Cormorants and Other Avifauna of the San Juan Channel

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Pelagic Ecosystem Function in the San Juan Archipelago Research Apprenticeship

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Abstract

Large populations of diving seabirds are found in the San Juan Archipelago, an important overwintering region for many seabirds. Previous Pelagic Ecosystem Function Apprenticeships have focused on the relationships of various diving seabirds and tidal conditions. Cormorants are the second most abundant diving seabirds of the San Juan Channel yet their feeding ecology is not commonly investigated. My objectives were to contribute to the long term seabird database by studying the abundance of all seabirds seen in the San Juan Channel during fall 2014 and comparing this information to recent autumns. I also explored cormorants by relating their abundance to previous autumns and distribution along the six zones for fall 2014. I observed their flight direction and water interaction in the most tidally active area (zone 5) to determine during which tidal conditions they flew in and out of the channel. The population of cormorants increased as the season progressed, likely due to the migration of Brandt’s cormorants to the region, with numbers highest in areas containing rookeries and tidally influenced prey abundance. A significant correlation between cormorant flight direction and fast tidal currents was found at Cattle Pass although they flew in the opposite direction of the current flow. I examined cormorant water interactions within the channel and found they were indeed in the water (proxy for foraging) on fast ebbing tides, reinforcing the countercurrent flight direction I observed at Cattle Pass. My results suggest that cormorants are very different from other diving seabirds and must be studied carefully. Additionally, my analyses confirm population declines for gulls and alcids which are likely due to the anomalously warm offshore ocean water.

Introduction

The San Juan Archipelago (SJA) is an important wintering region for diving seabirds, providing abundant food sources and natural protection from oceanic storms (Behnke & Reynolds 2005). Many of these wintering seabird populations are thought to be in decline over the past 40 years due to human impacts and prey availability (Aebischer et al 1990, Bower 2009). This makes the SJA an important area for monitoring populations of wintering seabirds because they indicate ecosystem change (Gaydos 2007, Piatt 2007).

The SJA has a large marine waterway named the San Juan Channel (SJC). This channel has complex underwater topography and strong tidal currents that concentrate prey, leading to large aggregations of feeding seabirds (Zamon 2003). In fact, the tidal exchanges determine when and where these feeding events will most likely occur. For example, in places such as Cattle Pass, faster currents coincide with higher seabird abundance.

Diving species, including alcids, cormorants, ducks, loons, and grebes, comprise the largest portion of the avifauna found in the channel. Although they are abundant here, their feeding ecology is difficult to study because they forage underwater. It is often necessary to rely on indirect evidence, such as distribution, to understand their relationship with prey. This information is reliable for most diving birds, but not cormorants.

Three similar, sympatric species of cormorants are seen in the channel throughout the year; the pelagic (*Phalacrocorax pelagicus*), Brandt's (*Phalacrocorax penicillatus*), and double-crested (*Phalacrocorax auritus*). They are less waterproof than other diving seabirds, less buoyant, and achieve greater diving depths. The trade-off for being less waterproof is cormorants become colder while diving and must periodically return to roosting sites on land to dry off and warm up (Lewis & Sharpe 1987). Cormorants flying to and from colonial roosts make distribution patterns difficult to interpret. Considering only in-the-water individuals might be a better indicator of cormorant foraging choices.

Since 2006, Pelagic Ecosystem Function (PEF) research apprentices have investigated distribution and abundance patterns for all seabirds in the San Juan Channel during autumn. Several (Nomura 2006, Wang 2008, Hainey 2008, Clatterbuck 2009, Eisenlord 2012, Albrecht 2012, Standish 2013, and others) have focused on the major diving families, especially alcids, and their relationship with tides in the channel and Cattle Pass. A few studies (Spatz 2007, Wang 2008, Palmer 2010) focused on cormorant distribution, but none looked closely at the proportion of flying versus in-the-water birds. Also, Ford (2011) found some correlations between cormorants and tidal cycles in Cattle Pass, but her sample size was small.

The goals of my study were to contribute to the apprenticeship's long term seabird dataset and understand more clearly the feeding ecology of cormorants. Specifically, I wanted to ascertain community composition and abundance of seabirds in the SJC for fall 2014 and compare these data to previous autumns. I researched cormorant feeding ecology by determining the distribution of cormorants in the channel, and comparing the distribution of flying versus in-the-water birds. Lastly, I examined the relationship of cormorant flight direction and tides in Cattle Pass. I chose Cattle Pass for my land-based surveys due to its historically high abundance of cormorants and strong tidal currents amplified by uniquely varied bathymetry.

Methods

San Juan Channel Study Site

All San Juan Channel bird abundance data was collected on a fixed route aboard a 58-foot research vessel, the University of Washington's *R/V Centennial,* at an average speed of approximately eight knots (Fig. 1). The 21.2 kilometer route was traversed twice per cruise and divided into six geographic zones according to varying bathymetric features (Behnke and Reynolds, 2005). Transect 1 (T1) began near Yellow Island (48.5667ºN, 123.0125ºW) progressing southbound through the zones and terminated after Cattle Pass near the Strait of Juan de Fuca (48.4269ºN, 122.9452ºW). Transect 2 (T2) progressed in the opposite direction, northbound through the San Juan Channel zones toward Yellow Island. Partial transects were surveyed on October 7th and November 5th due to inclement weather. Bird data from fourteen transects over seven weekly cruises from 29th September to 10th November, 2014 were recorded.

R/V Centennial Surveys

Two teams of Pelagic Ecosystem Function apprentices equipped with binoculars were stationed on each side of the bow of the *R/V Centennial* at three meters above the water level. Marine birds within a 400 meter observation corridor were counted, identified, and recorded for behavior (Fig. 2). Species identification was recorded if possible; all others were identified to the lowest possible taxon. Flight direction, interaction with the water, and time of bird sightings were recorded to the nearest minute.

Cattle Pass Study Site

The narrowest, most bathymetrically featured, and tidally active area of the SJC is found in zone 5 at Cattle Pass (Fig. 3). The greatest constriction point measures 0.7

kilometers wide with seafloor depths varying from 5 to 132 meters (Zamon 2003). I chose to survey cormorant activity from the lighthouse at Cattle Point, just west of Cattle Pass (48.4506° N, 122.9633° W). The largest rookery sites in the region are proximal. From this land point I had a clear view of Goose Island, across the channel to Whale Rocks, and southward to the Strait of Juan de Fuca.

Cattle Pass Survey Method

I conducted ten surveys of cormorant activity between 5th October and 8th November, 2014. The surveys totaled approximately 30 hours, not including travel time to and from the study site, and lasted between 2 to 6 hours with repeated observation rotations. A rotation consisted of thirty minutes of cormorant observation followed by a ten minute break. I identified cormorants with 8x42 magnification binoculars, documented their flight direction (north or south), and interaction with the water. Cormorants flying northbound past Whale Rocks were counted as flying into the channel while cormorants flying past Whale Rocks toward the Strait of Juan de Fuca were recorded as flying southbound, or out of the channel. Cormorants in the water were counted every half hour. I also noted the flight direction of individuals flying and landing in the channel water. The time of each observation was recorded to the nearest minute.

Analysis of San Juan Channel and Cattle Pass Data

All bird transect data was analyzed in Microsoft Excel 2013 and reported for the families Laridae (gulls), Alcidae (alcids), Phalacrocorax (cormorants), Anatidae (ducks), Gaviidae (loons), and Podicipedidae (grebes). I report all summaries of fall 2014 birds as $\bar{x} \pm 95\%$ confidence interval (± CI). I calculated abundances and densities to analyze the seasonal and spatial abundance variations for the cormorant family and species: double-crested (DCCO), Brandt's (BRCO), Pelagic (PECO), and unidentified birds as well (UNCO). Densities were standardized to transect or zone area (km^2) with the equation:

$$density = \frac{number\ of\ birds}{area\ (km^2)}$$

Cattle Pass cormorant data was analyzed in Microsoft Excel 2013 with statistical analyses generated in SigmaPlot 11.0 by Systat Software. I used current speed and direction information for SJC (South Entrance) on WWW Tide and Current Predictor (http://biol.sc.edu/tide) and used these data to categorize land-based cormorant observations into ten minute bins summarized by tidal phases based in part on current speed (Fig. 4 and Table 5).

Results

Seabird communities

During fall 2014, I surveyed 120.4 km^2 and counted 8,919 individual marine birds representing 6 families, and 33 species (Fig. 5). Mean season density of all birds combined was 74.08 birds per $km^2 \pm 18.01$. Alcids were the most abundant family comprising more than half (58%) of the birds seen. Gulls at (23%) were the next most abundant family, and cormorants were at (10%); all other families combined were a total of 9%.

Mean seabird abundance in 2014 was lowest since 2007 and significantly lower than only two years ago, 2012, when density exceeded 168 birds per km^2 (Fig. 6). Low densities in 2014 reflected lower numbers of all the major families. Specifically, alcids were lower and gulls were much lower in number, compared to 2012 (Fig. 7). Cormorant numbers were relatively constant among the last three years.

Cormorants

Aboard the R/V Centennial this season, I counted 874 cormorants with a mean density of 7.25 birds/km^2 ± 29.9. Of the three species of cormorants identified, Brandt's cormorants were the most abundant with an average density of 1.86 ± 9.02 (Fig. 8). Pelagic cormorants (1.08 ± 5.59) and double-crested (0.81 ± 3.63) were present at lower abundance. Importantly, unidentified cormorants made up almost half of all the cormorants counted on transect (3.49 ± 14.7). For this reason, all cormorant species plus unidentified cormorants were combined for all other analyses in this study.

Cormorants were observed throughout the fall but numbers increased from early to late in the season. In late September and early October, the abundance was low, at approximately 4 to 5 birds per km^2 (± 2.19 to 2.98) (Fig. 9). From mid-October to mid-November, density ranged from 5 to 10 birds/km^2 (± 1.50 to 2.99) except on 5 November, when the maximum density of 14.47 birds/km^2 (± 9.24) was observed.

Cormorants were observed throughout the entire transect but were concentrated in some areas (GIS map created by Jesse Kruttschnitt, Fig. 10). Total cormorant abundance was highest near Cattle Pass in zone 5, at 26.7 birds/km^2 (Fig. 11). This is 5 times higher than any other zone. Moderate numbers of cormorants were found in zone 3 and 4 (4.1 to 6.4 birds/km^2). Cormorant density was lowest (< 2.84 birds/km^2) in zones 1, 2, and 6. When only cormorants in-the-water are considered, the distribution pattern was somewhat different. Mean density was moderately high in zones 3 and 4 (2.45 to 2.84 birds/km^2) and highest (> 7.36 birds/km^2) in zone 5 (Fig. 12). In all other zones, density of cormorants on the water was less than 1.02 birds/km^2. The number of cormorants on the water also varied with tidal phase in some zones. For example, for zones 3 and 4 combined, the numbers of birds were higher during ebbing phases than in flooding phases (Fig. 13).

Cattle Pass Data

During about 1,700 minutes of counting flying cormorants from the Cattle Point lighthouse, I observed 445 individuals going northbound and 469 individuals going southbound. Although these totals are about even, the proportion of cormorants flying in each direction varied with tidal phase. During the flooding phases (from fast flood through slack-high), southbound birds were significantly higher in number than northbound birds (Fig. 14). Conversely, northbound birds were more numerous during ebbing phases (from fast ebb to slack-low). North and southbound birds were about even in proportion during the transitional phases at the start of each tidal cycle, slow flood 1 and slow ebb 1.

Tidal current speed also influenced the abundance of flying cormorants. Although northbound and southbound birds were seen flying during all observed tidal current speeds (Fig. 15), there was a small but significant trend of higher numbers at faster tidal current speeds. Northbound birds were most abundant during faster ebbing currents (-1.64 to -2.52 knots, R^2 = 0.116, P = 0.0001) (Fig. 16), whereas southbound birds were seen in higher numbers during faster flooding currents (0.82 to 2.51 knots, R^2 = 0.138, P = 0.0001) (Fig. 17).

Discussion

Seabird communities

My finding of very low seabird abundance in fall 2014 suggests that prey were not particularly plentiful. Previous research has shown that prey availability and seabird abundance vary with oceanographic conditions (Burthe et al 2014). Cold water years are generally more productive than warm water years (W. Breck Tyler, Jesse Krusttschnitt, Catherine Cougan, pers. comm.). High seabird density observed in San Juan Channel in the falls of 2010 through 2012 correlate with cooler La Niña conditions (Table 18). In contrast, fall 2014 was characterized by anomalously warm oceanic water offshore from the Washington coast (http://climate.washington.edu/newsletter/NPac_Overview_14.pdf).

The finding that gull numbers were especially low this year suggests that gulls were affected by the warm surface waters more than any other seabird family. It is possible cormorants were not as affected by the unusually warm water because they could forage at depths beyond the warm sea surface temperature (SST). Unlike cormorants, gulls are surface feeders that depend on abundance of zooplankton and sporadic feeding events linked with pinniped foraging (Zamon 2001, pers. obs.).

Cormorants

My finding that cormorants were present in all zones, but most abundant in zone 5, is consistent with previous PEF studies. For most species, seabird abundance is thought to correlate with prey availability; however, this is more complicated with cormorants because of their need to roost (Lewis and Sharpe 1987). Cormorants are less waterproof than other diving birds allowing them to achieve greater diving depths. Due to this, they become colder more quickly and must return to land to warm up and dry off between foraging events. No other diving species does this. This means that birds observed in a particular zone might be there to forage but they also might be traveling between roosting sites. This problem is especially prominent in zone 5 where some of the largest roosts in the San Juan Channel are located.

Although high numbers of birds in zone 5 certainly includes birds flying to and from roosts, my outcome of high number of cormorants in-the-water in zone 5 indicate this zone is also an important feeding area. In fact, on each tidal exchange, large volumes of water –and plankton suspended throughout – rip through the extremely narrow and bathymetrically variable underwater tunnel that is Cattle Pass. Fishes congregate in the pass during faster current speeds to feed on plankton traveling in the opposite direction which leads to more seabird activity (Zamon 2003).

Cormorants in Cattle Pass

In San Juan Channel, prey is most abundant during periods of high tidal current speeds (Zamon 2003, Palmer 2010). One might predict that cormorants would be most apt to leave the roost and fly to foraging sites when prey is most available (Spatz 2007). This means that flying birds can be useful in understanding the timing or specific patterns of foraging. My finding is consistent with this prediction; that is, cormorants are seen flying in highest numbers during high current speeds.

Previous studies have also shown that the location of feeding seabird concentrations varies with the tidal direction (Zamon 2003). Typically, abundance of seabirds is higher on the down current side of Cattle Pass; that is, higher on the north side during flooding tides and higher on the south side during ebbs. One would expect that birds would fly in the same direction as the tidal flow to reach the best feeding sites. My data, showing that flying cormorants did just the opposite, is fascinating. This suggests that cormorants may be reacting differently than other diving birds to tidal direction. It's possible that flying cormorants traveling against the tidal current direction are not necessarily going to feeding sites. But my data on high abundance of cormorants in-the-water during ebb tides, further inside the channel, suggests that cormorants do in fact fly against the tidal current direction to feeding areas.

This finding is compelling because it emphasizes the variability of cormorant foraging ecology compared to other diving birds. Future studies might consider the location of rookeries and the potentially confounding signal of birds traveling to and from these sites. Cormorants have also shown feeding-site fidelity when foraging (Coleman et al 2005, Kotzerka et al 2011). Perhaps one tidal current direction (ebb or flood) should be investigated at a time when considering a cormorant's flight direction and interaction with the water. One might confirm my findings by approaching cormorants as different from other diving seabirds.

Conclusions

My research emphasizes the importance of considering seabird interaction with the water, especially for cormorants. I'm very certain these deep divers would be further understood if future studies consider my discoveries on cormorant flight direction and water interaction relationships with tides. My findings on cormorants and tides compel us to reconsider why previous studies group cormorants with general feeding trends seen in other diving seabird families, because cormorants do indeed have different foraging ecology than other diving seabirds within SJC. Additionally, my findings would aid future apprentices by outlining how to better determine the location, behavior, and timing of cormorants in the channel. I do advise conducting surveys in areas without major rookeries and yet with moderate to high cormorant abundance. My study would also be useful when comparing interannual information on seabirds seen in the SJC for fall 2014. Alcids and gulls were much lower in abundance this autumn, suggesting that these two groups were affected by the anomalously warm water off the Washington coast, although cormorants were not in low numbers compared to other diving families in recent seasons. Cormorants indicate a dissimilar reaction to water temperatures than other diving seabirds as their abundance remained the same during cold and warm water seasons. I hope my research on cormorants will be useful to future PEF apprentices who share the same goal of diving into cormorant feeding ecology.

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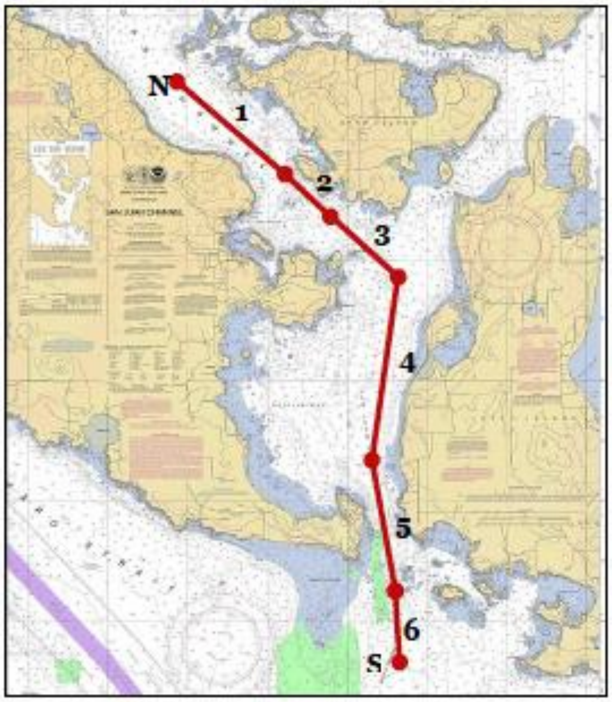

Fig. 1: Stations and zones throughout the PEF transect route in the San Juan Channel.

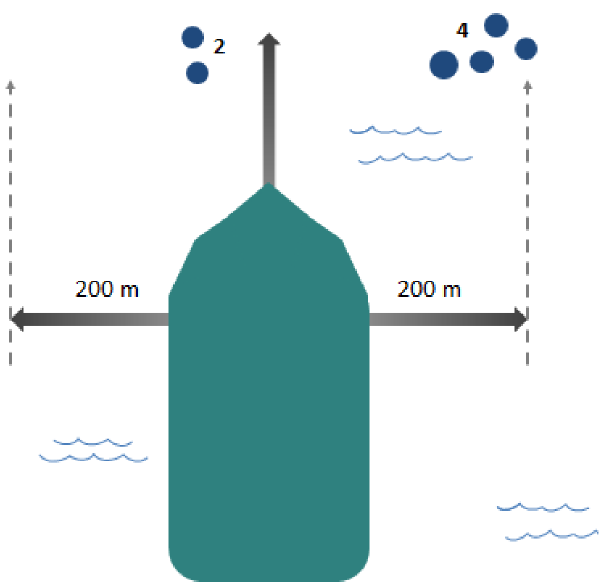

Fig. 2: Observation corridor aboard the *R/V Centennial* cruises.

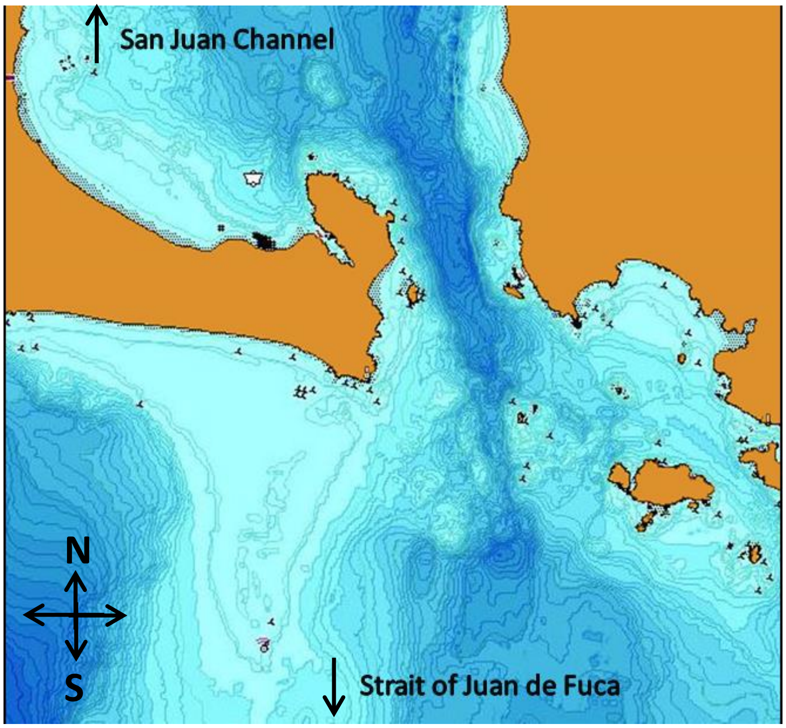

Fig. 3: Cattle Pass with the Cattle Point lighthouse (on San Juan Island) to the west, and Lopez Island to the east.

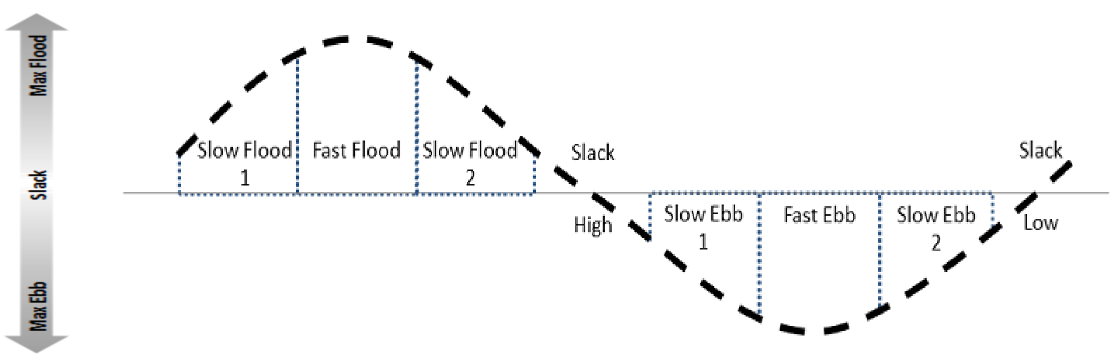

Fig. 4: One complete tidal cycle with sub-phases.

Tidal Phase	Current speed (knots)
Slow flood 1	+0.6 to +1.5
Fast flood	+1.6 to max to +1.6
Slow flood 2	+1.5 to +0.6
Slack-high	+0.5 to 0 to -0.5
Slow ebb 1	-0.6 to -1.5
Fast ebb	-1.6 to max to -1.6
Slow ebb 2	-1.5 to -0.6
Slack-low	-0.5 to 0 to +0.5

Table 5: Current speed range of each tidal phase. Note: All max current speeds surveyed were in excess of +2 and -2 knots.

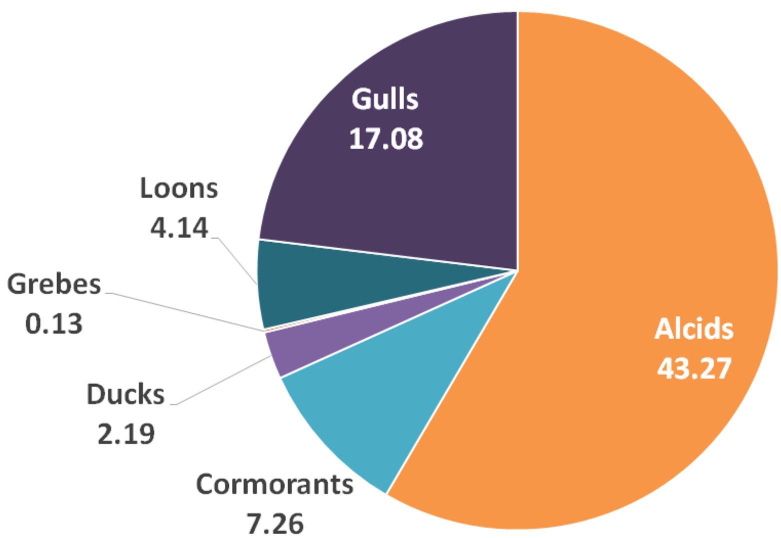

Fig. 5: Seabird family mean density for Fall 2014 (birds/km^2).

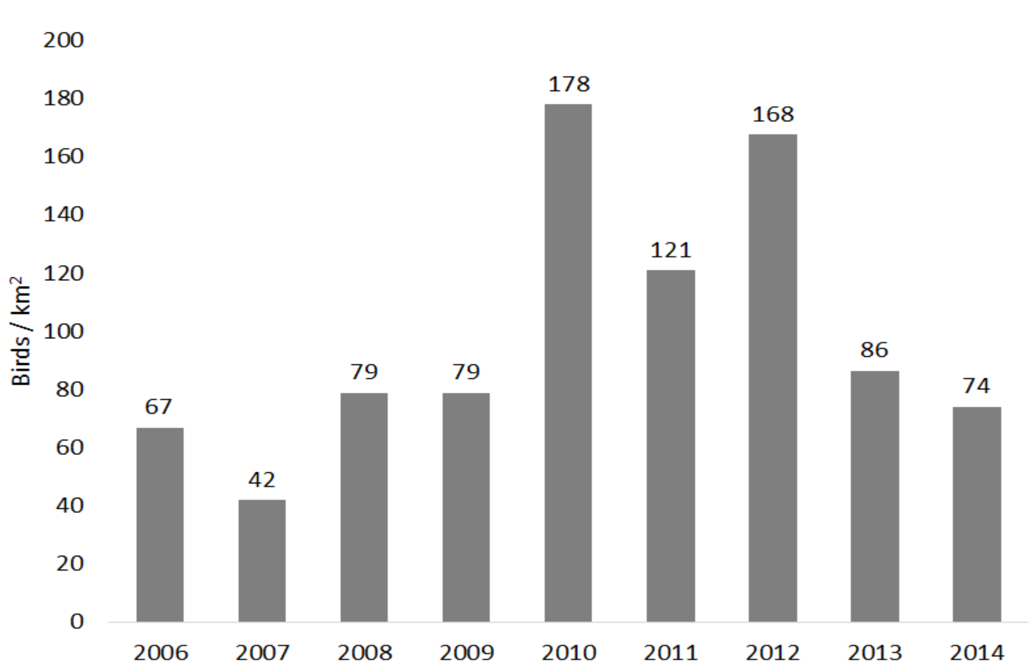

Fig. 6: Mean interannual seabird abundance for past autumns (birds/km^2).

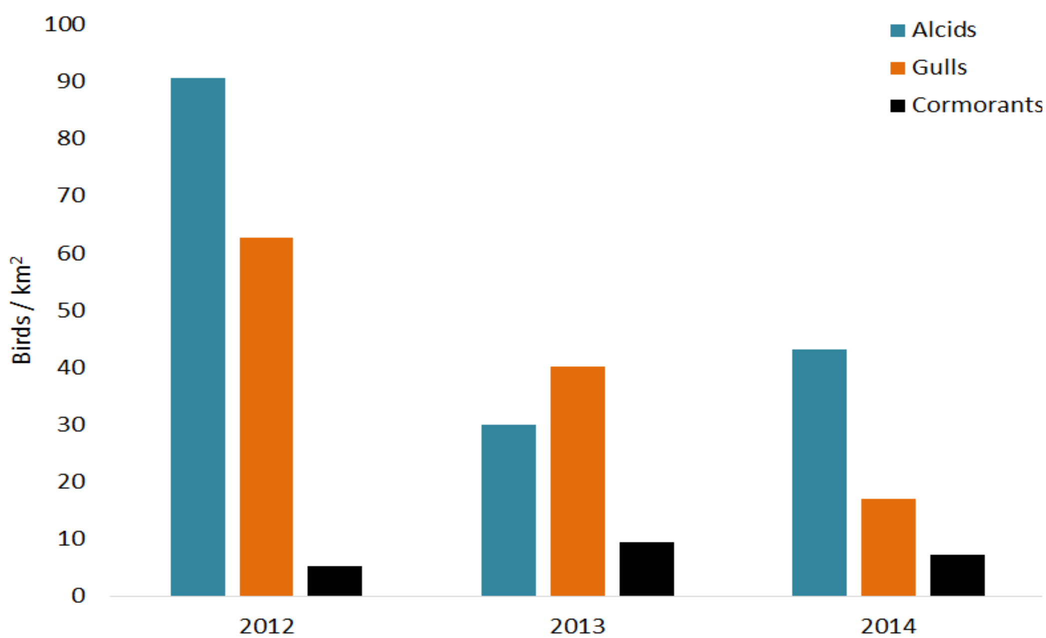

Fig. 7: Mean density of alcid, gull, and cormorant families in fall 2012, 2013, 2014.

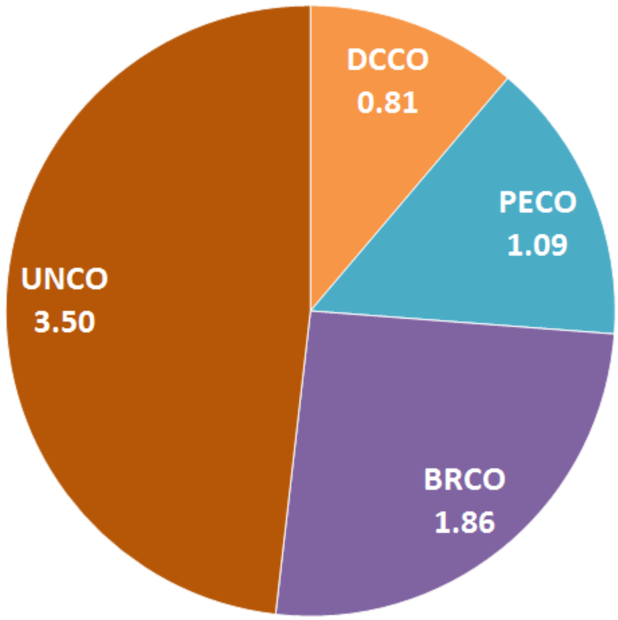

Fig. 8: Cormorant species (plus unidentified) composition and mean density for fall 2014 in birds / km^2.

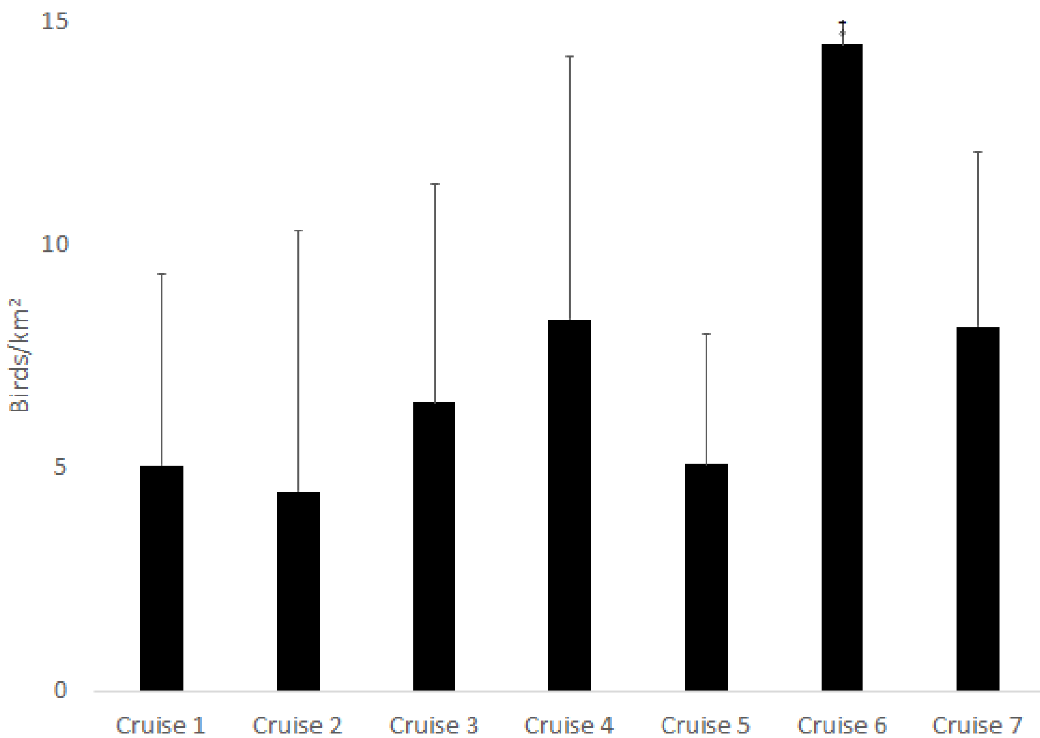

Fig. 9: Change in cormorant mean density throughout fall 2014 (CI = 95% as error bars).

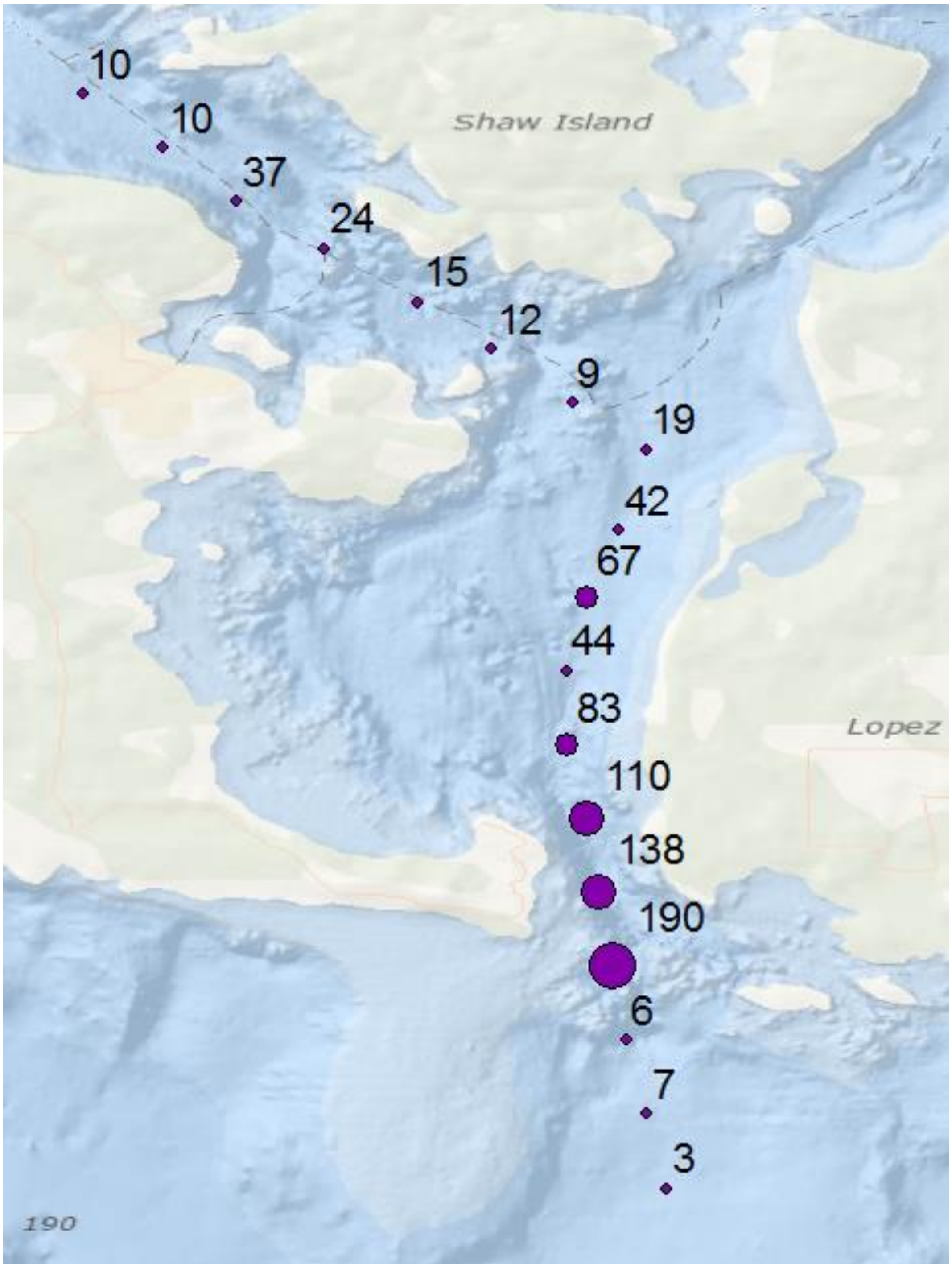

Fig. 10: Fall 2014 cormorant distribution and abundancein San Juan Channel (GIS Map created by Jesse Kruttschnitt).

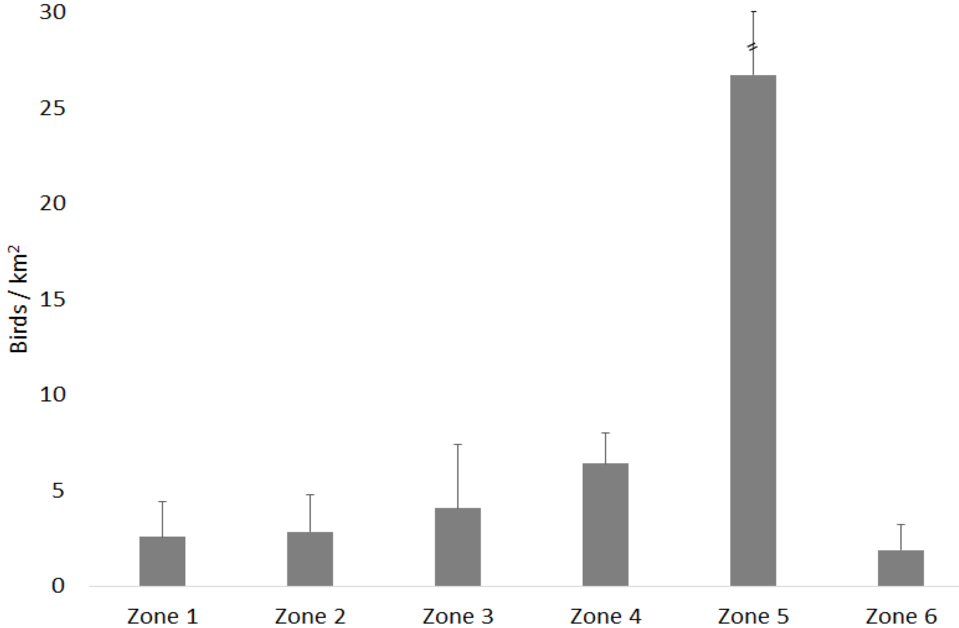

Fig. 11: Average density of flying and in-the-water cormorants by zone for fall 2014 (CI = 95% as error bars).

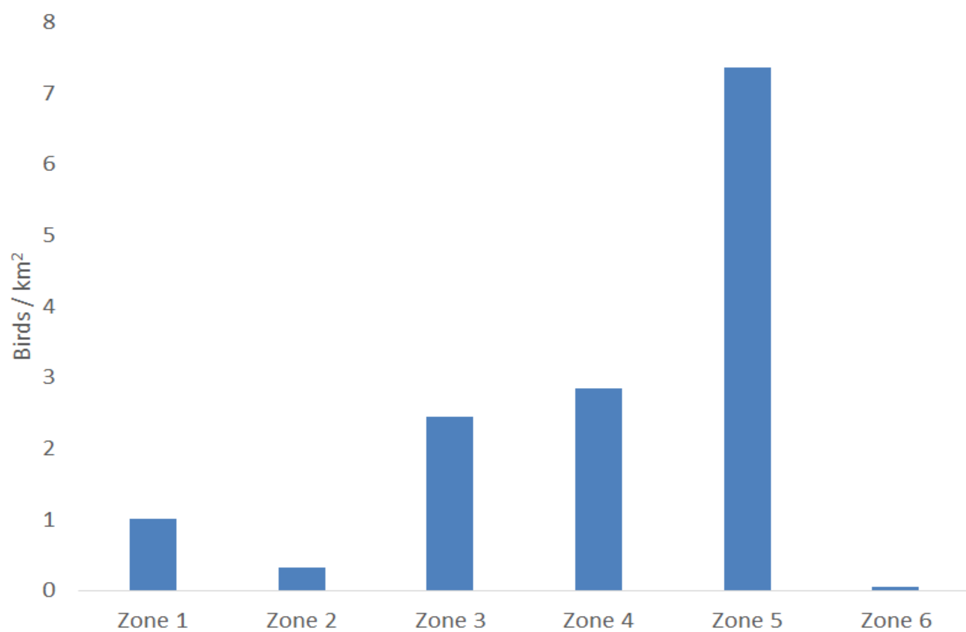

Fig. 12: Mean density of in-the-water cormorants by zone for fall 2014.

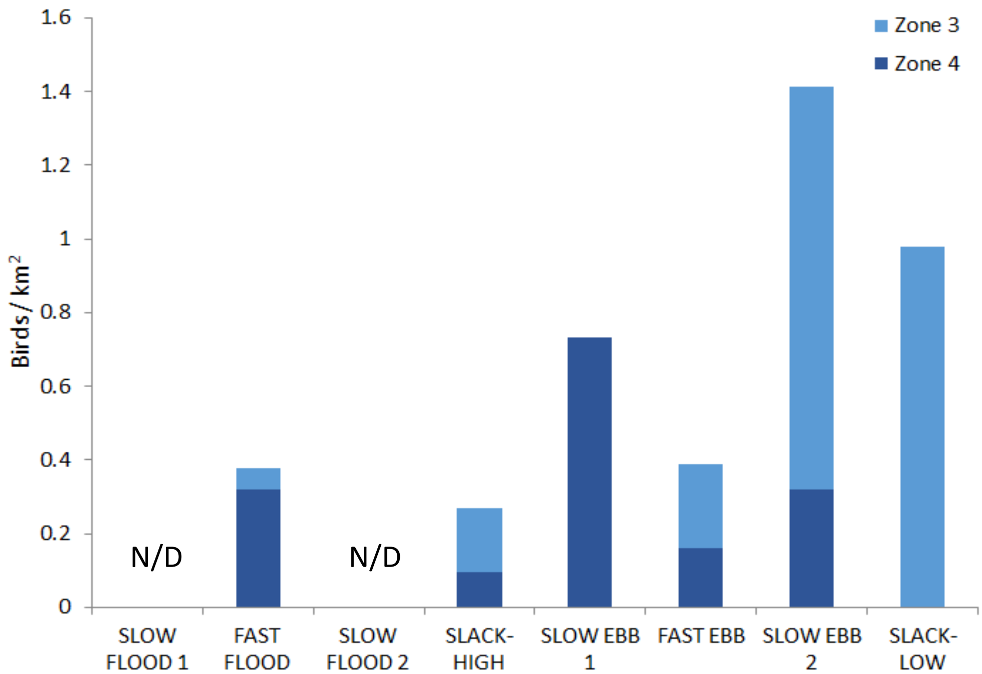

Fig. 13: Density of cormorants in-the-water in zones 3 and 4 during a tidal cycle (N/D = no data).

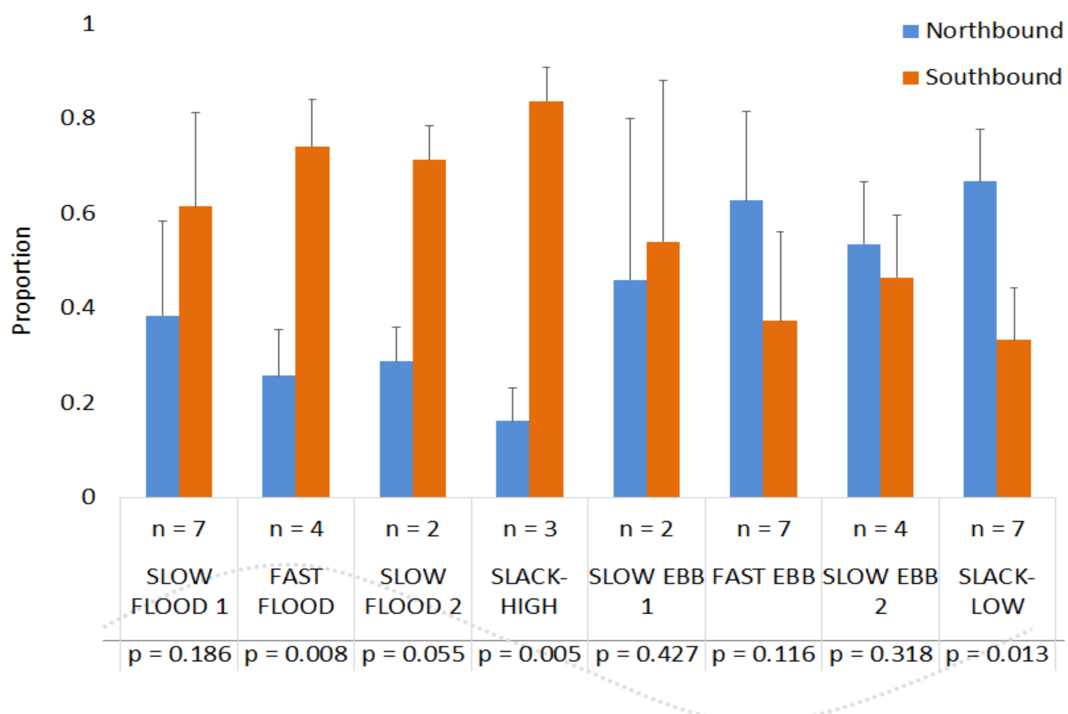

Figure 14: Proportion of cormorants flying north and south during a complete tidal phase in Cattle Pass.

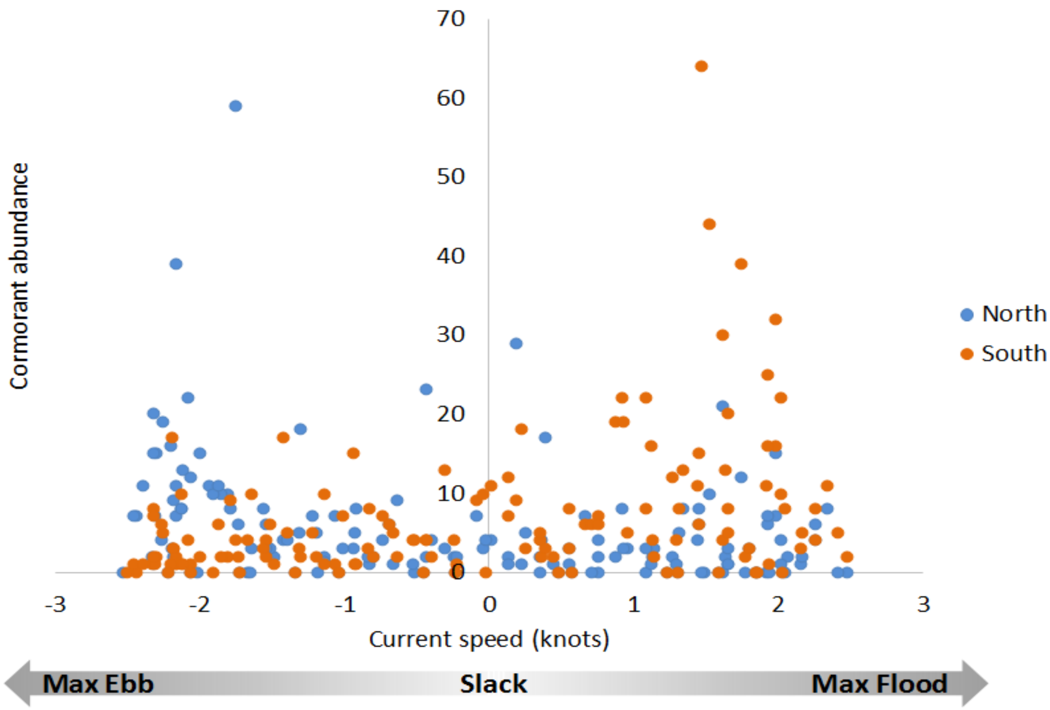

Fig. 15: Number of cormorants at Cattle Pass flying north and south at tidal current speeds between -2.53 to 2.52 knots.

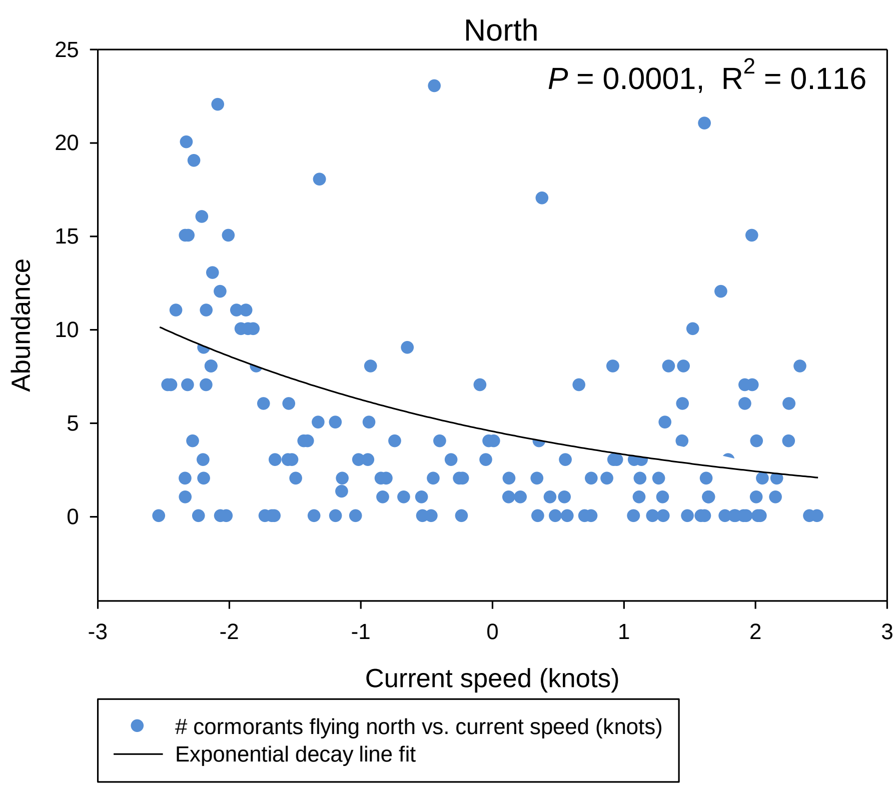

Fig. 16: Non-linear regression model of northbound cormorants at Cattle Pass.

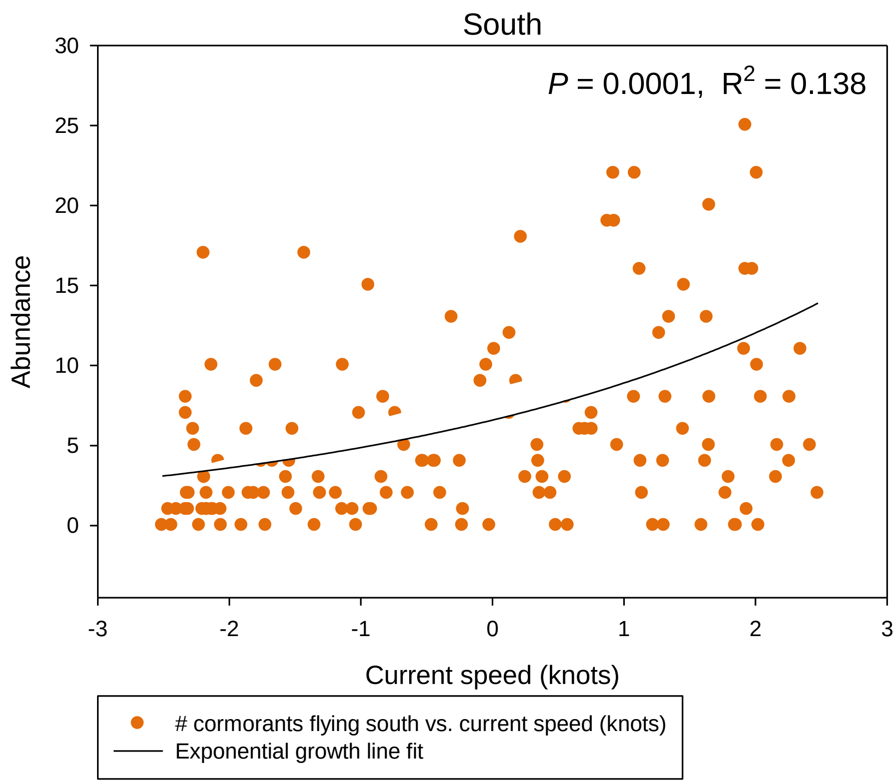

Fig. 17: Nonlinear regression model of southbound cormorants at Cattle Pass.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PDO	Neutral	Neutral	Neutral	Cool	Neutral	Cool	Cool	Cool	Cool	Warm
ENSO	Neutral	El Niño	La Niña	Neutral	El Niño	La Niña	La Niña	Neutral /Weak EN	Neutral	Neutral 58% EN
SeaTemp	Moderate	Warmer	Cooler	Moderate	Warmer	Cooler	Cooler	Mod to cooler	Mod to warmer	Warmest
FR flow	High	Low	High	Average	Low	Average	High	Low	Low to average	High
Salinity	Fresher	Saltier	Fresher	Saltier	Saltier	Fresher	Fresher	Average	Average	Fresher
DO	Lower	Lower	Higher	Lower	Higher	Higher	Higher	Mixed	Medium	Medium
Fall Trans	Early	Late	Early	Later	Early	Later	Earliest	Early	???	Middle
Phyto-plankton	Early Bloom	Mid Bloom	No Bloom	Early Bloom	Early Bloom	Early & Mid Bloom	Early Bloom	Early HUGE Bloom	Early to no bloom	Early bloom
Zoopk	Fewer		Highest	Fewer	High	Fewer	Fewer	Medium	Medium	Medium
Fish						High	Low	High	Low	Medium
Birds	Medium	Medium	Low	Low	Low	High	Medium	High	Low	Low
Cetac'n	Low	Low	Low	Low	Low	High	High	Low	Low	Low

Table 18: From the 2005 to 2014 PEF synthesis powerpoint created by mentors Drs. Jan Newton, Breck Tyler, and Matt Baker.