PREY OF THE STELLER SEA LION, *EUMETOPIAS JUBATUS*, IN THE GULF OF ALASKA

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ABSTRACT

Stomach contents of 250 Steller sea lions, *Eumetopias jubatus*, collected in the Gulf of Alaska consisted by volume of 95.7% fishes, 4.2% cephalopods, <0.1% decapod crustaceans, <0.1% shelled-gastropods, and <0.1% mammals. The 10 top-ranked prey were walleye pollock, *Theragra chalcogramma*; squids, Gonatidae; Pacific herring, *Clupea harengus pallasi*; capelin, *Mallotus villosus*; Pacific cod, *Gadus macrocephalus*; salmon, *Oncorhynchus* spp.; octopus, *Octopus* sp.; sculpins, Cottidae; flatfishes, Pleuronectidae; and rockfishes, Scorpaenidae. Walleye pollock was the predominant prey, composing about 58% of the total volume and occurring in 67% of the stomachs with food. Predation on capelin and salmon appeared to be largely limited to spring and summer when these species were abundant in nearshore waters. Utilization of walleye pollock by sea lions appeared to have increased between 1958-60 and 1975-78, perhaps because of an increase in the relative abundance of walleye pollock. There was nearly complete overlap in the diet of sea lions and the harbor seal, *Phoca vitulina richardsi*. Potential competition may have been ameliorated by differences in distribution, differing diving capabilities, a more diverse diet for harbor seals and use of larger prey by sea lions.

The importance of knowledge of diets of marine mammals has become increasingly apparent with the recent emphasis in offshore oil and gas development and the resulting potential for reduction or change in composition of prey resulting from pollution (Evans and Rice 1974). These data are also needed by both fisheries and marine mammal managers, particularly since recent legislation (The Marine Mammal Protection Act of 1972; United States PL 92-522 and The Fishery Conservation and Management Act of 1976; PL 94-265) requires management based on ecosystem concerns.

Between 1975 and 1978 I studied prey utilization by the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska from Cape Suckling to Sanak Island (Figure 1). This area contains an estimated 110,000 to 140,000 sea lions, 10 breeding rookeries, and a mimimum of 50 hauling areas and is considered to be the center of abundance for the species (Calkins and Pitcher[2]).

Several prior studies of sea lion foods (Imler and Sarber 1947; Mathisen et al. 1962; Thorsteinson and Lensink 1962; Fiscus and Baines 1966), although limited in geographic and seasonal coverage, provide a base for comparisons of prey use over time. Historical records of prey abundance (Pereyra and Ronholt[3]) provide valuable insight into prey utilization. The results of a concurrent study of harbor seal, *Phoca vitulina richardsi*, foods (Pitcher 1980) allowed me to compare prey utilization of these two resident pinnipeds with largely overlapping distributions.

METHODS

Between 1975 and 1978, 250 sea lions were collected by shooting from nearshore waters, rookeries, and hauling areas of the Gulf of Alaska (Table 1). Stomach contents were removed in the field, wrapped in muslin, and preserved in 10% Formalin.[4] In 15 cases, when large amounts of freshly eaten prey occurred, the prey were weighed, identified from external characteristics, and disposed of in the field. Volume (cubic centimeters) and weight (grams) of prey were assumed to be equal in these samples (Fiscus and

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[2]Calkins, D. G., and K. W. Pitcher. 1981. Population assessment, ecology and trophic relationships of Steller sea lions in the Gulf of Alaska. Outer Continental Shelf Environmental Assessment Program Final Report. Juneau Project Office, P.O. Box 1808, Juneau, AK 99802.

[3]Pereyra, W. R., and L. L. Ronholt. 1976. Baseline studies of demersal resources of the northern Gulf of Alaska shelf and slope. U.S. Dep. Commer., NOAA Processed Rep. NMFS NWFC, 281 p.

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

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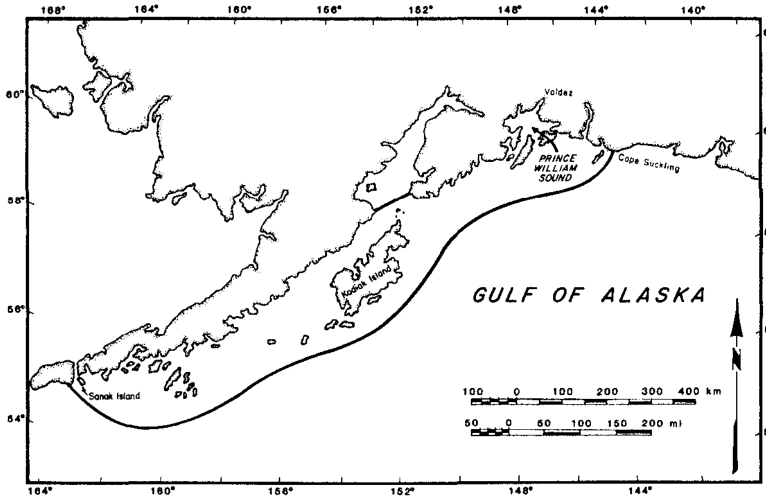

FIGURE 1.—Portion of the Gulf of Alaska where Steller sea lion prey utilization studies were conducted.

TABLE 1.—Comparison of seasonal and geographical distributions of 548 harbor seals and 250 Steller sea lions collected in the Gulf of Alaska. Numbers in the table are percentages of the samples taken during a particular season or in a geographical area.

Species	Winter	Spring	Summer	Fall	Northeastern Gulf of Alaska	Prince William Sound[1]	Kenai	Lower Cook Inlet	Kodiak	Alaska Peninsula
Harbor seals	21.7	44.3	13.3	20.7	5.7	35.8	10.9	6.8	36.7	4.2
Steller sea lions	28.4	35.2	6.0	30.4	4.4	37.2	17.2	0	34.4	6.8

[1]Includes 45 harbor seals from the Copper River Delta.

Baines 1966). For all other samples, volumes and occurrences of the various prey categories were determined in the laboratory. Prey identifications were based primarily on skeletal materials, particularly fish otoliths and cephalopod mandibles (beaks) (Fitch and Brownell 1968; Pinkas et al. 1971). Otoliths and other skeletal components from fish were identified to the lowest taxon possible by comparison with reference materials.

Food habit data were organized and examined as percentage of occurrence (number of stomachs in which a prey item occurred/total number of stomachs with food) and percentage of total volume (total volume of a prey item/total volume of all stomach contents). Confidence intervals for percentages of occurrence were calculated from tables presented by Rohlf and Sokal (1969). In the percent occurrence analysis, unimportant small but numerous organisms may be disproportionately evident (Perrin et al. 1973) as may species which have hard parts which resist digestion (Fiscus and Baines 1966). Volumetric analyses are distorting because various organisms are digested at different rates and because contents are at different stages of digestion when the collections are made (Perrin et al. 1973).

A combination rank index (CRI) was devised to integrate volumetric and occurrence data into a single indicator of prey use. Each prey category was ranked in descending order of percentage of occurrence and percentage of volume. The two rankings for each prey category were multiplied together to produce the CRI.

To compare sizes of walleye pollock, *Theragra chalcogramma*, eaten by Steller sea lions and harbor seals, random samples of walleye pollock otoliths recovered from stomachs were measured (total length). Fork lengths of the fish were then estimated, using a formula derived from regression analysis of otolith length and fish length (Frost and Lowry 1981). Estimated mean fork lengths are given in Table 2.

TABLE 2.—Estimated mean fork lengths based on otolith lengths, of walleye pollock eaten by Steller sea lions and harbor seals.

Item	Sea lions	Harbor seals
Otolith measurements, no.	2,030	2,180
Estimated mean fork length, cm	29.8	19.2
Standard deviation, cm	11.6	9.6
Range, cm	5.6-62.9	4.2-53.2

RESULTS AND DISCUSSION

Prey items were found in 153 of 250 sea lion stomachs examined. Fishes made up 95.7%, cephalopods 4.2%, decapod crustaceans <0.1%, shelled gastropods <0.1%, and mammals <0.1% of the volume of stomach contents (Table 3). Fishes included 14 species representing 11 families. Gadidae composed 59.7% of the total stomach contents and occurred in 82.4% of the stomachs with food. Walleye pollock was by far the dominant prey composing 58.3% of the total volume of stomach contents and occurring in 66.7% of the stomachs with food. Cephalopod remains occurred in 36.6% of stomachs with contents but made up only 4.2% of the total volume of stomach contents. This apparent disparity was probably the result of retention of cephalopod beaks in stomachs (Pitcher 1981) and the volumetric measurement was probably the most accurate measure of importance of cephalopods in the sea lion diet. Invertebrates other than cephalopods were found in 9.2% of the stomachs with food but composed <0.1% of total volume. Remains of two harbor seals were found in one stomach. Major prey were ranked (Table 4) using CRI.

TABLE 3.—Stomach contents of 153 Steller sea lions collected in the Gulf of Alaska.

Prey	Occurrence[1] No.	%[2]	95% C. I.[3]	Volume ml	%[4]
Gastropoda:					
Snails	2	1.3	0.1-4.5	20	<0.1
Cephalopoda	56	36.6	29.5-45.0	15,777	4.2
Octopus, *Octopus* sp.	20	13.1	8.2-19.2	250	<.1
Squids, Gonatidae	35	22.9	16.7-30.4	15,507	4.2
Unidentified cephalopods	1	.7	.1-4.5	20	<.1
Decapoda	11	7.2	3.6-12.2	130	<.1
Shrimps	8	5.2	2.2-9.7	100	<.1
Snow crab, *Chionoecetes* sp.	2	1.3	.1-4.5	20	<.1
Spider crab, *Hyas* sp.	1	.7	.1-4.5	10	<.1
Unidentified invertebrates	1	.7	.1-4.5	10	<.1
Rajidae:					
Skate, *Raja* sp.	1	.7	.1-4.5	960	.3
Clupeidae:					
Pacific herring, *Clupea h. pallasi*	16	10.5	5.8-15.8	76,920	20.6
Salmonidae:					
Salmon, *Oncorhynchus* spp.	6	3.9	1.5-8.4	19,160	5.1
Osmeridae:					
Capelin, *Mallotus villosus*	16	10.5	5.8-15.8	27,755	7.4
Gadidae	126	82.4	75.1-87.6	222,772	59.7
Saffron cod, *Eleginus gracilis*	2	1.3	.1-4.5	815	.2
Pacific cod, *Gadus macrocephalus*	19	12.4	7.4-18.1	3,471	.9
Pacific tomcod, *Microgadus proximus*	1	.7	.1-4.5	680	.2
Walleye pollock, *Theragra chalcogramma*	102	66.7	59.1-74.3	217,746	58.3
Unidentified gadid	2	1.3	.1-4.5	60	<.1
Zoarcidae:					
Eelpout, *Lycodes* sp.	1	.7	.1-4.5	10	<.1
Scorpaenidae:					
Rockfishes, *Sebastes* spp.	4	2.6	1.0-7.1	3,030	.8
Cottidae, sculpins	6	3.9	1.5-8.4	4,960	1.3
Agonidae:					
Sturgeon poacher, *Agonus acipenserinus*	1	.7	.1-4.5	60	<.1
Trichodontidae:					
Pacific sandfish, *Trichodon trichodon*	2	1.3	.1-4.5	300	<.1
Pleuronectidae, flatfishes	7	4.6	2.2-9.7	1,030	.3
Unidentified fishes	4	2.6	1.0-7.1	40	<.1
Harbor seal, *Phoca v. richardsi*	1	.7	.1-4.5	250	<.1
Total volume				373,184	

[1]Number of stomachs in which a prey item occurred.
[2]Number of occurrences/total number of stomachs with food (153).
[3]95% confidence interval.
[4]Total volume of a prey item/total volume of stomach contents.

TABLE 4.—Rankings by combination rank index (CRI, see Methods) of the 10 top-ranked prey of Steller sea lions collected in the Gulf of Alaska.

Rank	CRI	Prey	Percentage occurrence	Percentage volume
1	1	Walleye pollock	66.7	58.3
2	10	Squids	22.9	4.2
3	11	Pacific herring	10.5	20.6
4	16.5	Capelin	10.5	7.4
5	28	Pacific cod	12.4	.9
6	38	Salmon	3.9	5.1
7	51	Octopus	13.1	<.1
8	57	Sculpins	3.9	1.3
9	76	Flatfishes	4.6	.3
10	88	Rockfishes	2.6	.8

Predation on salmon, *Oncorhynchus* spp., and capelin, *Mallotus villosus*, appeared to be largely limited to spring and summer. Salmon occurred in 6 (12%) and capelin in 15 (30%) of 50 stomachs containing food collected from April through September. Salmon was not encountered and capelin was found only once (1%) in 103 stomachs containing food collected from October through March. This likely reflected seasonal, nearshore distribution associated with spawning in these species (Hart 1973; Jangaard 1974). I found a similar seasonal pattern of harbor seal predation on salmon and capelin in the Gulf of Alaska (Pitcher 1980).

Pacific herring, *Clupea harengus pallasi*, and squids were extensively used by sea lions in Prince William Sound but appeared to be relatively unimportant in other areas. Fifteen of 16 stomachs containing Pacific herring and 30 of 35 stomachs containing squids were from Prince William Sound both highly significant deviations (χ^2 = 12.30 and 16.61, $P<0.001$) from expected values based on the distribution of stomachs containing food (73 of 153 were from Prince William Sound). Harbor seals also appeared to utilize more squids and Pacific herring in Prince William Sound than in other areas of the gulf, which was attributed to differing water depths and bottom topography (Pitcher 1980).

Three studies of sea lion foods in which a total of 135 stomachs containing food were examined were conducted in the Gulf of Alaska between 1958 and 1960 (Mathisen et al. 1962; Thorsteinson and Lensink 1962; Fiscus and Baines 1966). Major prey included shelled mollusks; cephalopods; Pacific sand lance, *Ammodytes hexapterus*; rockfishes; and smelts. Because geographic and seasonal composition of these samples and my collections were not strictly comparable (previous collections were nearly all near rookeries during the breeding season, while I sampled throughout much of the year at a wide range of locations) strict comparisons of the data are not possible. However, one major difference was apparent; walleye pollock, the predominant prey in my sample, was not found in the earlier studies. Concurrent with this apparent increase of walleye pollock in the sea lion diet has been an increase in walleye pollock abundance in the Gulf of Alaska. Between 1961 and 1973-75 walleye pollock increased from 5 to 45% by weight of total demersal fish stocks and was found to be the predominant species (Pereyra and Ronholt footnote 3).

One additional collection of seven sea lions was made in 1945 (Imler and Sarber 1947). Walleye pollock and flatfishes were the major foods.

Harbor seals and Steller sea lions are the only abundant pinnipeds resident in nearshore regions of the Gulf of Alaska. Food habit studies of both species were conducted concurrently; both sea lions and harbor seals (Pitcher 1980) frequently were collected on the same trips. This resulted in relatively comparable geographic and seasonal coverage (Table 1). Results of the two studies were similar (Table 5) with nearly complete overlap of principal prey. Spearman rank correlation analysis showed a significant positive correlation (r_S = 0.67, $P<0.01$) between the rankings of principal prey eaten by both sea lions and harbor seals. The percentage of cephalopods eaten by both predators was similar; however, sea lions ate more squids while harbor seals consumed more octopus. Walleye pollock was the top-ranked prey of both sea lions and harbor seals; however, the percentage of occurrence was nearly twice as high for sea lions (66.7%) as for harbor seals (34.9%). Eulachon, *Thaleicthys pacificus*, and Pacific sand lance were both evident components of the harbor seal diet (occurring in 8.2% and 7.1% of the stomachs, respectively) but were not recorded as food of sea lions during this study. Most eulachon occurrences were from harbor seals collected in freshwater and estuarine habitats of the Copper River Delta (Pitcher 1980) where no sea lions occurred.

Although use of prey by sea lions and harbor seals was similar, several factors may have ameliorated potential competition. Mean length of walleye pollock eaten by sea lions was significantly greater (t = 32.4, $P<0.001$) than for those eaten by harbor seals, based on otoliths recovered from stomachs (Table 2). This may indicate a tendency towards use of larger prey by sea lions. Although distribution of the two species often overlaps in the Gulf of Alaska, sea lions range farther offshore (Fiscus et al.[5]). In addition, harbor seals often use freshwater and estuarine habitats rarely used by sea lions in the Gulf of Alaska. Harbor seals can probably stay submerged for considerably longer periods than sea lions (R. Elsner[6]) which may allow them to more efficiently utilize cryptic and solitary prey such as octopus and flatfishes. Although use of principal prey between the two species was similar, harbor seals had a more diverse diet. They preyed upon a minimum of 31 species (Pitcher 1980) compared with 20 for sea lions. Both sea lions and harbor seals appeared to modify their diets according to prey availability. Several lines of evidence led to this hypothesis. Walleye pollock, the predominant prey of sea lions and harbor seals, was the most abundant species of demersal fish in the area. Similar seasonal and geographic variations in the diets of both species were found which probably reflected use of abundant and readily available prey at that time and location. There were apparent changes over time in the relative composition of the sea lion diet (primarily walleye pollock) which appeared to correlate with changes in prey abundance. Also, reports in the literature indicated use of different prey in other geographic regions (Spalding 1964; Fiscus and Baines 1966).

Four of the five, top-ranked prey of both sea lions and harbor seals (Table 5) were off-bottom schooling species. Many of the important prey reported in other studies of Steller sea lion foods also fit into this category and include Pacific herring; smelts;

[5]Fiscus, C. H., H. W. Braham, R. W. Mercer, R. D. Everitt, B. D. Krogman, P. D. McGuire, C. E. Peterson, R. M. Sonntag, and D. E. Withrow. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. *In* Environmental assessment of the Alaskan Continental Shelf, Vol. 1, p. 19-264. Principal investigators reports for October-December 1976. Environmental Research Laboratories, NOAA, Boulder, Colo.

[6]R. Elsner, Professor of Physiology, Institute of Marine Science, University of Alaska, Fairbanks, AK 99701, pers. commun. January 1980.

TABLE 5.—Comparative frequency of principal prey ($N \geq 4$) of 250 Steller sea lions and 548 harbor seals collected in the Gulf of Alaska between 1973 and 1978.

	Steller sea lion occurrence				Harbor seal occurrence[1]			
Prey	Rank	No.	%	95% C. I.[2]	Rank	No.	%	95% C. I.[2]
Walleye pollock	1	102	66.7	59.1-74.3	1	94	34.9	29.4-40.9
Squid	2	35	22.9	16.7-30.4	8	20	7.4	4.3-10.7
Octopus	3	20	13.1	8.2-19.2	2	77	28.6	23.8-34.7
Pacific cod	4	19	12.4	7.4-18.1	5	28	10.4	6.8-14.1
Pacific herring	5.5	16	10.5	5.8-15.8	4	29	10.8	7.6-15.3
Capelin	5.5	16	10.5	5.8-15.8	3	40	14.9	11.1-19.8
Shrimps	7	8	5.2	2.2-9.7	10	17	6.3	3.6-9.5
Flatfishes	8	7	4.6	2.2-9.7	6	23	8.6	6.0-13.0
Salmon	9.5	6	3.9	1.5-8.4	13	9	3.3	1.4-5.7
Sculpins	9.5	6	3.9	1.5-8.4	11.5	10	3.7	2.1-7.0
Rockfishes	11	4	2.6	1.0-7.1	17	4	1.5	0.2-3.4
Saffron cod	12.5	2	1.3	0.1-4.5	16	5	1.9	0.8-4.4
Pacific sandfish	12.5	2	1.3	0.1-4.5	11.5	10	3.7	2.1-7.0
Pacific tomcod	14.5	1	.7	0.1-4.5	14	7	2.6	1.4-5.7
Eelpouts	14.5	1	.7	0.1-4.5	15	6	2.2	0.8-4.4
Eulachon	16.5	0	.0	0.0-2.4	7	22	8.2	5.2-11.8
Pacific sand lance	16.5	0	.0	0.0-2.4	9	19	7.1	4.3-10.7
Others		16				31		
Stomachs with food		153				269		

[1]Pitcher (1980).
[2]95% confidence interval.

Pacific cod, *Gadus macrocephalus*; Pacific whiting, *Merluccius productus*; walleye pollock; rockfishes; and Pacific sand lance (Imler and Sarber 1947; Spalding 1964; Fiscus and Baines 1966). Use of this prey type may be important in minimizing foraging effort and conserving energy, compared with the energy expenditures of capturing more solitary species (Smith and Gaskin 1974; Pitcher 1980).

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