J. Field Ornithol., 61(3):331-338

PREY DELIVERED TO ROSEATE AND COMMON TERN CHICKS; COMPOSITION AND TEMPORAL VARIABILITY

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Abstract.—We observed prey deliveries to Roseate (*Sterna dougallii*) and Common (*S. hirundo*) tern chicks. Roseate Terns were highly specialized and fed their chicks mostly sandeels (*Ammodytes americanus*), whereas Common Terns delivered a diversity of prey. Species composition of delivered prey varied annually and weekly. Of four major prey species, the proportion of deliveries containing anchovies, juvenile bluefish, and herring varied with the time of morning, whereas the proportion made up of sandeels remained generally constant.

ENTREGA DE ALIMENTO A POLLUELOS DE *STERNA DOUGALLII* Y *S. HIRUNDO*: COMPOSICIÓN Y VARIABILIDAD TEMPORAL

Sinopsis.—Observamos la entrega de alimento a polluelos de *Sterna dougallii* y *S. hirundo*. Los adultos de *S. dougallii* alimentaron a sus polluelos muy particularmente con individuos de *Ammodytes americanus*, mientras que la otra especie de gaviota alimentó a sus pichones con una gran diversidad de presas. La composición del alimento entregado a los pichones, resultó variable a través del estudio. De las cuatro especies de peces utilizadas principalmente como alimento para los pichones, la proporción entregada que contenía anchoas, pez azulado y arenca varió a través de las horas de la mañana, mientras que la que contenía *A. americanus* permaneció generalmente constante.

Ever since Volterra (1931) and Gause (1934) formulated what has become known as the competitive exclusion principle (Hardin 1960), there has been interest in resource partitioning by closely related sympatric species. The Common (*S. hirundo*) and endangered (Federal Register 52 FR 42064) Roseate (*Sterna dougallii*) terns often breed and forage together in the northeastern United States, and occasionally hybridize (Hays 1975). But their nest site microhabitat differs (Burger and Gochfeld 1988 and refs. therein), they exploit different foraging conditions (see Nisbet 1989, Safina 1990), and they are generally reproductively isolated. In this paper we report interspecific differences and temporal variability in prey delivered to Roseate and Common tern chicks.

METHODS

We observed prey deliveries to chicks of Roseate and Common terns at Cedar Beach, New York (40°N, 73°W). During the breeding seasons of 1984–1987, we watched 4, 7, 6, and 3 Roseate Tern broods and 4, 6, 9, and 9 Common Tern broods in each year, respectively. Dates varied

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from year to year because the terns bred later each year. Prior to or immediately after hatching, nests were fenced with 0.5 m high, 2.5 cm hexagonal mesh wire to keep chicks near the nest site. A 30 cm high band of fine mesh fiberglass cloth around the inner lower portion of the fences helped both to retain small chicks and prevent injury to chicks. All fenced compounds were 2–5 m in diameter and included adequate natural or added cover to allow chicks to hide and find shade.

Prey deliveries were observed with binoculars from blinds between 0500 and 0900 E.S.T. 3–5 days per week during the chick rearing period. We observed nests for a total of 1359 h for Roseate Terns and 2193 for Common Terns, during which 863 fish transfers occurred to roseate chicks and 2369 fish transfers to common chicks. We were able to record all prey deliveries during observation periods. Upon transfer of a fish to a chick, we noted fish species, tern species, and hour. We are confident that our fish identifications are accurate, Cezilly and Wallace's (1988) skepticism notwithstanding. Observers were very familiar with the fish species in the area, many of which were quite distinctive in shape and color, and numerous simultaneous observations by two or more of us in the field showed virtually complete agreement among observers, except when observers agreed that positive identification could not be made. We avoided using judgment in identifying fish; if the prey's specific identity was unclear, it was listed as unidentified. Observation blinds were positioned to take the best advantage of morning light in helping make prey identification. Identification was further facilitated by the fact that terns often circled repeatedly before attempting to transfer prey to chicks, and chicks' prey handling time, especially when young, often allowed excellent views of prey. *Alosa* and *Clupea* herring could not be identified to species during delivery and were clumped in the data. These two species were identified as being present because uneaten specimens were recovered adjacent to nests.

Fish size relative to terns' bill length was recorded in 1984 and 1985, but not in 1986 or 1987 because we feared that a change of observers in the latter two years might introduce inconsistency into this subjective measure. We trapped the adult terns and measured their bill length. Data were analyzed using SAS software at Rutgers University.

RESULTS

Inter-species differences in chick diets.—The composition of chick diets (Table 1) differed between tern species in each year and in all years combined ($\chi^2 = 499.29$, $P < 0.0001$, df = 5; prey other than sandeels, anchovies, butterfish, bluefish, and herring were clumped as 'other'). The most apparent difference was the preponderance of sandeels (*Ammodytes americanus*) in Roseate Tern diets compared to a greater diversity of prey species brought by Common Terns (Table 1).

We analyzed the proportion of each of five major prey species comprising prey fed to chicks of each tern species (Fig. 1). Roseates brought a higher proportion of sandeels to chicks than did Common Terns in each

TABLE 1. Prey brought to tern nests under observation at Cedar Beach; number of individuals observed, percent of each species' deliveries, and niche breadth values ($B = 1/\Sigma p_i^2$; Levins 1968).

Species		Common Terns n	Common Terns Percent	Roseate Terns n	Roseate Terns Percent
American sandeel	*Ammodytes americanus*	780	35.5	751	72.6
Bay anchovy	*Anchoa mitchilli*	168	7.7	42	4.0
Bluefish	*Pomatomus saltatrix*	267	12.2	137	13.4
Butterfish	*Peprilus triacanthus*	139	6.3	5	0.4
Herring	*Clupea* and *Alosa*	251	11.4	70	6.8
Common pipefish	*Syngnathus fuscus*	214	9.7	0	0
Atlantic mackerel	*Scomber scombrusa*	108	4.9	16	1.6
Long-finned squid	*Loligo pealei*	1	0.05	0	0
Round herring	*Etrumeus teres*	17	0.8	4	0.4
Scup	*Stenotomus chrysops*	1	0.05	0	0
Killifish	*Fundulus* spp.	16	0.2	1	0.1
Atlantic menhaden	*Brevoortia tyrannus*	4	0.2	0	0
Flatfish, probably Winter flounder or Windowpane	*Pseudopleuronectes americanus* *Scophthalmus aquosus*	1	0.05	0	0
Jack	*Caranx* spp.	1	0.05	0	0
Threespined stickleback	*Gasterosteus aculeatus*	1	0.05	0	0
Goosefish	*Lophius americanus*	1	0.05	0	0
Unid. hake	*Merluccius bilinearis?*	36	1.6	0	0
Common shore shrimp	*Palaemonetes vulgaris*	59	2.7	0	0
Moth	unidentified insect	53	2.4	0	0
Isopod	unidentified	12	0.6	0	0
Unidentified fish		35	1.6	9	0.9
Niche breadth		$B = 5.63$		$B = 1.81$	

year, and for all years pooled ($\chi^2 = 387.54$, df = 1, $P < 0.0001$). Common Terns delivered butterfish to chicks in higher proportion than did roseates in each year and all years pooled ($\chi^2 = 56.44$, df = 1, $P < 0.0001$). Anchovies were delivered in greater proportion by Common Terns than by roseates for all years pooled ($\chi^2 = 14.91$, df = 1, $P < 0.0001$). This difference was most pronounced in the first two years. Both tern species delivered herring (*Clupea harengus* and *Alosa aestivalis*) to observed chicks in three of the four years. In two of these three years there was virtually no difference in the proportion with which each species delivered herring to chicks, but in 1987 commons delivered a significantly higher proportion ($\chi^2 = 33.80$, df = 1, $P < 0.0001$), and this resulted in a significant difference between species for all years pooled ($\chi^2 = 17.09$, df = 1, $P < 0.0001$). Deliveries of juvenile bluefish (*Pomatomus saltatrix*) were observed in 1985–1987. Roseates delivered a significantly higher proportion of bluefish than commons in 1985 and 1986 (respectively, $\chi^2 = 7.10$, df = 1, $P < 0.01$; $\chi^2 = 13.41$, df = 1, $P < 0.0001$), but commons delivered a higher proportion of bluefish than roseates in 1987 ($\chi^2 = 5.10$, df = 1,

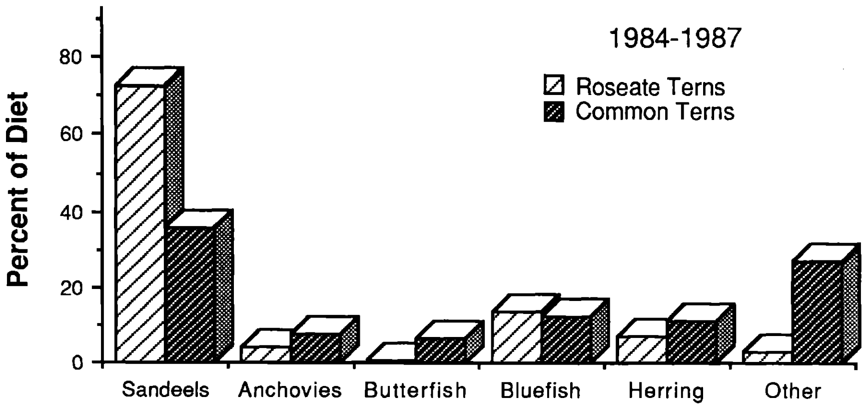

FIGURE 1. Diet composition of Roseate and Common terns, 1984–1987.

$P < 0.02$), resulting in no interspecific difference for pooled years ($\chi^2 = 0.76$, df = 1, $P < 0.4$).

Temporal differences in chick diets.—From year to year, diet composition showed considerable variability. Prey composition of chick diets differed among years for Roseate Terns ($\chi^2 = 264.82$, df = 15, $P < 0.0001$) and Common Terns ($\chi^2 = 816.58$, df = 15, $P < 0.0001$; Fig. 2). The proportion of diets composed of each of several principal prey species varied among years for both terns (Table 2).

Prey composition of chick diets was highly variable among weeks during the breeding season in each year and for all years pooled (Table 3), for both Roseate Terns ($\chi^2 = 179.06$, df = 24, $P < 0.0001$) and Common Terns ($\chi^2 = 1051.14$, df = 32, $P < 0.0001$).

Prey composition of chick diets differed among hours of the morning for Roseate Terns ($\chi^2 = 47.47$, df = 16, $P < 0.0001$) and Common Terns ($\chi^2 = 140.49$, df = 16, $P < 0.0001$) for all years combined. Of several major prey species, the proportion of deliveries made up of anchovies, juvenile bluefish, and herring showed increasing or decreasing patterns

TABLE 2. Results of χ^2 tests of inter-year variability in the proportion of each of 5 important prey species in diets fed to chicks (df = 3).

	Roseate Tern		Common Tern	
Prey sp.	χ^2	$P<$	χ^2	$P<$
Sandeels	33.54	0.0001	179.91	0.0001
Herring	129.59	0.0001	191.95	0.0001
Bluefish	81.41	0.0001	70.10	0.0001
Anchovies	14.21	0.003	379.17	0.0001
Butterfish	6.19	0.1	22.91	0.0001

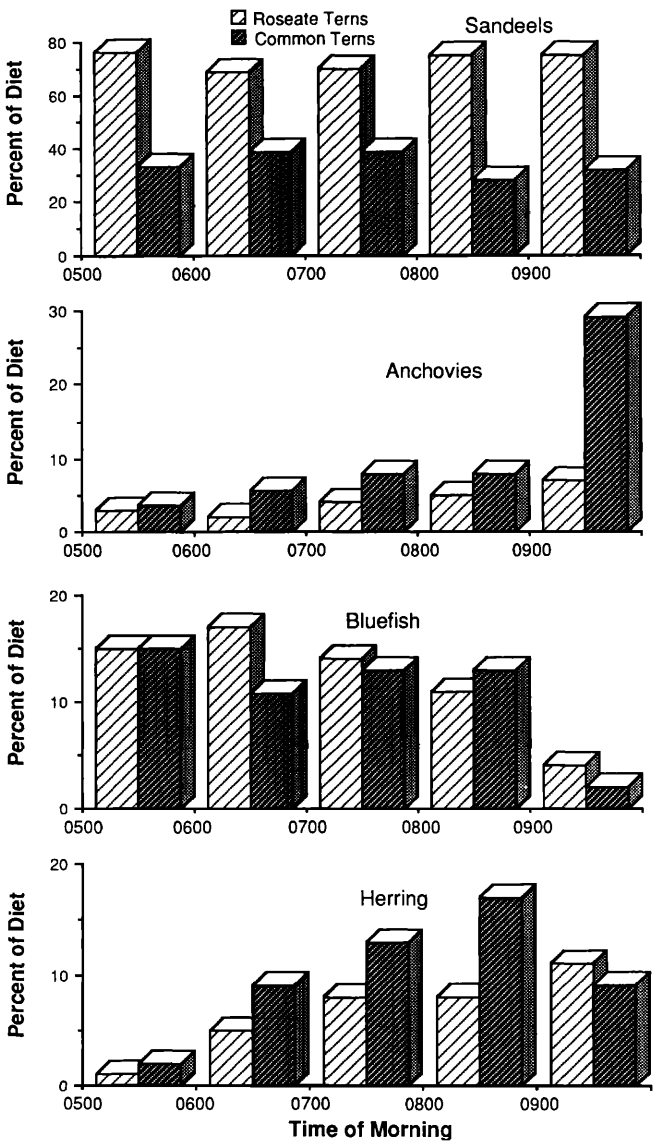

FIGURE 2. Inter-hour variability in proportions of major prey brought to nests of Roseate and Common terns, 1984–1987 pooled.

with time of morning, while the proportion made up of sandeels remained generally constant (Fig. 2).

Length of fish delivered.—Commons brought longer sandeels (Kruskal-Wallis $\chi^2 = 8.71$, df $= 1$, $P < 0.01$) and anchovies (Kruskal-Wallis χ^2

TABLE 3. Inter-week variability in the percent of Roseate and Common Tern chick diets comprised of major fish categories.

	Prey species				
Roseate Terns	Sandeels	Anchovies	Bluefish	Herring	Other
15–21 June	73	27	0	0	0
22–30 June	69	18	0	11	1
1–7 July	69	3	20	6	2
8–14 July	66	5	17	13	2
15–21 July	78	3	9	2	8
22–31 July	88	0	10	0	3
1–7 August	100	0	0	0	0

	Prey species				
Common Terns	Sandeels	Achovies	Bluefish	Herring	Other
15–21 June	5	95	0	0	0
22–30 June	37	53	3	6	2
1–7 July	42	9	22	7	21
8–14 July	45	4	19	6	26
15–21 July	30	3	5	17	46
22–31 July	22	1	3	31	31
1–7 August	12	1	4	2	82

= 8.22, df = 1, $P < 0.01$) than did roseates. Although there was no statistically significant difference between tern species in the length of bluefish, butterfish, or herring brought, the mean length of each of these species brought by roseates exceeded those brought by commons. For all prey other than sandeels and anchovies, roseates' brought prey that was longer than commons' (Kruskal-Wallis $\chi^2 = 10.92$, df = 1, $P < 0.001$). Length of fish brought to chicks increased from time of hatching in Common Terns (Kendall's *tau* = 0.10, $n = 301$, $P < 0.02$), but not in roseates (Kendall's *tau* = 0.05, $n = 303$, NS). Mean estimated length of fish brought by roseates was 1.54 bill lengths, approximately 59.3 mm. Mean length of fish brought by commons was 1.46 bill lengths, approximately 51.2 mm. Roseates had longer culmens (mean = 38.5 mm ± 0.54 SE) than did commons (mean = 35.1 mm ± 0.98 SE; Kruskal-Wallis $\chi^2 = 31.02$, df = 1, $P < 0.0001$).

DISCUSSION

The niche breadth indices (Table 1), highlight the Roseate Tern's heavy reliance on relatively few prey species, especially *Ammodytes.* Nisbet (1981, 1989) summarizes other findings of Roseate Terns' reliance on *Ammodytes* and relatively specialized foraging habits. The Roseate Tern's specialization may make it more vulnerable to environmental perturbations, which may be a factor in its endangered status. The higher diversity in Common Terns' diet appears to be characteristic in at least several parts of their range in North America and Europe (see Lemmetyinen 1976, Erwin 1977).

A divergence in the proportion of sandeels brought by each species in 1987 is difficult to explain. Relatively low availability of several other major species may have been a factor for Roseate Terns, and increased availability of minor 'other' species which Common Terns were capable of exploiting may have decreased their use of sandeels. Roseates appear better able to exploit sandeels than are Common Terns because roseates seem able to dive more deeply (Nisbet 1981; Safina, unpubl.) and sandeels tend to remain near the bottom unless pursued by predatory fish.

The conspicuous absence of silversides (*Menidia*) deserves mention. Though common in the nearby estuary, we have virtually never seen one at the colony in a decade of study. We were aware of the possibility that terns might deliver them, and feel confident that we did not misidentify *Menidia* as *Anchoa*. The lack of clarity in the estuary's waters may account for the low frequency of tern foraging there and the virtual absence of *Menidia* in our birds' diet.

Observing prey deliveries at nests cannot address the question of how foraging birds select prey or foraging habitat from the range of possibilities. However, the variability we found shows that either prey availability or birds' selection criteria changes, and that prey availability or selection varies differently between the two tern species. Some prey species may have their own consistent internal rhythms (or influencing factors) which make them differentially susceptible to tern predation on a daily time scale (Fig. 2).

ACKNOWLEDGMENTS

We thank Joanna Burger and Michael Gochfeld for valuable discussions. Rutgers University provided logistical support. Ken Feustel and the Town of Babylon's Department of Environmental Control has provided much assistance over the years. This study was partly funded by the South Shore Audubon Society, the Huntington Audubon Society, and the Natalie P. Webster Trust.

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Received 2 Jun. 1989; accepted 1 Dec. 1989.