# Royal Tern (*Sterna maxima*) Chick Diet at Fisherman Island National Wildlife Refuge, Virginia

DENIZ AYGEN[1, 2] AND STEVEN D. EMSLIE[1,3]

[1]University of North Carolina, Department of Biology and Marine Biology
601 S. College Road, Wilmington, NC 28403, USA

[2]Current address: Idaho Bird Observatory, Department of Biology, Boise State University
1910 University Drive, Boise, ID 83725, USA

[3]Corresponding author; Internet: emslies@uncw.edu

**Abstract.—**Royal Tern (*Sterna maxima*) chick diet at Fisherman Island National Wildlife Refuge, Virginia, was investigated in 2003 and 2004. Primary objectives were to document common prey species, annual and seasonal variation in prey selection, and seasonal variation in prey size based on average bill length in this species. Over 2200 Royal Terns bred on this island each year of the study. Single items of prey species carried in the bill by adult terns feeding their chicks were identified using 8 × 42 binoculars. A total of 11,566 and 33,646 prey items were identified during 44 and 87.5 h of systematic observations in 2003 and 2004, respectively. Terns foraged largely on anchovy (*Anchoa* spp.) early in the season, then switched to herrings (Clupeidae); average prey size also increased seasonally each year. Prey switching was similar to that of Royal Terns in North Carolina (but with drum as well as herring), indicating regional adaptations to forage fish availability by this species along the mid-Atlantic seaboard. *Received 17 January 2006, accepted 11 April 2006.*

**Key words.—**Royal Tern, *Sterna maxima*, chick diet, Fisherman Island, Virginia, prey switching.

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In North America, the Royal Tern (*Sterna maxima*) is a conspicuous colonial-nesting waterbird that primarily breeds on barrier islands or man-made dredge islands along the mid-Atlantic seaboard. The entire breeding range of this species extends south to Florida and the Caribbean, the Gulf of Mexico, southern California, and northern South American coasts as well as the west coast of Africa (Buckley and Buckley 2002). This range consists primarily of fragile coastal habitat that is under intense pressure from humans for recreation and development. Royal Terns are long-lived, have delayed sexual maturity, nest in dense breeding colonies, and usually lay a one-egg clutch. They are consistent inshore feeders, preying primarily on schooling fish, which they capture by plunge diving.

Past studies have provided limited information on the diet of Royal Terns in the eastern U.S. (Buckley and Buckley 1972, 1974; Erwin 1977; McGinnis and Emslie 2001; Wambach and Emslie 2003). Systematic observations of adults feeding young conducted over two breeding seasons in North Carolina by Wambach and Emslie (2003) have indicated that Royal Terns prey on a diversity of species, but anchovies (*Anchoa* spp.), herrings (Clupeidae), and drums (Sciaenidae) were mostly taken during both years of their study. Detailed information on diet in other regions along the mid-Atlantic seaboard is limited or lacking.

The purpose of this study was to document the diet of Royal Tern chicks at Fisherman Island National Wildlife Refuge, Virginia, over two breeding seasons. This refuge is located at the mouth of the Chesapeake Bay, the largest estuary on the east coast of North America. This study was conducted to provide a better understanding of the trophic connections between Royal Terns and forage fish in the boundary waters of the estuarine and marine system in this area. Tern diets should reflect foraging conditions, provisioning decisions, and energy budgets—all factors that depend on marine food availability before and during the breeding season. Thus, we quantified the diet of Royal Terns to determine if variations existed in seasonal and annual percent of prey consumed. These data are compared with those from previous investigations of tern diet in North Carolina and Virginia to complete regional comparisons of prey selection by this species.

## METHODS

### Study Area

This study was conducted at a colony of Royal Terns on Fisherman Island National Wildlife Refuge (FINWR, 37°8'N, 75°57'W) from early June to late July 2003 and 2004 (Fig. 1). This island supports one the most northern breeding populations of Royal Terns on the Atlantic seaboard. Fisherman Island is located at the southern tip of the Delmarva Peninsula, at the mouth of Chesapeake Bay. This location offers critical habitat and access to abundant prey for terns during their breeding cycle. In 2003, the colony consisted of ~1150 nests with a comparable number (~1120) in 2004, based on total chicks banded within the entire crèche at the end of the season. A small (<8 nests) number of Sandwich Terns (*Sterna sandvicensis*) also nested within the Royal Tern colony in both years.

### Diet Observations

Royal Tern diet was quantified for a continuous seven-week period throughout the breeding season with systematic stationary observations of adults returning to the colony with prey to feed their chicks. Observations were conducted from 06:30 to 21:00 h using 8 × 42 binoculars from the perimeter of the colony or crèche. Royal Terns quickly adapt to the presence of humans sitting or standing motionless near the colony and continue feeding their young. Thus, no blind was necessary to complete this study and it was possible to move with the crèche when necessary to maintain observations. During observations, the observer continuously scanned for adults returning to the colony with prey. Once spotted, the adult was observed with binoculars until the prey could be identified, often while feeding or attempting to feed the chick. Once the prey was identified, the observer then began to scan for a new adult returning with food. Thus, not all adults returning to the colony could be identified and observed during the observation periods. Weather depending, the colony was monitored in this manner during 30-minute periods 3-4 times per day for 3-5 days per week during most tidal stages (the colony was not accessible at high tides) from early June, when most chicks began hatching, until late July, when most chicks fledged (28-30 days old). As it was not possible to identify individual chicks within the crèche, these brief observation periods helped reduce the likelihood of observing multiple prey delivered to the same chick as the length of foraging bouts by adults would likely exceed the length of one of these periods (mean foraging bouts for Royal Terns = 2.5 h in the Chesapeake Bay, Erwin 1977). Observation locations changed after formation of the crèche and when the chicks became more mobile, but were typically conducted within 3-10 m from the periphery of the crèche.

Terns carry single prey items in their bills to their chicks thereby facilitating prey identification by visible external characters, morphology, and markings. Prey size was estimated relative to adult bill length (BL) and divided into five categories: <0.5, 0.5-1, 1-1.5, 1.5-2, >2 BL, following the methods of Wambach and Emslie (2003) and using an average (± SD) adult bill length (BL) of 63.9 ± 2.4 mm calculated by these authors. Most prey items were identified to family, or as unidentified finfish, or unknown. Seasonal observations were divided into four bi-weekly periods that corresponded to the spring tides that occurred during the full and new moon period.

To reduce observer bias in prey identifications (see Cezilly and Wallace 1988), fish that were regurgitated during the sampling effort were collected, identified, and cataloged as voucher specimens for those taxa identified during observation periods. Additionally, these fish, along with others obtained from beach seining efforts, were used to test observer accuracy. Ichthyologists D. Seaver (Virginia Institute of Marine Science) and T. Lankford (University of North Carolina Wilmington) confirmed identification of these specimens. When observations began in 2003, an assistant held a fish at varying distances from the observer (DA) who attempted to correctly identify the type and length of prey. This method allowed the observer to gain confident identification skills when observing terns returning with prey.

### Statistical Analysis

Pearson Chi-square tests were conducted to compare size categories and types of prey across time periods. Nonparametric correlation (using Spearman's correlation coefficient) analyses were used to determine relationships between diet and date within seasons. All statistical tests were completed with the SAS software program (Version 8.1, 1999-2000, SAS Institute, Inc.).

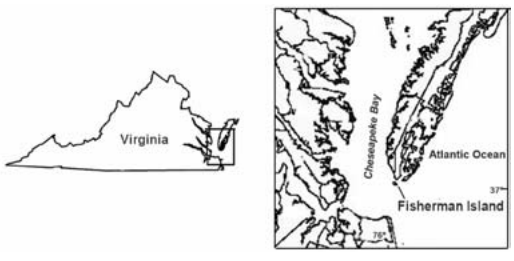


**Figure 1. Location of Fisherman Island National Wildlife Refuge and the position of the Royal Tern breeding colony in 2003 and 2004.**

## RESULTS

### Diet Composition

A total of 11,566 and 33,646 prey items was identified during 44 and 87.5 hours of observations during 2003 and 2004, respectively (Table 1). Because not all birds carrying identified prey were continuously observed until the chick was fed, the possibility that some prey items were counted more than once cannot be discounted. However, each adult tern returning with prey was identified from a distance while approaching the colony before another bird was monitored. Thus, it is unlikely that repeat observations

**Table 1. Royal Tern prey observed at Fisherman Island National Wildlife Refuge, Virginia, in 2003 and 2004. Numbers in parentheses are percent of total prey within each year.**

| Prey | 2003 | 2004 |
|---|---|---|
| Engraulidae (anchovies)<br>*Anchoa hepsetus*, *A. mitchilli* | 4757 (41.09) | 5652 (16.80) |
| Clupeidae (herrings)<br>*Brevoortia tyrannus*, *Opisthonema oglinum*, *Alosa* spp. | 4563 (39.41) | 23,086 (68.61) |
| Atherinidae (silversides)<br>*Menidia menidia* | 243 (2.09) | 2462 (7.32) |
| Brachyura (crabs) | 208 (1.79) | 587 (1.74) |
| Sciaenidae (drums)<br>*Micropogonias undulates*, *Leiostomus xanthurus*, *Cynoscion* spp. | 195 (1.68) | 430 (1.27) |
| Pleuronectiformes (unidentified) | 111 (0.96) | 155 (0.46) |
| Sparidae (porgies)<br>*Lagodon rhomboides*, *Archosargus probatocephalus* | 102 (0.88) | 1 (0.002) |
| Cyprinodontidae (killifish)<br>*Fundulus majalis* | 97 (0.84) | — |
| Syngnathidae (seahorses, pipefish)<br>*Hippocampus* spp., *Syngnathus* spp. | 76 (0.65) | 75 (0.22) |
| Merluccidae (hakes)<br>*Urophycis chuss* | 54 (0.46) | 234 (0.70) |
| Anguillidae (freshwater eels)<br>*Anguilla rostrata* | 38 (0.33) | 51 (0.15) |
| Carangidae (jacks)<br>*Caranx* spp. | 18 (0.15) | — |
| Belonidae (needlefish)<br>*Strongylura marina* | 11 (0.09) | 8 (0.02) |
| Triglidae (searobins)<br>*Prionotus* spp. | 9 (0.07) | 27 (0.08) |
| Cynoglossidae (tonguefish)<br>*Symphurus* spp. | 6 (0.05) | 33 (0.09) |
| Ophichthidae (eels) | — | 155 (0.46) |
| Serranidae (sea basses)<br>*Centropristis striata* | — | 62 (0.18) |
| Penaeidae (shrimps)<br>*Penaeus* spp. | 3 (0.02) | 4 (0.01) |
| Loliginidae (squids) | — | 4 (0.01) |
| Odonata (dragonflies) | 1 (0.64) | — |
| Unidentified finfish | 995 (8.59) | 605 (1.79) |
| Unknown | 90 (0.77) | 15 (0.04) |

occurred. In 2003, fewer prey items were observed than in 2004. The percentage of unidentified finfish to total prey observed was 8.6% in 2003 and 1.8% in 2004. The majority of identified prey items were anchovy, herrings, and Silversides (*Menidia menidia*) in both years. A third less prey was observed in 2003 than in 2004 due to poor weather and fewer hours of observation.

Prey fluctuated seasonally in type (Figs. 2-3). In both years, the proportion of anchovies to total prey brought to chicks decreased across time periods, but was significant only in 2004 (2003: $\chi^2_3 = 4.11$, P = 0.25; 2004: $\chi^2_3 =$

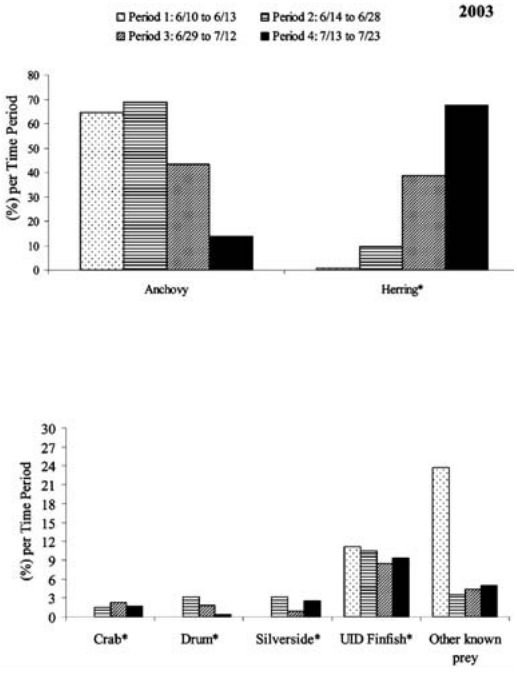


**Figure 2. Percent of anchovy and herring (top) and other common prey species (bottom) identified during 30-min observations in 2003, summarized into time periods that correspond to the spring tides that occurred during the full and new moon period that year. Asterisks indicate significant seasonal variation by date (P < 0.05) for prey items comprising at least 2% of total prey observed during any period. UID is unidentified.**

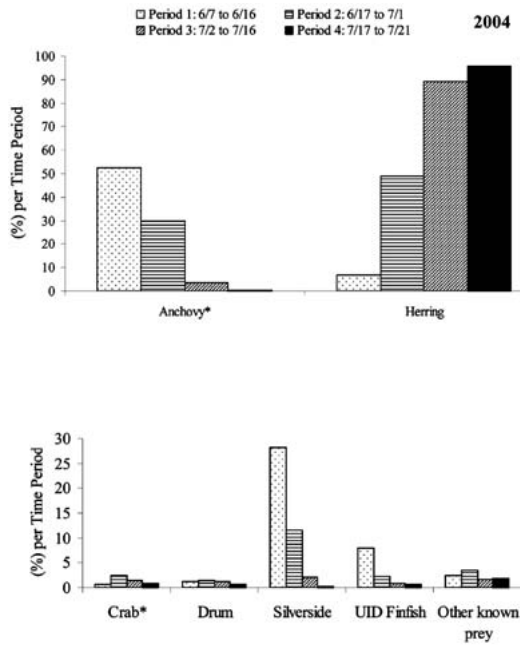


**Figure 3. Percent of anchovy and herring (top) and other common prey species (bottom) identified during 30-min observations in 2004, summarized into time periods that correspond to the spring tides that occurred during the full and new moon period that year. Asterisks indicate significant seasonal variation by date (P < 0.05) for prey items comprising at least 2% of total prey observed during any period. UID is unidentified.**

7.98, P < 0.05; Fig. 2). Daily variation was inversely correlated with date only in 2004 as well ($r_{150}$ = -0.02, P < 0.01). Herring increased by time period in both years, but was significant only in 2003 ($\chi^2_3$ = 19.73, P < 0.001; for 2004 $\chi^2_3$ = 2.51, P = 0.47; Fig. 2). Herring were observed more in the diet towards the end of the season in both years, but this was significant by date only in 2003 ($r_{140}$ = 0.31, P < 0.01). In addition, the terns were observed feeding herring more to their chicks earlier and throughout the 2004 season than in 2003.

The proportion of crab varied significantly across time periods during both years (2003: $\chi^2_3$ = 10.69, P < 0.02; 2004: $\chi^2_3$ = 9.0432, P < 0.03; Figs. 2-3) and was positively correlated with date in both 2003 ($r_{140}$ = 0.30, P < 0.01) and 2004 ($r_{150}$ = 0.21, P < 0.01). The proportion of drum observed decreased by time periods in 2003 ($\chi^2_3$ = 10.5636, P < 0.02; Fig. 2) and did not vary in 2004 ($\chi^2_3$ = 7.25, P = 0.06; Fig. 3), but was positively correlated by date in 2004 ($r_{150}$ = 0.17, P < 0.05). The proportion of silversides identified per trial was positively correlated with date in 2003 ($r_{140}$ = 0.16, P < 0.05) and varied significantly among time periods ($\chi^2_3$ = 10.19, P < 0.02; Fig. 2). However, in 2004 they were not significantly correlated with date ($r_{150}$ = -0.1538, P = 0.06) or across time periods ($\chi^2_3$ = 4.84, P = 0.18), though there is a clear decreasing trend (Fig. 3). Prey items that were not considered common prey (<2% of diet), which were analyzed collectively, did not vary among time periods (2003, $\chi^2_3$ = 0.63, P = 0.89; 2004, $\chi^2_3$ = 7.06, P = 0.07; Figs. 2-3) and were not correlated with date (2003, $r_{140}$ = 0.19, P = 0.13; 2004, $r_{150}$ = 0.09, P = 0.28) in either year.

Total seasonal percentages of prey sizes fed to chicks in 2003 and 2004 were, respectively: <0.5 BL = 2.9 and 0.8; 0.5-1 BL = 12.6

and 11.7; 1-1.5 BL = 80.57 and 87.1; 1.5-2 BL = 3.8 and 1.2, and >2 BL = 0.1 and 0. Fishes of size 0.5-1 and 1-1.5 BL comprised the bulk of the food being fed to the chicks, particularly those fish whose lengths corresponded to modal size 1-1.5 BL. The size of prey increased seasonally during both years (2003, $\chi^2_{12} = 325.81$, df = 12, $P < 0.001$; 2004, $\chi^2_{12} = 302.87$, df = 12, $P < 0.01$; Fig. 4). Intermediate fish sizes (0.5-1.5 BL) were the predominant dietary items during 2003 (92-98% of total) and 2004 (94-98%).

## DISCUSSION

Seasonal variation in prey type and size in Royal Tern diet have been examined in only a few studies along the Atlantic coast of the United States. Killifish (*Fundulus* sp.), anchovy (*Anchoviella* sp.), silversides (*Menidia* sp.), and menhaden (*Brevoortia* sp.) were found to be among the major food items in the diet of Royal Terns in North Carolina and Virginia (Buckley and Buckley 1972; Erwin 1977).

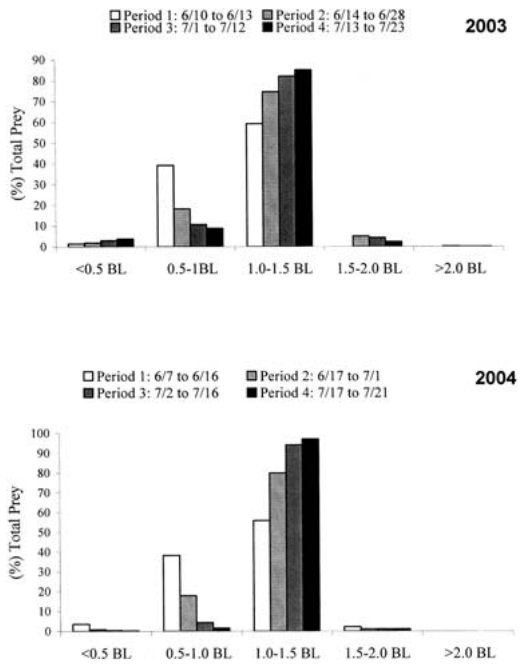


**Figure 4. Percent prey brought to chicks by size categories estimated relative to bill length. Prey size increased significantly among time periods throughout the breeding season; 2003 (top): Pearson $\chi^2 = 325.81$, df = 12, $P < 0.001$ and 2004 (bottom): $\chi^2 = 3375.15$, df = 12, $P < 0.001$.**

Ihle (1984) observed that fish (86%) and Soft-Shelled Blue Crabs (*Callinectes sapidus*; 14%) comprised the bulk of the diet of Royal Terns in Virginia. McGinnis and Emslie (2001) and Wambach and Emslie (2003) found that Royal Terns in North Carolina fed their chicks a variety of prey items such as anchovies, herring, jacks, mackerels, drums, porgies, and mullets. These results are consistent with those presented here.

The ranking of prey items seasonally may reflect differences in the availability of suitable prey. Wambach and Emslie (2003) found that four fish species important to terns during the chick-rearing period in North Carolina varied in frequency during two years of study. In 1999, anchovies (12.6%), herring (11.5%), drum (12.8%) and mullet (7.0%) were the most common prey items. The following year, anchovies (11.9%), herring (20.3%), and drum (24.7%) were the three most abundant fishes; however, tonguefish (Cynoglassidae, 4.1%) and shrimp (Penaeidae, 6.2%) also appeared in the diet. Wambach and Emslie (2003) also found that the proportions of major prey items in the diets of Royal Terns in North Carolina did not vary among ebb, flood, high and low tidal stages. This relationship could not be tested in this study during either year because of the inability to survey the colony efficiently during high tides, when access was restricted, resulting in observations not being evenly represented among the four tidal stages (ebb, low, flood, and high).

Size of prey brought to the chicks varied throughout the season, as has been demonstrated in Royal Terns (McGinnis and Emslie 2001, Wambach and Emslie 2003), Common Terns (*Sterna hirundo*; Burness *et al.* 1994, Brenninkmeijer *et al.* 2002) and Black Skimmers (*Rynchops niger*) in the Chesapeake Bay (Held 2003). Smaller fish were important early in the season, and as the season progressed, larger prey items became more predominant.

In its summer breeding area in the southern Chesapeake Bay, Royal Terns feed their chicks primarily juvenile herring and adult anchovies, but with great seasonal variation in prey size and species. Prey switching is most likely a product of the spawning and

migratory patterns of the forage fishes. This temporal variation in prey selection also extends to Royal Terns in North Carolina and reflects the patchy dynamics of forage fish and other prey populations along the mid-Atlantic seaboard. Moreover, the eclectic diet of Royal Terns indicates that they are opportunistic foragers, a behavior that helps them survive annual fluctuations in individual prey availability.

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