# SIZE SELECTIVE PREDATION AND FOOD HABITS OF TWO CALIFORNIA TERNS

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Evidence for size selective predation by seabirds is anecdotal or, at best, qualitative; however, several studies suggest that prey size selection is a fairly common phenomenon partitioning the food resource among sympatric seabirds (Bourne 1955, Ashmole 1968, Bédard 1969, Baltz and Morejohn 1977).

The present study documents size selection of prey species by two species of seabirds, the Caspian Tern *(Sterna caspia)* and the Forster's Tern *(S. forsteri)*. These two seabirds, although differing greatly in size, have broadly overlapping breeding seasons and similar foraging strategies. The study was done in Elkhorn Slough, Monterey County, California, where the fish fauna is well known (Cailliet et al. 1977); both terns forage in the slough and breed nearby. Since size differences are greater than 130:100 (culmen 174:100; gape width 191:100; weight 459:100), the terns were expected to exploit different elements of the prey community, as predicted by Hutchinson (1959) and MacArthur and Levins (1964).

## METHODS

Six specimens of both species of terns were collected on 11 July 1975. On 28 July 1977, 5 Caspian Terns and 9 Forster's Terns were collected. A total of 11 Caspian Terns and 15 Forster's Terns thus were utilized. Weights and measurements were taken from fresh specimens following Ashmole (1968). Contents of the proventriculus and ventriculus were removed and sorted. Otoliths were washed and stored dry as recommended by Fitch and Brownell (1968). Other contents such as fish flesh and bones were preserved in formalin and then stored in 40% isopropyl alcohol. The minimum number of prey represented by otoliths was taken to be the greatest number of right or left otoliths of similar size.

Weights and standard lengths (SL) of Shiner Perch *(Cymatogaster aggregata)* represented by otoliths were estimated from regressions on specimens collected in Elkhorn Slough (formulae available from authors). Two otoliths, one representing a juvenile and the other an adult Shiner Perch taken by a Forster's Tern and a Caspian Tern, respectively, were too eroded to determine prey size and were excluded from

statistical tests. For Northern Anchovy *(Engraulis mordax)*, lengths and weights were calculated from otolith measurements using relationships provided by Clark and Phillips (1952) and Spratt (1975). Sizes of other prey species were measured or estimated from reference collection specimens at Moss Landing Marine Laboratories.

Many of the prey items were represented only by otoliths. Some were represented by identifiable, partially digested whole fish. Since analysis on a gravimetric basis would have overestimated the importance of prey represented by partially digested or undigested items, the diets were compared numerically. Analyses of the stomach contents of terns collected in 1975 and 1977 were combined and are summarized in Table 1.

The distribution and abundance of fishes in Elkhorn Slough and adjoining Bennett Slough were the subject of concurrent studies by Cailliet et al. (1977) and Antrim (unpubl. data). Fishes were collected from several areas before, during and after terns were collected. Bennett Slough is shallow and was sampled with a small beach seine (15.2 x 1.4 m). The main channel in Elkhorn Slough was sampled at several stations with a small otter trawl having a 4.9 m headrope with 38 mm stretch mesh in the body and a 32 mm stretch mesh liner in the codend.

## RESULTS

Forster's Terns were observed foraging over the entire area of the slough, but primarily over mudflats covered at flood tide where the water depth was 1 m or less. Schools of small fish were observed in the clear, shallow water covering the mudflats; when startled, the schools quickly disappeared in one of the many smaller channels which meander through the mudflats. Caspian Terns foraged over the main channel and, to a lesser extent, over the shallows. Both species collected on 11 July 1975 were preying heavily on the same fish, the Shiner Perch, although other fishes were taken as well. Stomachs of all specimens contained identifiable contents. The Shiner Perch was ranked first overall in abundance throughout the slough from August 1974 to June 1976 (Cailliet et al. 1977). Size distributions of Shiner Perch found in the stomachs of both tern species represent opposite ends of the bimodal distribution of Shiner Perch trawled in Elkhorn Slough in July 1975 (Figure 1). Caspian Terns preyed primarily on adult Shiner Perch, whereas Forster's Terns preyed primarily on young-of-the-year. Mean prey lengths (Shiner Perch only) were significantly different between tern species (t-test, 19 d.f., $P < .001$). These differences are probably related to the large differences in predator size.

Specimens collected on 28 July 1977 were not preying as heavily on Shiner Perch, but differences in the size of prey were apparent. Stomachs of two of the Forster's Terns and one of the Caspian Terns did not contain identifiable food items. Forster's Terns preyed on juvenile

Table 1. Summary of stomach contents of Caspian Terns *(Sterna caspia)* and Forster's Terns *(S. forsteri)* collected in Elkhorn Slough, Monterey Co., California, in July of 1975 and 1977.

| | CASPIAN TERNS (N=10) | | | FORSTER'S TERNS (N=15) | | |
|---|---|---|---|---|---|---|
| PREY ITEMS | A | B | C | A | B | C |
| Shiner Perch, *Cymatogaster aggregata* | | | | | | |
| adult | 20 | 80.0 | 80.0 | 1 | 1.6 | 6.7 |
| juvenile | 1 | 4.0 | 10.0 | 27 | 42.2 | 40.0 |
| Northern Anchovy, *Engraulis mordax* | | | | | | |
| adult | 4 | 16.0 | 20.0 | 2 | 3.1 | 13.3 |
| juvenile | | | | 21 | 32.8 | 53.3 |
| Night Smelt, *Spirinchus starksi* | | | | | | |
| juvenile | | | | 1 | 1.6 | 6.7 |
| Top Smelt, *Atherinops affinis* | | | | | | |
| juvenile | | | | 1 | 1.6 | 6.7 |
| Arrow Goby, *Clevelandia ios* adult | | | | 8 | 12.5 | 13.3 |
| Unidentified gobies | | | | 3 | 4.7 | 13.3 |
| Gill Lice [1] *Lironeca vulgaris* | 2 | | 20.0 | 1 | | 6.7 |

A=Total number of items in each category.

B=Percentage of total individuals by number.

C=Percent frequency of occurrence of various prey items in stomachs.

1 Gill Lice were probably acquired indirectly from parasitized fishes; they are parasitic on many fishes and range from Washington to Baja California (Schultz 1969); lice are omitted from computation of percentage of total individuals.

Northern Anchovy, juvenile Shiner Perch and Arrow Gobies *(Clevelandia ios)*, whereas Caspian Terns preyed on adult Shiner Perch and adult Northern Anchovy. Size of prey taken in 1977 again reflected the large size difference between the terns; however, measurable prey items in Caspian Terns were too few for statistical testing. Comparisons of prey length in samples comprised of more than one species were deemed inappropriate due to the variety of fish body forms (Swennen and Duiven 1977); therefore, weights were used to compare prey size. Mean weights of all prey taken in 1975 were significantly different (t-test, 22 d.f., $P<.001$, as were combined collections (Figure 2) from 1975 and 1977 on a mean weight basis (t-test, 23 d.f., $P<.001$).

## DISCUSSION

The highly significant differences in the sizes of prey taken by the tern species were anticipated, since Salt and Willard (1971) reported that Caspian Terns ". . . consistently captured much larger fish in the same water than any taken by Forster's Tern." However, the almost exclusive predation on different age classes of the same prey species, Shiner Perch

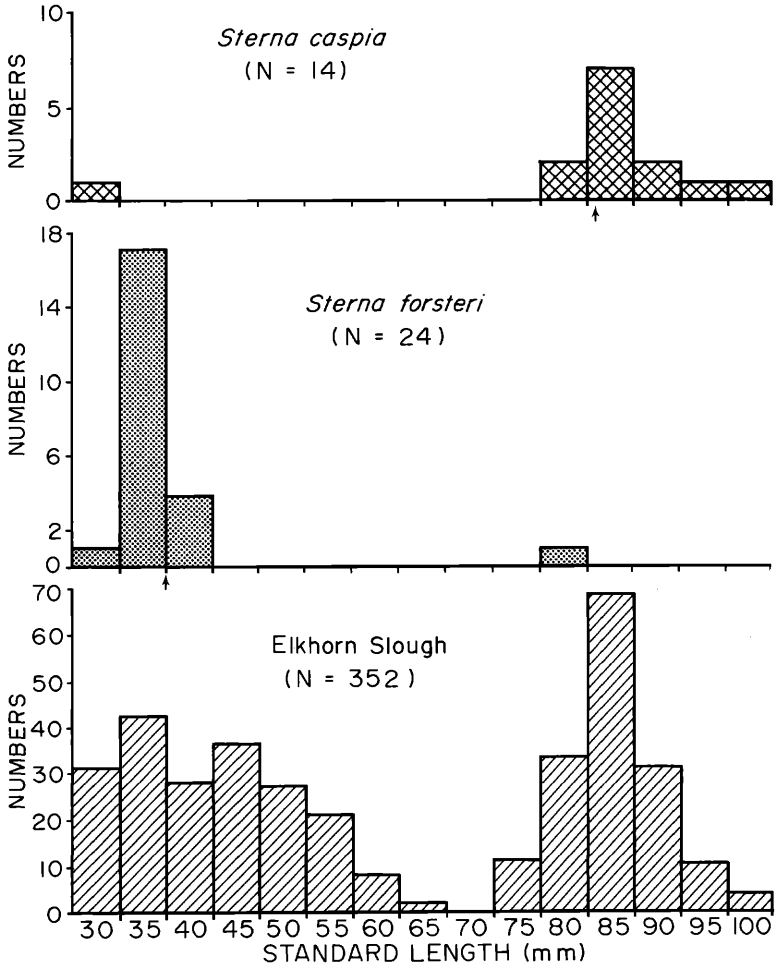


Figure 1. Size distributions of Shiner Perch *(Cymatogaster aggregata)* in the stomach contents of Caspian Terns *(Sterna caspia)* and Forster's Terns *(S. forsteri)* and in Elkhorn Slough. Numbers of Shiner Perch are in parentheses. Mean size taken by terns is indicated by arrow.

and Northern Anchovy, was unexpected. Whether this pattern continues thoughout the stay of both species in the study area is unknown, since the food habits of both terns have not been examined in Elkhorn Slough during months other than July. Notwithstanding the great size differences between the tern species, both species probably respond similarly in an opportunistic manner to the most available prey species. Bent (1921) summarized information which suggests that both Forster's and Caspian terns are opportunistic feeders and may utilize a variety of prey other than fishes; however, Salt and Willard (1971) and Salt (pers. comm.) studied nearby San Francisco Bay area populations of Caspian and Forster's terns which preyed exclusively on fishes while on the study area (April-January).

During a 23-month study of the distribution and abundance of fishes in Elkhorn Slough, the Shiner Perch was ranked first in overall

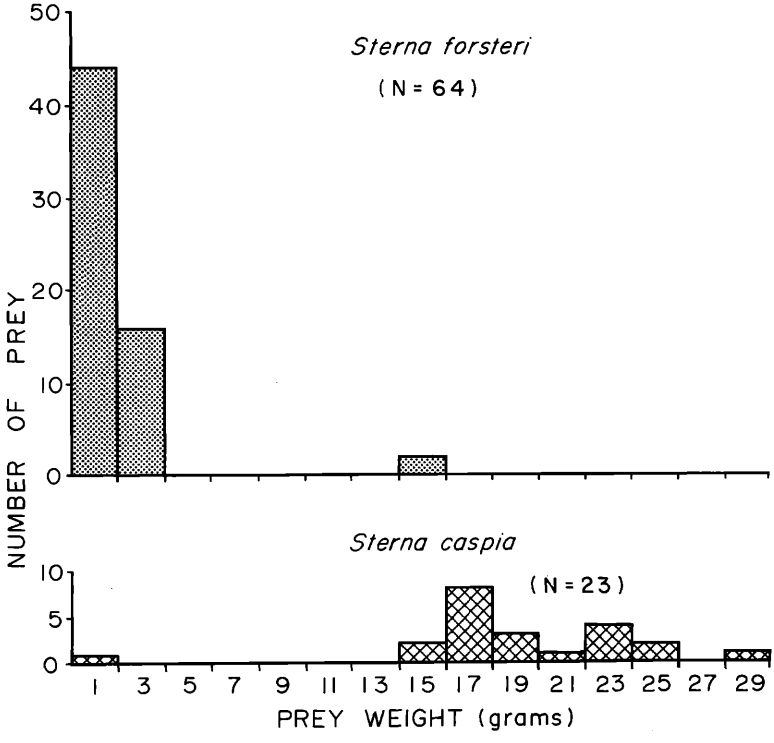


Figure 2. Size distributions by weight of all prey taken by Caspian Terns *(Sterna caspia)* and Forster's Terns *(S. forsteri)* in Elkhorn Slough in 1975 and 1977. Numbers of prey organisms are in parentheses.

abundance, whereas the Arrow Goby was ranked first in Bennett Slough, similar to the mudflat habitat in Elkhorn Slough (Cailliet et al. 1977). The size distribution of Shiner Perch in the 1975 trawl catch was bimodal (Figure 1) due to the presence of numerous young-of-the-year and five older age classes.

The Shiner Perch is viviparous and females give birth from early May through late June, with young ranging from 26 to 36 mm SL; young-of-the-year reach peak abundance in July in Elkhorn Slough (Antrim unpubl. data). The importance of Shiner Perch in the diets of Caspian and Forster's terns reflects their abundance in the slough. Shiner Perch have also been found to be important prey of other seabirds and dominate many marine and estuarine habitats on the Pacific coast (Martini 1964, Sealy 1972, Gill 1976).

Presence of otoliths from a juvenile Shiner Perch in the stomach contents of a Caspian Tern was probably due to predation on a pregnant female Shiner Perch. Cannibalism by Shiner Perch is an unlikely explanation, since adults are not piscivorous (Antrim unpubl. data). Alternatively, inexperienced terns might be expected to take prey of unusual size (Buckley and Buckley 1974); however, the tern in question was an adult. Inexperience might also account for the two largest fishes taken by Forster's Terns.

Salt and Willard (1971) found that the mean size of fishes taken by Forster's Terns declined from spring to fall and that Forster's Terns preyed most effectively on fishes of 75 mm total length (TL) or longer. They suggested that the observed decline in mean prey size was due to the passage of an age class begond the range of vulnerability. Our data support their suggestion. Shiner Perch were present in their study area and were probably important prey. Age one-plus Shiner Perch in the 75 mm TL (58 mm SL) size range constituted a minor portion of the population in Elkhorn Slough in July 1975 (Figure 1). Information on the growth rate of the one-plus age class is lacking for the Elkhorn Slough population, but individuals in the Navarro River Estuary grow from a mean of 83.7 mm TL (72.6 mm SL) in early April to a mean of 98.4 mm TL (85.5 mm SL) in late July and early August (Varoujean pers. comm.). The maximum size of prey that Forster's Terns have been observed to take is about 87 mm TL (75.6 mm SL) (Salt and Willard 1971). Assuming that growth rates are similar in both populations, it appears that the one-plus age class is much less vulnerable to attack by Forster's Terns by early summer. The decline in mean prey size observed by Salt and Willard (1971) is probably the result of the increasing availability of young-of-the-year and the declining abundance and increasing cost in handling time of age one-plus Shiner Perch. Other piscivorous birds prefer prey slightly smaller than half the maximum size manageable (Swennen and Duiven 1977). This suggests that Forster's Terns are quite capable of

preying on fishes much larger than the mean size taken in this study (37.5 mm SL).

The occurrence of Northern Anchovy was sporadic throughout the study, as was the occurrence of lesser prey species. The unidentified gobies recovered from Forster's Terns in 1975 were possibly Arrow Gobies; however, five other species of gobies occur in Elkhorn Slough (Brothers 1975, Cailliet et al. 1977). The Arrow Goby was the most abundant fish in beach seine catches in the extensive mudflat area of Bennett Slough throughout most of the year and is probably the most abundant fish on mudflats throughout the sloughs, but mudflats in Elkhorn Slough were not sampled.

The shallowness and clarity of the water over the mudflats probably enable terns to track their prey more effectively than is possible over deeper waters. Small fishes such as gobies are particularly vulnerable in shallow water to attack by Forster's Terns which can capture prey to a maximum depth of 30 cm below the surface (Salt and Willard 1971). Forster's Terns forage extensively over covered mudflats where small prey are abundant and more vulnerable. Caspian Terns also forage over covered mudflats, but concentrate their activity over deeper channels where larger prey are more abundant.

## ACKNOWLEDGMENTS

We thank John E. Fitch for kindly identifying the otoliths used in this study and for consultation on related matters. James T. Harvey assisted in the collection of birds and fishes. Gregor M. Cailliet and Daniel H. Varoujean made several helpful suggestions and provided useful data. This report is part of a study concerned with feeding habits of marine fishes, seabirds and marine mammals sponsored by NOAA, Office of Sea Grant, Department of Commerce, under Grant No. NOAA-04-5-158-20.

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*Accepted 18 December 1978*