*The Wilson Journal of Ornithology* 128(4):811–820, 2016

# INSIGHTS INTO DIET AND FORAGING BEHAVIOR OF IMPERIAL SHAGS (*PHALACROCORAX ATRICEPS*) BREEDING AT STATEN AND BECASSES ISLANDS, TIERRA DEL FUEGO, ARGENTINA

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ABSTRACT.—Diet and behavior are essential aspects of ecological studies, and are even more informative if both aspects are studied together. We collected samples of feathers ($n = 10$ of unknown sex at Becasses Island in 2013) and of both feathers and blood at Staten Island ($n = 5$ males and $n = 5$ females in 2011 and in 2013) from Imperial shags (*Phalacrocorax atriceps*). In addition, GPS devices were deployed on two individuals at each location that allowed us to record one or two foraging trips each. Stable isotope composition of carbon and nitrogen in blood differed amongst years and between sexes, albeit marginally within each year at Staten Island. Feather stable isotopes of carbon and nitrogen did not differ amongst sexes or years at Staten Island and between Staten and Becasses islands to show individuals did not have significantly different diets amongst locations during pre-molt. Foraging behavior parameters did not differ between individuals as they all searched in shallow waters and close to shore. Individuals flew to their feeding grounds and searched intensively at the furthest point reached by diving interspersed with floating on the surface. These results show individuals feed on similar prey, at least during pre-molt, and would seem to behave in a similar way at both locations while breeding, though sample size is too small to generalize on their behavior. The differences in isotopic compositions amongst years for Staten Island could be showing the fluctuations that occur among seasons in the isotopic signatures of prey, and in consequence, in seabirds over time. *Received 24 August 2015. Accepted 4 February 2016.*

Key words: diet, foraging behavior, *Phalacrocorax atriceps,* stable isotopes, Tierra del Fuego.

Foraging behavior and diet are vital components in studies of seabird ecology (González-Solís and Shaffer 2009). In addition, studies that combine both behavior and diet are very informative as they provide information on what individuals are feeding on, where, and how (Masello et al. 2010, Quillfeldt et al. 2010, Votier et al. 2010). By comparing these aspects of ecology of the same species at two locations with different surroundings (within vs. outside a channel), it is possible to determine if these differences are reflected in different behaviors or diet compositions, and even infer on the ability this species has to adapt to different conditions (Garthe et al. 2011). Besides, in areas where accessibility and seabird manipulations are difficult, information on these aspects of ecology are hard to come by.

Diet may be inferred through carbon and nitrogen stable isotope compositions in predator tissues, as they provide information on the trophic level and prey type consumed by the individual (coastal-pelagic; France 1995). Stable isotope information from blood integrates a time lapse of a couple of weeks prior and up until blood extraction, and the same information from feathers indicates diet a few weeks before feathers are created which takes place before molt and varies amongst species (Bearhop et al. 2006). With the use of GPS devices, it is possible to determine the location and duration of each foraging activity (flying, floating and diving, following Quintana et al. 2011). These data complement dietary information in order to determine important feeding areas, and in some cases even characteristics of seabird behavior linked to prey type (Wanless et al. 1992, Elliott et al. 2008).

The Imperial Shag (*Phalacrocorax atriceps*) is a common species throughout the Patagonian coast (Frere et al. 2005), and is the most abundant species within the Beagle Channel, Tierra del Fuego, Argentina, where its population has increased at a low rate over the past 10 years (Schiavini and Yorio 1995, Raya Rey and Schiavini 2000, Raya Rey et al. 2014). At Staten Island, Tierra del Fuego, information is lacking on population trends, though a census in 2012 indicated a population of ~4,600 pairs, in one location, Bahía Franklin, which represents an important percentage of the total population of the area (Schiavini and Yorio 1995). A previous study within the Beagle Channel showed Imperial Shags fed on crustaceans, *Munida gregaria* (54%),

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and pelagic fish such as *Sprattus fuegensis* (42%) as an opportunistic option when it becomes available in the summer. During shag early chick rearing, crustaceans predominate in their diet and towards late chick rearing, fish become the predominant prey item (Ravalli 2006). Another diving seabird, the Magellanic Penguin (*Spheniscus magellanicus*), which also breeds within the Beagle Channel and on Staten Island, feeds on similar prey types to Imperial Shags while breeding (Raya Rey et al. 2014, Scioscia et al. 2014).

*Sprattus fuegensis* becomes more available within the Beagle Channel in the summer and is the preferred food item by most seabirds, and mixed seabird species aggregations form to feed on this schooling fish (SH, pers. obs.). On the other hand, *Munida* sp. remains within the Channel throughout the year, can form large aggregations at the sea bottom, but also feeds in the water column. Because of its relatively tough exoskeleton, the latter is probably of lower nutritional value than *Sprattus fuegensis* but provides a relatively stable food source particularly when other options are scarce (Gonzalez Miri and Malacalza 1999, Quillfeldt et al. 2010). Little information is available on these prey items surrounding Staten Island; therefore, the information provided by this study may shed light on feeding behavior and diet of this species at this remote location.

The main objectives of this study are to: 1) describe the diet of Imperial Shags within the Beagle Channel and at Staten Island by stable isotope analysis, distinguishing between males and females, 2) to describe the behavior of a reduced number of tracked individuals within the breeding season.

## METHODS

Studies took place at two locations: at Becasses Island, within the Beagle Channel (54° 58′ S, 67° 01′ W), where ~6,200 pairs of Imperial Shags breed each year, and on Staten Island (54° 50′ S, 64° 41′ W) 20 km East of Tierra del Fuego, where ~4,600 pairs of Imperial Shags breed at colonies scattered amongst and near colonies of Rockhopper Penguins (*Eudyptes chrysocome*) throughout a large expansion of Franklin Bay, the southwest facing region of the island (Fig. 1; Raya Rey et al. 2014). Both regions are immersed in different oceanographic scenarios, which makes the comparison between them of great interest.

*Stable Isotope Analysis*.—Blood and feather samples were extracted from 10 individuals breeding at Staten Island in 2011 and 10 individuals in 2013 (5 males and 5 females each year from different nests, distinguished by vocalization as males 'honk' and females 'hiss'). We collected feather samples (10 feathers of individuals of unknown sex from different nests) from Becasses Island after the end of the breeding season in 2013. Molt is believed to be in March for body feathers of shags in this region (Bernstein and Maxson 1981). Blood samples were kept in alcohol at 70% and then dehydrated in an oven at 50°C and lyophilized. Feather samples were cleaned with a mixture of chloroform:methanol 2:1 and dried at room temperature. All samples were weighed, and ~0.40 mg of each were introduced in tin capsules and sent to the University of California Davis Stable Isotope Facility (Davis, CA, USA), in order to do isotopic analysis using an elemental analyzer interfaced to a continuous flow isotope ratio mass spectrometer (IRMS).

Results were expressed in delta notation (δ) using the equation:

$$\delta^{13}C \text{ or } \delta^{15}N = \left[\left(R_{sample}/R_{standard}\right) - 1\right]*1000,$$

where $R_{sample}$ and $R_{standard}$ are the $^{13}C$:$^{12}C$ or $^{15}N$:$^{14}N$ ratios of the sample and standard respectively. The standards are Vienna-Pee Dee Belemnite limestone (V-PDB) for carbon and atmospheric $N_2$ for nitrogen. The units were expressed as parts per thousand or per mil (‰). Analytical precision was 0.1‰ for $\delta^{13}C$ and 0.2‰ for $\delta^{15}N$.

*Device Deployment*.—Two types of GPS loggers were deployed: GPSlog devices (Earth and Ocean Technologies, Kiel, Germany; dimensions: 60 × 35 × 18 mm and weight: 37 g representing <2% of the bird's weight, continuous mode 1 fix per sec) were deployed on six individuals breeding at Becasses Island in 2006 of which only two were recovered and i-gotU devices (model GT-120, Mobile Action Technology Inc., New Taipei City, Taiwan; dimensions: 44 × 28 × 14 mm and weight: 22 g representing <2% of the bird's

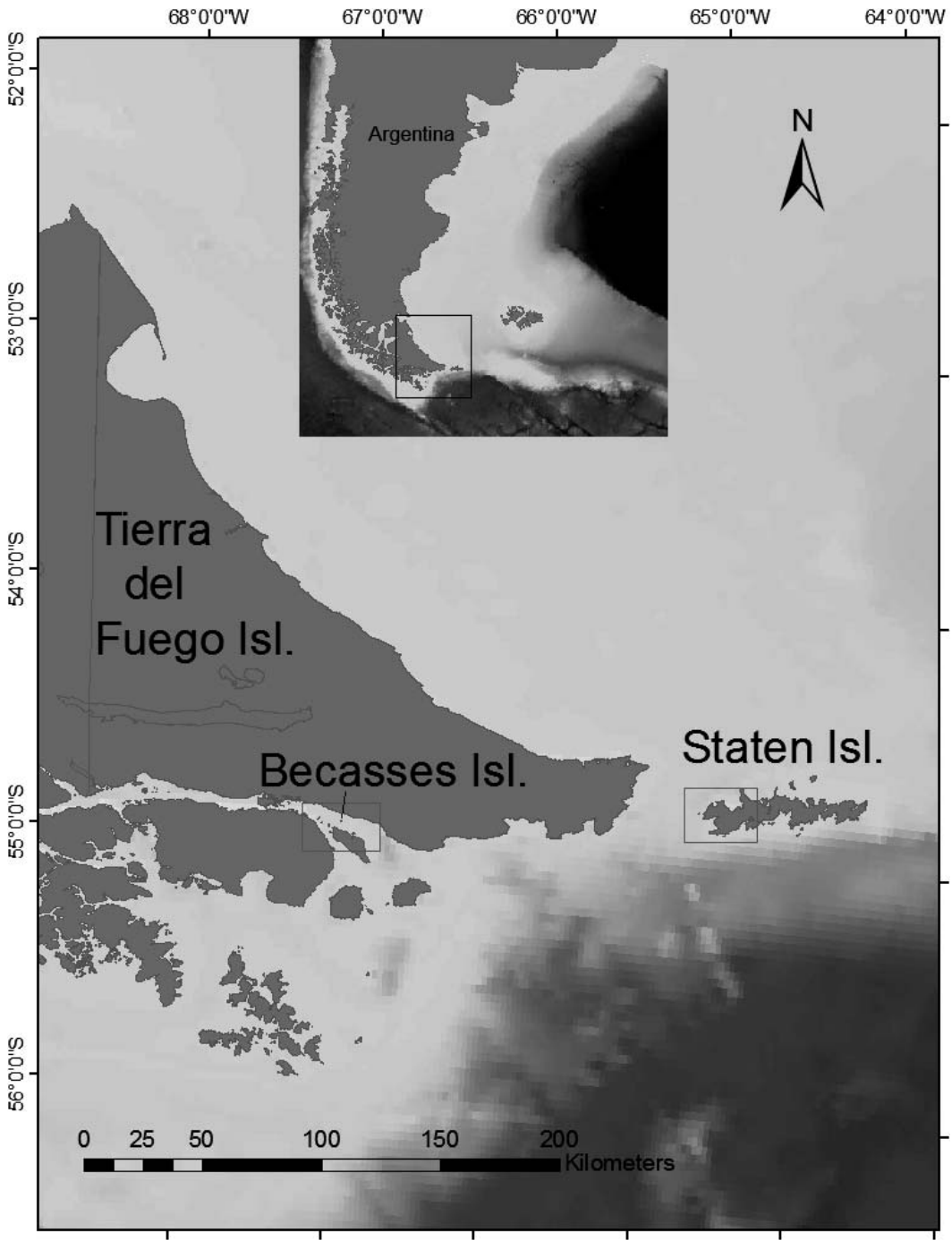


FIG. 1. Location of colonies of Imperial Shags at Becasses Island, within the Beagle Channel, and Staten Island, Tierra del Fuego, Argentina.

weight, intermittent mode every 30 secs) were deployed on two breeding Imperial Shags from different subcolonies at Staten Island in 2012. In both cases, individuals with young chicks (<10 days) were caught at their nest using a pole with a hook at the end. GPS devices were fixed to the lower back feathers using tesa tape (tesa tape inc., Charlotte, NC, USA; www.tesatape.com). Individuals returned to their nest within 5 mins of deployment. Devices were removed the following 1–2 days after deployment, once devices had stopped recording as battery charge ran out.

Because of difficulties in attachment and recovery of devices as individuals are very alert and easily frightened, data from only two individuals were obtained at each location: one male and one female breeding at Becasses, and two males from Staten Island. In spite of the low sample sizes, these results are very valuable as they are the first tracks obtained for this species at these locations. The results from these data are only illustrative of the possible behaviors individuals display and are not intended to be generalized for all of the population.

*Data Analysis*.—Stable isotopes were analyzed with the use of SIBER (Jackson et al. 2011) in order to compare isotopic niche breadth of each group of individuals and their overlap (Newsome et al. 2007). Standard ellipses represent the isotopic niche width of 40% of typical individuals within the groups based on bivariate normal distributions. A corrected version of the standard ellipses was used ($SEA_C$) as sample sizes were small. Given that overlap is sensitive to the size of the ellipses, these values are a semi quantitative measure (Newsome et al. 2007). However, standard ellipses give an idea of overlap ranging between 0 and 100%, and we defined no overlap for values <5% overlap, low overlap between 5–30%, moderate between 30–60%, and high overlap >60% (similar to Kiszka et al. 2014). Estimates of overlap will be conservative as they compute the overlap of 40% of a modeled population based on the centroids given by the data. In addition, after checking for normality in the residuals of both carbon and nitrogen isotopic values, GLMs were created in order to model the blood and feather isotopic signatures of individuals in relation to sex and year as fixed effects (e.g., C blood ~ sex + year). The correlation of blood versus feather isotopic signatures was also determined at Staten Island with GLMs ($\delta^{13}$C blood ~$\delta^{13}$C feather) and ($\delta^{15}$N blood ~$\delta^{15}$N feather) following Quillfeldt et al. (2010). The comparison between feather isotopic signatures between Becasses and Staten islands (both years) was also determined ($\delta^{13}$C feather ~ location, and $\delta^{15}$N feather ~ location, where location was a fixed effect divided into: Becasses Island and Staten Island 2011 and Staten Island 2013). Foraging tracks were described for all individuals at each location: the time individuals began foraging, trip durations (in hrs), maximum distance to the colony and to the shore (in km), time in Area-Restricted Search (ARS), depth of ARS area from a bathymetric grid (GEBCO, IOC et al. 2003, see methods in Harris et al. 2012). All statistics were performed in R 3.2 (R Core Team 2015) and significance was set at $P < 0.05$.

## RESULTS

*$\delta^{13}$C and $\delta^{15}$N in Whole Blood at Staten Island*.—Whole blood stable isotopes integrate diet of several days before and up until blood extraction. Males and females presented limited overlap in their niche range as blood stable isotope Bayesian ellipses of both sexes overlapped <5% within each year to indicate diets were slightly different (4.4% overlap in 2011 and 3.1% overlap in 2013). No overlap at all occurred amongst years as significant differences were detected between years for both sexes (Fig. 2a), which coincides with the analysis done of each isotope separately (Table 1). The stable isotope ellipses of males were slightly larger than females (0.25 vs. 0.10 in 2011 and 0.19 vs. 0.11% overlap in 2013) indicating a larger diversity of diets for this sex within this period during the breeding season. Average $\delta^{13}$C and $\delta^{15}$N differed between years, but not between sexes within each year (Table 1). The less than 5% overlap detected between sexes may be influenced by the size of the ellipses and the fact that analysis was conservative as graphically a certain degree of overlap is observed (Fig. 2a).

*$\delta^{13}$C and $\delta^{15}$N in Feathers at Staten Island*.—Feather stable isotopes integrate diet during feather creation, usually at the pre-molt stage after the breeding season. Feather stable isotope ratios did not differ amongst sexes or years at Staten Island as the Bayesian ellipses overlapped to some extent for all groups (male feather in 2011 vs. 2013 had low overlap of 12%; female feather in 2011 vs. 2013

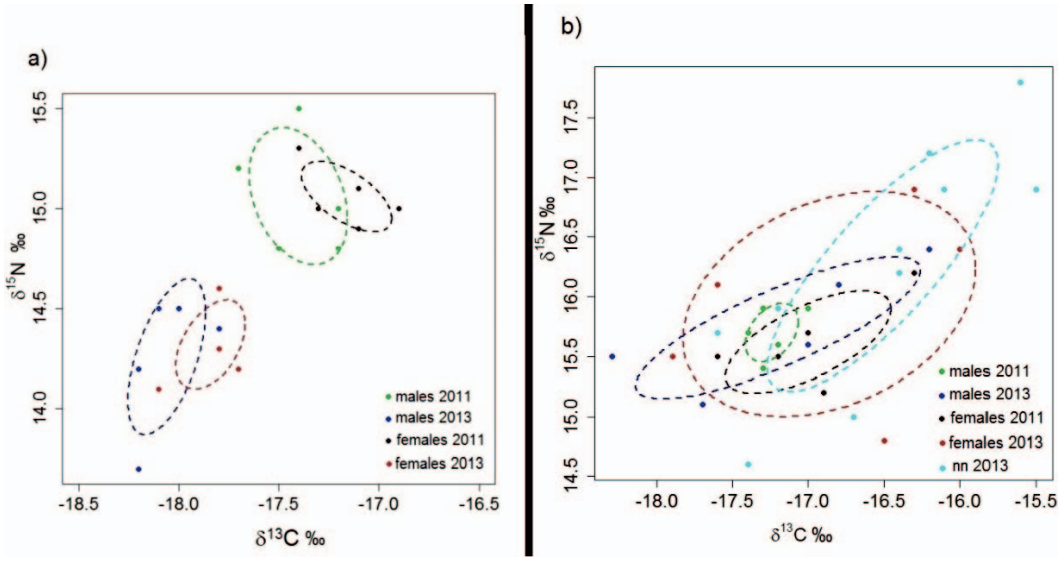


FIG. 2. a) Blood samples $\delta^{13}C$ and $\delta^{15}N$ from Imperial Shags (*Phalacrocorax atriceps*) at Staten Island ($n = 5$ for all categories). b) Feather samples $\delta^{13}C$ and $\delta^{15}N$ of the same individuals at Staten Island ($n = 5$ for all categories) and feather samples $\delta^{13}C$ and $\delta^{15}N$ of individuals breeding at Becasses Island in 2013 ($n = 10$).

had a moderate overlap of 56%; female vs. male 2011 had a low overlap 8%; female vs. male 2013 had a high overlap (88%); female 2011 vs. male 2013 a moderate overlap of 38%; female 2013 vs. male 2011 a low overlap of 12%, Fig. 2b). These results coincide with results for each isotope separately (Table 1). Female feather isotopic niche at this location, as opposed to blood, seemed larger than male isotopic range as Bayesian ellipses were larger for females than males in both years indicating a larger range of prey types consumed by this sex at the time (0.56 vs. 0.12 in 2011 and 2.71 vs. 1.02 in 2013). Neither $\delta^{13}C$ nor $\delta^{15}N$ differed between years or sexes (Table 1).

*$\delta^{13}C$ and $\delta^{15}N$ in Blood vs. Feathers at Staten Island*.—We compared blood and feathers of the same individual to see how its diet over the last few days contrasted with its diet during the pre-molt stage of the previous breeding season. Blood and feather $\delta^{13}C$ and $\delta^{15}N$ were not correlated for the same individuals, as the isotopic signature in feathers was not a significant factor to determine isotopic signature in blood (for blood $\delta^{13}C$: significance of feather $\delta^{13}C$ $t_{19} = 0.66$, $P =$

TABLE 1. Stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in feathers and blood of breeding Imperial Shags at Staten Island in 2011 and 2013 and at Becasses Island in 2013 (only feathers). M = males and F = females. Significant differences indicated with different letters.

| | Staten Island | | | | Becasses Island |
|---|---|---|---|---|---|
| Year | 2011 | | 2013 | | 2013 |
| Feather | M (5) | F (5) | M (5) | F (5) | (10) |
| $\delta^{13}C$‰ | $-17.2 \pm 0.2^{a}$ | $-17.0 \pm 0.5^{a}$ | $-17.2 \pm 0.8^{a}$ | $-16.9 \pm 0.8^{a}$ | $-16.5 \pm 0.7$ |
| $\delta^{15}N$‰ | $15.7 \pm 0.2^{b}$ | $15.6 \pm 0.4^{b}$ | $15.7 \pm 0.5^{b}$ | $15.9 \pm 0.8^{b}$ | $16.3 \pm 1.0$ |
| Blood | | | | | |
| $\delta^{13}C$‰ | $-17.4 \pm 0.2^{c}$ | $-17.2 \pm 0.2^{c}$ | $-18.1 \pm 0.2^{c}$ | $-17.8 \pm 0.2^{c}$ | |
| $\delta^{15}N$‰ | $15.1 \pm 0.3^{d}$ | $15.1 \pm 0.2^{d}$ | $14.3 \pm 0.3^{d}$ | $14.3 \pm 0.2^{d}$ | |

[a] Feather $\delta^{13}C$ between sexes $t_{17} = -0.60$ $P = 0.56$; between years $t_{17} = 0.35$ $P = 0.73$
[b] Feather $\delta^{15}N$ between sexes $t_{17} = 0.24$ $P = 0.81$; between years $t_{17} = 0.96$ $P = 0.35$
[c] Blood $\delta^{13}C$ between sexes $t_{17} = -2.07$ $P = 0.055$; between years $t_{17} = -5.87$, $P < 0.001$
[d] Blood $\delta^{15}N$ between sexes $t_{17} < 0.001$ $P = 0.99$; between years $t_{17} = -4.58$, $P < 0.001$

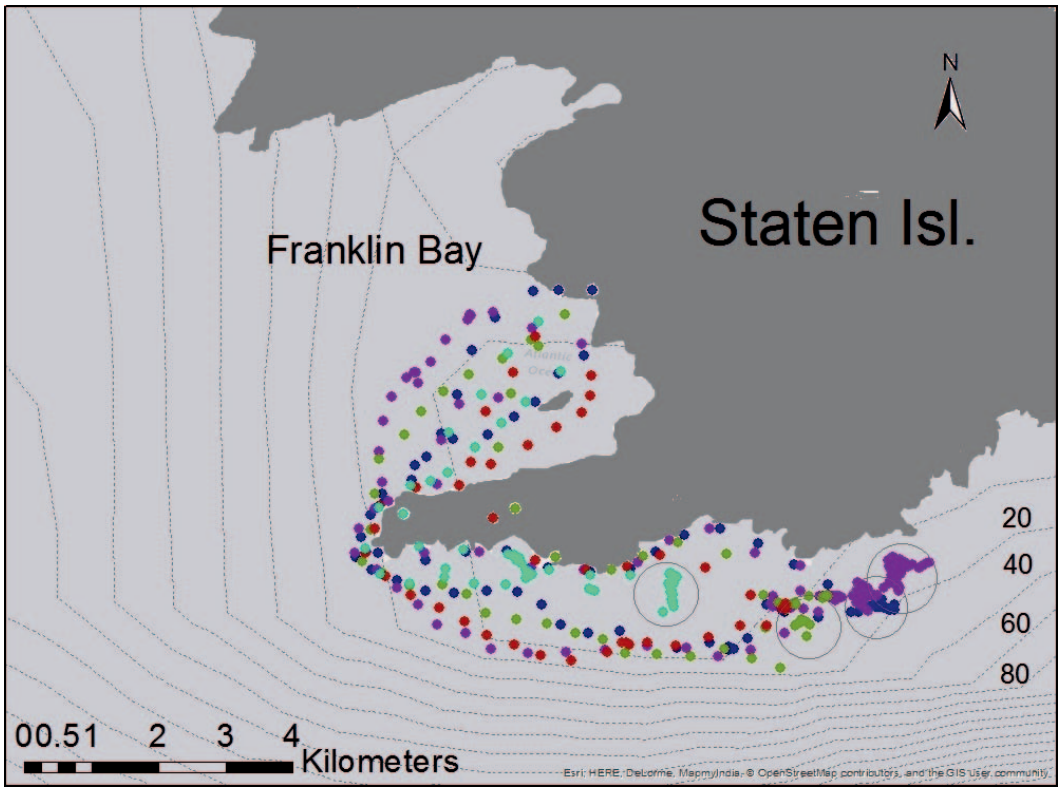


FIG. 3. Foraging trips of two male Imperial Shags breeding at Staten Island, Argentina, one trip (red) for one male and 4 trips of the other male (green, purple, blue, and light blue) at a frequency of 1 fix every 30 secs. Location of the colony, ARS areas, and 20-m isobaths are indicated.

0.517 and for blood $\delta^{15}N$: significance of feather $\delta^{15}N$ $t_{19} = -1.05$, $P = 0.308$).

*Feather $\delta^{13}C$ and $\delta^{15}N$ at Staten Island vs. Becasses Island*.—Feather stable isotopes did not differ between places as the Bayesian ellipses of both places overlapped a certain amount (limited overlap between Becasses vs. males at Staten Island, 5% in 2011 and moderate overlap of 50% in 2013; and vs. females at Staten Island, moderate in 2011 (43%) and 100% in 2013, Fig. 2b). While comparing feather isotopic composition between Becasses Island and Staten Island, there were significant differences in $\delta^{13}C$ but not $\delta^{15}N$ between both places (Becasses and Staten Island in 2011: $\delta^{13}C$ ($t_{27} = -2.09$, $P = 0.05$) and $\delta^{15}N$ ($t_{27} = -1.90$, $P = 0.07$)), with $\delta^{13}C$ being more positive, on average, at Becasses, but this difference was not evidenced comparing Becasses with Staten islands in 2013: $\delta^{13}C$ ($t_{27} = -1.78$, $P = 0.09$) and $\delta^{15}N$ ($t_{27} = -1.33$, $P = 0.19$).

*Foraging Trips at Staten Island*.—Imperial Shags breeding at Staten Island made one or several short foraging trips during the day, these males in particular fed during the afternoon and foraged near the shore (<2 km). Both individuals flew out to a specific location where they concentrated most of their dives. Area-restricted search (ARS) areas, linked to foraging, were at the farthest location reached during the trip, foraging lasted up to 4 hrs, after which individuals returned to the colony copying the coastline. Both individuals foraged together during part of their trips even though their feeding location was on the south side of the island, beyond Franklin Bay, and not within visual distance from the colonies (Fig. 3). The individual we tracked on two consecutive days returned to the same feeding location the following afternoon, on three short foraging trips and searched intensively at the same location on two of the three trips (in 25–30 m depth waters, Table 2).

TABLE 2. Summary of foraging trip characteristics of breeding Imperial Shags at Staten and Becasses islands. M = male and F = female.

| Location | Staten Island | | | | | Becasses Island | | |
|---|---|---|---|---|---|---|---|---|
| Bird ID | 360 | 754 | | | | 141 | | 144 |
| Sex | M | M | | | | M | | F |
| Date | 20/12/12 | 20/12/12 | 21/12/12 | | | 14/12/06 | | 15/12/06 |
| Trip *n* | 1 | 1 | 1 | 2 | 3 | 1 | 2 | 1 |
| Start time | 11:55:44 | 15:34:31 | 12:48:01 | 17:00:53 | 19:33:47 | 17:43:48 | 20:28:42 | 05:03:08 |
| Trip duration (hrs) | 3.93 | 3.98 | 0.57 | 0.67 | 1.46 | 1.37 | 1.69 | N/A |
| Max distance (km) | 6.6 | 6.3 | 5.7 | 5.6 | 5.1 | 9.3 | 5.9 | 5.1 |
| Max distance to shore (km) | 1.2 | 1.2 | 1.3 | 1.5 | 1 | 2.1 | 1.2 | 1.3 |
| Time in ARS (hrs) | 3.57 | 3.53 | 0.27 | 0.3 | 1.06 | 0.74 | 1.24 | N/A |
| Depth of ARS (m) | 28 | 28 | 26 | 27 | 14 | 33 | 40 | N/A |

*Foraging Trips at Becasses Island*.—Tracked Imperial Shags breeding at Becasses Island made one or several foraging trips within the day. One individual made two foraging trips within the day in which it flew east, closer to the shore of the main Island of Tierra del Fuego. Intensive search took place at the farthest point of the foraging trip, where it made many dives interspersed with floating on the sea surface (in 30–40-m depth waters; Fig.4). This individual then flew back to the colony in a straight line. This individual was distinguished as male by its vocalizations and behavior at the nest. The other individual foraged in the morning, went northwest, also close to the main shore of Tierra del Fuego and foraged intensively at the farthest point reached of the trip (at a similar depth and distance from the shore to the other individual; Fig. 4). Diving was interspersed with floating on the sea, and it then began flying back in direction of the colony in what seemed to be its return phase of the trip when the GPS stopped transmitting (Fig. 4). This individual was likely to have been a female based on the time of day it foraged, though we were not able to define this at the time (Harris et al. 2013). Both individuals searched in waters near the shore of the main island (<2 km) and within 10 km of the colony.

## DISCUSSION

*Diet through Stable Isotopes*.—Stable isotopes of carbon and nitrogen are similar to those observed for this species farther north (Forero et al. 2004, Ciancio et al. 2008, Harris et al. 2016). The marginal differences amongst sexes in blood stable isotopes suggests a certain degree of similarity in diets within each year at Staten Island. In addition, the differences amongst years are likely because of fluctuations in the basal values of C and N in the trophic chain particularly surrounding Staten Island, which would be affecting the value of the prey and, consequently, the values registered in blood (West et al. 2010). In future studies, data sets encompassing a longer time frame throughout the breeding season and on different years, as well as isotopic values of seabird tissues and all possible prey should be analyzed simultaneously in order to have a more complete picture of the trophic level of these individuals. Moreover, if information on the isotopic signatures of potential prey were available, it may even be possible to distinguish the proportion of each prey type consumed.

Males presented a larger range of isotopic values in blood than females.This difference may coincide with a wider range of prey targeted by the larger sex which can dive deeper if it needs to find a greater diversity of prey types (Quillfeldt et al. 2010, Ratcliffe et al. 2013). Even though feathers were not corrected for tissue discrimination, a correlation between both tissues is expected for the same individual on the same diet in time; therefore, the lack of correlation between blood and feathers shows that individuals did not maintain their diet in that given time frame. In addition, the larger range of isotopic compositions in feathers than in blood shows individuals had a wider range of prey isotopic ranges consumed during pre-molt than during early chick rearing at Staten Island.

*Becasses Island vs. Staten Island*.—The lack of differences in carbon and nitrogen isotopic compositions in feathers between Becasses and Staten islands indicates a similar diet range at both locations. The slightly more positive values for

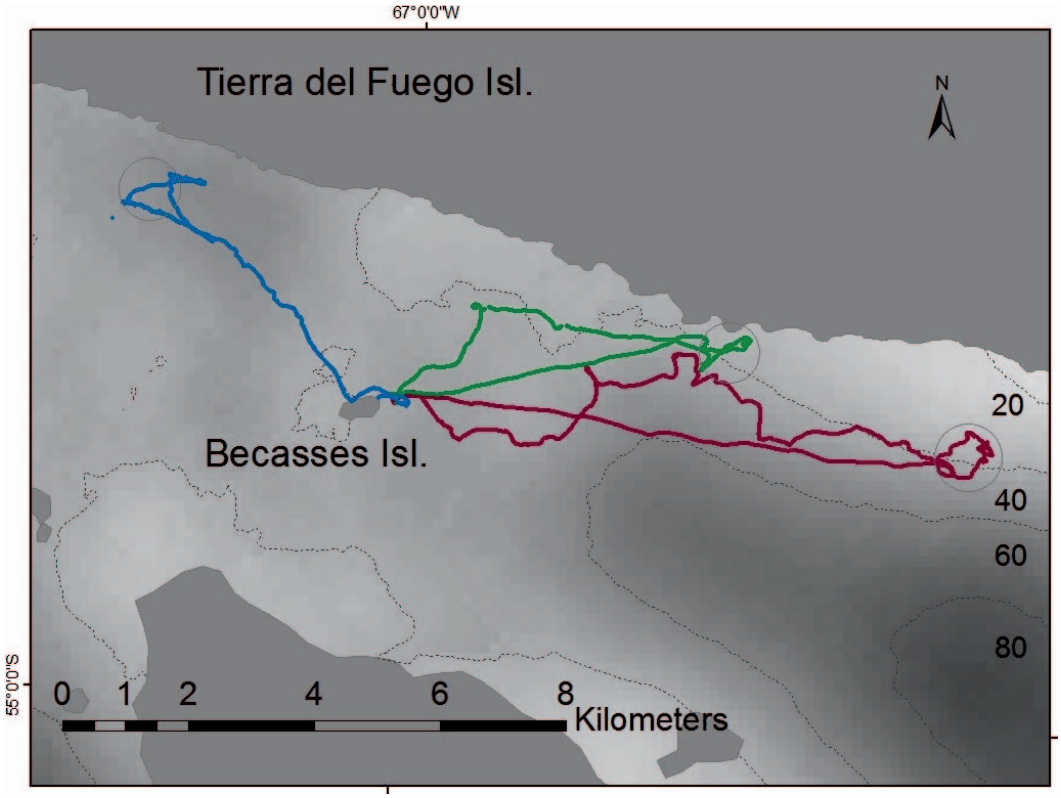


FIG. 4. Foraging trips of one male (red and green) and one female trip (blue) of Imperial Shags breeding at Becasses Island, Argentina. ARS areas are indicated with circles of the same color as the tracks and 20-m isobaths are also delimited.

feathers within the Beagle Channel could be explained by the more positive value observed for their prey, *Munida* sp., within the Beagle Channel than outside (Riccialdelli et al. 2016). The fact that the foraging behaviors of the observed individuals were similar at both locations coincides with diets also being similar, as individuals concentrated their search close to the shore presumably to feed on benthic crustaceans and to a lesser degree *Sprattus fuegensis*. In order to determine which prey items and in what proportion they are being consumed, future studies should include information on isotopic values for prey items concomitantly with values from tissues of Imperial Shags (Parnell et al. 2010).

The more positive values in the Beagle Channel are consistent with one of the prey types consumed. *Munida gregaria* have a more positive isotopic signature within the Beagle Channel ($\delta^{13}C = -16.7‰$ $\delta^{15}N = 14.1‰$; Riccialdelli et al. 2016) than outside the Channel in the south-west Atlantic Ocean ($\delta^{13}C = -16.7‰$ $\delta^{15}N = 12.2‰$; Riccialdelli et al. 2013). However, these results must be taken with caution as samples were collected on different breeding seasons and given the large dispersion in feather stable isotope signatures at both locations and amongst years, the observed differences may smoothen out if samples are taken over an extended period of time.

*Foraging Behavior.*—All tracked Imperial Shags from both Staten and Becasses islands seemed to have similar foraging behaviors as they chose locations close to shore (<2 km) and shallow waters (<30 m) to feed. In the case of the male from Staten Island that we tracked on two consecutive days, a certain level of consistency was observed in his behavior as he returned to the same place to feed the following day. Repeatability in foraging behavior has been detected in this and other species in other regions (Ratcliffe et al. 2013, Potier et al. 2015), and this behavioral consistency may be indicating an abundant and /or stable food

source in the area (Elliott et al. 2008). Moreover, both individuals tracked at Staten Island went to similar feeding areas and at the same time, which would be consistent with group feeding probably on schooling fish or crustaceans. Within the Beagle Channel, both individuals fed in shallow waters close to the shore of the main Island of Tierra del Fuego. According to a previous study, the most abundant food item consumed by Imperial Shags in this region was *Munida gregaria* (Ravalli et al., unpubl. data.), which is common within the Beagle Channel and is also present around Staten Island. This crustacean may have been the targeted prey during this stage of early chick rearing, when trip durations are shorter as nest defense is primordial for chick survival, and food quality may be lower (Grémillet et al. 1995). Individuals may be choosing a more common though lower quality prey item in order to secure foraging success efficiently in detriment of quality (as fish in this area such as *Sprattus* sp. have higher energy density than crustaceans [Ciancio et al. 2007]). Wanless et al. (1992) found Imperial Shags at South Georgia were feeding both on fish and on crustaceans during the breeding season and their behavior differed according to the targeted prey. This may also be the case in this study site though a larger data set of foraging behaviors would be needed for this analysis.

*Concluding Remarks*.—Differences were detected in stable isotope values in blood amongst years and only marginally between sexes within each year at Staten Island, and this may be because of slight differences in diet amongst sexes and fluctuations in the isotopic value of their prey, particularly in the area surrounding this island. No differences were detected between Staten and Becasses islands in isotopic signatures in feathers of individuals, which would be suggesting similar pre molt diets and all individuals consumed a larger range of prey types during pre-molt than while breeding. In spite of the differences in the oceanography surroundings of both studied locations, Imperial Shags had similar diets, and probably behaviors as the small set of behavioral data recorded showed feeding in coastal areas of similar depth and probably on similar prey types during early chick rearing.

## ACKNOWLEDGMENTS

We want to thank the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) for the scholarship for S. Harris and funding for the research as well as the work place at the Centro Austral de Investigaciones Científicas (CADIC). We also want to thank the Wildlife Conservation Society for funding. We are very thankful to Henk Boersma and the captain and crew of La Nativa for transportation to and from Staten and Becasses islands, respectively. In addition, we wish to thank Michael Polito for stable isotope analyses, and N. Rosciano and V. Bruno for field assistance.

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