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# TEMPORAL CHANGES IN DIET AND PREY SELECTION IN THE THREATENED OLROG'S GULL *LARUS ATLANTICUS* BREEDING IN SOUTHERN BUENOS AIRES, ARGENTINA

# CAMBIOS TEMPORALES EN LA DIETA Y SELECCIÓN DE PRESAS EN LA GAVIOTA DE OLROG *LARUS ATLANTICUS* CRIANDO EN EL SUR DE BUENOS AIRES, ARGENTINA

Nicolás SUÁREZ[1] *, María Valeria RETANA[1] and Pablo YORIO[1, 2]

SUMMARY.—*Temporal changes in diet and prey selection in the threatened Olrog's gull* Larus atlanticus *breeding in southern Buenos Aires, Argentina.*

We examined temporal changes in diet composition and prey selection in the threatened Olrog's gull *Larus atlanticus* breeding at Bahía San Blas, Argentina. Diet was assessed through pellet analysis (N = 360) and chick stomach samples (N = 120) during 2006 and 2007. Prey availability was sampled in 2,084 1m$^2$ quadrats distributed throughout Olrog's gull potential feeding areas. Gulls fed almost exclusively on three crabs: *Neohelice granulata*, *Cyrtograpsus altimanu*s and *Cyrtograpsus angulatus*. Diet composition was similar between years. The relative importance (%IRI) of different crab species, assessed through pellet analysis, varied across the breeding cycle. During incubation, *N. granulata* predominated (> 90%) while *C. altimanus* comprised less than 2% of the crabs taken. This relative contribution was reversed during the young chick stage (< 10% v. > 60%, respectively) and was 40-50% for both species during the old chick stage. Stomach sample analysis provided a similar pattern of %IRI values for the chick stages. Sizes of available crabs differed significantly between species, *C. angulatus* and *N. granulata* both being similar-sized but larger than *C. altimanus*. Gulls selected *N. granulata* during incubation and largely *C. altimanus* during the chick stages. Our study suggests that Olrog's gull depends on three crab species, confirming its specialised feeding ecology during the breeding season. Their relative consumption, however, can change temporally, probably in response to restrictions imposed by the different requirements of adults and chicks.

*Key words*: diet, *Larus atlanticus*, Olrog's gull, prey selection, seasonal changes.

RESUMEN.—*Cambios temporales en la dieta y selección de presas en la gaviota de Olrog* Larus Atlanticus *criando en el sur de Buenos Aires, Argentina.*

Se evaluaron los cambios temporales en la composición de la dieta y en la selección de presas de las gaviotas de Olrog *Larus atlanticus* que se reproducen en Bahía San Blas, Argentina. La dieta fue

[1] Centro Nacional Patagónico (CONICET). Boulevard Brown 2915, (9120) Puerto Madryn, Chubut, Argentina.

[2] Wildlife Conservation Society Argentina. Amenábar 1595, Piso 2, Of. 19, Ciudad Autónoma de Buenos Aires, Argentina.

* Corresponding author: suarez@cenpat.edu.ar

examinada mediante el análisis de egagrópilas (N = 360) y lavados estomacales de pollos (N = 120) durante las temporadas reproductivas 2006 y 2007. La disponibilidad de presas fue calculada mediante el muestreo de 2.084 parcelas de $1m^2$ distribuidas a lo largo del área de alimentación potencial de las aves. Las gaviotas se alimentaron casi exclusivamente de tres especies de cangrejo: *Neohelice granulata*, *Cyrtograpsus altimanus* y *Cyrtograpsus angulatus*. La composición de la dieta fue similar en los dos años de estudio. La importancia relativa (IRI%) de las diferentes especies de cangrejo, determinada a través del análisis de egagrópilas, varió a lo largo del ciclo reproductivo. Durante la incubación, *N. granulata* mostró una contribución mayor (> 90%) mientras que *C. altimanus* tuvo una contribución inferior al 2%. Este aporte relativo se invirtió en la etapa de pollos pequeños (< 10% vs. > 60%, respectivamente) y fue entre del 40% y el 50% para ambas especies en la etapa de pollos grandes. El análisis de lavados estomacales mostró valores similares de IRI% para las etapas de pollos. Las tallas de los cangrejos disponibles difirieron significativamente entre las especies, siendo similares para *N. granulata* y *C. angulatus*, pero ambas más grandes que *C. altimanus*. Las gaviotas seleccionaron la especie *N. granulata* durante la etapa de incubación y mayormente *C. altimanus* durante ambas etapas de pollos. Nuestro estudio sugiere que la gaviota de Olrog se sustentó con tres especies de cangrejo, lo que confirma su alimentación especialista durante la etapa reproductiva. Su consumo relativo, sin embargo, puede variar temporalmente en respuesta a restricciones impuestas por los requerimientos especificos de adultos y pollos.

*Palabras clave*: cambios estacionales, dieta, Gaviota de Olrog, *Larus atlanticus*, selección de presas.

## Introduction

Many studies have demonstrated relative plasticity in diet among seabirds (Shealer, 2002). Diet composition, for example, may change geographically, between years or seasonally in response to fluctuations in food availability and to changes in energy requirements or restrictions imposed by reproductive factors (Murphy *et al.*, 1984; Pierotti and Annett, 1991; Suryan *et al.*, 2002; Wilson *et al.*, 2004). Among seabirds, gulls show an opportunistic and generalist feeding strategy (Burger and Gochfeld, 1996). Most gulls feed on a great variety of prey and forage in a wide range of habitats (Burger, 1988), although some species have a specialised feeding ecology (Burger and Gochfeld, 1996).

Olrog's gull *Larus atlanticus* is endemic to the Atlantic Ocean coast of Argentina, Uruguay and southern Brazil, and has a small breeding population (4,000-5,000 pairs; BirdLife International, 2008) restricted to a relatively small coastal sector in northern Argentina (Yorio *et al.*, 2005). It has a rather specialised feeding ecology during the breeding season, preying almost exclusively on three crab species: *Neohelice granulata*, *Cyrtograpsus altimanus* and *C. angulatus* (Delhey *et al.*, 2001; Herrera *et al.*, 2005). Crabs are also an important component of the Olrog's gull diet outside the breeding season, although the gulls then often take other food items (Spivak and Sánchez, 1992; Martínez *et al.*, 2000; Copello and Favero, 2001; Delhey *et al.*, 2001; Berón *et al.*, 2007; Petracci *et al.*, 2007). Olrog's gull is considered globally vulnerable due to its small population, restricted breeding range and trophic specialisation (BirdLife International, 2008).

Over 90% of the total Olrog's gull population breeds along the coasts of southern Buenos Aires province, Argentina. Knowledge of its food requirements when breeding in this coastal sector has hitherto been based on a study of just one site during a single breeding season (Delhey *et al.*, 2001). Obtaining information on diet composition from more than one breeding season and from additional colonies in the region thus constitutes an important step towards understanding the food requirements and degree of specialisation of this threatened species. Specialised behaviours make populations more vulnerable to changes in selective pressures (Rabinowitz *et al.*, 1986; Reed, 1999) and to environmental modifications resulting from human activities. Understanding the degree of dependence of this gull on particular prey species would greatly contribute to the development of conservation strategies. This paper presents information on temporal changes in diet composition and prey selection of Olrog's gulls breeding at a colony in southern Buenos Aires, Argentina.

## METHODS

### *Study area and species*

Olrog's gull diet was studied at Islote Arroyo Jabalí Oeste (40° 33' S, 62° 16' W), in south-western San Blas bay (Buenos Aires Province) within the Bahía San Blas protected area. The coastal sector is characterised by extensive mudflats and marshes of *Spartina* spp. and *Salicornia ambigua*, with crab beds inhabited by *N. granulata*, *C. altimanus* and *C. angulatus* (Zalba *et al.*, 2008). These intertidal crabs are common in coastal and estuarine areas of the SW Atlantic (Iribarne *et al.*, 2003). Olrog's gulls capture prey by walking along the exposed intertidal zone or in shallow water and by surface seizing or, occasionally, by surface plunging, in shallow water (Martínez *et al.*, 2000; Copello and Favero, 2001; Delhey *et al.*, 2001; Gatto *et al.*, 2008). In the study area, Olrog's gulls start laying in late September, eggs start hatching in late October and chicks start fledging in early December.

### *Diet sampling*

The composition and temporal variation of Olrog's gull diet were studied using regurgitated pellets and stomach samples obtained through the water offloading technique (Wilson, 1984; Duffy and Jackson, 1986, Barrett *et al.*, 2007). Pellet analysis may overemphasise the presence of types of prey with indigestible hard parts and soft prey may not be well represented (Duffy and Jackson, 1986; Barrett *et al.*, 2007). However, other studies have demonstrated that the results reflect diet composition (Annett and Pierotti, 1989) and are valuable for detecting seasonal changes (Johnstone *et al.*, 1990; Barrett *et al.*, 1990). Pellets were collected weekly between November and December 2006 (N = 180) and between October and December 2007 (N = 180). All pellets collected during the first visit were discarded so as to eliminate old pellets from the analysis. Pellets were collected from around nests and always in the same area of the colony. The general breeding status of nests was noted during each visit when pellets and stomach samples were collected. The breeding cycle was divided into three stages: incubation, young chicks (< 15 days of age), and old chicks (> 15 days of age). Young and old chicks were distinguished by size and the degree of plumage development. Pellets were grouped within these three stages of the breeding cycle for the analysis. Stomach samples were obtained from 30 young and 30 old chicks in each study year. Only one chick per nest was sampled. Stomach contents were preserved in 70% alcohol for later analysis.

Each pellet and stomach sample was dissected in the laboratory under a zoom binocular microscope (×15 magnification) and food remains were identified to the lowest taxonomic level possible, using crustacean shell fragments and chelae, mollusc shell fragments and insect remains. Prey items were identified with the aid of published information (Castellanos, 1967; Spivak and Sánchez, 1992; Boschi *et al.*, 1992) and a reference collection from the study area. Size (carapace width) and weight of crabs found in pellets were estimated from linear regressions with maximum length or width of chelae, considering size differences between sexes, following Spivak and Sánchez (1992). The number of crabs present in each pellet was calculated by assuming one crab per two chelae (right and left) that differed by less than 0.1 mm (Spivak and Sánchez, 1992).

Frequency of occurrence (%F), numerical importance (%N) and importance by mass (%W) were calculated for each prey type (Duffy and Jackson, 1986). The mass of the three crab species was estimated from regressions based on carapace width (*N. granulata* and *C. angulatus*, Luppi *et al.*, 1997; *C. altimanus*, N. Suárez, pers. obs.). An Index of Relative Importance (IRI) and percentage IRI (%IRI) were estimated for each crab prey species (i) following Piankas *et al.*, (1971), where $IRI_i = \%F_i\ (\%W_i + \%N_i)$ and $\%IRI_i = (IRI_i{*}100)/IRI_{total}$. Prey selection was analysed using Savage's index (Savage, 1931), $S = U_i / D_i$, where $U_i$ is the proportion of prey *i* in the diet of Olrog's gull, and $D_i$ is availability of that prey in the environment. This index varies from 0 (maximum negative selection) to infinite, 1 being the central value of no selection. The statistical significance of the results was obtained by comparing the statistic $(w_i - 1)^2 / SE(w_i)^2$ where $w_i$ is the Savage's index for the prey species *i*, and $SE(w_i)$ its standard error, with the corresponding critical value of a chi-squared distribution with one degree of freedom (Manly *et al.*, 1993).

*Prey availability*

Prey availability was assessed during 2007 by analysing the distribution and characteristics of the main prey identified in the diet of Olrog's gulls during 2006. Samples were taken in their potential foraging areas, which were defined through radiotracking ten individuals from late incubation to the late chick stage in 2006 (unpublished data). Sampling was conducted throughout the breeding cycle, by placing $1m^2$ quadrats in the upper, middle and lower intertidal zones (Spivak *et al.*, 1994; Iribarne *et al.*, 1997; Gavio, 2003). In each intertidal zone we obtained ten random replicates, totalling 30 samples in each of 74 stations separated by at least 120 m and distributed throughout the study area (N = 2,084 plots). In each sample, the number of burrows and/or crab individuals was counted, prey species were identified, and a sub-sample of crabs was collected to assess prey size. For the analysis of changes in prey availability, we used sub-samples obtained during a seven-day period at the peak of each stage of the breeding cycle (late September, N = 180; early November, N = 220; mid December, N = 190).

*Data analysis*

Differences in the characteristics of each crab species between defined categories were assessed using the nonparametric Mann-Whitney or Kruskal-Wallis tests. Comparisons of diet composition, %IRI, and prey availability in different contexts were analysed using contingency tables and the $\chi^2$ statistic. Means are reported ± 1 standard deviation.

## Results

*Diet Composition*

Pellet analysis showed that the diet of Olrog's gulls comprised at least five prey items. The mean number of prey items per pellet was 2.15 ± 0.78 (N = 360). Crabs, particularly *N. granulata* and *C. altimanus* (table 1), were the main component. Bivalve and insect remains were also present, although in less than 1.5 % of samples in both cases. The mean number of crab individuals per pellet was 12.2 ± 4.5 (N = 360). In both years, %IRI values indicated that *N. granulata* showed the highest contribution (46% and 44% in 2006 and 2007, respectively), followed by *C. altimanus* with slightly lower values (39% and 38%, respectively) and *C. angulatus* (15% and 18%, respectively). The size of individuals identified in pellets was significantly different between the three crab species, being larger for *C. angulatus* (34.3 ± 7.4 mm, range = 13.4-44.8 mm, N = 727), followed for *N. granulata* (26.5 ± 5.3 mm, range = 11.6-38.8 mm, N = 1,414) and *C. altimanus* (15.1 ± 4.6 mm, range = 7.9-24.8 mm, N = 1922) (Kruskal-Wallis Test $H_2 = 8.41$, $P < 0.05$).

Pellet analysis indicated that diet composition during the incubation, young chick and old chick stages was similar between years (Chi-squared Test, $\chi^2_1$, all NS). Data from both study years were therefore pooled for the analysis of temporal variation. During incubation, *N. granulata* was clearly the crab species with the highest frequency of occurrence and it made the largest contribution by number and mass (table 1). Also, 81% of pellets (N = 120) consisted exclusively of *N. granulata*. The relative contribution of *C. altimanus* increased during the chick stages and it was the main prey during the young chick stage (table 1). In the old chick stage, this crab species also showed the highest values in frequency of occurrence and numerical importance, although the highest importance by mass corresponded to *N. granulata* (table 1).

TABLE 1

Frequency of occurrence (%F), numerical importance (%N) and importance by mass (%W) of prey recorded in pellets and chick stomach samples at the Olrog's gull colony of Islote Arroyo Jabalí Oeste, Argentina, during the different stages of the breeding cycle in 2006 and 2007.
*[Frecuencia de ocurrencia (%F), importancia numérica (%N) e importancia en peso (%W) de las presas registradas en las egagrópilas y lavados estomacales de gaviota de Olrog en la colonia del Islote Arroyo Jabalí Oeste, Argentina, durante las diferentes etapas del ciclo reproductivo en 2006 y 2007.]*

| | **Pellets** | | | | | | | | | **Stomach samples** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Incubation** (N = 120) | | | **Young chicks** (N = 120) | | | **Old chicks** (N = 120) | | | **Young chicks** (N = 60) | | | **Old chicks** (N = 60) | | |
| | %F | %N | %W | %F | %N | %W | %F | %N | %W | %F | %N | %W | %F | %N | %W |
| *N. granulata* | 96.7 | 81.4 | 89.6 | 25.8 | 15.2 | 33.0 | 55.0 | 35.7 | 56.6 | 24.5 | 8.9 | 16.6 | 60.5 | 33.0 | 44.9 |
| *C. altimanus* | 17.5 | 7.4 | 4.5 | 86.7 | 58.5 | 44.9 | 67.5 | 47.2 | 33.9 | 91.0 | 74.6 | 67.3 | 77.3 | 47.1 | 42.4 |
| *C. angulatus* | 25.1 | 9.7 | 6.0 | 70.8 | 25.1 | 22.1 | 34.2 | 17.1 | 9.5 | 50.5 | 16.5 | 16.1 | 32.2 | 19.1 | 16.5 |
| Insects | 0.6 | 1.5 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *B. rodriguezi* | 0 | 0 | 0 | 0.6 | 1.2 | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.8 | — |

The analysis of stomach samples showed that parents fed their offspring almost exclusively on crabs during both chick stages. Fish prey was also recorded, although only in 0.1% of samples and during the first study season. The mean number of crab individuals per stomach sample was 11.7 ± 5.0 (N = 120). Diet composition during each of the chick stages was similar between years ($\chi^2_1$, all NS), and therefore data for both study years were pooled for the comparison between young and old chick diets. This analysis showed an important relative contribution of *C. altimanus* in both chick stages. However, while *C. altimanus* was clearly the dominant prey supplied during the young chick stage, the relative contribution of *N. granulata* increased during the old chick stage, when it made a slightly larger contribution to dietary mass than *C. altimanus* (table 1).

The relative importance of each crab species identified in pellets differed between the different stages of the breeding cycle. During the incubation stage, *N. granulata* showed the highest %IRI values (> 90%) whereas *C. altimanus* showed values of less than 2% (fig. 1a). This relationship was reversed in the young chick stage, during which *N. granulata* showed %IRI values lower than 10%, whereas these were larger than 60% for *C. altimanus*. The relative importance of these two crab species during the old chick stage was similar (%IRI values between 40 and 50%). *C. angulatus* showed relatively low %IRI values during the incubation and old chick stages, but was the secondary prey item during the young chick stage (fig. 1a). A similar pattern was observed in the %IRI values of prey identified in chick stomach samples, *C. altimanus* being the dominant prey in both stages with *N. granulata* relatively more important during the old chick than the young chick stage (fig. 1b). However, the values corresponding to the relative contribution of each prey species during the young chick stage differed between methodologies, with significantly larger %IRI values for *C. altimanus* ($\chi^2_1 = 3.98$, $P < 0.05$) and significantly lower %IRI values for *N. granulata* and *C. angulatus* ($\chi^2_1 = 16.3$, $P < 0.05$ and $\chi^2_1 = 7.47$, $P < 0.05$, respectively) in stomach samples than in pellets. During the old chick stage, both methodologies gave similar %IRI values for the three crab species ($\chi^2_1$, all NS).

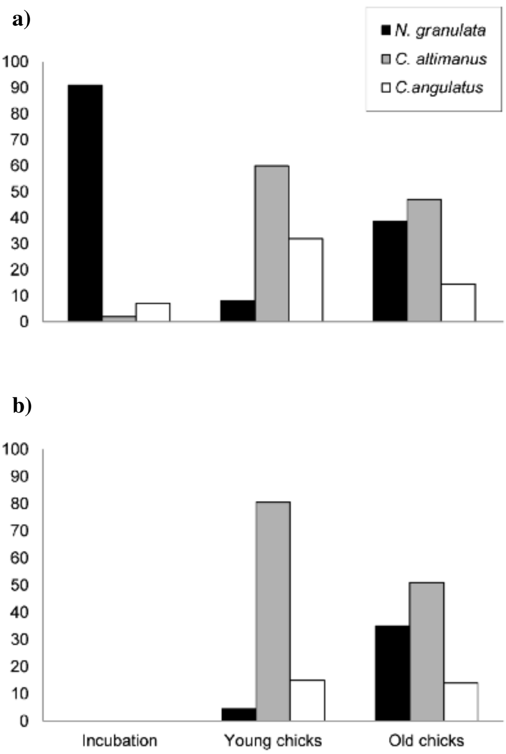


FIG. 1.—Temporal variation in the relative importance (%IRI) of the main prey species identified in Olrog's gull (a) pellets and (b) chick stomach samples at Islote Arroyo Jabalí Oeste, Argentina, during the 2006 and 2007 breeding seasons.
*[Variación temporal en la importancia relativa (IRI%) de las principales especies presa identificadas en las (a) egagrópilas y (b) lavados estomacales de la gaviota de Olrog en el Islote Arroyo Jabalí Oeste, Argentina, durante las temporadas reproductivas 2006 y 2007.]*

No significant differences between study years were found in the size of crabs consumed during each of the stages of the breeding cycle (Mann-Whitney U test, all NS), and therefore data from both years was pooled for the analysis of temporal variation. For each crab species, the size of consumed individuals obtained both from pellets and chick stomach samples was similar between stages of the breeding cycle (Kruskal-Wallis Test, all NS). For the three crab species, the size of consumed individuals in each chick stage did not differ between pellets and stomach samples (Mann-Whitney U test, all NS) (table 2).

*Prey availability and selection*

The three crab species differed in their availability in Olrog's gull potential feeding areas (frequency of occurrence: $\chi^2_2 = 12.1$, $P < 0.05$; numerical importance: $\chi^2_2 = 18.3$, $P < 0.05$; density: Kruskal-Wallis Test, $H_2 = 13.31$, $P < 0.05$). The density of *C. angulatus* was significantly lower than that of *N. granulata* and *C. altimanus*, but densities did not differ between the last two (Dunn's, $Q_{C.\ ang\text{-}C.\ alt} = 3.86$, $P < 0.05$, Dunn's, $Q_{C.\ ang\text{-}N.\ gra} = 3.92$, $P < 0.05$ and $Q_{N.gra\text{-}C.alt} = 0.32$, NS) (table 3). The size of available crabs differed significantly between species, being similar between *C. angulatus* and *N. granulata* both of which were larger than *C. altimanus* (Kruskal-Wallis Test, $H_2 = 8.41$, $P < 0.05$, Dunn's, $Q_{C.\ ang\text{-}C.\ alt} = 4.97$, $P < 0.05$ and Dunn's, $Q_{N.\ gran\text{-}C.\ alt} = 4.73$, $P < 0.05$) (table 3). No significant differences were found between the three stages of the breeding cycle with respect to the frequency of occurrence ($\chi^2_2 = 13.7$, NS), numerical importance

TABLE 2

Mean size (± SD) and size range (in parentheses) of three crab species consumed by Olrog's gulls during the different stages of the breeding cycle at the Isla Arroyo Jabalí Oeste colony, Argentina, in 2006 and 2007.

*[Tamaños (media ± DS) y rango (entre paréntesis) de las tres especies de cangrejo consumidas por las gaviotas de Olrog durante las diferentes etapas del ciclo reproductivo en la colonia de Islote Arroyo Jabalí Oeste, Argentina, en 2006 y 2007.]*

| | **Pellets** | | | **Stomach samples** | |
|---|---|---|---|---|---|
| | **Incubation** (N = 1456) | **Young** chicks (N = 1387) | **Old** chicks (N = 1399) | **Young** chicks (N = 748) | **Old** chicks (N = 716) |
| *N. granulata* | 26.4 ± 7.1 (14.5-40.0) | 27.5 ± 5.8 (10.7-35.9) | 28.8 ± 7.3 (13.1-38.3) | 22.6 ± 8.1 (9.8-37.6) | 24.9 ± 6.6 (12.3-39.0) |
| *C. altimanus* | 15.4 ± 5.3 (9.8-28.7) | 13.5 ± 5.6 (7.4-28.3) | 15.8 ± 5.7 (8.6-29.6) | 12.7 ± 4.2 (7.1-26.7) | 15.3 ± 3.9 (8.5-28.9) |
| *C. angulatus* | 37.8 ± 8.2 (14.3-41.2) | 34.6 ± 8.7 (11.2-40.1) | 33.9 ± 4.8 (13.6-43.8) | 30.4 ± 4.8 (10.7-39.7) | 34.6 ± 5.7 (12.8-44.0) |

($\chi^2_2 = 16.3$, NS), density (Kruskal-Wallis test: $H_2 = 71.42$; $P < 0.05$) or size (Kruskal-Wallis test: $H_2 = 61.23$; $P < 0.05$) of crabs in Olrog's gull potential feeding areas.

Prey selection analysis based on pellet information indicated that the proportion of consumption and availability of different prey species differed significantly during the three stages of the breeding cycle. Savage's index showed that gulls selected *N. granulata* during the incubation stage and *C. altimanus* during both chick stages. *C. angulatus* was also positively selected during the young chick stage, although to a lesser degree. Prey selection analysis based on stomach samples indicated that *C. altimanus* was positively selected in both chick stages (table 4).

Pellet analysis showed that during the incubation stage, the size of consumed crabs was significantly larger than that of available ones for both *C. altimanus* (Mann-Whitney U test, $U = 9.31$, $P < 0.05$) and *C. angulatus* (Mann-Whitney U test, $U = 6.24$, $P < 0.05$), while the size of consumed and available *N. granulatus* was similar (Mann-Whitney U test, $U = 1.23$, NS). No significant differences were found between the sizes of consumed and available individuals of the three crab species during the young chick stage (Mann-Whitney U test, all NS). During the old chick stage, significant differences were only found for *C. altimanus*, consumed individuals being larger (Mann-Whitney U test, $U = 9.87$, $P < 0.05$). During the incubation stage, gulls selected "medium" and "large" prey, avoiding the consumption of "small" crabs (table 4). In contrast, gulls selected "small" crabs during both chick stages, in addition to "medium" crabs when chicks were young and "large" crabs when chicks were old.

The analysis of stomach samples showed that in the young chick stage, the size of consumed *N. granulata* was significantly smaller than that available in the environment (Mann-Whitney U test, $U = 16.48$, $P < 0.05$). During the old chick stage, the pattern was similar to that observed in the analysis based on pellets, consumed crabs being larger than those available only in *C. altimanus* (Mann-Whitney U test, $U = 9.42$, $P < 0.05$). Prey selection during the young chick stage was

TABLE 3

Availability of the main prey identified in the diet of Olrog's gulls breeding at Islote Arroyo Jabalí Oeste, Argentina, obtained from 1m² quadrats placed randomly in the intertidal zone throughout the breeding season (N = 2084).

*[Disponibilidad de las principales presas identificadas en la dieta de las gaviotas de Olrog que se reproducen en el Islote Arroyo Jabalí Oeste, Argentina, obtenidas en parcelas de 1m² distribuidas al azar en la zona intermareal a lo largo de la temporada reproductiva (N = 2084).]*

| | *N. granulata* | *C. altimanus* | *C. angulatus* |
|---|---|---|---|
| Density (individuals/m²; mean ± SD; (range)) | 20 ± 41 (0-92) | 19 ± 37 (0-78) | 11 ± 47 (0-83) |
| Frequency of occurrence (%) | 41 | 47 | 32 |
| Numerical importance (%) | 39 | 42 | 19 |
| Size (mm) | 22.8 ± 11.6 | 10.2 ± 8.3 | 28.3 ± 10.1 |

biased towards "small" and "medium" crabs, while selection during the old chick stage was for "medium" and "large" crabs (table 4).

## DISCUSSION

The diet of Olrog's gull at Islote Arroyo Jabalí Oeste consisted almost exclusively of three crab species throughout its nesting cycle in both study years, confirming its specialised feeding ecology during the breeding season. Pellet analyses and stomach samples gave similar patterns for diet composition, reinforcing the conclusions. The results agree with previous opportunistic observations and quantitative studies on Olrog's gulls breeding in southern Buenos Aires and Chubut provinces, which showed the dominance of crabs in their diet (Daguerre, 1933;

TABLE 4

Prey type and size selection by Olrog's gulls during different stages of their breeding cycle at Islote Arroyo Jabalí Oeste, Argentina, during 2007. %FA: frequency of occurrence of available prey within the potential foraging areas of the Olrog's gull (see text). MS: Manly statistic; S: prey selection, S +, positive selection, S-, negative selection, NS, no selection; Size categories (carapace width): small (< 15 mm), medium (16-25 mm), large (26-35 mm), and very large (> 35 mm).
*[Selección de tipos y tamaños de presa por las gaviotas de Olrog durante las diferentes etapas del ciclo reproductivo en el Islote Arroyo Jabalí Oeste, Argentina, durante 2007. FA%: frecuencia de ocurrencia de presas disponibles dentro de las áreas de alimentación potenciales de la gaviota de Olrog (ver texto). MS: estadístico de Manly. S: selección de presas. S+, selección positiva. S-, selección negativa. NS, sin selección. Categorías de tamaño (ancho de caparazón): pequeño (< 15 mm), mediano (16-25 mm), grande (26-35 mm) y muy grande (> 35 mm).]*

| | | **Pellets** | | | | | | **Stomach samples** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%FA** | **Incubation** | | **Young** chicks | | **Old** chicks | | **Young** chicks | | **Old** chicks | |
| | | MS | S | MS | S | MS | S | MS | S | MS | S |
| **Prey species** | | | | | | | | | | | |
| *N. granulata* | 45.6 | 1.8 | S+ | 0.5 | S- | 0.9 | S- | 0.4 | S- | 0.8 | S- |
| *C. altimanus* | 36.8 | 0.3 | S- | 1.7 | S+ | 1.3 | S+ | 2.1 | S+ | 1.5 | S+ |
| *C. angulatus* | 26.7 | 0.7 | S- | 1.3 | S+ | 0.9 | NS | 0.9 | NS | 1.0 | NS |
| **Prey Size** | | | | | | | | | | | |
| Small | 32.9 | 0.4 | S- | 1.5 | S+ | 1.4 | S+ | 1.9 | S+ | 1.1 | NS |
| Medium | 35.7 | 1.6 | S+ | 1.2 | S+ | 0.9 | NS | 1.3 | S+ | 1.6 | S+ |
| Large | 26.3 | 2.7 | S+ | 0.5 | S- | 1.4 | S+ | 0.3 | S- | 1.3 | S+ |
| Very Large | 5.1 | 1.1 | NS | 0.9 | NS | 0.9 | NS | 0.1 | S- | 0.2 | NS |

Olrog, 1967; Devillers, 1977; Delhey *et al.*, 2001; Herrera *et al.*, 2005). Delhey *et al.* (2001) reported that gulls in adult plumage feeding in Puerto Cuatreros (38º S) during the spring and summer consumed *N. granulata* almost exclusively and they noted the absence of *C. altimanus* from their diet. Herrera *et al.* (2005) reported that the diet of Olrog's gulls breeding at two colonies in northern Golfo San Jorge (45º S) mainly comprised *C. altimanus* and *C. angulatus*, although with a clear dominance of the former. It is worth noting that 41º S is the southern distributional limit of *N. granulata*. Of the three crab species, *N. granulata* and *C. altimanus* together contributed 80% of the diet, although the relative exploitation of each varied across the breeding cycle (see below). The differential contribution of these crab species to Olrog's gull diet was very probably influenced by their availability, since the numerical importance and densities of *N. granulata* and *C. altimanus* in the environment were twice those of *C. angulatus*. It is interesting that although fish in the form of discards from sport and artesanal fisheries was regularly available near the colony throughout the breeding season (pers. obs.), this higher quality prey was rarely consumed. Previous studies have reported that Olrog's gulls feed on fish, although mostly outside the breeding season (Martínez *et al.*, 2000; Copello and Favero, 2001; Berón *et al.*, 2007).

During the incubation stage, *N. granulata* was the dominant prey and was clearly selected relative to the other two crab species. The preference for this crab species during incubation may be favoured by its relative high density and abundance in the environment, in addition to its being twice the size of *C. altimanus*. Moreover, during this stage gulls consumed larger than average *C. altimanus* and *C. angulatus* and in general avoided the smaller individuals of the three crab species. These results agree with previous studies that showed that gulls select larger prey individuals from those available in the environment (Ward, 1991; Silva *et al.*, 1999; Bertellotti *et al.*, 2003). It should be noted, however, that results may be partly biased due to smaller chelae possibly being more digestible.

During the chick stage, in contrast, the gulls selected only small and medium-sized crabs and mostly the smaller *C. altimanus*, a preference for this latter species being more evident when chicks were young. These results may reflect changes in the representation of adult and chick pellets in the sample, as the relative contribution of *N. granulata* and *C. altimanus* during the young chick stage differed between pellets and stomach sample analyses. Differences between the diets of adults and chicks have been recorded in several seabird studies (Schumtz and Hobson, 1998; Ydenberg, 1994, Davoren and Burger, 1999; Ramos *et al.*, 1998; Catry *et al.*, 2006). However, the significantly lower contribution of *N. granulata*, particularly during the young chick stage, was similarly reflected by both methodologies, suggesting that adult gulls partly replaced it as the main prey species for the smaller *C. altimanus*. The observed change in resource use with respect to the incubation stage may be the result of the adults' need to feed their chicks with small-sized prey, as has been reported for other seabird species (Pedrocchi *et al.*, 1996; Shealer, 1998; Ramos *et al.*, 2009).

Several seabird studies have shown that diet composition can also change throughout the season in response to fluctuations in food availability (Murphy *et al.*, 1984; Suryan *et al.*, 2002; Wilson *et al.*, 2004). The similarity in prey occurrence and density observed between the three stages of the breeding cycle suggests that the recorded diet changes were not due to changes in crab availability but resulted from a preference for particular prey. In addition, although the contribution of *N. granulata* clearly decreased during the young chick stage, its representation increased again during the late chick stage, suggesting its regular availability for the gulls throughout the breeding cycle.

During the old chick stage, *C. altimanus* continued to be the most strongly selected prey and thus dominated their diet. However, its relative contribution was lower than that observed during the young chick stage and *N. granulata* became the second prey in terms of relative importance. These differences between chick stages may have been related to the increase in chick size which consequently allowed a greater proportion of *N. granulata* to be fed to the offspring. Gulls in this latter stage again selected larger crabs to feed their chicks. The results show that Olrog's gulls in the study area depend on three crab species, although their relative consumption can change throughout the breeding cycle, possibly in response to restrictions imposed by the different requirements of adults and chicks.

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