Seasonal and Annual Variability in the Diet of California Sea Lions *Zalophus californianus* at San Nicolas Island, California, 1981-86

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California sea lions haul out and breed on islands along the Pacific coasts of southern and Baja California and in the Gulf of California. About half of all births occur in southern California waters (Fig. 1), principally at San Miguel and San Nicolas Islands (Stewart et al. In press). Some studies have shown that diet varies geographically, perhaps influenced by seasonal variability of various prey (Fiscus and Baines 1966, Ainley et al. 1982, Everitt et al. 1981, Hawes 1983, Antonelis et al. 1984, Aurioles et al. 1984, Antonelis et al. 1990, Lowry et al. 1990). Here we describe seasonal and annual variability in the diet of California sea lions that hauled out at San Nicolas Island from 1981 through 1986.

Methods

We collected sea lion scats every one or two months at several rookeries and hauling grounds at San Nicolas Island (Fig. 1). Scats were washed through nested sieves (mesh sizes of 2.8 mm, 1.5 mm, and 0.71 mm) to recover hard parts such as fish otoliths, cephalopod beaks (i.e., mandibles), shark teeth, and invertebrate exoskeletal fragments. We identified prey species by comparing those remains with museum and personal voucher collections.

The frequency of occurrence (FO) of each prey taxon was calculated as the proportion of scats in each sample that contained at least one hard part from a prey taxon. We pooled monthly samples into four groups: winter (December–February), spring (March–May), summer (June–August), and autumn (September–November). We tested the null hypotheses that frequencies of occurrence of the most common prey (those that occurred in 5% or more of all scats) did not differ among seasons nor among years using a two-way analysis of variance (Program 7D of BMDP-87; Dixon 1987); we excluded data for 1981 from this analysis because we lacked data for some seasons. We tested the null hypothesis that dietary diversity did not differ among seasons or among years using multiway contingency table analysis (Program 4F of BMDP-88; Dixon 1988).

Results

We examined 1232 scats from summer 1981 through autumn 1986; 1085 of those contained identifiable prey hard parts (Table 1). We identified 32 prey taxa to species and 6 to genus, but only two genera of cephalopods and five of fish occurred in 5% or more of the scats. Therefore, we confined our analyses of seasonal and annual variability in diet to the latter 7 taxa. Northern anchovy *Engraulis mordax* was the most common prey, occurring in about half (50.6%) of all scats; Pacific whiting *Merluccius productus*, jack mackerel *Trachurus symmetricus*, rockfish *Sebastes* spp., and market squid *Loligo opalescens* each occurred in about 22–30% of scats (Table 2).

We are limited in our generalizations about seasonal trends in the frequencies of occurrence of prey species because of strong seasonal-annual interactions (ANOVA, $P < 0.05$). There are, however, some differences apparent among some seasons and years (Fig. 2). Northern anchovy was eaten more often in winter than in other seasons in 1982, 1983, and 1984, but not in 1985 or 1986; anchovy was present in more than 60% of scats each season in 1986. Furthermore, anchovy occurred in scats more often from 1984 through 1986 than in earlier years. Pacific whiting was eaten frequently from summer 1981 through spring 1982, and in spring

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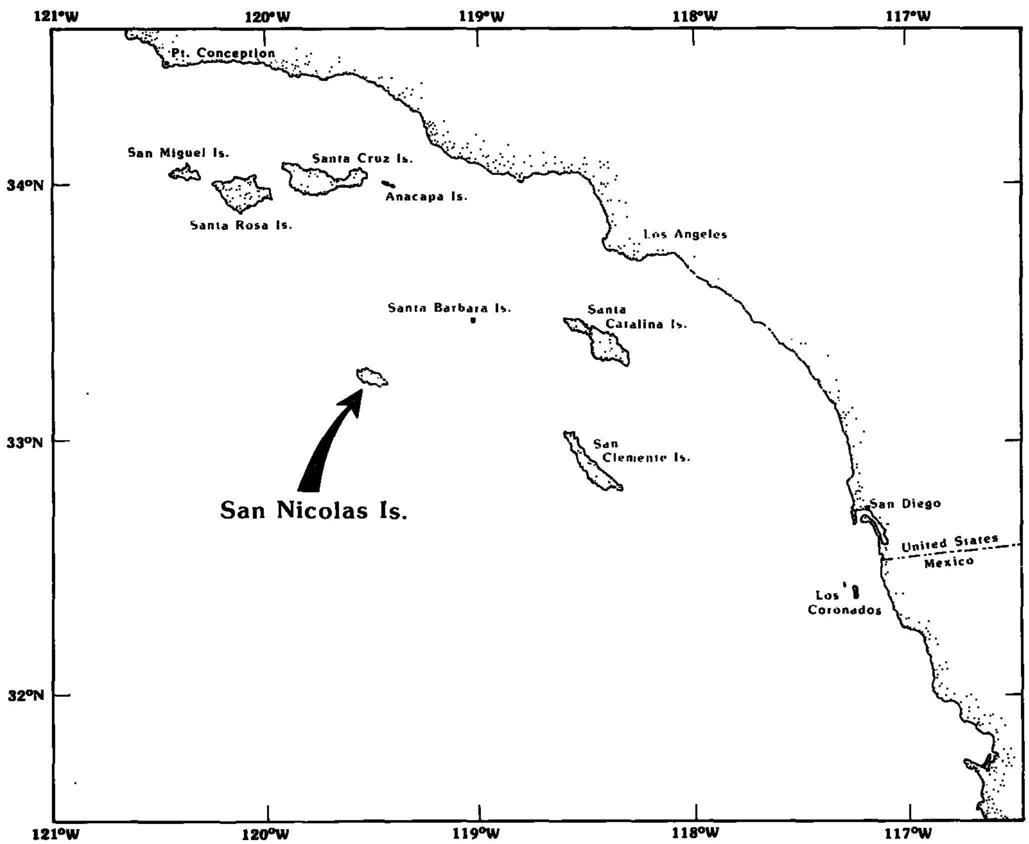

Figure 1
Map of Southern California Bight showing location of San Nicolas Island.

Table 1
Scat samples of *Zalophus californianus* collected at San Nicolas Island, California.

Year	Winter	Spring	Summer	Autumn	Total
1981	0	0	24	18	42
1982	12	15	68	13	108
1983	4	42	150	55	251
1984	75	35	107	93	310
1985	62	77	64	63	266
1986	35	24	80	116	255
Total	188	193	493	358	1232

1984 through spring 1985. Jack mackerel was found in scats more often in summer 1981 through autumn 1983 than after that period. Rockfish were commonly found in winter 1982, and spring 1984 through spring 1985. Market squid was more common in the diet prior to 1983 and its frequency of occurrence was higher in either autumn or winter, or both, each year except in 1984. Pelagic red crabs *Pleuroncodes planipes* appeared in scats in 1983, were frequently eaten through 1985, and then disappeared from the sea lions' diet. Pacific mackerel occurred frequently in summer and autumn 1982. *Octopus* spp. were eaten more often in spring 1984 than at any other time and appeared in the diet mostly in spring and summer of all years.

About 69% of all scats contained one or two prey taxa (Fig. 3). There were significant season-year interactions ($P<0.05$) for all years and seasons, but the number of prey taxa occurring in each scat was greatest from 1981 through 1984 and least in 1985 and 1986 (Fig. 3).

Discussion

California sea lions forage in a number of different habitats and depth strata in the Gulf of California and along the North American Pacific coast from Baja California to British Columbia. The composition of the sea lions' diet varies geographically (Jameson and

Table 2

Prey found in scat samples (n) and frequency of occurrence (expressed in %) for prey found in 1085 California sea lion scats collected at San Nicolas Island, California, 1981–86.

Prey: Scientific name	Prey: Common name	n	%
Teleosts			
Engraulis mordax	northern anchovy	550	50.6
Merluccius productus	Pacific whiting	318	29.3
Trachurus symmetricus	jack mackerel	303	27.9
Sebastes spp.	rockfish	282	25.9
Scomber japonicus	Pacific (chub) mackerel	123	11.3
Chromis punctipinnis	blacksmith	22	1.9
Oxyjulis californica	señorita	15	1.3
Porichthys notatus	plainfin midshipman	5	0.4
Cololabis saira	Pacific saury	5	0.4
Icichthys lockingtoni	medusafish	5	0.4
Lycodes cortezianus	bigfin eelpout	4	0.3
Chilara taylori	spotted cusk-eel	3	0.2
Microstomus pacificus	dover sole	3	0.2
Citharichthys spp.	sanddab	3	0.2
Cymatogaster aggregata	shiner surfperch	3	0.2
Zalembius rosaceus	pink seaperch	3	0.2
Lyopsetta exilis	slender sole	2	0.2
Leuroglossus stilbius	California smoothtongue	2	0.1
Symbolophorus californiensis	California lanternfish	2	0.1
Sardinops sagax	Pacific sardine	2	0.1
Phanerodon furcatus	white seaperch	2	0.1
Zaniolepis spp.	combfish	2	0.1
Citharichthys sordidus	Pacific sanddab	2	0.1
Girella nigricans	opaleye	1	0.1
Medialuna californiensis	halfmoon	1	0.1
Argentina sialis	Pacific argentine	1	0.1
Stenobrachius leucopsarus	northern lampfish	1	0.1
Anoplopoma fimbria	sablefish	1	0.1
Icelinus tenuis	spotfin sculpin	1	0.1
Unid. Myctophidae	lanternfish	10	0.9
Unid. Embiotocidae	surfperch	3	0.2
	unid. fishes	72	6.6
	unid. flatfish	3	0.2
Elasmobranchs			
Prionace glauca	blue shark	1	0.1
Cephalopods			
Loligo opalescens	market squid	238	21.9
Octopus spp.	octopus	70	6.4
Onychoteuthis borealijaponicus	squid	52	4.7
Abraliopsis spp.	squid	24	2.2
Gonatus spp.	squid	18	1.6
Gonatopsis borealis	squid	13	1.1
Chiroteuthis calyx	squid	1	0.1
Unid. Gonatidae	squid	4	0.3
	unid. cephalopod	20	1.8
Crustaceans			
Pleuroncodes planipes	pelagic red crab	118	10.8
	unid. crustacean fragments	5	0.4
Algas			
Unid. Algae	algae	6	0.5

Kenyon 1977, Bowlby 1981, Everitt et al. 1981, Jones 1981, Bailey and Ainley 1982, Antonelis et al. 1984, Aurioles et al. 1984, Roffe and Mate 1984), but dietary diversity appears to be rather low in each location relative to the number of prey taxa consumed rangewide. Our studies of seasonal and annual variability in diet of sea lions at San Nicolas Island further support the classification of California sea lions as plastic specialists (Morse 1980). California sea lions exploit a few resources at a time, but prey composition of the diet is temporally dynamic; they capitalize on the more seasonally abundant and accessible schooling or aggregating prey.

The dietary occurrence of the sea lions' primary prey (northern anchovy, Pacific whiting, rockfish, jack mackerel, and market squid) appears to be related to the seasonal and annual occurrence of those prey species near San Nicolas Island. Market squid were eaten most often in autumn and winter in most years corresponding with the seasonal nearshore movements of spawning squid in this area (Bedford et al. 1983, Klingbeil 1986). Market squid were not commonly eaten by sea lions in 1983 and 1984, a time when squid were uncommon in the Southern California Bight (cf. Bedford et al. 1983; Klingbeil 1984, 1985, 1986; Grant 1987).

The presence of northern anchovy in the diet of sea lions seems to be related to the availability of anchovy near San Nicolas Island. Northern anchovy were uncommon near San Nicolas Island from 1982 through 1984, but were quite abundant in that area in 1985 and 1986 (Bindman 1986, Methot and Lo 1987). Sea lions consumed northern anchovy frequently in all seasons in 1985 and 1986, but substantially lower from 1981 through 1984, except during winter when anchovy were spawning and evidently nearer to San Nicolas Island than in other seasons.

The number of prey taxa eaten appears to be closely linked to the abundance and availability of northern anchovy. When anchovy were abundant near San Nicolas Island, sea lions evidently ate them in preference to other species. Both seasonal and annual patterns indicate that when the frequency of occurrence of anchovy in the diet is high, the number of prey species consumed is low. When northern anchovy are not available the breadth of the diet increased, with 3 to 4 other species being eaten.

Jack mackerel were displaced northward out of the Southern California Bight in 1984 when ocean surface currents changed and warm water associated with the 1982/83 El Niño-Southern Oscillation intruded into that area from Baja California (Mason 1989); the presence of jack mackerel in sea lion scats declined substantially then. Pelagic red crabs were transported into the Southern California Bight during this warm-water intrusion and they were frequently eaten by sea lions in 1983 and, to a lesser extent, through 1985 when they disappeared from their diet.

The dietary and behavioral flexibility of California sea lions in response to movements and availability of prey and to environmental perturbations (e.g., El Niño Southern Oscillation) may be one of the most important factors contributing to the consistent increase in their abundance during the past several decades. Relative to other locations, it appears that northern anchovy may be one of the most important prey of California sea lions near San Nicolas Island. This regional phenomenon is due to the proximity of San Nicolas Island to large spawning aggregations of northern anchovy compared with other locations where dietary studies of California sea lion have been made.

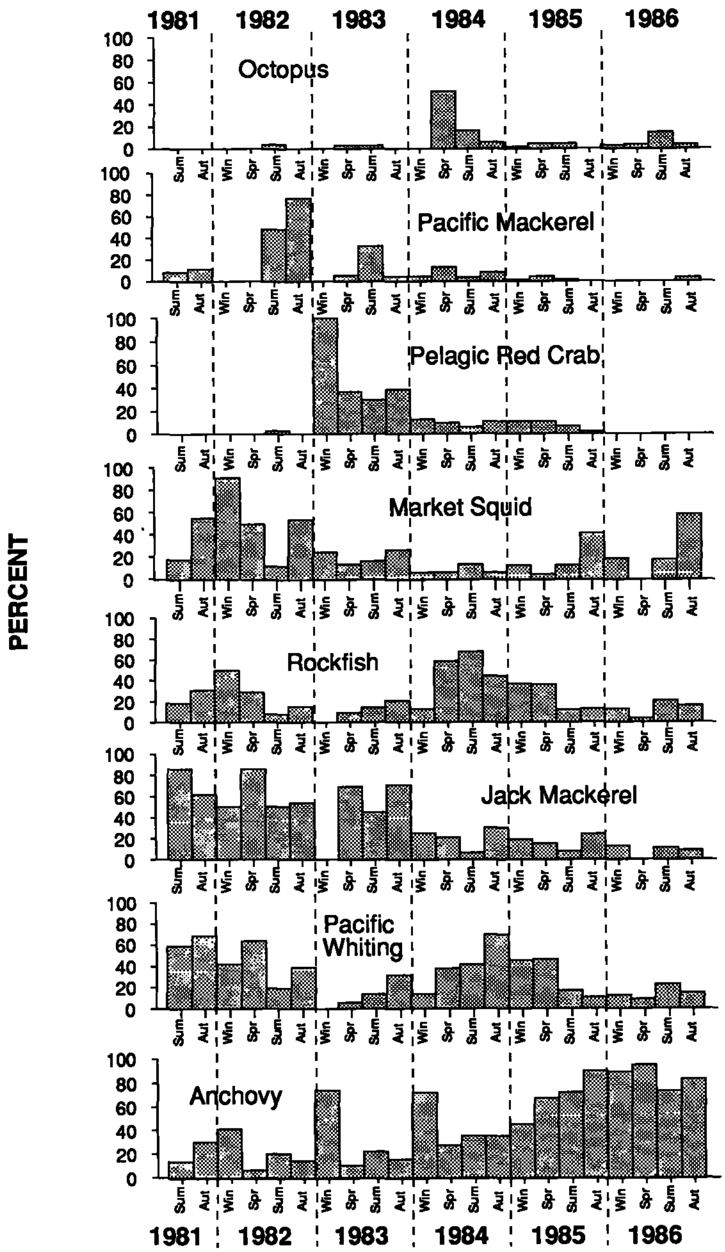

Figure 2

Seasonal frequency of occurrence (%) for eight prey taxa found in California sea lion scats collected at San Nicolas Island, California.

Acknowledgments

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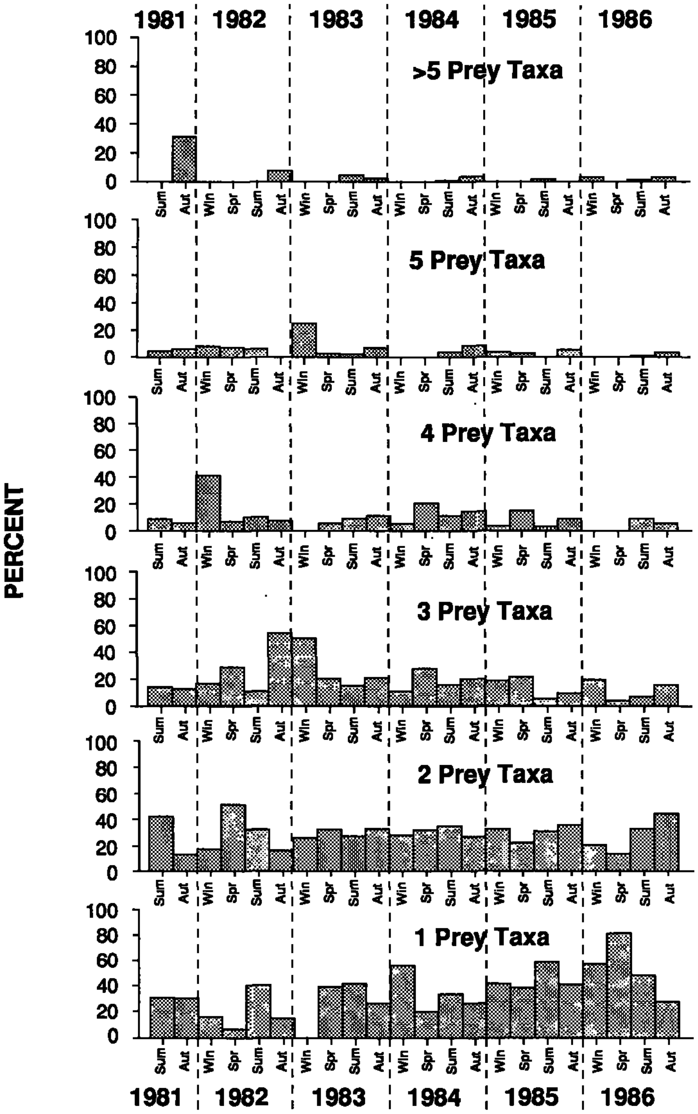

Figure 3
Frequency distributions of the numbers of prey taxa found in California sea lion scats collected at San Nicolas Island, California, summer 1981–autumn 1986.

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