SPRING AND SUMMER PREY OF CALIFORNIA SEA LIONS, *ZALOPHUS CALIFORNIANUS*, AT SAN MIGUEL ISLAND, CALIFORNIA, 1978-79.

GEORGE A. ANTONELIS, JR., CLIFFORD H. FISCUS, AND ROBERT L. DELONG[1]

ABSTRACT

During the late spring and summer of 1978 and 1979, 224 scats were collected from rookeries of the California sea lion, *Zalophus californianus*, at San Miguel Island for the purpose of identifying prey species. A total of 2,629 otoliths and 2,061 cephalopod beaks were recovered. The frequency of occurrence for the four most commonly identified prey species was 48.7% Pacific whiting, *Merluccius productus*; 46.7% market squid, *Loligo opalescens*; 35.9% rockfish, *Sebastes* spp.; and 20.0% northern anchovy, *Engraulis mordax*. Seasonal variability in the frequency of occurrence of these four prey species from late spring to summer indicates that California sea lions feed opportunistically on seasonally abundant schooling fishes and squids. Five species of fish (California smoothtongue, *Bathylagus stilbius*; northern lampfish, *Stenobrachius leucopsarus*; chub mackerel, *Scomber japonicus*; medusafish, *Icichthys lockingtoni*; sablefish, *Anoplopoma fimbria*) and one cephalopod (two-spotted octopus, *Octopus bimaculatus*) were identified as previously unreported prey of the California sea lion.

The California sea lion, *Zalophus californianus*, is the most abundant pinniped inhabiting the coastal waters off California (Le Boeuf and Bonnell 1980). During the summer most California sea lions are on or near their breeding sites which are located on islands south of Point Conception, along the coast of southern California, Baja California, and into the Gulf of California. After the breeding season in the summer, a portion of the subadult and adult male sea lion populations migrates north of Point Conception as far as British Columbia, while the rest of the population remains off the coasts of southern California and Baja California, Mexico (Peterson and Bartholomew 1967). Numerous studies of the food of migrant male California sea lions have been conducted in the areas north of their traditional breeding islands (Briggs and Davis 1972; Jameson and Kenyon 1977; Morejohn et al. 1978; Bowlby 1981; Everitt et al. 1981; Jones 1981; Ainley et al. 1982; Bailey and Ainley 1982), while comparatively little information has been reported on the feeding behavior of sea lions in areas off the coast of California south of Point Conception (Rutter et al. 1904; Scheffer and Neff 1948; Fiscus and Baines 1966). From the information presented in all of these studies, it has been suggested that California sea lions feed opportunistically on a variety of prey species (Antonelis and Fiscus 1980) and that "switch feeding" is probably an important component of their feeding behavior (Bailey and Ainley 1982). However, since most of the information on sea lion feeding behavior is based on observations north of their breeding islands, additional information from within their breeding range would allow us to determine if similar feeding characteristics can be expected in other geographical areas.

Studies conducted before 1970 usually obtained stomach contents for feeding information by killing sea lions, while most post-1970 feeding studies have used nonlethal techniques including examination of scats and oral rejecta (spewings) and direct behavioral observations. Another method was the examination of gastrointestinal tracts from animals found dead. In this study, prey-species classification is based on the identification of fish otoliths and cephalopod beaks found in scats collected during the spring and summer for two consecutive years on the California sea lion rookeries of San Miguel Island, Calif. In addition to the identification of prey, we calculated the percent frequency of occurrence of each prey, compared annual and seasonal differences in prey selection, and estimated the lengths and weights of the most frequently occurring prey species.

MATERIALS AND METHODS

Scats were collected from areas utilized exclusively

[1]Northwest and Alaska Fisheries Center National Marine Mammal Laboratory, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

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by California sea lions on the west end of San Miguel Island, Calif., during spring (2-3 May 1978; 2 and 16 May 1979) and summer (3-4 August 1978; 30-31 July 1979). During both sample periods, scats were collected from areas where mostly females and juveniles of both sexes occurred and relatively few (<12% of the total animals censused) adult and subadult males were present. In order to document the occurrence of prey species which were consumed at or close to the time of collections, only recent scats, which showed no obvious signs of desiccation, were collected. Each scat was placed in a plastic bag, where it was later soaked in water or a solution of about 1 part liquid detergent to 100 parts water for about 24 h. Each bag was shaken occasionally to facilitate emulsification of the digested organic material, and then rinsed with water through three nested sieves with screen mesh sizes of 3.35 mm, 2.00 mm, and 1.00 mm from top to bottom. After most of the soft digested organic material was washed away, fish otoliths and cephalopod beaks were removed and stored in a solution of 70% ethanol. Prey totals were determined by using the higher number of left or right otoliths and upper or lower squid beaks. The otoliths were identified by the late J. Fitch, California Department of Fish and Game, Long Beach, Calif., the octopus beaks by E. Hochberg, Santa Barbara Museum of Natural History, Santa Barbara, Calif., and the squid beaks by the second author.

The data for each of the four major prey species were summarized by a three-way (2×2×2) contingency table and tested for independence of occurrence by season, year, and both season and year (Fienberg 1977).

Length measurements of these otoliths and squid beaks were used to estimate the body lengths or ages of the most frequently occurring prey species. Although many otoliths and beaks of all sizes were recovered from the scats in good condition, some were not measured because they were broken or showed obvious signs of damage from digestion. We assumed that damage to the otoliths and squid beaks collected in this study was not dependent on size. Lengths of northern anchovy, *Engraulis mordax*, were estimated from a regression equation of fish lengths on otolith lengths (Spratt 1975). Length information for rockfish, *Sebastes* spp., was obtained from previously reported data (Phillips 1964) for specimens (bocaccio, *Sebastes paucispinis*) of the same age as most of the rockfish reported in this study. Bocaccio was chosen as the representative rockfish because it has been reported as the most abundant rockfish in the waters near San Miguel Island (Best and Oliphant 1965). The regression equation used to estimate the length of Pacific whiting, *Merluccius productus*, was derived in this study from specimens collected off the coast of southern California by the National Marine Fisheries Service (NMFS). The Pacific whiting otoliths and the corresponding length information were provided by K. Bailey of the NMFS Northwest and Alaska Fisheries Center, Seattle, Wash. Market squid, *Loligo opalescens*, lengths were estimated from a regression equation of dorsal mantle length on upper hood length of the beak. Upper hood measurements were chosen for the estimation of squid lengths because they were reported as having the highest correlation to dorsal mantle length (Kashiwada et al. 1979).

In order to detect changes in the diet which would reflect apparent yearly changes in the age and size composition of a specific prey-species population, we compared the lengths of otoliths for 1978 and 1979 using the Wilcoxon rank sum test (Hollander and Wolfe 1973).

Weight estimates of the most frequently occurring prey species were obtained by using the prey length estimate (described above) in regression equations of length and weight measurements or by obtaining weight data from fish which were the same age as those identified in the scats (Phillips 1964; Fields 1965; Dark 1975; Pacific Fishery Management Council 1978). The total estimated weight for each of the four major prey species was obtained by multiplying the weight of the average-sized prey by the number of individuals represented in the scat collection. Differences between these estimates could not be statistically analyzed because the raw data for the growth curves of each species were not available.

The names of fishes follow Fitch and Lavenberg (1968) and Robins (1980), and those of cephalopods follow Fields (1965) and Young (1972).

RESULTS

We collected 224 California sea lion scats on San Miguel Island during the spring and summer of 1978 and 1979. From 195 (87%) of those scats, we recovered 2,629 otoliths and 2,061 cephalopod beaks. Twenty-nine (13%) scats did not contain otoliths or cephalopod beaks. The prey species identified in the scats are shown in Table 1 by their percentage of occurrence. The four most frequently occurring prey in scats containing otoliths and/or cephalopod beaks were Pacific whiting (48.7%), market squid (46.7%), juvenile rockfish from the *Sebastes paucispinis-goodei-jordani* complex

TABLE 1.—Percentage occurrence of all prey species identified from 195 California sea lion scats collected on San Miguel Island, Calif., spring and summer, 1978-79.

Prey		Occurrence	
Scientific name	Common name	No.	%
Merluccius productus	Pacific whiting	95	48.7
Loligo opalescens	market squid	91	46.7
Sebastes spp.	rockfish (juvenile)	70	35.9
Engraulis mordax	northern anchovy	39	20.0
Octopus rubescens	red octopus[1]	19	9.7
Trachurus symmetricus	jack mackerel	9	4.6
Onychoteuthis borealijaponicus	nail squid	9	4.6
Gonatidae (other than *Gonatus* sp.)	squid	8	4.1
Scomber japonicus[2]	chub mackerel	7	3.6
Peprilus simillimus	Pacific pompano	5	2.5
Symbolophorus californiensis	California lanternfish	5	2.5
Gonatus sp.	squid	2	1.0
Microstomus pacificus	Dover sole	2	1.0
Bathylagus stilbius[2]	California smoothtongue	2	1.0
Seriphus politus	queenfish	2	1.0
Zalembius rosaceus	pink surf perch	1	0.5
Anoplopoma fimbria[2]	sablefish	1	0.5
Porichthys notatus	plainfin midshipman	1	0.5
Icichthys lockingtoni[2]	medusafish	1	0.5
Stenobrachius leucopsarus[2]	northern lampfish	1	0.5
Octopus bimaculatus[2]	two-spotted octopus	1	0.5

[1]Pelagic life stage
[2]Not previously reported as prey of the California sea lion.

(35.9%)[2], and northern anchovy (20.0%). All other prey species occurred in <10.0% of the scats.

Relative length and weight estimates of the four major prey species and the information used to calculate these estimates are shown in Figure 1 and Table 2, respectively. The length and weight information for rockfish is from data reported by Philips (1964) for one of the three species (*S. paucispinis*) represented in this study.

Measurements of otoliths from Pacific whiting and northern anchovy provided sufficient information to compare changes in the size and age of each prey group from 1978 to 1979. For Pacific whiting the lengths of otoliths were significantly greater ($W^* = 5.82, P < 0.0001$) in 1979 ($\bar{x} = 7.71$ mm, $n = 90$) than in 1978 ($\bar{x} = 6.71$ mm, $n = 132$). From these otolith measurements, we estimated the mean length of Pacific whiting at 156 mm in 1978 and 176 mm in 1979. All of the Pacific whiting otoliths were obtained from 1- and 2-yr-old fish. The occurrence of 1-yr-old fish in the sea lion diet was estimated at 98.5% in 1978 and 70% in 1979. For northern anchovy, the lengths of otoliths were significantly greater ($W^* = 4.36, P < 0.0001$) in 1978 ($\bar{x} = 3.58$ mm, $n = 19$) than in 1979 ($\bar{x} = 3.01$ mm, $n = 75$). For these otolith measurements we estimated the mean length of northern anchovy at 111 mm in 1978 and 92 mm in 1979. Although all age classes of northern anchovy were recovered from the scats, there was a notable change in the percent occurrence of yearling fish from 1978 (42%) to 1979 (81%).

The percentage of occurrence in the four major prey species is shown for the spring and summer of 1978 and 1979 in Figure 2. From the three-way contingency table analysis, it was determined that Pacific whiting occurred significantly more frequently in 1978 than in 1979 ($P < 0.01$), and there was a greater percentage of occurrence in spring than in summer ($P < 0.01$). For rockfish, there was no significant difference in occurrence between years; however, there was a greater percentage of occurrence in the summer than in spring ($P < 0.01$). The percentage occurrence of northern anchovy was not significantly different between season, but there was a significantly greater occurrence in 1979 than in 1978 ($P < 0.01$). The relative proportion of occurrence for the two seasons for each year was significantly different ($P < 0.01$) for Pacific whiting, rockfish, and northern anchovy. Tests of significance could not be done for market squid because of the strong three-way interaction between occurrence, season, and year. It is apparent, however, that the percent occurrence of market squid did increase from spring to summer during both years of the study (Fig. 2).

[2]About 95% of the juvenile rockfish were yearlings and were included in this three-species complex because their otoliths are too similar to differentiate.

TABLE 2.—Information used in estimating the length of the four major prey species identified from the scats of California sea lions, on San Miguel Island, Calif., 1978-79.

Prey species	Regression equation	n	R^2	Y	X	Reference
Market squid	$Y = 0.243 + 0.0481X$	60	0.974	upper hood length (mm)	dorsal mantle length (mm)	Kashiwada et al. 1979
Pacific whiting	$Y = 26.2 + 19.38X$	84	0.977	fork length (mm)	otolith length (mm)	This study
Juvenile rockfish[1]	([1])	155		([1])	([1])	Phillips 1964
Northern anchovy	$Y = -8.4946 + 33.216X$	677	0.774	standard length (mm)	otolith length (mm)	Spratt 1975

[1]Length measurements are from yearling bocaccio, *Sebastes paucispinis.*

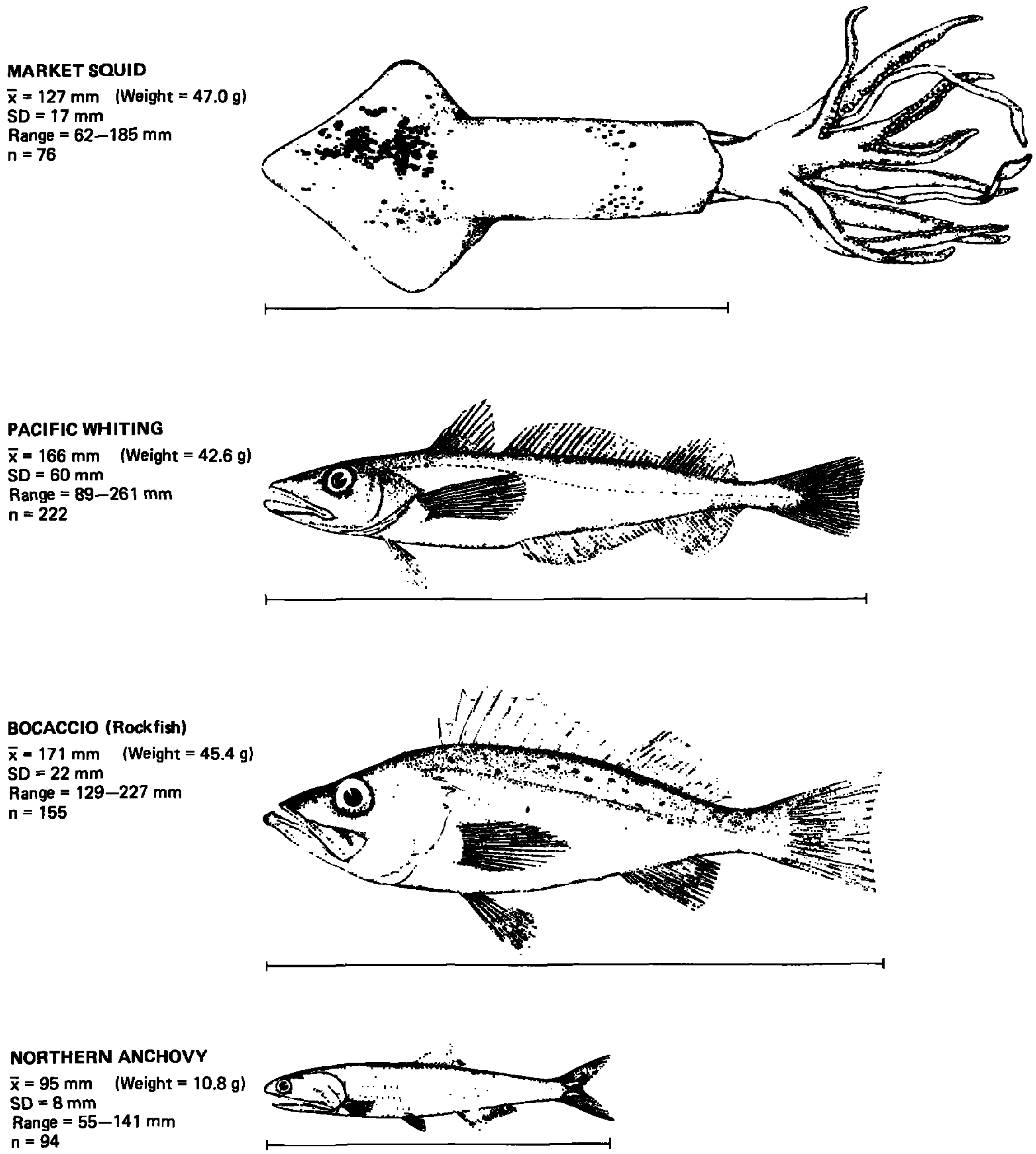

FIGURE 1.—Relative length and weight estimates of the four major prey species identified in California sea lion scats collected on San Miguel Island, Calif., spring and summer, 1978-79. Methods used to calculate these estimates are shown in Table 2.

The number of prey species occurring in individual scats changed from spring to summer. For combined years, the percentages of scats containing single or multiple prey are shown in Figure 3. In the spring, the percentage of singly occurring prey species in scats was 59.7%; in the summer the percentage dropped to 34.6%. Scats containing more than one prey increased from 17 species combinations occurring in 40.3% of the scats in the spring to 23 in 65.4% during the summer.

The percentages of the total estimated weight of the four major prey species for spring and summer are

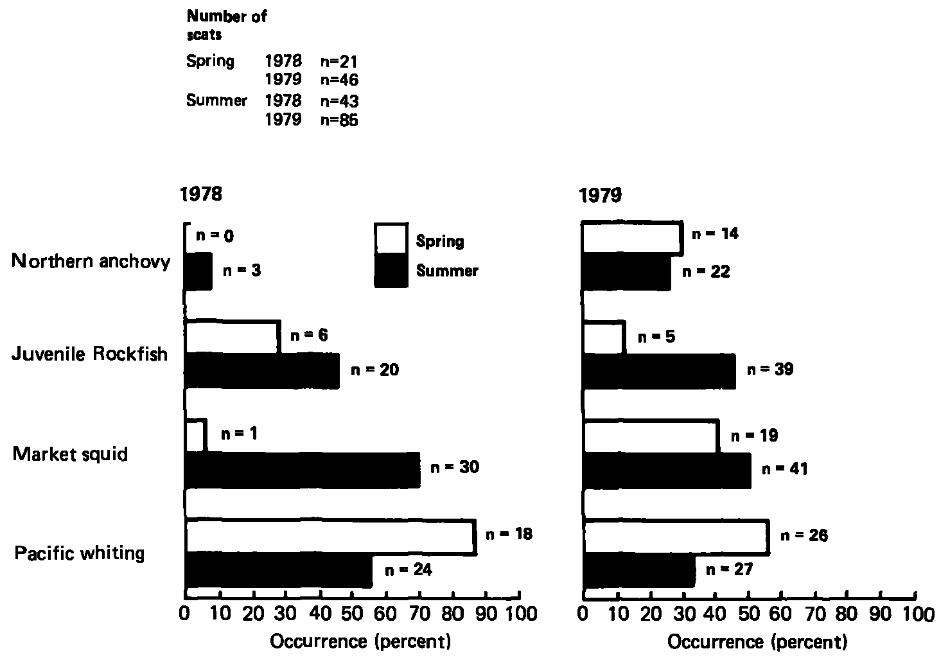

FIGURE 2.—Spring and summer occurrence (percentage) of the four major prey species identified in California sea lions scats collected on San Miguel Island, Calif., 1978-79.

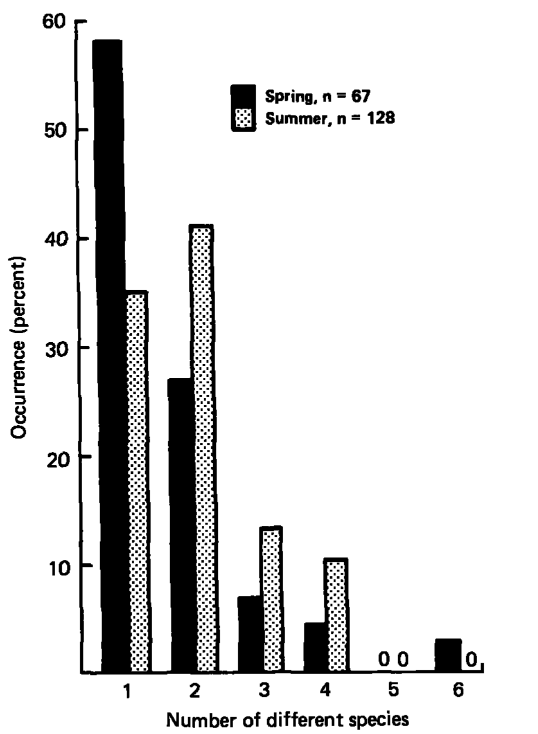

FIGURE 3.—Occurrence of single and multiple prey species in individual sea lion scats collected on San Miguel Island, Calif., 1978-79.

shown in Figure 4. The seasonal changes in the percent of weight for Pacific whiting showed a decrease from spring to summer in 1978 and 1979, while an increase occurred from spring to summer for market squid in 1978 and rockfish in 1979. There was relatively little change in the percentage of weight between the two seasons for market squid in 1979 and rockfish in 1978. The northern anchovy also showed little difference between the two seasons during both years. Additionally, the results from this analysis show that market squid made the greatest contribution to the total estimated weight of prey in the summer of 1978 (71.2%) and for both spring (53.9%) and summer (48.7%) of 1979, while Pacific whiting made the greatest contribution to the total estimated weight only in the spring of 1978 (87.3%).

DISCUSSION

Pacific whiting, market squid, juvenile rockfish, and northern anchovy were the four most important prey of California sea lions at San Miguel Island during the spring and summer of 1978 and 1979. These four prey species have also been reported as common prey of California sea lions in areas north of Point Conception (Morejohn et al. 1978; Everitt et al. 1981; Jones 1981; Ainley et al. 1982) and exemplify

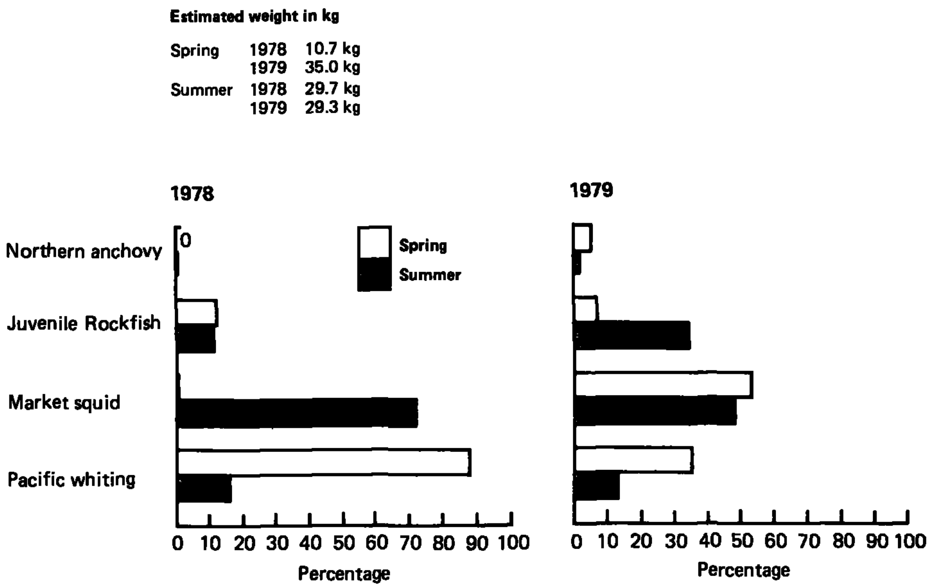

FIGURE 4.—Percentages of the total estimated weight for the four major prey species in spring and summer, 1978-79.

the type of large, dense schooling prey which are commonly fed upon by many of the pinnipeds in the coastal waters off California (Antonelis and Fiscus 1980). Furthermore, the variety of food items reported in this and other studies (Jameson and Kenyon 1977; Morejohn et al. 1978; Bowlby 1981; Jones 1981; Ainley et al. 1982) indicates that California sea lions are capable of foraging on a wide range of fish and cephalopods.

The range in the average length estimates of the four major prey species (95-171 mm) does not exhibit a great diversity in size, and may reflect a size preference for sea lions feeding in the waters near San Miguel Island. Both Pacific whiting and rockfish attain a much larger size as adults (Phillips 1964; Dark 1974), while the length estimates of northern anchovy and market squid are within the size range of juveniles and adults (Fields 1965; Spratt 1975).

As more information is obtained on the prey and the foraging behavior of California sea lions, researchers will attempt to evaluate the biomass of each prey species consumed (Bailey and Ainley 1982). These types of studies require information on the variations in the diet of California sea lions throughout their range. For this reason, we compare the estimated length data of market squid and Pacific whiting from this study with similar information reported in areas north of Point Conception. The estimated lengths were similar for market squid which were preyed upon by California sea lions in Monterey Bay, Calif. (Morejohn et al. 1978) and in the waters near San Miguel, with mean values of 130 mm (Morejohn et al. 1978, estimated from figure 27) and 127 mm, respectively. California sea lions foraged on all age classes of market squid in both areas. For Pacific whiting, however, differences between the northern and southern range of the California sea lion were apparent, with estimated length averages ranging from 250 to 360 mm at Southeast Farallon Island, Calif. (Bailey and Ainley 1982) compared with an average of 166 mm at San Miguel Island. Primarily 1- and 2-yr-old fish were preyed upon near San Miguel, while 2- and 3-yr-old fish were reported as prey at Southeast Farallon.

From these comparisons, we assume that squid of all sizes and age classes will be preyed upon by California sea lions, in both their breeding and nonbreeding ranges. For Pacific whiting, however, there are apparent differences in the size and age classes consumed by California sea lions in the two areas. These differences could be related to three possible factors: 1) There could be differential feeding according to various age and/or sex classes of sea lions which occur in the two areas. When present, there are mostly subadult and adult males at Southeast Farallon Island, and at San Miguel Island there are comparatively fewer subadult and adult males and many more females and juveniles of both sexes (Peterson and Bartholomew 1967; Le Bouef and Bonnell 1980; Ainley et al. 1982). 2) Differences between the two areas may be an artifact of the different methods used for estimating fish length. 3) What appears most probable to us, is the differential geographical distribution of Pacific whiting according to age. Generally, the younger fish occur in the southern portion of their range, and, although there is some overlap in age groups, the age and size of the fish increase in a northward direction (Bailey et al. 1982).

In cases where sufficient life history information is available, seasonal or annual changes in the occurrence of the four major prey (Fig. 2) can be related to known changes in the prey's relative abundance and availability to California sea lions. During both years of this study, the decrease in the occurrence of Pacific whiting in the scats from spring to summer appears to reflect known changes in the migration pattern of the species when adults and a portion of the juvenile population migrate toward shore and north of Point Conception (T. Dark[3]). For market squid and juvenile rockfish, however, the movement patterns off the coast of California are conspicuously different than Pacific whiting. Generally, market squid increase in abundance in shallow waters (5-50 m depth) near the northern California Channel Islands in late spring, and peak numbers occur in the early summer during spawning (S.Kato[4]). Inspection of the unpublished data from the 1970-75 commercial catches of market squid within 30 nmi of Point Bennett, San Miguel Island, also indicated that peak abundance occurs during the summer months.[5] Similarly, in spring through summer, juvenile rockfish (*S. paucispinis* and *S. jordani*) from the three-species complex identified in this study begin to move into more shallow waters (5-50 m depth) as they complete the pelagic stage of their life cycles (E. Hobson[6]). In these three instances, seasonal changes in the relative availability of Pacific whiting, market squid, and juvenile rockfish are reflected in the frequency of their occurrence in sea lion scats. A similar relationship was also suggested by Bailey and Ainley (1982), when they observed a seasonal change in the prey consumed by California sea lions near the Farallon Islands.

Although the percentage of occurrence of northern anchovy in the scats showed no significant seasonal changes from spring to summer, the annual occurrence of otoliths from northern anchovies in the sea lion scats was significantly greater in 1979 than in 1978. Their low numbers in the 1978 scats could be related to a decline in the northern anchovy population resulting from poor recruitment of the 1974-77 year classes (Mais 1981). In 1978, however, the year-class recruitment was strong (Mais 1981), and the increased abundance appears to be reflected in an increased percentage of occurrence in the 1979 collection. This explanation is corroborated by our comparison of the northern anchovy otoliths collected during the 2 years, where we found that the 1979 scats contained significantly smaller fish which were mostly (81%) yearlings from the 1978 year class.

Differences in the annual occurrence of Pacific whiting and market squid were also noted in this study. For market squid, there was no fishery information available during the time of this study which would provide us with a possible explanation for these differences. With Pacific whiting, however, the decrease in occurrence in the scats from 1978 to 1979 appears to be related to exceptionally high recruitment of the 1977 year class which was followed by an average, or possibly somewhat less-than-average, recruitment in 1978 (T. Dark footnote 3). This information is corroborated by a comparison of the Pacific whiting otoliths collected during the 2 years of our study. In 1978, sea lions preyed upon significantly smaller fish which were mostly (98.5%) yearlings from the 1977 year class.

Our analysis of the frequency occurrence of prey species per individual scat (Fig. 3) suggests that California sea lions commonly feed on single prey species during the spring and feed more frequently on multiple prey species in the summer. This shift from single to multiple occurrence of prey species in scats could reflect a decrease in the overall availability of the potential prey species in the summer which may necessitate foraging on a greater variety of food items for survival (Morse 1980). Alternatively, numerous potential prey species may become more available (Morse 1980) during the summer; thus, California sea lions could forage opportunistically on a greater variety of schooling fishes or squids which concentrate in a comparatively small area of high productivity.

There are, however, a variety of factors which could affect prey-species availability. Seasonal migration, diel vertical migration, variability in schooling behavior, or physiological changes associated with spawning (Moyle and Cech 1982) are probably some of the more important factors related to prey selec-

[3]T. Dark, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, WA 98112, pers. commun. 1982.

[4]S. Kato, Southwest Fisheries Center Tiburon Laboratory, National Marine Fisheries Service, NOAA, Tiburon, CA 94920, pers. commun. 1981.

[5]Data provided by E. Knaggs, Calif. Dep. Fish and Game, Long Beach, Calif., 1982.

[6]E. Hobson, Southwest Fisheries Center Tiburon Laboratory, National Marine Fisheries Service, NOAA, Tiburon, CA 94920, pers. commun. 1981.

tion and preference of California sea lions which necessitate additional research.

Unfortunately, virtually no information has been reported on the digestive rates or retention time of the prey species' hard parts in California sea lions. Therefore, it is presently impossible to ascertain how many meals, or portions thereof, are represented in a single scat. There is some evidence, however, from feeding studies (Pitcher 1980) of harbor seals, *Phoca vitulina*, and (Miller 1978) northern fur seals, *Callorhinus ursinus*, which indicates that cephalopod beaks are not readily passed through the intestinal tract and are regurgitated. This would result in an underrepresentation of cephalopod beak percentage-of-occurrence data from scats as suggested by Morejohn et al. (1978). Furthermore, the possible occurrence and identification of hard parts of secondary prey (from the stomach of the prey of the marine mammal) could bias the results of scat or stomach analysis (Perrin et al. 1973).

Additional information on the feeding habits of California sea lions can also be obtained from the weight estimates of the four major prey species identified in this study. The 1978 and 1979 percentages of total weight estimates (Fig. 4) for each major species showed seasonal changes that are similar to the analysis of percentage of occurrence (Fig. 2), although there are a few exceptions. In 1979 the market squid weight estimate showed a slight decrease, instead of an increase, from spring to summer, however, of more importance, is its relationship to Pacific whiting. The estimated weight of market squid from the scats clearly exceeded the relative weight of Pacific whiting and other prey species consumed during the spring and summer of 1979. These results suggest market squid may be a more important food item than was predicted from the analysis of their percent of occurrence. The importance of the squid in the diet of the California sea lion during the summer months near the northern California Channel Islands was also documented by Rutter et al. (1904), when they found that 84.6% ($n = 13$) of the animals examined had squid in their stomachs.

Bailey and Ainley (1982) estimated the spring and summer percent (weight) of Pacific whiting in the California sea lion diet in the southern region to be within a range of 50 to 90%. Yet our estimates fell below 40% in the spring of 1979 and below 20% in the summer of both 1978 and 1979, and only one instance (spring 1978) did our estimates fall within the range suggested by Bailey and Ainley (1982). Since Bailey and Ainley (1982) based their estimates on data from California sea lions in the northern region, we assume our estimates more accurately represent the percent (weight) of Pacific whiting in the diet of California sea lions south of Point Conception, and we recommend that additional feeding studies of California sea lions be conducted throughout their range.

The percentage of estimated weight results also suggests that Pacific whiting was preyed upon more heavily in the spring of 1978 than in the spring of 1979. This is consistent with the exceptionally high recruitment of the 1977 year class of Pacific whiting (discussed above) which was available as yearlings to California sea lions in 1978.

Although these weight (biomass) estimates are only approximate measurements, they appear instructive when used in conjunction with percentage-of-occurrence data. Unfortunately, there is some uncertainty as to the accuracy of using estimates of weight to estimate consumption. Our ability to make consumption estimates awaits the resolution of several questions: 1) What proportion of a given meal is represented in a single scat? 2) Are there differential digestive rates of fish and squid? 3) Do sea lions of different ages and sexes digest food differently?

The results of this study suggest that the California sea lions found on San Miguel Island feed opportunistically on prey species of changing availability, and we agree with Bailey and Ainley (1982) that they are behaviorally flexible enough to switch from one major prey species to another, both seasonally and annually. This type of flexibility in foraging appears to be adaptive and may be a major factor contributing to the success of the California sea lion population off the coasts of California and Baja California.

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