

## PATTERNS OF PREY PROVISIONING IN RELATION TO CHICK AGE IN THE SOUTH AMERICAN TERN (*STERNA HIRUNDINACEA*)

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**Resumen.** – Patrones de abastecimiento de presas en relación con la edad de pollos en el Gaviotín Sudamericano (*Sterna hirundinacea*). – El estudio de los patrones temporales en la composición de la dieta es clave para interpretar ciertos aspectos de la ecología e historia de vida de las aves marinas. La variación en la composición y tamaño de presas en relación con la edad de los pollos fue evaluado en una colonia de Gaviotín Sudamericano (*Sterna hirundinacea*) en Punta Loma, Argentina, durante la temporada reproductiva del 2006. La dieta de los pollos de Gaviotín Sudamericano incluyó al menos 12 especies de presa. El pescado, mayormente anchoíta (*Engraulis anchoíta*) y pejerrey (*Odontesthes argentinensis*) fue la principal presa entregada (91%) a los pollos. La proporción relativa de tipos de presa varió entre las clases de edad de los pollos, y la proporción de Anchoíta en la dieta se incrementó con la edad de los mismos, alcanzando el 58% en las crías mayores. El tamaño de las presas aumentó con la edad de los pollos. Las presas robadas por otros gaviotines adultos fueron significativamente más grandes que aquellas consumidas por los pollos. Los Gaviotines Sudamericanos en la colonia de Punta Loma parecen enfrentar la demanda creciente de los pollos en crecimiento aumentando la calidad de la presa en cada viaje de alimentación, reflejada tanto en presas más grandes como de mayor contenido energético.

**Abstract.** – The study of temporal patterns in diet composition is crucial to interpret adequately several aspects of seabird ecology and life history. The variation in prey composition and prey size in relation to chick age were evaluated in a South American Tern (*Sterna hirundinacea*) colony at Punta Loma, Argentina, during the 2006 breeding season. The diet of South American Tern chicks consisted of at least 12 prey items. Fish, mostly Argentine anchovy (*Engraulis anchoíta*) and silverside (*Odontesthes argentinensis*) were the main prey delivered (91%) to the chicks. The relative proportion of prey types varied among chick age-classes and the proportion of Argentine anchovy in the diet increased with chick age, reaching 58% in older chicks. Larger prey items were delivered to older chicks. Prey stolen by other adult terns was significantly larger than the prey actually consumed by the chicks. South American terns at the Punta Loma colony appear to confront the increasing demand of growing chicks by increasing the quality of prey in each feeding trip, reflected in larger and more energetic prey. *Accepted 31 May 2011.*

**Key words:** South American Tern, *Sterna hirundinacea*, food provisioning, chick age, Patagonia.

### INTRODUCTION

Diet composition in many seabird species varies throughout the breeding cycle as a

result of changes in food availability and individual requirements (Murphy *et al.* 1984, Pierotti & Annett 1991, Suryan *et al.* 2002, Wilson *et al.* 2004). The study of temporal

patterns in diet composition is crucial to interpret adequately several aspects of seabird ecology and life history. Among terns (*Sterna* spp.), in particular, diet composition can change in relation to chick age (Safina *et al.* 1990, Bogliani *et al.* 1994, Burness *et al.* 1994, Ramos *et al.* 1998). Prey type used to provision chicks may have important effects on their productivity, as prey energy and/or nutritional content can affect chick growth and survival (Massinas & Becker 1990, Beintema 1997, Dahdul & Horn 2003, Wanless *et al.* 2005). In addition, although larger prey may provide a higher energy return to developing chicks, they would be inadequate for small chicks that are unable to manipulate and swallow large prey (Shealer 1998a). Thus, an adequate food supply regarding prey type and size as a function of chick age may be an important determinant of breeding success (Monaghan *et al.* 1989).

South American terns (*Sterna hirundinacea*) are endemic to South America, breeding from the coasts of southern Peru and central Brazil to Tierra del Fuego, Argentina, including the Islas Malvinas (= Falkland Islands) (Gochfeld & Burger 1996, Yorio 2005). Despite its wide distribution, little is known about its foraging ecology. Recent studies have shown that in central Patagonia the South American terns feed their chicks with coastal pelagic fish, mainly Argentine anchovy (*Engraulis anchoita*) and silversides (*Odontesthes* spp.) (Gatto 2009). However, little is known about provisioning patterns as related to chick age. Knowledge on the temporal variability in diet composition in relation with different development stages of chicks is critical to understand adequately their food requirements and relationship with prey populations. The goals of this study were to characterize the diet of South American Tern chicks in Punta Loma, Chubut, and analyze the variation in prey composition and prey size in relation with chick age.

## METHODS

*Study area.* The study was conducted during the 2006–2007 breeding season at a South American Tern colony at the Punta Loma Protected Area (42°49'S, 64°28'W), Chubut, Argentina. The colony of about 3200 nests was located along the coast at the top of sedimentary cliffs. Nests were distributed in several patches defined by physiognomic features of the nesting substrate, especially cliff faces broken by small crags. To minimize disturbance, nest monitoring and feeding observations were conducted with binoculars (10x40) from a blind located at the colony periphery.

*Breeding cycle.* A study plot containing 61 nests was selected based on its visibility from the blind, and the location of each nest was sketched on a map to facilitate identification. To minimize disturbance, no adults, chicks, or nests were marked. All nests under study were checked every one to three days, from mid November 2006 until fledging, in early January 2007. During each nest check, the number of eggs or chicks was recorded. For nests checked every two days during hatching, hatching date was assumed to be the day after the egg was last seen, and when checked every three days, as the central day in that period. The limited mobility of chicks and variability in plumage facilitated their assignment to specific nests. Chicks less than 27 days of age, when they begin to fledge (Scolaro *et al.* 1996), that were not recorded in their nest on three consecutive nest checks were assumed to be dead.

*Feeding observations.* Direct observations of the prey delivered to the chicks in the study plot were made with binoculars (10x40), for a total of 52 h on 24 nonconsecutive days from 4 December 2006 to 4 January 2007. Observation periods lasted 12 h and were distributed throughout daylight hours and different

stages of the tidal cycle and weather conditions. Although the study of seabird diets based on direct observations of feeding birds has some disadvantages, the method allows the collection of large samples over short periods, with little or no disturbance to breeding birds, and provides the ability to document temporal variations in prey taken (Barrett *et al.* 2007). Adult terns carry only one prey item in the bill per trip. Adults attempting to land at the study patch with prey were continuously scanned. Once an adult was selected, it was observed with binoculars until the prey could be identified, often while the adult was attempting to feed its chick. Each item was identified to the lowest taxonomic level possible using morphological characters, and its length relative to the bill length of the adult was noted. At Punta Loma, bill length of adult South American terns is  $41 \pm 2$  mm ( $n = 74$ ) (A. Gatto, unpubl. data). Size of prey was categorized as tiny ( $< 1/2$  bill length;  $< 20$  mm), small (0.5–1.0x; 20–40 mm), medium (1.0–1.5x; 40–60 mm), and large ( $> 1.5x$ ;  $> 60$ mm) (Shealer 1998b). To reduce observer bias in determination of prey, all feeding observations and estimations of length of prey were made by the same observer (AFA). For each delivery, we recorded also if the prey was taken and swallowed by the chick, was stolen by another South American Tern, was consumed by one of the parents or was dropped and not consumed.

*Data analysis.* Based on hatching dates, chicks were grouped into one of three age-classes: = 7 days, 7–15 days, and  $> 15$  days. Nests for which we had  $> 20$  recorded deliveries were analyzed through contingency tables and Chi-square statistic to compare prey frequency among the chicks of different age. Comparisons of prey size among the three age groups were made using the Kruskal-Wallis test and Dunn's Multiple Comparisons test.

## RESULTS

First chicks were observed during late November, and last chicks hatched in late December. Seventy percent of chicks hatched between the first and second week of December and peak hatching occurred at the end of the first week. The total number of chicks in the study area was 64, and mean number of chicks per nest was  $1.05 \pm 0.7$  ( $n = 61$ ).

A total of 1008 prey deliveries were recorded throughout the study period, of which 77% were identified. Twenty percent of fish prey could not be identified, mostly because prey items were too small or, less frequently, because distinguishing characters of some silversides could not be observed. Diet of South American Tern chicks consisted of at least 12 prey items (Table 1). Fish were the main prey delivered (91%), and were mostly Argentine anchovy and silverside (*Odontesthes argentinensis*). The main secondary prey was the silver warehou (*Seriorella porosa*; 10%). These three prey items represented at least 70% of the diet in any occasion. Frequency of delivery of Argentine anchovy and silverside was not statistically different among study nests ( $33.9 \pm 5.6\%$  and  $18.5 \pm 8.6\%$  per nest, respectively;  $\chi^2_{15} = 20.35$ ;  $P = 0.16$ ).

The relative proportion of prey types, not considering unidentified prey, was different between chick age-classes ( $\chi^2_8 = 48.37$ ,  $P < 0.0001$ ). The proportion of Argentine anchovy in the diet increased with chick age, reaching 58% in chicks older than 15 days. Fish sizes, all species pooled, varied with chick age (Kruskal-Wallis test,  $H = 168.26$ ;  $P < 0.0001$ ), with larger prey sizes delivered to older chicks (Dunn's Multiple Comparisons test, all  $P < 0.05$ ; Fig. 1).

Of the 745 deliveries, the chicks consumed 89.5% of the prey, while non-parental adult South American terns stole 7.7% of the prey, and  $< 2.1\%$  was consumed by one of the parents, and 0.7% was dropped at the nest.

TABLE 1. Number (percentage) of prey items delivered to chicks by South American terns during the 2006 breeding season at Punta Loma, Argentina. Of the 1008 prey delivered, only 651 could be assigned to a chick age-class.

Prey	Age-class			All ages (n = 1008)
	I (n = 178)	II (n = 158)	III (n = 315)	
Argentine anchovy ( <i>Engraulis anchoita</i> )	36 (20)	36 (23)	157 (50)	356 (35)
Silverside A ( <i>Odontesthes argentinensis</i> )	44 (25)	31 (20)	56 (18)	214 (21)
Silver warehou ( <i>Seriolella porosa</i> )	21 (12)	18 (11)	29 (9)	108 (11)
Insects	11 (5)	6 (4)	4 (1)	35 (3)
Squid	2 (1)	3 (2)	7 (2)	19 (2)
Butterfish ( <i>Stromateus brasiliensis</i> )	2 (1)	7 (4)	4 (1)	18 (2)
Silverside B ( <i>Odontesthes nigricans</i> )	0 (0)	2 (1)	3 (1)	10 (1)
Silverside C ( <i>Odontesthes incisa</i> )	0 (0)	1 (< 1)	1 (< 1)	7 (< 1)
Polychete	0 (0)	1 (< 1)	3 (1)	6 (< 1)
Prawn	0 (0)	0 (0)	1 (< 1)	4 (< 1)
Signathid	1 (< 1)	1 (< 1)	0 (0)	2 (< 1)
Octopus	0 (0)	1 (< 1)	0 (0)	1 (< 1)
Unidentified fish	52 (31)	49 (31)	46 (15)	199 (20)
Other unidentified prey	9 (5)	2 (1)	4 (1)	29 (3)

Whether prey was stolen by other adults or not was affected by its size (Kruskal-Wallis test,  $H = 30.71$ ;  $P < 0.0001$ ), and prey stolen was significantly larger than that consumed by chicks (Dunn's Multiple Comparisons test;  $P < 0.001$ ). Most of the prey items not consumed by the small chicks were consumed by one of the parents, but prey not consumed by chicks  $> 7$  days was stolen by other, conspecific adults (Table 2).

## DISCUSSION

The diet of South American Tern chicks at our study plot in the Punta Loma colony during the study period consisted mainly of coastal pelagic fish, although it also included some marine invertebrates and terrestrial insects. The most frequent prey items were Argentine anchovy and silversides. The smaller prey within the small prey category corresponded to fish larval stages, of both anchovy and silverside, which are difficult to

identify to species from a distance. Our results agree with a recent study in the same colony (Gatto 2009) in that the South American Tern is mostly piscivorous, and Argentine anchovy and silversides are the main prey delivered to chicks, although the dominant silverside in the previous study was *Odontesthes nigricans*, while silver warehou were poorly represented (Gatto 2009). Given the data obtained in previous studies in the same and other sections of the colony, we believe that despite the relatively small number of nests included in our study, our data is applicable to the colony as a whole.

This study provides the first quantitative analysis of prey deliveries in relation to chick age for the South American Tern. Diet composition, both in terms of prey type and sizes delivered, varied with chick age. The composition of prey delivered to chicks exhibited an increase in the proportion of Argentine anchovy as chicks developed. Changes in diet composition during the chick stage has been

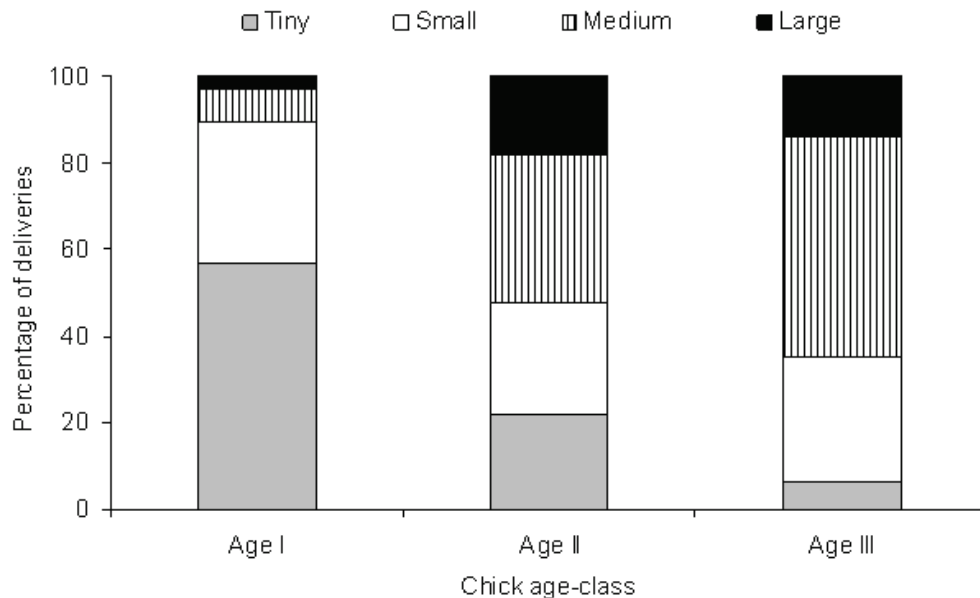


FIG. 1. Percentage occurrence of lengths of fish prey delivered to South American Tern chicks of different age-classes at the Punta Loma colony, Argentina. Tiny: < 20 mm; Small: 20–40 mm; Medium: 40–60 mm; Large: > 60 mm.

reported previously in other seabird species, included terns (Ramos *et al.* 1998, Stienen *et al.* 2000), and it has been argued that the main factors responsible for this variation are changes in prey availability and chick energetic requirements (Suryan *et al.* 2002, Wilson *et al.* 2004). We did not evaluate prey availability throughout this study, but courtship feeding observations in 2006 showed that Argentine anchovies were available since the early stages of the breeding cycle. This suggests that the variation observed in this prey species may be the result of selective capture. The increase in the proportion of Argentine anchovy in the diet of large chicks, which have higher energy demands, may be related to the higher quality of this prey species in relation to the other prey (Ciancio *et al.* 2007, García *et al.* 2010). In addition, it is possible that the low proportion of anchovy in the diet of younger chicks was due to a lower availability

of adequate sizes to feed small chicks (see below).

This study suggests that parents could respond to the requirements of their developing chicks by adjusting the sizes of prey captured to feed them. Prey sizes delivered to chicks were on average larger in the older age-classes. The increase in prey size with chick age has been reported for other tern species, including Common Tern (*Sterna hirundo*) (Wiggins & Morris 1987, Reed Rossell *et al.* 2000), Sandwich Tern (*Thalassens sandvicensis*) (Stienen *et al.* 2000), Roseate Tern (*S. dougallii*) (Shealer 1998b), Forster's Tern (*S. forsteri*) (Fraser 1997), Lesser Noddy (*Anous tenuirostris*) (Ramos *et al.* 2004), and Royal (*T. maximus*) and Cayenne (*T. sandvicensis eurygnathus*) terns (García *et al.* 2010). Previous studies at Punta Loma (Gatto 2009) showed that anchovies and silversides delivered to mates during the laying stage were similar in size or even larger

TABLE 2. Fate of prey (percentage in parentheses) brought by South American terns to their nests in relation to chick age during the 2006 breeding season at Punta Loma, Argentina.

Fate of delivered prey	Age-classes		
	I (%)	II (%)	III (%)
Consumed by chick	155 (91)	131 (86)	261 (90)
Stolen	3 (2)	15 (10)	25 (8)
Consumed by parent	9 (5)	3 (2)	3 (1)
Not consumed	2 (1)	0 (0)	3 (1)
Unknown	1 (< 1)	3 (2)	1 (< 1)

to those delivered to old chicks during this study, suggesting that prey larger than that delivered to small chicks were already available in the study area during chick hatching. The smaller prey delivered to small chicks possibly reflect the greater difficulty of small chicks to manipulate and swallow large prey (Hulsman 1981, Shealer 1998a). In addition, the increase in prey size with chick age, among other things, may allow covering their growing energy demands. Provisioning enough energy, perhaps through the largest prey that a chick can manipulate and ingest in their different development stages, may have an important effect on breeding success. Studies on the Arctic Tern (*Sterna paradisaea*), for example, exhibited very low productivity as a result of the lack of prey of adequate size to feed chicks (Monaghan *et al.* 1989).

The importance of prey size in chick feeding is also reflected in the rate of prey loss as a result from kleptoparasitism. Intraspecific kleptoparasitism is a common behavior among seabirds (Furness 1987), and has been reported for several tern species (Hulsman 1976, Yorio & Quintana 1997, Shealer & Spendelov 2002, García *et al.* 2011). Intraspecific robbing, a behavior as yet unreported for South American terns, resulted in the loss of at least 8% of the prey brought to the colony to feed the chicks. Stolen prey were significantly larger than prey consumed by chicks and prey robbing occurred generally during

the feeding of older chicks, possibly because of larger prey provided to them. The preference of kleptoparasites for larger and more conspicuous prey has been reported in many studies (Fuchs 1977, Brockmann & Barnard 1979, Hackl & Burger 1988, Amat 1990, Bertelotti & Yorio 2001, García *et al.* 2010). In general, a larger prey item is more beneficial in terms of energy return (Ratcliffe *et al.* 1997) and potential victims with larger prey are more vulnerable because of difficulty of prey manipulation (Furness *et al.* 1988).

In summary, South American terns at the Punta Loma colony appear to confront the increasing demand of growing chicks increasing the quality of prey in each feeding trip, reflected in both larger and more energetic prey. Future work should evaluate the energetic and nutritional composition of delivered prey and analyze the relationship between diet composition and both the growth and survival of South American Tern chicks in the study area.

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