

Interactions of Marine Mammals and Pacific Hake

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Introduction

There are from 3 to 11 recognized species of hake (*Merluccius* sp.) worldwide, depending on which authority is consulted. The Pacific hake, *Merluccius productus*, is the species present in the northeastern North Pacific Ocean.

Extensive and detailed information is available on the life history, distribution, and abundance of Pacific hake, with the exception of its early life. The commercial fishery and its development have been carefully followed and documented by scientists of the National Marine Fisheries Service. The importance of hake in the diet of marine mammals and interrelationships between marine mammals and hake is not well known. Information in this paper was obtained from sources either footnoted or listed in the Literature Cited and References sections.

Pacific Hake

Life History, Distribution, and Abundance

Pacific hake, maturing at about 3-4 years of age at about 35-42 cm in length, may live to age 16 but few older than age 9 have been found in unexploited stocks. Mature fish will average different lengths and weights depending on where taken, i.e., mature fish off Washington average 52 cm and 1 kg, but mature fish off northern California average about 47 cm and 0.5 kg. Sizes and ages are stratified latitudinally, and maximum observed length

is about 85 cm with females reaching a larger size than males.

Among the prey species utilized by hake off California are red crab, *Pleuroncodes planipes*; euphausiids; shrimp, *Pandalus jordani*; squid, *Loligo opalescens*; northern anchovy, *Engraulis mordax*; juvenile hake, *Merluccius productus*; queenfish, *Seriphus politus*; pink sea perch, *Zalembeus rosaceus*; sanddabs, *Citharichthys* sp.; slender sole, *Lyopsetta exilis*; curlfin sole, *Pleuronichthys decurrens*; and clam, *Solemya panamensis*. Gotshall (1969) found 31 different food items in the stomachs of 528 hake taken off northern California from July 1964 to September 1965. Shrimp, *Pandalus jordani*, and krill (euphausiids) composed 62.9 percent (44.4 and 18.5 percent, respectively) of all food found.

Among the prey species utilized by hake off Washington and northern Oregon during May to September, two euphausiids, *Thysanoessa spinifera* and *Euphausia pacifica*, and one species of pandalid shrimp predominated. Fish were of relatively minor importance during the sampling period. Species identified included Pacific herring, *Clupea harengus pallasii*; northern anchovy; eulachon, *Thaleichthys pacificus*; Pacific sand lance, *Ammodytes hexapterus*; and sablefish, *Anoplopoma fimbria*. Traces of squid species were also found.

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ABSTRACT—The biology, feeding habits, seasonal distribution, and range of the Pacific hake, *Merluccius productus*, are briefly described. The commercial hake fishery is also discussed. Marine mammals inhabiting the range of the Pacific hake are listed and population estimates are given

when known. The known or suspected marine mammal predators on hake are described in detail. The range and seasonal distribution of each species is given and principal prey species (including hake) are discussed. A partial listing of fish which prey on hake is given.

Hake are found along the Pacific coast from the Gulf of Alaska southward to the Gulf of California; however, they are generally found in numbers sufficient for commercial exploitation only from British Columbia southward to northern Baja California. This species is semipelagic and regularly found near the ocean floor and in midwater.

There are apparently both latitudinal and bathymetric migrations of Pacific hake which occur in about the following manner: Adult hake appear on the continental shelf and slope in April and early May off central and northern California and southern Oregon. They first occur off northern Oregon and Washington in April; however, they are most abundant from northern Oregon to central Washington in June through September in 20-150 fathoms (fm) (37-274 m). From July into September new incursions of adult hake appear from southern Oregon northward to the Vancouver Island area. In late September hake begin to move off the continental shelf into the deeper water of the slope and by December most adults are gone from the area — presumably moving southward to the spawning area, which is located well offshore from Baja California and southern California. Little spawning occurs north of San Francisco. Most spawning apparently occurs between January and April over deep water. Loose spawning aggregations have been identified at depths of 125-255 fm (229-466 m) and 500 fm (914 m).

Little is known about the early life history of Pacific hake. Most hake eggs and larvae have been found at depths of 25-55 fm (46-100 m). Hake, ages 1 and 2, occur over the continental shelf off California. Pacific hake begin to mature by age 3 and most are mature by age 4.

Schools of mature hake over the continental shelf display marked daily vertical movements. These diel movements probably are related to the movement of their euphausiid prey. Their nocturnal movement toward the surface layer at night makes hake more accessible to marine mammals.

The most recent estimate available on population size is from a 1977 sur-

vey by Dark et al¹. The estimate was about 1,200,000 metric tons (t).

¹Dark, T. A., M. O. Nelson, J. J. Traynor, and E. P. Nunnallee. 1979. Distribution, abundance, and biological characteristics of Pacific hake, *Merluccius productus*, in the California-British Columbia region during July-September 1977. Unpubl. manusc., 56 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Commercial Fishery

The U.S. hake fishery has been relatively small and sporadic. Hake have been taken in small quantities in the California animal food fishery since 1953. The U.S. fishery off Oregon and Washington occurred only during 1966-67 when a fish meal processor and

fish protein concentrate plant were taking deliveries at Aberdeen, Wash. In 1977 relatively small landings were made at Warrenton, Oreg., and Eureka, Calif., for processing into fillets. The Puget Sound, Wash., fishery persists but is quite small. A major Soviet fishery got underway in 1966 operating from off Vancouver Island to central California and has accounted for the major portion of the catch.

Annual Soviet catches fluctuated between about 103,000 and 167,000 t in 1975 and 1976. Under the Fishery Conservation and Management Act of 1976, it was recommended that the total allowable catch in 1977 off the U.S. west coast (California to Washington) be set at 130,000 t. Of the foreign fleets, only the U.S.S.R. and Poland fished for hake in 1977; they were allocated and took 105,000 and 18,000 t, respectively. Under the Act certain restrictions and regulations apply, and perhaps one of the more significant ones prohibits fishing for hake south of lat. 39°N (about the latitude of Point Arena, Calif.).

References consulted in the Pacific Hake section include: Pereyra and Richards (1969), Alton and Nelson (1970), Grinols and Tillman (1970), Nelson and Larkins (1970), Dark et al. (footnote 1), and Low².

Marine Mammals

Species Within Hake Range

Marine mammals known to occur in some portion of the range of Pacific hake in the northeastern North Pacific Ocean are listed in Table 1. One mustelid, 6 pinnipeds, 8 baleen whales and 23 toothed whales, porpoises, and dolphins are found in parts of the hake's range at some season of the year. Some of these species are so rare or their presence in hake habitat so slight that they can be ruled out as having any measurable effect on the hake resource.

Of the 38 marine mammals noted

²Low, L. L. 1976. Status of major demersal fishery resources of the northeastern Pacific: Bering Sea and Aleutian Islands. Processed Rep., 116 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Table 1.—Marine mammals inhabiting the range of Pacific hake.

Species ¹	Estimated population in hake range	Relation to hake				Data source
		Competes with	Preys on	Unknown		
California sea lion (<i>Zalophus californianus</i>)	80,000 total pop.	—	X	—		Fiscus and Baines (1966); Ainley et al. (1977); Best (1963)
Northern sea lion (<i>Eumetopias jubatus</i>)	California, 2,200-2,300 Oregon, 2,000 Washington, 500 British Columbia, 5,000	—	X	—		Spalding (1964)
Northern fur seal (<i>Callorhinus ursinus</i>)	500,000	—	X	—		Nor. Pac. Fur Seal Comm. Reps.
Guadalupe fur seal (<i>Arctocephalus townsendi</i>)	<2,000	—	—	X		—
Sea otter (<i>Enhydra lutris</i>)	Minimal	—	—	X		—
Harbor seal (<i>Phoca vitulina richardii</i>)	Minimal	—	X	—		Scheffer (1931) Spalding (1964)
Northern elephant seal (<i>Mirounga angustirostris</i>)	50,000	—	X	—		Best (1963)
Gray whale (<i>Eschrichtius robustus</i>)	11,000	X	—	—		—
Minke whale (<i>Balaenoptera acutorostrata</i>)	No estimate available	X	—	—		—
Brydes whale (<i>Balaenoptera edeni</i>)	No estimate available	X	—	—		—
Sei whale (<i>Balaenoptera borealis</i>)	9,000 in entire North Pacific	X	—	—		—
Fin whale (<i>Balaenoptera physalus</i>)	17,000 in entire North Pacific	X	—	—		—
Blue whale (<i>Balaenoptera musculus</i>)	1,700 in entire North Pacific	X	—	—		—
Humpback whale (<i>Megaptera novaeangliae</i>)	850 in entire North Pacific	X	—	—		—
Right whale (<i>Balaena glacialis</i>)	Minimal (220 in entire North Pacific)	X	—	—		—
Rough-toothed dolphin (<i>Steno bredanensis</i>)	Minimal (no estimate available)	—	—	X		—
Bottlenose dolphin (<i>Tursiops truncatus</i>)	Minimal (no estimate available)	—	—	X		—
Spinner dolphin (<i>Stenella longirostris</i>)	Minimal (1.9 million; only a portion in this area)	—	—	X		—

(Continued on next page)

Table 1. — Continued.

Species ¹	Estimated population in hake range ²	Relation to hake			Data source	Species	Relation to hake (see text)
		Competes with	Preys on	Unknown			
Bridled dolphin (<i>Stenella attenuata</i>)	Minimal (3.6 million; only a portion in this area)	—	—	X	—		
Striped dolphin (<i>Stenella coeruleoalba</i>)	Minimal (248,000; only a portion in this area)	—	—	X	—		
Saddleback dolphin (<i>Delphinus delphis</i>)	1.4 million; only a portion in this area	—	X	—	Fitch and Brownell (1968); Evans (1976)		
Pacific whiteside dolphin (<i>Lagenorhynchus obliquidens</i>)	No estimate available	—	X	—	Fiscus and Niggol (1965); Best (1963)	Guadalupe fur seal	B
Northern right-whale dolphin (<i>Lissodelphis borealis</i>)	No estimate available	—	X	—	Fitch and Brownell (1968)	Sea otter	A
Whitehead grampus (<i>Grampus griseus</i>)	No estimate available	—	—	X	—	Harbor seal	A-D
False killer whale (<i>Pseudorca crassidens</i>)	No estimate available	—	—	X	—	Northern elephant seal	D
Shortfin pilot whale (<i>Globicephala macro-rhynchus</i>)	No estimate available	—	—	X	—	Rough-toothed dolphin	A
Killer whale (<i>Orcinus orca</i>)	No estimate available	—	—	X	—	Bottlenose dolphin	A-B
Harbor porpoise (<i>Phocoena phocoena</i>)	Minimal (no estimate available)	—	—	X	—	Spinner dolphin	A-C
Dall porpoise (<i>Phocoenoides dalli</i>)	No estimate available	—	X	—	Loeb (1972); Norris and Prescott, (1961); Best (1963)	Bridled dolphin	A-C
Sperm whale (<i>Physeter macrocephalus</i>)	300,000 in entire North Pacific	—	X	—	Rice, pers. comm.	Striped dolphin	A-B-C
Pygmy sperm whale (<i>Kogia breviceps</i>)	Minimal (no estimate available; rare)	—	—	X	—	False killer whale	B
Dwarf sperm whale (<i>Kogia simus</i>)	Minimal (no estimate available; rare)	—	—	X	—	Killer whale	B-C
North Pacific giant-bottlenose whale (<i>Berardius bairdii</i>)	Minimal (no estimate available)	—	—	X	—	Harbor porpoise	A
Goosebeak whale (<i>Ziphius cavirostris</i>)	Minimal (no estimate available)	—	—	X	—	Sperm whale	D
Ginkgo-tooth whale (<i>Mesoplodon ginkgodens</i>)	Minimal (no estimate available)	—	—	X	—	Pygmy sperm whale	B
Archbeak whale (<i>Mesoplodon carlhubbsi</i>)	Minimal (no estimate available; rare)	—	—	X	—	Dwarf sperm whale	B
Sabertooth whale (<i>Mesoplodon stejnegeri</i>)	Minimal (no estimate available; rare)	—	—	X	—	North Pacific bottlenose whale	B
Densebeak whale (<i>Mesoplodon densirostris</i>)	Minimal (no estimate available; rare)	—	—	X	—	Goose beak whale	B
						Ginkgo-tooth whale	B
						Archbeak whale	B
						Sabertooth whale	B
						Densebeak whale	B

¹From Rice (1977).

²Unless qualified in text, population estimates are from the Marine Mammal Protection Act of 1972, Annual Report, April 1, 1977 through March 31, 1978. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., 183 p.

above, we can disregard the 21 species in the following list as unimportant (having no significant impact on the hake resource) because A) they are found only along the edge of the hake habitat, B) their numbers are so small that they are considered rare in this area, C) they are not known to or do not prey on hake, or D) they prey on hake but their impact is considered minimal. The letters in the right column refer to the above.

The harbor seal, *Phoca vitulina richardii*, is fairly abundant along the shore side of the hake range. Hake have been identified in stomachs of harbor seals taken in Puget Sound, Wash., and from "inside" waters of British Columbia (Scheffer and Sperry, 1931; Spalding, 1964). The hake populations in these areas are considered resident and probably do not contribute to the offshore hake population.

The northern elephant seal, *Mirounga angustirostris*, range coincides with that of hake, and although hake have been identified in the stomach contents of dead stranded specimens, most available evidence suggests that elephant seals prey primarily on deepwater fishes and squids (Best, 1963; Huey, 1930; Morejohn and Baltz, 1970).

The killer whale, *Orcinus orca*, is found throughout the range of hake, but hake has not been identified in the few killer whale stomachs examined to date. The number of killer whales

found in offshore hake areas is usually quite small with larger pods probably being more common along the shore side of the hake range.

The sperm whale, *Physeter macrocephalus*, migrates through the range of hake each year; hake were found in the stomachs of 4 of 456 sperm whales taken off San Francisco, Calif., from 1959 to 1970. The importance of hake in the diet of sperm whales is considered minimal (D.W. Rice, Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, Wash., pers. commun.).

The eight species of baleen whales which are found at some season of the year inhabiting the same range as the hake can be classed as competitors for the same food source rather than predators.

The remaining marine mammals are known to prey on hake as indicated by the presence of hake remains in stomachs or because they are considered likely predators as they frequent the same range as hake and have feeding habits similar to known predators.

Species	Known predators	Suspected predators
California sea lion	X	—
Northern sea lion	X	—
Northern fur seal	X	—
Saddleback dolphin	X	—
Pacific whiteside dolphin	X	—
Northern right whale dolphin	X	—
Whitehead grampus	—	X
Shortfin pilot whale	—	X
Dall porpoise	X	—

Known or Suspected Hake Predators

California Sea Lion

The California sea lion, *Zalophus californianus*, ranges along the west coast of Mexico northward to southern British Columbia; its breeding range extends from several of the Gulf of California islands north to San Miguel Island, Calif.—with a scattering of pups being born on islets in San Luis Obispo Bay (Braham, 1974). One pup was born each year for the past 3 years far north of the normal breeding range on Southeast Farallon Island off San Francisco (Ainley et al., 1977). During the breeding season (May-July) almost

the entire population is found south of lat. 34°N. Beginning in August there is a migration of a portion of the male population northward, some reaching Vancouver Island. It is estimated that 4,000 males may be found north of California from early fall (September) until spring (May) with approximately 2,500 found off Oregon, 500 off Washington, and 1,000 off southern British Columbia (Bigg, 1973; Mate, 1976b). Recent estimates of the entire population vary.

One estimate gives a population of about 80,000, with 40,000 in Mexican waters and 40,000 in U.S. waters (National Marine Fisheries Service, 1978). A July 1975 aerial survey of the sea lion range yielded counts as follows: Pacific coast (Oregon, California, Mexico) 65,862; Mexico (Gulf of California) 9,428; total = 75,290 (Mate, 1977). Another estimate was from a photographic count of the animals (Le Bouef et al.³). Sea lion counts or estimates range from 31,731 to 40,000 for California and from 20,000 to 43,653 for Mexico.

Prey species consumed by the California sea lion include: Pacific herring; northern anchovy; plainfin midshipman, *Porichthys notatus*; Pacific hake; Pacific tomcod, *Microgadus proximus*; jacksmelt, *Atherinopsis californiensis*; white croaker, *Genyonemus lineatus*; rockfish, *Sebastes* sp.; rex sole, *Glyptocephalus zachirus*; slender sole; English sole, *Parophrys vetulus*; and squid, *Loligo opalescens* (Ainley et al., 1977; Best, 1963; Fiscus and Baines, 1966).

Sea lion spewings were examined at Southeast Farallon Island when sea lions were present throughout the year (Ainley et al., 1977). Investigators found that hake was an important food item, being found almost exclusively in

³LeBoeuf, B. J., M. L. Bonnell, M. O. Pierson, D. H. Dettman, and B. D. Farrens. 1976. Pinnipedia: Numbers, distribution and movements in the Southern California Bight. Section I. In Regents of the University of California (editors), Marine mammal and seabird survey of the Southern California Bight area, p. III - 1-269. Draft final report 1975-1976, BLM contract 08550-CT5-28. Regents, Univ. Calif., Santa Cruz, Calif.

the spewings when the population peaked on their southbound migration in April and May. Sea lion numbers during this peak period in 1974-75 were slightly under 1,400 animals and in 1976, slightly under 1,200.

In comparing the migratory movement and range of hake with that of the California sea lion, we can presume that the sea lion is not an important predator of hake from northern California north to British Columbia simply because so few (4,000, mostly adult males) range north of about the latitude of the Farallon Islands (lat. 38°N). Virtually the entire population of California sea lions are found south of lat. 34°N in the southern portion of the hake range during May-July. During the remainder of the year their movements are not so well understood with the exception of the 4,000 odd males that move north of lat. 38°N. California sea lions do not usually range far from land with the exception of solitary males. Surveys for the Bureau of Land Management (BLM) of the U.S. Department of Interior, indicate that sea lions rarely venture more than 50 km from their hauling grounds and are seldom seen outside the 500-fm (914.4-m) depth contour (Le Bouef et al., footnote 3). During the fall most adult males moved northward out of the California bight (lat. 32°-34°N) waters. Based on aerial transects, scientists conducting the BLM studies concluded that the ratio of animals at sea to those on land remains constant and that there are about one-third as many animals at sea as there are on land.

Northern Sea Lion

The range of the northern sea lion, *Eumetopias jubatus*, extends around the North Pacific rim—from southern California to the Bering Sea, to the Kurile Islands, and to the Okhotsk Sea. The southern limit of the northern sea lions' breeding range in the eastern North Pacific is located at San Miguel Island at about lat. 34°N. In 1977, the breeding population of San Miguel and adjacent Castle Rock was comprised of four adult females and two large males; three pups were born during the season. A census was not made at Richardson

Rock near San Miguel but it usually has a population of 5-10 animals. The breeding colony at Ano Nuevo, at about lat. 37°N, in 1978 numbered about 1,200 animals (R. Gisiner, University of California, Santa Cruz, Calif., pers. commun.), a decline of about 33 percent from the population described in 1968-69 (Gentry, 1970). The breeding colony at Southeast Farallon Island, at about lat. 38°N, numbered less than 200 animals. Ainley et al. (1977) reported a breeding population of about 130 in 1976. The northern sea lion population on these three breeding areas has undergone a decline in numbers since the 1920's and 1930's as indicated in available census data. The northern sea lion population in California north of lat. 38°N in July contains about 800-900 animals; thus the California breeding season population numbers from 2,200 to 2,300 animals. A census made in July 1975 of sea lions in Oregon indicated a breeding season population of slightly over 2,000 (Mate, 1977). The Washington population (no rookeries) probably numbers less than 500 animals. The breeding population of northern sea lions in British Columbia is estimated to be about 5,000.

Northern sea lions are found in the central and northern portion of the hake habitat and number about 9,800 animals. The largest numbers (British Columbia) are found along the northern boundary of the hake range which is occupied by large numbers of hake only in the summer and early fall. There is apparently a general northward movement of northern sea lions after the breeding season similar to that which occurs in California sea lions.

Prey species consumed by the northern sea lion in this region include: Pacific lamprey, *Entosphenus tridentatus*; Pacific herring; salmon, *Oncorhynchus* sp.; Pacific hake; rockfish, *Sebastes* sp.; sanddab; turbot, *Pleuronichthys* sp.; squid; octopus; and other species of fishes and squids (Fiscus and Baines, 1966; Spalding, 1964).

Northern Fur Seal

The northern fur seal, *Callorhinus ursinus*, ranges across the subarctic

waters of the North Pacific and numbers about 1.8 million. In that portion of the eastern North Pacific inhabited by the Pacific hake the fur seal is essentially absent from mid-June until late November (6 months) except for the San Miguel Island populations which number about 2,000 animals. Few adult males are found south of the Gulf of Alaska. Adult and subadult females and juvenile males and females begin to appear in coastal waters between British Columbia and central California in late November and early December, the pups slightly later in January-February. The movement is generally southward along the continental shelf and slope from January into March with some animals ranging south to about lat. 32°N; however, most of the wintering population can be found between about lat. 35° and 49°N. Some northward migration out of this region may begin as early as March and most of the wintering population has moved north of the hake range by mid-June.

Most wintering seals are found from over the continental shelf seaward as much as several hundred miles. They seldom approach land, although there are a few exceptions. During 1965-66 off California and in 1967 off Washington, transects were run from nearshore over the continental shelf and slope seaward over deep water; seals were seldom seen within 18-28 km of shore, being most numerous along the continental slope and those areas where bottom topography caused upwellings of nutrient rich water.

Fur seals are usually observed as single animals at sea, although pairs and groups of three are fairly common. The largest group seen in 15 years of ocean research numbered about 100 animals and was feeding in a large school of anchovies off the Farallon Islands, Calif. Fur seal densities are quite variable ranging from 0 to 20 per km². One day in March 1972, 169 seals were seen during a 12-hour cruise off Grays Harbor, Wash. During 12 other days of that month, the number of seals sighted ranged from 0 to 44.

Fur seals tend to congregate in areas of abundant food supply. They usually feed at night, probably because most

prey species rise toward the surface after dark and are more readily available then.

The four most frequently identified prey species, according to percent of total stomach volumes in the sample and by frequency of occurrence, in stomachs of seals collected off California, Washington, and British Columbia are shown in Tables 2, 3, and 4, respectively. If a single hake appeared in the stomach contents, it is listed whether or not it was in the first four. Little sampling was done off Oregon and, as food items do not differ greatly from those found off northern California or Washington, Oregon data are not presented here. A brief summary of the presence and rank of hake in the stomachs of fur seals off California, Washington, and British Columbia is presented in Table 5.

In California waters in January and February (winter) hake was found in the stomachs of fur seals taken between lat. 33° and 36°N. Northern anchovy, squid, and saury form a major portion of the stomach contents at this time but hake did rank in the first four twice in four sampling periods. During the spring season, March through April, hake was found in samples taken between about lat. 36° and 41°N. These findings suggest that hake may be relatively unavailable in waters off central and northern California in winter but are present and available in spring and early summer.

In Washington and British Columbia waters, hake does not compose a significant part of the fur seal's diet in winter. Although hake is present in spring in the collections from these waters, only once was it among the first four in abundance. The entire northern fur seal population is estimated to be at least 1.8 million, and about 1.2 million may winter in the eastern North Pacific and the Bering Sea. The remaining 0.6 million winter in the western North Pacific, the Sea of Japan, and the Okhotsk Sea (National Marine Fisheries Service, 1976; Fiscus et al., 1977). The numbers of seals wintering in the range of Pacific hake will probably never be known; however, it seems reasonable to suggest that perhaps

500,000 fur seals utilize this area for approximately 3 months each year (January-March) and fewer than 500,000 for an additional 3 months (late November, December, April and May).

Saddleback Dolphin

In the eastern North Pacific, the saddleback dolphin, *Delphinus delphis*, is regularly found from about lat. 42°N south to lat. 10°N over the continental slope and for some distance offshore. Stragglers have been recorded as far north as British Columbia. Large populations occur from about lat. 32°N and southward along the west coast of Baja California. The total population is estimated to be 1.4 million; however, only an unknown portion of this species is found in the range of Pacific hake. This dolphin probably does not occur north of about lat. 38°N in sufficient numbers to have any appreciable effect on hake in the northern part of the hake range. In the California Bight, this species is the most numerous cetacean (Evans, 1976; Norris et al.⁴). Scientists conducting surveys for the BLM sighted approximately 34,000 animals including two schools whose size was estimated at over 8,000 animals in one school and from 6,000 to 7,000 animals in the second school. Prey species include: northern anchovy; Pacific hake; lanternfish, *Mycetophidae* sp.; saury, *Cololabis saira*; and squids, *Gonatus* sp., *Onychoteuthis* sp., and *Loligo opalescens* (Fiscus and Niggol, 1965; Fitch and Brownell, 1968).

Pacific Whiteside Dolphin

The Pacific whiteside dolphin, *Lagenorhynchus obliquidens*, occurs in the eastern North Pacific from the Gulf of Alaska (in summer) south to Baja California. It occurs year round from Washington to California and is com-

Table 2.—Stomach contents of northern fur seals collected off California, 1958-66; the four most important prey species according to percent total stomach volumes and by frequency of occurrence in stomachs of all seals collected during the sampling period (North Pacific Fur Seal Commission, 1962, 1969, 1975).

Year	Season	No. of stomachs with food	Principal prey species ¹		Principal prey species ¹		Sampling area	
			Species	Percent of total volume	Species	Frequency of occurrence		
1958	Winter (Feb.)	111	Saury	31.7	Squid-unident.	89	Central Calif. (Pt. Reyes to Pt. Sur)	
	Squid- <i>Loligo</i>		26.2	Saury	40			
Squid-unident.	10.6		Anchovy	18				
Anchovy	10.0		Jack mackerel	16				
Hake	2.8		Hake	4				
	Spring (Mar. Apr.)	212	Squid-unident.	24.6	Squid-unident.	174	Pt. Reyes to Pt. Conception	
	Hake		22.0	Saury	62			
	Saury		16.7	Hake	52			
	Anchovy		15.9	Jack mackerel	28			
1959	Winter (Jan. Feb.)	617	Anchovy	73.7	Anchovy	436	Pt. Reyes to Pt. Conception	
	Hake		22.0	Hake	207			
	Jacksmelt		1.7	Squid-unident.	126			
	Saury		1.1	Saury	39			
	Spring (Mar. Apr.)	276	Hake	36.3	Squid-unident.	138	Pt. Sur to Crescent City	
	Anchovy		16.3	Hake	111			
	Saury		10.2	Saury	65			
	Jack mackerel		9.2	Anchovy	40			
1961	Winter (Dec. Jan. Feb.)	490	Squid- <i>Onychoteuthis</i>	36.8	Squid- <i>Onychoteuthis</i>	262	Pt. Arena to Cortez Bank	
	Anchovy		27.5	Squid-unident.	157			
	Saury		18.0	Saury	94			
	Squid- <i>Loligo</i>		7.5	Squid-Gonatidae	92			
	Hake		1.1	Hake	9			
		Spring (Mar. Apr.)	75	Anchovy	35.5	Anchovy	26	Pt. Arena to Monterey Bay
		Hake		22.6	Hake	18		
		Squid- <i>Loligo</i>		21.2	Squid- <i>Onychoteuthis</i>	18		
			Shad	3.4	Squid- <i>Loligo</i>	15		
1964	Spring (Apr. May)	228	Hake	73.8	Hake	129	Eureka to Pt. San Louis	
	Squid- <i>Loligo</i>		12.9	Squid- <i>Loligo</i>	74			
	Squid-unident.			Fish unident.	62			
	<i>Onychoteuthis</i>		2.4	Squid- <i>Onychoteuthis</i>	27			
	Anchovy		2.1					
1965	Spring (Apr. May)	145	Hake	39.6	Squid- <i>Loligo</i>	60	Bodega Head to Pt. Sur	
	Squid- <i>Loligo</i>		28.0	Hake	49			
	Rockfish ²		12.2	Fish-unident.	41			
	Anchovy		11.7	Squid- <i>Onychoteuthis</i>	34			
		Summer (June)	81	Anchovy	29.7	Fish unident.	40	Bodega Head to Pt. Sur
		Hake		23.1	Squid- <i>Loligo</i>	25		
1966	Winter (Jan. Feb.)	187	Jack mackerel	14.6	Hake	21	Pt. Reyes to Cortez Bank	
			Squid- <i>Loligo</i>	10.4	Squid- <i>Onychoteuthis</i>	15		
			Anchovy	85.2	Anchovy	123		
			Hake	7.9	Squid- <i>Loligo</i>	60		
		Spring (Mar.)	144	Saury	3.4	Squid- <i>Onychoteuthis</i>	45	Pt. Reyes to Cortez Bank
				Squid- <i>Onychoteuthis</i>	1.3	Fish unident.	42	
				Anchovy	55.6	Anchovy	57	
				Hake	40.8	Hake	47	
			Saury	1.7	Fish unident.	43		
			Magnisudus	1.1	Squid- <i>Onychoteuthis</i>	26		

¹Hake included regardless of its rank among prey species.

²Mostly juvenile fish.

⁴Norris, K. S., T. P. Dohl, R. C. Guess, L. J. Hobbs, and M. W. Honig. 1976. Cetacea. Section II. In Regents of the University of California (editors), Marine mammal and seabird survey of the Southern California Bight area, p. III - 270-441. Draft final report 1975-1976, BLM contract 08550-CT5-28. Regents, Univ. Calif., Santa Cruz, Calif.

mon in southern California inshore waters in winter and spring. Scientists conducting marine mammal surveys in the California Bight for BLM report that the mean herd size varied from 8 in one 3-month period to 167 in another,

with a yearly mean of 90 (Norris et al., footnote 4).

Forty-five percent of the BLM sightings were in association with other cetaceans, (10 percent) pinnipeds, (7 percent) birds, or combination of these

(19 percent). This species may be the most abundant dolphin off northern California, but no estimate of its population size off the west coast of North America has been made.

Prey species include: Pacific herring; northern anchovy; salmon; Pacific hake; saury; jack mackerel, *Trachurus symmetricus*; and the squids, *Loligo opalescens*, *Onychoteuthis borealijaponicus*, *Gonatopsis borealis*, *Abrialopsis* sp., *Gonatus* sp., and *Octopoteuthis* sp. (Fiscus and Niggol, 1965; Fitch and Brownell, 1968; Houck, 1961; Stroud et al.⁵).

Northern Right Whale Dolphin

In the eastern North Pacific, the northern right whale dolphin, *Lissodelphis borealis*, is found along the continental slope and seaward from about lat. 50°N south to about lat. 29°N, although this species is most frequently sighted between lat. 42° and 32°N. It is fairly abundant in California waters and is most frequently seen in pods of several hundred or more. Scientists working on BLM marine mammal surveys in the California Bight reported group sizes from 1 to 500 as follows: 5 sightings (20 percent), groups of 10 or less; 15 sightings (60 percent), groups of 10-100; and five sightings (20 percent), groups of more than 100 (Norris et al., footnote 4). This dolphin was reported in association with birds, pinnipeds, and other cetaceans (46 percent) or alone (64 percent). There are no population estimates available.

Prey species include: northern anchovy, Pacific hake, and squids (Fitch and Brownell, 1968).

Whitehead Grampus

The whitehead grampus, *Grampus griseus*, is found in the eastern North Pacific from British Columbia southward to southern California over the

Table 3.—Stomach contents of northern fur seals collected off Washington by U.S. or Canadian research vessels 1958-68; the four most important prey species according to percent of total stomach volumes and by frequency of occurrence in stomachs of all seals collected during the sampling period (North Pacific Fur Seal Commission, 1962, 1969, 1975).

Year	Season	No. of stomachs with food	Principal prey species ¹		Principal prey species ¹	
			Species	Percent of total volume	Species	Frequency of occurrence
1958	Spring (Mar. Apr.)	50	Rockfish	51.2	Squid-uident.	30
			Herring	17.3	Rockfish	15
			Saury	12.2	Saury	7
			Squid-uident.	11.0	Herring	7
1959	Spring (Mar. Apr.)	123	Rockfish	44.9	Squid-uident.	57
			Sablefish	18.9	Rockfish	44
			Squid-uident.	9.5	Salmon	13
			Herring	7.2	Sablefish	12
			Hake	0.3	Hake	6
1960	Spring (Mar. Apr.)	124	Rockfish	48.0	Squid-uident.	46
			Squid-uident.	24.6	Fish-uident.	36
			Herring	10.2	Rockfish	34
			Anchovy	7.5	Herring	16
1961	Spring (Mar. Apr.)	184	Anchovy	37.8	Anchovy	58
			Rockfish	19.6	Herring	36
			Herring	17.4	Fish-uident.	35
			Shad	5.1	Rockfish	32
			Hake	0.3	Hake	2
1964	Spring (Apr. May)	18	Hake	47.8	Smelt	9
			Smelt	18.0	Hake	4
			Rockfish	15.0	Anchovy	4
			Salmon	12.3	Squid- <i>Loligo</i>	3
1965	Spring (Apr.)	98	Anchovy	47.6	Fish-uident.	39
			Smelt	17.7	Anchovy	21
			Salmon	11.3	Anchovy	20
			Herring	9.3	Smelt	11
1967	Winter (Jan. Feb.)	89	Herring	24.2	Squid- <i>Loligo</i>	47
			Rockfish	17.6	Fish-uident.	20
			Shad	11.5	Herring	15
			Anchovy	11.0	Squid-Gonatidae	14
			Hake	0.3	Hake	2
	Spring (Mar. Apr. May)	32	Salmon	45.4	Squid- <i>Onychoteuthis</i>	9
			Rockfish	14.3	Salmon	8
			Fish-uident.	10.2	Squid- <i>Beryteuthis</i>	7
			Herring	6.0	Squid-uident.	7
			Hake	4.5	Hake	1
1968	Winter (Dec. Jan.)	248	Salmon	22.7	Salmon	45
			Anchovy	15.9	Squid-Gonatidae	39
			Rockfish	14.3	Anchovy	36
			Smelt	11.6	Hake	9
			Hake	3.3		

¹Hake included regardless of its rank among prey species.

continental shelf and slope and seaward. This species is seen regularly but cannot be considered abundant in the area. It usually travels in small groups; however, one group of about 200 was seen off the Washington coast on 20 April 1972. No population estimates are available.

It is not known to prey on hake, but very few stomachs have been examined. The stomach from a grampus stranded on the Washington coast

contained the squids *Onychoteuthis borealijaponicus*, *Octopoteuthis* sp., *Chiroteuthis veranyi*, and *Gonatus fabricii* and two other gonatid species (Stroud, 1968).

Shortfin Pilot Whale

In the eastern North Pacific the shortfin pilot whale, *Globicephala macrorhynchus*, occurs from southern Alaska to the tropics, but it probably does not occur north of about lat. 38°N

⁵Stroud, R. K., C. H. Fiscus, and H. Kajimura. 1979. Food of the Pacific whiteside dolphin (*Lagenorhynchus obliquidens*), Dall porpoise (*Phocoenoides dallii*), and northern fur seal (*Callorhinus ursinus*) off California and Washington. Unpubl. manuscr., 30 p. National Marine Mammal Laboratory, Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

in sufficient numbers to have any appreciable effect on hake in the northern part of the hake range. This species is found in the California Bight at all seasons but in larger numbers during winter. During the California Bight surveys, scientists found that 92 percent of the shortfin pilot whale sightings were of herds of less than 100 animals and in 22 percent of these sightings they were associated with other cetaceans, generally bottlenosed dolphins (Norris et al., footnote 4). No population estimate is available.

It is not known to prey on hake; however, it is capable of doing so. It probably feeds in spawning schools of the squid *Loligo opalescens* in the California Bight area where it has been observed.

Dall Porpoise

The Dall porpoise, *Phocoenoides dalli*, is found in the eastern North Pacific from the Bering Sea to the California Bight and into northern Baja California waters in winter. It is abundant throughout the range of Pacific hake except for that portion south of about lat. 34°N. Between lat. 34° and 32°N, it occurs in fall and winter with few sightings at other seasons. No population estimate is available.

Prey species include: Pacific herring; Pacific hake; saury; jack mackerel; and squids, *Loligo opalescens*, *Gonatus* sp., *Onychoteuthis borealijaponicus*, and *Abraliopsis* sp. (Norris and Prescott, 1961; Scheffer, 1953; Loeb, 1972; Best, 1963; Stroud et al., footnote 5; Cowan, 1944).

Hake Predators Other Than Marine Mammals

Any discussion of predation on hake should mention those predators, in addition to marine mammals, which also include hake in their diet. Almost any large fish or squid probably takes hake whenever encountered. A partial listing of fishes having hake in their stomachs upon capture includes: White shark, *Carcharodon carcharias*; soupfin shark, *Galeorhinus zyopterus*; Pacific electric ray, *Torpedo californica*; longnose lancetfish, *Alepisaurus ferox*; Pacific hake; Pacific bonito, *Sarda*

Table 4.—Stomach contents of northern fur seals collected off British Columbia by Canadian research vessels, 1958-61; and four most important prey species according to percent of total stomach volumes and by frequency of occurrence in stomachs of all seals collected during the sampling period (North Pacific Fur Seal Commission, 1962, 1969, 1975).

Year	Season	No. of stomachs with food	Principal prey species ¹		Principal prey species ¹	
			Species	Percent of total volume	Species	Frequency of occurrence
1958	Spring (Mar.-Apr.)	251	Herring	78.9	Herring	124
			Sablefish	3.3	Squid-unident.	36
			Salmon	2.2	Sablefish	14
			Saury	2.2	Saury	13
			Hake	1.8	Hake	1
1959	Spring (Mar. Apr May)	149	Herring	29.4	Herring	55
			Salmon	20.0	Squid-unident.	46
			Sablefish	16.2	Fish-unident.	44
			Rockfish	13.1	Sablefish	27
			Hake	0.1	Hake	2
1960	Spring (Mar. Apr May)	136	Herring	34.9	Herring	54
			Sandlance	26.9	Fish-unident.	44
			Rockfish	14.9	Squid-unident.	24
			Salmon	6.9	Sandlance	21
			Hake	5.4	Hake	3
1961	Winter (Jan. Feb.)	61	Herring	88.7	Herring	30
			Sablefish	4.0	Fish-unident.	12
			Pacific cod	2.5	Squid- <i>Loligo</i>	7
			Squid- <i>Loligo</i>	1.2	Squid-unident.	6
	Spring (Mar. Apr May)	225	Herring	36.5	Fish-unident.	62
			Salmon	12.1	Squid-unident.	56
			Stickleback	10.4	Herring	52
			Shad	8.9	Stickleback	19
			Hake	3.1	Hake	3

¹Hake included regardless of its rank among prey species.

chiliensis; albacore, *Thunnus alalunga*; bluefin tuna, *Thunnus thynnus*; rockfish; sablefish; lingcod, *Ophiodon elongatus*; bigmouth sole, *Hippoglossina stomata*; and arrowtooth flounder, *Atheresthes stomias* (Best, 1963; Nelson and Larkins, 1970; Pinkas et al., 1971).

This report does not cover all aspects of marine mammal-hake interrelationships, or present complete life histories of all species of marine mammals and fishes that prey upon or are preyed upon by hake. It does provide background information on the life history of hake, the commercial fishery, and information on most marine mammals that interact with hake.

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Table 5.—Summary of data in Tables 2, 3, and 4 on the occurrence of Pacific hake in stomachs of fur seals collected off the western U.S. coast, 1958.

State and season	No. of seasons sampled	Occurrence of hake (from Tables 2, 3, 4)	Occurrence of hake in collection
California			
Winter ¹	4	2	4
Spring ²	6	6	6
Summer ³	1	1	1
Washington			
Winter	2	0	2
Spring	7	1	4
British Columbia			
Winter	1	0	0
Spring	4	0	4

¹Dec., Jan., Feb.

²Mar., Apr., May.

³June.

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