J. Field Ornithol., 69(3):419–429

# PREY DELIVERED TO ROSEATE TERN CHICKS IN THE AZORES

JAIME A. RAMOS[1], ENCARNACION SOLÁ, LUÍS R. MONTEIRO
*Departamento de Oceanografia e Pescas*
*Universidade dos Açores*
*9900 Horta (Azores), Portugal*

NORMAN RATCLIFFE
*Royal Society for the Protection of Birds*
*The Lodge, Sandy, Bedfordshire*
*SG19 2DL, United Kingdom*

Abstract.—We analyzed food provisioning of Roseate Tern (*Sterna dougallii*) chicks at a colony in the Azores, 16 Jun.–5 Jul. 1995. Prey offered to chicks and feeding frequency were examined in relation to the age of the chick, fish size, and time of day. Overall, Trumpet fish (*Macroramphosus scolopax*) predominated in the diet, but sauri (*Scomberesox saurus* and *Nanichthys simulans*), mackerel (*Trachurus picturatus*), garfish (*Belone belone gracilis*), and lanternfish (Myctophidae) were important on certain days. Mostly epipelagic fish were taken, but mesopelagic fish became more common prey as the season progressed. Garfish were delivered in early morning and lanternfish were ingested mostly around mid-day, when provisioning of other prey types was lower. Prey ingestion by chicks was influenced by age, with young birds ingesting thinner prey (sauri, garfish, and mackerel) and not consuming wider prey (trumpet fish and boarfish, *Capros aper*). Feeding frequency increased with chick age and varied significantly with time of day, being higher in early morning and lower in early afternoon. Mean length of fish consumed by chicks increased significantly with chick age for common prey species. Variability of Roseate Tern chick diet in the Azores can be explained by changes in the availability of fish species and changes in the adults' selection criteria as their chicks grew.

**PRESAS TRAIDAS A PICHONES DE *STERNA DOUGALLII* EN LAS AZORES**

Sinopsis.—Analizamos el aprovisionamiento de los pichones de *Sterna dougallii* en una colonia en Las Azores en el 1995. Registramos la presa llevada por los adultos, la presa traída a los polluelos, y los peces dejados caer por los polluelos diariamente entre junio 16 y julio 5. Las presas ofrecidas a los polluelos y la frecuencia en la alimentación se examinaron en relación a la edad del polluelo, el tamaño del pescado y la hora del día. En general, peces de *Macroramphosus scolopax* predominaron en la dieta, pero individuos de *Scomberesox saurus. Nanichthys simulans, Trachurus picturatus, Belone belone gracills* y de la familia Myctophidae fueron importantes en algunos días. Principalmente se tomaron peces epipelágicos, pero peces mesopelágicos se hicieron presa común con el progreso de la temporada. Individuos de *Belone belone gracilis* se llevaron temprano en la mañana y los de la familia Myctophidae fueron ingeridos principalmente cerca del mediodía, cuando el aprovisionamiento de otros tipos de presas era menor. La ingestión de los polluelos fué influenciada por la edad, con aves jóvenes ingiriendo presas más finas (*Scomberesox saurus, Nanichthys simulans, Belone belone gracilis* y *Trachurus picturatus*) y no consumiendo presas más anchas (*Macroramphosus scolopax* y *Capros aper*). La frecuencia de alimentación aumentó con la edad de las crías y varió significativamente con la hora del día, siendo mayor temprano en la mañana y menor temprano en la tarde. El largo promedio del pescado consumido por los pichones aumentó significativamente con la edad del pichón para las especies comunes de presas. La variabilidad en la dieta de los pichones de *Sterna dougallii* en Las Azores puede explicarse por los cambios en la disponibilidad de especies de peces y en el cambio en los criterios de selección de los adultos según los pichones crecieron.

[1] *Current address: Instituto Piaget, I.S.E.I.T./Mirandela, Av. 25 de Abril, 5370 Mirandela, Portugal.*

Roseate Terns (*Sterna dougallii*) have a predominantly tropical distribution (Gochfeld 1983), nest in high densities (Ramos and del Nevo 1995), lay small clutches (Langham 1968, Nisbet 1981), forage in inshore or nearby oceanic waters with particular physical features during the breeding season (Safina 1990a, Heinemann 1992), dive deeply (Nisbet 1981), and feed on relatively few prey species (Safina et al. 1990) in comparison to tern species with a more temperate distribution such as the Common Tern (*Sterna hirundo*). However, delivery of prey to Roseate Tern chicks has been quantified only in Europe and North America (Langham 1968, Richards and Schew 1989, Safina et al. 1990). Prey items of Roseate Terns in other parts of the world are poorly known, and seasonal variation in prey items and the influence of chick age on diet composition have not been examined thoroughly in this species. The availability of appropriately sized prey fish is crucial for young chicks and important in explaining breeding success (Uttley et al. 1989). Moreover, examining the contributions of date and chick age on diet composition can help to elucidate prey selection in the absence of knowledge of actual prey availability.

We worked on Vila Islet, a mixed Roseate and Common Tern colony in the Azores. Our primary purpose was to examine daily variability in prey delivered and consumed by Roseate Tern chicks, and then to relate this variability to chick age and time of day. The Roseate Tern is a threatened seabird (Gochfeld 1983) and its feeding characteristics in the Azores, which support the largest European population (del Nevo et al. 1993), are unknown.

## METHODS

We studied prey brought to Roseate Tern chicks on Vila, an islet off Santa Maria Island, Azores (36.9°N, 25°W) in 1995. At this site 236 pairs of Roseate Terns nested on a rocky and moderately vegetated area surrounded by 500–800 pairs of Common Terns nesting in more open areas. A blind was erected on a small rocky plateau about 0.6 m above the colony overlooking the densest Roseate Tern breeding area (approximately 2 pairs/$m^2$). Nests were individually marked in the study area and the peak of hatching occurred between 12–22 June. Prey items brought to the colony were observed daily from 0700–1900 h by observers working 3-h shifts using 10 × 25 and 10 × 40 binoculars. Three methods were used to collect data, each focusing on a particular feature of prey.

*Prey carried by adults.*—Fish carried by adults entering the study area were recorded each day between 16 June–5 July. We had a good view overlooking the study area, but a few adults carrying fish at the margins of the study area could have flown out of sight and returned later, and thus might have been counted twice. Fish size was estimated in relation to the adult Roseate Tern bill length (mean culmen = 38.93 mm, SE = 1.56, $n$ = 30) and classified into one of five size categories: <4 cm, 4–6 cm, 6–8 cm, 8–10 cm and >10 cm.

*Prey delivered to chicks.*—Seven to eleven single-chick broods situated 4–

10 m away from the blind were watched between 20 June–5 July. Nests were fenced with 0.5-m high, 1.5-cm square mesh plastic wire to keep chicks near the nest site. Dried grass around the inner, lower portion of the fences helped both to retain and prevent injury to chicks. Fences were about 1 m in diameter and included natural or added cover so chicks could hide and find protection from the sun and rain. Each fence was marked with a numbered flag and chicks were ringed. One or two stone perches were positioned beside the fences to help adults to land and deliver the fish. We observed all prey deliveries and recorded whether chicks ate or dropped fish and estimated fish size as stated above. Virtually no fish were dropped by the parents or stolen by other adults (though some adults with large fish were chassed). Prey not consumed by chicks refers to fish that were offered by the parents, but were dropped by their chicks after attempts to handle and swallow the fish. We started to record prey deliveries on day 1 because few deliveries were observed on the day of hatching (day 0).

*Prey dropped by chicks.*—Fresh and dried fish dropped near nests and chick feeding sites (hiding places under rocks or in thick vegetation) were collected between 16 June–5 July from 1900–2000 h, both from within chick enclosures and in the colony area under observation. All dropped fish collected were from Roseate Terns. Although Common Terns nested nearby, their nests were clearly in open areas and virtually no dropped fish were found in those areas. Entire and fresh fish specimens were measured (standard length and width) and weighed. Dropped fish were identified using Whitehead et al. (1984) and served as a reference for fish observed in the field.

We were familiar with the fish species in the area, having made occasional observations in previous breeding seasons in this and other colonies, and having collected and identified fish dropped near the nests. Most fish species were distinctive in shape or color, and fish carried and delivered by adults could be compared readily with fish dropped near the nests. During the changeover of observers, agreement was reached on identification of a few fish species. When positive identification was unclear, only the family was listed or the fish was classified as unidentified. The two species of Atlantic saury, *Scomberesox saurus* and *Nanichthys simulans* could not be distinguished and were pooled (=sauri).

We quantified daily variation in prey items brought to the colony as the breeding season progressed and daily proportions of each prey species in the diet. Seasonal trends in diet were quantified using Spearman rank correlation. We used chi-square to evaluate variation in prey consumption with time of day and ANCOVA to quantify dependence of feeding frequency on time of day. The following categories of time of day were used: 1 = 0700–1000 h, 2 = 1000–1300 h, 3 = 1300–1600 h, 4 = 1600–1900 h. We also quantified the influence of chick age on diet composition and assessed seasonal variation in prey consumption after controlling for chick age. Chicks were divided into two age groups, young (1–7 days) and old

(8–20 days), and prey ingested were compared for each group between early (21–26 June) and late (27 June–3 July) season.

## RESULTS

*Prey carried by adults.*—Trumpet fish (*Macroramphosus scolopax*) predominated in the prey items carried by adults (Table 1). There was a significant decrease through the breeding season in the proportion of sauri ($r_s = -0.69$, $P < 0.001$) and blue jack mackerel, *Trachurus picturatus* ($r_s = -0.72$, $P < 0.001$), whereas the proportion of lanternfish (Myctophidae) increased ($r_s = 0.87$, $P < 0.001$). Boarfish (*Capros aper*) and pilotfish (*Naucrates ductor*) comprised less than 5% of the prey items with the exception of two and three days, respectively (Table 1). Roseate Terns brought mostly epipelagic fish but, as the season progressed, mesopelagic prey (for information on habitat and depth of fish species see Whitehead et al. 1984) increased in importance (Table 1).

*Prey dropped by chicks.*—Fish were dropped by chicks at the time of delivery or during handling. Prey fell in crevices, cracks, or vegetation and could not be retrieved by parents. Qualitatively, fresh fish dropped at nests provided a fairly similar picture of daily variation in prey items as prey carried by adults, though sample sizes were smaller (Table 1). Sample sizes decreased as the season progressed because large chicks dropped fewer fish. Quantitatively, the agreement was less marked because the percentage of dropped prey made of trumpet fish and boarfish was much higher and the percentage of dropped prey made of sauri, mackerel, and garfish (*Belone belone gracilis*) much smaller (Table 1). Trumpet fish was the most common prey carried by adults, delivered to chicks, and dropped by chicks (Table 2). Boarfish comprised 12% of the items found at nests but less than 1% of the deliveries (Table 2). These data suggest that some chicks were unable to handle and/or swallow trumpet fish and boarfish of certain sizes.

Boarfish and trumpet fish, commonly dropped by young chicks, were significantly wider (mean ± 1 SD = 19.2 ± 2.61 and 11.9 ± 1.57 mm) than sauri and garfish, which were rarely dropped (9.8 ± 2.62 and 4.8 ± 0.71 mm; *t*-tests, all $P < 0.001$). Sauri and garfish were significantly longer (96.3 ± 25.7 and 81.9 ± 21.08 mm) than boarfish and trumpet fish (40.2 ± 5.78 and 63.4 ± 7.18 mm; *t*-tests, all $P < 0.001$), showing that young chicks can swallow long but thin prey. Fish width and the existence of an acute dorsal fin should be the main reasons why young chicks do not swallow boarfish and trumpet fish.

*Prey delivered to chicks.*—Of the five major prey species, the proportion of sauri, mackerel, and trumpet fish delivered to chicks varied significantly with time of day ($\chi^2 = 11.2$, $P < 0.01$; $\chi^2 = 8.7$, $P < 0.05$, and $\chi^2 = 11.7$, $P < 0.01$, respectively; df = 3), but varied less than the proportion of garfish and lanternfish delivered (Fig. 1). Garfish decreased sharply after mid-morning ($\chi^2 = 25.3$, $P < 0.001$, df = 3) and lanternfish showed a peak around mid-day ($\chi^2 = 18.5$, $P < 0.001$, df = 3). This peak corre-

TABLE 1. Daily variation in prey items carried by adult Roseate Terns and dropped by chicks at Vila Islet, Azores, 1995. Epipelagic and mesopelagic prey are identified with an E and M, respectively.

| Day | | 16 Jun | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 1 Jul | 2 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. records | adult | 124 | 86 | 132 | 156 | — | 136 | 211 | 178 | 204 | 221 | 274 | 264 | — | 263 | 246 | 280 | 350 | 207 |
| | dropped | 19 | 20 | 43 | 16 | 13 | 13 | 20 | 40 | 22 | 22 | 20 | 30 | 17 | 13 | 4 | 7 | 1 | 4 |
| Trumpet fish (E) | adult | 46 | 72 | 61 | 15 | — | 12 | 41 | 48 | 37 | 66 | 55 | 71 | — | 69 | 56 | 56 | 40 | 71 |
| | dropped | 53 | 45 | 47 | 38 | 62 | 23 | 50 | 78 | 77 | 77 | 80 | 87 | 65 | 69 | 0 | 86 | 0 | 25 |
| Sauri (E) | adult | 16 | 9 | <1 | 22 | — | 59 | 35 | 19 | 18 | 3 | 2 | 6 | — | 1 | 12 | <1 | 3 | 0 |
| | dropped | 10 | 5 | 2 | 25 | 8 | 15 | 20 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mackerel (E) | adult | 6 | 9 | 32 | 52 | — | 11 | 9 | 16 | 20 | 8 | 6 | 7 | — | 10 | 8 | 5 | 3 | 4 |
| | dropped | 0 | 5 | 14 | 25 | 0 | 0 | 10 | 2 | 5 | 5 | 0 | 7 | 6 | 0 | 0 | 0 | 0 | 0 |
| Garfish (E) | adult | 15 | 3 | 4 | 8 | — | 3 | <1 | 4 | 14 | 5 | 13 | 7 | — | 3 | 4 | 2 | <1 | 0 |
| | dropped | 0 | 5 | 0 | 6 | 0 | 8 | 0 | 2 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lanternfish (M) | adult | 2 | 2 | <1 | <1 | — | 8 | 4 | 7 | 5 | 9 | 16 | 5 | — | 14 | 18 | 31 | 49 | 23 |
| | dropped[a] | 16 | 0 | 9 | 0 | 15 | 15 | 10 | 0 | 0 | 9 | 5 | 3 | 29 | 0 | 50 | 0 | 100 | 50 |
| Boarfish (E)[b] | adult | 13 | 5 | 2 | 2 | — | 3 | 4 | 1 | <1 | 2 | 1 | 0 | — | 0 | <1 | 2 | <1 | 0 |
| | dropped | 21 | 40 | 23 | 6 | 15 | 39 | 10 | 8 | 18 | 0 | 5 | 0 | 0 | 23 | 25 | 0 | 0 | 0 |
| Pilotfish (E) | adult | 0 | 0 | 0 | 0 | — | 4 | 5 | 3 | 2 | 5 | 7 | 2 | — | 0 | 0 | 2 | 2 | <1 |
| | dropped | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 25 |
| Other and unidentified | adult | 2 | 0 | 1 | 1 | — | 0 | 2 | 2 | 4 | 7 | 1 | 2 | — | 3 | 2 | 2 | 3 | 2 |
| | dropped[c] | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 8 | 25 | 14 | 0 | 0 |

[a] Myctophidae (M): *Electrona rissoi* (it was the commonest), *Diaphus metopoclampus, Diaphus rafinesquei, Ceratoscopelus maderensis, Notoscopelus resplendens.*

[b] Epipelagic up to a length of 9–10 cm (Holzlohner and Orlowski 1986).

[c] *Atherina* (*hepsetia*) *presbyter* (E), *Argyropelecus aculeatus* (M), *Sternoptyx diaphana* (M), *Sternoptyx* sp. (M), Macrouridae (M), Melamphaidae (M), Exocoetidae (E), *Howella sherborni* (juveniles, E), *Pagellus bogaraveo* (juveniles, E). Some specimens were collected dry and are not included in the % composition of this table.

TABLE 2. Comparison of the three methods used to analyze diet of Roseate Tern chicks. Fish dropped by chicks includes fresh and dry fish.

| Method | Prey carried by adults (16 June–5 July). $n$ = 3894 | Prey delivered to chicks (20 June–5 July). $n$ = 1468) | Prey dropped by chicks (16 June–5 July). $n$ = 521 |
|---|---|---|---|
| Prey species | No. records (%) | No. records (%) | No. records (%) |
| Trumpet fish | 2122 (55) | 870 (59) | 341 (66) |
| Sauri | 359 (9) | 147 (10) | 26 (5) |
| Mackerel | 391 (10) | 133 (9) | 28 (6) |
| Garfish | 191 (4) | 61 (4) | 7 (1) |
| Lanternfish | 613 (16) | 180 (12) | 43 (8) |
| Boarfish | 59 (2) | 3 (<1) | 61 (12) |
| Pilotfish | 81 (2) | 32 (2) | 3 (<1) |
| Others and unidentified | 78 (2) | 42 (3) | 12 (2) |

sponded with the time when provisioning of other prey types, especially trumpet fish, was lower (Fig. 1).

Provisioning rate varied with time of day (ANCOVA; $F_{3,351} = 3.22$, $P < 0.02$). Terns delivered more food between 0700–1000 h (mean = 1.05 feeds/h, SD = 0.558) than between 1300–1600 h (mean = 0.84, SD = 0.585; Tukey test, $P < 0.04$). There were no significant differences between 1000–1300 h (mean = 1.04, SD = 0.711) and 1600–1900 (mean = 1.02, SD = 0.664).

Diet varied with age of chicks. The proportion of trumpet fish in the diet increased up to 10 days ($r_s = 0.988$, $P < 0.01$) and remained generally constant thereafter (Fig. 2), while the proportion of trumpet fish offered

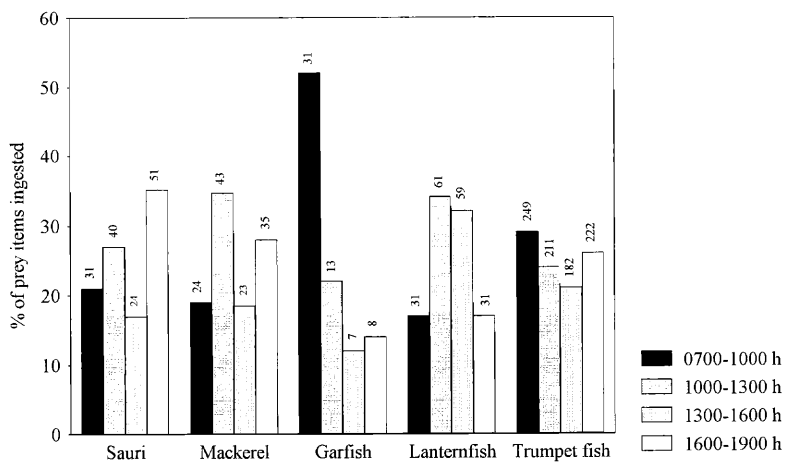


FIGURE 1. Diurnal variation in proportions of major prey consumed by Roseate Tern chicks, pooled data 21 Jun.–5 Jul. 1995. Numbers above bars indicate sample size.

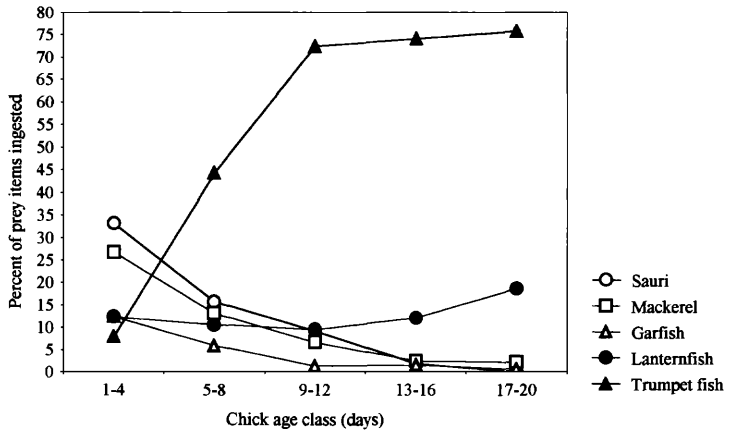


FIGURE 2. Relationship between chick age and the proportion of several major prey consumed by Roseate Tern chicks. Sample size varied between 3 and 9 chicks (median = 6).

but not consumed decreased ($r_s = -0.870$, $P < 0.01$, Fig. 2). Conversely, the proportion of mackerel and garfish ingested decreased up to the age of 10 days ($r_s = -0.82$ and $-0.94$, $P < 0.01$) and the proportion of mesopelagic fish was nearly constant over the same period (Fig. 2). In comparison with trumpet fish, fewer sauri, mackerel, garfish, and lanternfish were not consumed (3, 6, 5 and 7 items, respectively). These data suggest that: (1) trumpet fish were commonly available but not consumed by young (0–7 days) chicks, (2) sauri, mackerel and garfish were taken mostly by young chicks, and (3) chicks of all ages ate lanternfish equally.

Chicks less than 7-d old also were offered trumpet fish, but 31.5% ($n = 181$) was not consumed whereas chicks 8–10-d old did not consume 13.4% ($n = 187$, $\chi^2 = 16.4$, $P < 0.001$, df = 1 with Yates correction). Trumpet fish offered to young chicks were grouped into <4 cm, 4–8 cm and >8 cm. The proportion of fish rejected (1.7%, 21.5% and 8.3%) and accepted (12.7%, 51.4%, 4.4%; $n = 181$) differed significantly among these categories ($\chi^2 = 17.18$, $P < 0.001$, df = 2): Young chicks preferred fish <4 cm and avoided fish >8 cm (observed/expected = 23/17.8 and 15/7.2, respectively). Mean length of fish ingested by chicks increased significantly with age for trumpet fish ($r_s = 0.88$, $P < 0.001$, $n = 20$), mackerel ($r_s = 0.64$, $P < 0.01$, $n = 18$), garfish ($r_s = 0.84$, $P < 0.001$, $n = 14$), and lanternfish ($r_s = 0.51$, $P < 0.02$, $n = 20$) but not for sauri ($r_s = 0.06$, NS, $n = 14$).

The proportion of sauri, mackerel, and lanternfish delivered to young chicks decreased from early to late in the season, whereas the proportion of lanternfish and trumpet fish delivered to old chicks increased (Table 3). Within each breeding-season period, parents with young chicks delivered mainly sauri and mackerel while parents with old chicks delivered trumpet fish. If prey brought to the colony depended largely on their

TABLE 3. Comparison of the number of prey items consumed by young (1–7 days) and old (8–20 days) chicks between two periods during the breeding season.

| | Young chicks | | | | Old chicks | | | |
|---|---|---|---|---|---|---|---|---|
| | 21–26 June | 27 June–3 July | $\chi^2$ | $P<$ | 21–26 June | 27 June–3 July | $\chi^2$ | $P<$ |
| Sauri | 95 | 17 | 52.9 | 0.001 | 24 | 12 | 3.4 | |
| Mackerel | 45 | 27 | 4.0 | 0.05 | 21 | 22 | 0 | |
| Garfish | 26 | 17 | 1.5 | | 6 | 5 | 0 | |
| Lanternfish | 31 | 16 | 4.2 | 0.05 | 21 | 101 | 56.3 | 0.001 |
| Trumpet fish | 46 | 78 | 7.8 | 0.05 | 146 | 414 | 127.3 | 0.001 |

availability, this suggests important changes in the availability of prey species along the breeding season.

## DISCUSSION

Six prey species were important in the diet of Roseate Tern chicks in the Azores. In North America, Roseate Tern chicks and fledglings rely on 3–4 species, of which the most important is sand lance, *Ammodytes* sp. (Nisbet 1981, Richards and Schew 1989, Safina et al. 1990, Heinemann 1992, Shealer and Kress 1994). Like terns in other parts of the world, Roseate Tern chicks in the Azores consumed mostly epipelagic fish, although mesopelagic fish were an important dietary component. Mesopelagic prey have not been documented for other Roseate Tern populations, but are taken by Common Terns (Granadeiro et al. 1995) and Yellow-legged Herring Gulls (*Larus cachinnans atlantis*) in the Azores (Hamer et al. 1984).

We compared three methods of assessing prey delivered to Roseate Tern chicks in the Azores. The observation of prey delivered and consumed should be the most accurate method of assessing chick diet, but it is time consuming. Also, because the species of fish delivered varies from morning to evening, observations should be spread throughout the day to avoid biases. Observation of prey carried by adults reflects prey selected by adults and has the advantage that a large sample size can be obtained during a short period, but items dropped by the chicks will also be registered in this type of sample. Records of fish dropped at nests overestimates the proportion of wider fish delivered to small chicks, and underestimates the proportion of preferred thinner fish delivered. Most dropped fish were found at nests with young chicks; up to ten trumpet fish and boarfish were found daily at nests with chicks of 1–5-d old. The method to be used depends, obviously, on the objectives of the study. It is noteworthy that none of our methods missed any important prey types. Prey carried by adults and prey delivered to chicks gave similar results. Fish dropped at nests may be a quicker way of assessing general prey types captured by adults in a particular year, but they give a highly biased view of what the chicks are ingesting (Randall and Randall 1978). However, it

will be useful if the aim is to obtain a general picture of inter-colony and inter-annual variations in prey items.

Changes in prey composition through the breeding season observed in our study are common for terns (Frank 1992) including Roseate Terns (Richards and Schew 1989, Safina et al. 1990, Heinemann 1992). Echo sounder equipment has shown that abundance of small prey fish is highest when terns are feeding young chicks and declines sharply later in the season, which may coincide with the arrival of predatory fish (Safina and Burger 1985). We showed that prey selection is highly influenced by chick age, with young birds being fed a greater diversity of smaller and/or thinner prey (sauri, garfish and mackerel) and rejecting larger prey (especially boarfish and trumpet fish). We also detected an important seasonal decline in the intake of sauri and mackerel after controlling for the effect of chick age, which seems to agree with the fact that small prey fish decline later in the season (Safina and Burger 1985). Therefore, the variability in Roseate Tern chick prey found in our study can be explained by changes in the availability of prey species and changes in the bird's selection criteria as chicks grew.

Our study also shows daily variation in prey composition. Some prey species may have their own diel rhythms (or influencing factors) that make them differentially susceptible to tern predation on a daily scale (Safina et al. 1990). Our results suggest that garfish were probably easy to capture in the morning, whereas the availability of trumpet fish remained fairly constant throughout the day. The capture rate of one prey type also may be influenced by the relative availability of other prey types. Lanternfish were consumed more often around mid-day and later in the season, when deliveries of other prey types were at their lowest and decreased sharply, respectively. Although the abundance of lanternfish may have increased as the season progressed, these two points suggest that it is taken when other prey were less available. Two facts suggest that lanternfish might be more costly to capture: (1) Roseate Terns were observed bringing lanternfish at the same time as Common Terns and thus they might have been feeding in mixed flocks; in this situation Roseate Terns are at a competitive disadvantage (Safina 1990b); (2) Roseate Terns carrying lanternfish were seen arriving from the open ocean and thus may have been feeding farther from the colony.

Because young chicks cannot swallow large prey, the availability of smaller prey will determine the timing and success of breeding (Safina et al. 1988). In Shetland, low availability of appropriately-sized sandeels, *Ammodytes marinus,* has been the main cause of recent widespread breeding failure in the Common Tern and the Arctic Tern, *Sterna paradisaea* (Uttley et al. 1989). Roseate Terns may be better able than Common Terns to exploit smaller prey. Observations on three Common Tern broods close to our Roseate Tern fences revealed that parents brought mainly trumpet fish and boarfish (86% and 9%, $n = 58$). The seven chicks of these broods could not swallow fish this wide and died after 4–6 days. Such differences between Roseate and Common Terns could be

related to prey distribution; Roseate Terns feed more successfully in smaller groups over more dispersed prey than other terns (Duffy 1986, Safina 1990a, Shealer and Burger 1993) and may be better adapted to exploit prey over the subtropical Azores seas. For both species, predatory fish may be important in driving prey to the surface (pers. obs.), similar to the situation in North America (Safina and Burger 1985, Safina 1990a). The smaller clutch size of Roseate Terns at Vila Islet (the clutch size has been monitored since 1990 and the annual mean has been around 1.1–1.2 eggs/clutch) and other subtropical colonies when compared to that in more temperate areas (see Nisbet 1981) may be explained by scattered foraging resources in those areas. These are interesting points for further research.

## ACKNOWLEDGMENTS

This study was funded by the European Commision (contract LIFE B4-3200/95/351). We are indebted to Filipe Porteiro for fish identification and suggestions related to fish biology. We thank also José Maria and his family for access to Vila islet and Leslie Batty for commenting on a draft. Earlier versions were improved by the comments of Dr. Jeffrey Spendelow, Dr. Carl Safina, Dr. David Shealer and an anonymous referee.

## LITERATURE CITED

DEL NEVO, A. J., E. K. DUNN, F. M. MEDEIROS, G. LE GRAND, P. AKERS, M. I. AVERY, AND I. MONTEIRO. 1993. The status of Roseate Terns *Sterna dougallii* and Common Terns *Sterna hirundo* in the Azores. Seabird 15:30–37.

DUFFY, D. 1986. Foraging at patches: interactions between Common and Roseate Terns. Ornis Scandinavica 17:47–52.

FRANK, D. 1992. The influence of feeding conditions on food provisioning of chicks in Common terns *Sterna hirundo* nesting in the German Wadden sea. Ardea 80:45–55.

GOCHFELD, M. 1983. World Status and distribution of the Roseate Tern, a threatened species. Biol. Conserv. 25:103–125.

GRANADEIRO, J. P., L. R. MONTEIRO, R. W. FURNESS, AND M. C. SILVA. 1995. The food of Common terns *Sterna hirundo* in the Azores. Proceedings of the 5th International Seabird Group Conference, Glasgow, U.K., March 1995. Seabird Group, U.K.

HAMER, K. C., D. R. THOMPSON, A. J. RUNDLE, S. A. LEWIS, AND F. M. STEWART. 1994. Mesopelagic fish eaten by Yellow-legged Herring Gulls *Larus argentatus atlantis* in the Azores. Seabird 16:30–33.

HEINEMANN, D. 1992. Foraging ecology of Roseate Terns breeding on Bird Island, Buzzards Bay, Massachusetts. Final Report to the United States Fish and Wildlife Service, Newton Corner, Massachusetts.

HOLZLOHNER, S., AND A. ORLOWSKI. 1986. Hydroacoustic stock estimation and biological results on the Josephine Bank in August 1984. International Council for the Exploration of the Sea 57:27 pp.

LANGHAM, N. P. 1968. The comparative biology of terns *Sterna* spp. Ph.D. thesis. University of Durham, Durham, United Kingdom.

NISBET, I. C. T. 1981. Biological characteristics of the Roseate Tern *Sterna dougallii*. Report to U.S. Fish and Wildlife Service, Newton Corner, Massachusetts. Massachusetts Audubon Society, Lincoln, Massachusetts.

RAMOS, J. A., AND A. J. DEL NEVO. 1995. Nest-site selection by Roseate Terns and Common Terns in the Azores. Auk 112:580–589.

RANDALL, R. M., AND B. M. RANDALL. 1978. Diet of Roseate Tern during the breeding season at St. Croix Island, Algoa Bay. Cormorant 5:4–10.

RICHARDS, S. W., AND W. A. SCHEW. 1989. Species composition of food brought to Roseate Tern chicks on Falkner island, Connecticut in summer 1984. Connecticut Warbler 9:1–5.

SAFINA, C. 1990a. Foraging habitat partitioning in Roseate and Common terns. Auk 107:351–358.

———. 1990b. Bluefish mediation of foraging competition between Roseate and Common terns. Ecology 71:1804–1809.

———, AND J. BURGER. 1985. Common Tern foraging: seasonal trends in prey fish densities and competition with bluefish. Ecology 66:1457–1463.

———, J. BURGER, M. GOCHFELD, AND R. H. WAGNER. 1988. Evidence of prey limitation of Common and Roseate tern reproduction. Condor 90:852–859.

———, R. H. WAGNER, D. A. WITTING, AND K. J. SMITH. 1990. Prey delivered to Roseate and Common tern chicks; composition and temporal variability. J. Field Ornithol. 61:331–338.

SHEALER, D. A., AND J. BURGER. 1993. Effects of interference competition on the foraging activity of tropical Roseate terns. Condor 95:322–329.

———, AND S. W. KRESS. 1994. Post-breeding movements and prey selection of Roseate Terns at Stratton island, Maine. J. Field Ornithol. 65:349–362.

UTTLEY, J., P. MONAGHAN, AND S. WHITE. 1989. Differential effects of reduced sandeel availability on two sympatrically breeding species of tern. Ornis Scandinavica 20:273–277.

WHITEHEAD, P. J. P., M. L. BAUCHOT, J. C. MUREAU, J. NIELSEN, AND E. TORTONESE. 1984. Fishes of the North-eastern Atlantic and the Mediterranean. Vols. 1–3. U.N.E.S.C.O. Paris.

Received 18 Dec. 1996; accepted 27 May 1997.