gull and alcid flushing data.

Heermann's gulls and pigeon guillemots, the smallest of the studied gulls and alcids, each flushed at a lower rate than the other species in their family. Results like this are supported by previous literature which noted variations in disturbance response amongst bird species (Rodgers Jr. and Smith 1995). Details on why these variations may exist have yet to be uncovered. One possible explanation may be their size. The primary flushing technique for pigeon guillemots and Heermann's gulls in my study was flying. These smaller birds require relatively less work to achieve flight. They may remain steadfast for a longer time and flush only when it becomes clear that an incoming vessel would perturb them, because it takes less energy and time to escape.

Previous research indicates that there are regional differences in how marine bird species respond to similar modes of disturbance (Rodgers Jr. and Smith 1997). In my study, alcid flushing frequency was more variable across the Klahowya route than gull flushing frequency. Alcids flushed at greater rates in the two transects nearest Lopez Island, in comparison to the transects nearest Orcas Island. My conjecture for these results concerns habitat quality. The differences in habitat quality for gulls in the ferry route may be negligible. For alcids, the area around Lopez Island may be of poorer quality (i.e. worse foraging grounds). Therefore, they are less hesitant to vacate the area when faced with vessel traffic. Birds in the possibly-better foraging grounds nearer Orcas Island could be steadfast and more hesitant to leave a prime foraging area.

Baldock and Barber (2012) found that fast motorboats caused the largest rate of flushing behavior in marine birds, followed by slower motorboats and sailboats. My results show that flushing rates caused by ferry traffic fell is intermediate. This lines up well with my expectations. Speed is likely the primary factor of watercraft that influences flushing behavior (Bellefleur et al. 2009). It is not surprising that the fastest vessel type produces the largest flushing probabilities. When similar speeds for different watercraft are assumed, as I did for the ferry, sailboat, and slow motorboat, then size becomes the next most important factor. Larger vessels take up a larger area on the water and create larger wakes, thus increasing its potential to disrupt seabird activity. Accordingly, ferry traffic generated the largest flushing probability of the three slower-moving vessels.

Acknowledgments

I would like to thank my professors, W. Tyler Breck and Eric M. Anderson, and my teaching assistant Joshua Cummings for their instruction and assistance for my study. I also thank the Friday Harbor Laboratories for providing the facilities and equipment necessary for my research. Lastly, I thank the students and staff at FHL for lending their support in a variety of different ways.

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Figures



Figure 1: Map of Klahowya survey area surrounding Shaw Island (center). Routes between ferry terminals constituted four transects. Map created with Google Earth.

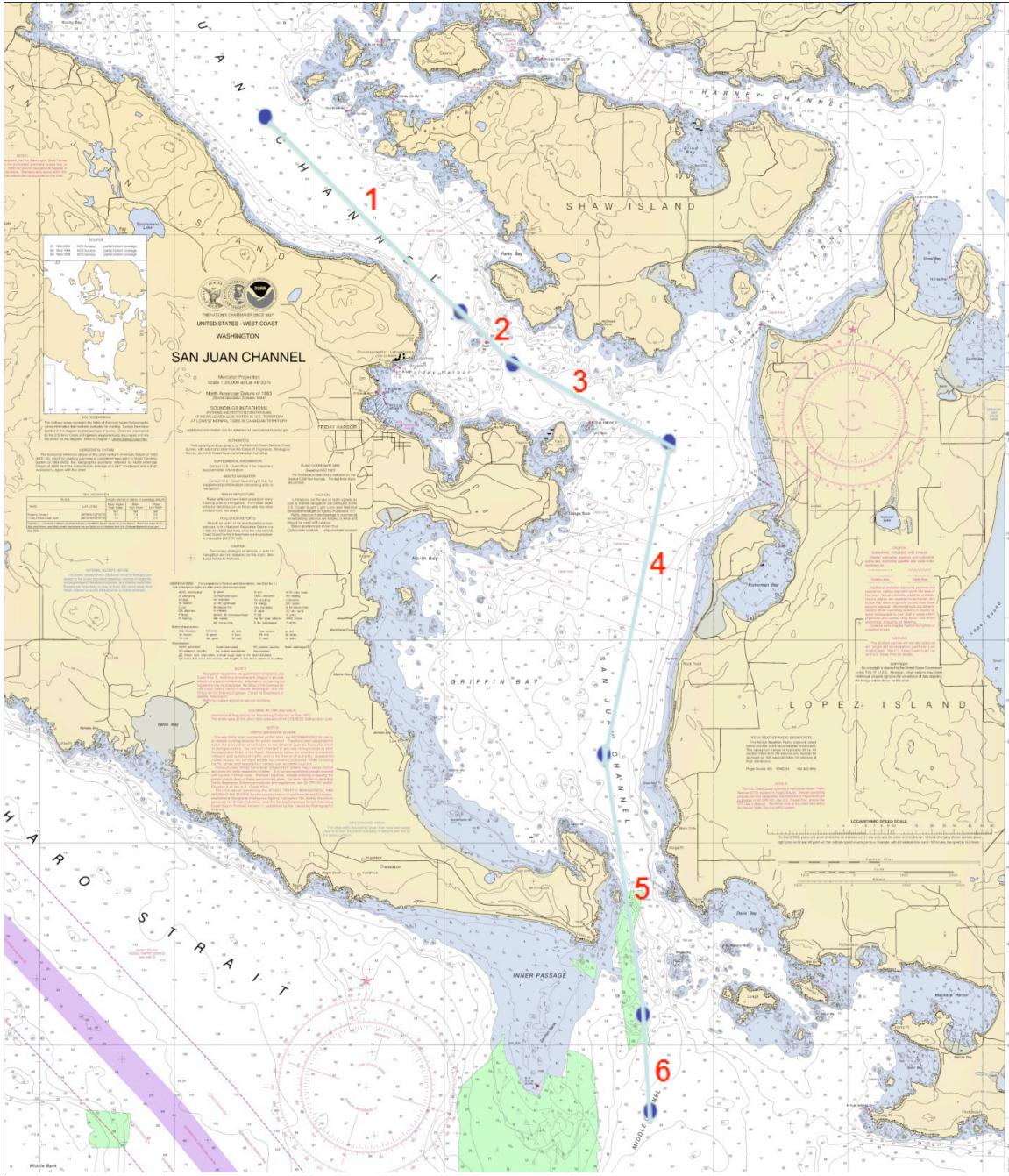


Figure 2: Map of Centennial survey area in the San Juan Channel. The six transects were predetermined.

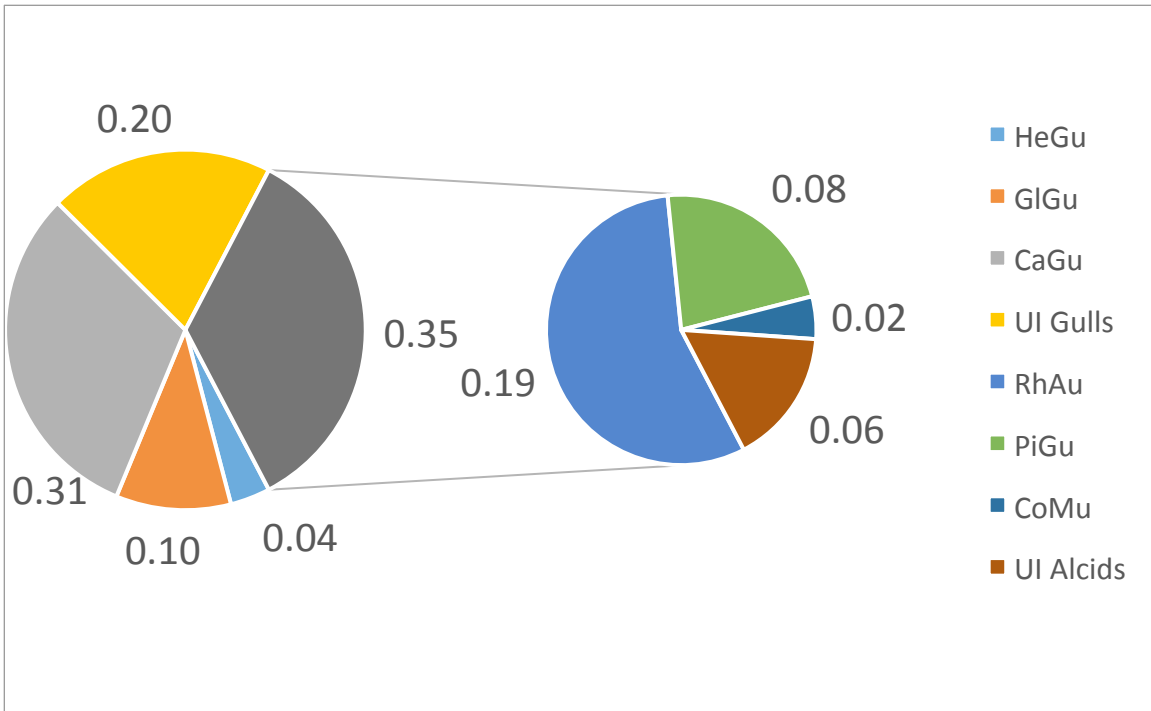


Figure 3: Contribution of each species to the total seabird population in the Klahowya route. “UI Gulls” and “UI Alcids” are birds whose species were not identified.

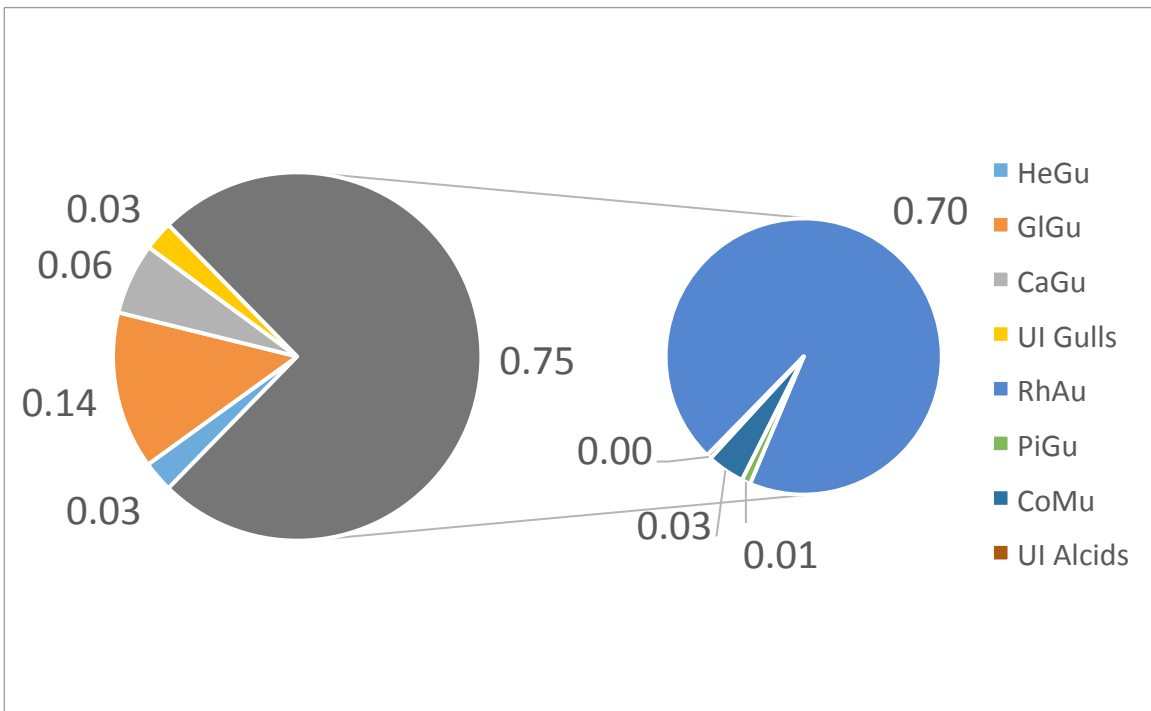


Figure 4: Contribution of each species to the total seabird population in the Centennial route. “UI Gulls” and “UI Alcids” are birds whose species were not identified.

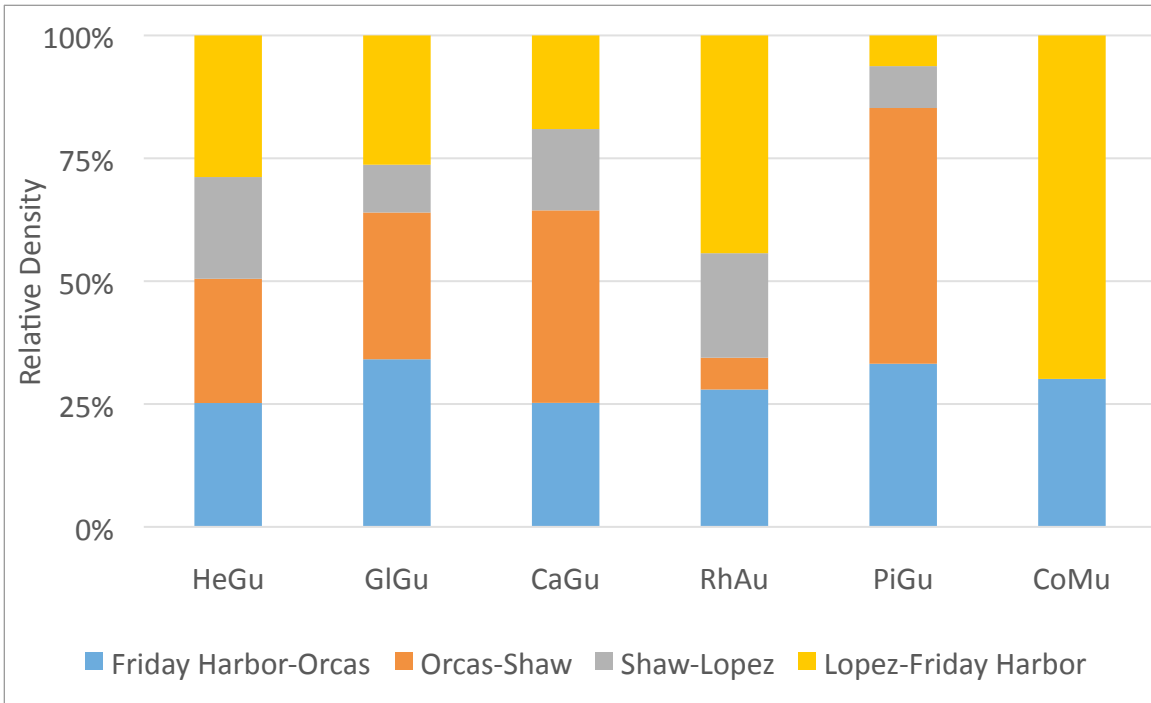


Figure 5: Relative densities of six seabird species in four Klahowya transects. Values significantly departed from 25% suggest a non-random distribution of birds across the survey area.

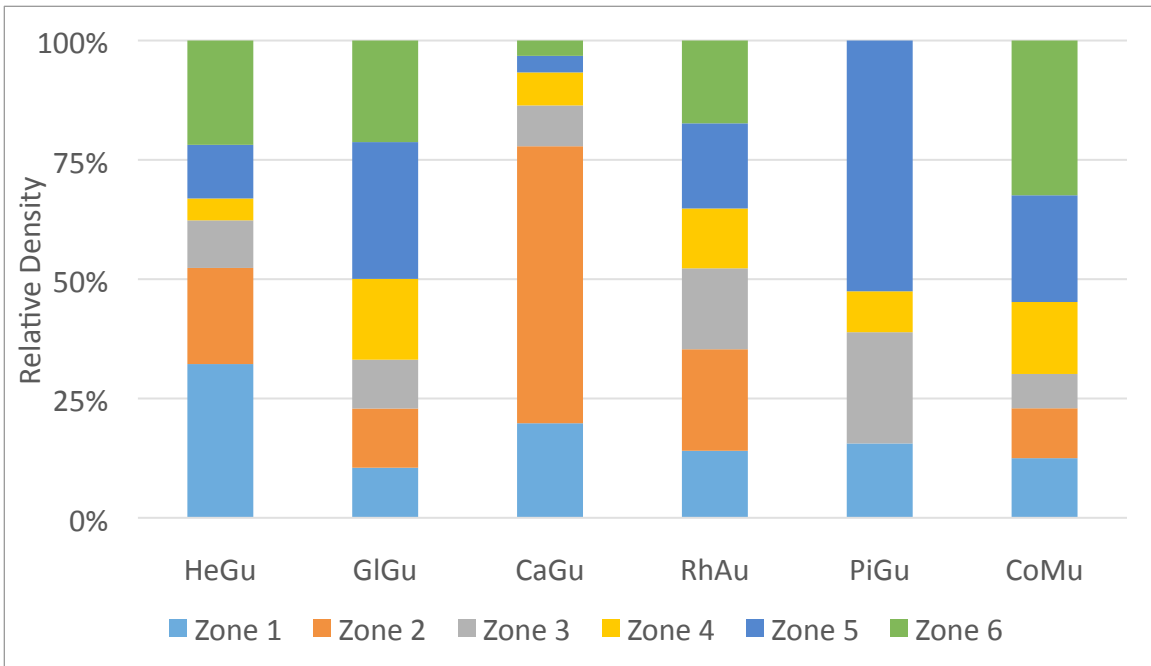


Figure 6: Relative densities of six seabird species in six Centennial transects. Values significantly departed from 17% suggest a non-random distribution of birds across the survey area.

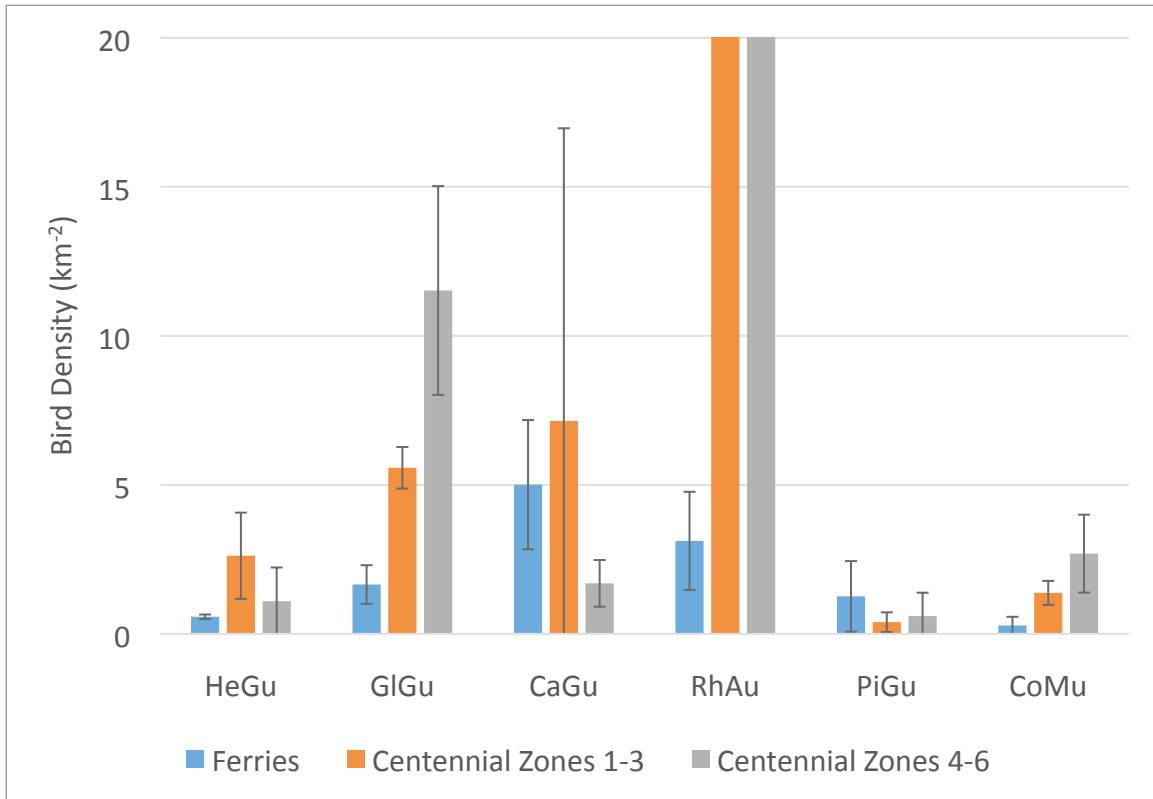


Figure 7: Mean densities ($\pm 95\%$ CI) of six seabird species in three vessel zones. Two extreme values for rhinoceros auklet density are 46.82 ± 11.97 birds/ km^2 in Centennial zones 1-3, and 44.44 ± 9.67 birds/ km^2 in Centennial zones 4-6.

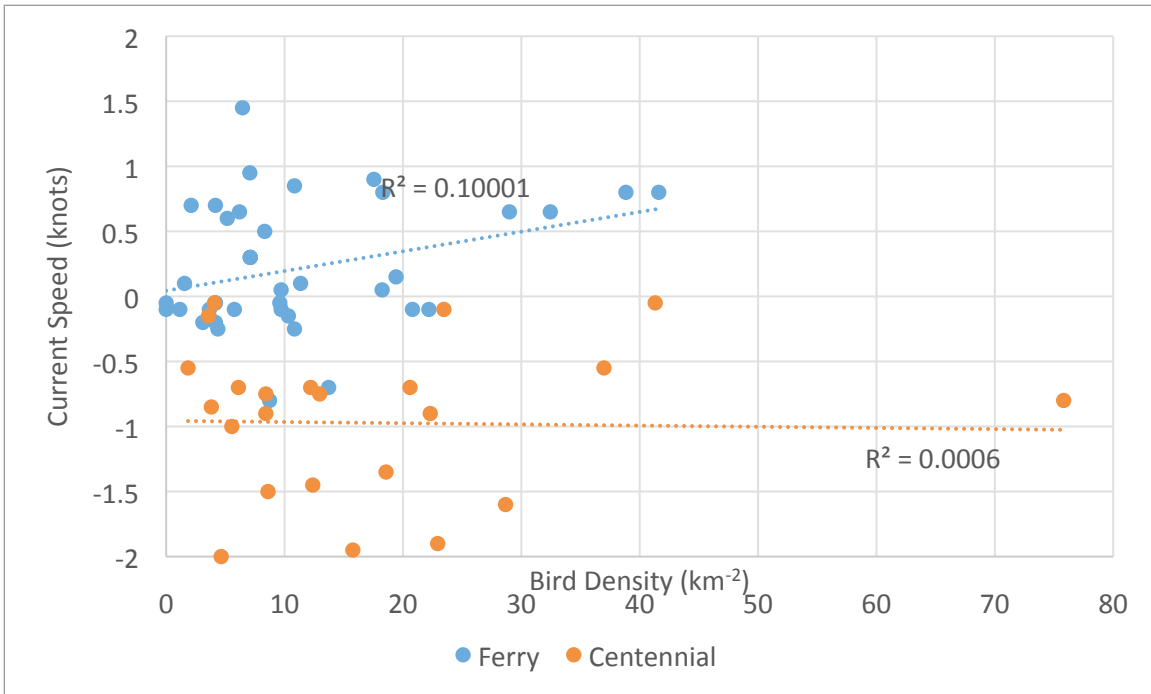


Figure 8: Density of gulls plotted against tidal current speeds. Positive speeds indicate flood tides, and negative speeds indicate ebb tides. R^2 values, coefficients of determination, are provided for the lines of best fit.

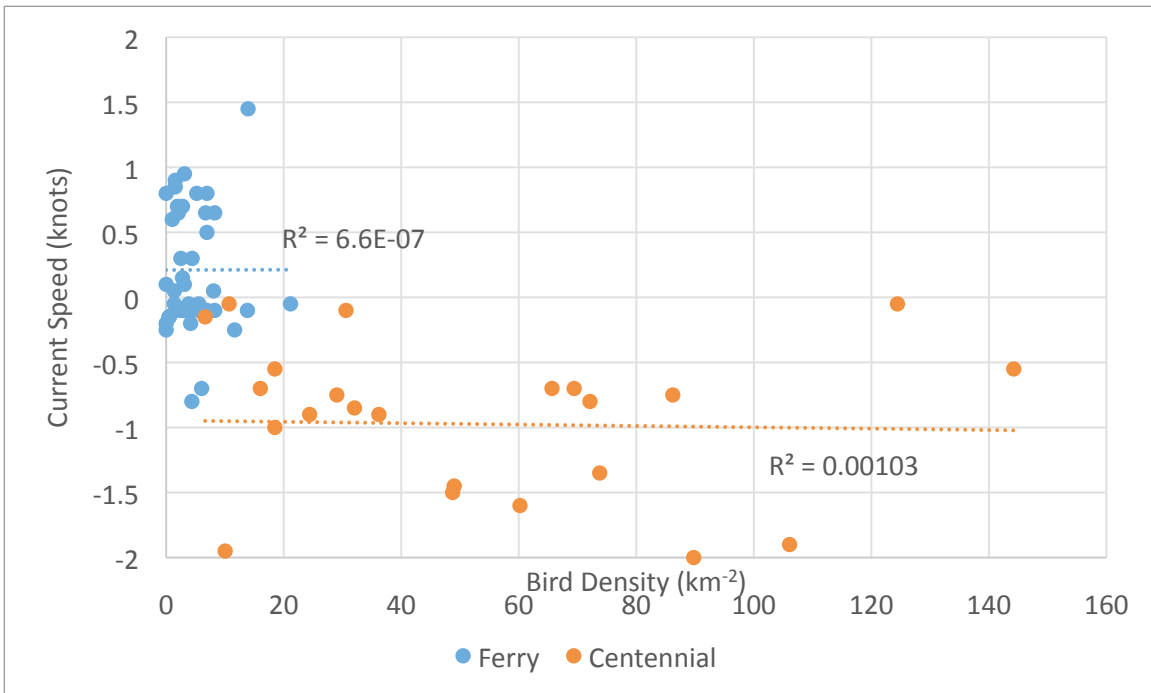


Figure 9: Density of alcids plotted against tidal current speeds. Positive speeds indicate flood tides, and negative speeds indicate ebb tides. R^2 values, coefficients of determination, are provided for the lines of best fit.

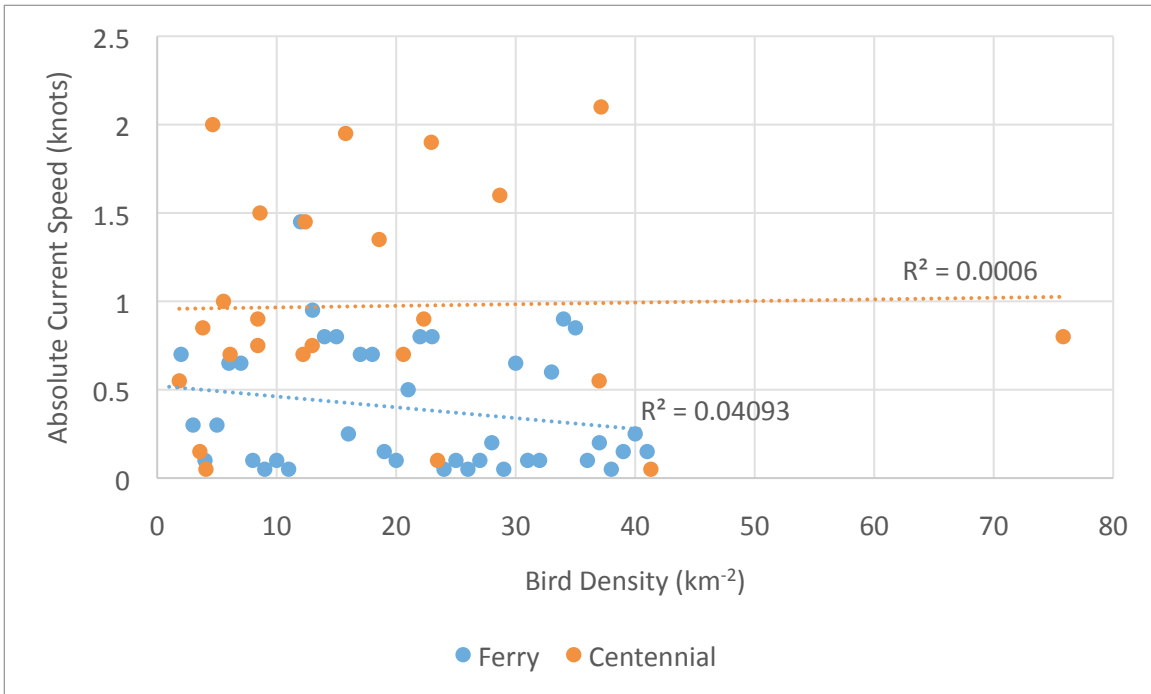


Figure 10: Density of gulls plotted against absolute values of tidal current speed. R^2 values, coefficients of determination, are provided for the lines of best fit.

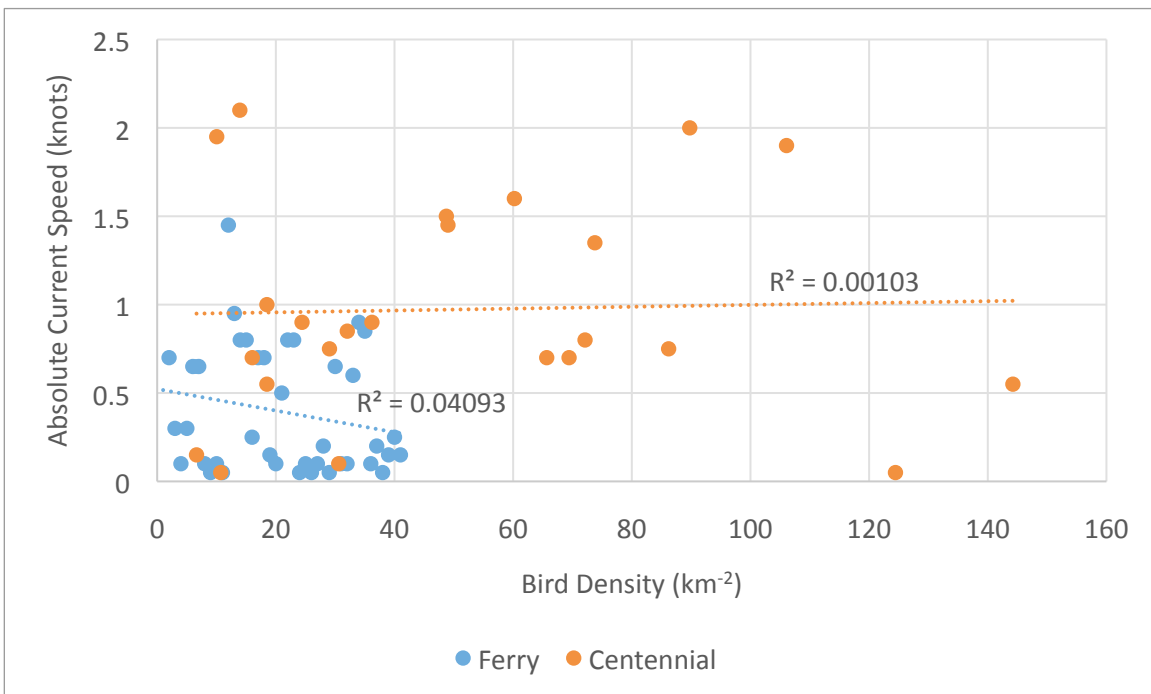


Figure 11: Density of alcids plotted against absolute values of tidal current speed. R^2 values, coefficients of determination, are provided for the lines of best fit.

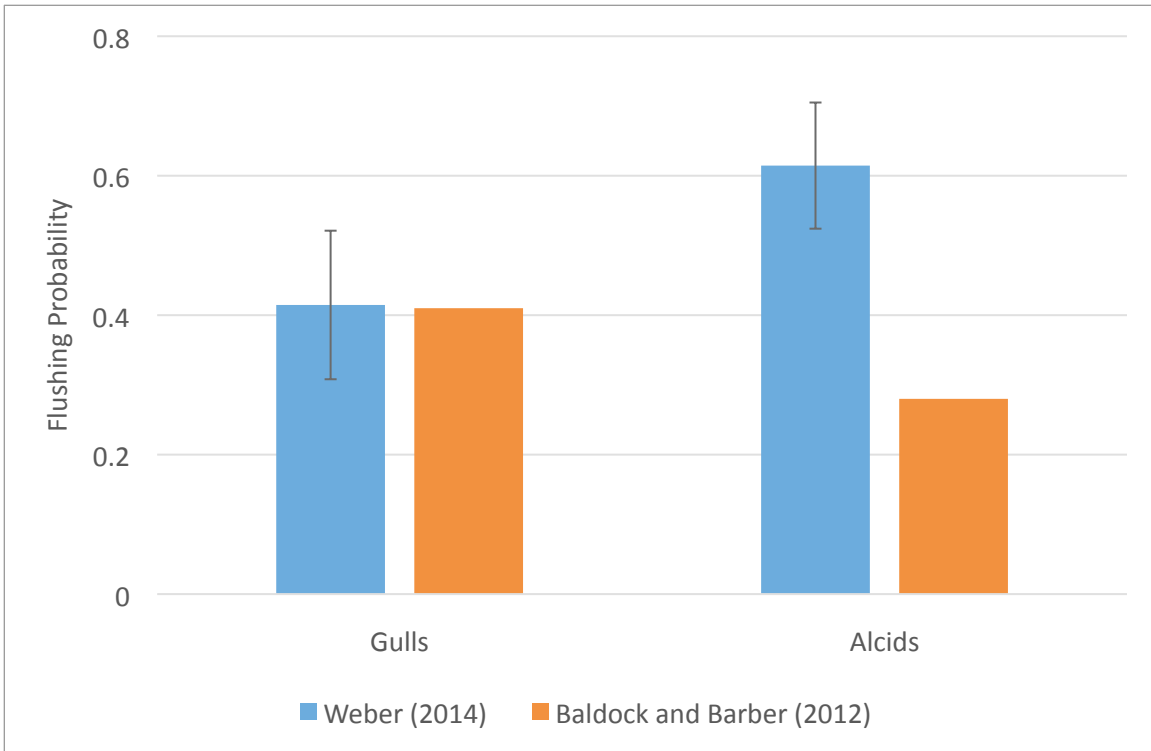


Figure 12: Flushing probability ($\pm 95\%$ CI) of marine bird families found by two studies conducted in the San Juan Islands region. No confidence intervals or error bars were provided by Baldock and Barber.

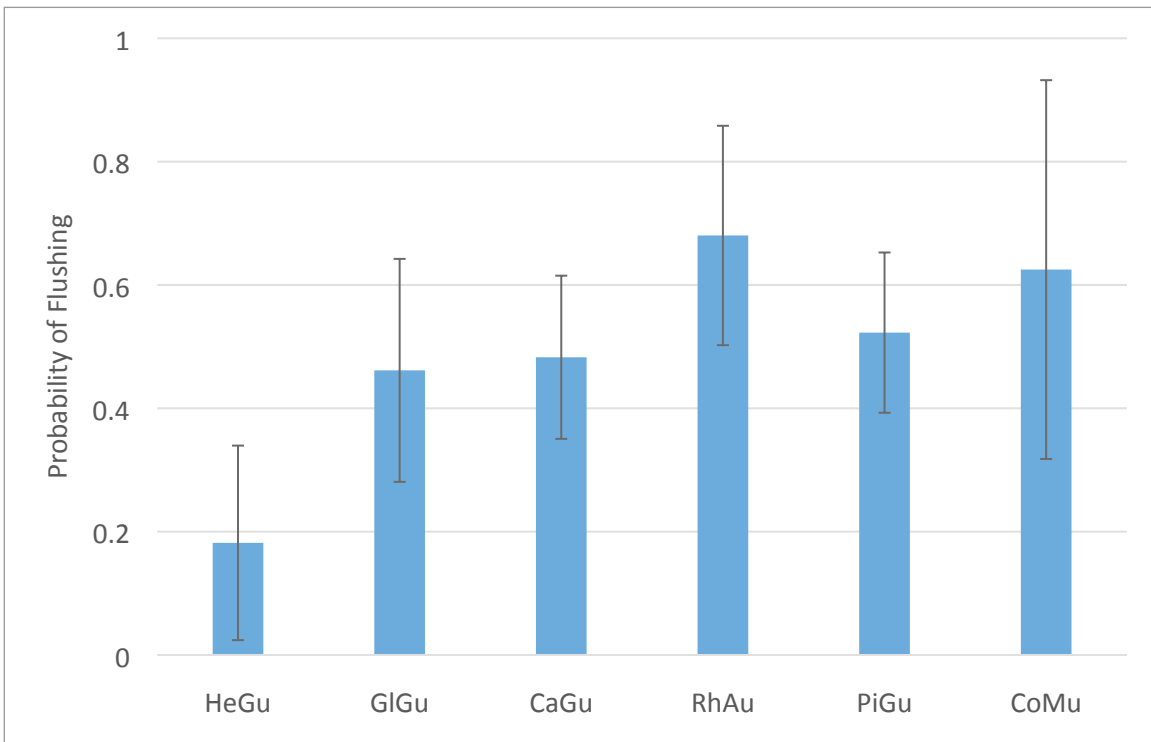


Figure 13: Flushing probability ($\pm 95\%$ CI) of six seabird species on the Klahowya route.

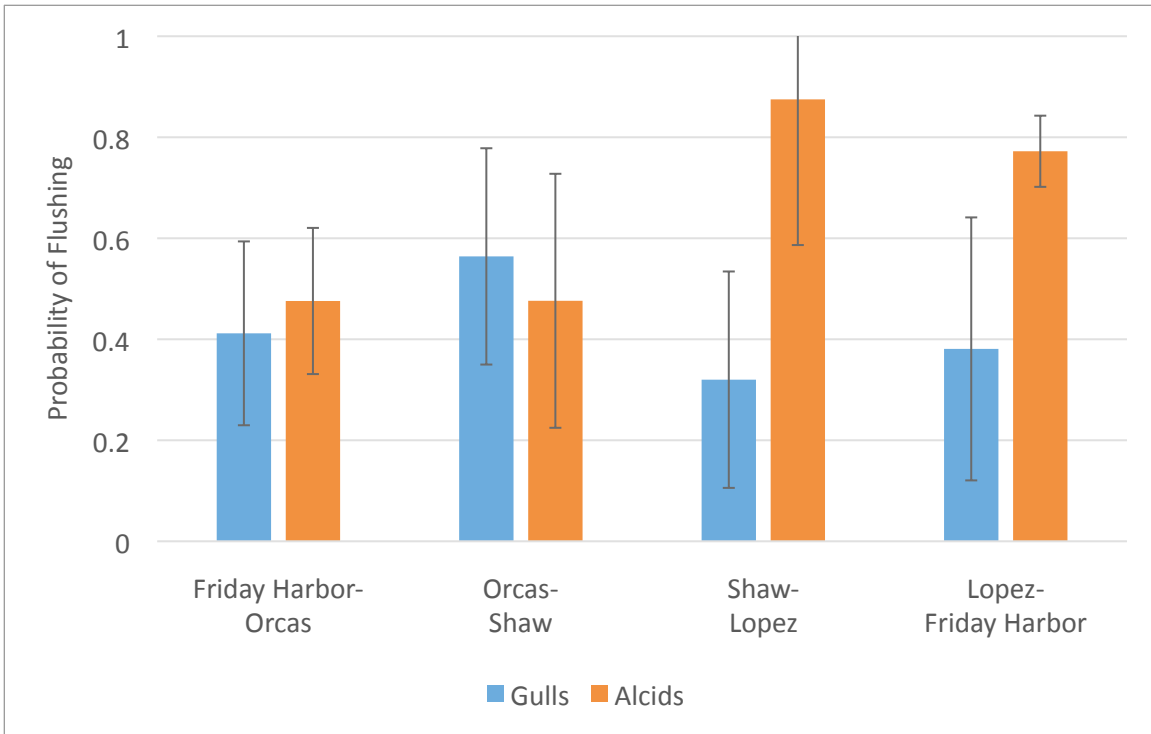


Figure 14: Flushing probability ($\pm 95\%$ CI) of two seabird groups in the four Klahowya transects.

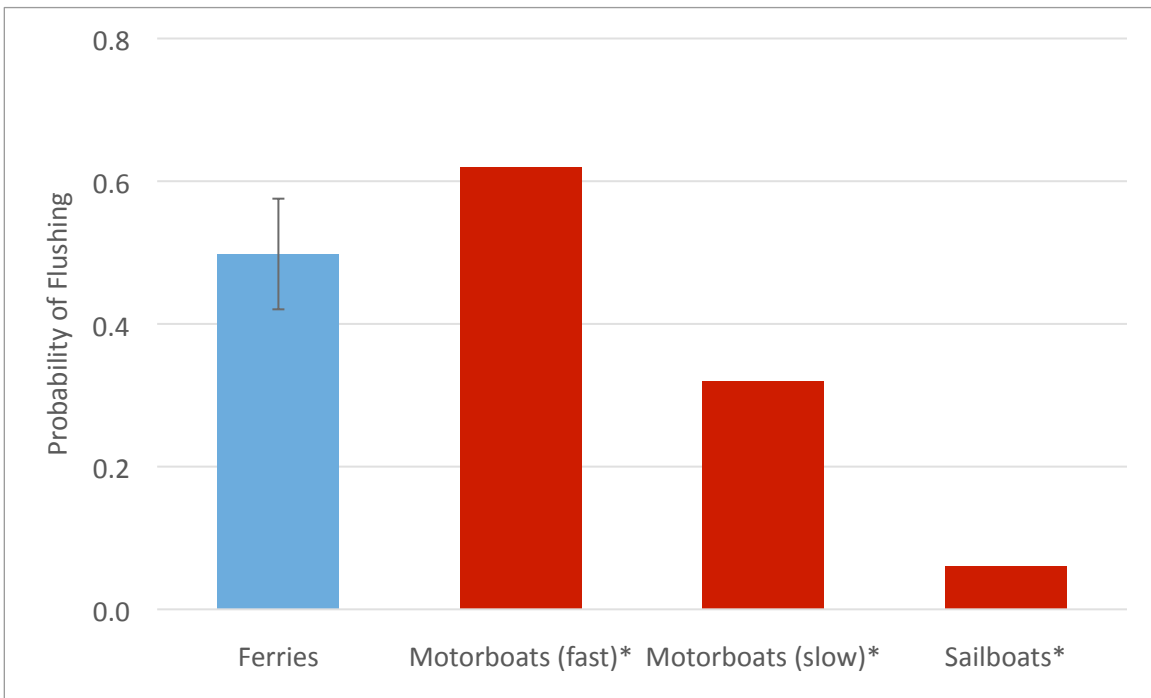


Figure 15: Flushing probability ($\pm 95\%$ CI) of all studied seabirds for four vessel types causing disturbance. Results for ferry vessels came from my study. Results for fast motorboats, slow motorboats, and sailboats came from Baldock and Barber (2012), who did not provide error bars or confidence intervals.