Austral ECOLOGY A Journal of ecology in the Southern Hemisphere

Ecological Society of Australia

Austral Ecology (2018) **43**, 861–875

Contribution of recreational fisheries to the diet of the opportunistic Kelp Gull

CRISTIAN MARINAO,[1]* TATIANA KASINSKY,[1] NICOLÁS SUÁREZ[1] AND PABLO YORIO[1,2]

[1]*Centro Para el Estudio de Sistemas Marinos, CONICET, Blv. Brown 2915 (U9120ACV), Puerto Madryn, Chubut* 9100 *(Email: marinao@cenpat-conicet.gob.ar), and* [2]*Wildlife Conservation Society Argentina, Ciudad Autónoma de Buenos Aires, Argentina*

Abstract We assessed Kelp Gull (*Larus dominicanus*) diet composition complementing conventional and stable isotope methods to determine the relevance of food derived from recreational fisheries. To achieve this goal, we quantified Kelp Gull diet composition breeding at the Bahía San Blas protected area, Argentina, between 2012 and 2014, assessing differences among four colonies, breeding stages and years. Diet analyses were based on pellets (n = 1054), chick stomach content samples (n = 351) and stable isotope analysis of adult and chick whole blood samples (n = 20 and 40, respectively). Kelp Gulls fed on at least 41 prey items, mainly fish complemented by marine invertebrates, Oat grain and insects. Stripped Weakfish (*Cynoscion guatucupa*), a demersal species, was in general the most frequent species among fish prey. Analyses of similarity indicated that diet composition based on pellet analysis was significantly different among the four colonies and, with a couple of exceptions, differed among breeding stages. Diet composition differed only between 2012 and 2013. Bayesian mixing model outputs confirmed demersal fish had in general the highest contribution to Kelp Gull diet. Stripped Weakfish is the most important target of recreational fisheries in the study area, and large quantities of waste resulting from the processing of this and other target fish is disposed mainly along the shore and in the Bahía San Blas refuse dump. The fact that it is a demersal species normally unavailable to surface feeding seabirds and the large size of Stripped Weakfish individuals found in diet samples (mean 41.5 ± 5.2 cm) strongly suggest that Kelp Gulls obtained this prey from the waste generated by the recreational fishery. Results show a strong association between the Kelp Gull and the recreational fishing activity that takes place in the Bahía San Blas protected area, likely resulting from the large amount of waste generated by the fishery.

Key words: Bahía San Blas, *Cynoscion guatucupa*, diet, *Larus dominicanus*, recreational fisheries.

INTRODUCTION

The role of anthropogenic food resources in shaping wildlife behaviour and the way its increased availability can result in different effects at the individual and population levels are growing concerns among researchers and wildlife managers (Lowry *et al.* 2013; Oro *et al.* 2013; Mateo-Tomás *et al.* 2015; Newsome *et al.* 2015). Many seabirds, particularly *Larus* gulls, have learned to take advantage of food derived from a variety of human activities, such as fishery waste (Garthe *et al.* 1996; Bicknell *et al.* 2013), domestic refuse (Belant *et al.* 1993; Duhem *et al.* 2003), and seeds and fruits (Calvino-Cancela 2011). These food subsidies can have important implications on the ecology of generalist and opportunistic gulls, and affect their individual condition, fecundity and survival (Auman *et al.* 2008; Weiser & Powell 2010; Oro *et al.* 2013). Regarding fishing activities, it is well-known that commercial trawl fisheries worldwide provide gulls with abundant and predictable food subsidies in the form of discards and offal (e.g. Furness *et al.* 1992; Bertellotti & Yorio 2000; Weichler *et al.* 2004; Wickliffe & Jodice 2010), but there is little information about gull use of waste derived from recreational fisheries. Millions of anglers participate in recreational fisheries globally, generating billions of dollars in economically developed countries and constituting an increasingly important activity in many developing countries (FAO 2012). Gulls worldwide associate with recreational fisheries, but studies up to date have only focused on the negative impacts resulting from gear related injuries and mortality (Berón & Favero 2009; Moore *et al.* 2009; Hong *et al.* 2013; Yorio *et al.* 2014) and have not yet assessed the relevance for gull populations of the waste derived from the on-shore processing of the anglers' catch.

The Kelp Gull (*Larus dominicanus*) is the most abundant and widely distributed gull in the Southern Hemisphere, nesting in South America, Africa, New Zealand, Australia, sub-Antarctic islands and Antarctic Peninsula (Burger & Gochfeld 1996). In

---

*Corresponding author.

Accepted for publication May 2018.

doi:10.1111/aec.12627

Argentina, its population breeding in coastal areas was estimated at 106 200 breeding pairs (Yorio *et al.* 2016). As most *Larus* gulls, the Kelp Gull has a generalist and opportunistic feeding ecology, consuming a wide variety of prey obtained in natural and human-related environments. Its plasticity in prey use has been reported in studies conducted throughout its breeding distribution, including South Africa (Steele 1992), Australia (Coulson & Coulson 1993), Chile (Ludynia *et al.* 2005) and the subantarctic sector (Favero & Silva 1998). Previous studies in Argentina based on conventional diet methods showed that this species feeds on fish, marine invertebrates and terrestrial insects, with an important anthropogenic component depending on the breeding location (Bertellotti & Yorio 1999; Petracci *et al.* 2004; Yorio *et al.* 2013; González-Zevallos *et al.* 2017).

At the Bahía San Blas protected area, in southern Buenos Aires, Argentina, Kelp Gulls nest at several locations, and their numbers have increased in the last two decades (Suárez *et al.* 2014). The area is the site of one of the largest shore-based marine recreational fisheries in the southwest Atlantic coasts (Llompart *et al.* 2012), which generates large amounts of waste resulting from the on-shore processing of the catch. Previous research on the diet composition of Kelp Gulls breeding in the study area indicated that the Stripped Weakfish (*Cynoscion guatucupa*), which is mostly obtained from recreational fishing in the form of fishery waste, is the most frequent consumed item (Yorio *et al.* 2013). However, this assessment relied only on pellet analysis, which may underestimate the presence of soft prey items such as fish waste consisting of flesh and guts, and on chick stomach content samples, which represent only a snapshot of recent diet. In addition, prey frequency of occurrence was used as a measurement of diet data, which may over-emphasize prey that are present in small numbers, persist longer in stomachs or may not be so significant in terms of biomass (Duffy & Jackson 1986; Barret *et al.* 2007). Stable isotope analysis is a less-invasive method that provides information on food assimilation over variable temporal scales depending on the analysed tissue, although it is inadequate for estimating the fine-scale taxonomic composition of seabird diet (Inger & Bearhop 2008). Several gull diet studies have shown the value of using stable isotope analysis (Ramos *et al.* 2009; Moreno *et al.* 2010; Steenweg *et al.* 2011), and it has been found that the analysis of pellets and food remains underestimate the contribution of fish relative to stable isotope estimates (Weiser & Powell 2011). The combination of conventional and biochemical methods is often recommended to overcome some of their respective limitations, minimize biases, and adequately assess diet requirements (Sydeman *et al.* 1997; Polito *et al.* 2011; Karnovsky *et al.* 2012). Given the apparent relevance of the anthropogenic component in Kelp Gull diet and its population trend in the study area, it is important to obtain a more thorough characterization of its diet, representative of the entire population breeding in the area and taking into account the potential variation throughout the breeding season and among years. Our goal was to assess diet composition complementing conventional and stable isotope methods in order to determine the relevance of food derived from recreational fisheries. To achieve this goal, we (i) quantified and compared Kelp Gull diet composition among four colonies located in the Bahía San Blas protected area and (ii) determined diet variation throughout the breeding cycle and among years.

METHODS

Study area

The study was conducted in the south-western sector of the Bahía San Blas protected area in Buenos Aires Province, Argentina (Fig. 1). The coastal sector is characterized by extensive mudflats and marshes of *Spartina* spp. and *Sarcocornia perennis* with crab beds of *Neohelice granulata* and *Cyrtograpsus* spp. (Zalba *et al.* 2008). The town of Bahía San Blas, of about 600 inhabitants, is located in Isla del Jabalí (Fig. 1).

The main economic activity in the area is recreational fishing (Zalba *et al.* 2008), targeting mainly Stripped Weakfish in addition to Whitemouth Croaker (*Micropogonias furnieri*), Narrownose Smooth-hound (*Mustelus schmitti*) and silversides (mainly *Odontesthes argentinensis* and *O. platensis*) (Llompart *et al.* 2012). The area receives an average of over 40 thousand fishers per year, mostly during the spring and summer months, and is both shore- and boat-based (about 40 licensed fishing boats) (Llompart *et al.* 2012). Catches of Stripped Weakfish, the main target fish, peak during November and December, and totalling about 69.9 metric tons for shore-based catches (Llompart *et al.* 2012). Recreational fishing generates large quantities of waste resulting from the on-shore processing of the shore-based catch, mostly Stripped Weakfish. Catches of Whitemouth Croakers are relatively smaller (19.6 metric tons), and only offal is discarded. Processing of Narrownose Smooth-hounds (6.4 metric tons) result in low amounts of waste profitable to gulls, as only heads and skin are discarded, and silversides are not processed on-site. Fish processing occurs mainly at two designated sites where fishers can clean their catch and the generated waste is later disposed at the urban refuse dump, although illegal fish cleaning and waste disposal also occurs at several other sites along the shores of the island. An estimated 70 metric tons are disposed between November and December (C. Marinao, unpubl. data, 2014). The adjacent continental sector of the bay is used mainly for cattle grazing and the production of annual crops, including wheat, oat, rye and several different pastures (Iurman 2011).

doi:10.1111/aec.12627

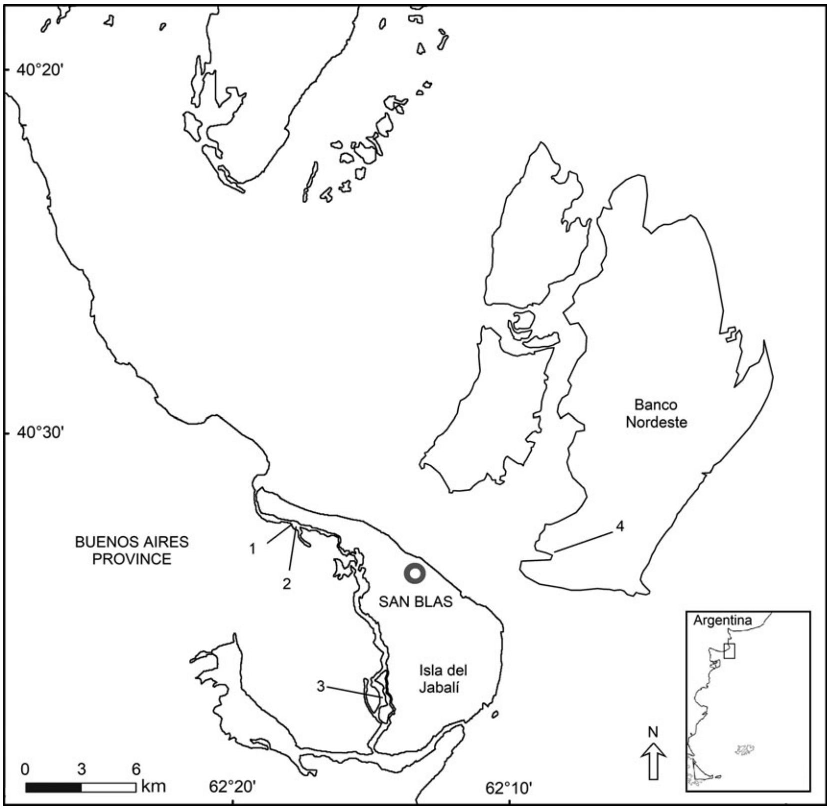

Fig. 1. Map of the study area showing the location of the Kelp Gull colonies of Islote Arroyo Jabalí Oeste (1), Islote Arroyo Jabalí Este (2), Islote Fondo Medialuna (3), Banco Nordeste (4) and the town of San Blas (empty circle).

We analysed Kelp Gull diet composition during the 2012, 2013 and 2014 breeding seasons at four colonies located less than 10 km from the town of Bahía San Blas: Islote Arroyo Jabalí Oeste (40°32′S, 62°17′W), Islote Arroyo Jabalí Este (40°32′S, 62°16′W), Islote del Fondo Medialuna (40°37′S, 62°14′W) and Banco Nordeste (40°32′S, 62°10′W) (Fig. 1), totalling an estimated 3600 nest in the 2013 breeding season (Suárez *et al.* 2014). In the study area, Kelp Gulls start laying in late September, eggs start hatching in late October and chicks start fledging in early December. The modal clutch size is three eggs (Yorio *et al.* 2005).

Conventional diet analysis

We collected pellets from around nests within previously determined study areas in each of the four colonies every three to 4 days from October to December. During each visit we collected all pellets found in the study areas, and discarded those found in the first visit so as to eliminate old pellets from the analysis. We noted the general breeding status of nests during each visit when diet samples were collected, and divided the breeding cycle into three stages: incubation, young chicks (<15 days of age) and old chicks (>15 days of age). We distinguished young and old chicks by size and the degree of plumage development (unpublished data). We collected a total of 1054 pellets in the four colonies and three above mentioned breeding stages. To assess possible diet differences among colonies and breeding stages, we used pellets collected during the 2013 breeding season (see Table 1 for sample sizes), and to assess possible diet differences among years we used pellets collected only in Banco Nordeste and in both chick stages of the 2012 to 2014 breeding season (see Table 2 for sample sizes).

We obtained stomach content samples from a total 351 young and old chicks captured by hand at the four colonies using the water offloading technique (Wilson 1984). We sampled only one chick per nest, the largest in the brood. We flushed individuals with sea water between one and three times until the water was clear, indicating the stomach was empty, using a 4.0 mm surgical catheter attached to a 60 mL syringe. We drained samples through a 0.5 mm mesh sieve and preserved them in 70% ethanol for later analysis. To assess possible differences in diet composition among colonies and stages of the breeding cycle, we used stomach content samples obtained in 2013 (see Table 3 for sample sizes), and to assess possible differences in diet composition among years we used samples obtained only at Banco Nordeste in both chick stages of the 2012 to 2014 breeding season (see Table 4 for sample sizes).

Back in the laboratory, we dissected each pellet and stomach content sample in a tray under a zoom binocular microscope (×15 magnifications) and identified food remains to the lowest taxonomic level possible, using fish otoliths and cranial bones, crustacean shell fragments and

doi:10.1111/aec.12627

Table 1. Frequency of occurrence (%) of prey items in pellets collected at four Kelp Gull colonies in the Bahía San Blas protected Area, Argentina, during the different stages of the 2013 breeding season

	Islote Arroyo Jabalí Oeste			Islote Arroyo Jabalí Este			Islote Fondo Medialuna			Banco Nordeste		
	Incubation (*n* = 99)	Young chicks (*n* = 62)	Old chicks (*n* = 70)	Incubation (*n* = 57)	Young chicks (*n* = 59)	Old chicks (*n* = 66)	Incubation (*n* = 60)	Young chicks (*n* = 71)	Old chicks (*n* = 68)	Incubation (*n* = 73)	Young chicks (*n* = 59)	Old chicks (*n* = 73)
Fish	35.4	48.4	41.4	52.6	64.4	69.7	40.0	49.2	85.9	76.7	81.4	81.7
Cynoscion guatucupa	19.2	32.3	25.7	42.1	22.0	30.3	25.0	16.4	57.7	68.5	50.8	46.7
Micropogonias furnieri	0.0	3.2	1.4	0.0	0.0	6.1	0.0	0.0	3.8	1.4	0.0	8.3
Engraulis anchoita	1.0	4.8	4.3	1.8	1.7	1.5	6.7	8.2	1.3	1.4	1.7	1.7
Trachurus lathami	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Odontesthes spp.	1.0	1.6	2.9	3.5	0.0	0.0	5.0	9.8	3.8	0.0	5.1	3.3
Odontesthes nigricans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Odontesthes smitti	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0
Odontesthes argentinensis	2.0	0.0	1.4	1.8	0.0	0.0	0.0	0.0	0.0	4.1	0.0	1.7
Porichthys porosissimus	4.0	3.2	5.7	0.0	39.0	21.2	0.0	6.6	6.4	1.4	10.2	6.7
Triathalassothia argentina	0.0	0.0	4.3	0.0	0.0	13.6	0.0	0.0	5.1	0.0	0.0	0.0
Pleuronectiforme	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	1.7	3.3
Unidentified fish	5.1	4.8	0.0	7.0	5.1	0.0	5.0	11.5	5.1	1.4	10.2	8.3
Molluscs	48.5	41.9	15.7	24.6	22.0	21.2	56.7	27.9	24.4	16.4	3.4	15.0
Brachidontes rodriguezi	45.5	40.3	7.1	24.6	11.9	15.2	53.3	26.2	17.9	16.4	3.4	10.0
Heleobia australis	4.0	6.5	8.6	3.5	1.7	1.5	8.3	4.9	2.6	0.0	0.0	0.0
Crassostrea gigas	0.0	0.0	0.0	0.0	1.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Polyplacophora	6.1	6.5	1.4	1.8	1.7	4.5	0.0	0.0	1.3	0.0	0.0	3.3
Pectinidae	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified molluscs	0.0	0.0	0.0	0.0	5.1	0.0	3.3	0.0	0.0	0.0	0.0	0.0
Crustaceans	3.0	4.8	0.0	5.3	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0
Cyrtograpsus angulatus	1.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyrtograpsus altimanus	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified isopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0
Unidentified crustaceans	1.0	4.8	0.0	3.5	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0
Insects	13.1	17.7	14.3	26.3	13.6	16.7	30.0	36.1	3.8	4.1	11.9	1.7
Coleoptera (7 taxa)	18.2	17.8	7.1	38.6	10.2	6.1	21.7	27.9	2.6	5.5	11.9	1.7
Lepidoptera	0.0	0.0	5.7	0.0	0.0	3.0	1.7	0.0	0.0	1.4	0.0	0.0
Ortoptera	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Hemiptera	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified insects	0.0	0.0	1.4	5.3	3.4	6.1	20.0	16.4	1.3	0.0	0.0	0.0
Avena sativa	8.1	21.0	31.4	8.8	8.5	16.7	1.7	16.4	2.6	0.0	0.0	0.0
Carrion	7.1	4.8	32.9	0.0	13.6	7.6	0.0	1.6	3.8	2.7	3.4	6.7
Urban refuse (inorganic material)	3.0	1.6	1.4	15.8	6.8	4.5	25.0	19.7	0.0	6.8	3.4	3.3

chelae, mollusc shell fragments and insect remains. We identified prey items with the aid of published information (Castellanos 1967; Boschi *et al.* 1992; Gordillo 1995; Gosztonyi & Kuba 1996; Deli Antoni 2008) and a reference collection. Except for Stripped Weakfish, otoliths and other diagnostic prey parts were too eroded for subsequent analysis of prey sizes. Only one Striped Weakfish otolith, cranial or scapular bone (angular, dentary, maxilla and cleithrum) in each pellet was selected and used to estimate individual prey sizes. Otolith and bone length was measured to the nearest 0.01 mm, and the size of each item was calculated applying the equations reported in Perez Comesaña *et al.* (2014) that relate otolith and bone length with total length of individual fish. We classified prey remains that were too degraded to be securely identified to species level as 'unidentified prey'.

We calculated frequency of occurrence (the percentage of sampling units containing a particular prey type) for each prey type obtained from pellet and stomach content samples (Duffy & Jackson 1986). Since many prey individuals were incomplete and most diagnostic prey parts encountered in samples were too eroded for subsequent analysis, we could not conduct a numerical analysis nor estimate the contribution by mass of prey species. For the analysis of the diet, we grouped samples within the above-defined three stages of the breeding cycle (incubation, young chicks and old chicks). We tested for differences in the frequency of occurrence of prey types between colonies, breeding stages and years using the analysis of similarities procedure (ANOSIM) with the PRIMER 6.1.6 package (Clarke & Gorley 2006). We constructed a similarity matrix of the samples using the Bray–Curtis similarity coefficient (Clarke & Gorley 2006), and employed similarity percentages (SIMPER) to determine the prey species that contributed most to the dissimilarities between groups (Clarke 1993; Clarke & Warwick 2001).

Stable isotope analysis

During 2013, we obtained whole blood samples (0.5–1 mL) from the brachial vein of randomly selected Kelp Gull adults during the late incubation stage at Islote Jabalí

Table 2. Frequency of occurrence (%) of prey items in pellets collected at the Banco Nordeste Kelp Gull colony, Bahía San Blas protected Area, Argentina, during the chick stages of 2012, 2013 and 2014

	2012		2013		2014	
	Young chicks (*n* = 33)	Old chicks (*n* = 66)	Young chicks (*n* = 59)	Old chicks (*n* = 73)	Young chicks (*n* = 70)	Old chicks (*n* = 68)
Fish	75.8	95.5	81.4	81.7	71.4	94.1
Cynoscion guatucupa	54.5	62.1	50.8	46.7	44.3	51.5
Micropogonias furnieri	0.0	4.5	0.0	8.3	0.0	0.0
Unidentified Sciaenidae	21.2	19.7	0.0	0.0	0.0	0.0
Engraulis anchoita	0.0	0.0	1.7	1.7	2.9	7.4
Pleuronectiforme	0.0	0.0	1.7	3.3	0.0	1.5
Odontesthes spp.	0.0	0.0	5.1	3.3	1.4	1.5
Odontesthes nigricans	0.0	0.0	0.0	1.7	0.0	0.0
Odontesthes smitti	0.0	0.0	1.7	0.0	0.0	0.0
Odontesthes argentinensis	0.0	0.0	0.0	1.7	1.4	2.9
Porichthys porosissimus	0.0	4.5	10.2	6.7	4.3	8.8
Ramnogaster arcuata	0.0	0.0	0.0	0.0	1.4	4.4
Triathalassothia argentina	0.0	0.0	0.0	0.0	1.4	1.5
Percophis brasiliensis	0.0	1.5	0.0	0.0	0.0	0.0
Unidentified fish	0.0	4.5	10.2	8.3	14.3	19.1
Molluscs	3.0	1.5	3.4	15.0	0.0	0.0
Brachidontes rodriguezi	3.0	0.0	3.4	10.0	0.0	0.0
Polyplacophora	0.0	0.0	0.0	3.3	0.0	0.0
Pelecipoda	0.0	1.5	0.0	0.0	5.7	1.5
Buccinanops globulosus	0.0	0.0	0.0	0.0	0.0	2.9
Crustaceans	3.0	1.5	0.0	0.0	1.4	0.0
Cyrtograpsus angulatus	0.0	0.0	0.0	0.0	1.4	0.0
Unidentified isopoda	3.0	0.0	0.0	0.0	0.0	0.0
Unidentified crustaceans	0.0	1.5	0.0	0.0	1.4	0.0
Insects	18.2	1.5	11.9	1.7	0.0	0.0
Coleoptera (11 taxa)	21.3	0.0	11.9	1.7	0.0	0.0
Lepidoptera	0.0	0.0	0.0	0.0	5.7	4.4
Odonata	0.0	0.0	0.0	0.0	1.4	0.0
Unidentified insects	3.0	1.5	0.0	0.0	18.6	7.4
Carrion	6.1	0.0	0.0	0.0	0.0	0.0
Larus dominicanus (chick)	3.0	0.0	3.4	6.7	0.0	0.0
Urban refuse (inorganic material)	18.2	6.1	3.4	3.3	20.0	11.8

Este (*n* = 20) and from randomly selected chicks older than 20 days old at each of the four study colonies (*n* = 40; 10 samples from each colony). Whole-blood samples integrate the isotopic composition of the prey ingested by an individual during approximately a month before the sample is collected (Hobson & Clark 1992). We captured adult gulls at their nests using leg-nooses and sampled only one chick per nest, the largest in the brood. We conserved blood samples in ethanol 70% as this procedure has been recommended when freezing is not possible and it has been shown that it has no significant effects on blood isotopic signatures (Hobson *et al.* 1997; Halley *et al.* 2008). We dried samples at 60°C over 24 h and then ground them in a micro mortar. We set a sub-sample of 1 ± 0.2 mg. in a tin capsule for stable isotope analysis. Sample analyses were performed by the Stable Isotope Facility of the University of California, Davis (USA). Stable isotope abundance is expressed using standard δ notation relative to carbonate Vienna PeeDee Belemnite and atmospheric nitrogen. The internal laboratory standards used were Bovine Liver, USGS-41 Glutamic Acid, Nylon 5 and Glutamic Acid. Observed analytical errors were 0.14‰ and 0.19‰, for $\delta\ ^{13}$C and $\delta\ ^{15}$N, respectively. We selected the potential main prey items in the diet of Kelp Gulls breeding at the Bahía San Blas protected area based on the results of this study and a previous study (Yorio *et al.* 2013). Information on the isotopic composition of Argentine Anchovy (*Engraulis anchoita*) (dorsal muscle; *n* = 10) and Stripped Weakfish (dorsal muscle; *n* = 10) corresponded to prey obtained during this study in the study area (δ^{13}C = −18.68 ± 0.45‰, δ^{15}N = 16.07 ± 0.74‰, and δ^{13}C = −15.92‰, δ^{15}N = 18.94, SD for both = 0.29‰). Lipids from Argentine Anchovy samples were extracted using chloroform–methanol (2:1) (Post *et al.* 2007). Isotopic information of the Mussel (*Brachidontes rodriguezi*) and insects from our study area could not be obtained, so prey isotopic values were carefully selected from published studies conducted in nearby areas and during, or as close as possible, to the breeding season. Information on the isotopic composition of the Mussel corresponded to prey obtained at the nearby Golfo San Matías (Storero *et al.* 2016; δ^{13}C = −19.5 ± 0.7‰, δ^{15}N = 11.4 ± 0.12‰). The isotopic

Table 3. Frequency of occurrence (%) of prey recorded in Kelp Gull chick stomach content samples during the young and old chick stages of the 2013 breeding season at four colonies located in the Bahía San Blas protected Area, Argentina

	Islote Arroyo Jabalí Oeste		Islote Arroyo Jabalí este		Islote Fondo Medialuna		Banco Nordeste	
	Young chicks (*n* = 30)	Old chicks (*n* = 31)	Young chicks (*n* = 30)	Old chicks (*n* = 30)	Young chicks (*n* = 32)	Old chicks (*n* = 10)	Young chicks (*n* = 29)	Old chicks (*n* = 31)
Fish	93.3	83.9	80.0	86.7	78.1	90.0	86.2	90.3
Cynoscion guatucupa	70.0	48.4	56.7	60.0	31.3	40.0	20.7	45.2
Engraulis anchoita	16.7	29.0	6.7	6.7	43.8	30.0	41.4	6.5
Pleuronectiforme	0.0	0.0	3.3	0.0	3.1	0.0	0.0	0.0
Trachurus lathami	0.0	0.0	6.7	0.0	0.0	0.0	6.9	0.0
Porichthys porosissimus	0.0	0.0	3.3	3.3	0.0	0.0	6.9	6.5
Squatina guggenheim	10.0	3.2	3.3	0.0	0.0	0.0	3.4	0.0
Triathalassothia argentina	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
Mustelus schmitti	0.0	9.7	0.0	3.3	0.0	0.0	0.0	0.0
Unidentified fish	13.3	19.4	13.3	23.3	6.3	30.0	20.7	32.3
Molluscs	63.3	0.0	6.7	3.3	0.0	0.0	0.0	0.0
Brachidontes rodriguezi	60.0	0.0	6.7	3.3	0.0	0.0	0.0	0.0
Ensis macha	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insects	93.3	35.5	33.3	16.7	59.4	30.0	31.0	16.1
Coleoptera (20 taxa)	60.0	22.6	23.3	16.7	31.3	20.0	20.7	16.1
Hemiptera (6 taxa)	6.7	0.0	0.0	0.0	3.1	0.0	13.8	3.2
Diptera (6 taxa)	3.3	0.0	6.7	3.3	9.4	10.0	10.3	0.0
Ortoptera (4 taxa)	3.3	3.2	0.0	0.0	9.4	10.0	3.4	0.0
Lepidoptera	3.3	3.2	0.0	0.0	31.3	0.0	13.8	3.2
Unidentified insects	46.7	0.0	3.3	0.0	6.3	0.0	0.0	3.2
Crustaceans	6.7	12.9	13.3	6.7	0.0	20.0	6.9	3.2
Isopoda (3 taxa)	0.0	12.9	10.0	0.0	0.0	10.0	0.0	0.0
Peisos petrunkevitchi	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0
Pleoticus muelleri	0.0	0.0	0.0	3.3	0.0	0.0	3.4	0.0
Unidentified squid	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified crustaceans	6.7	0.0	0.0	3.3	0.0	10.0	3.4	3.2
Avena sativa	6.7	22.6	16.7	6.7	6.3	10.0	0.0	0.0
Urban refuse (inorganic material)	3.3	38.7	10.0	10.0	18.8	20.0	6.9	9.7
*Larus dominicanu*s (chick)	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0

information of insects (δ^{13}C = −29.4 ± 0.3‰, δ^{15}N = 5.64 ± 1.94‰) corresponds to samples obtained north of our study area in coastal Buenos Aires Province (Garcia *et al.* (2011) and E. Garcia, unpublished data, 2017).

We analysed the relative contribution of the different prey to the isotope mixture using Bayesian mixing models within the R package SIAR (Parnell & Jackson 2013) following the guidelines suggested by Phillips *et al.* (2014). Before running the isotopic mixing models, we conducted the sensitive analysis proposed by Smith *et al.* (2013) in order to evaluate the feasibility of the proposed isotopic mixing polygon. As there are no diet-tissue discrimination factors available for the Kelp Gull, we used the average values of fractionation between prey and whole blood of four seabird species following Ceia *et al.* (2014). We tested for differences in centroid location, which provide information on isotopic position, and eccentricity, which provides insight into differences in the underlying distribution of δ^{13}C and δ^{15}N data, using nested linear models and residual permutation procedures (see Turner *et al.* 2010 for statistical details). We estimated niche width for each breeding site using multivariate ellipse-based metrics (Jackson *et al.* 2011). The analysis generates standard ellipse areas (SEA) which are bivariate equivalents to standard deviations in univariate analyses. We used SEA values corrected for small sample size (SEA_C) to calculate niche overlap and generated Bayesian estimates of SEA (SEA_B) to test differences in isotopic niche by comparing their 95% credible intervals (CI) (for examples see Jackson *et al.* 2012; Thomson *et al.* 2012; Zabala *et al.* 2013). We report means ± 1 SD.

RESULTS

Conventional diet analysis

Pellet analysis corresponding to the 2013 breeding season indicated that Kelp Gulls fed on at least 41 prey items, including fish, molluscs, crustaceans, insects, grain, carrion and refuse (Table 1). Fish were the most frequent prey at the four colonies and in all breeding stages (41.4–85.9%), except during the

doi:10.1111/aec.12627

Table 4. Frequency of occurrence (%) of prey items in chick stomach content samples at the Banco Nordeste Kelp Gull colony, Bahía San Blas protected Area, Argentina, during the chick stages of 2012, 2013 and 2014

	2012		2013		2014	
	Young chicks (*n* = 30)	Old chicks (*n* = 32)	Young chicks (*n* = 29)	Old chicks (*n* = 31)	Young chicks (*n* = 33)	Old chicks (*n* = 33)
Fish	100.0	84.4	86.2	90.3	75.8	93.9
Cynoscion guatucupa	30.0	28.1	20.7	45.2	27.3	24.2
Micropogonias furnieri	3.3	0.0	0.0	0.0	0.0	0.0
Engraulis anchoita	56.7	34.4	41.4	6.5	24.2	39.4
Trachurus lathami	3.3	3.1	6.9	0.0	6.1	0.0
Porichthys porosissimus	3.3	15.6	6.9	6.5	3.0	0.0
Percophis brasiliensis	0.0	0.0	0.0	0.0	3.0	0.0
Squatina guggenheim	0.0	0.0	3.4	0.0	3.0	0.0
Mustelus schmitti	3.3	3.1	0.0	0.0	0.0	6.1
Odontesthes smitti	0.0	0.0	0.0	0.0	0.0	3.0
Unidentified fishes	6.7	15.6	20.7	32.3	12.1	15.2
Molluscs	10.0	0.0	0.0	0.0	3.0	6.1
Brachidontes rodriguezi	3.3	0.0	0.0	0.0	0.0	0.0
Polyplacophora	0.0	0.0	0.0	0.0	0.0	3.0
Heleobia australis	0.0	0.0	0.0	0.0	3.0	6.1
Unidentified gasteropoda	6.7	0.0	0.0	0.0	0.0	0.0
Insects	20.0	68.8	31.0	16.1	54.5	48.5
Coleoptera (20 taxa)	10.0	34.4	20.7	16.1	36.3	15.1
Hemiptera(6 taxa)	0.0	9.4	13.8	3.2	15.2	3.0
Diptera(6 taxa)	13.3	12.5	10.3	0.0	27.3	6.1
Ortoptera(4 taxa)	0.0	37.5	3.4	0.0	3.0	0.0
Hymenoptera(4 taxa)	3.3	21.9	0.0	0.0	9.1	3.0
Nezara vindula	0.0	0.0	0.0	0.0	15.2	0.0
Lepidoptera	0.0	6.3	13.8	3.2	39.4	33.3
Unidentified insects	6.7	31.3	0.0	3.2	15.2	12.1
Crustaceans	3.3	9.4	6.9	3.2	3.0	6.1
Isopoda (3 taxa)	0.0	6.3	0.0	0.0	3.0	0.0
Peisos petrunkevitchi	0.0	0.0	0.0	0.0	3.0	0.0
Pleoticus muelleri	0.0	0.0	3.4	0.0	0.0	0.0
Neohelice granulata	0.0	0.0	0.0	0.0	0.0	3.0
Unidentified crustaceans	3.3	3.1	3.4	3.2	0.0	3.0
Urban refuse (inorganic material)	0.0	0.0	6.9	9.7	9.1	3.0

incubation stage at both the Islote Arroyo Jabalí Oeste and Islote del Fondo where molluscs were the most frequent (>48.5 and 56.7%, respectively) (Table 1). The Stripped Weakfish was the most frequent species among fish prey, except during the young chick stage at Islote Arroyo Jabalí Este where the Toadfish (*Porichthys porosissimus*) showed the highest value (Table 1); the rest of fish species were recorded in less than 13.6% of samples. Insects were present in all colonies and stages, with frequencies of occurrence that varied between 1.7 and 36.1%, with Coleoptera being the most represented group (Table 1). The Mussel *Brachidontes rodriguezi* was the most frequent among molluscs, being always more frequent during incubation at all breeding sites and reaching maximum values at Islote Arroyo Jabalí Oeste and Islote Fondo Medialuna (45.5 and 53.3%, respectively). Grain was represented only by Oat (*Avena sativa*), and was present in all sites except Banco Nordeste in frequencies between 2.0 and 32.0% (Table 1). Crustaceans were also absent in the diet of gulls breeding at Banco Nordeste and were rarely recorded during some stages of the breeding cycle at the other colonies (3.0–5.3%). Urban refuse consisted mostly of plastic trays and bags used for bait packaging and food wrappings.

Diet composition based on pellet analysis was significantly different among the four breeding sites (two-way crossed ANOSIM, Global $R = 0.083$, $P = 0.001$), and also for each of the pair wise comparisons ($R < 0.115$, $P < 0.001$), being the Stripped Weakfish the prey that contributed most to the observed differences (SIMPER, 20.1–28.9%). Diet composition was significantly different among breeding stages at Islote Arroyo Jabalí Este (one-way ANOSIM, Global $R = 0.058$, $P = 0.001$; all pair wise comparisons $R < 0.105$, $P < 0.037$) and at Islote Fondo Medialuna (one-way ANOSIM, Global $R = 0.133$, $P = 0.001$; all pair wise comparisons

doi:10.1111/aec.12627

$R < 0.172$, $P < 0.003$). Prey species that contributed most to these differences were the Stripped Weakfish and Toadfish at Islote Arroyo Jabalí Este (18.8–22.7% and 17.4–21.2%, respectively) and the Stripped Weakfish and Mussel in Islote Fondo Medialuna (13.7–25.9% and 12.6–22.2%, respectively). In Banco Nordeste, significant differences were only found between the incubation stage and each of the chick stages (one-way ANOSIM, Global $R = 0.055$, $P = 0.005$ and Global $R = 0.059$, $P = 0.001$ in the young and old chick stages, respectively), being also the Stripped Weakfish the species that contributed most to the observed differences (38.6 and 33.5%, respectively). At Islote Arroyo Jabalí Oeste, diet composition during the old chick stage was significantly different from that recorded during the incubation and young chick stages (one-way ANOSIM, Global $R = 0.085$, $P = 0.001$ and Global $R = 0.128$, $P = 0.001$, respectively), being in this case the Stripped Weakfish and the Mussel the prey that contributed most to the observed differences (SIMPER, 15.2–19.7% and 16.9–23.5%, respectively).

Fish, represented mainly by the Stripped Weakfish, presented high frequencies of occurrence (>70%) in Banco Nordeste in all 3 years. Diet composition differed only between the 2012 and 2013 breeding seasons (Table 2) (ANOSIM, Global $R = 0.035$, $P = 0.001$), being also the Stripped Weakfish the species that contributed most to the observed differences (32.9%).

A total of 73 Stripped Weakfish otoliths, cranial, and scapular bones were recovered intact from pellet samples and could be measured (16 otoliths, 18 cleithrum, 21 angular, 17 dentary and 1 maxilla). The total length of Stripped Weakfish found in Kelp Gull pellets averaged 41.5 ± 5.2 cm ($n = 73$; range = 28.4–59.5).

The analysis of chick stomach samples from the 2013 breeding season indicated that food provided by parents consisted of at least 56 prey items, being fish the most frequent diet component (78.1–93.3%) at the four colonies and in both chick stages (Table 3). Stripped Weakfish and Argentine Anchovy were the only fish prey with relevant frequencies in most colonies and stages (Table 3), with the rest of the fish species contributing less than 10.0% to chick diet (Table 3). Molluscs showed relatively high frequencies of occurrence only in the young chick stage at Islote Arroyo Jabalí Oeste (63.3%) (Table 3). Insects were present in the diet of chicks at all breeding sites, and their frequency was higher during the young chick stage (e.g. Islote Arroyo Jabalí Oeste: 93.3%; Islote Fondo Medialuna: 59.4%; Table 3). Coleoptera was the most frequent group among insects (16.1–60.0%), except during the young chick stage at Islote Fondo Medialuna where Lepidoptera were more frequent (31.3%) (Table 3). Many of the Coleoptera recorded were larval stages of underground habits. Oat grains were present in frequencies of less than 22.6%, and were absent in samples from the young chick stage at Islote Arroyo Jabalí Oeste and in all samples from Banco Nordeste. Crustaceans were present in both chick stages at all breeding sites, except during the young chick stage at Islote Fondo Medialuna but in relatively low frequencies of occurrence (3.2–20.0%). Similarly, urban refuse items similar to those found in pellets were recorded in both chick stages and at all breeding sites in relatively low frequencies, reaching a maximum of 38.7% during the old chick stage at Islote Arroyo Jabalí Oeste.

Except between Islote del Fondo and Banco Nordeste, diet composition differed significantly among colonies (two-way crossed ANOSIM, Global $R = 0.104$, $P = 0.001$), being the Stripped Weakfish the prey that contributed most to the differences (SIMPER, 16.6–25.7%). Diet composition differed significantly between chick stages at Islote Arroyo Jabalí Oeste (one-way ANOSIM, Global $R = 0.282$, $P = 0.001$), where the Coleoptera, Mussel and Stripped Weakfish contributed most to the observed differences (14.3, 14.1, and 13.4%, respectively). Diet Composition at Banco Nordeste also differed among chick stages (one-way ANOSIM, R Global = 0.001, $P = 0.001$), and the Stripped Weakfish and Argentine Anchovy were the prey that contributed most to these differences (21.2 and 19.8%, respectively). At the other two colonies, diet composition was similar between chick stages ($P > 0.05$).

Diet composition at Banco Nordeste differed significantly among years (Table 4) (ANOSIM, Global $R = 0.068$, $P = 0.001$, all pair wise comparisons $R < 0.086$, $P < 0.004$). The prey species that contributed most to the observed differences in diet composition among years, as designated by SIMPER, were Stripped Weakfish and Argentine Anchovy (14.3–18.1 and 16.7–17.5%, respectively) while all other species contributed less than 10%.

Stable isotope analysis

Mean δ^{13}C values of Kelp Gull incubating adults varied between −15.92 and −19.59‰ while mean δ^{15}N values varied between 14.5 and 20.6‰ (Fig. 2a). General mixing polygon sensitivity analysis (using 1500 iterations) showed that isotopic values of all individual samples, given the diet-tissue discrimination factors and prey isotopic values used, were included in more than 95% of the simulated mixing polygons, validating the proposed mixing model (Fig. 2b). On the basis of the isotopic values corresponding to adult gulls, the Bayesian mixing model outputs showed that Stripped Weakfish had the highest contribution (42.0 ± 10.3%) (Fig. 3).

doi:10.1111/aec.12627

In general, δ^{13}C values of Kelp Gull chicks varied between -15.6 and -21.4‰, while δ^{15}N values varied between 14.3 and 20.9‰ (Fig. 4a). General mixing polygon sensitivity analysis (using 1500 iterations) showed that isotopic values of all chick samples, given the diet-tissue discrimination factors and prey isotopic values used, were included in more than 95% of the simulated mixing polygons, validating all proposed mixing models (Fig. 4b). On the basis of the isotopic values corresponding to chicks from the four colonies, the Bayesian mixing model outputs showed that Stripped Weakfish has the highest contribution to gull diet (Islote Arroyo Jabalí Oeste: 34%; Islote Aroyo Jabalí Este: 75%; Islote Fondo Medialuna; 53%; Banco Nordeste: 65%) (Fig. 5).

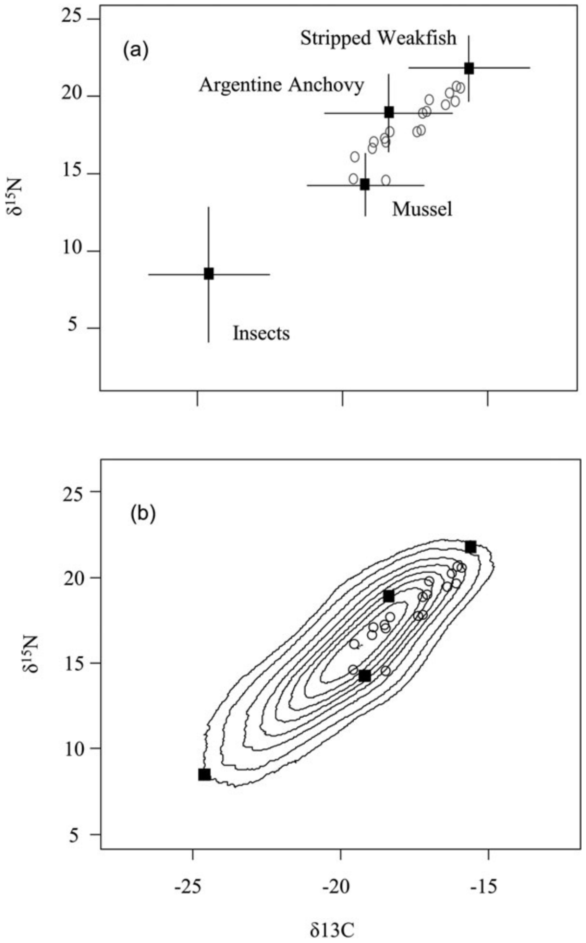

Fig. 2. Dual stable isotope plot of δ^{15}N (‰) and δ^{13}C (‰) showing the isotopic values of whole blood of adult Kelp Gulls breeding at Islote Arroyo Jabalí Este and their potential prey. (a) Isotopic mixing diagram. Open circles: incubating adults. Potential prey values corrected for fractionation are represented by solid squares (values are means and error bars ± SD). (b) Simulated mixing region for the biplot in a. The positions of individual Kelp Gulls (open circles) and the average source values (solid squares) are shown. Probability contours are at the 5% level (outermost contour) and at every 10% level.

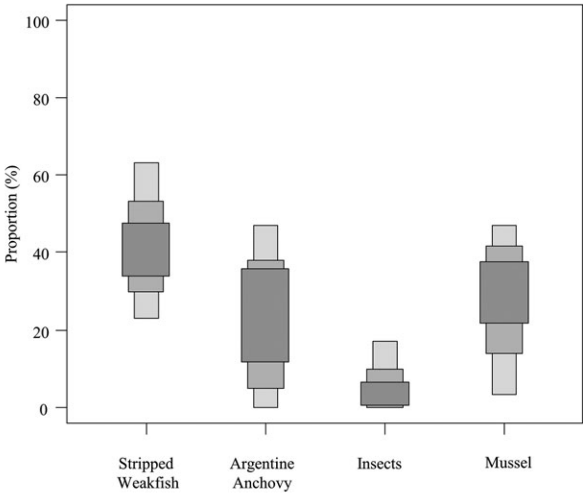

Fig. 3. Results of SIAR Bayesian isotope mixing model (50, 75 and 95% credibility intervals) showing the estimated prey contributions to the diet of incubating Kelp Gulls from Islote Arroyo Jabalí Este during the 2013 breeding season.

No differences were found among the four breeding sites in the isotopic positions of chicks, based on the observed differences in their centroid locations ($P > 0.05$, using 1000 permutations, Fig. 6). In accordance, there was an overlap in the isotopic niches estimated by SEA_C of chicks from the four breeding sites (Islote Arroyo Jabalí Oeste vs. Islote Arroyo Jabalí Este: 47.8%; Islote Arroyo Jabalí Oeste vs. Islote Fondo Medialuna: 58.1%; Islote Arroyo Jabalí Este vs. Islote Fondo Medialuna: 53.8%; Banco Nordeste vs. Islote Arroyo Jabalí Oeste: 41.6%; Banco Nordeste vs. Islote Arroyo Jabalí Este: 53.3%; Banco Nordeste vs. Islote Fondo Medialuna: 5.6%; Fig. 6). No differences were found in the isotopic niche width among individuals at the four breeding sites ($P > 0.05$).

DISCUSSION

Our results confirm once again the generalist and opportunistic feeding habits of the Kelp Gull. This is the first comprehensive evaluation of the diet of Kelp Gulls breeding in southern Buenos Aires Province and in the Bahía San Blas protected area, encompassing four nesting locations and considering the potential temporal variability. The combination of stable isotope and conventional methods (pellet and stomach content analysis) allowed the taxonomic characterization of the diet and the assessment of the relative importance of the main the prey. Kelp Gull diet comprised mostly fish, although it also included molluscs and insects.

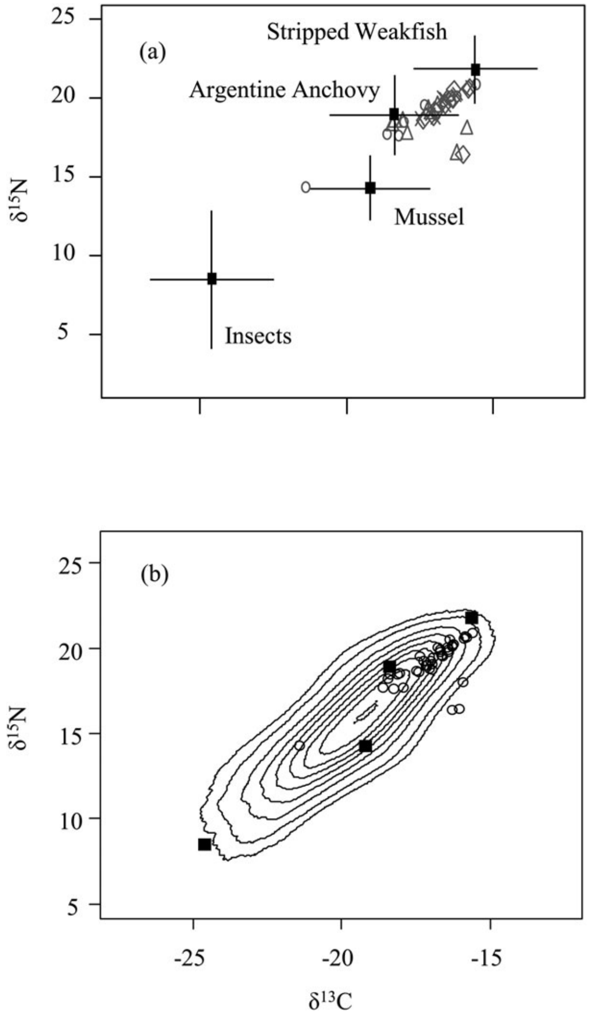

Fig. 4. Dual stable isotope plot of δ^{15}N (‰) and δ^{13}C (‰) showing the isotopic values of whole blood of Kelp Gull chicks at four colonies in the Bahía San Blas protected area and their potential prey. (a) Isotopic mixing diagram. Circle: Islote Arroyo Jabalí Oeste; Diamond: Islote Arroyo Jabalí Este; Triangle: Islote Fondo Medialuna; Cross: Banco Nordeste. Potential prey values corrected for fractionation are represented by solid squares (values are means and error bars ± SD). (b) Simulated mixing region for the biplot in Figure 2a. The positions of individual Kelp Gull chicks (open circles) and the average source values (solid squares) are shown. Probability contours are at the 5% level (outermost contour) and at every 10% level.

Results agree with a previous diet study conducted at Islote Arroyo Jabalí Oeste during the 2006 and 2007 breeding seasons in which a wide variety of prey was recorded, being the Stripped Weakfish and Argentine Anchovy the most frequent prey in pellet and chick stomach content samples, respectively (Yorio *et al.* 2013). Results also agree in general with previous studies on the diet of Kelp Gulls breeding at other locations along the Argentine coast and the Southern Hemisphere, where they mainly feed on marine invertebrates and fish complemented with food derived from human activities (Steele 1992; Coulson & Coulson 1998; Bertellotti & Yorio 1999; Ludynia *et al.* 2005). In coastal Chubut Province, Argentine Patagonia, domestic refuse can be a relevant component in the diet of breeding Kelp Gulls, being larger the contribution the closer the colony to the nearest refuse dump (Bertellotti & Yorio 1999). Urban refuse, however, was recorded in low frequencies in the diet of Kelp Gulls nesting in the Bahía San Blas protected area, despite all four colonies are located less than 8 km from the town of Bahía San Blas. Moreover, most urban refuse items recorded in diet samples were remains of plastic trays and bags used for fish bait packaging and food wrappings, suggesting they originated from recreational fishing activities. The low contribution of urban refuse may also result from the regular availability of abundant, predictable and higher quality alternative food in the form of fishery waste (see below).

The Stripped Weakfish was in general the main component in Kelp Gull diet as indicated by conventional analysis. This species is the most important target of recreational fisheries in the study area, and waste resulting from its on-site processing constitutes an abundant and predictable food source for Kelp Gulls. The high frequency of occurrence of Stripped Weakfish in Kelp Gull diet could also be the result of its abundance in coastal fish assemblages in waters along the coast of Buenos Aires Province (Jaureguizar *et al.* 2006; Llompart 2011). However, the fact that it is a demersal species normally unavailable to surface feeding birds and the large size of Stripped Weakfish individuals found in diet samples (averaged 40 cm) strongly suggest that this prey was obtained from the waste generated by the recreational fishery. Results from stable isotope analysis were in agreement with those obtained from conventional analysis, although they may also reflect the contribution of other demersal fish with similar stable isotope values. For example, recreational fishers also target the demersal Whitemouth Croaker and waste resulting from cleaning of the catch consists of offal which would not show in pellet samples. The presence of the Narrownose Smoothhound in gull stomach content samples, a prey species that given its size and habits is also unlikely to be obtained through direct capture, reinforces the association of feeding Kelp Gulls with recreational fishing activities. Moreover, Kelp Gulls were regularly observed during the course of this study feeding on fishery waste in recreational fishing sites and in the Bahía San Blas refuse dump, and a previous study using GPS born incubating individuals indicated that sites where fish waste is regularly disposed constituted their main foraging habitat (Kasinsky 2016).

The consumption of other prey items, such as Oat or many of the recorded insects, also indicates the

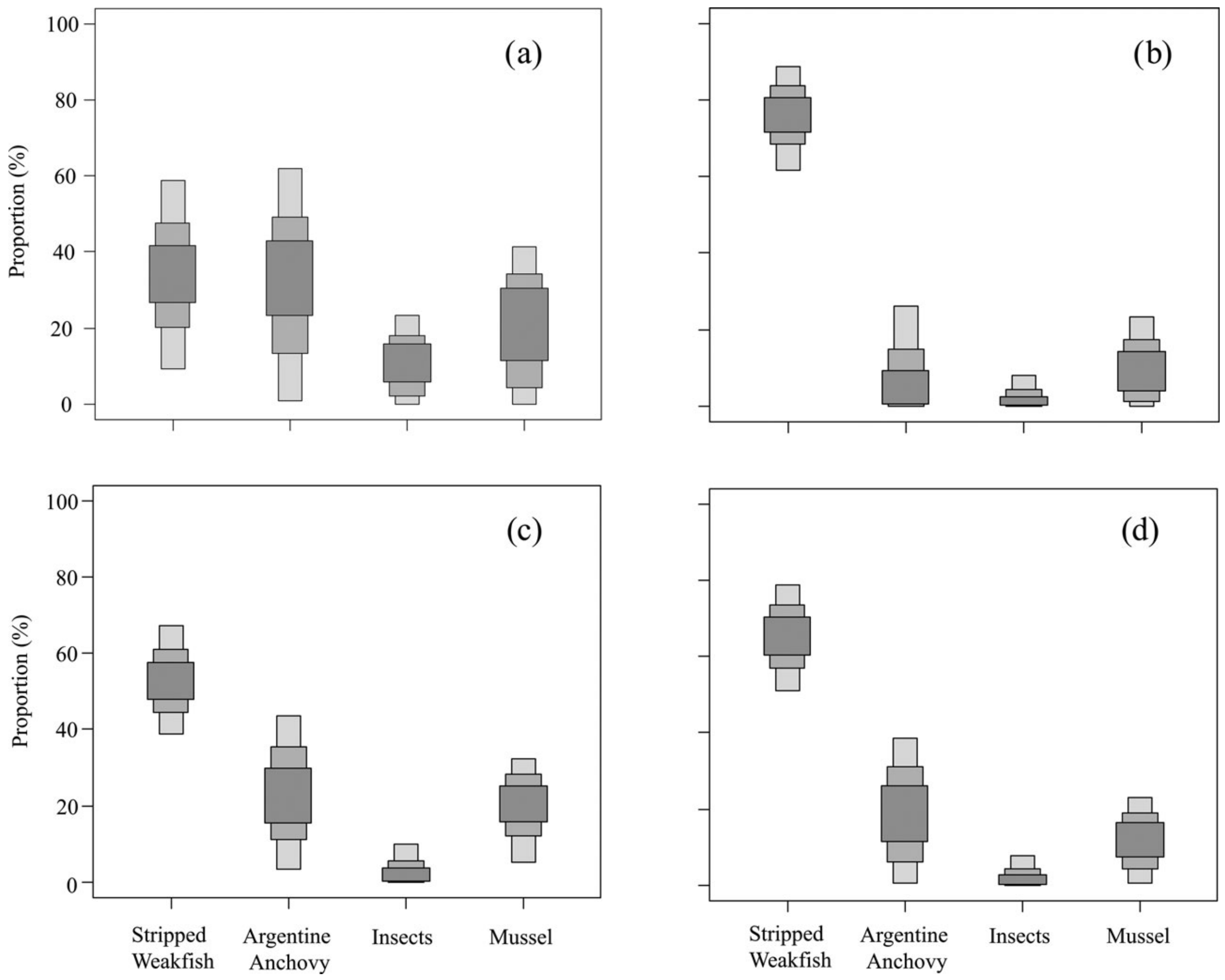

Fig. 5. Results of SIAR Bayesian isotope mixing models (50%, 75% and 95% credibility intervals) showing the estimated prey contributions to the diets of Kelp Gull chicks from (a) Islote Arroyo Jabalí Oeste, (b) Islote Arroyo Jabalí Este, (c) Islote Fondo Medialuna, and (d) Banco Nordeste, during the 2013 breeding season.

association of feeding Kelp Gulls with human activities. Kelp Gulls were observed feeding directly in oat fields relatively near their colonies (C. Marinao, pers. obs., 2013) and taking advantage of Oat grain fed to cattle in nearby feedlots (G. Gamero, pers. comm., 2014). Insect taxa generally associated to crops, such as those belonging to the families Scarabeidae and Curculionidae, were also recorded, with the presence in samples of adult individuals and of larvae of underground habits which are made accessible to feeding gulls during ploughing. Many studies in different gull species worldwide show that they regularly feed in agricultural lands, taking advantage of a variety of grain and fruit (see review in Calvino-Cancela 2011) as well as on terrestrial invertebrates (e.g. Schwemmer & Garthe 2008; Caron-Beaudoin *et al.* 2013). However, although terrestrial prey were frequently recorded in diet samples in the study area, stable isotope analysis indicated that they comprised a minor component in Kelp Gull diet.

Diet composition in most seabirds varies spatially and temporally in response to food availability, individual energetic demands and/or breeding requirements (e.g. Pierotti & Annett 1991; Suryan *et al.* 2002; Karnovsky *et al.* 2008; Chiaradia *et al.* 2012). Diet can differ among breeding locations, even at relatively small scales (Wanless & Harris 1993; Bertellotti & Yorio 1999; Velando & Freire 1999), mostly as a result of spatial variability in prey composition and availability. In our study area, stable isotope analysis of chick whole blood, which integrates diet through most of the growth period, indicated similar trophic niches among individuals of the four study colonies, suggesting that the differences observed using conventional diet methods were the result of opportunistic feeding events. Diet similarity composition of individuals from the four study colonies is

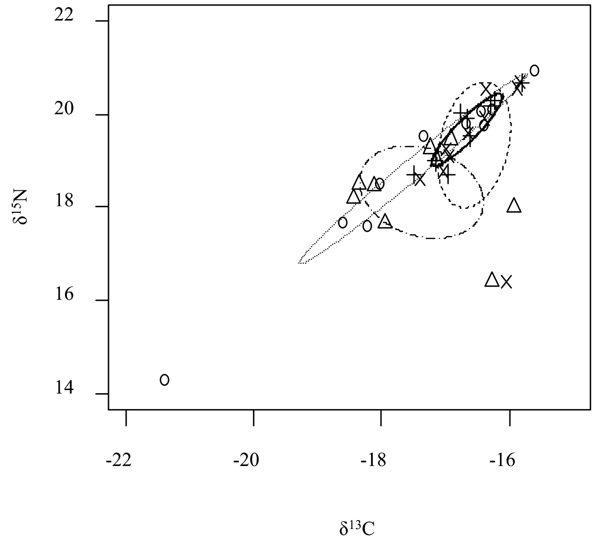

Fig. 6. $\delta^{15}N$ (‰) and $\delta^{13}C$ (‰) values for Kelp Gull chicks at the four breeding locations within the Bahía San Blas protected area. Isotopic niches are represented as the standard ellipses used to calculate SEA_C. Black dotted line: Islote Arroyo Jabalí Oeste; Black dashed line: Islote Arroyo Jabalí Este; Black dotdashed line: Islote Fondo Medialuna; Black solid line: Banco Nordeste. Circle: Islote Arroyo Jabalí Oeste; Cross: Islote Arroyo Jabalí Este; Triangle: Islote Fondo Medialuna; Plus: Banco Nordeste.

likely influenced by the relatively large foraging range of breeding Kelp Gulls in addition to the regular availability of fish waste provided by recreational fisheries. Unfortunately, we were unable to gather information to assess seasonal differences in diet composition using stable isotope analysis, but statistical differences among breeding stages were observed based on conventional methods, with no clear pattern for the four colonies. The Stripped Weakfish was the prey item most implicated in the observed differences, which may be due to the variability in fishing effort and waste generation throughout the season and between weekdays and weekends.

This study confirms that food derived from human activities is widely used by Kelp Gulls breeding at the Bahía San Blas protected area. Results particularly show a strong association between the Kelp Gull and the recreational fishing activity taking place in the protected area, likely resulting from the large amount of waste generated by the fishery. There are few reports, and mostly anecdotal, on trophic associations between gulls and recreational fisheries. In nearby coastal areas of Argentina and during the non-breeding season, Olrog's gull (*Larus atlanticus*) make use of fish waste generated by anglers (Berón *et al.* 2007) and Kelp Gulls in South Africa scavenge fish and offal provided by land-based and boat-based recreational fishermen (Whittington *et al.* 2006). Although the recreational fishery operating at Bahía San Blas may be fairly special in terms of the number of fishers, fishing effort and waste generated, it is likely that waste generated by smaller scale recreational fisheries in other coastal sectors may also contribute with supplementary food to gull breeding and wintering populations. It should be noted that the opportunistic feeding by Kelp Gulls on fishery waste is a common behaviour throughout their range. A large number of studies have described the consumption by Kelp Gulls of fishery discards provided by offshore commercial trawl fishing operations in Argentina (e.g. Yorio & Caille 1999; Bertellotti & Yorio 2000; González-Zevallos & Yorio 2006; Marinao & Yorio 2011; Seco Pon *et al.* 2013) and in other coastal sectors of South America and Southern Africa (Abrams 1983; Branco 2001; Villablanca *et al.* 2007; Soares Traversi & Vooren 2010; Carniel & Krul 2012). As in the Bahía San Blas protected area, Kelp Gulls have been recorded taking advantage of waste derived from the on-land processing of the catch from artisanal fisheries in Brazil (Carniel & Krul 2011) and at fish processing plants associated to commercial trawl fisheries in Argentine Patagonia (Yorio & Caille 2004). Despite the apparent benefits derived from the food subsidy provided by recreational fisheries, the association with this activity may also result in injuries and mortality (Yorio *et al.* 2014). Cost and benefits resulting from the association with recreational fisheries likely apply to Kelp Gull populations breeding at other Southern Hemisphere coastal sectors and to several other gull species worldwide.

ACKNOWLEDGEMENTS

This study was funded by Wildlife Conservation Society and Consejo Nacional de Investigaciones Científicas y Técnicas (project PIP N° 112 01 01061). Thanks to Centro para el Estudio de Sistemas Marinos (CCT CONICET-CENPAT) for institutional support and Dirección de Administración de Áreas Protegidas-Ministerio de Asuntos Agrarios of Buenos Aires Province for the permits to conduct the research on Kelp Gulls at the Bahía San Blas protected area. G. Cheli, N. Bovcon and D. Figueroa helped in the determination of prey species.

REFERENCES

Abrams R. W. (1983) Pelagic seabirds and trawl-fisheries in the southern Benguela current region. *Mar. Ecol. Prog. Ser.* **11,** 151–6.

Auman H. J., Meathrel C. E. & Richardson A. (2008) Supersize me: Does anthropogenic food change the body condition of silver gulls? A comparison between urbanized and remote, non-urbanized areas. *Waterbirds* **31,** 122–6.

Barret R. T., Camphuysen C. J., Anker-Nilssen T. *et al.* (2007) Diet studies of seabirds: A review and recommendations. *ICES J. Mar. Sci.* **64,** 1675–91.

Belant J. L., Seamans T. W., Gabrey S. W. & Ickes S. K. (1993) Importance of landfills to nesting Herring Gulls. *Condor* **95,** 817–30.

Berón M. P. & Favero M. (2009) Mortality of Olrog's Gulls *Larus atlanticus* associated with sport fishing activities. *Hornero* **24,** 99–102.

Berón M. P., Favero M. & Gómez Laich A. (2007) Use of natural and anthropogenic resources by the Olrog's Gull *Larus atlanticus*: Implications for the conservation of the species in nonbreeding habitats. *Bird Conserv. Int.* **17,** 351–7.

Bertellotti M. & Yorio P. (1999) Spatial and temporal patterns in the diet of the kelp gull in northern Chubut, Patagonia. *Condor* **101,** 790–8.

Bertellotti M. & Yorio P. (2000) Utilization of fishery waste by Kelp Gulls attending coastal trawl and longline vessels in northern Patagonia, Argentina. *Ornis Fenn.* **77,** 105–15.

Bicknell A. W., Oro D., Camphuysen K. C. & Votier S. C. (2013) Potential consequences of discard reform for seabird communities. *J. Appl. Ecol.* **50,** 649–58.

Boschi E., Fischbach C. & Iorio M. (1992) Catálogo ilustrado de los crustáceos estomatópodos y decápodos marinos de Argentina. *Frente Marítimo* **10,** 7–94.

Branco J. O. (2001) Descartes da pesca do camarão setebarbas como fonte de alimento para aves marinhas. *Rev. Bras. Zool.* **18,** 293–300.

Burger J. & Gochfeld M. (1996) Family Laridae (Gulls). In: *Handbook of the Birds of the World, Volume 3 (Hoatzin to Auks)* (eds J. del Hoyo, A. Elliot & J. Sargatal) pp. 572–623. Lynx Editions, Barcelona.

Calvino-Cancela M. (2011) Seed dispersal of alien and native plants by vertebrate herbivores. *Biol. Invasions* **13,** 895–904.

Carniel V. L. & Krul R. (2011) Kleptoparasitism in seabirds during interactions with artisanal fisheries on the coast of Paraná, south Brazil. *Rev. Bras. Ornitol.* **19,** 461–8.

Carniel V. L. & Krul R. (2012) Utilisation of discards from small-scale fisheries by seabirds in coastal waters of Paraná State, Brazil. *Seabird* **25,** 29–38.

Caron-Beaudoin É., Gentes M. L., Patenaude-Monette M., Hélie J. F., Giroux J. F. & Verreault J. (2013) Combined usage of stable isotopes and GPS-based telemetry to understand the feeding ecology of an omnivorous bird, the Ring-billed Gull (*Larus delawarensis*). *Can. J. Zool.* **91,** 689–97.

Castellanos Z. (1967) Catálogo de los moluscos bonaerenses. *Anales de la Comisión de Investigaciones Científicas* **8,** 1–365.

Ceia F. R., Paiva V. H., Fidalgo V. *et al.* (2014) Annual and seasonal consistency in the feeding ecology of an opportunistic species, the yellow-legged gull *Larus michahellis*. *Mar. Ecol. Prog. Ser.* **497,** 273–84.

Chiaradia A., Forero M. G., Hobson K. A. *et al.* (2012) Diet segregation between two colonies of little penguins *Eudyptula minor* in southeast Australia. *Aust. Ecol.* **37,** 610–9.

Clarke K. R. (1993) Nonparametric multivariate analyses of changes in community structure. *Aust. J. Ecol.* **18,** 117–43.

Clarke K. & Gorley R. (2006) *PRIMER v6: User Manual/ Tutorial*. PRIMER-E, Plymouth, UK.

Clarke K. R. & Warwick R. M. (2001) *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*, 2nd edn. PRIMER-E, Plymouth, UK.

Coulson R. & Coulson G. (1993) Diets of the Pacific gull *Larus pacificus* and the kelp gull *Larus dominicanus* in Tasmania. *Emu* **93,** 50–3.

Coulson R. & Coulson G. (1998) Population change among Pacific, kelp and silver gulls using natural and artificial feeding sites in south-eastern Tasmania. *Wildlife Res.* **25,** 183–98.

Deli Antoni M. Y. (2008) Análisis de la morfología ósea de peces de la laguna costera Mar Chiquita, Argentina. *Rev. Biol. Mar. Oceanog.* **43,** 355–80.

Duffy D. C. & Jackson S. (1986) Diet studies of seabirds: A review of methods. *Waterbirds* **9,** 1–17.

Duhem C., Vidal E., Legrand J. & Tatoni T. (2003) Opportunistic feeding responses of the yellow-legged gull *Larus michahellis* to accessibility of refuse dumps. *Bird Study* **50,** 61–7.

FAO (2012) *Recreational fisheries. FAO Technical Guidelines for Responsible Fisheries*. FAO, Rome.

Favero M. & Silva M. P. (1998) How important are pelagic preys for the Kelp Gull during chick-rearing at the South Shetland Islands? *Polar Biol.* **19,** 32–6.

Furness R. W., Ensor K. & Hudson A. V. (1992) The use of fishery waste by gull populations around the British Isles. *Ardea* **80,** 105–13.

Garcia E., Bertness M., Alberti J. & Silliman B. (2011) Crab regulation of cross-ecosystem resource transfer by marine foraging fire ants. *Oecologia* **166,** 1111–9.

Garthe S., Camphuysen C. J. & Furness R. W. (1996) Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. *Mar. Ecol. Prog. Ser.* **136,** 1–11.

González-Zevallos D. & Yorio P. (2006) Seabird use of discards and incidental captures at the Argentine hake trawl fishery in the Golfo San Jorge, Argentina. *Mar. Ecol. Prog. Ser.* **316,** 175–83.

González-Zevallos D., Marinao C. & Yorio P. (2017) Importancia de los descartes pesqueros en la dieta de la Gaviota Cocinera (*Larus dominicanus*) en el Golfo San Jorge, Patagonia. *Ornitol. Neotrop.* **28,** 103–11.

Gordillo S. (1995) *Moluscos Australes: Una guía ilustrada. Bivalvos y caracoles de las costas del extremo sur de América*. Zaiger y Urruty Publicaciones, Buenos Aires, Argentina.

Gosztonyi A. E. & Kuba L. (1996) Atlas de huesos craneales y de la cintura escapular de peces costeros patagónicos. *Informes Técnicos del Plan de Manejo Integrado de la Zona Costera Patagónica-Fundación Patagonia Natural (Puerto Madryn, Argentina)* **4,** 1–29.

Halley D. J., Minagawa M., Nieminen M. & Gaare E. (2008) Preservation in 70% ethanol solution does not affect δ^{13}C and δ^{15}N values of Reindeer blood samples – relevance for stable isotope studies of diet. *Rangifer* **28,** 9–12.

Hobson K. A. & Clark R. G. (1992) Assessing avian diets using stable isotopes II: Factors influencing diet-tissue fractionation. *Condor* **94,** 189–97.

Hobson K. A., Gibbs H. L. & Gloutney M. L. (1997) Preservation of blood and tissue samples for stable-carbon and stable-nitrogen isotopes analysis. *Can. J. Zool.* **75,** 1720–3.

Hong S., Lee J., Jang Y. C. *et al.* (2013) Impacts of marine debris on wild animals in the coastal area of Korea. *Mar. Pollut. Bull.* **66,** 117–24.

Inger R. & Bearhop S. (2008) Applications of stable isotope analyses to avian ecology. *Ibis* **150,** 447–61.

Iurman D. (2011) *Análisis de los sistemas de producción de la zona de secano del Partido de Patagones (Provincia de Buenos Aires)*. Informe Técnico Instituto Nacional de Tecnología Agropecuaria, Argentina.

Jackson A. L., Inger R., Parnell A. & Bearhop S. (2011) Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses in R. *J. Anim. Ecol.* **80,** 595–602.

Jackson M. C., Donohue I., Jackson A. L., Britton J. R., Harper D. M. & Grey J. (2012) Population-level metrics of trophic structure based on stable isotopes and their application to invasion ecology. *PLoS ONE* **7,** e31757.

Jaureguizar A. J., Menni R., Lasta C. & Guerrero R. (2006) Fish assemblages of the northern Argentine coastal system: Spatial patterns and their temporal variations. *Fish Oceanogr.* **15,** 326–44.

Karnovsky N. J., Hobson K. A., Iverson S. & Hunt G. L. Jr (2008) Seasonal changes in diets of seabirds in the North Water Polynya: A multiple-indicator approach. *Mar. Ecol. Prog. Ser.* **357,** 291–9.

Karnovsky N. J., Hobson K. A. & Iverson S. J. (2012) From lavage to lipids: Estimating diets of seabirds. *Mar. Ecol. Prog. Ser.* **451,** 263–84.

Kasinsky T. (2016) *Distribución espacial de las áreas de alimentación de la Gaviota Cocinera (Larus dominicanus) durante el periodo de incubación en el Área Protegida Bahía San Blas, Buenos Aires*. Unpublished Licenciatura Thesis. Universidad Nacional de la Patagonia San Juan Bosco, Argentina.

Llompart F. M. (2011) *La ictiofauna de Bahía San Blas (Provincia de Buenos Aires) y su relación con la dinámica de las pesquerías deportiva y artesanal*. Unpublished Doctoral Thesis. Universidad Nacional de la Plata, Argentina.

Llompart F. M., Colautti D. C. & Baigun C. R. M. (2012) Assessment of a major shore-based marine recreational fishery in the Southwest Atlantic, Argentina. *New. Zeal. J. Mar. Fresh.* **46,** 57–70.

Lowry H., Lill A. & Wong B. (2013) Behavioural responses of wildlife to urban environments. *Biol. Rev.* **88,** 537–49.

Ludynia K., Garthe S. & Luna-Jorquera G. (2005) Seasonal and regional variation in the diet of the Kelp Gull in Northern Chile. *Waterbirds* **28,** 359–65.

Marinao C. & Yorio P. (2011) Use of fishery discards and incidental mortality of seabirds attending coastal shrimp trawlers in Isla Escondida, Patagonia, Argentina. *Wilson J. Ornithol.* **123,** 709–19.

Mateo-Tomás P., Olea P. P., Moleón M. *et al.* (2015) From regional to global patterns in vertebrate scavenger communities subsidized by big game hunting. *Divers. Distrib.* **21,** 913–24.

Moore E., Lyday S., Roletto J. *et al.* (2009) Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001–2005. *Mar. Pollut. Bull.* **58,** 1045–51.

Moreno R., Jover L., Munilla I., Velando A. & Sanpera C. (2010) A three-isotope approach to disentangling the diet of a generalist consumer: The yellow-legged gull in northwest Spain. *Mar. Biol.* **157,** 545–53.

Newsome T. M., Dellinger J. A., Pavey C. R. *et al.* (2015) The ecological effects of providing resource subsidies to predators. *Global Ecol. Biogeogr.* **24,** 1–11.

Oro D., Genovart M., Tavecchia G., Fowler M. S. & Martínez-Abraín A. (2013) Ecological and evolutionary implications of food subsidies from humans. *Ecol. Lett.* **16,** 1501–14.

Parnell A. & Jackson A. (2013) *SIAR: Stable Isotope Analysis in R*. R package version 4.2. Computer program. http://CRAN.Rproject.org/package=siar.

Perez Comesaña J., Bechthold C., Arias K., Carrizo G. & Riestra C. (2014) Estimación de la longitud de la pescadilla de red (*Cynoscion guatucupa*) (Actinopterygii: Sciaenidae) utilizando relaciones morfométricas de huesos del cráneo y de la cintura escapular, otolitos y medidas específicas del cuerpo. *Revista del Museo Argentino de Ciencias Naturales* **16,** 89–93.

Petracci P. F., LaSala L. F., Aguerre G. *et al.* (2004) Dieta de la Gaviota cocinera (*Larus dominicanus*) durante el período reproductivo en el estuario de Bahía Blanca, Buenos Aires, Argentina. *Hornero* **19,** 23–8.

Phillips D. L., Inger R., Bearhop S. *et al.* (2014) Best practices for use of stable isotope mixing models in food-web studies. *Can. J. Zool.* **92,** 823–35.

Pierotti R. & Annett C. A. (1991) Diet choice in the Herring Gull: Constraints imposed by reproductive and ecological factors. *Ecology* **72,** 319–28.

Polito M. J., Trivelpiece W. Z., Karnovsky N. J., Ng E., Patterson W. P. & Emslie S. D. (2011) Integrating stomach content and stable isotope analyses to quantify the diets of pygoscelid penguins. *PLoS ONE* **6,** e26642.

Post D. M., Layman C. A., Arrington D. A., Takimoto G., Quattrochi J. & Montaña C. G. (2007) Getting to the fat of the matter: Models, methods and assumptions for dealing with lipids in stable isotope analyses. *Oecologia* **152,** 179–89.

Ramos R., Ramírez F., Sanpera C., Jover L. & Ruiz X. (2009) Feeding ecology of yellow-legged gulls (*Larus michahellis*) in the western Mediterranean: A comparative assessment using conventional and isotopic methods. *Mar. Ecol. Prog. Ser.* **377,** 289–97.

Schwemmer P. & Garthe S. (2008) Regular habitat switch as an important feeding strategy of an opportunistic seabird species at the interface between land and sea. *Estuar. Coast. Shelf S.* **77,** 12–22.

Seco Pon J. P., Copello S., Moretinni A. *et al.* (2013) Seabird and marine-mammal attendance and bycatch in semi-industrial trawl fisheries in near-shore waters of northern Argentina. *Mar. Freshwater Res.* **64,** 237–48.

Smith J. A., Mazumder D., Suthers I. M. & Taylor M. D. (2013) To fit or not to fit: Evaluating stable isotope mixing models using simulated mixing polygons. *Methods Ecol. Evol.* **4,** 612–8.

Soares Traversi G. & Vooren C. M. (2010) Interactions between seabirds and the trawl fishery in coastal waters of southern Brazil in summer. *Rev. Bras. Ornitol.* **18,** 183–93.

Steele W. K. (1992) Diet of Hartlaubs Gull *Larus hartlaubii* and the Kelp Gull *L. dominicanus* in the southwestern Cape Province, South Africa. *Ostrich* **63,** 68–82.

Steenweg R. J., Ronconi R. A. & Leonard M. L. (2011) Seasonal and age-dependent dietary partitioning between the great black-backed and herring gulls. *Condor* **113,** 795–805.

Storero L. P., Botto F., Narvarte M. A. & Iribarne O. O. (2016) Influence of maturity condition and habitat type on food resources utilization by *Octopus tehuelchus* in Atlantic Patagonian coastal ecosystems. *Mar. Biol.* **163,** 1–10.

Suárez N., Marinao C., Kasinsky T. & Yorio P. (2014) Distribución reproductiva y abundancia de gaviotas y gaviotines en el Área Natural Protegida Bahía San Blas, Buenos Aires. *Hornero* **29,** 29–36.

Suryan R. M., Irons D. B., Kaufman M. *et al.* (2002) Short-term fluctuations in forage fish availability and the effect on prey selection and brood-rearing in the Black-legged Kittiwake *Rissa tridactyla*. *Mar. Ecol. Prog. Ser.* **236,** 273–87.

Sydeman W. J., Hobson K. A., Pyle P. & McLaren E. B. (1997) Trophic relationships among seabirds in central California: Combined stable isotope and conventional dietary approach. *Condor* **99,** 327–36.

Thomson J. A., Heithaus M. R., Burkholder D. A., Vaudo J. J., Wirsing A. J. & Dill L. M. (2012) Site specialists, diet generalists? Isotopic variation, site fidelity, and foraging by Loggerhead Turtles in Shark Bay, Western Australia. *Mar. Ecol. Prog. Ser.* **453,** 213–26.

Turner T. F., Collyer M. L. & Krabbenhoft T. J. (2010) A general hypothesis testing framework for stable isotope ratios in ecological studies. *Ecology* **91,** 2227–33.

Velando A. & Freire J. (1999) Intercolony and seasonal differences in the breeding diet of European shags on the Galician coast (NW Spain). *Mar. Ecol. Prog. Ser.* **188,** 225–36.

Villablanca R., Luna-Jorquera G., Marin V. H., Garthe S. & Simeone A. (2007) How does a generalist seabird species use its marine habitat? The case of the Kelp Gull in a coastal upwelling area of the Humboldt Current. *ICES J. Mar. Sci.* **64,** 1348–55.

Wanless S. & Harris M. P. (1993) Use of mutually exclusive foraging areas by adjacent colonies of Blue-eyed Shags (*Phalacrocorax atriceps*) at South Georgia. *Waterbirds* **16,** 176–82.

Weichler T., Garthe S., Luna-Jorquera G. & Moraga J. (2004) Seabird distribution on the Humboldt Current in northern Chile in relation to hydrography, productivity, and fisheries. *ICES J. Mar. Sci.* **61,** 148–54.

Weiser E. L. & Powell A. N. (2010) Does garbage in the diet improve reproductive output of Glaucous Gulls? *Condor* **112,** 530–8.

Weiser E. L. & Powell A. N. (2011) Evaluating gull diets: A comparison of conventional methods and stable isotope analysis. *J. Field Ornithol.* **82,** 297–310.

Whittington P. A., Martin A. P. & Klages N. T. W. (2006) Status, distribution and conservation implications of the Kelp Gull (*Larus dominicanus vetula*) within the Eastern Cape region of South Africa. *Emu* **106,** 127–39.

Wickliffe L. C. & Jodice P. G. R. (2010) Seabird attendance at shrimp trawlers in nearshore waters of South Carolina. *Mar. Ornithol.* **38,** 31–9.

Wilson R. P. (1984) An improved stomach pump for penguins and other seabirds. *J. Field Ornithol.* **55,** 109–12.

Yorio P. & Caille G. (1999) Seabird interactions with coastal fisheries in northern Patagonia: Use of discards and incidental captures in nets. *Waterbirds* **22,** 201–16.

Yorio P. & Caille G. (2004) Fish waste as an alternative resource for gulls along the Patagonian coast: Availability, use, and potential consequences. *Mar. Pollut. Bull.* **43,** 778–83.

Yorio P., Bertellotti M. & García Borboroglu P. (2005) Estado poblacional y de conservación de gaviotas que se reproducen en el litoral marítimo argentino. *Hornero* **20,** 53–74.

Yorio P., Marinao C., Retana M.V. & Suárez N. (2013) Differential use of food resources between the kelp gull (*Larus dominicanus*) and the threatened Olrog's gull (*L. atlanticus*). *Ardeola*, **60,** 29–44.

Yorio P., Marinao C. & Suárez N. (2014) Kelp Gulls (*Larus dominicanus*) killed and injured by discarded monofilament lines at a marine recreational fishery in northern Patagonia. *Mar. Pollut. Bull.* **85,** 186–9.

Yorio P., Branco J. O., Lenzi J., Luna-Jorquera G. & Zavalaga C. (2016) Distribution and trends in Kelp Gull (*Larus dominicanus*) coastal breeding populations in South America. *Waterbirds* **39,** 114–35.

Zabala S., Bigatti G., Botto F., Iribarne O. O. & Galván D. E. (2013) Trophic relationships between a Patagonian gastropod and its epibiotic anemone revealed by using stable isotopes and direct observations. *Mar. Biol.* **160,** 909–19.

Zalba S. M., Nebbia A. J. & Fiori S. M. eds (2008) *Propuesta de Plan de Manejo de la Reserva Natural de Uso Múltiple Bahía San Blas*. Universidad Nacional del Sur, Bahía Blanca, Argentina.

doi:10.1111/aec.12627