The Abundance, Distribution, and Interaction of Rhinoceros Auklets, *Cerorhinca monocerata* and Gulls, *Laridae* In San Juan Channel, WA

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ABSTRACT

Rhinoceros Auklets and gulls use the San Juan Channel as foraging grounds. They have shown complementary roles in feeding activity; a kleptoparasitism interaction. Few studies have characterized the Rhinoceros Auklets and gulls community distribution over the summer. Therefore, investigating the short-term variation in gulls and Rhinoceros Auklets abundance during the summer is important because it can help us understand the complete and present ecology. To determine the distribution of abundance of these seabirds, I performed standard strip-transect methods and analyzed tidal direction. In addition, we used past season data to determine a definitive pattern in abundance. The R^2 value provided by the line of regression was used to determine the anklets-gull relationship. Here we report and discuss the patterns in distribution and abundance across the San Juan Channel. A definite pattern for Anklets-gull relationship was not attained due to the low abundance of gulls throughout the channel.

1. INTRODUCTION

San Juan Channel located in the archipelago between Juan de Fuca Strait and southern Georgia Strait Fuca serves as a habitat for a large seabird population (Lewis and Sharpe 1987). Rhinoceros Auklets are known to use the areas around the San Juan Channel and the Haro Strait as foraging grounds (Wahl and Speich 1994).

Seabird abundance is known to fluctuate significantly over short time scales in Cattle Pass, a narrow, shallow passage in the San Juan Channel that features strong but variable tidal currents (Lewis and Sharpe 1987, Zamon 2003). Short-term aggregations of seabirds within this area have shown tidal patterns (Coyle et al. 1992, Irons 1998, Zamon 2000, 2003, Holm and Burger 2002). Moreover, seabird distribution has been associated with prey abundance (Vermeer et al 1987, Vlietstra 2005). It is believed that changes in currents speed and direction of tides affect distribution of fish schools and plankton making them more accessible to Rhinoceros Auklets and Gulls. Therefore, the large number of seabirds feeding activities in this area makes this an ideal zone to study auklet-gull interactions.

Rhinoceros Auklets and Gulls have shown complementary roles in feeding activity. The high visibility of the gulls can help signal other birds that there is food present (Hoffman *et. al* 1981), as well as provide other benefits from social foraging such as easier access to prey (Wittenberger and Hunt 1985; Gotmark *et. al* 1986; Valone 1989; Davoren and Burger 1999). The auklets, as well as other diving birds, help drive the fish to the surface, thus making the food available to gulls and other birds (Grover and Olla 1983; Zamon 2003). However, there is a high risk of kleptoparasitism by Gulls on Auklelts (Hennessey and Hunt 2010).

In this study, I further investigate the relationship between Auklets and Gulls in the San Juan Channel by exploring the effect of gull's density on rhinoceros auklets abundance. Past researches have investigated the distribution of diving birds in the San Juan Channel; however, few studies have characterized the Rhinoceros auklets community distribution over the summer.

In this paper, I present: (1) the short-term variation in gulls and auklets abundance in the San Juan Channel during the summer of 2011, (2) the correlation between abundance patterns and tidal direction, a (3) combination of past-seasons data observed in 2011 to determine a definitive pattern in abundance, and (4) the auklets-gulls interaction.

2. METHODS AND MATERIALS

2.1 Study Site

The San Juan Channel in Washington State was selected because of its archipelago location, complex topography, strong tidal currents, and its large number of seabirds. The archipelago location between eastern Juan de Fuca Strait and southern Georgia Strait (Figure 1) creates unequal tides, with flood currents moving approximately northward and ebb currents moving approximately southward. Cattle point (0.7 km wide) creates the strongest tidal interaction due to it is location at a juncture where the colder and saltier waters of the Strait of Juan de Fuca meet the warmer and fresher waters of the San Juan Channel *(*Nomera 2006).

2.2 Surveys

I used a standard strip-transect method to collect data on seabird's distribution in the San Juan Channel. Observations of seabird activity were made during August 3rd, 9th, and 16th of 2011. The Centennial University of Washington Research was used to perform the surveys from the North Station (48° 35.00' N, 123° 02.50' W) to the South Station (48° 25.20' N, 122° 56.60' W). The San Juan Channel was divided into six zones (Table 1, Figure 2). For purpose of analysis, the channel was divided into six geographic zones as determined in previous years (Nomura 2006, Behnke and Reynolds 2005). The total length of transect was 21.11 km.

Visual observations were recorded on a minute-by-minute basis. Cruises ran along the six transect zones, from north to south and south to north. The separation of observers into two groups allowed one group to observe off port side while the other one observed off the starboard side of the boat. Groups from each side of the boat counted and identify species diversity within the six transect zones using hand-held binoculars. The transect area was limited to 150 m to either side of the boat creating a 300 corridor of data collection (Figure 3); this corridor width allowed all species of birds to be identified accurately.

2.2 Data Analysis

I used density data analysis to determine the short-term variation in abundance of Rhinoceros Auklets and Gulls. Data collection of Gulls included: Glaucous-winged Gull, Heermann's gull, Mew Gull, California Gull, and Bonaparte's Gull.

In order to understand within-week variance in species abundance, I compared seabird densities against different aspects of tides, specifically current direction. Mr. Tides program permitted the measurement of the tide's direction for the times the surveys were collected. Current's direction was characterized as flood or ebb. Bar graphs were used to compare species abundance levels at different season of 2011. Past seasons consisted of March and July surveys data, collected by other students from Friday Harbor Laboratories. Heermann's gull data from August was not compared with past seasons because of its very low numbers in March and July; it is migratory bird.

The relationship between Rhinoceros Auklets and Gulls was analyzed between the following Gull species: Glaucous-winged, Herman's and California. The relationship was determined by plotting 36 data points which represent the number of abundance of each specie in each zone for 3 trips, times the two observers groups in each side of the boat. The relationship strength was measured by the R^2 value provided by the trend line. The closer the R^2 value to 1.00, the stronger the relationship.

3. RESULTS:

3.1 Rhinoceros Auklets and Gull Species distribution—August of 2011

During this study, Rhinoceros Auklets abundance varied spatially. Mean abundance for all surveys was much higher (> 185 birds / km^2) in the southern zones than in the northern zones (< 65 birds / km^2 ; Figure 6). But patterns in distribution also varied from week to week. For example, on August 3rd and 16th of 2011 abundance showed an apparent clear trend, gradually increasing from north to south (Figure 5). Densities were lowest in Zone 1, <15 birds/km^2, and highest in Zone 6 exceeding 230 birds per km^2. In contrast, the transect on August 9th of 2011 showed an apparent difference in distribution pattern. Maximum density was found in Zone 4, 549 birds / km^2, the highest density from all three surveys-transects. Density was also higher in Zones 1, 2, 3, 5, than on any other survey. The exception was Zone 6 were density was lower than any previous surveys.

In general, Gulls also showed a spatially distribution (Figure 8). Maximum abundance was higher in Zone 5 (> 140 birds/km^2; Figure 7). However, patterns in distribution varied from week to week. August 9th and 16th showed a clear correlation; both surveys recording 28 gulls per km^2 in Zone 1, gulls abundance decreased from Zones 1 to 2 and Zones 5 to 6, density abundance only increased from Zones 3 to 5 (Figure 8). Maximum abundance was recorded on August 9th, 2011, 150 gulls per km^2. However, mean density varied among species.

Glaucous-winged Gull distribution varied between southern outer zones and northern inner zones (Figure 10). Mean densities were lowest (< 5 birds / km^2) in Zones 1, 2, 3 and highest (> 17 birds / km^2) in Zones 4, 5, 6 (Figure 9). Pattern in distribution also varied from week to week. For example, August 3rd and 16th of 2011 abundance showed an apparent clear trend; gradually increasing from Zone 2 (> 1 bird / km^2) to Zone 5 (<105 birds/km^2), decreasing from Zone 5 to 6; and recording 10 birds per km^2 in Zone 2 (Figure 9). In contrast, August 8 showed an apparent gradually increasing trend from Zone 1 to Zone 6. Maximum density was found in Zone 6, 126 birds / km^2, the highest density from all three surveys-transects.

Heermann's gull also distribution varied southern-outer zones and northern-inner zones (Figure 12). Mean densities were lowest in Zones 1, 2, 3 (< 0.87 birds / km^2) and highest Zones 4, 5, 6 (> 5 birds / km^2; Figure 11). However, distribution pattern varied from week to week. August 3rd and 16th showed an apparent gradually increasing trend from Zones 1 to 6 (Figure 11). The exception was zones 2 and 3, where Heermann's gulls were not seen within these zones. In addition, the August 16th survey did not see Heermann's gull within Zone 4. In contrast, the transect on August 9th was the only survey that recorded gulls in all six zones. Its density gradually increased from Zone 3 to Zone 5. Zones 2 and 3 remained constant, 0.50 birds per km^2. Maximum density was found in Zone 5, 46 birds / km^2, the highest density from all three surveys-transects.

California Gull abundance varied spatially. Mean distribution gradually increased from Zone 1 to 6 (Figure 14). The exception was in Zone 2 where the mean density was the lowest, 0.7 birds per km^2. Pattern in distribution still varied from week to week. In August 3rd , lowest density was found in Zones 1, 2, 3 4, 5 (<2 birds per km^2). Density stayed constant in Zones 2, 3, 4 (0.5 birds per km^2, Figure 13). Maximum density was found in Zone 5 (36 birds per km^2). In August 9th, density gradually increased from Zones 1 to 5 (>1.2 birds / km^2). The exception was in Zone 2 (0.5 birds / km^2). August 3rd and 16th recorded the same density of 2.2 birds / km^2 in Zone 6. August 16th of 2011, density increased gradually from Zone 1 to 6, with the exceptions of Zones 2 and 5 (Figure 13). Maximum density was found in Zone 6, 62 birds per km^2, the highest density from all three surveys-transects.

3.2 Rhinoceros Auklets and Gulls Relationship

Rhinoceros Auklets and Gulls overall relationship during the summer of 2011 was weak (<0.1R^2). Glaucous-Winged Gull and Rhinoceros Auklets had the strongest relationship than any other gull, with a value of 0.152 R^2(Figure 15). In addition, its patterns in abundance per zones during variations in condition from week to week, were also the same. Both recorded the same pattern of gradually increasing from north to south on August 3rd and 16th of 2011. However, Glaucous-winged gull abundance increased from Zone 2 to Zone 5 (Figure 9). Rhinoceros Auklets abundance distribution increased from Zone 1 to Zone 6(Figure 5).

California Gull had the second strongest relationship, 0.0932 R^2 (Figure 17). Not patterns between abundance in zones and dates were found.

Heermann's gull had the weakest relationship, 0.0459 R^2 (Figure 16). Heermann's gull and Rhinoceros Auklets did not have similarities in patterns between week to week variations. But both showed an apparent gradual increasing pattern from Zone 1 to Zone 6 on August 3rd of 2011 (Figure 5,11). However, Heermann's gulls were *not* seen in Zones 2 and 3 (Figure 11).

Rhinoceros Auklets maximum density in Zone 4 did not match with other gulls' maximum-density zones.

3.3 Rhinoceros Auklets and Gull species abundance—March and July of 2011

By comparing surveys from this summer with past seasons of 2011, Rhinoceros Auklets and Glaucous winged-Gulls total population abundance varied per month.

Rhinoceros Auklets density abundance increased gradually from March (>53 birds per km^2) to August (<704 birds per km^2; Figure 11). In contrast, Glaucous winged

Gulls population stayed relative constant during the months of March and July (~56 birds per km^2). Its maximum population was in August, 147 birds/km^2.

4. RESULTS

The pattern of high mean densities of rhinoceros and gulls observed in the southern San Juan Channel is probably because of the higher current speed due to the decrease length in width of Zones 4, 5, and 6. Cattle Pass is located in the southern zones. Higher currents in Cattle Pass lead to more birds because of the increase in prey abundance (Zamon 2003, Spatz 2007, Wang 2008). Prey abundance increase due to the tidal changes that alters the distribution of plankton in the channel by forcing certain plankton species to the surface (Zamon 2002). As a result, the interrelationship of physical oceanography and plankton distribution affects the distribution of planktivorous seabirds (Vermeer et al. 1987; Haney 1991).

The distinct distribution patterns on different survey days are probably due to change of direction in the tidal current. When the tidal current was ebb, most birds appear to move from south out of the channel into Strait of Juan de Fuca. In contrast, when the tidal current was flood, higher numbers of birds were found around the beginning area of Cattle Pass. This divergent distribution due to the change in direction is affected by its prey shift in location. Heermann's gull and California gull are relative small birds that feed on small fish and plankton (Vlietstra 2005). Plankton cannot move independently of currents. Therefore, tidal stage has a correlation with the feeding activity of certain seabirds (Zamon 2003). As a result, tidal coupling exist between the predators and prey.

The differences in the distribution and abundance of Rhinoceros Auklets and gulls are probably due to the distinguishable feeding behavior. Gulls are surface feeders; it uses its high visibility to locate and track subsurface, even though they may not be able to reach them (Hoffman *et. al* 1981). Therefore, gulls are limited in its feeding areas; it depends on diving birds to drive food like fish to the surface (Grover and Olla 1983; Ostrand 1999; Zamon 2003). This limited feeding skill affects the equal distribution of gulls in the San Juan Channel. In contrast, Rhinoceros Auklets, a diving bird, has more access to prey in variety of feeding-water-habitats; due to its diving feeding-technique (Wahl and Speich 1994). Rhinoceros Auklets spend 90% of their dive time in the top 10m even though they are able to dive to depths of 60m (Burger et al. 1993).

The variant abundance levels of Rhinoceros Auklets and gulls during the past seasons of 2011 are probably due to bird migration and variations in habitat conditions. Heermann's gull migrates to the San Juan Channel region during mid to late summer from their breeding grounds in Mexico (Sibley 2003). California gull also follows seasonal migration patterns; during sprig they are concentrated in southern California and northern Mexico (Pugesek 1999). Glaucous-winged gull is typically non-migratory and it is a resident of the state of Washington (Reid 1988). Therefore, slight changes in Glaucous-winged gull abundance are probably due to change in habits conditions like an increase of prey availability due to the seasonal variation.

The weak relationship between gulls and Rhinoceros Auklets was probably due to the limited numbers of surveys collected and the seasonal migration of some birds which resulted in small numbers (36 data points, Figure 4) for the analysis in auklets-gulls interaction.

The findings presented here support earlier studies; higher mean densities of gulls were also found in the southern zones of the San Juan Channel (Levato 2007). Levato agrees that gulls were abundant in Cattle Pass and the Strait of Juan de Fuca. She also states that gulls were not seen as often in the northern parts of San Juan Channel.

My recommendations for future studies on the distribution of Rhinoceros Auklets and gulls involve increasing the number of sighting surveys, data from different current's direction and speed, and variation between times when the surveys are collected.

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TABLES:

Zone	*Latitude and Longitude*	*Area*
Upper boundary of 1	48°35'N, 123°02,54'W	1.26 km^2
Boundary between 1 and 2	48°33'N, 122°59,67'W	0.96 km^2
Boundary between 2 and 3	48°32'N, 122°58'W	0.93 km^2
Boundary between 3 and 4	48°31'N, 122°56,89'W	1.68 km^2
Boundary between 4 and 5	48°28'N, 122°57	1.17 km^2
Boundary between 5 and 6	48°26'N, 122°56'72"W	0.45 km^2

Table 1. Latitude and Longitude of zones.

FIGURES:

Figure 1: The San Juan Archipelago

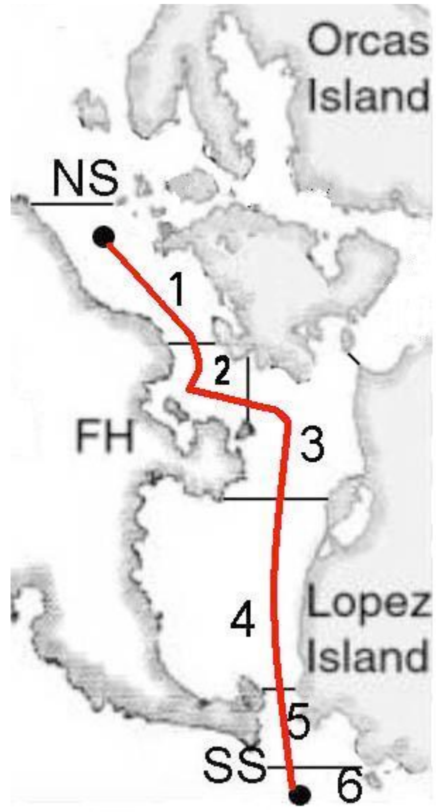

Figure 2: Map of the Study Site in the San Juan Channel with the six zones marked

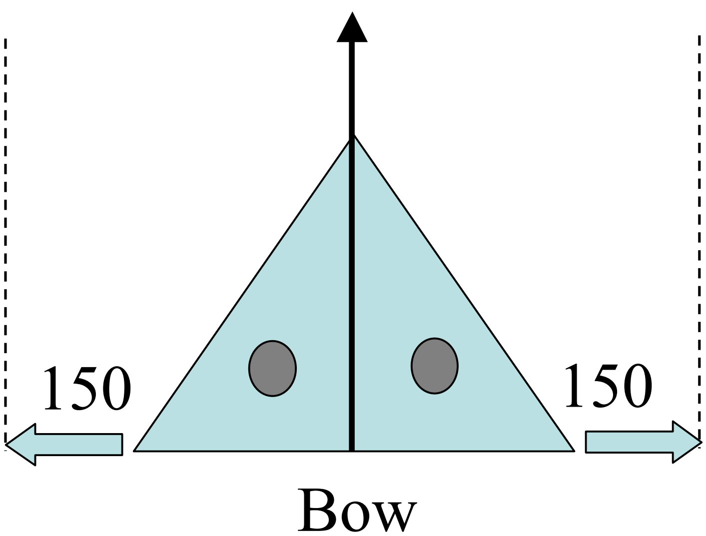

Figure 3: The strip transect method with 2 groups of observers and a 300m corridor

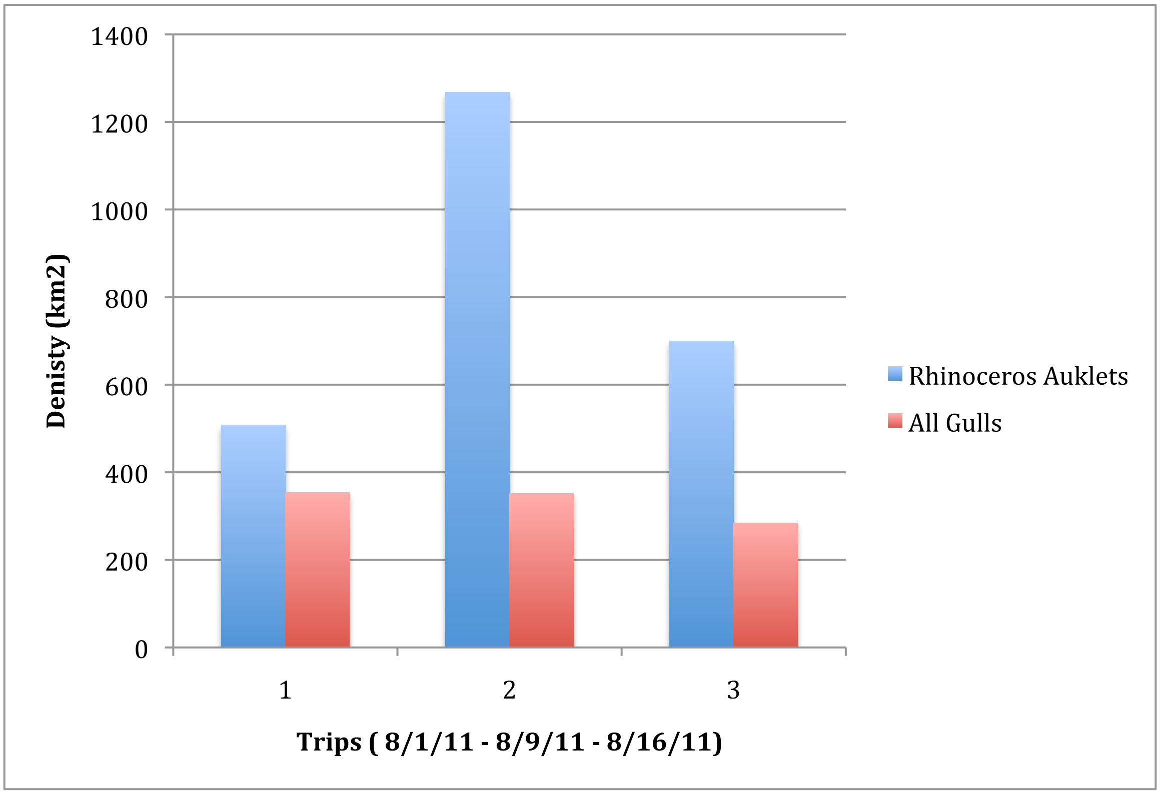

Figure 4. Total abundance of Rhinoceros Auklets and Gulls in this study.

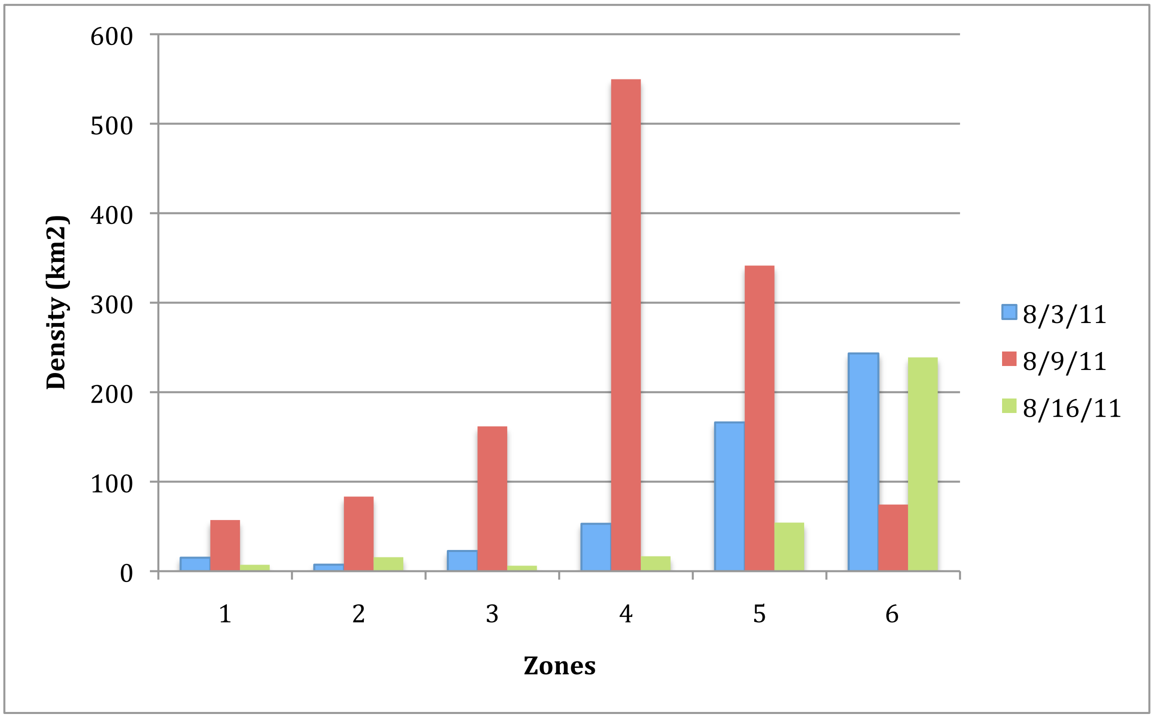

Figure 5. The distribution and abundance of Rhinoceros Auklets across zones for each cruise date.

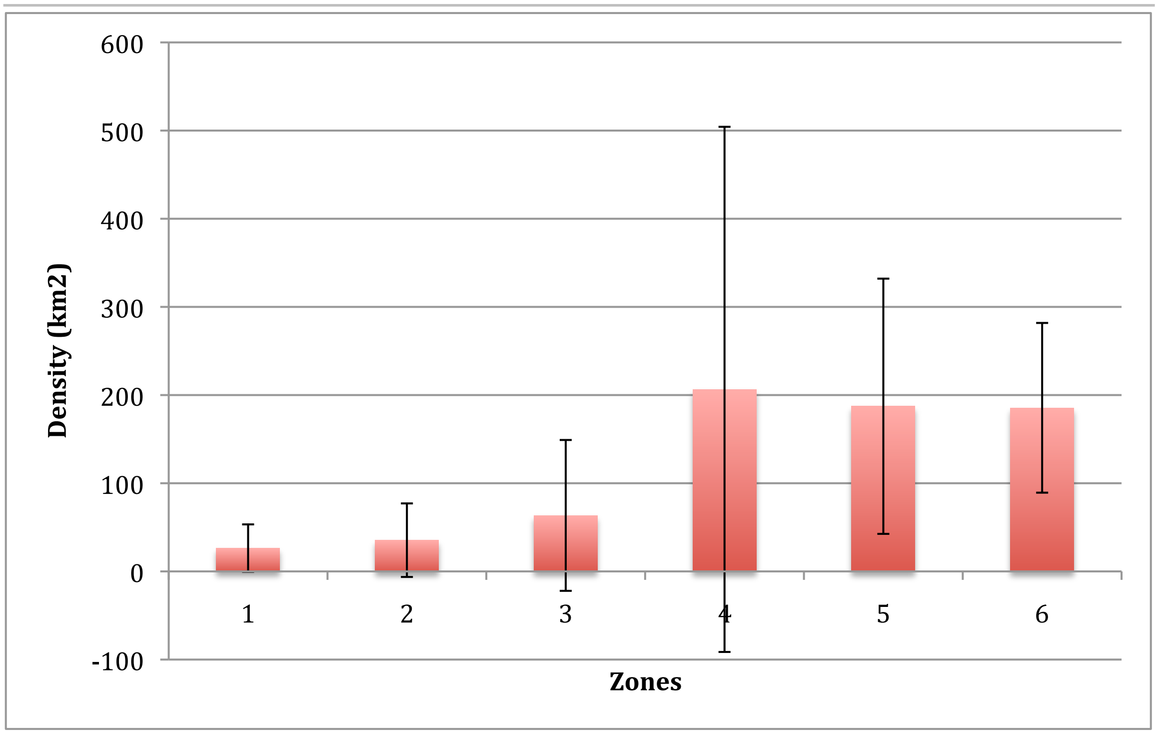

Figure 6.The mean abundance and distribution of Rhinoceros Auklets across zones.

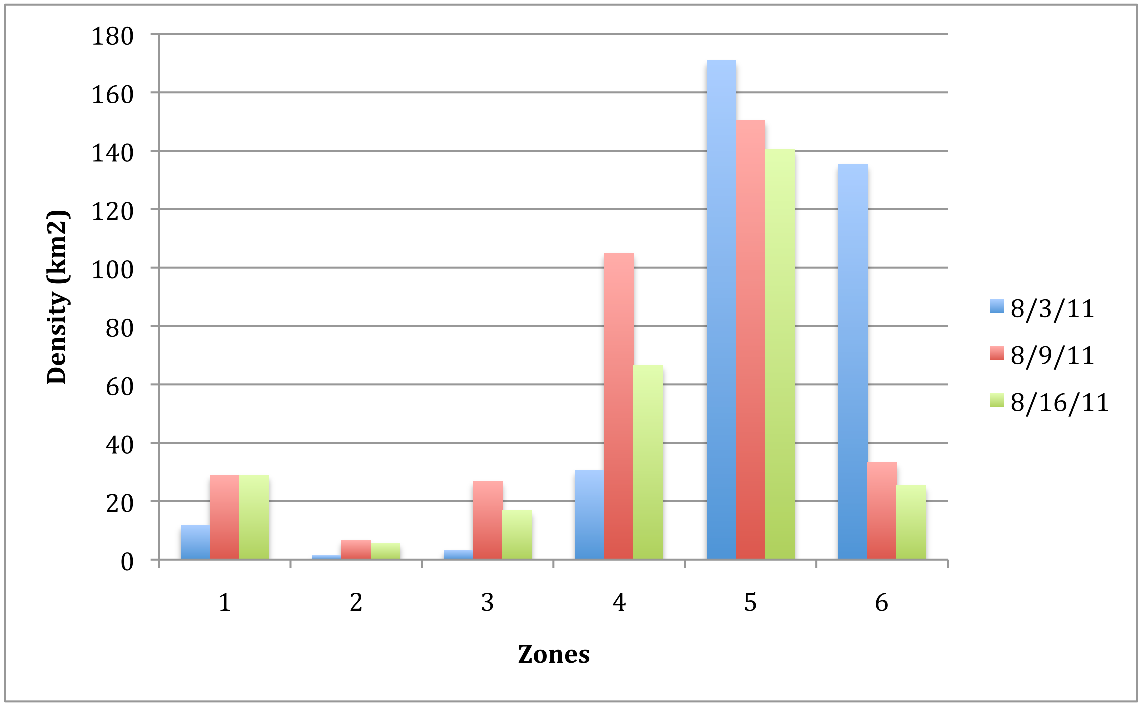

Figure 7.The distribution and abundance of all gull species across zones for each cruise date

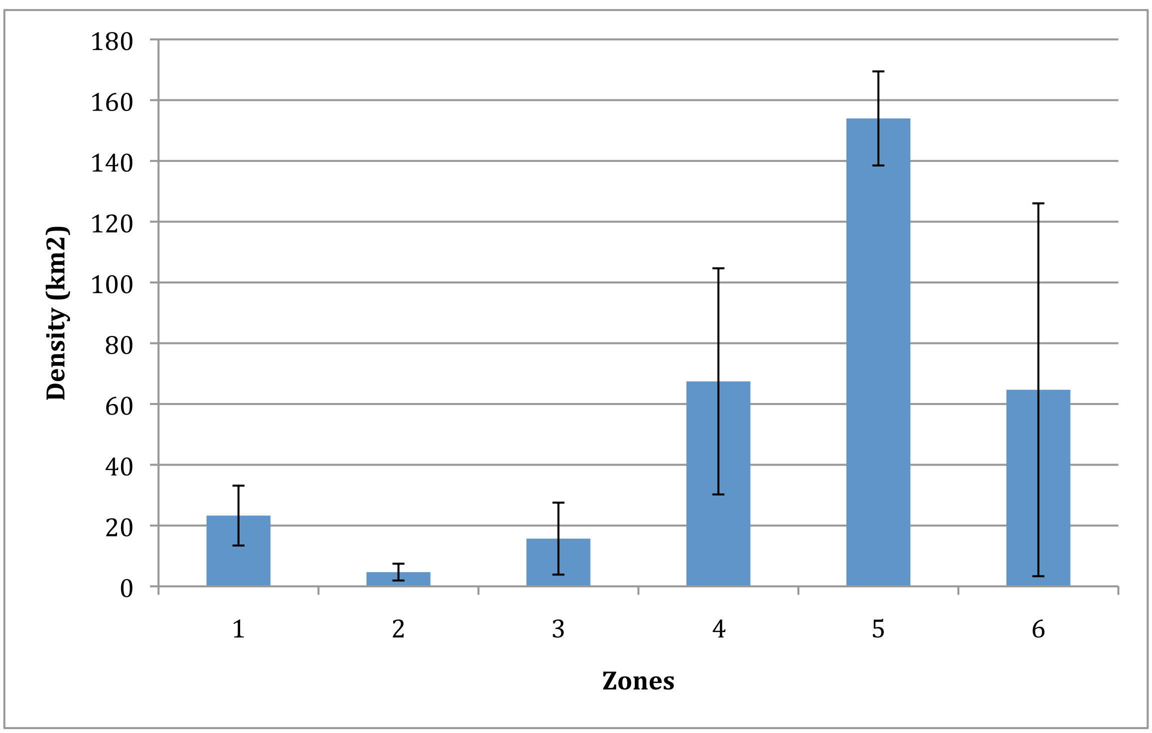

Figure 8.The mean abundance and distribution for all gull species across zones.

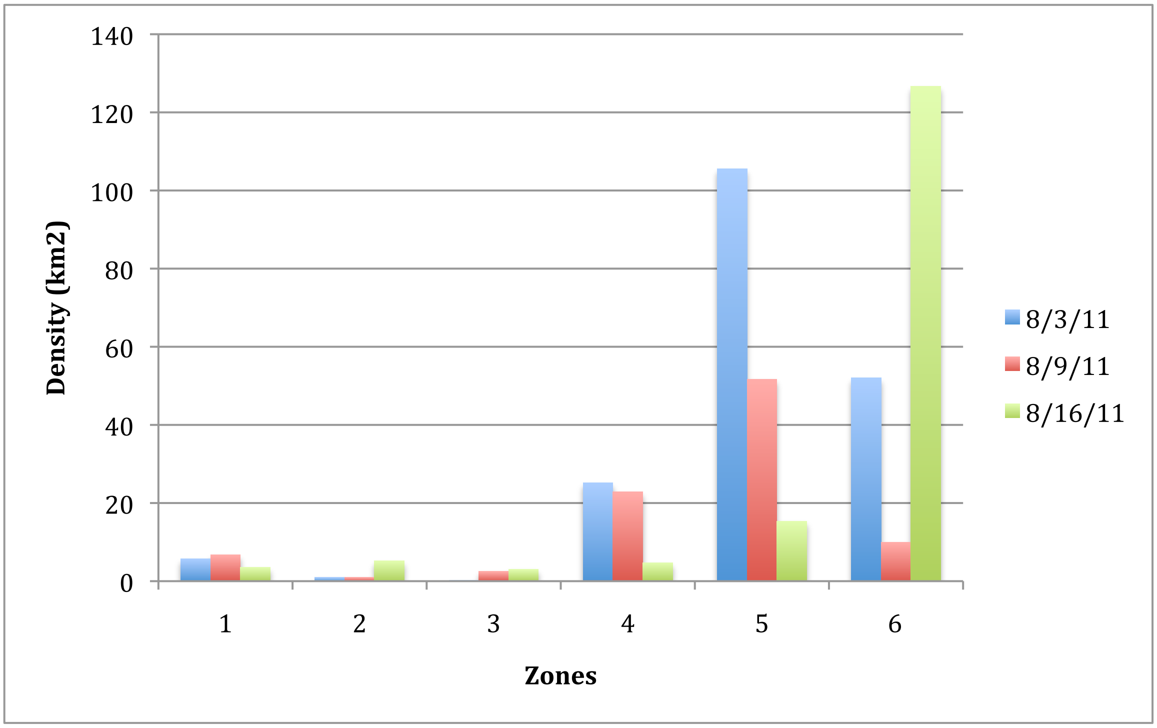

Figure 9.The distribution and abundance of Glaucous-winged Gull across zones and for each cruise date.

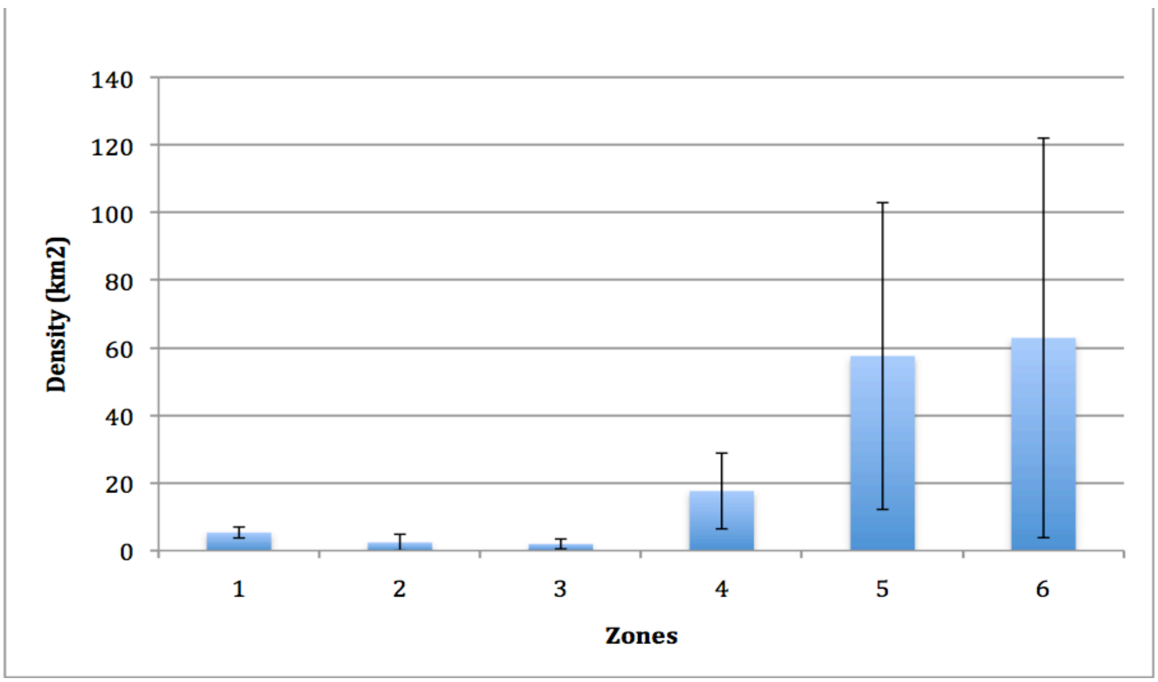

Figure 10.The mean abundance and distribution of Glaucous-winged Gull across zones.

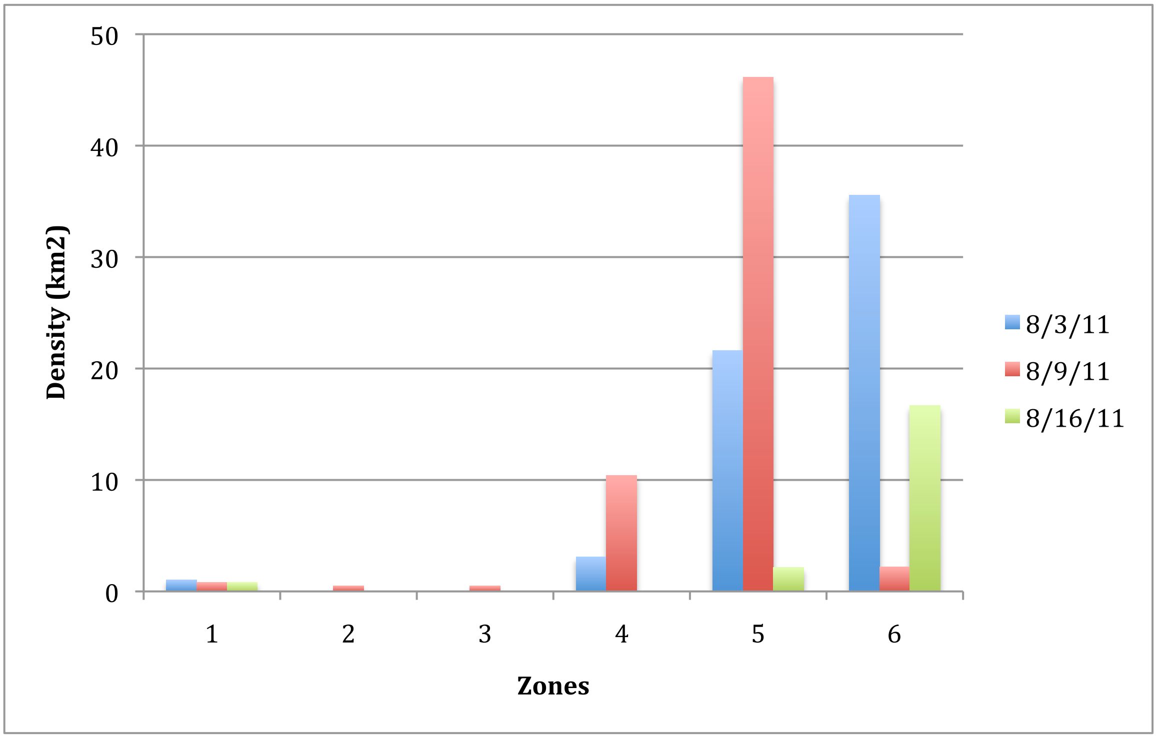

Figure 11.The distribution and abundance of Heermann's gull across zones and for each cruise date.

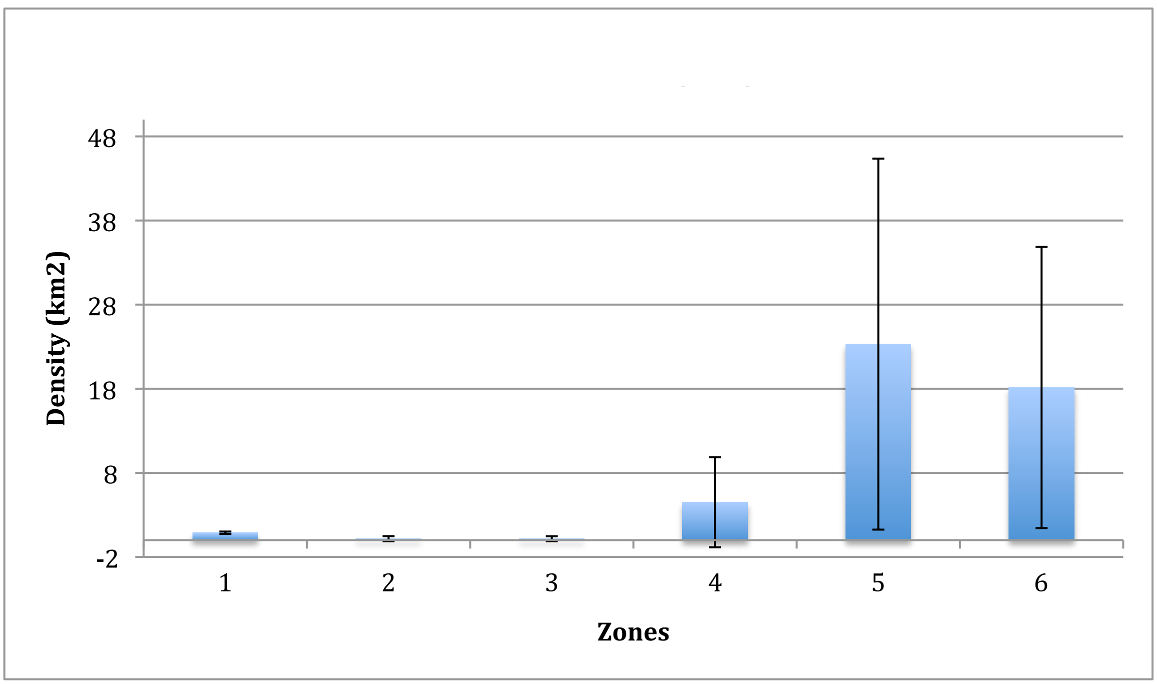

Figure 12.The mean abundance and distribution of Heermann's gull across zones.

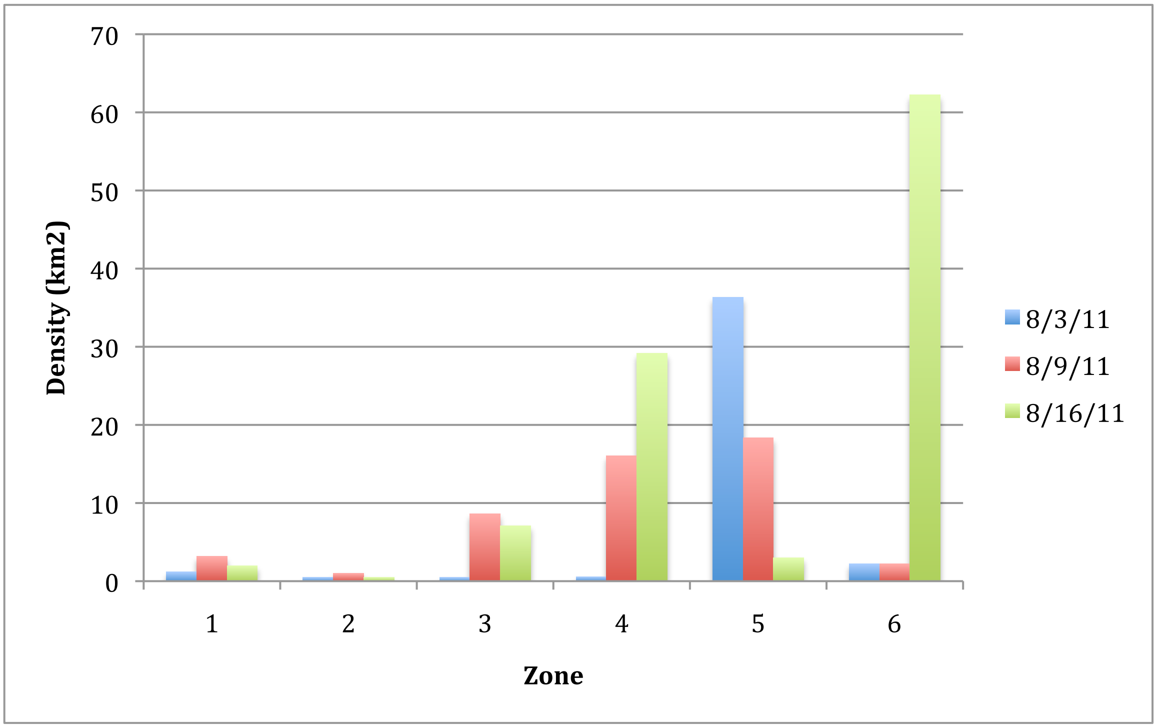

Figure 13.The distribution and abundance of California Gull across zones and for each cruise date.

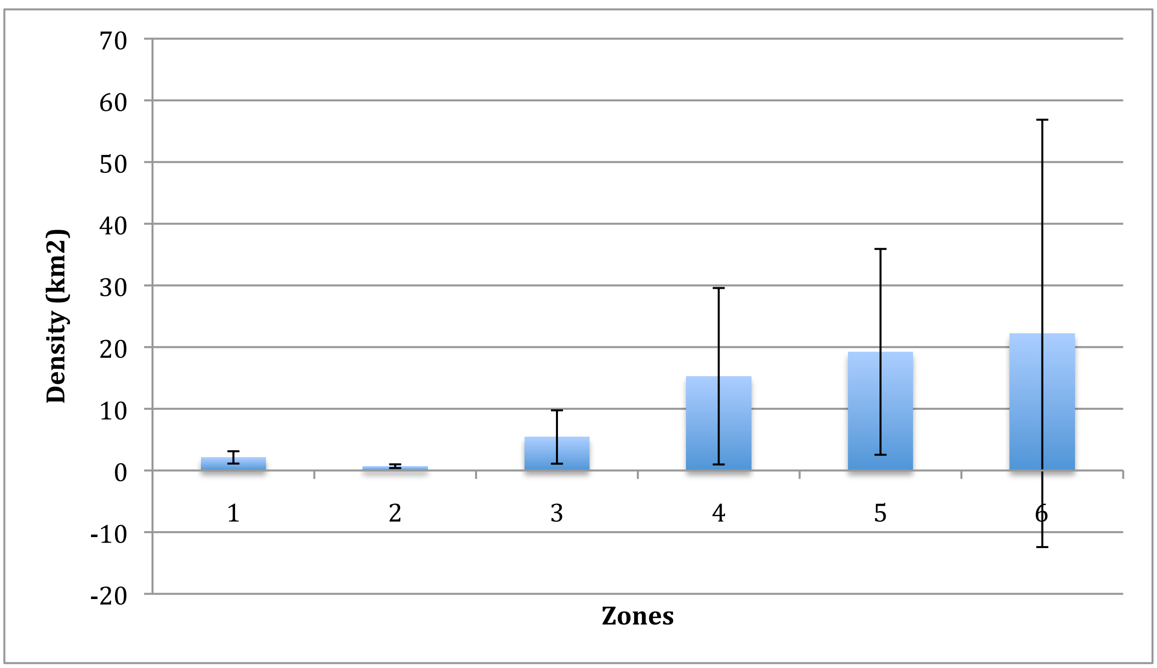

Figure 14.The mean abundance and distribution of California Gull across zones.

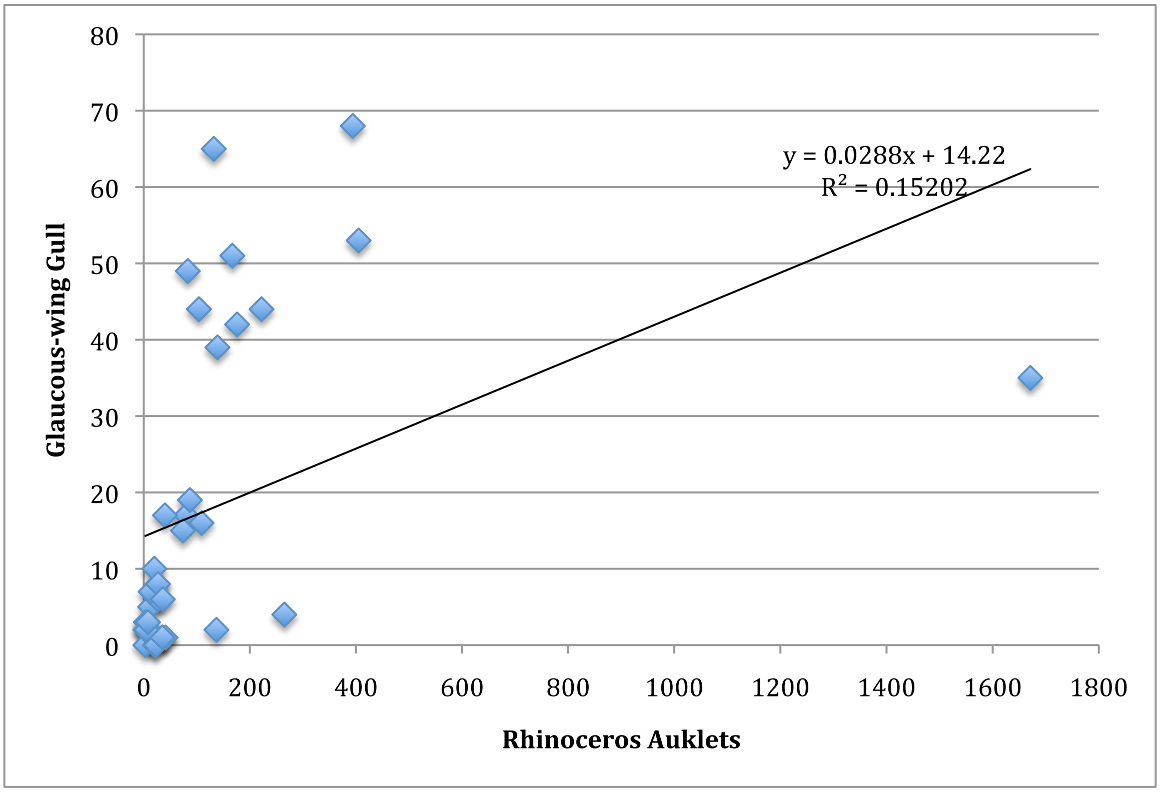

Figure 15.The relationship between Glaucous-winged Gull and Rhinoceros Auklets.

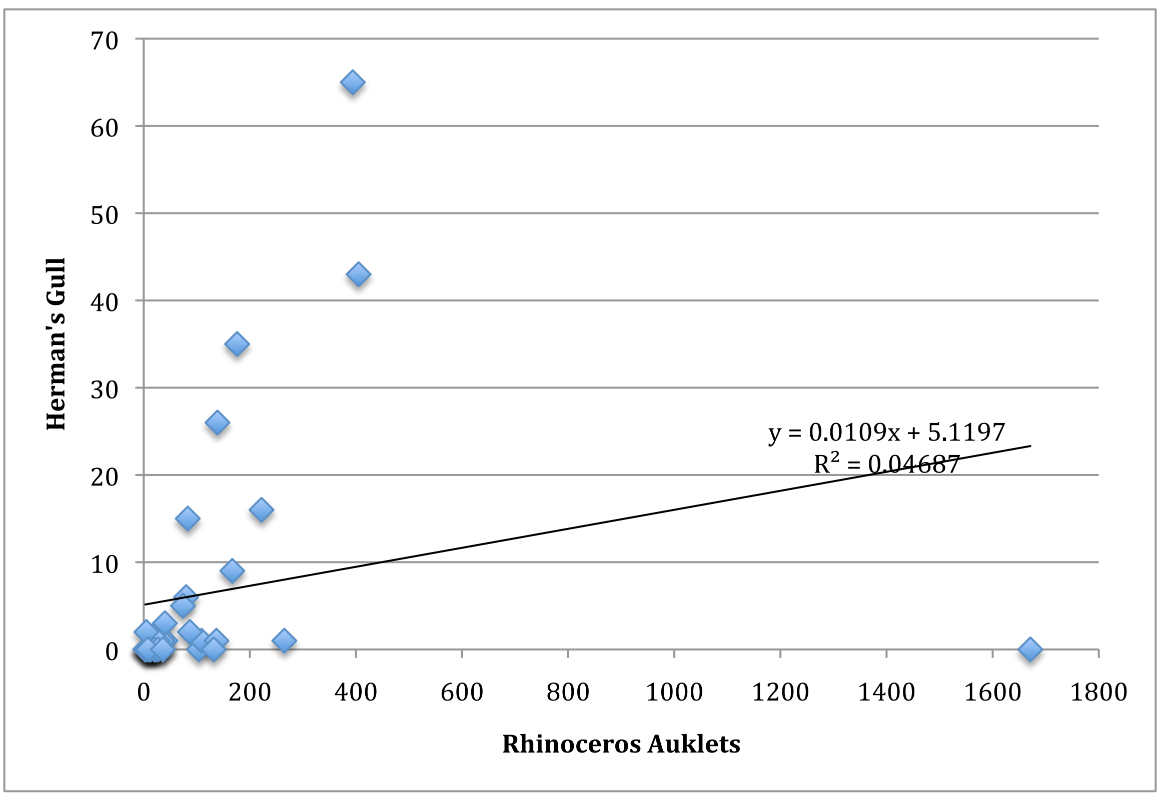

Figure 16.The relationship between Heermann's gull and Rhinoceros Auklets.

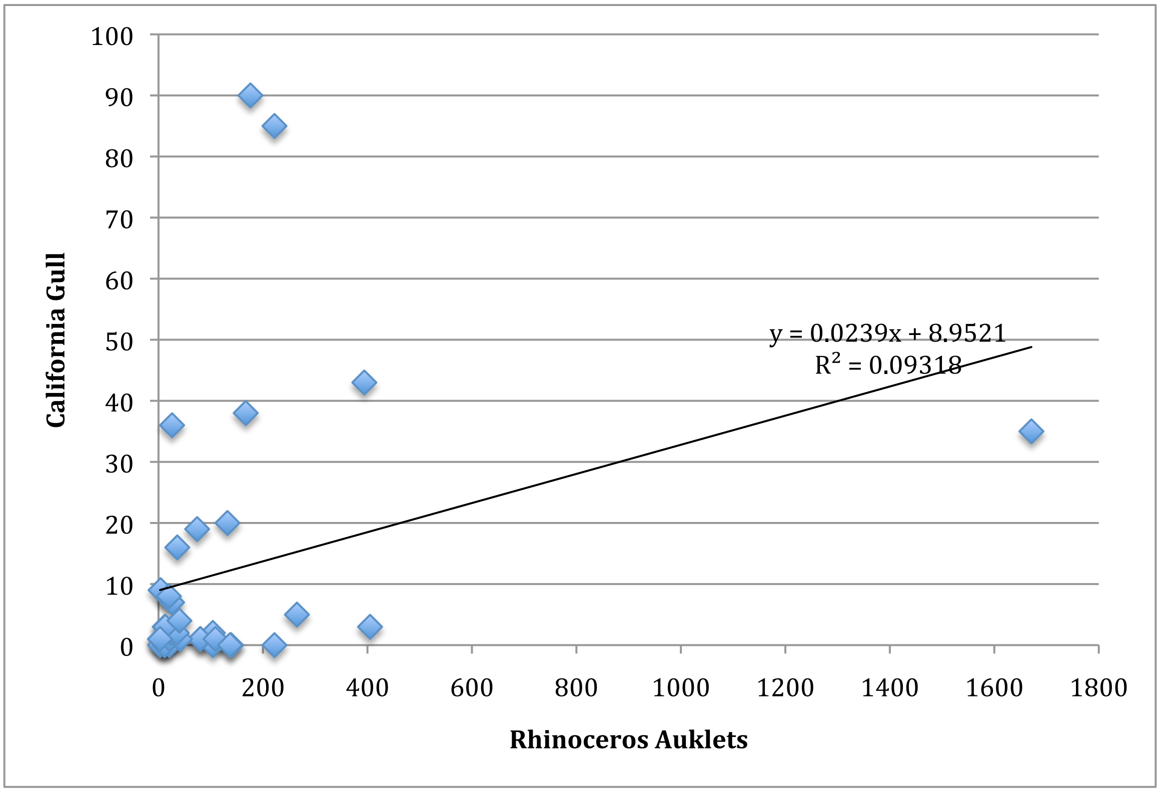

Figure 17.The relationship between California Gull and Rhinoceros Auklets

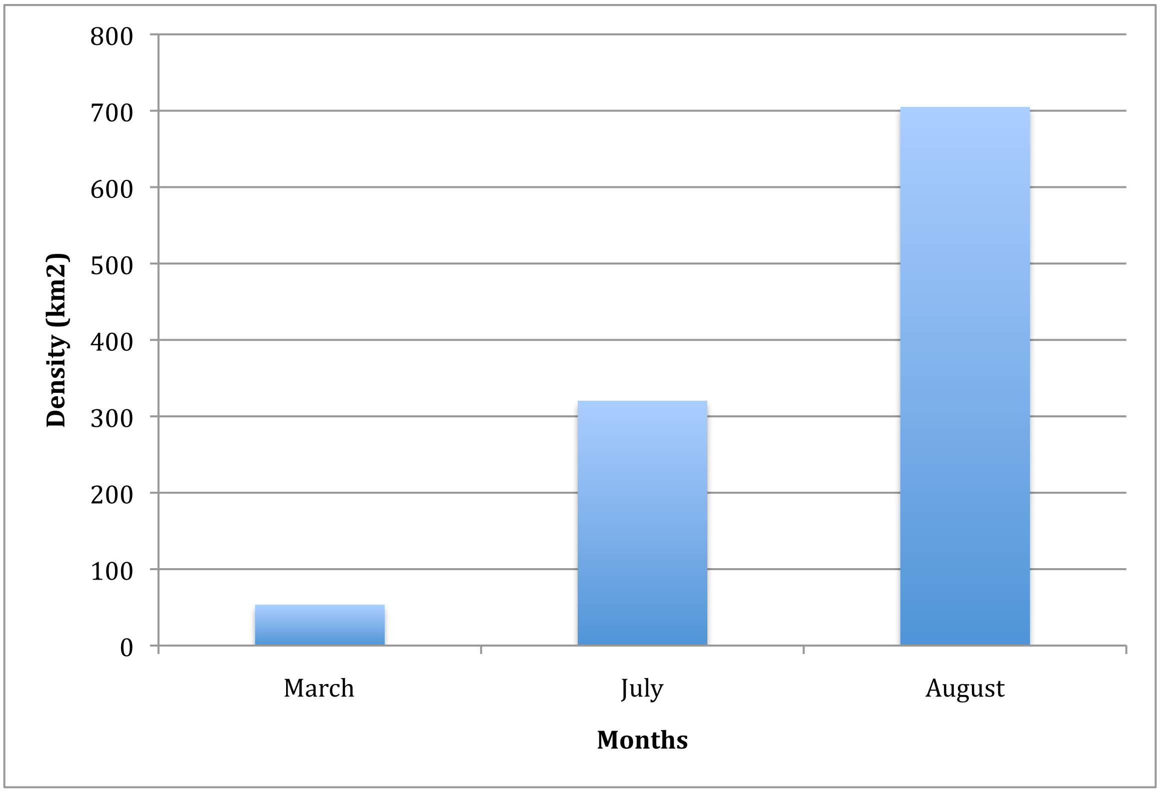

Figure 2.The abundance of Rhinoceros Auklets across months.

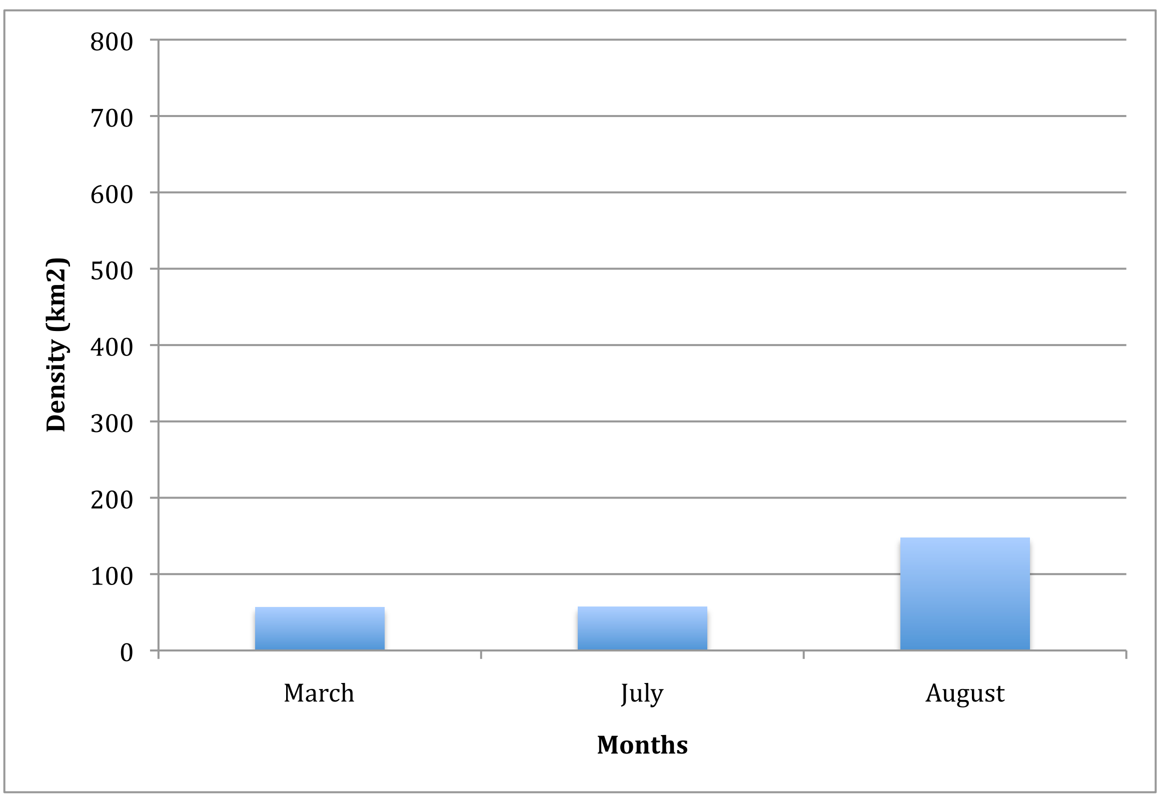

Figure 3.The abundance of Glaucous-winged gull across months.