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Diets of the Important Groundfishes in the Aleutian islands in Summer 1991

by
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U.S. DEPARTMENT OF COMMERCE
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Diets of the Important Groundfishes in the Aleutian Islands in Summer 1991

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ABSTRACT

The diets of commercially important groundfish species in the waters surrounding the Aleutian Islands during the summer of 1991 were studied. Important prey types, predator-prey size relationships, and prey distribution are discussed in detail.

CONTENTS

INTRODUCTION

The estimated biomass of groundfish resources in the Aleutian Islands region from long. 170° 30' E to 170° W, and the southern Bering Sea from long. 170° W to 165° W is about 2.0 million metric tons (t) (Harrison 1993). The objective of this study was to describe the food habits of key predators in the waters surrounding the Aleutian Islands and in the southern Bering Sea. Eleven commercially important groundfish species were studied: Pacific cod, Gadus macroceohu; walleye pollock, Theragra chalcogramma; Pacific halibut, Higooalossus stenolepis; arrowtooth flounder, Atheresthes stomias; Greenland turbot, Reinhardtius hippoglossoides; Atka mackerel, Pleurogrammus monopterygius Pacific ocean perch, Sebastes alutua; northern rockfish, Sebastes polyspinis; rougheye rockfish, Sebastes aleutianus; shortraker rockfish, Sebastes borealis; and shortspine thornyhead, sebastolobus alascanus.

METHODS

Study Area

From July to September 1991, the Resource Assessment and Conservation Engineering (RACE) Division at the Alaska Fisheries Science Center, Seattle, Washington, conducted a groundfish resources survey in' the Aleutian Islands region. This survey area (Fig. 1) covered the southern Bering Sea from long 165°W to 170° W and the Aleutian Islands waters from long. 170° W to 170° 30' E. The Resource Ecology and Fishery Management (REFM) Division's Trophic Interactions Program collected fish stomach samples during this survey.

Sample Collection

Fish stomach samples were collected by scientists aboard the charter vessel Green Hope from July to September in 1991. Before excising a stomach, fish were examined for evidence of regurgitation or net feeding. If a fish had food in its mouth or around the gills, or if its stomach was inverted or flaccid, the

fish was categorized as having regurgitated food, and the specimen was discarded. If a predator had fresh food (usually fish) sticking out of the mouth or the throat, it was categorized as a net-feeding fish and was also discarded. When a sampled stomach was retained, it was put in a cloth stomach bag. A field tag with the species name, fork length (FL) of the fish, and haul data (vessel, cruise, haul number, specimen number) was also put in the bag. All of the samples collected were then preserved in buckets containing a 10% buffered formalin solution. When the samples arrived at the laboratory, they were transferred into a 70% ethanol solution before the stomach contents were analyzed.

Stomach Contents Analysis

In the laboratory, the stomach contents were first blotted with a paper towel and the wet weight was then recorded to the nearest one-tenth of a gram. After obtaining the total weight for a stomach's contents, the contents were placed in a petri dish and examined under the microscope. Each prey item was classified to the lowest practical taxonomic level. The numbers of non-commercially important prey were not counted; instead the percent volume of these prey items was visually estimated. Prey weights and numbers of commercially important crabs and fish were recorded. If pollock otoliths were found, otolith lengths were measured and the pollock's standard length (SL) was derived. through an otolith length-fish length regression table (from REFM Aging Task). Standard lengths of prey fish, carapace widths (CW) of Tanner crabs, (Chionoecetes spp.), and Korean horse-hair crabs (Eriamacru isenbeckii) were also recorded.

Data Analysis

The general diet of each species was summarized by showing the overall percent frequency of occurrence, and the percent of the total weight of each prey item found-in the stomach. Change in diet by predator size in terms of percent by weight of main prey items was identified by dividing predator size into 10 cm FL groups. The prey size frequency data of the commercially important fish and crabs were also summarized by different predator size groups.

The geographic distribution of the important prey consumed (expressed as percent by weight of the total stomach contents weight in each haul) by the predators were also shown. The

important prey found in this study include walleye pollock, Atka mackerel, capelin (Mallotus villosus), myctophid, Tanner crabs, and Korean horse-hair crabs.

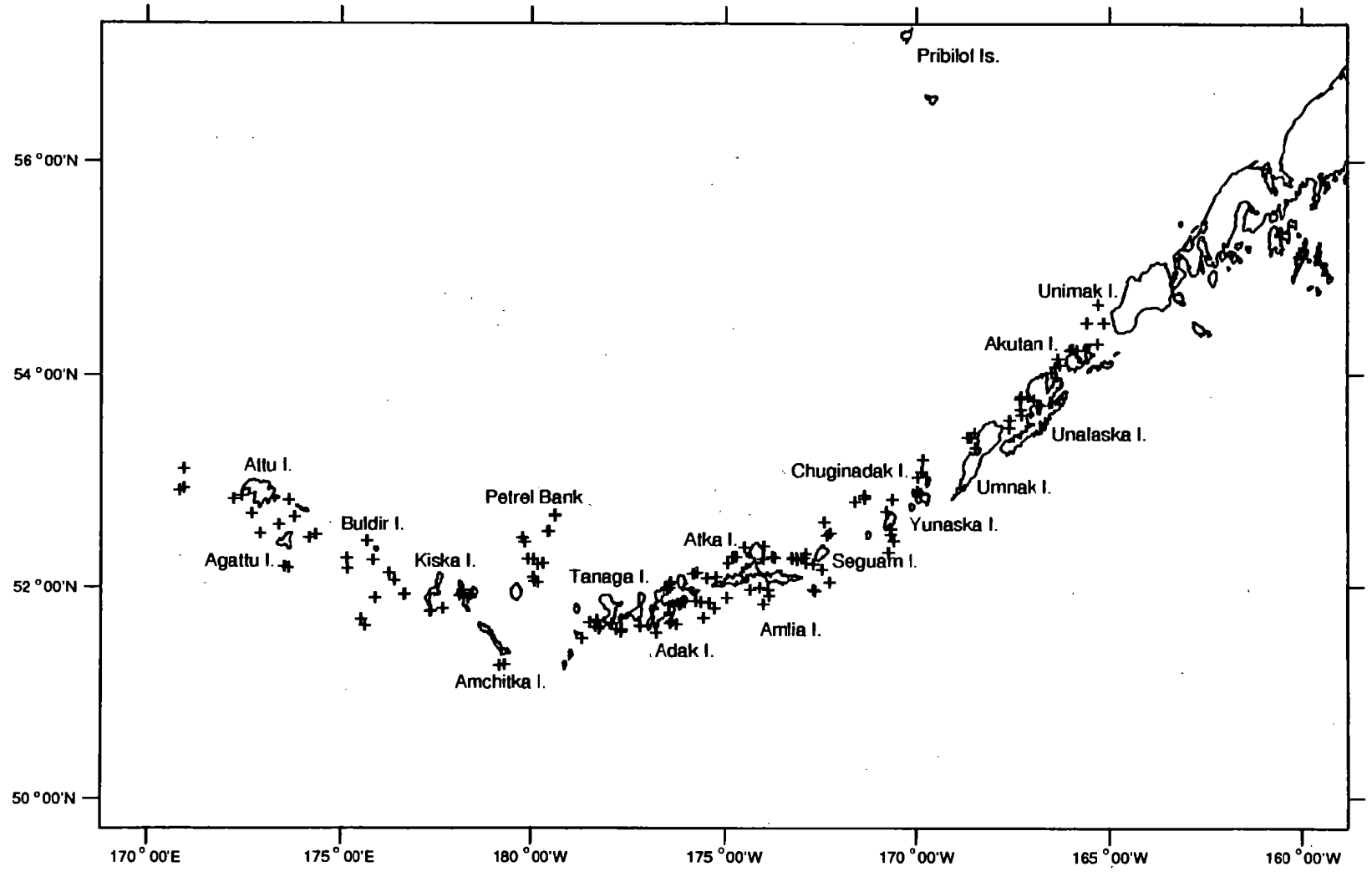

Figure 1.--Sampling locations (+) for the stomachs of groundfish collected in the Aleutian Islands area in 1991.

WALLEYE POLLOCK

The projected 1995 exploitable biomass of walleye pollock (Theragra chalcogramma for the Aleutian Islands region was 189,000 t (NPFMC 1994). Along with Atka mackerel, Pacific ocean perch, northern rockfish, and Pacific cod, walleye pollock was one of the five most abundant species in the Aleutian Islands region in 1991 (Harrison 1993). An earlier study suggested that euphausiids were the most frequently occurring prey of pollock in the Aleutian Islands area (Simenstad et al. 1977). Other prey items included shrimp, amphipods, cephalopods, myctophids, bathylagids, and Sebastes spp.

RESULTS

General Diet

A total of 546 walleye pollock stomachs were analyzed, of which 540 (99%) contained food. Pollock size ranged from 16 to 68 cm FL with a mean and standard deviation (SD) of 45.1 ± 10.1 cm. The average depth of the 44 haul locations where pollock stomachs were collected was 198 ± 78 m with a range from 81 to 397 m. Table l-l lists the main prey found in the pollock stomachs, the frequency of occurrence of prey (%), and the percentage of prey weight to the total food weight. The data presented in Table l-l suggests that pollock feed mainly on euphausiids (43% by weight). Though calanoid copepods, mysids, amphipods, and shrimp were frequently found in stomachs, they were relatively less important as pollock as food. Zoea and megalops of Chionoecetes spp. were found in pollock stomachs, but they comprised less than 1% by weight of the total stomach contents. Table l-l lists the diversity of prey fish found in pollock stomachs. Myctophids (37% by weight of the total stomach contents) were the most important prey fish of walleye pollock in the Aleutian Islands region. Some commercially important fish, such as Pacific cod, arrowtooth flounder, and Kamchatka flounder (Atheresthes evermanni) were found. Capelin, eulachon (Thaleichthys pacificus), deepsea smelts (Bathylagidae), and Pacific sand lance (Ammodytes hexapterus) were also considered to be important prey.

Variation of Diet Based on Predator Size

Figure l-i illustrates the main prey items of walleye pollock by predator length. Calanoid copepods were mainly consumed by pollock less than 20 cm FL. Euphausiids comprised the largest portion of food of pollock between 20 and 49 cm FL. Myctophids were the most important food for pollock larger than 50 cm FL -- making up about 50% of the diet for this group. Cannibalism of pollock was not observed in this study.

Size of Prey Fish

The number, mean, and SD of standard length of the prey fish for pollock are listed in Table l-2. Since a large number of, myctophids were consumed, the myctophid length data were further divided into two predator size groups (< 40 cm and < 40 cm FL) for analysis. Figure l-2 shows that walleye pollock less than 40 cm FL consumed mainly smaller sized (< 70 mm SL) myctophids whereas larger pollock <40 cm FL) consumed many larger 70 mm SL) myctophids.

Geographic Distributions of Prey

Figure l-3 shows the percentage by weight of myctophids consumed by walleye pollock in different locations. The figure illustrates that myctophids were consumed on both sides of the Aleutian Islands chain primarily in waters of bottom depths greater than 150 m. Myctophids made up more than 50% of the stomach contents weight for walleye pollock collected in these areas.

DISCUSSION

The diet of walleye pollock from this study was compared to data on pollock diet from the Gulf of Alaska (Yang 1993) and the eastern Bering Sea (Livingston 1991). The weight (%) of the major prey categories for pollock from three study areas are compared in Table l-3. These data show that the diet similarity (49%) between Aleutian Islands region and the Gulf of Alaska was higher than the other areas. This was primarily caused by the high consumption <39% of the total) of euphausiids in these two

areas. In the Bering Sea, pollock (41% by weight) was the main food of pollock, whereas pollock comprised only 2% of the diet in the Gulf of Alaska, and no pollock cannibalism was observed in the Aleutian Islands area. In the Gulf of Alaska, capelin comprised the highest percentage (13%) by weight of prey fish consumed by pollock, whereas myctophids (comprised 37% by weight) were the main prey fish found in pollock stomachs in the Aleutian Islands area. Another difference was that pollock consumed more pandalid shrimp in the Gulf of Alaska (19%) than in the eastern Bering Sea (4%) and Aleutian Islands area (2%).

Simenstad et al. (1977) found that euphausiids were the most important prey (87% by weight) of walleye pollock in the Amchitka Island area. They also found myctophids, Sebastes spp., shrimp, squid, and octopus in the pollock stomachs.

Table 1-1. --Main prey items (expressed in frequency of occurrence (%) and percentage of total weight consumed) of Theragra chalcogramma (walleye pollock) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta	4.07	0.23
Pteropoda (snail)	3.89	0.04
Cephalopoda (squid & octopus)	1.30	0.03
Teuthoidea (squid)	9.44	1.74
Calanoida (copepod)	68.89	3.18
Mysidacea (mysid)	18.15	0.98
Cumacea (cumacean unidentified)	2.22	0.01
Isopoda (isopod)	1.11	0.06
Gammaridea (amphipod)	25.19	1.89
Hyperiidea (amphipod)	65.93	1.55
Euphausiacea	85.56	43.16
Sergestidae (shrimp)	1.86	0.19
Caridea (unidentified shrimp)	35.00	0.83
Hippolytidae (unidentified shrimp)	4.44	0.37
Pandalidae (unidentified shrimp)	11.48	1.80
Crangonidae (unidentified shrimp)	3.89	0.44
Paguridae (hermit crab)	9.81	0.07
Chionoecetes spp. (snow & Tanner crab)	5.19	0.03
Chaetognatha (arrow worm)	14.26	0.39
Larvacean (tunicate)	11.85	1.74
Teleostei (unidentified fish)	7.78	0.55
Non-gadoid fish remains	4.26	1.42
Mallotus villosus (capelin)	0.93	0.25
Thaleichthys pacificus (eulachon)	0.50	0.04
Bathylagidae (deepsea smelts)	1.30	1.10
Chauliodontidae (viperfishes)	0.56	0.27
Myctophidae (lanternfish)	11.85	37.10
Gadidae (unidentified gadid)	0.19	<0.01
Gadus macrocephalus (Pacific cod)	0.19	0.03
Cottidae (sculpin)	2.04	0.14
Cyclopteridae (snailfish)	1.11	0.02
Bathymaster spp. (searcher)	0.19	<0.01
Stichaeidae (prickleback)	0.74	0.04
Ammodytes hexapterus (Pacific sand lance)	0.19	0.06
Pleuronectidae (unidentified flatfish)	0.37	0.01
Atheresthes evermanni (Kamchatka flounder)	0.37	0.02
Atheresthes stomias (arrowtooth flounder)	0.37	0.03
Misc. unidentified materials	5.56	0.15
Total prey weight	2,811 g	
Number of stomachs with food	540	
Number of empty stomachs	6	

Table 1-2.--Mean, standard deviation (SD), and range of standard length of the miscellaneous, prey fish consumed by walleye pollock in the Aleutian Islands area in 1991.

Prey name	No.	Mean (mm)	SD (mm)	Range (mm)
Arrowtooth flounder	4	34.7	5.2	30-42
Bathylagid	4	88.7	49.2	45-145
Capelin	2	95.0	7.0	90-100
Cattid	7	30.1	6.8	23-41
Kamchatka flounder	1	25.0		
Myctophid	165	71.9	22.1	22-110
Pacific cod	1	58.0		
Pacific sand lance	5	53.0	4.5	50-60
Searcher	1	30.0		
Snailfish	6	18.0	6.0	12-27
Stichaeid	2	33.5	10.6	26-41
Viperfish	2	107.5	10.6	100-115

Table l-3. --Percent by weight of the major prey categories of walleye pollock in the Aleutian Islands area (AI) compared to the eastern Bering Sea (EBS) (from Livingston 1991), and Gulf of Alaska (GOA) (from Yang 1993). "-" indicates < 1.

Prey name	AI	GOA	EBS
Copepoda	3	1	6
Mysid	1	1	1
Amphipod	3	3	1
Euphausiid	43	39	25
Pandalid	2	19	4
Crangonid	-	2	1
Pasiphaeid	0	2	0
Chionoecetes sp.	-	0	-
Capelin	-	13	0
Pollock	0	2	41
Myctophid	37	-	2
Miscellaneous fish	2	15	4
Unidentified fish	2	1	8

% similarity between AI and EBS: 38
% similarity between AI and GOA: 49
% similarity between EBS and GOA: 40

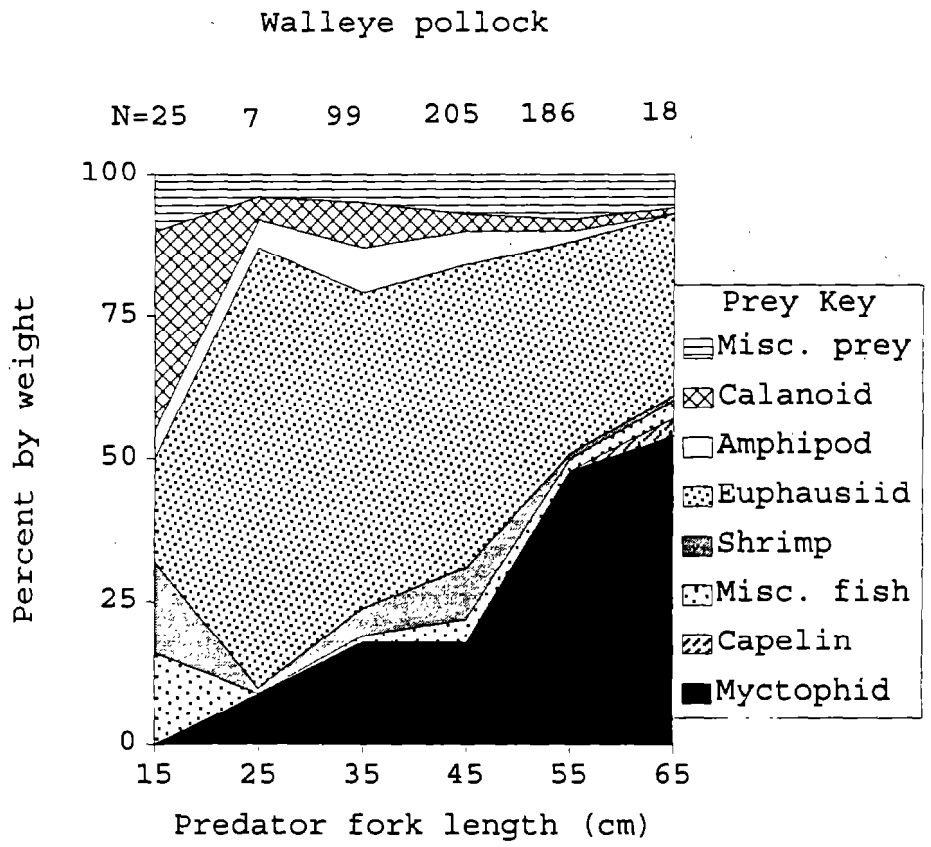

Figure l-l.-- Main food items of walleye pollock, by predator size, in the Aleutian Islands area in 1991. N = sample size.

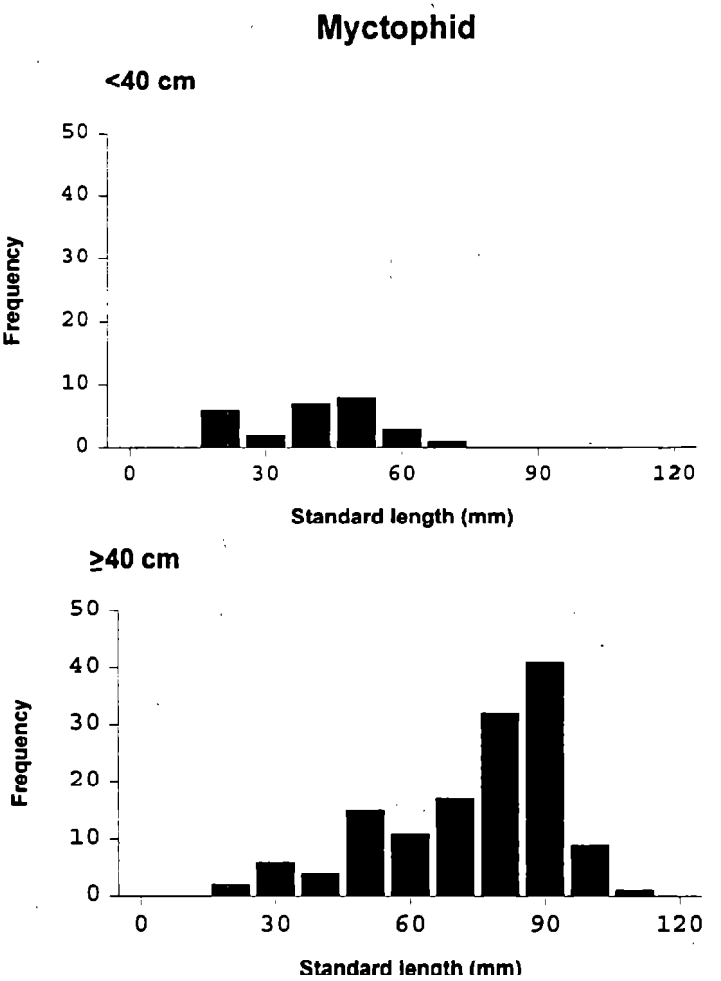

Figure 1-2.-Size frequency distributions of myctophid consumed by two size groups (< 40 cm FL and ? ?40 cm FL) of walleye pollock in the Aleutian Islands area in 1991.

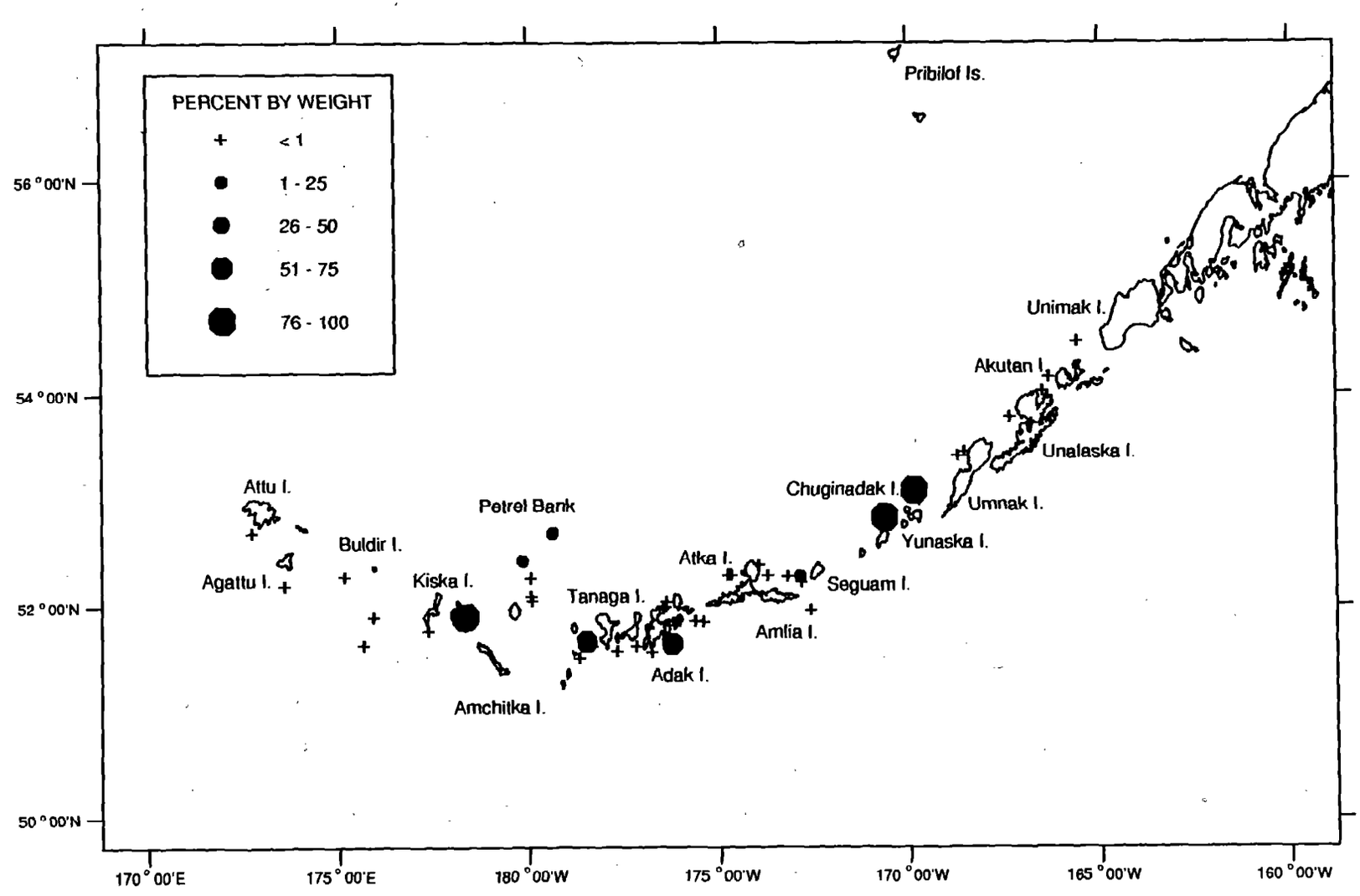

Figure 1-3.-- Geographic distribution of myctophids consumed by walleye pollock in the Aleutian Islands area in 1991.

PACIFIC COD

Pacific cod (Gaus marocenhalus) is one of the five most abundant species (in biomass) in the Aleutian Islands area (Harrison 1993). The projected exploitable biomass of Pacific cod in 1995 was 220,000 t (Thompson 1994). Pacific cod have a high variety of prey in their diets (including many commercially important fish and crabs) since they feed both on the bottom and in the water column.

RESULTS

General Diets

A total of 659 Pacific cod stomachs were analyzed, of which 651 contained food. Pacific cod lengths ranged from 15 to 109 cm FL with a mean and SD of 56.0 cm and; 17.0 cm, respectively. The average depth of the 69 haul locations was 142 ± 55 m with a range from 58 to 348 m. Pacific cod, an opportunistic feeder,, ate many different invertebrates and various fish (33% and 67% of the total stomach content weight, respectively). Squid comprised the highest proportion (9% of the total stomach content weight) of the invertebrates consumed. Shrimp (hippolytid, pandalid, and crangonid) also comprised about 9% of the total stomach content weight. Pacific cod also consumed Korean horse-hair crab (Erimacrus isenbeckii), Tanner crabs (Chionoecetes bairdi), and other crabs (Table 2-l). The crabs consumed by Pacific cod also made up about 9% of the total stomach content weight. Polychaetes, mysids, gammarid amphipods, and euphausiids were also found frequently in the stomachs but they were not very important food of Pacific cod in terms of the percentage of the total stomach content weight. Atka mackerel and walleye pollock were the two main fish species consumed by Pacific cod. The two species comprised 27% and 17% of the total stomach content weight, respectively. Other commercially important prey fish include juvenile Pacific cod, greenlings (hexagrammid), Sebastes spp., sablefish (Anoplopoma fimbria), rex sole (Errex zachirus), flathead sole (Hippoglossus elassodon), rock sole, (Pleuronectes bilineatus, and Pacific halibut. Pacific cod also consumed many non-commercially important prey

fish, such as zoarcids, macrourids, cottids, agonids, cyclopterids, bathymasterids, Pacific sand lance, and stichaeids.

Variation of Diet Based on Predator Size

Figure 2-l shows that Pacific cod consumption of fish increased with increasing body size, especially for cod greater than or equal to 70 cm FL. Fish comprised about 75% of the total stomach contents in this larger size group. This group of Pacific cod ??70 cm FL) consumed large amounts of Atka mackerel and walleye pollock (31% and 23% by weight, respectively). No walleye pollock were found in the stomachs of Pacific cod smaller than 60 cm FL. Other fish species made up between 10% and 30% of the diet by weight throughout all the different size groups of cod. Cod between 20 and 70 cm FL consumed some shrimp (between 17% and 39% of the diet). Tanner crabs ??14%) were consumed mainly by Pacific cod between 20 and 70 cm FL, The smallest size group (< 20 cm FL) of cod ate primarily large amounts (70%) of amphipods.

Size of Important Prey

The commercially important prey consumed by Pacific cod were analyzed by two predator size groups (< 60 cm, and ??60 cm FL). No walleye pollock were found in the stomachs of Pacific cod less than 60 cm FL. Pacific cod longer or equal to 60 cm FL consumed many age 3+ pollock (approximately >300 mm SL) and some age 0 to age 2 pollock (Fig. 2-2). The mean SL of pollock consumed by Pacific cod was 334.4 ± 131.3 mm with a range from 65 to 518 mm SL. Figure 2-3 (right) illustrates that Atka mackerel were primarily consumed by larger Pacific cod(??60 cm FL). The mean standard length of all Atka mackerel consumed by Pacific cod was 226.2 ± 57.2 mm with a range from 107 to 330 mm SL. The mean SL of the myctophids consumed was 71.8 ± 21.8 mm with a range from 28 to 105 mm SL. Figure 2-3 (left) also shows that myctophids were mainly consumed by larger Pacific cod (³-60 cm FL). Larger cod fed on larger prey. In general, larger Pacific cod ??60 cm FL) fed on larger Tanner crabs than smaller cod (< 60 cm FL) (Fig. 2-4, left). The average carapace width (CW) of the Tanner crabs consumed was 19.3 ??9.9 mm with a range of 5 to 53 mm. Most of the Tanner crabs measured from Pacific cod stomach contents were age-l crab (9-34 mm CW). Pacific cod also consumed a fair number of Korean horse-hair crab (Fig. 2-4, right). The

average carapace width of the Korean horse-hair crab was 27.6 ± 10.8 mm with a range of 14 to 57 mm. Only one Pacific halibut (27 mm SL) was observed in our Pacific cod samples. One flathead sole (195 mm SL), one rex sole (260 mm SL), two juvenile cod (123 and 146 mm SL), six Sebastes spp. (125-260 mm SL), and two rock sole (62 and 260 mm SL) were also observed in the samples. Miscellaneous prey fish data are listed in Table 2-2.

Geographic Distributions of Prey

Figures 2-5 to 2-9 'illustrate the geographic distributions of the important prey (percent by weight) for Pacific cod in each haul where stomach samples were collected. The high percentage of Atka mackerel in the diet of Pacific cod was observed mainly in the western part of the Aleutian Islands area (Fig. 2-5). Walleye pollock were consumed by Pacific cod at many locations in the Aleutian Islands area (Fig. 2-6), the percent (> 75%) consumption peaked in the Agattu Island area. Figure 2-7 shows the geographic distribution of the Tanner crabs consumed by Pacific cod. The figure illustrates that Tanner crab consumption was low ??25%), except in the Unalaska Island area (66%). Consumption of Korean horse-hair crab by Pacific cod was mainly located in the western part (west of Atka Island) of the Aleutian Islands chain, and the highest percent (> 75%) consumption was found in the Atka Island area. Myctophids were consumed by Pacific cod mainly in the Yunaska Island area, and the percent by weight was low (about 30% at two haul locations) (Fig. 2-9).

DISCUSSION

Simenstad et al. (1977) found that Pacific cod in the Amchitka Island area fed mainly on fish (including cottids and Pacific sand lance). Shrimp, Korean horse-hair crab, squid, and octopus also occurred in their samples frequently. In our study, cottids were also found frequently (27% frequency of occurrence) in the stomachs of Pacific cod.

Table 2-3 lists the percentage by weight of the major prey categories of Pacific cod from the Aleutian Islands area (this study), Gulf of Alaska (Yang 1993), and the eastern Bering Sea (Livingston 1991). Based on the data in Table 2-3, the percent similarity of the diets between the three areas was about 30%.

Two major differences were observed. First, Atka mackerel was the most important prey (27% by weight) of Pacific cod in the Aleutian Islands area, whereas no Atka mackerel were found in samples from the Gulf of Alaska or eastern Bering Sea. Second, walleye pollock were prey of Pacific cod in all three areas, however, the amounts differed. In the eastern Bering Sea, pollock were the most important prey of Pacific cod, making up 40% of the total stomach contents weight. On the other hand, pollock comprised only 17% and 8% of the total stomach content weight of Pacific cod in the Aleutian Islands area and Gulf of Alaska, respectively. The high percentage (27%) of Atka mackerel and relatively low percentage (17%) of pollock consumed by Pacific cod in the Aleutian Islands area can be attributed to the higher biomass of Atka mackerel (about 700,000 t) compared to that of pollock (about 200,000 t) in the Aleutian Islands area (Harrison 1993).

Table 2-1.--Prey items (expressed in frequency of occurrence (%), and percentage of total weight) of Gadus macrocephalus (Pacific cod) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	40.25	0.70
Gastropoda (unidentified)	3.53	0.15
Bivalvia (clam)	2.30	0.02
Cephalopoda (unidentified).,	4.30	0.09
Teuthoidea (squid unidentified)	14.59	8.65
Octopoda (unidentified)	7.07	3.50
Calanoida (copepod unidentified)	1.84	0.01
Mysidacea (mysid unidentified)	10.29	0.08
Isopoda (isopod)	4.61	0.04
Gammaridea (amphipod)	52.84	0.93
Hyperiid (amphipod)	1.38	0.03
Euphausiacea (unidentified)	11.83	0.21
Reptantia (crab)	3.69	0.11
Caridea (unidentified)	16.90	0.90
Hippolytidae (unidentified)	45.16	2.12
Pandalidae (unidentified)	45.39	5.54
Crangonidae (unidentified)	22.12	0.95
Paguridae (hermit crab)	8.76	0.34
Lithodidae (king crab)	0.31	0.07
Acantholithodes hispidus (fuzzy crab)	0.31	0.19
Lopholithodes foraminatus (box crab)	0.40	1.68
Placetron wosnessenski (scale crab)	0.31	0.17
Lithodes couesi (couesi king crab)	0.15	0.01
Munida quadrispina (pinch bug)	0.15	0.01
Majidae (unidentified)	9.98	0.69
Chionoecetes sp. (unidentified)	3.38	0.50
Chionoecetes bairdi (Tanner crab)	7.07	1.51
Frimacrus isenbeckii (crab)	5.68	3.39
Pinnotheridae (pea crab)	0.31	<0.01
Sipuncula (peanut worm)	0.15	<0.01
Raja spp.	0.15	0.08
Teleostei (unidentified fish)	11.37	0.37
Non-gadoid fish remains	23.50	3.36
Clupea pallasi (Pacific herring)	0.31	0.52
Chauliodus macouni, (Pacific viperfish)	1.39	0.12
Myctophid (lantern fish)	6.91	3.08
Gadidae (unidentified gadid)	0.77	0.12
Gadus macrocephalus (Pacific cod)	0.46	0.61
Theragra chalcosramma (walleye pollock)	4.45	17.22
Zoarcidae (unidentified eelpout)	0.92	0.02

Table 2-l.--Continued.

Prey Name	% Freq. occur.	% Total weight
Macrouridae (rattail)	0.15	0.16
Sebastes spp. (rockfish)	1.23	2.15
Hexagrammidae (greenling)	0.15	0.08
Pleurogrammus monopterygius (Atka mackerel)	6.76	27.00
Anoplopoma fimbria (sablefish)	0.46	0.17
Cottidae (unidentified)	27.04	6.32
Artediellus spp. (sculpin)	0.15	0.03
Icelinus borealis (Northern sculpin)	1.54	0.03
Triglops pingeli (ribbed sculpin)	0.15	0.24
Triglops scepticus (spectacled sculpin)	0.46	0.18
Agonidae (poacher)	2.30	0.12
Cyclopteridae (unidentified snailfish)	6.30	0.26
Aptocyclus ventricosus (smooth lumpsucker)	0.15	0.29
Bathymaster signatus (searcher)	1.07	1.38
Stichaeidae (unidentified)	1.84	0.14
Pholis ornata (saddleback gunnel)	0.61	0.02
Ammodytes hexapterus (Pacific sand lance)	0.61	0.16
Pleuronectidae (unidentified flatfish)	2.31	0.98
Errex zachirus (rex sole)	0.15	0.60
Hippoglossoides elassodon (flathead sole)	0.31	0.26
Pleuronectes bilineatus (rock sole)	0.31	0.89
Hippoglossus stenolepis (Pacific halibut)	0.46	0.01
Fishery discards	0.61	0.06
Misc. unidentified materials	7.68	0.72

Total prey weight	26,534 g
Number of stomachs with food	651
Number of empty stomachs	8

Table 2-2.--Mean, standard deviation (SD), and range of the standard length of the miscellaneous prey fish consumed by Pacific cod in the Aleutian Islands area in 1991.

Prey name	No.	Mean (mm)	SD (mm)	Range (mm)
Agonid	7	70.0	27.7	35-115
Atka mackerel	33	226.2	57.2	107-330
Cottid	201	61.9	44.2	12-270
Flathead sole	1	195.0	-	-
Myctophid	54	71.8	21.8	28-105
Pacific cod	2	134.5	12.3	123-146
Pacific halibut	1	27.0	-	-
Pacific sand lance	3	159.6	32.0	123-182
Rex sole	1	260.0	-	-
Rattail	1	200.0	-	-
Rock sole	2	161.0	140.0	62-260
Searcher	7	175.8	70.4	82-270
Sebastes spp.	6	191.6	60.5	125-260
Snailfish	36	39.5	22.8	8-109
Stichaeid	18	72.9	25.8	30-150
Viperfish	1	210.0	-	-
Walleye pollock	25	334.4	131.3	65-518
Zoarcid	6	66.0	19.0	34-85

Table 2-3. --Percent by weight of the major prey categories of Pacific cod in the Aleutian Islands area (AI) compared to the eastern Bering Sea, (EBS) (from Livingston 1991), and Gulf of Alaska (GOA) (from Yang 1993). "-I" indicates <l.

Prey name	AI	GOA	EBS
Polychaete	1	5	1
Cephalopod	12	10	2
Pandalid	6	9	1
Chionoecetes spp.	2	12	9
Korean horse-hair crab	3	0	0
Other decapod	4	8	1
Osmerid	-	2	-
Myctophid	3	0	0
Pollock	17	8	40
Atka mackerel	27	0	0
Flatfish	3	9	12

% similarity between AI and GOA: 34
% similarity between AI and EBS: 27
% similarity between GOA and EBS:44

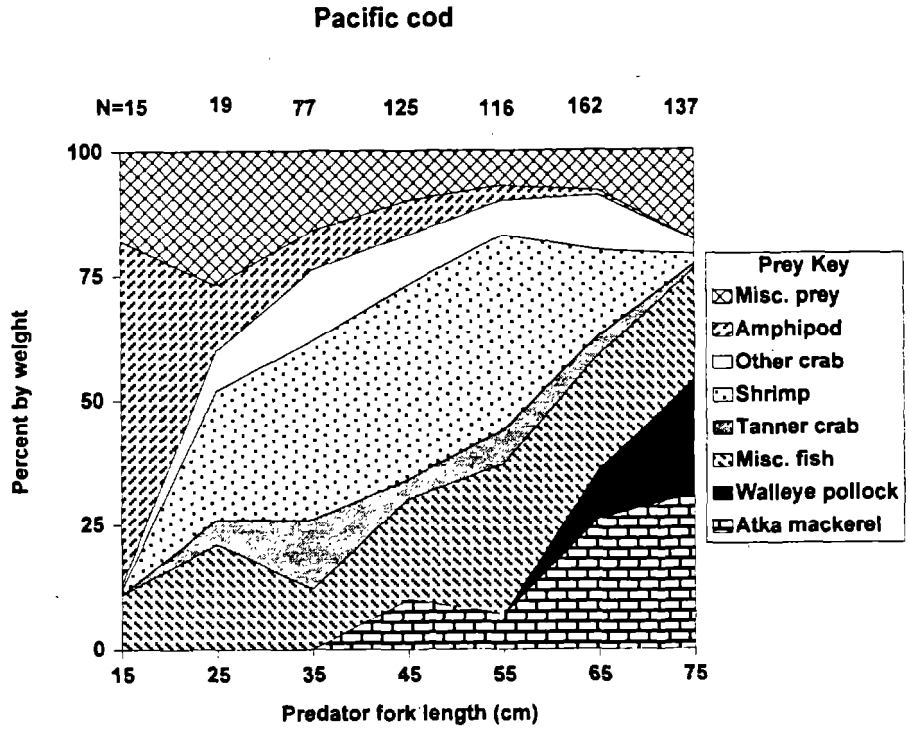

Figure 2-1.-Variation in the main food items of Pacific cod, by predator size, in the Aleutian Islands area in 1991. N = sample size.

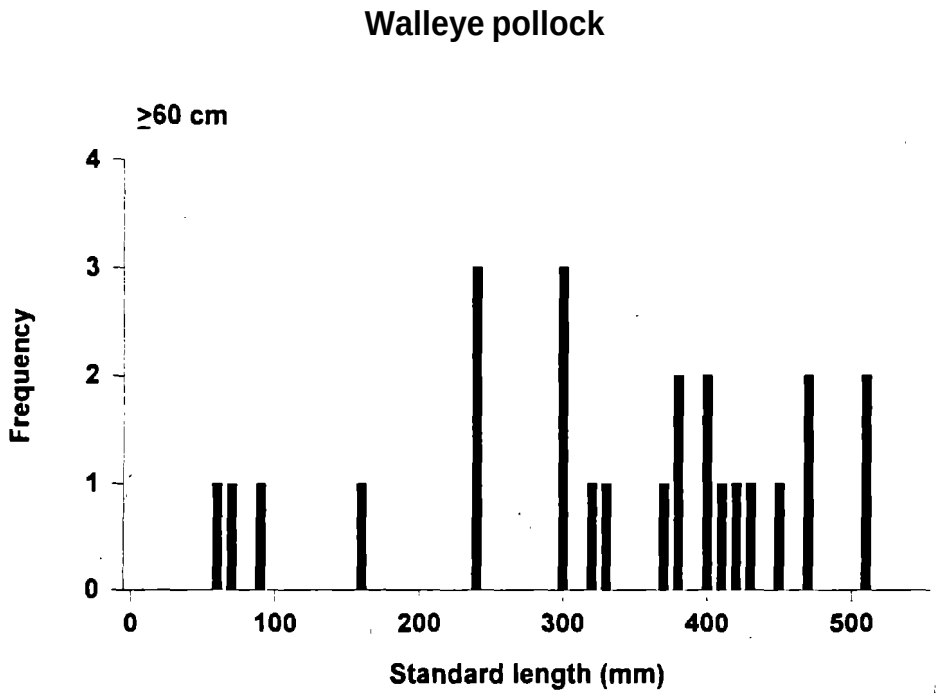

Figure 2-2.-Size frequency distributions of walleye pollock consumed by Pacific cod ????cm in the Aleutian Islands area in 1991.

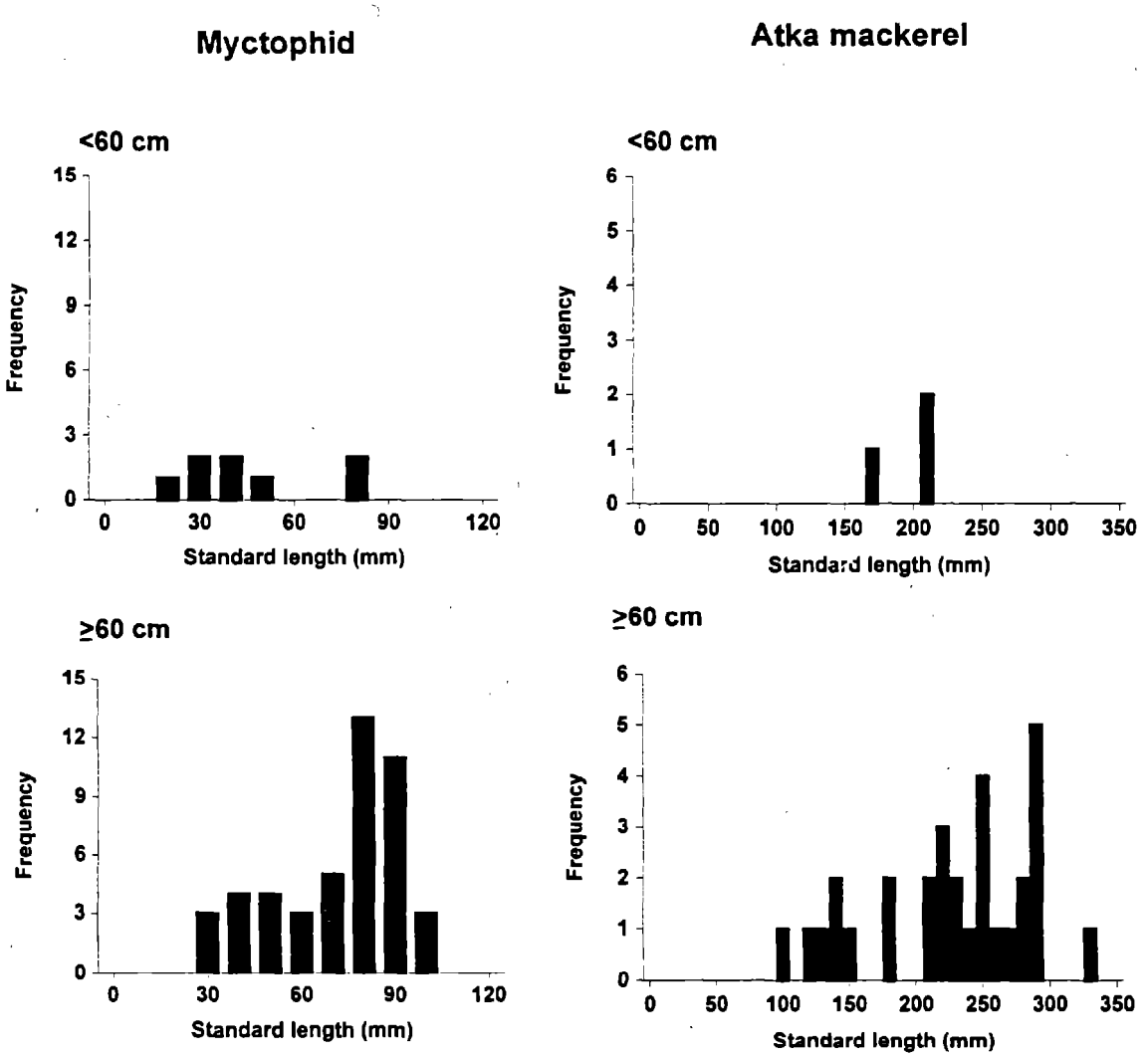

Figure 2-3.--Size frequency distributions of Atka mackerel and myctophid consumed by two size groups (< 60 cm FL and ? ?60 cm FL) of Pacific cod in the Aleutian Islands area in 1991.

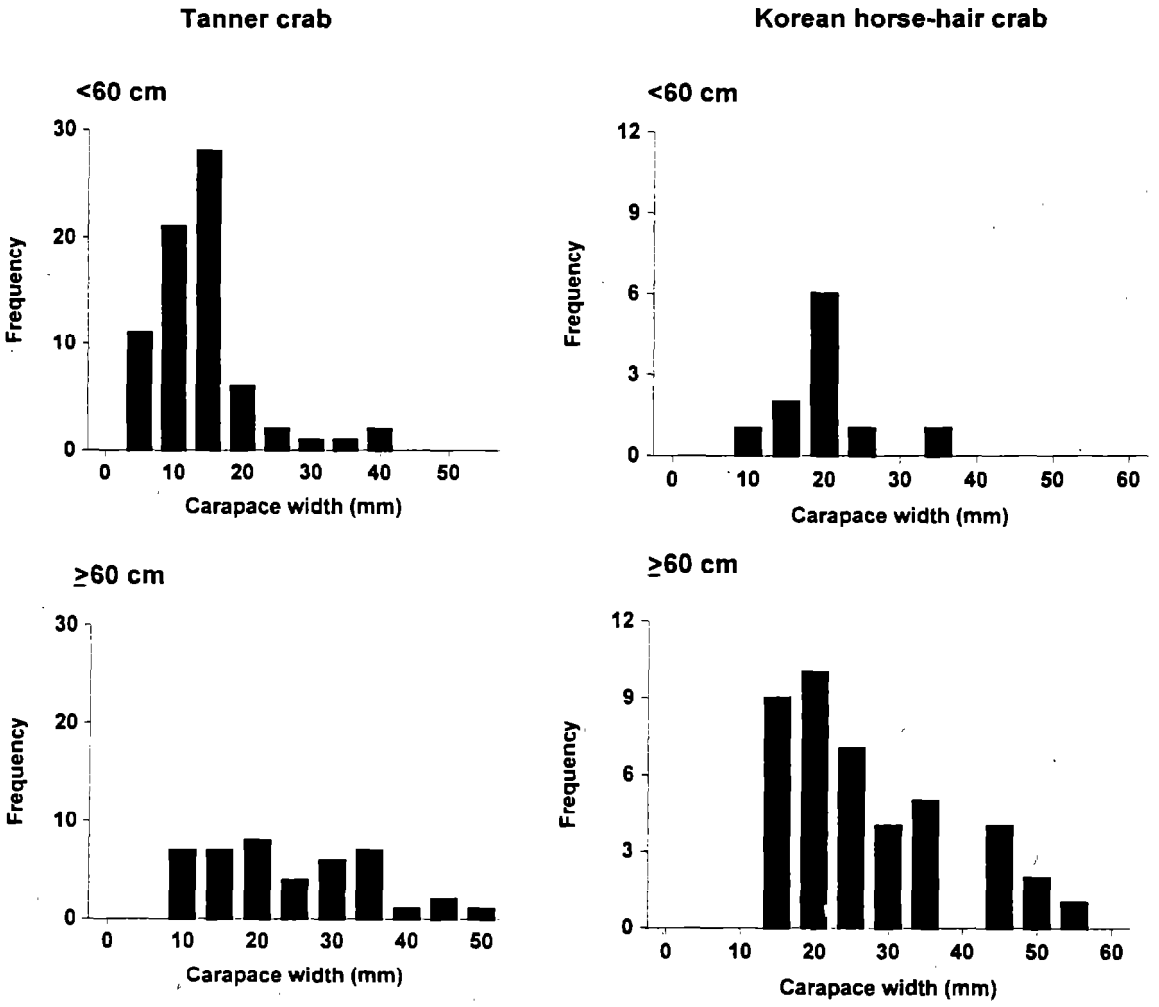

Figure 2-4 Size frequency distributions of Tanner crab and Korean horse-hair crab consumed by two size groups (< 60 cm FL and ? ?60 cm FL) of Pacific cod in the Aleutian Islands area in 1991.

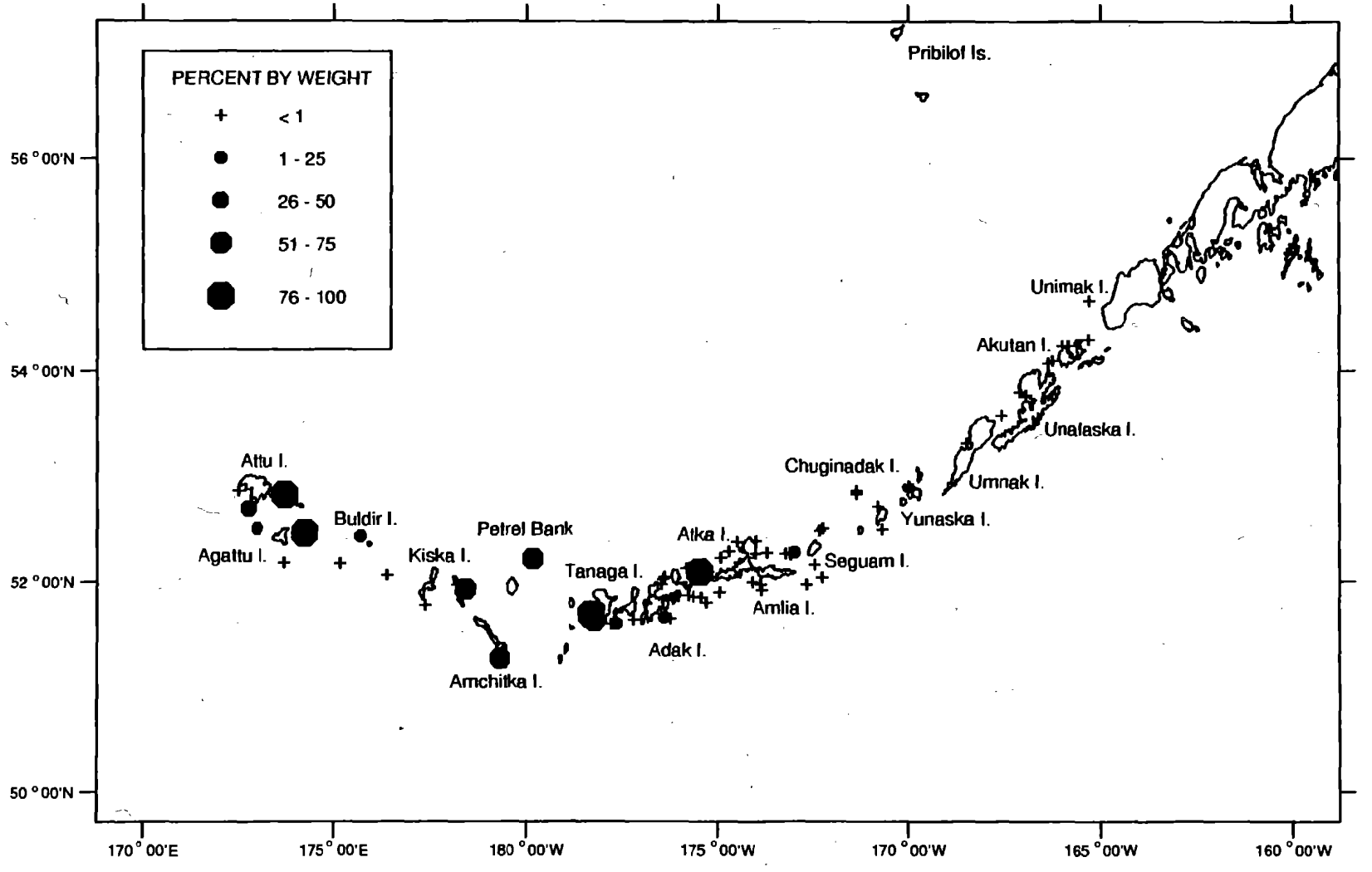

Figure 2-5.-- *Geographic distribution of* Atka mackerel consumed by Pacific cod in the Aleutian Islands area in 1991.

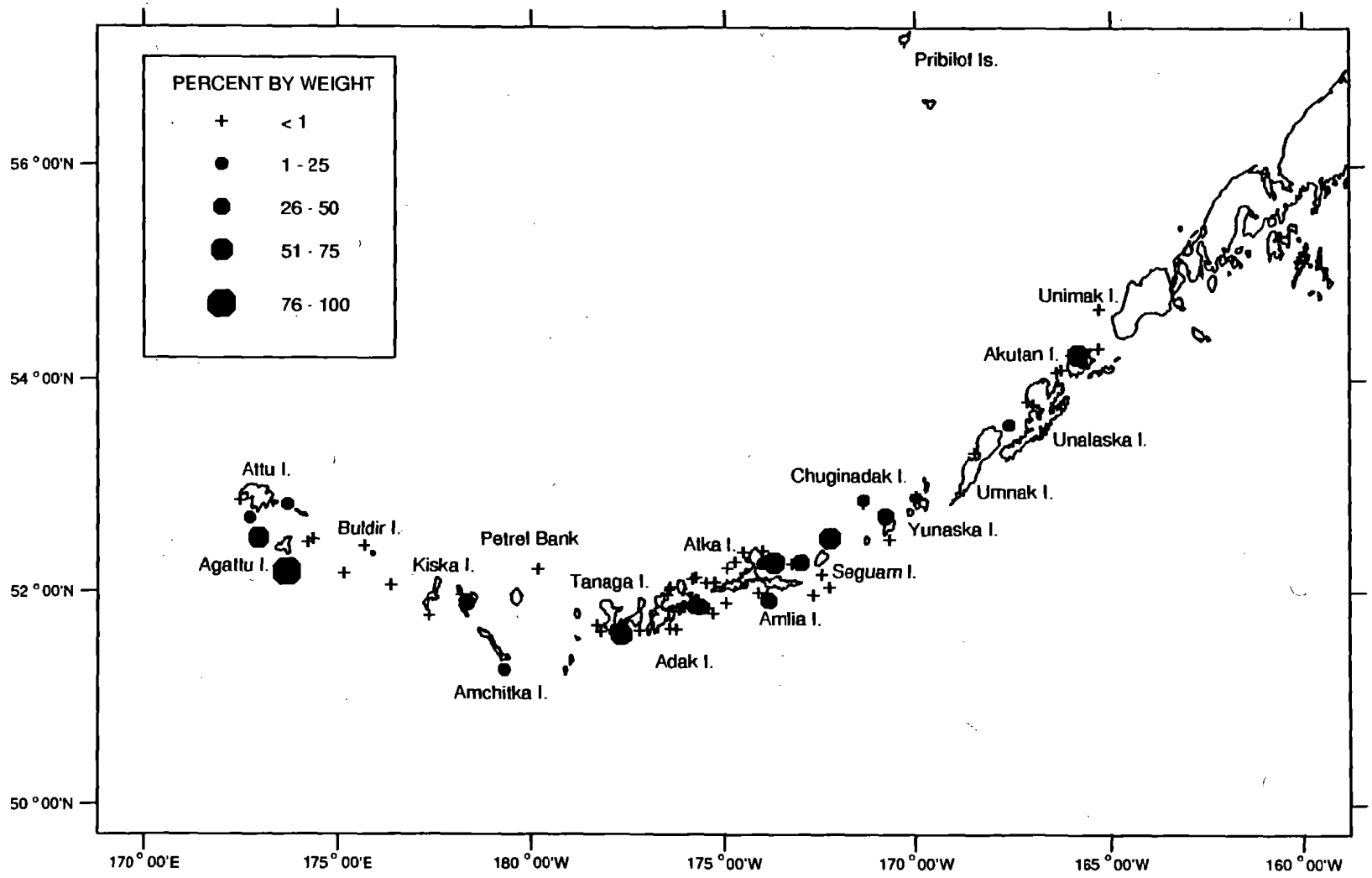

Figure 2-6.-- Geographic distribution of walleye pollock consumed by Pacific cod in the Aleutian Islands area in 1991.

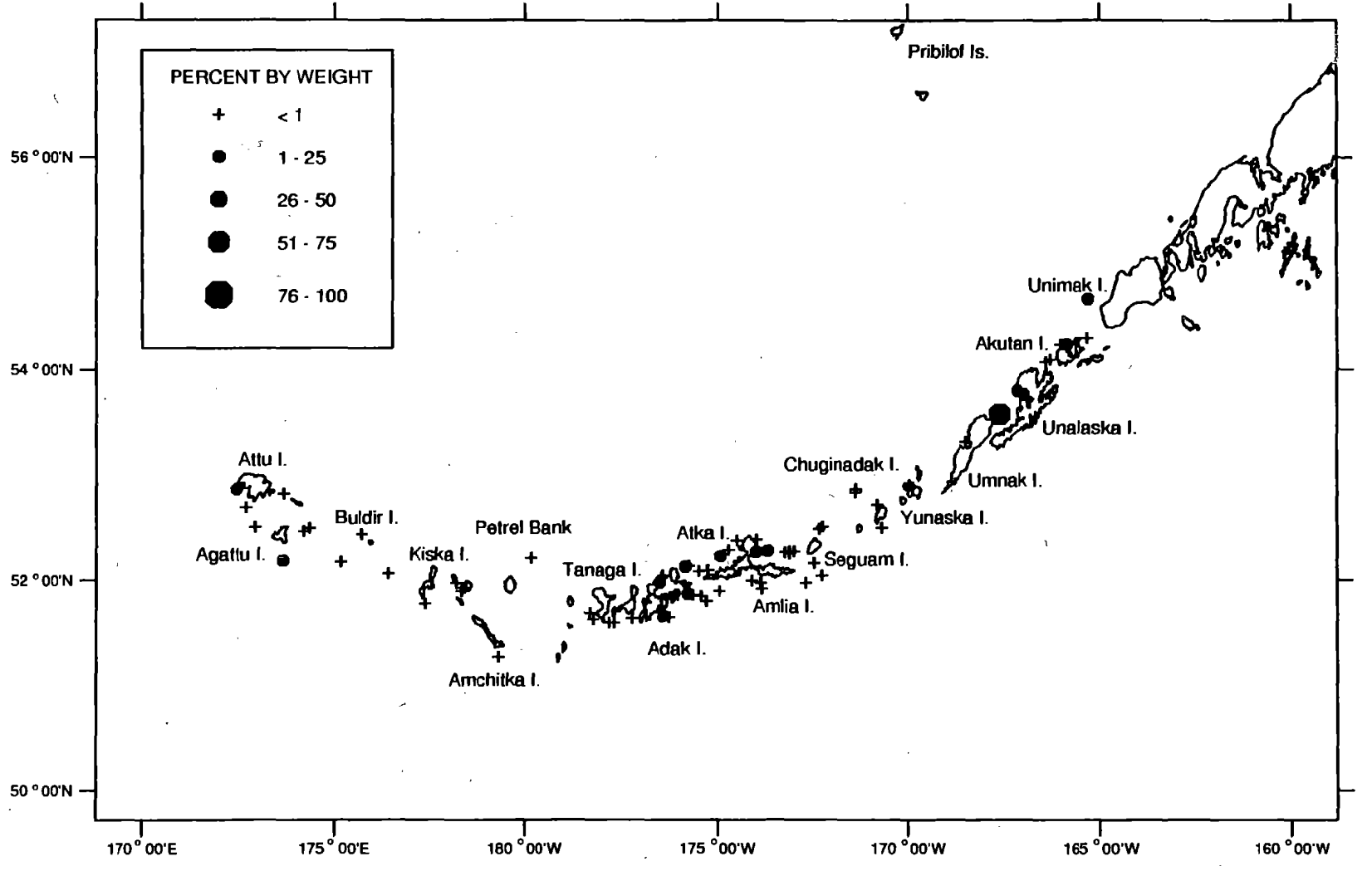

Figure 2-7.-- *Geographic distribution of Tanner crabs consumed by Pacific cod in the Aleutian Islands area in 1991.*

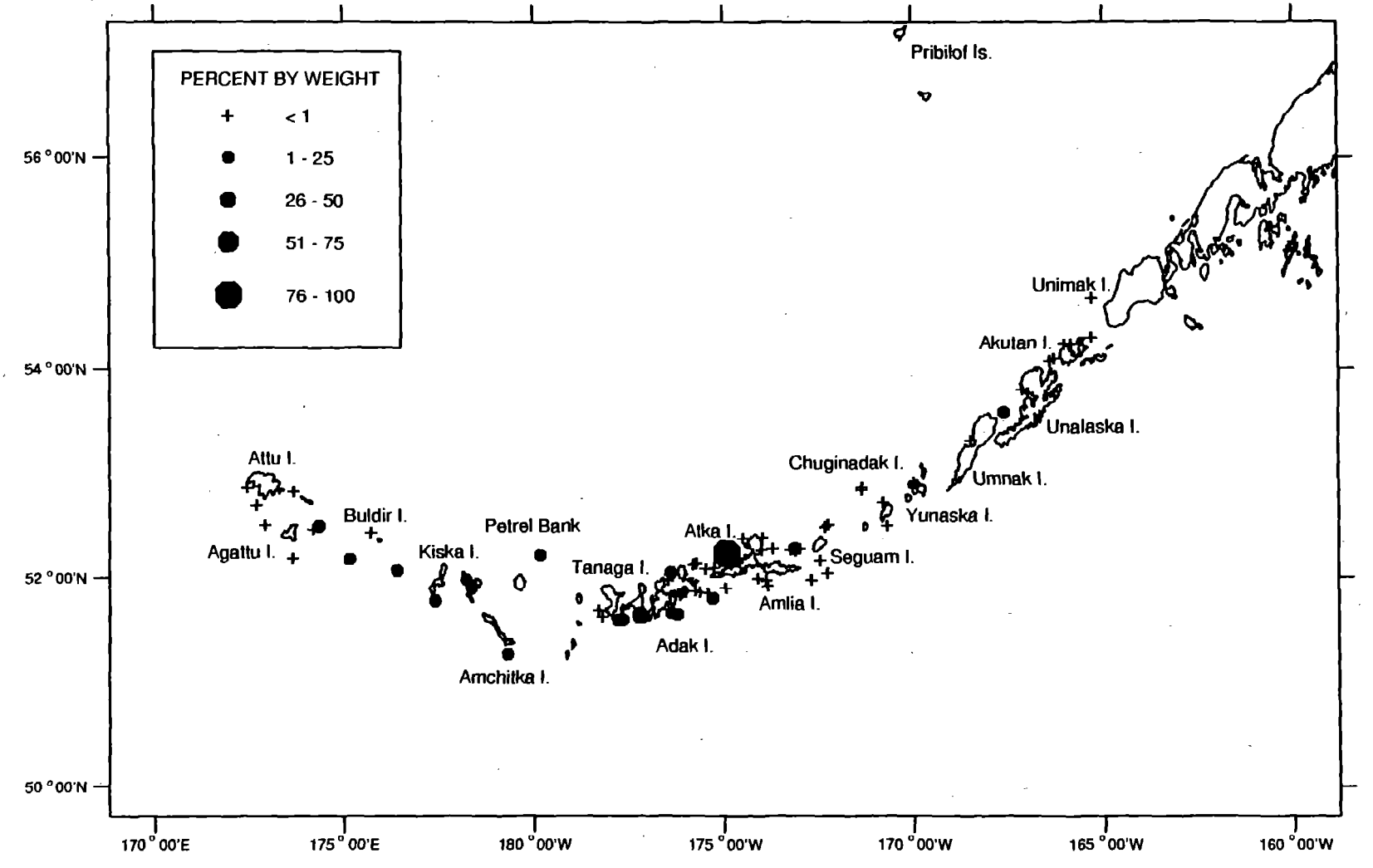

Figure 2-8-- Geographic distribution of Korean horse-hair crabs consumed by Pacific cod in the Aleutian Islands area in 1991

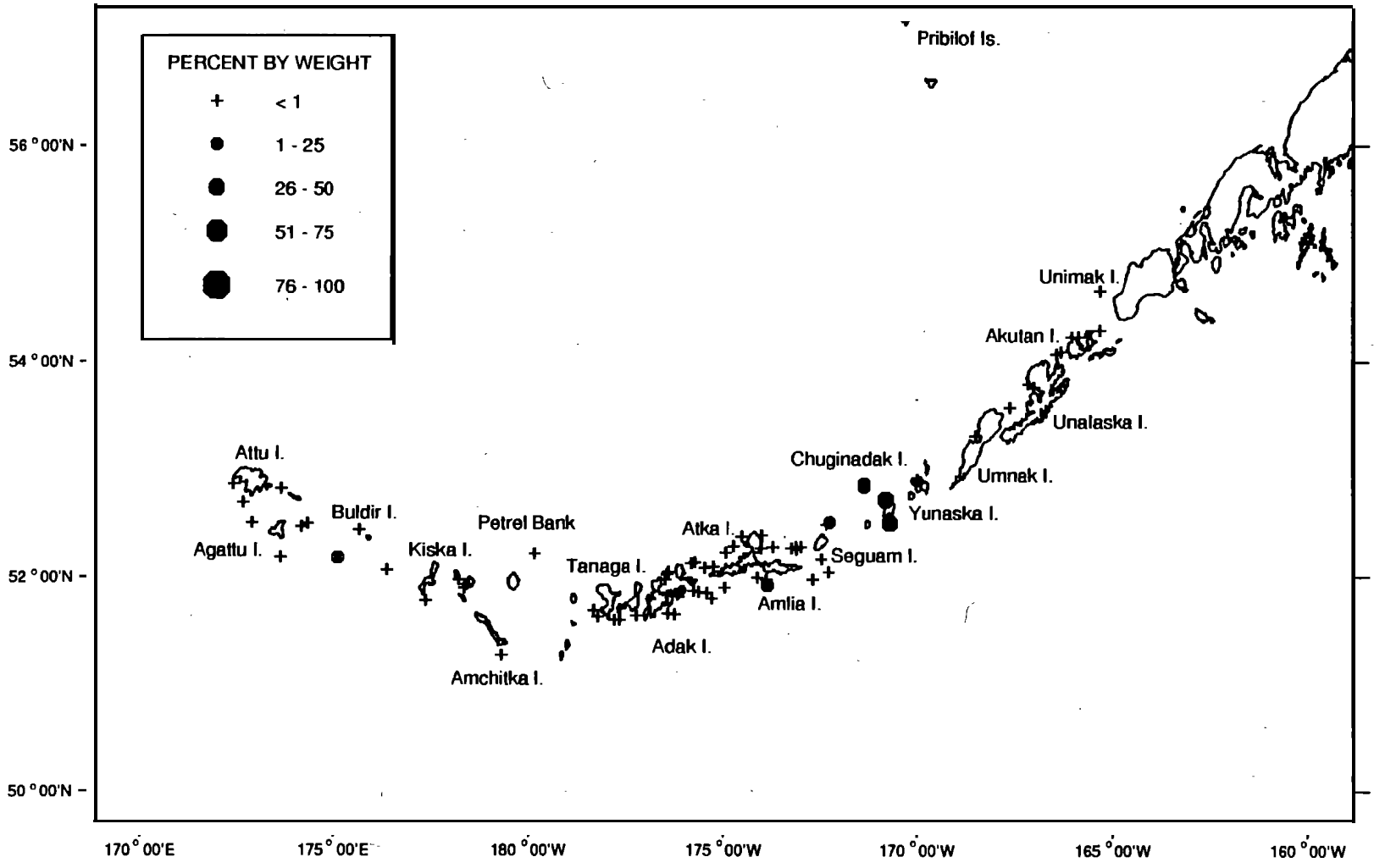

Figure 2-9.-- Geographic distribution of myctophids consumed by Pacific cod in the Aleutian Islands area in 1991.

ARROWTOOTH FLOUNDER

The projected 1995 exploitable biomass of arrowtooth flounder (Atheresthes stomias) in the Aleutian Islands area was 43,500 t (Wilderbuer and Sample 1994). This resource has been in good condition because of minimal exploitation and steady increases in biomass throughout the 1980s and into the 1990s. Arrowtooth flounder is a large flatfish with a symmetrical mouth and sharp teeth that feeds on fish like walleye pollock and capelin, as well as shrimp and other crustaceans (Yang 1993). Therefore, it is important to study its food habits and its impact on the important prey. Kamchatka flounder, a very similar congeneric species to the arrowtooth flounder in morphology and biology, is also distributed in the Aleutian Islands area. Because of the high similarity of the diets of arrowtooth flounder and Kamchatka flounder (Yang and Livingston 1986), data of these two species from the Aleutian Islands area were pooled together for analysis,

RESULTS

General Diets

A total of 339 arrowtooth flounder stomachs were analyzed. Of this total, 194 (57%) contained food. Arrowtooth flounder sizes ranged from 17 to 73 cm FL with a mean and SD of 38.3 and ± 9.9 cm, respectively. The average depth of the 47 haul locations where samples were collected was 149 ± 60 m with a range from 59 to 331 m.

Table 3-l lists the food items found in arrowtooth flounder stomachs. Even though many invertebrate species like euphausiids (34.8% by frequency of occurrence), pandalid shrimp, squid, mysids, and amphipods were found in the diet, of arrowtooth flounder, they comprised only 10% of the total stomach contents weight. The remaining 90% of stomach content weight was made up of fish. Atka mackerel comprised 44% by weight of the total stomach contents. Walleye pollock occurred more frequently in the diet, but comprised only 11% by weight. Myctophids, the third most important prey of arrowtooth flounder, comprised about 7% of the total stomach contents

weight. Other fish consumed by arrowtooth flounder included Pacific herring (Clupea pallasi), Pacific cod, sablefish, Pacific halibut, Pacific sand lance, snailfish (Cyclopteridae), searcher (Bathymaster spp.), prickleback (Stichaeidae), rockfish (Scorpaenidae), greenling (Hexagrammidae), and some cottids.

Variation of Diet Based on Predator Size

Figure 3-l illustrates the percentage by weight of the main prey items for different arrowtooth flounder size groups. Atka mackerel were the predominant prey fish (>50%) for arrowtooth flounder greater than or equal to 50 cm whereas walleye pollock were the predominate prey in the diets of the arrowtooth flounder between 40 and 49 cm long. Figure 3-l also shows that fish from the miscellaneous category were important to the diet of arrowtooth flounder less than 40 cm long. These miscellaneous fish included stichaeid, cottid, Pacific sand lance, searcher, rockfish, and some flatfish. Amphipods, euphausiids, and shrimp were important food for smaller sized (< 40 cm) arrowtooth flounder.

Sizes of the Prey Fish

Table 3-2 illustrates the standard length, standard deviation, and size range of the miscellaneous prey fish consumed by arrowtooth flounder. The four Atka mackerel observed in my samples for arrowtooth flounder were between 210 and 330 mm SL. Walleye pollock consumed were between 60 and 190 mm SL. Because of the small numbers of prey fish consumed by arrowtooth flounder, prey fish data were not analyzed by size groups.

Geographic Distributions of the Prey

Figure 3-2 shows the geographic distribution of the walleye pollock consumed by arrowtooth flounder. My sampling shows that walleye pollock were consumed by arrowtooth flounder at a limited number of locations in the Aleutian Islands area. Only around Adak Island did pollock comprise more than 25% of the stomach content weight of arrowtooth flounder. Figure 3-3 shows that high percentages (>75%) of Atka mackerel consumed by arrowtooth flounder were mainly distributed in the western

Aleutian Islands between Attu Island, Agattu Island, and Kiska Island. There was also a high percentage of Atka mackerel consumed by arrowtooth flounder on the west side of Unalaska Island.

DISCUSSION

Simenstad et al. (1977) found that shrimp and cottids were the main diet of arrowtooth flounder in the Amchitka Island area. However, their results were derived from a small sample. In this study, I compared the diets of arrowtooth flounder from the Aleutian Islands area to those from the Gulf of Alaska (Yang 1993) and the eastern Bering Sea (Yang 1991). Table 3-3 lists the percentage by weight of the major prey categories of arrowtooth flounder from these three study areas. It illustrates that pollock were the main food of arrowtooth flounder in the eastern Bering Sea (56%) and in the Gulf of Alaska (66%), but not in the Aleutian Islands area (11%). On the other hand, Atka mackerel were the-main food of arrowtooth flounder in the Aleutian Islands area but were not found in the diet of fish collected in the eastern Bering Sea and the Gulf of Alaska areas. Data in Table 3-3 also indicates that fish in the miscellaneous category comprised a higher percentage (15%), in the stomach contents of arrowtooth flounder in the Aleutian Islands area than in the other two areas. Another difference is that myctophids were only found in the arrowtooth flounder stomachs in the Aleutian Islands area (6.5%). Though the composition of prey fish and their percentages were different in the arrowtooth flounder stomachs, the overall degree of piscivory (about 90%) was relatively constant across the three areas.

Table 3-1.--Prey items (expressed frequency of occurrence (%), and percentage of total weight consumed) of Atheresthes stomias (arrowtooth flounder) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	1.03	0.01
Cephalopoda (unidentified)	1.03	0.86
Teuthoidea (squid unidentified)	2.58	2.31
Calanoida (copepod)	1.55	<0.01
Mysidae (mysid)	3.09	0.02
Gammaridea (unidentified)	10.82	0.38
Caprellidea (amphipod)	0.52	<0.01
Euphausiacea (unidentified)	32.47	5.44
Caridea (unidentified)	3.61	0.03
Hippolytidae (unidentified)	1.55	0.10
Pandalidae (unidentified)	9.79	1.68
Crangonidae (unidentified)	2.58	0.10
Paguridae (hermit crab)	0.52	<0.01
Urochordata (tunicate)	1.03	1.21
Teleostei (unidentified fish)	11.34	0.61
Non-gadoid fish remains	17.01	10.56
Clupea pallasi (Pacific herring)	0.52	0.49
Chauliodus macouni (Pacific viperfish)	0.52	0.05
Myctophidae (lanternfish)	6.70	6.50
Gadidae (unidentified gadid)	4.12	1.86
Gadus macrocephalus (Pacific cod)	0.52	0.09
Theragra chalcogramma (walleye pollock)	6.70	10.89
Scorpaenidae (rockfish)	0.52	2.61
Hexagrammidae (greenling)	0.52	0.69
Pleurogrammus monopterygius (Atka mackerel)	2.06	43.98
Anoplopoma fimbria (sablefish)	1.03	2.62
Cottidae (sculpin)	4.12	1.94
Triglops scepticus (spectacled sculpin)	0.52	0.71
Cyclopteridae (snailfish)	1.03	0.20
Bathymaster spp. (searcher)	0.52	2.39
Stichaeidae (prickleback)	3.09	1.31
Ammodytes hexapterus (Pacific sand lance)	0.52	0.30
Pleuronectidae (unidentified flatfish)	2.06	0.03
Hippoglossus stenolepis (Pacific halibut)	0.52	0.01
Unidentified material	0.30	0.56
Total prey weight	1,673 g	
Number of stomachs with food	194	
Number of empty stomachs	145	

Table 3-2.--Mean, standard deviation (SD), and range of the standard length of the miscellaneous prey fish consumed by arrowtooth flounder in the Aleutian Islands area in 1991.

Prey name	No.	Mean (mm)	SD (mm)	Range (mm)
Atka mackerel	4	255.0	51.9	210-330
Cottid	11	57.0	43.8	16-145
Myctophid	9	83.1	20.9	45-105
Pacific cod	1	60.0	-	-
Pacific halibut	1	20.0	-	-
Pacific sand lance	1	125.0	-	-
Searcher	1	160.0	-	-
Snailfish	2	33.0	9.9	26-40
Stichaeid	5	76.4	35.4	50-120
Walleye pollock	11	107.4	58.7	60-190

Table 3-3. --Percentage by weight of the major prey categories of arrowtooth flounder in the Aleutian Islands area (AI) compared to the eastern Bering Sea (EBS) (from Yang 1991), and Gulf of Alaska (GOA) (from Yang 1993). "-" indicates cl.

Prey name	AI	GOA	EBS
Cephalopod	3	2	6
Euphausiid	5	3	2
Pandalid	2	4	2
Pacific herring	1	9	3
Zoarcid	0	1	9
Capelin	-	8	
Atka mackerel	44	1	0
Pollock	11	66	56
Myctophid	7	0	0
Miscellaneous fish	15	5	8
Unidentified fish	11		11

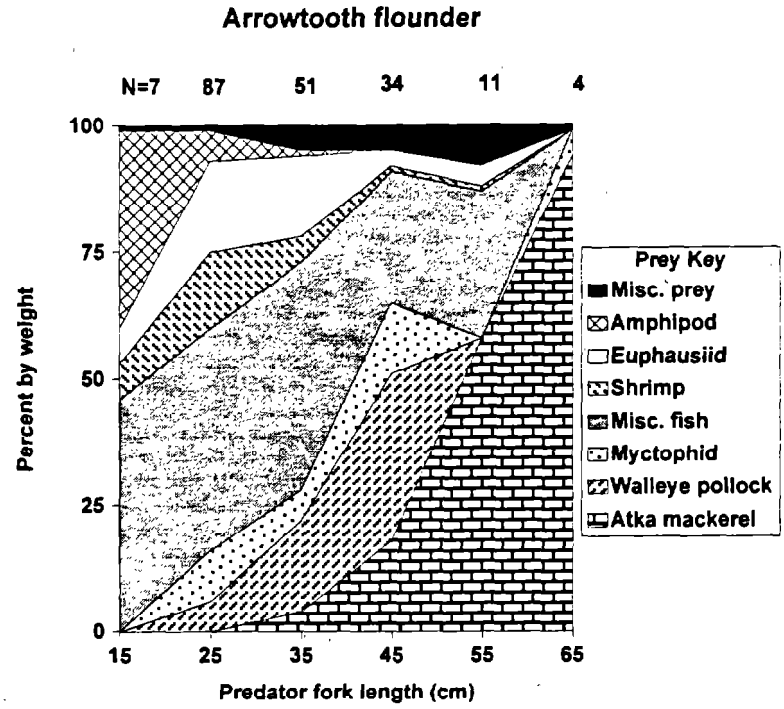

Figure 3-1.--Variation in the main food items of arrowtooth flounder, by predator size, in the Aleutian Islands in 1991. N = sample size.

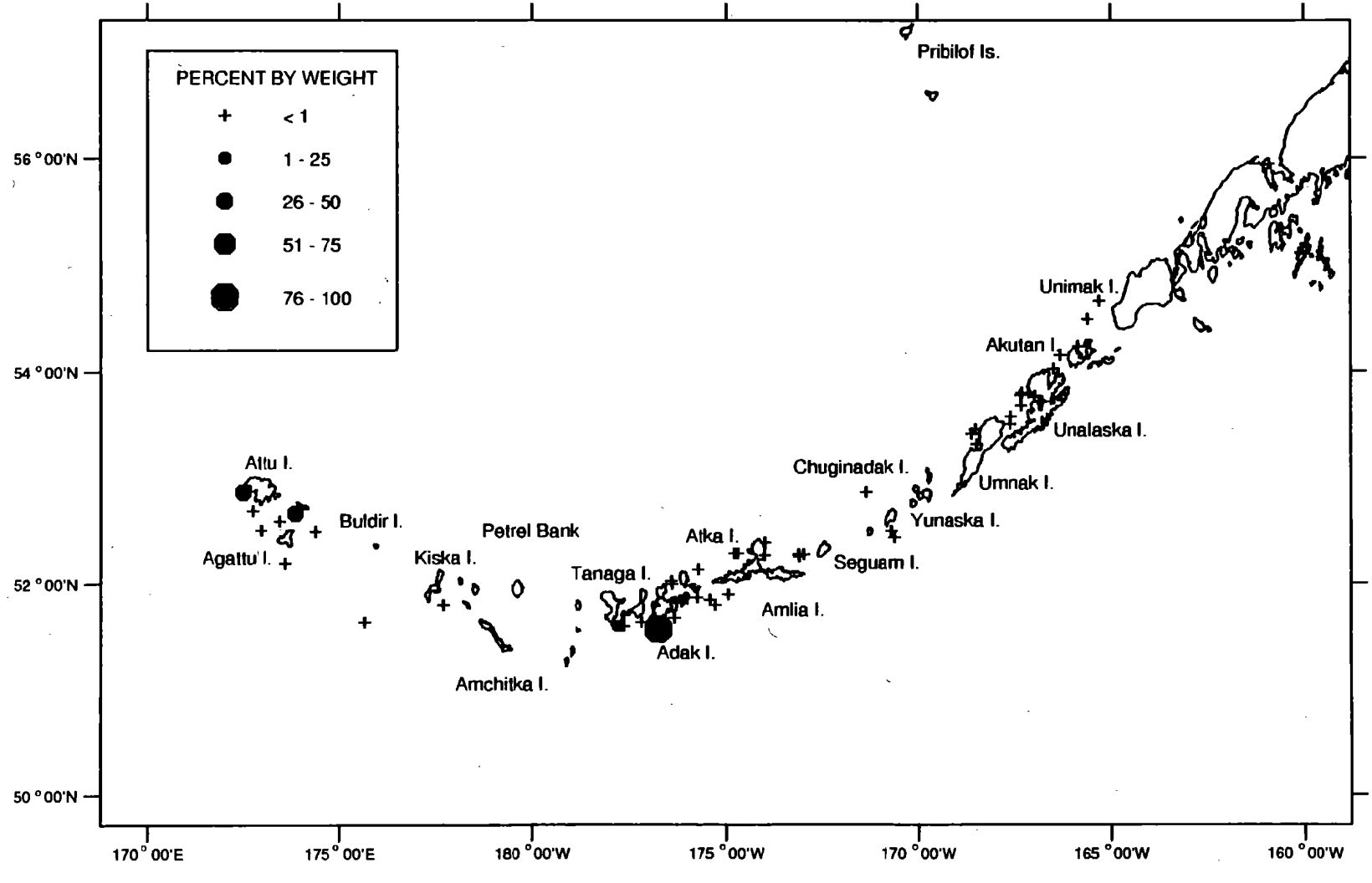

Figure 3-2.-- Geographic distribution of walleye pollock consumed by arrowtooth flounder in the Aleutian Islands area in 1991.

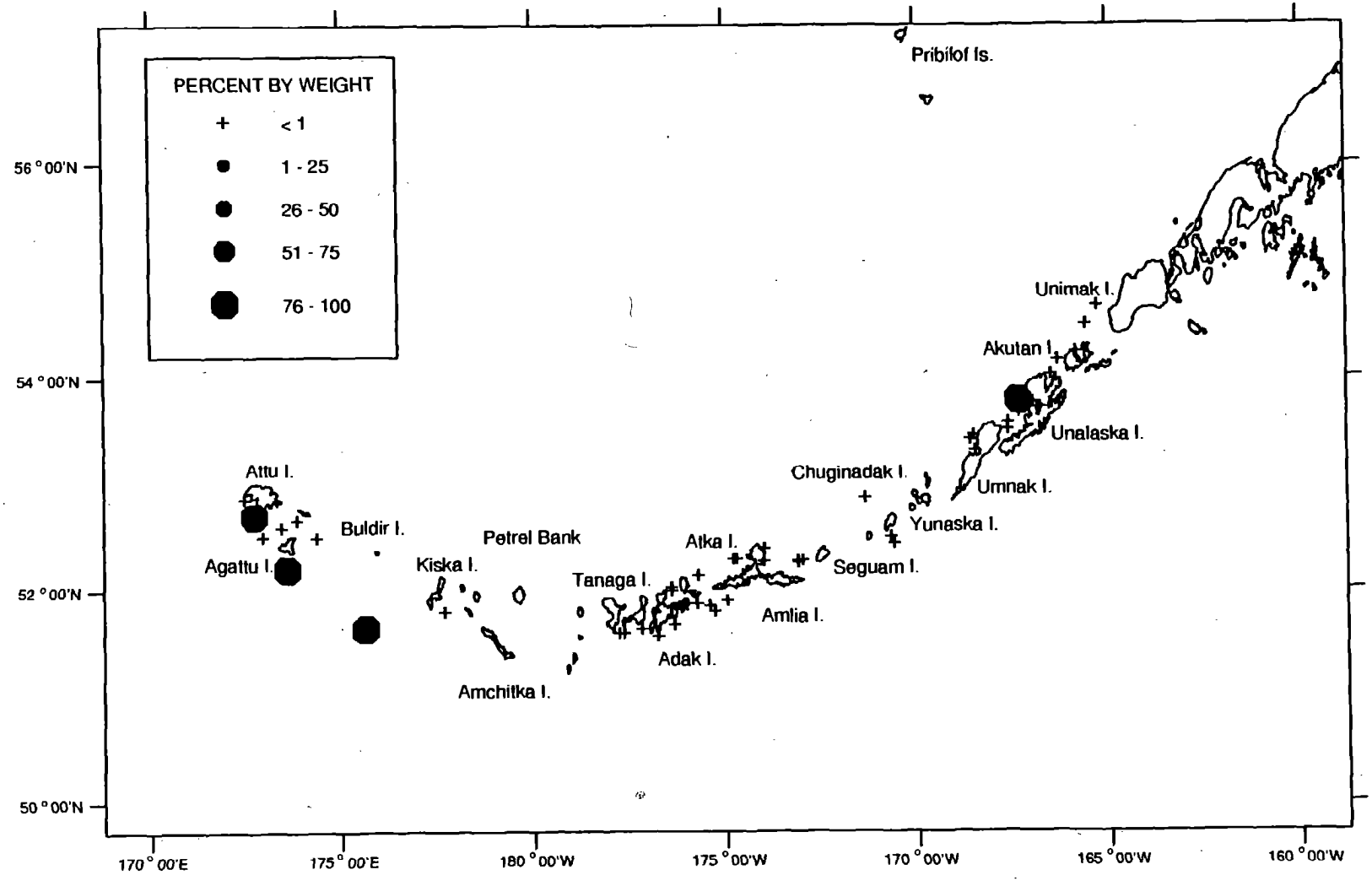

Figure 3-3.-- Geographic distribution of Atka mackerel consumed by arrowtooth flounder in the Aleutian Islands area in 1991.

PACIFIC HALIBUT

The exploitable biomass of Pacific halibut (Hippoglossus stenolenis) was estimated at 17,400 t round weight for the eastern Bering Sea and Aleutian Islands areas (IPHC 1994). The commercial catches in these areas totaled 3,800 t round weight (head off weight). Since Pacific halibut feed on fish, crab, and squid, it is important to study their food habits and their impact on other commercially important species in the Aleutian Islands area.

RESULTS

General Diets

A total of 202 Pacific halibut stomachs were analyzed, of which 180 (89%) contained food. The size range of Pacific halibut was between 28 and 116 cm FL with a mean and SD of 61.8 ± 17.7 cm. The average depth of the 39 haul locations was 114 ± 46 m with a range from 37 to 229 m. Table 4-l lists the frequency of occurrence (%), and the percent by weight of the prey found in Pacific halibut stomachs. By-weight, 55% of the total stomach contents were fish, with the remainder made up by invertebrates. Walleye pollock (19% by weight) was the most important prey item. Atka mackerel was another important prey of Pacific halibut; comprising 12% of the total stomach content weight. Other commercially important fish consumed by Pacific halibut include Pacific herring, Pacific cod, flathead sole, sablefish, and rockfish Sebastes spp.). Pacific halibut also consumed fishery discards (processed fish carcasses), but they comprised less than 1% by weight of the total stomach content. Many non-commercially important fish (capelin, cottids, agonids, cyclopterids, and bathymasterids) were also consumed by Pacific halibut; however, they comprised only a small percent of the total stomach contents weight.

Squid and octopus were the most important invertebrate prey of Pacific halibut; comprising 17% and 10% of the total stomach contents weight, respectively. Chionoecetes bairdi was the most frequently occurring prey (24%) of Pacific halibut and comprised 7% of the total stomach contents weight. Less important invertebrate' prey included lyre crab (Hyas spp.)

(2.4%), hermit crab (1.3%), and decorator crab (Oregonia spp.) (0.6%). The other invertebrates consumed (polychaetes, gastropods, clams, euphausiids, shrimp, and other crustaceans) were considered to be less important as food for Pacific halibut.

Variation of Diet Based on Predator Size

The diet of Pacific halibut varied greatly by predator size (Fig. 4-l). Walleye pollock and Atka mackerel were primarily consumed by Pacific halibut greater than or equal to 70 cm FL. Capehin were important food for halibut 40 to 60 cm FL, whereas miscellaneous prey fish (e.g., rockfish, flatfish, Pacific herring, and sablefish) were consumed by all size groups. Tanner crabs were the primary food of Pacific halibut between 50 and 70 cm FL. Hermit crabs, Korean horse-hair crabs, lyre crabs, and decorator crabs were important food items for Pacific halibut less than 60 cm FL. Hermit crabs. were especially important (55% by weight) for fish less than 40 cm FL. Cephalopods were important to the diet of halibut greater than 60 cm FL.

Sizes of the Commercially Important Prey

For analysis, prey length data of Pacific halibut were divided into two predator size groups (c 80 cm and ??80 cm FL) (Figs. 4-2 to 4-4). Figure 4-2 (left) shows that small Pacific halibut (< 80 cm FL) consumed more walleye pollock than large halibut ??80 cm FL). The sizes of the walleye pollock consumed by these two size groups were similar (between 200 and 450 mm SL) except that the smaller Pacific halibut also consumed age-0 (< 140 mm SL) pollock. The mean standard length and standard deviation of pollock consumed by Pacific halibut was 211.8 ± 134.9 mm with a range from 41 to 453 mm SL.

Figure 4-2 (right) shows that large Pacific halibut consumed larger Atka mackerel. The mean SL of the Atka mackerel consumed by Pacific halibut was 260.1 ± 56.3 mm with a range from 171 to 360 mm.

The sizes of capelin consumed by the two size groups of Pacific halibut were similar (Fig. 4-3, right). The mean SL of capelin consumed was 100.3 ± 11.5 mm with a range from 79 to 121 mm. Figure 4-3 (left) also shows that sizes of the myctophids consumed by the two size groups of Pacific halibut

were similar. The mean SL of the myctophid consumed was 47.9 ± 11.3 mm with a range from 34 to 68 mm.

Figure 4-4 shows that large numbers of Tanner crabs were consumed by the small Pacific halibut (< 80 cm FL); whereas only a few Tanner crabs were consumed by large Pacific halibut ??80 cm FL). The Tanner crabs consumed were mainly age-l (9-34 mm CW) crabs and a few age-2 and older crabs. The mean CW of the Tanner crabs consumed was 19.1 ± 4.9 mm with a range from 5 to 51 mm.

In one sample, a Pacific halibut had consumed a 280 mm SL Pacific herring. Other prey fish were also reported for halibut in the Aleutian Islands area. The length data of these prey fish are listed in Table 4-2.

Geographic Distributions of the Prey

The geographic distributions of important prey consumed by Pacific halibut are shown in Figures 4-5 to 4-10. Figure 4-5 illustrates that walleye pollock were consumed by Pacific halibut at many of the survey stations, and the high percentages (> 75%) of walleye pollock consumed were observed in the Unalaska and Akutan Islands areas. High percentages of Atka mackerel by weight were also found in the Agattu and Tanaga Islands area. The highest percentage of capelin consumption was primarily in the Unalaska area (Fig. 4-7). Based on my sample, Tanner crabs were- consumed mainly in Umnak Island and Atka Island areas (Fig. 4-8). Figure 4-9 illustrates that while the Korean horse-hair crabs were consumed by Pacific halibut at many stations, the amounts (percent by weight) were not high. High percentages by weight of myctophids were found in the Yunaska Island area though myctophids were not found in Pacific halibut stomachs at many stations (Fig. 4-10).

DISCUSSION

Simenstad et al. (1977) found that, in the Amchitka Island area, Pacific halibut fed principally on walleye pollock, sculpins, rock sole, Pacific sand lance, sturgeon poacher (Podothecus acipenserinus.) and secondarily on squid, octopus, and crabs. The diet composition of Pacific halibut from this

study was similar to that found by Simenstad et al. (1977) except that Atka mackerel were not observed in their samples.

Many earlier studies (Novikov 1968; Simenstad et al. 1977; Best and Pierre 1986; Livingston et al. 1993; Yang 1993) show a trend of changing diet composition of Pacific halibut by size. This trend of predator size to diet preference was also indicated in this study. When Pacific halibut are young, they feed mainly on crustaceans. As they grow and increase in size, they feed primarily on fish, squid, and octopus.

In this study, I compared the major prey categories of the Pacific halibut in the Aleutian Islands area to those from the Gulf of Alaska (Yang 1993). Table 4-3 indicates that walleye pollock was the dominant prey (57% by weight) of Pacific halibut in the Gulf of Alaska area; however, walleye pollock comprised only 19% of the total stomach contents weight in the Aleutian Islands area. Atka mackerel and cephalopods were also important food (12% and 27%, respectively) of Pacific halibut in the Aleutian Islands area, whereas none of these were important food in the Gulf of Alaska area. Most of diet differences can be attributed to increased cephalopod and Atka mackerel consumption and lower pollock consumption in the Aleutian Islands area compared with the Gulf of Alaska. Less than one-half of the diet in Aleutian Islands was fish, whereas about 64% of Gulf of Alaska diet was fish.

Table 4-1.--Prey items (expressed in frequency of occurrence (%), and percentage of total weight) of Pacific halibut (Hippoglossus stenolepis) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	1.67	0.04
Gastropoda (unidentified)	5.00	2.12
Bivalvia (clam)	11.67	0.37
Cephalopoda (unidentified)	2.22	0.06
Teuthoidea (squid unidentified)	14.44	17.00
Octopoda (unidentified)	5.56	10.01
Gammaridea (amphipod)	3.33	0.01
Euphausiacea (unidentified)	6.67	0.32
Hippolytidae (unidentified)	2.22	0.03
Pandalidae (unidentified)	2.78	0.11
Crangonidae (unidentified)	6.11	0.13
Paguridae (hermit crab)	20.00	1.93
Decapoda Brachyura (crab)	5.56	0.67
Oregonia spp. (decorator crab)	7.20	0.61
Hyas sp. (lyre crab)	13.90	2.42
Chionoecetes bairdi (Tanner crab)	24.45	7.22
Erimacrus isenbeckii (Horse-hair crab)	5.56	0.92
Sipuncula (peanut worm)	0.56	<0.01
Teleostei (unidentified fish)	8.33	0.64
Non-gadoid fish remains	15.56	2.65
Clupea pallasi (Pacific herring)	1.67	1.72
Mallotus villosus (capelin)	5.00	5.19
Myctophidae (lantern fish)	2.78	0.23
Gadidae (unidentified gadid)	1.67	0.04
Gadus macrocephalus (Pacific cod)	0.56	0.93
Theragra chalcogramma (walleye pollock)	7.78	19.17
Sebastes spp. (unidentified rockfish)	1.11	1.71
Pleurogrammus monopterygius (Atka mackerel)	7.78	12.00
Anoplopoma fimbria (sablefish)	1.67	2.54
Cottidae (unidentified sculpin)	7.23	0.45
Agonidae (unidentified poacher)	4.45	0.14
Cyclopteridae (unidentified snailfish)	1.12	0.28
Bathymaster signatus (searcher)	0.56	1.03
Ammodytes hexapterus (Pacific sand lance)	1.67	0.22
Pleuronectidae (unidentified flatfish)	0.56	0.97
Hippoglossoides elassodon (flathead sole)	1.67	1.57
Fishery discards	2.22	0.89
Misc. unidentified materials	16.67	3.01
Total prey weight	13,800 g	
Number of stomachs with food	180	
Number of empty stomachs	22	

Table 4-2.--Mean standard length, standard deviation (SD), and size range of the miscellaneous prey fish consumed by Pacific halibut in the Aleutian Islands area in 1991.

Prey name	No.	Mean (mm)	SD (mm)	Range (mm)
Agonid	7	65.0	40.6	19-141
Atka mackerel	8	260.1	56.3	171-360
Capelin	65	100.3	11.5	79-121
Cottid	19	37.9	17.1	16-66
Flatfish (unknown)	1	210	-	-
Flathead sole	3	204.6	49.2	153-251
Myctophid	10	47.9	11.3	34-68
Pacific cod	1	230.0	-	-
Pacific herring	1	280.0	-	-
Pacific sand lance	3	126.3	14.4	110-137
Rockfish spp.	2	260.0	42.4	230-290
Sablefish	4	217.5	5.0	210-220
Searcher	1	250.0	-	-
Snailfish	2	46.5	7.7	41-52
Walleye pollock	21	211.8	134.9	41-453

Table 4-3. --Percentage by weight of the major prey categories of Pacific halibut in the Aleutian Islands area (AI) compared to the Gulf of Alaska (GOA) (from Yang 1993).

Prey name	AI	GOA
Cephalopod	27	5
Tanner crab	7	6
Other crabs	7	8
Osmerid	5	1
Myctophid	3	0
Pacific cod	1	1
Pollock	19	57
Atka mackerel	12	0
Flatfish	3	5

Percent similarity between AI and GOA: 42%

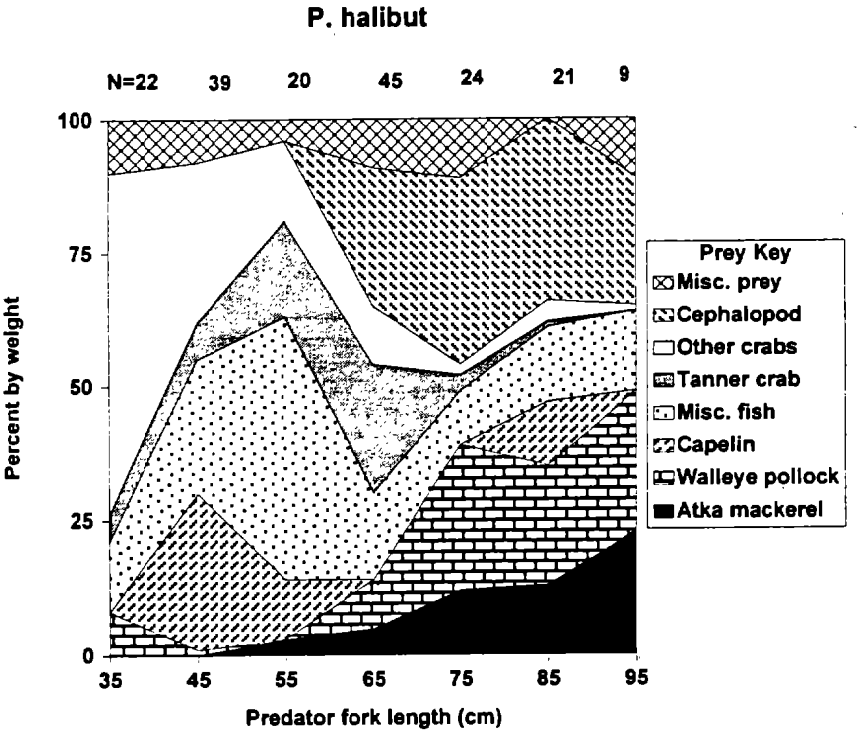

Figure 4-1.--Variation in the main food items of Pacific halibut, by predator size, in the Aleutian Islands area in 1991. N = sample size.

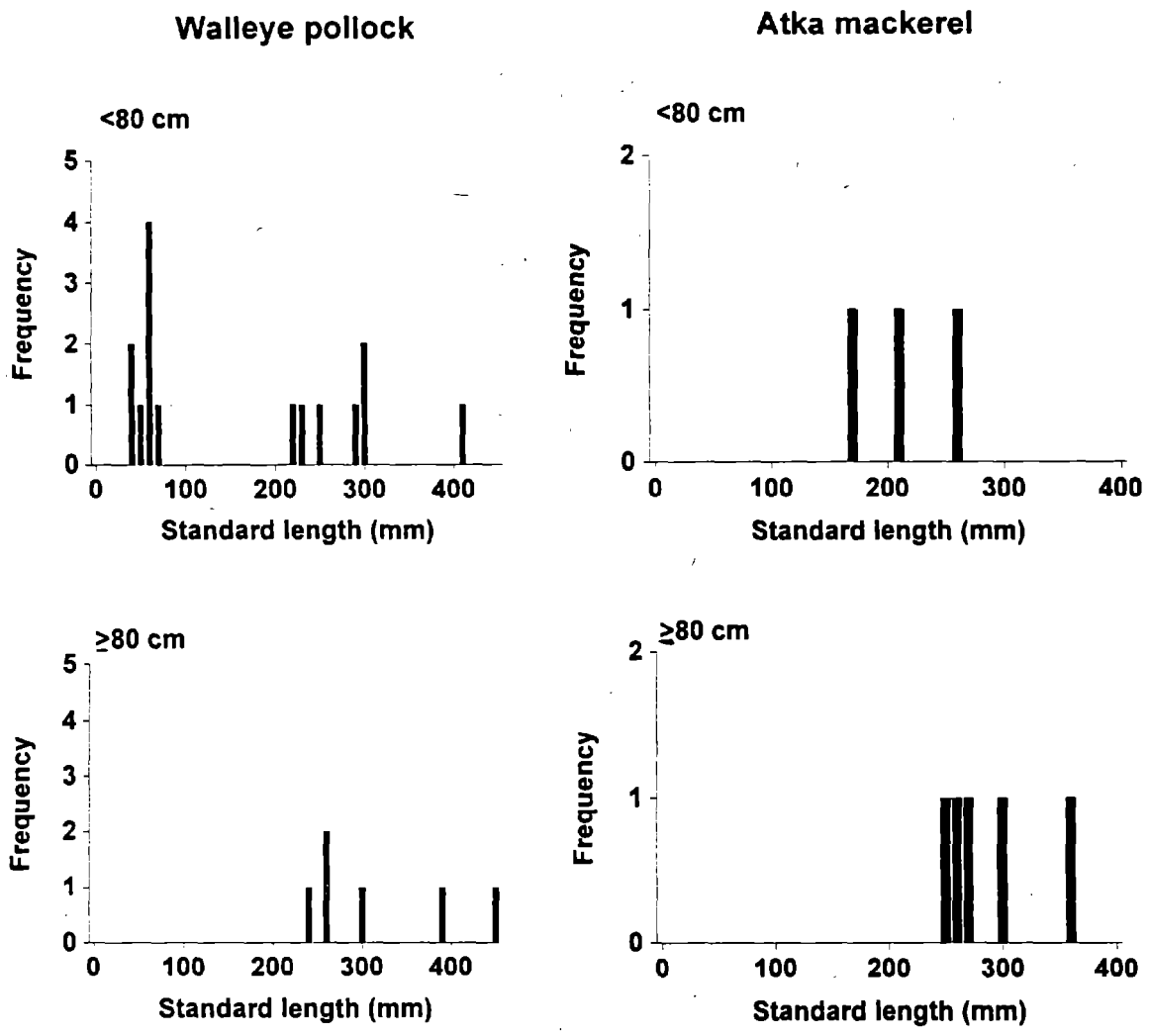

Figure 4-2.--Size frequency distributions of walleye pollock and Atka mackerel consumed by two size groups (< 80 cm FL and ?? ?80 cm FL) of Pacific halibut in the Aleutian Islands area in 1991.

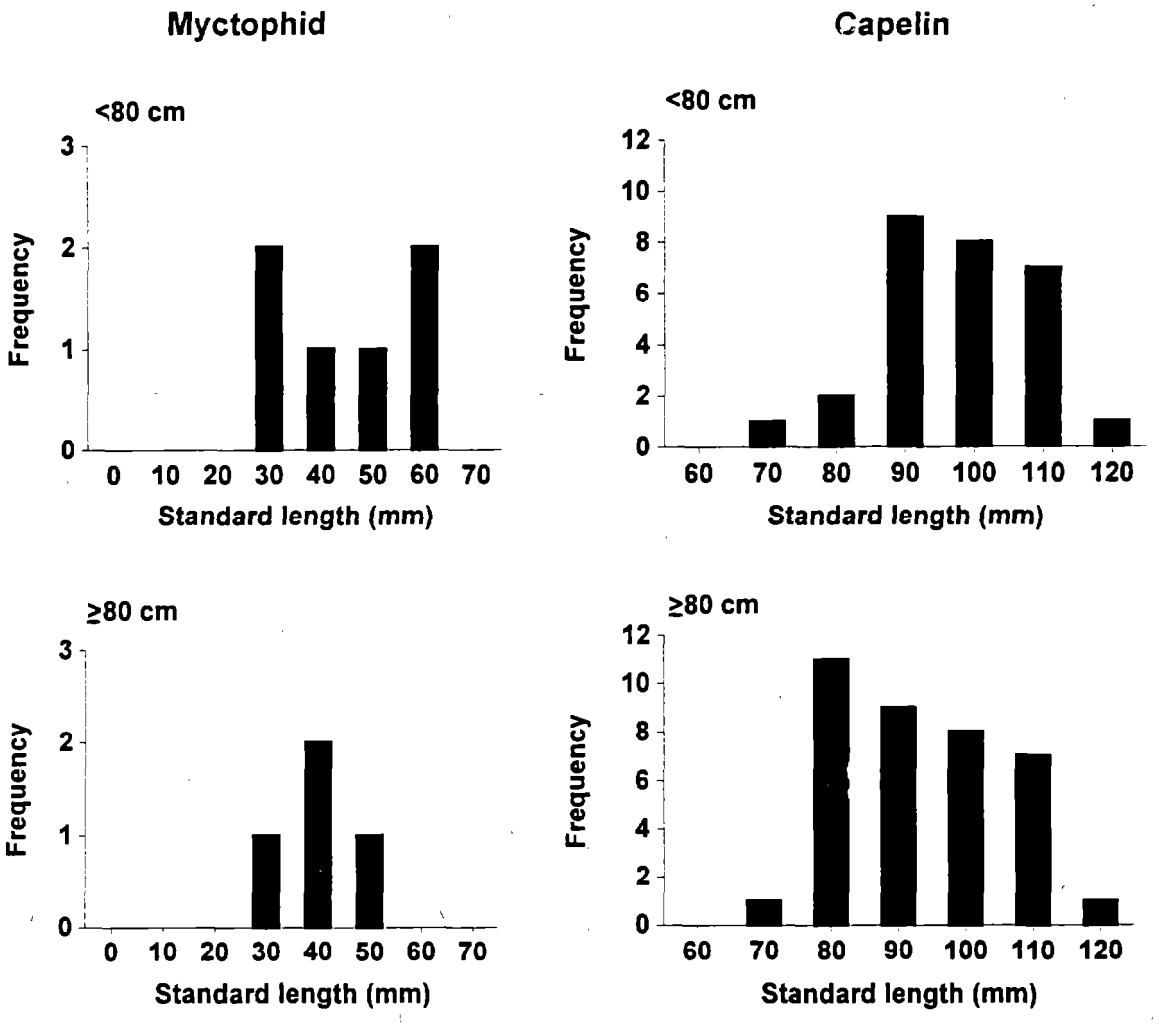

Figure 4-3.--Size frequency distributions of capelin and myctophid consumed by two size groups (< 80 cm FL and ? ?80 cm FL) of Pacific halibut in the Aleutian Islands area in 1991.

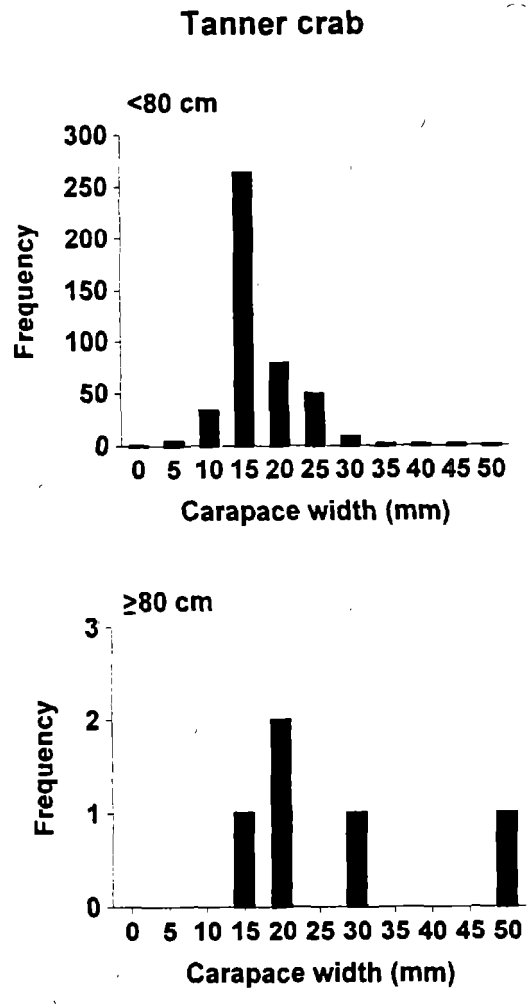

Figure 4-4.--Size frequency distributions of Tanner crab consumed by two size groups (< 80 cm FL and ? ?80 cm FL) of Pacific halibut in the Aleutian Islands area in 1991.

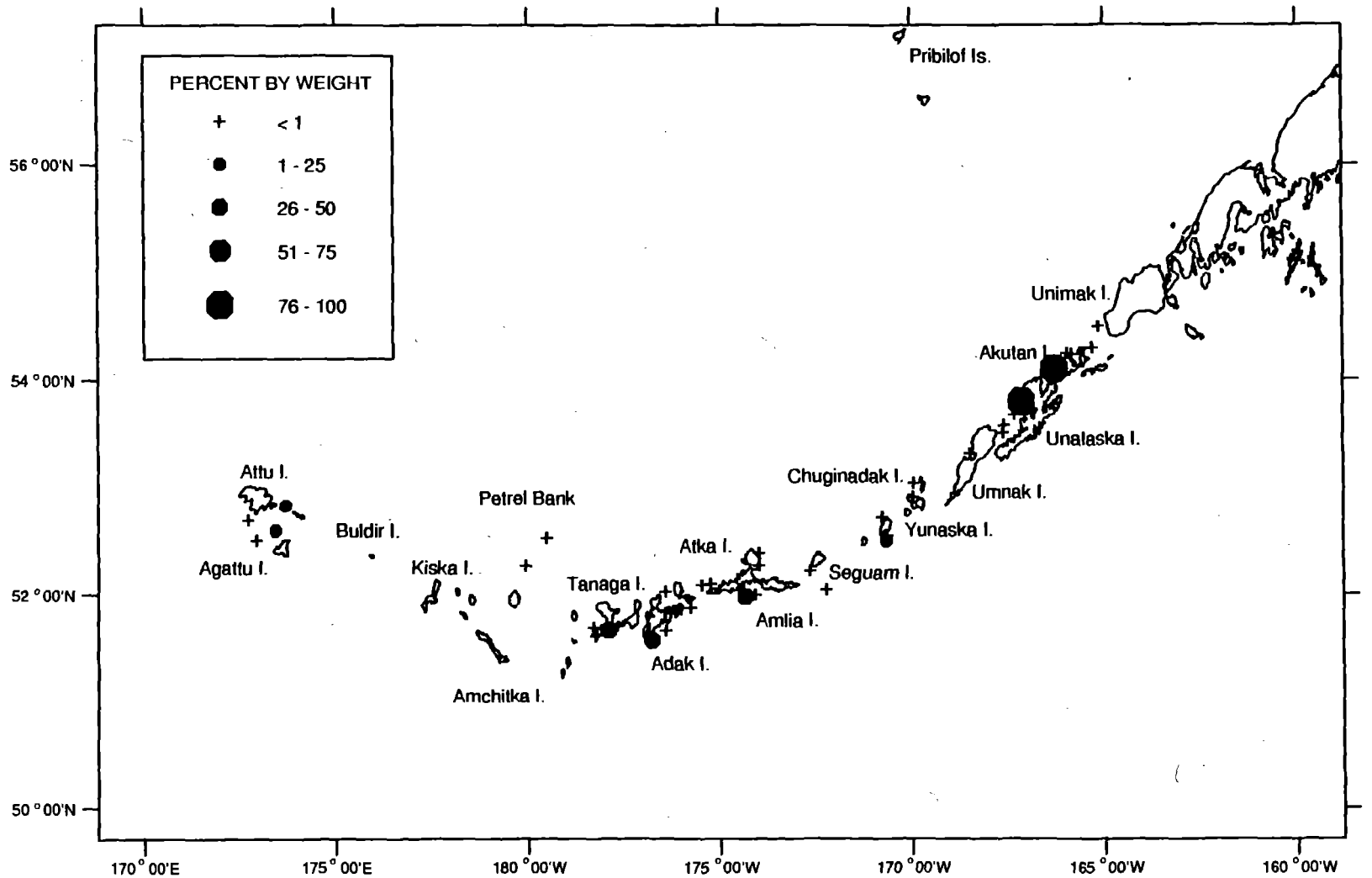

Figure 4-5.-- Geographic distribution of walleye pollock consumed by Pacific halibut in the Aleutian Islands area in 1991.

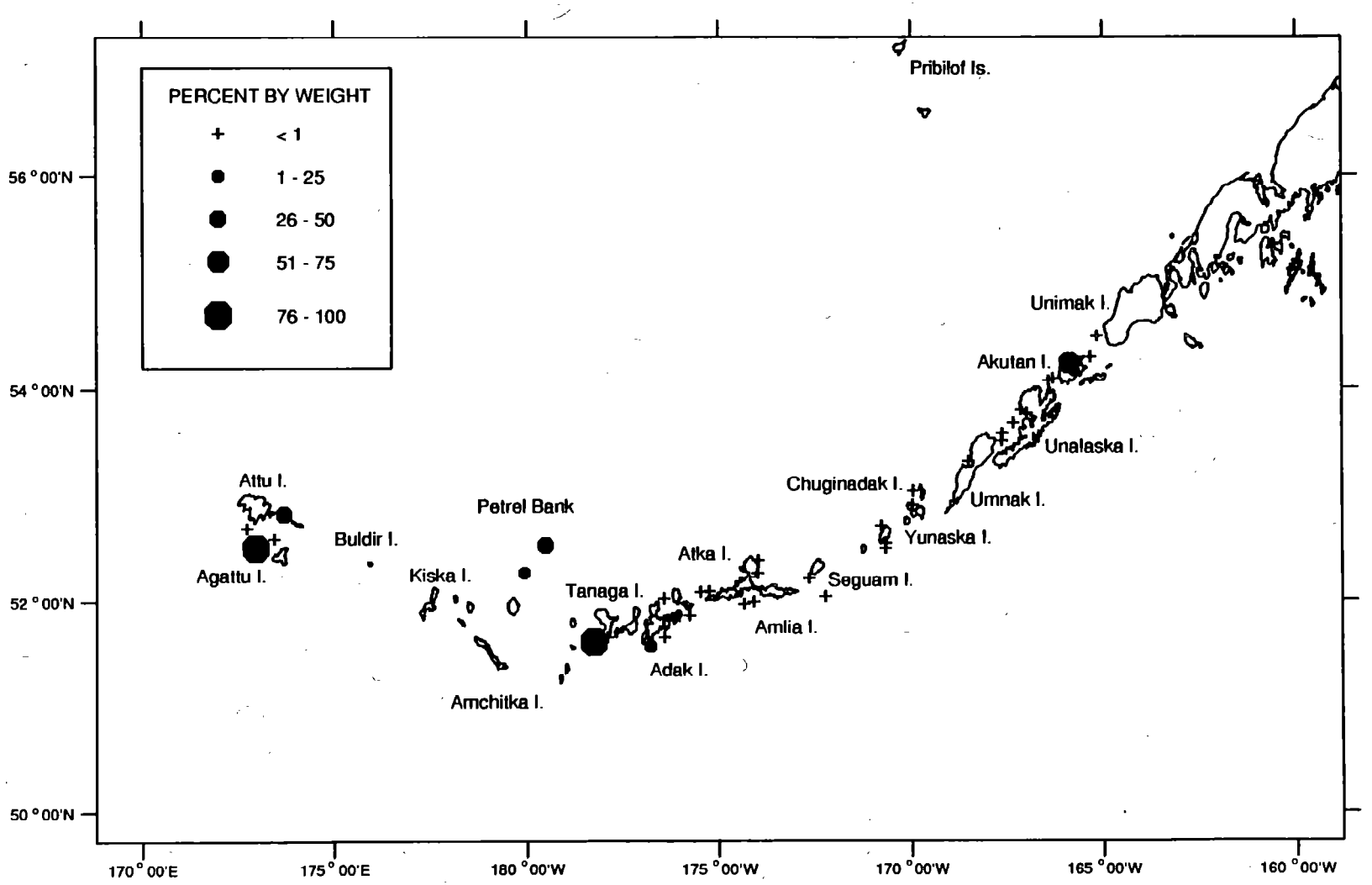

Figure 4-6.-- Geographic distribution of Atka mackerel consumed by Pacific halibut in the Aleutian Islands area in 1991.

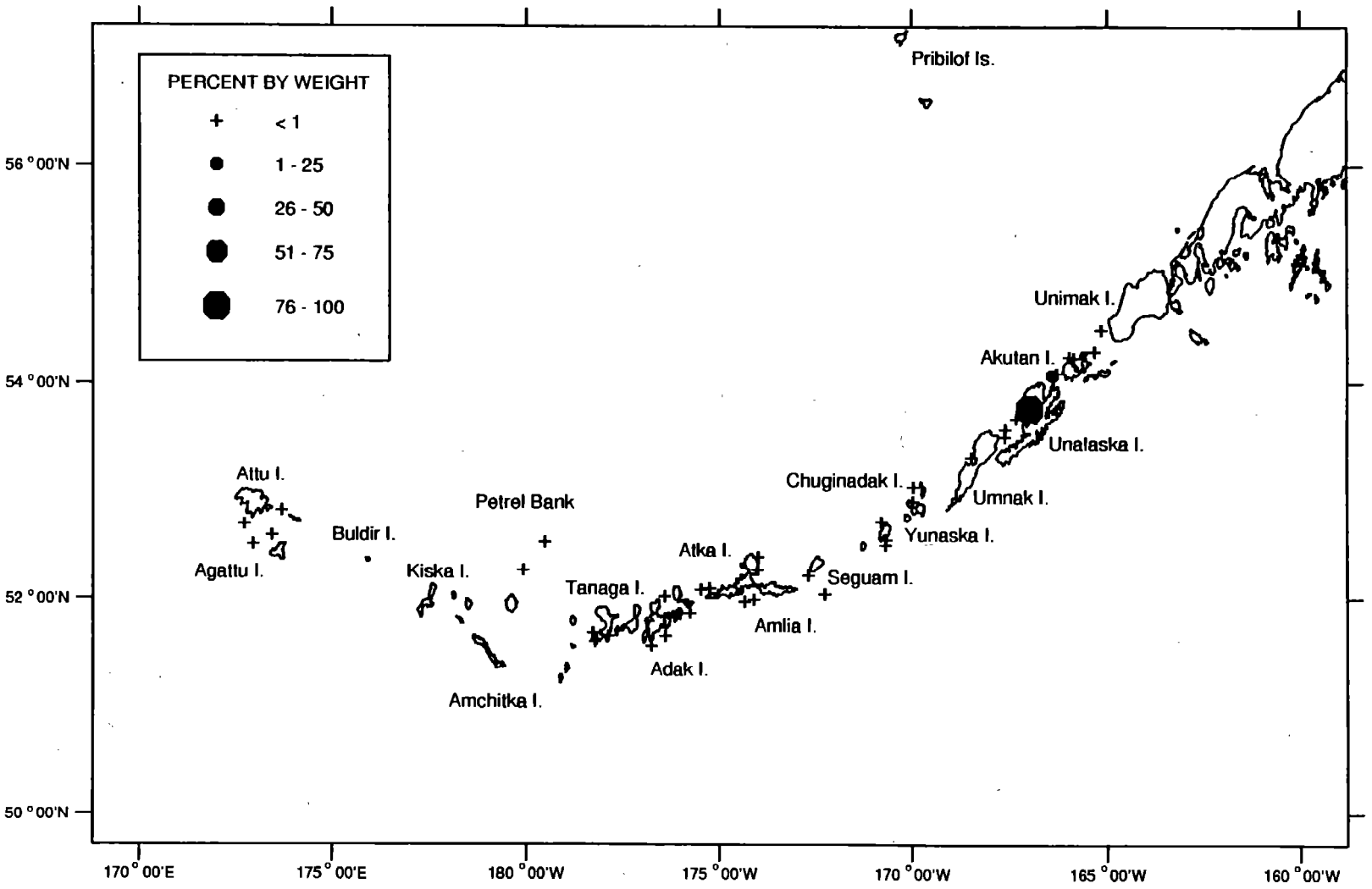

Figure 4-7.-- Geographic distribution of capelin consumed by Pacific halibut in the Aleutian Islands area in 1991.

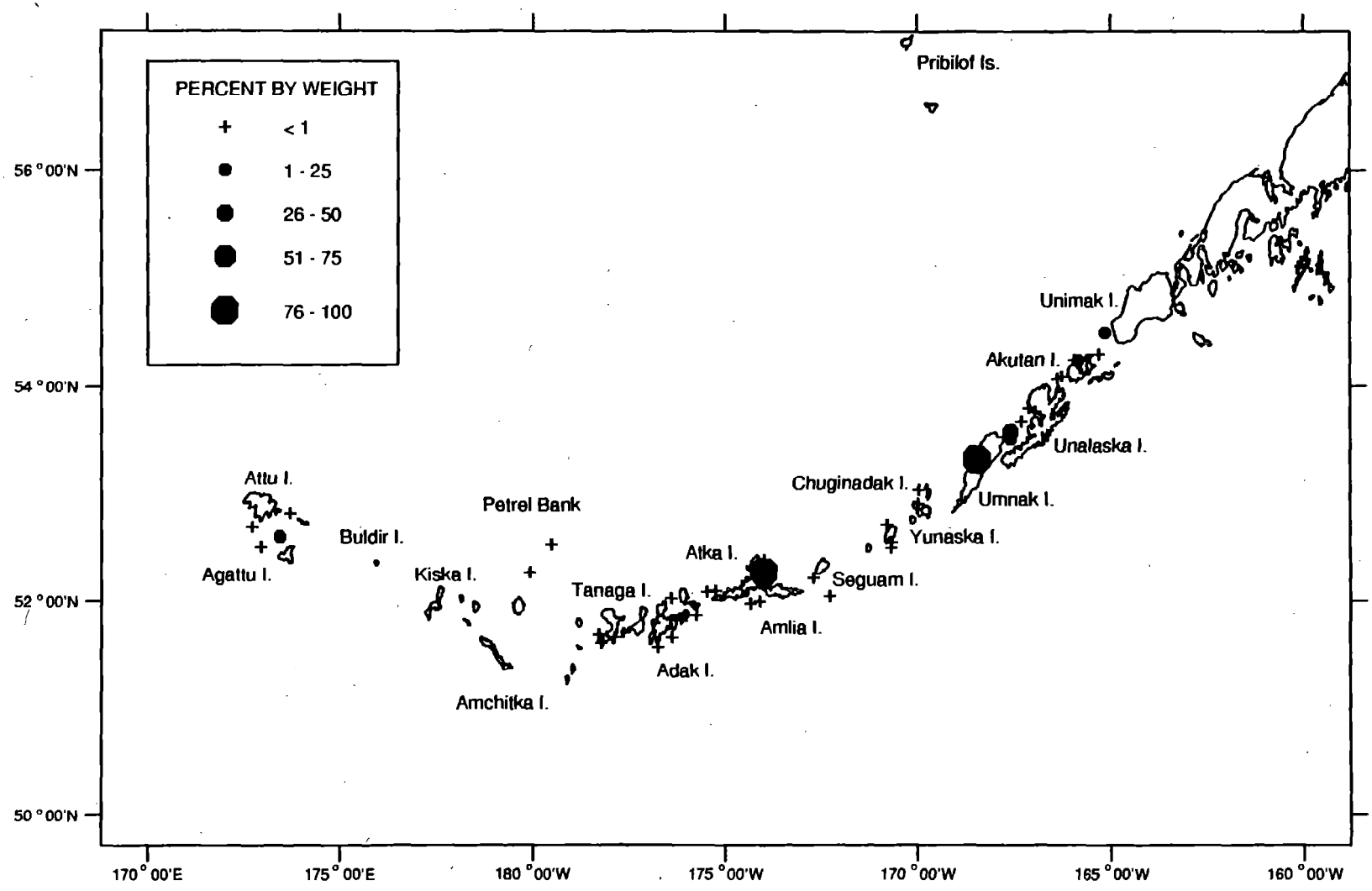

Figure 4-8-- Geographic distribution of Tanner crabs consumed by Pacific halibut in the Aleutian Islands area in 1991.

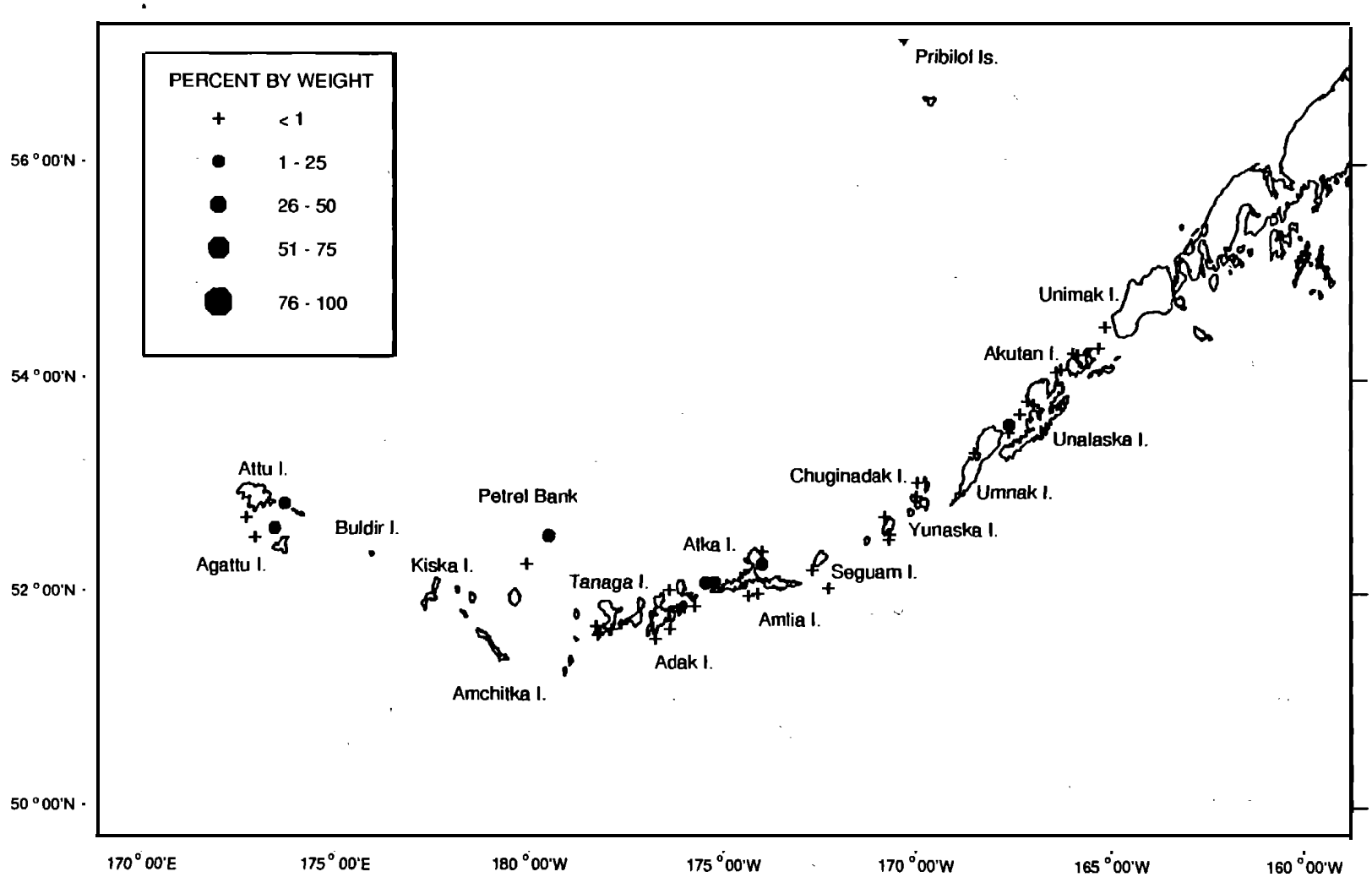

Figure 4-9.-- Geographic distribution of Korean horse-hair crabs consumed by Pacific halibut in the Aleutian Islands area in 1991.

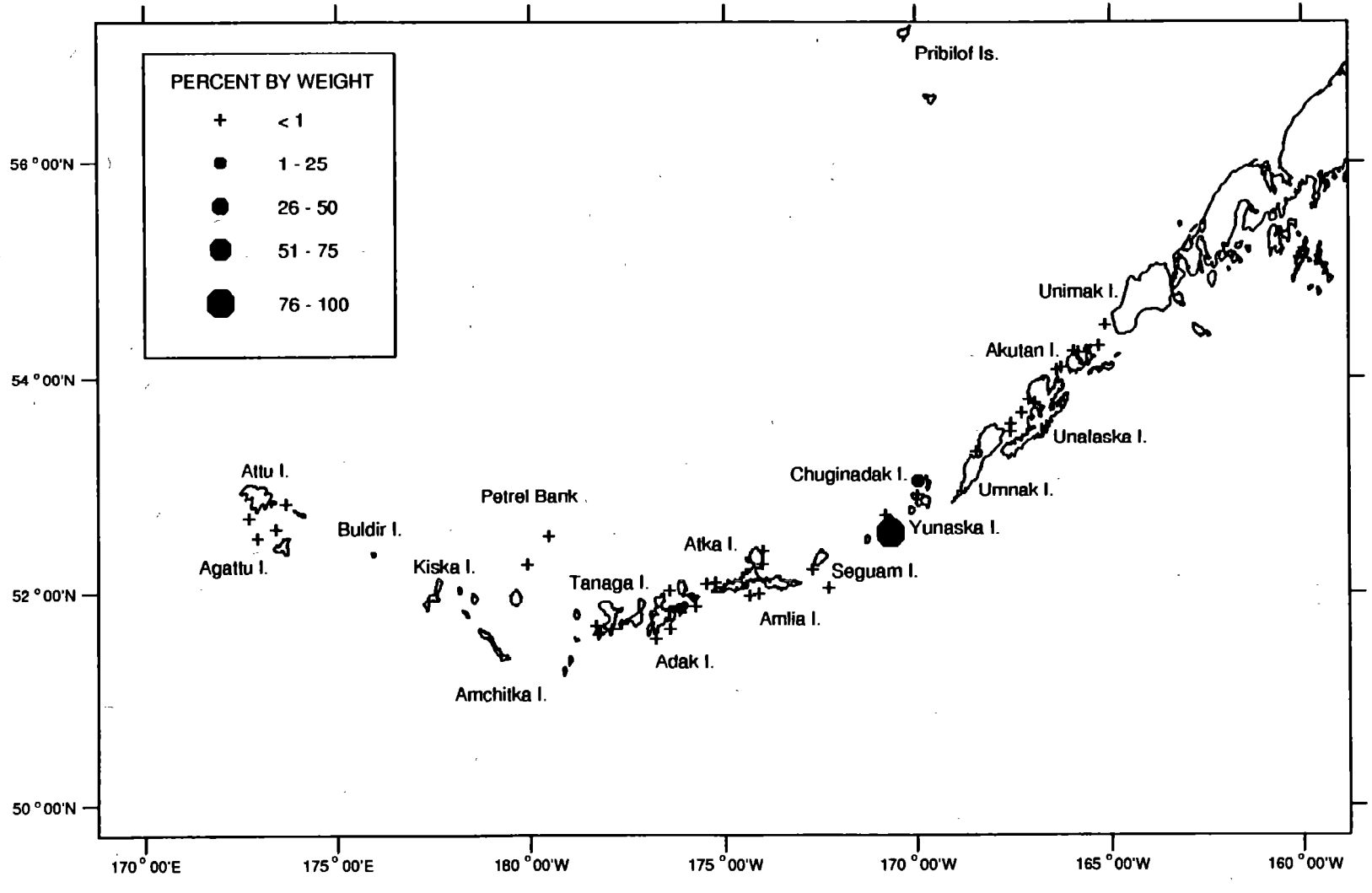

Figure 4-10.-- Geographic distribution of myctophids consumed by Pacific halibut in the Aleutian Islands area in 1991.

ATKA MACKEREL

Atka mackerel (Pleurogrammus monopterygius) ranked first in terms of biomass for the groundfish complex in the Aleutian Islands area in 1991 (Harrison 1993). Based on the stock synthesis (SS) model, the estimated exploitable biomass for 1995 estimated from the stock synthesis (SS) model was 832,000 t (Lowe 1994). The catch of Atka mackerel has been increasing from 24,000 t in 1991 to 68,000 t in 1994 (Lowe 1994). Because of the abundance and the commercial value of Atka mackerel, it is important to study its food habits and the possible impact to the ecosystem in the Aleutian Islands area.

RESULTS

General Diet

A total of 238 Atka mackerel stomachs were analyzed, of which 231 (97%) contained food. Atka mackerel ranged in size from 22 to 44 cm FL with a mean and SD of 33.5 cm and ± 4.5 cm, respectively. The average depth of the 21 haul locations (Fig. 5-l) was 127.4 ± 37.9 m with a range from 66 to 181 m. Table 5-l lists the frequency of occurrence (%) and the percentage by weight of the prey found in Atka mackerel stomachs. More than 90% of the total stomach contents weight was made up of invertebrates and less than 10% was fish. Euphausiids (mainly Thysanoessa inermis and Thysanoessa rachii) were the most important prey item. The two species comprised 55% of the total stomach contents. Calanoid copepods were another important prey of Atka mackerel, comprising 17% of the total stomach content weight. Larvaceans and hyperiid amphipods occurred frequently (81% and 68%, respectively), but the two categories comprised less than 6% of the total stomach contents weight, respectively. Squid was another invertebrate prey of Atka mackerel; they comprised 8% of the total stomach contents weight.

Atka mackerel eggs comprised 3% of the total stomach contents weight and occurred in 9% of the Atka mackerel stomachs analyzed. Walleye pollock were the second most important prey fish of Atka mackerel; they comprised about 2%

of the total stomach contents weight. Myctophids, bathylagids, zoarcids, cottids, stichaeids, and pleuronectids were also found in the Atka mackerel stomachs. However, each of the categories comprised less than 1% of the total stomach contents weight.

Variations of Diet Based on Predator Size

Figure 5-2 illustrates the percentage by weight of the main prey items for different Atka mackerel size groups. Calanoid copepods (42% by weight) and larvaceans (22% by weight) were the most important food of the smallest (< 25 cm FL) size groups of Atka mackerel. Euphausiids (69% by weight) were the most important prey of Atka mackerel between 26 and 35 cm FL. The largest (> 35 cm FL) Atka mackerel also consumed a fair amount of euphausiids (21% by weight) in addition to cephalopods (29%). Cannibalism (preying on their own eggs). occurred mainly in this size group (> 35 cm FL) of Atka mackerel. Eggs comprised 13% of the total stomach contents weight of this size group.

The size of walleye pollock consumed by Atka mackerel ranged from 49 to 63 mm SL with a mean and SD of 56.2 ± 4.8 mm. The cottids consumed by Atka mackerel ranged from 12 to 21 mm SL with mean and SD of 15.9 ± 3.1 mm. Other fish consumed by Atka mackerel included one bathylagid (11 mm SL), one zoarcid (61.4 mm SL), one myctophid (59 mm SL), and one stichaeid (29 mm SL).

DISCUSSION

Simenstad et al. (1977) found that planktonic crustaceans, hyperiid amphipods, calanoid copepods, and oikopleura (larvaceans) occurred frequently in the Atka mackerel stomachs collected from the Amchitka Island area. In the current study, euphausiids were the most important food (55% by weight). This is contrary to Simenstad et al. (1977) findings that euphausiids occurred in only 1% of Atka mackerel stomachs.

The guarding of eggs by males is a characteristic of the reproductive behavior of Atka mackerel (Zolotov and Tokranov 1991). Many studies (Zolotov and Tokranov 1991, Zolotov and Medveditsyna 1978, Takemura and Yamane 1953) have shown that

Atka mackerel eat their own eggs. We compared the diets of males and females to see if there was any diet differences that could be linked to the egg-guarding behavior of males. Table 5-l indicates that the diet of male Atka mackerel was comprised of 62% euphausiids, 18% calanoid copepods, 6% larvaceans, 4% Atka mackerel eggs, and 2% walleye pollock. Similarly, the diet of female Atka mackerel was comprised of 48% euphausiids, 16% calanoid copepods, 6% larvaceans, 3% Atka mackerel eggs and 2% walleye pollock. The main differences were that male Atka mackerel consumed more euphausiids than the females (62% vs. 48%) and female Atka mackerel consumed more squid than the males (15% vs. 1%). Based on this study, it appears that male and female Atka mackerel do not feed differently despite the egg-guarding behavior of the males.

Table 5-1.--Main prey items (expressed in frequency of occurrence (%FO), and percent total weight (%WT)) of Atka mackerel (Pleurogrammus monopterygius) collected in the Aleutian Islands area in 1991.

Prey Name	Male		Female		Total	
	%FO	%WT	%FO	%WT	%FO	%WT
Polychaeta (unidentified)	1.8	0.3	3.4	0.1	2.6	0.2
Gastropoda (unidentified)	44.7	0.4	36.8	0.5	40.7	0.5
Cephalopoda (unidentified)	4.4	0.1	7.7	0.1	6.1	0.1
Teuthoidea (squid unidentified)	26.3	0.3	35.9	14.9	31.2	7.8
Octopoda (unidentified)	2.6	0.1	0.9	0.1	1.7	0.1
Calanoida (copepod)	68.4	17.5	67.5	15.7	68.0	16.6
Gammaridea (amphipod)	24.6	0.4	17.1	0.2	20.8	0.3
Hyperiidea (amphipod)	66.7	1.2	70.9	2.3	68.8	1.8
Caprellidea (amphipod)	4.4	0.1	1.7	0.0	3.0	0.1
Euphausiacea (unidentified)	58.8	61.7	66.7	48.4	62.8	54.9
Caridea (shrimp)	17.5	0.2	15.4	0.1	16.5	0.2
Majidae (crab)	6.1	0.1	4.2	0.1	5.2	0.1
Chionoecetes bairdi (Tanner crab)	3.5	0.1	2.6	0.1	3.0	0.1
Chaetognath (arrow worm)	26.3	0.4	28.2	0.7	27.3	0.5
Larvacean (tunicate)	83.3	5.8	78.6	5.8	81.0	5.8
Teleostei (unidentified fish)	1.8	0.1	1.7	0.1	1.7	0.1
Non-gadoid fish remains	1.8	0.1	3.4	0.1	2.6	0.1
Bathylagidae (deepsea smelt)	0.0	0.0	0.9	0.1	0.4	0.1
Myctophidae (lantern fish)	1.8	0.6	0.9	0.3	1.3	0.5
Theragra chalcogramma (pollock)	2.6	1.6	2.6	1.6	2.6	1.6
Zoarcidae (eelpout)	0.9	0.3	0.0	0.0	0.4	0.2
Atka mackerel eggs	7.9	3.7	10.3	2.9	9.1	3.3
Cottidae (unidentified sculpin)	0.9	0.1	1.7	0.1	1.3	0.1
Stichaeidae (prickleback)	0.0	0.0	0.9	0.1	0.4	0.1
Pleuronectidae (flatfish)	0.0	0.0	0.9	0.1	0.4	0.1
Fishery discards	0.9	1.1	0.0	0.0	0.4	0.6
Misc. unidentified materials	26.3	3.6	25.6	5.2	26.0	4.4
Total prey weight	340 g		360 g		700 g	
Number of stomachs with food	114		117		231	
Number of empty stomachs	5		2		7	

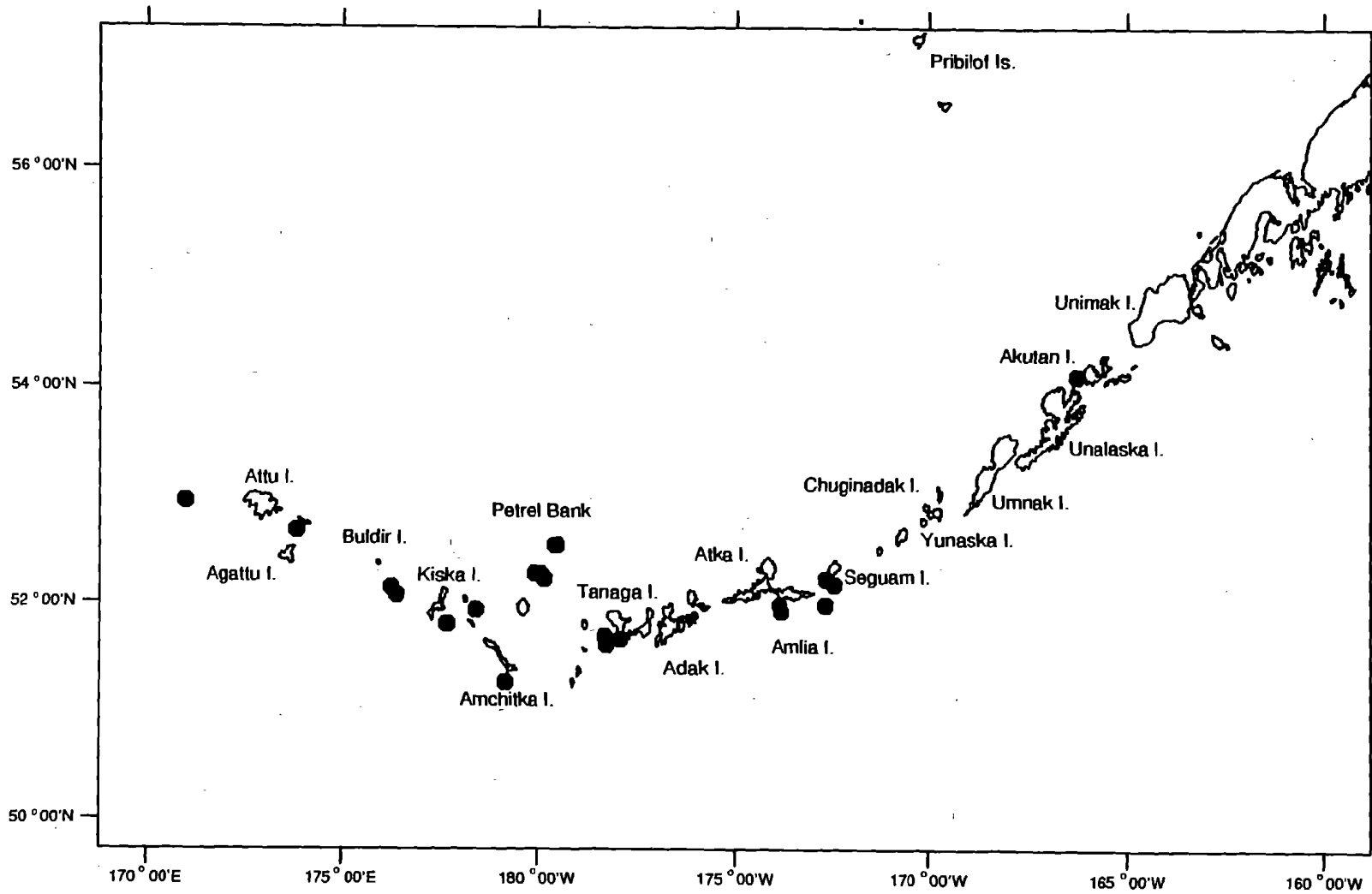

Figure 5-1.--Sampling locations (black dots) of the stomach samples of Atka mackerel collected in the Aleutian Islands area in 1991.

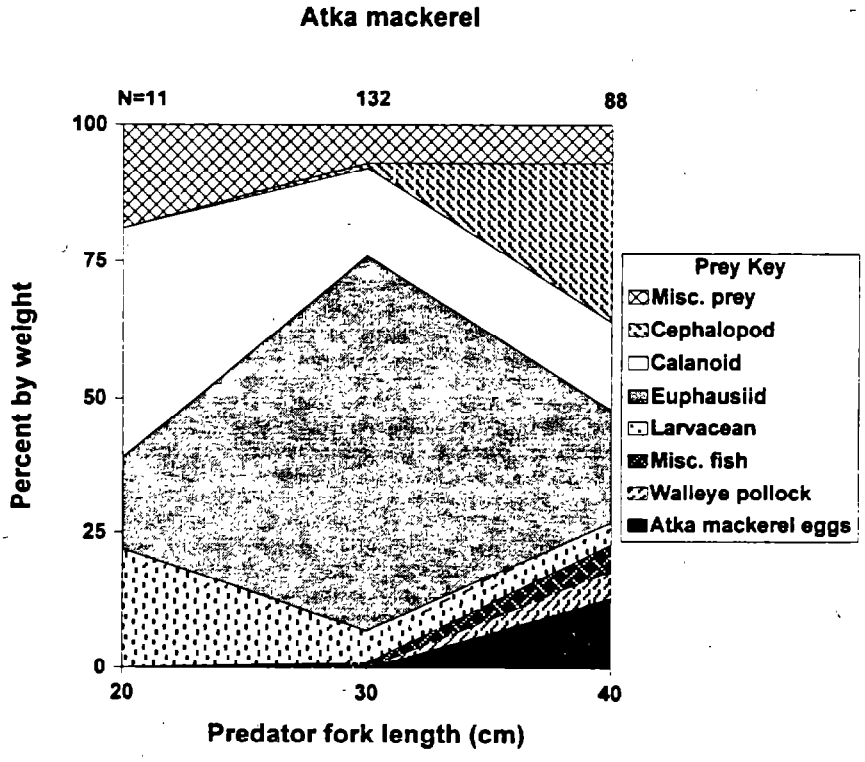

Figure 5-2.-Variation in the main food items of Atka mackerel, by predator size, in the Aleutian Islands area in 1991. N = sample size.

GREENLAND TURBOT

The total estimated biomass of Greenland turbot (Reinhardtius hippoglossoides) in the Aleutian Islands area was 12,072 t in 1991 (Harrison 1993). The catch of the Greenland turbot in the Aleutian Islands in 1994 was 2,933 t (Ianelli et al. 1994). Earlier studies on the diet of Greenland turbot (Mito 1974, Smith et al. 197-8, Yang and Livingston 1988) have shown that Greenland turbot are primarily piscivorous, and walleye pollock is the most important prey of Greenland turbot in the eastern Bering Sea. Therefore, it is important to study the diet of the Greenland turbot in the Aleutian Islands area. To avoid confusion with the Pacific halibut (Hippoglossus stenoleois), we use the "official" market name (Greenland turbot) instead of Greenland halibut which is the common name used by the American Fisheries Society (AFS 1991).

RESULTS

A total of 44 Greenland turbot stomachs were analyzed, of which 25 (57%) contained food. Greenland turbot sizes ranged from 58 to 100 cm FL with a mean and standard deviation of 67.6 ± 7.7 cm. Figure 6-l illustrates the haul locations for the collected stomach samples of the Greenland turbot in the Aleutian Islands area in 1991. The average depth of the 5 haul locations was 332.7 ± 87.5 m with a range from 181 to 390 m.

Table 6-l lists the frequency of occurrence (%) and the percentage by total weight of Greenland turbot prey. Fish comprised about 50% by weight of the diet of Greenland turbot. Myctophids were the most important prey fish of Greenland turbot. This group comprised 36% of the frequency of occurrence and 29% of the total stomach contents weight. Bathylagids were the second most important prey fish. This latter category comprised 13% of the total stomach contents weight. Although walleye pollock were found in the stomachs of Greenland turbot, they comprised only 1.4% of the total stomach contents weight. Squid were the most important invertebrate prey. They comprised 46% of the total stomach contents weight. Polychaetes and octopus were also consumed by Greenland turbot;

however, they comprised very low percentages by weight of the total diet.

Diet was not analyzed by different predator size groups because all turbot collected were larger than 55 cm and the total sample size was small. However, some prey fish length data were collected during the analysis. The length of measurable myctophids consumed by Greenland turbot had a mean and SD of 101.2 ± 5.8 mm SL with a range between 92 and 108 mm. The average SL of the four bathylagids collected from stomach contents was 124.7 ± 17.1 mm with a range of 102 to 143 mm. One measurable Pacific viperfish (Chauliodus macouni) (140 mm SL) was also identified during the analysis.

DISCUSSION

Yang and Livingston (1988) found that walleye pollock was the most important prey of Greenland turbot in the eastern Bering Sea. However, in this study, walleye pollock was not an important prey. Instead, myctophids and squid were the most important prey for Greenland turbot in the Aleutian Islands area. This difference in diet composition can be related to the fact thatwalleye pollock abundance is so much higher in the Bering Sea than in the Aleutian Islands area. Though the compositions of the prey fish in the diet of Greenland turbot were different in these two areas, the total percentages of the fish and cephalopods consumed were similar in this study (50% fish and 50% cepahlopods) and for the same depth area (200-399 m) in the Bering Sea (49% fish and 50% cephalopods) (Yang and Livingston 1988).

Because of the small sample size (n = 25) in this study, diet variation between different size groups of Greenland turbot were not analyzed.

Table 6-1.--Prey items (expressed in frequency of occurrence (%), and percentage of total weight) of Greenland turbot (Reinhardtius hippoglossoides) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	4.00	0.03
Teuthoidea (squid unidentified)	28.00	46.19
Octopoda (unidentified)	4.00	3.68
Mysidacea (mysid)	4.00	0.05
Teleostei (unidentified fish)	8.00	0.23
Non-gadoid fish remains	20.00	4.03
Bathylagidae (deepsea smelt)	16.00	13.28
Chauliodus macouni (Pacific viperfish)	4.00	2.62
Myctophidae (lantern fish)	36.00	28.48
Theragra chalcogramma (walleye pollock)	4.00	1.42

Total prey weight	397 g
Number of stomachs with food	25
Number of empty stomachs	19

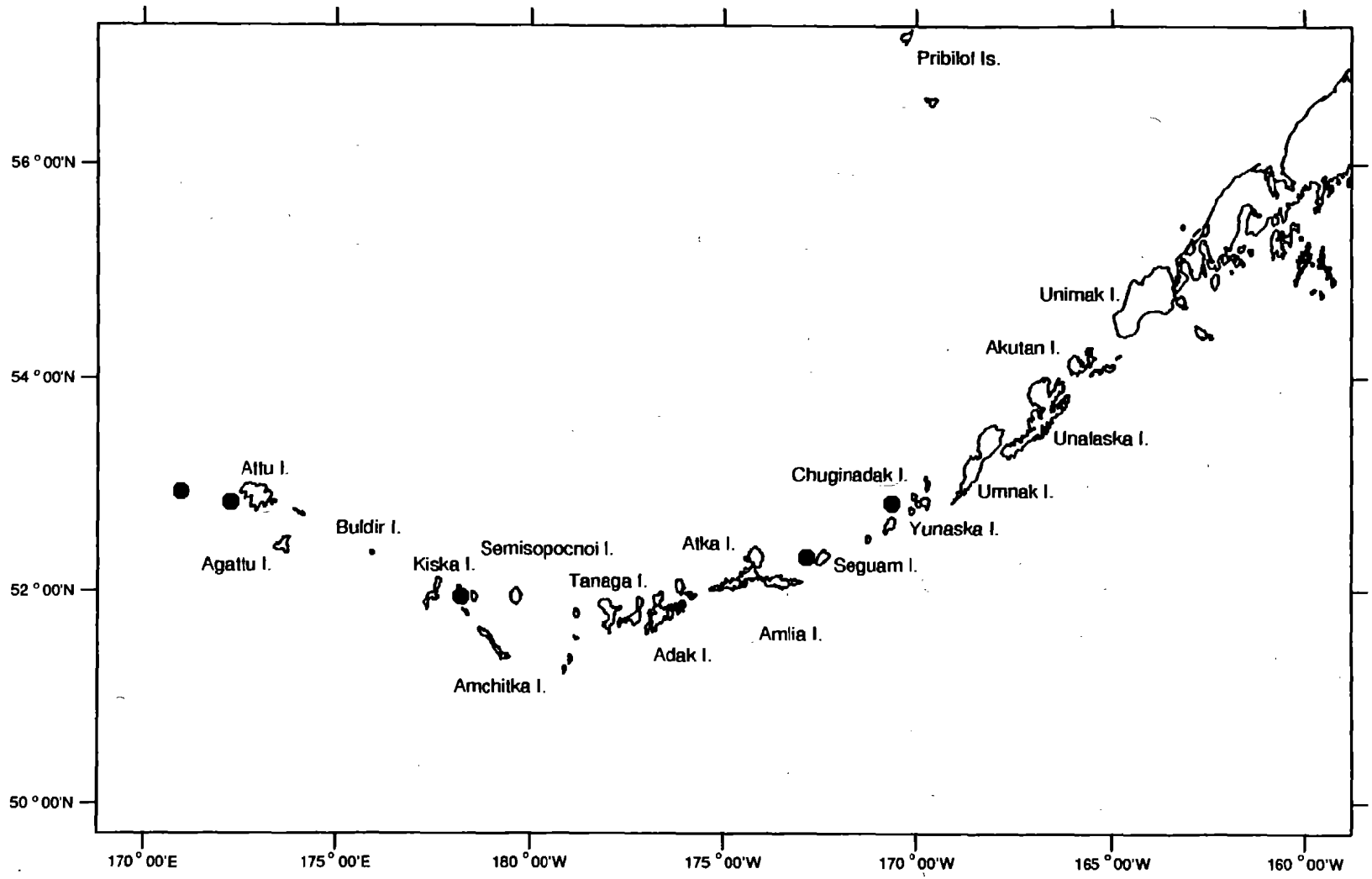

Figure 6-1.--Haul locations (black dots) of the stomach samples of Greenland turbot collected in the Aleutian Islands area in 1991.

SHORTSPINE THORNYHEAD

Shortspine thornyheads (Sebastolobus alascanus) account for the bulk of the "other rockfish" catch in the Aleutian Islands area (Ito 1994). The "other rockfish" category includes all species of Sebastes and Sebastolobus other than the Pacific ocean perch (Sebastes alutus) complex. The estimate of the exploitable biomass for "other rockfish" for 1995 was 15,450 t in the Aleutian Islands area (Ito 1994). In the past, thornyheads were not the primary target of the rockfish fleet. Today, thornyheads are one of the most commercially valuable rockfish species (Dawson 1991).

RESULTS

A total of 67 shortspine thornyhead stomachs were analyzed, of which 44 (66%) contained food. Shortspine thornyhead sizes ranged from 17 to 52 cm FL with a mean and SD of 33.4 ± 7.8 cm. Figure 7-l shows the haul locations for the collected stomach samples of the shortspine thornyhead in the Aleutian Islands in 1991. The average depth of the 8 haul locations was 350.4 ± 43.3 m with a range from 271 to 410 m.

Table 7-l lists the frequency of occurrence (%) and the percentage by total weight of the prey items of shortspine thornyhead. Fish made up about 65% by weight of the diet of shortspine thornyhead. Cottids were the most important prey fish of shortspine thornyhead, Comprising 51% of the total stomach contents weight. Other prey fish included unidentified rockfish, cyclopterids, and other unidentified fish remains. Pandalid shrimp, at 18% of the total stomach contents weight, were the most important invertebrate prey. Shortspine thornyhead also consumed Korean horse-hair crab (8% by weight), deep sea king crab (Lithodes couesi) (< 1%) and other crustaceans (< 5%).

Figure 7-2 illustrates the variation of the main food items of different size groups of shortspine thornyhead. The smallest size group (25 cm FL) consumed high percentages (66% of the total stomach contents weight) of shrimp and euphausiids (13%) but no fish. Medium-sized (26-35 cm FL) shortspine thornyhead consumed a high percentage (88% by weight) of cottids. The largest size group of shortspine thornyhead also consumed a high

percentage (47% by weight) of cottids plus some miscellaneous fish, shrimp, and Korean horse-hair crab (35 mm CW). The average standard length of the cottids consumed in this study was 71 ± 23.8 mm with a range from 27 to 92 mm SL.

DISCUSSION

Yang (1993) found that shortspine thornyhead consumed large amounts (67% of the total stomach contents weight) of shrimp (mainly pandalids) in the Gulf of Alaska area. In this study, cottids were the most important prey of the shortspine thornyhead in the Aleutian Islands area; they comprised 51% of the total stomach contents weight. Shrimp (mainly pandalids) were also important; however, they comprised only 23% of the total stomach contents weight of the shortspine thornyhead. Differences in abundance of the main prey between the two areas might be the main reason for the observed diet differences. Predator size might be another reason for the difference since the average shortspine thornyhead in the Aleutian Islands area was larger than that in the Gulf of Alaska (33.4 cm vs 29.7 cm FL).

Yang (1993) has already described that shortspine thornyhead mainly feeds on epibenthic shrimp and fish. Yang (1993) suggested that this species' elongated body, relatively large terminal mouth, and gill raker structure all contribute to the diet differences between shortspine thornyhead and other rockfish species. The present study supports Yang's (1993) observations except that the analysis found more fish than shrimp in the stomachs of shortspine thornyhead in the Aleutian Islands area.

Table 7-1 .--Prey items (expressed in frequency of occurrence (%), and percentage of total weight) of shortspine thornyhead (Sebastolobus alascanus collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Octopoda (unidentified)	2.30	0.32
Mysidacea (mysid)	6.80	0.15
Isopoda (isopod)	9.10	0.34
Gammaridea (amphipod)	25.00	1.10
Caprellidea (amphipod)	2.30	0.03
Euphausiacea (euphausiid)	13.60	1.43
Hippolytidae (shrimp)	13.60	3.21
Pandalidae (shrimp)	13.60	17.90
Crangonidae (shrimp)	4.50	1.84
Lithodes couesi (deep sea king crab)	2.30	0.20
Erimacrus isenbeckii (horse-hair crab)	6.80	8.33
Non-gadoid fish remains	9.10	8.67
Rockfish (unidentified)	6.80	5.24
Cottidae (sculpin)	18.20	47.28
Triglops scepticus (spectacled sculpin)	2.30	3.42
Cyclopteridae (snailfish)	4.50	0.54

Total prey weight	149 g
Number of stomachs with food	44
Number of empty stomachs	23

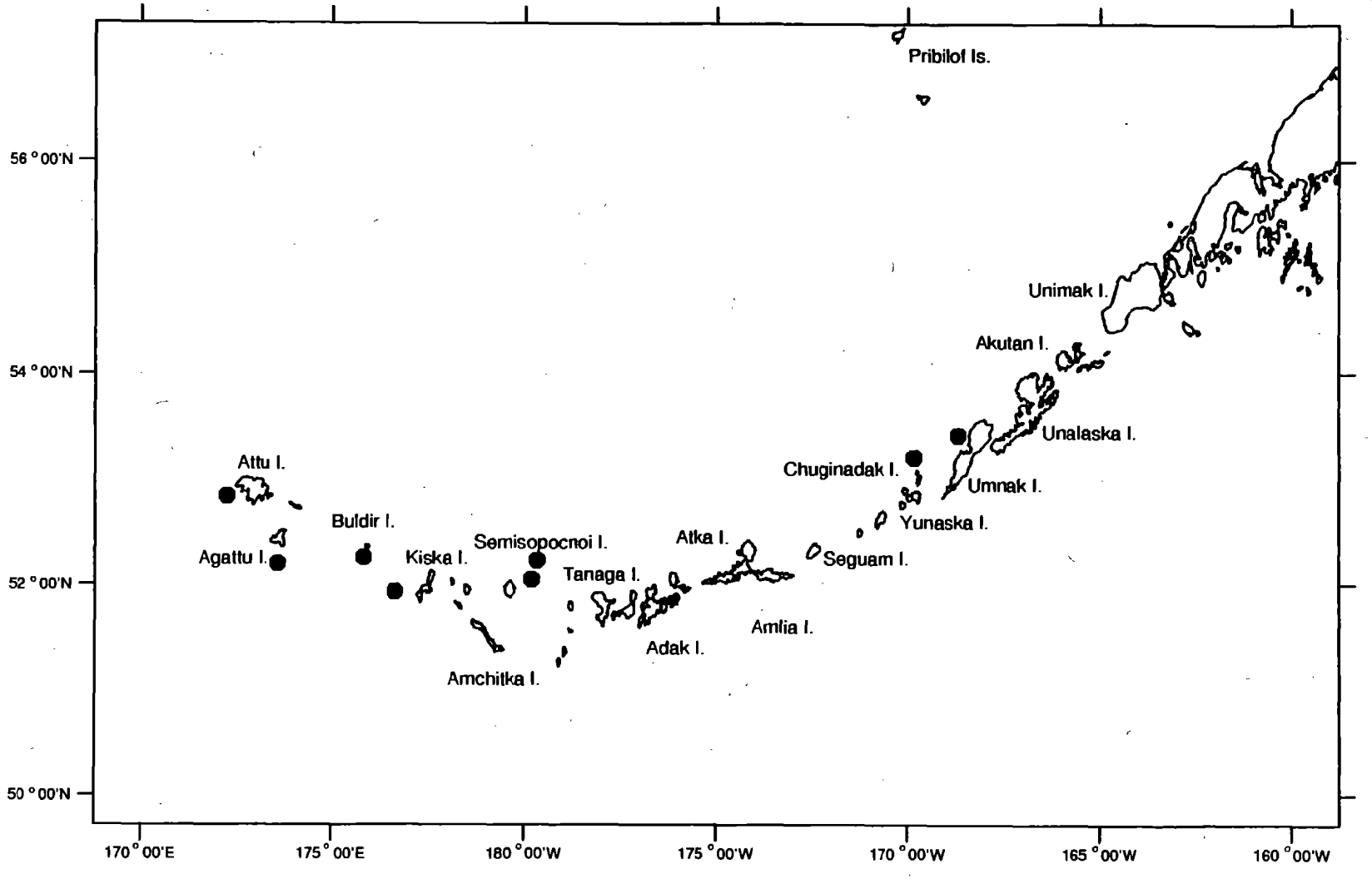

Figure 7-1.--Haul locations (black dots) of the stomach samples of shortspine thornyhead collected in the Aleutian Islands area in 1991.

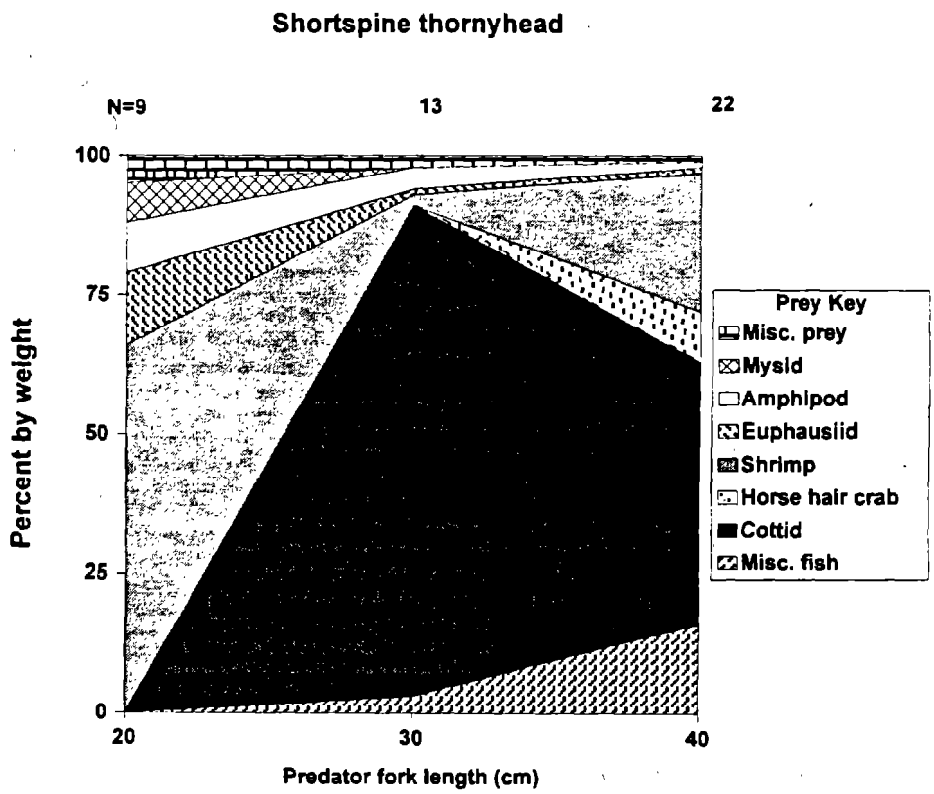

Figure 7-2.–Variation in the main food items of shortspine thornyhead, by predator size, in the Aleutian Islands area in 1991. N = sample size.

NORTHERN ROCKFISH

Northern rockfish (Sebastes polyspinis) were distributed mainly in the western Aleutian Islands area and on the Petrel Bank (Harrison 1993). It was the fourth most abundant groundfish encountered during the 1991 Aleutian Islands groundfish survey (Harrison 1993). Because of its abundance, it is considered important to study the food habits of the northern rockfish in the Aleutian Islands area.

RESULTS

A total of 153 northern rockfish stomachs were analyzed, of which 115 (75%) contained food. Northern rockfish lengths ranged from 14 to 45 cm FL with a mean and standard deviation of 28.6 ± 5.5 cm. Figure 8-l shows the haul locations where stomach samples of northern rockfish were collected in the Aleutian Islands area in 1991. The average depth of the 18 haul locations was 152 ± 43.5 m with a range from 77 to 236 m.

Table 8-l lists the frequency of occurrence (%), and the percentage by total weight of the prey items of northern rockfish. The analysis indicated that northern rockfish were mainly planktivorous. Euphausiids were the most important prey of the northern rockfish, comprising 50% of the total stomach contents weight. Calanoid copepods occurred 'the most frequently (71%) in northern rockfish stomachs, but they comprised only 17% of the total stomach contents weight. Other food included polychaetes, pteropods, amphipods, shrimp, pagurid crabs, and arrow worms. One myctophid (52 mm SL consumed by one 34 cm FL fish) was the only prey fish found in northern rockfish stomachs; they comprised only 1% of the total stomach contents weight.

Calanoid copepods (65% by weight) were the most important food of the smaller-sized group ??25 cm FL) of northern rockfish whereas euphausiids (57%) were the main food of the larger-sized fish (> 25 cm FL) (Fig. 8-2).

DISCUSSION

Earlier studies in the Gulf of Alaska (Yang 1993), and Bering Sea (Skalkin 1964, Mito 1974) showed a similar diet for northern rockfish: euphausiids, calanoid copepods, arrow worms, and hermit crabs. All these studies indicate that northern rockfish are planktivorous.

Table 8-1.--Prey items (expressed in percent frequency of occurrence (%), and percentage of total weight) of northern rockfish (Sebastes polyspinsis) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (worm)	13.04	7.05
Pteropod (snail)	10.43	0.41
Teuthoidea (squid)	4.35	0.73
Crustacea (unidentified)	25.22	1.50
Calanoida (copepod)	71.30	17.17
Mysidacea (mysid)	1.74	0.14
Gammaridea (amphipod)	13.04	1.23
Hyperiidea (amphipod)	15.65	3.27
Euphausiacea (euphausiid)	45.22	50.15
Caridea (shrimp)	22.61	2.83
Paguridae (hermit crab)	10.43	0.49
Chionoecetes spp. (Tanner crab)	1.74	0.01
Chaetognatha (arrow worm)	26.09	3.19
Myctophidae (lanternfish)	0.87	0.98
Fishery discards	0.87	9.23
Unidentified material	11.30	1.58
Total prey weight	77 g	
Number of stomachs with food	115	
Number of empty stomachs	38	

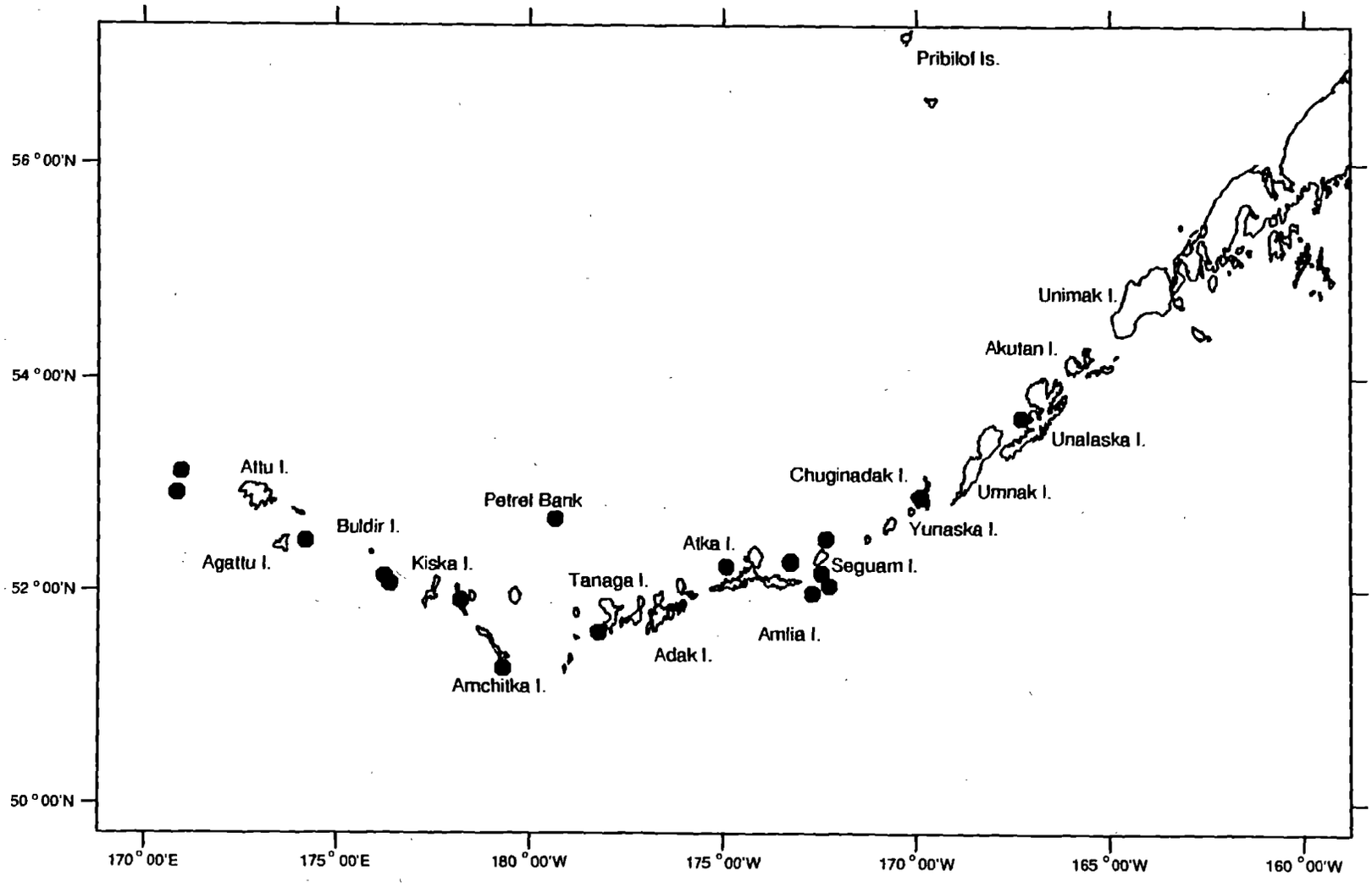

Figure 8-1.--Haul locations (black dots) of the stomach samples of northern rockfish collected in the Aleutian Islands area in 1991.

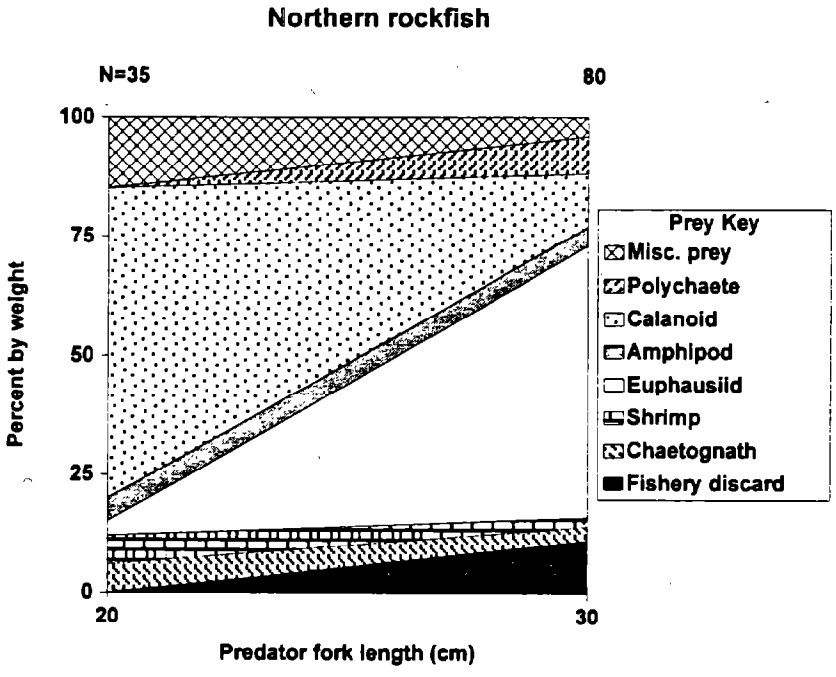

Figure 8-2.–Variation in the main food items of northern rockfish, by predator size, in the Aleutian Islands area in 1991. N = sample size.

PACIFIC OCEAN PERCH

The estimated 1995 exploitable biomass of Pacific ocean perch (Sebastes alutus) in the Aleutian Islands area was 252,000 t (NPFMC 1994). It ranked second in mean catch per unit effort (CPUE) among the most abundant groundfish species in the 1991 Aleutian Islands groundfish survey (Harrison 1993). The objective of this study was to understand the food habits of Pacific ocean perch and their relation to other marine fishes in the Aleutian Islands area.

RESULTS

A total of 266 Pacific ocean perch stomachs were analyzed, of which 128 were empty and 138 (52%) contained food. Pacific ocean perch length ranged from 10 to 45 cm FL with a mean and SD of 30.4 ± 7.4 cm. The average depth of the 16 haul locations was 203.7 ± 54.4 m with a range from 77 to 331 m.

Table 9-l lists the frequency of occurrence (%), and the percentage of total weight for the prey items of Pacific ocean perch. Euphausiids were the most important prey of Pacific ocean perch in terms of frequency of occurrence (75%) and percentage of total weight (51%). Calanoid copepods, amphipods, and polychaetes were also found frequently, however, they comprised low percentages by weight of the total diet of Pacific ocean perch. Myctophids were the most important prey fish consumed by Pacific ocean perch; they comprised 34% of the total stomach contents weight. The myctophids consumed by Pacific ocean perch had a mean standard length and SD of 58.0 ± 28.2 mm with a range from 24 to 97 mm SL. A high (>75%) percentage of myctophids were found in the stomachs of Pacific ocean perch from the Seguam Island area (Fig. 9-l).

Figure 9-2 illustrates the variation in diet between the different size groups of Pacific ocean perch. The smaller ??25 cm FL) Pacific ocean perch fed mainly on calanoid copepods and euphausiids, whereas both the medium-sized (26-35 cm FL) and largest (> 35 cm FL) fish consumed high percentages of euphausiids (65% and 35%, respectively). This figure also shows that large amounts (55% by weight) of myctophids were consumed by fish from the largest size group.

DISCUSSION

Simenstad et al. (1977) found that, in the Amchitka Island area, Pacific ocean perch fed mainly on euphausiids (86% by weight) and hyperiid amphipods (6% by weight) with incidental exploitation of mesopelagic fishes like myctophids. The present study generally agrees with the earlier findings except that a much higher percentage (34%) of myctophids were consumed by Pacific ocean perch in the present study. Because of the wide distributional range (from southern California to the Bering Sea) of the Pacific ocean perch, the diets of this species have been documented for many other areas (Yang [1993] in the Gulf of Alaska; Skalkin [1964] and Mito [1974] in the Bering Sea; and Brodeur and Pearcy [1984] along the West Coast). The results from the previous studies were similar to the results of this study. That is, Pacific ocean perch are mainly planktivorous; the smaller fish eat a higher percentage of calanoid copepods and the larger fish eat a higher percentage (usually more than 85%) of euphausiids and some shrimp. The main difference between the earlier studies and this study is that a high percentage of myctophids (34% by weight) was found in the diet of Pacific ocean perch collected for this study.

Table 9-l.--Prey items (expressed in frequency of occurrence (%), and percentage of total weight) of Pacific ocean perch (Sebastes aleutus) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (worm)	11.59	2.43
Teuthoidea (squid)	1.45	1.28
Octopoda (octopus)	1.45	0.99
Calanoida (copepod)	50.00	6.41
Mysidacea (mysid)	4.35	0.27
Gammaridea (amphipod)	29.71	1.36
Hyperiidea (amphipod)	0.72	0.02
Euphausiacea (euphausiid)	75.36	50.47
Teleostei (unidentified fish)	0.72	1.19
Non-gadoid fish remains	1.45	0.36
Myctophid (lanternfish)	12.32	34.34
Pleuronectid (flatfish)	0.72	0.73
Total prey weight	263 g	
Number of stomachs with food	138	
Number of empty stomachs	128	

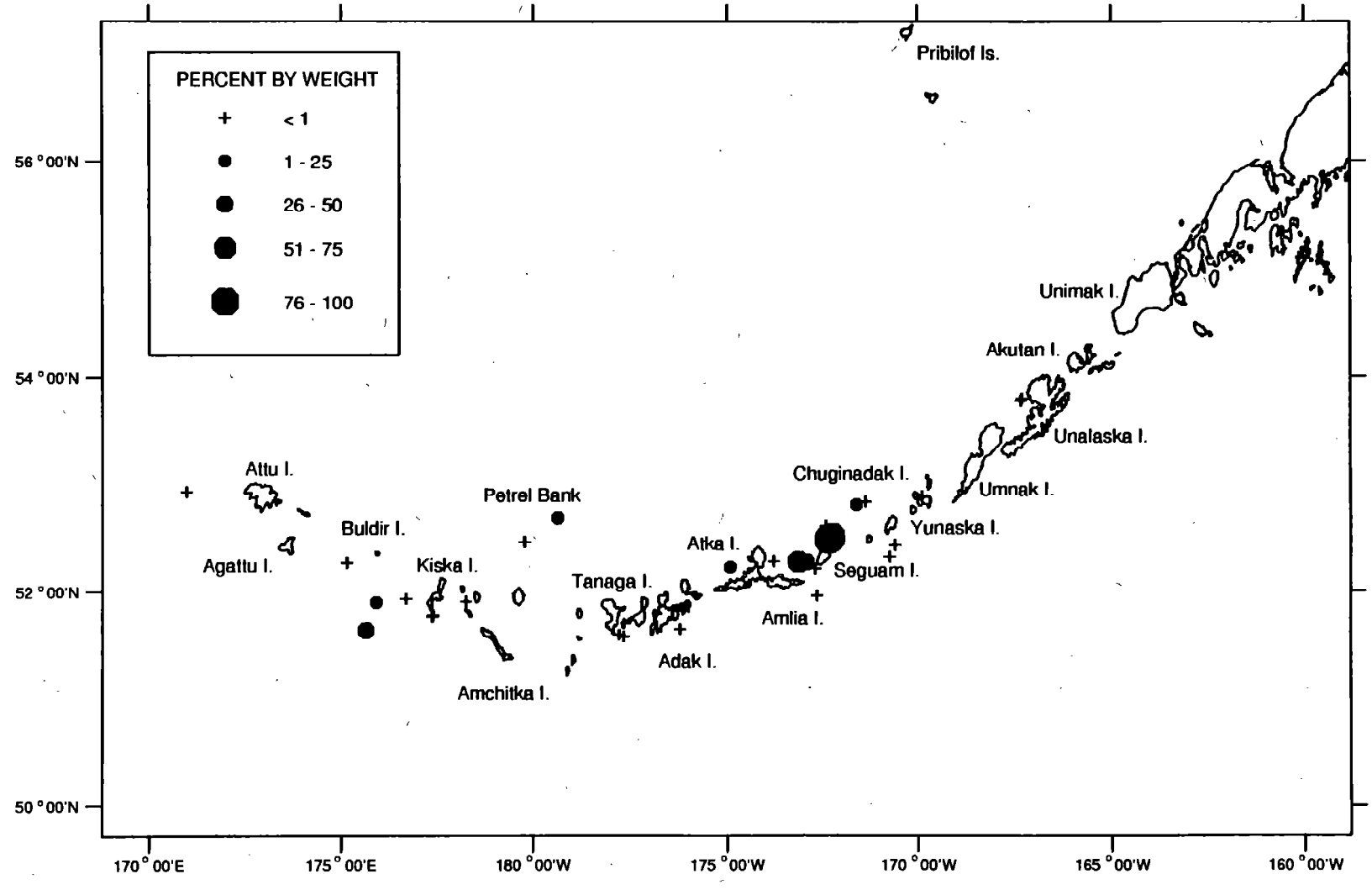

Figure 9-1.-- Geographic distribution of myctophids consumed by Pacific ocean perch in the Aleutian Islands area in 1991.

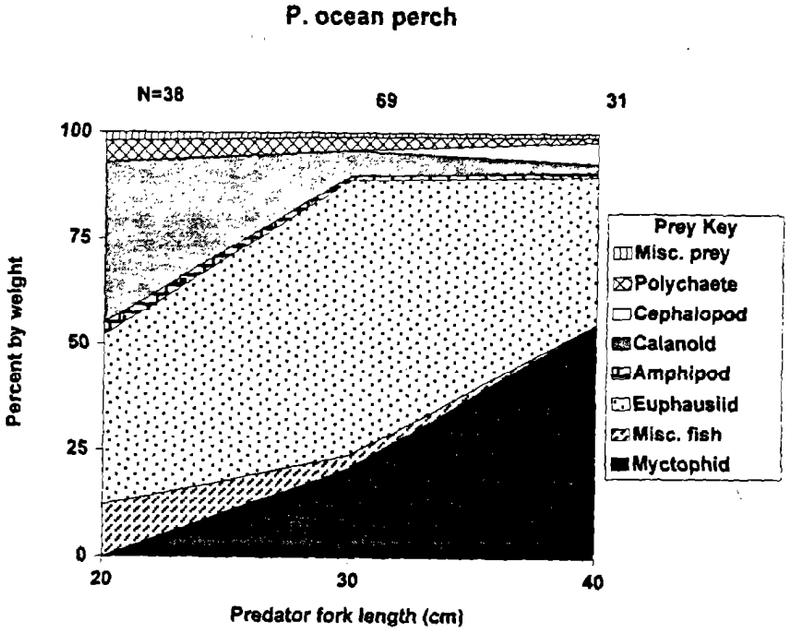

Figure 9-2.–Variation in the main food items of Pacific ocean perch, by predator size, in the Aleutian Islands area in 1991. N = sample size.

ROUGHEYE ROCKFISH

Rougheye rockfish (Sebastes aleutianus) has been managed with the shortraker rockfish as a deep-water species in the Pacific ocean perch complex in the Aleutian Islands area since 1991. The projected exploitable biomass of rougheye rockfish in the Aleutian Islands area in 1995 was 25,278 t (Ito and Ianelli 1994).

RESULTS

A total of 58 rougheye rockfish stomachs were analyzed, of which only 11 (19%) contained food. The average size of the rougheye rockfish was 38.7 cm FL with a SD of 5.8 cm. Fish size ranged from 24 to 48 cm FL. The average depth of the 11 haul locations (Fig. 10-l) was 297 ± 102 m with a range from 152 to 410 m.

Table 10-l shows the frequency of occurrence (%) and percentage by weight of the prey items of rougheye rockfish. It illustrates that shrimp, including pandalids and hippolytids, were the primary invertebrate prey of the rougheye rockfish. Snailfish were the most important fish prey; they comprised 44% of the stomach contents weight. Rougheye rockfish also consumed some myctophids (4% by weight), and non-gadoid fish remains (3% by weight). Other food items included polychaetes, amphipods, mysids, euphausiids, and isopods.

Because of the small sample size of rougheye rockfish stomachs, an analysis of diet variation between different size groups was not available.

DISCUSSION

Some earlier studies on rougheye rockfish show similar results to this study. Yang (1993) found that shrimp (pandalids, hippolytids, crangonids) comprised more than 50% of the total stomach contents weight for rougheye rockfish collected in Gulf of Alaska. Feder (1980) found that shrimp occurred in 75% of the rougheye rockfish stomachs collected in the southeastern Gulf of

Alaska. Both authors also reported that snailfish, squid, and mysids were part of the rougheye rockfish diet.

Table 10-l.--Prey items (expressed in frequency of occurrence (%), and percentage of total weight) of rougheye rockfish (Sebastes aleutianus) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	9.10	0.34
Mysidacea (mysid)	9.10	0.28
Isopoda (isopod)	9.10	0.71
Gammaridea (amphipod)	9.10	0.35
Euphausiacea (unidentified)	18.20	1.48
Hippolytidae (unidentified)	27.30	25.58
Pandalidae (unidentified)	18.20	20.35
Non-gadoid fish remains	9.10	2.83
Myctophidae (lantern fish)	9.10	3.53
Cyclopteridae (unidentified snailfish)	18.20	44.54

Total prey weight	28 g
Number of stomachs with food	11
Number of empty stomachs	47

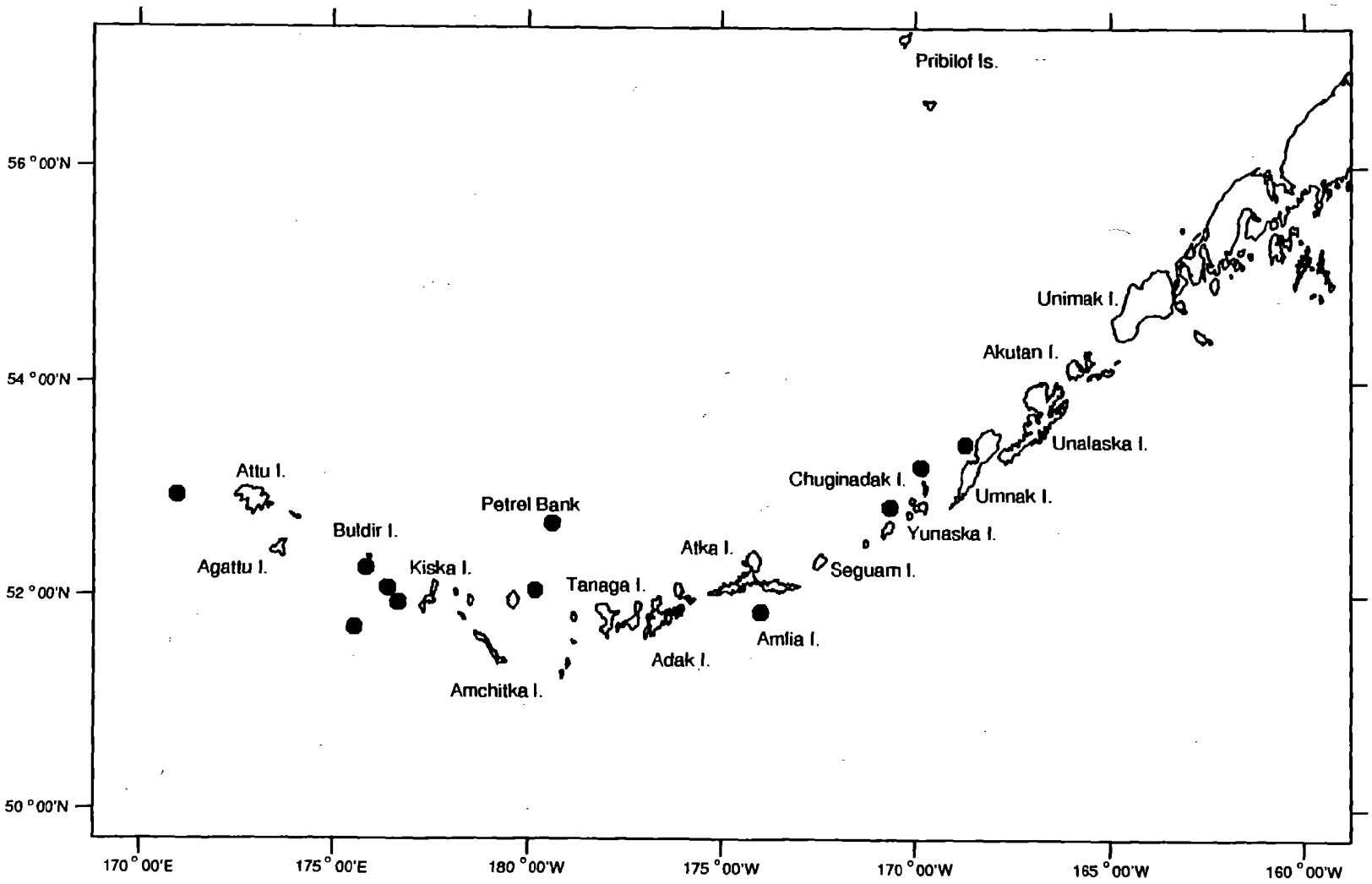

Figure 10-1.--Haul locations (black dots) of the stomach samples of rougheye rockfish collected in the Aleutian Islands area in 1991.

SHORTRAKER ROCKFISH

Shortraker rockfish (Sebastes borealis) had an exploitable biomass of 19,694 t in the Aleutian Islands area in 1991 (Ito and Ianelli 1994). Because of their special morphological characteristics (large mouth, short gill rakers, and low gill raker number), they are considered to be a potential predator of fish, cephalopods, and other commercially important species. Therefore, it is important to study the food habits of the shortraker rockfish.

RESULTS

A total of 33 shortraker rockfish stomachs were analyzed, of which 16 were empty and 17 (52%) contained food. The average size of the shortraker rockfish was 43.2 cm FL with a SD of 7.6 cm. Fish length ranged between 33 and 67 cm FL. The average depth of the 7 haul locations (Fig. 11-l) was 385 ± 39 m with-a range from 331 to 456 m.

Table 11-l lists the frequency of occurrence (%), and the percentage by weight of the prey items found in the stomachs of shortraker rockfish. Shrimp (including hippolytids and pandalids) were the most important food of shortraker rockfish in terms of frequency of occurrence and percentage of the total stomach contents weight. Fish prey comprised 37% of the total stomach contents weight, of which myctophids and cottids comprised 15% and 19%, respectively. The samples revealed one myctophid (96 mm SL) that had been consumed by a 39 cm FL shortraker rockfish. Two cottids (39 mm and 92 mm SL) were consumed by shortraker 45 cm and 40 cm FL, respectively. One shortraker rockfish also consumed a Korean horse-hair crab (44 mm CW). Another important shortraker rockfish prey were isopods; they comprised 16% of the total stomach contents weight although their percent frequency of occurrence (6%) was low.

DISCUSSION

It is difficult to collect stomach samples of shortraker rockfish since many fish brought up in bottom trawl samples had already regurgitated. An earlier food habits study of shortraker rockfish (Yang 1993) shows that this fish fed mainly on squid and myctophids in the Gulf of Alaska. This study also indicates that myctophids were important food of shortraker rockfish in the Aleutian Islands area. However, the sample sizes for all of these studies were small.

Table 11-1.--Prey items (expressed in frequency of occurrence (%), and percentage of total weight) of shortraker rockfish (Sebastes borelais) collected in the Aleutian Islands area in 1991.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	11.80	2.96
Octopoda (octopus)	5.90	2.92
Mysidacea (mysid)	5.90	0.22
Isopoda (isopod)	5.90	15.90
Gammaridea (amphipod)	5.90	0.15
Euphausiacea (unidentified)	11.80	1.28
Hippolytidae (unidentified)	29.40	10.20
Pandalidae (unidentified)	29.40	22.35
Erimacrus isenbeckii (horse-hair crab)	5.90	6.48
Non-gadoid fish remains	17.60	3.26
Myctophidae (lantern fish)	5.90	14.73
Cottidae (sculpin)	11.80	19.39

Total prey weight	46 g
Number of stomachs with food	17
Number of empty stomachs	16

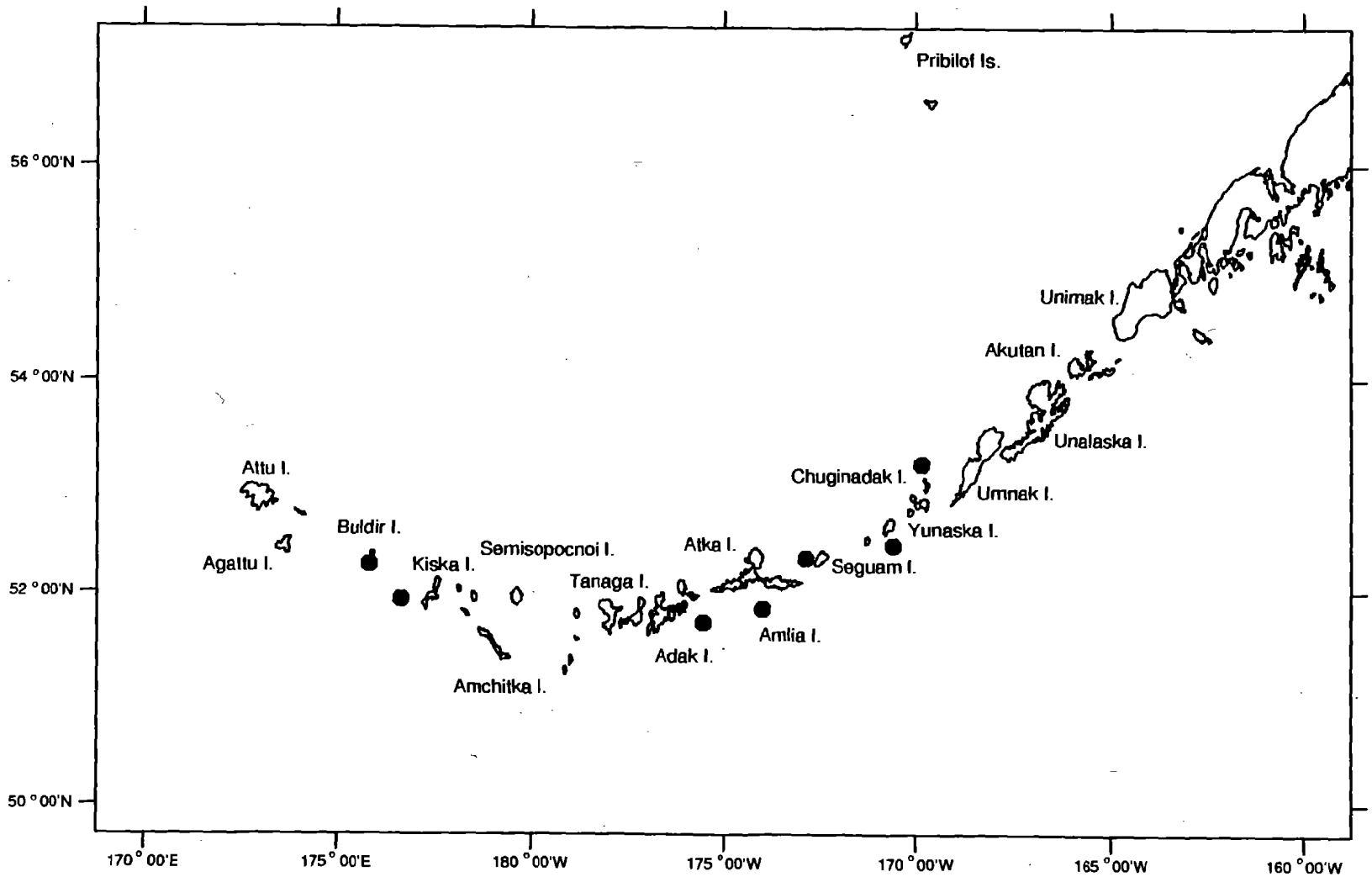

Figure 11-1.--Haul locations (black dots) of the stomach samples of shortraker rockfish collected in the Aleutian Islands area in 1991.

SUMMARY

A total of 2,606 stomachs collected from 11 species were analyzed to describe the food habits of the major groundfish species in the Aleutian Islands area. The analysis emphasized predation on commercially important fish, crab, and shrimp. The predator sizes and the number of the stomachs collected for each species are summarized in Table 1. Although juveniles of some species (e.g., walleye pollock, Pacific cod, Pacific halibut, and arrowtooth flounder) were sampled, the main focus was on the food habits of the adult fish.

Table 2 lists the percent by weight of the important prey or prey groups consumed by groundfish. The analysis revealed that arrowtooth flounder, Pacific halibut, Pacific cod, Greenland turbot, and pollock were primarily fish eaters. In the present study, the main predators to feed on Tanner crabs were Pacific halibut and Pacific cod. Shortspine thornyhead, rougheye rockfish, and shortraker rockfish were the main consumers of pandalid shrimp. Atka mackerel, Pacific ocean perch, northern, rockfish, and walleye pollock were the main consumers of euphausiids. Atka mackerel, Pacific ocean perch, northern perch were also the main calanoid copepod eaters. The main cephalopod eaters were the Greenland turbot and Pacific halibut.

The data in Table 2 indicates that Atka mackerel were the dominant prey fish and were consumed mainly by arrowtooth flounder (44%), Pacific halibut (12%), and Pacific cod (27%). Pollock was another important prey and was consumed mainly by Pacific halibut (19%), Pacific cod (17%), and arrowtooth flounder (13%). In the Aleutian Islands area, myctophids were important food for many fish. Even though they did not comprise a high percentage of the total stomach contents weight of arrowtooth flounder (7%), and Pacific cod (3%), myctophids were important food of many other fish (Greenland turbot, 28%; walleye pollock, 37%; shortraker rockfish, 15%; and Pacific ocean perch, 34%). Cottids were found in the diet of many species; however, the dominant consumer appeared to be the shortspine thornyhead (51%) and shortraker rockfish (19%). The flatfish consumed by the groundfish include arrowtooth flounder, flathead sole, Kamchatka flounder, rock sole, rex sole, and Pacific halibut. Each of these species comprised less than 5% of the stomach contents weight (Table 2). Pacific sand lance were consumed by the main predator species (arrowtooth flounder, Pacific halibut, Pacific

cod, and pollock) but comprised less than 1% of the stomach content weight of each species. Pacific cod (1% each) were consumed by Pacific halibut and Pacific cod. The commercially important Tanner crabs were mainly consumed by Pacific halibut and Pacific cod (7% and 2% of the total stomach contents weight, respectively), though they were also consumed by walleye pollock (<l%) and Atka mackerel (<1%). Table 2 indicates that almost all predator species consumed a certain amount of cephalopods (squid and octopus), of which Greenland turbot (50%), Pacific halibut (27%), and Pacific cod (12%) were the three main predators of the cephalopods. Shrimp (mainly pandalids, hippolytids, and crangonids) were mainly consumed by rougheye rockfish (45%), shortraker rockfish (32%), shortspine thornyhead (23%), and Pacific cod (10%). The main euphausiids feeders in the Aleutian Islands were Atka mackerel (50%), Pacific ocean perch (51%), northern rockfish (50%), and walleye pollock (43%). Calanoid copepods were mainly consumed by Atka mackerel (17%), northern rockfish (17%), and Pacific ocean perch (7%).

By using the proportions of the prey items in the stomachs (values in Table 2), I calculated the Schoener's (1970) index to show the dietoverlap between groundfish species in the Aleutian Islands (Fig. 1). Schoener's index (C,) is calculated as

$$C_{xy} = 1 - 0.5 \left(\Sigma | P_{x,i} - P_{y,i} | \right),$$

where $P_{x,i}$ and $P_{y,i}$ are the proportions by weight of prey i in the diets of species x and y, respectively.

The upper diagonal section of Figure 1 shows the Schoener's indices (percentage) between different species. For example, the value 40 in column 3 and row 2 means the diet overlap between arrowtooth flounder (ATF) and Pacific halibut (PH) was 40% in term of Schoener's index. The lower diagonal section of Figure 1 shows the diet overlap between species by categorizing the Schoener's indices into low (<30%), medium (30-55%), and high (>55%) values. These values are denoted as blank cells (for <30% overlap), gray cells (for 30-55% overlap) and black cells (for >55% overlap). For example, in column 2, it shows that arrowtooth flounder has high diet overlap (black cell) with Pacific cod, medium diet overlap (gray cell) with Pacific halibut and low diet overlap (blank cells) -with all other species in this study. Overall, Figure 1 shows that Pacific cod had high (>55%),

dietary overlap with Pacific halibut and arrowtooth flounder since they fed mainly on Atka mackerel, pollock, and cephalopods. High dietary overlap values (85%) also occurred between walleye pollock and Pacific ocean perch because they all consumed large amounts of myctophids and euphausiids. Another high dietary overlap was found between Atka mackerel, northern rockfish, and Pacific ocean perch since they were mainly zooplankton eaters; they all consumed large amounts of eupahausiids and calanoid copepods.

Table 3 lists the size of the commercially important prey consumed by each predator species. The details of the prey size of each of the predators were presented in the different sections of this publication which give species descriptions. This summary attempts to compare the prey size of the same prey species consumed by different predators.

Table 3 indicates that the length of consumed pollock varies from species to species. The average length (334 ± 131 mm SL) of the prey pollock consumed by Pacific cod was the highest, whereas arrowtooth flounder consumed smaller prey pollock (107 ± 58 mm). The mean length of Atka mackerel consumed by different predators ranged from 226 to 260 mm SL. The size of the flat-head sole varied from 195 mm SL consumed by Pacific cod to 205 ± 49 mm consumed by Pacific halibut. Larvae arrowtooth flounder (35 ± 5 mm SL) were found in walleye pollock diet, whereas larger-sized arrowtooth flounder (200 ± 74 mm SL) were consumed by Pacific halibut. Prey Pacific cod included one 58 mm juvenile consumed by pollock,, 135 ± 12 mm consumed through cannibalism, and one 230 mm adult consumed by the Pacific halibut. The mean size of Pacific sand lance consumed varied from 53 ± 5 mm SL consumed by pollock, to 126 ± 14 mm SL consumed by Pacific halibut, to 160 ± 32 mm SL consumed by Pacific cod. The mean length of myctophid ranged from 48 ± 11 mm (consumed by Pacific halibut) to 101 ± 6 mm (consumed by Greenland turbot). The mean carapace widths of the Tanner crabs consumed by Pacific halibut was 19 ± 5 mm. Korean horse-hair crabs consumed by Pacific halibut had a mean and SD of 28 ± 9 mm. One 35 mm Korean horse-hair crab was also found in shortspine thornyhead stomach.

Table 1. --Number of stomachs and fish size analyzed in the Aleutian Islands in 1991. F, stomachs with food; E, empty stomachs; T, total; SD, standard deviation.

Species	No. of stomachs			Fish size (cm)	
	F	E	T	Range	Mean ± SD
Arrowtooth flounder	194	145	339	17-73	38.3 ± 10.0
Pacific halibut	180	22	202	28-116	61.8 ± 17.7
Atka mackerel	232	7	239	22-44	33.4 ± 4.5
Pacific cod	651	8	659	15-109	56.1 ± 17.0
Pollock	540	6	546	16-68	45.1 ± 10.1
Greenland turbot	25	19	44	58-100	67.7 ± 7.7
Shortspine thornyhead	44	23	67	17-52	33.4 ± 7.8
Rougheye rockfish	11	47	58	24-48	38.7 ± 5.8
Shortraker rockfish	17	16	33	33-67	43.2 ± 7.6
Pacific ocean perch	138	128	266	10-45	30.3 ± 7.4
Northern rockfish	115	38	153	14-45	28.6 ± 5.6
Total	2,147	459	2,606		

Table 2.-- Percent by weight of the important prey or prey group consumed by the groundfish in the Aleutian Islands in 1991. "t" means less than 1% . ATF, arrowtooth flounder; PH, P. halibut; GT, Greenland turbot; COD, P. cod; PLK, pollock; SST, shortspine thornyhead; ROU, rougheye rockfish; SHR, shortraker rockfish; ATK, Atka mackerel; POP, P. ocean perch; NOR, northern rockfish; HER, herring; CAP, capelin; MYC, myctophid; FLA, misc. flatfish; SAN, sand lance; SAB, sablefish; RF, misc. rockfish; STI, stichaeid; COT, cottid; SER, searcher; BAT, bathylagid; VIP, viperfish; CYL, cyclopterid; TAN, Tanner crab; SHP, shrimp; CEP, cephalopod; MSF, misc. fish; EUP, Euphausiid, PAG, hermit crab; OCR, other crabs; MOL, molluscs; POL, polychaete; CAL, calanoid; MSP, misc. prey; TUN, tunicate; CRU, other crustaceans.

						Predator					
Prey	ATF	PH	COD	GT	PLK	SST	ROU	SHR	ATK	POP	NOR
ATK	44	12	27	0	0	0	0	0	0	0	0
PLK	13	19	17	1	0	0	0	0	2	0	0
HER	t	2	1	0	0	0	0	0	0	0	0
CAP	0	5	0	0	t	0	0	0	0	0	0
MYC	7	0	3	28	37	0	4	15	1	34	1
COT	3	1	7	0	t	51	0	19	t	0	0
CYL	t	t	t	0	t	1	45	0	0	0	0
BAT	0	0	t	13	1	0	0	0	0	0	0
FLA	1	3	3	0	t	0	0	0	t	1	0
SAN	t	t	t	0	t	0	0	0	0	0	0
COD	0	1	1	0	t	0	0	0	0	0	0
SAB	3	3	t	0	0	0	0	0	0	0	0
RF	3	2	2	0	0	5	0	0	0	0	0
STI	2	0	t	0	t	0	0	0	t	0	0
SER	3	1	1	0	t	0	0	0	0	0	0
VIP	t	0	t	3	t	0	0	0	0	0	0
MSF	10	3	6	4	2	8	3	4	4	1	0
TAN	0	7	2	0	t	0	0	0	t	0	0
SHP	2	t	10	0	4	23	45	32	t	0	3
CEP	3	27	12	50	2	t	0	3	8	2	1
EUP	5	t	t	0	43	1	2	1	55	51	50
PAG	0	2	1	0	t	0	0	0	t	0	1
OCR	0	5	5	0	t	9	0	7	t	0	0
MOL	0	3	t	0	t	0	0	0	1	0	0
POL	0	t	1	0	t	0	t	3	t	2	7
CAL	t	0	t	0	3	0	0	0	17	7	17
MSP	1	3	1	1	2	1	1	0	5	0	11
TUN	0	0	0	0	2	0	0	0	5	0	3
CRU	t	t	1	0	4	1	t	16	2	2	6

Table 3. --Standard length (mm) of the prey fish and the carapace width (mm) of the prey crabs consumed by groundfish in the Aleutian Islands in 1991. "*" indicates no data. ATF, arrowtooth flounder; ATK, Atka mackerel; BAT, bathylagid; CAP, capelin; COD, Pacificcod; COT, cottid; FHS, flathead sole; GT, Greenland turbot; KAM, Kamchatka flounder; KHC, Korean horse-hair crab; HER, herring; MYC, myctophid; NOR, northern rockfish; PH, Pacific halibut; PLK, walleye pollock; POA, poacher; POP, Pacific ocean perch; RAT, rattail; REX, rex sole; RF, rockfish; ROU, rougheye rockfish; RS, rock sole; SAB, sablefish; SAN, Pacific sand lance; SEA, searcher; SHR, shortraker rockfish; SNA, snailfish; SST, shortspine thornyhead; STI, stichaeid; TAN, Tanner crab; VIP, Pacific viperfish.

Prey	Predator							
	ATF		PH		GT	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
ATF	*	*	85-360	200 ± 74	*	*
ATK	210-330	255 ± 52	171-360	260 ± 56	*	*
BAT	*	*	*	*	102-143	125 ± 17
CAP	*	*	79-121	100 ± 12	*	*
COD	60	*	230	*	*	*
COT	16-145	57 ± 44	16-66	38 ± 17	*	*
FHS	*	*	153-251	205 ± 49	*	*
KHC	*	*	21-40	28 ± 9	*	*
HER	*	*	280	*	*	*
MYC	45-105	83 ± 21	34-68	48 ± 11	92-108	101 ± 6
PH	20	*	*	*	*	*
PLK	60-190	107 ± 58	41-453	212 ± 135	*	*
POA	*	*	19-141	65 ± 41	*	*
RF	*	*	230-290	260 ± 42	*	*
SAB	*	*	210-220	218 ± 5	*	*
SAN	125	*	110-137	126 ± 14	*	*
SEA	160	*	250	*	*	*
SNA	26-40	33 ± 10	41-52	47 ± 8	*	*
STI	50-120	76 ± 35	*	*	*	*
TAN	*	*	5-51	19 ± 5	*	*
VIP	*	*	*	*	140	140

Table 3.- -Continued.

Prey	Predator					
	COD		PLK		SST	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
ATF	*	*	30-42	35 ± 5	*	*
ATK	107-330	226 ± 57	*	*	*	*
BAT	*	*	45-145	89 ± 49	*	*
CAP	*	*	90-110	95 ± 7	*	*
COD	123-146	135 ± 12	58	*	*	*
COT	12-270	62 ± 44	23-41	30 ± 7	27-92	71 ± 24
FHS	195	195	*	*	*	*
KAM	*	*	25	*	*	*
KHC	*	*	*	*	35	*
MYC	28-105	72 ± 22	22-110	72 ± 22	*	*
PH	27	27	*	*	*	*
PLK	65-518	334 ± 131	*	*	*	*
POA	35-115	70 ± 28	*	*	*	*
RAT	200	200	*	*	*	*
REX	260	260	*	*	*	*
RF	125-260	192 ± 61	*	*	54	*
RS	62-260	161 ±140	*	*	*	*
SAB	*	*	*	*	*	*
SAN	123-182	160 ± 32	50-60	53 ± 5	*	*
SEA	82-270	176 + 70	30	*	*	*
SNA	8-109	40 ± 23	12-27	18 ± 6	12-32	22 ± 14
STI	30-150	73 ± 26	26-41	34 ± 11	*	*
TAN	*	*	*	*	*	*
VIP	210	210	100-115	108 ± 11	*	*
ZOA	34-85	66 ± 19	*	*	*	*

Table 3.- -Continued.

Prey	Predator					
	ATK		POP		NOR	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
ATF	*	*	*	*	*	*
ATK	*	*	*	*	*	*
BAT	11	*	*	*	*	*
CAP	*	*	*	*	*	*
COD	*	*	*	*	*	*
COT	12-21	16 ± 3	*	*	*	*
FHS	*	*	*	*	*	*
HER	*	*	*	*	*	*
KAM	*	*	*	*	*	*
KHC	*	*	*	*	*	*
MYC	59	*	24-97	58 ± 28	52	*
PH	*	*	*	*	*	*
PLK	49-63	56 ± 5	*	*	*	*
POA	*	*	*	*	*	*
RAT	*	*	*	*	*	*
REX	*	*	*	*	*	*
RF	*	*	*	*	*	*
RS	*	*	*	*	*	*
SAB	*	*	*	*	*	*
SAN	*	*	*	*	*	*
SEA	*	*	*	*	*	*
SNA	*	*	*	*	*	*
STI	29	*	*	*	*	*
TAN	*	*	*	*	*	*
VIP	*	*	*	*	*	*
ZOA	61	*	*	*	*	*

Table 3. --Continued.

Prey	Predator			
	ROU		SHR	
	Range	Mean ± SD	Range	Mean ± SD
ATF	*	*	*	*
ATK	*	*	*	*
BAT	*	*	*	*
CAP	*	*	*	*
COD	*	*	*	*
COT	*	*	39-92	66 ± 37
FHS	*	*	*	*
HER	*	*	*	*
KAM	*	*	*	*
KHC	*	*	44	*
MYC	*	*	96	*
PH	*	*	*	*
PLK	*	*	*	*
POA	*	*	*	*
RAT	*	*	*	*
REX	*	*	*	*
RF	*	*	*	*
RS	*	*	*	*
SAB	*	*	*	*
SAN	*	*	*	*
SEA	*	*	*	*
SNA	43	*	*	*
STI	*	*	*	*
TAN	*	*	*	*
VIP	*	*	*	*
ZOA	*	*	*	*

	ATF	PH	COD	GT	PLK	SST	ROU	SHR	ATK	POP	NOR
ATF		40	62	16	19	18	12	20	16	16	10
PH			62	32	6	12	4	22	17	4	5
COD				21	13	32	17	34	20	9	9
GT					34	5	8	22	12	31	3
PLK						9	9	28	56	85	59
SST							29	56	7	3	6
ROU								40	5	7	7
SHR									8	23	15
ATK										64	81
POP											63
NOR											

Diet Overlap

<30 %	30-55%	>55 %
Low	Medium	High

Figure 1.- Schoener's index (%) of dietary overlap of groundfish species in the Aleutian Islands area in 1991 ATF, arrowtooth flounder; PH, Pacific halibut; COD, Pacific cod; GT, Greenland turbot; PLK, pollock; SST, shortspine thornyhead; ROU, rougheye rockfish; SHR, shortraker rockfish; ATK, Atka mackerel; POP, Pacific ocean perch; NOR, northern rockfish.

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