FINAL REPORT

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Assessment of Marine Mammal-Fishery Interactions in the Western Gulf of Alaska and Bering Sea: Consumption of Commercially Important Fishes by Bering Sea Pinnipeds

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I. Background

In January 1985, the U.S. Congress made a special appropriation of funds for the specific purpose of making an assessment of marine mammal-fishery interactions in the western Gulf of Alaska and Bering Sea. Those funds were appropriated to the National Marine Mammal Laboratory/NMFS, and a contractual agreement for expenditure of part of the money was entered into between NMFS and the Alaska Department of Fish and Game (ADF&G). The ADF&G undertook three projects: a study of Steller sea lions, Eumetopias jubatus, in the western Gulf of Alaska ($160,857), a census of harbor seals, Phoca vitulina richardsi, along the north side of the Alaska Peninsula ($11,000), and an investigation of the consumption of commercially important fishes by Bering Sea pinnipeds ($7,770). This report is about the project last mentioned.

The very limited funding available for the study of marine mammal food habits in Bering Sea was utilized basically as "seed money" that allowed our participation in three research cruises during which data and specimens could be obtained. The research cruises included two phases of the prolonged expedition of the Soviet vessel Zakharova and an expedition on the American vessel Alpha Helix. The Soviet vessel was available to us in conjunction with ongoing cooperative Soviet-American studies of marine mammals. We participated in the Alpha Helix expedition on a space-available basis.

Contract funds ($7,770) were used to purchase transportation and to ship equipment, supplies, and specimens to and/or from the remote sites at which the principal investigators boarded and disembarked from the research vessels. All other required financial support was provided by the Alaska Department of Fish and Game.

II. Introduction

The Bering Sea supports a diverse and abundant marine mammal fauna which includes eight species of pinnipeds (Table 1). Two species, the bearded seal and the Pacific walrus, feed primarily on benthic invertebrates, while for the remaining six species, pelagic and semi-demersal fishes comprise a large portion of the diet (Lowry and Frost 1981). A review of available information on feeding of Bering Sea marine mammals (Lowry et al. 1982) indicated that several species of present or potential significance to commercial fisheries are also major foods of pinnipeds. Fishes such as walleye pollock and herring, and in some cases squids, are principal prey of harbor seals, spotted seals, ribbon seals, sea lions, and fur seals. Clams, crabs, shrimps, and snails make up most of the diet of bearded seals and walruses. The common and scientific names of fishes and invertebrates mentioned in this report are indicated in Appendix I.

An understanding of the foods eaten by Bering Sea pinnipeds is essential for several reasons. First, the Marine Mammal Protection Act requires that management of marine mammal populations considers the carrying capacity of the area in which they live. The quantity of food available is obviously one component of carrying capacity, and it is therefore necessary to know what foods are acceptable to and utilized by the mammal species. Second,

Table 1. Relative importance of major prey types in the diet of pinnipeds in the eastern Bering Sea (adapted from Lowry and Frost 1981).

Predator species	Pelagic and semidemersal fishes	Demersal fishes	Pelagic nektonic invertebrates	Nektobenthonic invertebrates	Epifaunal benthic invertebrates	Infaunal benthic invertebrates
Harbor seal (*Phoca vitulina richardsi*)	Major	Minor		Minor		
Spotted Seal (*Phoca largha*)	Major	Minor	Major for juveniles	Minor for adults Major for juveniles	Minor	
Ribbon seal (*Phoca fasciata*)	Major	Major		Minor		
Ringed seal (*Phoca hispida*	Major	Minor	Major	Major		
Bearded seal (*Erignathus barbatus*)		Minor		Major	Major	Major in some areas
Pacific walrus (*Odobenus rosmarus divergens*)				Minor	Minor	Major
Northern fur seal (*Callorhinus ursinus*)	Major		Major			
Steller sea lion (*Eumetopias jubatus*)	Major	Minor	Minor	Minor		

the estimated amounts of food consumed by Bering Sea marine mammals are so great that estimates of marine mammal consumption have been used as driving variables in the ecosystem model DYNUMES (Laevastu and Favorite 1977). Utility of the model depends on accuracy of the inputted values for marine mammal consumption. Third, because of the similarity of prey species being exploited, it is highly likely that there are reciprocal interactions between marine mammals and fisheries in the Bering Sea (Lowry et al. 1982).

One requirement for consideration of any of these topics is a reasonably refined understanding of the diet of each marine mammal species. Available data indicate that a few prey species usually comprise the bulk of a predator's diet (Lowry et al. 1982). However, for those species which have been most thoroughly investigated, significant seasonal, regional, and age/sex-class-related differences in foods have been documented (Lowry et al. 1980a, b; Perez and Bigg 1981; Lowry et al. 1982).

Reviews of available data (Lowry and Frost 1981; Lowry et al. 1982) have identified major gaps in the data on foods of all Bering Sea pinnipeds except fur seals. Data are not adequate to provide inputs to ecosystem models or to examine the possibility of interactions with fisheries in more than a general way (Lowry et al. 1982). This project was therefore initiated to provide additional information on the diets of Bering Sea marine mammals with emphasis on consumption of commercially important fishes.

III. Objectives

The principal objective of this study was to obtain additional data on foods of Bering Sea pinnipeds, particularly harbor seals, spotted seals, ribbon seals, and bearded seals. Attention was to be focused on areas where they may feed on species of present or potential commercial importance.

The overall goal of this study was to quantitatively describe the diet of each species, including an analysis of geographical, seasonal, and age/sex-related patterns of feeding, and to evaluate the importance of commercially important fishes in the diet.

IV. Methods

This project did not have the benefit of funding to charter dedicated vessels from which to conduct the research. We therefore arranged to utilize logistics provided by other programs and conducted our work on a largely opportunistic basis. We participated in three research cruises. The first two, from 15 March-26 April 1985, were aboard the Soviet sealing vessel Zakharova. These cruises were arranged by the Soviet Ministry of Fisheries as part of the U.S./U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection. The Zakharova collected sea lions, walruses, and ice-associated seals in the central and western Bering Sea. The third cruise, from 25 May-14 June 1985, was on the University of Alaska/NSF research vessel Alpha Helix. Our participation in the cruise was arranged courtesy of Dr. John Oliver, Moss Landing Marine Laboratories. From the Alpha Helix we collected harbor seals in the southeastern Bering Sea.

Our data on food consumption is based on examination of gastrointestinal tracts of animals collected by shooting with rifles. On the Zakharova, seals, sea lions, and walruses hauled out on the ice were collected by Soviet hunters. On the Alpha Helix, seals swimming in the water were collected by one of the principal investigators. For all specimens we recorded the date, time, and location of collection. Sex was determined by examination of the genital area, and a series of standard measurements were taken. The body cavity was opened and the stomach removed. In some cases, stomachs were opened in the field by longitudinal incision and the contents removed by gently washing onto a 1.0-mm-mesh sieve. In other cases, stomachs were frozen intact and were later opened and washed in the laboratory. Two claws from one foreflipper and the lower jaw were removed from each seal to be used for age determination.

Contents of stomachs were sorted into taxonomic groups and identified using appropriate keys and reference specimens. Where possible, the number of each type of prey consumed was estimated based on counts of whole specimens or characteristic hard parts such as otoliths. The volume of each type of prey was determined by water displacement. Intact and non-degraded otoliths of gadid fishes were measured (total length to the nearest 0.1 mm) using vernier calipers.

On the Alpha Helix, the entire small intestine of each seal was removed from the mesentery and frozen. Intestines were shipped frozen to Ms. Ann Adams, University of Washington. They were thawed, slit longitudinally, then carefully examined for the presence of otoliths, cephalopod beaks, and parasites. Otoliths and beaks were preserved in 70% ethanol and sent to the Alaska Department of Fish and Game in Fairbanks where they were identified and measured.

Walruses collected on the Zakharova were taken primarily for commercial utilization and secondarily for scientific purposes. Carcasses were brought on board and weighed, sex was determined, and several standard measurements were taken by the scientific party. The ship's crew then skinned, gutted, and cut up each carcass. Stomachs were retrieved as possible during this process, opened on the deck, and the contents poured into buckets and weighed.

In the ship's factory, the contents were washed in muslin paint strainer bags, drained, and then sorted into taxonomic groups. Some stomach contents were weighed again after washing and draining and a conversion factor determined for unwashed:washed and drained contents.

Prey items were enumerated based on counts of whole individuals or of characteristic parts such as clam feet or siphons and snail operculae. As possible, the prey items in each taxonomic group were weighed with a small spring scale, or the volume was determined by water displacement. For most marine animals, volume and weight are approximately equivalent measures with 1 cc equal to 1 g. Voucher specimens of each species in each stomach were preserved in ethanol and retained for later examination at the Alaska Department of Fish and Game in Fairbanks.

V. Results

A. Zakharova

On the Zakharova collections were made in three general areas: Area I south and west of Saint Matthew Island, Area II near the Koryak coast southwest of Cape Navarin, and Area III in Karaginski Bay (Figure 1). A total of 63 seals were examined, all of which were collected while hauled-out on the ice.

Spotted seals were collected only in Areas I and III. Thirty were examined, of which 15 had food remains in their stomachs (Table 2). Seals collected in Area I had been feeding almost entirely on fishes. Herring occurred in 10 of 12 stomachs with food, often in large volumes (up to 2600 ml) of recently ingested fish. Intact herring were 27-30 cm long with large, maturing gonads. Pollock, although overall accounting for 60% of the identified fishes, occurred in only four stomachs. Most of the remains of pollock were in two stomachs (otoliths from 25 and 87 individuals), neither of which contained any herring. Based on sizes of measureable otoliths, seals had eaten one large pollock, estimated as 39.3 cm long, and 115 small pollock, averaging 10.8 cm long with a range of 8.5-14.3 cm. The spotted seals collected in Area III contained only small amounts of food in their stomachs, including invertebrates and fishes. Pollock were the primary fish prey. The few otoliths recovered represented a wide range of sizes but were too degraded to measure reliably.

Small collections of bearded seals were made in all three areas. Of 18 seals examined, contents were found in the stomachs of eight (Table 3). Primary prey were clams, crabs, and sand lance. Overall in the samples, the clams were comprised of 62.8% surf clam, 23.0% Greenland cockle, and 14.2% other species. Surf clams were eaten in Areas II and III. The principal prey in Area I was tanner crabs, which were eaten in substantial quantities (170.0-1590.0 ml) by all three seals collected there. Only the abdominal flaps of the tanner crabs were eaten. In one stomach there were 154 abdomens, all from female crabs bearing eggs. Another stomach contained 628 abdomens, 29 from male crabs, and 599 from female crabs. That sample was somewhat digested; however, it was estimated that 85% of the abdomens from female crabs carried eggs.

Of 11 ribbon seals examined, only one contained food remains. That specimen, collected in Area I, contained only otoliths from two large pollock. The otoliths were degraded and could not be measured.

Four ringed seals were collected, all of which had empty stomachs.

On the first Zakharova cruise, the stomach contents of seven female walruses collected in Area I were examined by F. H. Fay from the University of Alaska (Table 4). Five phyla and at least 17 genera were represented in those seven stomachs. No data were obtained on the weights or volumes of the different taxa. However, frequency of occurrence and number of individuals per stomach were recorded. Snails, primarily the whelks Buccinum and Neptunea were the numerically dominant prey ($\bar{x}$=576/stomach) and occurred in all seven stomachs. Tanner crabs also occurred in every stomach and were relatively abundant ($\bar{x}$=30/stomach).

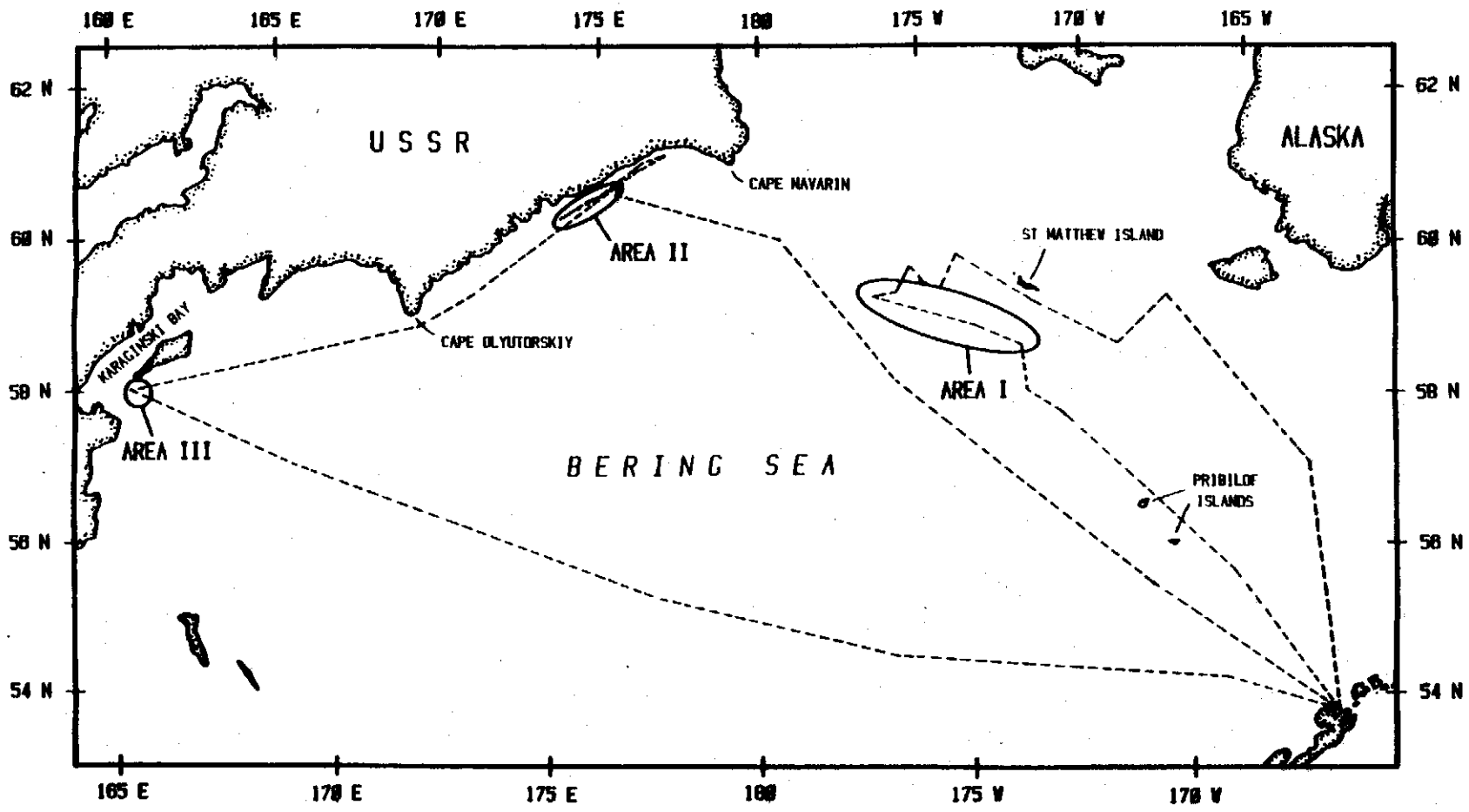

Figure 1. Cruise track of the ZRS Zakharova during the Soviet-American marine mammal research expedition, 15 March-26 April 1985, showing the three areas in which pinnipeds were collected.

Table 2. Stomach contents of spotted seals collected on the Zakharova.

Prey Item	30-31 March 1985 Area I (n=12)			21 April 1985 Area III (n=3)		
	% volume	% # of fishes	# of occurrences	% volume	% # of fishes	# of occurrences
Fish Total	98.4	--	12	14.3	--	3
Walleye pollock	--	57.9	4	--	83.3	2
Pacific cod	--	2.5	2	--	--	--
Pacific herring	--	27.8	10	--	--	--
Capelin	--	9.9	2	--	--	--
Sand lance	--	0.5	1	--	16.7	1
Eelpout	--	1.0	2	--	--	--
Prickleback	--	0.5	1	--	--	--
Invertebrate Total	1.6	--	2	85.7	--	3
Octopus	1.6	--	2	23.8	--	2
Squid	--	--	--	23.8	--	1
Hermit crab	--	--	--	38.1	--	1
Mean volume contents (ml)		724.8			7.0	
Total number identified fishes		202			6	

Table 3. Stomach contents of bearded seals collected on the Zakharova (tr=trace amount, <0.1%).

Prey Item	27 March 1985 Area I (n=3)			9 April 1985 Area II (n=1)			11-21 April 1985 Area III (n=4)		
	% volume	% # of fishes	# of occurrences	% volume	% # of fishes	# of occurrences	% volume	% # of fishes	# of occurrences
Fish Total	2.3	--	2	tr	--	1	57.2	--	4
Walleye pollock	--	10	1	--	--	--	--	--	--
Arctic cod	--	10	1	--	--	--	--	--	--
Sand lance	--	--	--	--	84.2	1	--	99.0	4
Eelpout	--	80	2	--	--	--	--	--	--
Sculpin	--	--	--	--	10.5	1	--	1.0	2
Flatfish	--	--	--	--	5.3	1	--	--	--
Invertebrate Total	97.7	--	3	100.0	--	1	42.8	--	4
Octopus	tr	--	1	--	--	--	tr	--	1
Clam	4.9	--	2	82.9	--	1	32.6	--	1
Snail	tr	--	1	--	--	--	tr	--	1
Gammarid amphipod	--	--	--	--	--	--	0.1	--	2
Shrimp	--	--	--	tr	--	1	3.6	--	3
Spider crab	--	--	--	17.1	--	1	6.3	--	3
Tanner crab	92.8	--	3	--	--	--	0.1	--	1
Mean volume of contents (ml)		866.0			205.0			455.8	
Total number of identified fishes		10			19			310	

Table 4. Stomach contents of walruses collected on the Zakharova (tr=trace amount, <0.1%).

Prey items	21, 24 March 1985 Area I (n=7)[1]		9-20 April 1985 Area II (n=49)			
	# of occurrences	mean # per stomach	# of occurrences	% weight	mean per stomach weight (g)	mean per stomach number
Cockles	4	12	44	14.7	1,749	49
Soft-shelled clams						
Mya arenaria	--	--	47	80.6	9,620	721
Mya truncata	--	--	24	1.3	154	17
Mya sp.	3	1	2	tr	7	<1
Surf clams	--	--	31	0.4	53	5
Tellins	4	2	12	tr	4	2
Yoldia sp.	2	18	--	--	--	--
Hiatella sp.	--	--	3	0.6	74	6
Moon snails	7	34	28	0.1	17	10
Whelks	7	574	15	0.1	13	7
Snail eggs	1	14	--	--	--	--
Polychaetes	7	3	6	0.1	13	2
Echiuroids	2	<1	1	tr	tr	<1
Sipunculids	--	--	4	tr	5	1
Priapulids	3	1	--	--	--	--
Tunicates	--	--	1	tr	3	<1
Hermit crabs	3	12	1	tr	tr	<1
Amphipods	--	--	5	tr	3	6
Crabs	7	30	4	tr	tr	<1
Holothuroids	--	--	1	tr	tr	<1
Octopus	3	1	--	--	--	--
Anemones	--	--	6	tr	3	<1
Sand lance	--	--	6	0.2	27	3
Sand/rocks	--	--	27	1.5	184	--

[1] From F. H. Fay, Inst. of Marine Science, University of Alaska, Fairbanks.

On the second Zakharova cruise, 261 male walruses were collected in Area II. Stomach contents were analyzed from a sample of 49 walruses. Nine phyla and over 20 genera were represented (Table 4). All 49 animals had eaten primarily clams, which made up approximately 98% of the total weight of contents. The soft-shelled clam, Mya arenaria, made up 81% of the total contents and was the dominant prey in 40 stomachs. A mean of 9.6 kg and over 700 individuals were found per stomach. Cockles (mostly Greenland cockles) composed 15% of the total food ($\bar{x}$=49 individuals/stomach, 1.7 kg/stomach) but were the dominant prey in only seven stomachs. Mean weight of total contents was similar for stomachs in which Mya dominated ($\bar{x}$=12.3 kg/stomach, range 1.0-36.8 kg) and those with mostly cockles ($\bar{x}$=11.4 kg/stomach, range 1.1-28.5 kg).

Two other species, Mya truncata and Spisula (the surf clam), occurred in 50% or more of the stomachs examined, but usually in small quantities. In combination, the two made up less than 2% of the total weight of contents. Mya truncata was the dominant species in one stomach with a weight of 7.5 kg. Snails (primarily moon snails), which were present in 63% of the stomachs examined, were the other most commonly occurring prey in the sample. However, they were present in very small numbers (<20/stomach) and amounts ($\bar{x}$=30 g/stomach).

Mean weight of contents (washed and drained) for all 49 stomachs was 11.9 kg/stomach (range 1.0-36.8 kg). The largest stomach contents weight of 36.8 kg (49 kg before washing and draining) was for a 336-cm-long, 1320-kg walrus. This represented 2.8% of total body weight.

In 18 of the 49 stomachs examined (37%), stomach contents weights (washed and drained) were greater than 1% of total body weight, and in two (8%), they were greater than 2%. For the sample as a whole, the average weight of stomach contents was 0.95% of total walrus body weight.

The mean weight of stomach contents was compared for walruses of different lengths and weights (Tables 5 and 6). The stomachs of larger walruses contained more food than did those of smaller walruses; however, the average percent of body weight was similar for both small and large animals.

Unit weights of the different types of clams that were eaten could be determined and compared in only a very approximate manner. In most of the stomachs we examined, digestion had progressed to the point that the stomachs of clams were either no longer recognizable, or were detached from the siphons and/or feet. Counts of individuals were therefore made based on the most persistent and characteristic part of a particular species (siphons for soft-shelled clams and surf clams, feet for cockles). Shells were absent except for a few small fragments, indicating that only the soft parts were eaten.

Unit weights (g/individual) for the major clam species found in stomachs were determined by two methods: (1) total weight of a taxon for the sample as a whole was divided by total number estimated for that taxon, and (2) a random assortment of the least digested siphons and feet was weighed and the mean weight determined (Table 7). Cockles had the largest unit weight,

Table 5. Mean weight of stomach contents vs. body weight for 45 male walruses collected along the Koryak coast in April 1985.

Walrus weight (kg)	n	$\bar{x}$ weight of stomach contents (kg)
600-699	1	7.5
700-799	1	3.2
800-899	2	4.3
900-999	0	--
1000-1099	8	8.5
1100-1199	8	13.0
1200-1299	9	8.7
1300-1399	10	15.5
1400-1499	3	16.4
1500-1599	3	16.5

Table 6. Mean weight of stomach contents vs. standard length (SL) for 45 walruses collected along the Koryak coast in April 1985.

Walrus SL (cm)	n	$\bar{x}$ weight of stomach contents (kg)
225-250	1	7.5
251-275	1	3.2
276-300	2	4.3
301-310	6	10.2
311-320	11	7.3
321-330	12	13.1
331-340	7	13.4
341-350	4	16.8
351-360	1	29.3

Table 7. Unit weights (g/individual) of different types of clams in the stomach contents of walruses collected along the Koryak Coast, April 1985.

Clam	Method 1 $\frac{\text{total weight in sample}}{\text{total number in sample}}$	Method 2 random weighed individuals	
		g	n
F. Cardiidae	35.8	22.4	31
Mya arenaria	13.3	18.0	58
Mya truncata	9.0	8.1	26
Spisula sp.	11.2	16.2	12
Hiatella sp.	--	0.4	15

by both methods, followed by Mya arenaria. In one stomach, a single intact M. arenaria, including siphon, mantle and stomach, weighed 170 g. Hiatella individuals were smallest.

B. Alpha Helix

On the Alpha Helix we collected 22 harbor seals at six locations in Bristol Bay (Figure 2). Sixteen had recognizable food remains in their stomachs (Table 8). Based on the number of fishes consumed, herring and capelin were the principal prey at all locations except Amak Island where the single seal collected had eaten only flatfishes. Herring were the only prey found in seals collected at Ugashik Bay and Nanvak Bay. More herring than capelin were eaten at Port Heiden while the opposite was true at Nelson Lagoon. This may have resulted partly from the dates on which seals were collected. In eight seals with food collected on or before 1 June, herring occurred in seven and capelin did not occur. In eight seals collected on or after 9 June, herring occurred in two, and capelin were found in five. The largest volumes of food (2120 and 1835 ml) were found in seals that had eaten herring. The next largest food volume (620 ml) was only about 1/3 as large and occurred in a seal that had eaten mostly capelin.

Stomach contents of seals that had recently eaten herring generally contained a mixture of flesh, bones, and egg masses. Three seals were noted to have herring eggs adhering to their faces, particularly near the mouth. Two of those had herring bones in their stomachs, the third contained only 30 ml of herring eggs.

Otoliths were recovered from the intestines of 17 seals, including four that had empty stomachs. Combining data from stomachs and intestines produced information on the foods eaten by a total of 20 seals (Table 9). Based on the combined data, capelin were the primary prey in seals collected at Port Heiden, Nanvak Bay, and Nelson Lagoon. Herring were the only food eaten at Ugashik Bay and were of secondary importance in seals at Port Heiden and Nanvak Bay. Sand lance were eaten quite commonly at Port Heiden. Principal prey of the seal collected at Amak Island were eelpout and flatfish.

Most of the pollock otoliths recovered were somewhat digested and not suitable for measuring, but they were from small fishes, probably 10 to 15 cm long. Based on measurements of otoliths from stomachs, Pacific cod eaten averaged 13.6 cm long and ranged in length from 8.5 to 21.3 cm.

VI. Discussion

A. Ice-associated seals

Results of analysis of spotted seal stomach contents are compared to those reported by Bukhtiyarov et al. (1984) in Table 10. Both collections were made in the pack ice during spring. In the central Bering Sea, walleye pollock and eelpout were identified as major prey in both studies. Pollock eaten are generally small, ranging in length from 8 to 15 cm. Herring, which occurred in 10 of 12 seals with food in this study, were not found in

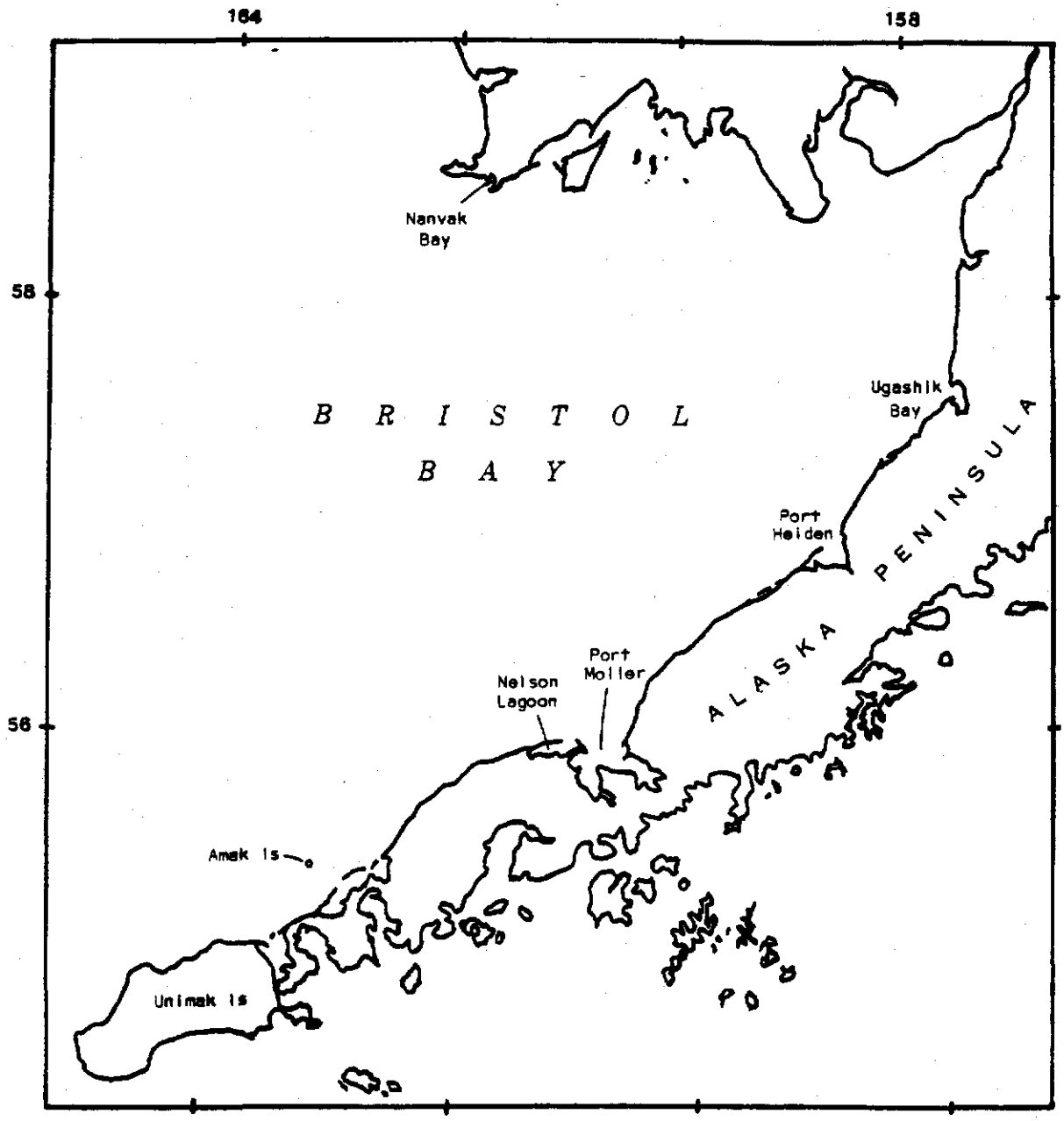

Figure 2. Map of Bristol Bay showing locations where harbor seals were collected from the RV Alpha Helix, May-June 1985.

Table 8. Stomach contents of harbor seals collected on the Alpha Helix, May-June 1985.

Specimen #	Location	Date	Number of fishes										Total fish volume	Comments
			Herring	Capelin	Smelt	Eulachon	Cod	Pollock	Sand lance	Eelpout	Sculpin	Flatfish		
AH-01-85	Port Moller	05/27/85												Empty
AH-02-85	Port Heiden	05/28/85	1										2.0	
AH-03-85	Port Heiden	05/28/85										1	22.0	Probably sole
AH-04-85	Port Heiden	05/28/85	8										2,120.0	Mature fish w/eggs
AH-05-85	Ugashik Bay	05/29/85	1										3.0	Herring eggs on face
AH-06-85	Ugashik Bay	05/29/85	2										290.0	Mature fish w/eggs
AH-07-85	Nanvak Bay	06/01/85	1										0.0	Bones only
AH-08-85	Nanvak Bay	06/01/85	1										1.0	Bones only; herring eggs on face
AH-09-85	Nanvak Bay	06/01/85	0										30.0	Eggs only; herring eggs on face
AH-10-85	Port Heiden	06/09/85												Empty
AH-11-85	Port Heiden	06/09/85												Empty
AH-12-85	Port Heiden	06/09/85	2										210.0	Mature fish w/eggs
AH-13-85	Port Heiden	06/09/85												Empty
AH-14-85	Port Heiden	06/09/85		2									9.0	Bones only
AH-15-85	Nelson Lagoon	06/10/85		6									140.0	Bones and some eggs
AH-16-85	Nelson Lagoon	06/10/85	10										1,835.0	Mature fish w/eggs
AH-17-85	Nelson Lagoon	06/12/85		23	1	1	8	2			1		620.0	Lots of eggs
AH-18-85	Nelson Lagoon	06/12/85												Empty
AH-19-85	Nelson Lagoon	06/12/85		5		1			22	1			150.0	Very digested
AH-20-85	Nelson Lagoon	06/12/85		2		1				1			56.0	Mostly eggs
AH-21-85	Nelson Lagoon	06/12/85												Empty
AH-22-85	Amak Island	06/13/85										15	320.0	Mostly bones; probably sole

Table 9. Otoliths recovered from stomachs and intestines of harbor seals collected on the Alpha Helix. Sample sizes indicate the number of seals containing food remains.

	28 May and 9 June 1985 Port Heiden (n=7)		29 May 1985 Ugashik Bay (n=2)		1 June 1985 Nanvak Bay (n=3)		10-12 June 1985 Nelson Lagoon (n=7)		13 June 1985 Amak Island (n=1)	
	% # of otoliths	% frequency of occurrence	% # of otoliths	% frequency of occurrence	% # of otoliths	% frequency of occurrence	% # of otoliths	% frequency of occurrence	% # of otoliths	% frequency of occurrence
Pacific herring	9.4	42.9	100.0	100.0	8.9	100.0	2.1	28.6	--	--
Capelin	88.8	42.9	--	--	91.1	66.7	72.6	100.0	--	--
Eulachon	--	--	--	--	--	--	2.7	71.4	--	--
Rainbow smelt	0.6	14.3	--	--	--	--	0.1	14.3	--	--
Walleye pollock	--	--	--	--	--	--	5.3	57.1	--	--
Pacific cod	--	--	--	--	--	--	2.9	14.3	--	--
Sand lance	0.6	14.3	--	--	--	--	11.7	57.1	2.1	100.0
Eelpout	--	--	--	--	--	--	1.1	57.1	66.7	100.0
Sculpin	--	--	--	--	--	--	0.1	14.3	--	--
Flatfish	0.6	14.3	--	--	--	--	--	--	31.3	100.0
Sandfish	--	--	--	--	--	--	1.3	14.3	--	--
Mean volume stomach contents (ml)	472.6		146.5		10.3		560.2		320.0	
Total number identified otoliths	170		18		56		701		48	

Table 10. Rank order of importance of prey in spotted seals in this study and reported by Bukhtiyarov et al. (1984).

	Central Bering Sea		Karaginski Bay	
Rank	n=12 this study	n=5 Bukhtiyarov et al.	n=3 this study	n=68 Bukhtiyarov et al.
1	Herring	Pollock	Hermit crab	Sand lance
2	Pollock	Eelpout	Octopus	Herring
3	Capelin	Pricklebacks	Squid	Octopus
4	Pacific cod	Sclupins	Pollock	
5	Eelpout		Sand lance	

any of the five seals reported on by Bukhtiyarov et al. (1984). In Karaginski Bay, octopus and sand lance were identified as major prey in both studies. Additional sampling is obviously required in order to assess the relative importance of herring, pollock, capelin, and Pacific cod in the diet of spotted seals in the central Bering Sea.

Based on the small samples examined in this study, the principal prey of bearded seals varied greatly with location, in a manner similar to that previously reported (Lowry et al. 1980a). Of particular interest with respect to interactions with fisheries is the predation on ovigerous female tanner crabs in the central Bering Sea. The habit of selectively consuming the abdomens of ovigerous crabs has been noted previously (Lowry and Frost, unpublished) and may be of some significance to crab populations in areas of high bearded seal density. Where they consume clams, bearded seals may compete for food with walruses (Lowry et al. 1980a).

Results of the examination of ribbon seals were consistent with previous reports (Frost and Lowry 1980). Ribbon seals feed little during spring, and pollock are one of their major prey.

B. Walruses

The prey eaten by walruses in the central Bering Sea (Area I) and along the Koryak Coast (Area II) differed substantially. In Area I, gastropods and tanner crabs made up most of the stomach contents, with only small numbers of clams and other species. Three bearded seals collected in the same general area had also eaten tanner crabs. In contrast, in the western Bering Sea, off the Koryak coast, 98% of all walrus stomach contents consisted of clams, mostly soft-shelled clams and surf clams. No tanner crabs and very few snails had been eaten by those walruses. Bivalve and gastropod mollusks are known to be major prey of walruses throughout the Bering and Chukchi seas (Fay and Lowry 1981; Fay 1982; Fay and Stoker 1982; Fay et al. 1984). The dominant prey types are very similar in all Bering Sea samples (Table 11). In all but one sample (of 11 area and year combinations summarized in Table 11), clams were the major food item. In seven of the 11 samples, clams of the genus Mya were the number-one-ranked prey. Cockles, mostly Greenland cockles, were among the top-three-ranked prey in nine of the 11 samples.

Fay (1982) reported maximum wet weights of walrus stomach contents of 25 to 43.5 kg. The contents from the largest stomach in the 1985 Koryak Coast sample weighed 36.8 kg (49 kg unwashed and undrained). If that amount is doubled on the assumption that walruses fill their stomachs twice each day, daily intake of that 1320 kg walrus would be about 74 kg, or 5.6% of total body weight. This closely approximates the estimated daily intake of a 1300 kg walrus of 69.8 kg (5.4% of total body weight), which Fay (1982) calculated, based on the mean gross energy intake of walruses in captivity. Minimum and maximum gross energy intakes of captive walruses gave a range of 54 to 103 kg of food per day for a 1300-kg walrus.

On the average, the clams eaten by walruses along the Koryak Coast were larger than those found in the stomachs of walruses feeding in other areas (Table 12). The mean unit weight for cockles (35.8 g) in that sample was

Table 11. Rank order of importance of prey in walruses in this study and in other spring Bering Sea samples.

	Southern			Central	Western		Northern (St. Lawrence Island)			Bering Strait	
	1976[1] n=21	1981[2] n=15	1981[2] n=4	1985[3] n=7	1980[1] n=?	1985[3] n=49	1975[1] n=19	1975[1] n=14	1980-82[4] n=108	1980-82[4] n=50	1975[1] n=77
1	Cockles	Tellins	Surf clams	Whelks	Mya*	Mya	Mya	Mya	Mya	Mya	Mya
2	Tanner crabs	Surf clams	Tellins	Tanner crabs	Cockles*	Cockles	Hiatella	Cockles	Cockles	Cockles	Hiatella
3	Whelks	Cockles	Hydrozoans				Cockles	Sea cucumbers	Echiurids	Sea cucumbers	Cockles
4									Snails		

[1] Fay 1982.
[2] Fay and Lowry 1981.
[3] This report.
[4] Fay et al. 1984.
* Relative rank not indicated in the original data; these two types of clams listed as most important.

Table 12. Comparative unit weights (g) of clams in stomach contents of walruses collected in different areas of the Bering Sea.

	This study Koryak Coast[1]	Fay and Lowry 1981 S. Kuskokwim Bay	Fay and Lowry 1981 Bristol Bay[1]	Fay and Stoker 1982 St. Lawrence Island[1]		
	1985	1981	1981	1975	1980	1982
Cockles	35.8	13.7	9.0	21.8	18.4	14.9
Surf clams	11.2	18.9	12.5	--	--	--
Myacids[2]	13.3	--	--	22.8	1.7	11.3
Total (all clams)	14.6	5.2	4.9	12.3	4.9	7.6

[1] Males only.
[2] Includes *Mya arenaria*, *M. truncata*, and *Mya* sp.

60% to 400% greater than for St. Lawrence Island or southeastern Bering Sea samples. Unit weights for surf clams were smaller than those in southern Kuskokwim Bay and Bristol Bay, but even so probably represented clams nine or more years old (Fay and Lowry 1981). The largest myacids were present in 1975 samples from St. Lawrence Island. However, the mean unit weight has decreased by 50% or more since then and the unit weight for myacids in the Koryak sample is larger than either the 1980 or 1982 St. Lawrence samples. It is interesting to note that the mean unit weight for all clams combined was 200% to 300% higher for the Koryak walruses than for any others except those from St. Lawrence Island in 1975. Fay and Stoker (1982) suggested that the reduction in the unit size of prey between 1975 and 1980-82 indicated a depleted food supply and overexploitation by walruses in the area around St. Lawrence Island. Conversely, it appears that the large unit size of prey along the Koryak Coast indicates that extensive and relatively unexploited clam beds still occur there and that use of the area by large numbers of foraging walruses is quite recent. According to A. Kibal'chich, a Soviet walrus specialist that was aboard the Zakharova in 1985, walruses began to reappear in large numbers near the Koryak Coast in 1970-1971.

C. Harbor seals

The harbor seals collected in May through June 1985 from the Alpha Helix contained only fishes in their stomachs. Based on the number of otoliths in stomachs and intestines and the frequency of occurrence of various species, the three most important prey were capelin, herring, and sand lance. Most of the stomachs with large amounts of food in them contained mature herring in pre-spawning condition. Other commercially important species eaten were walleye pollock, Pacific cod, and flatfish. The flatfish otoliths were probably from yellowfin sole, although it is very difficult to identify flatfish otoliths to species.

There have been only two other collections of harbor seals in the southeastern and central Bering Sea that have yielded significant data on foods consumed. Fifteen harbor seals were collected at Otter Island in the Pribilofs on 13 April 1979. Eight animals had food in their stomachs which was comprised of 63.5% fish, 28.7% octopus, 4.6% other invertebrates, and 2.9% algae (Lowry and Frost 1981). The number of fish of each species identified in the stomach contents of seals from Otter Island was: pollock - 16; Pacific cod - 12; flatfish - 3; eelpout - 3; sculpins - 1; and unidentified - 1 (Frost and Lowry, unpublished). The pollock eaten ranged from 10.3 to 56.3 cm long with a mean length of 31.8 cm (Frost and Lowry, in press).

The other collection was made during 4-12 October 1981 at several coastal locations from Nunivak Island to Unimak Pass. Sample sizes from each location were small (two-five stomachs with food), and the observed major prey varied significantly as follows: Nunivak Island - greenling and sculpins; Cape Pierce - smelt, greenling, and lamprey; Port Heiden - sculpins, sand lance, flatfish, and pollock; Port Moller - sand lance and pollock; and Akun Island - Pacific cod, octopus, pollock, and halibut (Lowry et al. 1982). Pollock eaten by seals at Port Heiden were all small with a mean length of 10.6 cm (Frost and Lowry, in press).

The importance of fish species in the diet of harbor seals based on those three collections is summarized in Table 13. The obvious variations in major prey species utilized is probably due to both geographical and seasonal factors. Pollock and cod may be relatively more abundant near the Pribilof Islands than in Bristol Bay. Capelin and herring, which spawn in the coastal zone in late spring, were probably not available to seals during the October collection in Bristol Bay.

The number of harbor seals that have been collected is not adequate to qualitatively describe seasonal and geographical variations in foods consumed. Octopus and fishes are their primary prey. Commercially important fish species, especially herring, pollock, Pacific cod, and flatfishes, make up a substantial portion of their diet.

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Table 13. Rank order of importance of fishes in harbor seal stomach contents. Brackets indicate tied ranks.

Rank	Bristol Bay May-June 1985 n=16	Bristol Bay October 1981 n=19	Otter Island April 1979 n=8
1	Capelin	Sand lance	Pollock
2	Herring	Sculpins	Pacific cod
3	Sand lance	Rainbow smelt	Flatfish
4	Flatfish	Pollock	Eelpout
5	Pacific cod	Greenling	Sculpins
6	Eulachon	Flatfish	
7	Pollock	Pacific cod	
8	Eelpout	Pacific halibut	
9	Sculpin	Rockfish	
10	Rainbow smelt	Lamprey	

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APPENDIX I. Common and scientific names of fishes and invertebrates in this report.

Fishes

Walleye pollock - Theragra chalcogramma
Pacific cod - Gadus macrocephalus
Arctic cod - Boreogadus saida
Pacific herring - Clupea harengus
Capelin - Mallotus villosus
Eulachon - Thaleichthys pacificus
Rainbow smelt - Osmerus mordax
Sand lance - Ammodytes hexapterus
Eelpout - Lycodes spp.
Sculpin - family Cottidae
Greenling - Hexagrammos sp.
Flatfish - family Pleuronectidae
Pacific halibut - Hippoglossus stenolepis
Yellowfin sole - Limanda aspera
Sandfish - Trichodon trichodon
Prickleback - Lumpenus sp.
Lamprey - Lampetra sp.

Invertebrates

Octopus (Octopus spp.)
Squid - family Gonatidae
Clam - Spisula polynyma (surf clam), family Cardiidae (cockles), Serripes groenlandicus (Greenland cockle), Mya spp. (soft-shelled clam), Yoldia sp., Hiatella sp., family Tellinidae (tellins)
Snail - Natica clausa, Natica sp., Polinices sp. (moon snails), Buccinum sp., Neptunea sp. (whelks)
Gammarid amphipod - Acanthostepheia sp., Anonyx sp.
Shrimp - family Hippolytidae (Eualus spp., Spirontocaris spp.), family Crangonidae (Argis spp., Crangon spp.)
Hermit crab - Pagurus sp.
Spider crab - Hyas coarctatus
Tanner crab - Chinoecetes spp.
Echiurid - Echiurus echiurus