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U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

This document describes the feeding habits of major. groundfish species in the eastern Bering Sea based on stomach content information collected during 1987, 1988, and 1989. The total consumption of commercially important prey species by groundfish populations is calculated for the main feeding period of May through September during 1987, 1988, and 1989. Walleye pollock (*Theragra chalcogramma*) cannibalism is also calculated for the period of May through December. Estimated predation mortality in terms of numbers and biomass during this period is presented. These estimates are compared with existing knowledge of prey species abundance. Possible impact of predation on prey species abundance patterns is discussed.

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CONTENTS

EXECUTIVE SUMMARY

This document summarizes groundfish predation on commercially important stocks of fish and crabs on the eastern Bering Sea shelf from 1987 to 1989. The amount of predation is calculated using estimates of predator biomass, daily ration, and the proportion of various prey categories in the stomach contents. Estimates are presented in terms of number and biomass of prey consumed during the main sampling period of May through September of each year.

Predator and Prey Species

The following groundfish predators are included in this report because they are dominant members of the eastern Bering Sea shelf fish fauna that consume commercially important fish or crab. The commercially important prey eaten by some of these predators are also listed below:

Groundfish	Commercially important prey
Walleye pollock	Walleye pollock
Pacific cod	Pacific cod
Yellowfin sole	Yellowfin sole
Greenland turbot	Greenland turbot
Arrowtooth flounder	Arrowtooth flounder
Flathead sole	Flathead sole
Pacific halibut	Rock sole
Alaska plaice	Pacific halibut
Rock sole	Pacific herring
	King crabs
	Snow crab
	Tanner crab

Total Groundfish Consumption Estimates

The total amount of each prey consumed from May to September of 1984 to 1989 is presented in Tables 1 and 2. These estimates are the sum of the consumption by each predator species. Consumption of walleye pollock also includes cannibalism estimates during the period October to December of 1985 and 1989. Biomass consumed is converted to number consumed using available prey size information. If prey size information was lacking for a predator, number consumed could not be estimated. Total number consumed is an underestimate in these cases and is shown in parentheses.

Estimated number at-age of snow crab (*Chionoecetes opilio*), Tanner crab (C. *bairdi*), and walleye pollock (*Theragra chalcogramma*) consumed by groundfish predators are presented along with the estimated natural mortality coefficients at-age in Tables 3-8 and Figure 1. Fluctuations in the number consumed at-age can occur through several processes: changes in predator or prey abundance, changes in prey availability, or changes in predation rate due to predators switching to an abundant prey source. If predators respond to increases in prey species abundance by switching preferentially to feeding on the more abundant prey, they can cause density-dependent mortality on that prey species. This means that predators can alter the relative size of the prey population. Changes across years in annual natural mortality coefficients at-age of juvenile prey populations provide a signal that this process may be occurring.

Fluctuations in estimates of the annual natural mortality coefficient at-age for snow crab, Tanner crab, and walleye pollock were present (Tables 4,6, and 8). Large fluctuations in coefficients for snow crab ages 1 and 2 were estimated, particularly for age-l crab from 1984 to 1985 and age-2 crab from 1985 to 1986. There was a large recruitment of snow crab possibly in 1983 or 1984, and the large natural mortality coefficients estimated from groundfish predation data show larger than average natural mortality at-age for the 1983 year class. Larger mortality at-age for Tanner crab was noted at-age 0 for the 1984 year class, which was also suspected to be above average. Finally, natural mortality coefficients for the 1985 year class of walleye pollock are larger at-age than for adjacent year classes. The 1985 year class was more abundant than the 1986 to 1989 year classes at age 1 but later proved to be about the same size as the 1986 and 1987 year classes at age 3. It appears that differential predation by groundfish on the 1985 year class from ages 0-2 may have reduced the relative abundance of this year class upon recruitment to the fishery.

Table 1.--Estimated total biomass (metric tons) by year of commercially important prey consumed by groundfish from May through September in the eastern Bering Sea. (Consumption of walleye pollock also includes cannibalism estimates from May through December.)

Prey	Year 1984	1985	1986	1987	1988	1989
King crabs	2,684	1,136	2,867	845	568	1,935
Snow crab (*Chionoecetes opilio*)	98,818	132,467	149,078	151,242	62,173	129,343
Tanner crab (*Chionoecetes bairdi*)	63,189	89,991	48,822	107,134	55,825	88,520
Pacific cod	13,430	9,978	9,302	8,881	1,330	7,762
Walleye pollock	314,783*	3,846,851	1,493,712	1,489,131	920,500	1,817,425
Pacific herring	0	19,322	44,440	12,286	5,440	79
Atka mackerel	0	0	0	1,650	0	0
Arrowtooth flounder	4,327	15,436	781	13,761	0	464
Flathead sole	9,787	5,929	13,993	1,965	1,454	25,718
Rock sole	8,020	20,843	38,804	18,552	5,156	15,283
Yellowfin sole	56,291	28,359	42,330	17,394	9,671	7,190
Greenland turbot	3,919	0	0	0	16	17,635
Pacific halibut	89	0	0	0	185	0
Alaska plaice	0	0	0	0	0	13

*Walleye pollock cannibalism estimate was not available for 1984.

Table 2.--Estimated number (millions) by year of commercially important prey consumed by groundfish from May through September in the eastern Bering Sea. (Consumption of walleye pollock also includes cannibalism estimates from May through December.) Values in parentheses indicate cells with some missing prey size information and therefore are underestimates of the total number consumed.

Prey	Year					
	1984	1985	1986	1987	1988	1989
King crabs	(35,566)[a]	(2)	(5)	(1)	8	(3)
Snow crab (*Chionoecetes opilio*)	(30,921)	12,235	13,042	(10,666)	11,870	(20,805)
Tanner crab (*Chionoecetes bairdi*)	(152,850)	(13,926)	9,898	42,632	14,659	(27,244)
Pacific cod	(1,124)	3,263	(76)	8,194	2	(75)
Walleye pollock	(47,832)[b]	(1,049,617)	(231,641)	260,249	228,658	864,166
Pacific herring	0	(303)	(554)	(23)	140	(1)
Atka mackerel	0	0	0	8	0	0
Arrowtooth flounder	1,920	(3)	(40)	3,791	0	(101)
Flathead sole	363	2,128	381	210	761	(4,292)
Rock sole	23,611	5,514	1,688	1,531	(5,809)	1,694
Yellowfin sole	480	313	651	63,767	(87)	16,909
Greenland turbot	81,721	0	0	0	17	(30,328)
Pacific halibut	728	0	0	0	665	0
Alaska plaice	0	0	0	0	0	9

[a]Most king crab consumed in 1984 were blue king crab megalops larvae.
[b]Walleye pollock cannibalism estimate was not available for 1984.

Table 3.--Estimated number (millions) of snow crab, Chionoecetes opolio, consumed by age by groundfish from May through September in the eastern Bering Sea.

Age	Year					
	1984	1985	1986	1987	1988	1989
0	0	0	0	0	312	0
1	28,597	7,001	5,880	5,293	10,017	17,239
2	1,700	4,386	6,464	2,809	920	2,531
3	559	792	656	1,514	530	925
4	65	56	41	16	69	102
5	0	0	0	9	0	4
6	0	0	0	13	0	4

Table 4.--Estimates of the instantaneous annual natural mortality coefficient by age for snow crab, obtained from reconstructing population sizes at-ages 0-2 using survey estimates of population size at age 3 and assuming the only mortality is mortality from predation by groundfish (Table 3).

Age	Year					
	1984	1985	1986	1987	1988	1989
0	-	-	-	-		
1	1.77	0.41	0.59	0.56	0.93	
2	1.53	1.37	0.63	0.48	0.14	0.49

Table 5.--Estimated number (millions) of Tanner crab, <u>Chionoecetes bairdi</u>, consumed by age by groundfish from May through September in the eastern Bering Sea.

	Year					
Age	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
0	139,313	5,372	3,371	27,883	1,074	18,646
1	13,161	7,693	6,645	10,638	13,205	7,926
2	296	651	191	576	362	549
3	88	198	7	99	12	82
4	0	13	0	0	3	32
5	0	0	0	0	3	8

Table 6.--Estimates of the instantaneous annual natural mortality coefficient by age for Tanner crab, obtained from reconstructing population sizes at ages 0-2 using survey estimates of population size at age 3 and assuming the only mortality is mortality from predation by groundfish (Table 5).

	Year					
Age	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
0	2.92	0.55	0.26	1.10		
1	3.00	3.22	2.34	2.92	2.96	
2	2.69	2.66	0.93	1.68	0.94	1.45

Table 7.--Estimated number (billions) of walleye pollock consumed by age by groundfish from May through September and by cannibalism from May through December in the eastern Bering Sea.

Age	1984*	1985	1986	1987	1988	1989
0	43.82	1,033.12	191.27	248.54	215.48	851.68
1	4.04	28.64	37.43	9.59	11.83	11.31
2	0.19	0.55	1.09	1.80	0.67	0.49
3	0.15	0.21	0.35	0.23	0.19	0.16
4	0.08	0.10	0.06	0.06	0.23	0.16
5	0.05	0.05	0.07	0.01	0.13	0.15
6+	0.04	0.03	0.09	0.01	0.13	0.22

* Walleye pollock cannibalism estimate was not available for 1984.

Table 8.--Estimates of the instantaneous annual natural mortality coefficient by age for walleye pollock, obtained from reconstructing population sizes at ages 0-2 using cohort analysis estimates of population size at age 3 and assuming the only mortality is mortality from predation by groundfish (Table 7).

Age	1984*	1985	1986	1987	1988	1989
0		3.19	2.67	2.75		
1		1.25	1.88	1.13	1.18	
2		0.17	0.10	0.31	0.16	0.10

*Mortality coefficients were not estimated for 1984 because walleye pollock cannibalism estimate was not available for that year.

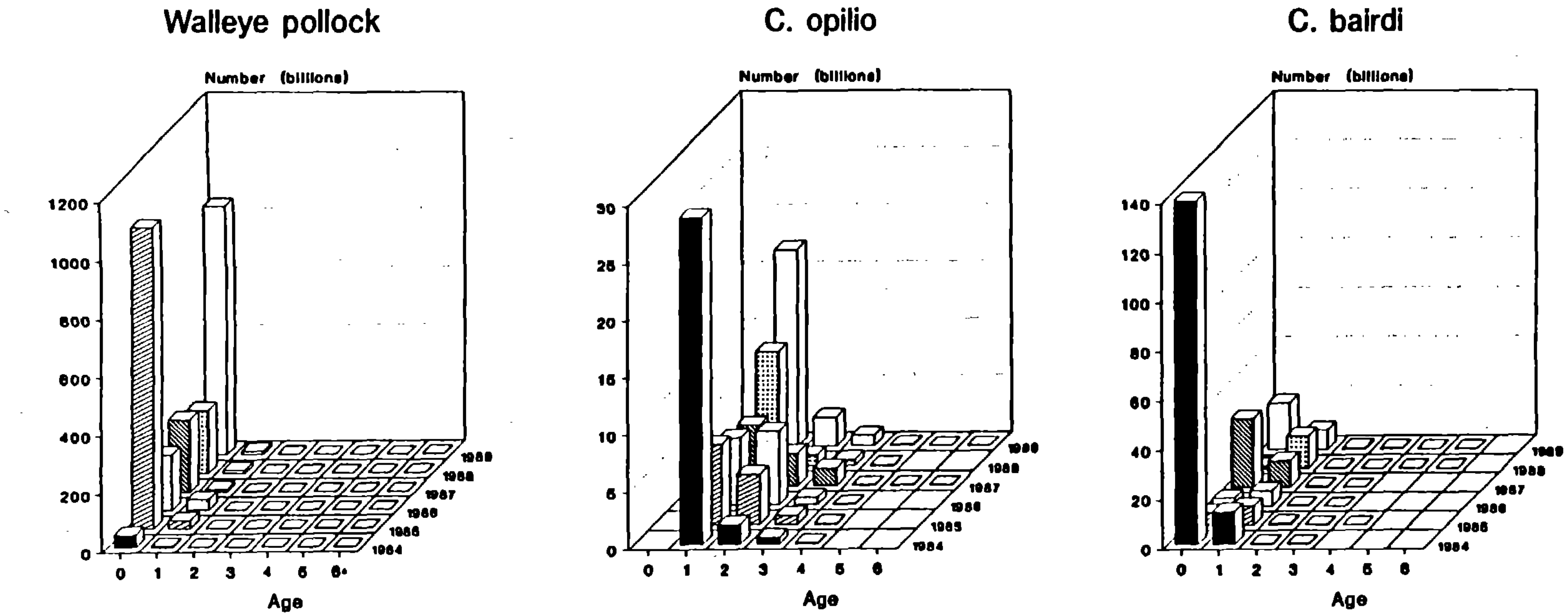

Figure 1.--Estimated number at-age of walleye pollock, snow crabs (Chionoecetes opilio), and Tanner crabs (c. bairdi) consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea.

INTRODUCTION

Many large marine fish are predators of either juvenile or small adult fish and crab. Because predation forms the largest part of natural mortality of young fish and crab, it is important to estimate the magnitude of predation loss on commercially important populations. Population models that assume constant natural mortality rates due to a lack of information on actual rates can be improved by providing more accurate estimates of predation losses. The move toward multispecies management of stocks can be helped through studying the food web connections between components of marine ecosystems, which include fish, crabs, marine mammals, and birds.

The primary purpose of the Trophic Interactions Program of the Resource Ecology and Fishery Management Division (REFM) at the Alaska Fisheries Science Center (AFSC) is to study the consumption of commercially important fish or crab by key fish predators in the eastern Bering Sea. These fish and the fish they consume are commercially important species and form a major part of the groundfish biomass in the eastern Bering Sea. Program objectives include providing impact assessments relating to fish predation effects on prey species populations, improving population model estimates of predation mortality by marine fish, and detecting possible changes in abundance and distribution of juvenile fish and crab populations.

This paper reports the progress of the Trophic Interactions Program of the REFM Division of the AFSC in analyzing available data from 1987 to 1989 on the predation of commercially important fish and crab species. The first section details the methods used to estimate the total biomass and numbers of prey consumed by the major groundfish species in the area. The second section summarizes the consumption of commercially important prey by all the major predators. Appendices summarize the diet and total prey consumption by the following predators: walleye pollock, Pacific cod (Gadus macrocephalus), yellowfin sole (Pleuronectes asper), flathead sole (Hippoglossoides elassodon), rock sole (Pleuronectes bilineata), Alaska plaice (Pleuronectes quadrituberculatus), Greenland turbot (Reinhardtius hippoglossoides), arrowtooth flounder (Atheresthes stomias), and Pacific halibut (Hippoglossus stenolepis).

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METHODS

Sample Collection and Laboratory Analysis

Stomachs were collected from major groundfish species during 1987, 1988, and 1989 in the eastern Bering Sea. Samples were taken year-round, but primarily during May through September using bottom and pelagic trawl gear on research and commercial fishing vessels. Sampling occurred throughout the 24-hour day, although most sampling occurred between 0600 and 2000 Alaska daylight time. For all species except walleye pollock, stomachs were removed at sea and placed in cloth bags labelled with information regarding the location of capture, fork length, sex, and sexual maturity of the fish. Fish showing evidence of regurgitation (i.e., food in the mouth or throat or a flaccid stomach) were not included in the sample. Stomachs were preserved in 10% formalin and later transferred to 70% ethyl alcohol. Contents were identified to the lowest taxonomic level possible and enumerated. Wet weights were recorded after the contents were blotted with paper towels. Standard length (SL) measurements of prey fish and carapace width (CW) or lengths (CL) of crab prey were taken when whole prey were available.

For walleye pollock, a combination of collection and analysis methods was used. Information collected during the main sampling period of May through September (months 5 to 9) includes stomachs collected and analyzed using the methodology described above. Most of the information collected outside the main sampling period was from fishery observers aboard commercial fishing vessels who performed quantitative shipboard scans of walleye pollock stomach contents. Only fish with no visible evidence of regurgitation were selected for scans. Once a fish was selected for scanning, the stomach was excised and the volume of the stomach contents was determined by a water displacement method by emptying the stomach contents into a graduated cylinder or beaker containing a known amount of water. The difference between the initial water level and the water level after the stomach contents were added was the stomach volume. Volume was later converted to weight by assuming 1 ml of volume displaced was equal to 1 g. The contents were then emptied onto a petri dish or tray, prey were separated into the lowest taxonomic categories possible, and the volume (expressed as a percentage of the total) was visually estimated and recorded for each prey category. Numbers of individuals in a prey category were counted, if practical. Measurements of fish and crab prey were taken if an item was whole.

For both quantitative shipboard scans and detailed laboratory analysis, the prey category "fishery discards" was used if the ingested item had obviously been discarded from a processor (i.e., a consumed fish that had its head sliced off with a clean diagonal cut). Due to the difficulties involved in shipboard identification of taxonomic categories, particularly by inexperienced biologists, some prey taxa may have been misidentified in shipboard stomach scans.

Data Analysis

Prey Consumption by Predator Populations

Estimates of the total biomass of each prey species consumed by the continental shelf portion of each groundfish population were calculated according to

$$C_i = DR_i * D * B_i * P_i , \qquad (1)$$

where C_i is the consumption (by weight) of a prey species by size group i of a predator species, DR_i is the daily ration (as a proportion of body weight daily, BWD) of predator size group i, D is the number of days in the sampling period when the prey species was vulnerable to predation, B_i is the biomass of the predator size group i, and P_i is the proportion by weight of the prey species in the diet of predator size group i.

Total consumption estimates using Equation (1) were computed within each major stratum of the eastern Bering Sea (Fig. 1). These strata were devised by the Resource Assessment and Conservation Engineering (RACE) Division of the AFSC to reflect, in general, natural boundaries based on bottom depth. Strata 1 and 2 are considered inner continental shelf areas, strata 3 and 4 comprise the middle shelf, and strata 5 and 6 are the outer shelf zones.

Predator size groupings used for total consumption estimates were based on size groupings used previously (Livingston et al. 1986, Livingston 1991) and on knowledge of each predator's diet. If consumption of commercially important prey groups differed among predator sizes, then predator size groups were chosen to minimize such consumption differences within a size group.

Daily ration (DR) estimates (Table 1) were derived using some basic bioenergetic considerations as an alternative to using rations estimated from gastric evacuation rate models and field-estimated stomach content weights. As Livingston et al. (1986) found, estimates derived from gastric evacuation rate models tend to be lower than expected based on known annual growth patterns of eastern Bering Sea species. Part of the problem with rations estimated in this fashion may be due to undetected regurgitation of stomach contents from field collections. It is believed that more realistic rations can be derived using bioenergetic variables such as annual growth increments and food conversion efficiency estimates; thus, that is the approach used here. Daily growth in weight of each species size group was estimated

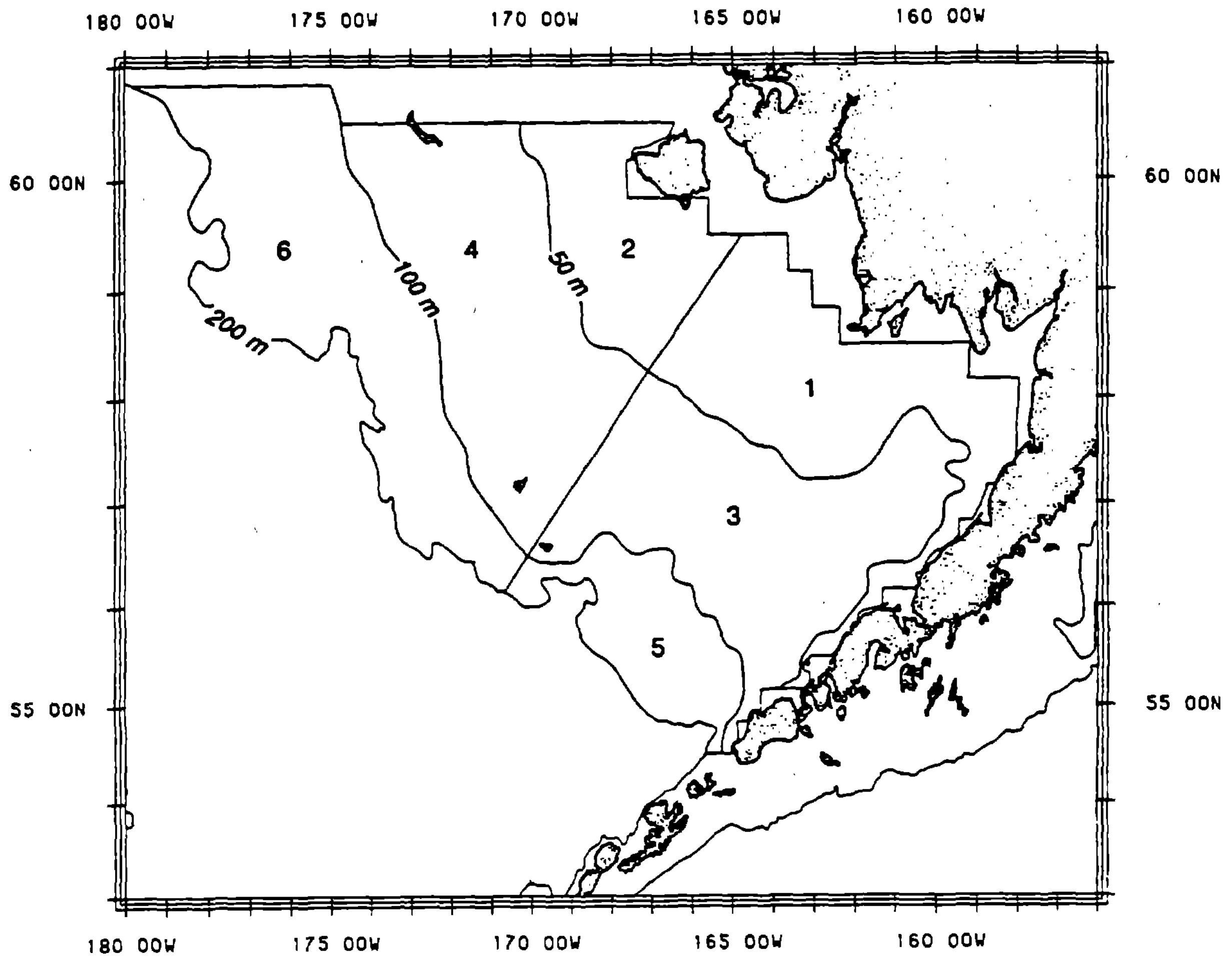

Figure 1.--Map of the eastern Bering Sea shelf showing bottom depth zones and strata used in this report.

Table 1.--Estimated daily ration of groundfish species in the eastern Bering Sea, expressed as a fraction of body weight daily.

Predator	Predator size (cm)	Daily ration
Pacific cod	<30	0.012
	30-59	0.009
	≥60	0.007
Walleye pollock	<30	0.011
	30-39	0.011
	40-49	0.008
	≥50	0.004
Greenland turbot	<30	0.011
	30-49	0.013
	≥50	0.005
Arrowtooth flounder	<20	0.009
	20-39	0.009
	≥40	0.007
Pacific halibut	<30	0.014
	30-59	0.010
	≥60	0.004
Flathead sole	all sizes	0.007
Yellowfin sole	all sizes	0.004
Alaska plaice	all sizes	0.005
Rock sole	all sizes	0.007

from annual growth increments by length and length-weight relationships for each species. A gross conversion efficiency rate of food to somatic tissue for juvenile fish was assumed to be 25% and for adult fish was assumed to be 10% based on estimates presented by Brett and Groves (1979). Daily growth increments could thus be converted to the amount of food required to produce that growth. When the daily food requirements are divided by mean fish weight, then the result is daily ration expressed as a fraction of body weight.

The time period of analysis (D) for total consumption estimates by all predator species was months 5 to 9, or 153 days. The analysis was restricted to this time period because most stomach samples were collected during this period and survey estimates of groundfish biomass were obtained at this time. Unquantified migrations of fish into different strata occur and insufficient numbers of stomach samples were taken in each stratum outside of this time period. Thus, total consumption estimates made outside of this time period would not be very reliable. Since months 5 to 9 are probably the main feeding and growth period for groundfish in the eastern Bering Sea, these total consumption estimates can be considered conservative estimates of total annual predation removals by these groundfish populations.

Total consumption estimates of king crabs by Pacific cod were restricted to a 31-day period during months 5 to 9 when it is most likely that soft-shell (newly molted) king crabs were available. Total consumption estimates for walleye pollock cannibalism were also made for months 10 to 12 since there were more walleye pollock stomach content data available during this time period when compared to the other groundfish species. However, walleye pollock biomass estimates for each stratum were assumed to be the same as during the months 5 to 9 period. Unknown changes in walleye pollock biomass within each stratum in winter cause greater uncertainty in these estimates than those derived during the main feeding period.

Predator biomass estimates (B) (listed in the respective appendix for each species) for all species except walleye pollock and yellowfin sole were obtained from RACE Division bottom trawl survey data. These trawl surveys are conducted in the eastern Bering Sea during June to August of each year. Biomass estimates of. arrowtooth flounder and Greenland turbot include only the shelf portion of the populations. Thus, total predation estimates for these populations refer only to predation occurring on the shelf. Biomass estimates of walleye pollock, a semipelagic fish, were probably underestimated by the trawl survey, so the cohort analysis estimates of Wespestad, Bakkala, and Dawson (1990) were used and biomass was apportioned into each stratum by using the proportion of the trawl survey biomass found in each stratum. Biomass estimates of yellowfin sole from trawl surveys has fluctuated unreasonably in recent years, so cohort analysis estimates of biomass for age-7+ fish from Bakkala and Wilderbuer

(1990) were used along with trawl survey estimates of fish less than age 7. Cohort analysis estimates of yellowfin sole biomass were apportioned into each stratum using the proportion of the trawl survey biomass found in each stratum.

The proportion by weight of each prey item in the diet of each predator size group was calculated for each stratum in the following fashion. First, all stomach content data for a particular fish species size group that was collected in a stratum during months 5 to 9 in a given year were used. Estimates of the percentage by weight of a given prey item in the stomach contents were then calculated for each 20 nautical mile square in the stratum where stomachs were collected. The estimated percent by weight of the prey item in the whole stratum was then calculated as the average of the percentages from each 20 nautical mile square. Standard errors of the stratum percentages were derived from the variance between squares.

For strata where prey size information was available, total, consumption estimates in terms of biomass were converted to number of prey. The size frequency of a particular prey in the stomach contents of a given predator size group from a stratum in. a particular year during months 5 to 9 was used along with the length-weight relationship for the prey to convert biomass consumed within a particular prey size interval to number consumed. If prey size information for a given predator size group was not available for a given stratum, then the size frequency of that prey in all strata combined for the predator size group was used. Finally, when no prey size information was available, the number consumed could not be estimated.

Snow (Chionoecetes opilio) and Tanner (c. bairdi) crabs and walleye pollock were assigned to approximate age groups based on the following age-length conversions:

Age (years)	Carapace width (mm)		Standard length (cm) Walleye pollock	
	C. opilio	C. bairdi	mos. 5-9	mos. 10-12
0	<5	<9	<10	<14
1	5-24	9-34	10-19	14-22
2	25-39	35-49	20-27	23-29
3	40-59	50-69	28-33	30-34
4	60-74	70-84	34-37	35-38
5	75-94	85-104	38-40	39-41
6+	≥95	≥105	≥41	≥42

RESULTS AND DISCUSSION

Groundfish Predation on Commercially Important Prey

The total impact of groundfish predation on a particular prey species was estimated by summing the individual predator species removals described in the appendices. Comparison of total fish predation with each predator species' removals provides an indication of which predator population tends to be the most important source of mortality for a prey population. Also, comparison of total predation removals with prey population size demonstrates the relative importance of predation as a source of mortality. Finally, interannual fluctuations in predation on a particular age group of prey may give early indications of changes in abundance of prey age groups before they are vulnerable to assessment by trawl survey. The total consumption of each important prey group is summarized in terms of estimated biomass and numbers removed by groundfish predation in the eastern Bering Sea for segments of the years 1987 to 1989.

King Crabs

Tables 2-3 present the estimated total biomass and number of king crabs consumed by all groundfish predators for 31 days during months 5 to 9 in 1987 through 1989.

Red king crab--Pacific cod was the main predator of red king crabs (*Paralithodes camtschatica*) and king crabs that could not be identified to the species level. Most of the unidentified king crabs consumed by Pacific cod were assumed to be red king crabs based on the locations where unidentified king crabs were consumed. These crabs were assumed to be soft-shell females based on the timing and location of consumption by Pacific cod. Walleye pollock and yellowfin sole were minor predators on king crabs and consumed mostly small larval or newly settled juveniles. Pacific cod consumption of red king crab and unidentified king crab was 836, 554, and 1,928.2 metric tons (t) in 1987, 1988, and 1989, respectively. Groundfish predation on king crab in terms of biomass during these three years was lower than the estimated predation for the 1984-1986 period, which ranged from 1,136 t to 2,867 t (Livingston 1991).

Abundance of female red king crab (Stevens and MacIntosh 1990) during the 1987 to 1989 time period declined from 35.1 million crab to 21.2 million crab. Pacific cod consumption of unidentified and red king crab (which were assumed to be females) was 3.8%, 4.8% and 14.3% of the estimated population numbers of female red king crab for 1987, 1988, and 1989, respectively.

Blue king crab--Blue king crab megalops larvae (*Paralithodes platypus*) were consumed by walleye pollock in 1987. The blue

Table 2.--Estimated total biomass (metric tons) of king crabs consumed by groundfish by year for 31 days during months 5 to 9 in the eastern Bering Sea.

Prey	Predator	Biomass consumed 1987	1988	1989
Lithodidae				
	Pacific cod	165.6	554.1	17.8
	Walleye pollock	0	0	0.8
	Total	165.6	554.1	18.6
Paralithodes sp.				
	Pacific cod	179.7	0	1,854.1
	Walleye pollock	0	0	5.8
	Yellowfin sole	0	14.1	0
	Total	179.7	14.1	1,859.9
Paralithodes camtschatica (red king crab)				
	Pacific cod	490.7	0	36.0
Paralithodes platypus (blue king crab)				
	Pacific cod	0	0	20.3
	Walleye pollock	8.7	0	0
	Total	8.7	0	20.3

Table 3.--Estimated total number (millions) of king crabs consumed by groundfish by year for 31 days during months 5 to 9 in the eastern Bering Sea. Values in parentheses indicate cells with some missing prey size information. Prey size was assumed to be 97.5 mm carapace length for Pacific cod predator cells without prey size information.

Prey	Predator	Number consumed 1987	1988	1989
Lithodidae				
	Pacific cod	**0.26**	**0.88**	**<0.04**
	Walleye pollock	**0**	**0**	**(0)**
	Total	**0.26**	**0.88**	**<0.04**
***Paralithodes* sp.**				
	Pacific cod	**0.28**	**0**	**2.93**
	Walleye pollock	**0**	**0**	**(0)**
	Yellowfin sole	**0**	**6.83**	**0**
	Total	**0.28**	**6.83**	**2.93**
***Paralithodes camtschatica* (red king crab)**				
	Pacific cod	**0.78**	**0**	**0.07**
***Paralithodes platypus* (blue king crab)**				
	Pacific cod	**0**	**0**	**0.02**
	Walleye pollock	**(0)**	**0**	**0**
	Total	**(0)**	**0**	**0.02**

king crab consumed by Pacific cod in 1989 were soft-shell crabs (presumably females). Pacific cod predation on blue king crab in 1989 was less than 1% of the number of blue king crab females in the Pribilof District. Consumption of blue king crab by groundfish predators appears to be a sporadic occurrence and was found at only one or two stations sampled during the May through September period. In the previous 3-year period (1984-86), yellowfin sole was the only predator on blue king crab (Livingston 1991). Predation occurred only in 1984 and was on megalops larvae.

Snow and Tanner Crabs

Total biomass of snow and Tanner crabs consumed by groundfish predators is presented in Table 4. Table 5 presents data on the estimated number of snow crabs consumed in areas where prey size information was available, so they should be considered the minimum number consumed by groundfish predators. Figures 2-5 show the biomass and numbers removed by prey size including results from the 1984-86 period for comparison.

Snow crabs--The main predator of snow crabs, in terms of estimated biomass removed, was Pacific cod. Pacific cod consumed at least 90% of the total biomass removals of snow crabs in all three years.- The remaining predators were flathead sole, walleye pollock, Pacific halibut, rock sole, and yellowfin sole. Biomass of snow crabs consumed by Pacific cod decreased from 1987 (151,226.5 t) to 1989 (116,609 t), while numbers consumed by Pacific cod were relatively constant over the time period. Consumption of snow crab by the other groundfish predators did not occur every year; 1989 was the only year out of the three where more than two groundfish species were consuming snow crab. Total number of snow crab consumed by all groundfish predators doubled from 1987 to 1989, primarily due to the large numbers of small crab consumed by flathead sole in 1989.

Most of the sampled snow crab consumed in 1988 and 1989 were between 5 and 15 mm CW or approximately age 1. Stevens et al. (1991) note strong recruitment of postlarval crab in the last few years. The large numbers of age-l crab consumed in 1988 and 1989 may be a reflection of above-average numbers of small crab recruiting into the southeastern Bering Sea shelf population. Monitoring the amount of predation on small crabs by these predators may provide early indications of the presence of abundant year classes of crabs.

Reconstructing age-l snow crab population size (which was the age most preyed upon) according to the methods of Forney (1977) could be done for 1986-88 by using trawl estimates of numbers at age 3 and backcalculating age-l population size assuming predation removals were the main source of mortality between age 1 and age 3. Consumption of age-l snow crabs by all predators, expressed as a proportion of reconstructed age-l population size from 1986 to 1988, was 44%, 43%, and 60%, respectively. The large change in percent predation removals from 1987 to 1988 is an indication that predators may be exerting density-dependent influences on snow crab populations at age 1. This means that the number of crabs recruiting into the fishable stock may be dampened depending on groundfish predation amounts.

Tanner crabs--Estimated total biomass of Tanner crabs consumed by all predators decreased from 1987 (107,134 t) to 1988 (55,825 t) with a subsequent increase in 1989 (88,520 t). Like snow crabs, most of the biomass removed was due to Pacific cod predation. However, most of the numbers consumed were due to predation on small (1-10 mm CW) crab by flatfish such as flathead sole, rock sole, and yellowfin sole. Total number consumed was highest in 1987 (42,632 million) but was still much lower than the estimate of total number consumed in 1984, which was 152,850 million (Livingston 1991). This may be an indication that there has not been any increased recruitment of Tanner crab since 1984.

Reconstruction of age-0 population size for 1985-87 and age-1 population size for 1986 to 1988, using trawl estimates of year-class abundance at age 3 and backcalculating abundance assuming predation removals were the main source of mortality, was done to determine whether predation was a variable proportion of year-class abundance. Changing proportions of predation removals would be an indication that predators were exerting density-dependent control of prey population size. Predation on Tanner crabs as a percent of the reconstructed age-0 population size from 1985 to 1987 was 42%, 23%, and 67%, respectively. Percent predation removals of age-l crabs from 1986 to 1988 was 90%, 95%, and 95%, respectively. Removals at age 0 are variable, while those at age 1 appear to be high but stable rates of removal across years. This may indicate predators are exerting a density-dependent influence on the Tanner crab population size at age 0 but not at age 1.

Roundfish

Roundfish, for the purposes of this report, is defined as any groundfish species that is not a flatfish. Total estimated biomass and minimum numbers of Pacific cod, walleye pollock, -Pacific herring (*Clupea pallasi*), and Atka mackerel (*Pleurogrammus monopterygius*) consumed by all groundfish predators are summarized in Tables 6-7 and Figures 6-11.

Pacific cod--Total estimated biomass of Pacific cod consumed by groundfish predators (Table 6) decreased from 1987 (8,880 t) to 1988 (1,330 t) and increased in 1989 back to a level similar to 1987 (7,762 t). Predators on- Pacific cod include Pacific cod, walleye pollock, arrowtooth flounder, and Pacific halibut. There was no dominant groundfish predator on Pacific cod across years. Although Pacific cod cannibalism did occur each year, it was not always the major source o-f predation mortality. The number consumed was highest in 1987 (7.7 billion) and was primarily due to Pacific cod cannibalism on age-0 fish. Most Pacific cod

Table 4.--Estimated total biomass (metric tons) of Tanner crabs (*Chionoecetes bairdi*) and snow crabs (*C. opilio*) consumed by groundfish by year during months 5 to 9 in the eastern Bering Sea. (- = no samples taken.)

Prey	Predator	Biomass consumed 1987	1988	1989
C. opilio				
	Pacific cod	151,226.5	61,210.9	116,608.8
	Walleye pollock	0	0	3,463.4
	Flathead sole	0	0	4,811.5
	Rock sole	15.5	0	1,871.3
	Yellowfin sole	0	962.2	0
	Greenland turbot	0	0	0.1
	Pacific halibut	-	-	2,588.0
	Total	151,242.0	62,173.1	129,343.1
C. bairdi				
	Pacific cod	92,005.2	43,944.4	66,338.2
	Walleye pollock	0	0	4,137.4
	Flathead sole	12,277.9	4,275.9	9,612.4
	Rock sole	12.7	7,604.3	0
	Yellowfin sole	2,838.5	0	6,288.8
	Pacific halibut	-	-	2,143.1
	Total	107,134.3	55,824.6	88,519.9

Table 5.--Estimated total number (millions) of Tanner crabs (*Chionoecetes bairdi*) and snow crabs (c. *opilio*) consumed by groundfish by year during months 5 to 9 in the eastern Bering Sea. Values in parentheses indicate cells where some prey size information was not available. (- = no samples taken.)

Prey	Predator	Number consumed 1987	1988	1989
C. opilio				
	Pacific cod	10,665.7	9,980.8	12,767.7
	Walleye pollock	0	0	(0)
	Flathead sole	0	0	5,760.4
	Rock sole	(0)	0	2,119.7
	Yellowfin sole	0	1,889.3	0
	Greenland turbot	0	0	(0)
	Pacific halibut	-	-	157.6
	Total	(10,665.7)	11,870.1	(20,805.4)
C. bairdi				
	Pacific cod	10,665.0	5,789.0	4,125.1
	Walleye pollock	0	0	(0)
	Flathead sole	26,378.0	3,539.2	5,901.4
	Rock sole	8.9	5,330.4	0
	Yellowfin sole	5,579.8	0	17,012.6
	Pacific halibut	-	-	204.6
	Total	42,631.7	14,658.6	27,243.7

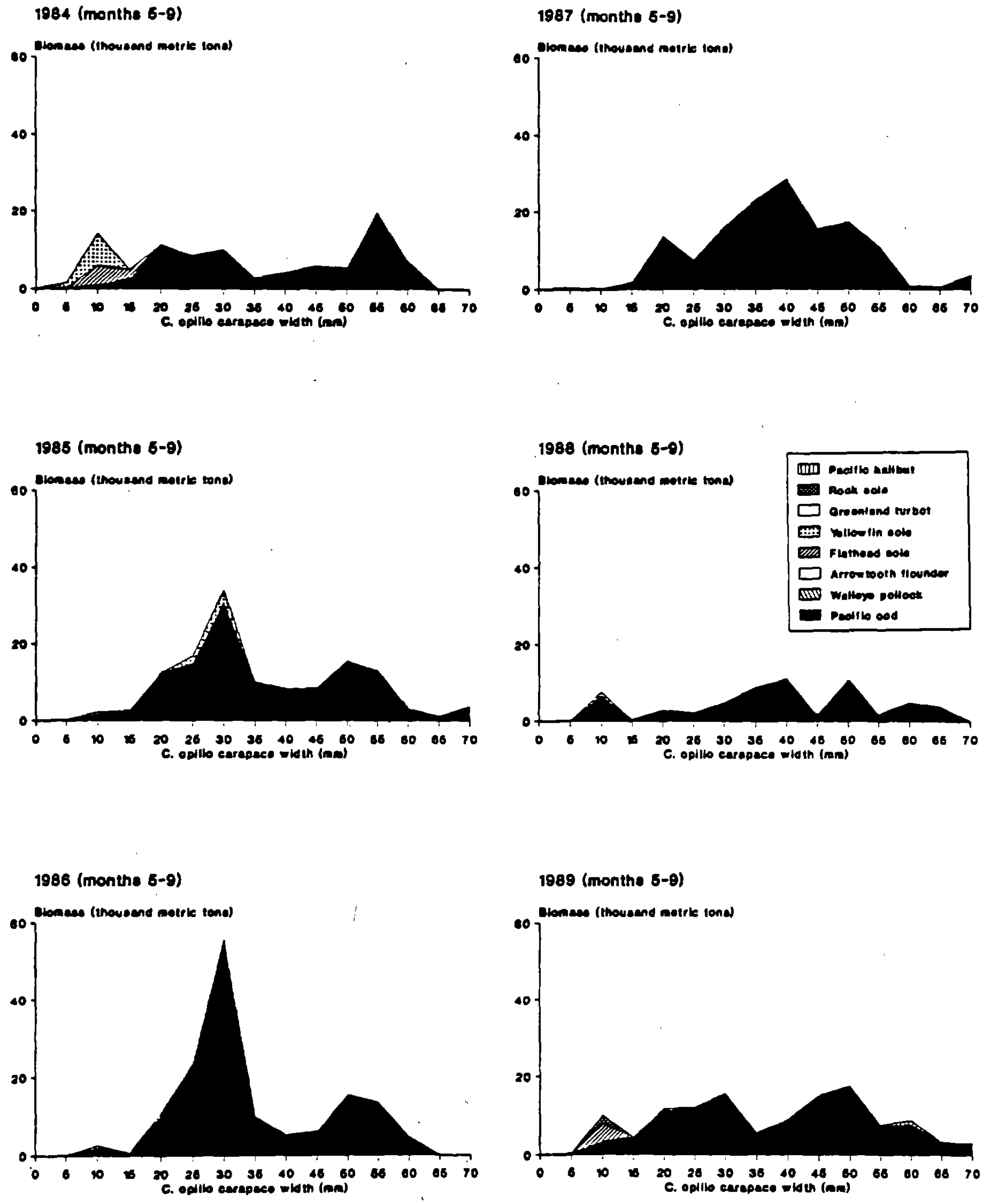

Figure 2.--Estimated biomass of snow crabs (<u>Chionoecetes opilio</u>) consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

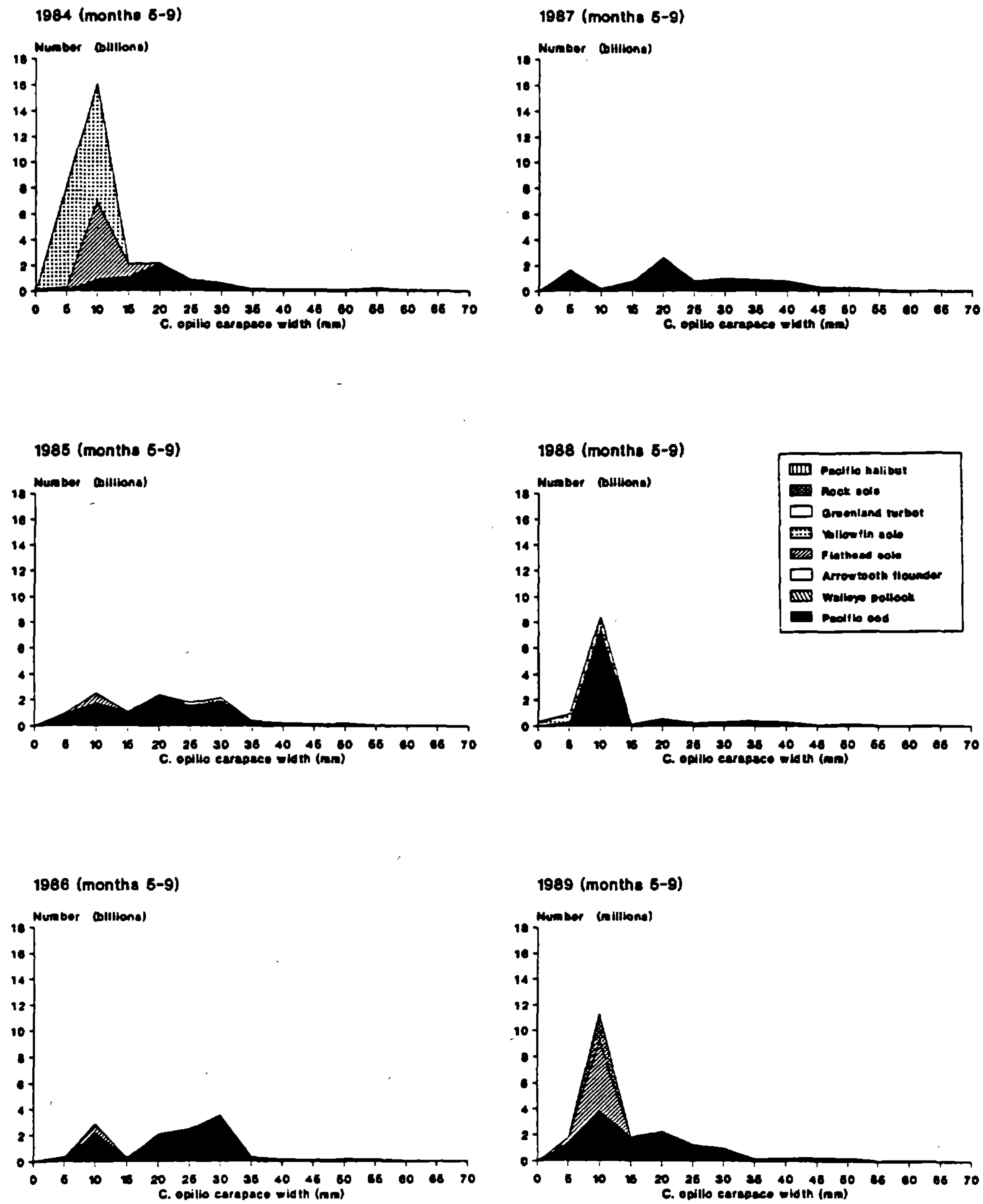

Figure 3. --Estimated number of snow crabs (Chionoecetes opilio) consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

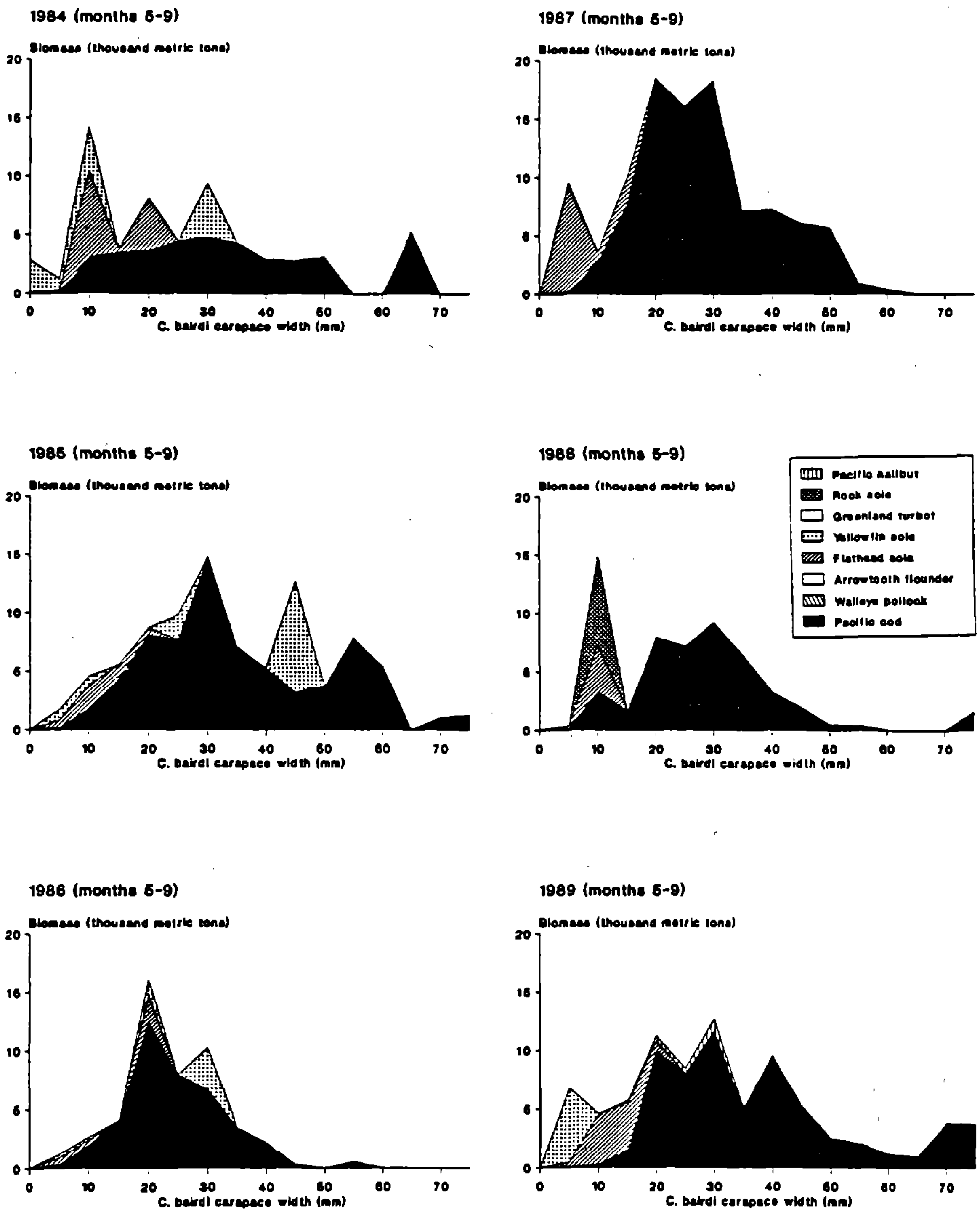

Figure 4.--Estimated biomass of Tanner crabs (Chionoecetes bairdi) consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

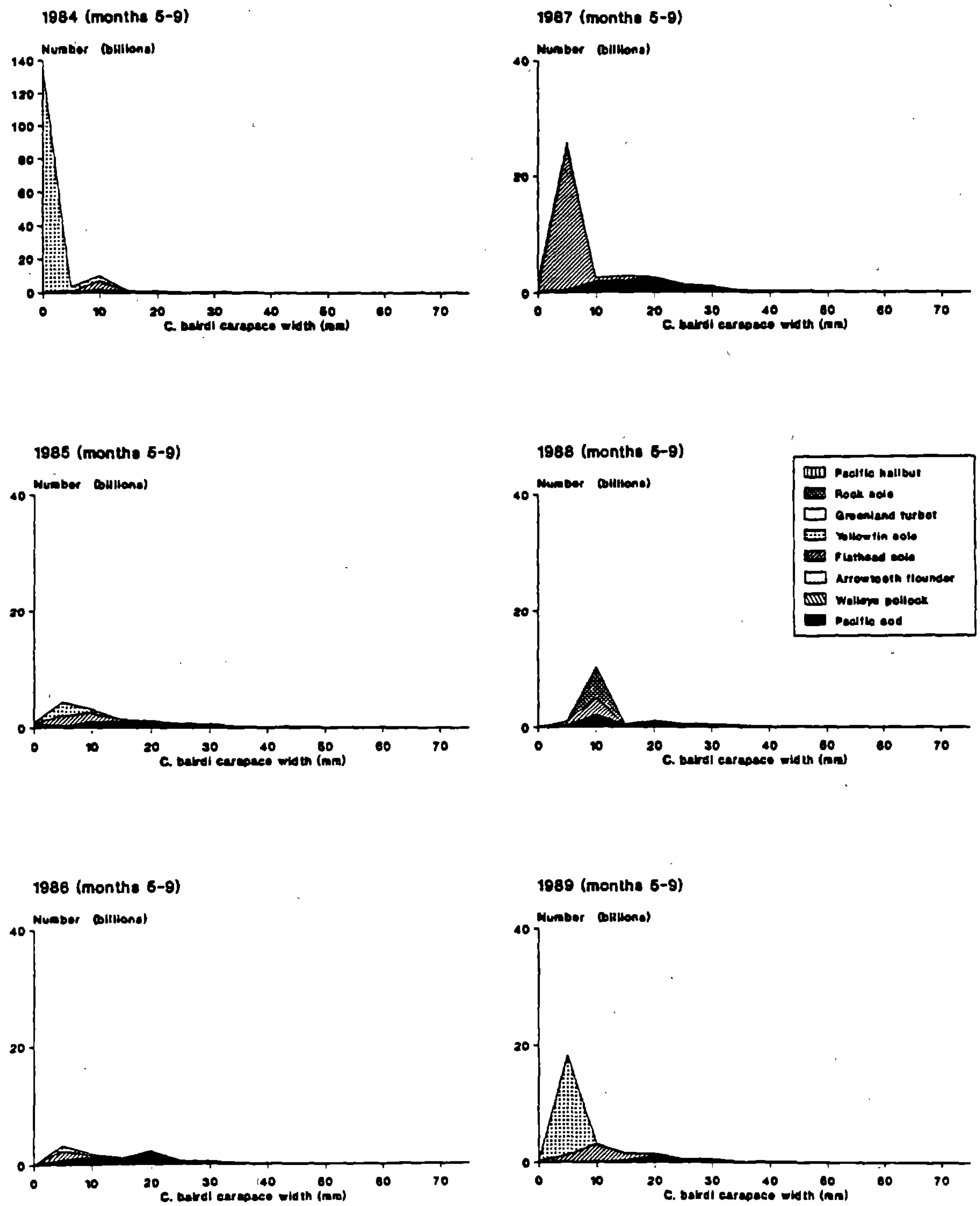

Figure 5. --Estimated number of Tanner crabs (Chionoecetes bairdi) consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size. (Note different y-axis scale for 1984.)

consumed by groundfish from 1984 through 1989 were age-0 fish. There does not seem to be any relationship between the number of age-0 Pacific cod consumed in a year and the strength of that Pacific cod year class. For example, Thompson (1991) found the 1987 year class to be one of the smallest on record while our data show that 1987 was the year with the largest number of age-0 Pacific cod consumed. It appears that Pacific cod is not a major dietary component of any groundfish species. Therefore, consumption of Pacific cod tends to be a sporadic occurrence that may not necessarily be related to its abundance.

Walleye pollock--Walleye pollock was consumed by most-of the major groundfish predators considered here. Walleye pollock cannibalism dominated walleye pollock removals in terms of biomass and numbers in all years. Pacific cod was the next most important predator in terms of biomass removals, while yellowfin sole and flathead sole were the next most important predators in terms of numbers removed.

Sizes of walleye pollock consumed by predators indicate most were age-0 walleye pollock (less than 14 cm SL) in all years (Figs. 8-9). Pacific cod tended to consume a wide range of walleye pollock sizes, mainly from 5 to 45 cm SL. Most age-l pollock (approximately 14-22 cm SL) were consumed by Pacific cod, walleye pollock, and arrowtooth flounder. More age-0 pollock were consumed in 1989 than in 1987 and 1988. Wespestad et al. (1990) show that the 1989 pollock year class at age 1 was larger than the 1987 year class by about 40% and larger than the 1988 year class at age 1 by about 50%. However, the consumption of age-0 pollock in numbers in 1989 is about three times more than the consumption of age-0 walleye pollock in 1988. This might be an indication that the 1989 year class was preyed on more heavily at age 0 in relation to its abundance than the two previous year classes. Age-O walleye pollock consumed in 1989 were smaller than those consumed from 1985 to 1988. There may have been some factor making smaller walleye pollock more available to predators in 1989 that caused the increased predation.

Livingston (1992) found for the period from 1985 to 1988 that predation on age-0 walleye pollock was about proportional to the amount remaining at age 1, indicating no density-dependent predation pressure on age-0 walleye pollock in those years. However, there was evidence of density-dependent predation on the 1985 walleye pollock year class beyond age 0. The apparent effect of the density-dependent predation on the 1985 year class was to decrease its relative abundance upon recruitment to the fishery at age 3. Although the 1985 year class was more abundant at age 1 than the subsequent three year classes following it, its abundance at age 3 was similar to the year classes following it. There are many factors that could influence predation on a particular year class including the relative availability of other prey to a predator and the availability and overlap of a particular prey (and prey size) with the predator. Prediction of density-dependent predation effects will be difficult until we can understand more about each predator's prey size preferences and about the abundance of important prey such as juvenile walleye pollock.

Pacific herring--Pacific cod was the main predator on Pacific herring, consuming the species in all three years. Walleye pollock, arrow-tooth flounder, and Pacific halibut consumed Pacific herring only during 1989. Biomass of Pacific herring consumed by predators decreased from 1987 to 1989 and numbers consumed were low for all three years. The level of Pacific herring consumption by groundfish predators was much lower than in 1985 and 1986.

Pacific herring consumed in 1988 and 1989 were immature (< 20 cm) while those consumed in 1987 were larger than 25 cm. Groundfish predation in 1987 and 1988, expressed as a percentage of the available Pacific herring biomass, was 5% in 1987 and 3% in 1988. (There was no cohort analysis estimate of biomass for 1989.) Pacific herring consumption by groundfish predators tended to be sporadic in time and space and may depend on encounter rates of Pacific herring schools rather than overall biomass. Furthermore, most of the Pacific herring available during the summer feeding period on the shelf are immature Pacific herring because adults have moved inshore to spawn. Pacific herring may constitute a larger fraction of the diet of groundfish predators in other time periods when adult Pacific herring have migrated to outer shelf waters for the winter feeding period. However, we have insufficient samples during autumn and winter to quantify Pacific herring consumption during those periods.

Atka mackerel--Our samples indicated that Atka mackerel was consumed only by Pacific cod and only in 1987. The last AFSC groundfish predation report (Livingston 1991) noted no consumption of Atka mackerel from 1984 to 1986. The current center of distribution of Atka mackerel is in the Aleutian Islands. Although their distribution in the past has extended north to the Pribilof Islands, catches of Atka mackerel in the Bering Sea are low. Atka mackerel were consumed at only one station in the southwestern portion of the shelf, close to the Aleutian Islands. The estimated consumption by Pacific cod in 1987 was less than 1% of the standing stock estimated in the 1991 Aleutian Islands survey (Lowe 1991). The sizes of Atka mackerel consumed by Pacific cod ranged from 26 to 27 cm SL.

Flatfish

Arrowtooth flounder--Consumption of arrowtooth flounder by all predators was variable across years (Tables 8-9). Estimated total biomass consumed in 1987 (13,761 t) was about thirty times greater than consumption in 1989 (464 t). No arrowtooth flounder consumption was observed in 1988. In both years where arrowtooth flounder were consumed, Pacific cod was the main predator in terms of biomass removed. Arrowtooth flounder cannibalism and

Table 6.--Estimated total biomass (metric tons) of roundfish consumed by groundfish by year during months 5 to 9, including walleye pollock cannibalism during months 10 to 12, in the eastern Bering Sea. (- = no samples taken.)

Prey	Predator	Biomass consumed 1987	1988	1989
Pacific cod				
	Pacific cod	2,889.9	1,329.7	766.8
	Walleye pollock	5,990.9	0	851.0
	Arrowtooth flounder	0	0	4,597.8
	Pacific halibut	-	-	1,546.9
	Total	8,880.8	1,329.7	7,762.5
Walleye pollock				
	Pacific cod	240,310.3	316,497.9	334,855.6
	Walleye pollock	1,119,846.9	436,708.4	1,326,393.0
	Arrowtooth flounder	102,008.9	127,902.2	109,720.4
	Flathead sole	18,216.9	14,854.7	14,139.4
	Rock sole	44.9	0	0
	Yellowfin sole	1,438.9	13,702.1	10,730.3
	Greenland turbot	7,264.5	10,835.0	6,013.0
	Pacific halibut	-	-	15,573.2
	Total	1,489,131.3	920,500.3	1,817,424.9
Pacific herring				
	Pacific cod	3,216.6	5,440.0	8.2
	Walleye pollock	2,766.7	0	0
	Arrowtooth flounder	6,302.9	0	0
	Pacific halibut	-	-	70.7
	Total	12,286.2	5,440.0	78.9
Atka mackerel				
	Pacific cod	1,649.5	0	0

Table 7.--Estimated total number (millions) of roundfish consumed by groundfish by year during months 5 to 9, including walleye pollock cannibalism during months 10 to 12, in the eastern Bering Sea. Values in parentheses indicate cells where some prey size information was not available. (- = no samples taken.)

Prey	Predator	Number consumed 1987	1988	1989
Pacific cod				
	Pacific cod	**7,707.6**	**1.5**	**1.7**
	Walleye pollock	**486.1**	**0**	**72.8**
	Arrowtooth flounder	**0**	**0**	**(0)**
	Pacific halibut	**-**	**-**	**0.9**
	Total	**8,193.7**	**1.5**	**75.4**
Walleye pollock				
	Pacific cod	**8,029.0**	**6,082.8**	**921.6**
	Walleye pollock	**233,029.3**	**182,215.4**	**831,317.6**
	Arrowtooth flounder	**1,600.4**	**5,958.8**	**5,196.1**
	Flathead sole	**13,722.8**	**1,862.4**	**15,705.0**
	Rock sole	**124.4**	**0**	**0**
	Yellowfin sole	**3,658.7**	**32,243.9**	**10,478.4**
	Greenland turbot	**84.5**	**294.4**	**168.3**
	Pacific halibut	**-**	**-**	**378.8**
	Total	**260,249.1**	**228,657.7**	**864,165.8**
Pacific herring				
	Pacific cod	**14.1**	**140.4**	**1.0**
	Walleye pollock	**(0)**	**0**	**0**
	Arrowtooth flounder	**9.2**	**0**	**0**
	Pacific halibut	**-**	**-**	**(0)**
	Total	**(23.3)**	**140.4**	**(1.0)**
Atka mackerel				
	Pacific cod	**7.7**	**0**	**0**

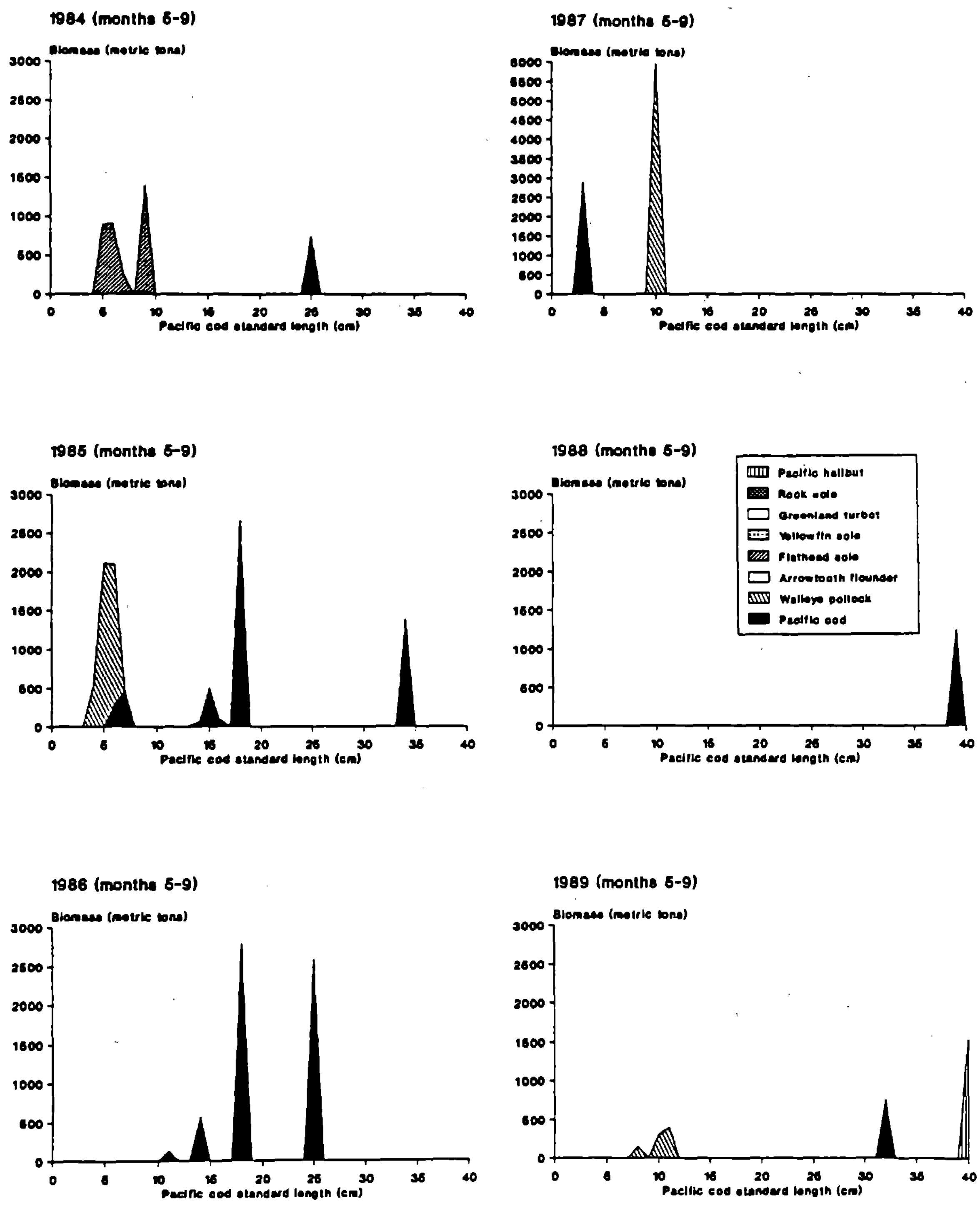

Figure 6.--Estimated biomass of Pacific cod consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size. (Note different y-axis scale for 1987.)

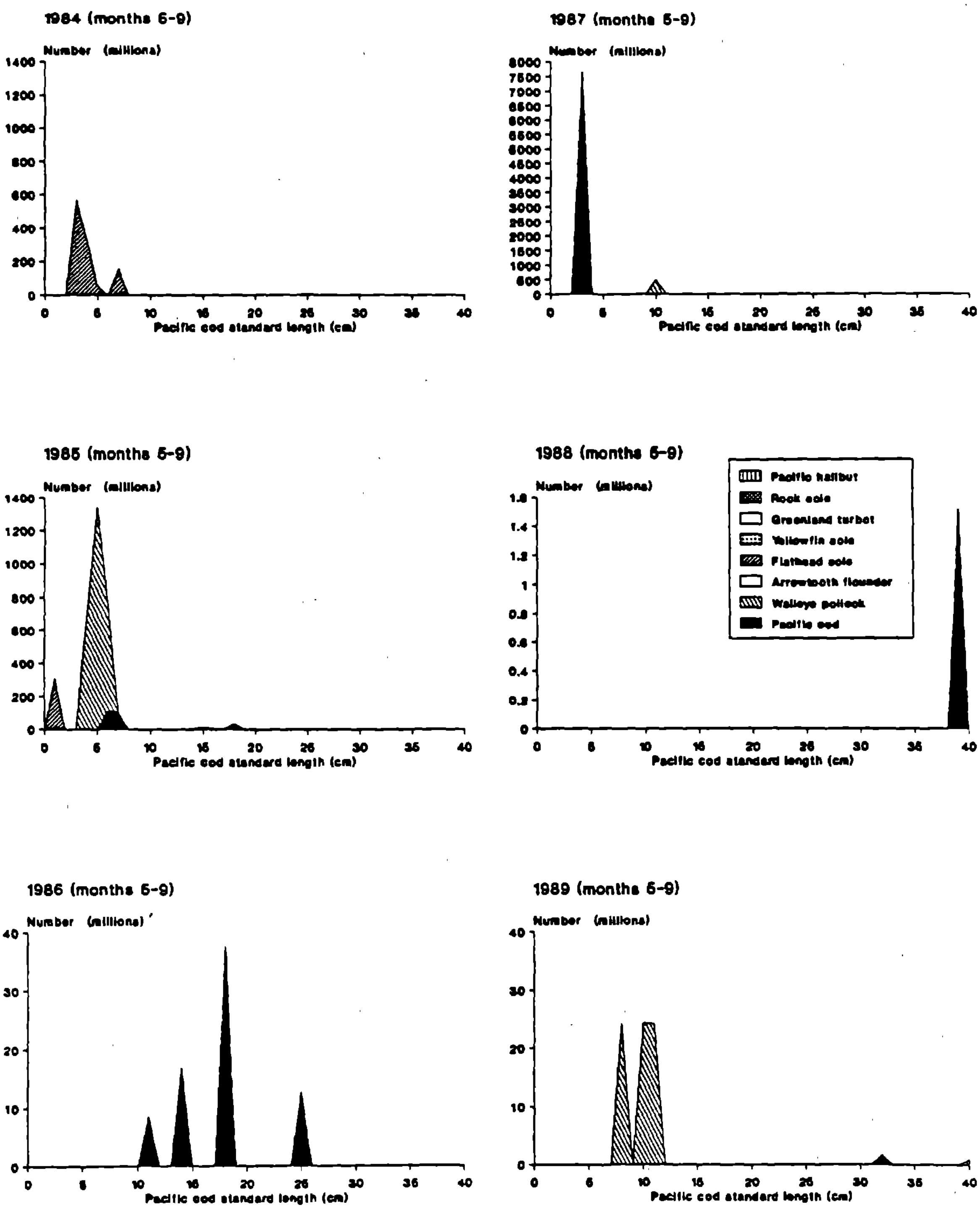

Figure 7. --Estimated number of Pacific cod consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size. (Note different y-axis scales throughout.)

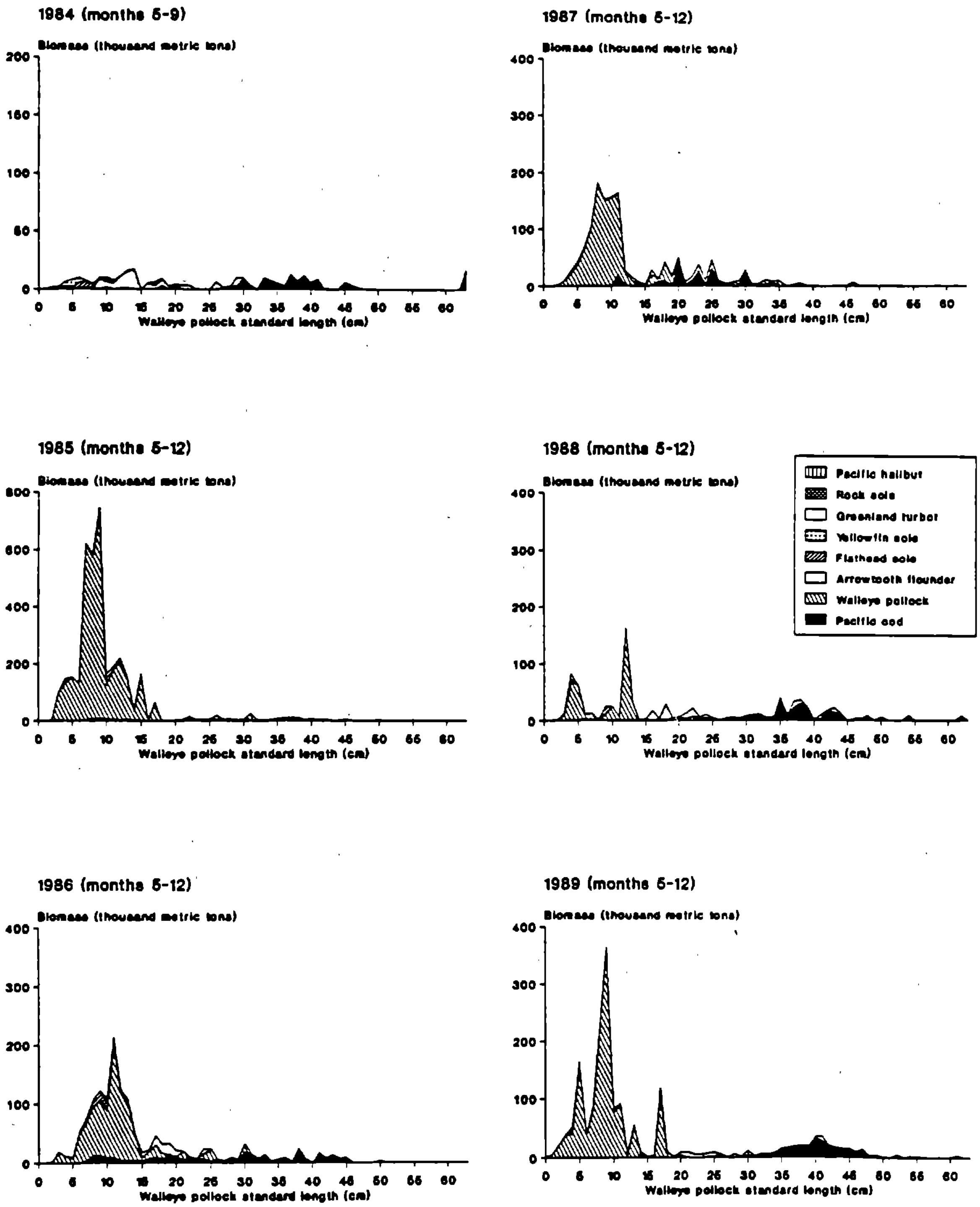

Figure 8.--Estimated biomass of walleye pollock consumed by groundfish other than walleye pollock during months 5 to 9 in 1984 and by groundfish including walleye pollock during months 5 to 9 plus cannibalism by walleye pollock during months 10 to 12 from 1985 to 1989 in the eastern Bering Sea by prey size. (Note different y-axis scales for 1984 and 1985.)

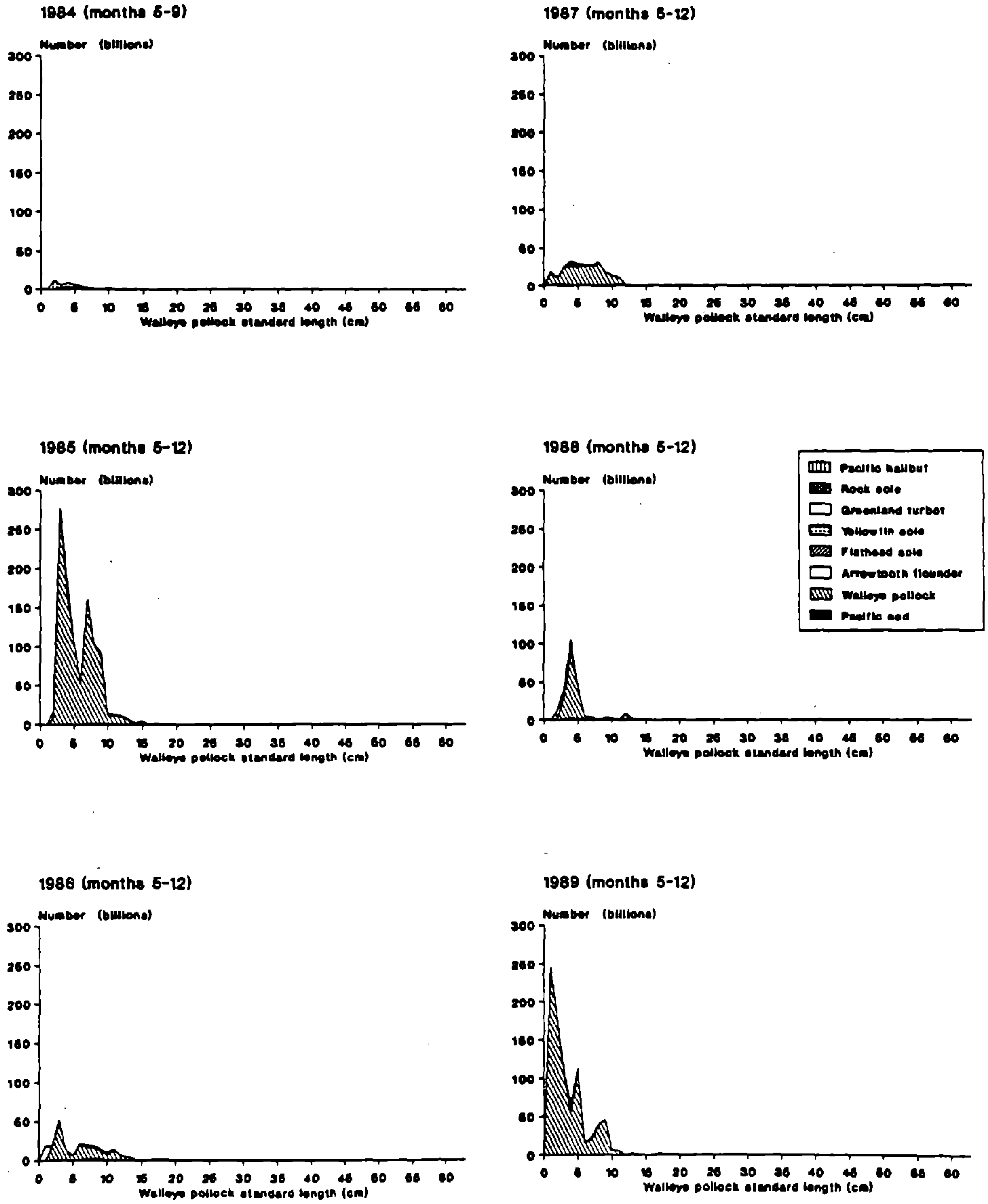

Figure 9. --Estimated number of walleye pollock consumed by groundfish other than walleye pollock during months 5 to 9 in 1984 and by groundfish including walleye pollock during months 5 to 9 plus cannibalism by walleye pollock during months 10 to 12 from 1985 to 1989 in the eastern Bering Sea by prey size.

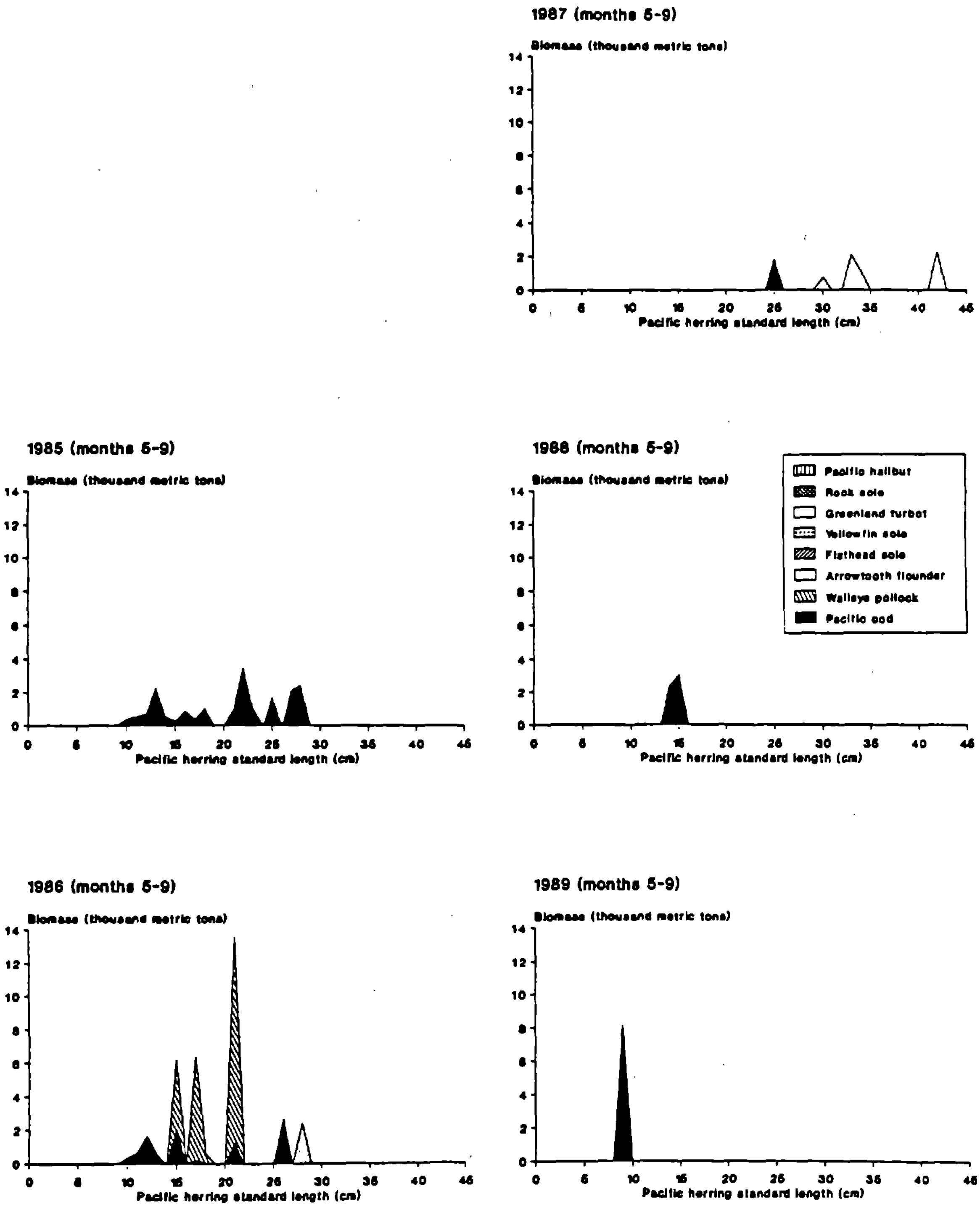

Figure 10.--Estimated biomass of Pacific herring consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

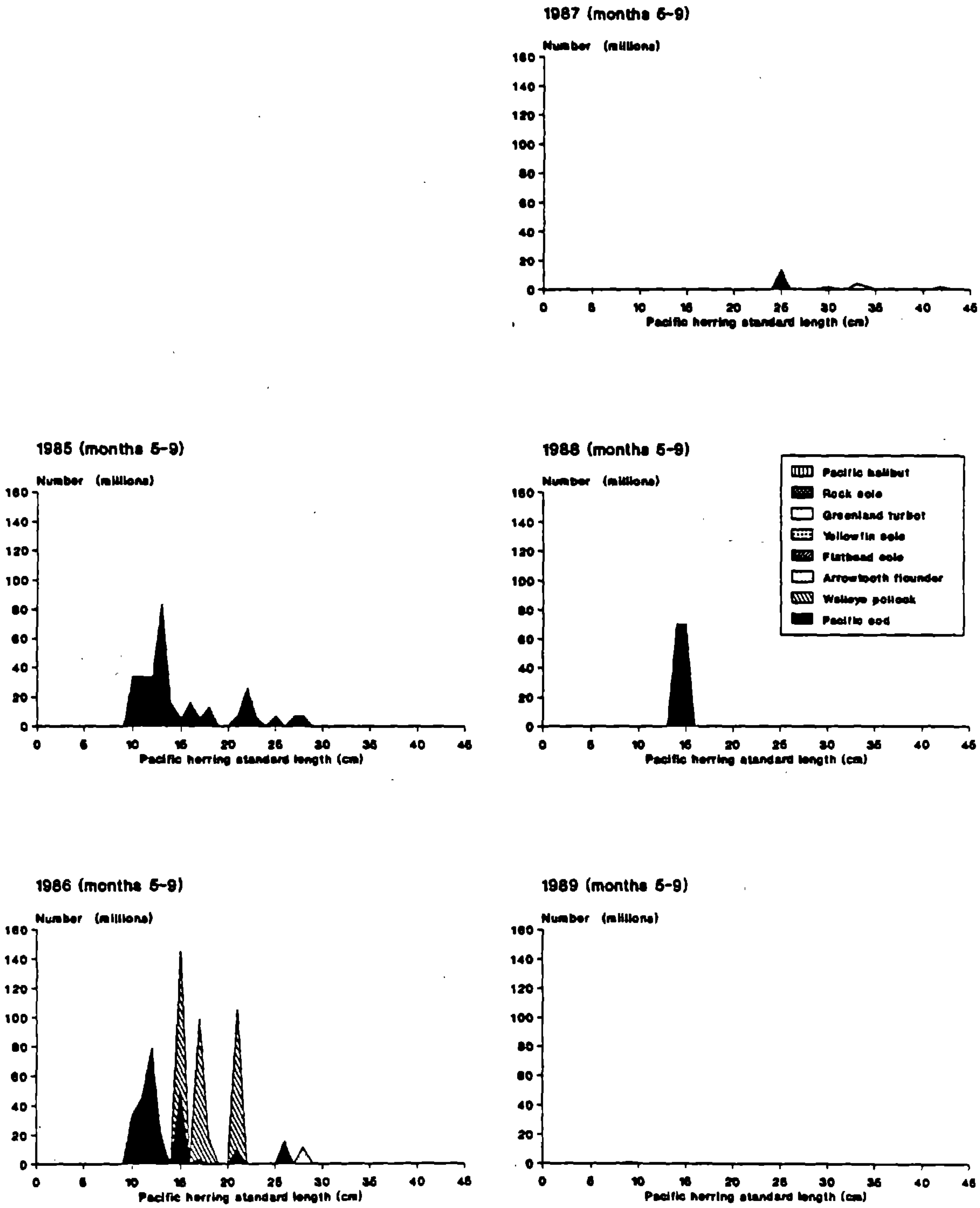

Figure 11.--Estimated number of Pacific herring consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

predation by walleye pollock also occurred in both years. Walleye pollock consumed the largest number of arrow-tooth flounder. Most of the arrowtooth flounder consumed by walleye pollock were 2 to 5 cm SL.

Total biomass consumed in each year can be compared with the estimated standing stock of arrowtooth flounder to determine the relative importance of predation on the arrow-tooth flounder population (Table 10). Total consumption in each year, expressed as a percentage of trawl-estimated biomass of arrowtooth flounder, is less than 5%. This is a small percentage of the arrowtooth flounder population, indicating predation is probably not a major source of mortality. Examination of possible predation impact on arrowtooth flounder too small to be assessed by the trawl survey is not possible given the current state of knowledge about juvenile arrowtooth flounder abundance. However, most of the numbers of arrowtooth flounder consumed in 1987 were age-0 fish, and Sample and Wilderbuer (1991) note that 1987 was a year of strong recruitment. The increased consumption of arrowtooth flounder in that year may have been the result of increased availability of small fish.

Flathead sole--Estimated total biomass of flathead sole consumed by groundfish predators was relatively low in 1987 (1,965 t) and 1988 (1,453 t) but was much higher in 1989 (25,718 t). Numbers consumed followed a similar trend. Most of the biomass consumed in 1989 was by Pacific cod, but walleye pollock consumed the most in terms of numbers in that year (Table 9). This difference between biomass and number was due to the large number of small (5-7 cm SL or possibly age 0) flathead sole consumed by walleye pollock in that year (Figs. 12-13). Pacific cod was the most important predator of flathead sole in all years if biomass consumed is considered. Other predators on flathead sole included arrowtooth flounder, flathead sole, and Pacific halibut.

Most of the flathead sole consumed were less than 20 cm SL or less than age 3. Walters and Wilderbuer (1990) report that flathead sole do-not recruit to trawl fisheries until age 3, and although some age-2 fish are caught in research trawls, they are probably not fully recruited. This precludes a relevant comparison of predator removals of juveniles with the juvenile flathead sole population size. However, total biomass removals by predators expressed as a percentage of trawl survey estimates of biomass for 1987-89 (Table 10) are less than 5% for each year. This is a small proportion, at least of the adult portion of the population, indicating predation may not be a significant source of mortality for flathead sole.

In all three years, predators consumed some flathead sole that were possibly age 0, but total numbers of age-0 flathead sole consumed in 1989 were much higher than the other two years (Fig. 13). This might be an indication of an abundant year class produced in 1989.

<u>Rock sole</u>--Total estimated biomass of rock sole consumed by groundfish predators ranged from 5,155 t in 1988 to 18,552 t in 1987. The number of rock sole consumed followed an opposite trend. Pacific cod was the most important predator in terms of biomass removals. Other predators included walleye pollock, arrowtooth flounder, flathead sole, and yellowfin sole. Size composition of rock sole consumed in all three years tended to consist of fish mainly between 5 and 15 cm SL (Figs. 14-15), sizes that are probably not fully vulnerable to trawl surveys.

Flathead sole consumed large numbers of age-0 rock sole -in 1988, which might indicate an abundant 1988 year class of rock sole. However, relative numbers at age 2 in the 1990 survey (Walters and Wilderbuer 1991a) suggest this year class was not necessarily a strong one. Total biomass consumed, expressed as a percentage of survey estimates of biomass in the three years (Table 10) was less than 2% in each year.

<u>yellowfin sole</u>--Pacific cod, walleye pollock and Pacific halibut were predators of yellowfin sole during the 1987 to 1989 period. Pacific cod predation in terms of biomass dominated all three years. Consumption by all groundfish in terms of biomass decreased from 17,394 t in 1987 to 7,190 t in 1989. Consumption was much lower in this period than in the 1984 to 1986 period where values ranged from 28,359 t to 56,291 t (Livingston 1991). These changes in consumption do not seem to be related to changes in biomass of yellowfin sole on the shelf because total biomass of yellowfin sole has been relatively stable from 1984 to 1989 according to stock synthesis model results (Bakkala and Wilderbuer 1991).

Unlike the other years in the time series, consumption in 1987 was dominated by age-0 yellowfin sole in terms of numbers eaten by walleye pollock (Figs. 16-17). Pacific cod also consumed mainly small yellowfin sole in 1989. In other years, most predation was on yellowfin sole ranging in size from 10 to 25 cm SL (ages 3-10). There is no information yet available to support the conclusion that 1987 or 1989 produced a large year class of yellowfin sole. When estimates of total yellowfin sole consumption in terms of biomass are compared to the biomass estimated from trawl surveys (Table 10), it seems that groundfish predation constitutes only a small proportion (< 1%) of the standing stock biomass.

<u>Greenland turbot</u>--Pacific cod and walleye pollock were the only groundfish that consumed Greenland turbot (Tables 8-9). Amounts consumed were negligible in 1987 and 1988. Walleye pollock was the main predator on Greenland turbot in 1989, consuming 17,628 t. Sizes consumed by walleye pollock ranged from 2 to 4 cm SL (probably age 0). There is currently no evidence to support an above-average Greenland turbot year class in 1989. It seems likely that consumption of Greenland turbot by groundfish predators is sporadic and limited to small areas of the shelf.

Pacific halibut--Pacific halibut was consumed by walleye pollock during 1988 (Tables 8-9). Sizes consumed ranged from 2 to 4 cm SL (probably age 0). The size of Pacific halibut consumed suggests they were post-larvae that had not yet settled to the bottom. Deriso (1987) suggests that Pacific halibut may be transported into the Bering Sea from the Gulf of Alaska. It is possible that groundfish consumption of Pacific halibut is a transitory phenomenon, occurring during restricted time periods when postlarvae are swept into shallow waters and start settling to the bottom. The total consumption estimates assume that predation is occurring throughout the month 5 to 9 period, whereas the vulnerability of young Pacific halibut to walleye pollock feeding in the water column may be of shorter duration, implying that consumption estimates are probably high.

Alaska plaice--Alaska plaice was consumed by walleye pollock during 1989. The size of Alaska plaice consumed was 4 cm SL (probably age 0). The amount consumed (13 t) was small relative to the standing stock of Alaska‘ plaice (599,400 t) (Walters and Wilderbuer 1991b), suggesting groundfish predation on Alaska plaice may not be a significant source of mortality.

Table 8.--Estimated total biomass (metric tons) of flatfish consumed by groundfish by year during months 5 to 9 in the eastern Bering Sea. (- = no samples taken.)

Prey	Predator	Biomass consumed 1987	1988	1989
Arrowtooth flounder				
	Pacific cod	9,882.7	0	274.7
	Walleye pollock	1,271.0	0	44.5
	Arrowtooth flounder	2,607.7	0	144.6
	Total	13,761.4	0	463.8
Flathead sole				
	Pacific cod	1,965.2	331.6	11,800.1
	Walleye pollock	0	19.0	9,561.9
	Arrowtooth flounder	0	0	4,279.3
	Flathead sole	0	1,102.9	0
	Pacific halibut	-	-	77.1
	Total	1,965.2	1,453.5	25,718.4
Rock sole				
	Pacific cod	17,320.2	2,242.8	8,295.6
	Walleye pollock	220.3	332.4	1,917.2
	Arrowtooth flounder	0	0	1,659.1
	Flathead sole	1,011.8	2,181.3	0
	Yellowfin sole	0	399.3	3,410.6
	Total	18,552.3	5,155.8	15,282.5
Yellowfin sole				
	Pacific cod	13,864.7	9,240.2	6,838.1
	Walleye pollock	3,528.9	430.3	0
	Pacific halibut	-	-	352.2
	Total	17,393.6	9,670.5	7,190.3
Greenland turbot				
	Pacific cod	0	0	7.0
	Walleye pollock	0	16.2	17,628.3
	Total	0	16.2	17,635.3
Pacific halibut				
	Walleye pollock	0	185.2	0
Alaska plaice				
	Walleye pollock	0	0	13.0

Table 9.--Estimated total number (millions) of flatfish consumed by groundfish by year during months 5 to 9 in the eastern Bering Sea. Values in parentheses indicate cells where some prey size information was not available. (- = no samples taken.)

Prey	Predator	Number consumed 1987	1988	1989
Arrowtooth flounder				
	Pacific cod	1,441.8	0	5.5
	Walleye pollock	1,861.0	0	95.4
	Arrowtooth flounder	488.3	0	(0)
	Total	3,791.1	0	(100.9)
Flathead sole				
	Pacific cod	210.2	36.3	578.3
	Walleye pollock	0	52.0	3,632.0
	Arrowtooth flounder	0	0	(73.8)
	Flathead sole	0	672.9	0
	Pacific halibut	-	-	7.8
	Total	210.2	761.2	4,291.9
Rock sole				
	Pacific cod	1,103.3	242.7	360.2
	Walleye pollock	11.4	585.0	109.9
	Arrowtooth flounder	0	0	272.2
	Flathead sole	416.3	(4,278.6)	0
	Yellowfin sole	0	702.7	952.2
	Total	1,531.0	5,809.0	1,694.5
Yellowfin sole				
	Pacific cod	416.2	87.4	16,901.6
	Walleye pollock	63,350.6	(0)	0
	Pacific halibut	-	-	6.9
	Total	63,766.8	87.4	16,908.5
Greenland turbot				
	Pacific cod	0	0	(0)
	Walleye pollock	0	16.6	30,328.3
	Total	0	16.6	(30,328.3)
Pacific halibut				
	Walleye pollock	0	665.3	0
Alaska plaice				
	Walleye pollock	0	0	9.2

Table 10.--Total biomass of flatfish consumed by groundfish, trawl survey estimates of biomass, and percent consumed by year in the eastern Bering Sea. (Biomass in metric tons.)

Species	Year	Biomass consumed	Trawl biomass*	Percent consumed
Arrowtooth flounder				
	1987	13,761	290,600	4.7
	1988	0	308,900	0
	1989	464	410,693	0.1
Flathead sole				
	1987	1,965	406,000	0.5
	1988	1,453	557,500	0.3
	1989	25,718	523,229	4.9
Rock sole				
	1987	18,552	1,249,800	1.5
	1988	5,156	1,903,500	0.3
	1989	15,282	1,318,312	1.2
Yellowfin sole				
	1987	17,394	2,465,800	0.7
	1988	9,670	2,897,700	0.3
	1989	7,190	2,832,180	0.2

*Sources: Low and Narita(1990) and Wilson and Armistead(l991).

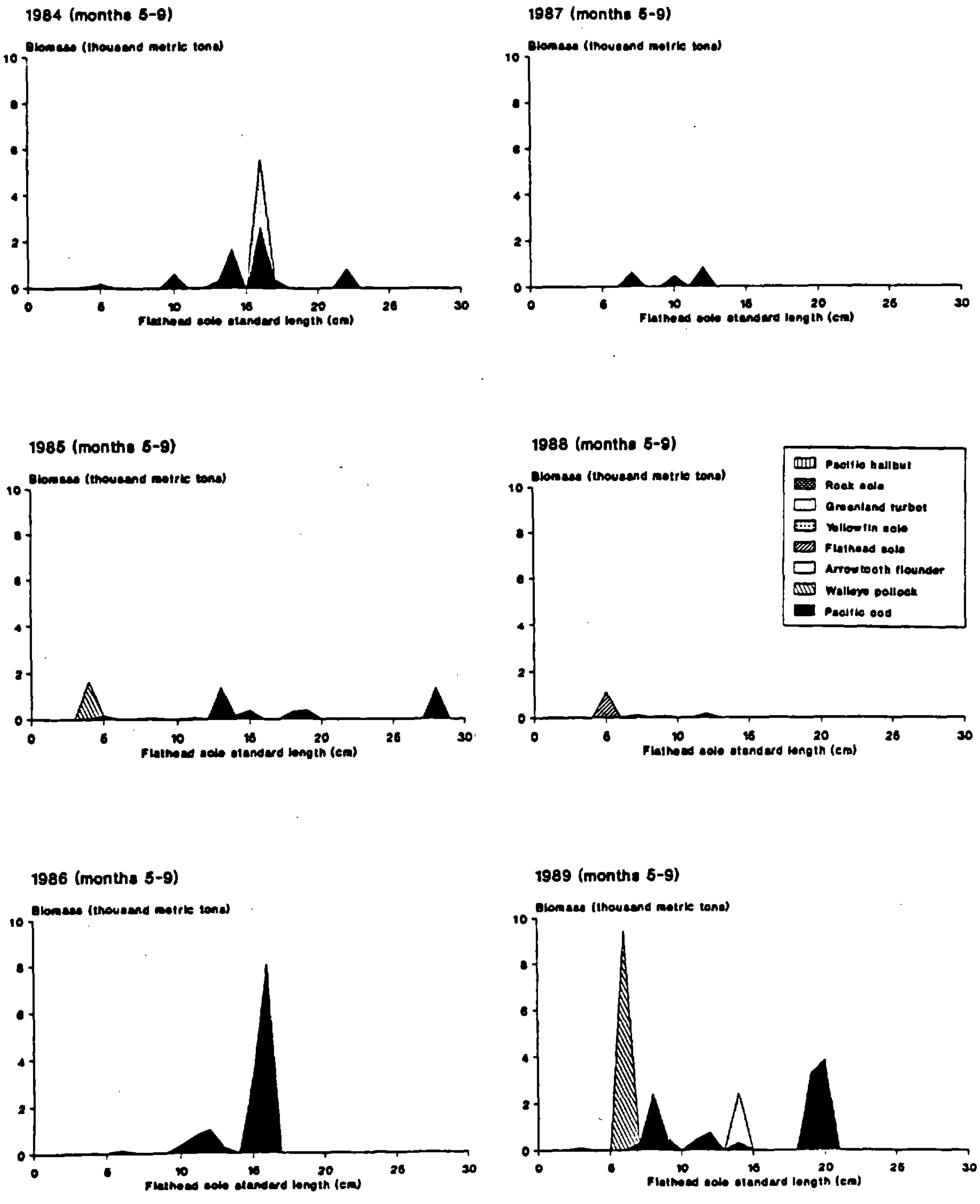

Figure 12.--Estimated biomass of flathead sole consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

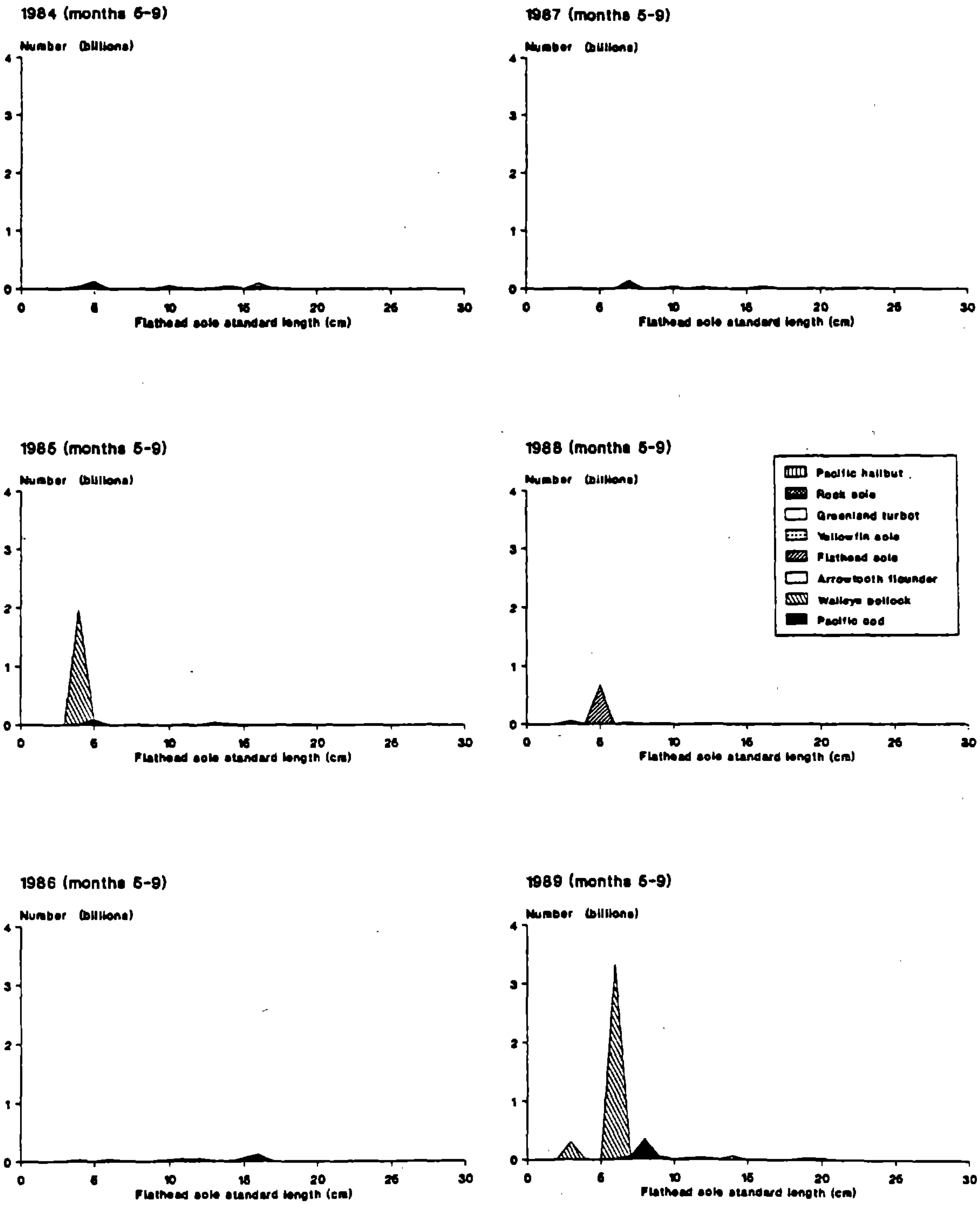

Figure 13.--Estimated number of flathead sole consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

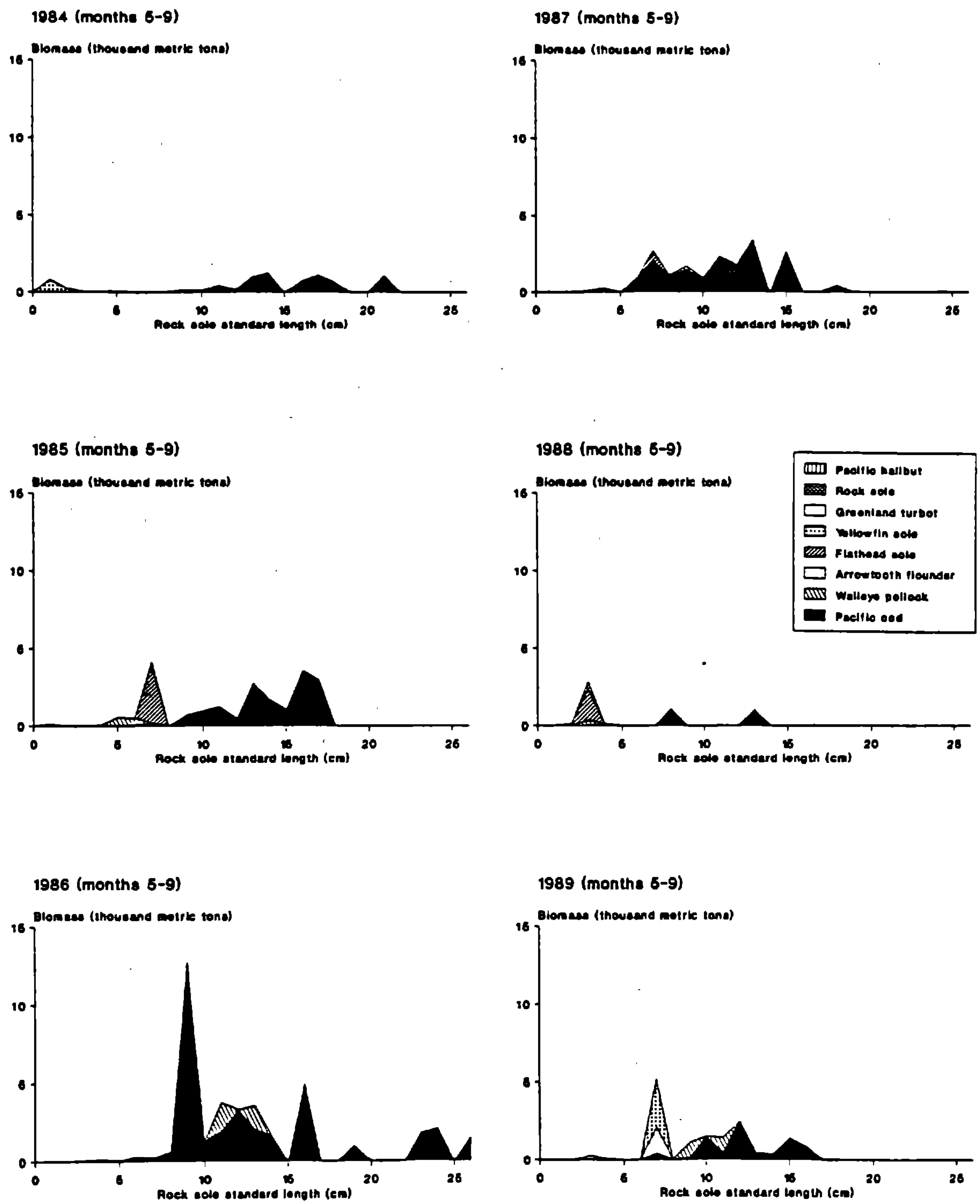

Figure 14.--Estimated biomass of rock sole consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

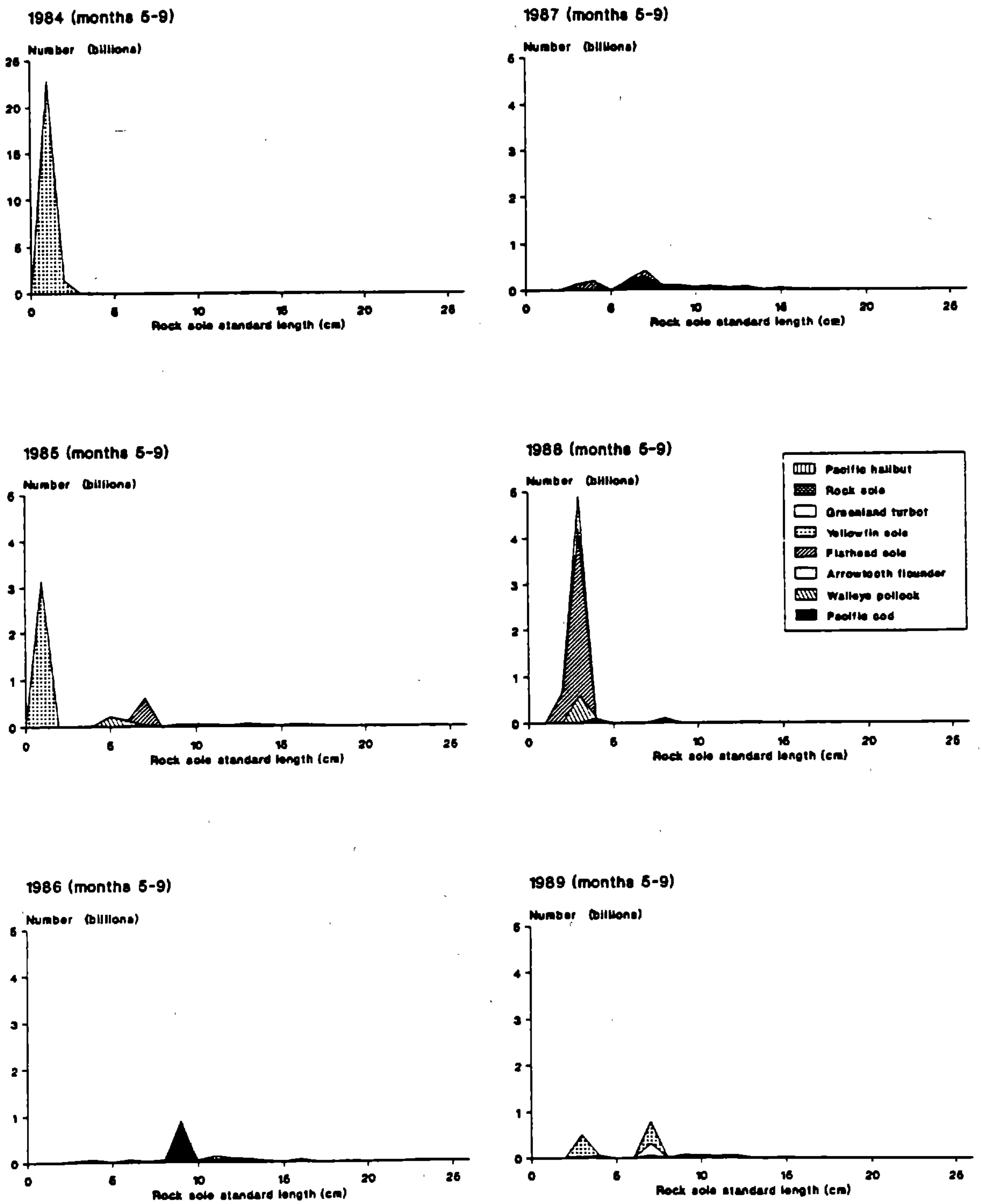

Figure 15.--Estimated number of rock sole consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size. (Note different y-axis scale for 1984.)

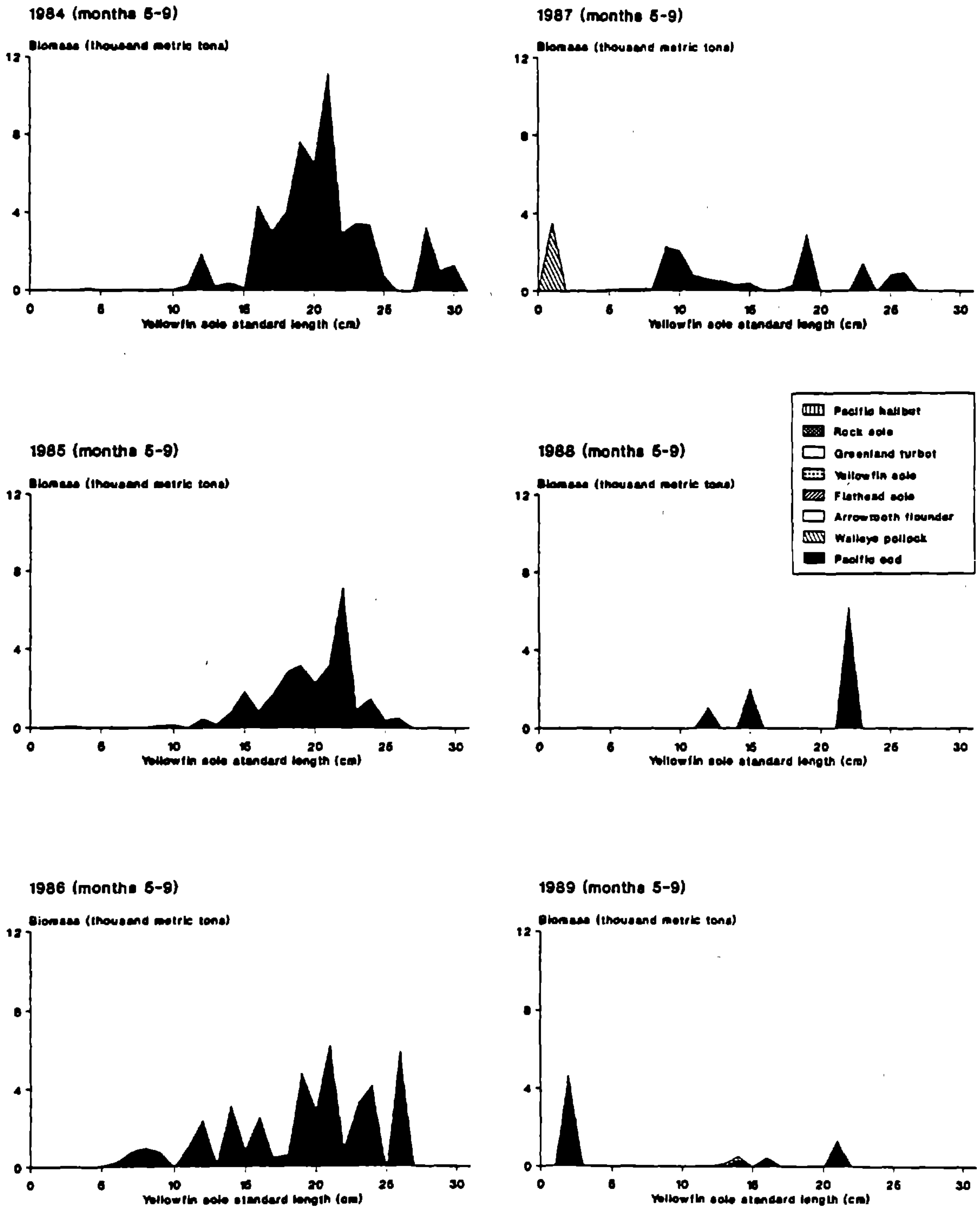

Figure 16.--Estimated biomass of yellowfin sole consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size.

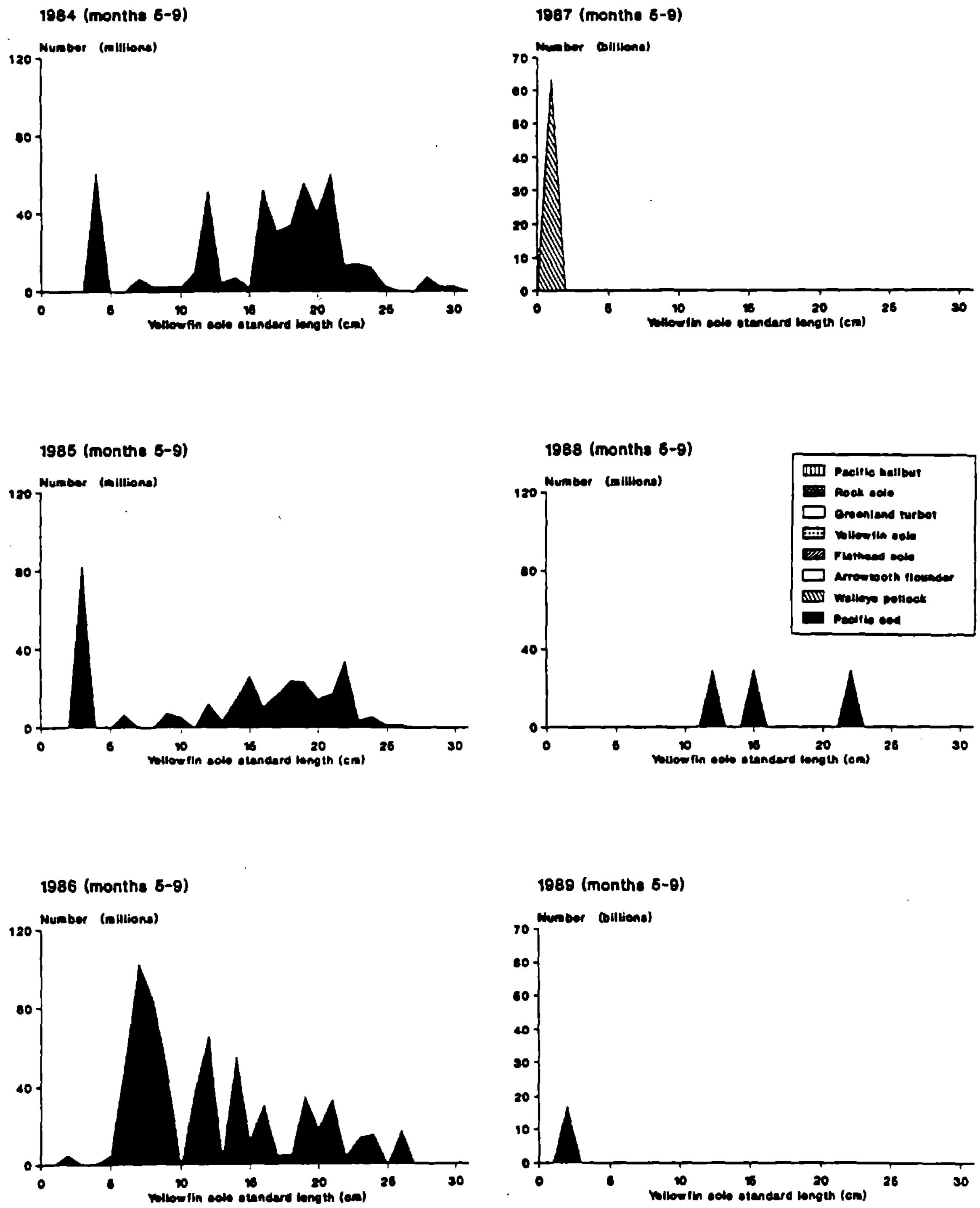

Figure 17. --Estimated number of yellowfin sole consumed by groundfish during months 5 to 9 from 1984 to 1989 in the eastern Bering Sea by prey size. (Note different y-axis scales for 1987 and 1989.)

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CONCLUSIONS

Predation by Pacific cod on Tanner and snow crabs in the eastern Bering Sea may constitute a large portion of the juvenile populations of these two species and may be a density-dependent factor that regulates the number of crabs that recruit to the fishery. Walleye pollock cannibalism was the most important source of groundfish predation on age-0 walleye pollock and may also prove to be a density-dependent factor. A longer time series of predation data is needed to determine whether these data can be used as early indicators of year-class abundance. A better understanding of Tanner and snow crab size at-age and of the juvenile abundances of both these crabs as well as walleye pollock are needed to determine whether predation is a density-dependent factor controlling population size.

In many cases, groundfish appeared to be an early sampler of Tanner and snow crabs, blue king crabs, and several flatfish species. Again, more information on juvenile abundance of these prey species may determine whether this predation is an early indicator of the presence of abundant year classes.

Consumption estimates for all prey should be viewed at the present time more as indices of consumption rather than actual consumption for several reasons. First, most of the calculations (except for walleye pollock cannibalism) consider only the time period from May through September in each year. Although this is the main feeding period for most fishes in the Bering Sea, consumption of prey certainly occurs during other parts of the year. Inadequate numbers and spatial distribution of stomach samples during other parts of the year combined with gaps in knowledge about the seasonal migrations of groundfish predators make calculation of predation in other parts of the year difficult without seasonal resource assessment surveys in the area.

Predation estimates during the time period considered here may be underestimates for prey that are consumed year-round, such as Tanner and snow crabs that are consumed by Pacific cod. Predation estimates for groundfish predation on newly settling stages of crabs and flatfishes may be overestimates if the prey species are not available to the predator during the whole time period. Also, for prey that have a very limited spatial distribution within a stratum, such as red and blue king crabs, inadequate stomach sampling throughout the whole stratum can provide biased estimates of consumption. For these prey, consumption estimates would be biased upwards if sampling was concentrated more in areas where king crabs occur and estimates would be biased downwards if stomach sampling was not performed in king crab areas. Sampling density was doubled beginning in 1989 so that problems such as this will be minimized in 1989 and future years.

Estimates of total numbers consumed are underestimates for some prey since prey size data were not available for all predators consuming a particular prey due to advanced digestion of prey.

Total consumption estimates in terms of biomass are underestimates of total groundfish predation if important groundfish predators of a particular prey have not been sampled. Skates are growing parts of the groundfish biomass in the eastern Bering Sea and consideration of their predation is becoming important. Stomach sampling of skates was initiated in 1992 and will be a regular part of the food habits sampling if it proves to be an important consumer of commercially important prey.

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APPENDIX A

Walleye Pollock

Appendix A presents biomass, food habits, prey composition, prey size, and prey consumption estimates for walleye pollock during months 5 to 9 and months 10 to 12 from 1987, 1988, and 1989 in the eastern Bering Sea.

List of Tables

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Table A-l.--Cohort analysis estimates of walleye pollock biomass (metric tons) in the eastern Bering Sea from Wespestad, Bakkala and Dawson (1990) by pollock size, year, and stratum.

Size group (cm)	Stratum	Biomass 1987	1988	1989
<30	1	6,607	3,381	2,514
	2	4,396	7,043	7,275
	3	314,585	21,213	19,055
	4	196,800	23,504	51,134
	5	73,797	1,024	30
	6	377,815	700,835	211,992
30-39	1	485	1,381	0
	2	0	0	103
	3	658,325	144,849	98,759
	4	257,549	214,280	459,588
	5	203,472	90,516	73,885
	6	2,092,169	3,742,974	2,119,665
40-49	1	10,520	6,149	3,082
	2	70	92	298
	3	457,218	410,129	491,273
	4	445,952	388,849	767,385
	5	152,943	166,812	343,973
	6	2,539,297	2,189,469	1,955,989
≥50	1	253,778	68,578	65,093
	2	36,504	21,930	23,562
	3	484,281	343,311	365,444
	4	559,470	335,550	643,995
	5	156,661	105,283	139,408
	6	518,306	305,848	315,498
Total		9,801,000	9,293,000	8,159,000

Table A-2.--Mean percent by weight (%W) and standard error (SE) of prey walleye pollock in the stomach contents of walleye pollock by year, stratum, predator size group, and time of year in the eastern Bering Sea. (* - no standard error estimate since only one station was sampled, - = no samples taken.)

Size group (cm)	Stratum	1987 mos. 5-9 %W	1987 mos. 5-9 SE	1987 mos. 10-12 %W	1987 mos. 10-12 SE	1988 mos. 5-9 %W	1988 mos. 5-9 SE	1988 mos. 10-12 %W	1988 mos. 10-12 SE	1989 mos. 5-9 %W	1989 mos. 5-9 SE	1989 mos. 10-12 %W	1989 mos. 10-12 SE
<30	3	0	0	-	-	0	0	-	-	4.6	4.6	1.3	1.3
	5	-	-	-	-	0	0	-	-	22.1	*	-	-
30-39	3	0	0	-	-	0	0	-	-	1.2	1.2	0	0
	4	5.0	3.6	-	-	0	0	-	-	0	0	-	-
	5	13.0	13.0	0	0	0	0	0	0	39.2	*	-	-
	6	0.5	0.5	0	0	0	0	-	-	0.1	0.1	1.3	1.3
40-49	2	-	-	33.3	*	-	-	0	0	0	0	-	-
	3	0	0	-	-	0.4	0.4	0	0	4.2	2.8	39.7	18.7
	4	3.4	2.1	0	0	5.1	4.9	-	-	5.5	3.3	78.6	4.6
	5	1.8	1.8	11.4	7.7	1.0	1.0	0	0	0	0	19.9	19.9
	6	2.5	1.6	27.2	7.8	5.9	4.1	-	-	1.5	1.2	14.6	8.2
≥50	1	5.2	4.9	-	-	6.1	5.6	14.8	*	1.4	1.1	-	-
	2	0	0	70.0	*	17.2	7.5	0	0	17.3	6.3	-	-
	3	5.0	2.5	-	-	0	0	83.9	*	1.1	0.6	41.1	19.2
	4	7.7	3.6	69.4	4.3	2.9	1.6	85.8	5.9	13.5	3.1	58.5	7.2
	5	2.2	1.8	25.3	9.4	0	0	0	0	6.7	6.7	0	0
	6	29.5	8.6	54.7	7.0	13.4	6.8	-	-	11.3	4.8	0	0

Table A-3.--Mean percent by weight (%W) and standard error (SE) of miscellaneous commercial crab species in the stomach contents of walleye pollock by prey species, pollock size group, year, strata, and time of year. (- = no samples taken.)

Prey	Pollock size(cm)	Year	Stratum	mos. 5-9 %W	mos. 5-9 SE	mos. 10-12 %W	mos. 10-12 SE
Lithodid crabs	40-49	1989	3	<0.01	<0.01	0	0
	≥50	1987	6	0	0	0.03	0.03
		1989	4	<0.01	<0.01	0	0
***Paralithodes* sp.**	≥50	1989	4	0.01	0.01	0	0
Blue king crab	≥50	1987	3	0.01	0.01	-	-
Snow crab	<30	1989	6	0.54	0.54	0	0
	30-39	1989	6	0.04	0.04	0	0
	40-49	1987	6	0	0	0.08	0.08
Tanner crab	30-39	1989	6	0.04	0.04	0	0
	40-49	1987	6	0	0	0.19	0.19
		1989	6	0.11	0.11	0	0
	≥50	1989	3	<0.01	<0.01	0	0
			6	0.02	0.02	0	0

Table A-4.--Mean percent by weight (%W) and standard error (SE) of miscellaneous commercial fish species in the stomach contents of walleye pollock by prey species, pollock size group, year, strata, and time of year. (- = no samples taken.)

Prey	Pollock size(cm)	Year	Stratum	mos. 5-9 %W	mos. 5-9 SE	mos. 10-12 %W	mos. 10-12 SE
Pacific herring	≥50	1987	1	1.78	1.30	-	-
Pacific cod	40-49	1987	4	1.10	1.10	0	0
	≥50	1989	4	0.22	0.22	0	0
Arrowtooth flounder	≥50	1987	4	0.37	0.30	0	0
		1989	4	0.01	0.01	0	0
Flathead sole	40-49	1989	6	0.39	0.39	0	0
	≥50	1988	2	0.14	0.14	0	0
		1989	4	0.03	0.03	6.07	6.07
Rock sole	≥50	1988	1	0.21	0.21	0	0
		1989	1	4.63	3.25	-	-
		1987	2	0.99	0.99	0	0
		1988	2	1.80	1.46	0	0
		1989	2	0.49	0.49	-	-
Yellowfin sole	≥50	1987	1	2.20	1.51	-	-
		1988	1	1.03	1.03	0	0
		1987	3	0.04	0.04	-	-
Greenland turbot	40-49	1989	4	0.74	0.74	0	0
			6	0.31	0.18	0	0
	≥50	1988	4	0.01	0.01	0	0
		1989	4	0.01	0.01	0	0
			6	1.69	1.66	0	0
Pacific halibut	≥50	1988	6	0.10	0.10	-	-
Alaska plaice	≥50	1989	1	0.03	0.03	-	-

Table A-5.--Estimated total biomass (thousand metric tons) of prey walleye pollock consumed by walleye pollock by year, stratum, predator size group, and time of year in the eastern Bering Sea. Numbers in parentheses indicate cells where no prey size information was available. (- = no samples taken.)

Size group (cm)	Stratum	Biomass consumed 1987 mos. 5-9	1987 mos. 10-12	1988 mos. 5-9	1988 mos. 10-12	1989 mos. 5-9	1989 mos. 10-12
<30	3	0	-	0	-	1.5	0.3
	5	-	-	0	-	<0.1	-
30-39	3	0	-	0	-	2.0	0
	4	21.7	-	0	-	0	-
	5	44.6	0	0	0	48.7	-
	6	18.9	0	0	-	3.2	29.0
40-49	2	-	0.1	-	0	0	-
	3	0	-	1.8	0	25.3	143.7
	4	18.3	0	24.2	-	51.5	444.2
	5	3.4	12.9	2.1	0	0	50.2
	6	76.0	507.8	158.2	-	36.2	210.4
≥50	1	8.0	-	2.6	3.7	0.6	-
	2	0	9.4	2.3	0	2.5	-
	3	14.9	-	0	104.8	2.5	55.2
	4	26.3	142.9	6.0	106.0	53.3	138.6
	5	2.1	14.6	0	0	5.7	0
	6	93.6	104.3	25.0	-	21.7	0
Total		327.8	792.0	222.2	214.5	254.8	1,071.6

Table A-6.--Estimated number (billions) of, prey walleye pollock consumed by walleye pollock by year, stratum, predator size group, and time of year in the eastern Bering Sea. Numbers in parentheses indicate cells where no prey size information was available. (= - no samples taken.)

Size group (cm)	Stratum	Numbers consumed					
		1987		1988		1989	
		mos. 5-9	mos. 10.12	mos. 5-9	mos. 10-12	mos. 5-9	mos. 10-12
<30	3	0	-	0	-	1.9	2.0
	5	-	-	0	-	<0.1	-
30-39	3	0	-	0	-	0.5	0
	4	(0)	-	0	-	0	-
	5	11.0	0	0	0	33.3	-
	6	(0)	0	0	-	1.0	2.3
40-49	2	-	(0)	-	0	0	-
	3	0	-	(0)	0	2.7	39.5
	4	3.4	0	(0)	-	251.1	156.7
	5	(0)	7.8	0.2	0	0	5.8
	6	(0)	139.2	8.5	-	4.3	14.8
≥50	1	(0)	-	(0)	1.8	<0.1	-
	2	0	1.3	0.2	0	0.3	-
	3	1.4	-	0	125.2	1.7	44.6
	4	33.5	11.2	0.3	44.8	7.1	43.7
	5	(0)	3.0	0	0	217.9	0
	6	6.0	6.7	0.4	-	0.1	0
Total		55.3	169.2	9.6	171.8	521.9	309.4

Table A-7.--Total biomass (metric tons) of miscellaneous commercial crab species consumed by walleye pollock by prey species, pollock size group, year, strata, and time of year. Values in parentheses indicate cells where no prey size information was available. (- = no samples taken.)

Prey	Pollock size(cm)	Year	Stratum	Biomass consumed mos. 5-9	Biomass consumed mos. 10-12
Lithodid crabs	40-49	1989	3	0.3	0
	≥50	1987	6	0	51.5
		1989	4	0.4	0
***Paralithodes* sp.**	≥50	1989	4	5.8	0
Blue king crabs	≥50	1987	3	8.7	-
Snow crabs	<30	1989	6	1,917.7	0
	30-39	1989	6	1,434.7	0
	40-49	1987	6	0	1,443.4
Tanner crabs	30-39	1989	6	1,414.2	0
	40-49	1987	6	0	3,623.9
		1989	6	2,689.7	0
	≥50	1989	3	1.7	0
			6	31.9	0

Table A-8.--Total biomass (metric tons) of miscellaneous commercial fish species consumed by walleye pollock by prey species, pollock size group, year, strata, and time of year. Values in parentheses indicate cells where no prey size information was available. (- = no samples taken.)

Prey	Pollock size(cm)	Year	Stratum	Biomass consumed mos. 5-9	Biomass consumed mos. 10-12
Pacific herring	≥50	1987	1	2,766.7	-
Pacific cod	40-49	1987	4	5,990.9	0
	≥50	1989	4	851.0	0
Arrowtooth flounder	≥50	1987	4	1,271.0	0
		1989	4	44.5	0
Flathead sole	40-49	1989	6	9,448.4	0
	≥50	1988	2	19.0	0
		1989	4	113.4	14,377.4
Rock sole	≥50	1988	1	90.2	0
		1989	1	1,846.2	-
		1987	2	220.3	0
		1988	2	242.2	0
		1989	2	71.0	-
Yellowfin sole	≥50	1987	1	3,416.2	-
		1988	1	430.3	0
		1987	3	112.6	-
Greenland turbot	40-49	1989	4	6,915.9	0
			6	7,416.8	0
	≥50	1988	4	16.2	0
		1989	4	35.3	0
			6	3,260.4	0
Pacific halibut	≥50	1988	6	185.2	-
Alaska plaice	≥50	1989	1	13.1	-

Table A-9.--Total number (millions) of miscellaneous commercial crab species consumed by walleye pollock by prey species, pollock size group, year, strata, and time of year. Values in parentheses indicate cells where no prey size information was available. (- = no samples taken.)

Prey	Pollock size(cm)	Year	Stratum	Number consumed mos. 5-9	Number consumed mos. 10-12
Lithodid crabs	40-49	1989	3	(0)	0
	≥50	1987	6	0	(0)
		1989	4	(0)	0
***Paralithodes* sp.**	≥50	1989	4	(0)	0
Blue king crabs	≥50	1987	3	(0)	-
Snow crabs	<30	1989	6	(0)	0
	30-39	1989	6	(0)	0
	40-49	1987	6	0	59.7
Tanner crabs	30-39	1989	6	(0)	0
	40-49	1987	6	0	197.3
		1989	6	(0)	0
	≥50	1989	3	(0)	0
			6	(0)	0

Table A-10.--Total number (millions) of miscellaneous commercial fish species consumed by walleye pollock by prey species, pollock size group, year, strata, and time of year. Values in parentheses indicate cells where no prey size information was available. (- = no samples taken.)

Prey	Pollock size(cm)	Year	Stratum	Number consumed mos. 5-9	mos. 10-12
Pacific herring	≥50	1987	1	(0)	-
Pacific cod	40-49	1987	4	486.1	0
	≥50	1989	4	72.8	0
Arrowtooth flounder	≥50	1987	4	1,861.0	0
		1989	4	95.4	0
Flathead sole	40-49	1989	6	3,322.3	0
	≥50	1988	2	52.0	0
		1989	4	309.6	362.5
Rock sole	≥50	1988	1	158.8	0
		1989	1	102.7	-
		1987	2	11.4	0
		1988	2	426.3	0
		1989	2	7.2	-
Yellowfin sole	≥50	1987	1	61,328.2	-
		1988	1	(0)	0
		1987	3	2,022.4	-
Greenland turbot	40-49	1989	4	10,343.7	0
			6	15,530.0	0
	≥50	1988	4	16.6	0
		1989	4	27.0	0
			6	4,427.6	0
Pacific halibut	≥50	1988	6	665.3	-
Alaska plaice	≥50	1989	1	9.2	-

Table A-ll.--Size ranges of some commercially important prey consumed by walleye pollock during months 5 to 9 in the eastern Bering Sea during 1987 to 1989.

Prey	Predator size (cm)	Prey size range (mm)
Pacific cod	40-49	100
	≥50	80-110
Arrowtooth flounder	≥50	20-50
Flathead sole	40-49	60
	≥50	30
Rock sole	≥50	30-110
Yellowfin sole	≥50	10
Greenland turbot	40-49	20-40
	≥50	20-40
Pacific halibut	≥50	20-40
Alaska plaice	≥50	40

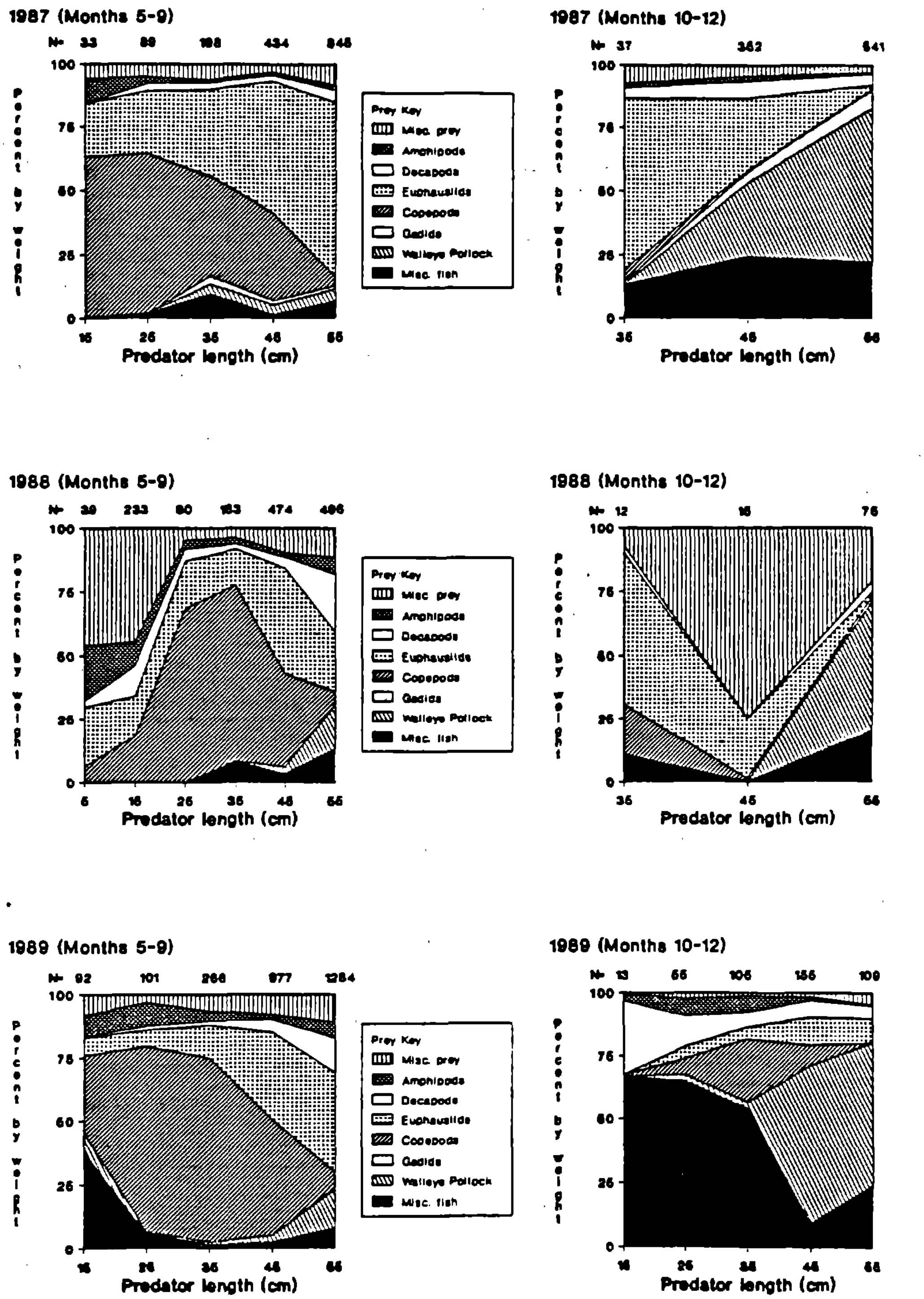

Figure A-1.--Diet composition of walleye pollock, in terms of percent by weight, during months 5 to 9 and months 10 to 12 by predator size for 1987 to 1989 in the eastern Bering Sea.

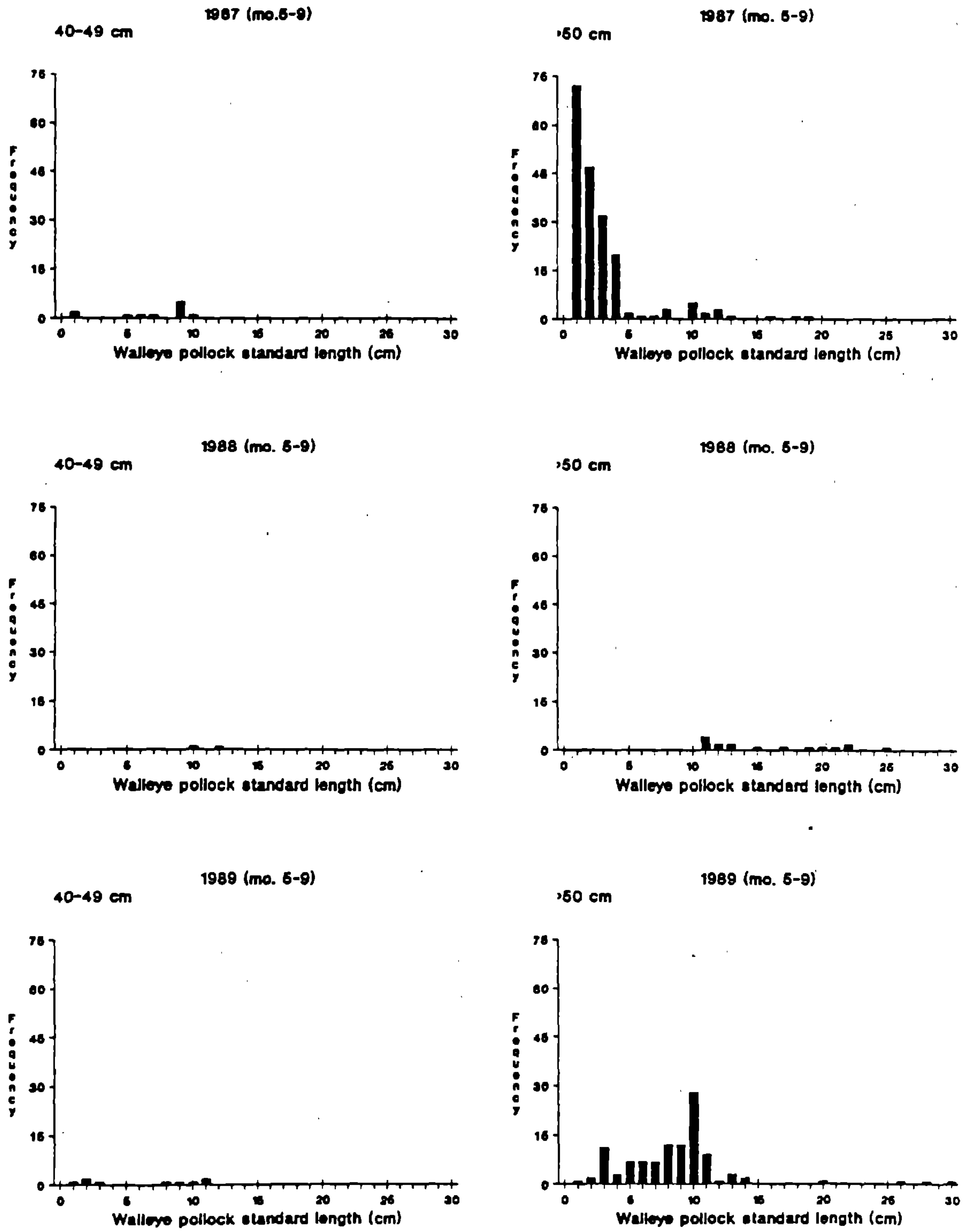

Figure A-2.--Size frequency of prey walleye pollock found in two size groups of walleye pollock during months 5 to 9 in 1987, 1988, and 1989 in the eastern Bering Sea.

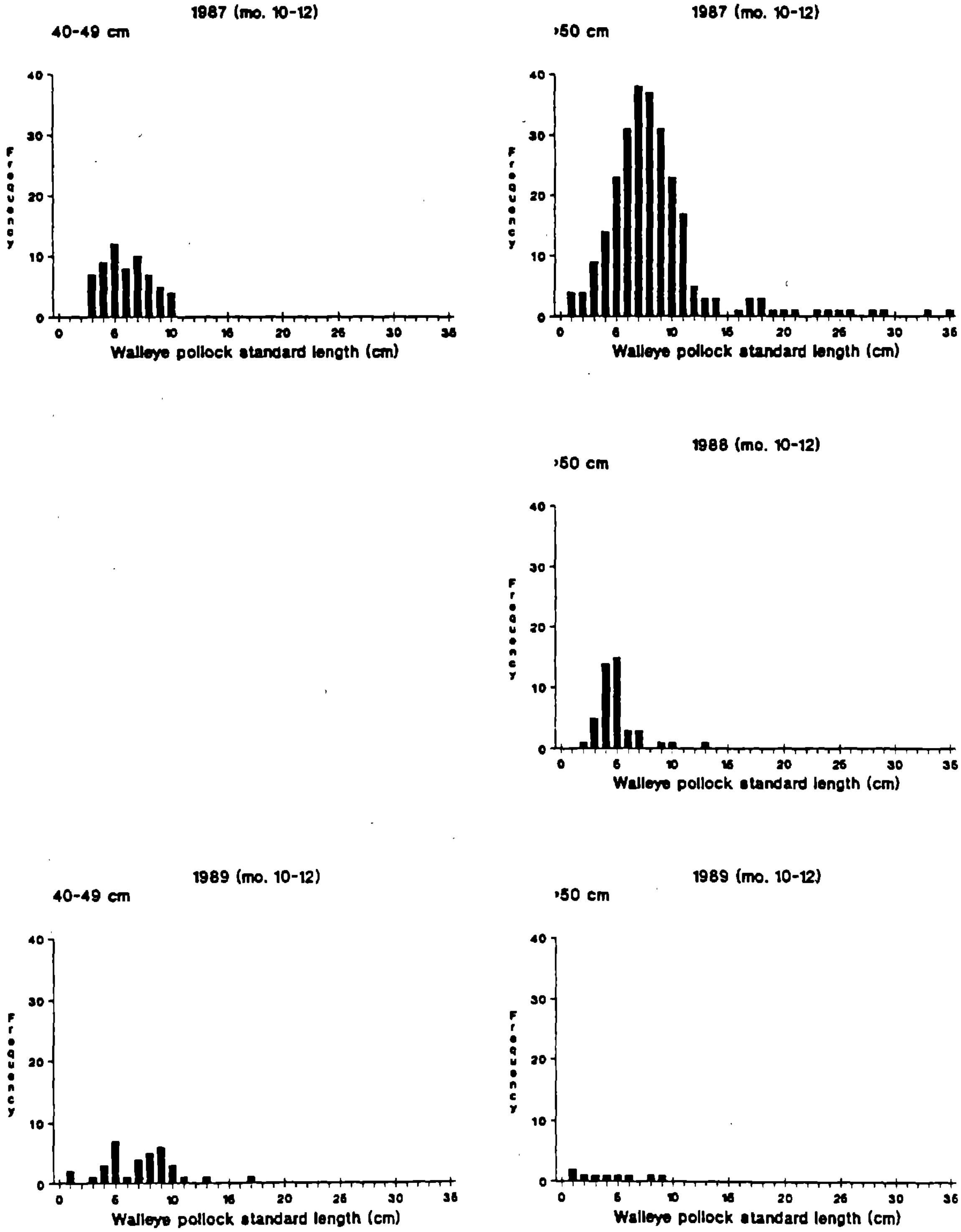

Figure A-3. --Size frequency of prey walleye pollock found in two size groups of walleye pollock during months 10 to 12 in 1987, 1988, and 1989 in the eastern Bering Sea.

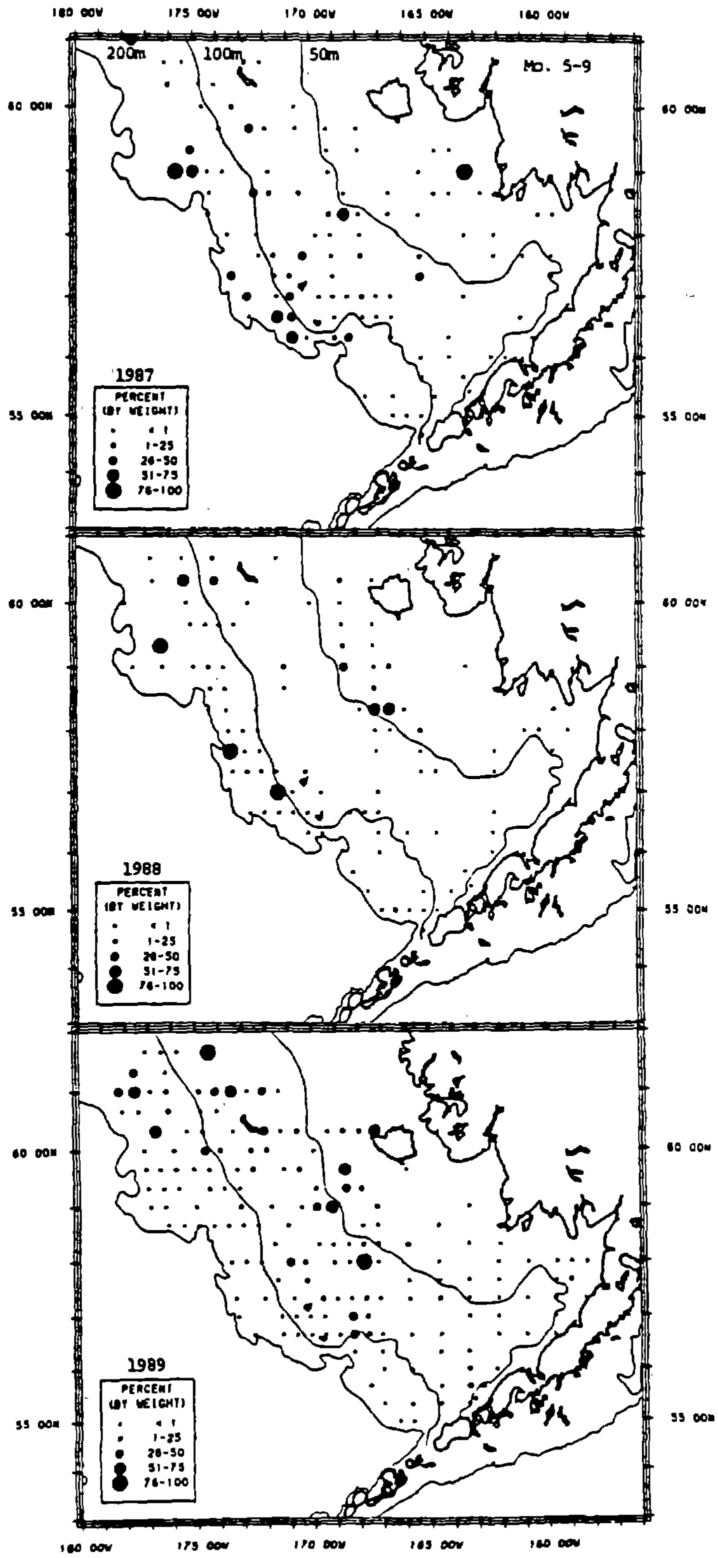

Figure A-4.--Percent by weight of prey walleye pollock in the diet of walleye pollock by sampling station during months 5 to 9 in 1987, 1988, and 1989 in the eastern Bering Sea.

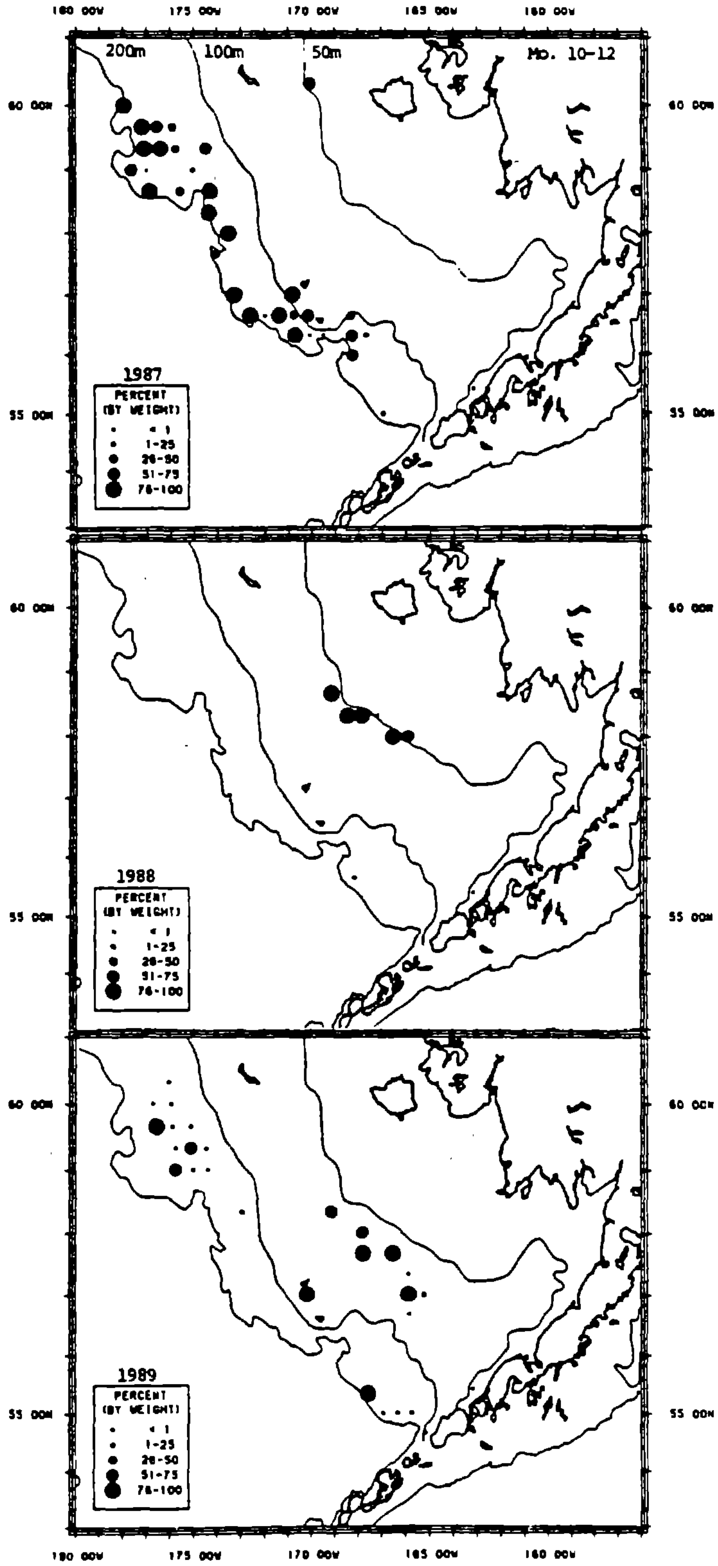

Figure A-5. --Percent by weight of prey walleye pollock in the diet of walleye pollock by sampling station during months 10 to 12 in 1987, 1988, and 1989 in the eastern Bering Sea.

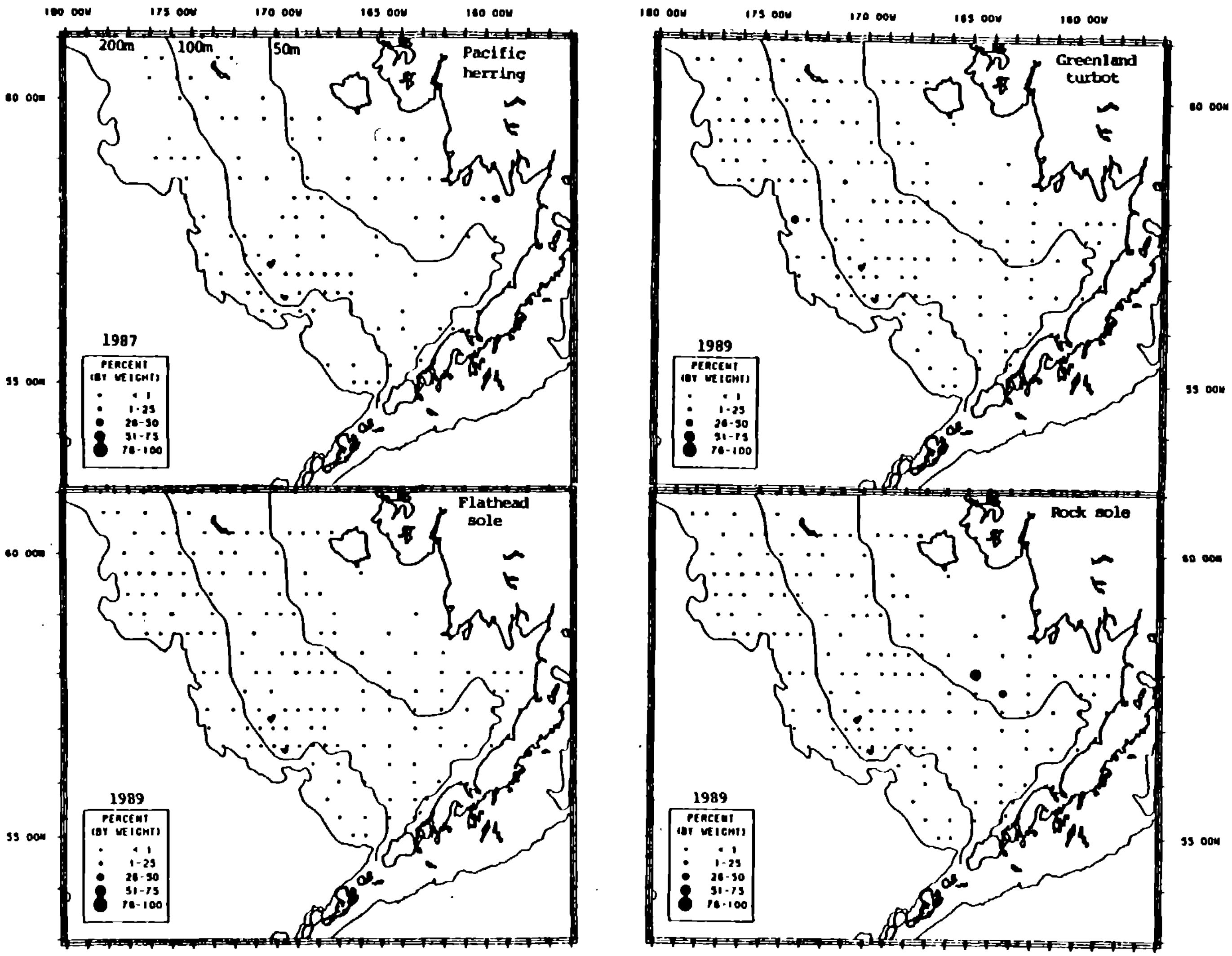

Figure A-6.--Percent by weight of Pacific herring, Greenland turbot, flathead sole, and rock sole in the diet of walleye pollock by sampling station during months 5 to 9 in various years in the eastern Bering Sea.

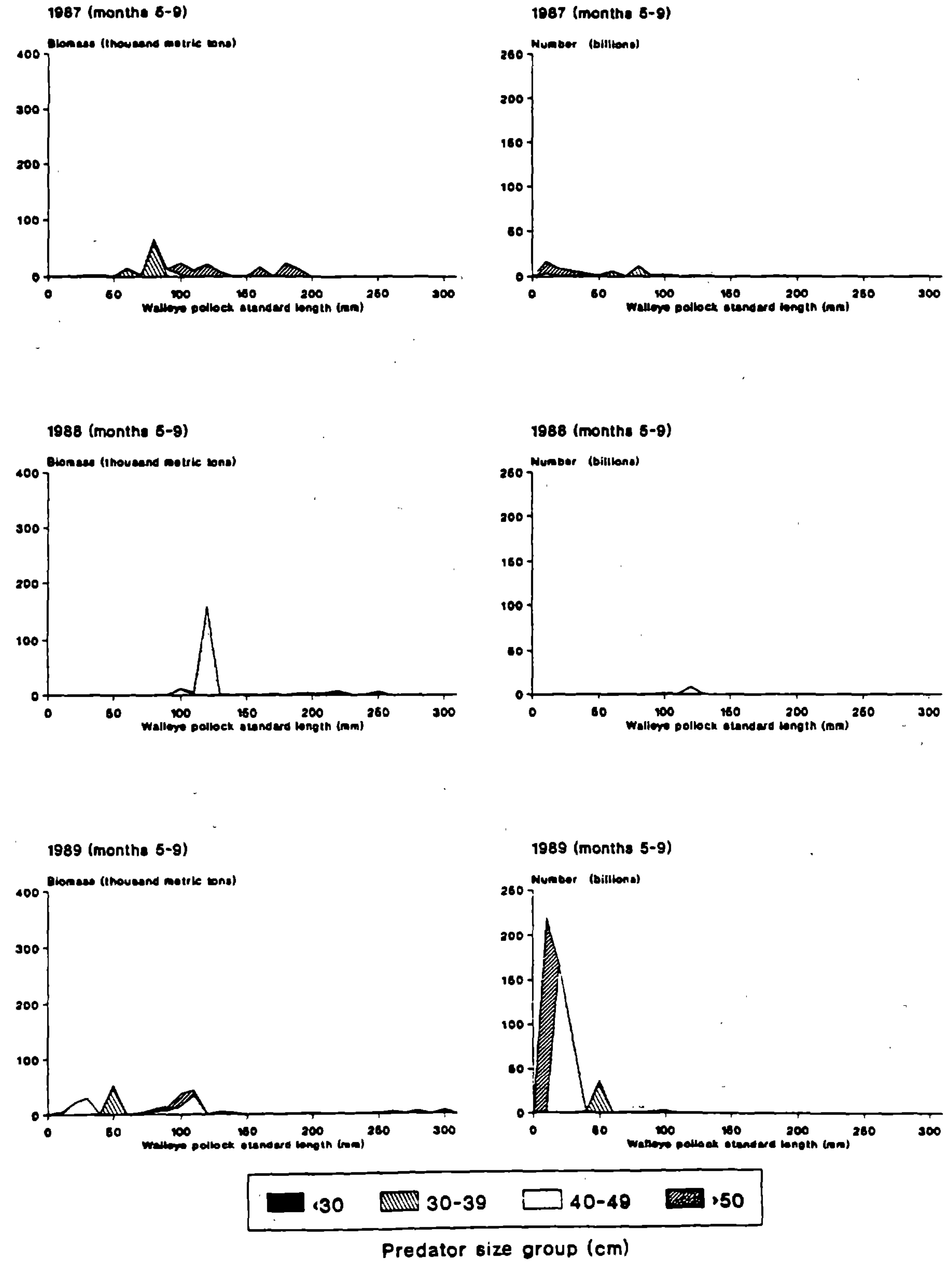

Figure A-7. --Biomass and number of prey walleye pollock consumed by four size groups of walleye pollock during months 5 to 9 of 1987, 1988, and 1989 by prey size.

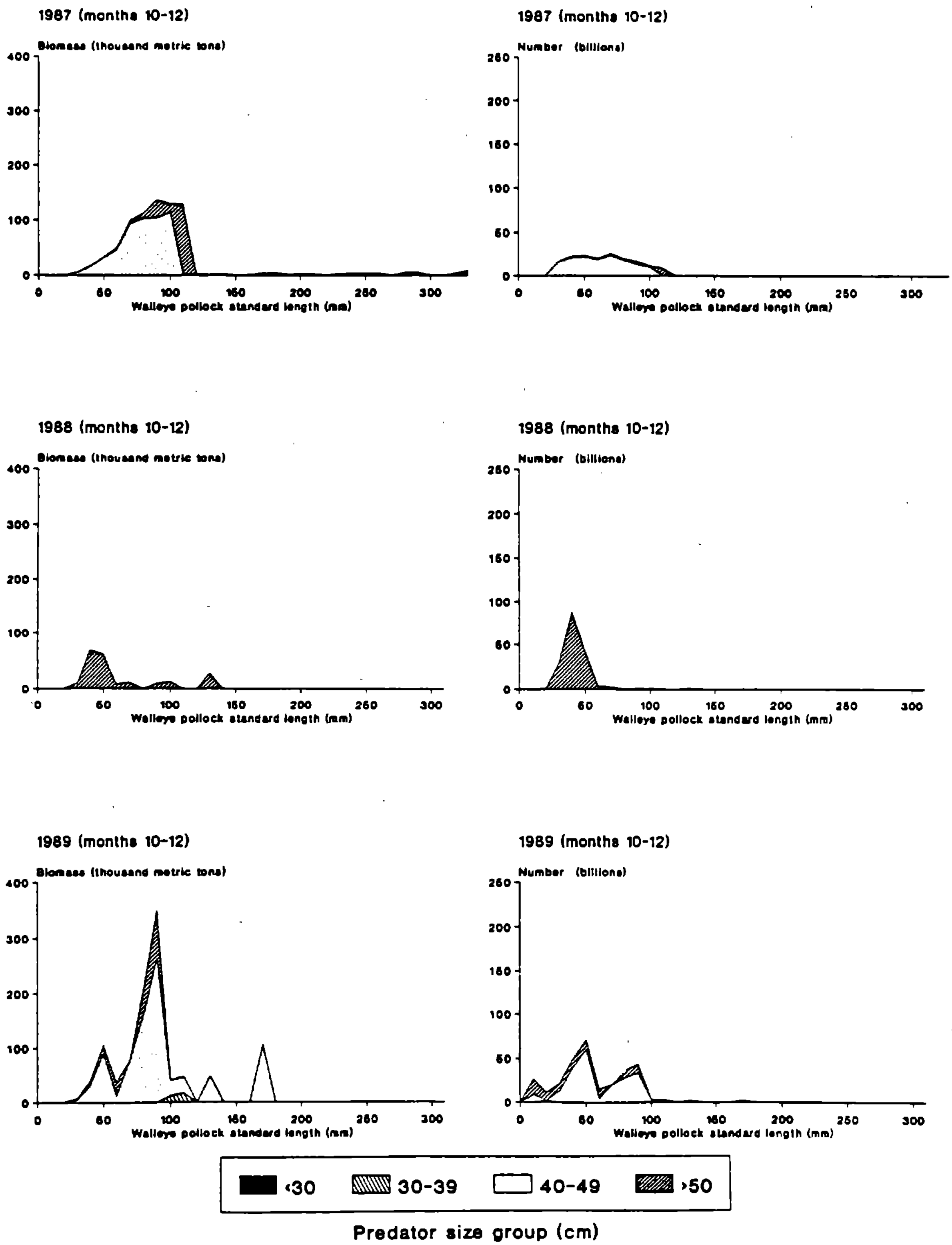

Figure A-8. --Biomass and number of prey walleye pollock consumed by four size groups of walleye pollock during months 10 to 12 of 1987, 1988, and 1989 by prey size.

APPENDIX B

Pacific Cod

Appendix B presents biomass, food habits, prey composition, prey size, and prey consumption estimates for Pacific cod during months 5 to 9, from 1987, 1988, and 1989 in the eastern Bering Sea.

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Table B-l.--Estimated biomass in metric tons of Pacific cod in the eastern Bering Sea by cod size, year, and stratum.

Cod size (cm)	Stratum	Biomass 1987	1988	1989
<30	1	5,248	631	163
	2	1,348	245	33
	3	3,350	462	204
	4	3,384	4,506	1,677
	5	1	0	0
	6	30	116	32
30-59	1	79,591	41,919	4,278
	2	17,334	16,843	4,401
	3	131,314	116,101	62,706
	4	133,072	108,465	92,204
	5	17,961	15,194	13,375
	6	73,559	92,825	46,454
≥60	1	110,986	69,780	26,536
	2	39,874	20,825	14,666
	3	99,428	127,844	186,220
	4	85,873	52,460	98,439
	5	75,155	86,199	97,038
	6	264,941	205,128	312,010
Total		1,142,449	959,543	960,436

Table B-2.--Mean percent by weight (%W) and standard error (SE) of roundfish in the stomach contents of Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea. (* = no standard error estimate since only one station was sampled.)

Prey	Cod size (cm)	Stratum	1987 %W	1987 SE	1988 %W	1988 SE	1989 %W	1989 SE
Pacific cod	30-59	6	0	0	0.07	0.07	0	0
	≥60	4	3.14	3.14	0	0	0.73	0.73
		6	0	0	0.57	0.57	0	0
Walleye pollock	<30	2	0	0	50.59	*	0	0
		4	0	0	2.70	2.70	5.50	5.50
	30-59	1	1.01	0.66	16.20	16.20	0	0
		2	0.84	0.84	7.68	7.68	1.17	1.17
		3	11.54	4.62	9.38	5.65	0.62	0.49
		4	6.98	4.68	3.52	2.55	8.00	2.62
		5	3.52	3.11	4.16	3.62	2.59	2.59
		6	4.36	4.24	31.90	10.10	8.64	3.34
	≥60	1	0	0	0	0	6.47	4.61
		2	4.67	2.42	0	0	4.47	3.66
		3	40.67	8.72	31.92	11.16	32.38	8.34
		4	20.89	7.83	24.31	23.81	26.87	4.88
		5	28.39	11.47	63.78	9.94	49.41	8.70
		6	39.71	11.13	57.70	10.99	51.21	5.06
Pacific herring	30-59	3	0	0	3.40	2.34	0	0
	≥60	1	0.02	0.02	0	0	0	0
		2	0	0	0	0	0.05	0.05
		3	0	0	6.40	6.40	0	0
		4	1.98	1.98	0	0	0	0
		5	1.71	1.71	0	0	0	0

Table B-3.--Mean percent by weight (%W) and standard error (SE) of flatfish in the stomach contents of Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea.

Prey	Cod size (cm)	Stratum	1987 %W	1987 SE	1988 %W	1988 SE	1989 %W	1989 SE
Arrowtooth flounder	30-59	1	2.83	2.83	0	0	0	0
		2	<0.01	<0.01	0	0	0	0
		3	2.63	2.11	0	0	0	0
		5	0.01	0.01	0	0	0	0
	≥60	2	0.46	0.46	0	0	0	0
		5	0.38	0.38	0	0	0.25	0.24
		6	0	0	0	0	<0.01	<0.01
Flathead sole	30-59	1	0	0	0	0	5.26	5.26
		3	0	0	0.04	0.04	0.02	0.02
		4	0.72	0.72	0	0	0.48	0.45
		5	0	0	0.17	0.12	0	0
		6	0	0	0	0	0.10	0.10
	≥60	1	0.54	0.54	0	0	0	0
		3	0	0	0	0	1.01	1.01
		4	0	0	0	0	0.04	0.03
		5	0	0	0.25	0.19	0.51	0.37
		6	0	0	0	0	2.46	1.65
Rock sole	30-59	1	7.83	5.40	0	0	1.06	1.06
		2	1.05	0.77	0	0	1.90	1.90
		3	0	0	0	0	4.52	3.60
		4	0	0	0.69	0.69	0.01	0.01
	≥60	1	6.43	3.63	1.63	1.63	8.74	5.83
		2	1.98	1.68	0	0	0	0
		3	0	0	0	0	0.58	0.48
		4	0	0	0	0	0.53	0.49
Yellowfin sole	≥60	1	5.34	4.43	12.36	6.82	6.85	4.79
		2	11.23	5.71	0	0	0	0
		3	2.55	1.88	0	0	2.32	2.32
		4	0	0	0	0	0.26	0.26
Greenland turbot	≥60	6	0	0	0	0	<0.01	<0.01

Table B-4.--Mean percent by weight (%W) and standard error (SE) of king crabs in the stomach contents of Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea.

Prey	Cod size (cm)	Stratum	1987 %W	1987 SE	1988 %W	1988 SE	1989 %W	1989 SE
Lithodidae	30-59	3	0.43	0.43	0.07	0.07	0	0
	≥60	1	0.03	0.03	0	0	0.02	0.02
		3	0	0	1.91	1.91	0.04	0.04
Paralithodes sp.	30-59	1	0.75	0.59	0	0	0	0
	≥60	1	0.05	0.04	0	0	0.40	0.40
		3	0	0	0	0	4.53	4.34
Paralithodes camtschatica (red king crab)	≥60	1	1.73	1.73	0	0	0.62	0.62
		2	0.87	0.87	0	0	0	0
Paralithodes platypus (blue king crab)	≥60	1	0	0	0	0	0.35	0.35

Table B-5.--Mean percent by weight (%W) and standard error (SE) of snow (Chionoecetes opilio) and Tanner (C. bairdi) crabs in the stomach contents of Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea. (* = no standard error since only one station was sampled, - = no samples taken.)

Prey	Cod size (cm)	Stratum	1987		1988		1989	
			%W	SE	%W	SE	%W	SE
C. opilio	<30	2	11.08	11.08	0	0	0	0
		4	1.01	1.01	0	0	0.67	0.67
	30-59	1	0	0	1.93	1.93	6.81	5.74
		2	18.76	6.94	14.60	5.01	47.55	12.78
		3	8.97	5.99	0.92	0.60	9.33	3.33
		4	10.95	3.42	11.67	4.37	18.05	2.81
		5	0	0	0	0	4.25	3.56
		6	16.67	6.70	1.49	0.99	15.48	3.27
	≥60	1	0	0	0	0	2.94	2.02
		2	18.86	9.62	83.18	*	39.23	8.29
		3	11.92	6.86	0	0	2.89	1.32
		4	22.28	5.44	19.36	11.86	21.93	3.77
		5	2.70	2.70	0.73	0.48	6.09	3.01
		6	17.56	6.15	2.64	2.35	8.80	2.39
C. bairdi	<30	3	7.16	4.96	-	-	0	0
		4	1.53	1.53	0	0	0	0
	30-59	1	0.02	0.02	0.66	0.66	0	0
		2	0.28	0.28	2.46	1.15	0	0
		3	7.40	2.38	4.67	2.54	7.41	2.93
		4	13.34	4.93	6.35	1.81	3.49	1.59
		5	30.01	9.24	11.67	5.10	22.42	8.97
		6	15.28	6.68	9.42	4.49	11.05	3.47
	≥60	1	1.11	1.11	0	0	0.52	0.37
		2	0.07	0.07	0	0	0.29	0.29
		3	5.45	3.76	3.82	3.63	4.56	2.69
		4	3.42	1.88	1.70	1.70	1.09	0.67
		5	9.73	6.17	4.17	4.01	13.18	5.91
		6	4.41	4.24	0.69	0.31	6.03	1.82

Table B-6.--Estimated total weight (metric tons) of roundfish consumed by Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea.

Prey	Cod size (cm)	Stratum	Biomass 1987	Biomass 1988	Biomass 1989
Pacific cod	30-59	6	0	84.8	0
	≥60	4	2,889.9	0	766.8
		6	0	1,244.9	0
Total			2,889.9	1,329.7	766.8
Walleye pollock	<30	2	0	227.6	0
		4	0	223.3	169.4
	30-59	1	1,104.2	9,352.7	0
		2	201.5	1,780.3	70.7
		3	20,873.3	14,998.0	532.7
		4	12,782.0	5,261.5	10,161.1
		5	870.1	869.4	476.3
		6	4,419.5	40,775.7	5,524.1
	≥60	1	0	0	1,839.6
		2	1,995.0	0	702.1
		3	43,306.3	43,700.0	64,582.0
		4	19,216.1	13,659.3	28,332.8
		5	22,854.1	58,877.0	51,353.4
		6	112,688.2	126,773.1	171,111.5
Total			240,310.3	316,497.9	334,855.6
Pacific herring	30-59	3	0	5,440.0	0
	≥60	1	20.6	0	0
		2	0	0	8.2
		4	1,822.2	0	0
		5	1,373.9	0	0
Total			3,216.7	5,440.0	8.2

Table B-7.--Estimated total number (millions) of roundfish consumed by Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea. Parentheses indicate cells where no prey size information was available.

Prey	Cod size (cm)	Stratum	Number 1987	1988	1989
Pacific cod	30-59	6	0	(0)	0
	≥60	4	7,707.5	0	1.7
		6	0	1.5	0
Total			7,707.5	1.5	1.7
Walleye pollock	<30	2	0	28.5	0
		4	0	9.8	44.2
	30-59	1	66.7	4,730.2	0
		2	29.6	207.5	6.5
		3	1,447.4	29.2	1.6
		4	251.2	184.2	144.1
		5	234.5	2.9	0.6
		6	185.5	319.2	22.7
	≥60	1	0	0	2.4
		2	379.9	0	2.0
		3	313.4	79.0	99.7
		4	166.6	23.3	94.6
		5	3,541.1	142.9	91.4
		6	1,413.2	325.9	411.9
Total			8,029.1	6,082.6	921.7
Pacific herring	30-59	3	0	140.4	0
	≥60	1	0.1	0	0
		2	0	0	1.0
		4	8.0	0	0
		5	6.0	0	0
Total			14.1	140.4	1.0

Table B-8.--Estimated total biomass (metric tons) of flatfish consumed by Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea.

Prey	Cod size (cm)	Stratum	Biomass 1987	Biomass 1988	Biomass 1989
Arrowtooth flounder	30-59	1	3,101.8	0	0
		2	0.1	0	0
		3	4,746.7	0	0
		5	1.9	0	0
	≥60	1	1,529.1	0	0
		2	198.6	0	0
		5	304.5	0	263.4
		6	0	0	11.3
Total			9,882.7	0	274.7
Flathead sole	30-59	1	0	0	310.0
		3	0	68.8	19.1
		4	1,323.7	0	612.1
		5	0	36.4	0
		6	0	0	61.4
	≥60	1	641.6	0	0
		3	0	0	2,012.2
		4	0	0	46.1
		5	0	226.5	531.1
		6	0	0	8,208.1
Total			1,965.2	331.6	11,800.1
Rock sole	30-59	1	8,582.8	0	62.5
		2	251.4	0	114.9
		3	0	0	3,903.0
		4	0	1,025.5	16.3
	≥60	1	7,639.6	1,217.3	2,484.6
		2	846.5	0	0
		3	0	0	1,156.7
		4	0	0	557.6
Total			17,320.3	2,242.8	8,295.6
Yellowfin sole	≥60	1	6,350.6	9,240.2	1,945.4
		2	4,797.5	0	0
		3	2,716.6	0	4,623.4
		4	0	0	269.3
Total			13,864.7	9,240.2	6,838.1
Greenland turbot	≥60	6	0	0	7.0

Table B-9.--Estimated total number (millions) of flatfish consumed by Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea. Numbers in parentheses indicate cells where no prey size information was available.

Prey	Cod size (cm)	Stratum	Number 1987	1988	1989
Arrowtooth flounder	30-59	1	(0)	0	0
		2	(0)	0	0
		3	(0)	0	0
		5	(0)	0	0
	≥60	1	688.9	0	0
		2	100.0	0	0
		5	652.9	0	3.3
		6	0	0	2.1
Total			(1,441.8)	0	5.4
Flathead sole	30-59	1	0	0	68.4
		3	0	15.1	4.2
		4	69.4	0	48.1
		5	0	8.0	0
		6	0	0	6.2
	≥60	1	140.8	0	0
		3	0	0	292.6
		4	0	0	0.3
		5	0	13.2	33.5
		6	0	0	125.3
Total			210.2	36.3	578.6
Rock sole	30-59	1	317.2	0	3.2
		2	48.3	0	2.7
		3	0	0	256.2
		4	0	23.8	3.9
	≥60	1	715.1	218.9	61.4
		2	22.7	0	0
		3	0	0	17.5
		4	0	0	15.2
Total			1,103.3	242.7	360.1
Yellowfin sole	≥60	1	271.6	87.4	18.0
		2	128.4	0	0
		3	16.3	0	16,882.1
		4	0	0	1.5
Total			416.3	87.4	16,901.6
Greenland turbot	≥60	6	0	0	(0)

Table B-10.--Estimated total biomass (metric tons) of king crabs consumed by Pacific cod by prey species, cod size group, year, and strata for 31 days during months 5 to 6 in the eastern Bering Sea.

Prey	Cod size (cm)	Stratum	Biomass 1987	1988	1989
Lithodidae	30-59	3	158.0	23.1	0
	≥60	1	7.6	0	0.9
		3	0	531.1	16.9
Total			165.6	554.1	17.9
Paralithodes sp.	30-59	1	167.0	0	0
	≥60	1	12.7	0	23.2
		3	0	0	1,830.9
Total			179.7	0	1,854.1
Paralithodes camtschatica (red king crab)	≥60	1	415.7	0	36.0
		2	75.0	0	0
Total			490.7	0	36.0
Paralithodes platypus (blue king crab)	≥60	1	0	0	20.3

Table B-11.--Estimated total number (millions) of king crabs consumed by Pacific cod by prey species, cod size group, year, and strata for 31 days during months 5 to 6 in the eastern Bering Sea. Values in parentheses estimated from an average king crab size of 97.5 mm carapace length.

Prey	Cod size (cm)	Stratum	Number 1987	Number 1988	Number 1989
Lithodidae	30-59	3	(0.25)	(0.04)	0
	≥60	1	(0.01)	0	(<0.01)
		3	0	(0.84)	(0.03)
Total			(0.26)	(0.88)	(<0.04)
Paralithodes sp.	30-59	1	(0.26)	0	0
	≥60	1	(0.02)	0	(0.04)
		3	0	0	(2.89)
Total			(0.28)	0	(2.93)
Paralithodes camtschatica (red king crab)	≥60	1	(0.66)	0	0.07
		2	(0.12)	0	0
Total			(0.78)	0	0.07
Paralithodes platypus (blue king crab)	≥60	1	0	0	0.02

Table B-12.--Estimated total biomass (metric tons) of snow (Chionoecetes opilio) and Tanner (C. bairdi) crabs consumed by Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea. Values in parentheses indicate cells where no prey size information was available. (- = no samples taken.)

Prey	Cod size (cm)		Biomass 1987	Biomass 1988	Biomass 1989
C. opilio	<30	2	274.2	0	0
		4	62.9	0	20.8
	30-59	1	0	1,114.5	401.4
		2	4,478.0	3,386.0	2,881.5
		3	16,220.3	1,471.1	8,057.9
		4	20,062.0	17,434.3	22,923.4
		5	0	0	783.1
		6	16,885.4	1,900.2	9,904.2
	≥60	1	0	0	835.2
		2	8,054.1	18,552.5	6,162.0
		3	12,688.1	0	5,771.8
		4	20,489.0	10,875.6	23,121.9
		5	2,176.0	676.5	6,325.5
		6	49,836.5	5,800.4	29,420.2
Total			151,226.6	61,210.9	116,608.8
C. bairdi	<30	3	440.5	-	0
		4	95.0	0	0
	30-59	1	19.0	379.9	0
		2	67.8	571.4	0
		3	13,375.8	7,461.8	6,395.1
		4	24,451.5	9,489.2	4,434.0
		5	7,421.9	2,442.1	4,129.4
		6	15,476.2	12,037.5	7,068.6
	≥60	1	1,322.3	0	147.5
		2	30.8	0	45.8
		3	5,800.6	5,227.1	9,104.3
		4	3,144.6	955.3	1,152.6
		5	7,833.1	3,853.7	13,697.6
		6	12,526.2	1,526.5	20,163.4
Total			92,005.2	43,944.5	66,338.2

Table B-13.--Estimated total number (millions) of snow (Chionoecetes opilio) and Tanner (C. bairdi) crabs consumed by Pacific cod by prey species, cod size group, year, and strata during months 5 to 9 in the eastern Bering Sea. Values in parentheses indicate cells where no prey size information was available. (- = no samples taken.)

Prey	Cod size (cm)		Number 1987	1988	1989
C. opilio	<30	2	1,443.2	0	0
		4	331.3	0	(0)
	30-59	1	0	22.2	56.2
		2	666.5	685.3	233.4
		3	1,115.9	484.8	1,821.6
		4	2,292.5	7,674.0	6,756.4
		5	0	0	121.4
		6	1,496.6	293.3	1,056.9
	≥60	1	0	0	45.2
		2	324.4	550.3	350.3
		3	362.4	0	372.2
		4	698.7	128.4	1,143.3
		5	24.7	4.7	140.8
		6	1,909.5	137.8	670.1
Total			10,665.7	9,980.8	12,767.8
C. bairdi	<30	3	126.1	-	0
		4	66.6	0	0
	30-59	1	0.3	0.4	0
		2	9.9	400.5	0
		3	2,281.6	828.7	525.8
		4	3,296.3	2,191.4	424.5
		5	1,242.5	308.7	691.3
		6	2,211.1	1,296.1	442.6
	≥60	1	34.8	0	12.0
		2	0.1	0	2.5
		3	210.6	230.2	488.1
		4	154.1	18.2	39.0
		5	666.4	402.3	627.1
		6	354.6	112.4	872.2
Total			10,655.0	5,788.9	4,125.1

Table B-14.--Size ranges of some commercially important prey consumed by Pacific cod during months 5 to 9 in the eastern Bering Sea during 1987 to 1989.

Prey	Predator size (cm)	Prey size range (mm)
Red king crab	≥60	80-95
Blue king crab	≥60	100
Pacific herring	30-59	140-150
	≥60	90-250
Pacific cod	≥60	30-390
Atka mackerel	≥60	260-270
Arrowtooth flounder	≥60	30-170

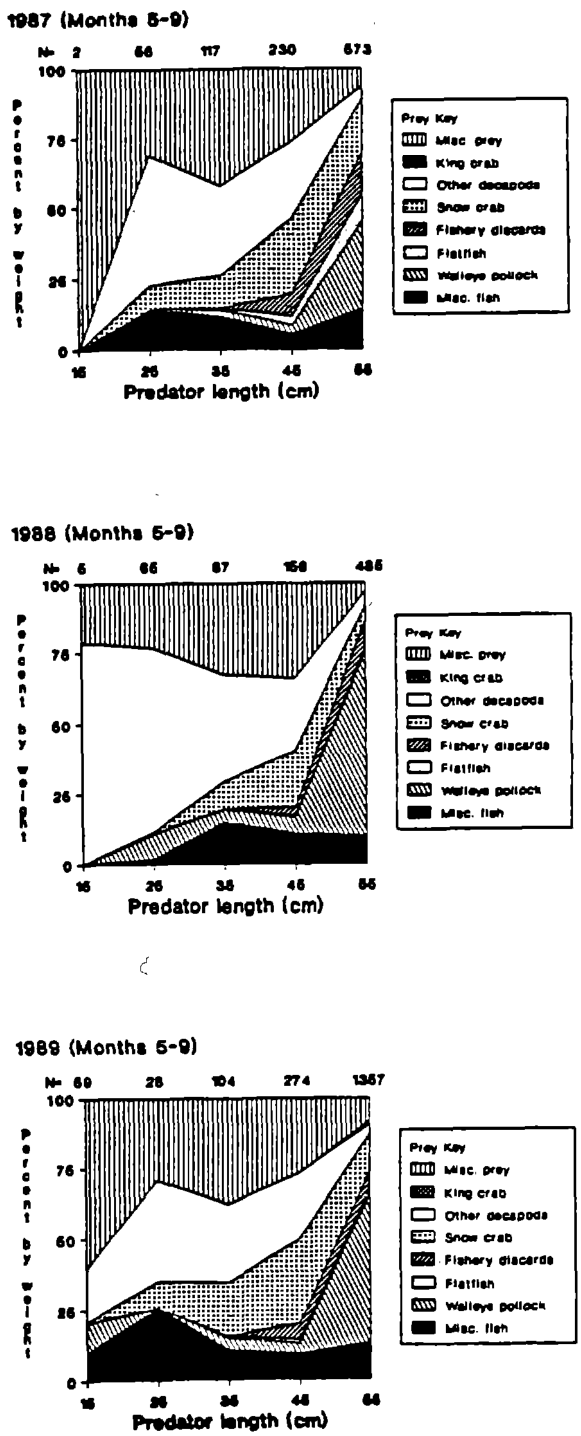

Figure B-l. --Diet composition of Pacific cod, in terms of percent by weight, during months 5 to 9 by year and predator size in the eastern Bering Sea. N = number of stomachs.

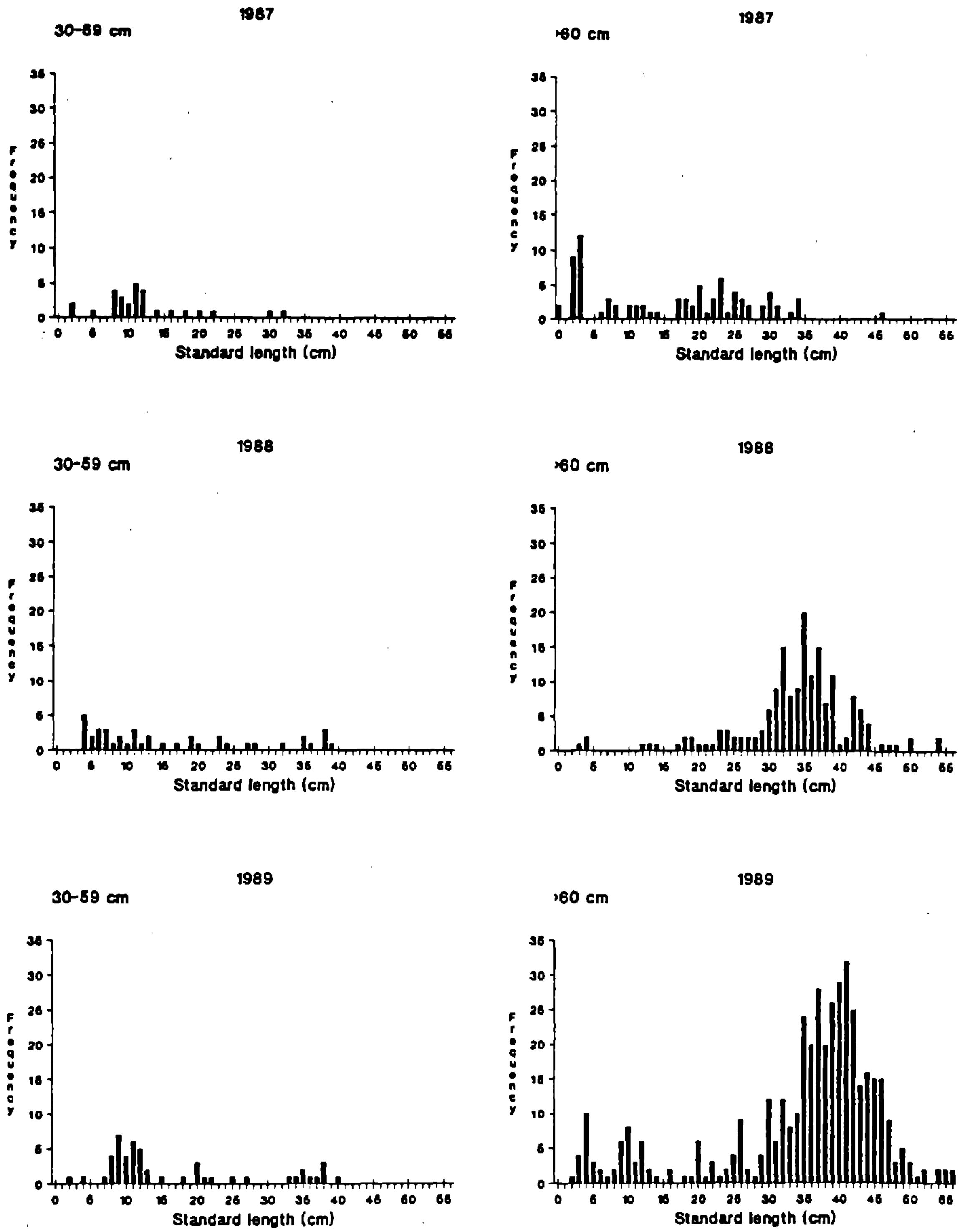

Figure B-2. --Size frequency of walleye pollock as prey in two size groups of Pacific cod from 1987 to 1989 in the eastern Bering Sea.

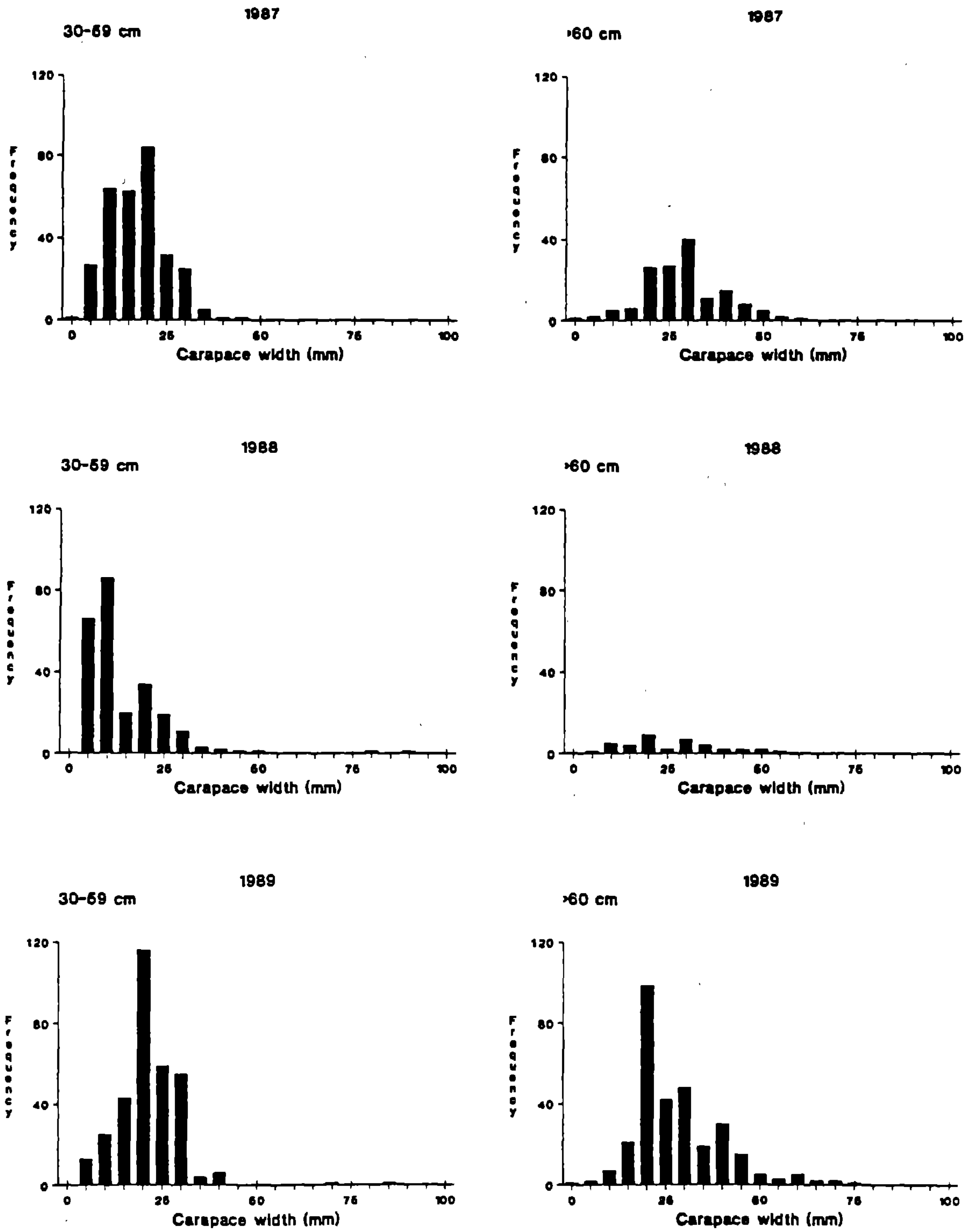

Figure B-3.--Size frequency of <u>Chionoecetes bairdi</u> as prey in two size groups of Pacific cod from 1987 to 1989 in the eastern Bering Sea.

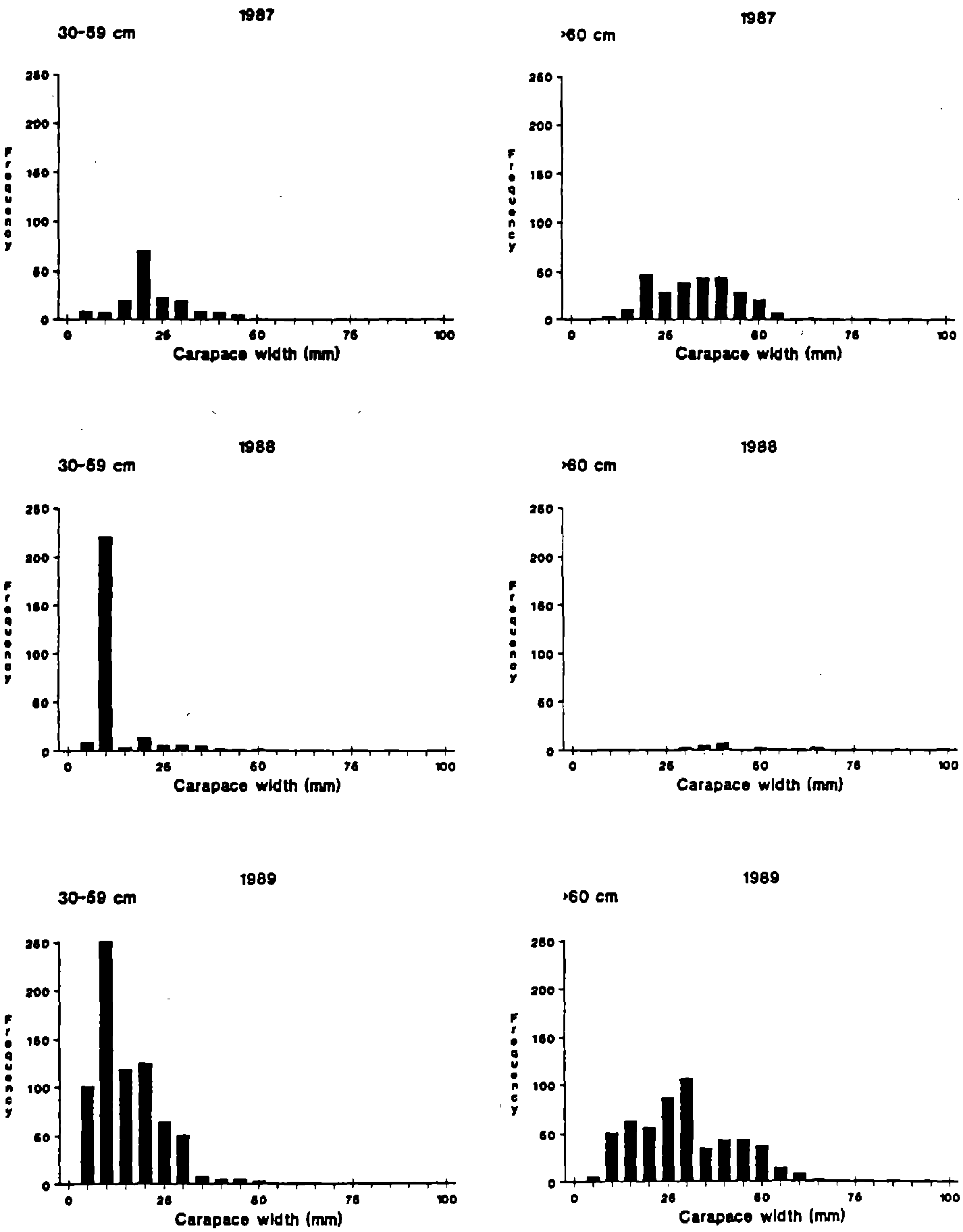

Figure B-4.--Size frequency of <u>Chionoecetes opilio</u> as prey in two size groups of Pacific cod from 1987 to 1989 in the eastern Bering Sea.

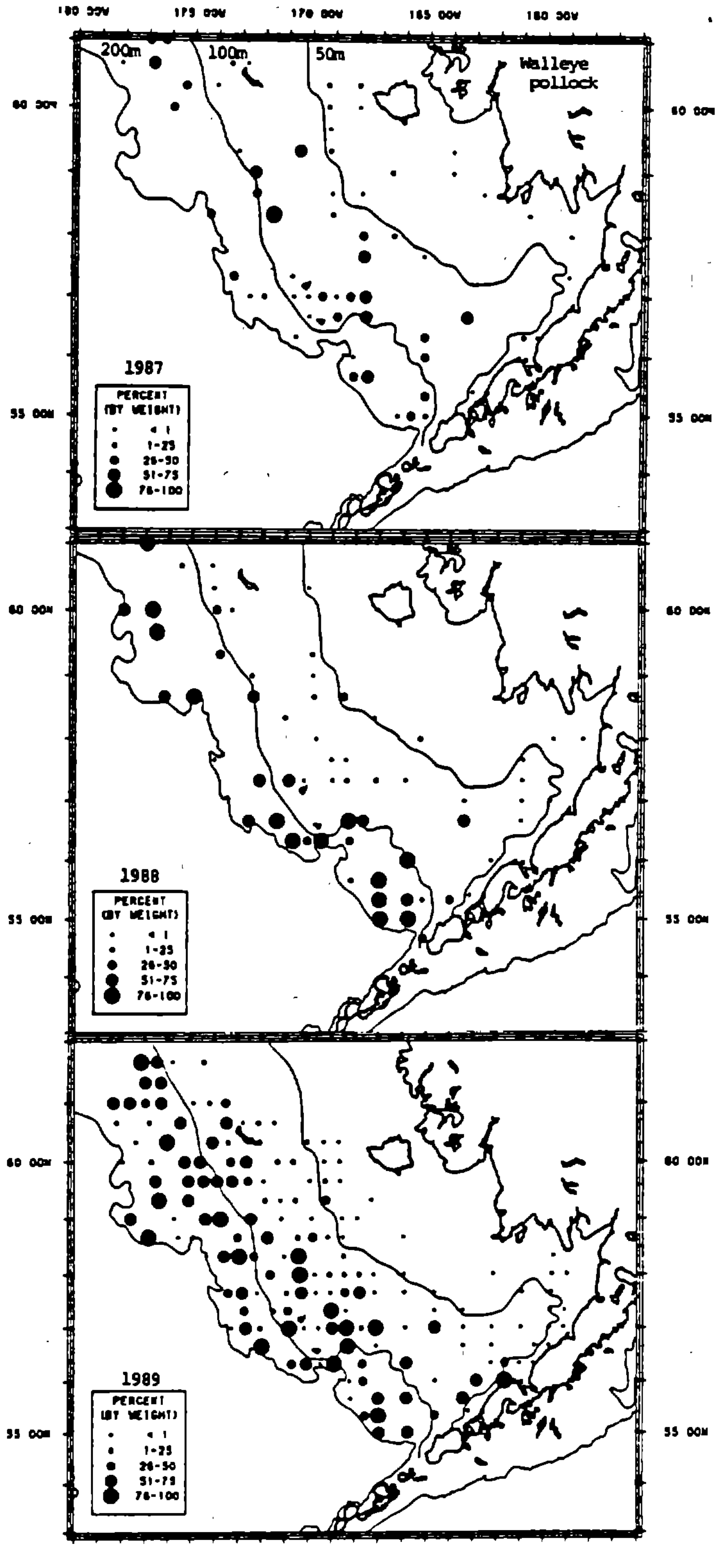

Figure B-5. --Percent by weight of walleye pollock in the diet of Pacific cod by sampling station during months 5 to 9 from 1987 to 1989.

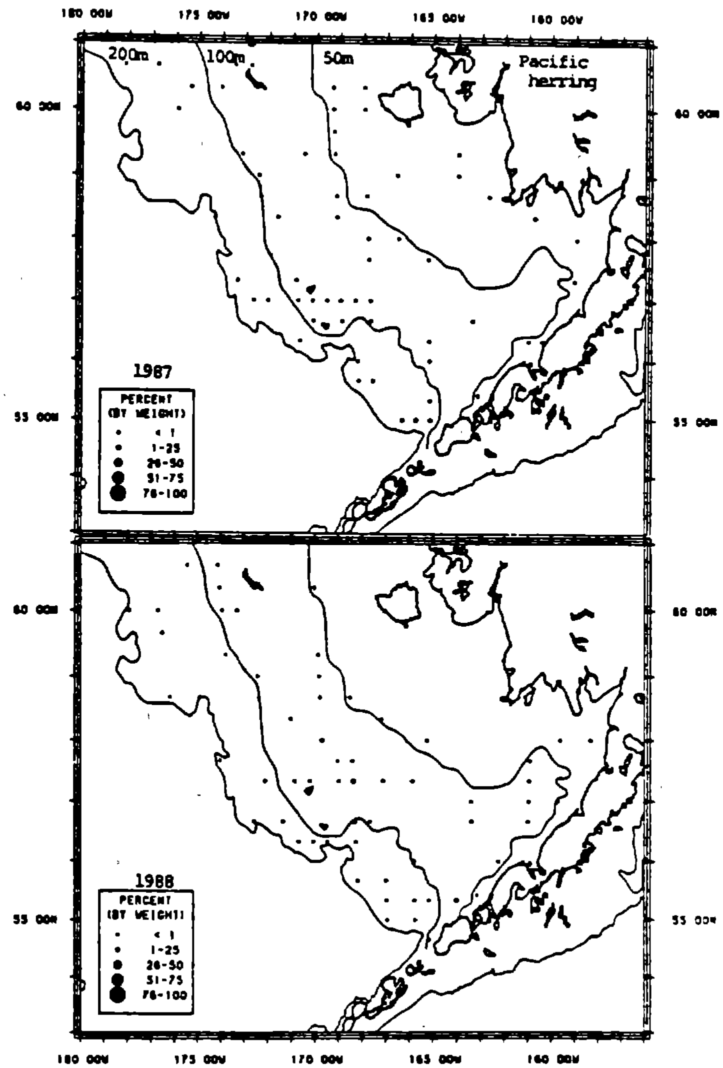

Figure B-6.--Percent by weight of Pacific herring in the diet of Pacific cod by sampling station during months 5 to 9 from 1987 to 1989.

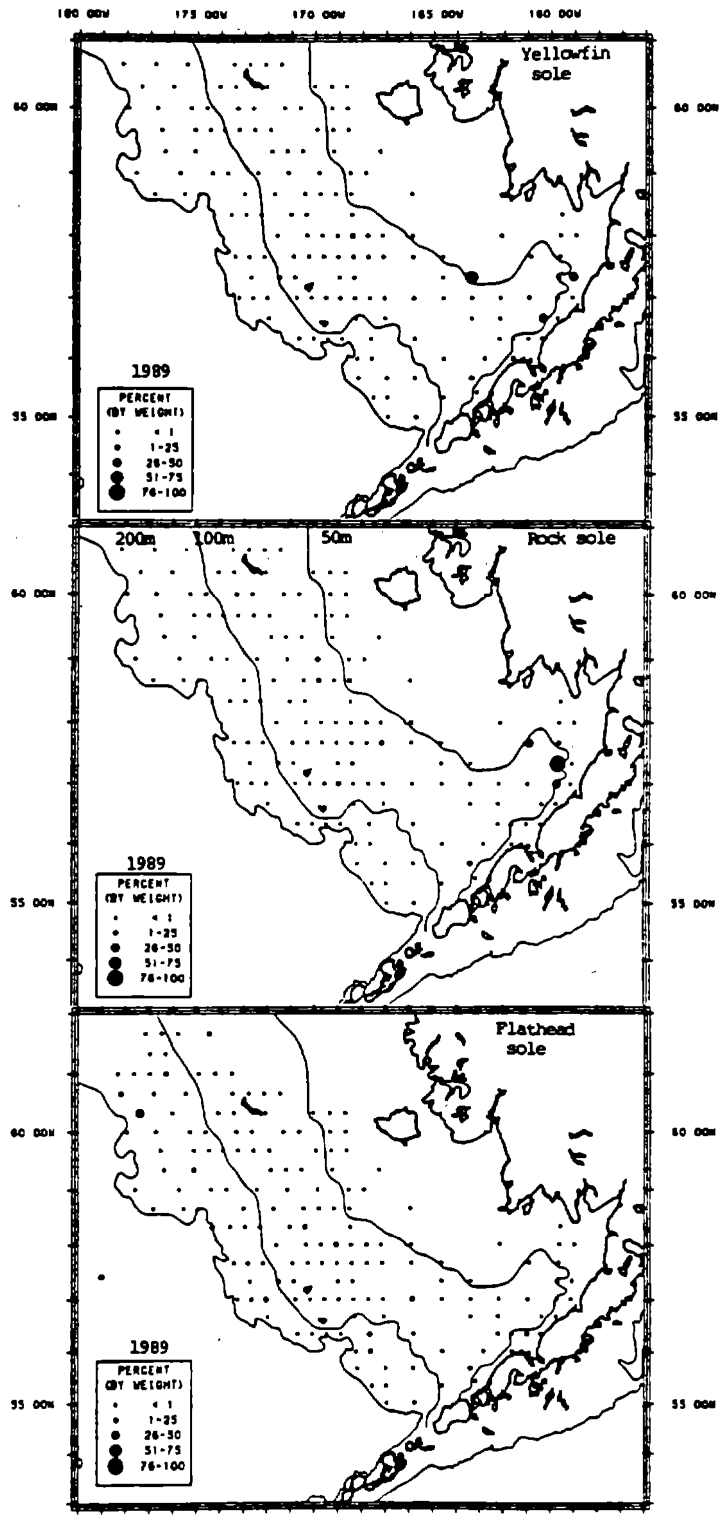

Figure B-7. --Percent by weight of yellowfin sole, rock sole, and flathead sole in the diet of Pacific cod by sampling station during months 5 to 9 in 1989.

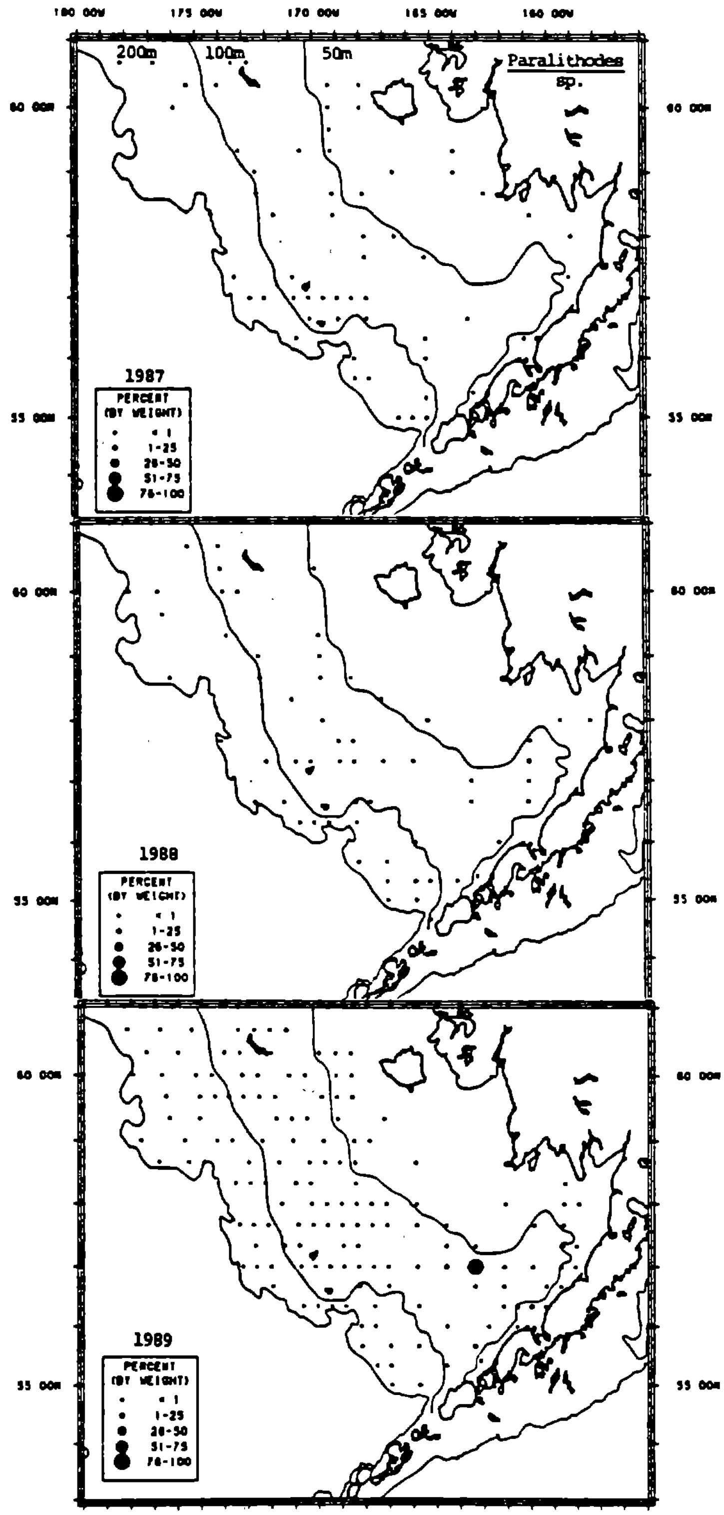

Figure B-8.--Percent by weight of king crab (<u>Paralithodes</u> sp.) in the diet of Pacific cod by sampling station during months 5 to 9 from 1987 to 1989.

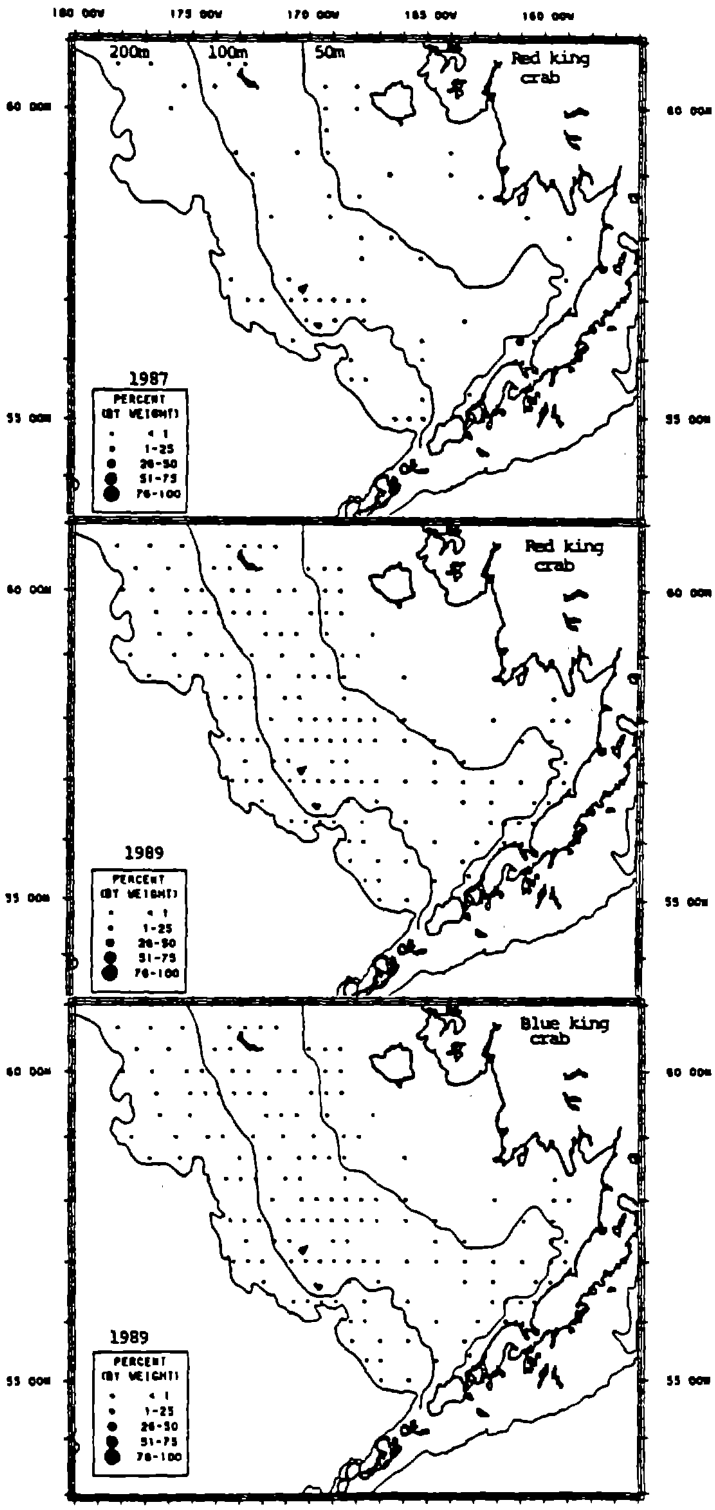

Figure B-9. --Percent by weight of red king crab and blue king crab in the diet of Pacific cod by sampling station during months 5 to 9 by year.

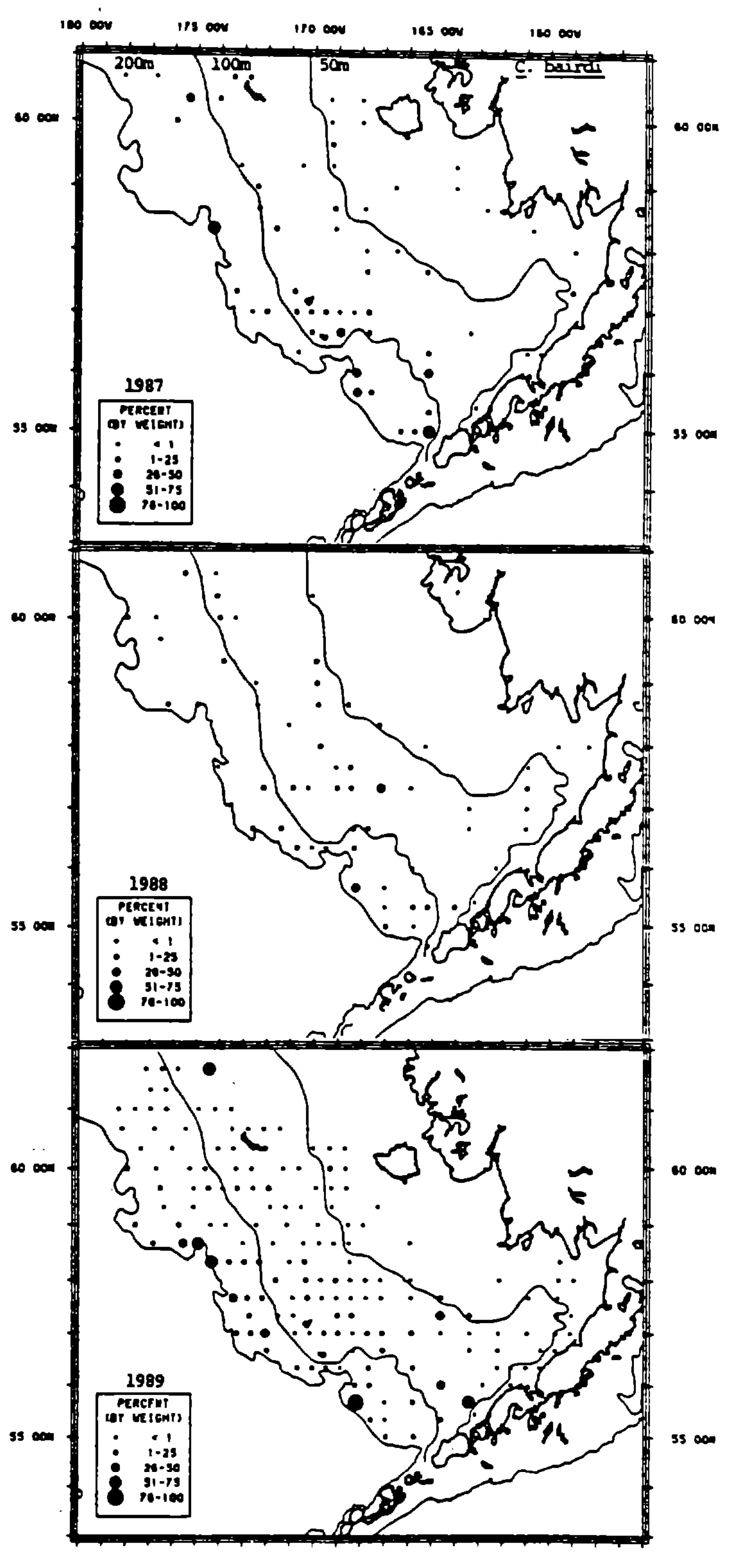

Figure B-10. --Percent by weight of Tanner crab, Chionoecetes bairdi, in the diet of Pacific cod by sampling station during months 5 to 9 from 1987 to 1989.

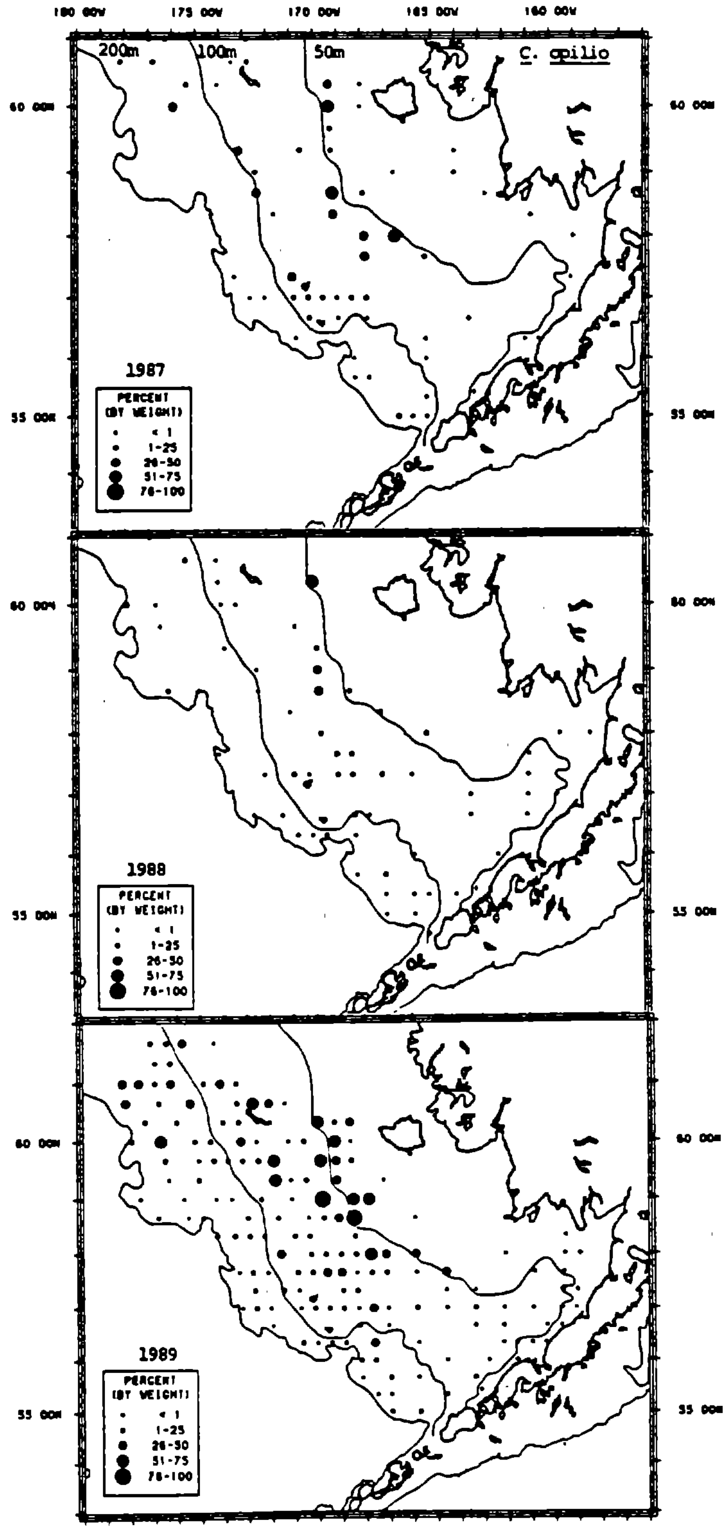

Figure B-11.--Percent by weight of snow crab, Chionoecetes opilio, in the diet of Pacific cod by sampling station during months 5 to 9 from 1987 to 1989.

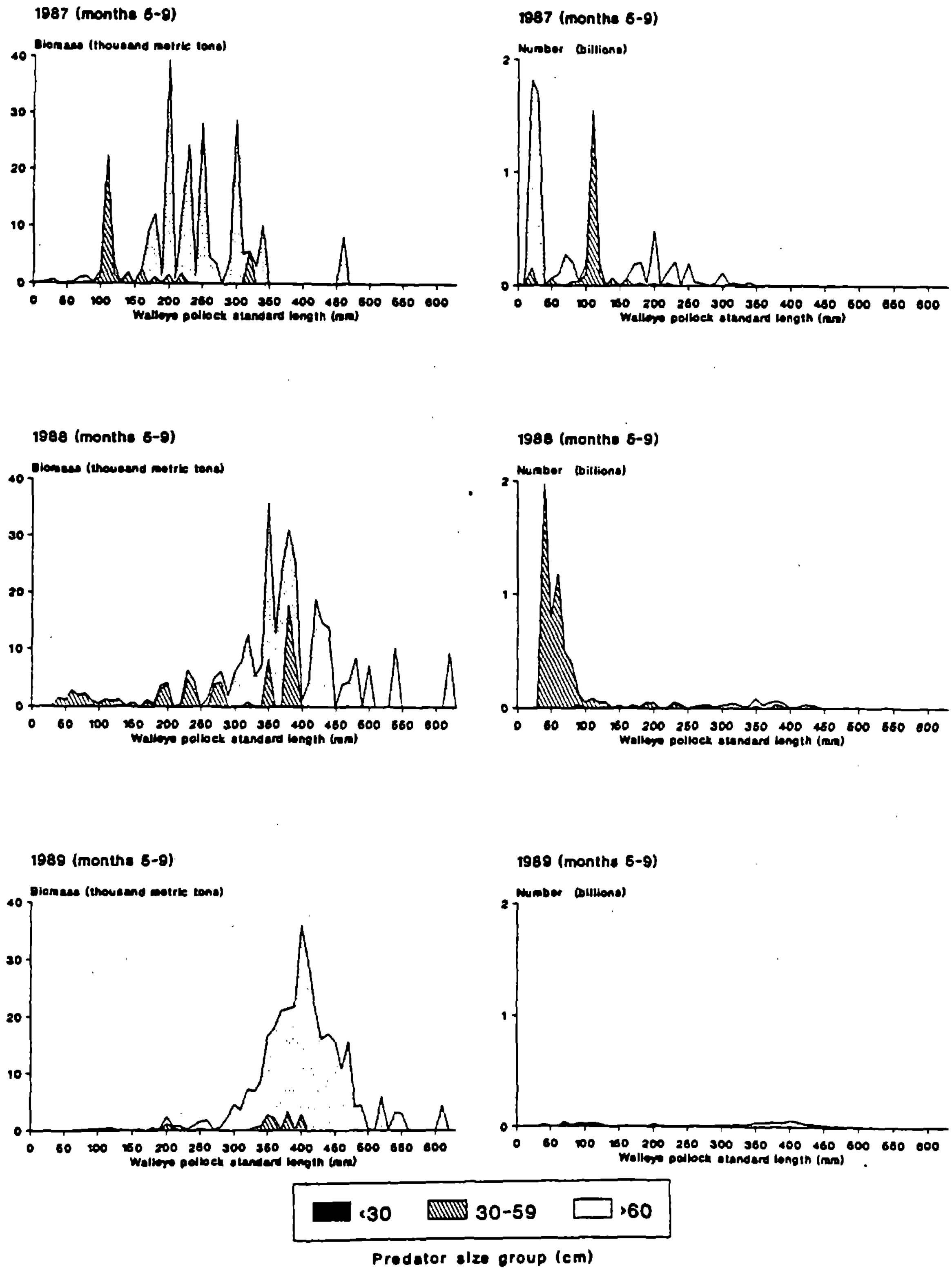

Figure B-12. --Biomass and number of walleye pollock consumed by three size groups of Pacific cod during months 5 to 9 from 1987 to 1989 in the eastern Bering Sea by prey size.

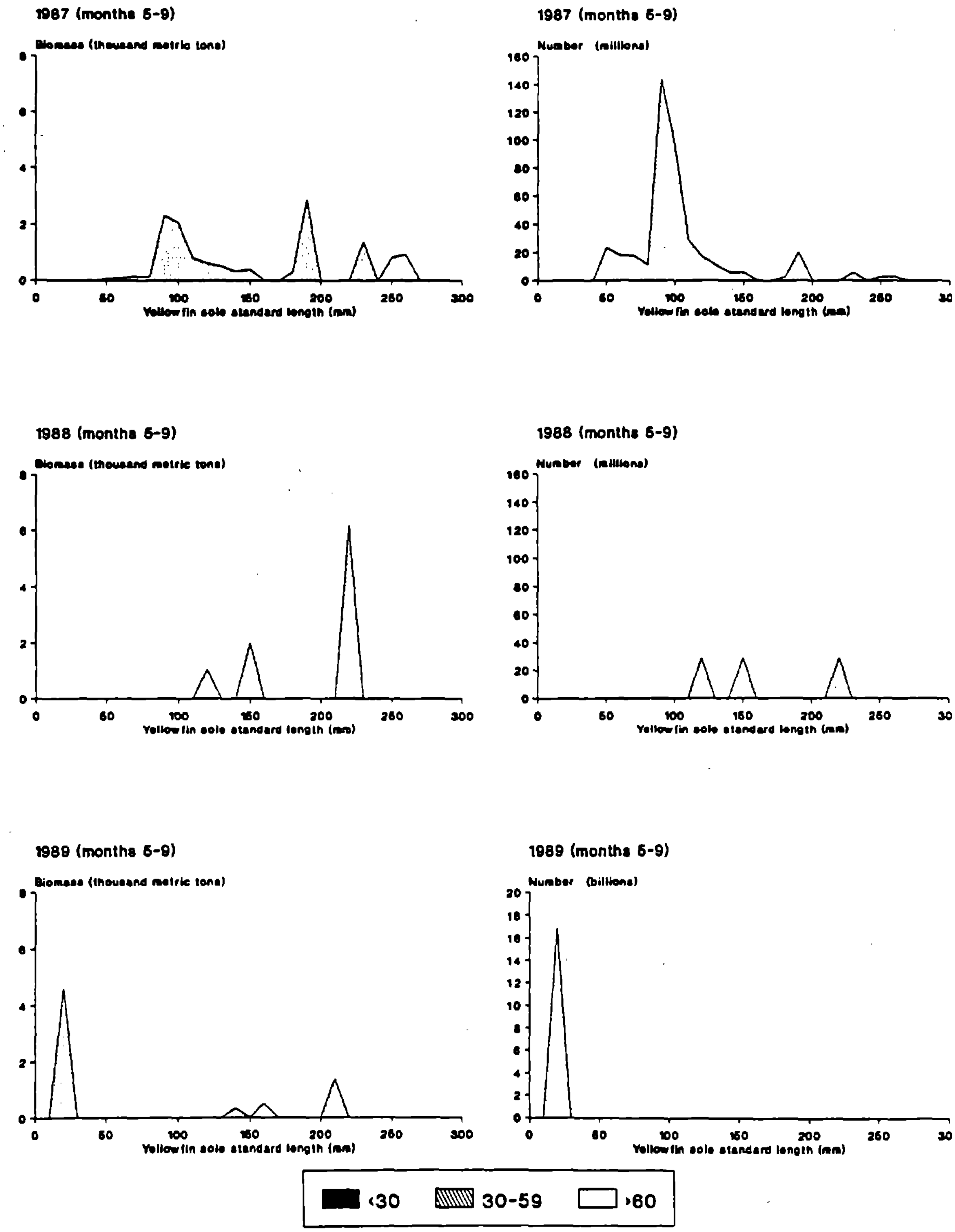

Figure B-13. --Biomass and number of yellowfin sole consumed by three size groups of Pacific cod during months 5 to 9 from 1987 to 1989 in the eastern Bering Sea by prey size.

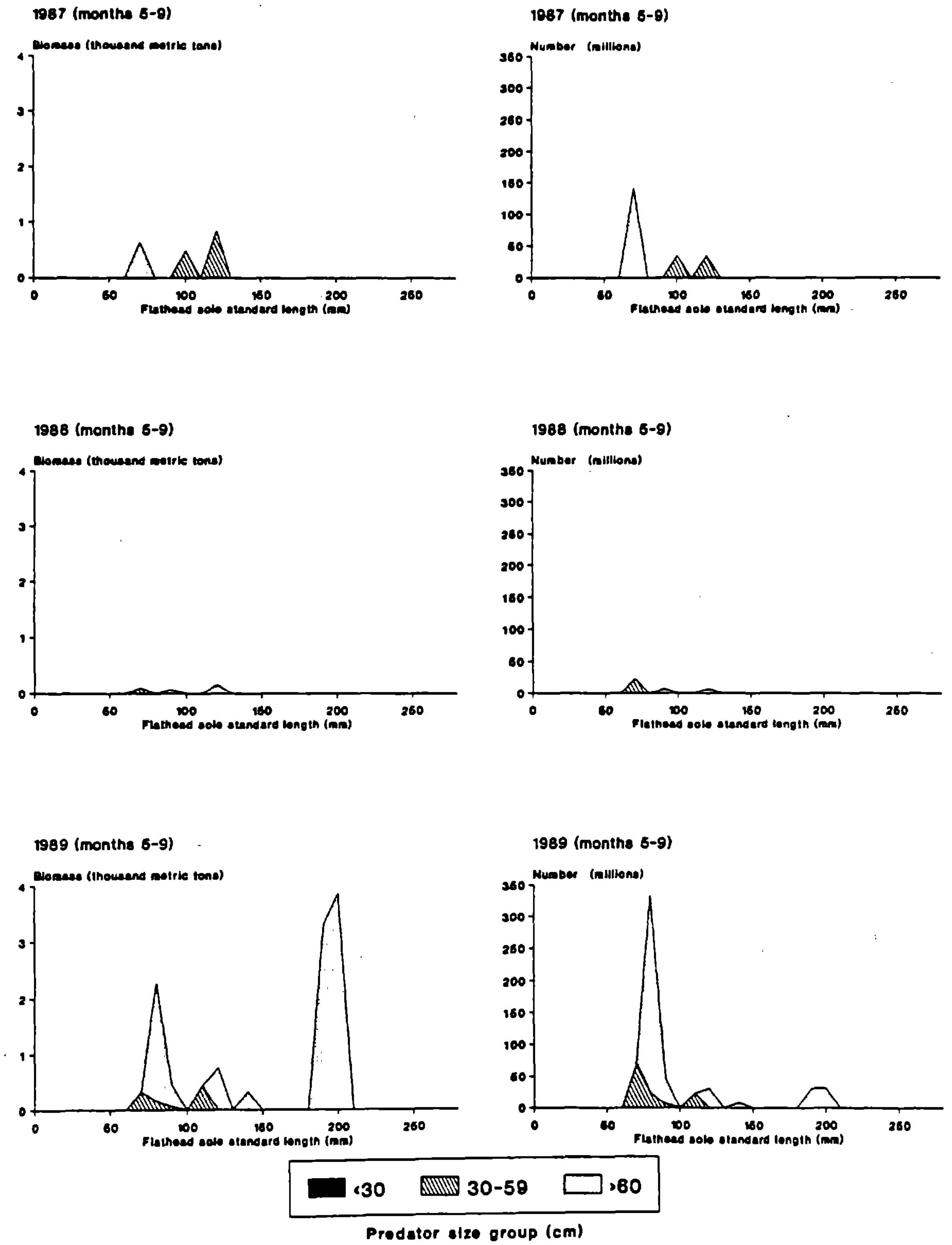

Figure-B-14. --Biomass and number of flathead sole consumed by three size groups of Pacific cod during months 5 to 9 from 1987 to 1989 in the eastern Bering Sea by prey size.

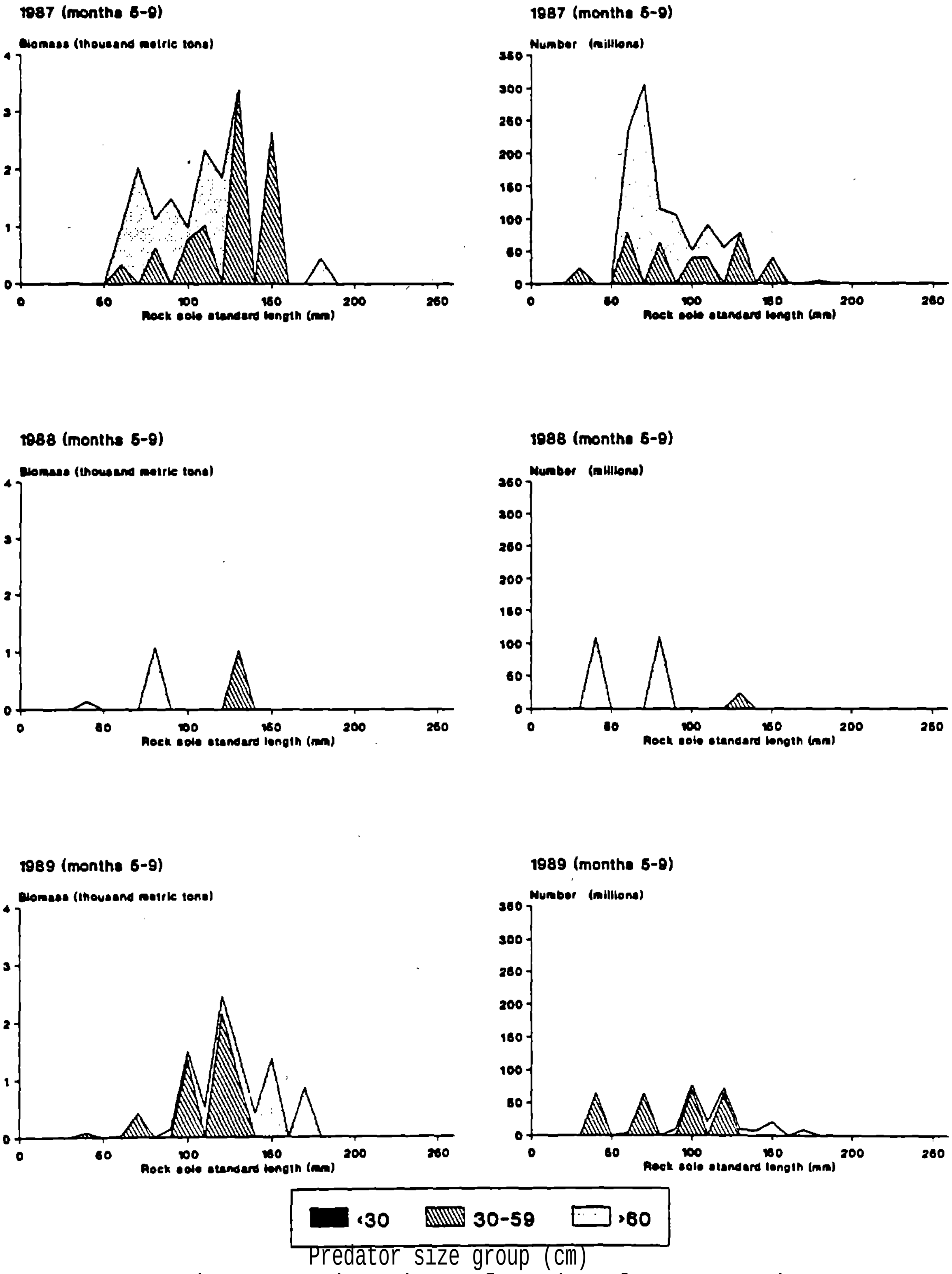

Figure B-15. --Biomass and number of rock sole consumed by three size groups of Pacific cod during months 5 to 9 from 1987 to 1989 in the eastern Bering Sea by prey size.

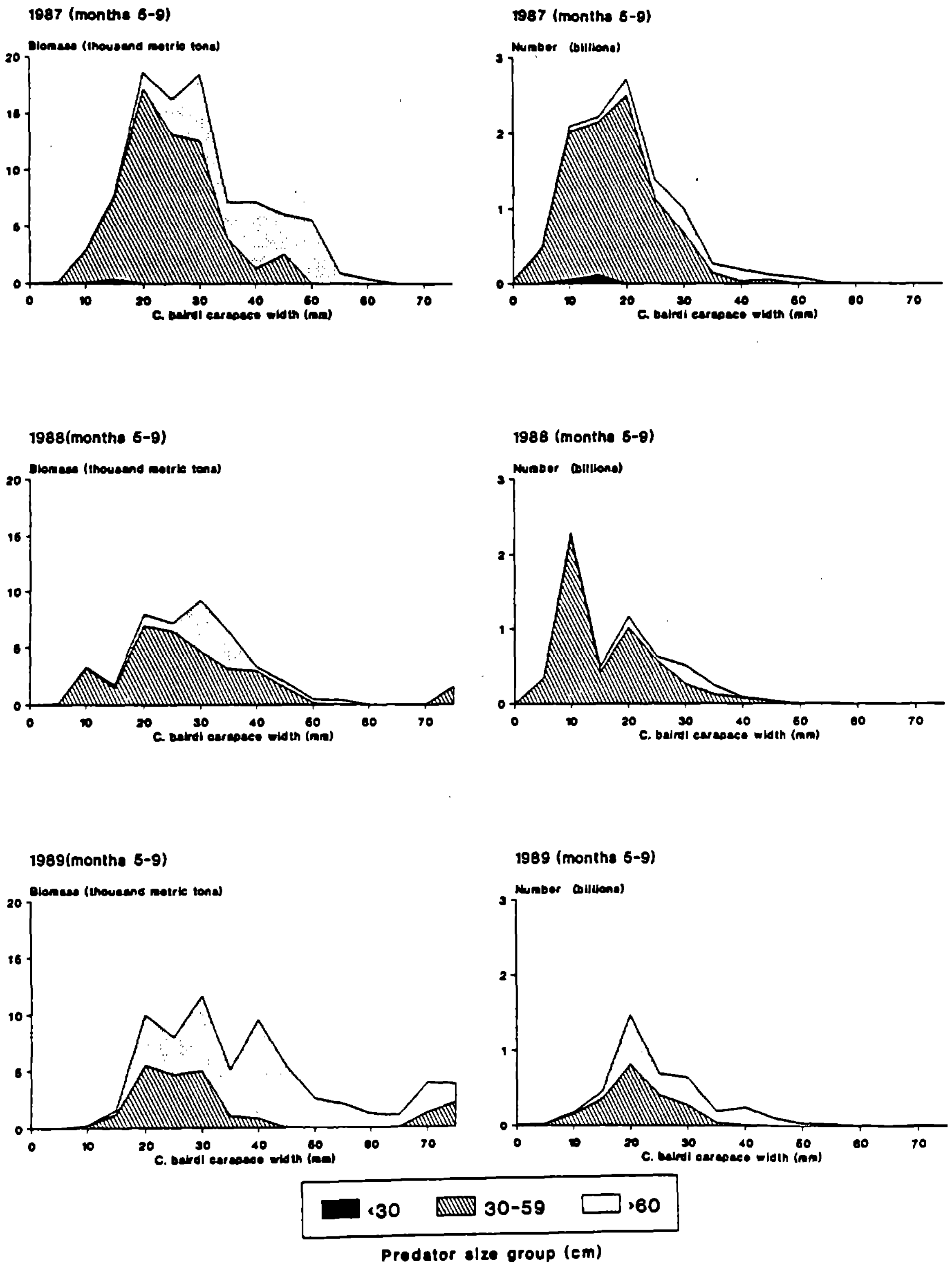

Figure B-16.--Biomass and number of Tanner crab, Chionoecetes bairdi, consumed by three size groups of Pacific cod during months 5 to 9 from 1987 to 1989 in the eastern Bering Sea by prey size.

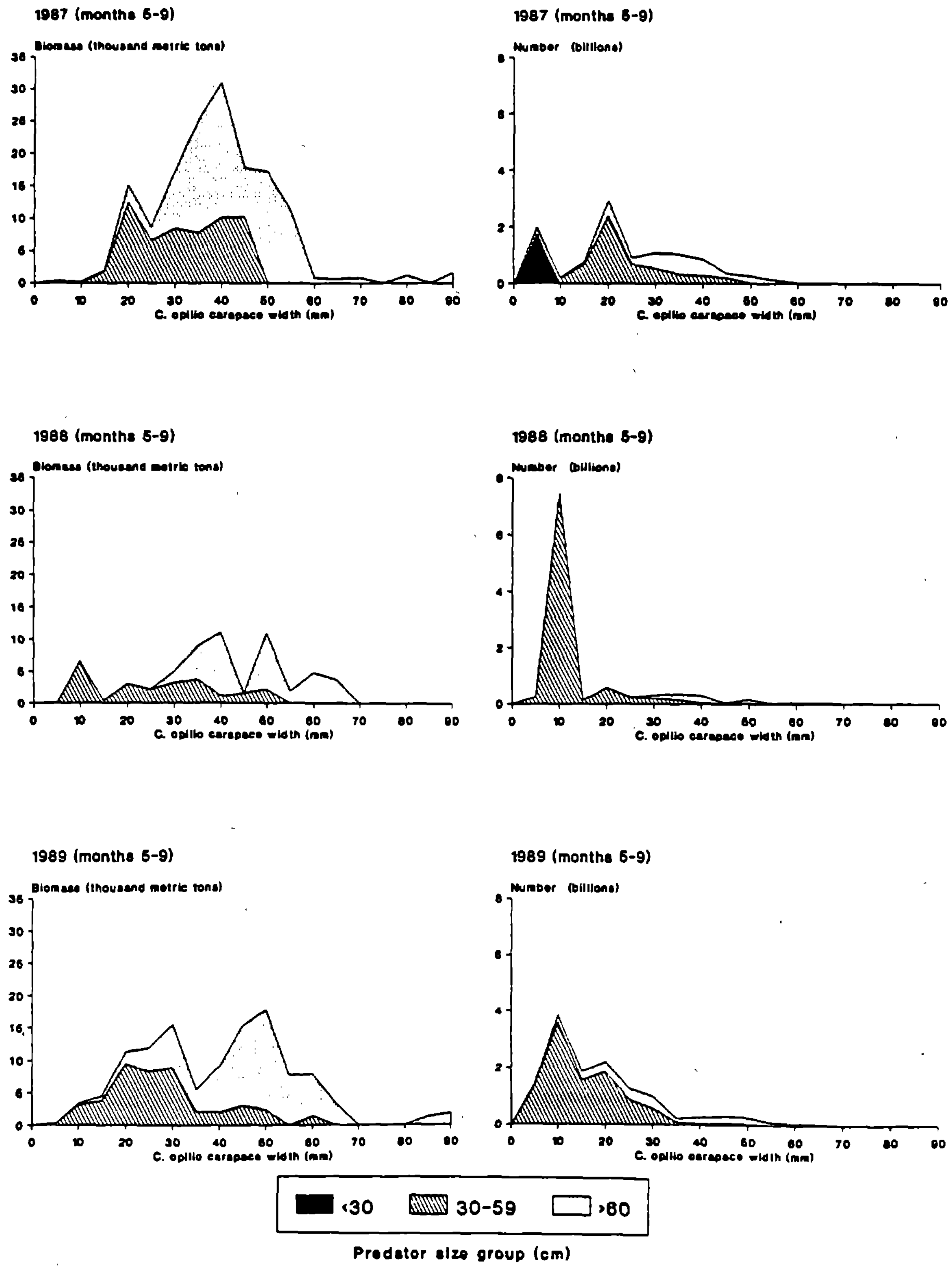

Figure B-17. --Biomass and number of snow crab, Chionoecetes opilio, consumed by three size groups of Pacific cod during months 5 to 9 from 1987 to 1989 in the eastern Bering Sea by prey size.

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APPENDIX C

Yellowfin Sole, Alaska Plaice, Rock Sole, and Flathead Sole

Appendix C presents biomass, food habits, prey composition, prey size, and prey consumption estimates for yellowfin sole, Alaska plaice, rock sole, and flathead sole during months 5 through 9 from 1987, 1988, and 1989 in the eastern Bering Sea.

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Table C-1.--Yellowfin sole, flathead sole, and rock sole biomass estimates, in metric tons, by year and stratum.

Predator	Stratum	Biomass 1987	1988	1989
Yellowfin sole	1	1,310,926	1,212,723	1,057,890
	2	285,203	328,480	360,609
	3	919,578	878,994	559,036
	4	159,153	235,803	221,747
	5	112	0	0
	6	0	113	18
Total		2,674,972	2,656,113	2,199,300
Flathead sole	1	18,319	13,667	8,010
	2	965	628	354
	3	144,658	201,515	190,908
	4	41,754	46,884	62,302
	5	69,924	98,571	87,241
	6	130,074	196,218	174,415
Total		405,698	557,483	523,230
Rock sole	1	563,123	878,172	505,172
	2	83,831	114,095	108,695
	3	355,542	590,458	336,243
	4	198,298	265,793	324,030
	5	5,294	3,633	2,016
	6	43,273	51,393	42,060
Total		1,249,361	1,903,544	1,318,316

Table C-2.--Mean percent by weight (%W) and standard error (SE) of snow crab in the diet of yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Dash (-) indicates stratum where predator was not sampled.

Predator	Stratum	1987		1988		1989	
		%W	SE	%W	SE	%W	SE
Yellowfin sole	1	0	0	0	0	0	0
	2	0	0	0.28	0.25	0	0
	3	0	0	0	0	0	0
	4	0	0	0.27	0.19	0	0
	5	-	-	-	-	-	-
	6	-	-	-	-	-	-
Flathead sole	1	0	0	0	0	0	0
	2	-	-	-	-	-	-
	3	0	0	0	0	1.83	1.83
	4	0	0	0	0	1.25	0.70
	5	0	0	0	0	0	0
	6	0	0	0	0	0.12	0.10
Rock sole	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	-	-	0	0	0	0
	4	0	0	0	0	0.54	0.54
	5	0	0	-	-	-	-
	6	0.03	0.03	0	0	0	0

Table C-3.--Mean percent by weight (%W) and standard error (SE) of Tanner crab in the diet of yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Dash (-) indicates stratum where predator was not sampled.

		1987		1988		1989	
Predator	**Stratum**	**%W**	**SE**	**%W**	**SE**	**%W**	**SE**
Yellowfin sole	1	0	0	0	0	0.51	0.51
	2	0.12	0.12	0	0	0	0
	3	0.01	0.01	0	0	0	0
	4	2.67	2.67	0	0	2.19	2.19
	5	-	-	-	-	-	-
	6	-	-	-	-	-	-
Flathead sole	1	0	0	0	0	0	0
	2	-	-	-	-	-	-
	3	5.23	5.03	0.19	0.19	0.13	0.13
	4	0.88	0.88	0	0	3.00	2.51
	5	2.61	2.21	0.44	0.44	3.43	2.01
	6	1.32	0.78	1.62	1.62	2.22	1.27
Rock sole	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	-	-	0	0	0	0
	4	0	0	2.67	2.67	0	0
	5	0	0	-	-	-	-
	6	0.03	0.03	0	0	0	0

Table C-4.--Mean percent by weight (%W) and standard error (SE) of walleye pollock in the diet of yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Dash (-) indicates stratum where predator was not sampled.

Predator	Stratum	1987		1988		1989	
		%W	SE	%W	SE	%W	SE
Yellowfin sole	1	0	0	0	0	0.83	0.60
	2	0.75	0.75	0	0	2.43	2.43
	3	0.01	0.01	2.55	1.61	0	0
	4	0.07	0.07	0	0	0	0
	5	-	-	-	-	-	-
	6	-	-	-	-	-	-
Flathead sole	1	13.00	10.31	0	0	7.74	7.74
	2	-	-	-	-	-	-
	3	0	0	0	0	4.50	3.38
	4	0	0	15.20	15.20	6.41	3.78
	5	6.61	4.38	0	0	0	0
	6	7.69	5.11	3.44	3.44	0	0
Rock sole	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	-	-	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	-	-	-	-
	6	0	0	0.10	0.10	0	0

Table C-5.--Estimated snow crab biomass (metric tons) consumed by yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated. Dash (-) indicates stratum where predator was not sampled.

		Biomass		
Predator	Stratum	1987	1988	1989
Yellowfin sole	1	0	0	0
	2	0	565.90	0
	3	0	0	0
	4	0	396.27	0
	5	-	-	-
	6	-	-	-
Total		0	962.17	0
Flathead sole	1	0	0	0
	2	-	-	-
	3	0	0	3,746.00
	4	0	0	466.70
	5	0	0	0
	6	0	0	229.08
Total		0	0	4,441.78
Rock sole	1	0	0	0
	2	0	0	0
	3	-	0	0
	4	0	0	1,871.27
	5	0	-	-
	6	(15.48)	0	0
Total		15.48	0	1,871.27

Table C-6.--Estimated number of snow crab (millions) consumed by yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated. Dash (-) indicates stratum where predator was not sampled.

Predator	Stratum	Number 1987	1988	1989
Yellowfin sole	1	0	0	0
	2	0	641.02	0
	3	0	0	0
	4	0	1,248.26	0
	5	-	-	-
	6	-	-	-
Total		0	1,889.28	0
Flathead sole	1	0	0	0
	2	-	-	-
	3	0	0	4,242.31
	4	0	0	1,090.02
	5	0	0	0
	6	0	0	427.08
Total		0	0	5,760.41
Rock sole	1	0	0	0
	2	0	0	0
	3	-	0	0
	4	0	0	2,119.77
	5	0	-	-
	6	(0)	0	0
Total		0	0	2,119.77

Table C-7.--Estimated Tanner crab biomass (metric tons) consumed by yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated. Dash (-) indicates stratum where predator was not sampled.

Predator	Stratum	Biomass 1987	1988	1989
Yellowfin sole	1	0	0	3,320.15
	2	201.03	0	0
	3	33.50	0	0
	4	2,603.86	0	2,968.70
	5	-	-	-
	6	-	-	-
Total		2,838.49	0	6,288.85
Flathead sole	1	0	0	0
	2	-	-	-
	3	8,099.34	409.39	255.90
	4	392.32	0	2,004.07
	5	1,953.74	465.65	3,207.98
	6	1,832.49	3,400.85	4,144.50
Total		12,277.89	4,257.89	9,612.45
Rock sole	1	0	0	0
	2	0	0	0
	3	-	0	0
	4	0	7,604.28	0
	5	0	-	-
	6	12.73	0	0
Total		12.73	7,604.28	0

Table C-9.--Estimated number of Tanner crab (millions) consumed by yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated. Dash (-) indicates stratum where predator was not sampled.

Predator	Stratum	Number		
		1987	1988	1989
Yellowfin sole	1	0	0	8,981.68
	2	544.10	0	0
	3	1,610.15	0	0
	4	3,425.59	0	8,030.96
	5	-	-	-
	6	-	-	-
Total		5,579.84	0	17,012.64
Flathead sole	1	0	0	0
	2	-	-	-
	3	21,910.39	289.97	73.29
	4	159.54	0	705.57
	5	1,965.42	326.41	2,577.17
	6	2,342.69	2,925.82	2,545.42
Total		26,378.04	3,539.29	5,901.45
Rock sole	1	0	0	0
	2	0	0	0
	3	-	0	0
	4	0	5,330.40	0
	5	0	-	-
	6	8.93	0	0
Total		8.93	5,330.40	0

Table C-9. --Estimated walleye pollock biomass (metric tons) consumed by yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated. Dash (-) indicates stratum where predator was not sampled.

Predator	Stratum	Biomass 1987	Biomass 1988	Biomass 1989
Yellowfin sole	1	0	0	5,360.96
	2	1,312.35	0	5,369.39
	3	58.92	13,702.13	0
	4	67.63	0	0
	5	-	-	-
	6	-	-	-
Total		1,438.90	13,702.13	10,730.35
Flathead sole	1	2,550.40	0	663.75
	2	-	-	-
	3	0	0	9,199.71
	4	0	7,632.15	4,275.92
	5	4,948.54	0	0
	6	10,718.02	7,222.54	0
Total		18,216.96	14,854.69	14,139.38
Rock sole	1	0	0	0
	2	0	0	0
	3	-	0	0
	4	0	0	0
	5	0	-	-
	6	44.91	0	0
Total		44.91	0	0

Table C-10.--Estimated number of walleye pollock (millions) consumed by yellowfin sole, flathead sole, and rock sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated. Dash (-) indicates stratum where predator was not sampled.

Predator	Stratum	Number 1987	Number 1988	Number 1989
Yellowfin sole	1	0	0	6,814.47
	2	232.27	0	3,663.47
	3	10.28	32,243.86	0
	4	3,416.19	0	0
	5	-	-	-
	6	-	-	-
Total		3,658.74	32,243.86	10,477.94
Flathead sole	1	319.75	0	173.17
	2	-	-	-
	3	0	0	14,924.73
	4	0	956.87	607.09
	5	2,822.15	0	0
	6	10,580.91	905.51	0
Total		13,722.81	1,862.38	15,704.99
Rock sole	1	0	0	0
	2	0	0	0
	3	-	0	0
	4	0	0	0
	5	0	-	-
	6	124.41	0	0
Total		124.41	0	0

Table C-11. --Estimated biomass (metric tons) of miscellaneous species consumed by yellowfin sole and flathead sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated using conventional methods.

Predator	Prey	Stratum	Biomass 1987	1988	1989
Yellowfin sole	Rock sole	1	0	0	3,410.56
		2	0	399.31	0
	Paralithodes sp.	4	0	14.07	0
Flathead sole	Rock sole	1	1,011.80	125.86	0
		3	0	(2,055.45)	0
	Flathead sole	3	0	1,102.87	0

Table C-12.--Estimated number (millions) of miscellaneous species consumed by yellowfin sole and flathead sole by year and stratum, months 5 through 9. Numbers in parentheses correspond to year-stratum combinations where number consumed could not be calculated using conventional methods.

Predator	Prey	Stratum	Number 1987	Number 1988	Number 1989
Yellowfin sole	Rock sole	1	0	0	952.23
		2	0	702.75	0
	Paralithodes sp.	4	0	6.83	0
Flathead sole	Rock sole	1	416.30	661.18	0
		3	0	(0)	0
	Flathead sole	3	0	672.93	0

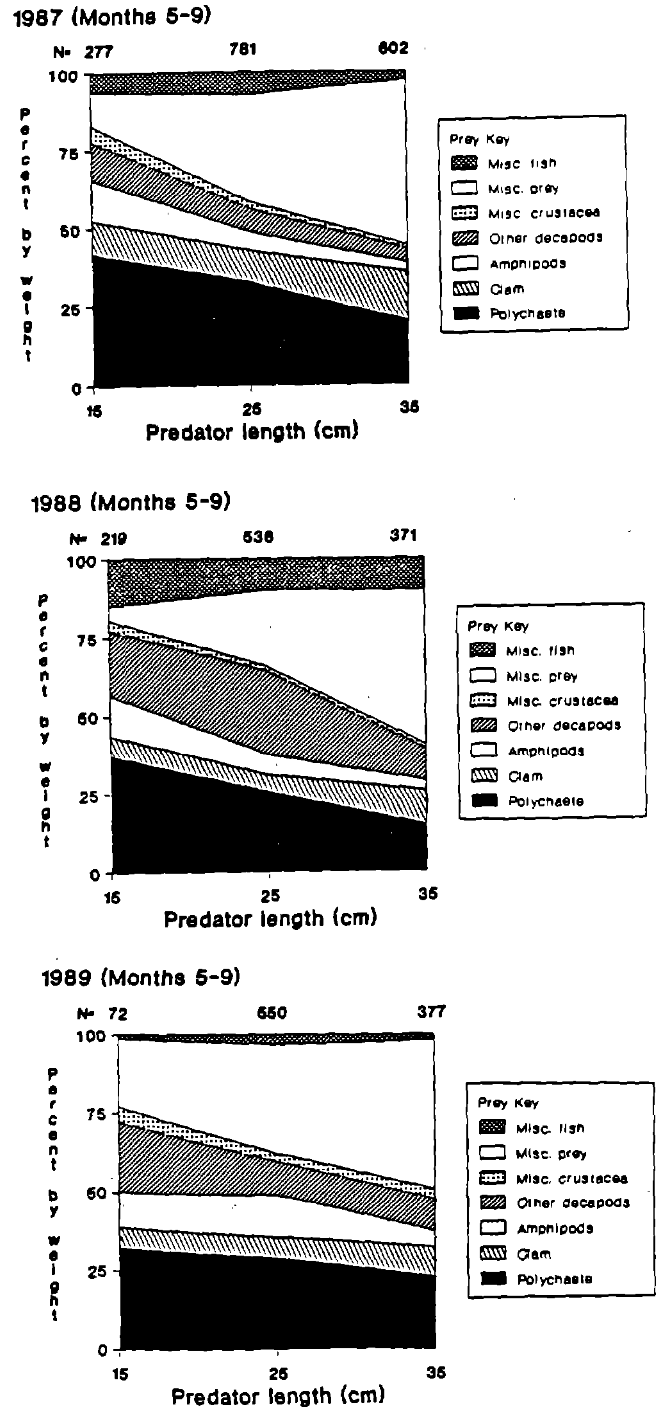

Figure C-1.--Annual diet composition of yellowfin sole in terms of percent by weight, months 5 through 9, by predator size in the eastern Bering Sea, 1987-1989. N=number of stomach samples.

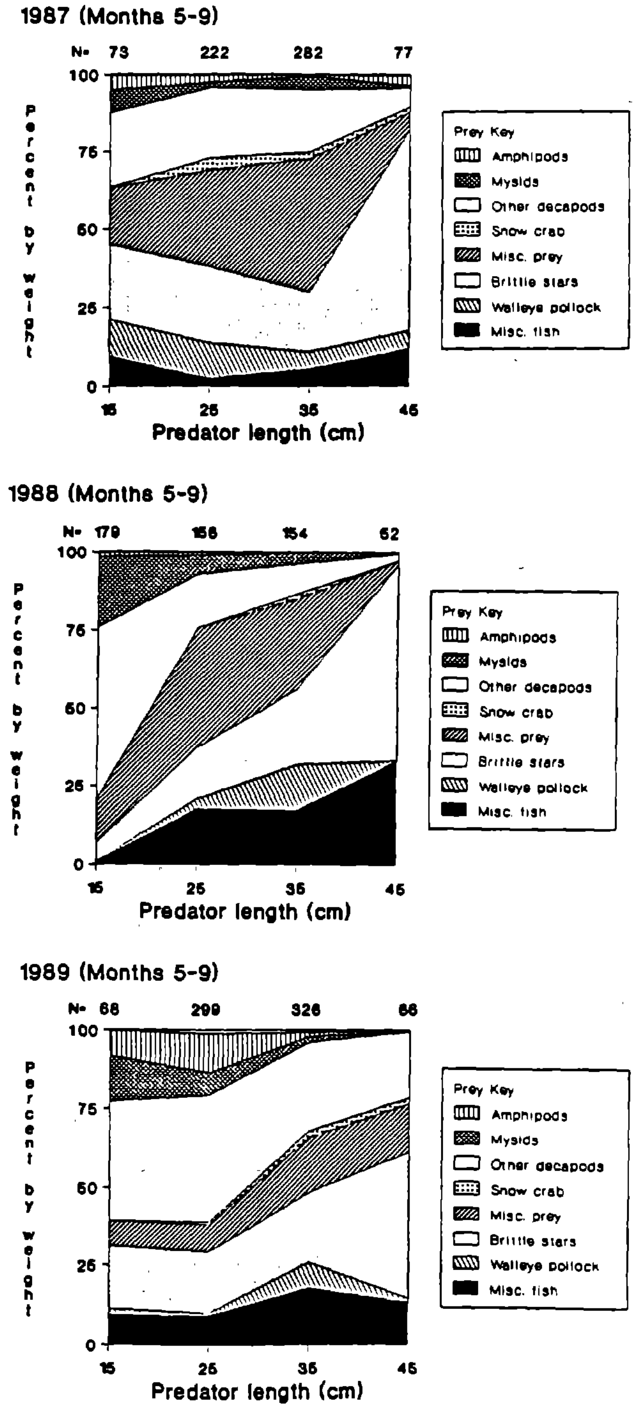

Figure C-2. --Annual diet composition of flathead sole in terms of percent by weight, months 5 through 9, by predator size in the eastern Bering Sea, 1987-1989. N=number of stomach samples.

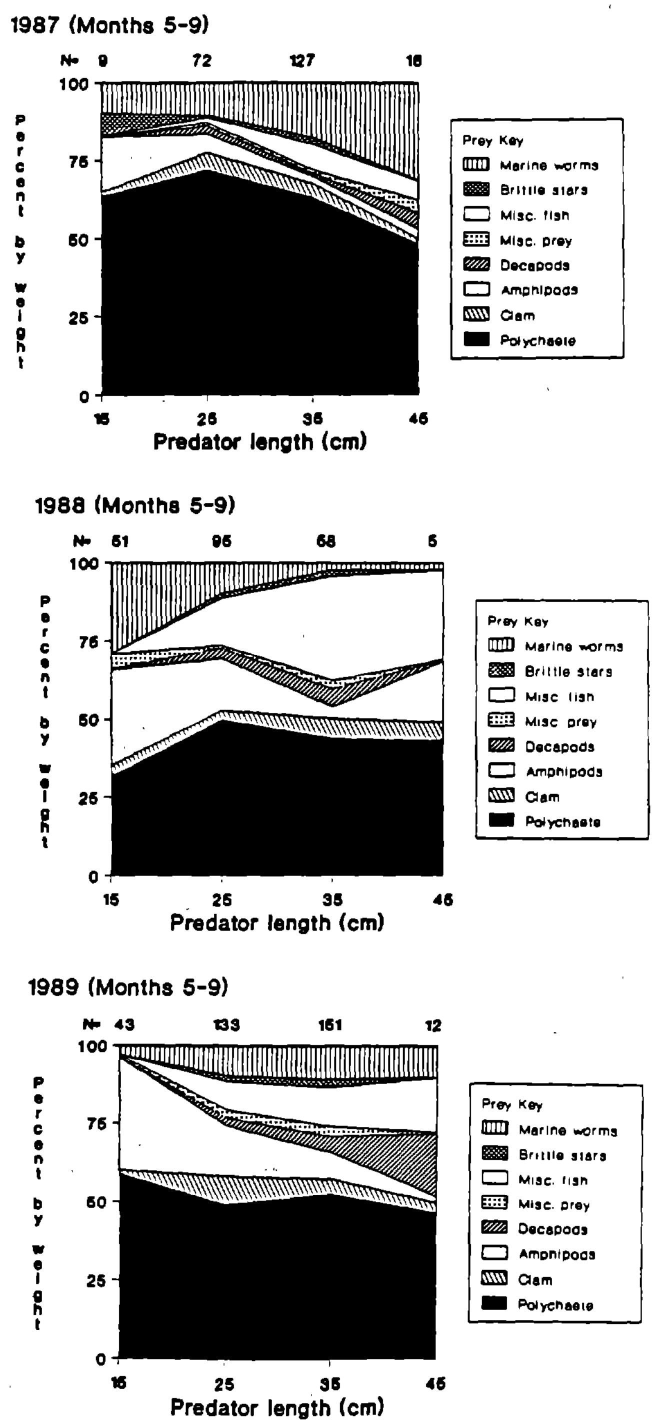

Figure C-3. --Annual diet composition of rock sole in terms of percent by weight, months 5 through 9, by predator size in the eastern Bering Sea, 1987-1989. N=number of stomach samples.

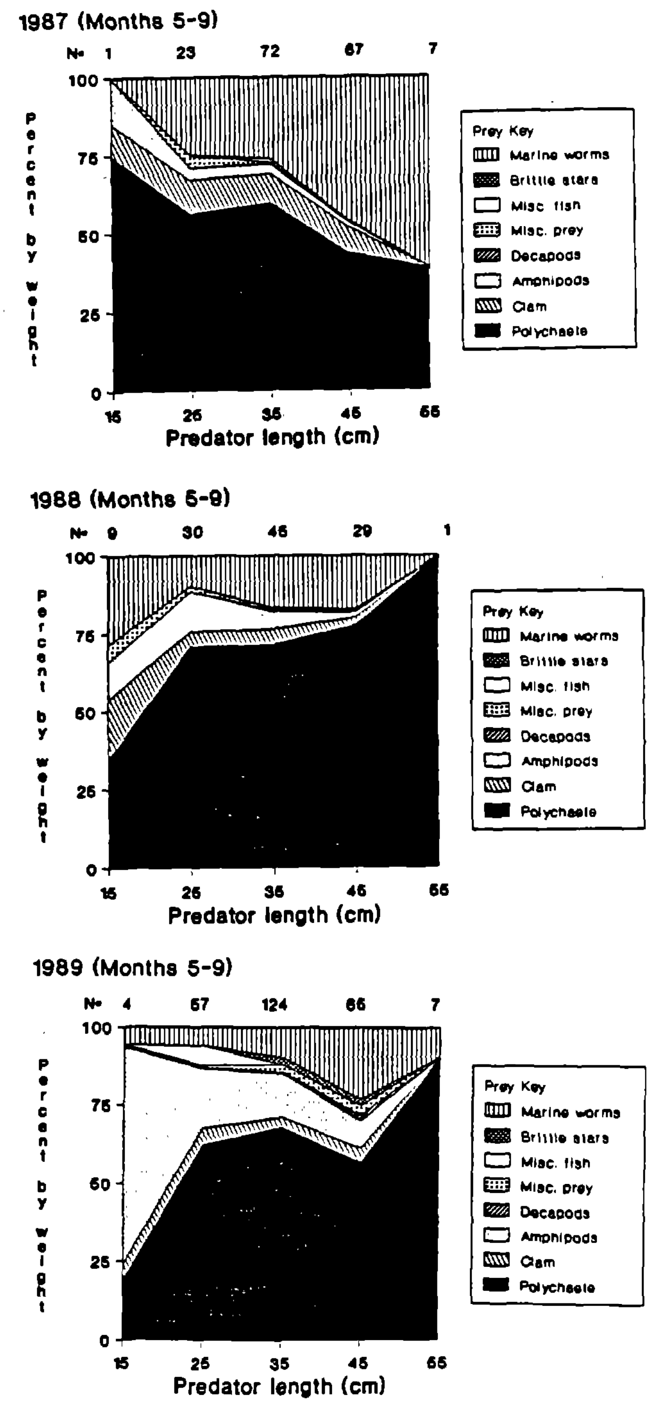

Figure C-4. --Annual diet composition of Alaska plaice in terms of percent by weight, months 5 through 9, by predator size in the eastern Bering Sea, 1987-1989. N-number of stomach samples.

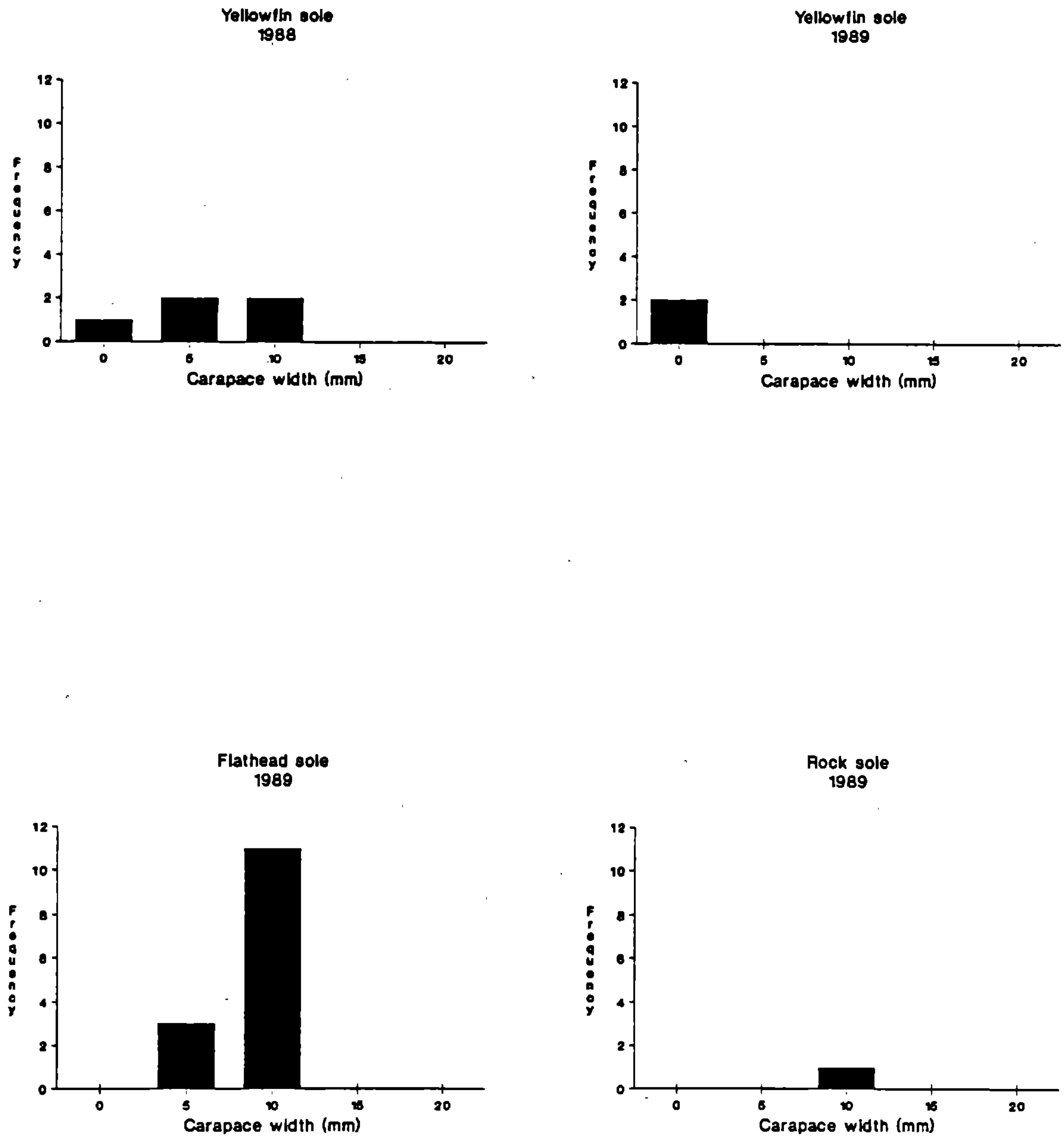

Figure C-5. --Size frequency of snow crab prey found in yellowfin sole during 1988 and 1989, flathead sole in 1989, and rock sole in 1989 in the eastern Bering Sea, months 5 through 9.

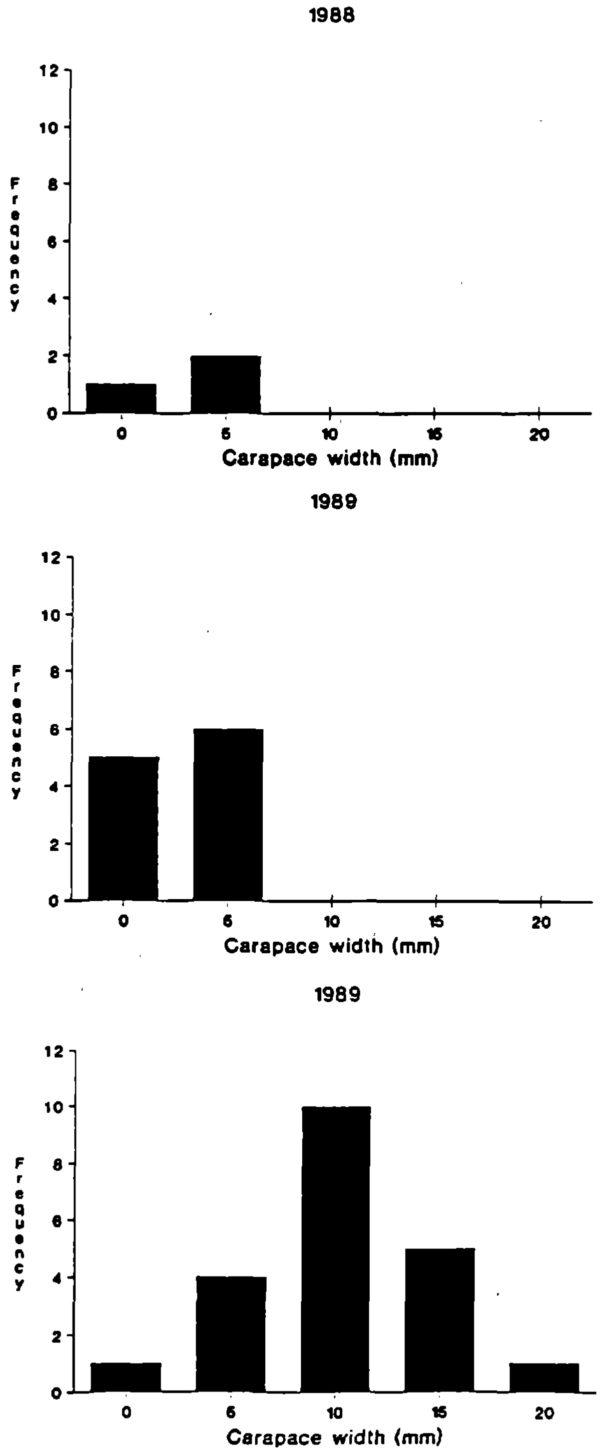

Figure C-6. --Size frequency of Tanner crab prey found in yellowfin sole in 1988 and 1989, and flathead sole in 1989 in the eastern Bering Sea, months 5 through 9.

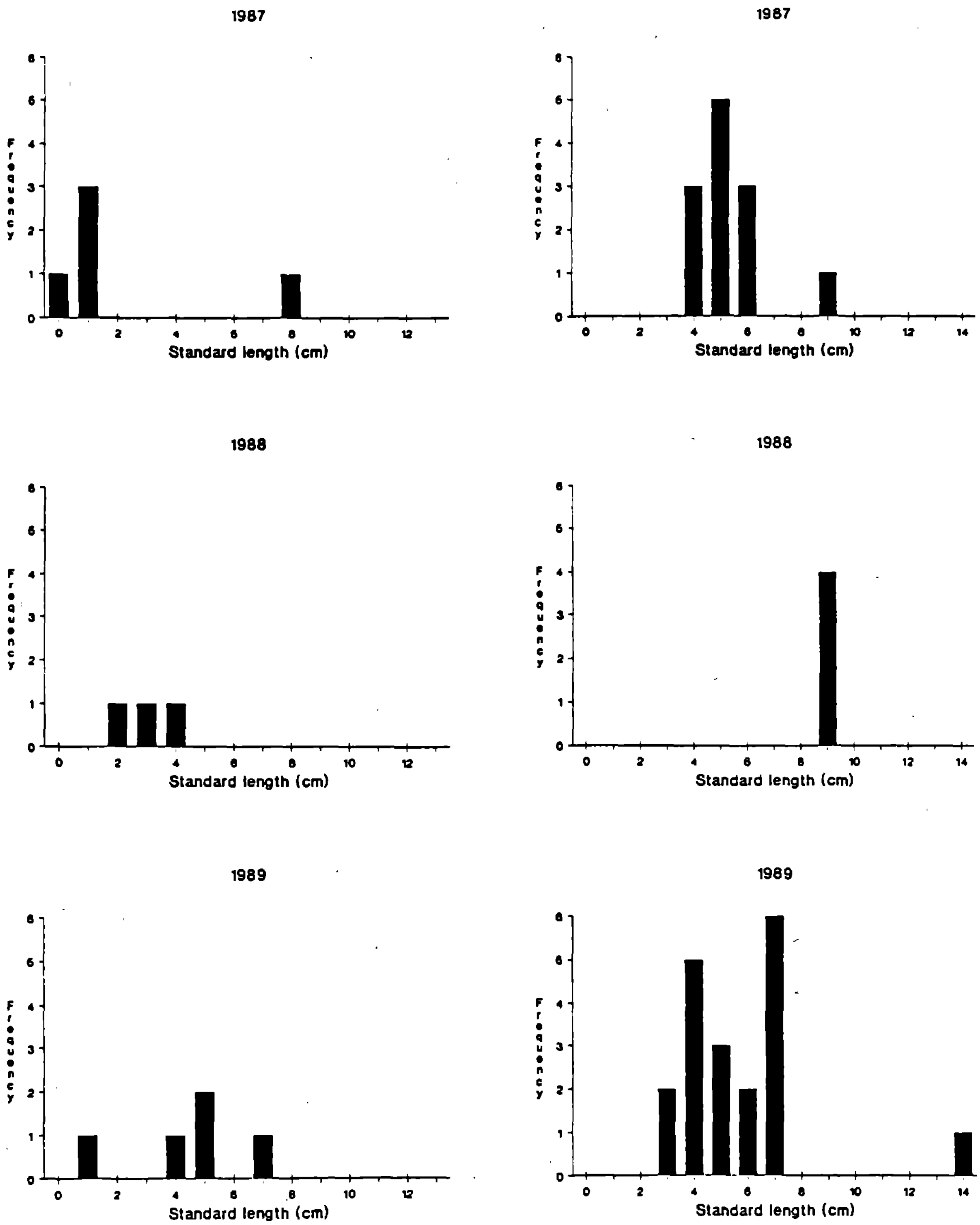

Figure C-7.--Size frequency of walleye pollock prey found in yellowfin sole and flathead sole in 1987-1989, months 5 through 9.

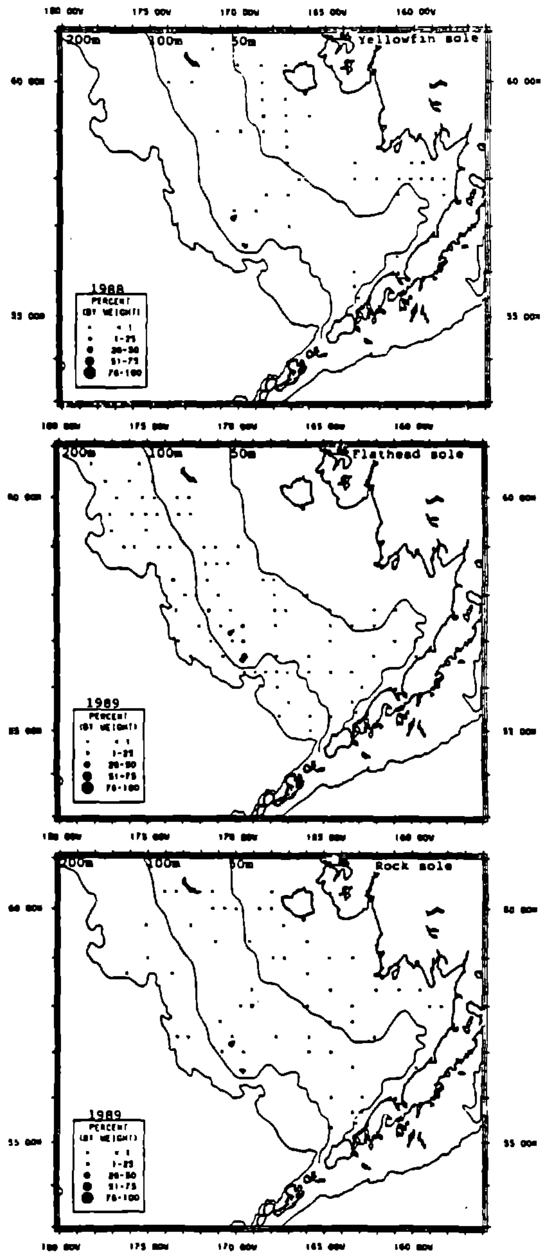

Figure C-8. --percent by weight of snow crab in the diet of yellowfin sole in 1988, and flathead sole and rock sole in 1989, by sampling station in the eastern Bering Sea, months 5 through 9.

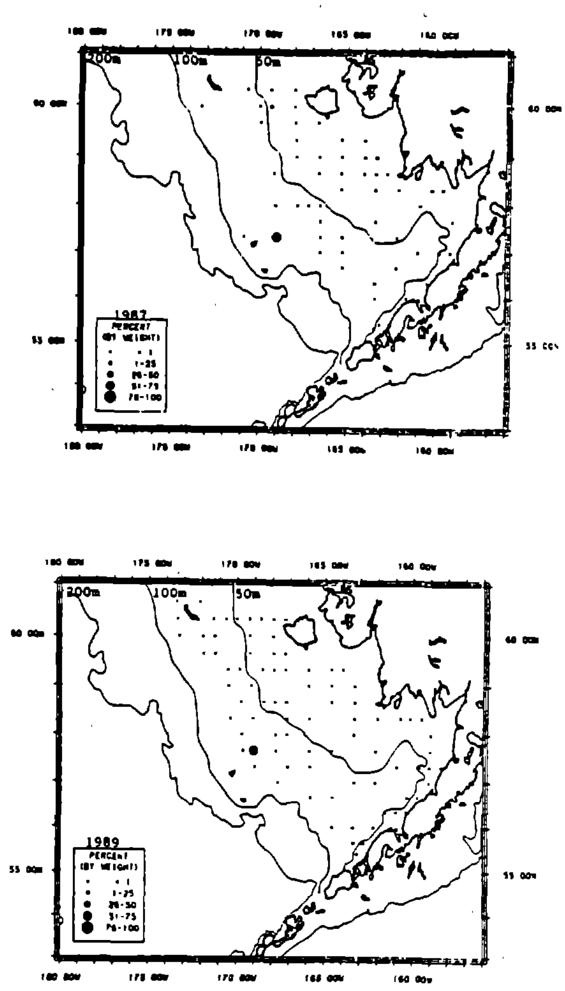

Figure C-9. --Percent by weight of Tanner crab in the diet of yellowfin sole in 1987 and 1989 by sampling station in the eastern Bering Sea, months 5 through 9.

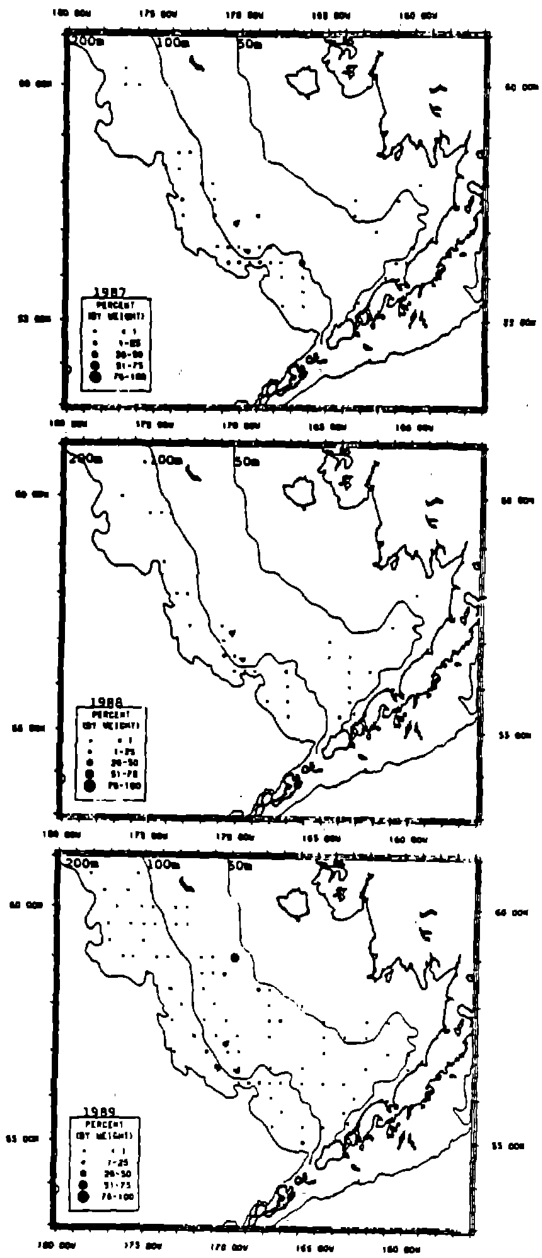

Figure C-10. --percent by weight of Tanner crab in the diet of flathead sole, 1987-1989, by sampling station in the eastern Bering Sea, months 5 through 9.

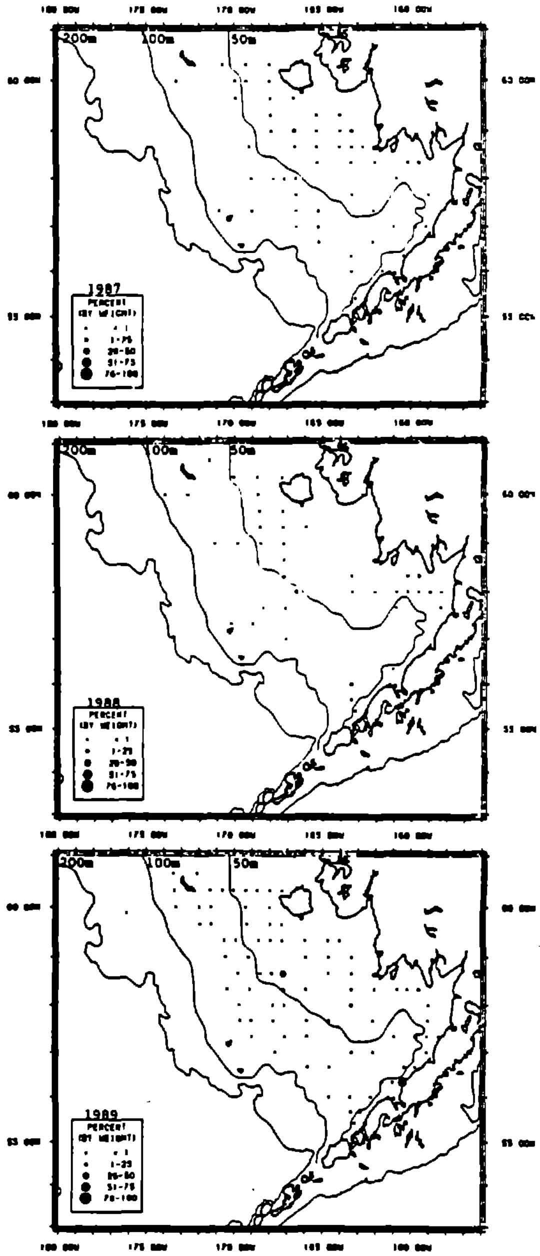

Figure C-11.--Percent by weight of walleye pollock in the diet of yellowfin sole, 1987-1989, by sampling station in the eastern Bering Sea, months 5 through 9.

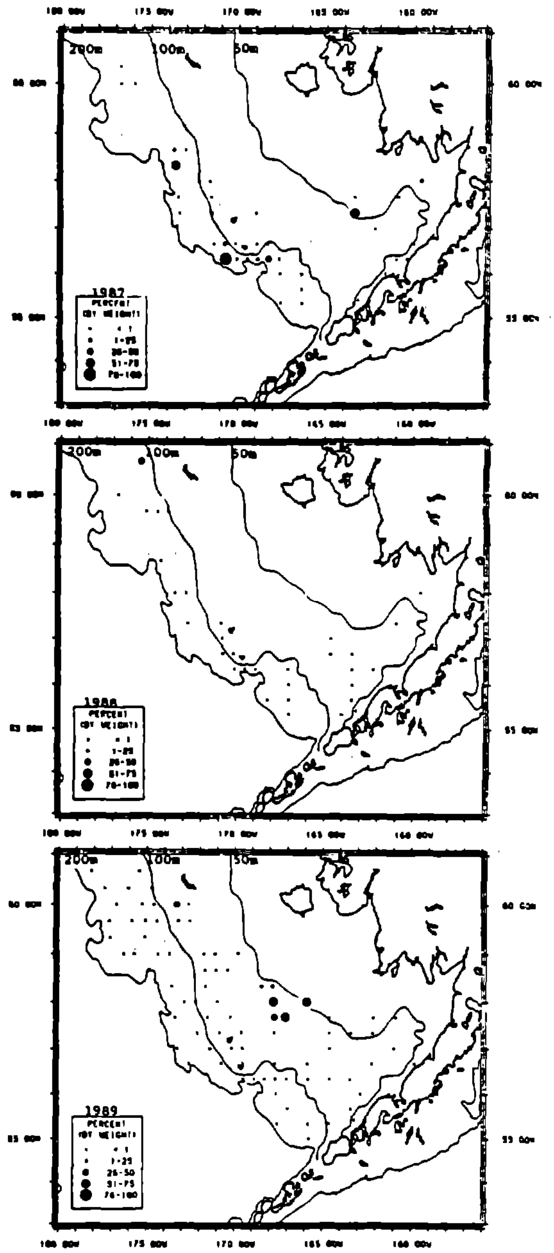

Figure C-12. --Percent by weight of walleye pollock in the diet of flathead sole, 1987-1989, by sampling station in the eastern Bering Sea, months 5 through 9.

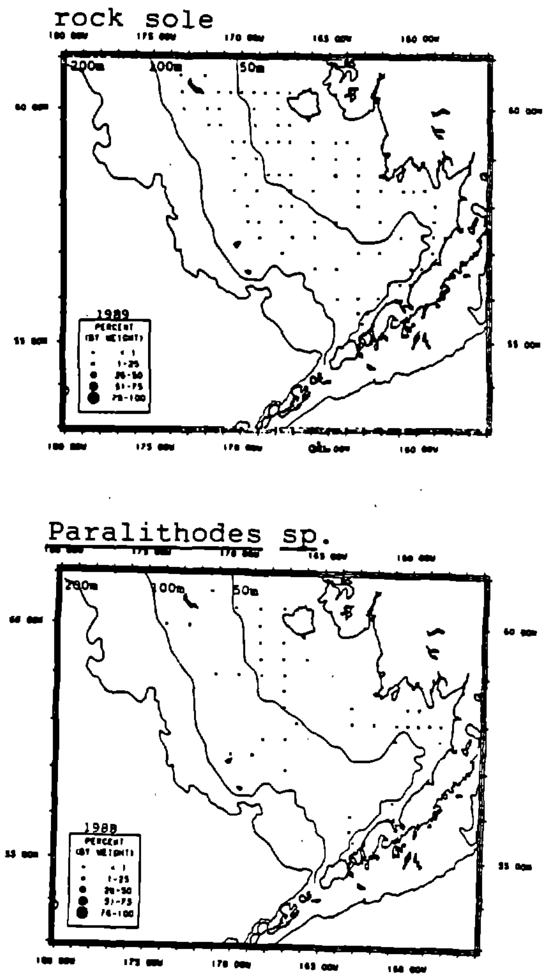

Figure C-13.--Percent by weight of rock sole in the diet of yellowfin sole in 1989, and <u>Paralithodes</u> sp. in the diet of yellowfin sole in 1988 by sampling station in the eastern Bering Sea, months 5 through 9.

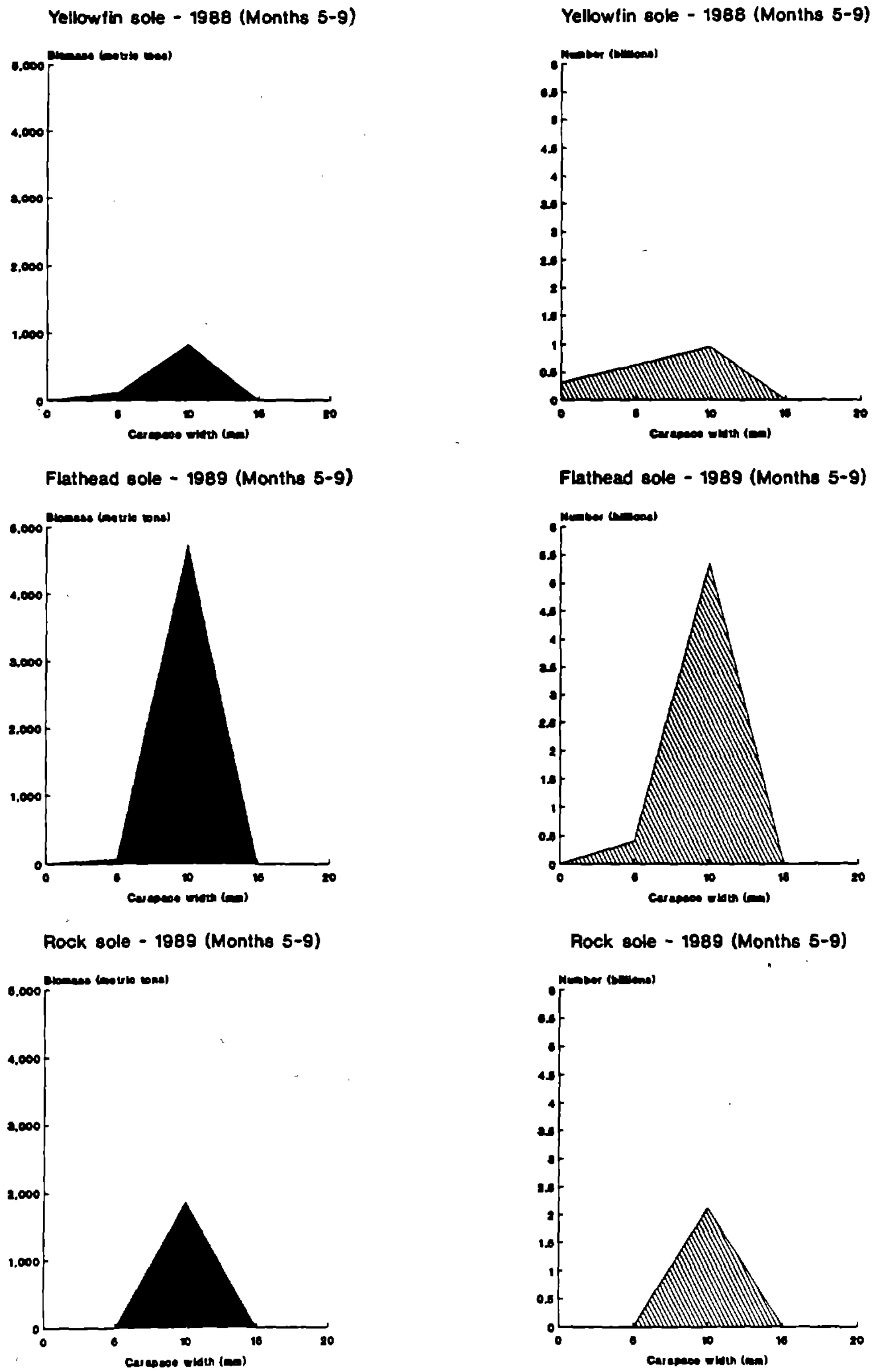

Figure C-14. --Biomass (metric tons) and number (billions) of snow crab consumed by yellowfin sole in 1988, and flathead sole and rock sole in 1989, by prey size, in the eastern Bering Sea, months 5 through 9.

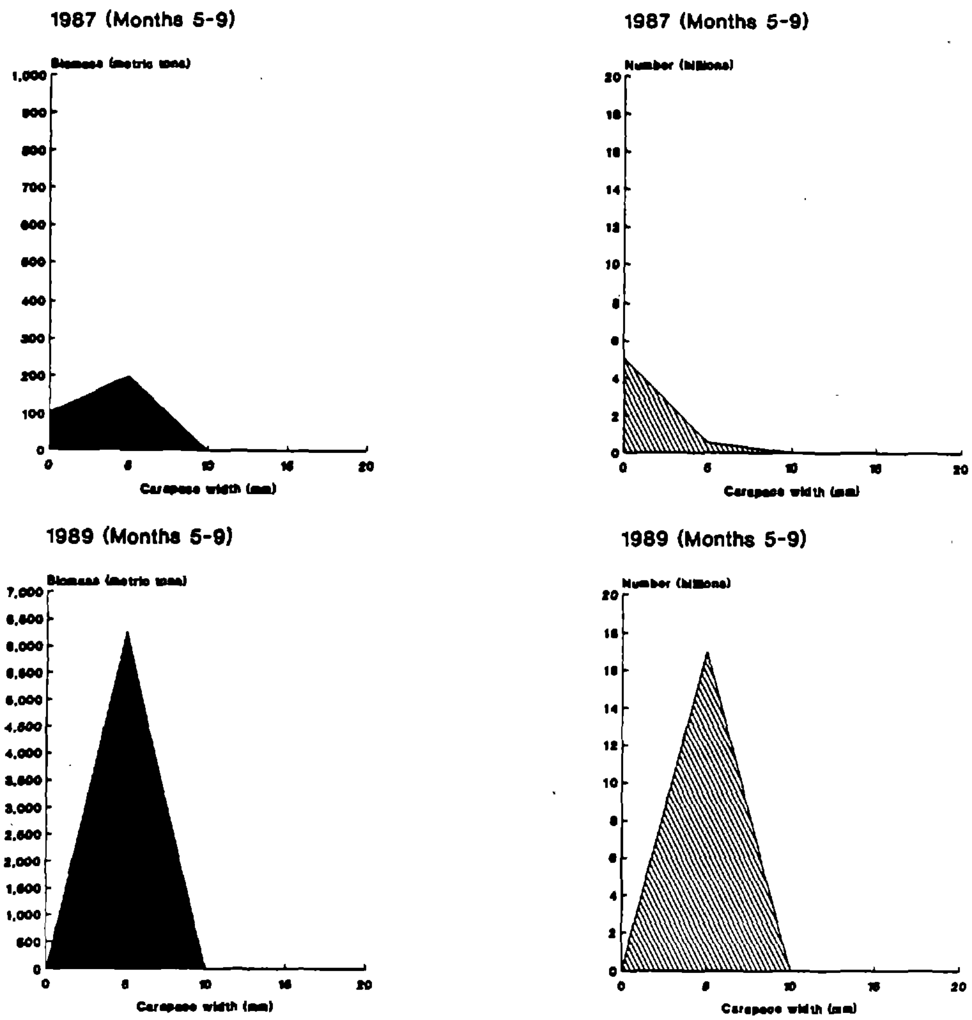

Figure C-15. --Biomass (metric tons) and number (billions) of Tanner crab consumed by yellowfin sole in 1987 and 1989, months 5 through 9.

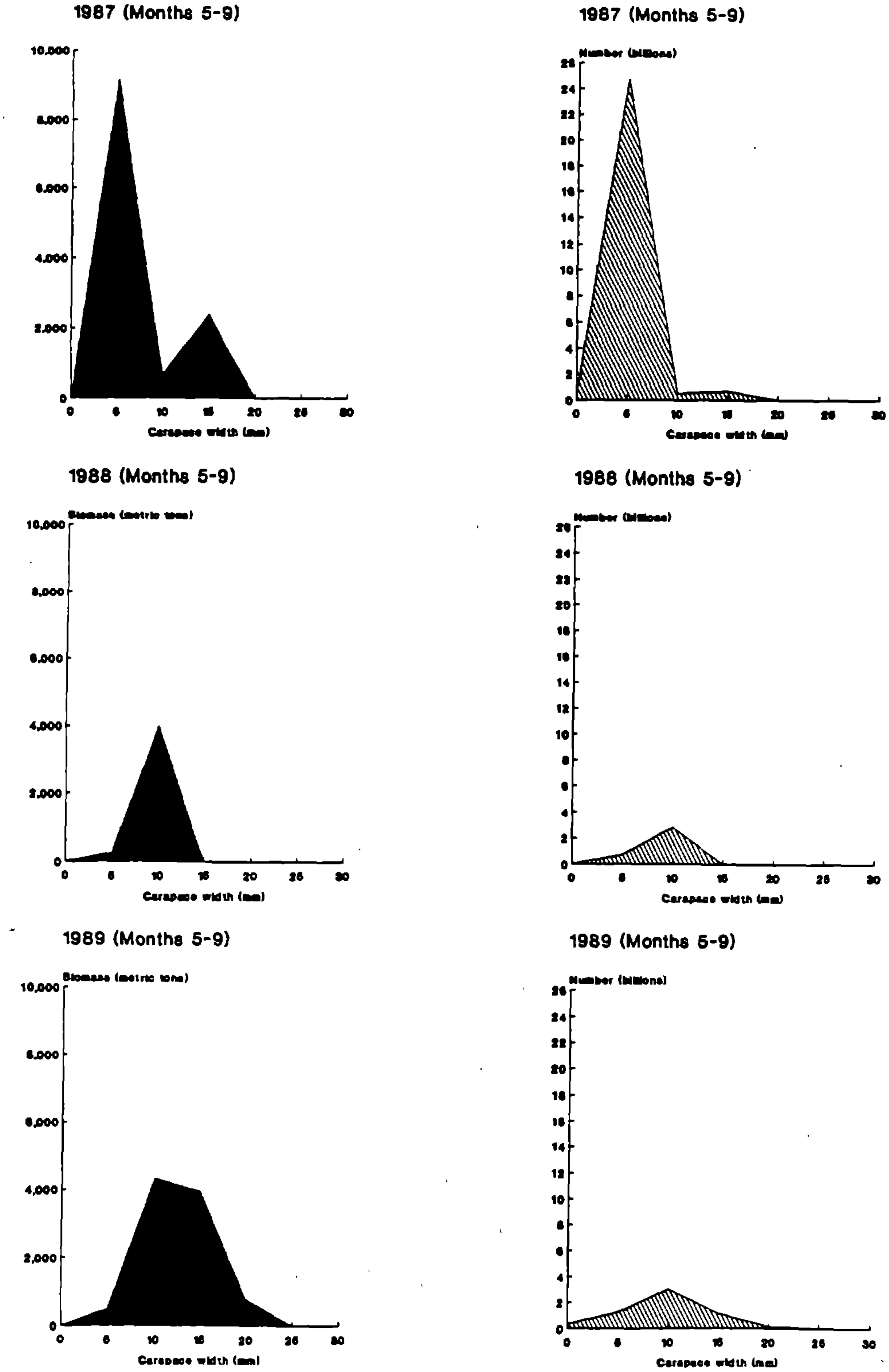

Figure C-16.--Biomass (metric tons) and number (billions) of Tanner crab consumed by flathead sole, 1987-1989, by prey size in the eastern Bering Sea, months 5 through 9.

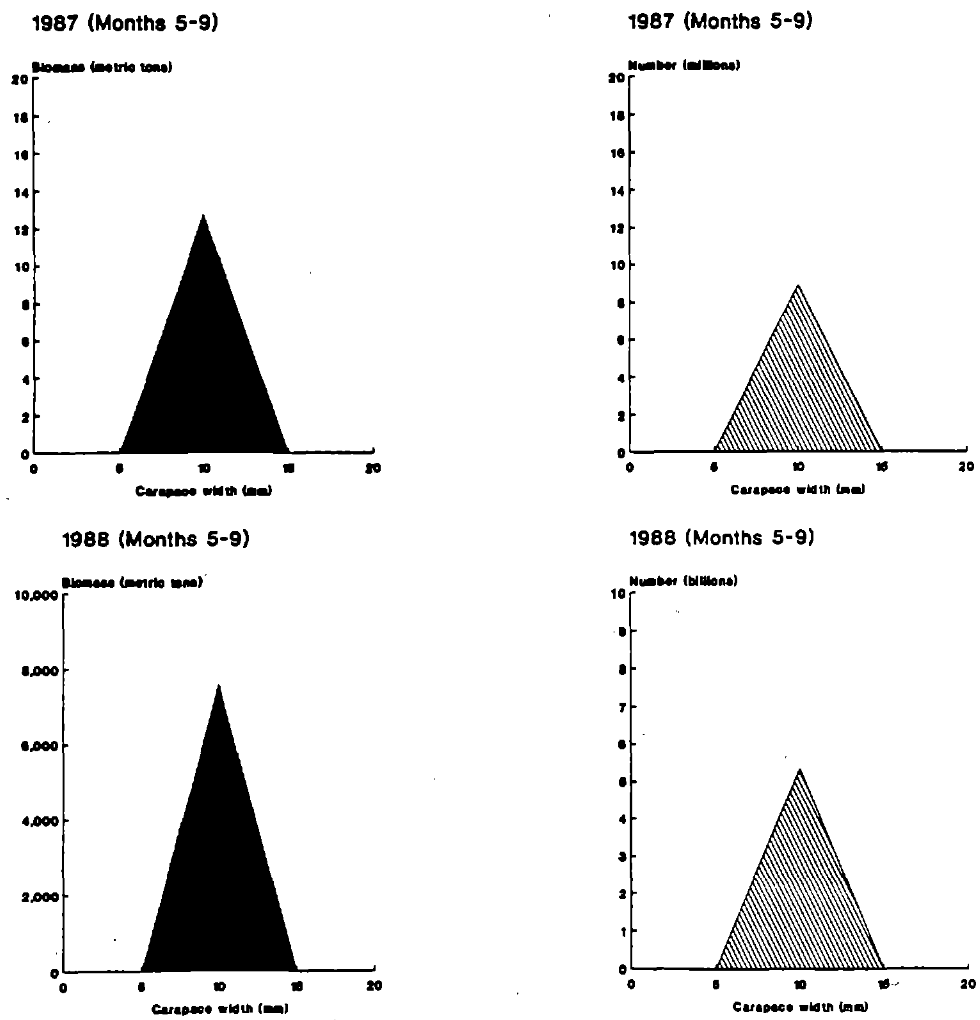

Figure C-17.--Biomass (metric tons) and number (billions) of Tanner crab consumed by rock sole in 1987 and 1988, by prey size in the eastern Bering Sea, months 5 through 9. Note: 1987 Numbers reported in millions.

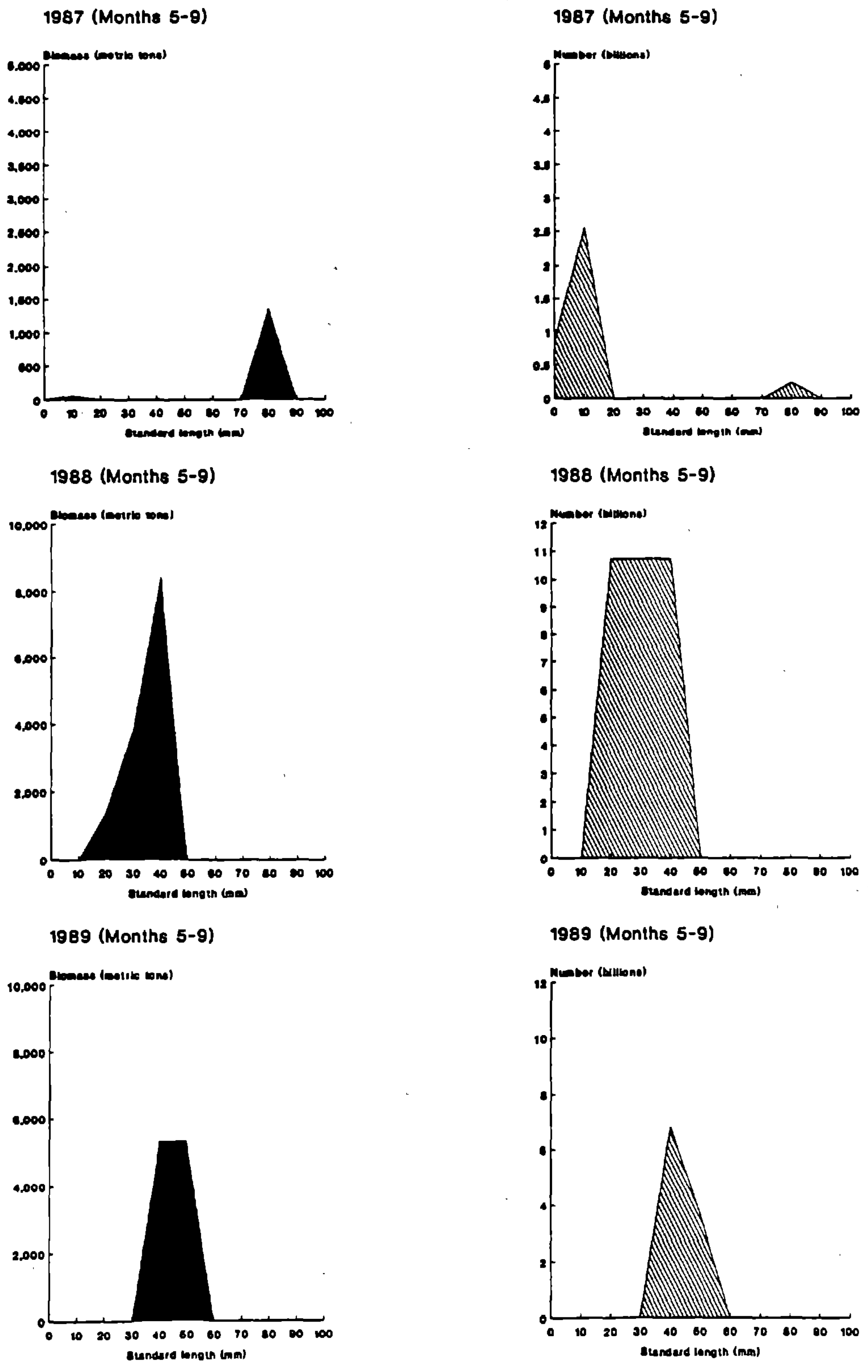

Figure C-18.--Biomass (metric tons) and number (billions) of walleye pollock consumed by yellowfin sole, 1987-1989, by prey size in the eastern Bering Sea, months 5 through 9.

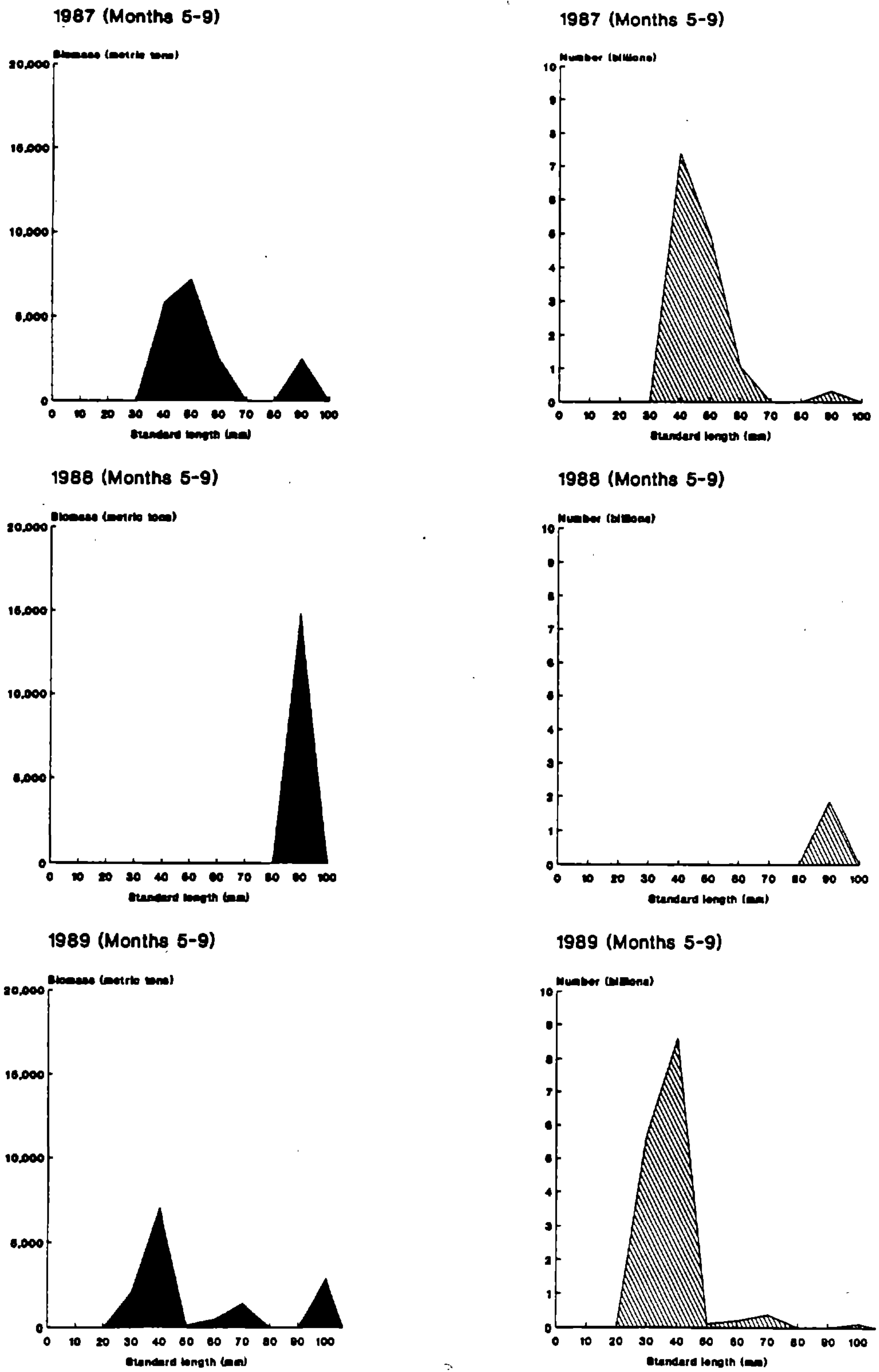

Figure C-19.--Biomass (metric tons) and number (billions) of walleye pollock consumed by flathead sole, 1987-1989, by prey size in the eastern Bering Sea, months 5 through 9.

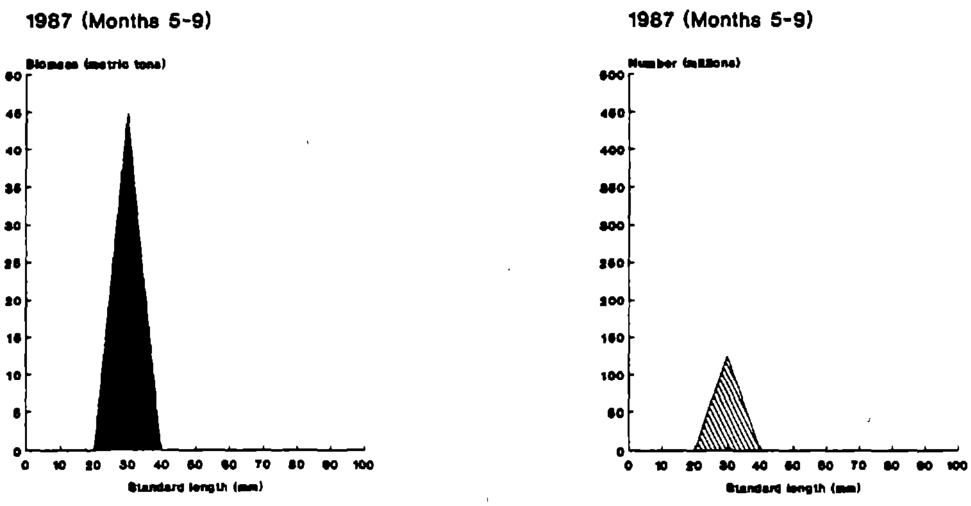

Figure C-20. --Biomass (metric tons) and number (billions) of walleye pollock consumed by rock sole in 1987 by prey size in the eastern Bering Sea, months 5 through 9.

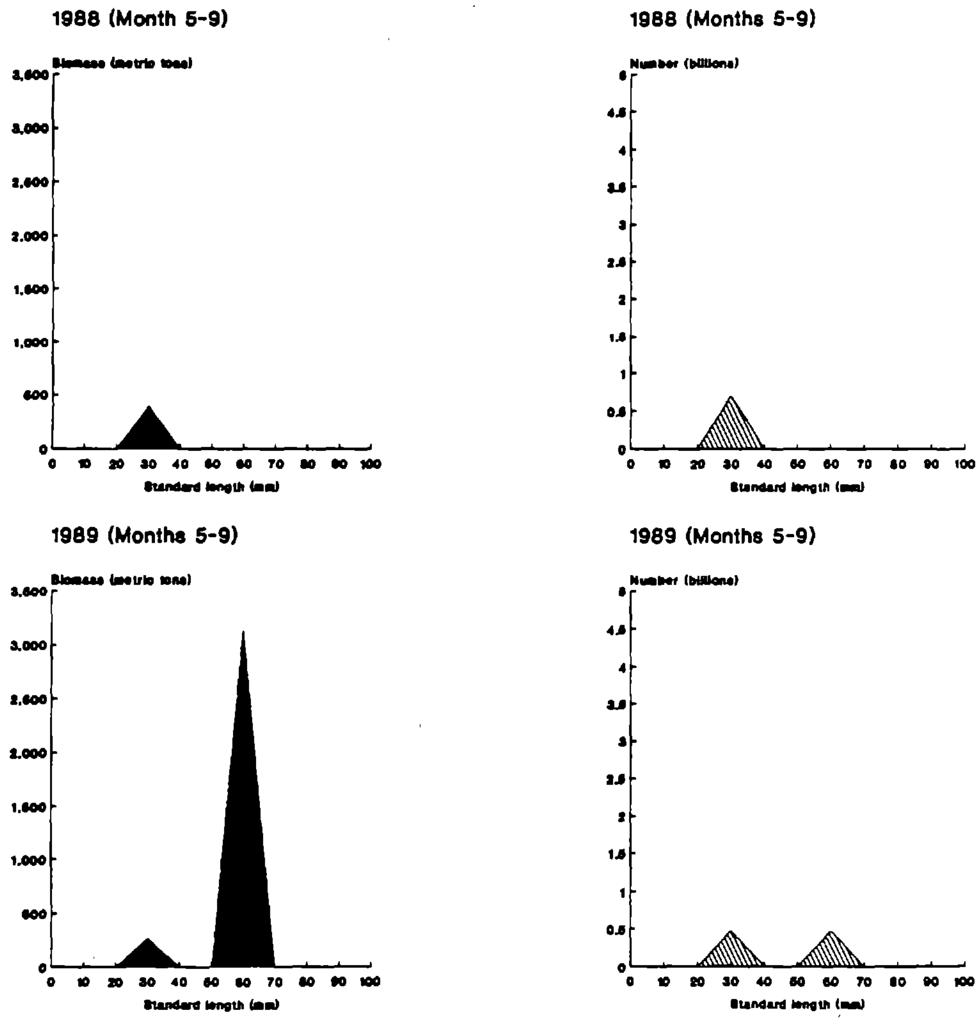

Figure C-21. --Biomass (metric tons) and number (billions) 'of rock sole consumed by yellowfin sole in 1988 and 1989, by prey size in the eastern Bering Sea, months 5 through 9.

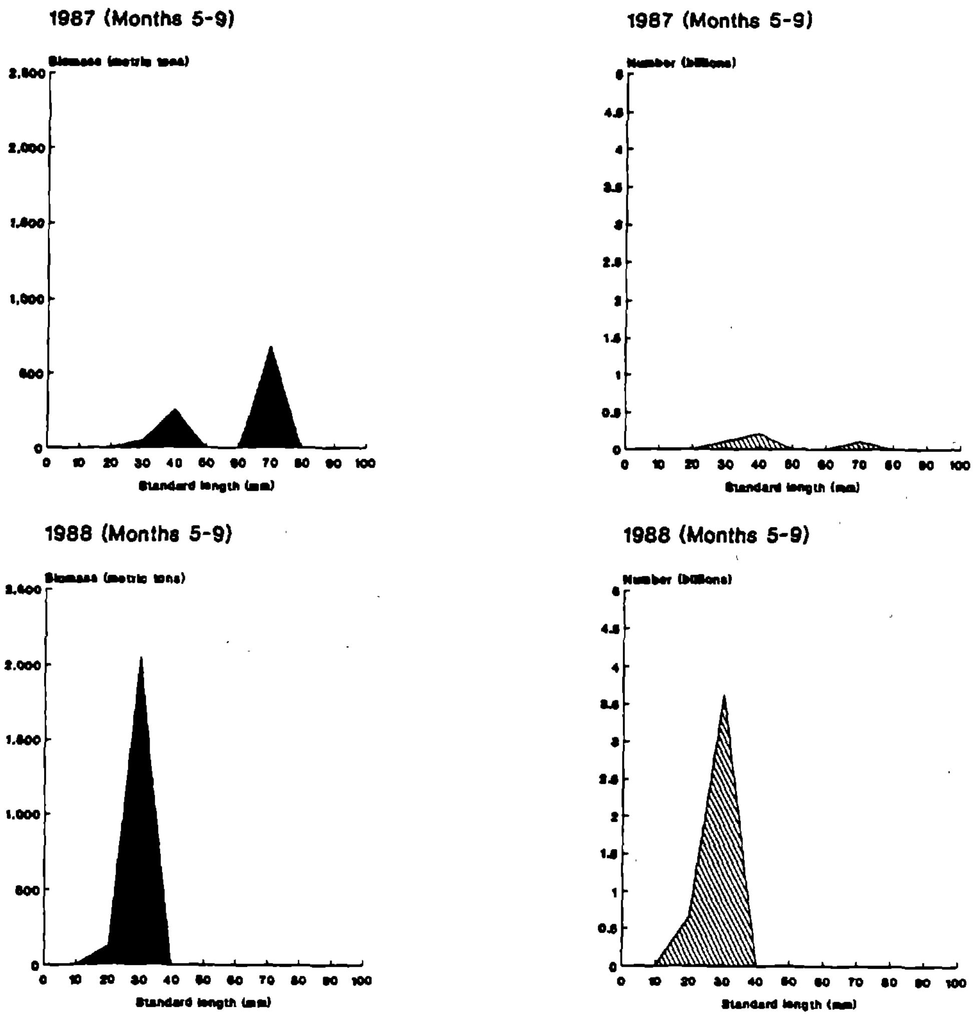

Figure C-22. --Biomass (metric tons) and number (billions) of rock sole consumed by flathead sole in 1987 and 1988, by prey size in the eastern Bering Sea, months 5 through 9.

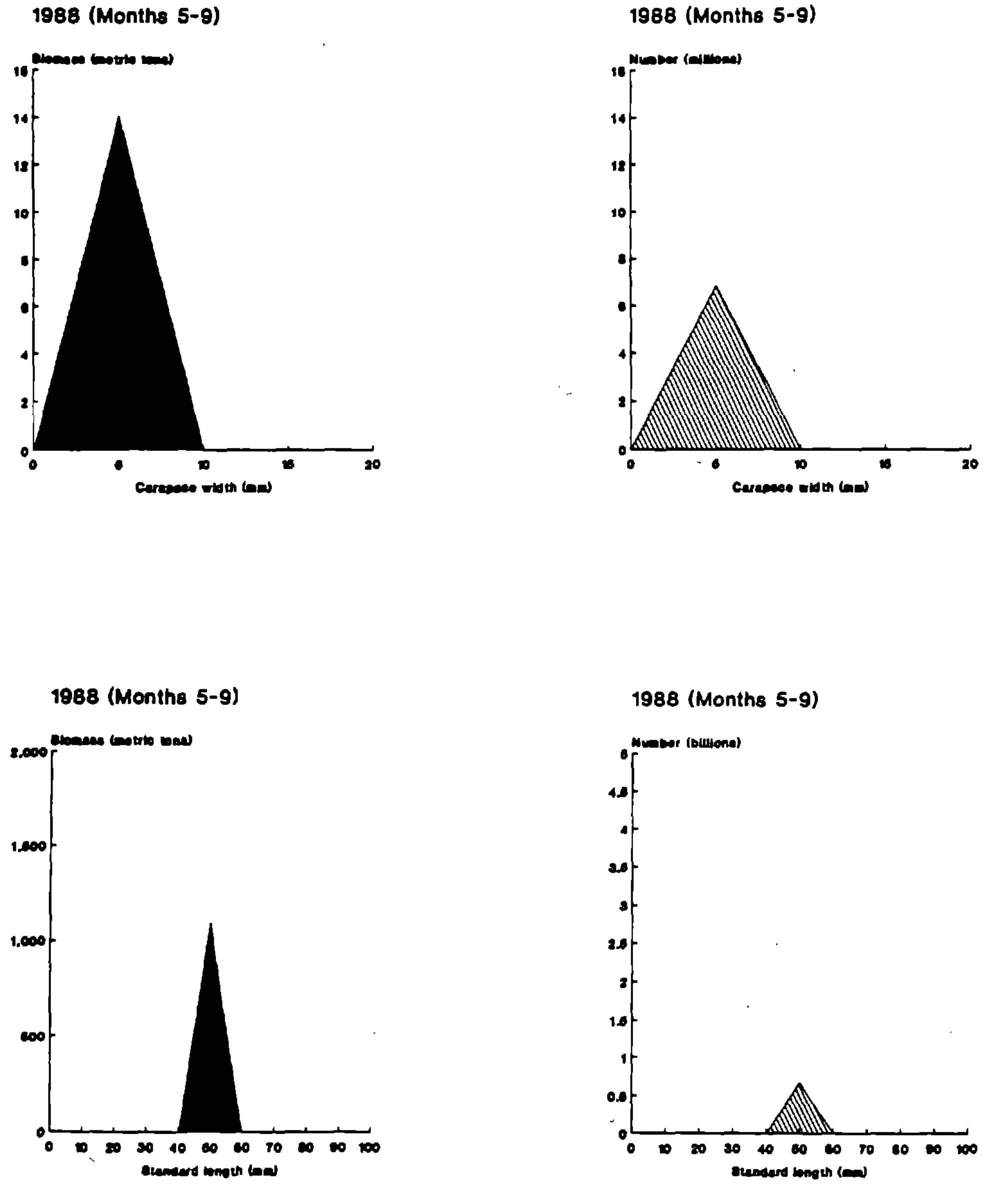

Figure C-23. --Biomass (metric tons) and number (millions) of <u>Paralithodes</u> sp. consumed by yellowfin sole in 1988, and biomass and numbers (billions) of flathead sole consumed by flathead sole in 1988 by prey size in the eastern Bering Sea, months 5 through 9.

APPENDIX D

Greenland Turbot

Appendix D presents biomass, food habits, prey composition, prey size, and prey consumption estimated for Greenland turbot during months 5 to 9, from 1987, 1988, and 1989 in the eastern Bering Sea.

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Table D-1.--Biomass (by predator size, stratum, and year) of Greenland turbot in the eastern Bering Sea from 1987 through 1989 (data based on the bottom trawl survey conducted by the RACE Division of the Alaska Fisheries Science Center, NMFS).

Predator size (cm)	Stratum	Biomass (metric tons) 1987	1988	1989
<30				
	4	46	98	111
	5	0	0	0
	6	339	706	122
	Subtotal	385	804	233
30-49				
	4	83	111	728
	5	0	0	0
	6	640	4,228	3,481
	Subtotal	723	4,339	4,209
≥50				
	4	651	0	0
	5	221	286	0
	6	8,669	6,137	4,463
	Subtotal	9,541	6,423	4,463
Total		10,649	11,506	8,905

Table D-2.--Mean percent by weight and standard error (%W + S.E.) of walleye pollock in the diet of Greenland turbot by predator size, stratum, and year in the eastern Bering Sea (sampled in months 5 to 9). (- = no samples taken.)

Predator size (cm)	Stratum	%W ± S. E. 1987	1988	1989
<30				
	4	0	15.7 ± 15.7	12.1 ± 12.1
	5	-	-	-
	6	33.3 ± 33.3	41.0 ± 18.8	0
30-49				
	4	50.0 ± 50.0	43.2 ± 43.2	36.3 ± 15.2
	5	-	-	-
	6	46.9 ± 16.5	66.7 ± 16.9	46.6 ± 13.6
≥50				
	4	-	-	-
	5	-	76.5 ± 9.4	-
	6	96.4 ± 3.6	94.7 ± 2.0	65.6 ± 15.6

Table D-3.--Estimated biomass of walleye pollock consumed by Greenland turbot in the eastern Bering Sea (by predator size, stratum, and year). (- = no samples taken.)

Predator size (cm)	Stratum	Biomass (metric tons) 1987	1988	1989
<30				
	4	0	26	23
	5	-	-	-
	6	190	487	0
	Subtotal	190	513	23
30-49				
	4	83	95	526
	5	-	-	-
	6	597	5,612	3,225
	Subtotal	680	5,707	3,751
≥50				
	4	-	-	-
	5	-	167	-
	6	6,395	4,446	2,239
	Subtotal	6,395	4,613	2,239
Total		7,265	10,833	6,013

Table D-4.--Estimated number (millions) of walleye pollock consumed by Greenland turbot in the eastern Bering Sea (by predator size, stratum, and year). (- = no samples taken.)

Predator size (cm)	Stratum	Number (millions) 1987	1988	1989
<30				
	4	0	5	6
	5	-	-	-
	6	24	37	0
	Subtotal	24	42	6
30-49				
	4	1	5	76
	5	-	-	-
	6	21	238	81
	Subtotal	22	243	157
≥50				
	4	-	-	-
	5	-	1	-
	6	39	10	5
	Subtotal	39	11	5
Total		85	296	168

Table D-5.--Estimated biomass and number of miscellaneous commercial prey consumed by Greenland turbot (sampled in months 5-9) by prey item, predator size group, year, and stratum. Numbers in parentheses indicate cells with no prey size information.

Prey	Predator size (cm)	Year	Stratum	Biomass (metric tons)	Number (millions)
Chionoecetes opilio	<30	1989	6	(0.12)	0

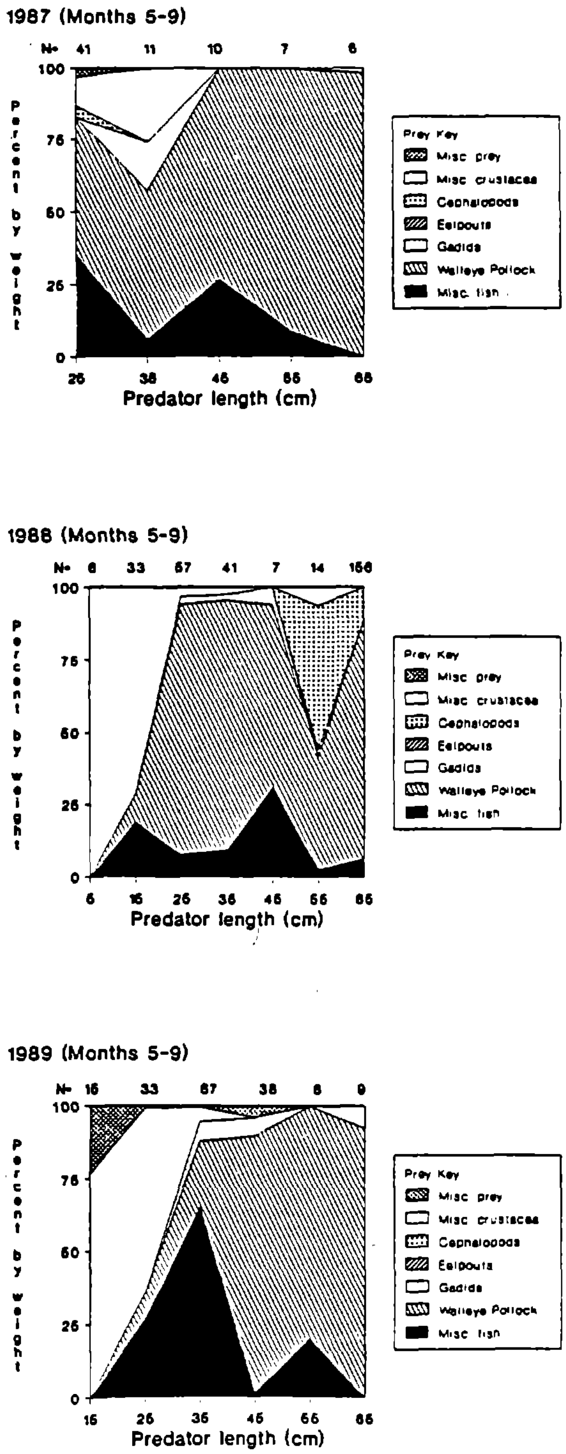

Figure D-l. --Diet composition of Greenland turbot, in terms of percent by weight, during months 5 to 9 by year and predator size in the eastern Bering Sea, 1987-89. N = sample size.

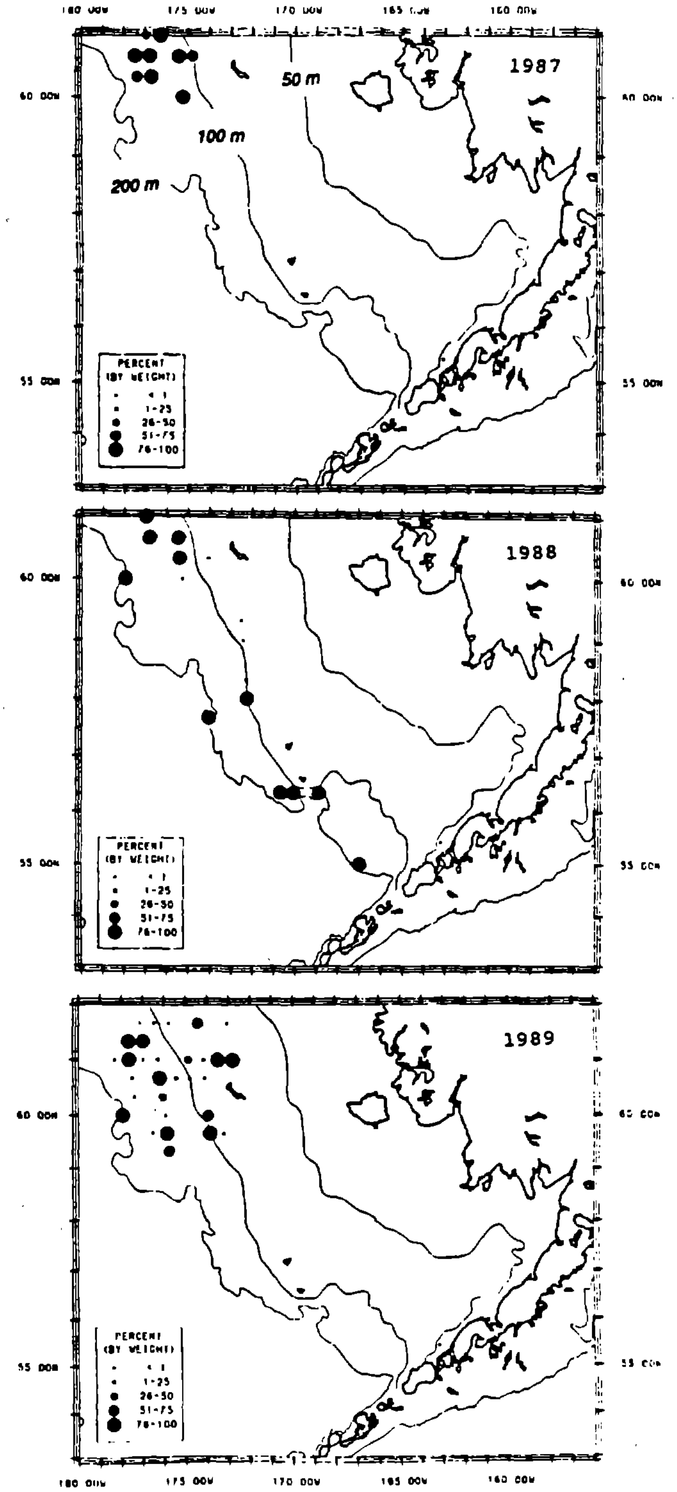

Figure D-2. --Percent by weight of walleye pollock in the diet of Greenland turbot in the eastern Bering Sea, 1987-89 (months 5 to 9).

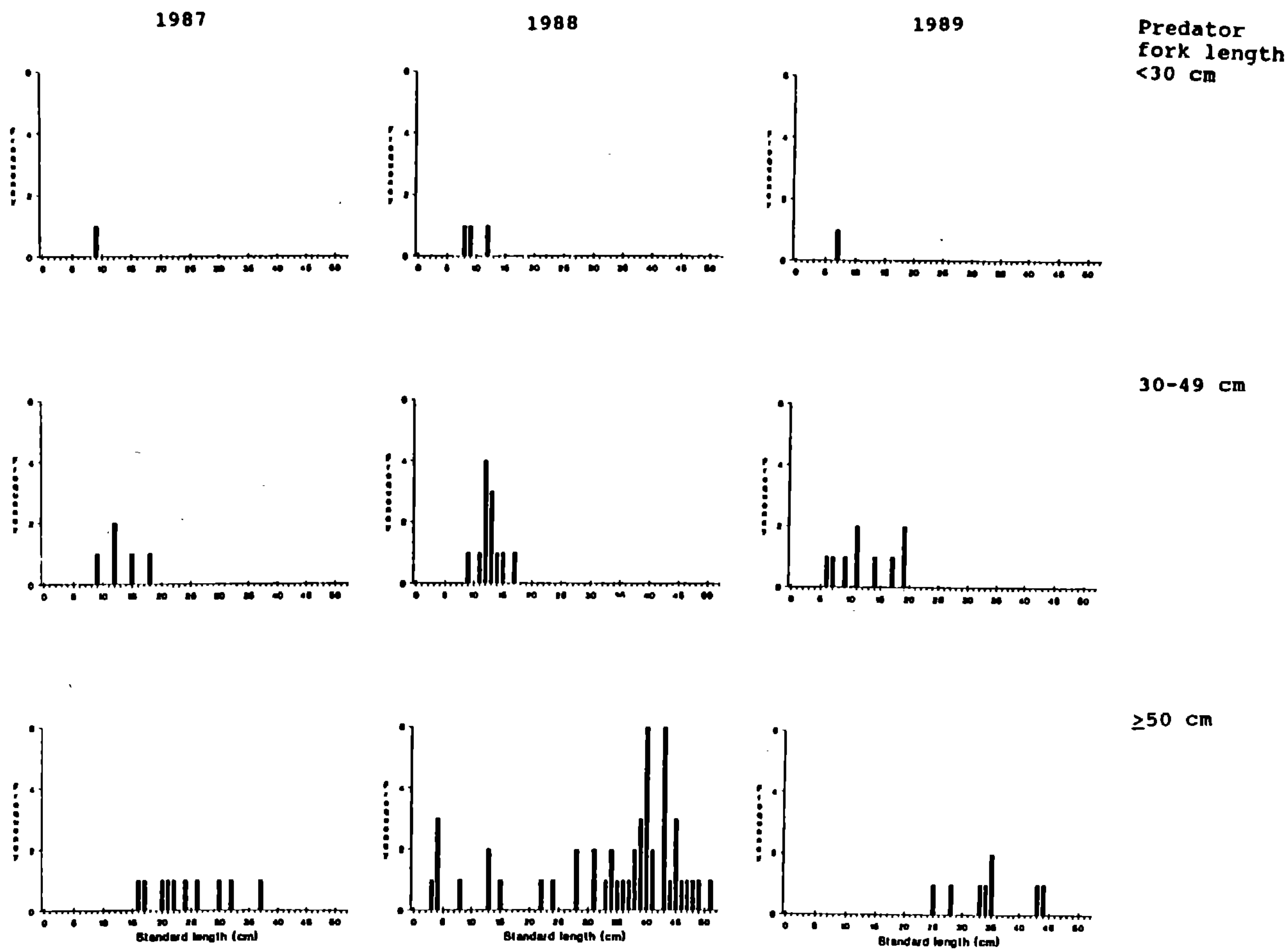

Figure D-3.--Size frequency distributions of walleye pollock consumed by Greenland turbot in the eastern Bering Sea by year, 1987-89.

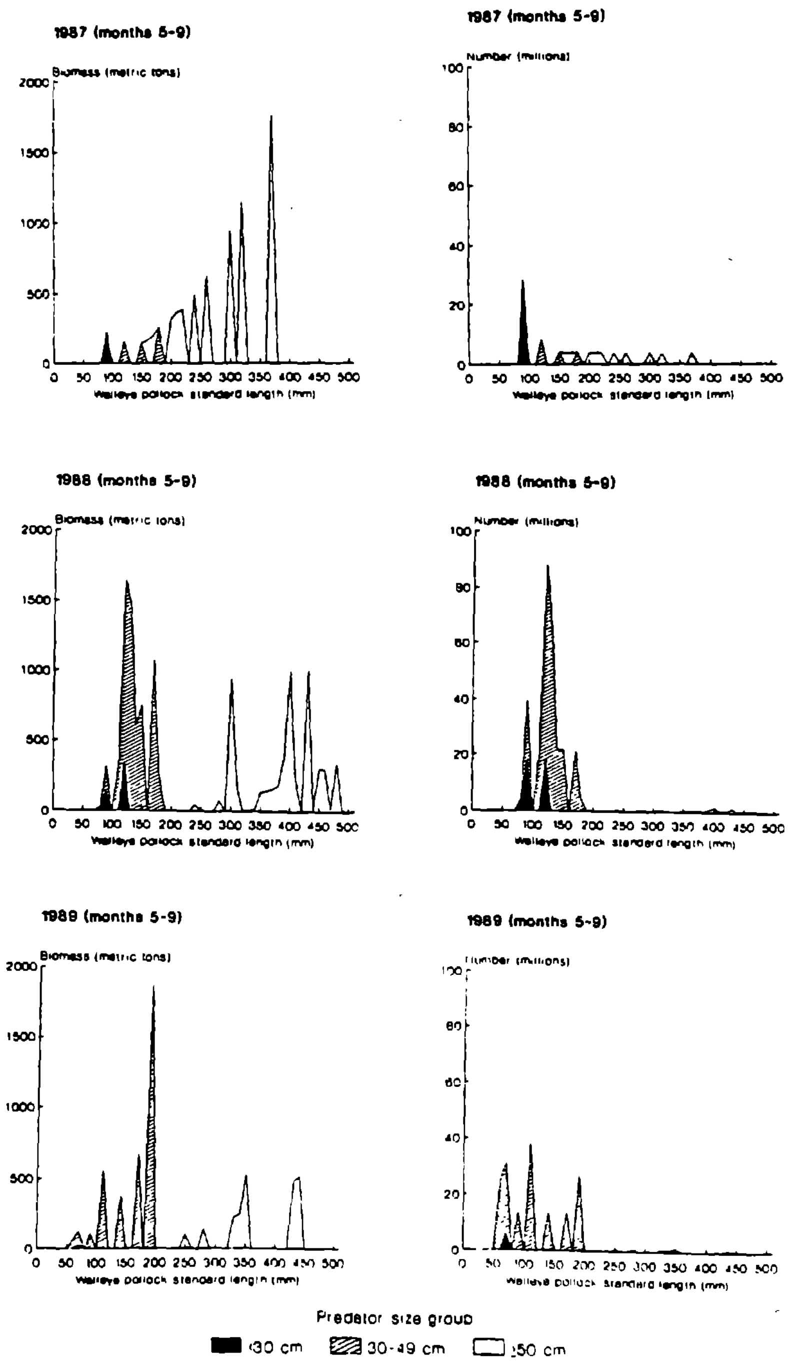

Figure D-4. --Estimated biomass and number of walleye pollock consumed by Greenland turbot in the eastern Bering Sea by year, 1987-89 (months 5 to 9).

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APPENDIX E

Arrowtooth flounder

Appendix E presents biomass, food habits, prey composition, prey size, and prey consumption estimates for Pacific cod during months 5 to 9, from 1987, 1988, and 1989 in the eastern Bering Sea.

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Table E-l.--Biomass (by predator size, stratum, and year) of arrowtooth flounder in the eastern Bering Sea from 1987 through 1989 (data based on the bottom trawl survey conducted by the PACE Division of the Alaska Fisheries Science Center, NMFS).

Predator size (cm)	Stratum	Biomass (metric tons) 1987	1988	1989
<20				
	1	105	107	467
	2	0	0	0
	3	873	1,476	2,494
	4	178	2,128	497
	5	541	1,252	2,061
	6	297	1,205	989
	Subtotal	1,994	6,168	6,508
20-39				
	1	723	824	821
	2	0	0	0
	3	39,087	46,262	49,175
	4	11,442	9,698	30,051
	5	30,630	44,494	50,938
	6	32,312	48,184	46,989
	Subtotal	114,194	148,638	177,974
≥40				
	1	826	87	0
	2	0	0	0
	3	25,570	29,817	32,403
	4	7,143	1,616	11,600
	5	59,339	46,253	60,235
	6	81,576	72,959	121,963
	Subtotal	174,454	150,732	226,201
Total		290,642	305,538	410,683

Table E-2.--Mean percent by weight and standard error (%W + SE) of walleye pollock in the diet of arrowtooth flounder by predator size, stratum, and year in the eastern Bering Sea (sampled in months 5 to 9). (- = no samples taken.)

Predator size (cm)	Stratum	%W ± SE 1987	1988	1989
20-39				
	1	-	-	42.3 ± 42.3
	2	-	-	0
	3	0	5.6 ± 5.6	18.3 ± 11.6
	4	51.8 ± 25.9	0	21.3 ± 10.9
	5	11.0 ± 8.0	0	10.3 ± 10.3
	6	28.2 ± 14.5	59.8 ± 19.5	26.6 ± 9.0
≥40				
	1	-	-	-
	2	-	-	-
	3	-	0	0
	4	87.6 ± 0.0*	-	59.5 ± 24.3
	5	21.4 ± 11.5	88.9 ± 6.8	6.8 ± 6.8
	6	64.5 ± 10.8	52.0 ± 14.9	39.7 ± 9.0

* Only one station was sampled.

Table E-3.--Mean percent by weight and standard error (%W + SE) of miscellaneous commercial prey consumed by arrowtooth flounder (sampled in months 5-9) by prey item, predator size group, year, and stratum.

Prey	Predator size (cm)	Year	Stratum	%W ± SE
Pacific herring	≥40	1987	5	7.92 ± 9.92
Pacific cod	20-39	1989	4	11.11 ± 11.11
Arrowtooth flounder	20-39	1987	6	5.86 ± 5.86
	≥40	1989	5	0.22 ± 0.22
Flathead sole	20-39	1989	4	4.94 ± 4.94
	≥40	1989	5	0.22 ± 0.22
		1989	6	1.60 ± 1.60
Rock sole	<20	1989	4	1.88 ± 1.88
	20-39	1989	3	2.43 ± 2.43

Table E-4.--Estimated biomass (metric tons) of walleye pollock consumed by arrowtooth flounder in the eastern Bering Sea (by predator size, stratum, and year). (- = no samples taken.)

Predator size (cm)	Stratum	Biomass (metric tons) 1987	1988	1989
20-39				
	1	-	-	478
	2	-	-	0
	3	0	3,552	12,418
	4	8,156	0	8,798
	5	4,646	0	7,204
	6	12,536	39,642	17,200
	Subtotal	25,338	43,194	46,098
≥40				
	1	-	-	-
	2	-	-	-
	3	-	0	0
	4	6,697	-	7,394
	5	13,613	44,052	4,395
	6	56,360	40,656	51,833
	Subtotal	76,670	84,708	63,622
Total		102,008	127,902	109,720

Table E-5. --Estimated number (millions) of walleye pollock consumed by arrowtooth flounder in the eastern Bering Sea (by predator size, stratum, and year). (- = no samples taken.)

Predator size (cm)	Stratum	Number (millions) 1987	1988	1989
20-39				
	1	-	-	4
	2	-	-	0
	3	0	4,514	1,355
	4	440	0	482
	5	14	0	1,880
	6	166	785	644
	Subtotal	620	5,299	4,361
≥40				
	1	-	-	-
	2	-	-	-
	3	-	0	0
	4	160	-	35
	5	65	111	8
	6	755	548	790
	Subtotal	980	659	833
Total		1,600	5,958	5,194

Table E-6.--Estimated biomass (metric tons) and number (millions) of miscellaneous commercial-prey consumed by arrowtooth flounder (sampled in months 5-9) by prey item, predator size group, year, and stratum. Numbers in parentheses indicate cells with no prey size information.

Prey	Predator size (cm)	Year	Stratum	Biomass (metric tons)	Number (millions)
Pacific herring	≥40	1987	5	6,303	9.2
Pacific cod					
	20-39	1989	4	(4,598)	0.0
Arrowtooth flounder	20-39	1987	6	2,608	488.3
	≥40	1989	5	(145)	0.0
Flathead sole	20-39	1989	4	(2,043)	0.0
	≥40	1989	5	145	21.0
		1989	6	2,091	52.7
Rock sole	≤20	1989	4	13	22.6
	20-39	1989	3	1,646	249.6

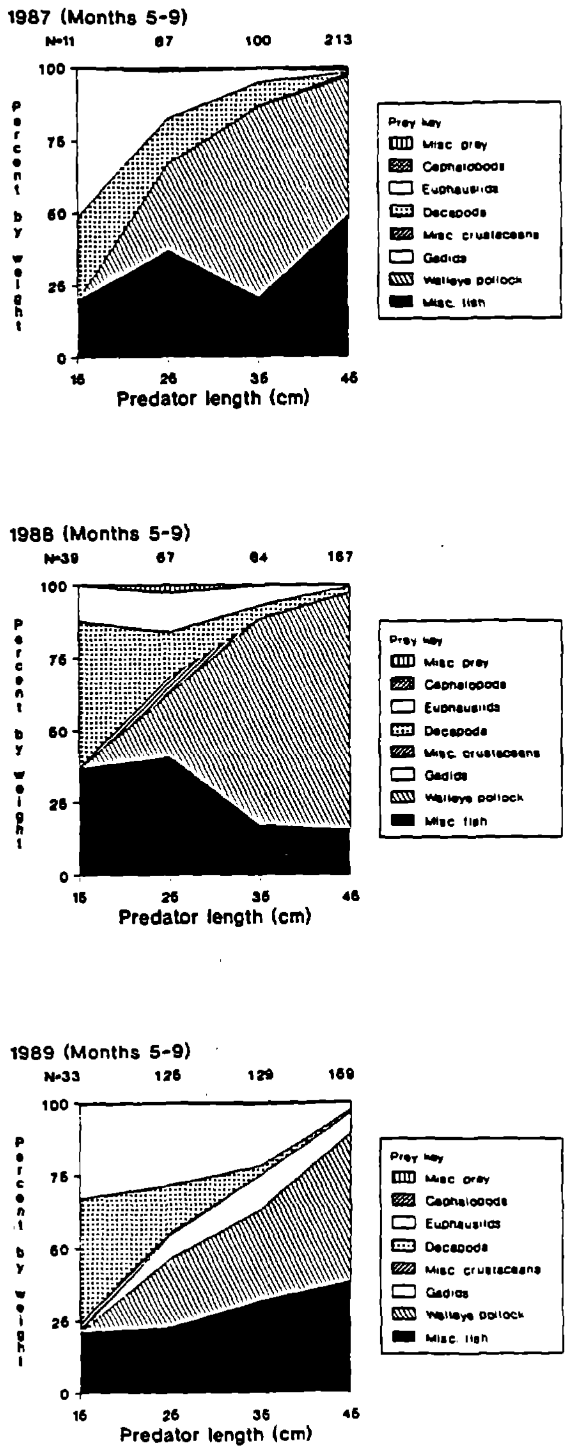

Figure E-l. --Diet composition of arrowtooth flounder, in terms of percent by weight, during months 5 to 9 by year and predator size in the eastern Bering Sea, 1987-89. N = sample size.

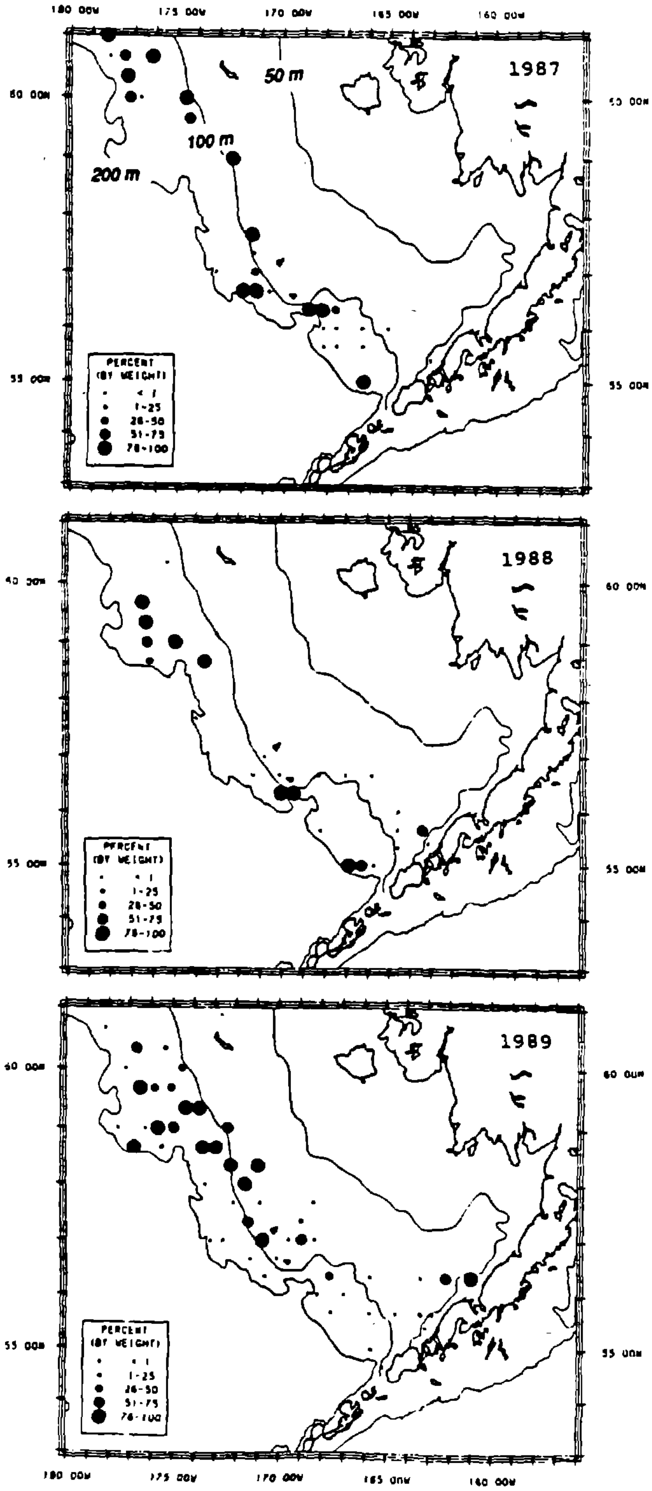

Figure E-2. --Percent by weight of walleye pollock in the diet of arrowtooth flounder in the eastern Bering Sea by year, 1987-89 (months 5 to 9).

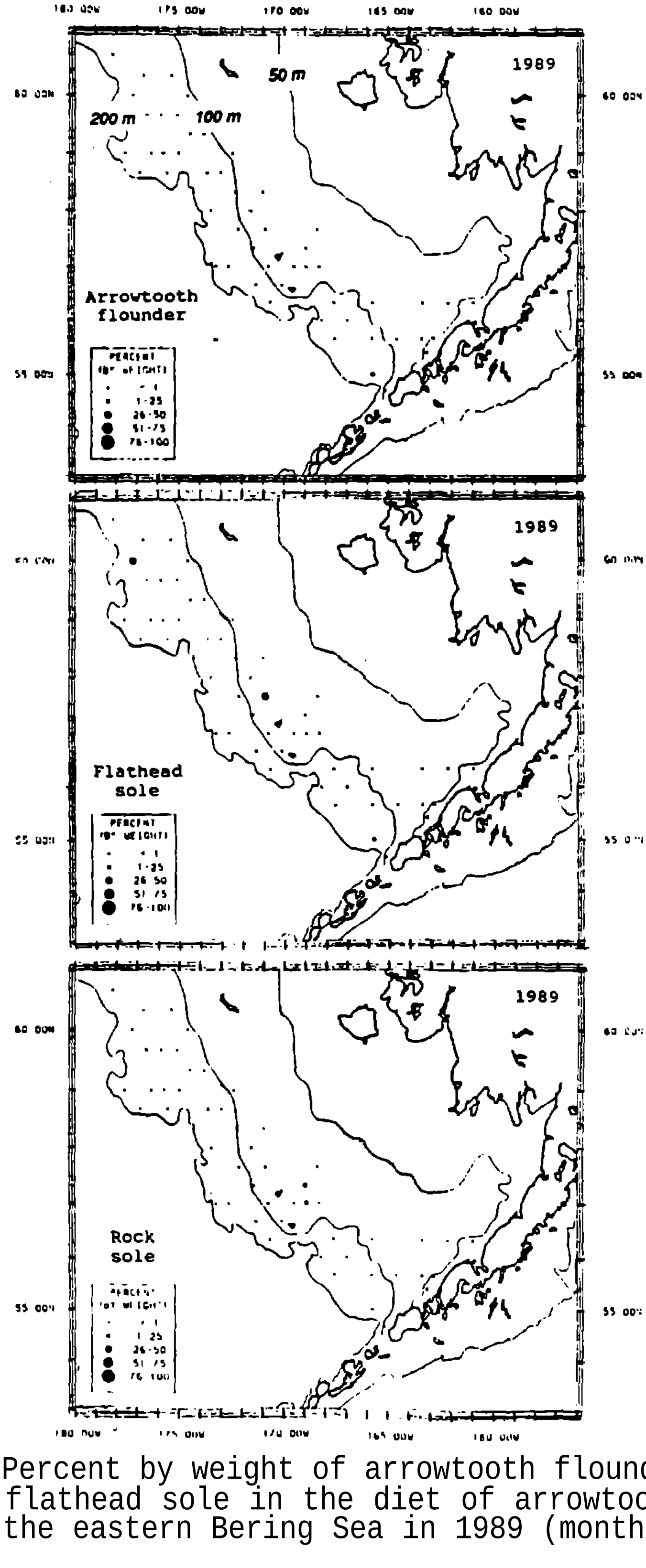

Figure E-3. --Percent by weight of arrowtooth flounder, rock sole flathead sole in the diet of arrowtooth flounder in the eastern Bering Sea in 1989 (months 5 to 9).

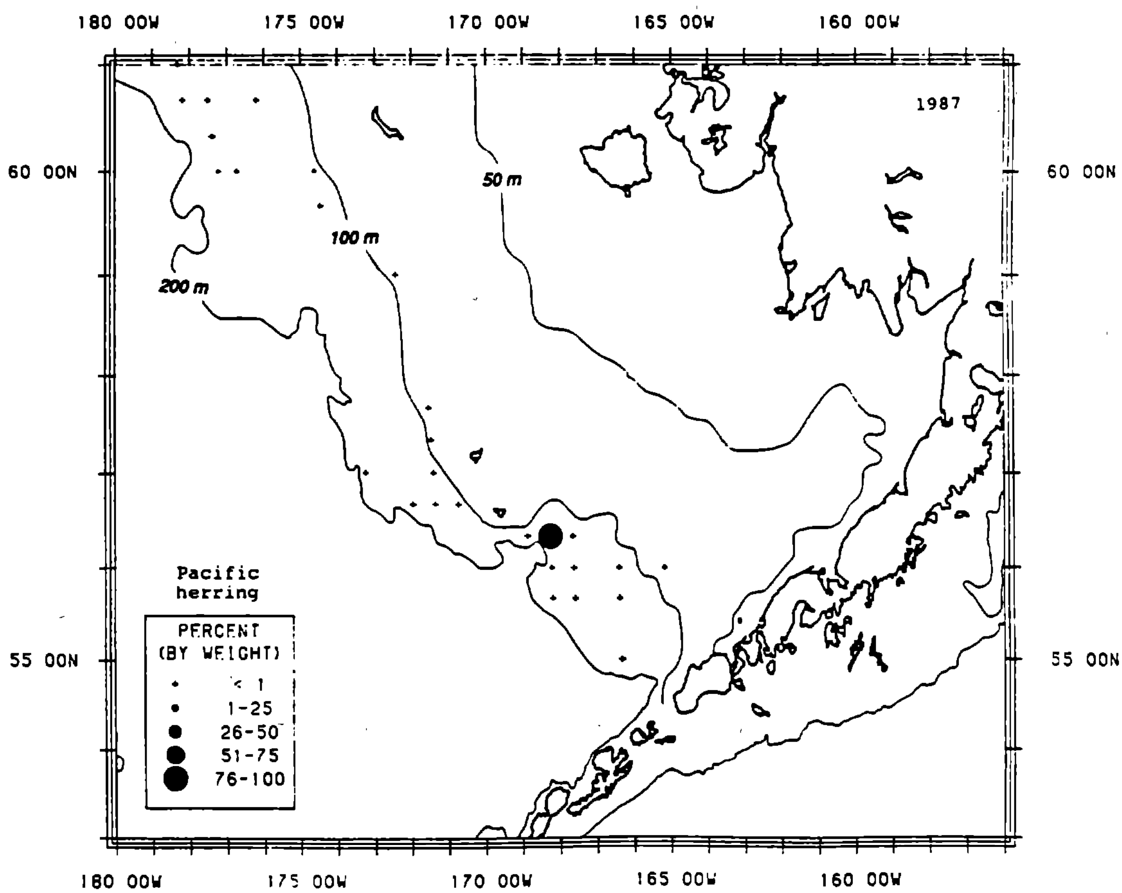

Figure E-4. --Percent by weight of Pacific herring in the diet of arrowtooth flounder in the eastern Bering Sea in 1987 (months 5 to 9).

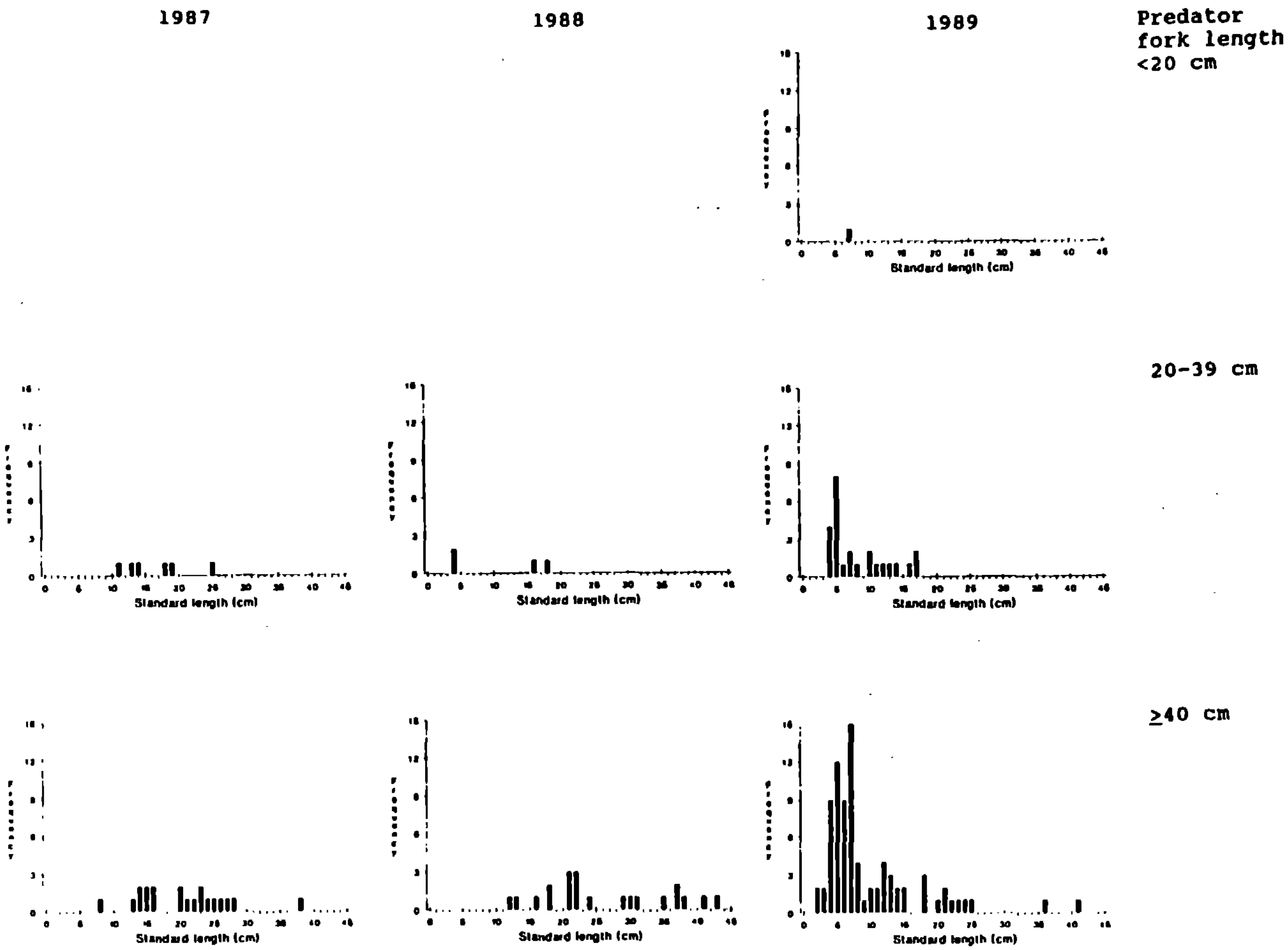

Figure E-5.--Size frequency distributions of walleye pollock consumed by three size groups of arrowtooth flounder in the eastern Bering Sea by year, 1987-89.

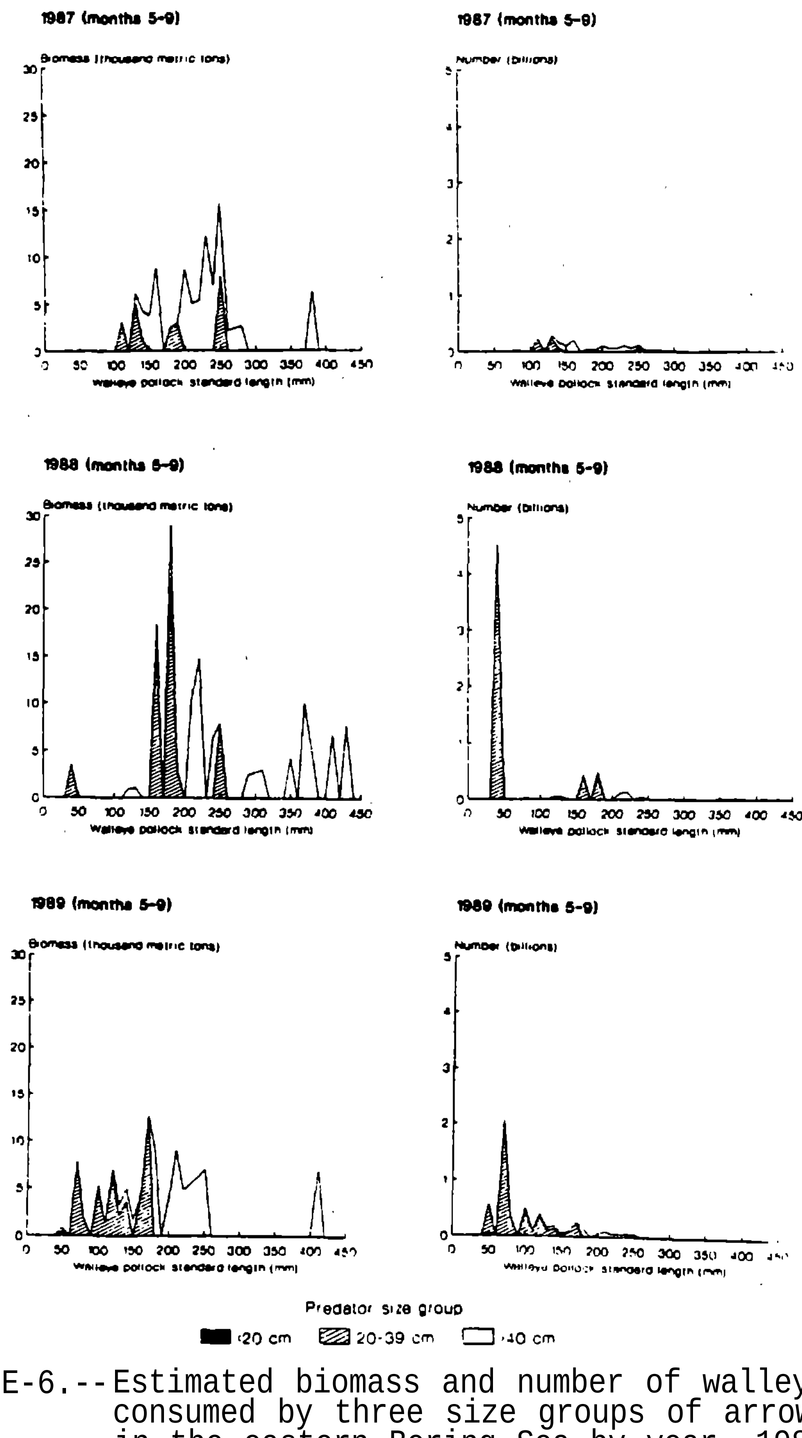

Figure E-6.--Estimated biomass and number of walleye pollock consumed by three size groups of arrowtooth flounder in the eastern Bering Sea by year, 1987-89 (months 5 to 9).

APPENDIX F

Pacific Halibut

Appendix F presents biomass, food habits, prey composition, prey size, and prey comsumption estimates for Pacific halibut during months 5 to 9 in 1989 in the eastern Bering Sea.

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Table F-l.--Estimated biomass in metric tons of Pacific halibut for 1989 in the eastern Bering Sea by halibut size group and stratum.

Stratum	Biomass		
	<30 cm	30-59 cm	≥60 cm
1	740	2,512	7,627
2	110	2,396	5,041
3	59	4,820	15,334
4	7	3,088	12,539
5	0	68	13,162
6	0	544	9,034

Table F-2.--Mean percent by weight (%W) and standard error (SE) of fish in the stomach contents of Pacific halibut by prey species, halibut size group, and stratum during months 5 to 9 in 1989 in the eastern Bering Sea.

Prey	Halibut size (cm)	Stratum	%W	SE
Walleye pollock	<30	1	5.64	5.64
		2	33.62	18.32
	30-59	1	18.04	10.03
		2	12.50	12.50
		3	15.40	10.18
		4	5.31	5.31
		5	0	0
		6	3.93	3.93
	≥60	1	7.11	7.11
		2	28.93	13.66
		3	49.81	11.54
		4	35.50	12.32
		5	18.52	15.42
		6	49.16	15.04
Pacific cod	≥60	5	19.20	19.20
Pacific herring	≥60	4	0.92	0.92
Flathead sole	30-59	1	2.01	2.01
Yellowfin sole	≥60	1	7.55	6.42

Table F-3.--Mean percent by weight (%W) and standard error (SE) of Tanner(Chionoecetes bairdi) and snow (C. opilio) crab in the stomach contents of Pacific halibut by prey species, halibut size group, and stratum during months 5 to 9 in 1989 in the eastern Bering Sea.

Prey	Halibut size (cm)	Stratum	%W	SE
C. opilio	30-59	2	0.38	0.38
		4	11.77	11.53
	≥60	4	7.46	6.81
		5	13.36	13.36
		6	6.68	6.68
C. bairdi	30-59	1	2.40	2.40
		3	5.50	3.83
		4	0.71	0.71
		5	47.82	47.82
		6	7.92	5.05
	≥60	3	11.15	7.77
		4	1.90	1.50
		5	3.42	3.32
		6	0.51	0.26

Table F-4.--Estimated total biomass (metric tons) and number (millions) of fish consumed by Pacific halibut by prey species, halibut size group, and stratum during months 5 to 9 in 1989 in the eastern Bering Sea.

Prey	Halibut size (cm)	Stratum	Biomass	Number
Walleye pollock	<30	1	89.34	113.56
		2	79.22	54.06
	30-59	1	693.32	63.74
		2	458.23	16.98
		3	1,135.98	37.31
		4	251.04	26.06
		5	0	0
		6	32.75	1.44
	≥60	1	331.91	35.21
		2	892.61	2.54
		3	4,674.74	13.16
		4	2,724.06	5.57
		5	1,491.82	2.47
		6	2,718.24	6.68
Total			15,573.26	378.78
Pacific cod	≥60	5	1,546.87	0.87
Pacific herring	≥60	4	70.75	(0)
Flathead sole	30-59	1	77.06	7.78
Yellowfin sole	≥60	1	352.24	6.88

Table F-5.--Estimated total biomass (metric tons) and number (millions) of Tanner (*Chionoecetes bairdi*) and snow (C. *opilio*) crab consumed by Pacific halibut by prey species, halibut size group, and stratum during months 5 to 9 in 1989 in the eastern Bering Sea.

Prey	Halibut size (cm)	Stratum	Biomass	Number
C. opilio	30-59	2	14.08	0.37
		4	556.31	81.25
	≥60	4	572.16	56.25
		5	1,076.18	15.67
		6	369.29	4.01
Total			2,588.02	157.55
C. bairdi	30-59	1	92.23	7.87
		3	405.50	59.59
		4	33.71	2.88
		5	49.76	5.88
		6	65.93	7.79
	≥60	3	1,046.22	74.31
		4	145.66	9.40
		5	275.79	33.43
		6	28.28	3.42
Total			2,143.08	204.57

Table F-6.--Size range of fish consumed by Pacific halibut by prey species, and halibut size group during months 5 to 9 in 1989 in the eastern Bering Sea.

Prey	Halibut size (cm)	Prey size range (mm)
Pacific cod	≥60	500
Flathead sole	30-59	90
Yellowfin sole	≥60	130-140

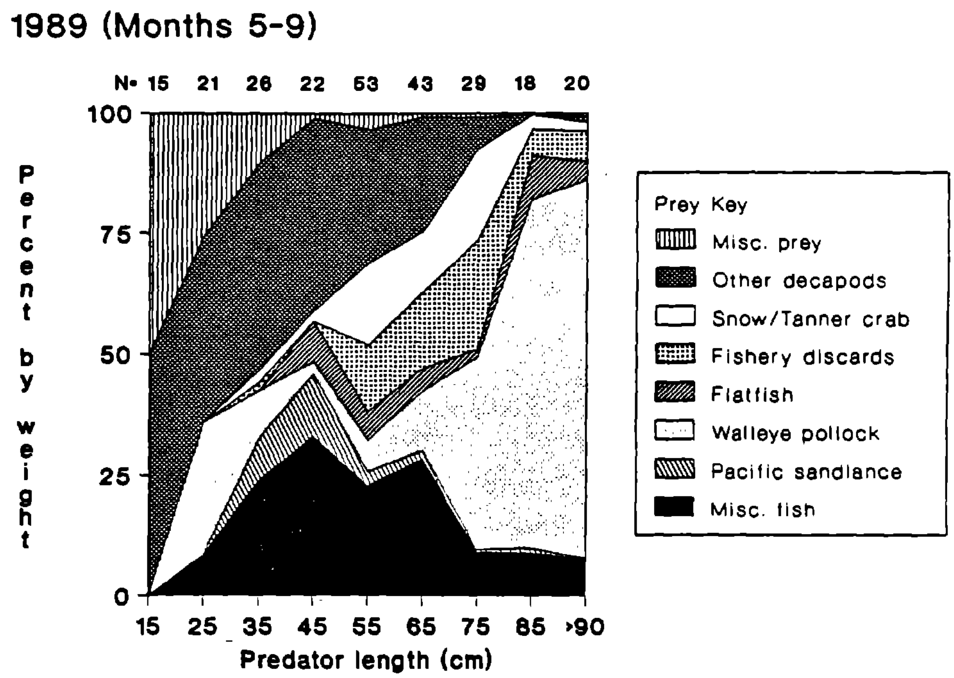

Figure F-l. --Diet composition of Pacific halibut, in terms of percent by weight and predator size during months 5 to 9 in the eastern Bering Sea in 1989. N= number of stomachs.

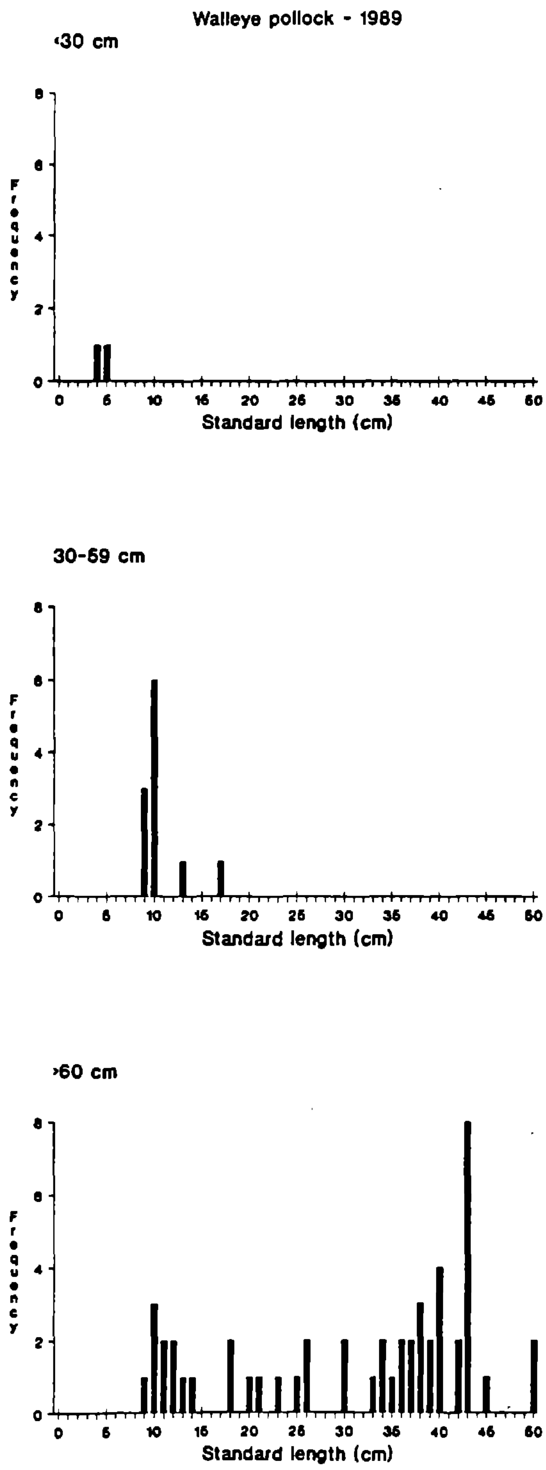

Figure F-2. --Size frequency of walleye pollock consumed by Pacific halibut during months 5 to 9 in the eastern Bering Sea in 1989.

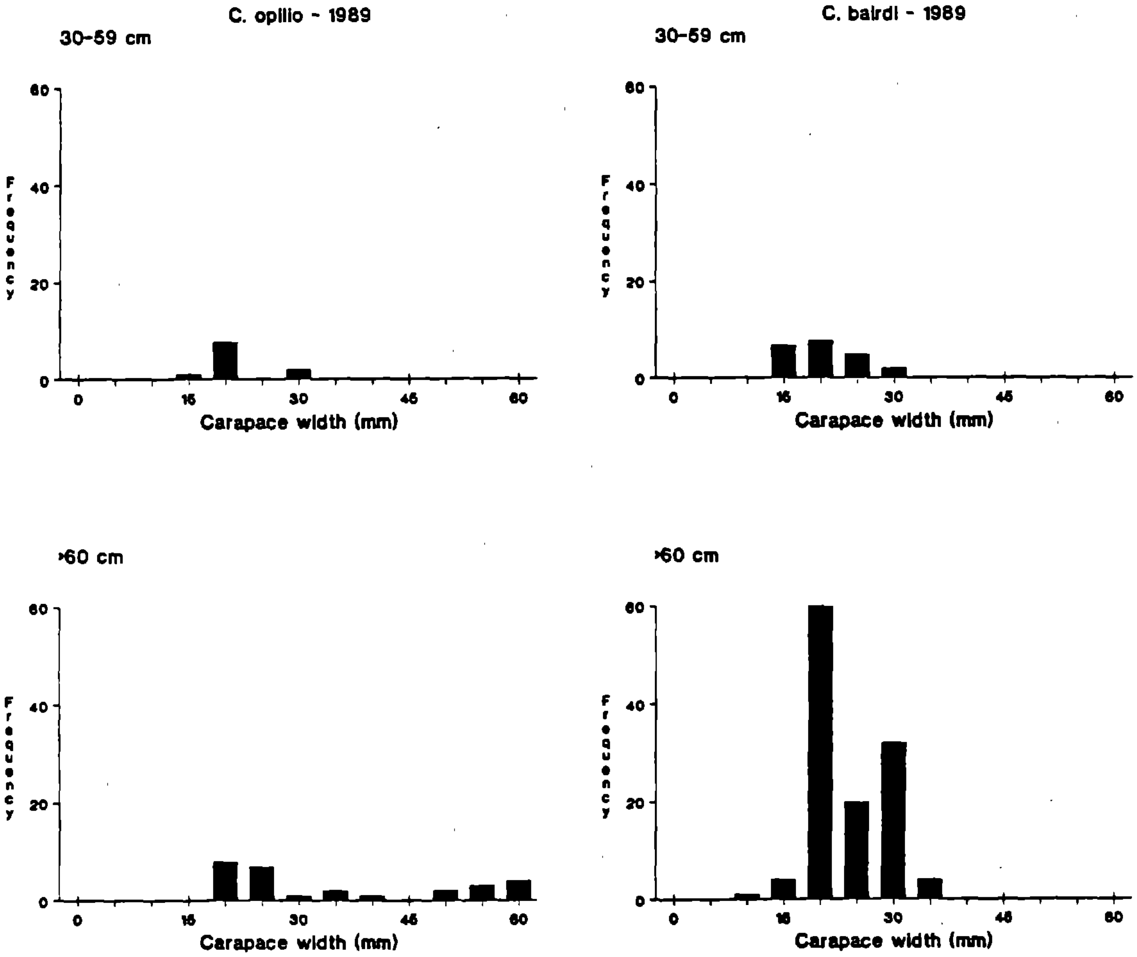

Figure F-3. --Size frequency of C. opilio and C. bairdi consumed by Pacific halibut during months 5 to 9 in the eastern Bering Sea in 1989.

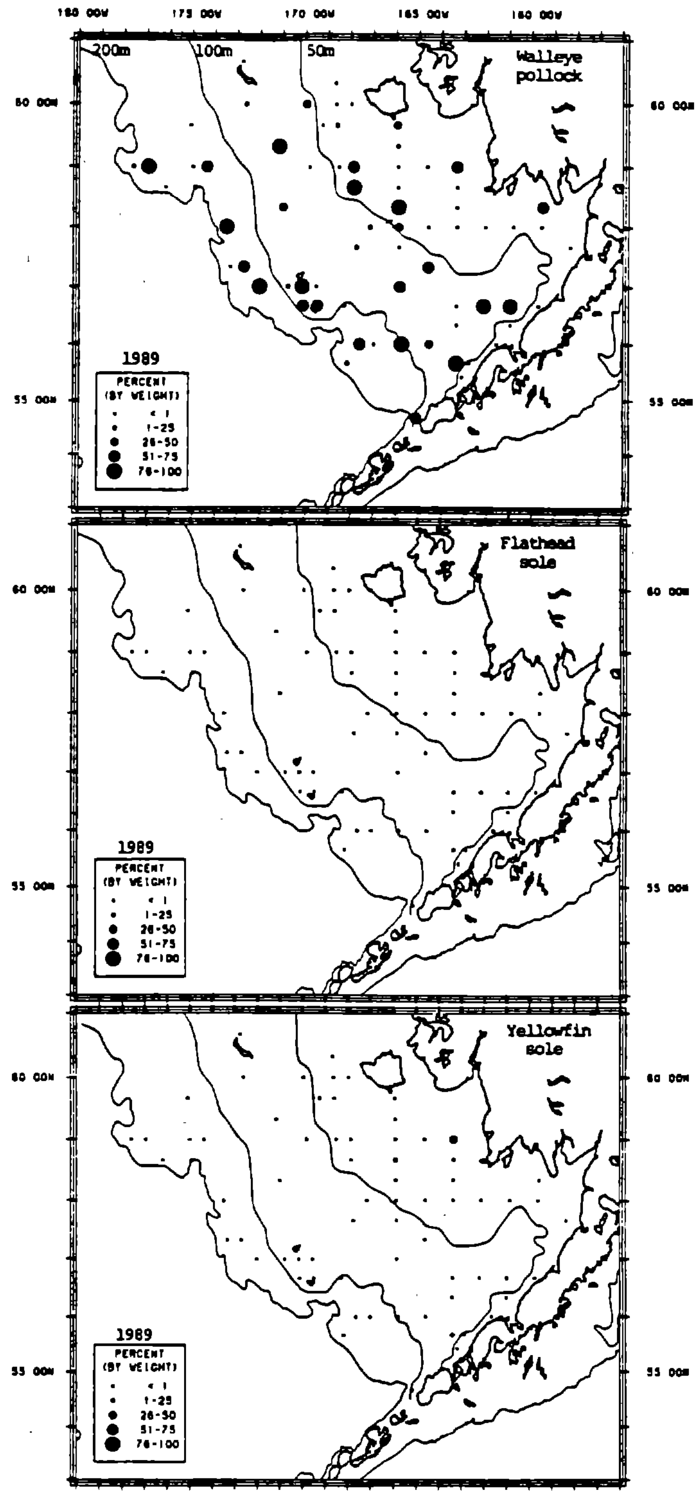

Figure F-4. --Percent by weight of walleye pollock, flathead sole and yellowfin sole in the diet of Pacific halibut by sampling station during months 5 to 9 in 1989.

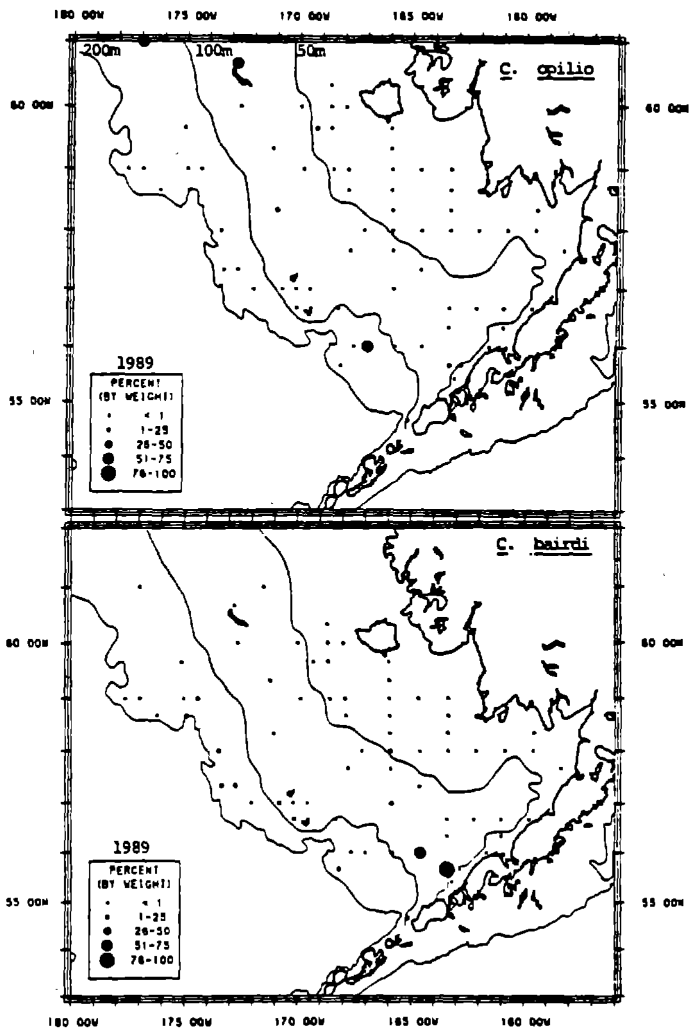

Figure F-5. --Percent by weight of C. <u>opilio</u> and C. <u>bairdi</u> in the diet of Pacific halibut by sampling station during months 5 to 9 in 1989.

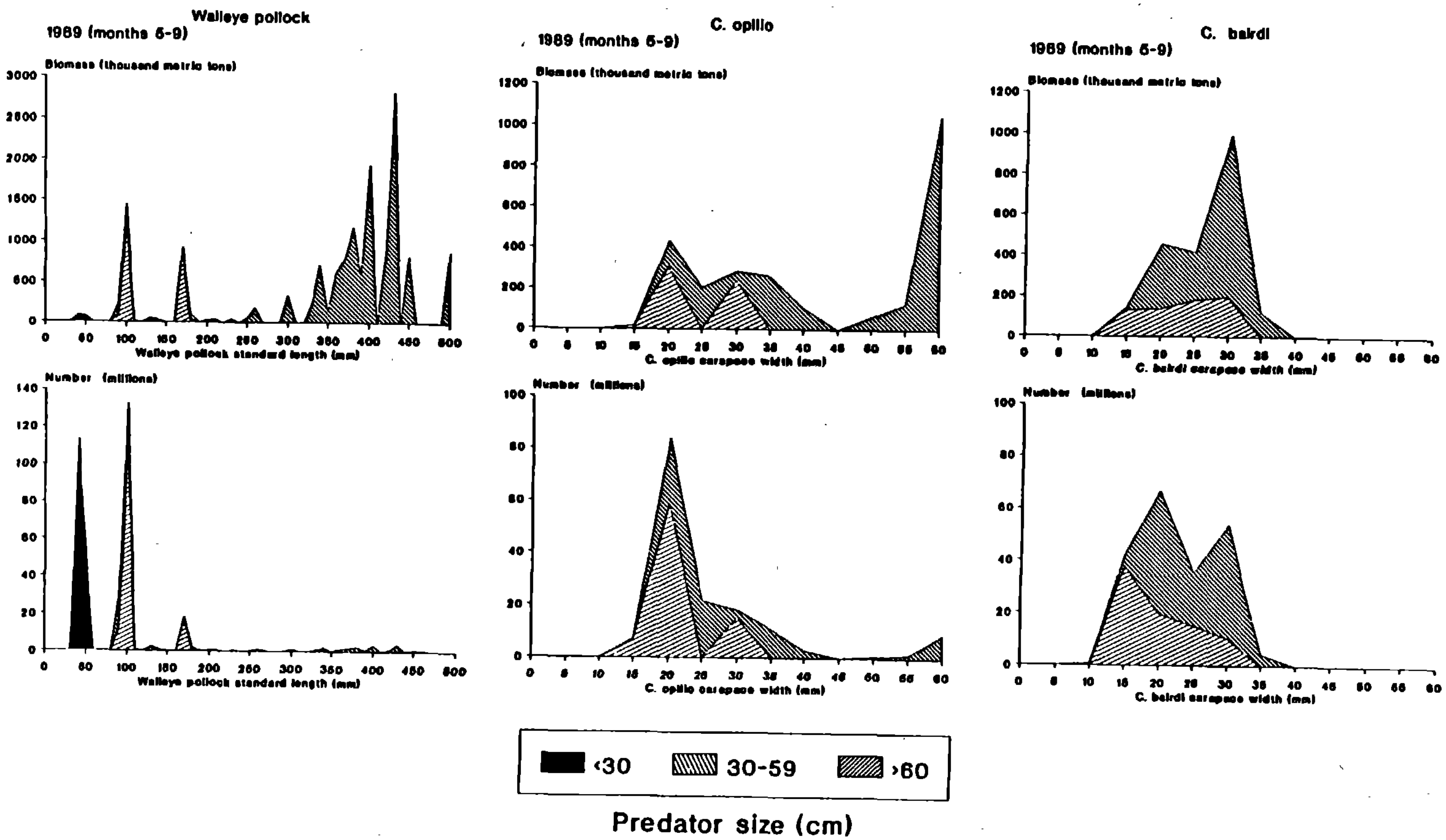

Figure F-6.--Biomass and number of walleye pollock, C. opilio and C. bairdi consumed by Pacific halibut during months 5 to 9 in the eastern Bering Sea by prey size in 1989.

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