

Spring 2016

Intercolony Comparison of Diets of Western Gulls in Central California

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DOI: <https://doi.org/10.31979/etd.x89d-fj2b>
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INTERCOLONY COMPARISON OF DIETS OF WESTERN GULLS IN
CENTRAL CALIFORNIA

A Thesis

Presented to

The Faculty of the Department of Biological Sciences

San José State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Anne L. Cassell

May 2016

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The Designated Thesis Committee Approves the Thesis Titled

INTERCOLONY COMPARISON OF DIETS OF WESTERN GULLS IN
CENTRAL CALIFORNIA

by

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May 2016

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ABSTRACT

INTERCOLONY COMPARISON OF DIETS OF WESTERN GULLS IN CENTRAL CALIFORNIA

by Anne L. Cassell

As human populations expand, they force free-ranging animals to adapt to an increasingly urban environment, resulting in changes in diets, reproductive success, and mortality. The diets of two western gull (*Larus occidentalis*) breeding populations in central California were compared. One colony, Año Nuevo Island (ANI), is 1 km from shore and within 30 km of a municipal landfill. The other colony, Southeast Farallon Island (SEFI), is located 45 km off the shore of San Francisco, CA. Given the proximity of ANI to the shore and the landfill, I predicted that gulls from ANI would have more garbage in their diets. Indeed, gulls from ANI consumed over three times more garbage. Twenty-three percent of wet diets from gulls at ANI contained garbage, whereas garbage made up only 6% of wet diets from gulls at SEFI. Despite the appearance of garbage in gull diets, birds from both colonies consumed a range of marine prey, and Clupeiformes, Euphausiacea, and Gadiformes were important to both colonies. Isotopic values (^{15}N and ^{13}C) measured in gull feathers were similar between colonies, suggesting that gulls from both populations consume similar prey from the marine environment during the non-breeding phase. The reliance on stable, easily accessible food from landfills during the breeding season may be an important adaptation for western gulls to cope with urbanization and declines in prey species in the California Current during the energy-intensive chick-rearing period.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Scott Shaffer, for his support and advice throughout this process. Without his guidance and patience, this project would not have been possible. He shared invaluable knowledge, from bird handling to statistical analysis to writing, as well as spending considerable time in the field to help make this project successful. I would also like to thank my committee members, Dr. Leslee Parr and Dr. Jaime Jahncke. Dr. Parr, thank you for supporting me when I realized my interests had changed after beginning my graduate career, for helping me to see this through to the end, and for your excellent comments and advice on during the writing process. Dr. Jahncke, thank you for helping make the work at the Farallones possible, for coordinating the use of Point Blue's prey identification lab, and for providing valuable comments to improve this manuscript. I would also like to thank Dr. Hillary Young for providing advice and assistance with the isotope analysis. I am grateful for the excellent work done by Meredith Elliott and the interns at the Point Blue prey identification lab. Without their persistence and attention to detail, the diet analysis would not have been possible. I want to thank Michelle Hester, Ryan Carle, and Jessie Beck from Oikonos for providing logistical support in getting to and working on Año Nuevo Island and for sharing their knowledge and love of the island and its birds with us. I would also like to thank Dr. Patricia Morris and Dr. Patrick Robinson for assisting with the permitting process, transport to Año Nuevo Island, and sharing their knowledge and love of the park's pinnipeds. This project would not have been possible without the assistance of Pete Warzybok and Russell Bradley from Point Blue, who assisted with this project on the

Farallones and provided feedback on the project's direction and this manuscript. I would like to thank my lab mates, including Stacy Moskal, Catherine Yi, and especially Caitlin Kroeger, Corey Clatterbuck, and Emma Kelsey, for their assistance in the field and for their sense of humor. I could not have done it without your help. Dr. Magali Lucia also provided excellent assistance in the field and shared her knowledge of bird handling with me. I greatly appreciate the work of Lawrence Young, RVT, LATg, CPIA, and the San José State University (SJSU) Institutional Animal Care & Use Committee for their dedication to animal welfare and for ensuring that this project was carried out as humanely as possible.

I want to thank my family. To my parents, Dona and Peter McShane, for always encouraging my love of science, supporting and believing in me, and babysitting on numerous occasions during this project—thank you. To my wonderful husband, Bryan Cassell, for his support, patience, and willingness to do much more than his share of the housework and child care while I was writing this and also for his sense of humor, which helped me keep everything in perspective—thank you. I would like to thank my children for making me laugh and for their attempts to add their own edits to this manuscript. I want to acknowledge my in-laws for providing their support, especially all the babysitting—their help made finishing this project possible.

Lastly, this project would not have been possible without generous financial support from the California State University Council on Ocean Affairs, Science, and Technology; Dr. Earl H. Myers and Ethel M. Myers Oceanographic and Marine Biology Trust; and SJSU Biological Sciences Department.

TABLE OF CONTENTS

LIST OF TABLES	ix
LIST OF FIGURES	ix
Introduction.....	1
Materials and Methods.....	6
Location	6
Adult Capture.....	7
Adult Sample Collection.....	8
Wet Diet Collection	8
Stable Isotope Analysis.....	9
Data Analysis	10
Results.....	12
Wet Diet.....	12
Intercolony Comparison of Diets During the Non-Breeding Period	15
Morphology.....	18
Influence of Non-Breeding Diet on Gull Body Mass	22
Discussion.....	23
Summary	23
Differences in the Frequency of Prey Items in the Wet Diet	24

Stable Isotope Analysis (Non-Breeding Diet)	27
Morphometrics	28
Relationship Between Isotopic Values and Morphometrics	29
Conclusion	30
References	33
Appendix A: Table of Prey Items	41

LIST OF FIGURES

- Figure 1. Frequency of prey orders in diets of adult western gulls from Año Nuevo Island and Southeast Farallon Island from 2013..... 13
- Figure 2. Differences in feather isotope signature from western gulls at two colonies... 16
- Figure 3. Body size vs. mass. Males (■) are larger and heavier than females (●)..... 21

LIST OF TABLES

Table 1 Chi-Squared Analysis of the Differences in Frequency of Diet Items Between the Colonies	14
Table 2 Wet Diet Diversity by Colony.	14
Table 3 T-Test and Power Analysis of the Difference in Average Number of Prey Found in Each Regurgitant by Colony.....	15
Table 4 Two-Way ANOVA Results Between $\delta^{13}\text{C}$ and Sex:Location and $\delta^{15}\text{N}$ and Sex:Location.	16
Table 5 Power Analysis of $\delta^{13}\text{C}$ ANOVA Comparing $\delta^{13}\text{C}$ to Sex and Location.	17
Table 6 Power Analysis of $\delta^{15}\text{N}$ ANOVA Comparing $\delta^{15}\text{N}$ to Sex and Location	17
Table 7 Two-Way ANOVA Examining Differences in Mass Based on Sex, Location, and the Interaction of the Two.....	18
Table 8 Results of a Two-Way ANOVA Showing the Influence of Sex and Location on Skeletal Body Size.....	19
Table 9 Summary of T-Test and Power Analysis on Mass When Examined by Sex and Location.....	20
Table 10 Summary of T-Test Power Analysis of Skeletal Body Size vs. Sex and Location	20
Table 11 Actual and Predicted Body Masses of Male and Female Western Gulls Nesting on ANI and SEFI.	22
Table 12 ANOVA Results Comparing the Difference Between Actual and Expected Masses Based on Skeletal Size.	22
Table 13 Results of the Multiple Regression Model of Mass vs. Body Size + $\delta^{13}\text{C}$ + $\delta^{15}\text{N}$	23

Introduction

Species best adapted to urban environments are 1) generalist species, which can catch and use a variety of prey items, including anthropogenic food sources (Aragona & Setz, 2001; Auman, 2008; Bicknell, Oro, Camphuysen, & Votier, 2013; Bonier, Martin, & Wingfield, 2007; Kristan, Boarman, & Crayon, 2004; Pierotti & Annett, 2001; Yom-Tov, Yom-Tov, & Baagøe, 2003), 2) species adapted to habitats that are patchy or fragmented in either space or time (Marzluff, 2001; Okecha & Newton-Fisher, 2006), or 3) those adapted to wide ranges of latitudes or altitudes (Bonier et al., 2007). Generalist predators are classically defined as those species with a broad foraging niche under a wide range of environmental conditions that can utilize many different prey resources. Furthermore, these animals encounter variation in food supply across their home range and likely have adapted to exploiting urban environments to supplement food intake (Bonier et al., 2007). In contrast, specialists have a narrow food niche and one or few prey species. Thus, specialists perform well in consistent environments but cannot adapt as quickly to changing environmental conditions such as urbanization.

There are several examples of generalist predators that thrive in urban environments. Maned wolves (*Chrysocyon brachyurus*) in Brazil eat more trash during the summer tourist season, when there is a consistent source of food available in trash bins, rather than searching for natural prey sources (Aragona & Setz, 2001). Coyotes (*Canis latrans*) also increase the amount of anthropogenic food in their diet when living near urban settings (Morey, Gese, & Gehrt, 2007). Similarly, red foxes (*Vulpes vulpes*)

(Yom-Tov et al., 2003), Eurasian badgers (*Meles meles*) (Yom-Tov, 2003; Yom-Tov et al., 2003), wolves (*Canis lupus*), golden jackals (*Canis aureus*), and striped hyenas (*Hyaena hyaena*) have all increased in body size in response to increases in the availability of anthropogenic food sources (Yom-Tov, 2003). Population densities of some generalist carnivores, such as the red fox, raccoon (*Procyon lotor*), and coyote, have increased in urban environments (Šálek, Drahníková, & Tkadlec, 2015). Olive baboons (*Papio anubis*) eat more trash during the dry season, when their natural prey is scarce (Okecha & Newton-Fisher, 2006).

Birds can also adapt to urban environments. Desert eagle owls (*Bubo ascalaphus*) primarily consume Norway rats (*Rattus norvegicus*) and house mice (*Mus musculus*), which are introduced species associated with urban settings (Sándor & Moldován, 2010). Common raven (*Corvus corax*) populations are larger in urban areas due to heavy reliance on anthropogenic food sources (Kristan et al., 2004). Some bird species are so well adapted to living with humans that it is reflected in their names, e.g., house sparrows (*Passer domesticus*), house wrens (*Troglodytes aedon*), house finches (*Haemorhous mexicanus*), barn swallows (*Hirundo rustica*), and barn owls (*Tyto alba*). Some of these birds even have cities or towns listed as their primary habitat (Kaufman, 1996).

Some seabird species are also well adapted to human interaction. For example, some albatrosses and petrels rely heavily on fisheries' discards, and their populations have increased in areas where these discards are abundant (Bertellotti & Yorio, 1999; Bicknell et al., 2013; Calixto-Albarrán & Osorno, 2000; Martínez-Abraín, Maestre, & Oro, 2002). Gulls (family Laridae) are commonly associated with urban environments.

They can exploit both fisheries' waste (Bertellotti & Yorio, 1999; Buckley, 1990; Furness, Ensor, & Hudson, 1992; Martínez-Abraín, Maestre, & Oro, 2002; Oro, Bosch, & Ruiz, 1995) and garbage sources such as landfills (Belant, Ickes, & Seamans, 1998; Frixione, Casaux, Villanueva, & Alarcón, 2012; Weiser & Powell, 2010) and common picnic sites (Auman, Bond, Meathrel, & Richardson, 2011). Gulls are considered generalist predators (Frixione et al., 2012; Osterback et al., 2013; Pierotti & Annett, 1991). They consume several naturally occurring prey, including fish, invertebrates, intertidal mollusks, other seabirds, insects, earthworms, and carrion, as well as a variety of human garbage (Annett & Pierotti, 1999; Bernhardt, Kutschbach-Brohl, Washburn, Chipman, & Francoeur, 2010; Bertellotti & Yorio, 1999; Brousseau, Lefebvre, & Giroux, 1996; Curtis, Galbraith, Smyth, & Thompson, 1985; Ellis, Chen, O'Keefe, Shulman, & Witman, 2005; Hunt & Hunt, 1976). The natural prey of gulls can be patchy in both space and time (Hunt & Hunt, 1976), but gulls have adapted to foraging in pelagic, freshwater, and terrestrial habitats. Gulls can lose nest space (or gain it by nesting on buildings) and experience greater predation pressure by terrestrial carnivores, yet thrive in urban settings (Pierotti & Annett, 2001). Numerous gull species have expanded their range into urban environments farther inland because they can rely on human-disturbed habitats (Belant et al., 1998; Frixione et al., 2012). Consequently, several gull populations are increasing around urban areas (Belant et al., 1998; Bernhardt et al., 2010; Rock, 2005). Gull population increases are attributed to a combination of increased legal protection for migratory birds, the cessation of egg collection by humans, and an increase in food from refuse (Belant et al., 1998; Pierotti & Annett, 2001). Increased food

subsidies from human refuse (hereafter, collectively called garbage) are thought to be an important contribution to the success of urban gulls (Belant et al., 1998; Frixione et al., 2012; Pierotti & Annett, 2001). Given that more than half the human population lives within 200 km of the ocean (Hinrichsen, 1999) and most gull species are coastal, human interactions have a measureable effect on gull ecology.

Gulls change foraging tactics and locations to maximize foraging efficiency (Sibly & McCleery, 1983; Snellen, Hodum, & Fernandez-Juricic, 2007). Many gull species preferentially feed during low tide, when there is greater access to energy-dense foods (Ellis et al., 2005; Irons, Anthony, & Estes, 1986; Sibly & McCleery, 1983). Spring tides can expose especially valuable prey not usually available (Irons et al., 1986), leading to daily and seasonal feeding patterns. Thus gulls are adept at changing foraging tactics to use whatever food is available, an advantage in an urban environment (Greig, Coulson, & Monaghan, 1986).

Breeding success is highly correlated with diet composition (e.g., percentage of forage fish vs. percentage of refuse in diet) in many species, including gulls (Batzli, 1986; Cury et al., 2011; Golet, Kuletz, Roby, & Irons, 2000; Hlista, Sosik, Martin Traykovski, Kenney, & Moore, 2009; Hunt & Butler, 1980; Kilpi & Ost, 1998; Kowalczyk, Chiaradia, Preston, & Reina, 2014; Kristan et al., 2004; Lindley et al., 2009; Pierotti & Annett, 1990; Sorensen, Hipfner, Kyser, & Norris, 2009). Some gull studies show that a high refuse diet is positively correlated with reproductive success (Hunt, 1972; Kilpi & Ost, 1998; Martínez-Abraín, Maestre, & Oro, 2002; Oro et al., 1995; Weiser & Powell, 2010), while others show the opposite (Annett & Pierotti, 1999; Blight,

2011; Blight, Drever, & Arcese, 2015; Pierotti & Annett, 1990, 1991, 2001; Ramos, Cerda-Cuellar, Ramirez, Jover, & Ruiz, 2010). This influence has led to the “junk food hypothesis,” which states that feeding on prey containing inferior nutrients and energy can retard overall breeding success (Alverson, 1992; Davis, 1996; Gremillet et al., 2008). Despite the potential negative consequences of eating garbage, this behavior is maintained in the population, probably because natural foods vary with environmental conditions (Annett & Pierotti, 1999). Understanding how garbage use affects breeding success is important for understanding species distribution and differences in intercolony breeding success.

In this study, I compared the diet and breeding success of western gulls (*Larus occidentalis*) from two colonies in central California. One population was located on Año Nuevo Island (ANI), which is located 1 km off the coast and approximately 20 km from a metropolitan center. This gull population experienced remarkable growth, from about 400 breeding adults in the early 1980s to a high of 2,400 in 2005. By 2012, the population had decreased to 2,000 breeding adults (Hester, Carle, Beck, & Calleri, 2013). The second population was located on Southeast Farallon Island (SEFI); it reached a maximum population size of 25,000 breeding adults in the 1980s and has declined since (Penniman, Coulter, Spear, & Boekelheide, 1990; Warzybok & Bradley, 2011). The SEFI population is the largest colony of western gulls in their range, accounting for 30% of the total population, so its decline is cause for concern. Nest productivity also varies between colonies. ANI typically had higher mean productivity and fewer poor years. The lowest observed productivity on ANI was 0.9 chicks per nest (Hester et al., 2013),

whereas in bad years, SEFI had almost complete reproductive failure (Warzybok & Bradley, 2011). Good years on ANI have also been more productive than good years on SEFI, with ANI producing nearly 2.0 chicks per nest at the highest productivity measured (Hester et al., 2013), whereas SEFI has barely exceeded 1.0 in recent seasons (Warzybok & Bradley, 2011). A decline in natural prey species, especially anchovies, may be related to the lower reproductive rates at SEFI (Warzybok & Bradley, 2011). Thus, a comprehensive analysis of intercolony diets was warranted to examine whether possible differences in diet explain variations in breeding success between populations.

I hypothesized that gulls from ANI rely more on human refuse in their diet than the gulls from SEFI. This hypothesis was tested by comparing 1) the frequency of prey species in regurgitations during the breeding season, 2) stable isotope ratios of ^{15}N and ^{13}C from feathers as a proxy for non-breeding season diet, and 3) body condition of adult gulls in both colonies to determine if there was a difference in size or mass between colonies. This study has implications for understanding seabird diets in general and comparisons at the population level. Finally, this information may inform resource managers about the use of garbage in diets of free-ranging species and the influence of urbanization on wildlife.

Materials and Methods

Location

Western gulls were studied in two breeding colonies along the central California coast. The first, ANI (37.11°N, 122.34°W), is a 4-ha island located 1 km off Año Nuevo Point in Año Nuevo State Park and 26 km north of the Santa Cruz Resource Recovery Facility (36.973931, -122.104879). Gulls at ANI were captured at their nests during the

incubation and chick-rearing periods between May and July 2013. Nest productivity of captured gulls was compared to productivity of a non-disturbed area of the island to ensure that research activities were not negatively impacting the nests in the study area.

A second population of gulls was studied at SEFI, which is a 31-ha island located 48 km west of San Francisco, CA, near the continental shelf (37.70°N, 123.00°W). SEFI is a National Wildlife Refuge covered with low vegetation and rocks, and gulls nest all over the island. In addition to the gulls, SEFI is home to 12 other seabird species and five marine mammal species. Gulls were captured at several sub-colonies on the southeast side of the island during May 2013. These dates included the mid-to-late incubation phase for western gulls. The productivity of study nests was compared to the island-wide productivity to determine if research activities negatively impacted study nests.

Adult Capture

Adults were captured at their nests using 0.75 m x 0.75 m noose carpets made from steel mesh netting and loops tied from 50 lb test fishing line. Each noose carpet was attached with a 4-m line to a 3-kg dumbbell to keep a captured gull from flying away with the noose carpet. Noose carpets were deployed in front of or adjacent to a nest. Consequently, birds had to walk across the carpet to return to a nest and, subsequently, their feet would become entangled. Once caught, the gulls were restrained by a researcher while a second researcher untangled them. Adults were then placed in a cardboard pet carrier or a pillowcase and moved away from the rest of the colony for the collection of measurements and diet collection. Either unprotected nests were guarded by a researcher or chicks were also removed and returned at the same time as the adult.

Noose mats were never left unattended to prevent accidental capture or injury of adults or chicks.

Adult Sample Collection

Body morphometrics were collected to provide a cursory metric of body condition (Labocha & Hayes, 2011) and to assign gender based on body size (Hunt, Wingfield, Newman, & Farner, 1980; Pierotti, 1981). Gulls were weighed (± 20 g) in a pillowcase suspended from a Pesola spring scale (capacity 2,500 g, increments 20 g, Pesola, Baar, Switzerland). Morphometric measurements were collected using dial calipers (± 0.1 mm; CaliMax), including the total skull length (skull and beak); minBill, the narrowest height on the bill; maxBill, the maximum height of the bill; exposed culmen, the length from where the skin meets the bill to the tip of the bill; and tarsus, the length from the ankle to the knee. After the measurements were taken, three to four body contour (non-flight) feathers were collected from the head or breast and stored in a plastic bag. After all sampling was complete, the birds were released near their nests.

Wet Diet Collection

Wet diets (i.e., regurgitates) were collected opportunistically from gulls that regurgitated during capture. Each sample was collected and placed in a separate, sterile plastic bag and then frozen until analysis. Additional opportunistic, confirmed western gull samples were also collected from nearby gulls that were not captured. All regurgitations were stored in plastic bags and marked with the date and location of collection as well as the specific bird or nest they were collected from, if known.

During analysis, each wet diet sample was thawed and weighed prior to prey identification. All prey identification was performed at Point Blue Conservation Science (Petaluma, CA) by trained staff. Fish were identified to the lowest taxonomic level by examination of body scales or, when present, otoliths (i.e., ear bones). Cephalopods (squid and octopuses) were identified by beak size and shape, which is the only indigestible feature of octopuses and squid. Crustaceans were identified by shell or carapace. All garbage was identified from obvious particles of plastic, glass, Styrofoam, foil, or non-natural diet items, such as bacon or cooked beef and chicken.

Stable Isotope Analysis

The analysis of stable isotope signatures in gull breast feathers was used as a proxy of diet during the non-breeding season, when gulls molt old feathers and replace them with new feathers containing the isotopic signatures of prey consumed at the time the feathers are grown (Bearhop et al., 1999, 2006; Bond & Jones, 2009; Sorensen et al., 2009). Stable isotope ratios in feathers remain unchanged from when the feathers are formed. Feather samples were analyzed using a mass spectrophotometer elemental analyzer (Control Equipment Corp CEC 440HA) at the Marine Science Institute at the University of California, Santa Barbara.

$\delta^{13}\text{C}$ was calculated by:

$$\delta^{13}\text{C} (\text{‰}) = \frac{\left[\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{sample}} - \left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{standard}} \right]}{\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{standard}}} \times 1000$$

$\delta^{13}\text{C}$ values were used to classify a marine diet based on ($\delta^{13}\text{C}$ -12 to -16), mixed ($\delta^{13}\text{C}$ -16 to -20), and terrestrial from ($\delta^{13}\text{C}$ -20 to -26) (Bearhop et al., 1999).

$\delta^{15}\text{N}$ was calculated by:

$$\delta^{15}\text{N} (\text{‰}) = \frac{\left[\left(\frac{^{15}\text{N}}{^{14}\text{N}} \right)_{\text{sample}} - \left(\frac{^{15}\text{N}}{^{14}\text{N}} \right)_{\text{standard}} \right]}{\left(\frac{^{15}\text{N}}{^{14}\text{N}} \right)_{\text{Air}}} \times 1000$$

$\delta^{15}\text{N}$ was converted to a trophic level using the formula (Sydemann, Hobson, Pyle, & McLaren, 1997):

$$TL = 2.5 + \frac{[\delta^{15}\text{N}] - 11.2}{3.1}$$

Where 2.5 is the assumed trophic value for krill, 3.1‰ is the isotopic fraction factor, and 11.2‰ is the average $\delta^{15}\text{N}$ of krill.

Data Analysis

All statistical analyses were carried out using the program R, version 3.1.0. The measurements of culmen, tarsus, headBill, minBill, and maxBill were normalized using the formula $z = \frac{x-\mu}{\sigma}$, where x is the measurement, μ is the mean, and σ is the standard deviation. The scores were combined using principal component analysis to create a composite body size index using the function `prcomp` in R. A correlation table for the components was created using the function `cor`. A two-way ANOVA using the function `aov` was used to compare mass or bodyScore to sex and location. A two-way ANOVA was also used to compare $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ between sexes and populations. Effect scores (eta^2) and partial effect scores (eta^2P) for the ANOVAs were calculated using `etaSquared` from the library `lsr`. Student's two sample t-tests were used to compare averages between mass and predicted mass by location, $\delta^{13}\text{C}$, and $\delta^{15}\text{N}$ averages between locations and sexes as well as between the average numbers of prey items found in each sample

between the two colonies using the function `t.test`. Effect size was calculated using the `cohen.d` function from package `effsize`, and the results were used to calculate power using `pwr.t2n.test` (if sample sizes were different) or `pwr.t.test` (if sample sizes were the same) from the package `pwr`.

A linear regression of mass vs. body size + $\delta^{13}\text{C}$ + $\delta^{15}\text{N}$ was performed using the function `lm` and compared to the linear regression of mass vs. body size using ANOVA to determine if diet + body size produced a better prediction of mass compared to body score alone. Effect size for the regression model was calculated in Excel using the formula: $f^2 = \frac{R^2}{1-R^2}$, and R^2 was obtained from the output of the function `lm` in R. Power analysis was run for the regression analysis using `pwr.f2.test` from the package `pwr` in R.

A Chi^2 goodness of fit analysis was used to compare the differences in frequencies of prey order, prey type, and natural vs. garbage in regurgitates using the function `chisq.test`. Effect size (Cramer's V) was calculated using the function `cramersV` from the package `lsr`. Effect size was then used to calculate power using the function `pwr.chisq.test` from the package `pwr`. Power calculations were also used to determine what sample sizes would be necessary for future studies to ensure powers of 0.75 and 0.95 for all tests. Wet diet diversity was examined using a Shannon–Wiener index, and the function `diversity` from the package `vegan`. The function `rarity` from the same package was used to calculate the average number of orders likely to be obtained from every 10 items from ANI and SEFI.

Results

Wet Diet

Thirty-nine diet items were collected from 29 regurgitations that came from 27 birds at 25 nests. Overall, the samples contained 12 different orders and eight identifiable species, but many prey items could not be identified to the species level because of varying states of decomposition. Out of 29 regurgitations, 17 were from gulls at ANI representing 17 birds and 15 nests. These samples contained 22 items representing eight prey orders (including garbage) and five prey species. In contrast, 12 samples from SEFI were collected from nine nests containing 17 items in which eight prey orders (including garbage) were found, out of which six species could be identified (see Appendix A for a complete list of prey found).

Forty-five percent of prey orders identified in the diet samples from both colonies overlapped (Figure 1). There were four orders, including Clupeiformes (herring), Euphausiacea (krill), Gadiformes (cod), and garbage, present in the diets at both colonies (Figure 1). These four orders made up 68% of identified prey at ANI and 54% at SEFI. Euphausiacea and Gadiformes were important for both colonies and combined made up 36% of the identified prey at both colonies (Figure 1).

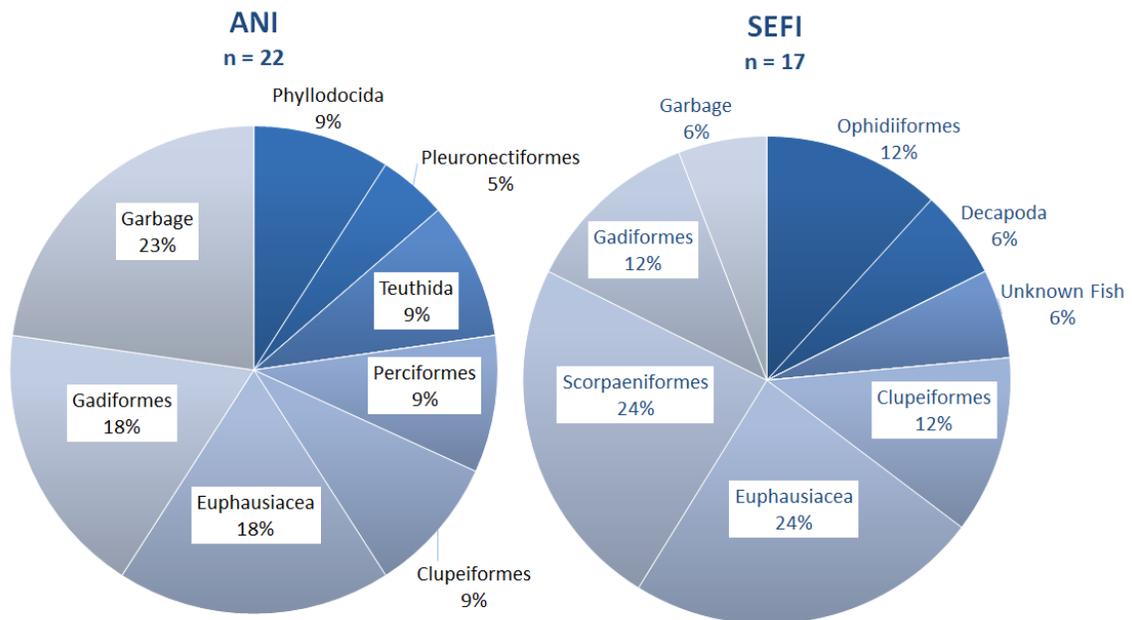


Figure 1. Frequency of prey orders in diets of adult western gulls from Año Nuevo Island and Southeast Farallon Island from 2013.

Perciformes (perch) made up 9% of the prey on ANI but were absent from SEFI.

Ophidiiformes (cusk eel) made up 12% of the prey on SEFI but were absent on ANI

(Figure 1). Garbage was much more common in the diets of gulls from ANI, making up 23% of the prey compared to only 6% of prey from gulls at SEFI (Figure 1). A complete list of prey items is provided in Appendix A. A chi-squared goodness of fit analysis revealed that differences in frequency of the various prey items between ANI and SEFI were not significant at any level of division of prey (Table 1). Statistical power was high for prey orders (0.83) but lower for prey type (0.51) and very low (0.17) for natural prey vs. garbage (Table 1).

Table 1

Chi-Squared Analysis of the Differences in Frequency of Diet Items Between the Colonies

Breeding diet prey frequency	Chi ² P	df	Cramer's V	Power	N 0.75	N 0.95
Orders	0.82	11	0.68	0.83		55
Type	0.20	5	0.43	0.51	63	107
Natural or Garbage	0.32	1	0.16	0.17	272	509

Note. Orders refers to the taxonomic orders of the prey. Type refers to broad types, such as fish, cephalopod, or garbage, which can encompass multiple orders but are still more refined than natural vs. garbage. Degrees of freedom is abbreviated df. N 0.75 and N 0.95 refer to the total number of samples required to reach a power of 75 or 95, respectively. N = 39.

In addition to looking at prey items in the diet, the diversity of the diets at both locations was compared using several methods. Orders per colony were equal between the sites (eight orders per colony). The number of orders expected to be found for every 10 items was also similar (ANI = 1.30, SEFI = 1.42). A Shannon-Wiener diversity index showed little difference between the two colonies (ANI = 1.97, SEFI = 1.94) in overall dietary diversity. The average number of prey items per sample was also compared and found to be similar (ANI = 1.3, SEFI = 1.42; Table 2) between colonies.

Table 2

Wet Diet Diversity by Colony

Wet diet diversity	ANI	SEFI
Avg. Prey/Sample	1.3	1.42
Shannon–Wiener	1.97	1.94
Orders/10 Items	6.15	6.27
Orders/Colony	8	8

Note. All measures of diversity show that the diversity of diets was similar between colonies.

To determine if differences between average prey items per sample was significant, a two sample t-test and power analysis were performed. The t-test revealed that differences were not significant ($p = 0.5$) and that statistical power was low (0.11) (Table 3).

Table 3

T-Test and Power Analysis of the Difference in Average Number of Prey Found in Each Regurgitant by Colony

Wet diet diversity	ANI	SEFI	P	Effect (d)	Power	n 0.75	n 0.95
Avg. Prey/Sample	1.3	1.42	0.5	-0.28	0.11	183	342

Note. In this table, n 0.75 and n 0.95 refer to the number of samples from each group required to reach a power of 75 or 95, respectively.

Intercolony Comparison of Diets During the Non-Breeding Period

Isotopic signatures from feathers revealed only a slight difference in proximate diets between colonies, where $\delta^{15}\text{N}$ was lower in samples from gulls at ANI compared to samples from gulls at SEFI. However, this difference was not statistically significant (Figure 2). Average $\delta^{13}\text{C}$ from gull feathers collected at ANI and SEFI was similar, where the average for ANI was $\delta^{13}\text{C} -14.70 \pm 0.16$ (N = 18) compared to SEFI ($\delta^{13}\text{C} -15.11 \pm 0.57$; N = 7) and these differences were not statistically significant ($p = 0.796$). The mean $\delta^{15}\text{N}$ from ANI was 15.28 ± 0.36 (N = 18), in comparison to SEFI, which was $\delta^{15}\text{N} 16.87 \pm 0.79$ (N = 7; $p = 0.09$) (Figure 2).

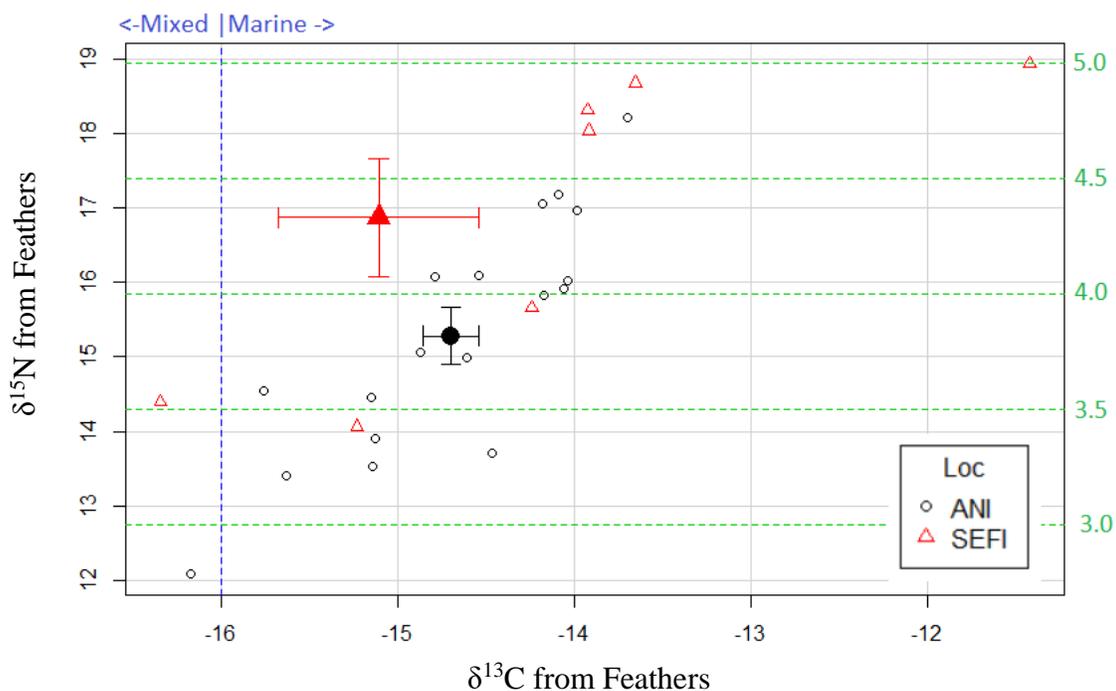


Figure 2. Differences in feather isotope signature from western gulls at two colonies.

A two-way ANOVA was used to test for differences in the relationship between $\delta^{13}\text{C}$ and sex and location and $\delta^{15}\text{N}$ and sex and location, but none of the relationships was statistically significant (Table 4).

Table 4

Two-Way ANOVA Results Between $\delta^{13}\text{C}$ and Sex:Location and $\delta^{15}\text{N}$ and Sex:Location

$\delta^{13}\text{C}$	P	eta ²	eta ² P	$\delta^{15}\text{N}$	P	eta ²	eta ² P
Sex	0.80	0.003	0.004	Sex	0.43	0.02	0.03
Location	0.70	0.007	0.008	Location	0.16	0.09	0.10
Sex:Loc	0.33	0.050	0.050	Sex:Loc	0.36	0.04	0.04

Note. Sex:Loc represents the interaction of the variables sex and location. None of the interactions was significant.

A power analysis using t-tests showed that statistical power was low and that larger sample sizes were needed to evaluate intercolony differences (Table 5 and Table 6).

Table 5

Power Analysis of $\delta^{13}\text{C}$ ANOVA Comparing $\delta^{13}\text{C}$ to Sex and Location

$\delta^{13}\text{C}$	Average	n	SE	t-test p	Cohen's d	Power	n 75	n 95
ANI	-14.7	18	0.16	0.36	-0.6	0.26	40	73
SEFI	-15.11	7	0.57					
Female	-14.69	15	0.2	0.38	-0.41	0.16	552	1032
Male	-14.29	10	0.39					
ANI	-14.66	11	0.19	0.79	0.14	0.06	728	1364
Female								
ANI	-14.76	7	0.31	0.22	-1.16	0.23	12	21
Male								
SEFI	-14.79	4	0.62					
Female								
SEFI	-13.2	3	0.89					
Male								

Note. SE refers to standard error and n 0.75 and n 0.95 refer to the number of samples from each group required to reach a power of 75 or 95, respectively. None of the relationships was significant.

Table 6

Power Analysis of $\delta^{15}\text{N}$ ANOVA Comparing $\delta^{15}\text{N}$ to Sex and Location

$\delta^{15}\text{N}$	Average	n	SE	t-test p	Cohen's d	Power	n 75	n 95
ANI	15.28	18	0.38	0.1	-0.91	0.5	18	33
SEFI	16.87	7	0.79					
Female	15.81	15	0.41	0.79	0.12	0.06	999	1869
Male	15.59	10	0.73					
ANI	15.64	11	0.38	0.3	0.59	0.21	42	76
Female								
ANI	14.71	7	0.75	0.43	0.62	0.1	37	68
Male								
SEFI	16.29	4	1.2					
Female								
SEFI	17.64	3	1					
Male								

Note. SE refers to standard error and n 0.75 and n 0.95 refer to the number of samples from each group required to reach a power of 75 or 95, respectively. None of the relationships was significant.

Morphology

Adults from SEFI were heavier and larger (in body size) than gulls from ANI, and this was true for both sexes (Table 9 and Table 10). A two-way ANOVA indicated that only the differences in mass were statistically significant between sexes ($F = 65.88$, $df = 1$, $n = 25$, $p < 0.01$). The differences between mass grouped by location or by the interaction between the two were not significant. Effect size shows that sex had the greatest influence on mass, whereas location and the interaction of location and sex only had minor effects on mass (Table 7).

Table 7

Two-Way ANOVA Examining Differences in Mass Based on Sex, Location, and the Interaction of the Two

Mass	P	eta ²	eta ² P
Sex	<0.01	0.69	0.75
Loc	0.06	0.04	0.16
LocSex	0.11	0.03	0.12

Note. LocSex refers to the interaction of the location and sex variables. Only the effect of sex on mass was significant.

A two-way ANOVA of the effects of sex and location on skeletal body size demonstrated that size differed significantly by sex and location ($F_{\text{sex}} = 85.31$, $F_{\text{location}} = 10.94$, $df = 1$, $n = 25$, $p < 0.01$ for both); however, the interaction of these variables was not significant ($p = 0.46$). As with mass, sex had the largest effect on body size (Table 8).

Table 8

Results of a Two-Way ANOVA Showing the Influence of Sex and Location on Skeletal Body Size

Size	P	eta ²	eta ² P
Sex	<0.01	0.70	0.80
Loc	<0.01	0.09	0.34
LocSex	0.46	0.00	0.03

Note. LocSex refers to the interaction of the location and sex variables. Both the effect of sex and location on mass was significant.

Because R cannot perform a power analysis for two-way ANOVAs, two sampled t-tests comparing mass between females from ANI and SEFI and a t-test comparing mass of males between ANI and SEFI were conducted. Location was not significant in the ANOVA; however, it had a p-value of 0.06 barely missing the significance cut off. The results of the t-tests show that there is a significant difference between the body masses of males between the two colonies ($t = -3.55$, $df = 6.33$, $p = 0.01$) but not of females ($t = -0.38$, $df = 3.88$, $p = 0.72$). Statistical power for both sexes was low, and larger sample sizes are necessary to confirm an actual lack of variation between female body masses of these two colonies (Table 9).

A t-test power analysis was also performed on the size data comparing the sizes of each sex between ANI and SEFI. The power for both sexes was low ($f = 0.6$; $m = 0.51$). A larger sample size is needed to determine if there is an actual difference in size between the females on ANI and the females on SEFI or between the males on ANI and the males on SEFI (Table 10).

Table 9

Summary of t-Test and Power Analysis on Mass When Examined by Sex and Location

Mass	Average	n	SE	t-test p	Cohen's d	Power	n 75	n 95
ANI Female	917	11	16.68	0.72	-0.28	0.07	180	337
SEFI Female	935	4	44.44					
ANI Male	1117	7	34.05	0.01	-1.57	0.52	7	12
SEFI Male	1240	3	5.77					

Note. SE refers to standard error and n 0.75 and n 0.95 refer to the number of samples from each group required to reach a power of 75 or 95, respectively.

Table 10

Summary of t-Test Power Analysis of Skeletal Body Size vs. Sex and Location

Size	Average	n	SE	t-test p	Cohen's d	Power	n 75	n 95
ANI Female	-2.13	11	0.22	0.13	-1.40	0.60	9	15
SEFI Female	-0.97	4	0.56					
ANI Male	1.30	7	0.46	0.06	-1.55	0.51	7	12
SEFI Male	3.12	3	0.57					

Note. SE refers to standard error. N 0.75 and n 0.95 refer to the number of samples from each group required to reach a power of 75 or 95, respectively.

Body size vs. mass scaled differently for each sex (Figure 3). For both sexes as body size increased so did mass.

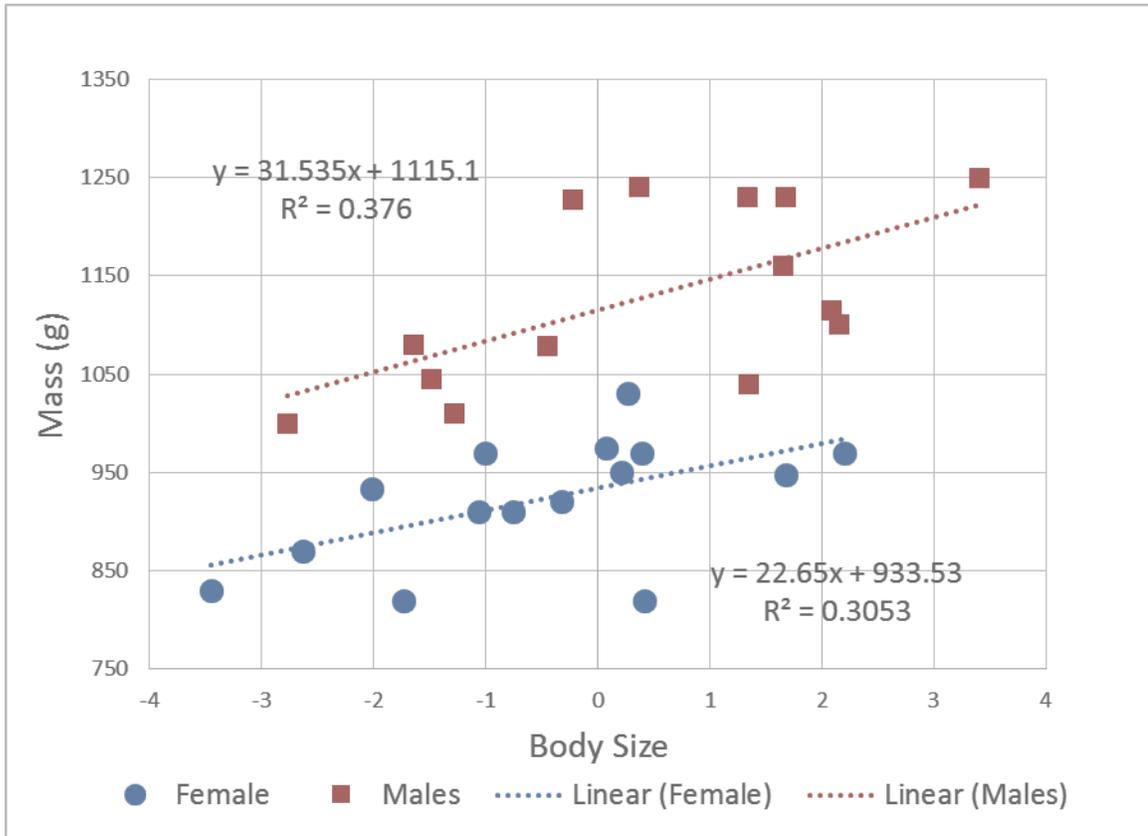


Figure 3. Body size vs. Mass. Males (■) are larger and heavier than females (●).

When actual body masses were compared to predicted masses from the linear equation of body size vs. mass, only SEFI females were smaller than expected (actual mass was 98.63% of predicted). ANI females were slightly larger (100.52%) than expected, ANI males were larger than expected (101.67%), and SEFI males were much larger than expected (105.77%) (Table 11). However, the differences in average mass and average predicted mass for each group were not significant, and statistical power is low (Table 11).

Table 11

Actual and Predicted Body Masses of Male and Female Western Gulls Nesting on ANI and SEFI

Mass	Avg. (g)	P Mass (g)	Mass- P Mass (g)	Percent Predicted	n	t-test p	Cohen's d	Power	n 0.75	n 0.95
ANI Female	917.00	912.28	4.72	100.52	11	0.81	0.10	0.06	1308	2447
ANI Male	1117.29	1098.98	18.31	101.67	4	0.79	-0.20	0.06	352	658
SEFI Female	935.00	947.97	-12.97	98.63	7	0.65	0.25	0.07	223	416
SEFI Male	1240.00	1172.36	67.64	105.77	3	0.13	1.95	0.45	5	8

Note. Avg. refers to Average. P mass is predicted mass. Percent Predicted is predicted masses' percent of actual mass. N 0.75 and n 0.95 refer to the number of samples from each group required to reach a power of 75 or 95, respectively.

An ANOVA was run to examine how location and sex affected the difference between the actual and predicted body mass. The results of this analysis were not significant, and effect size was small (Table 12).

Table 12

ANOVA Results Comparing the Difference Between Actual and Expected Masses Based on Skeletal Size

MassDiff	P	eta ²	eta ² P
Sex	0.15	0.09	0.10
Loc	0.67	0.01	0.01
SexLoc	0.18	0.08	0.08

Note. LocSex refers to the interaction of the location and sex variables

Influence of Non-Breeding Diet on Gull Body Mass

A multiple regression using mass vs. body size + $\delta^{13}\text{C}$ + d^{15}N was performed to determine whether an interaction between these factors influenced gull body mass at each colony. Separate models were run for each of the sexes. The influence of body size on

body mass was significant in both models (females $F = 2.79$, $df = 11$, $p = 0.5$; males $F = 6.64$, $df = 6$, $p = 0.2$) (Table 13). Isotope scores were not found to be significant for either isotope in either sex (Table 13). Statistical power was 0.64 for females and 0.76 for males.

Table 13

Results of the Multiple Regression Model of Mass vs. Body Size + $\delta^{13}C$ + $\delta^{15}N$

mass v	Body Size + $\delta^{13}C$ + $\delta^{15}N$	n	P	P model	R ²	f ²	Power	n 95
Female	Body Size		0.05					
	$\delta^{13}C$	10	0.15	0.09	0.432	0.761	0.76	24
	$\delta^{15}N$		0.19					
Male	Body Size		0.02					
	$\delta^{13}C$	15	0.51	0.02	0.769	3.329	0.99	
	$\delta^{15}N$		0.25					

Note. The total number of female samples to reach a power of 95% is indicated by n 95.

An ANOVA was used to compare the results of the body mass vs. body size + $\delta^{13}C$ + $\delta^{15}N$ to a regression of just mass vs. body score, and the results were not statistically significant (females $p = 0.33$; males $p = 0.42$), indicating that adding diets to the model does not produce a better fit for mass than body size alone.

Discussion

Summary

The wet diet data support the hypothesis that diets differ between colonies and that wet diets from gulls at ANI contained more garbage. However, statistical analyses indicate that these differences are not significant. Moreover, all measures of diversity in diet between colonies suggest that diversity is similar at each colony. Concomitantly,

stable isotope analysis (SIA) indicates a possible difference in trophic level between non-breeding diets at the two colonies, but this difference was not significant. Non-breeding diets from both colonies contained mostly marine organisms, and it does not appear that garbage is an important component of the non-breeding birds from either colony. It is unclear whether diet differences are responsible for lower breeding success at SEFI compared to ANI. Gulls from SEFI are heavier than those on ANI (Table 11), suggesting that they are able to find enough food to maintain a healthy body mass, but they may struggle to obtain enough food to sustain themselves and fledge more chicks. Non-breeding diets do not appear to influence gull mass, where the best predictor of body mass for gulls was body size.

Differences in the Frequency of Prey Items in the Wet Diet

The wet diet samples from ANI suggest that gulls from ANI consume more garbage when breeding compared to gulls from SEFI (Figure 1). However, chi-squared analysis indicates that this difference is not significant. The difference in orders had a statistical power of 0.86, suggesting that a difference between prey used at the two colonies is not likely. Statistical power for difference in natural prey vs. garbage was low (0.17). Therefore, there may still be a difference in garbage use between the two colonies. Larger sample sizes of at least 272 samples from each colony would be necessary in order to determine definitively if there is a difference in garbage use between the two colonies (Table 1). This is important because previous studies on western gulls have found that when adults feed their chicks more trash, breeding success is lowered (Annett & Pierotti, 1999; Pierotti & Annett, 1990, 2001). Thus, if ANI gulls

consume more trash and reproduce better, it is anomalous and suggests that another factor is influencing the relationship. Other species also increase the consumption of trash when breeding (Morey et al., 2007).

There was no statistically significant difference in the composition of prey species between the two colonies (Table 2). Declines in primary forage fish can lead to a decrease in prey diversity, which negatively impacts breeding success (Kowalczyk et al., 2014). If overall prey diversity is equivalent between colonies, this likely does not explain differences in breeding success. However, the statistical power to resolve a difference was low (0.11) (Table 3), so larger sample sizes (e.g., >180) are needed to confirm the equality of the prey diversity between colonies. Prey could also differ in total abundance between the colonies, which needs to be examined in future studies. These results demonstrate how effective western gulls are as generalist predators, despite major differences in distance to both the mainland and continental shelf edge as well as to landfills or major urban centers.

In general, gulls from SEFI have to fly farther and expend more energy to obtain garbage. Two studies observed a large increase in garbage in the diets of gulls at SEFI in 1978 and 1983 during major El Niño events (Ainley, Strong, Penniman, & Boekelheide, 1990; Pierotti & Annett, 2001). During these years, gull diets on SEFI consisted of up to 40% garbage (Ainley et al., 1990; Pierotti & Annett, 2001), similar to what we observed at ANI in 2012 (Cassell et al. 2012; unpublished data). During a long-term study at SEFI (Pierotti & Annett, 2001), gulls had a higher mean fledging rate than gulls breeding at Alcatraz Island in the San Francisco Bay. Alcatraz Island is an urban colony. However,

during the 1983 El Niño, Alcatraz gulls consumed more garbage and had a higher fledging rate (Pierotti & Annett, 2001). Thus, when natural prey are scarce, eating garbage can enhance reproductive performance in western gulls. Pierotti and Annett (2001) hypothesized that poor breeding performance during El Niño years was due to an inability to provide chicks with good nutrition. In a recent study focused on western gulls, researchers found evidence of a shift to greater reliance on anthropogenic food, away from more natural prey (Osterback, Frechette, Hayes, Shaffer, & Moore, 2015). They also reported a decrease in the trophic level of diets of western gulls and Brandt's cormorants (*Phalacrocorax penicillatus*) (Osterback, Frechette, Hayes, Shaffer, & Moore, 2015). Cormorants are piscivorous seabirds, so if trophic levels concurrently declined in fish-eating seabirds, it suggests an overall shift in prey availability, rather than an increase in appetite for garbage by gulls (Osterback et al., 2015). This observation could explain the steady decline in reproductive success of gulls at SEFI in recent years (Warzybok, Berger, & Bradley, 2012). If SEFI gulls cannot find enough food to feed their chicks, egg size, chick growth rate, and chick survival rate should be lower than chicks reared at ANI. Future research should compare clutch sizes, egg size, mass, chick mass at hatching, and nest productivity between the two colonies.

This study did not have enough regurgitates from known birds to attempt a direct comparison between wet diets and breeding success. However, gulls from ANI, where more garbage was consumed, were lighter and smaller. The P value for the differences in mass was 0.06, just missing the significance cutoff; however, power analysis is low so a larger sample size is needed to truly determine if there is a difference in masses between

the two locations. The difference in size was significant ($P < 0.01$). If gulls on ANI do weigh less, it is surprising because garbage consumed by western gulls in the California Current has been found to be a fattier food source (Pierotti & Annett, 1991). Although most of the garbage collected in regurgitations was edible, a considerable amount of inedible trash, including hard plastic, was found around gull nests, indicating that gulls swallow it and regurgitate it on the island. It is not clear how this affects the gulls, but it likely has implications for long-term health risks from contaminant exposure.

Stable Isotope Analysis (Non-Breeding Diet)

Estimates of gull diets during the non-breeding period (based on SIA of feathers) show that diets were similar between colonies. The $\delta^{13}\text{C}$ values were nearly identical between colonies, suggesting that both gull populations foraged in similar marine habitats (Figure 2). However, the SEFI population had a higher $\delta^{15}\text{N}$, suggesting that it may be consuming prey at a slightly higher trophic level than the prey consumed by ANI gulls (Table 4). It is important to note that statistical power for all SIA comparisons was very low (Table 5), indicating that larger sample sizes are needed to more accurately evaluate whether differences in non-breeding diets exist. The analysis reveals that a minimum of 70 samples is required to detect a true difference. Gulls from both colonies disperse to unknown locations during the non-breeding season; therefore, the populations may mix and/or overlap in their resource use during the non-breeding season. Freed from the constraints of breeding at a colony, adult gulls may increase foraging efforts to find higher-quality natural prey, rather than relying on the low-quality garbage that is relatively consistent. Further research is needed to characterize where the gulls disperse

to when breeding finishes. Some studies have shown that differences in winter diets are strongly correlated to breeding success (Ainley & Hyrenbach, 2010; Blight, 2011; Robb et al., 2008; Sorensen et al., 2009). Greater samples sizes should be compared to the number of eggs laid, egg volume, chick mass at hatching, mass of the third chick at hatching, fledging success, and overall recruitment to evaluate the influence of non-breeding diets on reproduction.

Comparisons of isotopic values by sex were inconclusive (Table 4), and the power analysis indicates that larger sample sizes are necessary to detect a difference between sexes. The within colony variation between sexes of $\delta^{15}\text{N}$ requires a manageable sample size for both colonies ($n = 76$ for ANI, $n = 68$ for SEFI) (Table 5). Unfortunately, determining if there is a variation of $\delta^{13}\text{C}$ within the colonies requires a prohibitively large sample size, including 1,364 samples from ANI alone. Within colony variation of isotopes between the sexes would indicate sex-specific diets at each colony.

Morphometrics

If reproduction was poor at SEFI based on inability to find food, gulls should have been lighter at SEFI compared to gulls at ANI. However, only SEFI females showed a slight non-significant trend of being lighter than expected compared to similar-sized gulls on ANI, which was the opposite of what a previous study comparing non-breeding diets of urban and rural gulls reported (Auman, Meathrel, & Richardson, 2008). My results also do not agree with studies on other animals, which found that urban populations of the same species were larger (Yom-Tov, 2003). Future studies could examine whether female gulls from ANI are heavier. If they are heavier, is it because

they can maintain a higher mass while breeding by supplementing their diet with garbage. Whereas female gulls from SEFI may not be able to consume enough to maintain their body mass during the breeding season. It is still plausible that differences in diet are responsible for the differences in reproductive success between sites. It may be that in years where natural prey are less abundant, adults from ANI can feed a higher percentage of their natural prey to chicks and supplement their own diet with more garbage. Whereas adult gulls at SEFI cannot supplement their diet with enough garbage due to the significantly farther flight to the mainland, which requires more energy and more time away from the nest. Gulls at SEFI may be eating most of the food they find in bad years and not have enough energy left over to feed their chicks adequately, thus contributing to lower reproductive success. Other studies show that nutrient-stressed breeding birds will forgo or abandon breeding attempts (Blight, 2011; Shochat, 2004) or that adult mass remains constant while reproductive success and chick growth decrease (Pinaud, Cherel, & Weimerskirch, 2005). This could explain why the gulls on SEFI are not lighter even if they are food limited. Adult gulls at SEFI have been observed eating their own chicks when food was scarce on at least one occasion (Warzybok & Bradley, 2011), indicating that gull parents prioritize their own health over that of their chicks.

Relationship Between Isotopic Values and Morphometrics

Non-breeding diet did not have a significant effect on the mass of gulls during the breeding season, as shown by the high p values from the linear regression analysis (Table 13). Statistical power was 0.64, indicating there is a 64% likelihood that the non-breeding diet does not affect breeding season mass. An increase in the number of birds

captured to at least 30 from each site would allow for greater certainty that non-breeding diet does not affect mass. It may be that SEFI gulls are genetically larger than ANI birds, a population genetics study to examine gene flow between populations could help resolve whether there is enough genetic isolation for the SEFI gulls to be phenotypically different from the ANI gulls. The data suggest that the SEFI birds might be heavier, but our sample size was too small for the size difference to be significant ($p = 0.06$). It could be that eating trash has other health risks, such as disease and parasites, which prevent the birds from gaining more mass. There is evidence in other gull species that feeding at dumps leads to increased risk of parasitism (Martínez-Abraín, Merino, Oro, & Esparza, 2002).

Conclusion

Although these results suggest that there could be a difference in diets between the two populations, additional data are needed to resolve this comparison fully. Specifically, a study that compares both adult food loads and chick growth over the course of several breeding seasons is required. Larger sample sizes equally split between incubation and chick rearing for adults of both sexes at both locations spanning a longer time are needed. Furthermore, collecting data during some El Niño and La Niña years is especially important to understand how each population responds to changes in natural prey availability. Differences in energy content between prey species and trash items should also be examined. A long-term study would also allow for an examination of how diet affects recruitment, which can be a better measurement of breeding success than fledgling rate (Spear & Nur, 1994). Previous studies have shown that the majority of

western gull recruits eat a diet high in fish (Annett & Pierotti, 1999). Western gull diet preferences may also be heritable (Annett & Pierotti, 1999), but a long-term study is required to examine this aspect. Long-term data would also allow for the determination of how diet influences lifetime breeding, including factors such as number of breeding seasons and age of first clutch. Some studies have found that older birds that are more experienced have increased breeding success. Therefore, if gulls that eat less trash live longer and breed more, they are more likely to fledge a higher percentage of their chicks (Pyle, Spear, Sydeman, & Ainley, 1991; Sydeman, Penniman, Penniman, Pyle, & Ainley, 1991). Prey availability in the first year may affect lifetime diet choices (Spear, 1988), and a long-term study would allow for a comparison of diets between birds of known hatching years. It is possible that decreased prey availability for consecutive years is causing a shift in prey utilization by SEFI gulls as they continue to use inferior prey they relied upon during their first year.

A larger sample size is needed to determine if there is a difference in non-breeding season diets and, if so, if it is influencing breeding success. Growth rates and fledging masses should be compared between the two populations and diet types. In addition to the factors looked at this season, nest attendance should also be monitored. It is possible that SEFI birds have a more difficult time finding food, leading to longer foraging times and lower nest attendance. Longer foraging times could result in higher predation of chicks by neighboring gulls or more energy expenditure finding food, making the total caloric requirements for gulls breeding on SEFI higher than those for gulls breeding on ANI. Geolocation tags can also be used to determine if there is a

difference in foraging times or habitats between colonies. Future studies should look at breeding isotopes on SEFI and compare them to the breeding isotopes on ANI as a way to confirm diet choice indicated by regurgitant data.

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Appendix A: Table of Prey Items

Loc	Date	N/G	Type	Order	Family	Genus	Species	Common Name
ANI	7/5/2013	G	G	Garbage	Garbage	Garbage	Garbage	Garbage
ANI	7/8/2013	G	G	Garbage	Garbage	Garbage	Garbage	Garbage
ANI	6/17/2013	G	G	Garbage	Garbage	Garbage	Garbage	Garbage
ANI	7/5/2013	G	G	Garbage	Garbage	Garbage	Garbage	Garbage
ANI	6/10/2013	G	G	Garbage	Garbage	Garbage	Garbage	Garbage
ANI	5/20/2013	N	Ceph	Teuthida	Loliginidae	Doryteuthis	Opalescens	Market squid
ANI	6/5/2013	N	Ceph	Teuthida	Loliginidae	Doryteuthis	Opalescens	Market squid
ANI	6/5/2013	N	F	Clupeiformes	Clunkwn	Clunkwn	Clunkwn	Clupeiforme
ANI	6/5/2013	N	F	Clupeiformes	Clunkwn	Clunkwn	Clunkwn	Clupeiforme
ANI	6/26/2013	N	F	Gadiformes	Merlucciidae	Merluccius	Productus	Pacific hake
ANI	6/26/2013	N	F	Gadiformes	Merlucciidae	Merluccius	Productus	Pacific hake
ANI	6/5/2013	N	F	Gadiformes	Merlucciidae	Merluccius	Productus	Pacific hake
ANI	6/17/2013	N	F	Gadiformes	Merlucciidae	Merluccius	Productus	Pacific hake
ANI	7/8/2013	N	F	Perciformes	Sciaenidae	Genyonemus	Lineatus	White croaker
ANI	5/20/2013	N	F	Perciformes	Sciaenidae	Genyonemus	Lineatus	White croaker
ANI	5/13/2013	N	F	Pleuronectiformes	Pleuronectidae	Hippoglossus	Stenolepis	Pacific halibut
ANI	5/20/2013	N	K	Euphausiacea	Euphausiidae	Thysanoessa	Spinifera	Krill
ANI	5/20/2013	N	K	Euphausiacea	Euphausiidae	Thysanoessa	Spinifera	Krill
ANI	6/5/2013	N	K	Euphausiacea	Euphausiidae	Thysanoessa	Spinifera	Krill
ANI	6/17/2013	N	K	Euphausiacea	Euphausiidae	Thysanoessa	Spinifera	Krill
ANI	6/5/2013	N	W	Phyllodocida	Nereidae	Nereis	Nerunkwn	Polychete
ANI	6/5/2013	N	W	Phyllodocida	Nereidae	Nereis	Nerunkwn	Polychete
SEFI	5/29/2013	G	G	Garbage	Garbage	Garbage	Garbage	Garbage
SEFI	5/29/2013	N	F	Clupeiformes	Clupidae	Cluunkwn	Cluunkwn	Clupidae
SEFI	5/27/2013	N	F	Clupeiformes	Clupeidae	Sardinops	Sagax	Pacific sardine
SEFI	5/26/2013	N	F	Gadiformes	Merlucciidae	Merluccius	Productus	Pacific hake
SEFI	5/27/2013	N	F	Gadiformes	Merlucciidae	Merluccius	Productus	Pacific hake
SEFI	5/28/2013	N	F	Ophidiiformes	Ophidiidae	Chilara	Taylori	Spotted cusk eel
SEFI	7/6/2013	N	F	Ophidiiformes	Ophidiidae	Chilara	Taylori	Spotted cusk eel
SEFI	5/26/2013	N	F	Scorpaeniformes	Sebastidae	Sebunkwn	Sebunkwn	Rockfish
SEFI	5/26/2013	N	F	Scorpaeniformes	Sebastidae	Sebunkwn	Sebunkwn	Rockfish
SEFI	5/29/2013	N	F	Scorpaeniformes	Sebastidae	Sebunkwn	Sebunkwn	Rockfish
SEFI	5/27/2013	N	F	Scorpaeniformes	Sebastidae	Sebunkwn	Sebunkwn	Rockfish
SEFI	5/26/2013	N	F	Unknown Fish	Unknown Fish	Unknown Fish	Unknown fish	Unknown fish
SEFI	5/26/2013	N	K	Euphausiacea	Euphausiidae	Euphausia	Pacifica	Krill
SEFI	5/28/2013	N	K	Euphausiacea	Euphausiidae	Euphunkwn	Euphunkwn	Krill
SEFI	5/26/2013	N	K	Euphausiacea	Euphausiidae	Thysanoessa	Spinifera	Krill
SEFI	5/29/2013	N	K	Euphausiacea	Euphausiidae	Thysanoessa	Spinifera	Krill
SEFI	5/27/2013	N	L	Decapoda	Decapoda	Decapoda	Decapoda	Crab larvae