ABUNDANCE, MOVEMENTS, AND FEEDING HABITS OF HARBOR SEALS, *PHOCA VITULINA*, AT NETARTS AND TILLAMOOK BAYS, OREGON

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ABSTRACT

Patterns of seasonal abundance of harbor seals at Netarts and Tillamook Bays, Oregon, were documented by recording numbers of seals hauling out on tidally exposed sand flats in both bays. Harbor seal abundance at Tillamook Bay peaked during pupping (May-June) and molting (August) periods, while peak abundance at Netarts Bay coincided with the annual return (October-November) of chum salmon, *Oncorhynchus keta*, to a hatchery on Whiskey Creek. Observations of seals preying on adult salmon resulted in estimated losses of 6.1, 7.2, and 1.5% of the total chum returns for 1978, 1979, and 1980, respectively, due to seal predation in the Whiskey Creek area. Other prey species of harbor seals at Netarts Bay were identified by the recovery of prey hard parts from seal feces collected on haul-out areas. The Pacific sand lance, *Ammodytes hexapterus*, was the most frequently identified prey item. Ten species of flatfish (Order Pleuronectiformes) were identified as harbor seal prey with five species (*Parophrys vetulus*, *Glyptocephalus zachirus*, *Citharichthys sordidus*, *Microstomus pacificus*, and *Lyopsetta exilis*) ranking among the seven most frequently occurring food items. In general, benthic and epibenthic fish appeared to be important in the harbor seal diet. Distributions, abundances, and estimated sizes of identified prey species indicated that harbor seals had fed both in Netarts Bay and in the nearshore ocean. Movements of radio-tagged harbor seals between Netarts Bay and Tillamook Bay were common (45.4% of tagged seals made at least one move between bays). Tagged harbor seals frequented at least four different estuaries and one coastal haul-out area, ranging from 25 to 550 km from the tagging area.

The Pacific harbor seal, *Phoca vitulina richardsi* (Shaughnessy and Fay 1977), a year-round resident of Oregon, is commonly found in estuaries, along isolated shorelines, and on nearshore rocky islets. Before protection was afforded the harbor seal by the Marine Mammal Protection Act of 1972, a combination of bounties offered by the State of Oregon and traditional harassment from commercial and sport fishermen kept these animals at relatively low numbers in most bays and rivers. During the years following 1972, the numbers of harbor seals seen in many of Oregon's estuaries began to increase. At Netarts Bay, where the Department of Fisheries and Wildlife at Oregon State University operated a hatchery for chum salmon, *Oncorhynchus keta*, a similar increase in harbor seal abundance was observed (Lannan[2]).

A primary objective of the hatchery program at Netarts Bay was to rebuild the vestigial stock of chum salmon that returns annually to Whiskey Creek (Lannan 1975). Each year, during the months of October and November, predation by harbor seals on returning adult chum salmon was observed near the mouth of Whiskey Creek by hatchery staff. Our study of harbor seals in this area was initiated to learn how harbor seals use Netarts Bay and its resources. The specific objectives of this study were to 1) document the seasonal abundance of harbor seals (adults and pups) hauling out in Netarts Bay and in Tillamook Bay, the nearest estuary also used by harbor seals; 2) examine possible movements of harbor seals between Netarts and Tillamook Bays; 3) estimate the level of predation on returning chum salmon by harbor seals near the hatchery; and 4) identify other food items of harbor seals using Netarts Bay.

STUDY AREA AND METHODS

Netarts and Tillamook Bays are located on the northern Oregon coast, 110 and 95 km south of the Columbia River, respectively (Fig. 1). Harbor seal abundance in the bays was monitored by recording the number of animals hauled out on sand flats exposed during low tides. All counts were made from the shoreline using a 45× spotting scope. The numbers of harbor seals were recorded at a minimum of twice per month from May 1977 through November 1981 at Netarts Bay and from June 1978 through November 1981 at Tillamook Bay. A student's t-test was used to ascertain statistical differences in ob-

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[2]J. E. Lannan, Department of Fisheries and Wildlife, Oregon State University, Marine Science Center, Newport, OR 97365, pers. commun. April 1977.

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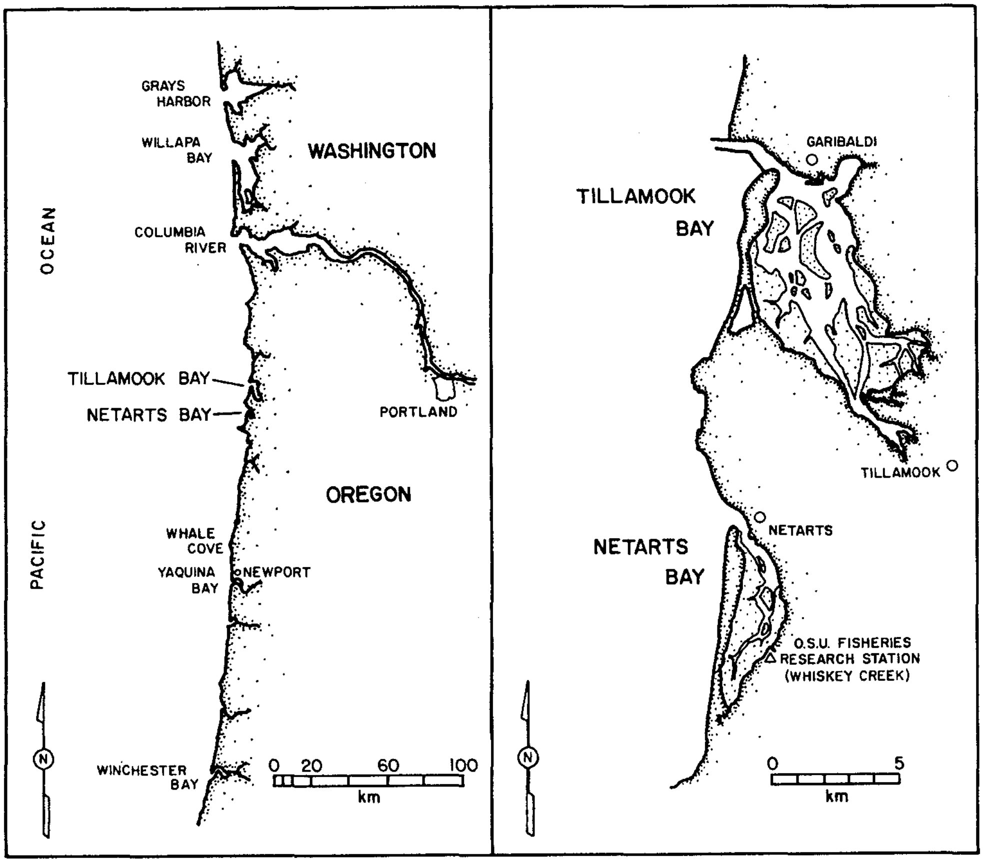


FIGURE 1.—Harbor seal study area of Netarts and Tillamook Bays on the northern Oregon coast.

served abundances between years.

To examine movements, 12 harbor seals were captured in August and October 1978, using a modified gill net (Brown 1981), and tagged with numbered plastic cattle tags and radio transmitters (Telonics Inc., Mesa, Ariz.[3]). The plastic tags were placed in the webbing of each hind flipper of all harbor seals, and radio tags were attached by an anklet to a hind appendage of 11 seals. Each transmitter package (84 g) was operated on a discrete frequency between 148 and 149 MHz, allowing identification of individual animals. Movements of tagged harbor seals were documented by identification of plastic tags and by reception of radio signals from seals carrying transmitters. Radio signals could be received only when tagged animals were out of the water. All haulout sites in Netarts and Tillamook Bays were checked visually and by radio for tagged harbor seals during a minimum of seven low tides per month, from August 1978 through June 1979. An additional 36 harbor seals were tagged and released at Netarts and Tillamook Bays in 1979, 1980, and 1981. Movements of these harbor seals were not monitored on a regular basis.

Harbor seals preying on chum salmon near the mouth of Whiskey Creek were observed during daylight hours from a 4 m high blind using binoculars and a spotting scope. The observation area included the lower 25 m of the creek and a semicircular area centered at the creek mouth and extending out onto the bay at a radius of about 200 m. Whiskey Creek enters Netarts Bay in its shallow upper reaches so that low tides prevent chum salmon from returning to the hatchery. Only when the rising tide has flooded this area can chum salmon approach and enter the creek. Harbor seals use this area only when the tide is high enough to allow them deepwater access or averaged over all observation periods, about 2.5 h before and after the peak of each high tide.

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

The numbers of chum salmon taken by harbor seals in the Whiskey Creek area were estimated by multiplying observed predation rates by the estimated number of hours that seals fed in this area. The observed predation rate was the number of chum salmon seen taken by harbor seals per hour of observation. The number of hours that harbor seals could feed near Whiskey Creek was estimated to be 5 h per high tide over the total number of high tides during each chum salmon run. The impact on the chum salmon return through predation by harbor seals near Whiskey Creek was then calculated as:

$$\text{Percent of total salmon taken by seals} = \frac{\text{estimated no. of salmon taken by seals}}{\begin{array}{c}\text{total no. salmon} \\ \text{taken at hatchery}\end{array} + \begin{array}{c}\text{estimated no. salmon} \\ \text{taken by seals}\end{array}} \times 100$$

Other food items of harbor seals using Netarts Bay were identified by prey hard parts recovered from feces collected on haul-out areas. Harbor seals were not purposely disturbed to gather feces. Samples were collected on an opportunistic basis when harbor seals left the haul-out areas before the flooding tide had covered them. Fecal samples were frozen after collection and later thawed and emulsified in either a 5% buffered Formalin solution or 70% isopropyl alcohol for a period of 24 h. Prey hard parts were removed and stored dry after samples were washed with water over a 0.5 mm sieve.

To estimate the size of fish taken by harbor seals, otoliths removed from fecal samples were measured under a dissecting microscope with an ocular micrometer and, when possible, compared with the lengths of otoliths from fish of known sizes. Data on otolith length versus standard length of fish were gathered from available specimens in collections at the School of Oceanography at Oregon State University. A simple linear regression was performed on these data. Standard body lengths (SL) of fish consumed by harbor seals were estimated for 12 prey species. A subsample of 621 Pacific sand lance, *Ammodytes hexapterus,* otoliths (20.9% of the total number recovered) from 11 randomly selected fecal samples (29.7% of those samples that contained Pacific sand lance otoliths) was measured to estimate the size range of this prey species.

RESULTS AND DISCUSSION

Seasonal Haul-Out Patterns

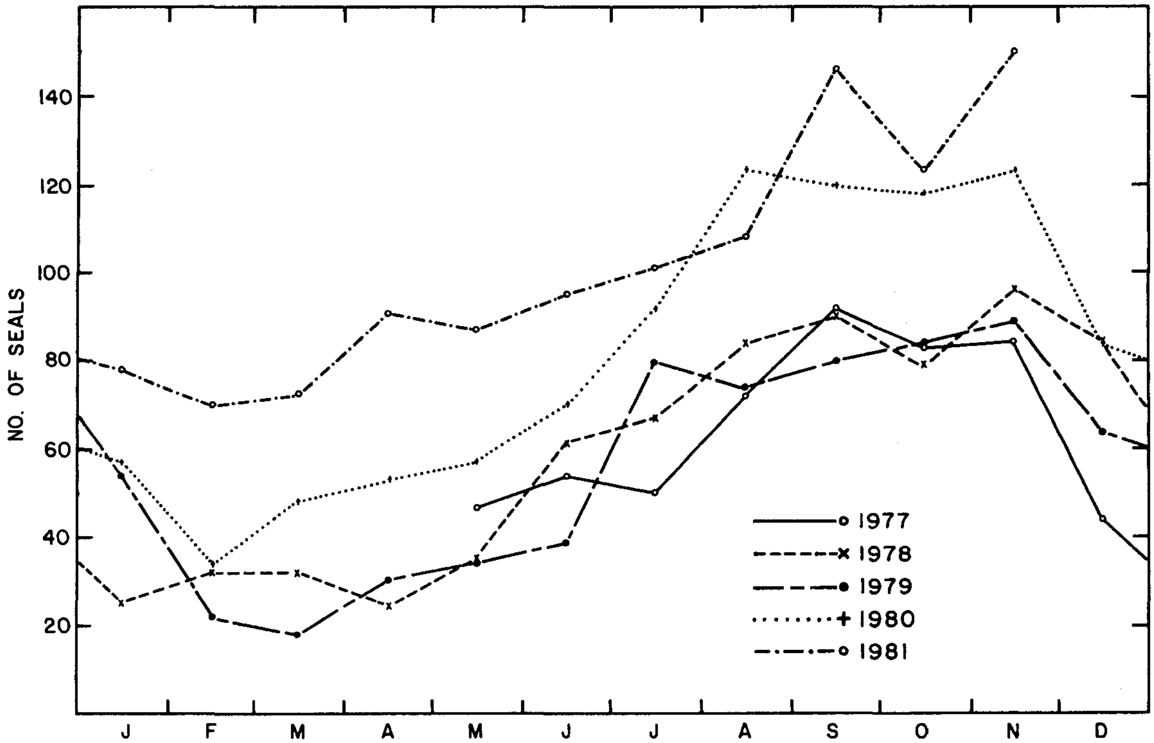
Examination of mean monthly counts of harbor seals hauled out in Netarts Bay revealed a seasonal cycle of low abundance in late winter and early spring, an increase through late spring and summer to a peak in late fall-early winter, followed by a midwinter decline. With the exception of 1977, the highest annual counts were made during the month of November (Fig. 2). Seasonal numbers of harbor seals hauled out in Tillamook Bay showed a general trend of peak abundance during the spring and summer months with relatively lower numbers at other times of the year (Fig. 3).

An increase in the use of Netarts Bay haul-out areas was observed over the latter part of the study period (Fig. 2). Numbers of harbor seals hauled out during the period of peak annual abundance (September-November) were significantly greater in the years 1980-81 than during 1978-79 ($P<0.05$). Similarly, from February through April (annual low abundance) a significantly greater number of harbor seals hauled out during 1980-81 than during 1978-79 ($P<0.05$). There was no apparent change in numbers of harbor seals using Tillamook Bay over the study period (Fig. 3).

In Netarts and Tillamook Bays, pupping began during the first 2 wk of May and peaked in the first 2 wk of June. Molting seals were first observed in late July and the process was generally complete for all animals by early September. Percentages of pups among groups of harbor seals hauled out in the study area during the peak of the pupping periods of 1978-81 ranged from 16.3 to 21.4% at Netarts Bay and from 14.2 to 17.8% at Tillamook Bay (Table 1). Pup counts at Netarts Bay were made at close range and it is unlikely that any newborn pups were missed. However, counts made from aerial photographs have shown that ground censuses at Tillamook Bay underestimated pup abundance and that actual pup percentages in this part of the study area may have been closer to 22.4% in 1980 and 24.3% in 1981 (Jeffries[4]). Similar percentages were reported for harbor seals in British Columbia (20.0%) by Bigg (1969), in northern Puget Sound (13.2 to 19.4%) by Calambokidis et al.,[5] and in the Columbia River and adja-

[4]S. J. Jeffries, Washington State Department of Game, Marine Mammal Project, 53 Portway St., Astoria, OR 97103, pers. commun. August 1982.

[5]Calambokidis, J., K. Bowman, S. Carter, J. Cubbage, P. Dawson, T. Fleischner, J. Schuett-Hames, J. Skidmore, and B. Taylor. 1978. Chlorinated hydrocarbon concentrations and the ecology



	J	F	M	A	M	J	J	A	S	O	N	D
1977					47	54	61	73	110	107	109	55
1978	34	32	32	26	41	70	74	99	100	115	127	97
1979	66	26	23	30	45	46	86	84	100	103	107	85
1980	89	41	69	74	64	86	103	128	123	138	167	83
1981	78	94	95	106	100	108	101	121	161	154	205	

FIGURE 2.—Seasonal abundance of harbor seals at Netarts Bay, Oreg., shown by a plot of monthly mean numbers of seals hauled out in the bay. Listed at bottom of figure are monthly maximum numbers of seals observed on haul-out areas.

cent waters, including Netarts and Tillamook Bays (10.0%), by Everitt et al.[6]

Seasonal increases in numbers of harbor seals hauled out in many areas are common during the pupping and molting periods (Johnson and Jeffries 1977[7]; Everitt et al. 1979; Johnson and Johnson 1979[8]; Stewart 1981). Prior to giving birth, female harbor seals may seek out areas preferred for parturition and nursing. Roffe (1981) described the departure of harbor seals from the Rogue River by the end of April, presumably to use sites more

TABLE 1.—Maximum pup counts, number of non-pup animals present during counts, and number of pups expressed as a percentage of the total number of animals present for the 1978, 1979, 1980, and 1981 harbor seal pupping seasons at Netarts and Tillamook Bays, Oreg.

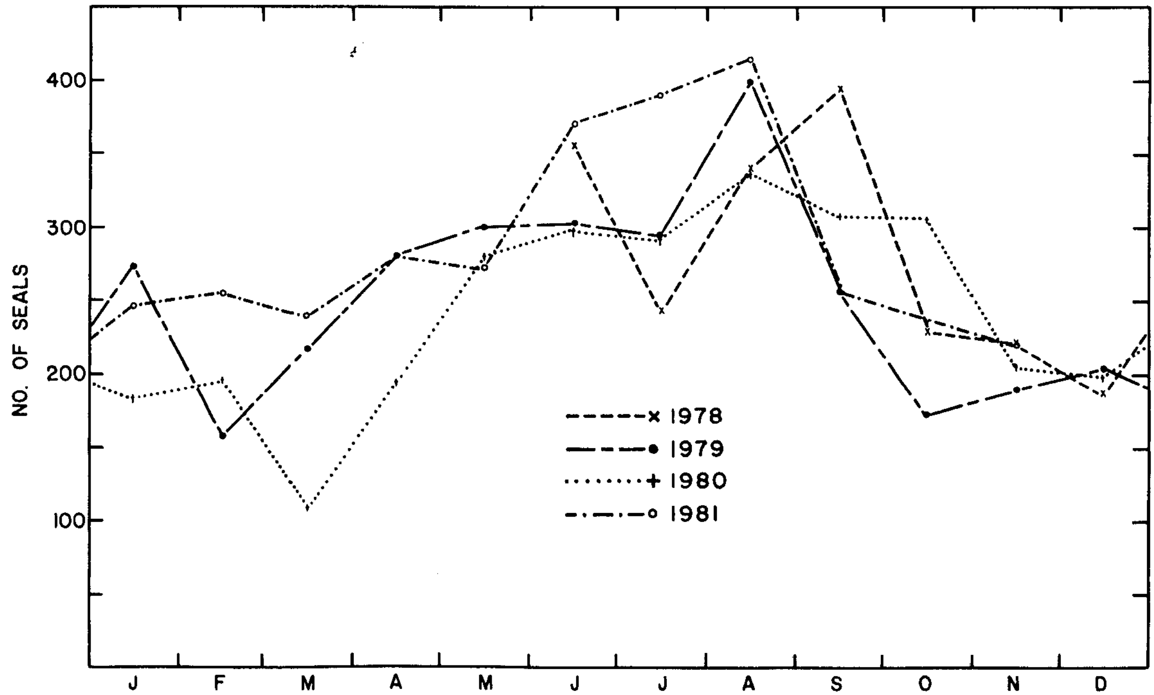
Year	Pups	Netarts	Tillamook Bay
1978	Pups	15	63
	Non-pups	55	381
	Pups/total (X100)	21.4%	14.2%
1979	Pups	9	58
	Non-pups	36	334
	Pups/total (X100)	20.0%	14.8%
1980	Pups	16	55
	Non-pups	80	254
	Pups/total (X100)	16.7%	17.8%
1981	Pups	15	70
	Non-pups	77	330
	Pups/total (X100)	16.3%	17.5%

and behavior of harbor seals in Washington State waters. The Evergreen State College, Olympia, WA 98505, 121 p.

[6]Everitt, R. D., R. J. Beach, A. C. Geiger, S. J. Jeffries, and S. D. Treacy, 1981. Marine mammal-fisheries interactions on the Columbia River and adjacent waters, 1980. [First] Annual Report March 1, 1980 to October 31, 1980. Wash. State Dep. Game to Northwest and Alaska Fish. Cent., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98115, 109 p.

[7]Johnson, M. L., and S. J. Jeffries. 1977. Population evaluation of the harbor seal (*Phoca vitulina richardi*) in the waters of the State of Washington. Contract Report to the U.S. Marine Mammal Commission, Washington, D. C., 27 p. National Technical Information Service, 5285 Port Royal road, Springfield, VA 22151

[8]Johnson, B. W., and P. A. Johnson. 1979. Population peaks during the molt in harbor seals. *In* Abstracts from presentations at the Third Biennial Conference of the Biology of Marine Mammals, October 7-11, 1979, Seattle, Wash., p. 31.



	J	F	M	A	M	J	J	A	S	O	N	D
1978						444	262	375	437	273	260	229
1979	273	200	304	285	392	353	353	485	289	191	255	207
1980	183	195	138	260	312	314	394	434	386	316	250	198
1981	246	307	325	359	330	456	390	414	310	236	220	

FIGURE 3.—Seasonal abundance of harbor seals at Tillamook Bay, Oreg., shown by a plot of monthly mean numbers of seals hauled out in the bay. Listed at bottom of figure are monthly maximum numbers of seals observed on haul-out areas.

desirable for birth and care of young. Beach et al.[9] identified females with neonates in Grays Harbor and Willapa Bay, Wash., and in Tillamook Bay, Oreg., (Jeffries footnote 4) that were tagged as pregnant females in the Columbia River. No pups were observed in the Rogue River and very few were seen in the Columbia River. Peaks in seasonal abundances of harbor seals during the winter months have been observed in the Rogue (Roffe 1981) and Columbia Rivers (Everitt and Jeffries[10]), although this pattern has been less commonly reported.

Local changes in harbor seal abundance may occur in response to variations in the availability of food (Scheffer and Slipp 1944; Fisher 1952; Graybill 1981). Beach et al. (footnote 9) suggested that the winter increase in harbor seal abundance in the Columbia River occurred in response to the presence of eulachon, *Thaleichthys pacificus*, in the river at that time. At Netarts Bay, the late fall return of chum salmon constitutes the only regular occurrence of a salmonid species in the Bay (Lannan footnote 2). The coincidence of peak harbor seal abundance and the chum salmon run suggests that this highly seasonal food source may have influenced harbor seal abundance in the bay.

At Tillamook Bay, seasonal peaks in harbor seal numbers and salmonid abundance did not coincide. The numbers of harbor seals declined to low annual levels from September through December while steelhead, *Salmo gairdneri*; chinook salmon, *Oncorhynchus tshawytscha*; coho salmon, *O. kisutch*; and chum salmon were passing through the estuary (Heckeroth[11]). High counts of harbor seals during the summer did, however, coincide with peaks in annual abundances of northern anchovy, *Engraulis mordax*;

[9]Beach, R. J., A. C. Geiger, S. J. Jeffries, and S. D. Treacy. 1982. Marine mammal-fisheries interactions on the Columbia River and adjacent waters, 1981. Second Annual Report November 1, 1980 to November 1, 1981. Wash. State Dep. Game to Northwest and Alaska Fish. Cent., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98115. NWAFC Proc. Rep. 82-04, 186 p.

[10]Everitt, R. D., and S. J. Jeffries. 1979. Marine mammal investigations in Washington State. *In* Abstracts from presentations at the Third Biennial Conference of the Biology of Marine Mammals, October 7-11, 1979, Seattle, Wash., p. 18.

[11]D. Heckeroth, Oregon Department of Fish and Wildlife, 6617 Officers Row, Tillamook, OR 97141, pers. commun. September 1978.

surf smelt, *Hypomesus pretiosus*; shiner perch, *Cymatogaster aggregata*; Pacific herring, *Clupea harengus pallasi*; and English sole, *Parophrys vetulus*, in Tillamook Bay (Forsberg et al.[12]). All five species were identified as prey of harbor seals using Netarts Bay (see results of fecal analysis) and have been commonly reported as food of harbor seals in other areas (Pitcher 1980a; Bowlby 1981; Graybill 1981; Calambokidis et al. footnote 5; Beach et al. footnote 9).

The differences in seasonal abundances of harbor seals at Netarts and Tillamook Bays may be in part related to the quality of habitat available for pupping and nursing. As in other areas (Johnson and Jeffries footnote 7), harbor seals at Netarts and Tillamook Bays use more haul-out sites within each bay during the pupping season than at other times of the year. Females with pups tend to form smaller, more isolated groups, usually in the more remote parts of the estuaries. Tillamook Bay, because of its greater size and more varied bottom topography, has a larger number of small channels in the upper portions of the bay. These channels rarely carry boat traffic and so offer access to a substantially greater number of preferred haul-out areas for female-pup pairs.

Movements of Tagged Harbor Seals

Between August 1978 and March 1979, 5 of 11 radio-tagged harbor seals (45.4%) made at least one move from Netarts Bay to Tillamook Bay (a distance by sea of about 25 km). Three of the five harbor seals made at least one trip from Netarts Bay to Tillamook Bay and back, and one visited both bays at least twice (Fig. 4). The propensity for movement seemed to vary among individuals. One harbor seal (no. 900) moved between Netarts and Tillamook Bays at least three times during the first 19 d following its release. Another animal (no. 580) was resighted more often and more regularly (27 times in 9 mo) than any other seal, yet was always found at Netarts Bay. Harbor seals carrying plastic tags have been identified at Netarts Bay up to 29 mo after tagging.

Long-range movements of harbor seals tagged in 1979, 1980, and 1981 include one harbor seal that traveled 75 km south (Whale Cove; Fig. 1) and later returned to Netarts Bay, and another animal that was found hauled out among a large group of harbor seals about 220 km south of the tagging site (Winchester Bay; Fig. 1). Single flipper tags from two harbor seals were recovered during commercial fishing operations at two locations. One tag was found entangled in a set herring gill net in Humboldt Bay, Calif., 550 km south of Netarts Bay, and another tag was recovered in a scallop drag fishing operation 75 km north of the tagging site.

Similar evidence of haul-out site fidelity and long-distance movements in harbor seals has been reported for other areas. A newborn pup, flipper-tagged on Tugidak Island, Alaska, was found 3 yr later <5 km from the tagging site (Divinyi 1971). Bonner and Witthames (1974) reported the dispersal of 55 flipper-tagged juveniles from the Wash, East Anglia, England, and their subsequent recovery up to 250 km from the tagging area. Pitcher and McAllister (1981) radio-tagged 35 harbor seals in Alaska and reported that while 8 animals had used haul-out areas, ranging from 24 to 194 km from the tagging site, 23 were found only at the hauling area where they were captured.

Predation on Chum Salmon at Whiskey Creek

Predation on chum salmon by harbor seals was not often seen in other parts of the bay. Harbor seals clearly took advantage of the concentrations of fish that occurred as chum salmon funneled from the wide open bay into the narrow mouth of Whiskey Creek. Harbor seals preying on chum salmon in this area took an estimated 6.1, 7.2, and 1.5% of the 1978, 1979, and 1980 returns, respectively (Table 2). It is important to note that while the average number of harbor seals feeding in this area per high tide was similar from year to year, the percent loss of each

TABLE 2.— Estimated impacts on 1978, 1979, and 1980 chum salmon returns at Netarts Bay, Oreg. through predation by harbor seals in the Whiskey Creek area.

	1978	1979	1980
Observation hours[1] (days)	44(11)	76.5(15)	91.6(28)
Mean estimated no. seals feeding/high tide	5.0	4.1	5.4
No. salmon seen taken by seals	22	12	24
No. salmon trapped following observation periods	432	242	3,015
Total no. salmon trapped	1,774	539	4,972
Observed predation rate (salmon/hour)	0.5	0.2	0.3
Estimated no. hours seals fed in area during run	230	210	255
Estimated no. salmon taken by seals	115	42	76.5
Percent of total return taken by seals (95% C.L.)	6.1(±4.9)	7.2(±5.5)	1.5(±0.9)

[1]Observation periods averaged 4.1 and ranged from 1.2 to 7.3 h in duration.

[12]Forsberg, B. D., J. A. Johnson, and S. M. Klug. 1977. Identification, distribution, and notes of food habits of fish and shellfish in Tillamook Bay, Oregon. Federal Aid Progress Reports, Fisheries, Contract No. 14-16-0001-5456RBS, Research Section, Oregon Department of Fish and Wildlife, 117 p.

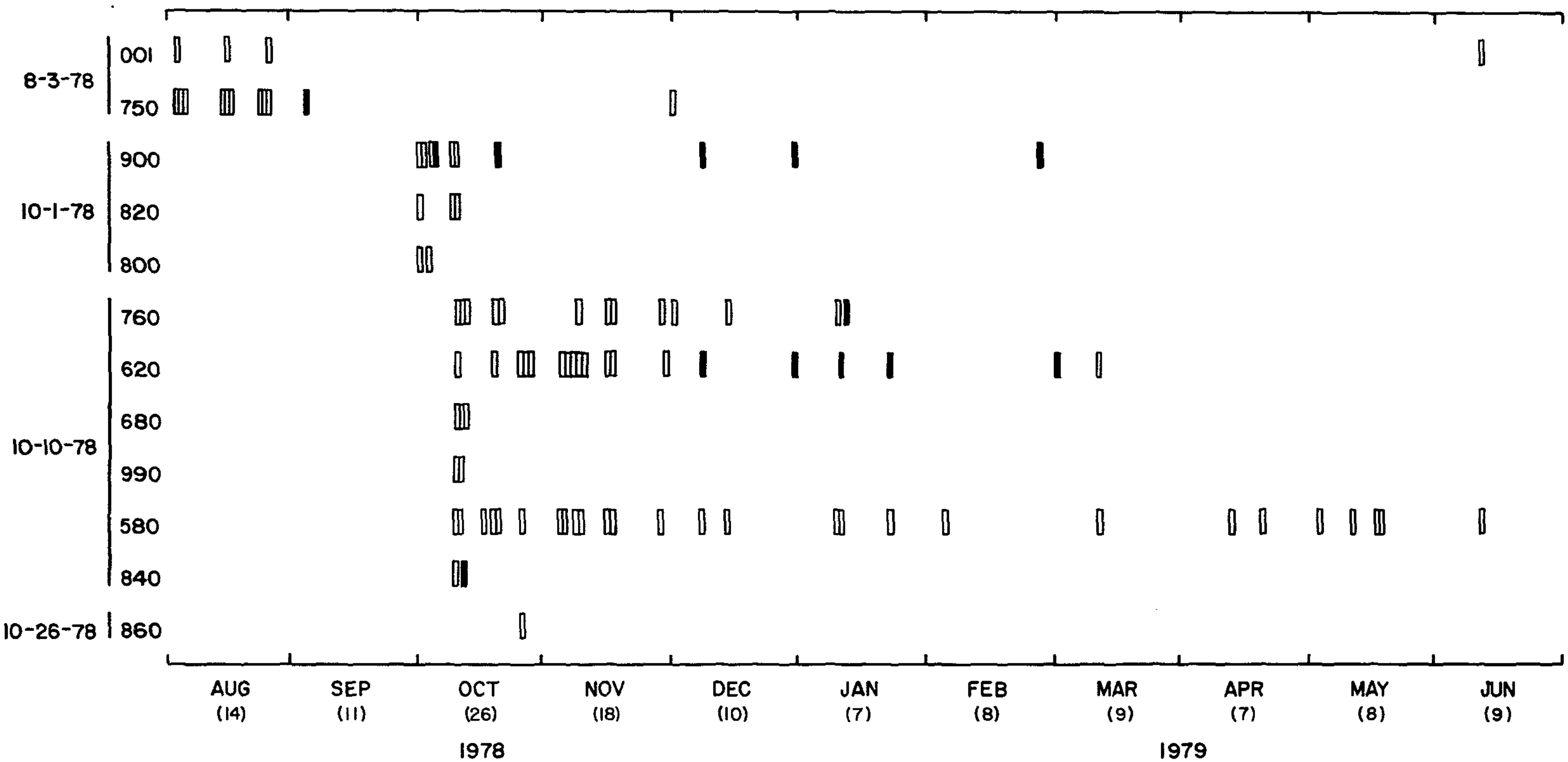


FIGURE 4.—Summary of radio signal receptions and visual sightings of 12 harbor seals captured, tagged, and released at Netarts Bay, Oreg. (tagging date appears at left margin). Open and closed boxes represent identification of tagged seals at Netarts and Tillamook Bays, respectively. Figures in parentheses under months are resighting efforts in number of haul-out periods (low tides) per month that were checked for tagged seals.

return declined as the number of returning chum salmon increased. The hydrography of this area may set an upper boundary on predation by limiting the number of harbor seals that can occupy the area and the amount of time during which feeding can occur.

These estimates assume that predation rates were equal during both day and night high tides. Night feeding by harbor seals has been reported as common behavior in many areas (Scheffer and Slipp 1944; Spalding 1964; Boulva and McLaren 1979; Roffe 1981). Generally, more chum salmon return to the Netarts Bay hatchery on high tides at night, resulting in a potential for greater losses at this time. However, as visual predators, harbor seals may be less successful at capturing free-swimming chum salmon at night. In the unlikely event that no predation occurred at night, the estimated losses would be half those presented in Table 2. Unrecorded feeding events within the observation area were believed to be few since harbor seals usually bring large fish, such as salmon, to the surface at least once during consumption. The predation estimates presented here may underestimate the overall impact on the return, since any predation on salmon occurring in other parts of the bay was not considered.

Other Harbor Seal Prey Items

Identifiable prey hard parts (fish otoliths and teeth) were found in 95 (63.3%) of 150 harbor seal fecal samples collected at Netarts Bay from May 1977 through August 1979. Teeth from hagfish (*Eptatretus* sp.) were present in six samples; teeth of the arrowtooth flounder, *Atheresthes stomias*, were found in three samples; and 3,800 fish otoliths were recovered from 91 samples, representing a total of at least 27 different prey species (Table 3). Since the majority of those samples containing identifiable prey hard parts (91.5%) were collected during the months of August, September, and October, some of the species listed in Table 3 may be only seasonally important in the diet of harbor seals in this area. The presence or absence of chum salmon otoliths in the harbor seal feces could not be documented, since attempts to collect samples during the chum salmon returns were unsuccessful. The 12 prey species for which size was estimated ranged from 40 to 280 mm SL (Table 4).

Otoliths of the Pacific sand lance, found in 37 (38.9%) of the 95 samples containing identifiable hard parts, were the most common in the collection. A minimum of 1,503 Pacific sand lance was represented, with a mean number per sample of 40.6 (range of 1-338 per sample). These fish may have been taken by harbor seals within Netarts Bay. In a limited survey of the icthyofauna of Netarts Bay, the size range of Pacific sand lance found by Howe (1980) (60-140 mm SL) was similar to that taken by harbor seals in the present study (80-130 mm SL).

TABLE 3.—Fish species identified as harbor seal prey by recovery and identification of prey hard parts (otoliths and teeth) from seal fecal samples collected at Netarts Bay, Oreg. Prey items are ranked by frequency of occurrence in 95 samples that contained identifiable hard parts. The minimum number of each species represented in the entire collection is presented.

Species	Frequency No.	Frequency %	Minimum no. fish
Ammodytes hexapterus	37	38.9	1,503
Parophrys vetulus	30	31.6	126
Glyptocephalus zachirus	25	26.3	79
Citharichthys sordidus	17	17.9	53
Leptocottus armatus	16	16.9	54
Microstomus pacificus	16	16.9	39
Lyopsetta exilis	11	11.6	16
Clupea h. pallasi	8	8.4	22
Allosmerus elongatus	7	7.4	10
Eptatretus sp.	6	6.3	6
Sebastes sp.	5	5.3	20
Microgadus proximus	5	5.3	6
Cymatogaster aggregata	5	5.3	24
Hexagrammos decagrammus	4	4.2	6
Thaleichthys pacificus	4	4.2	11
Anoplopoma fimbria	4	4.2	14
Citharichthys stigmaeus	4	4.2	20
Isopsetta isolepis	4	4.2	6
Hypomesus pretiosus	3	3.2	8
Atheresthes stomias	3	3.2	3
Platichthys stellatus	2	2.1	1
Engraulis mordax	2	2.1	4
Psettichthys melanostictus	2	2.1	2
Embiotocid juveniles	2	2.1	7
Salmo gairdneri	1	1.0	1
Spirinchus starksi	1	1.0	1
Merluccius productus	1	1.0	1
Radulinus asprellus	1	1.0	1
Unidentified osmerid	1	1.0	2
Unidentified embiotocid	1	1.0	1
Unidentified pleuronectid	1	1.0	1
Total			2,048

The Pacific sand lance has been frequently reported as prey of harbor seals in the northeastern Pacific (Scheffer and Sperry 1931; Calambokidis et al. footnote 5; Pitcher 1980a), but has not been identified as a numerically important prey species. Pacific sand lance otoliths were found in only 2.6% of 387 harbor seal fecal samples collected in Washington (Beach et al. footnote 9) and in just 4.0% of 296 samples collected in Oregon (Graybill 1981).

Ten species of flatfishes (Order Pleuronectiformes) were identified as food of harbor seals hauling out in Netarts Bay. Of these species, five (*Parophrys vetulus*, *Glyptocephalus zachirus*, *Citharichthys sordidus*, *Microstomus pacificus*, and *Lyopsetta exilis*) were each found in 11.6% or more of the samples. English sole otoliths were found in 30 (31.6%) of the 95 fecal samples and ranked second only to the Pacific

TABLE 4.—Estimated sizes of 12 harbor seal prey species based on the relationship between otolith length (OL) and standard length (SL) of collected fish specimens. Also given are the coefficient of determination (r^2) and the sample sizes of otoliths from both the collected fish specimens and the fecal samples.

Species	Regression equation	r^2	No. otoliths from: Collected specimens	No. otoliths from: Fecal samples	Estimated prey size (SL,mm): Range	Estimated prey size (SL,mm): Mean
Ammodytes hexapterus	SL = 25.0(OL) +52.2	0.98	8	621	80-130	95
Parophrys vetulus	SL = 33.3(OL)−17.7	0.98	81	140	40-240	70
Glyptocephalus zachirus	SL = 50.0(OL)−51.0	0.96	78	113	50-280	165
Citharichthys sordidus	SL = 50.0(OL)−53.5	0.86	46	74	40-215	60
Leptocottus armatus	SL = 33.3(OL)−43.7	0.96	14	85	40-210	110
Microstomus pacificus	SL = 50.0(OL)−31.0	0.94	45	62	70-210	150
Lyopsetta exilis	SL = 50.0(OL)−15.0	0.96	47	21	80-205	135
Microgadus proximus	SL = 20.0(OL)−28.4	0.98	61	8	40-230	140
Cymatogaster aggregata	SL = 20.0(OL)−10.4	0.98	34	31	65-110	85
Citharichthys stigmaeus	SL = 33.3(OL)−11.7	0.92	61	29	50-100	65
Isopsetta isolepis	SL = 33.3(OL)− 5.3	0.96	44	10	70-260	180
Psettichthys melanostictus	SL = 50.0(OL)−44.5	0.94	14	2	100-180	140

sand lance by frequency of occurrence. However, English sole otoliths represented far fewer fish (a minimum of only 126, with a mean number of 4.2 and a range of 1-38 per sample) than did those of the Pacific sand lance. This observation may reflect differing prey densities (e.g., schooling behavior in the Pacific sand lance) or variation in the passage rates of otoliths from different species.

English sole taken by harbor seals using Netarts Bay ranged from 40 to 240 mm SL, but about 90% were under 100 mm SL. Since English sole (juveniles) ranging from 39 to 120 mm SL were common in Netarts Bay (Howe 1980) and very few under 100 mm SL were found in the nearby coastal ocean (Demory 1971), it is likely that harbor seals fed on most of these fish within the bay. In contrast, Morejohn et al.[13] found harbor seals hauling out in Elkhorn slough, Calif., had taken primarily larger (120-320 mm SL) English sole from over the oceanic shelves, rather than smaller (20-140 mm SL) sole that were widely distributed throughout the slough.

Rex, Dover, and slender sole (*Glyptocephalus zachirus*, *Microstomus pacificus*, and *Lyopsetta exilis*), ranking third, sixth, and seventh, respectively, by frequency of occurrence in the harbor seal fecal samples (Table 3), were not found in Netarts Bay by Howe (1980). Demory (1971) found small (≤180 mm SL) rex, Dover, and slender sole in no less than 20, 10, and 30 fathoms of water, respectively. These fish species, and the few larger English sole, were most likely taken by harbor seals outside of Netarts Bay. Demory (1971) also found little separation by depth of large and small flatfish of the same species. Although harbor seals had taken some larger fish, they may have selected primarily for rex, Dover, and slender sole under 200 mm SL.

Flatfishes (Order Pleuronectiformes) have been a frequently reported prey of harbor seals (Imler and Sarber 1947; Morejohn et al. footnote 13; Pitcher 1980a; Bowlby 1981) and a numerically important group. Scheffer and Sperry (1931) identified flatfish in 28.4% of 79 harbor seal stomachs collected in Washington. Beach et al. (footnote 9) reported 9 Pleuronectiforme species in 27.1% of 387 seal fecal samples collected in the Columbia River and southwestern Washington. Graybill (1981) identified 12 pleuronectid species, representing 27% of all fish identified in 296 seal fecal samples collected in southern Oregon.

There are limitations to the utility of feces collection and prey hard part identification in the analysis of feeding habits. The relative importance of different prey in the diet may be biased if the ratio between consumption of the head (i.e., otoliths and teeth) and the body is not the same for all species. Some observations suggest that the heads of large fish, such as salmon, may not be consumed as often as those of smaller ones (Scheffer and Slipp 1944; Boulva and McLaren 1979; Pitcher 1980b; Roffe 1981). Harbor seals at Netarts Bay have occasionally been observed consuming heads of adult chum salmon (average weight 4.5 kg). Thus they are able to swallow fish of considerably larger size than those identified from the otolith collection. The magnitude of this potential bias is not known.

Other sources of bias in the relative importance of identified food items included variation in rates of digestion or passage through the gastrointestinal tract of hard parts from different prey species (Pitcher 1980b). Variation in the amount of time between seal feeding and hauling out may have resulted in the otoliths of some species being eliminated in the water. Prey items that lack resistant hard parts will

[13]Morejohn, G. V., J. T. Harvey, R. C. Helm, and J. L. Cross. 1979. Feeding habits of harbor seals, *Phoca vitulina*, in Elkhorn Slough, Monterey Bay, California. Unpubl. manuscr., 30 p. Oregon State University, Marine Science Center, Newport, OR 97365.

not be identified. Even in the presence of such limitations, feces collection and prey hard part identification can provide useful information on the prey species being used by seals (Pitcher 1980b).

SUMMARY AND CONCLUSIONS

The seasonal abundance of harbor seals auling out in Tillamook Bay displayed a general peak during June, July, and August, coincident with the pupping and molting periods. These high counts did not coincide with the fall peak in salmonid abundance in the bay. Two other factors may be more important in regulating seal abundance here: 1) High densities of many smaller fish species, known to be seal prey, occur during the summer months, and 2) Tillamook Bay provides the habitat preferred by seals during the pupping season.

The peak in the seasonal abundance of harbor seals at Netarts Bay coincided with the return of chum salmon to the Whiskey Creek hatchery during the months of October and November. Conditions for successful predation were ideal here: Shallow water, narrow channels, the concentrating effect that occurs as salmon funneled into the creek, and a general lack of disturbance to feeding harbor seals. Compared with the fall, the lower numbers of harbor seals hauled out during the spring months may indicate that Netarts Bay was not a highly preferred pupping area.

The estimated losses to the Netarts Bay chum salmon returns through harbor seal predation at Whiskey Creek (1.5-7.2% per year) might have been tolerated if numbers of returning chum salmon were great enough to provide ample brood stock for future releases (Lannan[14]). However, while an attempt was being made to build the stock, any loss of eggs through predation on female spawners was considered serious.

Recovery and identification of prey hard parts from feces indicated that while feeding in Netarts Bay and in coastal waters, harbor seals appeared to select fish species that were found near the bottom of the water column. The seven top-ranking food items were benthic or epibenthic species, or, as in the case of the Pacific sand lance, spent at least some time closely associated with the bottom (Howe 1980).

As evidenced by movements of tagged animals, interchange of harbor seals between coastal estuaries was common and occurred up to distances of at least 550 km. Groups of harbor seals hauling out in different estuaries apparently do not represent isolated stocks, but may instead be part of a common population of animals. The movements of harbor seals were seemingly related to the use of particular areas specifically preferred by harbor seals for feeding, for birth and care of young, or for both.

[14]J. E. Lannan, Department of Fisheries and Wildlife, Oregon State University, Marine Science Center, Newport, OR 97365, pers. commun. March 1980.

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LITERATURE CITED

BIGG, M. A.
1969. The harbour seal in British Columbia. Fish. Res. Board Can., Bull. 172, 33 p.

BONNER, W. N., AND S. R. WITTHAMES.
1974. Dispersal of common seals (*Phoca vitulina*), tagged in the Wash, East Anglia. J. Zool. (Lond.) 174:528-531.

BOULVA, J., AND I. A. MCLAREN.
1979. Biology of the harbor seal, *Phoca vitulina*, in eastern Canada. Fish. Res. Board Can., Bull. 200, 24 p.

BOWLBY, C. E.
1981. Feeding behavior of pinnipeds in the Klamath River, northern California. M.A. Thesis, Humboldt State Univ., Arcata, Calif., 74 p.

BROWN, R. F.
1981. Abundance, movements and feeding habits of the harbor seal, *Phoca vitulina*, at Netarts Bay, Oregon. M.S. Thesis, Oregon State Univ., Corvallis, 69 p.

DEMORY, R. L.
1971. Depth distribution of some small flatfishes off the northern Oregon-southern Washington coast. Res. Rep. Fish. Comm. Oreg. 3:44-48.

DIVINYI, C. A.
1971. Growth and movements of a known-age harbor seal. J. Mammal. 52:824.

EVERITT, R. D., C. H. FISCUS, AND R. L. DELONG.
1979. Marine mammals of the northern Puget Sound and the

Strait of Juan de Fuca, a report on investigations November 1, 1977-October 31, 1978. U.S. Dep. Commer., NOAA Tech. Memo. ERL MESA-41, 191p.

FISHER, H. D.
1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Fish. Res. Board Can., Bull. 93, 58 p.

GRAYBILL, M. R.
1981. Haul out patterns and diet of harbor seals, *Phoca vitulina*, in Coos County, Oregon. M.S. Thesis, Univ. Oregon, Eugene, 56 p.

HOWE, K. M.
1980. Habitats, distribution and abundance of the summer ichthyofauna of Netarts Bay, Oregon. Oreg. State Univ. Agric. Exp. Stn. Tech. Pap. 5416, 38 p.

IMLER, R. H., AND H. R. SARBER.
1947. Harbor seals and sea lions in Alaska. U.S. Fish Wildl. Serv., Spec. Sci. Rep. 28, 23 p.

LANNAN, J. E.
1975. Netarts Bay chum salmon hatchery. An experiment in ocean ranching. Oreg. State Univ. Sea Grant Coll. Prog. Publ. ORESU-H-75-001, Agric. Exp. Stn., Stn. Bull. 621, 28 p.

PITCHER, K. W.
1980a. Food of the harbor seal, *Phoca vitulina richardsi*, in the Gulf of Alaska. Fish. Bull., U.S. 78:544-549.
1980b. Stomach contents and feces as indicators of harbor seal, *Phoca vitulina*, foods in the Gulf of Alaska. Fish. Bull., U.S. 78:797-798.

PITCHER, K. W., AND D. C. MCALLISTER.
1981. Movements and haulout behavior of radio-tagged harbor seals, *Phoca vitulina*. Can. Field-Nat. 95:292-297.

ROFFE, T. J.
1981. Population, food habits, and behavior of pinnipeds in the Rogue River and their relation to salmonid runs. Ph.D. Thesis, Oregon State Univ., Corvallis, 155 p.

SCHEFFER, T. H., AND C. C. SPERRY.
1931. Food habits of the Pacific harbor seal, *Phoca richardii*. J. Mammal. 12:214-226.

SCHEFFER, V. B., AND J. W. SLIPP.
1944. The harbor seal in Washington State. Am. Midl. Nat. 32:373-416.

SHAUGHNESSY, P. D., AND F. H. FAY.
1977. A review of the taxonomy and nomenclature of north Pacific harbour seals. J. Zool. (Lond.) 182-385-419.

SPALDING, D. J.
1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbia coast. Fish. Res. Board Can., Bull. 146, 52 p.

STEWART, B. S.
1981. Seasonal abundance, distribution, and ecology of the harbor seal, *Phoca vitulina richardsi*, on San Miguel Island, California. M.S. Thesis, San Diego State Univ., San Diego, Calif., 66 p.