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ORIGINAL PAPER

Aspects of the foraging behaviour of the Antarctic Tern *Sterna vittata gaini* at Harmony Point, South Shetland Islands

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Abstract During January and February of 2002 and 2003, we studied the diet of the Antarctic Tern *Sterna vittata gaini* at two colonies in Nelson Island, South Shetland Islands, by identifying the prey fed to chicks by breeders. The fish *Notothenia coriiceps* was the main prey in both seasons, followed by the myctophid *Electrona antarctica*, Antarctic krill *Euphausia superba* and gammarid amphipods. The contribution of fish to the diet increased as chicks grew older. Fish and amphipods were brought to chicks during the day, whereas adults brought Antarctic krill at sunrise and sunset. Both the duration of the feeding trips and the number of trips per foraging bout varied according to the type of prey caught. Preliminary information suggests that, among other causes, the foraging strategy is strongly influenced by the predation pressure of skuas on chicks. Results are compared with the only two previous study on the diet of the Antarctic Tern at the South Shetland Islands.

Keywords Antarctic Tern · Diet composition · Antarctica

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Introduction

The Antarctic Tern *Sterna vittata* is a circumpolar species found in sub-Antarctic and Antarctic regions. The estimated total population is about 50,000 pairs, 35,000 of which belong to the subspecies *S. v. gaini* and breeds in the South Shetland Islands (Gochfeld and Burger 1996). Although not globally threatened, at several localities this subspecies is being negatively affected by frequent reproductive failures and colony abandonment due to human disturbance (Gochfeld and Burger 1996; Silva et al. 1998; Millius 2000), predation pressure (Casaux unpublished information) and, probably, food shortage (see Howes and Montevecchi 1993). Despite of its vulnerability and population size, the studies aimed to understand its biology are scarce (see Parmelee and Maxson 1975; Cordier et al. 1983; Peter et al. 1988); only two published studies have focused its foraging behaviour (Jablonski 1995; Jazdzewski and Konopacka 1999).

Industrial fish exploitation around the South Shetland Islands at the end of the 1970s resulted in a marked decrease of *Gobionotothen gibberifrons* and *Notothenia rossii* in inshore trammel-net catches over the last 21 years

(Barrera-Oro et al. 2000). The commercial fishing also affected the ecology of the fish species that remained unexploited given that they were forced to the adaptation to a new scenario. On the other hand, recent studies on the diet of top predators suggest that the distribution patterns of pelagic fish changed in littoral waters at the South Shetland Islands during the last two decades (Casaux et al. 1998, 2003; Trivelpiece unpublished information, quoted in Casaux et al. 1998, see below). Thus, new studies aimed to better understand the structure of the littoral fish community in this area are required. Owing to characteristics of the littoral sea bottom, however, such an operation from research vessels are difficult to implement.

The study of the composition of the diet and foraging strategies of seabirds is an useful tool not only to understand the foraging behaviour of the species under study, but also to obtain information on the status of the marine ecosystem (see Furness and Greenwood 1993, for review, among others). The aim of the present study is to provide information on the composition of the diet of Antarctic terns breeding at Harmony Point, South Shetland Islands, thus to increase our understanding, not only of the biology of this bird, but also of the food web and patterns of distribution of fish in coastal littoral waters of this archipelago.

Materials and methods

The information presented herein was obtained at two colonies of Antarctic terns located at Harmony Point (SCAR Antarctic Specially Protected Area N° 133), Nelson Island, South Shetland Islands. Information from colony 1 (coast of Nelson Strait, 62°18.55′S, 59°12.79′W) and colony 2 (coast of the Drake Passage, 62°17.94′S, 59°13.53′W) was obtained during January and February 2002 and 2003, respectively. Terns under observation (8 and 9 pairs in both seasons, respectively) were rearing chicks 3–33 days old in 2002 (mean 11.2 days, SD 9.1) and 5–35 days old in 2003 (mean 25.4 days, SD 8.3).

Diet was assessed by observing “ad libitum” (see Altmann 1974) 3–7 nests for periods of 3.5–15.0 h during daylight. We compiled 319 bird-hours of observation; 155 and 164 bird-hours in 2002 and 2003, respectively. The overall period of observation ranged 4:23–19:53 h. During the observations the wind was calm to moderate and the precipitations (snowfall or rainfall) were absent. Prey carried in the bill by breeders to their chicks were identified using a 10 × 50 binocular or a 18–36× monocular. At the start of the study, only prey tentatively identified were recovered from the chicks by stomach massage; these samples helped to corroborate identifications. The prey recovered from the chicks were measured in total length (TL) using a digital vernier calliper (accuracy 0.01 mm) and weighed. The mass of *Euphausia superba* and *Bovallia gigantea* specimens, species that were not recovered from chicks, was estimated by comparison with whole specimens collected in the area.

The timing of feeding each item was recorded to the nearest minute using a portable tape recorder. Occasionally (see below) we also recorded the duration of foraging trips. Because parents often flew around the colony before arriving at the nest (perhaps to avoid kleptoparasitism by other terns or as part of a display), these values are overestimated. The time is expressed as local time (GMT–3 h).

Results

A total of 291 prey items were identified. The composition of the diet differed among years and colonies (ANOVA, $P < 0.001$). Crustaceans (mainly small unidentified gammarid amphipods) predominated by number in 2002, whereas fish (mainly fingerlings of *Notothenia coriiceps*) predominated in 2003 (Table 1). *Notothenia coriiceps* was the most important prey by mass in both seasons, followed by the myctophid *Electrona antarctica* and the Antarctic krill *E. superba* in 2002 and by *E. antarctica* and the gammarid amphipod *B. gigantea* in 2003. The importance of fish as prey increased as chicks grew older (Spearman, $r = 0.37$, $P < 0.001$).

The total length of prey recovered from chicks were as follow: *N. coriiceps*, 62.1 ± 6.2 mm, range 57.0–72.2,

Table 1 The composition of the diet of the Antarctic Tern at Harmony Point as reflected by the preys carried to the nest by breeding individuals

	2002, *n* = 182		2003, *n* = 109	
	N%	*M*%	*N*%	*M*%
Unidentified	4.95	–	–	–
Crustaceans				
Gammarid amphipods				
Unidentified species	37.9	–	7.3	–
Eurimera monticulosa	2.2	0.2	–	–
Bovallia gigantea	1.7	2.9	2.8	2.3
Euphausiids				
Euphausia superba	13.7	4.3	0.9	0.1
Fish				
Unidentified fish	5.0	–	7.3	–
Species A	2.8	–	0.9	–
Notothenia coriiceps	26.4	67.5	78.9	93.7
Electrona antarctica	5.5	25.1	1.8	3.9

N%, importance by number; *M*%, importance by mass

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$n = 8$; *E. antarctica*, 64.4 ± 2.3 mm, range 61.8–66.3, $n = 3$; and *Eurimera monticulosa*, 19.1 mm, $n = 1$.

Fish (both, *N. coriiceps* and *E. antarctica*) and gammarid amphipods were represented in the diet throughout the day, but Antarctic krill occurred mainly around sunrise and the sunset (and probably also during the night, see below; Fig. 1).

Although individuals under observation were not marked, in some occasions (e.g. when one of the parents remained at the nest while its partner was foraging or when one of the partners exhibited a particular plumage colour) the duration of the foraging trips was determined. Trip duration ranged 1–16 min (Table 2) and varied according to prey type (ANOVA, $F = 11.0$, df 2, $P < 0.001$); terns carrying gammarid amphipods displayed shorter trips than those carrying Antarctic krill (N-K, $P < 0.001$) or fish (N-K, $P < 0.05$).

Occasionally, we were able to observe continuously for 15 h the foraging pattern of two neighbouring pairs. During such observation we noted some alternation in the feeding turns between pairs (Fig. 2) and that terns made more frequent trips when preying on crustaceans compared to fish (Fig. 3).

Discussion

As observed in other subspecies (see Jablonski 1995; Gochfeld and Burger 1996, for review), fish, krill and gammarid amphipods constituted the bulk of the diet of Antarctic terns at Harmony Point. Jablonski (1995) also reported these three groups as dominating the tern diet at Admiralty Bay, a locality close to Harmony Point. However, whereas he observed that krill was the main prey, fish predominated in our study. The difference in the overall composition of the diet among terns at these two close localities might be related to (1) differences in prey availability between localities, (2) differences in the period of the breeding cycle investigated, (3) differences in predation pressure on chicks by Brown Skuas *Catharacta antarctica* between localities, and (4) differences in the daily period of observation. We investigate each of these hypotheses below.

Unfortunately, there is no information available related to the availability of preys within the foraging areas used by terns at both localities which do not allow us analyse hypothesis 1. In regard to hypothesis 2, as also observed in our study, Jablonski (1995) reported that the consumption of fish increased as chicks grew older. Jablonski (1995) analysed prey carried to chicks 6–20 days old, but we continued observation up to 35 days of age. Similarly (hypothesis 4), given that our observations were performed during daylight and that Jablonski (1995) found krill to be captured more intensively at night (mainly between 10 pm and 2 am), the dietary contribution of krill might have been underestimated in our study. These differences in study design, thus, at least partially could explain some of the differences between the studies.

Finally (hypothesis 3), under intense predation pressure on chicks, breeders should optimise foraging effort in order to invest more time in defence activities (see below). Given that terns carry single prey items per trip and that fish individuals of the sizes ingested largely provide more

Table 2 Duration of the foraging trips (in minutes) in the Antarctic Tern at Harmony Point according to the type of prey caught

	2002	2003
Gammarid amphipods		
Unidentified species	3.9 ± 1.5 (2–8), $n = 35$	3.3 ± 0.6 (3–4), $n = 3$
Eurimera monticulosa	9.0, $n = 1$	–
Euphausiids		
Euphausia superba	7.9 ± 3.2 (3–16), $n = 15$	–
Fish		
Species A	5.0, $n = 1$	–
Notothenia coriiceps	9.4 ± 4.7 (2–15), $n = 5$	10.0, $n = 1$
Electrona antarctica	3.0 ± 2.0 (1–5), $n = 3$	–

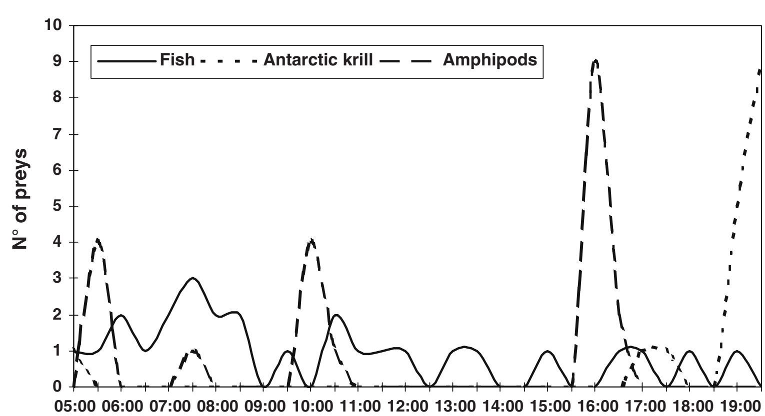

Fig. 1 Number of preys carried to the nest by breeding Antarctic terns during a session of observation of foraging activity

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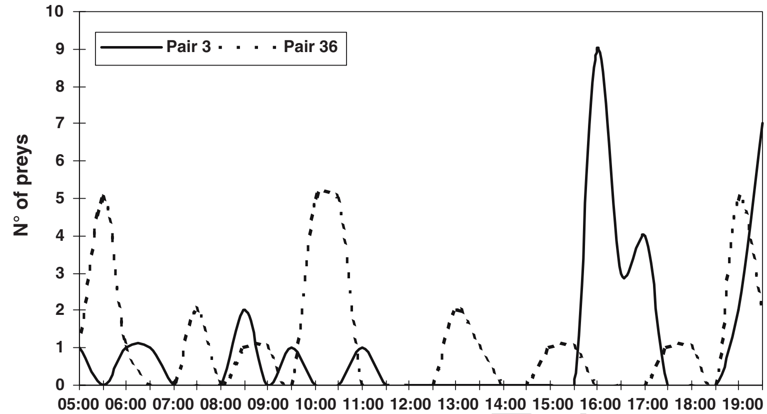

Fig. 2 Foraging activity in neighbour pairs of Antarctic terns at Harmony Point

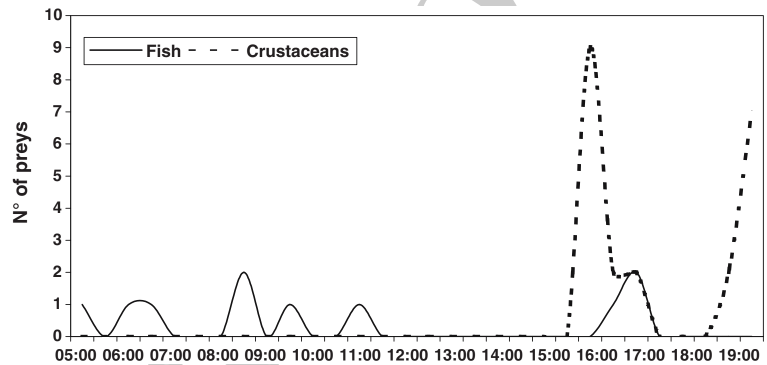

Fig. 3 Number of preys caught (or feeding trips displayed) per foraging bout by Antarctic terns preying on fish and crustaceans at Harmony Point

energy than krill ones (Casaux et al. unpublished data), it is expected that at colonies under an intense predation pressure on chicks breeders positively select fish when available within the foraging area. At Admiralty Bay chick loss due to predation in three consecutive seasons ranged between 0 and 4.8% of the total losses (mean 2.5%), but during some seasons at Harmony Point loss exceeded 50% (Casaux et al. unpublished data). Such predation pressure is reflected in the breeding success at both localities: 0.23 chicks per nest at Admiralty Bay (Jablonski 1995) compared to 0.06 chicks per nest at Harmony Point (Casaux et al. unpublished data). Thus, the different predation pressure by skuas on chicks might also contribute to explain the differences in the composition of the diet between localities.

Regarding fish, Jablonski (1995) reported for Admiralty Bay that during the breeding seasons 1978/79 to 1980/81, *Pleuragramma antarcticum*, followed by juveniles belonging to other nototheniid species, was the main prey of Antarctic terns but reported no myctophids. Differently, in our study *N. coriiceps*, followed by the myctophid *E. antarctica*, predominated in the diet whereas *P. antarcticum* was absent from the samples. The difference in the consumption of *P. antarcticum* and myctophids (mainly *E. antarctica*) was also evident in the diet of Cape Petrels *Daption capense* at Harmony Point and Admiralty Bay (Casaux et al. 1998) and, therefore, might reflect spatial differences in prey availability. However, Trivelpiece (pers. com., quoted in Casaux et al. 1998) observed an annually variable occurrence of *P. antarcticum* and an increasing prevalence of myctophids in the diet of South Polar Skuas *Catharacta maccormicki* at Admiralty Bay since the late 1980s. Therefore, considering the time elapsed between our study and that of Jablonski (1995), the hypothesis of a relative change in the abundance of *P. antarcticum* and myctophids throughout years within the foraging area of these birds should be considered as well. Moreover, since the early 1990s the importance of myctophids and *P. antarcticum* in the Antarctic fur seal *Arctocephalus gazella* diet at some localities of the South Shetland Islands has increased and decreased, respectively, to the point that myctophids have become the most important fish prey in recent years (Casaux et al. 2003). Alternatively, as observed in Cape petrels (Casaux et al. 1998) and Antarctic terns (Jablonski 1995), if parents must select smaller fish (compensating for handling limitations by the chicks), it is expected that myctophids, when present and abundant within the foraging area, would be preferred over *P. antarcticum*.

The predation pressure on chicks by Brown Skuas at Harmony Point is so intense that, together with weather-related causes, terns frequently failed or almost failed to fledge chicks (Casaux, unpublished information). Under such pressure breeding terns display foraging and breeding

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strategies that reduces their own time-energy expenditure and optimises that invested in defence. They do this by increasing the energy carried to the nest per unit time (Fig. 1). Although gammarid amphipods (which are small and contain less energy per gram than fish or krill; Casaux et al., unpublished data) are available throughout the day in near-colony waters, fish are selected when present within foraging range. The terns organise their foraging activity in bouts (sequence of closely- repeated trips) and the number of trips per bout varies according to the chick's energy requirements (chicks provisioned until satiated) and on the type of prey caught (see also Jablonski 1995). When terns preyed on fish, foraging bouts were composed by one or two trips but when they preyed on crustaceans (mainly small gammarideans), up to nine consecutive foraging trips were required to satiate the chick (see Fig. 3). This observation is coincident with that reported by Hulsman et al. (1989) for Crested terns *Sterna bergii*.

The foraging activity at the colony was continuous, which imply that preys were available at any time of the day. Thus, timing of foraging bouts seemed to have been determined mainly by defence activity instead of prey availability. In this sense, neighbour pairs seemed to alternate foraging bouts (Fig. 2), which implies that different areas of the colony were protected at any given time (terns' defense against skuas is by mobbing). On the other hand, as commented above, breeders seems to display as many trips per bout as needed to satiate the chicks. The continuous provision of food to the chicks up to satiation might be advantageous to protect them from the attacks of predators given that, in this way, the time that the chicks are exposed begging for food is reduced.

Considering the short duration of foraging trips (which were overestimated, see above), the daily period of observation and the fact that the Antarctic Tern is predominantly a shallow plunge-diver that switches to contact-dipping in rough waters (Gochfeld and Burger 1996), the diet was composed of prey found at short distances from the colony in surface waters during light hours (except the Antarctic krill, see above). The inclusion of gammarid amphipods, and to a lesser extent for fingerlings of *N. coriiceps*, is therefore not surprising. The presence of myctophids, however, is a surprise. Hulley (1990) indicated that *E. antarctica* is a mesopelagic species that exhibits the "Antarctic pattern": south of the Antarctic Polar Front adults occur at 250 m depth during the day and migrate to 50–100 m depth at night. Although Kock (1992) considered that *E. antarctica* is a meso-pelagic species that is regularly found over the shelf and even in fjords, it is surprising that terns were finding *E. antarctica* in littoral surface waters during the day. According to the measurements, Antarctic terns preyed on juvenile *E. antarctica*. Perhaps juvenile and adult *E. antarctica* exhibit a different pattern of distribution which might explain the presence of this fish in surface coastal waters during light hours. Due to difficulties in operating research vessels close to the coast, there is a lack of information on myctophids from shallow coastal waters. Perhaps the presence of *E. antarctica* in shallow coastal waters during the day is more frequent than previously thought. In this sense, the analysis of the diet of Antarctic terns provides useful information on the occurrence of fish and krill in very shallow coastal waters.

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