POPULATION FLUCTUATIONS OF CALIFORNIA SEA LIONS AND THE PACIFIC WHITING FISHERY OFF CENTRAL CALIFORNIA[1]

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ABSTRACT

Seasonal fluctuations in the number, age ratios, and diet of California sea lions, *Zalophus californianus*, were studied at the Farallon Islands, central California, from 1971 to 1980. During these years, average monthly numbers increased geometrically, except for April and May. Before 1977, the annual peak in population occurred during April and May, almost no animals were present late June to early July, and a slight peak occurred during fall; adult males predominated. Beginning in 1977, fall numbers equaled or exceeded those in spring, large numbers remained throughout summer, and subadults predominated. We hypothesize that seasonal fluctuations in sea lion numbers were related to the availability of their principal prey, Pacific whiting, *Merluccius productus*, and that the changes that began in 1977 were related to termination of the whiting fishery off central California beginning that year.

The California sea lion, *Zalophus californianus*, ranges along the North American west coast from the Gulf of California to British Columbia. Bartholomew (1967) hypothesized that most adult males migrate to the north from breeding sites in Baja California and southern California beginning in midsummer and remain there until the early spring when they return south, and that females and young animals remain in the vicinity of breeding areas or move somewhat southward during the nonbreeding season. This has become the accepted explanation to account for the seasonal movements in the population (e.g., Mate 1975). Preliminary analysis of census and diet information collected at the Farallon Islands during 1971-80 led to a related hypothesis that the movements of male sea lions toward the north could be a response to the seasonal occurrence and availability of an important prey species, the Pacific whiting, *Merluccius productus* (Huber et al.[4]). This information was later quoted by Fiscus (1979). Additional analysis, presented here, provides more insight into the ecological relationship between the two species.

The Pacific whiting is an abundant midwater fish of the continental slope and shelf off California. A summary of its biology and of the whiting fishery is provided by Dark (1975), Fiscus (1979), and Dark et al. (1980). Pertinent to the present study are the fish's migrational patterns. Pacific whiting migrate vertically from near bottom in daytime towards the surface at night, except in the winter spawning season when they remain at depth. They spawn off the coast from Baja California to central California and migrate northwards in spring and summer to feed off the Oregon, Washington, and British Columbia coasts. Small adults and juveniles migrate a lesser distance—1 to 3-yr-olds are mainly located off central and southern California from spring through fall. Also pertinent is the major harvest of whiting conducted by eastern European trawlers off the Pacific coast states and Canada from 1966 to 1976. Much of the fishing was concentrated in the Farallon area. Under the Fishery Conservation and Management Act of 1976 (FCMA), the fishery was prohibited off central California (south of lat. 39°N); we hypothesize that termination of the fishery affected the occurrence of California sea lions and possibly other pinnipeds.

METHODS

California sea lions were counted at the south Farallon Islands (lat. 37°42'N, long. 123°00'W), which are situated at the continental shelf break 32 km offshore from Point Reyes and Bolinas Point, Calif. Counts were irregular but fairly frequent from 1971 through 1973, but were regu-

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[4]Huber, H. R., D. G. Ainley, S. Morrell, R. R. LeValley, and C. S. Strong. 1979. Studies of marine mammals at the Farallon Islands, California, 1977-78. Final rep., 50 p. Marine Mammal Commission, Wash., D.C.; available Natl. Tech. Inf. Serv., Springfield, VA 22151, as PB80-111602.

Manuscript accepted November 1981.
FISHERY BULLETIN: VOL. 80, NO. 2, 1982.

lar and weekly during following years to January 1980. They were made year-round and occurred after 1400 h when maximum numbers of sea lions haul out at Southeast Farallon (Fig. 1; see also Mate 1975). In the following analyses the 1971-73 censuses were combined (Fig. 2) to correct for sporadic coverage. During censuses in the last 9 mo of both 1975 and 1976, and in all censuses since, animals were differentiated into adults and subadults, virtually all of which were males. Total count results are presented in Huber et al. (footnote 4).

Whiting otoliths and squid beaks were collected at regular biweekly intervals from the boat dock at North Landing, Southeast Farallon Island. This is a favored haul out site for California sea lions but not for other pinnipeds. Whiting otolith radii were measured and prey length was determined from the relationship of fish length to otolith radius. We assume that significant dissolution of otoliths did not occur as a result of digestion. Prey totals were determined by dividing otoliths by two and taking the higher number of upper and lower squid beaks.

Counts of trawlers fishing for whiting were made by the Division of Enforcement and Surveillance, National Marine Fisheries Service. Catch statistics were made available by the Northwest and Alaska Fisheries Center, NMFS.

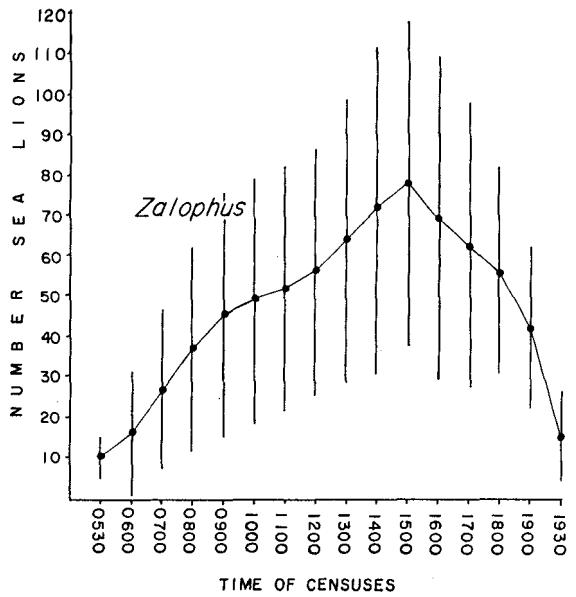

FIGURE 1.—The number of California sea lions hauled out during hourly periods at Shubrick Point, Southeast Farallon Island; the mean and ± standard deviation are shown based on 12 all-day watches during April and May 1974.

RESULTS AND DISCUSSION

California Sea Lion Biology

Aside from the one pup born at Southeast Farallon, every year since 1974 except 1978 (plus its mother and at least one bull) (Pierotti et al. 1977; Huber et al. [footnote 4]; Point Reyes Bird Observatory unpubl. data), the California sea lion population was comprised of nonbreeding males. Major breeding sites are located in the southern California islands (Bartholomew 1967; LeBoeuf and Bonnell 1980). From 1971 to 1976 a large peak in numbers was reached each year at the Farallones in late April or early May, when animals migrating south toward southern breeding sites hauled out for short periods (Fig. 2). A majority of animals departed (temporarily?) each evening to feed (Hobson 1966); about an hour after dawn they began to return and by early afternoon maximum numbers were hauled out. Numbers present each day rapidly declined in late May, and by late June only a few *Zalophus* hauled out. Population size increased again in late July, reached a peak in August or September that was much smaller than in spring, and than declined to a level maintained through the

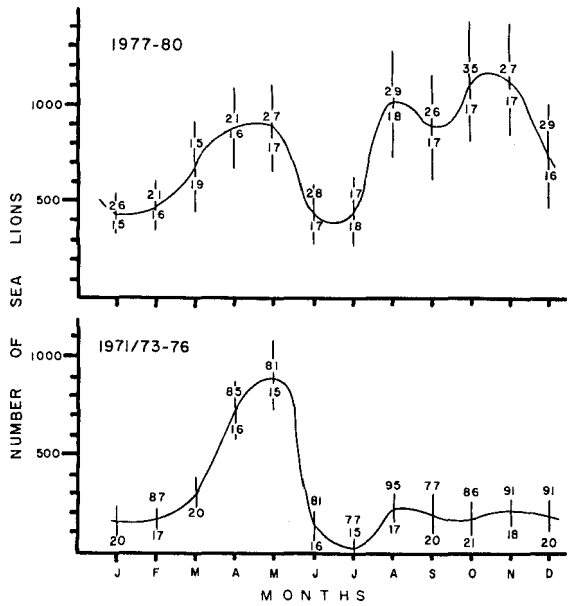

FIGURE 2.—The mean (± standard deviation) number of California sea lions hauled out at Southeast Farallon Island each month during two periods: 1971/73-76 and 1977-80; below each curve are the number of censuses each month and above are the proportion of adults present.

winter. Average monthly population size increased slightly from one year to another (Fig. 3). The proportion of adults present each month ranged between 73 and 95%.

Since 1977, population fluctuations of the California sea lions have been markedly different in several ways. First, except for April and May, average monthly population size began to increase rapidly from one year to the next (Fig. 3). This was especially evident for the summer and fall and thus, secondly, by 1978 the timing of the annual maximum population had shifted and fall counts were exceeding those of the spring peak (Fig. 2). In fact, for each month except April and May, average monthly numbers increased geometrically from 1971-73 to 1980 (least squares; r ranged 0.7745 to 0.9537, $P<0.01$). Finally, the percentage of adults during 1977-80 was reduced to a range between 15 and 35%. These differed significantly from percentages of adults in the period 1971/73-76 ($P<0.01$; percentage test, Sokal and Rohlf 1969:608). Young animals were thus migrating north rather than remaining in southern California and Baja California waters as Bartholomew (1967) had noted in earlier years.

Seasonal population fluctuations and age ratios at the Farallones from 1971 to 1976 were largely similar to those at coastal sites, as measured at Año Nuevo Island (80 km away, Orr and Poulter 1965; Lance and Peterson 1968), and sites farther north (Mate 1975). Exceptional at the Farallones was the fact that there was almost no fall peak, whereas at coastal sites it greatly exceeded the peak in spring. When the fall peak increased in 1977 the Farallon pattern became similar to coastal sites. However, it is possible that the age composition, for which few comparative data are available, and the size of the spring peak were changing then at the Farallons. At coastal sites there is a small spring peak and a large fall peak, but at the Farallones the two peaks became equal in magnitude.

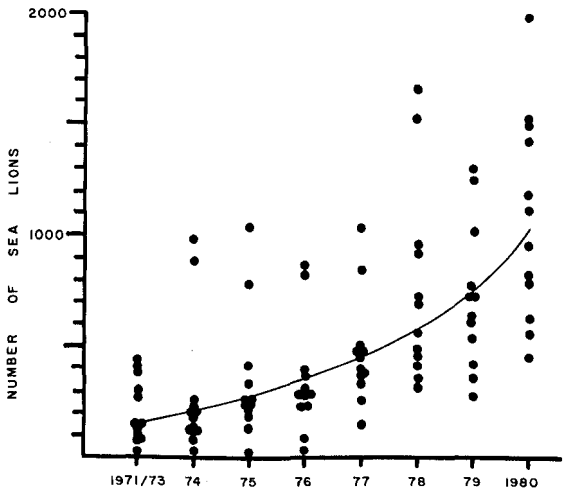

FIGURE 3.—The average number of California sea lions hauled out annually at Southeast Farallon Island. Dots above each year are monthly averages; the curve is described by the geometric equation: $y = a\lambda^x$, where $a = 9.5 \times 10^{-8}$ and $\lambda = e^{0.2979}$; $r = 0.6557$, $P<0.01$.

The diet of California sea lions at the Farallones, as revealed by regurgitated items, has been comprised of at least 20 species of prey (Table 1) (some otoliths could actually have come from the stomachs of sea lion prey). Outstanding were the predominance of Pacific whiting, particularly from April to August, and the diversification in diet from September to March. The whiting eaten averaged 25 to 36 cm in length and were 2 to 3 yr of age (Bailey and Ainley in press). Except for the short period during summer when they were away at breeding sites, California sea lions were most abundant when whiting predominated in their diet. At coastal sites of central California, the market squid, *Loligo opalescens*, along with whiting and northern anchovies, *Engraulis mordax*, are dominant prey of this pinniped (Morejohn et al. 1978).

California Sea Lions and the Pacific Whiting Fishery

From 1967 to 1972 most Pacific whiting were caught off the coasts of British Columbia, Washington, and Oregon (Fig. 4). After 1972, catches increased off the California coast, and especially high catches of around 100,000 t occurred from 1974 to 1976. This southward shift of fishing is believed to be due to a depletion of large adults in the Pacific Northwest. Fishing off central California targeted juvenile whiting.[5] After the FCMA restriction on fishing south of lat. 39°N, the total whiting catch dropped significantly (Fig. 4).

Whiting prevalence in the diet of Farallon sea lions was directly correlated to the average monthly number of trawlers fishing for whiting in the Farallon area (Table 2; $r = 0.747$, $t = 3.55$,

[5]Anonymous. 1976. Summary of National Marine Fisheries Service views on the status of the Pacific hake resource. Unpubl. rep., 4 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98115.

TABLE 1.—Percent composition of California sea lion diet as determined by otoliths and beaks regurgitated at haul out sites, Southeast Farallon Island, 1974-78.

Months:	J	F	M	A	M	J	J	A	S	O	N	D
Cephalopods												
Octopus rubescens		1	2									
Berryteuthis (?) sp.									1			
Gonatus sp.				1								
Loligo opalescens									3			
Fishes												
Merluccius productus	54	36	28	87	94	98	96	84	38	43	28	30
Sebastes spp.	45	27	61	11	5	<1		14	30	16	69	30
Porichthys notatus		1	6	1	1	<1		<1	1	31	1	
Engraulis mordax		20						<1				1
Glyptocephalus zachirus	1					<1			10	1	1	40
Chilara taylori		8				<1			9			
Parophrys vetulus		2						<1	3			
Genyonemus lineatus						<1		<1	2	2		
Citharichthys sordidus		1							2	3		
Microgadus proximus		1	2					<1	<1			
Atherinopsis californiensis								<1	<1			
Leptocottus armatus									<1	2		
Zalembius rosaceus									<1	2		
Microstomus pacificus									<1			
Trachurus symmetricus							4	<1	<1			
Clupea pallasi								<1				
Lyopsetta exilis									<1			
Total prey (no.)	11	147	55	550	1,077	291	45	535	267	102	140	10

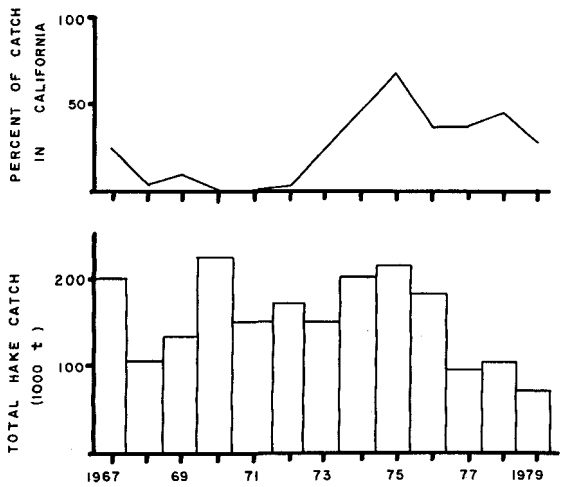

FIGURE 4.—The total catch of whiting in the Pacific coast fishery and the proportion of that catch taken off California, 1967-79.

TABLE 2.—Number of stern trawlers fishing for Pacific whiting over the California continental slope between lat. 39° and 37°N from January through December 1974-77; data summarized from NMFS monthly surveillance reports.

Year	J	F	M	A	M	J	J	A	S	O	N	D
1974	0	0	13	43	55	60	57	55	11	0	0	0
1975	3	8	60	64	90	64	2	?	0	0	0	0
1976	0	0	10	35	55	50	38	13	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
$\bar{x}$ 1974/76	1	2	28	47	67	58	32	34	3	0	0	0

df = 10, $P<0.01$, Spearman rank correlation). Considering the whole coast of California, trawlers concentrated near the Farallones, at least from 1974 to 1976, when fishery surveillance records were available to us. If we assume that the number of trawlers and the prevalence of whiting in sea lion diets, in conjunction with sea lion population size, reflect whiting availability, we conclude that both sea lions and humans were attracted to continental slope waters at the same time in order to catch whiting. The only difference was that the sea lions departed at the peak of harvest in order to return to traditional breeding sites.

Associated with the unavailability of whiting, both fishing activity and the preponderance of whiting in the sea lion diet dropped off from September to March. During the winter months adult whiting migrate off the continental shelf to spawn in deeper waters of the continental slope (Bailey 1980), and juveniles probably show the same behavior. In addition, during the spawning months they do not diurnally migrate but remain deep (Nelson and Larkins 1970). They are thus unavailable to both the fishery and the sea lions.

We offer the following hypothesis to explain the patterns observed in the sea lions' behavior. First, they are attracted to continental slope waters of central California by whiting which, due to their own migrations, become available there during spring and summer. The trawler fishery, also attracted by greater fish availability, was perhaps depleting whiting stocks seasonally to such an extent during the early to mid-1970's that by late summer when sea lions were

returning north from breeding sites, offshore waters near the Farallones were no longer as attractive to the pinnipeds as during the spring. The sea lions thus remained along the coast to feed on other prey. Then in 1977, when trawlers no longer fished for whiting off central California, the sea lions responded in three ways, all possibly due to increased food supply during summer and fall: 1) Young animals moved farther north or farther off the coast than previously, 2) more adults remained during summer instead of migrating south, and 3) adults returning from southern breeding sites moved offshore in larger numbers than they had in previous falls. The size of the sea lion population peak during spring was not affected by termination of the fishery, because fishing was only just getting under way each year at that time.

Adding coincidental support to the hypothesis that the 1966/76 whiting fishery off central California was indirectly depressing the numbers of California sea lions in the vicinity are data from other localities. Populations of California sea lions at breeding sites on southern California islands have been increasing geometrically for the past several decades (Bartholomew 1967; LeBoeuf and Bonnell 1980; LeBoeuf[6]). At the crease in numbers at the Farallon Islands is likely a reflection of this. Successive counts at coastal Año Nuevo Island during the early 1960's also reflected this increase, but beginning sometime between 1963 and 1967 numbers began a decline there that lasted through 1975; since then, however, they have begun to increase again (LeBoeuf and Bonnell 1980; LeBoeuf[6]). At the Monterey breakwater, about 80 km farther south, D. J. Miller[7] has noted that numbers of subadult California sea lions since about 1978 have been much higher than in previous years.

Changes in the occurrence of another pinniped, the northern fur seal, *Callorhinus ursinus*, at the Farallones, provide additional support to the hypothesis. Also an important whiting predator (Fiscus 1979), this species breeds at San Miguel Island in southern California and in the Bering Sea, and during the nonbreeding season frequents waters of the California continental slope. From 1970 to 1976 we observed individual fur seals at the farallones on only 3 single days, each 2 yr apart. Since then, however, their occurrence has changed dramatically: the species has occurred annually during the summer and fall, and at least 10 different individuals (determined by tags or peculiar scars) have hauled out, some repeatedly, for periods of variable length. Two that hauled out were tagged at San Miguel; another has hauled out for 5 yr in succession. The fur seal breeding population on San Miguel Island has been increasing geometrically from the early 1960's to the present (LeBoeuf and Bonnell 1980) and the increasing occurrence of this species on the Farallones is likely a reflection of this trend. The dramatic jump in numbers at the Farallones beginning after 1976, however, is out of line with the continuous increase in breeding numbers. Cessation of the whiting fishery off central California in 1976 may account for the change at the Farallones, just as this may be responsible for the change in population dynamics of California sea lions in central California.

[6]B. J. LeBoeuf, Division of Natural Sciences, University of California at Santa Cruz, Santa Cruz, CA 95064, pers. commun. June 1981.

[7]D. J. Miller, California Department of Fish and Game, Monterey, CA 93940, pers. commun. June 1981.

ACKNOWLEDGMENTS

Field work at the Farallon Islands was funded by the Point Reyes Bird Observatory, U.S. Fish and Wildlife Service, Marine Mammal Commission, and National Marine Fisheries Service (Marine Mammal Laboratory and Southwest Fisheries Center). Logistic support was provided by the U.S. Coast Guard and the Oceanic Society, San Francisco Bay Chapter. The Farallones comprise a national wildlife refuge, and we thank the personnel of the San Francisco Bay National Wildlife Refuge for their help. Marine mammal food items were collected under NMFS permit No. 146; fish otoliths were identified by J. E. Fitch and cephalopod beaks were identified by D. G. Ainley; G. Galbraith, Division of Enforcement and Surveillance, NMFS, provided data on the occurrence of whiting trawlers. C. S. Strong, T. J. Lewis, R. J. Boekelheide, R. P. Henderson, R. R. LeValley, S. H. Morrell, J. W. Higbee, B. Bainbridge, K. Darling, and W. Clow assisted with counts. O'B. Young helped to prepare the manuscript. Valuable comments were offered by R. L. DeLong, D. P. DeMaster, C. H. Fiscus, B. J. LeBoeuf, and P. F. Major.

LITERATURE CITED

BAILEY, K. M.
1980. Recent changes in the distribution of hake larvae: causes and consequences. Calif. Coop. Oceanic Fish. Invest. Rep. 21:167-171.

BAILEY, K. M., AND D. G. AINLEY.
In press. The dynamics of California sea lion predation on Pacific whiting. Fish. Res.

BARTHOLOMEW, G. A.
1967. Seal and sea lion populations of the California Islands. *In* R. N. Philbrick (editor), Proceedings of the symposium on the Biology of the California Islands, p. 229-244. Santa Barbara Botanic Garden, Santa Barbara.

DARK, T. A.
1975. Age and growth of Pacific hake, *Merluccius productus*. Fish. Bull., U.S. 73:336-355.

DARK, T. A., M. O. NELSON, J. J. TRAYNOR, AND E. P. NUNNALEE.
1980. The distribution, abundance and biological characteristics of Pacific whiting, *Merluccius productus*, in the California-British Columbia region during July-September 1977. Mar. Fish. Rev. 42(3-4):17-33.

FISCUS, C. H.
1979. Interactions of marine mammals and Pacific hake. Mar. Fish. Rev. 41(10):1-9.

HOBSON, E. F.
1966. Visual orientation and feeding in seals and sea lions. Nature (Lond.) 210:326-327.

LANCE, C. C., AND R. S. PETERSON.
1968. Seasonal fluctuations in populations of California sea lions. Año Nuevo Rep. 2:30-36. (Univ. Calif., Santa Cruz.)

LEBOEUF, B. J., AND M. L. BONNELL.
1980. Pinnipeds of the California Islands: abundance and distribution. *In* D. M. Power (editor), The California Islands: Proceedings of a Multidisciplinary Symposium, p. 475-493. Santa Barbara Museum of Natural History.

MATE, B. R.
1975. Annual migrations of the sea lions *Eumetopias jubatus* and *Zalophus californianus* along the Oregon coast. Rapp. P.-V. Réun. Cons. Int. Explor. Mer 169: 455-461.

MOREJOHN, G. V., J. T. HARVEY, AND L. T. KRASNOW.
1978. The importance of *Loligo opalescens* in the food web of marine vertebrates in Monterey Bay, California. *In* C. W. Recksiek and H. W. Frey (editors), Biological, oceanographic, and acoustic aspects of the market squid, *Loligo opalescens* Berry, p. 67-98. Calif. Dep. Fish Game, Fish. Bull. 169.

NELSON, M. O., AND H. A. LARKINS.
1970. Distribution and biology of Pacific hake: A synopsis. *In* Pacific hake, p. 23-33. U.S. Fish Wildl. Serv. Circ. 332.

ORR, R. T., AND T. C. POULTER.
1965. The pinniped population of Año Nuevo Island, California. Proc. Calif. Acad. Sci., Ser. 4, 32:377-404.

PIEROTTI, R. J., D. G. AINLEY, T. J. LEWIS, AND M. C. COULTER.
1977. Birth of a California sea lion on Southeast Farallon Island. Calif. Fish Game 63:64-66.

SOKAL, R. R., AND F. J. ROHLF.
1969. Biometry. W. H. Freeman, San Franc., 776 p.