Use of winter habitat at an early age: spatial ecology and association with human activities of juvenile Olrog's Gull *Larus atlanticus*

MARÍA TERESA RAVASI, JUAN PABLO SECO PON, JESICA ANDREA PAZ, MARCO FAVERO and SOFÍA COPELLO (iD)

Summary

Olrog's Gull *Larus atlanticus* is an endemic species of the Atlantic coast of southern South America and is currently listed as 'Near Threatened' on the IUCN Red List. The species breeds in coastal wetlands of Buenos Aires and Chubut provinces of Argentina and during winter migrates northwards as far as southern Brazil. During the breeding season the species is considered to have a specialised diet, foraging mostly on crabs. However, during the non-breeding season the gull presents a wider dietary spectrum (including fish) as a result of a potential association with commercial and sport fishing activities. The main goal of this study was to analyse the habitat use and overlap with natural and anthropogenic food resources of juvenile Olrog's Gull during the winter in Mar Chiquita Lagoon, Buenos Aires. Twenty-two GPS devices were deployed during the winters of 2013 and 2014. A total of 1,088 fixes was gathered by GSM (both seasons combined). Analysis showed that the individuals were (kernel 95%) distributed in a limited area along the mouth of the lagoon. The core area (kernel 50%) covered only 0.3 km² and was located in the south of the mouth. The overlap between juveniles and crab densities was lower than expected, while the overlap between juveniles and fishing effort was higher than expected during weekdays and lower during weekends. These results are of value for the further development of marine conservation measures for wintering areas which have so far been somewhat neglected while addressing the conservation status of the species.

Introduction

Juvenile individuals play a key role in the dynamics of animal populations, particularly in long-lived species such as seabirds, for which they can represent up to 50% of the total population (Schreiber and Burger 2002). Juvenile birds show extensive foraging times, lower foraging efficiency and different feeding strategies than adults (Schreiber and Burger 2002). These differences in feeding efficiency have been attributed to differences in individual experience (Wunderle 1992). Moreover, it has been argued that juvenile birds can compensate the low feeding success by means of extending foraging bouts, selecting different size and type of prey, using different foraging tactics, or stealing food from other individuals (Wunderle 1992, Bertellotti and Yorio 2000a). How such less experienced individuals use their environment and interact with human activities has been identified as a priority for research (Croxall *et al.* 2012). Gulls stand out as an interesting model for considering this kind of ecological study, given their well-documented relationship with human activities (Schreiber and Burger 2002). In general terms, gulls have generalist food habits, exploiting different habitats during the breeding and non-breeding seasons (Burger and Gochfeld 1996, del Hoyo *et al.* 1996). Clearly, the habitat use of gulls outside their breeding period has an

important and profound effect on the survival of individuals, recruitment, and quality of the forthcoming breeding season (Birkhead and Furness 1985).

Olrog's Gull *Larus atlanticus* is endemic to the southern coast of South America (Harrison 1983). Its breeding range is restricted to only two nesting areas along 2,500 km of the central Argentinian coast. The number of breeding sites varied between seven and 12 per year, with locations differing among years and the global breeding population was estimated at 8,000 pairs (Yorio *et al.* 2013). The breeding season starts at the end of October and hatching usually occurs in early November–December. During the austral winter the species disperses chiefly to the north, reaching the coasts of Buenos Aires province (Silva Rodríguez *et al.* 2005, Favero *et al.* 2016), Uruguay (Azpiroz 2003), and occasionally, southern Brazil (Pacheco *et al.* 2009). The species is listed as 'Near Threatened' on the IUCN Red List (BirdLife International 2018) and is listed in Appendix I of the Convention on Migratory Species (CMS 2015) due to its confined distributional range, low population size, specialised food requirements, and conservation threats (Yorio *et al.* 2005).

Despite the fact that the majority of gull species are considered generalist feeders, Olrog's Gull has been considered historically as one of the few gulls with relatively specialised feeding habits (Burger and Gochfeld 1996). Several authors reported that individuals breeding in coastal wetlands feed primarily on crabs (*Neohelice granulata, Cyrtograpsus altimanus* and *Cyrtograpsus angulatus*; Devillers 1977, Delhey *et al.* 2001, Herrera *et al.* 2005, Suárez *et al.* 2011). Likewise, studies conducted on wintering grounds located in southern Buenos Aires province also refer to the importance of crabs in the diet of the species outside the breeding season (Burger and Gochfeld 1996, Copello and Favero 2001). However, non-breeding adults and immatures have also been described as more generalist foragers, preying on other invertebrates, fish and resources facilitated by agricultural and fishery activities (Escalante 1966, Olrog 1967, Spivak and Sánchez 1992, Martínez *et al.* 2000, Berón *et al.* 2007, Petracci *et al.* 2007, Seco Pon *et al.* 2012, 2013, Berón *et al.* 2013). Although the provision of food facilitated by commercial fishing activities such as waste offal and discards (Bertellotti and Yorio 2000b, Furness 2003, Giaccardi and Yorio 2004) could be expected to be beneficial for Olrog's Gull (Martínez *et al.* 2000), there is evidence showing the risk of incidental mortality and injuries due to entanglement in, and ingestion of, sport fishery gear may lead to an unsustainable increase in mortality (Berón *et al.* 2007, Berón and Favero 2009).

The south-eastern sector of Buenos Aires province lies within an important refuelling and wintering area for several coastal seabirds, including Olrog's Gull (Silva Rodríguez *et al.* 2005, Favero *et al.* 2016). In particular, Mar Chiquita Lagoon is one of the most important areas of Buenos Aires province in terms of biodiversity (Isacch *et al.* 2016). Due to its unique environmental features Mar Chiquita Lagoon was declared a World Biosphere Reserve by MAB-UNESCO in 1996, and a Provincial Reserve in 1999 (Isacch 2008). This environment is regularly used by Olrog's Gull juveniles (first-year birds), subadults and adults with varying abundances throughout the year. The greatest abundance of gulls occurs during austral autumn and winter (June to September; Azpiroz 2003, Berón *et al.* 2007, Berón 2009), with juvenile individuals dominant in numbers (Berón 2009). A study using radio transmitters (VHF), showed a high site fidelity in this species with immature individuals using mostly the mouth of the lagoon associated with crab beds and sport fishing activities (Berón *et al.* 2007). Adult Olrog's Gulls show greater abilities to catch and handle crabs compared to subadults and juveniles, and adults also dominate juveniles in the selection of foraging areas (Berón *et al.* 2011). Feeding methods used by Olrog's Gull include surface seizing, surface plunging and walking (Copello and Favero 2001). Once the crab is captured, it is often rinsed and swallowed whole or after dismembering (Delhey *et al.* 2001). The foraging behaviour of adult birds could force juveniles to use alternative food resources such as discards from sport fishing activities which are easier to obtain in terms of foraging skills. Understanding habitat use, foraging behaviour and the impact of anthropogenic activities in non-breeding areas is important to develop effective management and conservation strategies. As mentioned above, there is a previous study on habitat use by the species, however the tracking devices used showed low temporal and spatial resolution and only four juveniles were tracked (Berón *et al.* 2007).

This study was designed with the objectives of: (1) identifying areas of importance for juvenile gulls during the winter period and (2) determining the use of habitat by juvenile individuals while preying on natural (crab beds) and anthropogenic resources (fishing discards and by-products from sport fishing activities) in one of the most important wintering grounds for the species in Argentina. We hypothesised that during winter, the distribution and habitat use of juvenile Olrog's Gull in Mar Chiquita are affected by the sport fishing activity along the coast. Our predictions are: (1) that juvenile gulls are distributed in areas where sport fishing is concentrated, irrespective of the occurrence of crab beds. That is, a greater spatial overlap with fishing effort compared with crab densities; and (2) that on weekdays, due to reduced fishing effort, gulls will spend less time in areas where fishers are distributed, compared to weekends when the sport fishing activity is more intense. That is, a lower spatial overlap with fishing effort during weekdays than during weekends.

Methods

Study area

The study area was located at the Mar Chiquita Reserve (Buenos Aires province, Argentina, 37°46′S, 57°27′W; Figure S1 in the Online supplementary material). It encompasses a 46-km² body of tidal brackish water along the coast, with mudflats surrounded by *Spartina densiflora* grassland and inhabited by large numbers of various groups of macro-invertebrates, including the intertidal crabs, *C. angulatus* and *N. granulata* as the most conspicuous organisms (Spivak *et al.* 2001). Fish diversity is relatively high (including both benthic and pelagic fishes), many of which are frequently targeted by sport fishing activities in the area (Pellegrino and Cousseau 2005).

Habitat use by gulls

In order to identify habitat use and movements of juvenile individuals (first-year birds) during winter, 22 GPS devices (CatTraQ live 3 Mr. Lee, 17 g) were deployed on gulls during the following periods: 9–14 July 2013 (3 males, 4 females and 1 undetermined sex) and 26 May–12 July 2014 (eight males and six females). A total of 17 tags sent enough fixes in order to make the data analysis (Table S1). The devices weighed less than 3 % of the total weight of the gulls (949 ± 112 g; *n* = 35 birds; unpubl. data), which is within the maximum recommended to avoid adverse effects on bird behaviour (Phillips *et al.* 2003). On average, gulls were followed for 2.5 days (range 1–5 days, both sexes combined). When necessary, the device was removed from birds when the battery was depleted. However, given that bird recapture was not always successful, and that the batteries had low capacity, the tags transmitted for only a short period of time. Individuals were captured using a Bal-chatri trap (Bloom 1987) with fish as bait (once the capture was completed the fish was removed from the area).

The devices were deployed on the back of the birds using Tesa® tape 4651 (Wilson *et al.* 1997) and programmed to transmit one position every 30 minutes. Locations were received as a text message (SMS) on a mobile phone via a GSM system (Tomkiewicz *et al.* 2010). Each individual bird was marked with a numbered plastic ring that allowed its remote identification (Table S1). A drop of blood from the wing vein of captured individuals was collected and settled on filter paper for further molecular sex determination following methods described in Quintana *et al.* (2008).

Availability of natural and anthropogenic food resources

To determine the overlap between the distribution of gulls and food resources, the focal area (kernel 75 %) used by gulls was selected for analysis. The densities of *C. angulatus* and *N. granulata* (the two species providing the bulk of crab biomass in the estuary, and a large proportion of the diet of Olrog's Gull) were assessed following different methodologies depending on their behaviour

(burrowing vs. non-burrowing species). For *N. granulata,* an inter-tidal burrowing crab species, 39 stratified random plots measuring 50 x 50 cm were placed in different environments previously characterised in Isacch *et al.* (2006) and sampled during 18–22 July 2014 (Figure S1). In each quadrat, the number of burrows was counted as a proxy indicator of crab abundance (Suárez *et al.* 2012). For the sub-tidal *C. angulatus*, seven transects were performed during low tide along the edge of the estuary during 22–25 July 2014 (Figure S1). Each transect was 100 m long and 10 m wide, covering 5 m in the subtidal zone and 5 m in the intertidal zone. The number of crabs observed was recorded along each transect.

The number of coastal fishers was used as a proxy for the availability of anthropogenic food resources (i.e. discards and offal by-products of the sport fishery) (Smallwood *et al.* 2011). To analyse the distribution of this resource, sport fishing effort was estimated by conducting point counts where the number of fishers (including absences) was recorded following procedures described in Smallwood *et al.* (2011). For this, 146 counts (88 and 58 for weekends and weekdays respectively) of fishers in different locations within the study area (at the mouth of the lagoon and subsidiary streams) were conducted between 26 May and 12 July 2014.

Data analysis

Given the varying number of locations obtained for each bird (mean = 60; range = 10–247; Table S1) due to the performance of the GPS devices, an interpolation of fixes every 15 minutes was carried out using the function 'redisltraj' of the package *adehabitatLT* in program R (Calenge 2006). Daily distance travelled per individual was determined by summing the distances obtained between consecutive points per day. Then to evaluate the habitat use of tracked gulls, a kernel analysis was fitted using utilization distribution (UD areas, Spatial Analysis Toolbox, ArcGis 10.1). This analysis calculates the magnitude of locations per unit area using a smoothing algorithm (Worton 1989). The bandwidth ('smoothing parameter' *h*) used in this study was 50 km and the kernel contour levels were estimated for 50% (core area), 75% (focal area) and 95% (range) of the locations (Hyrenbach *et al.* 2006). This analysis has frequently been used to assess important areas for seabirds (Quintana *et al.* 2010, Copello *et al.* 2014).

To analyse the differences in size of core areas and daily distances travelled in relation to years and sexes, Generalized Linear (GLM) and Mixed (GLMM) Models were used, respectively. A gamma error structure and loglink function were used in both models (Crawley 2007, Zuur *et al.* 2009). The sex and year variables were used as fixed effects and the identity of individuals was modelled as a random effect. Model fit was evaluated by visual inspection of the residuals. Analysis of variance (ANOVA) was used for inference and model selection (McCullagh and Nelder 1989).

Comparison of average fishing effort between weekdays and weekends was analysed using the Wilcoxon signed-rank test (*W*) because distribution of data was not normal (Zar 2010). To analyse the degree of overlap between the areas used by gulls and availability of food resources (i.e. crabs and discards) a cell size of 30 x 30 m was used. The density of the two crab species in the whole area was estimated using the inverse distance weighting univariate interpolation method (Fortin and Dale 2005) in the Spatial Analysis toolbox of ArcGIS using the samples mentioned above. Then the number of fixes of gulls in each cell was calculated using the Spatial Join tool in ArcGIS. Finally, a spatial overlap index (SOI) was calculated using the estimated maps. This index is widely used to assess the extent of spatial correlation between a predator and its prey (Williamson 1993), and is defined as:

$$\text{SOI} = \frac{\sum_{z=1}^{m} (P_z \times N_z) m}{\sum_{z=1}^{m} (P_z) \times \sum_{z=1}^{m} (N_z)}$$

where z is a sample location, *m* is the total number of samples, P_z is the predator density (Olrog's Gull) and N_z is the density of prey (i.e. crab species or sport fishery discards and offal). A SOI

value of one represents a uniform distribution of predator and prey populations, while an SOI value > 1 represents a greater overlap than expected and an SOI value < 1 represents a lesser overlap than expected (McClellan *et al.* 2009, Harden and Williard 2012).

All spatial and statistical analysis were performed using ArcGIS 10.1 (ESRI) and the free program R i386 3.1.2 (http://www.r-project.org). In all cases, differences were considered significant at $P < 0.05$.

Results

A total of 1,088 positions of tracked individuals was obtained throughout the study period (299 locations in 2013 and 789 in 2014). Juvenile gulls were distributed in a relatively small area lying between 37°26′–37°44′S, and 57°27′– 57°30′W (Figure 1A). The distribution range of tracked individuals (kernel 95%) was chiefly restricted to the vicinity of the mouth of the lagoon (Figure 1B), in an area of 4.5 km². However, the core area (kernel 50%) was restricted to a smaller section of 0.3 km² around the convergence of a number of subsidiary streams. Core areas from 82% of individuals overlapped with each other, averaging 31.4 ± 27.9% overlap. The remaining individuals were distributed in core areas away from the village of Mar Chiquita, especially in the north and within subsidiary streams. The focal area (kernel 75%) included the mouth of the lagoon covering an area of 1.2 km² (Figure 2A). No offshore locations were observed (both years combined).

The size of core areas (2.2 ± 0.9 km²) was not significantly different between years or sexes ($F_{1,14} = 2.28$, $P = 0.09$; $F_{1,14} = 1.33$ $P = 0.27$, respectively). Similarly, the daily distance travelled (5.7 ± 7.9 km) was similar between years and sexes ($X_1^2 = 3.76$, $P = 0.05$; $X_1^2 = 2.73$, $P = 0.1$, respectively).
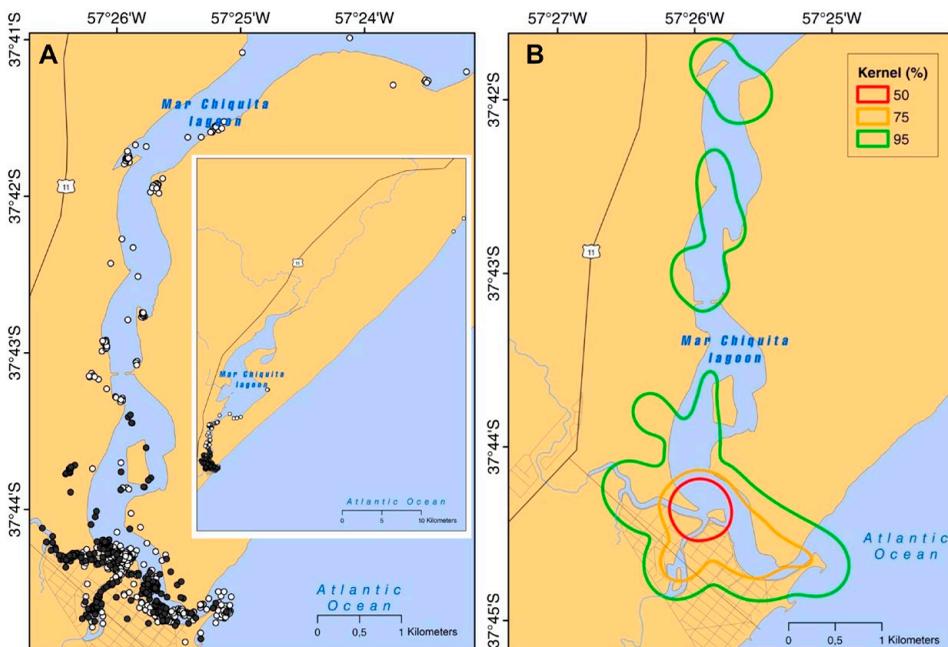

Figure 1. (A) Locations obtained from juvenile Olrog's Gull followed by GPS during the 2013 (black dots) and 2014 (white dots) winter seasons (*inset:* detail of locations in 2014 including one individual that ranged 42 km to the north of the estuary); (B) areas of use (Kernel plot) pooled for winters 2013 and 2014.
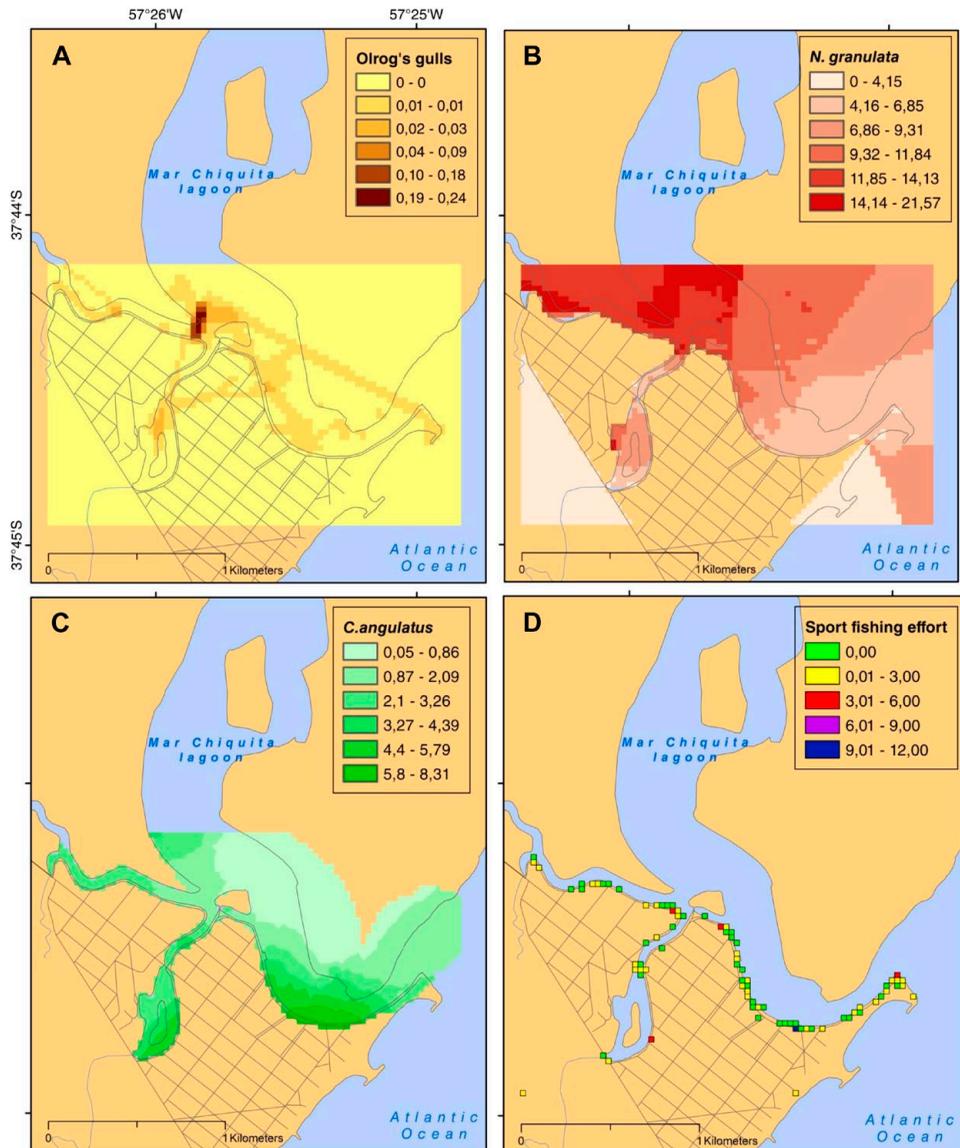
Figure 2. Distribution of Olrog's gulls in the focal area (A) (time spent/900 m²), and density of natural and anthropogenic resources: *N. granulata* (B), *C. angulatus* (C) (crabs/900 m²), and sport and recreational fishing (D; number of fishermen /900 m²).

The mean density for *N. granulata* and *C. angulatus* were estimated as 0.3 ± 0.1 and 0.1 ± 0.1 individuals per m², respectively. While the highest densities of *N. granulata* were found in the northwest section of the study area, for *C. angulatus* the highest densities were concentrated in the south-east of the mouth of the lagoon and subsidiary streams (Figures 2B and C).

The average effort of sport fishing was significantly higher at weekends (we) than weekdays (wd) (1.8 ± 3.3 and 0.8 ± 1.9 fishers/900 m², respectively; $W_{1,147} = 3051.50$, $P < 0.05$). A higher concentration of fishing effort was observed at the south-east coast of the mouth, although some isolated points of high effort were observed in subsidiary streams (Figure 2D).

The overlapping analysis revealed a patchy distribution of gulls and prey (crabs and discards) (SOI ≠ 1) which deviated from an expected uniform spatial co-distribution. The overlap between crab densities and gulls was lower than expected by a uniform distribution (SOI_{wd} = 0.714 and SOI_{we} = 0.686 for *N. granulata* and SOI_{wd} = 0.897 and SOI_{we} = 0.972 for *C. angulatus*). However, the overlap index obtained between gulls and sport fishing effort was higher than expected by a uniform distribution during weekdays (SOI = 3.499) and lower during weekends (SOI = 0.401).

Discussion

Our results showed that tracked juveniles use a small area, concentrating their activities in the vicinity of the mouth of the lagoon. This pattern is consistent with a previous study using radio telemetry (Berón *et al.* 2007). This limited space use may be due to large food abundances in the area. Olrog's Gulls have easy access not only to their main natural food (Copello and Favero 2001, Berón 2003) but also to sport fishery discards as a supplementary source (Berón *et al.* 2013). This observation is supported by the predator-prey overlap index, indicating that, at least during weekdays, the overlap between gulls and fishing effort distribution was higher than expected by a uniform distribution (SOI > 1). During weekends, the overlap with fishing effort was lower than expected by a uniform distribution (SOI < 1). These results are partially in line with the predictions formulated for this study and also with the results reported by Berón *et al.* (2007) that showed a strong fidelity of the species to foraging patches with crab-bed areas and beaches where sport fishing activities occurred. We predicted a greater overlap with fishing effort during the weekends and the opposite was found. The difference in the overlap values between weekdays and weekends could be due to the spatial spread of fishing effort along the lagoon during weekdays. Juvenile gulls were more closely associated with fishermen during weekdays, while at weekends when the fishers' distribution was more restricted, the overlap was less marked because gulls may compete intraspecifically for access to the discards. On the other hand, the greater degree of recreational and tourist activities (for example kite-surfing, kayaking, etc.) during weekends compared with weekdays in the area (Friedman, pers. comm. 2017) could cause greater disturbance to juveniles, potentially diminishing the time in association with the fishing activities.

The association between gulls and sport fishing could be considered beneficial for the species given the supplementary supply of food, as has been shown in other gull species (Furness 2003). Besides, assuming more limited skills in juveniles to manipulate crabs, the alternative food obtained from sport fishing activities could be beneficial for this particular age-class. However, more information is needed in order to determine the effect of this alternative food on the Olrog´s Gull population. In addition, this species has been reported to regularly attend semi-industrial trawl and purse seine fishing operations in northern Patagonia outside the breeding season (Seco Pon *et al.* 2012, 2013), so at this stage it has become apparent that the use of anthropogenic sources of food by Olrog's Gull could be more important than originally thought. It could also be that the species might have expanded its dietary spectrum, chiefly driven by the expansion of commercial fisheries and changes in coastal areas during recent decades, similarly to other pelagic seabirds such as albatrosses (Mariano-Jelicich *et al.* 2017). It is important to note that the species has been recorded interacting with sport fishing in the study area, with negative effect for the birds in terms of direct mortality due to fishing gear ingestion and severe injuries due to entanglement with fishing lines (Berón and Favero 2009).

In relation to spatial segregation in seabirds, there is abundant evidence indicating that different sexes show variation in distances travelled, at least in adults during the breeding season (Guilford *et al.* 2009, Rayner *et al.* 2012, Hedd *et al.* 2014, Camphuysen *et al.* 2015). However, there is little information about spatial segregation in juvenile seabirds. In this study, we found no differences between the daily distances travelled and the size of the core area between males and females, nor between years. Further studies are needed to evaluate the degree of competition between the sexes in this species, as well as to evaluate the relative contribution of natural and anthropogenic food resources in the diet of female and male gulls.

Given the evidence of undesired impacts resulting from the interaction between coastal gulls (*Larus atlanticus* and *Larus dominicanus*) with sport fishing activities in Argentina (Berón and Favero 2009, Yorio *et al.* 2014) and the 'Near Threatened' conservation status of the study species, our results are relevant to the development of conservation strategies in Mar Chiquita Lagoon, considered the main wintering ground of this endemic species. However, some shortcomings in the study must be acknowledged: 1) the low battery lifetime of the tags and as a consequence the short tracking period; 2) the use of GPS devices without storage of the positions recorded in case of failure of GSM coverage; and 3) the fact that samples of natural and anthropogenic food resources were not taken concomitantly with tracked birds. It will be crucial to consider in further studies the tracking of individuals for a longer period of time considering that many juvenile gulls ringed at Mar Chiquita lagoon were sighted in surrounding areas such as Mar del Plata harbour (the most important commercial harbour in Argentina) (authors' unpubl. data). Besides, it would be also relevant to track adult and sub-adult birds.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S0959270919000029

Acknowledgements

References

Azpiroz, A. B. (2003) *Aves del Uruguay. Lista e introducción a su biología y conservación*. Montevideo, Uruguay: Aves Uruguay-GUPECA.

Berón, M. P. (2003) Dieta de juveniles de la Gaviota Cangrejera (*Larus atlanticus*) en estuarios de la provincia de Buenos Aires. *El Hornero* 18: 113–117.

Berón, M. P. (2009) Ecología trófica de la Gaviota de Olrog (*Larus atlanticus*) en ambientes naturales y antropizados del Este y Sudeste Bonaerense. Doctoral Thesis, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina.

Berón, M. P. and Favero, M. (2009) Mortality and injuries of olrog's gull (*Larus atlanticus*) individuals associated with sport fishing activities in Mar Chiquita coastal lagoon, Buenos Aires Province. *Hornero* 24: 99–102.

Berón, M. P., Favero, M. and Gómez Laich, A. (2007) Use of natural and anthropogenic resources by Olrog´s Gull *Larus atlanticus*: implications for the conservation of the species in non-breeding habitats. *Bird Conserv. Internatn.* 17: 351–357.

Berón, M. P., García, G., Luppi, T. A. and Favero, M. (2011) Age-related prey selectivity and foraging efficiency of Olrog's Gulls (*L. atlanticus*) feeding on crabs in their non-breeding grounds. *Emu* 111: 172–178.

Berón, M. P., Seco Pon, J. P., García, G. O., Paterlini, C. A., Mariano-Jelicich, R. and Favero, M. (2013) The diet of Olrog's Gull (*Larus atlanticus*) reveals an association with fisheries during the non-breeding season. *Emu* 113: 69–76.

Bertellotti, M. and Yorio, P. (2000a) Age-related feeding behaviour and foraging efficiency in Kelp gulls *Larus dominicanus*

attending coastal trawlers in Argentina. *Ardea* 88: 207–214.

Bertellotti, M. and Yorio, P. (2000b) Utilisation of fishery waste by Kelp Gulls attending coastal trawl and longline vessels in northern Patagonia, Argentina. *Ornis Fennica* 77: 105–115.

BirdLife International (2018) *Larus atlanticus*. The IUCN Red List of Threatened Species 2018: e.T22694286A132538305.

Birkhead, T. R. and Furness, R. W. (1985) Regulation of seabird populations. Pp. 145–167 in R. M. Sibly and R. H. Smith, eds. *Behavioural ecology: ecological consequences of adaptive behaviour*. Oxford, UK: Blackwell.

Bloom, P. H. (1987) Capturing and handling raptors. Pp. 99–123 in B. A. Giron Pendleton, B. A. Millsap, K. W. Cline and D. M. Bird, eds. *Raptor management techniques manual*. Washington, DC: National Wildlife. Federation.

Burger, J. and Gochfeld, M. (1996) Family Laridae (Gulls). In J. del Hoyo, A. Elliot and J. Sargatal, eds. *Handbook of the birds of the world. Vol. 3*. Barcelona, Spain: Lynx Edicions.

Calenge, C. (2006) The package 'adehabitat' for the R software: a tool for the analysis of space and habitat use by animals. *Ecol. Model.* 197: 516–519.

Camphuysen, K. C. J., Shamoun-Baranes, J., Loon, E. E. v. and Bouten, W. (2015) Sexually distinct foraging strategies in an omnivorous seabird. *Mar. Biol.* 162: 11.

CMS (2015) Apéndices I y II de la Convención sobre la Conservación de las Especies Migratorias de Animales Silvestres (CMS). In Vol. 2015. (Convención sobre la Conservación de Especies Migratorias de Animales Silvestres).

Copello, S. and Favero, M. (2001) Foraging ecology of Olrog´s Gull *Larus atlanticus* in Mar Chiquita Lagoon (Buenos Aires, Argentina): are there age-related differences? *Bird Conserv. Internatn.* 11: 175–188.

Copello, S., Seco Pon, J. and Favero, M. (2014) Spatial overlap of Black-browed albatrosses with longline and trawl fisheries in the Patagonian Shelf during the non-breeding season. *J. Sea Res.* 89: 44–51.

Crawley, M. J. (2007) *The R Book*. Hoboken, New Jersey: John Wiley & Sons.

Croxall, J. P., Butchart, S. H. M., Lascelles, B., Stattersfield, A. J., Sullivan, B., Symes, A. and Taylor, P. (2012) Seabird conservation status, threats and priority actions: a global assessment. *Bird Conserv. Internatn.* 22: 1–34.

del Hoyo, J., Elliott, A. and Sargatal, J. (1996) *Handbook of the birds of the world*. Barcelona: Lynx Edicions.

Delhey, J. K. V., Carrete, M. and Martínez, M. M. (2001) Diet and feeding behaviour of Olrog's Gull *Larus atlanticus* in Bahía Blanca, Argentina. *Ardea* 89: 319–329.

Devillers, P. (1977) Observations at a breeding colony of *Larus (belcheri) atlanticus*. *Le Gerfaut* 67: 22–43.

Escalante, R. (1966) Notes on the Uruguayan population of *Larus belcheri*. *Condor* 68: 507–510.

Favero, M., Copello, S., García, G., Mariano-Jelicich, R., Ravasi, T. and Seco Pon, J. (2016) Aves marinas de las costas bonaerenses. Pp. 368–384 in C. C. J. Athor, ed. *La costa atlántica de Buenos Aires – naturaleza y patrimonio cultural*. Buenos Aires: Azara Fundacion.

Fortin, M.-J. and Dale, M. (2005) *Spatial analysis: A guide for ecologists*. New York: Cambridge University Press.

Furness, R. W. (2003) Impacts of fisheries on seabird communities. *Scientia Marina* 67: 33–45.

Giaccardi, M. and Yorio, P. (2004) Temporal patterns of abundance and waste use by Kelp Gulls at a urban and fishery waste tip in northern coastal Patagonia, Argentina. *Ornitol. Neotrop.* 15: 93–102.

Guilford, T., Meade, J., Willis, J., Phillips, R. A. and Boyle, D. (2009) Migration and stop-over in a small pelagic seabird, the Manx Shearwater *Puffinus puffinus*: insights from machine learning. *Proc. Biol. Sci.* 276(1660): 1215–1223.

Harden, L. A., and Williard, A. S. (2012) Using spatial and behavioral data to evaluate the seasonal bycatch risk of diamondback terrapins *Malaclemys terrapin* in crab pots. *Mar. Ecol. Progr. Ser.* 467: 207–217.

Harrison, P. (1983) *Seabirds: An identification guide*. Beckenham, UK: Croom-Helm.

Hedd, A., Montevecchi, W. A., Phillips, R. A. and Fifield, D. A. (2014) Seasonal sexual

segregation by monomorphic Sooty Shearwaters *Puffinus griseus* reflects different reproductive roles during the pre-laying period. *PLoS ONE* 9(1): 10.

Herrera, G., Punta, G. and Yorio, P. (2005) Diet specialization of Olrog's Gull *Larus atlanticus* during the breeding season at Golfo San Jorge, Argentina. *Bird Conserv. Internatn.* 15: 89–97.

Hyrenbach, K. D., Keiper, C., Allen, S. G., Ainley, D. G. and Anderson, D. J. (2006) Use of marine sanctuaries by far-ranging predators: commuting flights to the California Current System by breeding Hawaiian albatrosses. *Fisheries Oceanography* 15: 95–103.

Isacch, J. P. (2008) Implementing the biosphere reserve concept: the case of Parque Atlántico Mar Chiquito biosphere reserve from Argentina. *Biodivers. Conserv.* 17: 1799–1804.

Isacch, J., Bó, M., Vega, L., Favero, M., Baladrón, A., Pretelli, M., Stellatelli, O., Cardoni, D., Copello, S., Block, C., Cavalli, M., Comparatore, V., Mariano-Jelicich, R., Biondi, L. M., García, G. and Seco Pon, J. (2016) Evaluación de la diversidad de Tetrápodos en un mosaico de ambientes del sudeste de la ecoregión Pampeana como herramienta para planificar en conservación. *Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"* 18: 211–233.

Isacch, J. P., Costa, C. S. B., Escapa, M., Gagliardini, D.A., Iribarne, O. O., Rodríguez-Gallego, L. and Conde, D. (2006) Distribution of saltmarsh plant communities associated with environmental factors along a latitudinal gradient on the south-west Atlantic coast. *J. Biogeogr.* 33: 888–900.

Mariano-Jelicich, R., Copello, S., Seco Pon, J. and Favero, M. (2017) Long-term changes in Black-browed albatrosses diet as a result of fisheries expansion: an isotopic approach. *Mar. Biol.* 164(6): 148.

Martínez, M. M., Isacch, J. P. and Rojas, M. (2000) Olrog´s Gull *Larus atlanticus*: specialist or generalist? *Bird Conserv. Internatn.* 10: 89–92.

McClellan, C. M., Read, A. J., Price, B. A., Cluse, W. M. and Godfrey, M. H. (2009) Using telemetry to mitigate the bycatch of long-lived marine vertebrates. *Ecol. Applic.* 19: 1660–1661.

McCullagh, P. and Nelder, J. A. (1989) *Generalized linear models*. 2nd edition. London, UK: Chapman & Hall.

Olrog, C. (1967) Breeding of the Band-Tailed Gull (*Larus Belcheri*) on the Atlantic Coast of Argentina. *Condor* 69: 42–48.

Pacheco, J. F., Olinto Branco, J. and de Queiroz Piacentini, V. (2009) Olrog's Gull *Larus atlanticus* in Santa Catarina, Brazil: northernmost occurrence and first state record. *Cotinga* 31: 80–81.

Pellegrino, J. F. and Cousseau, M. B. (2005) *La pesca deportiva desde la costa en Mar del Plata. Los peces costeros*. Mar del Plata: EMDER MGP.

Petracci, P., Delhey, K. and Sotelo, M. (2007) Hábitos granívoros en la Gaviota Cangrejera (Larus atlanticus): implicancias sobre su estatus de especialista. *Hornero* 22: 51–54.

Phillips, R., Xavier, J. C. and Croxall, J. P. (2003) Effects of satellite transmitters on albatrosses and petrels. *The Auk* 120: 1082–1090.

Quintana, F., López, G. and Somoza, G. (2008) A cheap and quick method for DNA-based sexing of birds. *Waterbirds* 31: 485–488.

Quintana, F., Dell' Arciprete, P. and Copello, S. (2010) Foraging behavior and habitat use by the Southern Giant Petrel on the Patagonian Shelf. *Mar. Biol.* 157: 515–525.

Rayner, M. J., Taylor, G. A., Gummer, H. D., Phillips, R. A., and Sagar, P. M. (2012) The breeding cycle, year-round distribution and activity patterns of the endangered Chatham Petrel (*Pterodroma axillaris*). *Emu* 112: 107–116.

Schreiber, E. A. and Burger, J. (2002) Seabirds in the marine environment. Pp. 1–15 in E. A. Schreiber and J. Burger, eds. *Biology of marine birds*. Boca Raton, Florida: CRC Press.

Seco Pon, J. P., García, G., Copello, S., Moretinni, A., Lértora, P., Pedrana, J., Mauco, L. and Favero, M. (2012) Seabird and marine mammal attendance at Chub mackerel (*Scomber japonicus*) semi-industrial purse seine fishery in coastal waters of northern Argentina. *Ocean & Coastal Manage.* 64: 56–66.

Seco Pon, J. P., Copello, S., Moretinni, A., Lértora, H. P., Bruno, I., Bastida, J., Mauco, L., and Favero, M. (2013) Seabird and marine-mammal attendance and by-catch

in semi-industrial trawl fisheries in near-shore waters of northern Argentina. *Mar. Freshw. Res.* 64: 237–248.

Silva Rodríguez, M. P., Favero, M., Berón, M. P., Mariano-Jelicich, R. and Mauco, L. (2005) Ecología y conservación de aves marinas que utilizan el litoral bonaerense como área de invernada. *El Hornero* 20: 111–130.

Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G. and Gaughan, D. J. (2011) *Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area, Western Australia*. Fisheries Research Report No. 216.

Spivak, E., Luppi, T. and Bas, C. (2001) Cangrejos y Camarones: las relaciones organismo-ambiente en las distintas fases del ciclo de vida. Pp. 320 in O. Iribarne, ed. *Reserva de Biosfera Mar Chiquita: Características físicas, biológicas y ecológicas*. Mar del Plata, Argentina: Editorial San Martin.

Spivak, E. D. and Sánchez, N. (1992) Prey selection by Larus belcheri atlanticus in Mar Chiquita lagoon, Buenos Aires, Argentina: a possible explanation for its discontinuous distribution. *Chilean J. Nat. Hist.* 65: 209–220.

Suárez, N., Retana, M. V. and Yorio, P. (2011) Temporal changes in diet and prey selection in the threatened Olrog´s gull *Larus atlanticus* breeding in southern Buenos Aires, Argentina. *Ardeola* 58: 35–47.

Suárez, N., Retana, V. and Yorio, P. (2012) Spatial patterns in the use of foraging areas and its relationship with prey resources in the threatened Olrog's Gull (*Larus atlanticus*). *J. Ornithol.* 153: 861–871.

Tomkiewicz, S. W., Fuller, M. R., Kie, J. G. and Bates, K. K. (2010) Global positioning system and associated technologies in animal behaviour and ecological research. *Phil. Trans. Roy. Soc.* 365(1550): 2163–2176.

Wilson, R. P., Puetz, K., Peters, G., Culik, B., Scolaro, J. A., Charrassin, J. B. and Ropert-Coudert, Y. (1997) Long-term attachment of transmitting and recording devices to penguins and other seabirds. *Wildl. Soc. Bull.* 25: 101–106.

Williamson, C. E. (1993) Linking predation risk models with behavioral mechanisms: identifying population bottlenecks. *Ecology* 74: 320–331.

Worton, B. J. (1989) Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70: 164–168.

Wunderle, J. M. J. (1992) Age-specific foraging proficiency in birds. *Curr. Ornithol.* 9: 273–324.

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

Yorio, P., Petracci, P. and Borboroglu, P. G. (2013) Current status of the threatened Olrog's Gull *Larus atlanticus*: global population, breeding distribution and threats. *Bird Conserv. Internatn.* 23: 477–486.

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

Zar, J. H. (2010) *Biostatistical analysis*. 5th edition. London, UK: Pearson.

Zuur, A. F., Ieno, E. N., Walker, N. J., Saveliev, A. A. and Smith, G. M. (2009) *Mixed effects models and extensions in ecology with R*. New York, USA: Springer.

MARÍA TERESA RAVASI, JUAN PABLO SECO PON, JESICA ANDREA PAZ, MARCO FAVERO, SOFÍA COPELLO*

Instituto de Investigaciones Marinas y Costeras (IIMyC), Universidad Nacional de Mar del Plata, CONICET. Rodríguez Peña 4046 nivel 1, B7602GSD, Argentina.

*Author for correspondence; e-mail: scopello@mdp.edu.ar