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Kelp Gull (*Larus dominicanus*) Use of Alternative Feeding Habitats at the Bahía San Blas Protected Area, Argentina

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Abstract.—Kelp Gull (*Larus dominicanus*) foraging patterns were studied by deploying GPS loggers on 20 incubating individuals at their colony in the Bahía San Blas protected area, Argentina. Mean number of trips per day was 1.5 ± 0.5, and mean trip duration was 272.6 ± 165.2 min. Mean maximum distance from the colony was 19.6 ± 24.4 km. Incubating Kelp Gulls visited natural and anthropogenic environments. Individuals switched between two or three different habitat types 47% of the time during a given foraging trip. Kelp Gulls showed a differential use of feeding areas, with a significantly higher use of refuse dumps (75%; n = 151 trips) than coastal (47%), terrestrial (10%) and offshore (10%) habitats. In 72% of the recorded trips, Kelp Gulls targeted the dump located in the small town of Bahía San Blas, where waste generated by recreational fishing is regularly disposed. Moreover, most visited shoreline locations were those regularly used by recreational fishers. Despite showing plasticity in foraging habitat use, the local refuse dump and nearby shoreline sites where fish waste is regularly disposed were the main feeding habitats for incubating Kelp Gulls. *Received 4 August 2017, accepted 24 April 2018.*

Key words.—anthropogenic food sources, foraging patterns, Kelp Gull, *Larus dominicanus*, Patagonia, recreational fishing, seabirds.

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Studies on several gull species have shown they have a great plasticity in the use of feeding habitats, being able to alternatively use intertidal, open sea, and terrestrial environments, as well as areas with human derived food sources (Kubetzki and Garthe 2003; Caron-Beaudoin *et al.* 2013; Patenaude-Monette *et al.* 2014). The ability to exploit novel food provided by human activities can result in improved individual body condition, higher breeding success and ultimately population growth (Oro *et al.* 2013), often leading to conflicts with human populations (Thomas 1972; Belant 1997; but see Oro and Martínez-Abraín 2007). Knowledge of how gulls make use of alternative natural and anthropogenic food sources may increase our understanding of their role in coastal ecosystems, assess potential conflicts with humans and define management actions.

The Kelp Gull (*Larus dominicanus*) is a widely distributed seabird throughout the Southern Hemisphere, breeding in South America, southern Africa, Australia, New Zealand, subantarctic islands, and the Antarctic Peninsula (Jiguet *et al.* 2012). It is a generalist and opportunistic feeder that consumes a wide variety of prey during the breeding season (Steele 1992; Coulson and Coulson 1993; Bertellotti and Yorio 1999; Ludynia *et al.* 2005). Studies at different coastal breeding locations in Argentina have shown they have a wide trophic spectrum that includes different species of fish, mollusks, crustaceans and insects (Yorio and Bertellotti 2002; Petracci *et al.* 2004; Yorio *et al.* 2013), reflecting their great plasticity in the use of foraging habitats. Their generalist and opportunistic feeding habits also allows them to take advantage of anthropogenic food subsidies such as urban and fishery waste (Yorio and Giaccardi 2002; Marinao and Yorio 2011). Although previous diet studies provided indirect evidence of the different feeding habitats used, direct information on the spatial use of foraging areas by breeding individuals is still lacking.

The Bahía San Blas protected area in Argentina is an important breeding ground for several seabirds including the Kelp Gull (Suárez *et al.* 2014) and the site of one of the main shore-based marine recreational fisheries of the southwestern Atlantic coast (Llompart *et al.* 2012). Knowledge of Kelp Gull foraging patterns and their relationship with human activities taking place in the protected area will not only contribute to the understanding of the foraging ecology of this generalist species but is also key for coastal zoning and the development of adequate management guidelines.

The objective of this study was to quantify the spatial foraging patterns of incubating Kelp Gulls to: 1) characterize their foraging trips; 2) identify their foraging areas; and 3) assess the importance of anthropogenic feeding habitats to their feeding ecology.

METHODS

Study Area

The study was conducted in the southwestern area of the Bahía San Blas protected area in Buenos Aires Province, Argentina (Fig. 1). The Kelp Gull study colony was located at Islote Arroyo Jabalí Este (40° 32′ 50″ S, 62° 16′ 46″ W), 3 km from the town of Bahía San Blas. Colony size during 2013 was estimated at 1,275 breeding pairs (Suárez *et al.* 2014).

The coastal area is mainly characterized by extensive mudflats and marshes of cordgrass (*Spartina* spp.) and pickleweed (*Sarcocornia perennis*), with crab beds consisting of burrowing crab (*Neohelice granulate*), rock crab (*Cyrtograpsus altimanus*) and mud crab (*C. angulatus*) (Zalba *et al.* 2008). The town of Bahía San Blas is located on Isla del Jabalí (Fig. 1) and has about 600 inhabitants. The main human activity in this area is recreational fishing (Zalba *et al.* 2008). The recreational fishing activity is both shore- and boat-based and is concentrated during the spring and summer months. Main target species include striped weakfish (*Cynoscion guatucupa*), whitemouth croaker (*Micropogonias furnieri*), narrownose smooth-hound (*Mustelus schmitti*), and rays (*Sympterygia bonapartii* and *S. acuta*) (Llompart *et al.* 2012). Nearby lands are used for cattle (*Bos primigenius* and *Ovis orientalis*) grazing and crop production. A refuse dump is located within the town limits, approximately 4.5 km from our Kelp Gull study colony. This dump receives domestic waste in addition to waste derived from recreational fishing, oyster harvesting and ranching activities.

Tracking of Individuals and Spatial Analyses

We visited the area every 3 days from 3 October to 30 November 2013. We assessed the foraging patterns of incubating Kelp Gulls using global positioning system (GPS) loggers (Cat-Track), sealed using a rubber shrink tube. Studies using GPS with other gull species suggest minimum effects on weight, breeding success and/or survival (Masello *et al.* 2013; Camphuysen *et al.* 2015; Thaxter *et al.* 2016). Using a leg-noose trap, we captured one incubating adult from 20 nests at which both parents were present, with captures distributed

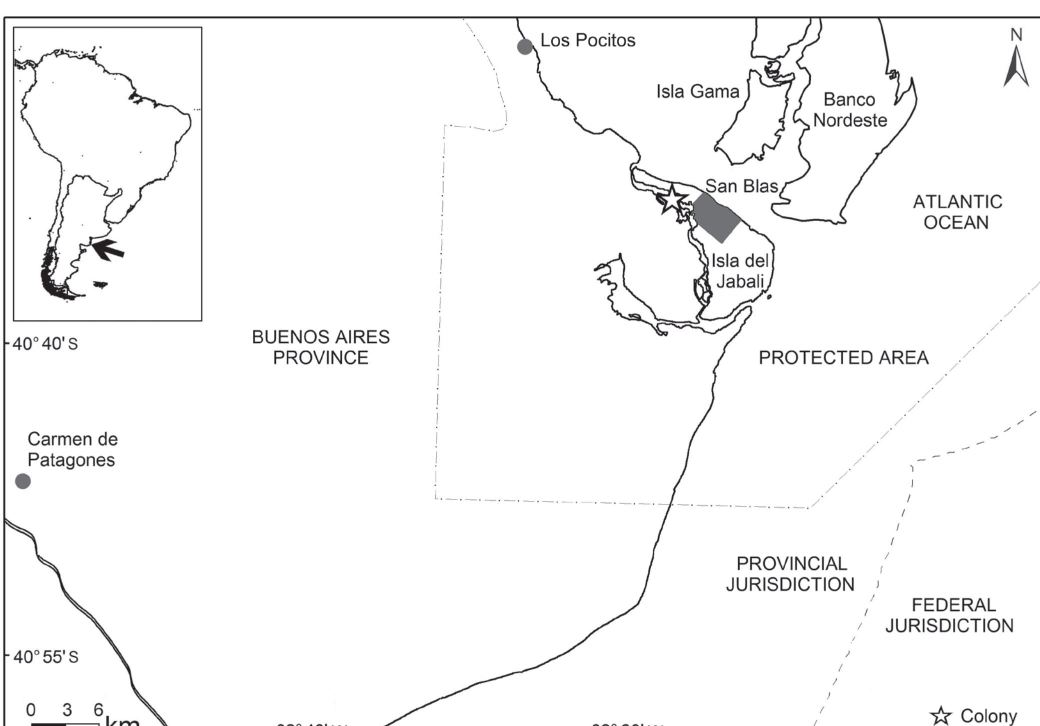

Figure. 1 Map of the study area showing the location of the Kelp Gull colony (star) and the town of San Blas (gray box).

evenly between 20 October and 23 November 2013 to obtain a representative sample throughout the incubation period. We tagged 10 males and 10 females, which were sexed using a discriminant function on head and bill dimensions following Torlaschi *et al.* (2000). We attached the GPS loggers to the dorsal feathers with TESA tape and programmed loggers to collect locations every 1 min, with accuracy within the 5-10 m range. GPS devices weighed 15-18 g, which represents less than 2.5% of Kelp Gull adult body mass (Range = 730-1,200 g; Torlaschi *et al.* 2000) and was assumed to have negligible impact on individual flight performance. We also marked instrumented individuals with an orange pigment on the neck or breast feathers and banded them with a numbered plastic color-band to facilitate individual identification at a distance. We marked nests and retrieved loggers after 4 to 9 days to download information. We completed the capture and recapture procedures in less than 10 min; all released birds returned to their nests in less than 10 min and resumed normal incubating behavior. We did not record egg losses in any of the 20 nests at the time of Kelp Gull recapture.

We assigned GPS positions to a foraging trip when they were > 500 m from the colony boundaries. We excluded positions located up to 500 m from the colony as our field observations indicated that Kelp Gulls used them only as resting areas associated with the colony. For each feeding trip, we calculated the maximum distance from the colony (km), total trip length (km) and trip duration (min). We also determined the number of feeding trips made per day. We tested for individual effects on foraging trip parameters using linear mixed-effects models (LMMs) with trip or day as random effects to prevent pseudoreplication, using the *nlme* library (Pinheiro *et al.* 2009) for statistical program R (R Development Core Team 2014). The models were corrected using a uniform composite symmetry correlation structure (CorComp SyM), specifying the variance weighting function varIdent. We considered models with all possible combinations of predictor variables and selected best-fitting models using Akaike's Information Criterion for small samples sizes (AIC_c; Akaike 1973; Hurvich and Tsai 1989). We used all trips made by each of the 20 individuals to characterize Kelp Gull spatial use, considering records for the whole trip. We made this analysis using the fixed kernel method (Wood *et al.* 2000) with ArcGIS (Environmental Systems Research Institute 2008). We calculated the 50, 75 and 90% density contour areas, defining the core area as the area enclosed by the 50% area contour. In addition, we divided the study area in 1 x 1 km grid cells built with Hawth's Tools (Beyer 2004) and determined the number of different instrumented individuals that used each cell.

We considered a Kelp Gull was in a potential feeding area when it remained at the same site for at least 15 min, based on travel speed (m per sec) calculated from consecutive GPS records. We identified different types of environments used by Kelp Gulls by overlaying foraging trips on a SPOT satellite image (15-m resolution) and on the basis of field observations made throughout the study period. We classified feeding habitats into four categories based on previous information on Kelp Gull diet composition in the study area (Yorio *et al.* 2013): 1) refuse dumps; 2) terrestrial environments; 3) coastal areas; and 4) open sea. To test the differential use of habitats types, we used generalized linear mixed-effects models (GLMMs) with individual as the random effect to prevent pseudoreplication, using the *lme4* library (Bates *et al.* 2011) for statistical program R (R Development Core Team 2014). We assumed a binomial error distribution and used a logit link function because this is a binary variable (Zuur *et al.* 2009; Logan 2011). We considered models with all possible combinations of predictor variables and selected best-fitting models using Akaike's Information Criterion for small samples sizes (AIC_c; Akaike 1973; Hurvich and Tsai 1989).

RESULTS

Spatial Patterns

We recorded a total of 151 trips for the 20 individuals with GPS loggers. One or two trips per day were made by 80% of the Kelp Gull individuals we marked with a maximum of five trips per day recorded for one individual. Mean number of trips per day was 1.5 ± 0.5 (n = 20). The LMM, which included the effect of the individual, explained 2.4% of the variation ($AIC_{c:\ null}$ = 248 and $AIC_{c:\ Ind}$ = 256). The parameters of the model indicated that the individual did not have a significant effect on the number of trips made per day (βi = 1.6; df = 127; t_{127} = 0.9; P = 0.3) (Table 1). Mean trip duration was 272.6 ± 165.2 min (Range = 36.5-1,656.7; n = 20) (Table 1). The variance explained by the LMM, which included individual effects, was 0.1% ($AIC_{c:\ null}$ = 2,110 and $AIC_{c:\ Ind}$ = 2,109). The parameters of the model indicated that the individual did not have a significant effect on the number of trips made per day (β_i = 0.1; df = 83; t_{83} = 1.2; P = 0.2). Mean maximum distances from the colony was 19.6 ± 24.4 km (Range = 3.7-76.9 km; n = 20), while mean total distance traveled was 58.1 ± 74.1 km (Range = 10.6 - 281.8 km; n = 20). The maximum foraging range recorded was 158.5 km (Table 1). Half of the individuals traveled during all of their trips to maximum distances of less than 7 km (mean = 4.8 ± 0.6 km; n = 20), while the rest of the individuals combined relatively short and long trips, generally > 24 km (Table 1).

Table 2. Estimated parameters for predictors of probability of use (presence of individuals) for the selected model. The table shows the estimated parameter (β_i), standard error (SE), statistic value ($t_{df.}$) and associated probability (*P*) for each predictor.

Variable	β_i	SE	t_{600}	*P*
Refuse dumps	1.0513	0.2153	4.883	< 0.001
Coastal areas	-1.1012	0.2481	-4.439	< 0.001
Open sea	-3.2122	0.3350	-9.588	< 0.001
Terrestrial environments	-3.2122	0.3350	-9.588	< 0.001

The 50% kernel contour allowed the identification of two main foraging areas, one at the urbanized sector of Isla del Jabalí and the other on the southwest coast of Isla Gama (40° 33′ 55.26″ S, 62° 27′ 02.55″ W; Fig. 2). Only the urbanized sector of Isla del Jabalí was used by many individuals (75%; $n = 20$) (Fig. 3). The southwest coast of Isla Gama was visited by only one individual who made several trips and remained there for extended periods of time while other locations in the study area were used by 1-3 tagged individuals (Fig. 3). Seven of the instrumented individuals (35%; $n = 20$) used areas within the Provincial and Federal jurisdictions located beyond the boundaries of the Bahía San Blas protected area in all or part of their foraging trips.

Feeding Areas

The 15,589 positions obtained during 151 feeding trips made by 20 individuals allowed the identification of foraging areas in both natural and anthropogenic environments. Forty-seven percent of the individuals

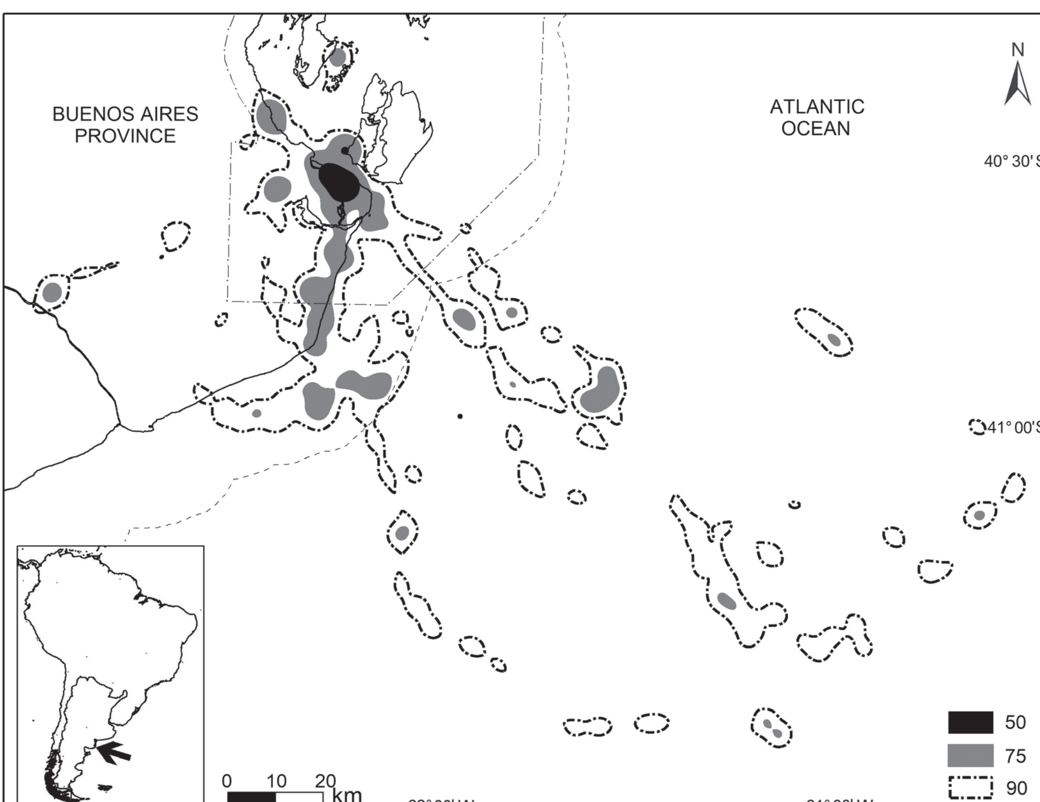

Figure. 2 Use of areas by Kelp Gulls incubating at Islote Arroyo Jabalí Este, Bahía San Blas, Argentina, during 2013. Kernel contours shown as 50, 75 and 90% of locations.

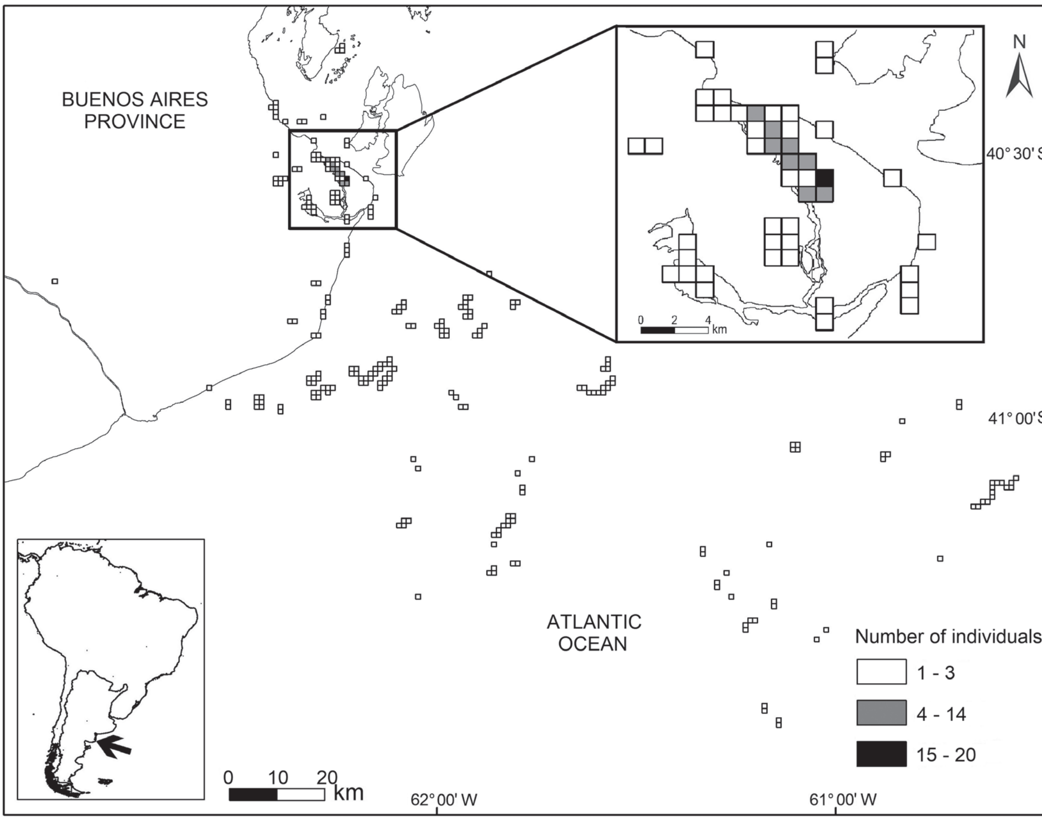

Figure 3. Use of areas by Kelp Gulls incubating at Islote Arroyo Jabalí Este, Bahía San Blas, Argentina, as a function of the number of tagged individuals (1 km^2 cells).

switched between two or three different habitat types during a given foraging trip. Of the used habitats, refuse dumps were the most visited with 113 trips (75%; *n* = 151 trips). Of the 113 trips to refuse dumps, 108 were to the dump in Bahía San Blas, four were to the dump in Los Pocitos, located 17 km north of the colony, and one was to the dump in Carmen de Patagones, located 63 km southwest of the colony. In 47% (*n* = 151) of the trips, Kelp Gulls visited coastal habitats that included intertidal areas and beaches regularly used by recreational fishers located to the north and south of the colony. In a total of 15 trips (10%), Kelp Gulls also visited terrestrial environments that are regularly used for cattle grazing and crop production. In 10% (*n* = 151) of cases, trips included offshore locations, two to the north of the colony within the San Blas Bay (10 and 24 km, respectively) and the remaining eight to areas located between 33 and 158 km offshore to the southeast of the colony. Seventy-five percent of the tagged individuals (*n* = 20) visited the Bahía San Blas refuse dump in over half of their foraging trips.

Based on the GLMMs, the best model describing the variation in habitat use during the feeding trip included the effect of the different types of habitats visited and the individual ($AIC_{c:\ Ind} = 783$ and $AIC_{c:\ Ind+Hab} = 592$). The model with these factors explained 25.3% of the variation. The probability of a habitat being used by Kelp Gulls (presence of individuals) was positively related to refuse dumps (Table 2).

Discussion

Kelp Gulls during incubation visited a variety of habitats including both natural and anthropogenic environments. The analysis of foraging trips complemented with satel-

Table 1. Trip parameters (mean ± SD; range in parentheses) during the incubation period of Kelp Gulls breeding at Islote Arroyo Jabalí Este, Bahía San Blas, Argentina.

# Individual	Total Trips	Days	Trips Per Day	Trip Duration (min)	Maximum Distance (km)	Total Distance Traveled (km)
1	7	4	1.6 ± 0.5 (1-2)	240.9 ± 108.7 (111.3-176.7)	3.7 ± 1.9 (0.8-5.2)	12.6 ± 6.3 (2.4-18.7)
2	3	9	1.5 ± 0.7 (1-2)	215.7 ± 125.6 (109.7-354.5)	4.8 ± 0.1 (4.7-4.9)	11.9 ± 1.0 (10.7-12.8)
3	2	2	1.0 ± 0.0	205.6 ± 100.2 (134.8-276.4)	4.8 ± 0.1 (4.7-4.8)	16.3 ± 6.3 (11.2-20.8)
4	14	2	1.7 ± 0.4 (1-2)	87.3 ± 23.8 (45.9-132.8)	4.8 ± 0.1 (4.6-5.1)	11.3 ± 1.3 (10.2-14.8)
5	7	8	1.1 ± 0.4 (1-2)	377.2 ± 195.6 (201.2-689.1)	4.6 ± 1.3 (1.7-5.9)	19.1 ± 9.0 (13.2-36.9)
6	6	6	2.0 ± 0.0	95.9 ± 18.8 (69.4-115.4)	4.8 ± 0.2 (4.7-5.1)	11.1 ± 1.2 (9.6-13.1)
7	7	3	1.2 ± 0.6 (1-2)	60.9 ± 19.8 (44.2-88.8)	4.8 ± 0.2 (4.6-5.1)	10.6 ± 1.2 (9.4-12.0)
8	8	7	2.0 ± 1.4 (1-4)	154.7 ± 204.7 (49.2-656.1)	4.8 ± 0.1 (4.6-4.9)	15.3 ± 4.9 (11.2-23.6)
9	7	4	1.2 ± 0.5 (1-2)	389.8 ± 560.9 (113.1-1,656.7)	4.9 ± 1.2 (4.9-5.1)	15.4 ± 2.2 (11.5-19.0)
10	13	6	1.8 ± 1.5 (1-4)	178.1 ± 230.3 (43.5-842.3)	5.1 ± 0.6 (4.6-6.3)	15.7 ± 10.8 (9.8-21.7)
11	15	7	1.6 ± 0.5 (1-2)	145.3 ± 67.4 (42.4-248.9)	6.2 ± 5.2 (4.6-25.0)	14.9 ± 11.1 (9.2-53.8)
12	3	2	1.5 ± 0.7 (1-2)	450.3 ± 387.1 (37.6-805.4)	15.8 ± 11.8 (2.8-25.8)	57.1 ± 45.4 (6.2-93.7)
13	29	9	3.2 ± 0.9 (2-5)	86.2 ± 38.8 (36.5-179.8)	7.0 ± 4.3 (0.7-16.8)	18.4 ± 11.5 (2.7-40.8)
14	2	2	1.0 ± 0.0	398.1 ± 48.8 (363.6-432.6)	31.7 ± 0.1 (31.7-31.8)	75.7 ± 1.6 (74.5-76.8)
15	4	3	1.3 ± 0.5 (1-2)	528.9 ± 233.9 (211.1-754.3)	43.7 ± 28.8 (1.6-66.5)	148.3 ± 101.0 (9.18-244.1)
16	8	7	1.1 ± 0.3 (1-2)	570.8 ± 398.8 (118.7-1,147.0)	76.0 ± 68.0 (4.6-158.5)	190.7 ± 172.4 (11.2-429.5)
17	6	4	1.5 ± 0.2 (1-2)	180.6 ± 170.9 (70.8-520.1)	10.9 ± 17.4 (0.5-46.2)	29.6 ± 47.6 (10.6-126.1)
18	4	3	1.3 ± 0.5 (1-2)	211.4 ± 259.3 (39.3-592.4)	18.5 ± 32.1 (1.1-66.5)	65.5 ± 117.2 (3.1-241.1)
19	4	3	1.3 ± 0.5 (1-2)	310.5 ± 239.1 (67.8-624.7)	57.8 ± 60.7(2.4-144.3)	139.8 ± 142.6 (6.7-341.8)
20	2	2	1.0 ± 0.0	564.5 ± 321.5 (337.1-791.8)	76.9 ± 31.8 (54.4-99.3)	281.8 ± 8.5 (275.8-287.9)

lite images corroborated the use of refuse dumps as their primary foraging habitat. Urban waste is a common component in Kelp Gull feeding ecology at other breeding locations worldwide (Steele 1992; Coulson and Coulson 1993; Bertellotti and Yorio 1999), but information obtained at a nearby islet indicated that domestic refuse is little represented in their diet (Yorio *et al.* 2013). On the other hand, the waste generated by recreational fishing, which is regularly disposed of at the Bahía San Blas refuse dump, was identified as an important diet component of Kelp Gulls breeding in the study area (Yorio *et al.* 2013). In agreement with individual tracking and diet information, our field team regularly observed large flocks of up to 700 individuals in adult plumage feeding on fish waste at the Bahía San Blas refuse dump during the study period, suggesting this food source is important for Kelp Gull populations breeding in the protected area.

Many gull species around the world use intertidal environments during the breeding season (Kubetzki and Garthe 2003; Ellis *et al.* 2005; Suárez *et al.* 2012). Research conducted at the study site (Yorio *et al.* 2013) and at different locations in coastal Argentina shows the significance of intertidal habitats for breeding Kelp Gulls, where they prey on a wide variety of crustaceans, mollusks, polychaetes and echinoderms (Yorio and Bertellotti 2002; Petracci *et al.* 2004; Yorio *et al.* 2013). The analysis of tracking data in combination with satellite images shows that in fact Kelp Gulls at Bahía San Blas used different shoreline locations. Although they were in part likely preying on mollusks or crabs at several feeding sites, observations by our field team confirmed that shoreline locations used by several of the tracked individuals corresponded to sites where fish caught by recreational fishers were regularly cleaned and where Kelp Gull flocks were feeding on the generated waste. This suggests that Kelp Gull use of the shoreline in our study area is highly influenced by recreational fishing activities. Given the methodology used, however, some of the identified coastal sites may have been used in fact as roosting areas. Our observations documented that some of the sites along the Arroyo del Jabalí that were used by instrumented individuals for short periods before and after visiting the Bahía San Blas refuse dump were also regularly used as roosting areas by Kelp Gull flocks (T. Kasinsky, pers. obs.). This indicates that the use of shoreline environments as feeding habitat was somewhat overestimated.

Several instrumented individuals were recorded traveling offshore to areas where they may have been preying upon pelagic fish such as argentine anchovy (*Engraulis anchoita*) (Yorio *et al.* 2013) or taking advantage of waste discarded from commercial trawl vessels. Seco Pon and Favero (2011) reported that Kelp Gulls feed on discards from vessels operating during the austral spring in areas offshore from our study site. Similarly, the at-sea locations of two of the tracked individuals in nearshore locations within the San Blas Bay correspond to areas regularly used for boat-based recreational fishing, suggesting that Kelp Gulls were also likely feeding on waste generated during on-board processing of fish.

Although less often, Kelp Gulls also visited terrestrial environments that are used for crop production and cattle grazing. Several studies on different gull species indicate they regularly forage in agricultural areas, taking advantage of a variety of food items such as cereals (Calvino-Cancela 2011) and invertebrates, some made available during ploughing (Schwemmer and Garthe 2008; Caron-Beaudoin *et al.* 2013). This is consistent with previous dietary analyses conducted in the Bahía San Blas area, which show that breeding Kelp Gulls consume cereal and insects, particularly of the order Coleoptera (Yorio *et al.* 2013).

Even though the Bahía San Blas refuse dump was a primary feeding site for most of our tagged Kelp Gulls, individuals alternated the use of urban, coastal, open-sea and/or terrestrial habitats between feeding trips and even during the same trip. However, given the methodology used, we cannot rule out that individuals obtained food in only one of the visited habitats and thus assess the degree of individual specialization. Further studies are needed to simultaneously assess foraging patterns and food consumption of marked individuals. Moreover, further research is needed to confirm Kelp Gull foraging strategy during other breeding stages, as in many seabirds the spatial requirements may change throughout the reproductive cycle (Huin 2002; Boersma and Rebstock 2009; Suárez *et al.* 2012). Nevertheless, previous diet studies at a nearby colony indicated that prey composition was similar between the incubation and chick stages (Yorio *et al.* 2013), suggesting a similar spatial foraging pattern throughout the season. Foraging habitat choice can be also affected by foraging profitability and distance from the colony (Duhem *et al.* 2005; Patenaude-Monette *et al.* 2014). Most foraging trips made by Kelp Gulls were to feeding habitats located relatively close to their colony, mainly the Bahía San Blas refuse dump which is located 4.5 km away, but several relatively long trips of up to almost 156 km were made to offshore waters. The relatively low numbers of individuals and foraging trips associated with offshore and terrestrial environments may be because nesting Kelp Gulls have an alternative predictable and apparently abundant high quality food source close to their nesting site.

Gulls breeding near urban centers or fishing grounds may greatly benefit from anthropogenic food resources (see review in Oro *et al.* 2013; but see Ramírez *et al.* 2012). As in other opportunistic gull species (Oro *et al.* 2013), the use of these anthropogenic food subsidies could favor Kelp Gull individual survival and reproductive success and ultimately result in population growth (Lisnizer *et al.* 2011). Censuses conducted between 2000 and 2013 indicated a significant increase in the number of breeders at colonies located in the Bahía San Blas area (Suárez *et al.* 2014), suggesting a possible causal link between Kelp Gull demographic behavior and availability of anthropogenic food resources, and the need for effective recreational fishery waste management. Feeding areas most frequently used by Kelp Gulls were associated with recreational fishing within the boundaries of the Bahía San Blas protected area, thus facilitating decision making and the implementation of management actions. However, our results also show that Kelp Gulls traveled outside the boundaries of the protected area and even went from Provincial to offshore Federal waters. Therefore, management approaches will require the coordination of different jurisdictions to implement complementary actions beyond the boundaries of the protected area.

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