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Summary of Joint Research on the Diets of Northern Fur Seals and Fish in the Bering Sea During 1985

December 1986

SUMMARY OF JOINT RESEARCH ON THE DIETS OF NORTHERN FUR SEALS AND FISH IN THE BERING SEA DURING 1985

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INTRODUCTION

The population of northern fur seals (_Callorhinus ursinus_) which breeds on the Pribilof Islands, Alaska, has declined at the rate of 5-8% per year from 1976 to 1980 and 0-4% from 1980 to present; these declines resulted in a decrease in population size from about 1.2 million animals to the current estimate of about 800,000 animals (Fowler 1985; York and Kozloff in press). The decline is correlated with entanglement which may serve as an explanation (Fowler, 1985), but other explanations can not be ruled out. For example it may be linked to the quality or quantity of prey available. It has been postulated that reductions in fish through foreign and domestic groundfish fisheries or by consumption of fish by other marine fish in the eastern Bering Sea may have reduced the amount of food available resulting in lower fur seal population levels.

During a 1983 workshop on the biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea (Alaska Sea Grant College Program 1984), a working group identified research on the relationships between northern fur seals and groundfish stocks and northern fur seals and fisheries as high priority. That workshop identified four components of a sequence which describe the possible mechanism for fisheries to impact marine mammal populations. The components of the sequence included:

1. The removal of food resources by the fishery, in combination with other predators, must affect food resources differently than predation alone.

2. Changes in food resource abundance must affect intake of food by marine mammals.

3. A change in food intake must result in a change in vital parameters (growth, survival, reproduction) of individual marine mammals.

4. Changes in individual life history parameters must affect population parameters such as abundance and productivity.

During 1985 the Northwest and Alaska Fisheries Center (NWAFC) conducted research designed specifically to address the topics raised at the workshop. The work was conducted by the National Marine Mammal Laboratory (NMML) and Resource Ecology and Fisheries Management (REFM) Divisions of the NWAFC. This report is a presentation of research conducted by the two NWAFC elements as it addresses the first two topics. Research by the NMML involved a study of fur seal feeding habits by analysis of stomach contents of fur seals collected at sea, analysis of fur seal scats collected at St. Paul Island, analysis of colon contents from fur seals killed in the harvest at St. Paul Island, and a study using radio telemetry to determine feeding locations and movement patterns at sea. The objectives of the REFM research were to quantify the food habits and consumption rates of fish predators which consume the same prey as northern fur seals and to assess the removal of prey by fishing activities. Each project will be presented separately then followed by a summary of the cooperative research.

SECTION I--NATIONAL MARINE MAMMAL LABORATORY

Pelagic Food Habits of Northern Fur Seals

by

Elizabeth S. Hacker and George A. Antonelis, Jr.

Introduction

Although the food habits of fur seals were thoroughly studied in the early 1970's, there has been inadequate sampling in recent years or since the era of intense commercial fisheries to assess the impact of commercial fishing on fur seal feeding habits (Kajimura 1984). The purpose of the present study was to determine the current food habits of northern fur seals (Callorhinus ursinus). Fur seals examined on shore do not provide adequate food habits information due to the advanced state of digestion of most food items; therefore, fur seals were collected at sea during 1985 to examine their stomachs as soon after a meal as possible. A secondary purpose of the project was to assess the relative quantity and size of different fish and cephalopod species in the water column available to fur seals in the feeding areas. The following report is a summary of the 1985 study on food habits data for northern fur seals in the Bering Sea, and prey sizes and distributions relative to trawl survey results (Section II).

Methods

Based on food habits data available from earlier pelagic fur seal studies, R. DeLong and M. Perez (NMML) selected 11 sampling blocks over the continental shelf, shelf edge, and deep water basin within 160.9 km (100 miles) of St. Paul Island for collection areas (Fig. 1). The blocks were distributed to include various habitat types and known prey assemblages, based on fur seal collections in 1962 through 1964 and 1973 and 1974. During the study, 43 northern fur seals were collected 6-16 August 1985 (Fig. 1). The location, time of collection, sex, and age of each animal is presented in Table 1. The stomach, small intestines, and colon of each animal were removed and frozen for subsequent transport to the NMML where they were examined. Necropsy included examination of the esophagus for evidence of regurgitation. Gastrointestinal tracts were thawed and total volume and weight of the combined contents found in each stomach were measured as well as the volumes and weights of the major prey groups. Contents of the digestive tract segments were rinsed and sorted through a series of four fine meshed sieves (4.75 mm - 500ìm). Fish otoliths (sagittae) were stored dry. Cephalopod beaks and all bony and fleshy material were stored in 70% isopropyl alcohol.

Cephalopod beaks, otoliths, fish bones, and the few whole squid remains were identified to the lowest possible

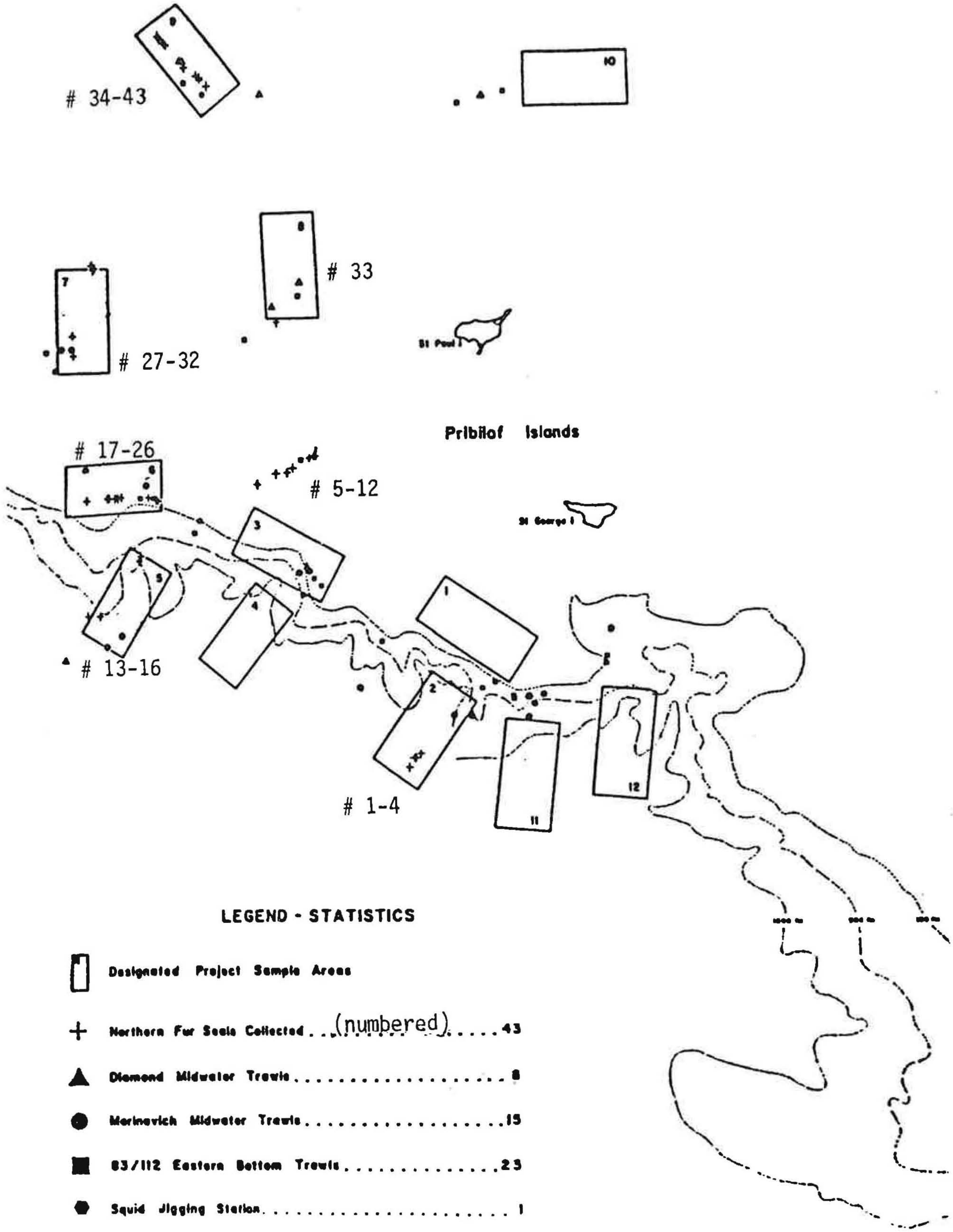

Figure 1.--Study area for the joint NMML/REFM fur seal and fish studies in the southeastern Bering Sea, 1985. The location for fur seal and fish collections are shown by numbered sample box. Legend shows other areas of interest.

Table 1--Date and position of northern fur seals (Callorhinus ursinus) collected in the Bering Sea, 6-16 August 1985.

Seal specimen	Date	Depth (m)	Area[a] (box #)	Sex	Age	Weight (kg)	Prey in stomachs Volume (cc)	Weight (g)
1	8-06	3073	2	F	7	33	200	200
2	8-06	3018	2	F	6	30	trace	trace
3	8-06	3000	2	F	4	22	trace	trace
4	8-06	2972	2	F	5	*	1150	1180
5	8-10	115	NB3[b]	F	7	44	185	210
6	8-10	122	NB3	M	3	25	trace	trace
7	8-10	123	NB3	F	9	32	trace	trace
8	8-10	123	NB3	F	5	27	trace	trace
9	8-10	123	NB3	F	7	30	trace	trace
10	8-10	121	NB3	F	7	35	480	380
11	8-10	121	NB3	M	3	25	200	200
12	8-10	121	NB3	M	2	20	trace	trace
13	8-12	1417	5	F	7	30	800	800
14	8-12	1555	5	M	2	22	1280	1260
15	8-12	2325	5	F	6	27	700	700
16	8-12	2560	5	F	7	38	180	150
17	8-12	136	6	F	7	37	700	700
18	8-12	142	6	F	9	47	trace	trace
19	8-12	142	6	F	7	45	trace	trace
20	8-12	150	6	F	5	47	trace	trace
21	8-12	163	6	F	9	32	trace	trace
22	8-12	165	6	F	4	24	trace	trace
23	8-12	159	6	F	5	33	trace	trace
24	8-12	166	6	F	7	*	trace	trace
25	8-12	154	6	F	7	38	trace	trace
26	8-12	159	6	F	7	37	trace	trace
27	8-13	121	7	F	7	47	3000	2990
28	8-13	119	7	F	7	51	7000	7120
29	8-13	123	7	F	7	38	700	760
30	8-13	123	7	F	8	37	trace	trace
31	8-13	121	7	F	8	37	1000	1020
32	8-13	121	7	F	7	40	trace	trace
33	8-13	106	8	F	8	45	trace	trace
34	8-16	112	9	F	8	31	trace	trace
35	8-16	112	9	F	5	37	trace	trace
36	8-16	112	9	F	7	44	625	700
37	8-16	112	9	F	9	36	trace	trace
38	8-16	112	9	F	9	36	trace	trace
39	8-16	112	9	M	4	37	trace	trace
40	8-16	108	9	F	7	43	trace	trace
41	8-16	108	9	F	7	30	trace	trace
42	8-16	108	9	F	7	50	trace	trace
43	8-16	108	9	F	7	36	trace	trace

[a]Refer to Figure 1 for location.
[b]NB3 = north of box 3.
*Not available.

taxonomic level by comparison with identified specimens from the reference collections of the NMML and the Oregon State University (OSU), College of Oceanography. Cephalopod identifications were made by E. Hacker (OSU) and confirmed by C. H. Fiscus (NMML) and K. Jefferts (OSU). Otolith identifications were made by us and bony remains of fishes by J. Dunn (REFM). Descriptive references used included Iverson and Pinkas (1971), Young (1972), Roper and Young (1975), Morrow (1979), and Clarke (1986). All voucher material is housed at the NMML.

The highest number of either upper or lower cephalopod beaks and left or right otoliths was recorded as the maximum count for each species identified. Lengths of the lower rostra of squid and the total length of fish otoliths were measured with vernier calipers to the nearest .05 mm.

Lower rostral length measurements were made on 222 gonatid squid (Fig. 2). Regression anaylses were not applied to the cephalopod measurements from the prey samples due to the high number of tentative identifications. However, the beak-to-body length ratio of gonatid squid collected in the trawls are presented for comparison with the prey sample (Fig. 3). Measured cephalopod beaks were all judged to be in good condition. Chipped or broken beaks were rare and were not measured. The two major groups of gonatids identified cannot presently be separated based on beak structure alone and will be referred to here as

Figure 2a

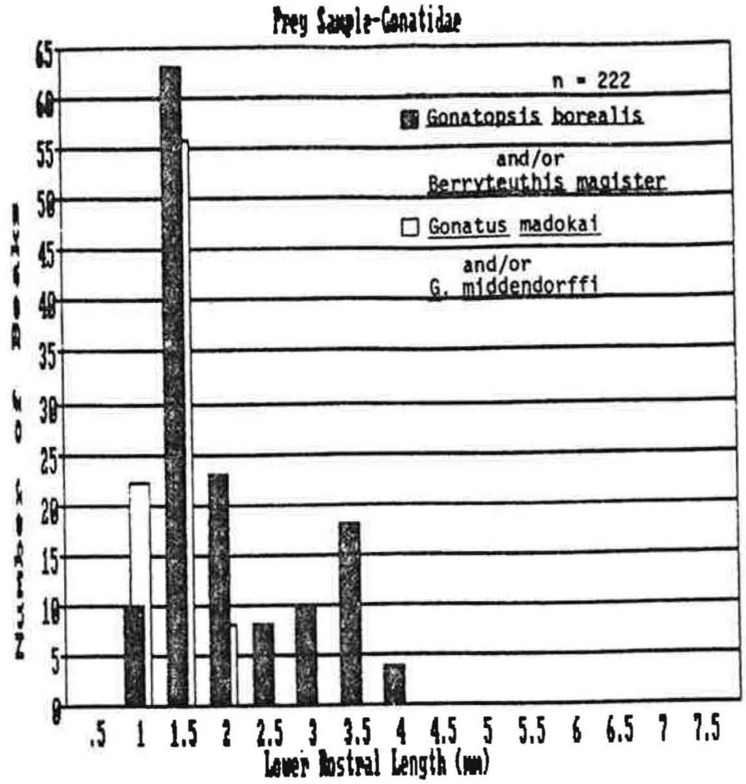

Figure 2b

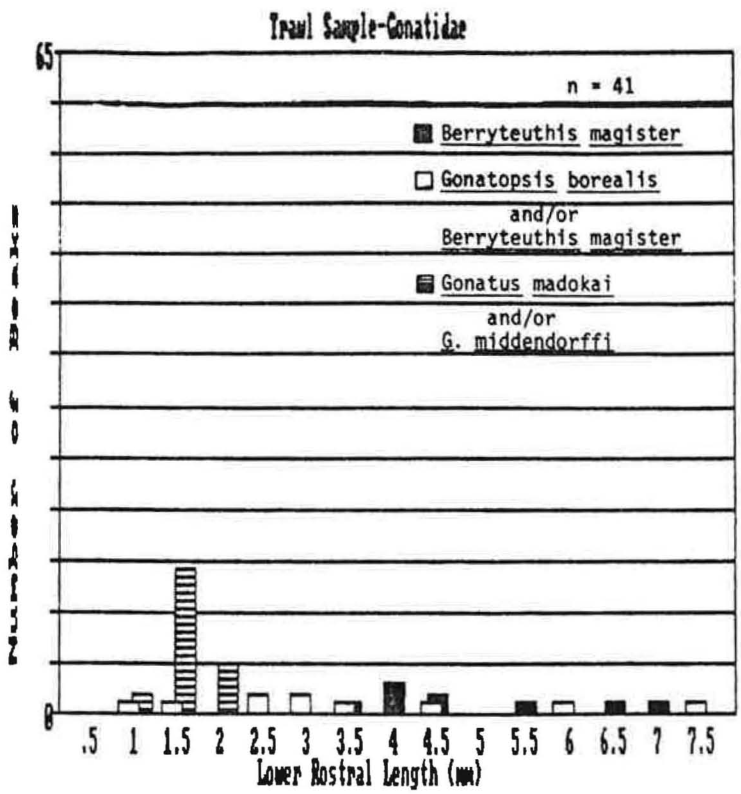

Figure 2.--Length of lower rostra (mm) of the major Gonatidae represented in the fur seal prey and the bottom and midwater trawls.

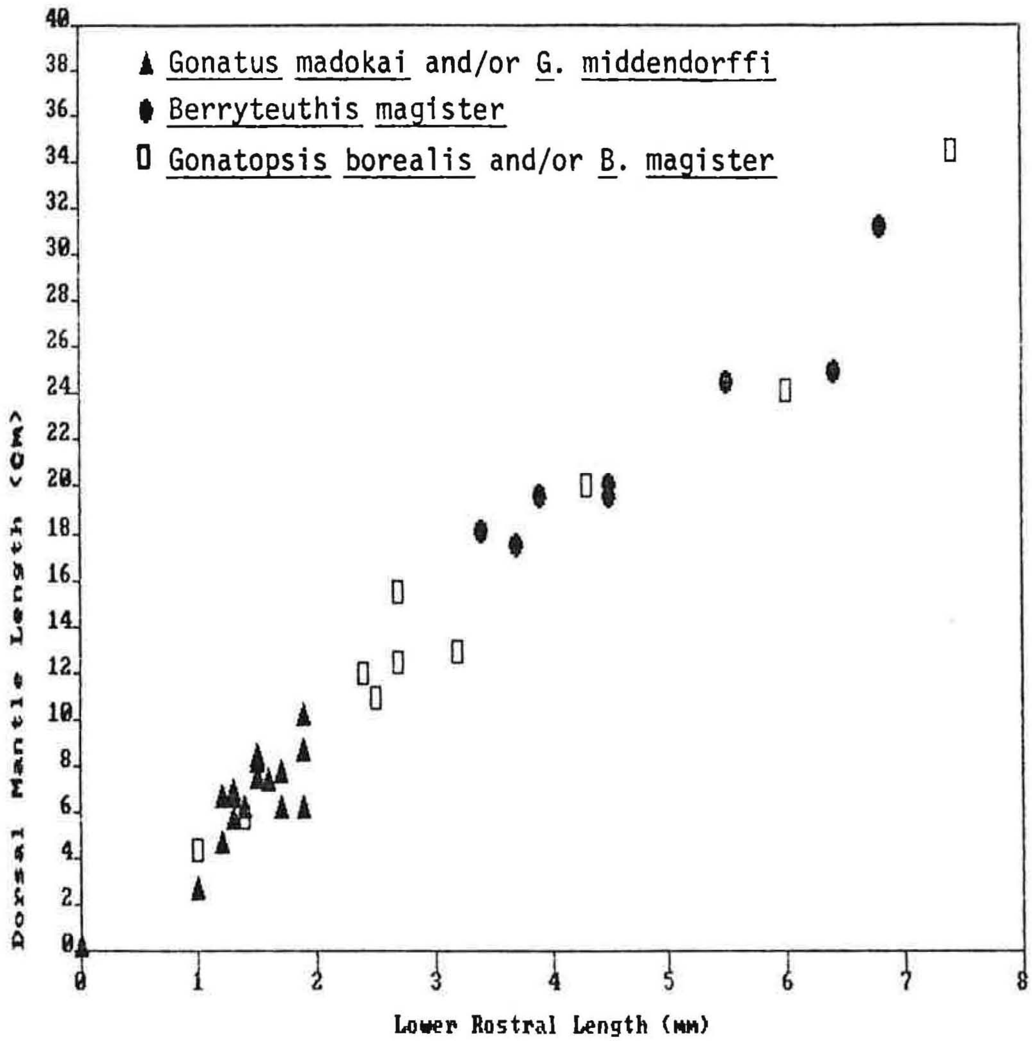

Figure 3.--Beak-(mm) to-body length (cm) ratios in Gonatidae from the bottom and midwater trawl samples.

Gonatopsis borealis or Berryteuthis magister and Gonatus madokai or Gonatus middendorffi.

The maximum lengths of 1,499 walleye pollock (Theragra chalcogramma) otoliths and 18 unidentified gadid type otoliths were measured for regression analysis. Calcareous material is readily degraded during digestion in marine mammal stomachs. As a result, otoliths of prey are generally worn to varying degrees and the length frequencies derived from otolith measurements are potentially biased. An attempt was made to reduce this bias by the development of "quality" categories. The condition of the otoliths was categorized as "excellent," "good," fair," or "poor." The latter were broken or worn beyond the point where key features were not identifiable and were not measured. "Fair" otoliths appeared either completely smooth or sometimes chalky in appearance, but were still identifiable to species. "Good" otoliths, though worn, retained the detail at the edges and sulcus. Fork lengths of walleye pollock were estimated from the otolith length to fork length regression equation developed for Bering Sea walleye pollock (Frost and Lowry 1981).

Twenty-three midwater and 23 bottom trawls were made in the vicinity of the fur seal collection positions (Fig. 1). Bottom trawls were conducted with an 83/112 eastern bottom trawl (1 1/4" codend mesh). A diamond midwater net (1 1/4" codend mesh) and a Marinovitch herring trawl (3/8" codend mesh) were used for midwater sampling. Cephalopods and fishes caught in the trawls were subsampled, identified and measured. Dorsal mantle length and lower rostral length was measured on the squids and fork length was measured on the fishes (see Section II for methods).

Results

All fur seal samples contained at least a trace of identifiable prey remains. Three species of fish and six species or species groupings of squid were identified from the gastrointestinal tracts of fur seals. The numbers, volumes, weights, and frequency of occurrence of prey from the gastrointestinal tract of each seal are summarized in Tables 1 and 2. Single vertebrae and small pieces of fish bone were categorized as single unidentified fish. Based on this procedure, 5 of 43 gastrointestinal tracts that would have otherwise been considered empty contained one unidentified fish. Only 15 of 43 stomachs (34.9%) contained enough material for volumetric and weight measurements. Identified prey consisted of cephalopods (11.6% total prey; 46.5% frequency of occurrence) and fish (88.3% total prey; 83.7% frequency of occurrence).

Walleye pollock were the most numerous and frequently occurring fish prey (77.4% of fishes; 67.4% frequency of occurrence). Regression analysis of walleye pollock otoliths indicated that 91% of those in the excellent and good categories were from fish 10-18 cm in length (Fig. 4A).

Table 2--Gastrointestinal contents of northern fur seals (*Callorhinus ursinus*) collected 6-16 August 1985.

Prey	Number[a]	% Occurrence	Seal Specimen Number
Fish total	1936	100.	1-43
Bathylagidae			
Leuroglossus stilbius schmidti (t)	279	9.3	3, 13, 14, 15
Gadidae			
Gadus macrocephalus (t)	3	7.0	12, 28, 31
Theragra chalcogramma	1499	67.4	1, 4, 5, 6, 8-12, 17, 21, 22, 25, 27-41, 43
T. chalcogramma (t)	2	4.7	40, 42
unidentified Gadidae	18	20.9	5, 6, 10, 13, 28, 32, 33, 35, 40
unidentified fishes	135	48.8	2, 7, 10, 15, 16, 18-24, 26-28, 30, 35, 36, 38, 41, 43
Cephalopod total	253	46.5	1, 2, 4, 13-17, 20, 22-24, 27, 28, 30-33, 37, 38
Gonatidae			
Gonatus berryi	1	2.3	14
G. pyros	1	2.3	2
G. tinro	1	2.3	14
G. tinro (t)	3	2.3	13
G. madokai or *G. middendorffi*	104	34.9	1, 13, 15, 17, 20, 22, 24, 27, 28, 30-33, 37, 38
Gonatus sp.	1	2.3	14
Gonatopsis borealis or *Berryteuthis magister*	139	20.9	1, 2, 4, 13-17, 23
unidentified Gonatidae	3	7.0	1, 2, 16

[a]Number of individuals.
t=Tentative identification.

Figure 4a.

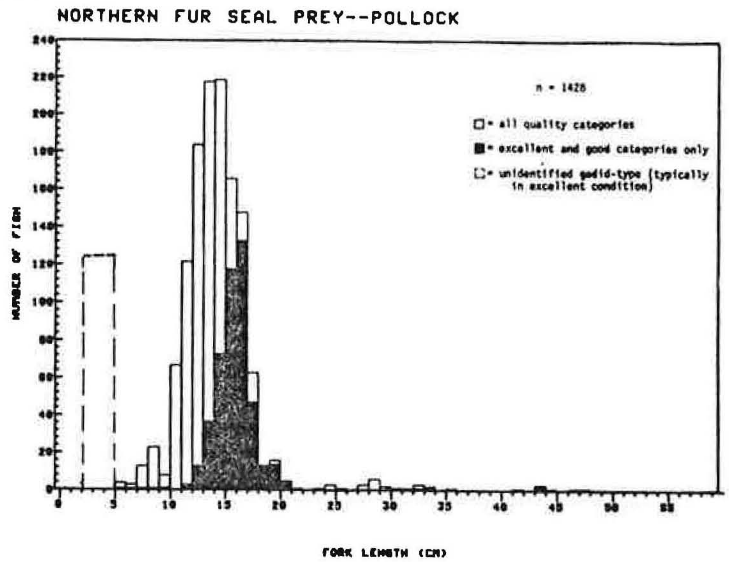

Figure 4b.

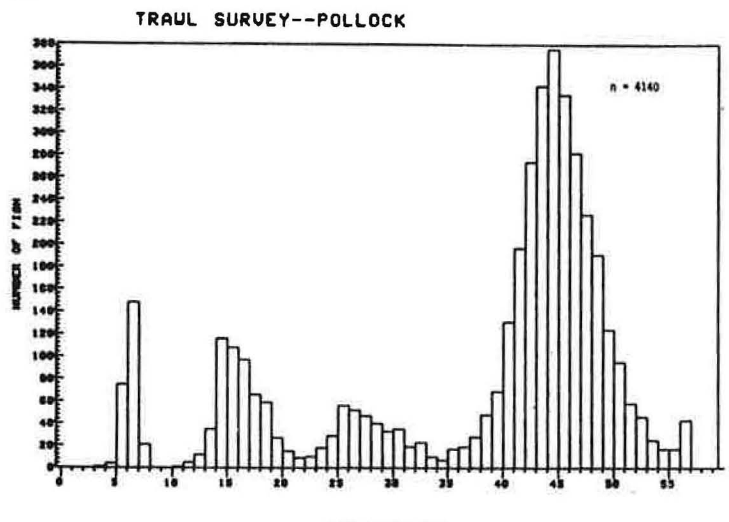

Figure 4.--Fork length frequencies (cm) for walleye pollock from fur seal prey contents and bottom and midwater trawls (note: the y axes on each graph are scaled differently).

Otoliths from two smaller categories of fish were also found. One category was from walleye pollock 5-10 cm in length and the other from an unidentified gadid type fish 2.4-4.7 cm in length. The latter represented 91.9% of the fishes in the unidentified category. Based on gadid distributional data in the Bering Sea (Bakkala and Wakabayashi 1985) this fish is probably walleye pollock but it is presented as an unidentified gadid-type fish in Figure 4A. Approximate ages of pollock corresponding to the size ranges of measured otoliths are age 0 (0-10 cm) and age 1 (10-22 cm).

The result of rigidly applying the otolith quality categories to the sample can be seen in Figure 4A. When measurements made on otoliths of "fair" quality are dropped, the graph appears to shift to the right. For example, the low number of walleye pollock in the 5-10 cm range in the prey samples drops even lower when only "good" and "excellent" otoliths are considered, and the predominant 10-18 cm categories shift to 12-20 cm length range.

Bathylagidae, tentatively identified as northern smoothtongue (Leuroglossus schmidti) were the second most numerous group of fishes (14.5% of fish numbers; 9.3% frequency of occurrence). They occurred in four seals (003, 013, 014, 015) collected on the continental slope. These four seals contained no gadid otoliths, but had the greatest numbers of squid, especially Gonatopsis borealis or

Berryteuthis magister, suggesting high availability of both these squid and the bathylagids in this area. Other seals taken in this vicinity (001, 002, 004, 016) contained a total of only three walleye pollock, all >10 cm in estimated length.

Cephalopods were primarily represented by juvenile Gonatopsis borealis or Berryteuthis magister (54.9% of squid) and Gonatus madokai or Gonatus middendorffi (41.1% of squid) in the gastrointestinal samples. Gonatopsis borealis or B. magister were found only in seals collected on or near the continental slope. Although Gonatus madokai or G. middendorffi were less abundant in the samples than Gonatopsis borealis or B. magister, they had a higher frequency of occurrence and were identified from seals collected at stations across the shelf and slope (Fig. 1; Tables 2 and 3). This inshore-offshore distribution pattern did not appear to be a factor of size. As shown in Figure 2A, Gonatus madokai or G. middendorffi actually fell within a narrower beak size range than Gonatopsis borealis or B. magister. Based on mantle length measurements from several whole squid found in one stomach, and the relative beak-to-mantle length ratio of trawl-caught squid (Fig. 3), the majority of this group of prey ranged from 6-12 cm dorsal mantle length. The size of Gonatopsis borealis or B. magister caught in the trawls was largely dependent on the

Table 3--Number and percent frequency of fish and cephalopods collected in trawls and as prey in seals taken off the Continental Slope and Shelf.

	SHELF				SLOPE				NEAR-SLOPE			
Prey	Seal no.	Percent	Trawl no.	Percent	Seal no.	Percent	Trawl no.	Percent	Seal no.	Percent	Trawl no.	Percent
Bathylagidae	0	-	0	-	4	50	4	50	0	-	0	-
Walleye Pollock (<10 cm)	8	47.1	3	18.8	1	12.5	0	-	2	11.1	0	-
Gonatus madokai or *G. middendorffi*	8	47.1	8	50	3	37.5	1	12.5	4	22.2	1	4.5
Gonatopsis borealis or *Berryteuthis magister*	0	-	1	6.3	7	87.5	8	100	2	11.1	0	-

type of trawl used. Larger specimens were most commonly caught in bottom trawls (Table 3).

Comparison of the size frequency distribution of squid (Figs. 2 and 3), and the modal pattern of 10-18 cm walleye pollock in both the trawl and gastrointestinal samples (Fig. 4) suggests that trawls effectively catch the sizes of squid and fish preyed upon by fur seals (Table 3), at least within this limited sampling period. The 2.4-4.7 cm fishes were not found in the trawls because small fish pass through the large codend mesh which selects for larger fish. These smaller fish may have been introduced secondarily by larger pollock

Discussion

The results of the fish trawl survey are analyzed in Section II. However, the prey lengths captured by both the trawls and fur seals are worth review here.

Walleye pollock in the 10-18 cm length range (age 1) were prevalent in the gut content samples. Only 9% of the measured pollock otoliths from the fur seal samples falls outside this length range compared to 88% of the lengths falling above and below this range in the trawl data. The 10-18 cm length range appears as a distinct peak in both trawl catches and fur seal stomach contents (Fig. 4). (It should be noted that Figure 4B represents only the size frequency of fish measured during survey operations and does not represent the size frequency of the pollock population.

Thus only the presence or absence of a size mode in the trawls can be discussed; the height of the mode in Figure 4A may not reflect those of the population without further data analysis.) Whether or not the quality restrictions placed on the otoliths prove to be valid, the trawl sample appears to reflect the prey sample structure within the 10-20 cm length range, or age 1 walleye pollock. Similarly, the length frequency distribution pattern of squid shows a distinct mode at 5-20 cm in both the trawl and gut samples. The fur seals from our sample appear to be selecting prey 5-20 cm in length.

The unidentified 2.4-4.7 cm fish are well represented in the fur seal samples, yet, there are few 5-10 cm walleye pollock, even though the 5-8 cm length range is present in the trawls (Fig. 4). The remains of larger 10-20 cm walleye pollock were always found with the unidentified 2.4-4.7 cm fish in the fur seal samples, and the 10-20 cm length range appears as a peak in both the fur seal sample and trawl sample. This suggests that the small gadid type otoliths may be introduced secondarily from the stomachs of the 10-20 cm walleye pollock.

The fur seal samples containing otoliths of 2.4-4.7 cm unidentified fish, and those of walleye pollock 5-22 cm in length were collected on the shelf and near the continental slope (Table 3). Assuming that the small unidentified otoliths are pollock, these results are in concurrence with the Resource Ecology and Fisheries Management (REFM) Division's trawl and fish food habits survey which found that age 0 walleye pollock occur in areas near the continental shelf and slope, and age 1 pollock are found primarily on the shelf. If the close relationship between the sizes and distribution of prey in the fur seal stomachs and trawl collections is any indication, it seems that the trawls are collecting a representative sample of the nektonic environment in this region. The midwater trawls seem especially relevant to the fur seal feeding habits with the exception that they do not select for 0-age pollock.

The distributional pattern of Bathylagidae, juvenile walleye pollock, and gonatid squid in the trawl catches is nearly identical to the presence of these three groups in the fur seal samples in the same locations. Bathylagidae were caught in sample areas 3, 5, and 6, and between areas 2 and 4 (Fig. 1). They were found in fur seals collected in areas 2 and 5. These stations are either near the continental slope or just off the 1,000 fathom contour line (Fig. 1). Juvenile walleye pollock (<10 cm; age 0) were collected from all sample areas on the shelf and near the slope where both midwater trawls and fur seal collections were made. Trawl-caught walleye pollock 10-20 cm in length were collected only on the shelf. This pattern is mirrored in the fur seal prey analysis where walleye pollock was noticeably absent in samples containing Bathylagidae.

Gonatopsis _borealis_ or _Berryteuthis_ _magister_ was found in the continental slope and near slope trawl and fur seal sample areas. _Gonatopsis_ _borealis_ or _B_. _magister_ showed a close association with the Bathylagidae in the gut samples. _Gonatus_ _madokai_ or _Gonatus_ _middendorffi_ was found throughout the sampling area but primarily on the shelf and near slope sampling areas.

(The above text is modified from a final report to the NMML by Elizabeth Hacker, August 1986, titled "Gut content analysis of northern fur seals (_Callorhinus_ _ursinus_)--Bering Sea 1985." That report is part of a thesis being prepared by E. Hacker for a M.S. degree from Oregon State University.)

Fur Seal Food Habits Identified From Scats and Colons

by

George A. Antonelis, Jr., Patrick Gearin,

Robert L. DeLong, and Thomas R. Loughlin

Introduction

In recent years there has been an increased emphasis on the use of non-lethal methods to determine pinniped food habits. As an alternative to killing animals for stomach contents, the analysis of scats from California sea lions (Zalophus californianus) and other pinnipeds has been shown to be a successful method of obtaining dietary information (Antonelis et al. 1984; Brown and Mate 1983). Fish and cephalopods comprise a significant component of the diet of most pinnipeds and teleost sagittal otoliths and cephalopod beaks can often be identified to species level (Fitch and Brownell 1968; Antonelis et al. 1984). Although it seems practical to use scat analysis in place of the more direct methods of collecting dietary information, some studies indicate that the digestion of fish otoliths may bias results and that cephalopod beaks often were regurgitated rather than passed through the gut and were not present in scats (Pitcher 1980; North et al. 1983). The primary objective of the present study was to compare food habits information obtained from fur seal scats with that obtained from stomachs from fur seals taken at sea (Section I, Pelagic Studies) to assess the practicality of using information obtained from scats as the principal source of diet information in future studies. We also collected colons to compare the feeding habits of subadult males killed in the harvest to adult females killed at sea and to the dietary information obtained from the scats.

Methods

Scats were collected from five major rookeries on St. Paul Island during July and August 1985 from areas occupied primarily by adult females. Each scat was placed in a plastic bag, where it was later soaked in water or a solution of approximately 1 part liquid detergent to 99 parts water for about 24 hours. Colons were collected from subadult male fur seals killed during the subsistence harvest at St. Paul Island during July and August 1985. Each colon was collected and analyzed intact at St. Paul Island.

Biological material obtained from the scats and colons was rinsed with water through three nested sieves with screen mesh sizes of 2.00, 1.00, and 0.50 mm from top to bottom. Fish otoliths and cephalopod beaks were removed and stored in a solution of 70% ethanol. Otoliths were identified by using the reference collection at NMML.

Length measurements of otoliths were used to estimate body lengths and ages of walleye pollock. Many otoliths and beaks of all sizes were recovered from the scats and colons;

however, due to the amount of digestive damage to the otoliths their sizes could only be estimated by visually comparing them to otoliths in the NMML reference collection and classifying them into categories according to their relative size and shape. Walleye pollock otoliths were divided into three size categories; small (<5.8 mm), medium (5.8-8.5 mm), and large (>8.5 mm). Length or age of prey items were estimated from published regression equations, as in the section above on pelagic food habits.

Results

A total of 429 scats were collected of which 195 (45%) contained identifiable material. Walleye pollock otoliths were found in 79% of the scats, followed by identifiable material of squid (28%), Pacific sand lance (<u>Ammodytes hexapterus</u>) (3%), and unidentified fish (8%; Table 4).

A total of 150 colons were collected from subadult male fur seals of which 47 (31.5%) contained identifiable material. Walleye pollock otoliths were found in 46% of the colons with identifiable material, followed by unidentified otoliths (38%), unidentified flatfish (13%), and squid (6%).

Of the 2,558 walleye pollock otoliths identified from scats, 57% were grouped as small (<5.8 mm long), 41% as medium (5.8-8.5 mm long), and 2% as large (>8.5 mm). Walleye pollock otoliths (n=872) found in colons were principally small (81%) and medium (19%); <1% were large (Table 5). Estimated fork lengths for walleye pollock based

Table 4.--Frequency of occurrence of prey found in northern fur seal scats and colons collected from St. Paul Island, 1985.

	Percent Occurrence	
Prey	Scat (n=195)	Colon (n=47)
Walleye pollock	79	46
Sand lance	3	--
Unidentified flat fish	--	13
Unidentified fish	8	38
Cephalopods	28	6

Table 5.--Frequency of occurrence of walleye pollock (Theragra chalcogramma) otoliths by size category found in northern fur seal scats and colons collected at St. Paul Island, 1985.

	Otolith		
	Small[a] (<5.8 mm)	Medium[b] (5.8-8.5 mm)	Large[c] (>8.5 mm)
Scats (n=2558)	57%	41%	2%
Colons (n=872)	81%	19%	<1%

[a]<12.5 cm fork length (age 0).

[b]12.5-18.6 cm fork length (age 1).

[c]>18.6 cm fork length (>age 1).

on these size categories are <12.5 cm for the small otoliths, 12.5-18.6 cm for the medium, and >18.6 cm for the long. According to these estimates, walleye pollock found in scats and colons are principally from fish 18.6 cm in length or smaller and correspond to young of the year and 1-year-old fish.

Discussion

The frequency of occurrence of walleye pollock otoliths was 79% in scats and 46% in colons; for squid it was 28% in scats and 6% in colons (Table 5). A possible reason for this difference is that scats were collected from areas principally occupied by adult females and colons from immature males killed in the subsistence harvest. If this difference is real and not an artifact of the sampling regime, it suggests differences in exploitation of the prey resource by sex. The significant difference (X^2=9.8, p=0.01) in the occurrence of squid beaks provides the strongest evidence for differences between the two groups. For the otoliths in colons, however, a high proportion were unidentified (38%). If most of these unidentified otoliths are pollock, then the observed differences in frequency occurrence would likely be reduced for this prey item.

We also compared the frequency of occurrence of pollock otoliths in scats to those collected in stomachs as discussed in Pelagic Studies (above). In both cases walleye pollock otoliths were found in high proportion (67% in stomachs and 79% in scats; Tables 2 and 4) with no significant differences between the two (X^2=3.2, p=0.05). This suggests that in future studies scats may be useful to indicate the relative proportion of pollock in the diet of female fur seals in the Bering Sea. However, the frequency of occurrence of cephalopod remains in scats and stomachs was not as indicative (28% in scats; 46.5% in stomachs), probably because cephalopod beaks get caught in stomach rugae and are slowed during their passage through the intestines and colon; they are often regurgitated (Pitcher 1980).

The estimate of the size of pollock from scats were within the same range as those estimated from stomachs and trawls (see previous section and below). However the occurrence of small otoliths in scats is probably overrepresented since many of these otoliths (99%) had undergone a significant amount of digestion which resulted in their placement into the small rather than medium size category. In either event, the dominant age classes of walleye pollock found in both scats and stomachs were the age 0 and age 1 cohorts; the proportion of each varied slightly because of possible sampling bias (scats) and low sample size (stomachs).

In summary, there is an indication, based on comparison of scats and colons, that subadult males and adult females may feed on different food resources. Also, the collection and examination of scats and colons shows promise for evaluation of food resources for female northern fur seals. However, captive studies are needed to improve our analysis of scats. Such studies should concentrate on the passage rates of various otoliths and cephalopod beaks, evaluation of otoliths once passed to assess the effect of digestion on otolith size and estimated fish size based on otolith size, and determination of the number of meals represented in a scat. Another important point is to determine if the rate of digestion is similar or different between ages and sexes of northern fur seals (the rate of digestion may also vary depending on the fullness of the stomach with digestion in full stomachs progressing slower than in partially full stomachs).

ESTIMATED TOTAL CONSUMPTION OF WALLEYE POLLOCK BY NORTHERN FUR SEALS IN THE EASTERN BERING SEA USING DIET COMPOSITION DATA

by

Michael A. Perez

Introduction

Walleye pollock (Theragra chalcogramma) is the major prey item of northern fur seals (Callorhinus ursinus) in the eastern Bering Sea (Kajimura 1984; Perez and Bigg 1986; Pelagic Studies above). It is important to estimate the amount of walleye pollock consumed by fur seals in this region in order to properly manage the fishery and marine mammal resources within the ecosystem. The purpose of this paper is to estimate the total amount of walleye pollock eaten by fur seals during July-October in the eastern Bering Sea.

Methods

The estimate of walleye pollock consumed by fur seals was calculated by using diet compostion data based on stomach content analyses from earlier studies reported in the literature and from the 1985 NMML pelagic study. For purposes of comparison between years of research and type of prey, it was necessary to use frequency of occurrence data (including trace occurrences) normalized to sum to 100% over all prey species. This was also done to their respective subtotals for related species, such as walleye pollock and

Pacific cod (Gadus macrocephalus). It was not possible to use biomass data (i.e., volume) because such data were not available from all years. Unidentified fish categories were also included as other fish species, even though there was probably an overlap with the identified categories.

Fur seal population and body weight data were taken from Perez and Mooney (1986) for adult females (age ≥ 4 years), and McAlister and Perez (1986) for other ages and sex. Estimates of energy equivalents of prey species were taken from Perez and Mooney (1986) and Perez and Bigg (1986). Food requirements were calculated for adult females using data and methods reported by Perez and Mooney (1986), and the same approach was extended to other seal classes regardless of any different requirements or limitations that might apply.

Results and Discussion

Table 6 lists the diet composition of northern fur seals (all ages, both sexes) based on stomach content data from the eastern Bering Sea during July-October in six different time periods (1892, 1955, 1960-62, 1963-64, 1973-74, and 1985). The research area was the same (55^{o} to 59^{o} N; 170^{o} to 175^{o} W) in the latter four time periods, although some data from animals over the shelf near Unimak Pass were included (as well as data from late June) in 1955. It is not known where collections occurred in 1892; I assume they were probably near the Pribilof Islands. The results

Table 6.--Diet composition data of northern fur seals in the eastern Bering Sea during July to October based on frequency of occurrence data normalized to sum to 100%.

	Percent Frequency of Occurrence (Normalized)					
	Eastern Bering Sea (Area unspecified)		Study area near Pribilof Islands (55-59 °N x 170-175 °W)			
Prey species	1892[a] A	1955[b] B	1960-62[c] C	1963-64[c] D	1973-74[c] E	1985[d] F
FISH:						
Walleye pollock (*Theragra chalcogramma*)	46.47	25.53	42.92	13.01	22.00	26.99
Pacific cod (*Gadus macrocephalus*)	0.52	-	0.81	-	0.12	2.70
Gadidae (Unidentified)[e]	-	-	-	5.97	19.85	8.10
Lamprey (*Entosphenus tridentatus*)	2.11	-	-	-	0.12	-
Pacific herring (*Clupea harengus pallasi*)	-	-	-	7.43	-	-
Salmonidae	3.70	0.71	2.43	2.48	0.36	-
Osmeridae (Unidentified)	-	-	0.81	-	1.09	-
Capelin (*Mallotus villosus*)	-	31.91	4.05	4.95	1.69	-
Eulachon (*Thaleichthys pacificus*)	-	-	0.81	-	-	-
Bathylagidae	12.14	-	-	4.95	1.33	4.88
Myctophidae	-	-	-	-	0.12	-
Sablefish (*Anoplopoma fimbria*)	-	-	-	-	0.24	-
Atka mackerel (*Pleurogrammus monopterygius*)	-	-	1.62	1.93	1.33	-
Lumpsuckers (Cyclopteridae)	-	-	-	1.10	-	-
Pacific sandfish (*Trichodon trichodon*)	-	-	-	0.28	-	-
Pacific sand lance (*Ammodytes hexapterus*)	-	1.71	-	3.03	-	-
Wolffish (Anarchichadidae)	0.53	-	-	1.10	0.24	-
Pleuronectidae (Unidentified)	-	-	-	1.93	-	-
Pacific halibut (*Hippoglossus stenolepsis*)	-	-	0.81	-	-	-
Greenland turbot (*Reinhardtius hippoglossoides*)	-	-	-	8.53	9.17	-
Unidentified Fish[f]	-	1.42	7.29	4.68	7.36	25.59
Subtotal (Fish)	65.47	60.28	61.54	61.34	65.01	68.25
CEPHALOPODS:						
Octopus	0.70	-	-	-	-	-
Squid (Gonatidae)[g]	33.83	39.72	38.46	38.66	34.99	31.75
Subtotal (Cephalopods)	34.53	39.72	38.46	38.66	34.99	31.75
Total	100.00	100.00	100.00	100.00	100.00	100.00
Number of Stomachs With Food	100	114	97	217	486	43

[a] Study by Alexander; data given in Lucas (1899). Collections presumably near Pribilof Islands.

[b] Collections made primarily near Unimak Pass and in transit to the Pribilof Islands during 17 June to 20 July (Wilke and Kenyon, 1957). The actual frequency of stomachs with fish was not given, and the percentage of total fish may be underestimated relative to squid.

[c] Based on re-analysis of the original data for the specified area.

[d] Calculated from data in Table 2 (Section I).

[e] Gadidae (Unidentified) includes mainly specimens of walleye pollock and/or Pacific cod which could not be identified to species.

[f] Unidentified fish may also include some specimens of the other given prey species where the remains could not be identified to taxa, in addition to species not listed in the table.

[g] Only squids of the family Gonatidae have been identified to date in stomach contents of northern fur seals taken in the Bering Sea. Due to difficulties in identification to taxa in past years, all squid species have been pooled.

show that the percentage of fish and squid in the diet of fur seals has remained about the same (X^2 = 2.83, DF = 5) during all years of research ranging from 60.3%-68.3% for fish and 31.8%-39.7% for squid (Table 6; 60.4%-66.9% fish and 33.1%-39.6% squid, 95% CI, arcsin transformation).

The best estimate of total pollock consumption by fur seals is the estimated total gadid percentage (which includes walleye pollock and Pacific cod) because the large percentage of unidentified gadid specimens in stomachs from 1963-85 are presumably walleye pollock, and because of the low level of predation on Pacific cod. The proportion of gadid fishes in the diet was significantly different among the six research studies (X^2 = 98.9, DF = 5), but there were no significant differences in proportions of total gadid fishes to other fishes in the diet among the years 1960-62, 1973-74, and 1985; there was a significant difference between the 1963-64 data and the 1960-62 and later years (X^2 = 76.69, DF = 1). Therefore, data from 1960-62, 1973-74, and 1985 were pooled to estimate walleye pollock consumption by northern fur seals. Any differences with other years can be partially accounted for by an increase in take of other fish species during years of low gadid composition, for example, capelin (Mallotus villosus) in 1955 and Pacific herring (Clupea harengus pallasi) in 1963-64. Also, the research areas and percentage ranking methods were somewhat different for 1892 and 1955, although both indicate a pattern of prey composition that is similar to that of the later years.

Fur seals consumed walleye pollock in the size range 4-40 cm during 1958-74 (Perez and Bigg 1986); the mean size of pollock eaten during 1974 was 19.3 cm (McAlister and Perez 1977). During 1985 fur seals ate predominantly 10-18 cm pollock (NMML Pelagic Studies).

Table 7 provides estimates of the biomass of food consumed by adult female northern fur seals in the eastern Bering Sea based on the diet composition data in Table 6 for 1963-64 and the pooled data set, assuming in both cases the same 1985 fur seal population parameters. Estimates of total food consumption are slightly different between the two data sets. This is because the total biomass consumed will decrease as the caloric value of the diet increases (estimated at 1.37 kcal/g for 1963-64 and 1.34 kcal/g for the pooled years), assuming all other conditions affecting metabolism and population size remain constant. Table 7 indicates that for years with low predation on walleye+ pollock (e.g., 1963-64), biomass of gadids consumed by adult females will be about 48.6 x 10^3 t whereas, in other years consumption will increase up to 111.3 x 10^3 t for the adult female fur seal population. As shown in Tables 7 and 8, adult females are the primary fur seals producing an impact on the pollock resource.

Table 7.--Estimated consumption of fish and squid by adult (age ≥4 years), female northern fur seals in the eastern Bering Sea (55-59 °N x 170-175 °W) during July to October (122 days). Total population of lactating females: 2.48 x 10^5; total population of nonlactating females: 1.32 x 10^5.

		Lactating Females		Nonlactating females		
Prey species	Relative dietary importance (%)	Individual average consumption (kg/d)[a]	Total seasonal consumption by population (x 10^3 t)	Individual average consumption (kg/d)[a]	Total seasonal consumption by population (x 10^3 t)	Total adult female consumption (x 10^3)
Based on the 1963-64 diet study:[b]						
Walleye pollock	13.01	0.85	25.7	0.47	7.6	33.3
Pacific cod	-	-	-	-	-	-
Gadidae (all)	18.98	1.24	37.5	0.69	11.1	48.6
Fish (all)	61.34	4.01	121.3	2.21	35.6	156.9
Squid	38.66	2.53	76.6	1.40	22.5	99.1
Total food consumption	100.00	6.54	197.9	3.61	58.1	256.0
Based on the pooled 1960-62, 1973-74, and 1985 diet studies:[c]						
Walleye pollock	25.00	1.67	50.5	0.92	14.8	65.3
Pacific cod	0.47	0.03	0.9	0.02	0.3	1.2
Gadidae (all)	41.85	2.86	86.5	1.54	24.8	111.3
Fish (all)	64.76	4.33	131.0	2.39	38.5	169.5
Squid	35.24	2.36	71.4	1.30	20.9	92.3
Total food consumption	100.00	6.69	202.4	3.69	59.4	261.8

[a] Following the method used by Perez and Mooney (1986). Individual average consumption (kcal/d) was derived from the following relationship: 375.47 $M^{0.75}$. Average weight of lactating females is 35.26 kg, and the average weight of nonlactating females is 31.11 kg. Food consumption for lactating females is approximately 1.6 times higher than for nonlactating females, or 8960 kcal/d for lactating females, and 4940 kcal/d for nonlactating females. Daily consumption in biomass (kg/d) was calculated from the relative average energy value of the diet for the study being considered using caloric values for prey given in Perez and Mooney (1986), and using 1.46 kcal/g as the estimate for miscellaneous fish species.

[b] The estimated energy value of the 1963-64 diet was 1.37 kcal/g.

[c] The estimated energy value of the pooled 1960-62, 1973-74, and 1985 diet studies was 1.34 kcal/g.

Table 8 summarizes the estimated biomass of gadid fishes consumed by all northern fur seals in the eastern Bering Sea during the months of July-October. The total fur seal population consumes a collective total of 312.4×10^3 t of food during the 122 days in the Bering Sea, of which 132.5×10^3 t are gadid fishes, mainly walleye pollock. This estimate is approximately the same as that for walleye pollock consumed by pollock (134×10^3 t), and is greater than the estimate (117×10^3 t) of pollock consumed by Pacific cod (Section II).

The values in Table 8 should be considered maximum consumption estimates of walleye pollock by northern fur seals in the eastern Bering Sea. As shown in Table 7, the estimate of walleye pollock consumed by fur seals based on the 1963-64 diet study is about 44% of the amount estimated from the pooled 1960-62, 1973-74, and 1985 diet studies. This difference could be from a variety of causes. The estimations of diet composition of fur seals greatly influences the estimation of biomass of any single prey species eaten and is exaggerated by errors or biases in the estimation of frequency of occurrence. Also, the availability and abundance of prey species may vary from year to year due to environmental conditions or other factors (as well as the method used to rank importance of prey in the diet; Bigg and Perez 1985) resulting in different values for frequency of occurrence of individual prey species. Since the diet data in Tables 7 and 8 are based only on a small portion of the Bering Sea (near the Pribilof Islands) where walleye pollock is usually greatest in abundance and importance in the fur seal diet (Perez and Bigg 1986), and the fur seal population parameters represent the entire eastern Bering Sea, the estimated pollock/gadid biomass consumed by fur seals may, therefore, be lower than the values given in Tables 7 and 8.

In addition, the estimates in Tables 7 and 8 depend significantly on the estimation of average daily individual food requirements. There are few studies on food requirements of northern fur seals, and all are based on captive animals with varing exponents of body weight (M, in kg). McAlister and Perez (1986) reported a relationship of daily food requirements (kcal/day = $324M^{0.67}$), based on captive marine mammals, which yields estimates of total food consumption by fur seals that are similar to those listed in Table 8. However, these estimates will only be similar if the different values used to estimate energy content of the diet in the two studies are considered. Food consumption requirements of marine mammals reported in the literature have usually been based on studies of captive animals fed herring or mackerel, both of which are high in energy value relative to walleye pollock. Thus, as stated earlier, the energy value of the diet used to estimate food requirements appreciably affects the estimates of biomass. The values in Table 8 should, therefore, be considered maximum estimates of fur seal predation on walleye pollock.

Table 8--Summary of estimates of northern fur seal consumption of gadid fishes in the eastern Bering Sea during July-October (based on the pooled 1960-62, 1973-74, and 1985 diet studies)

Fur seal sex/age class	Average individual weight (kg) A[a]	Estimated Individual average consumption (kg/d) B[b]	Estimated population C[a]	Estimated total Consumption (122 d) ($x 10^3$ t) Total food D[c]	Gadidae E[d]
Males/Females, age 1 yr.	14	2.03	3,000	0.7	0.3
Males/Females, age 2 yr.	18	2.45	17,000	5.1	2.1
Females, age 3 yr.	18	2.45	11,000	3.3	1.4
Females, age ≥4 yr. nonlactating	31	3.69	132,000	59.4	24.8
Females, age ≥4 yr. lactating	35	6.69	248,000	202.4	86.5
Males, ages 3-8 yr.	52	5.43	40,000	26.5	11.1
Males, age ≥9 yr.	209	15.40	8,000	15.0	6.3
Total population				312.4	132.5

[a]From McAlister and Perez (1986), except for females age ≥4 yr. which were taken from Perez and Mooney (1986).

[b]Calculated using the food intake (kcal/d) relationship for adult females given in Perez and Mooney (1986), based on data in Bigg et al. (1978), and converting to biomass (kg/d) using a dietary energy estimate of 1.34 kcal/g.

[c]Calculated as follows: [(Column B) X (Collumn C) X (122 d)].

[d]Calculated as 41.85% of the value in column D.

Movement Patterns and Feeding Locations

by

Thomas R. Loughlin, John L. Bengtson,

and Richard L. Merrick

Introduction

For northern fur seals on the Pribilof Islands, parturition and copulation occur soon after females arrive on the rookery, at which time females begin a sequence of feeding trips of varying length with subsequent visits to land to suckle their pups (Bartholomew and Hoel 1953; Peterson 1968). Extensive data are available on the general distribution and feeding habits of fur seals at sea around the Pribilof Islands (e.g., Kajimura 1984); however, very little is known about the location or characteristics of their movements while on feeding trips.

During 1984 we used a vessel to determine the characteristics of feeding trips of radio-equipped northern fur seals by following animals at sea. Our primary purpose was to determine the location of feeding and the general pattern of movement to and from the feeding location by female fur seals. In 1985 we used an airplane to provide a broader overview of distribution and feeding locations.

Study area and methods

This study was conducted on St. Paul Island, Pribilof Islands, Alaska, and in the adjoining waters of the southeastern Bering Sea during June-August 1984 and 1985 (Fig. 5). Each female northern fur seal was captured with a noose pole, removed from the rookery, and placed on a restraint board (Gentry and Holt 1982) where it was tagged on each foreflipper with a plastic tag. A radio transmitter was attached to the top of its head with quick-drying epoxy resin (Fedak et al. 1982). In 1984, transmitters were attached to 40 females from Zapadni Reef rookery (Fig. 5), and in 1985, a total of 50 transmitters were attached to 30 females from Zapadni Reef rookery and 20 from Northeast Point rookery. The animals were released into the rookery once the resin had hardened--approximately 10-15 minutes.

During 1984, we determined arrival and departure times and the durations of trips at sea and stays on land with an automated recording station using event recorders wired to frequency-scanning radio receivers. Female fur seals may have 11 or more feeding bouts before the pups are weaned in October and November (DeLong 1982; Gentry and Holt 1986). Our records included the first seven post partum at-sea trips.

During 1984, we followed transmitter-equipped fur seals at sea with the NOAA ship Surveyor, a 90-m oceanographic research vessel. Four 4-element Yagi antennas were mounted

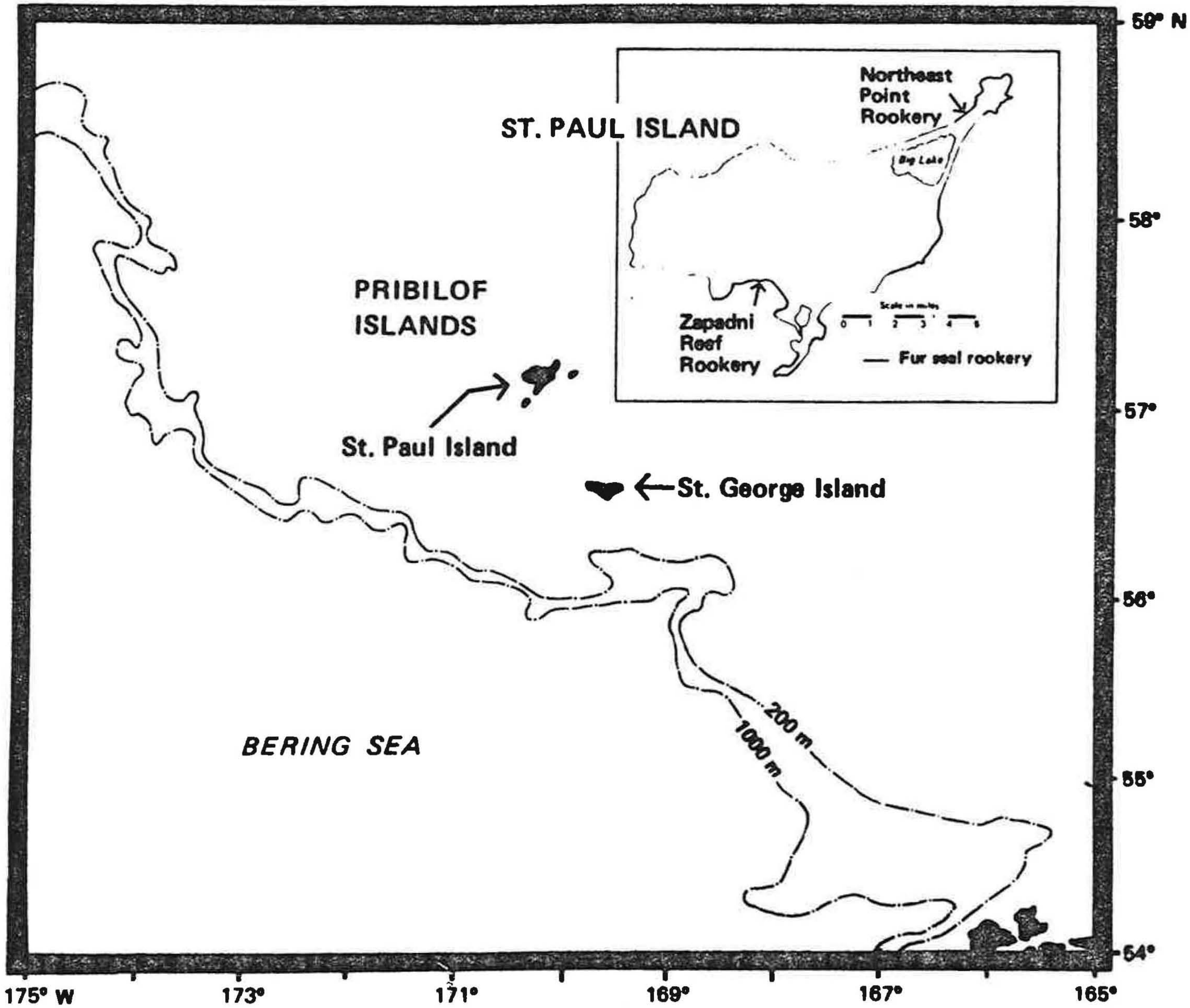

Figure 5.--Map of the radio-telemetry study area near St. Paul Island and names and locations of northern fur seal rookeries on the island.

30 m above the waterline on the aft mast. Each antenna was pointed toward a different quadrant, and, by use of a switch box, we were able to determine which antenna had the strongest signal and turn the vessel in the appropriate direction to follow the fur seal. Maximum reception distance was about 14 km in good sea surface conditions and about 7-9 km in poor sea surface conditions. The animals were monitored 24 hours each day. We had visual sightings of two animals (one animal was sighted twice) but we generally were far enough away (approximately 1 km) from the animals during tracking to dismiss any notion that the ship's presence influenced seal movements. Ship location was estimated using Loran C and satellite navigation instrumentation on the vessel.

We inferred that certain areas were feeding locations, based on our interpretation of the transmitted signal from the radio-equipped fur seal and its movement patterns. A strong-to-weak signal with breaks of between 20 seconds and 2 or more minutes suggested to us that the animal was active and probably diving for food. Gentry et al. (1986) showed that mean duration of dives for C. ursinus was 2.2 minutes. Thus reception of a signal indicating feeding associated with movements that differed in direction and speed and a general tendency to remain in one broad area over a long period (a day or more) were interpreted by us to indicate feeding location.

In 1985 we used a twin engine airplane with a 2-element Yagi antenna mounted on each side. Flights were designed to cover a region within 300 km of St. Paul Island (except for one flight to the eastern Aleutian Islands, 350 km south of St. Paul Island) and followed predetermined transects. They were flown at air speeds of about 100-120 knots and an altitude of about 1,200 m, and totaled 60 hours of flight time.

Nonparametric statistics were used in most data analyses. Friedman's block treatment test and Wilcoxon matched pairs test were used to compare differences in the time on land and at sea (Hollander and Wolfe 1973). Parametric statistics were applied where it could be assumed that the data followed or approximated normal distribution.

Results

Time at sea

The mean duration of time at sea for all feeding trips combined for the 40 females studied during July and August 1984 was 141.88 hours or 5.91 days; for all trips made during July the mean duration was 5.7 days; and the mean duration for the first trip to sea postpartum was 3.5 days (Table 9). For 32 of the 40 radio-tagged females, it was determined that our record of the first feeding trip represented the first feeding trip postpartum (any feeding trip following a stay on land of at least 3 days, which represented the perinatal period, was assumed to be the

Table 9.--Mean duration (dur.) in days of the first feeding trip, all feeding trips beginning in July, and all feeding trips observed during July and August for northern fur seals from St. Paul Island, Alaska, 1951 to 1985.

		1st trip			July trips			All trips			
Rookery	Year	dur.	SD	N	dur.[a]	SD	N[b]	dur.	SD	N	Ref[c]
Kitovi	1951	5.9	1.5	12	7.2	1.9	30	7.2	1.9	30	1
Kitovi	1962	7.8	2.3	33	8.4	2.8	58	9.7	2.8	146	2
Kitovi	1963	6.6	1.8	26	7.4	1.9	49	8.0	2.1	85	2
Kitovi	1976	5.0	2.2	11	7.0	2.4	25	8.5	2.4	106	3
Kitovi	1977	5.7	2.1	26	6.8	2.3	77	7.1	2.1	314	3
Zapadni	1984	3.5	1.4	32	5.7	2.5	151	5.9	2.5	171	4
Kitovi	1985	3.5	1.4	20	4.5	1.6	59	---	---	---	5
ANOVA		p>0.99			p>0.99			p>0.99			

[a]Includes only feeding trips that began in July.
[b]N = number of trips.
[c]References: 1) Bartholomew and Hoel (1953); 2) Peterson (1968; used only values for females when the 1st at-sea trip was provided); 3) Gentry and Holt (1986), and NMML files (for July data); 4) present study; and 5) Goebel, in press.

first trip postpartum). Comparison of the mean duration for each feeding trip showed a significant difference in the duration of times at sea and that trip length increased from the first trip through trip 5 (Friedman's block/treatment test, $p<0.05$, $T = 54.7764$) (Fig. 6). Trip 1 had a mean of 3.5 days (sd = 1.4) and was significantly shorter than all other trips (Wilcoxon signed ranks test; $p = .05$). Trip 2 was shorter than all subsequent trips (mean = 5.2 days; sd = 2.6, $p = .05$). Trip 3 was significantly ($p<.05$) shorter than trip 5, but no significance was found between any of the remaining comparisons even though the mean duration for trip length continued to increase to 7.51 days for trip 5 (Fig. 6). Gentry and Holt (1986) showed that trip length increases at the rate of 1.2 days for every 30 days postpartum for noninstrumented females. Our mean duration for later trips may be biased toward shorter trips since we may have concluded our study before females with fewer, longer trips returned to the rookery. The longest duration for a trip at sea was 15.25 days and the shortest 1.17 days. Both extremes occurred during trip 2 but for different animals.

Time on land

The mean duration of all times on land following feeding bouts was 1.93 days (n = 163; sd = 1.09). Analysis of the duration of all times on land showed no significant

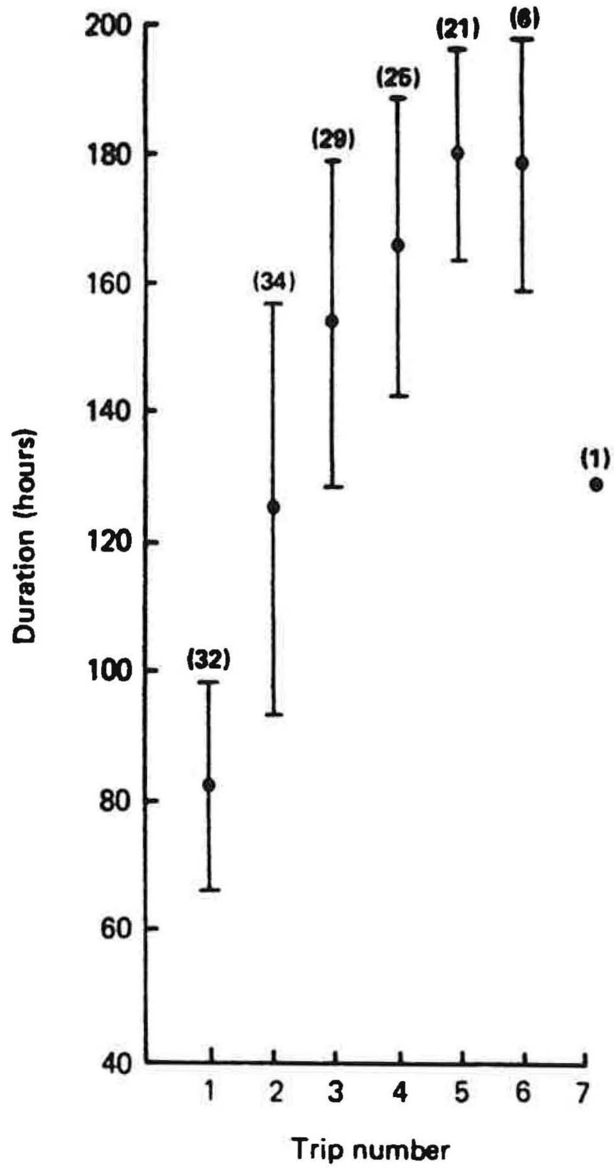

Figure 6.--Mean duration for feeding trips 1-7 for radio-tagged female northern fur seals from Zapadni Reef Rookery, St. Paul Island, July 1984. The mean, standard deviation, and number of trips recorded for each trip are shown.

difference in duration (Friedman's block/treatment test, $p = 0.05$; $T = 1.357$).

Location and distribution at sea

In 1984 we followed four fur seals from St. Paul Island out to their feeding locations and heard signals from seven others while enroute. We followed only one animal at a time with the ship. The feeding locations were between 160 and 200 km from St. Paul Island, which represents round trip distances of up to 400 km (Fig. 7). Two animals went northwest of the island and two to the south-southwest. The two animals that went northwest remained over the continental shelf, which protrudes significantly farther west when north of St. Paul Island than it is to the south (Fig. 7). Those that went south-southwest passed over the continental slope and swam into water over 3,000 m deep.

In 1985, 17 radio-equipped fur seals were located and identified from the airplane while 3 others were located but could not be identified. All animals were located northwest and southwest of St. Paul Island, as in 1984, and some as far as 370 km from St. Paul Island (Fig. 7). No animals were located east of St. Paul Island during 1984 or 1985.

While following animals by ship we found that they generally swam in direct lines to and from the feeding site, but once there they swam in more irregular patterns. They generally returned in the reciprocal compass direction to that which they used going out to sea (e.g., animal 304 in

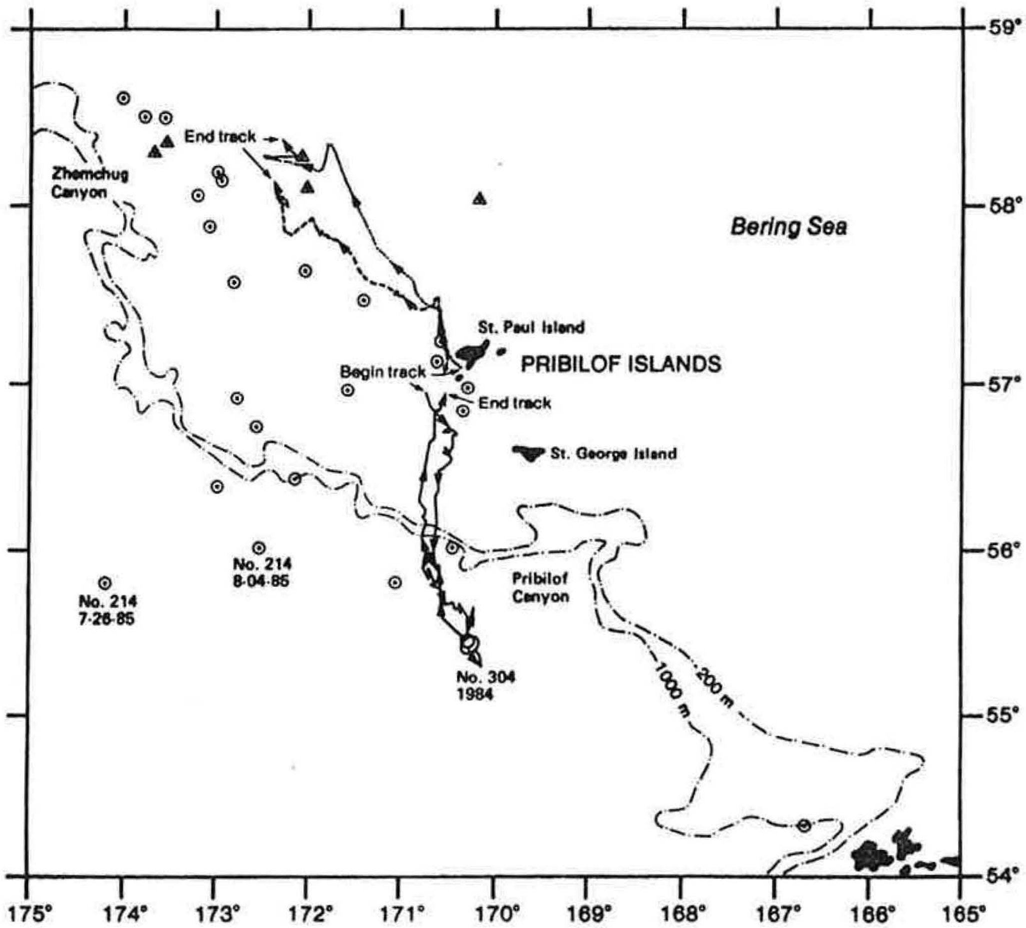

Figure 7.--Track lines and locations of fur seals in the southeastern Bering Sea as determined by radio telemetry during July 1984 and 1985. The track lines for three of four animals followed in 1984 are shown. Animals located by airplane in 1985 are shown as circles (Zapadni Reef Rookery) or triangles (Northeast Rookery).

Fig. 7). Swimming occurred during all hours of the day with substantial variation in resting and active periods. However, there was often a rest period between 0500 and 0700 hours and 1700 and 1900 hours and most activity appeared to occur at night and early evening. These findings concur with those of Gentry et al. (1986) for females instrumented with time-depth-recorders.

Our best record was for one animal that went southwest. It was away from the rookery 6.04 days (145 hours) on its third feeding trip. It left the rookery at 0223 hours on 20 July 1984 and required 2 days to transit to the feeding area, 1.5 days to forage in the feeding area, 1.5 days to transit back to the island, a sixth day to mill around the island prior to returning to the rookery when it hauled out at 0245 hours on 26 July. Transit time to the feeding area was similar for the other three animals that we followed, but because of limited ship time we ceased contact once they reached their feeding location. Thus we did not measure the amount of time spent in the feeding area or for the return trip to the rookery for those animals.

Another interesting record is for animal 214 which we located on 26 July 1985 southwest of St. Paul Island in water over 3,400 m deep. This same animal was located again while on another feeding trip on 4 August 1985 in approximately the same area (Fig. 7). This is the first documentation and our only record demonstrating that a female fur seal will return to the same area on successive feeding bouts.

Water depth

Fur seals that fed in locations west and northwest of St. Paul Island remained over the continental shelf in water that ranged from 72 to 137 m deep. Fur seals that went southwest generally concluded their outward trip over the Aleutian Basin in water that exceeded 3,000 m in depth. The feeding areas were bordered on the northwest by Zhemchug Canyon and on the southwest by Pribilof Canyon, although some individuals did travel beyond these submarine features.

Discussion

Duration of feeding trips

The mean duration of all feeding trips for fur seals from Kitovi Rookery, St. Paul Island, was 7.2 days in 1951, 9.7 days in 1962, 8.0 days in 1963, 8.5 days in 1976, and 7.1 days in 1977 (Peterson 1968; Gentry and Holt 1986). The mean duration of 5.9 days from our study of Zapadni Rookery is significantly different from the observed duration of trips in the 1960s and 1970s (ANOVA $P>0.99$; $t = -3.756$; $p = .064$; $df = 3$). However, as mentioned above, our data may be biased toward shorter trips and those of the earlier studies toward longer trips. Therefore we compared our data to the mean duration of the first feeding trip and the mean duration for feeding trips during July for each of the data sets for 1951 to 1976 and found that the mean duration for our data was significantly less than the mean duration for first feeding trips for each of the earlier studies (ANOVA $P>0.99$; $t = -2.836$; $p<0.05$; $df = 4$; Table 9). This comparison shows a downward trend in feeding trip duration for St. Paul Island fur seals. The reasons for the decrease in feeding trip duration are unknown, but possible explanations include more plentiful food supplies (resulting in less time needed to search for food), closer feeding locations (resulting in shorter distances to swim), a density dependent response to reduced competition while feeding as the fur seal population declined, or a combination of these and other unknown factors.

Depth of dives and presumed prey

During 1985 a collaborative study was undertaken to assess the depth of dives by equipping animals with both a radio transmitter and a time-depth-recorder, thereby determining both feeding location and depth of dives while in the feeding area (Goebel et al. in prep.). We present a summary of that work here as it relates to our understanding of the use of various foraging locations by feeding fur seals.

The results of the collaborative study show that female fur seals that traveled to feeding locations over the shallow continental shelf had dives averaging over 100 m and generally had feeding bouts all through the day; they would be classified as deep divers by Gentry et al. (1986).

Animals that fed over deep water in the Aleutian Basin had dives that averaged less than 100 m and had feeding bouts principally during the night; they would be classified as shallow divers by Gentry et al. (1986).

The study results are consistent with the known distribution of fur seal prey items. Kajimura (1984) summarized the variation in principal forage species for fur seals, depending on location. Fur seals feeding in the Bering Sea beyond the continental shelf over deep water fed on oceanic squid of the family Gonatidae (primarily Gonatus spp., Berryteuthis magister, and Gonatopsis borealis) or deep-sea smelts of the family Bathylagidae. These prey items, especially cephalopods and fish with swim bladders (e.g., myctophids), exhibit diurnal vertical migration and are at relatively shallow depths during nighttime as they move vertically in synchrony with the deep scattering layer (Roper and Young 1975; Pearcy et al. 1977). It is during nighttime that they are fed upon by fur seals; during daytime squid and vertically migrating fish are usually too deep to be preyed upon by fur seals which rarely dive beyond 200 m (Gentry et al. 1986). Fur seals foraging over the shelf were likely to feed on walleye pollock (Theragra chalcogramma), Pacific herring (Clupea harengus pallasi), and capelin (Mallotus villosus) (Kajimura 1984). Each of these prey items are distributed throughout the water column over the shelf, depending on sex and age of the individual and time of day; however, they are principally found near bottom (Bakkala and Wakabayashi 1985). Even when prey are near bottom over most of the shelf floor they are shallower than the maximum diving depths of most fur seals and are accessible during all hours of the day.

One possible explanation of the recent decline in numbers of northern fur seals is a reduction in available resources, perhaps as a result of extensive commercial fishing. However, cohort analysis indicates that the biomass of walleye pollock in the eastern Bering Sea may have increased substantially during the 1960's and peaked in the early 1970's, then declined and remained relatively stable at moderately high levels in 1976-1980 before increasing in 1981 and 1982 (Bakkala et al. in press). Further evidence that the decline in resources is not the primary reason for the decline in fur seals is: the increase in survival of pups prior to leaving land, increase in pup weight at age 2 months, increase in weight of males collected at the breeding grounds, and a number of other important components of population dynamics which vary with density if food resources are not influenced outside the system (Fowler in press). Our observation that the duration of time spent at sea for feeding has significantly declined over the past 20 years and that time on land has not changed, implies that resources are not the singular cause for the population decline. This finding supports the suggestion by Chapman (1961) that decreased survival of younger age classes in the 1940's and 1950's (compared to the earlier centuries) may have been a result of increased competition for food and females commuting less distance to feed, resulting in shorter feeding trips. However, Gentry and Holt (1986) found no significant difference in the duration of feeding trips between their data and that collected 26 years earlier (1951 to 1977) and further concluded, based on the complexity of foraging, that the duration of feeding trips was not an adequate indicator of the effect that the possible reduction of fish numbers could have on the fur seal population. But further evidence in support of Chapman's (1961) suggestion comes from southern California. During the El Nino/Southern Oscillation event of 1982-1983 when food was thought to be in limited supply, the duration of the first three feeding trips for female northern fur seals from San Miguel Island increased in length by about 2 days compared to earlier years (Antonelis and DeLong 1985). Clearly, further studies are needed to determine the relationship between fur seal population dynamics and the quality, quantity, and distribution of prey items.

Acknowledgments

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Section II--RESOURCE ECOLOGY AND FISHERIES MANAGEMENT

Food Web Interactions of Key Predatory Fish With Northern Fur Seal, *Callorhinus ursinus*, in the Eastern Bering Sea During Summer 1985

by

P. A. Livingston and D. A. Dwyer

Introduction

One hypothesis to explain the decline in numbers of northern fur seals, *Callorhinus ursinus*, in the eastern Bering Sea is that it is a result of extensive commercial groundfish fishery causing reduced food resources available to the seals. However, ecosystem modelling studies (Laevastu et al. 1980; Swartzman and Haar 1983) indicate that fisheries may act in a beneficial manner by increasing the abundance of prefishery juvenile fish which are the appropriate size for fur seal consumption. In addition to modelling studies, current research on fish food habits (Livingston et al. 1985a; Dwyer et al. in review) demonstrates that the consumption of food resources by fish in the eastern Bering Sea may constitute a larger source of removal than that of marine mammals or commercial fisheries. Since some fish consume prey fish which in general are smaller than those taken in groundfish fisheries (Livingston et al. 1985b), these predatory fish may be a more direct source of competition with marine mammals for appropriate sized food resources than fisheries.

The purpose of the current study was to show that commercial fisheries utilize only a small proportion of the total biomass of suitable-sized food resources available to fur seals in their feeding areas in the eastern Bering Sea, and to show that predatory fish consume most of that resource. Our objective is to quantify the food habits and consumption rates of predatory fish which compete with northern fur seals for their main food item, walleye pollock (*Theragra chalcogramma*), in areas and seasons where the distribution of fur seals and predatory fish overlap. These predatory fish include walleye pollock, Pacific cod (*Gadus macrocephalus*), arrowtooth flounder (*Atheresthes stomias*), Greenland halibut (*Reinhardtius hippoglossoides*), flathead sole (*Hippoglossoides elassodon*), Pacific halibut (*Hippoglossus stenolepis*), and sablefish or black cod (*Anoplopoma fimbria*). We compared the size and amount of pollock consumed by predatory fish to that taken in the fishery.

Methods

Collection of stomachs from the main predatory fish in the area near the Pribilof Islands was completed between 3 and 23 August 1985 (Fig. 8). A total of 1,171 stomachs were collected on the joint NMML/REFM cruise and 415 additional stomachs were collected during standard resource

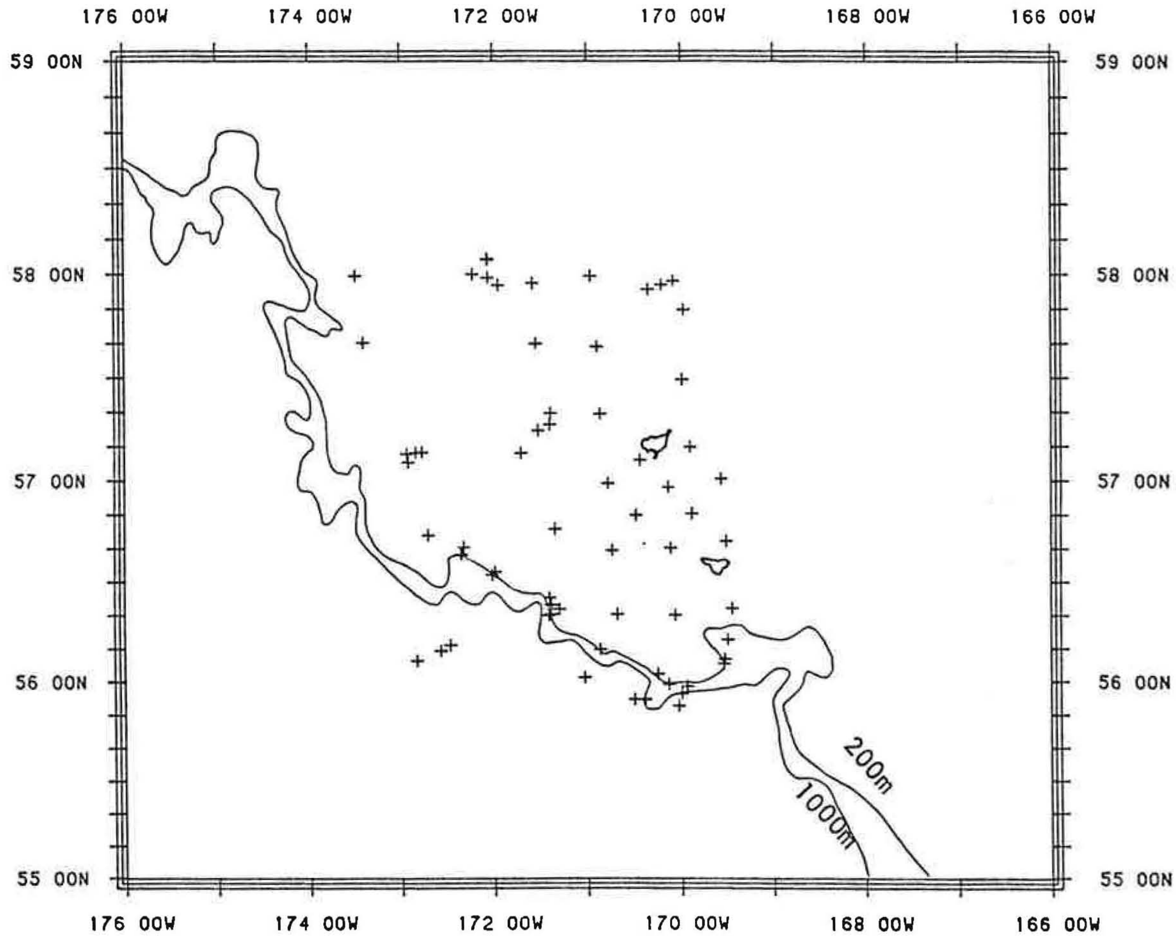

Figure 8.--Sample locations of fish taken for stomach content analysis during summer 1985 in fur seal, <u>Callorhinus ursinus</u>, feeding areas in the eastern Bering Sea.

assessment surveys occurring in the same area and time period. Table 10 shows the total catch weight of fish and invertebrates from the NMML/REFM cruise and the number of stomachs collected by fish species for both cruises. These are the primary data used for food consumption analysis; additional data from observer collections and other REFM collections were used for daily ration calculations. NMML/REFM cruise fish collections were made using an 83/112 eastern bottom trawl net and two midwater sampling nets, the Diamond midwater trawl and Marinovitch herring trawl. Fish sampling was done in areas which coincided with the collection or occurrence of fur seals. Fish sampling generally occurred between 1900 and 0600 hours Alaska Daylight Savings Time. A total of 23 bottom trawls and 23 midwater trawls were completed with a total catch of 36,000 lbs. Selected fish and cephalopod specimens were retained and frozen for NMML studies. Length frequencies of major predatory fish and other important groundfish were performed after each haul.

Stomachs were preserved in a 9:1 seawater-to-formaldehyde mixture and sent to Seattle for detailed laboratory analysis of the contents. Stomachs were analyzed individually in the laboratory. Prey items were identified to the lowest practical taxon and weighed damp weight to the nearest milligram and number of each prey taxon were

Table 10.--Summary of catch weight (in pounds) of fish and invertebrates caught in bottom and midwater trawls during summer 1985 on the NMML-REFM cruise in the eastern Bering Sea in fur seal feeding areas, and number of stomachs by fish species collected during NMML-REFM cruise and RACE[a] resource assessment survey cruise in fur seal feeding areas.

Species	Weight (lb.)	Number of stomachs
Pacific cod	3,780.9	318
Flathead sole	740.5	269
Arrowtooth flounder	1,695.0	335
Yellowfin sole	664.5	51
Greenland halibut	123.5	4
Pacific halibut	506.3	194
Black cod	221.3	7
Walleye pollock	20,994.0	409
Rockfish	1,808.5	--
Sculpins	700.1	--
Crabs	407.2	--
Invertebrates	1,914.0	--
Miscellaneous fish	2,847.6	
TOTAL	36,403.4	1,587

[a]Resource Assessment and Conservation Engineering Division

recorded. Length measurements of fish and crab prey were taken when enough remained of the items to permit measurement.

Preliminary data analysis to show food consumption by marine mammal sample area and size distribution of walleye pollock prey by fish species was performed on a subset of data from 926 fish stomachs, the total sample size available at the time the analysis was performed. All other calculations use the total sample size of 1,587 fish stomachs.

Size comparisons of prey separate walleye pollock into small (<12.5 cm), medium (12.5-18.6 cm), and large (>18.6 cm) fork length categories since these were the categories used in fur seal stomach content analysis. These categories closely correspond to 0-age walleye pollock as the small size, age 1 as medium, and >1 year old for the large size group.

Population consumption estimates by predatory fish are calculated in the fashion of Livingston et al. (1985a) and Dwyer et al. (in review). Essentially the method requires estimates of daily consumption for each predator, the proportion by weight of walleye pollock in the diet of each predator, and the biomass of the predator population. The total amount of walleye pollock consumed by a particular predator population was then calculated with the following equation:

$$C = DR * D * B * P \tag{1}$$

where C is the consumption in tons of walleye pollock by a given predator population, DR is the daily ration of the predator expressed as a fraction of body weight daily (BWD), D is the number of days in the time period of consideration, B is the biomass in tons of the predator in the area of consideration, and P is the proportion by weight of walleye pollock in the diet of the predator. Daily ration estimates for these calculations were taken from Livingston et al. (1985a). The number of days for population consumption estimates was considered to be the number of days per year that northern fur seals are in the eastern Bering Sea making feeding excursions from the Pribilof Islands: approximately 1 July through 31 October, or 123 days. Biomass estimates of key predatory fish were taken from the U.S.-Japan joint bottom trawl survey of the eastern Bering Sea during summer 1985, Resource Assessment and Conservation Engineering (RACE) division data base. The biomass estimates were limited to the area shown by NMML radio-equipped experiments (Section I) to be the feeding area of fur seals from St. Paul Island in the eastern Bering Sea (bounded by 59^{o} N and 55^{o} N; 170^{o} W and 175^{o} W; hereafter defined as the feeding area). From the equation, P, was calculated from the fish stomach samples collected only in the sample areas in summer 1985.

Estimates of commercial fishery removals of pollock were derived from the REFM observer data base of observer estimated catch weights by foreign and joint venture fisheries summarized by 1/2 degree latitude and 1 degree longitude squares during 1 July through 31 October 1985 in the fur seal feeding areas of the eastern Bering Sea. Since observer coverage was greater than 90% for this period (Jerry Berger, REFM, pers. commun.), these estimates are considered a close estimate of the true fishing removal.

Results

The major predatory fish and prey species which occurred in bottom and midwater trawls in the marine mammal sampling areas are shown in Table 11. Walleye pollock, Pacific cod, Pacific halibut, arrowtooth flounder, and flathead sole occurred in most bottom trawls. Greenland halibut, black cod, squid, Bathylagidae, and Myctophidae were encountered in deeper tows performed at the shelf break. Pollock was encountered in both bottom and midwater hauls at virtually all sampling areas with the exception of two midwater sampling efforts in areas 12 and 17.

Pollock was the major prey item consumed as a percent of total stomach content weight by most predatory fish (Table 12). The percentage by weight of pollock in the diet by a particular predatory fish varied among sampling areas.

Table 11.--Major predatory fish and prey species in bottom and midwater trawls performed during NMML-REFM cruise, summer 1985, in fur seal feeding areas of the eastern Bering Sea.

	BOTTOM											MIDWATER			
BOX	POL[a]	COD	HAL	ATF	FHS	YFS	GT	BC	SQ	BA	MY	POL	SQ	BA	MY
2					(TOO DEEP)[b]							x	-	-	x
3	x	x	x	x	x	-	x	x	x	x	x	x	x	-	-
4	x	x	-	x	x	-	x	-	x	-	-	x	-	x	x
5					(TOO DEEP)							x	x	x	x
6	x	x	-	x	x	-	-	x	x	x	x	x	-	-	-
7	x	x	x	x	x	-	-	-	x	-	-	x	x	-	-
8	x	x	x	x	x	-	-	-	-	-	-	x	x	-	-
9	x	x	x	x	x	x	x	-	-	-	-	x	x	-	-
10	x	x	-	x	x	x	-	-	-	-	-	x	-	-	-
11	x	x	x	x	-	-	x	x	x	-	-	x	x	-	x
12	x	x	-	x	x	-	x	x	-	-	-	-	-	-	-
17*	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-

[a]POL - walleye pollock; COD - Pacific cod; HAL - Pacific halibut; ATF -arrowtooth flounder; FHS - flathead sole; YFS - yellowfin sole; GT - Greenland halibut; BC - black cod (or sablefish); SQ - squid; BA - Bathylagidae; MY - Myctophidae

[b]Bottom depth greater than 300 fm was considered too deep for bottom trawling gear.

*17 is haul 17.

Table 12.--Walleye pollock consumption by major predatory fish expressed as a percent of total stomach content weight. These values are calculated from a subset of the stomachs collected during summer 1985 in the eastern Bering Sea in the area of fur seal feeding. (Sample size in parentheses.)

BOX	POL[a]	COD	ATF	FHS	HAL	BC
3	--	79.8	45.2	--	91.3	57.2
	(21)	(32)	(29)	(21)	(5)	(4)
4	--	10.1	--	--	--	98.8
	(22)	(6)	(4)	(0)	(0)	(1)
6	20.5	93.7	11.7	1.3	--	--
	(21)	(33)	(16)	(42)	(0)	(1)
7	32.1	50.1	84.2	0.6	87.4	--
	(41)	(10)	(35)	(40)	(11)	(0)
8	4.2	12.6	95.9	1.4	67.8	--
	(21)	(29)	(35)	(42)	(3)	(0)
9	55.2	42.5	97.4	--	55.6	--
	(22)	(25)	(19)	(28)	(1)	(0)
10	67.1	0.3	61.1	41.1	--	--
	(14)	(38)	(3)	(39)	(0)	(0)
11	--	79.3	3.1	--	91.6	--
	(35)	(32)	(7)	(0)	(5)	(1)
12	--	0.4	15.9	--	--	--
	(36)	(13)	(8)	(5)	(0)	(0)
17*	1.3	3.8	76.3	2.1	100.0	--
	(21)	(8)	(19)	(21)	(1)	(0)

[a]POL - walleye pollock; COD - Pacific cod; ATF - arrowtooth flounder; FHS - flathead sole; HAL - Pacific halibut; BC - Black cod (or sablefish).

*17 is haul 17.

For instance, pollock did not consume pollock in areas 3, 4, 11, and 12, while pollock formed up to 67% by weight of its diet in area 10. Pollock constituted over 90% by weight of the diet of Pacific cod, arrowtooth flounder, Pacific halibut, and black cod in some areas. Greenland halibut sampled in this study did not contain any walleye pollock.

The size groups of pollock measured from trawl catches can be compared to the sizes of pollock measured from predatory fish stomach contents (Fig. 9). Pollock sizes ranged from 5 cm to over 53 cm (fork length) in trawl catches and from 2 to 53 cm (standard length) in predatory fish stomach contents. Small, medium, and large pollock size group modes were present in both trawl catches and fish stomach contents.

The presence of these size groups of pollock in hauls and fish stomachs can be compared within sample areas (Table 13). Small (age 0) pollock occurred in near-slope and shelf sample areas, medium (age 1) pollock in shelf areas, and large (>1 year old) pollock in all areas. The presence of these age groups in predator stomachs closely mirrors the pattern of occurrence in trawl catches. In some cases (areas 11, 12, and haul 17) pollock of ages 0 and 1 were found in predator stomachs but were not found in trawl catches.

The size distribution of pollock prey consumed by each predatory fish is shown in Figure 10. Flathead sole and

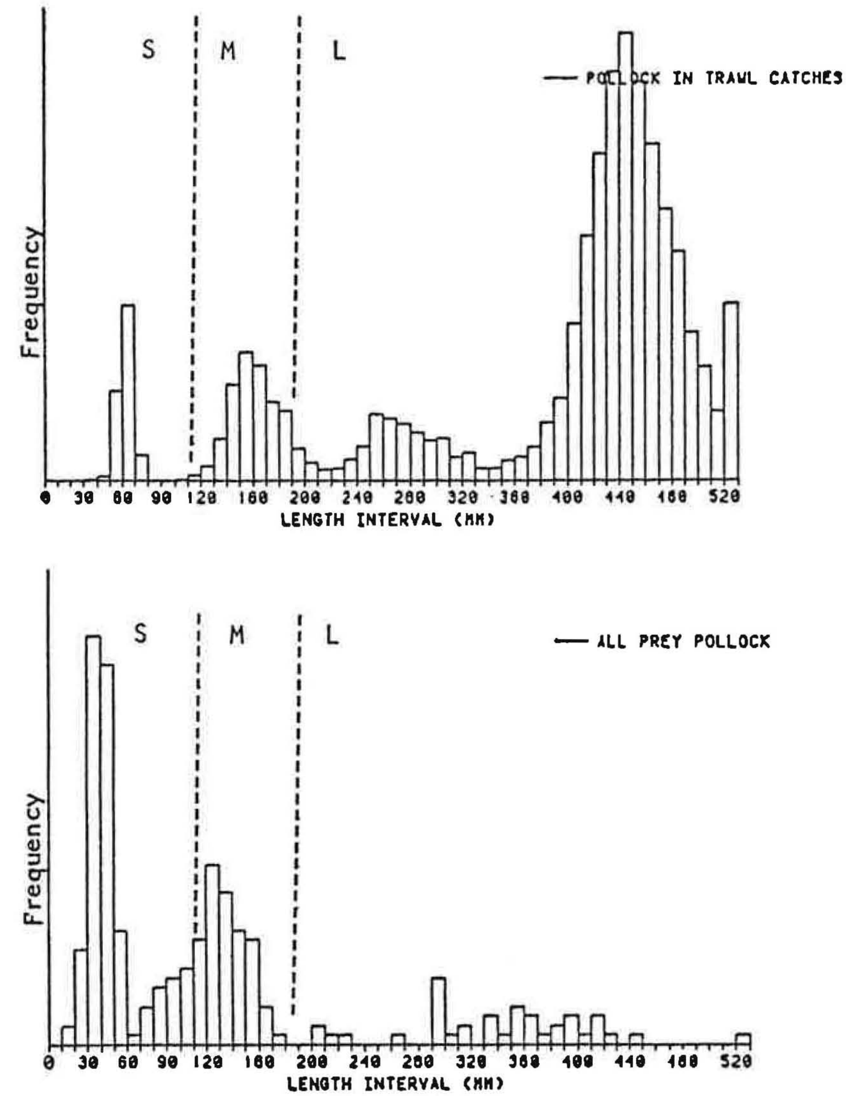

Figure 9.--Size-frequency distributions of walleye pollock, Theragra chalcogramma, measured in bottom and midwater trawl catches and from predatory fish stomachs taken during summer 1985 in fur seal, Callorhinus ursinus, feeding areas in the southeastern Bering Sea. Dotted lines delineate small (S), medium (M), and large (L) pollock size categories used in fur seal stomach content anaylsis. These data are derived from a subset of fish sampled for stomach content analysis.

Table 13.--Presence of various age groups of walleye pollock in hauls (0) and predatory fish stomachs (X) by marine mammal box number.

	Pollock Age Group					
Box	0		1		>1	
2	--	--	--	--	0	--
3	0	X	--	--	0	X
4	--	--	--	--	0	--
5	--	--	--	--	0	--
6	0	X	--	--	0	X
7	0	X	0	X	0	X
8	0	X	0	X	0	--
9	0	X	0	X	0	X
10	0	X	0	--	0	--
11	0	--	--	X	0	X
12	--	X	--	--	0	--
17*	--	X	--	X	0	--

*17 is haul 17

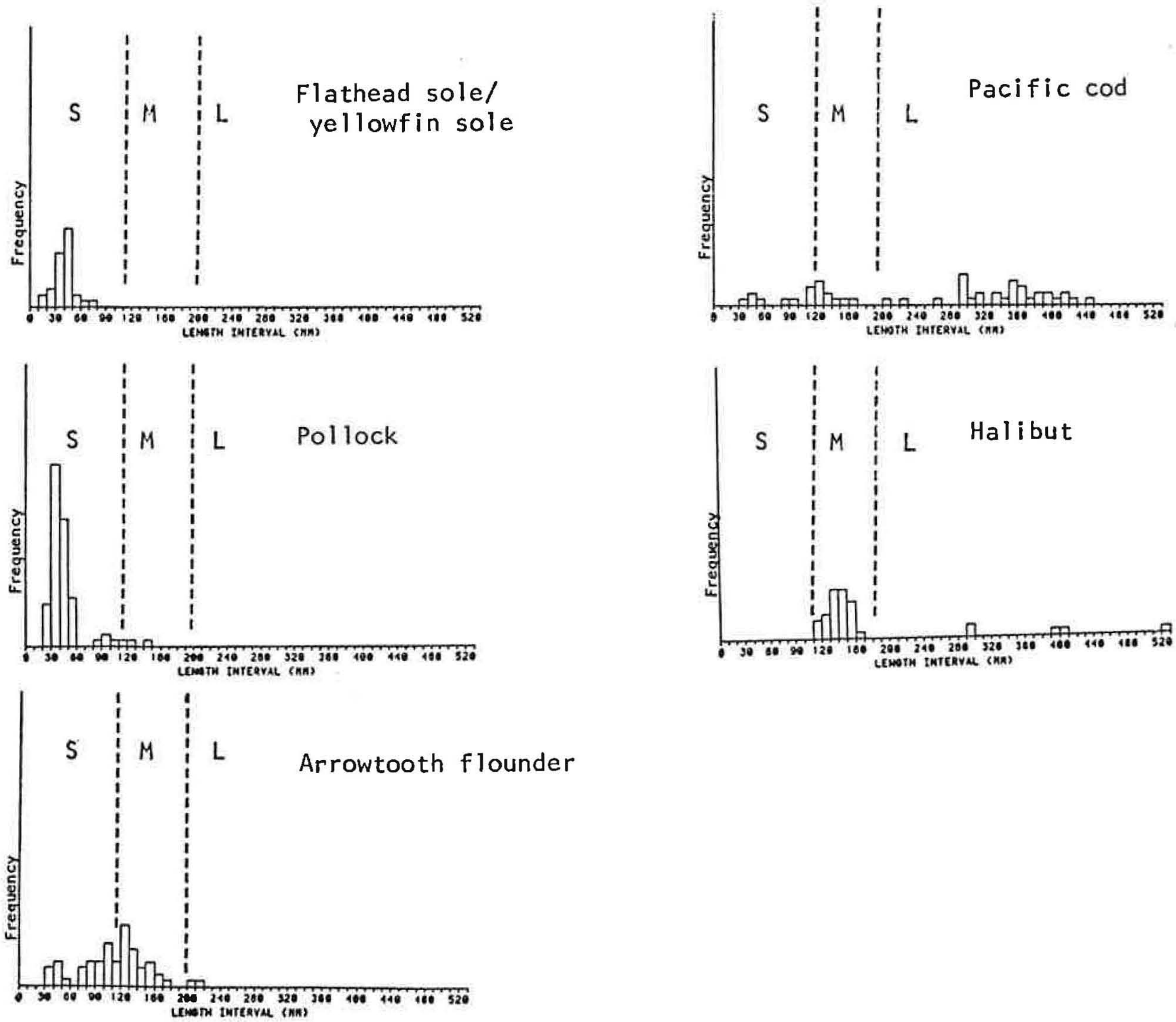

Figure 10.--Size-frequency distributions of walleye pollock, Theragra chalcogramma, consumed by various key predators during summer 1985 in fur seal, Callorhinus ursinus, feeding areas in the southeastern Bering Sea. Dotted lines delineate small (S), medium (M), and large (L) pollock size categories used in fur seal stomach content analysis. These data are derived from a subset of fish sampled for stomach content analysis.

yellowfin sole (Limanda aspera) consumed only small (age 0) pollock while pollock and arrowtooth flounder consumed both small and medium pollock. Pacific cod and Pacific halibut consumed a wide range of pollock sizes, from 4 to 53 cm in length.

Estimates of the total amount of pollock consumed by predatory fish populations within the fur seal feeding area for the period 1 July through 31 October 1985 were calculated using equation (1) (Table 14). Pollock consumed the most pollock in terms of weight (134,124 t). Pacific cod also consumed a large amount of pollock, totalling 116,865 tons. Other key predatory fish consumed much less pollock in terms of weight; amounts ranged from 30,794 tons for arrowtooth flounder to 433 tons for yellowfin sole.

The consumption estimates of pollock by key predatory fish populations were divided into consumption of small (age 0), medium (age 1), and large (>1 year old) pollock (Table 15) based on length-frequency distributions of those size groups in each predator's food composition. In terms of biomass, most pollock eaten by predatory fish were large pollock. Large amounts of small pollock were also consumed and pollock cannibalism accounted for most of that removal. Medium, or 1-year-old pollock, were not consumed in such large quantities and arrowtooth flounder and pollock were responsible for most of the consumption by weight of medium pollock. Most of the pollock consumed were small (age 0).

Table 14.--Estimates of population level consumption of walleye pollock, Theragra chalcogramma, from 1 July through 31 October 1985 by fish predators in the main fur seal, Callorhinus ursinus, feeding areas of the eastern Bering Sea. (BWD is body weight daily.)

Predator	Daily ration[a] (fraction BWD)	Pollock consumption fraction total stomach content weight)	Predator[b] biomass (tons)	Population consumption (tons)
Arrowtooth flounder	.0062	.541	74,639	30,794
Greenland halibut	.0066	--	28,480	--
Pacific halibut	.0066[c]	.521	19,503	8,249
Flathead sole	.0012	.052	69,792	535
Yellowfin sole	.0012	.053	55,350	433
Black cod	.0043[d]	.561	16,019	4,753
Pacific cod	.0133	.469	152,319	116,865
Walleye pollock	.0043	.326	777,890	134,125
			TOTAL	295,755

[a]Values from Livingston et al. 1985a, averaged over size groups.

[b]Biomass estimates from RACE 1985, U.S.-Japan eastern Bering Sea bottom trawl survey restricted to fur seal feeding areas,

[c]Pacific halibut ration assumed to be the same as Greenland halibut.

[d]Black cod ration assumed to be the same as walleye pollock.

Table 15.--Population consumption by weight and numbers of small (<12.5 cm), medium (12.5-18.6 cm), and large (>18.6 cm) walleye pollock, Theragra chalcogramma, by predatory fish from 1 July to 31 October 1985 in the main fur seal, Callorhinus ursinus, feeding areas of the eastern Bering Sea.

Predator	Biomass (tons)			Numbers (x 10^9)		
	small	medium	large	small	medium	large
Arrowtooth flounder	5,494	20,022	5,278	1.493	0.901	0.063
Pacific halibut	271	1,836	6,141	0.021	0.075	0.021
Flathead sole	535	--	--	0.047	--	--
Yellowfin sole	433	--	--	0.058	--	--
Black cod	--	--	4,753	--	--	0.017
Pacific cod	585	3,716	112,564	0.012	0.016	0.037
Walleye pollock	115,629	18,495	--	154.163	0.081	--
TOTAL	122,947	44,069	128,736	155.794	1.073	0.138

Pollock cannibalism accounted for most of the consumption of 0-age pollock. The number of medium-size pollock consumed was two orders of magnitude less than that of small pollock.

Discussion

Predatory fish populations consumed large amounts of small (age 0) and large (>1 year old) pollock in terms of weight during 1985 in fur seal feeding areas of the eastern Bering Sea. In terms of numbers, small (age 0) pollock were the dominant size group consumed by fish. A contrasting result reported by Dwyer et al. (in review) showed that in 1981 and 1982 in the eastern Bering Sea, pollock consumed mostly age 1 pollock during summer. Pollock cannibalism on age 0 pollock in those years occurred mostly in the autumn. Different sampling areas and the timing of age 0 pollock availability among years may account for part of the difference between these two studies. Also, most medium (age 1) pollock were consumed by >50 cm adult pollock in 1982 (Dwyer, 1984) while most adult pollock in fur seal feeding areas during 1985 were <50 cm. The RACE hydroacoustic surveys of small (age 0) pollock in the eastern Bering Sea during 1984 and 1985 show that some of the larger catches of age 0 pollock occurred in the fur seal feeding area (Fig. 11) but that most medium (age 1) pollock occurred north of the fur seal feeding area (J. Traynor, RACE, pers. commun.). However, RACE bottom trawl surveys in 1985 showed a peak of medium pollock in the fur seal feeding

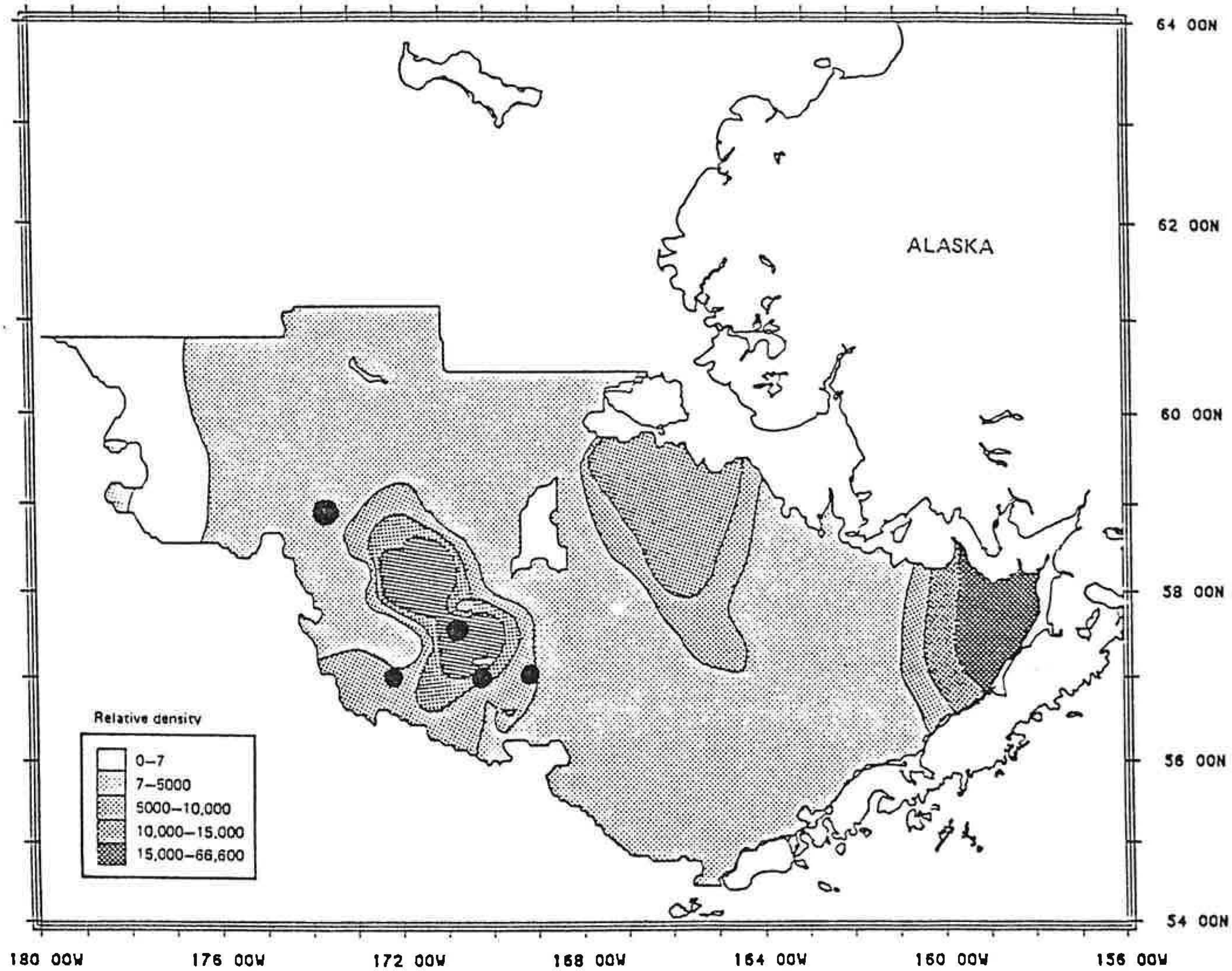

Figure 11.--Catch per unit effort (number/hectare) of 0-age walleye pollock, Theragra chalcogramma, during 1984 (cruise results Miller Freeman cruise 84-4, RACE hydroacoustic survey). Black dots represent areas of abundant 0-age walleye pollock, determined from the 1985 RACE hydoacoustic survey.

area (Fig. 12) and fur seal stomach content analysis in 1985 showed most pollock consumed (approximately 81%) were medium (age 1) pollock (NMML, Pelagic Studies). Although information is not yet available on the relative abundance of small and medium pollock during 1985 in the fur seal feeding area, it seems that both were available to fish predators but that more small pollock were eaten. Since the total removal by weight of medium (age 1) pollock by the fur seal population is not known, it cannot be compared with the estimated total removal of age 1 pollock by predatory fish populations. However, the total amount of all age groups of pollock consumed by fur seals (132.5×10^3 t; NMML Section) is approximately the same as that consumed by walleye pollock (134×10^3 t).

Foreign fishery statistics collected by observers during 1 July through 31 October 1985 show the amounts and sizes of pollock removed by the fishery in fur seal feeding areas (Figs. 13 and 14). The fishery removed about 104,650 tons of pollock averaging 37-49 cm in length, corresponding to the large (>1 year old) size category of pollock consumed by fish and fur seals. The fishery removal of large pollock is somewhat less than the removal of large pollock by fish predation which amounted to almost 129,000 tons. Although only 5% of pollock otoliths from fur seal stomachs were from large pollock (NMML, Pelagic Studies) it is not clear how much large pollock, in terms of total weight, the fur seal

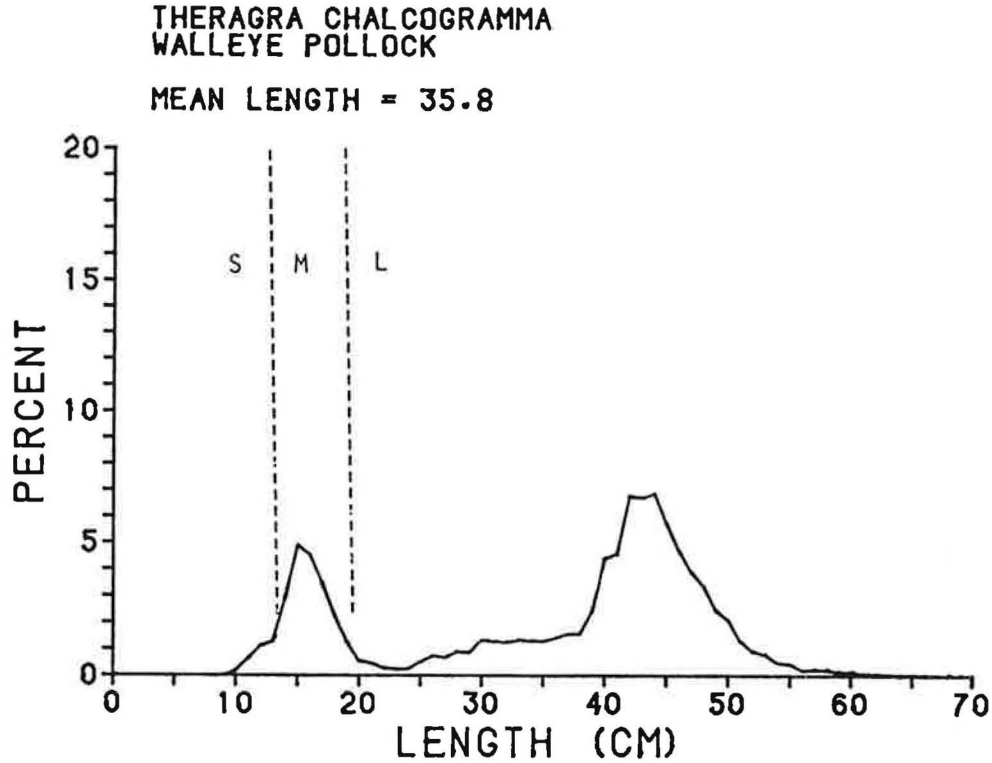

Figure 12.--Size-frequency distribution of the walleye pollock, <u>Theragra</u> <u>chalcogramma</u>, population during summer 1985 in fur seal feeding areas in the southeastern Bering Sea. (Data source: U.S.-Japan joint survey of the eastern Bering Sea, 1985, RACE Division data, bottom trawl survey only). Dotted lines delineate small (S), medium (M), and large (L) categories used in fur seal stomach content analysis.

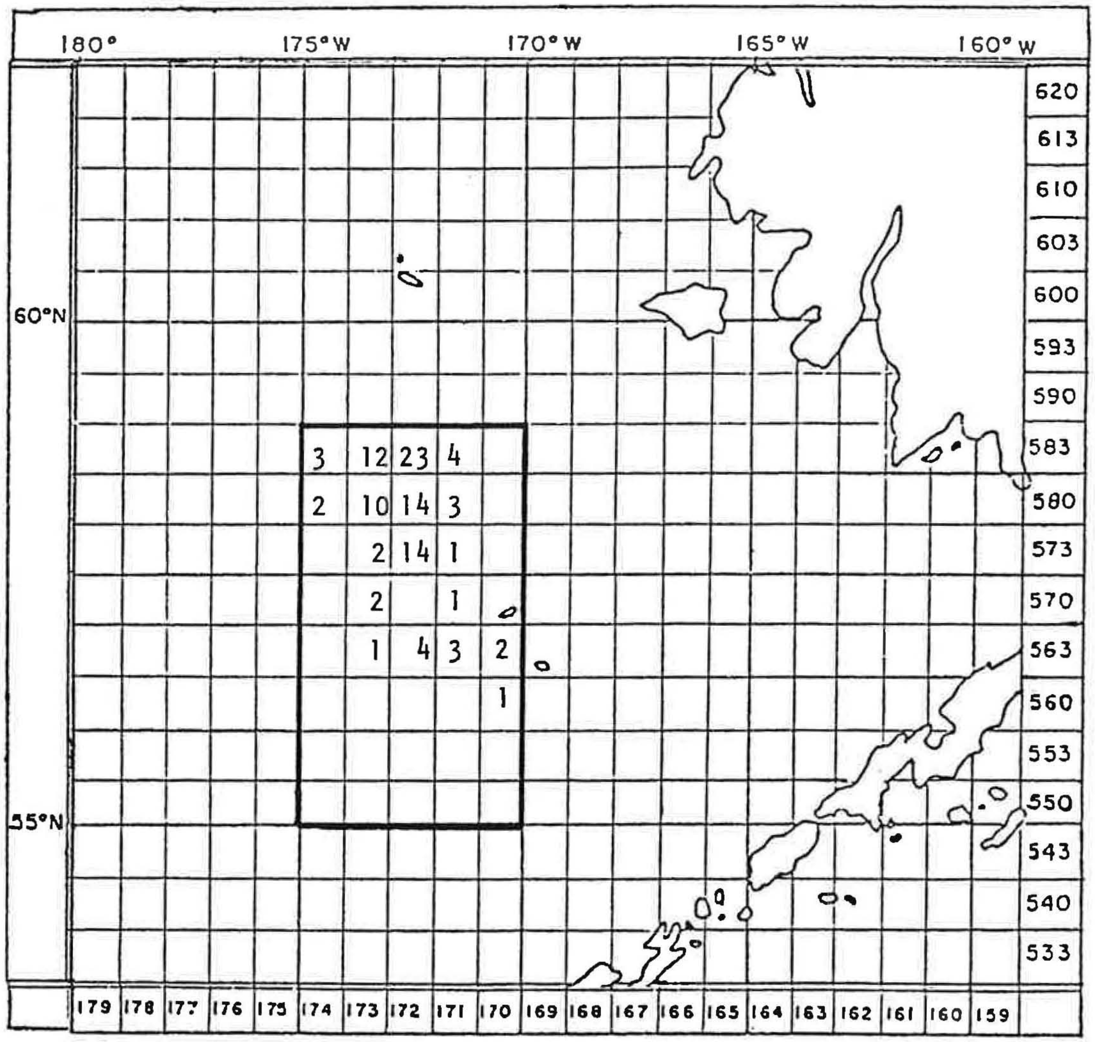

Figure 13.--Foreign and joint venture catch of walleye pollock, *Theragra chalcogramma*, in 1,000 metric tons from 1 July through 31 October 1985 in the summer feeding range of the northern fur seal, *Callorhinus ursinus*. (Total catch in the feeding area equals 104,650 t.)

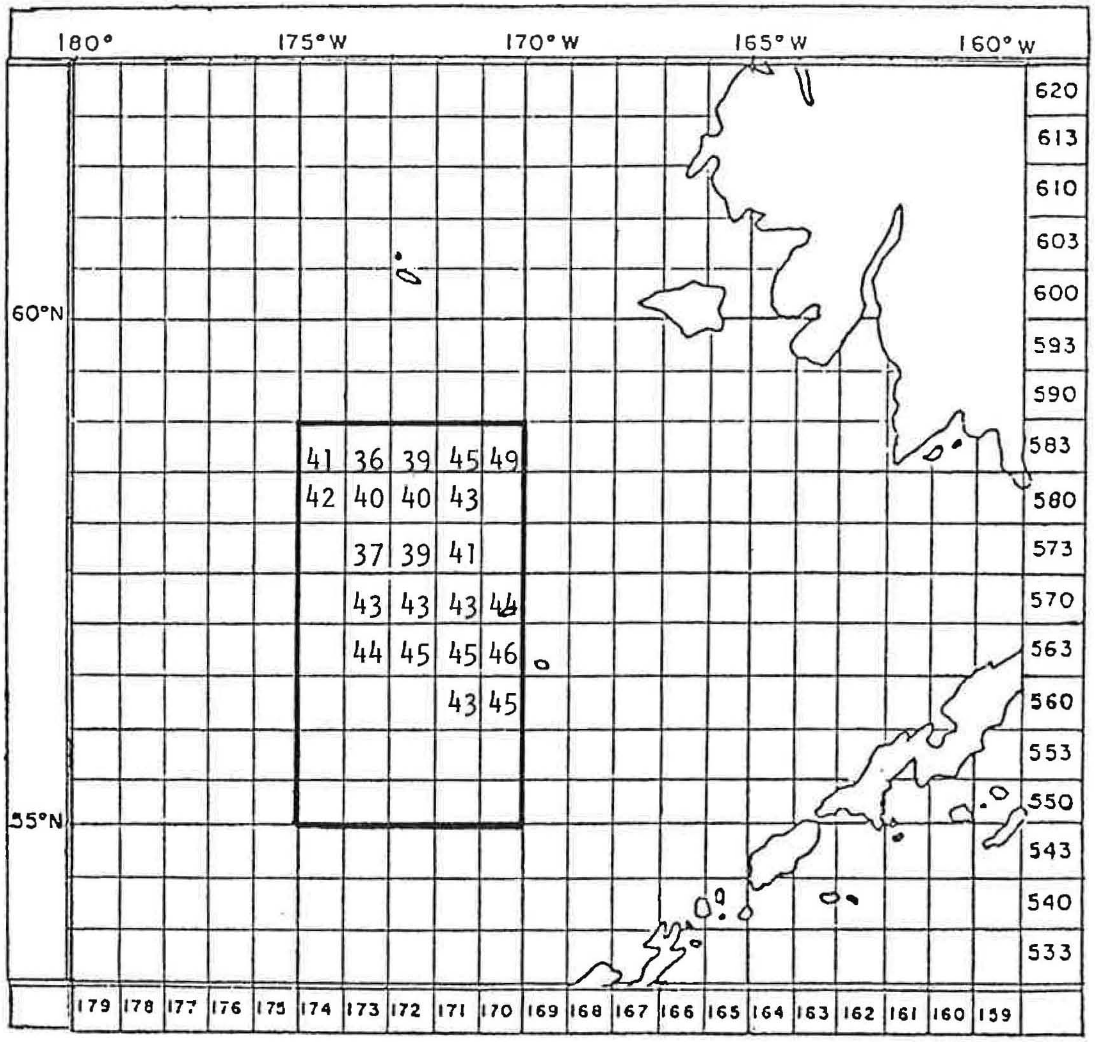

Figure 14.--Average fork length (cm) of walleye pollock, Theragra chalcogramma, caught in foreign and joint venture fisheries from 1 July through 31 October 1985 in the summer feeding range of the northern fur seal, Callorhinus ursinus.

population may have consumed during its stay in the eastern Bering Sea. Nevertheless, the above evidence suggests that predatory fish and the commercial fishery are equally important sources of removal of large pollock food resources.

Since fur seals consumed mostly medium (age 1) pollock in 1985 (NMML, Pelagic Studies), the removal of large pollock by the fishery and predatory fish may not be considered a removal of the main fur seal food resources. Because pollock larger than 50 cm consume 1-year-old pollock, this removal of large pollock by predatory fish and the fishery may even enhance the supplies of 1-year-old pollock available to fur seals (as suggested by Swartzman and Haar 1983).

SUMMARY

Comparison of past studies on fur seal feeding habits showed that the percentage of fish (60-66%) and squid (33-39%) in the fur seal diet has remained relatively constant. Walleye pollock was the predominant food item in most years, except 1963-64 when pollock abundance may have been low. The amount of time spent at sea on feeding trips has declined from the early 1960's to 1985 even though the diet has not changed appreciably. This suggests that reduction of resources is not the singular cause of observed declines in fur seal numbers.

NMML and REFM studies near the Pribilof Islands during 1984 and 1985 showed that key predatory fish and fur seals consumed walleye pollock as a major dietary component. During the 1985 studies, walleye pollock 38-48 cm long were abundant in the sample area but fur seals consumed mostly 12.5-18.6 cm pollock (age 1) in terms of numbers. Fur seals consumed walleye pollock in the size range of 4-40 cm during previous study years. Examination of fur seal scats and colons in 1985 yielded diet information similar to information gathered from fur seal stomach analysis.

Predatory fish consumed all sizes of pollock but small (age 0) pollock were the dominant size group eaten in terms of numbers. Thus, in 1985 when age 1 pollock were abundant, predatory fish and northern fur seals utilized this common food resource. These results indicate that the pollock food

web of Kajimura and Fowler (1984) should also show a major flow of pollock juveniles (2-20 cm) going to the northern fur seal (Fig. 15). There was a noticeable lack of 2- to 3-year-old (22-35 cm) pollock found during trawl surveys in 1985; it would, therefore, be informative to study the change in diet of predatory fish and fur seals in years of abundant 2- to 3-year-old pollock.

It also appears that the fishery removal of large walleye pollock did not remove food resources utilized by fur seals in 1985. Since large pollock consume 1-year-old or medium pollock, which were the major food source of fur seals sampled in 1985, the walleye pollock fishery in the fur seal feeding areas of the eastern Bering Sea may even have a beneficial effect on the abundance of appropriately sized prey for fur seals (as suggested by Swartzman and Haar 1983). It may, however, be detrimental to other marine mammals species (Frost and Lowry 1986).

Fur seals consumed about as much pollock (132.5 x 10^3 t) as did walleye pollock eating pollock (134 x 10^3 t). Commercial pollock fisheries operating in the sample areas removed about 104 x 10^3 t of mostly large pollock during 1 July to 31 October. Predatory fish consuming all size groups of pollock accounted for 296 x 10^3 t of pollock.

Studies of radio-tagged female fur seals during 1984 and 1985 showed that feeding locations were predominantly northwest and southwest of St. Paul Island. Some had

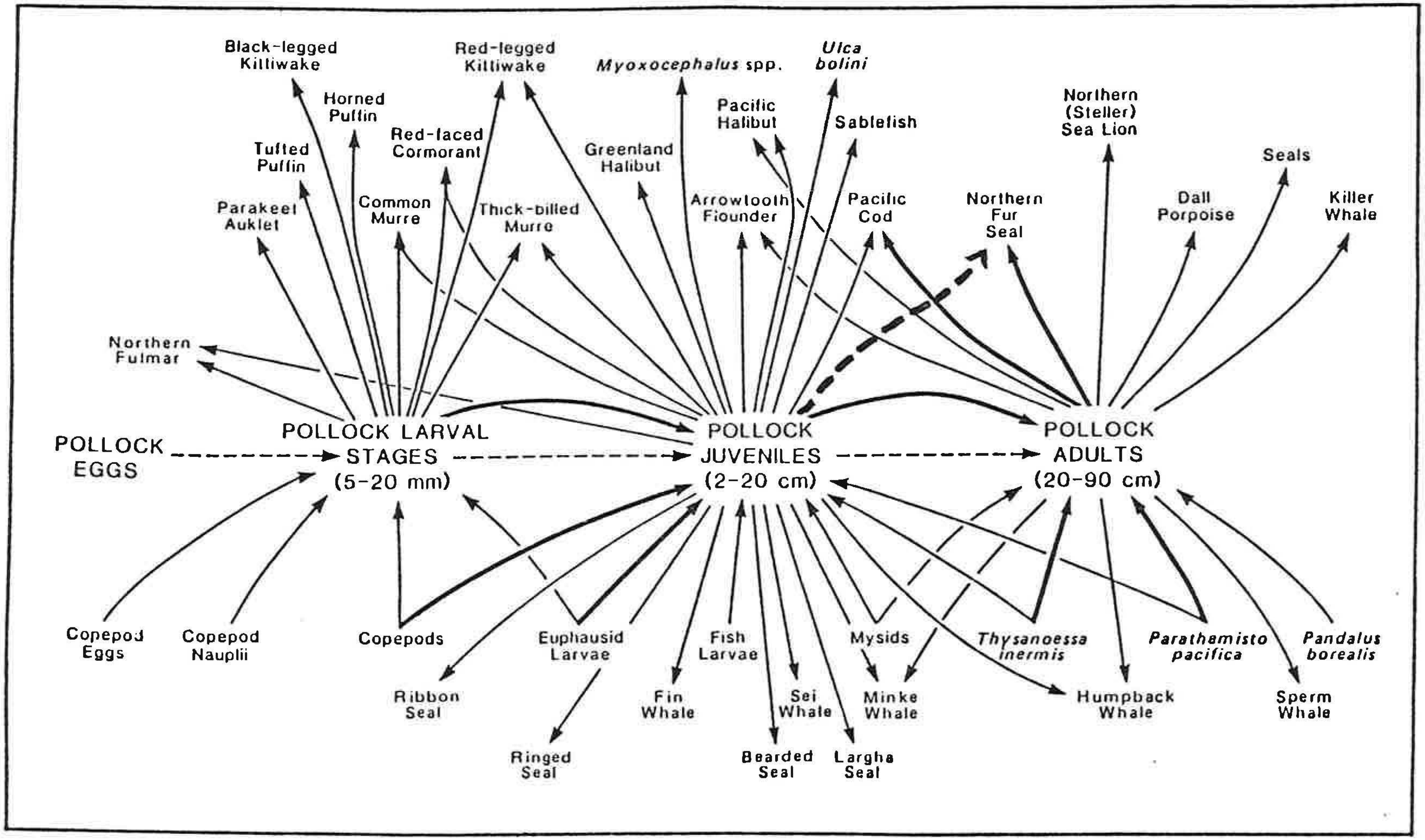

Figure 15.--Apparent food web based on walleye pollock in the eastern Bering Sea (from Kajimura and Fowler 1984). The dashed line (---) shows the modification to the food web based on the results of this study.

feeding trips resulting in round-trip distances of over 400 km. Further research on the feeding range of fur seals in the eastern Bering Sea and the competition for food resources with predatory fish throughout this range is important. It would provide more details about the dynamics of food chain interactions in years with differing availability of pollock age groups--the major resource for fish, mammals, sea birds, and man in this area of the eastern Bering Sea.

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