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Marine Mammals
in Fisheries Ecosystem
in the Eastern Bering Sea and
in the Northeastern Pacific Ocean

Part 2. Consumption of fish and other
marine biota by mammals in the eastern
Bering Sea and Aleutian region

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MARINE MAMMALS IN FISHERIES ECOSYSTEM
IN THE EASTERN BERING SEA AND IN THE
NORTHEASTERN PACIFIC OCEAN

Part 2. Consumption of fish and other marine biota
by mammals in the eastern Bering Sea and Aleutian region

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CONTENTS

Abstract.

1. Introduction
2. Predation by marine mammals on marine resources in the eastern Bering Sea and in the Aleutian region.
3. Some relations between predation by marine mammals and fishery.
4. References.
5. Figures.
6. Tables.

LIST OF FIGURES AND TABLES

Figure 1.--Computation areas for PROBUB 80-1 in the eastern Bering Sea and western Gulf of Alaska.

Figure 2.--Schematic presentation of the effects of predation by marine mammals. A-The effect of mammal predation on the distribution of biomass of a species with age. B-The effect of mammal predation on the biomass level of total finfish biomass in an ecosystem.

Table 1.--Marine mammals in the eastern Bering Sea, Gulf of Alaska, and west coast of North America.

Table 2.--Consumption by marine mammal groups in the eastern Bering Sea and in the Aleutian region (in 1,000 tonnes).

Table 3.--Consumption of fish and other marine biota by marine mammals in the eastern Bering Sea and in the Aleutian region (in 1,000 tonnes).

ABSTRACT

The total consumption of finfish by marine mammals in the eastern Bering Sea and in the Aleutian region is about 3 million tonnes annually, of which about two-thirds are commercial species. The total consumption of fish by marine mammals is about twice the present catch by domestic and foreign fisheries.

The greatest fish consumers are pinnipeds, followed by toothed and sperm whale groups, the latter consuming mainly offshore squid and fish resources.

The effect of marine mammal predation on fishery resources can be demonstrated theoretically, but empirical proof is lacking. The effect of fishing (i.e. competition of fishermen with marine mammals for a common resource) on marine mammals can be neither demonstrated theoretically nor empirically until causes of fluctuations in marine mammal abundance can be quantified, and the magnitude and periods of "natural fluctuations" of different fishery resources are investigated.

I. INTRODUCTION

Apex predation is one of the driving functions in "top down" ecosystem simulation models, especially if the amounts of marine mammals are high in the area under consideration.

This report summarizes the results of computations of consumption by marine mammal groups in the eastern Bering Sea and Aleutian region, using the PROBUB 80-1 model. The basic input data for the computations are presented in another NWAFC Processed Report (Laevastu, Livingston, and

Niggol, 1980a). The computation areas are shown in Figure 1. Areas 1, 2, and 3 encompass the eastern Bering Sea and areas 4 and 5 together form the Aleutian region. A summary of some marine mammal data in the North Pacific is given in Table 1.

Determination of the effects of predation by marine mammals on the fishery resources, and vice versa--the effects of fishing on marine mammals via their food resources--requires considerable additional study; this report is an initial progress report on this subject.

2. PREDATION BY MARINE MAMMALS ON MARINE RESOURCES IN THE EASTERN BERING SEA AND IN THE ALEUTIAN REGION

The consumption of fish and other marine biota by marine mammals in the eastern Bering Sea and in the Aleutian region is summarized in Tables 2 and 3. This consumption is based on data presented by Laevastu, Livingston, and Niggol, 1980a. Although plausible average estimates of abundance of marine mammals, as well as plausible average food requirements, were used in the computations, the values presented in Tables 2 and 3 might be considered as plausible maximum consumptions because the simulated Bering Sea and Aleutian ecosystems do not "tolerate" (permit) this high consumption unless their carrying capacity is considerably higher than presently estimated (see also Laevastu, Livingston, and Niggol, 1980b). The most plausible consumption by marine mammals seems to be ca 12% lower than the values given in Tables 2 and 3. These differences might be due to (a) overestimation of the number of mammals present (very unlikely if comparing the relatively conservative estimates of the numbers given in this report

with estimates available in the literature); (b) overestimation of the food requirements by mammals (a likely cause, i.e. marine mammals might consume less in the ocean than aquarium research results indicate, and also might grow slower in the ocean as a consequence); (c) partial starvation of marine mammals in the ocean (a likely cause in combination with (b) above and also a consequence of (b)).

The total consumption of finfish by marine mammals in the eastern Bering Sea is estimated by the model to be 1.77×10^6 tons and in the Aleutian region 0.89×10^6 tons, together 2.56×10^6 tons. The quantities of present commercially important species taken by mammals are 1.33×10^6 ; 0.72×10^6 ; and 2.05×10^6 tons, respectively.

The most heavily consumed species is the most abundant species--pollock (0.73×10^6 , 0.40×10^6 , and 1.13×10^6 tons, respectively). Flatfishes are subject to the lowest relative consumption because they occupy the regime (benthic) which is least available to air breathing mammals. Only mammals adapted to long and deep dives consume more flatfish. The estimated consumption of salmon by mammals is 35×10^3 , 21×10^3 , and 56×10^3 tons, respectively. Squids are consumed mainly off the continental shelf (total 2.98×10^6 tons, or about the same amount as finfish).

The consumption of crabs in the eastern Bering Sea is 35×10^3 tons and from the Aleutian region only 5×10^3 tons. It is not possible at present to separate the consumed crabs into commercial and noncommercial groups. The consumption of shrimps (mostly "noncommercial") is 132×10^3 and 20×10^3 , respectively.

The consumption of benthos by mammals in the Bering Sea is 2.01×10^6 tons, or slightly less than the consumption of finfish. The corresponding consumption in the Aleutian region is only 0.32×10^6 tons (re. deep area). The total consumption of zooplankton (copepods and euphausiids) by marine mammals in the eastern Bering Sea is 2.01×10^6 tons, or slightly more than the consumption of finfish. The corresponding consumption in the Aleutian region is 1.33×10^6 tons, i.e. about 40% more than the corresponding consumption of finfish in this region.

The consumption of various ecological groups by ecological groups of marine mammals is summarized in Table 2. The baleen whales consume mostly zooplankton, but also take some small schooling fish. The take of fish by baleen whales is highest off the continental slope in the Bering Sea (303×10^3 tons). The benthos taken by baleen whales is mainly epibenthic crustaceans (e.g. amphipods). Sperm whales take, besides squids, schooling pelagic fish. Their fish consumption is slightly higher in the Aleutian region than in the Bering Sea due to their distribution in space.

Toothed whales feed mainly on fish over the continental shelf. Therefore, the consumption of fish by these whales is highest over the eastern Bering Sea shelf (239×10^3 tons, including 10×10^3 tons of salmon). The consumption of fish by dolphins and porpoises is rather insignificant (8.2×10^3 in the eastern Bering Sea, 10.8×10^3 tons in the Aleutian region) as compared to corresponding consumption by whales and pinnipeds.

Group I pinnipeds (mainly fur seal and sea lion, which feed during the summer in the Bering Sea) consume significant amounts of finfish (460×10^3

tons in the Bering Sea and 327×10^3 tons in the Aleutian region) including salmon (15×10^3 and 12×10^3 , respectively). Consumption of flatfish by this group of pinnipeds is very low.

Group II pinnipeds (which feed mainly during the winter in the Bering Sea), consume a considerable amount of finfish in the Bering Sea (546×10^3 tons) and lesser amounts in the pelagic area north of the Aleutian chain (147×10^3 tons). Because of their diving and benthic feeding habits they can take flatfishes from and near the bottom (61×10^3 tons from the Bering Sea), their consumption of benthos being, however, considerably higher ($1,449 \times 10^3$ tons from the Bering Sea).

Consumption of fish by mammals is highest during the summer months when their abundance in the region is highest.

The consumption of herring by pinnipeds in Group I is obviously highest over the continental shelf in the Bering Sea where both the pinnipeds and the herring occur in greater abundance. On the other hand, the consumption of herring over deep subregions in the Aleutian area is higher than over the Aleutian continental shelf (the main reason is the small size of the continental shelf there).

There are a great number of tables on the distribution of consumption by individual mammals of individual food items in space and time produced as simulation outputs.

3. SOME RELATIONS BETWEEN PREDATION BY MARINE MAMMALS AND FISHERY

The nature and magnitudes of the effects of mammals on the marine ecosystem and on the commercial resources in it vary from one ecological type of mammal to another and this variation depends on several factors which are briefly described below.

The "offshore" baleen whales feed on the same "trophic level" as most pelagic fish and consume the offshore zooplankton as a food resource, competing possibly with salmon, herring, and pollock in this regime; gray, white, and bowhead whales compete directly with many of the commercial fish on the continental shelf where they consume epibenthos. At this time it is difficult to evaluate the competition between whales and pelagic fish, as the empirical data for zooplankton production (especially euphausiids) are deficient in the North Pacific (Laevastu and Livingston 1980). The standing stocks and production of epibenthos in the Bering Sea is virtually unknown, mainly due to experimental difficulties in obtaining quantitative samples. The monthly zooplankton standing stock is simulated in the model, based on best available data. Less than 25% of this standing stock is consumed in offshore areas per month.

Among pinnipeds, only walrus and bearded seals use considerable amounts of benthos as food. As these animals use larger benthic organisms which are unsuitable for fish food because of their size, the competition for the benthic food resource between demersal fish and these mammals is minimal. On the other hand, toothed whales and most pinnipeds feed directly on fish and, therefore, compete directly with man. Because mammals often prey on juvenile fish, that predation can affect both the size distribution of the fish and the size of the exploitable biomass of the fish (Fig. 2). Additional numerical studies on the effects of mammal predation on fishery resources will be conducted with the dynamical ecosystem model DYNUMES.

Conversely, the effects of fishing on the food of marine mammals cannot be empirically demonstrated at present. There is no empirical proof that the fishery in the Bering Sea (maximum 2.2 tons per km² as compared to 6.7 tons per km² from the North Sea) has adversely affected the total finfish biomass; in fact, there is good evidence that pollock, cod, herring, and yellowfin sole biomasses have increased substantially during these years. The rejuvenation of biomass (which is a consequence of fishing) might be working in favor of marine mammals who feed predominantly on smaller fish than taken by fishery. Although there have apparently been rather violent fluctuations of the biomasses of some species, there is no proof that the total finfish biomass has decreased. There is theoretical evidence, as well as empirical observations, from several areas (e.g. North Sea) that fishing does not affect total finfish biomass, because when one species declines in abundance other species might incline. (Exceptions to this role are "quasi-monospecies" fish ecosystems in upwelling areas.)

Studies of the possible effects of fishing on marine mammals require new hypotheses as to causes and effects and also accurate observations on the dynamics of mammal populations. Studies of the magnitudes and periods of natural fluctuations of finfish biomasses will be conducted with ecosystem simulation model, in order to be able to separate any effects of fishery and/or mammal consumption from these natural fluctuations.

4. REFERENCES

Laevastu, T., P. Livingston, and K. Niggol.

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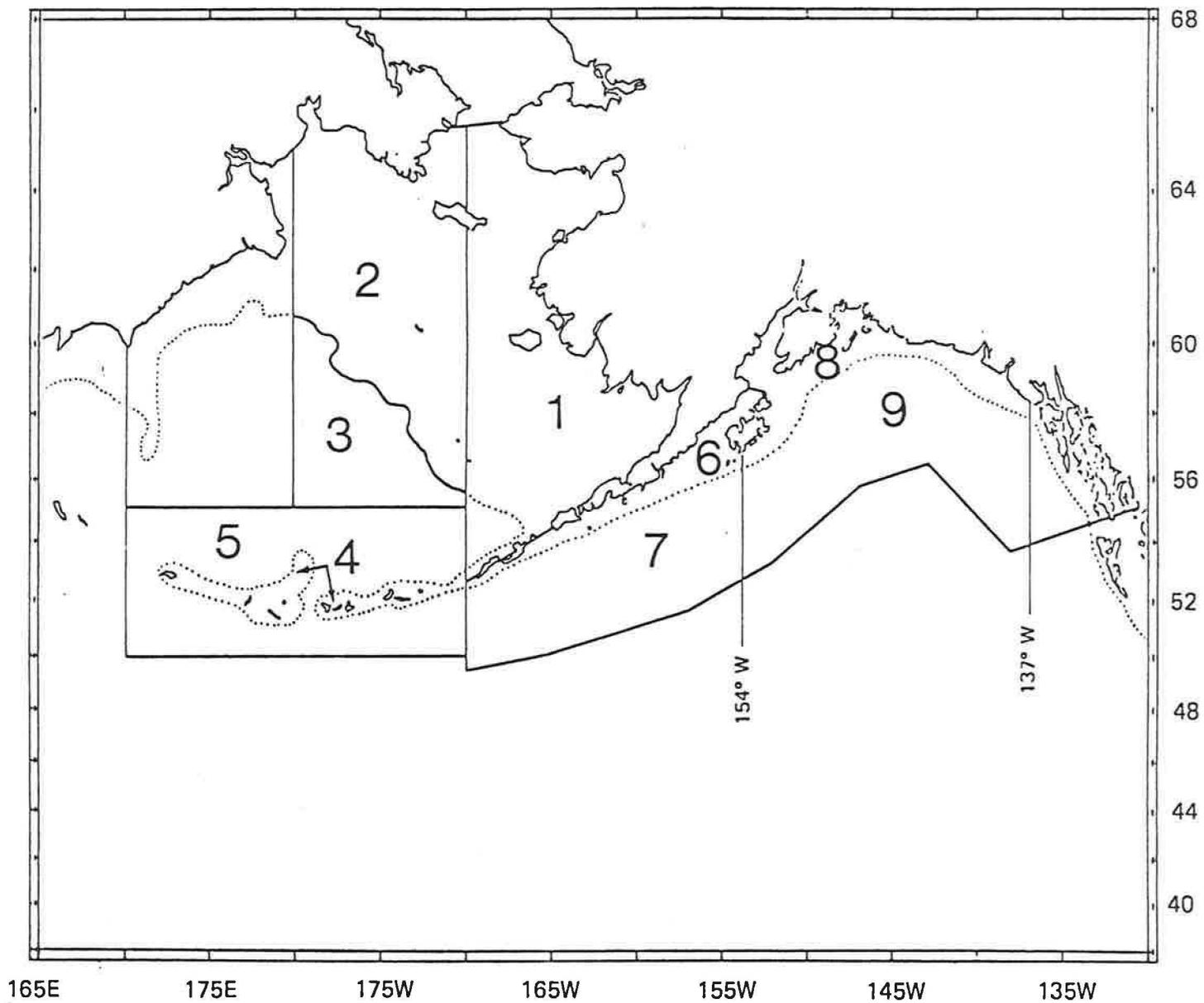


Figure 1.--Computation areas for PROBUB 80-1 in the eastern Bering Sea and western Gulf of Alaska

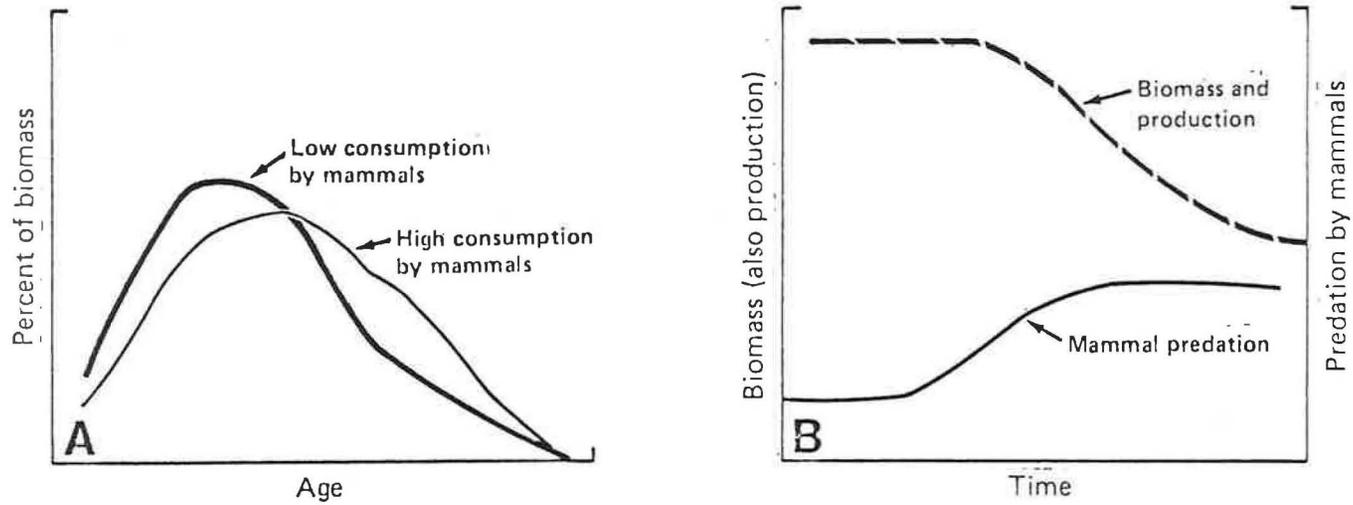


Figure 2.--Schematic presentation of the effects of predation by marine mammals. A.--The effect of mammal predation on the distribution of biomass of a species with age. B.--The effect of mammal predation on the biomass level of total finfish biomass in an ecosystem.

Table 1.--Marine mammals in the eastern Bering Sea, Gulf of Alaska and west coast of North America

Rank no.	Name	Latin name	Grp. wt.	Avg. wt.	Est. no. in N. Pacific	Maximum and minimum numbers and months			
						Areas 1 to 9	Areas 11 to 16		
<u>Baleen whales</u>									
1	{ Gray whale Right whale	Eschrichtius robustus	31	30t	11,000(E)	8,000(7)-	-	4,100(1)-	1,150(7)
		Balaena glacialis		50	(200) ?	50(8)-	-	50(12)-	-
2	{ Fin whale Minke whale	Balaenoptera physalus	36	50	17,000	4,000(8)-	-	1,300(12)-	1,000(7)
		Balaenoptera acutorstrata		9	?	3,000(8)-	-	800(12)-	-
3	Bowhead whale	Balaena mysticetus		35	3,000	2,500(3)-	200(8)	-	-
4	{ Blue whale Sei whale	Balaenoptera musculus	45	75	1,700	Aleut. 500	-	800(12)-	200(7)
		Balaenoptera borealis		30	28,000	Alaska 1,500(8)	-	1,500	-
5	Bryde's whale	Balaenoptera edeni (brydei)		30	25,000	-	-	500(7)-	100(2)**
<u>"Sperm whales" ***</u>									
6	{ Giant bottlenose whale Bering Sea beaked whale	Berardius bairdi	8	10	10,000 ?	2,000(8)-	-	1,000(2)-	500(8)
		Mesoplodon steinegeri		2.5	?	600(8)-	-	200(2)-	100(8)
7	Sperm whale	Physeter catodon		32	200,000	20,000(8)-	-	10,000(11)-	6,000(8)
<u>"Toothed whales" ***</u>									
8	Humpback whale ****	Megaptera novaengliae		25	1,400	200(6)-	-	200(2)-	50(6)
9	Beluga (white) whale	Delphinapterus leucas		2.0	60,000(A)	10,000	-	-	-
10	{ Killer whale Goosebeak (or Cuyler's) whale	Orcinus orca	8	10	3,000 ?	900	-	600	-
		Ziphius cavirostris		3	500 ?	200	-	200	-
<u>Porpoises and Dolphins</u>									
11	{ Pacific white-sided dolphin Dall's porpoise	Lagenorhynchus obliquidens	120	60kg	10,000(E) ?	3,000(8)-	-	4,000	-
		Phocoenoides dalli		140	500,000	30,000(8)-	10,000(3)	10,000	-
12	Harbour porpoise	Phocoena phocoena (vomerina)		80	20,000	5,000(8)-	4,000(3)	500	-
13	{ Northern right whale dolphin Risso's dolphin Common dolphin Bottlenose dolphin Pilot whale	Lissodelphis borealis	85	70	40,000	-	-	20,000	-
		Grampus griseus		100	?	-	-	2,000	-
		Delphinus delphinus		55	?	-	-	4,000	-
		Tursiops truncatus		100	?	-	-	2,000	-
		Globicephala macrorhyncha (scammoni)		200	500 ?	-	-	1,000	-
14	Sea otter	Enhydra lutris		35	120,000	100,000	-	18,000	-
<u>Pinnipeds, group 1</u>									
15	Northern fur seal	Callorhinus ursinus		45	1,400,000(E)	1,100,000(7)-	200,000(3)	800,000(1)-	150,000(7)
16	Steller (northern) sea lion	Eumetopias jubatus		350	275,000	100,000(8)-	55,000(3)	60,000(3)-	15,000(7)
17	California sea lion	Zalophus californianus		100	110,000	-	-	50,000(7)-	35,000(2)
18	Northern elephant seal	Mirounga angustirostris		900	35,000	-	-	20,000	-
19	Harbour seal	Phoca vitulina (Richardi)		50	750,000 ?	270,000	-	19,000	-
<u>Pinnipeds, group 2</u> ("ice seals")									
20	Walrus	Odobenus rosmarus		800	175,000	175,000(3)-	20,000(8)	-	-
21	Bearded seal	Erignathus barbatus		200	300,000	250,000(3)-	50,000(8)	-	-
22	{ Ribbon seal Larga (spotted) seal Ringed seal	Phoca fasciata	56	70	100,000	100,000(3)-	60,000(8)	-	-
		Phoca vitulina largha		55	250,000	220,000(3)-	30,000(8)	-	-
		Phoca hispida		60	up to 1 mil.	200,000(3)-	20,000(8)	-	-
23	Sharks			100	?	50,000(8)-	10,000(3)	40,000	-

* - Estimated Arctic population.

** - Rare occurrence north of 35°N.

*** - The groups "sperm whales" and "toothed whales" signify groupings by feeding habits.

**** - Humpback whale, although a baleen whale, has been included in the "toothed whale" group because of its rather extensive fish diet.

Table 2.--Consumption by marine mammals in the eastern Bering Sea and in the Aleutian Region. (In 1,000 tonnes.)

Species/groups of species consumed	1		2		3		4		5		6	
	Baleen whales		"Sperm whales"		Toothed whales		Dolphins, porpoises		Pinnipeds I		Pinnipeds II "ice seals"	
	Bering Sea	Aleutian Region	Bering Sea	Aleutian Region	Bering Sea	Aleutian Region	Bering Sea	Aleutian Region	Bering Sea	Aleutian Region	Bering Sea	Aleutian Region
Flatfishes	-	-	2.3	1.8	21.9	4.8	0.3	0.2	13.6	14.0	61.2	14.0
Cod and sablefish	19.0	0.2	2.2	2.1	21.3	6.5	1.1	1.7	15.3	14.7	114.9	36.0
Pollock	129.6	31.6	100.8	122.4	98.2	28.3	2.8	3.8	218.0	154.1	182.1	57.6
Herring	47.3	15.4	19.8	22.5	16.5	4.0	0.9	1.3	35.2	23.6	12.0	2.8
Salmon	-	-	3.3	3.9	10.3	2.9	0.4	0.6	15.3	12.3	5.5	1.4
Atka mackerel	16.5	5.5	38.8	45.5	2.7	2.1	0.5	0.7	32.5	22.6	-	-
Rockfish	15.2	3.8	24.4	28.2	9.5	3.6	0.5	0.8	22.3	20.4	-	-
Total commercial spp.	227.6	56.5	191.6	226.4	180.5	52.3	6.5	9.0	352.2	261.6	375.6	111.7
Other fish	75.0	30.6	25.8	27.8	58.9	14.6	1.7	1.8	107.4	65.7	169.9	35.3
Total finfish	302.6	87.1	217.4	254.1	239.3	66.9	8.2	10.8	459.6	327.3	545.5	147.0
Squids	109.5	82.6	1,209.2	1,476.0	8.3	7.0	2.2	3.7	39.7	37.6	-	-
Crab and shrimp	121.7	17.4	-	-	-	-	0.1	-	1.1	1.0	44.0	6.8
Benthos*	538.7	54.1	19.7	22.0	0.4	0.3	0.4	0.5	3.2	2.9	1,448.5	240.4
Zooplankton**	1,829.8	1,135.8	142.4	176.2	2.6	2.4	-	-	-	-	38.5	11.2

* Includes epifauna and infauna

** Copepods and euphausiids

Table 3.--Consumption of fish and other marine biota by mammals in the eastern Bering Sea and in the Aleutian Region (in 1,000 tonnes)

Species/groups of species consumed	Consumption							Total Bering Sea/Aleutian Region
	Region 1	Region 2	Region 3	Bering Sea Total	Region 4	Region 5	Aleutian Region Total	
Flatfish	53.4	37.0	9.0	99.4	26.1	8.7	34.8	134.2
Cod and sablefish	74.8	57.4	41.5	173.7	25.1	36.1	61.2	234.9
Pollock	255.0	205.4	271.1	731.5	130.6	267.1	397.7	1,129.2
Herring	48.6	38.5	44.6	131.7	24.3	45.2	69.5	201.1
Salmon	11.3	10.3	13.2	34.8	9.1	12.0	21.1	55.9
Atka mackerel	23.0	19.8	48.3	91.1	18.1	58.3	76.3	167.4
Rockfish	19.6	15.6	36.7	71.9	17.4	39.5	56.7	128.7
Total commercial spp.	485.6	384.0	464.4	1,334.0	250.7	466.7	717.4	2,051.4
Other fish	190.2	152.2	96.3	438.7	83.7	92.2	175.8	614.5
Total finfish	675.8	536.2	560.7	1,772.7	334.4	342.9	893.2	2,557.9
Squids	122.2	95.4	1,151.2	1,368.8	125.2	1,481.7	1,606.9	2,975.7
Crab and shrimp	83.7	62.4	20.7	166.8	12.1	13.2	25.2	192.1
Benthos	1,145.4	778.8	86.8	2,011.0	246.4	73.9	320.3	2,331.3
Zooplankton	670.1	474.3	868.8	2,013.3	280.9	1,044.7	1,325.6	3,338.9