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Food Habits of the Commercially Important Groundfishes in the Gulf of Alaska in 1990

by
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ABSTRACT

This report describes the food habits of the main commercially important groundfish species in the Gulf of Alaska during the summer of 1990. Commercially important prey, predator-prey size relationships, and the distribution of the prey--consumed are discussed.

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INTRODUCTION

There is about 5.2 million metric tons (t) of estimated biomass of groundfish resources in the Gulf of Alaska (Stark and Clausen 1993). The predator-prey relationships between these species form a complex food web within the groundfish community (Smith et al. 1978). Because of these complex relationships, there have been many fish food habits studies in the Gulf of Alaska (Jewett 1978, Smith et al. 1978, Hunter 1979, Frost and Lowry 1981, Clausen 1983, Albers and Anderson 1985, Best and St-Pierre 1986, Kendall et al. 1987, Grover and Olla 1990, and Brodeur et al. 1991). However, in some cases, these studies were either restricted to a small study area or focused on a single species. The objective of this study was to describe the food habits of several commercially important groundfish in the Gulf of Alaska. Most of the western and central Gulf of Alaska (North Pacific Fisheries Management Council Regulatory areas) was sampled for 11 predator species (Pacific cod, *Gadus macroceohalus*; walleye pollock, *Therasra chalcogramma*; Pacific halibut, *Hipposlossus stenolepis*; arrowtooth flounder, *Atheresthes stomias*; sablefish, *Anoplopoma fimbria*; Pacific ocean perch, *Sebastes alutus*; northern rockfish, *Sebastes polyspinis*; dusky rockfish, *Sebastes ciliatus*; rougheye rockfish, *Sebastes aleutianus*; shortraker rockfish, *Sebastes borealis*; and shortspine thornyhead, *Sebastolobus alascanus*).

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METHODS

Study Area

In 1990, the Resource Assessment and Conservation Engineering (RACE) Division at the Alaska Fisheries Science Center conducted the third comprehensive triennial survey of groundfish resources in the western and central Gulf of Alaska (North Pacific Fishery Management Council Regulatory areas). This survey covered the area from the Islands of Four Mountains (170° W long.) to Cape St. Elias (144° 30' W long.). The Food Habits Program at the Resource Ecology and Fishery Management (REFM) Division collected fish stomach samples during this survey. The food habits study area (Fig. 1) was smaller than the survey area. It covered the area from 161° 35' W long. to 144° 30' W long. and did not include the westernmost portion (from 170° W long. to 161° W long.) of the 1990 Gulf of Alaska survey area.

Sample Collection

Fish stomach samples were collected by scientists on board the charter boats Pat San Marie and Green Hope from late June to early September in 1990. 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

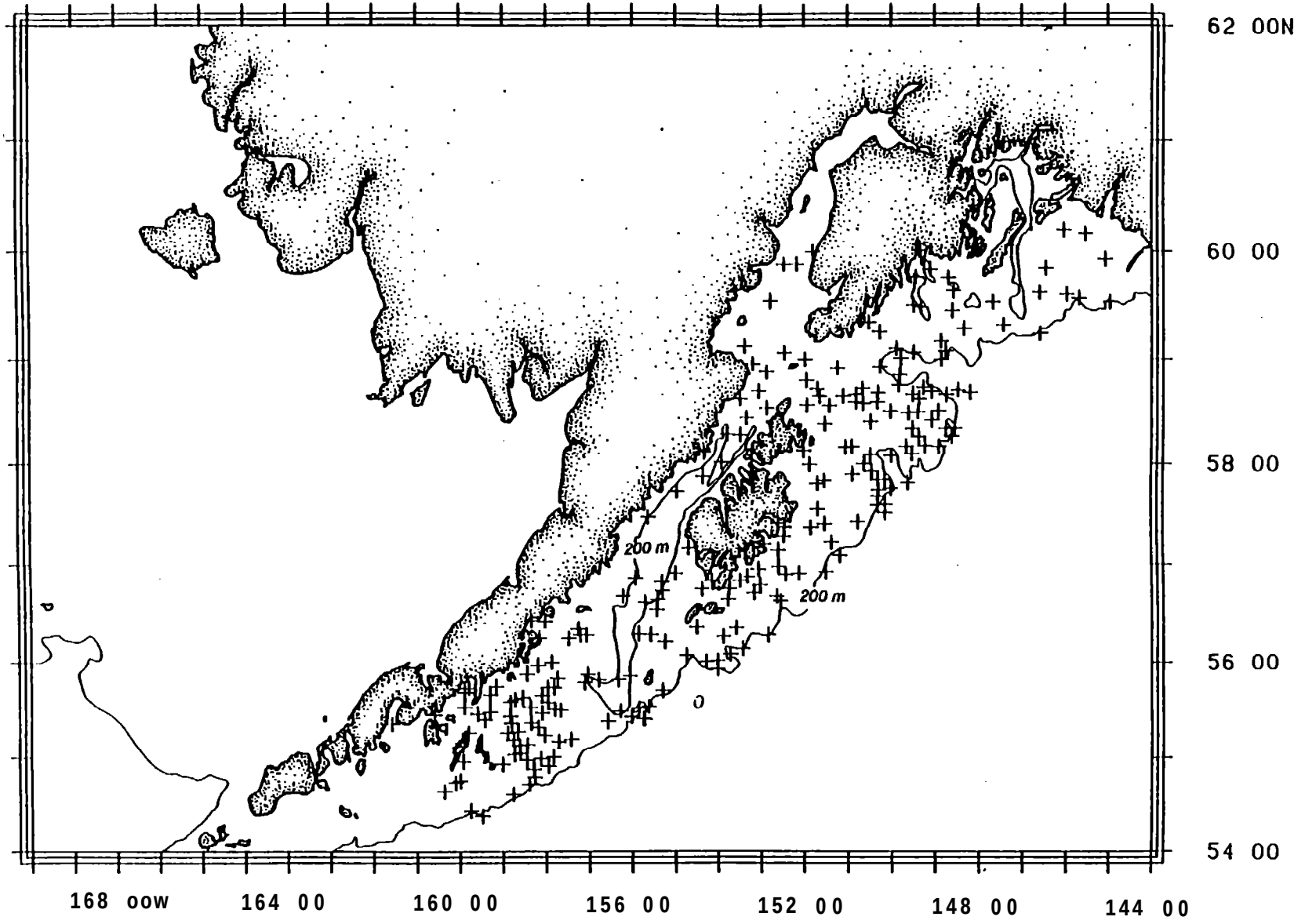

Figure 1. --Sampling locations (+) for the stomachs of groundfish collected' in the Gulf of Alaska in 1990.

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% formalin solution. When the samples arrived at the laboratory, they were transferred into a 70% ethanol alcohol 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 on a petri dish and examined under the microscope. Each prey item was classified to the lowest practical taxonomic level. The prey items of all rockfishes, Pacific halibut, and sablefish were weighed and enumerated. The numbers of non-commercially important prey were not counted for Pacific cod, walleye pollock, and arrowtooth flounder; instead the percent volume of these prey items were 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. Standard lengths of prey fish, carapace widths (CW) of Tanner crabs and snow crabs (*Chionoecetes* spp.) were also recorded.

During this study, discarded fish parts from commercial fish processing operations were also found quite frequently in the stomachs of some marine fishes (e.g., sablefish). Fish were identified as a fishery discard if the parts (usually heads or tails) had a clean cut.

Data Analysis

The general diet of each species was summarized by showing the overall percent frequency of occurrence, percent of numbers (if available), 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 shown in each 10 cm FL group. The prey size frequency data of the commercially important fish and crabs were also summarized by predator size groups.

The geographic distribution of the commercially important prey consumed (expressed as percent by weight of the total stomach contents weight in each haul) by the predators were also shown. The commercially important prey found in this study include walleye pollock, Pacific cod, Pacific halibut, yellowfin sole (*Pleuronectes asper*), rock sole (*Pleuronectes bilineatus*), flathead sole (*Hippoglossoides elassodon*), rex sole (*Errex zachirus*), Dover sole (*Microstomus pacificus*), arrowtooth flounder, Greenland turbot (*Reinhardtius hippoglossoides*), Pacific herring (*Clupea pallasi*), coho salmon (*Oncorhynchus kisutch*), all rockfish species, Tanner crabs, and pandalid shrimp. Although capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), and eulachon (*Thaleichthys pacificus*)

were not commercially important fish in the Gulf of Alaska area, they were food of many commercially important fish and were economically important in some other areas (e.g., Japan); therefore, data on these prey fish were also analyzed in this report.

WALLEYE POLLOCK

Walleye pollock (Theraura chalcouramma) ranked second (next to arrowtooth flounder) in biomass in the groundfish complex in the Gulf of Alaska in 1990. The exploitable biomass in 1990 estimated from the stock synthesis (SS) model was 1,050,000 metric tons (t) (North Pacific Fishery Management Council 1991). Walleye pollock feed mainly on euphausiids, majids (in the megalops stage), and shrimp. With increasing size, pollock also eat juvenile pollock and other teleosts (Smith et al. 1978, Clausen 1983). Therefore, it is important to understand the food habits of the pollock and their possible impact on other commercially important fishes.

RESULTS

General Diet

A total of 1,059 walleye pollock stomachs were analyzed, of which 985 (93%) contained food. Pollock size ranged from 8 to 70 cm FL with a mean and standard deviation (hereafter, the standard deviation will be denoted as SD) of 45.4 + 13.0 cm. The average depth of the 76 haul locations where pollock stomachs were collected was 173 + 61 m with a range from 46 to 337 m. Table l-l lists all of the food items found in the pollock stomachs, the percentage of the frequency of occurrence of the prey, and the percentage of the prey weight to the total food weight. The data presented in Table l-1 suggests that walleye pollock feed mainly on euphausiids and shrimp (39% and 33% by weight, respectively). Though copepods, mysids, and amphipods

Table l-l.--Prey items (expressed in percent frequency of occurrence and percent total weight) of Theragra chalcogramma (walleye pollock) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	3.40	0.57
Pteropoda (snail)	1.20	0.01
Bivalvia (clam)	0.30	0.02
Cephalopoda (unidentified)	1.70	0.08
Teuthoidea (squid unidentified)	2.30	0.36
Gonatidae (squid)	0.10	1.87
Berryteuthis masister (squid)	0.10	0.33
Octopoda (octopus unidentified)	0.30	0.19
Calanoida (copepod unidentified)	33.30	0.80
Neocalanus cristatus (copepod)	0.80	<0.01
Eucalanus bunaii (copepod)	0.20	<0.01
Pseudocalanus sp. (copepod)	0.10	<0.01
Mysidacea (mysid unidentified)	15.50	0.81
Acanthomysis macronsis (mysid)	0.10	<0.01
Acanthomysis pseudomacronsis (mysid)	0.30	0.01
Holmesiella anomala (mysid)	0.60	0.05
Meterythrops robusta (mysid)	3.40	0.10
Neomysis czerniawskii (mysid)	0.50	<0.01
Neomysis rayii	0.40	0.09
Pseudomma truncatum (mysid)	0.60	0.03
Cumacea (cumacean unidentified)	1.60	0.08
Leucon sp. (cumacean)	1.90	0.03
Isopoda (isopod)	0.30	0.06
Gammaridea (unidentified)	16.00	0.80
Ampeliscidae (amphipod)	0.90	0.05
Themisto sp. (amphipod)	42.20	1.73
Euphausiacea (unidentified)	79.30	38.49
Thysanoessa inermis (euphausiid)	0.40	0.27
Thysanoessa rachii (euphausiid)	0.10	0.01
Thysanoessa sninifera (euphausiid)	0.30	0.01
Caridea (unidentified)	27.20	9.55
Pasinhaea pacifica (shrimp)	1.30	2.34
Hippolytidae (unidentified)	0.70	0.10
Spirontocaris arcuata (shrimp)	0.20	0.04
Eualus barbata (shrimp)	0.10	0.03
Eualus avinus (shrimp)	0.40	0.10
Pandalidae (unidentified)	18.10	13.52
Pandalus borealis (northern shrimp)	2.70	3.92
Pandalus goniurus (shrimp)	0.10	0.03
Pandalus iordani (shrimp)	0.60	0.67
Pandaloosis sp. (shrimp)	1.00	0.49
Crangonidae (unidentified)	6.40	1.98

Table l-l. --Continued.

Prey Name	% Freq. occur.	% Total weight
Crangon communis (shrimp)	0.80	0.14
Paguridae (hermit crab)	13.40	0.72
Chaetognatha (arrow worm)	1.80	0.01
Larvacean (tunicate)	1.30	0.01
Teleostei (unidentified fish)	6.80	0.88
Non-gadoid fish remains	3.00	0.46
Cluoea harengus pallasi (Pacific herring)	0.10	0.20
Mallotus villosus (capelin)	3.20	12.90
Thaleichthys pacificus (eulachon)	0.50	0.04
Bathylagidae (deepsea smelts)	0.10	<0.01
Chauliodontidae (viperfishes)	0.10	0.01
Stenobrachius leucoosarus (northern lampfish)	0.50	0.01
Gadidae (unidentified gadid)	0.50	0.07
Gadus macrocephalus (Pacific cod)	0.30	0.01
Theragra chalcogramma (walleye, pollock)	4.30	2.05
Zoarcidae (unidentified eelpout)	0.60	0.20
Scorpaenidae (unidentified)	0.20	0.03
Cottidae (sculpin)	0.60	0.06
Cyclopteridae (snailfish)	1.90	0.53
Stichaeidae (prickleback)	0.60	0.12
Lumoenus fabricii (slender eelblenny)	0.10	0.07
Lumoenus maculatus (daubed shanny)	0.50	0.28
Poroclinus rothrocki (whitebarred prickleback)	0.10	0.03
Lyconectes aleutensis (dwarf wrymouth)	0.10	0.16
Ammodvtes hexaoterus (Pacific sand lance)	0.50	0.20
Pleuronectidae (unidentified flatfish)	0.40	0.02
Atheresthes stomias (arrowtooth flounder)	0.60	0.04
Hipposlossoides elassodon (flathead sole)	0.40	0.23
Microstomus pacificus (Dover sole)	0.10	0.54
Reinhardtius hipposlossoides (Greenland halibut)	0.10	<0.01
Misc. unidentified materials	0.30	0.07

Total prey weight	2,746 g
Number of stomachs with food	985
Number of empty stomachs	74

were frequently found in pollock stomachs, they were relatively less important as pollock food. Table l-l also demonstrates the high diversity of prey fish found in pollock stomachs. Among which, the commercially important fish, such as Pacific herring (Clunea oallasi), Pacific cod (Gadus macrocephalus), walleye pollock, arrowtooth flounder (Atheresthes stomias), flathead sole (Hippoglossoides elassodon), Dover sole (Microstomus pacificus), and Greenland halibut (Reinhardtius hippoglossoides) were found. Other important prey fish like capelin (Mallotus villosus), eulachon (Thaleichthys pacificus), and Pacific sand lance (Ammodytes hexapterus) were also found. Overall, capelin (12.9% by weight of the total stomach contents) was the most important prey fish of walleye pollock in the Gulf of Alaska.

Variation of Diet Based on Predator Size

Figure l-l illustrates the main prey items of walleye pollock by predator FL. Calanoids and amphipods were mainly consumed by smaller-sized (<40 cm) pollock. Euphausiids comprised the largest portion of pollock food through all size groups. Shrimp comprised the second largest portion of pollock food in all but the smallest (<20 cm) size group. Capelin was important food for pollock larger than 40 cm. It comprised 25% of the food for the size group greater than or equal to 60 cm. For all size groups, walleye pollock only consumed very small amounts (<5%) of prey pollock.

Sizes of the Commercially Important Prey Consumed

Prey size data of walleye pollock were divided into three

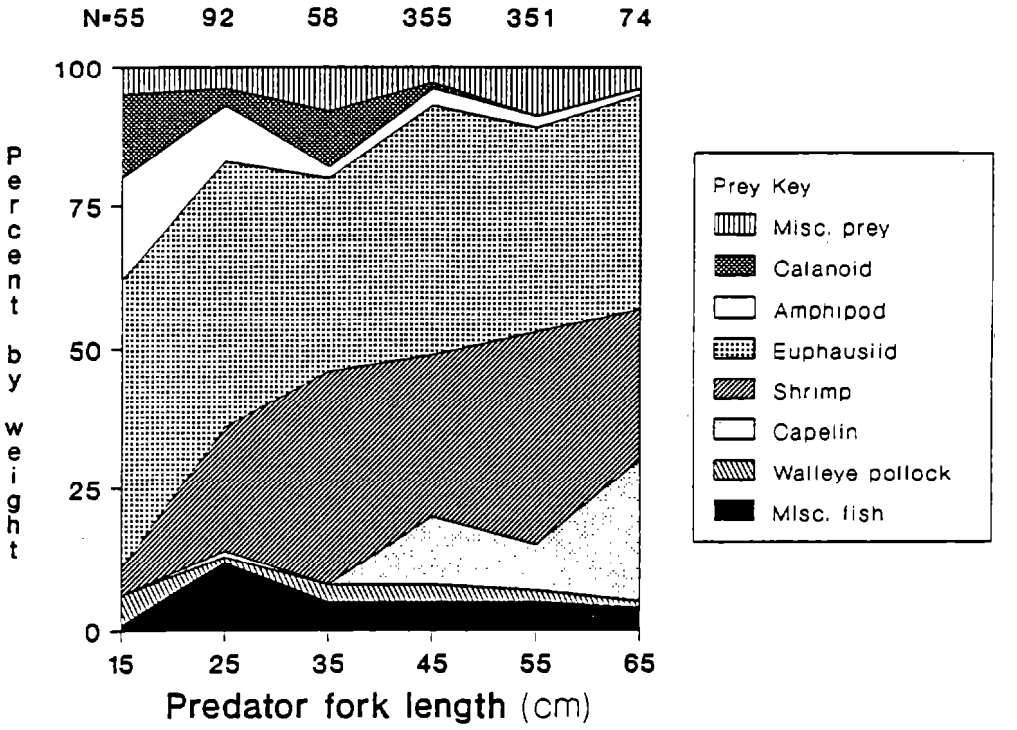

Figure l-l. --Variations in the main food items of walleye pollock, by predator size, in the Gulf of Alaska in 1990. N = sample size.

predator size groups (<40 cm, 40-49 cm, and 150 cm) for analysis. The size frequencies of the walleye pollock, capelin, and Pacific sand lance consumed by walleye pollock are shown in Figures l-2 and l-3. Figure l-2 shows that the two larger size groups of walleye pollock consumed only age-0 walleye pollock (approximately less than 140 mm SL). These age-0 pollock sizes had a mean and SD of 43.7 + 24.6 mm SL and ranged from 14 to 110 mm SL. No measurable juvenile walleye pollock were found in pollock less than 40 cm FL. Figure l-4 shows the size relationship between walleye pollock as predator and as prey. Capelin were primarily consumed by the two larger size groups (40-49 cm and >50 cm) of pollock (Fig. l-3). They had a mean SL of 95.2 + 23.7 mm and a range from 43 to 140 mm SL. Pacific sand lance were only consumed by pollock greater than or equal to 40 cm (Fig. l-3), and they had a mean SL of 40.8 + 21.7 mm and a range from 28 to 118 mm SL. Walleye pollock also consumed Pacific cod, arrowtooth flounder, Greenland halibut (Reinhardtius hippoglossoides), flathead sole (Hippoqlossoides elassodon), Dover sole (Microstomus pacificus), snailfish (Cyclopteridae), and daubed shanny (Lumpenus maculatus). The number, mean SL, and the SD of these prey fish are listed in Table l-2.

Geographic Distributions of the Prey Consumed

Figures l-5 to l-7 show the percentage by weight of prey pollock, capelin, and pandalid shrimp consumed by walleye pollock in different locations. Figure l-5 shows that small amounts of pollock were consumed northeast of Kodiak Island. Large amounts of capelin were primarily consumed northeast of Kodiak Island

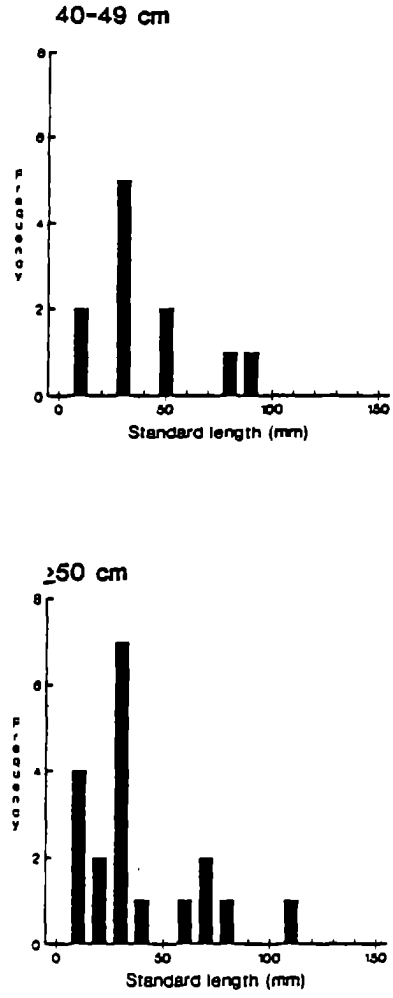

Figure l-2. --Size frequency distributions of prey walleye pollock consumed by two size groups of walleye pollock in the Gulf of Alaska in 1990.

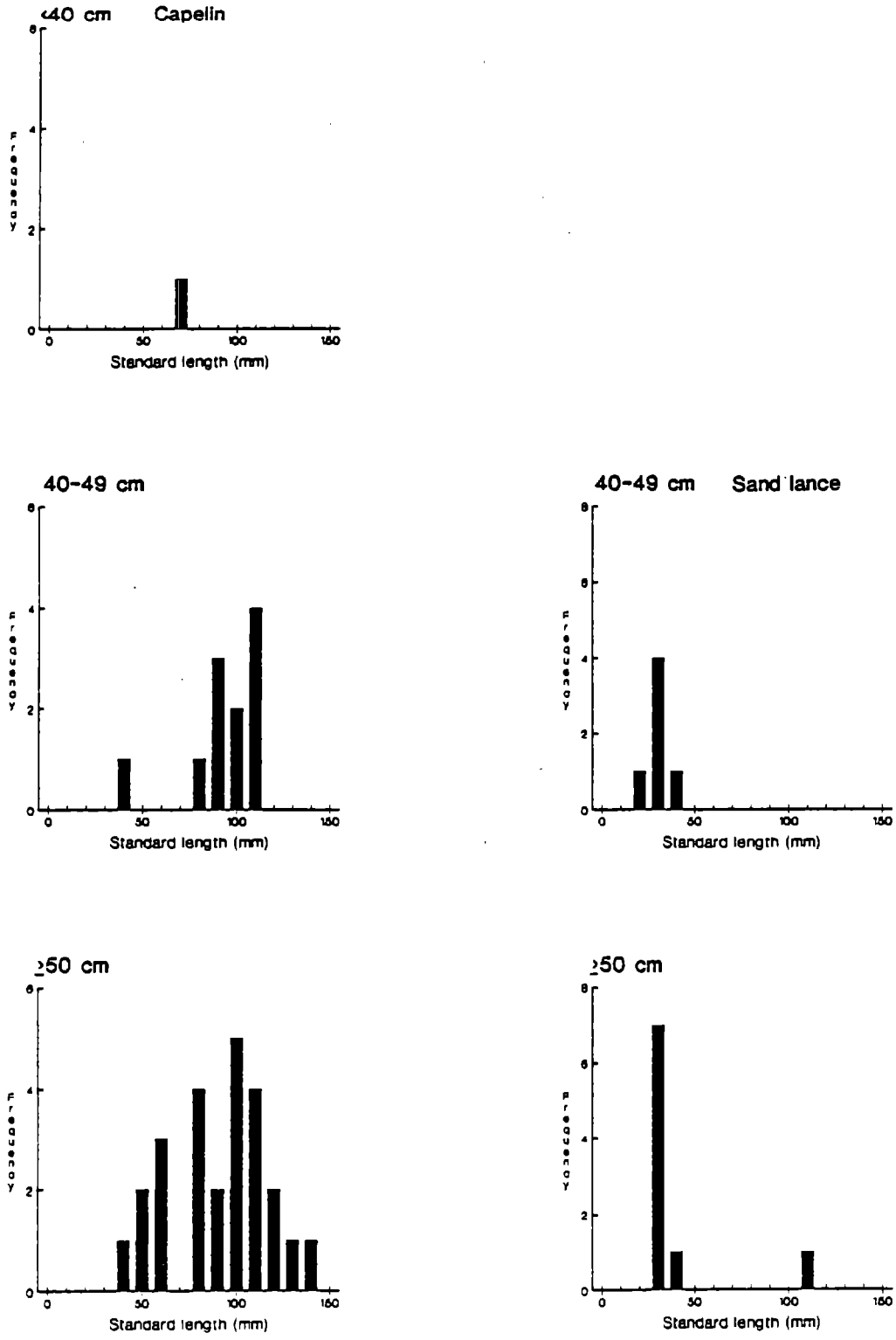

Figure 1-3 .--Size frequency distributions of capelin and Pacific sand lance consumed by different size groups of walleye pollock in the Gulf of Alaska in 1990.

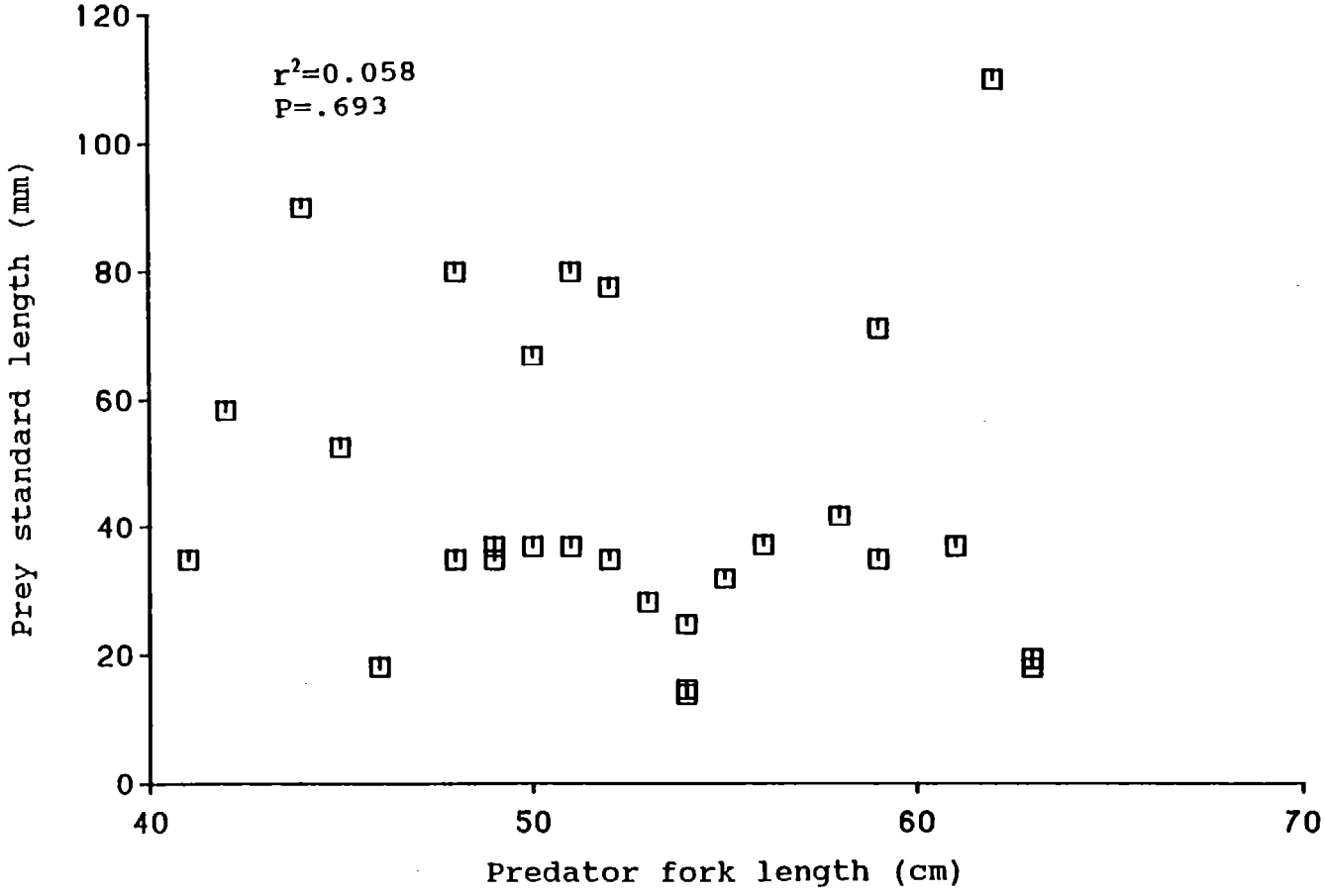

Figure l-4. --Relationship between the predator walleye pollock fork length (cm) and the prey walleye pollock standard length (mm) in the Gulf of Alaska in 1990.

Table l-2.--Mean standard length and standard deviation of the miscellaneous prey fish consumed by walleye pollock in the Gulf of Alaska in 1990.

Prey name	No. measured	Mean (mm)	SD (mm)
Pacific cod	3	16.4	2.5
Arrowtooth flounder	5	26.5	9.3
Greenland halibut	1	23.0	0.0
Flathead sole	4	50.5	19.8
Dover sole	1	114.8	0.0
Snailfish	78	20.3	5.3
Daubed shanny	12	62.1	17.5

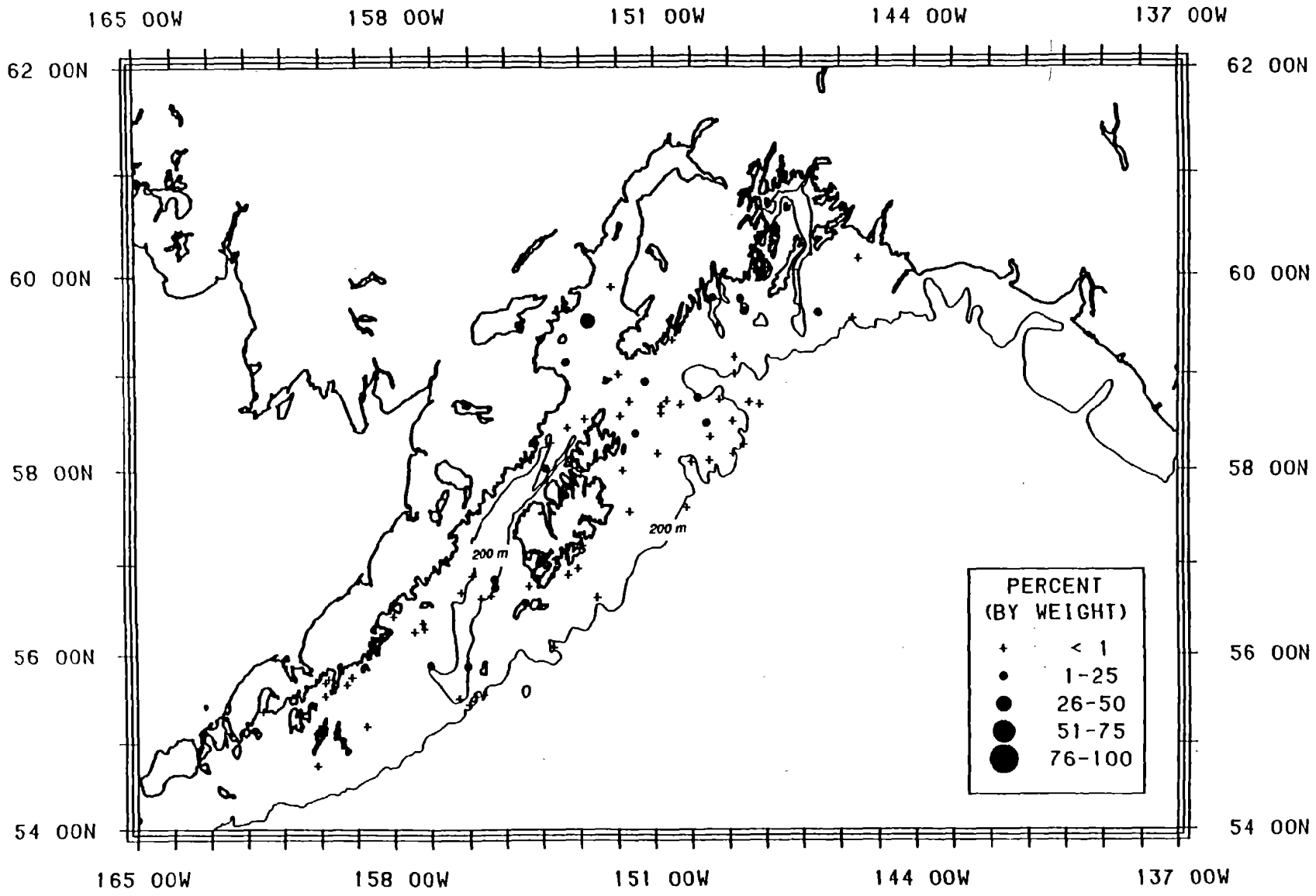

Figure 1-5.--Geographic distribution of prey walleye pollock consumed by walleye pollock in the Gulf of Alaska in 1990.

(Fig. 1-6). Pandalid shrimp were consumed both northeast and west of Kodiak Island (Fig. l-7).

DISCUSSION

In my analysis, I compared the diets of walleye pollock from the Gulf of Alaska to those reported by Livingston (1991) for pollock from the eastern Bering Sea. Table l-3 lists the percentage by weight of the major prey categories for pollock from the two study areas. This data shows that prey pollock, (comprised 41% by weight) was the main food of pollock in the Bering Sea area, whereas pollock comprised only 2% of the total food in the Gulf of Alaska area. On the other hand, capelin were consumed by pollock in the Gulf of Alaska area (about 13% by weight), whereas no capelin were found in pollock stomachs in the eastern Bering Sea area. Another difference is that pollock consumed more miscellaneous fish species (n=22) in the Gulf of Alaska area than in the eastern Bering Sea (n=7). As for the crustacean consumed, euphausiids comprised a high percentage of the stomach contents in both the eastern Bering Sea (25%) and in the Gulf of Alaska (39%). However, pollock consumed more pandalids in the Gulf of Alaska area (19%) than in the eastern Bering Sea (4%).

Smith et al. (1978) did a food habits study of benthic and demersal fishes in the northern Gulf of Alaska and Clausen (1983) did a pollock food habits study in Southeast Alaska. Their studies also showed that large amounts of euphausiids (87% in Smith's study and 17% in Clausen's study) and shrimp (14% in

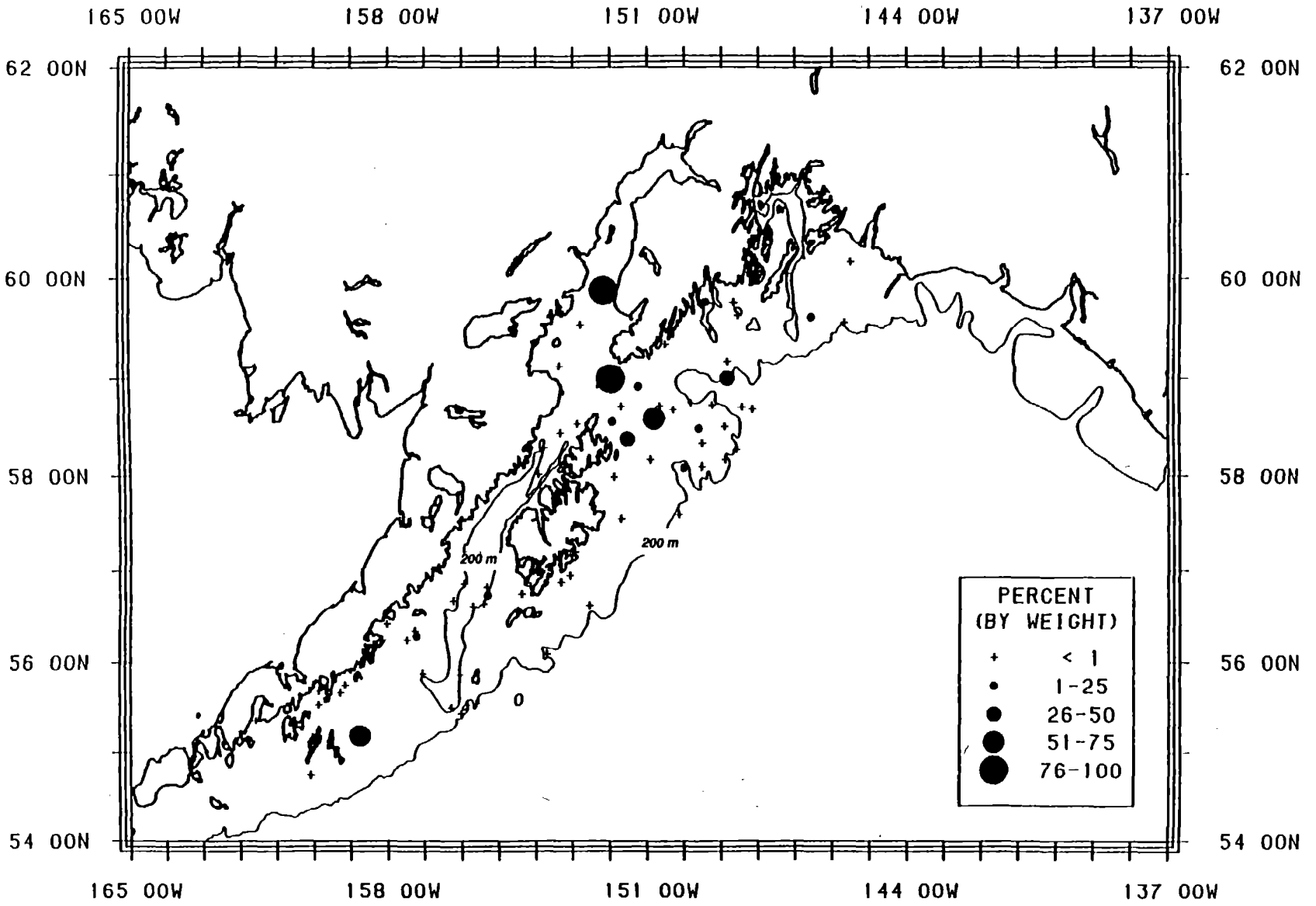

Figure 1-6.--Geographic distribution of capelin consumed by walleye pollock in the Gulf of Alaska in 1990.

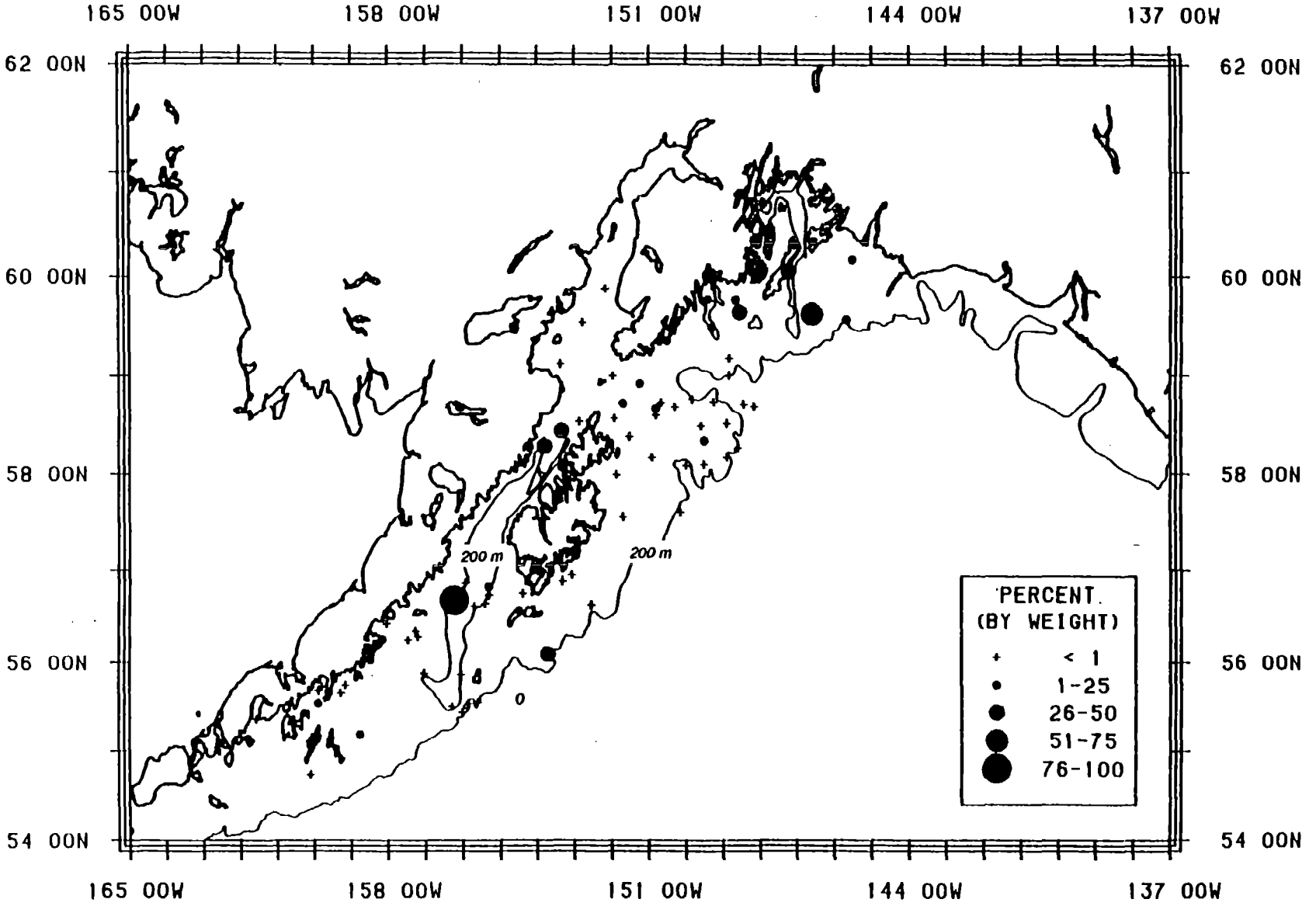

Figure l-7. --Geographic distribution of Pandalid shrimp consumed by walleye pollock in the Gulf of Alaska in 1990.

Table l-3. --Percent by weight of the major prey categories of walleye pollock in the eastern Bering Sea and in the Gulf of Alaska. EBS, eastern Bering Sea (from Livingston 1991); GOA, Gulf of Alaska (from this study).

Prey name	EBS	GOA
Copepoda	6.3	0.8
Mysid	1.4	1.1
Amphipod	1.0	2.6
Euphausiid	24.6	38.8
Pandalid	3.8	18.6
Crangonid	0.9	2.1
Pasiphaeid	0.0	2.3
Chionoecetes sp.	0.1	0.0
Capelin	0.0	12.9
Pollock	41.0	2.1
Miscellaneous fish	5.6	15.0
Unidentified fish	7.7	0.9

Clausen's study) were consumed by pollock. However, in these studies, 'the authors either reported a large amount of unidentified digested materials (26% in Clausen's study) or the prey fish consumed (less than 10% in both studies) by pollock were only listed as being teleost.

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PACIFIC COD

Pacific cod (Gadus macrocephalus), with an exploitable biomass of 387,658 t (Zenger and Thompson 1991), ranks fourth in abundance in the Gulf of Alaska groundfish community. The landings of Pacific cod have been increasing in recent years (up to about 66,000 t in 1990). Pacific cod feed both in the water column and in benthic areas; hence, they have a high variety of prey in their diets, including several commercially important fish and crabs.

RESULTS

General Diets

A total of 916 Pacific cod stomachs were analyzed, of which 892 (97%) contained food. Pacific cod length ranged from 7 to 90 cm FL with a mean and SD of 54.7 cm and + 12.1 cm, respectively. The average depth of the 78 haul locations was 127 + 39 m with a range from 20 to 205 m. The long list of prey items presented in Table 2-l shows that Pacific cod is an opportunistic feeder. They ate many different invertebrates and various fish (54% and 33% of the total stomach content weight, respectively). The remaining 13% of the Pacific cod diet was made up of fishery discards (processed fish carcasses). Polychaetes were the most frequently found invertebrate in the stomachs but they were not very important food of Pacific cod in terms of the percentage of the total stomach content weight. Octopus and pandalid shrimp were relatively more important. Pacific cod also consumed decorator crabs (Oregonia spp.), and

Table 2-1. --Prey items (expressed in percent frequency of occurrence, and percent total weight) of *Gadus macrocephalus* (Pacific cod) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	48.20	2.62
Aphroditidae (polychaete)	7.00	1.99
Gastropoda (unidentified)	9.00	0.23
Buccinum sp. (snail)	1.20	0.10
Neptunea sp. (snail)	0.50	0.05
Pteropoda (snail)	0.10	<0.01
Bivalvia (clam)	7.90	0.21
Cephalopoda (unidentified)	5.80	0.05
Teuthoidea (squid unidentified)	2.00	0.59
Gonatidae (squid)	0.10	1.87
Octopoda (unidentified)	16.50	7.41
Calanoida (copepod unidentified)	2.40	0.01
Cirripedia (barnacle)	0.70	0.01
Mysidacea (mysid unidentified)	7.40	0.04
Holmesiella anomala (mysid)	0.10	<0.01
Meterythrops robusta (mysid)	0.10	<0.01
Neomysis rayii	0.10	<0.01
Pseudomma sp. (mysid)	0.30	<0.01
Cumacea (cumacean unidentified)	1.10	0.20
Leucon sp. (cumacean)	0.40	<0.01
Isopoda (isopod)	6.00	0.12
Gammaridea (unidentified)	37.10	0.40
Ampeliscidae (amphipod)	6.20	0.08
Themisto sp. (amphipod)	2.40	<0.01
Caprellidea (amphipod)	0.30	<0.01
Euphausiacea (unidentified)	23.20	0.65
Thysanoessa spinifera (euphausiid)	0.10	<0.01
Reptantia (crab)	4.60	0.14
Caridea (unidentified)	28.30	2.47
Pasiphaea pacifica (shrimp)	0.20	<0.01
Hippolytidae (unidentified)	16.50	0.35
Spirontocaris sp. (shrimp)	2.40	0.06
Spirontocaris lamellicornis (shrimp)	0.10	<0.01
Spirontocaris ochotensis (shrimp)	0.80	0.01
Spirontocaris arcuata (shrimp)	0.60	0.02
Lebbeus sp. (shrimp)	0.20	<0.01
Lebbeus froenlandicus (shrimp)	0.20	0.04
Eualus sp. (shrimp)	2.20	0.07
Eulaus barbata (shrimp)	0.40	0.02
Eualus biunguis (shrimp)	0.10	<0.01
Eualus townsendi (shrimp)	0.10	<0.01

Table 2-1. --Continued.

Prey Name	% Freq. occur.	% Total weight
Eualus stoneyi (shrimp)	0.10	<0.01
Eualus avinus (shrimp)	3.00	0.04
Heptacarpus sp.	0.10	0.01
Pandalidae (unidentified)	38.00	6.34
Pandalus borealis (northern shrimp)	6.10	1.63
Pandalus goniurus (shrimp)	1.20	0.37
Pandalus jordani (shrimp)	0.10	<0.01
Pandalus montasui tridens (shrimp)	1.30	0.31
Pandaloosis sp. (shrimp)	3.30	0.22
Pandaloosis dispar (shrimp)	0.10	0.19
Crangonidae (unidentified)	39.50	2.56
Cranson alaskensis (shrimp)	0.10	0.03
Cranson stylirostris (shrimp)	0.10	0.01
Crangon dalli (shrimp)	0.30	<0.01
Crangon communis (shrimp)	16.70	1.68
Rhynocranson alata (shrimp)	0.40	0.01
Arsis sp. (shrimp)	5.30	0.29
Arais lar (shrimp)	0.70	0.13
Argis dentata (shrimp)	0.20	0.02
Argis ovifer (shrimp)	0.20	0.02
Argis alaskensis (shrimp)	0.10	<0.01
Metacrangon munita (shrimp)	0.40	0.02
Anomura (unidentified)	0.60	0.03
Paguridae (hermit crab)	20.40	3.72
Pacrurus aleuticus (hermit crab)	0.20	0.03
Pasurus rathbuni (hermit crab)	0.30	0.03
Elassorhirus sp. (hermit crab)	0.10	0.01
Elassachirus tenuimanus (hermit crab)	0.30	0.02
Acantholithodes hisnidus (fussy crab)	0.10	0.22
Lopholithodes foraminatus (box crab)	0.40	1.68
Munida auadrispina (pinch bug)	1.90	0.16
Majidae (unidentified)	2.80	0.23
Oresonia sp. (decorator crab)	0.40	0.01
Oregonia sracilis (decorator crab)	1.60	0.16
Oresonia bifurca (decorator crab)	0.10	<0.01
Hyas sp. (lyre crab)	3.60	1.07
Hyas lyratus (lyre crab)	3.10	0.94
Hyas coarctatus (lyre crab)	0.20	0.01
Chionoecetes sp. (unidentified)	6.20	0.84
Chionoecetes opilio (snow crab)	0.30	0.05
Chionoecetes bairdi (Tanner crab)	34.60	10.77
Erimacrus isenbeckii (crab)	0.10	0.01
Cancer sp. (crab)	0.30	0.01
Cancer oresonensis (pygmy cancer crab)	2.10	0.10
Pinnotheridae (pea crab)	5.40	0.33

Table 2-l. --Continued.

Prey Name	% Freq. occur.	% Total weight
Pinnixa sp. (pea crab)	5.30	0.27
Sipuncula (peanut worm)	0.70	0.08
Echiura (marine worm)	5.00	0.65
Asteroidea (starfish)	0.80	0.04
Ophiurida (brittle star)	0.90	0.02
Teleostei (unidentified fish)	18.00	6.81
Non-gadoid fish remains	9.90	0.55
Cluoea pallasi (Pacific herring)	0.30	0.37
Mallotus villosus (capelin)	5.00	1.91
Thaleichthvs oacificus (eulachon)	0.20	0.26
Gadidae (unidentified gadid)	1.80	0.15
Therasra chalcosramma (walleye pollock)	5.00	7.43
Zoarcidae (unidentified eelpout)	1.60	1.34
Lvcodes brevioes (shortfin eelpout)	1.20	0.51
Cottidae (sculpin)	9.40	0.97
Hemilenidotus sp. (sculpin)	0.10	0.55
Dasvcottus setiser (sculpin)	0.20	0.86
Icelinus borealis (sculpin)	0.10	<0.0l
Agonidae (poacher)	2.60	0.07
Asterotheca alascana (poacher)	0.10	<0.01
Asterotheca oentacanthus (poacher)	0.10	0.02
Sarritor frenatus (poacher)	0.80	0.06
Cyclopteridae (unidentified snailfish)	0.60	<0.01
Eumicrotremus orbis (snailfish)	0.10	0.02
Bathymaster signatus (searcher)	0.80	0.73
Stichaeidae (unidentified)	8.40	0.74
Lumpenus fabricii (slender eelblenny)	0.10	0.01
Lumpenus maculatus (daubed shanny)	1.00	0.09
Poroclinus rothrocki (whitebarred prickleback)	0.60	0.29
Lyconectes aleutensis (dwarf wrymouth)	1.70	0.34
Ammodvtes hexapterus (Pacific sand lance)	1.20	0.34
Pleuronectidae (unidentified flatfish) 1	4.80	1.25
Atheresthes stomias (arrowtooth flounder)	2.00	5.80
Errex zachirus (rex sole)	0.10	0.06
Hipooqlossoides elassodon (flathead sole)	2.70	1.74
Pleuronectes bilineatus (rock sole)	0.30	0.33
Hippoalossus stenolepis (Pacific halibut)	0.20	0.01
Fishery discards	2.90	12.51
Misc. unidentified materials	0.90	0.03

Total prey weight	20,872 g
Number of stomachs with food	892
Number of empty stomachs	24

lyre crabs (Hyas spp.). However, Tanner crab (Chionoecetes bairdi) comprised the highest proportion (11% of the total stomach content weight) of the invertebrates consumed. Hermit crabs, euphausiids, amphipods, and marine worms were also invertebrates consumed by Pacific cod. Of the fish consumed by Pacific cod, walleye pollock (Theragra chalcogramma) comprised the highest proportion (7%) of the total stomach contents weight. Other commercially important prey fish include arrowtooth flounder (Atheresthes stomias),. capelin (Mallotus villosus), flathead sole (Hippoglossoides elassodon), rock sole (Pleuronectes bilineatus), Pacific halibut (Hippoglossus stenolepis), Pacific herring (Clupea Dallasi), eulachon (Thaleichthys pacificus), Pacific cod, Pacific sand lance (Ammodytes hexapterus), and rex sole (Errex zachirus). Pacific cod also consumed many non-commercially important prey fish, such as zoarcids, cottids, agonids, cyclopterids, bathymasterids, and stichaeids.

Variation of Diet Based on Predator Size

Figure 2-l shows that Pacific cod ate more prey fish with increasing cod size (FL), especially for cod greater than or equal to 70 cm FL. The fish consumed (including fish and fishery discards) comprised about 75% of the total stomach contents in this size group. Only this group of larger Pacific cod (270 cm FL) consumed a significant amount (17%) of walleye pollock. All other smaller size groups consumed very small amounts of pollock (<5%). All but the largest size groups consumed a fair amount of shrimp (>15%). Tanner crabs were consumed by Pacific cod between

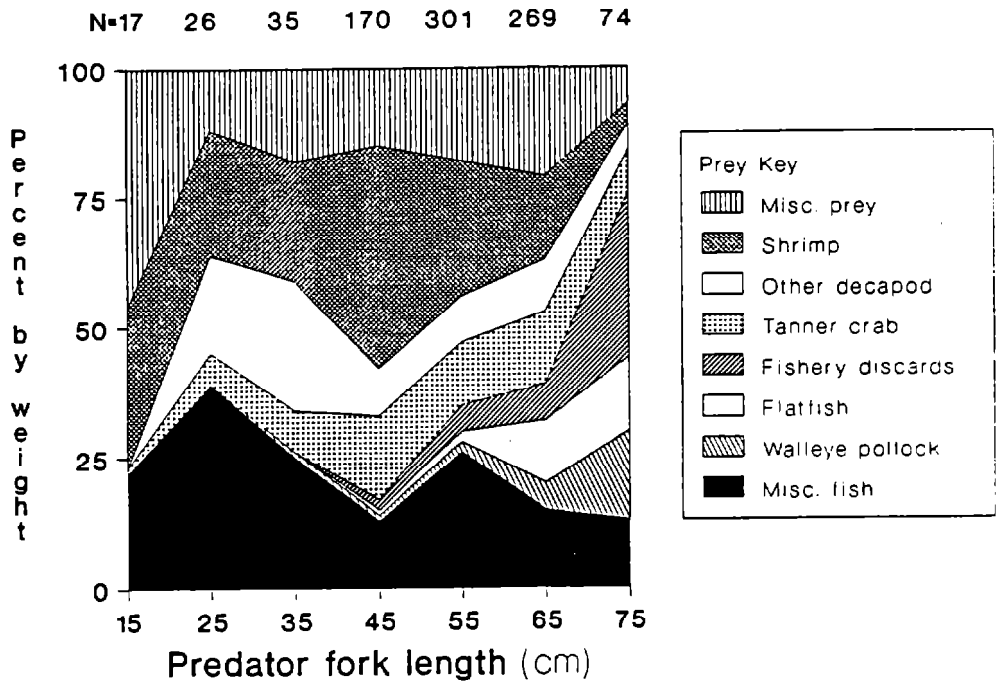

Figure 2-1. --Variations in the main food items of Pacific cod, by predator size, in the Gulf of Alaska in 1990. N = sample size.

40 and 70 cm FL. The smallest size group (<20 cm FL) of cod ate a large amount (45%) of miscellaneous prey (mainly amphipods and mysids).

Sizes of the Commercially Important Prey Consumed

The commercially important prey consumed by Pacific cod were analyzed by three predator size groups (<30 cm, 30-59 cm, and >60 cm FL). Because of insufficient 'measurable' prey data in the size group less than 30 cm, this group was not included in the analysis. Examination of Figure 2-2 suggests that the walleye pollock consumed by 30-59 cm Pacific cod were mainly age-0 fish plus some age-l fish, whereas Pacific cod greater than or equal to 60 cm consumed age-O, 1, 2, and 3+ walleye pollock. The body size relationship between Pacific cod and the pollock they consumed is shown in Figure 2-3. The mean SL of pollock consumed by Pacific cod was 161.5 + 133.0 mm with a range from 33 to 468 mm. Figure 2-2 also shows that Pacific sand lance were primarily consumed by Pacific cod 30-59 cm long. The mean SL of all Pacific sand lance consumed by Pacific cod was 94.4 +. 32.7 mm with a range from 46 to 165 mm. The mean SL of the capelin consumed was 78.9 + 14.0 mm with a range from 57 to 125 mm. Figure 2-4 shows that capelin were mainly consumed by Pacific cod 30-59 cm long. The length distributions of flathead sole and arrowtooth flounder consumed by Pacific cod are shown in Figure 2-5. Larger predators fed on larger prey. The mean SL of flathead sole consumed by Pacific cod was 80.5 + 46.2 mm, with a range from 17 to 220 mm, The mean SL of arrowtooth flounder consumed was 153.2 + 135.3 mm with a range between 33 to 390 mm.

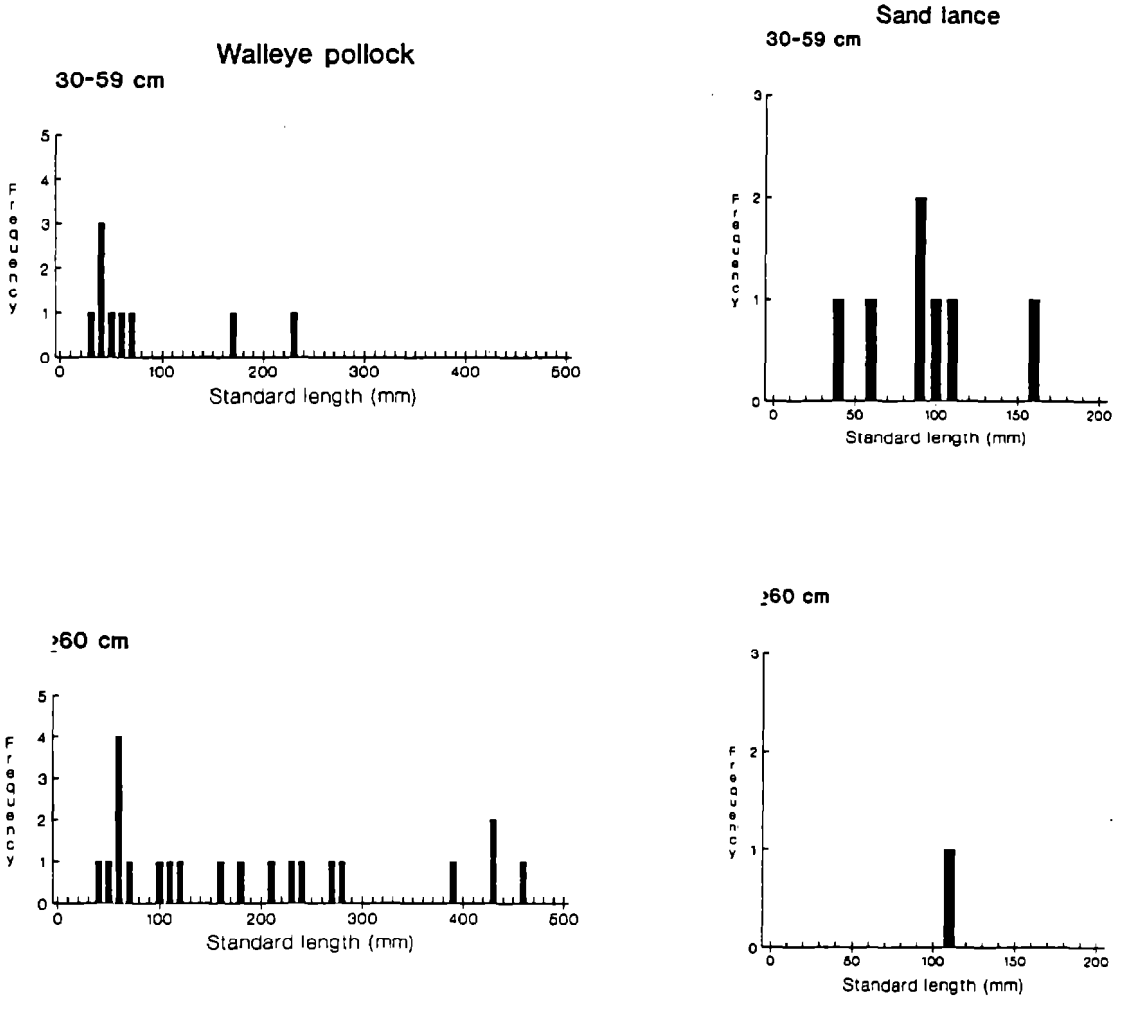

Figure 2-2.--Size frequency distributions of walleye pollock and Pacific sand lance consumed by two size groups of Pacific cod in the Gulf of Alaska in 1990.

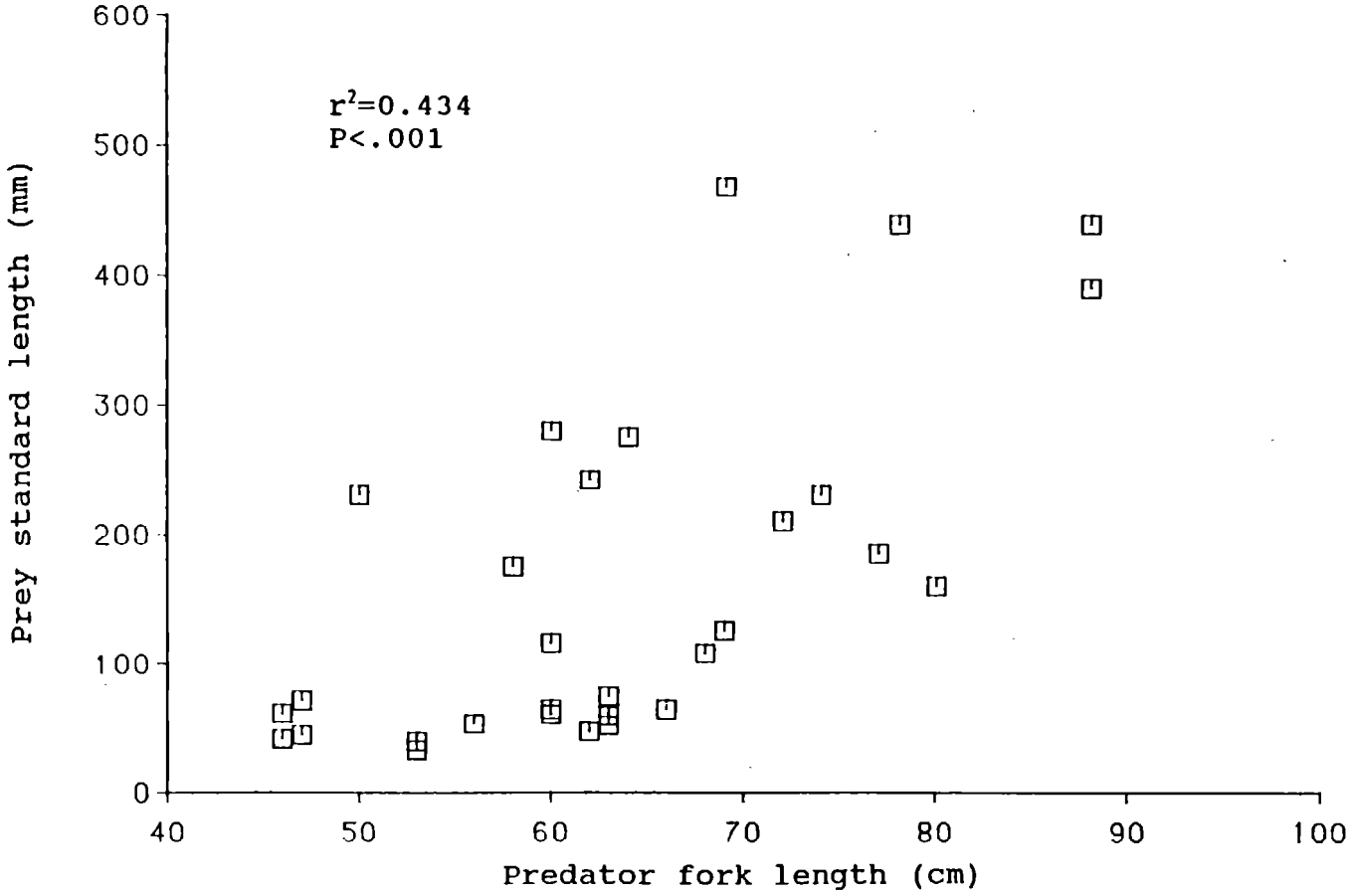

Figure 2-3. --Scatterplot of walleye pollock prey size versus Pacific cod in the Gulf of Alaska in 1990.

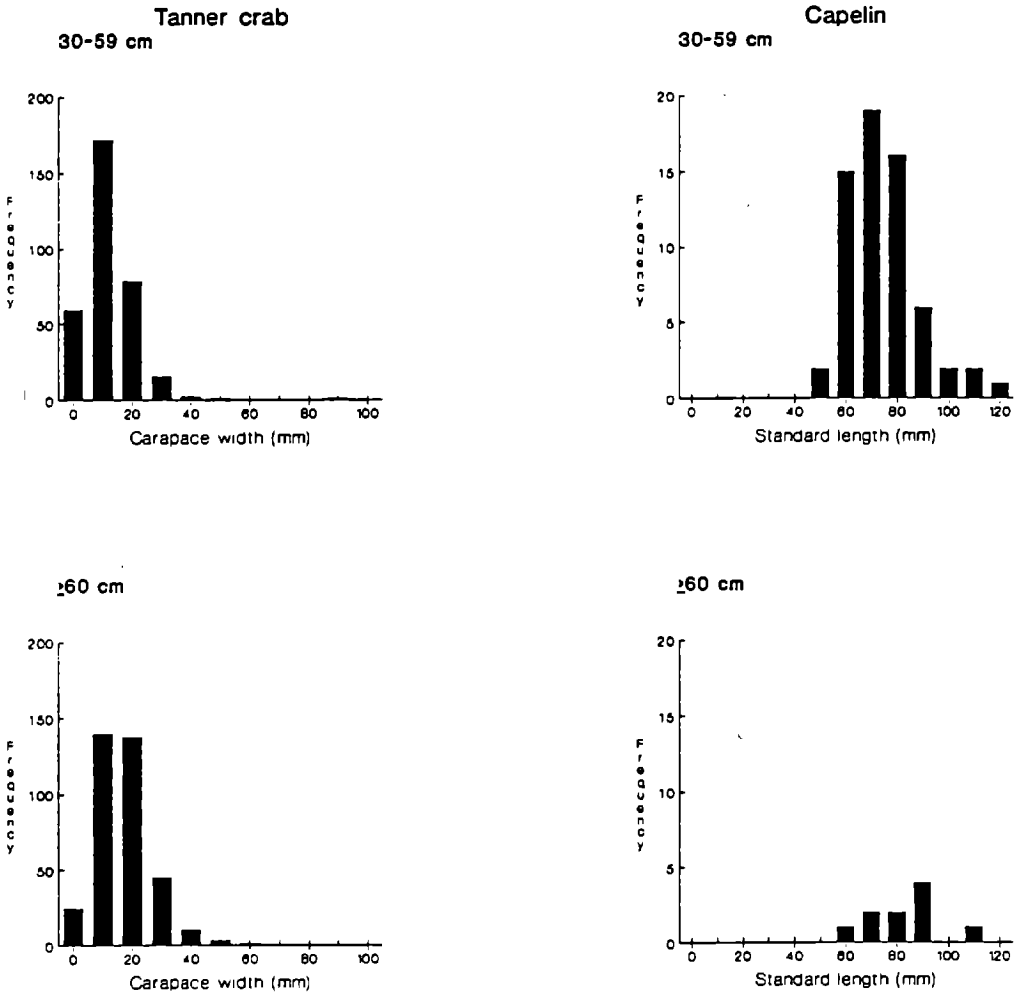

Figure 2-4. --Size frequency distributions of Tanner crab and capelin consumed by two size groups of Pacific cod in the Gulf of Alaska in 1990.

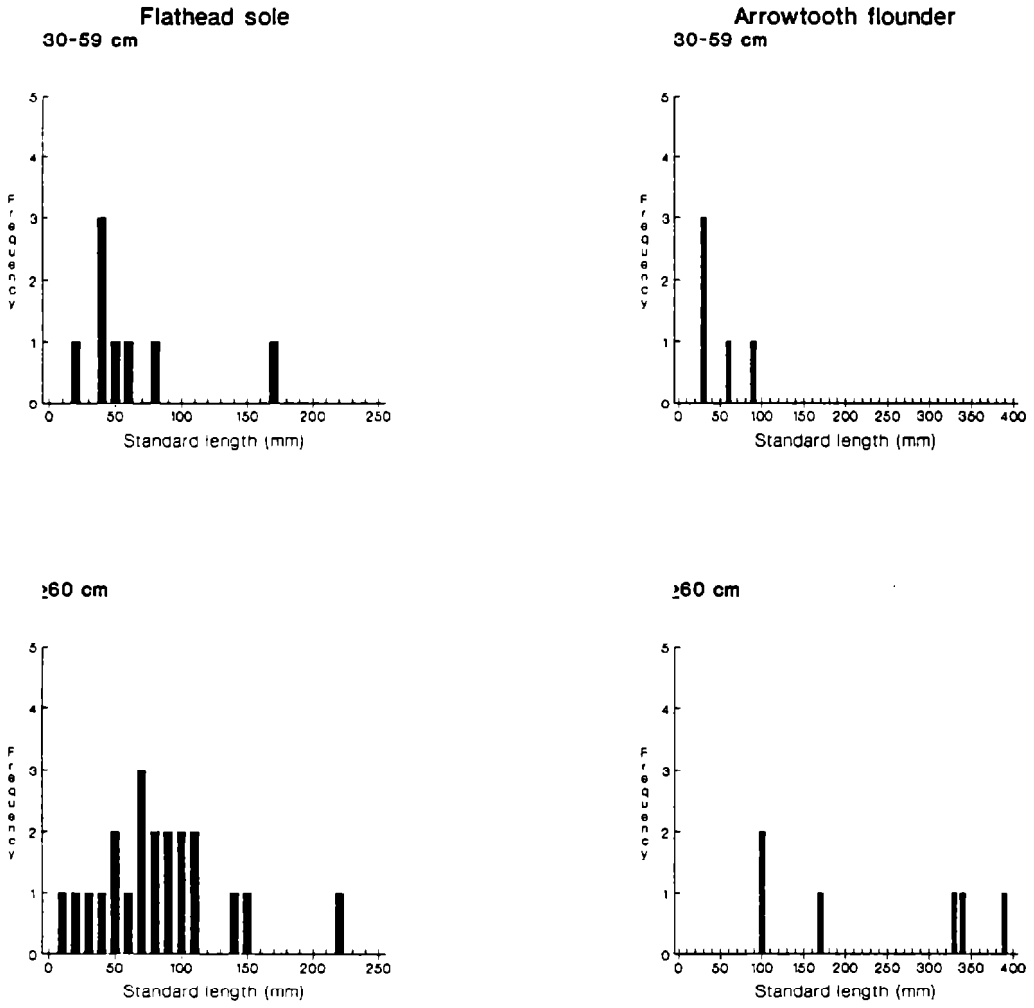

Figure 2-5.--Size frequency distributions of flathead sole and arrowtooth flounder consumed by two size groups of Pacific cod in the Gulf of Alaska in 1990.

In general, Pacific cod greater than or equal to 60 cm fed on larger Tanner crabs than cod 30-59 cm in length (Fig. 2-4). The average carapace width (CW) of the Tanner crabs consumed was 19.8 + 9.4 mm with a range of 3 to 99 mm. Most of the Tanner crabs measured from Pacific cod stomach contents were age-l crab (9-34 mm cw). Some commercially important prey fish were not analyzed in detail because of insufficient data. For example, only two Pacific halibut were consumed (21 and 60 mm SL) by Pacific cod in this study. Pacific cod also consumed one rex sole (121 mm SL), two eulachon (132 and 180 mm SL), and three rock sole (95, 140, and 150 mm SL).

Geographic Distributions of the Prey Consumed

Figures 2-6 to 2-15 illustrate the geographic distributions of the commercially important prey (percent by weight) consumed by Pacific cod in each haul where stomach samples were collected.

Consumption of walleye pollock by Pacific cod was not widespread (26 out of 78 hauls) (Fig. 2-6). In addition, the proportion of walleye pollock in the stomach content weights at each station was not high. Only in the area southwest of Kodiak Island did pollock make up a higher percentage (>75%) of prey found in the stomach content samples.

The consumption of arrowtooth flounder by Pacific cod was also found mainly in the area southwest of Kodiak Island (Fig. 2-7).

Figures 2-8, 2-9, and 2-10 illustrate that the consumption of Pacific halibut, rock sole, and rex sole by Pacific cod was not significant in the Gulf of Alaska area. Compared to the

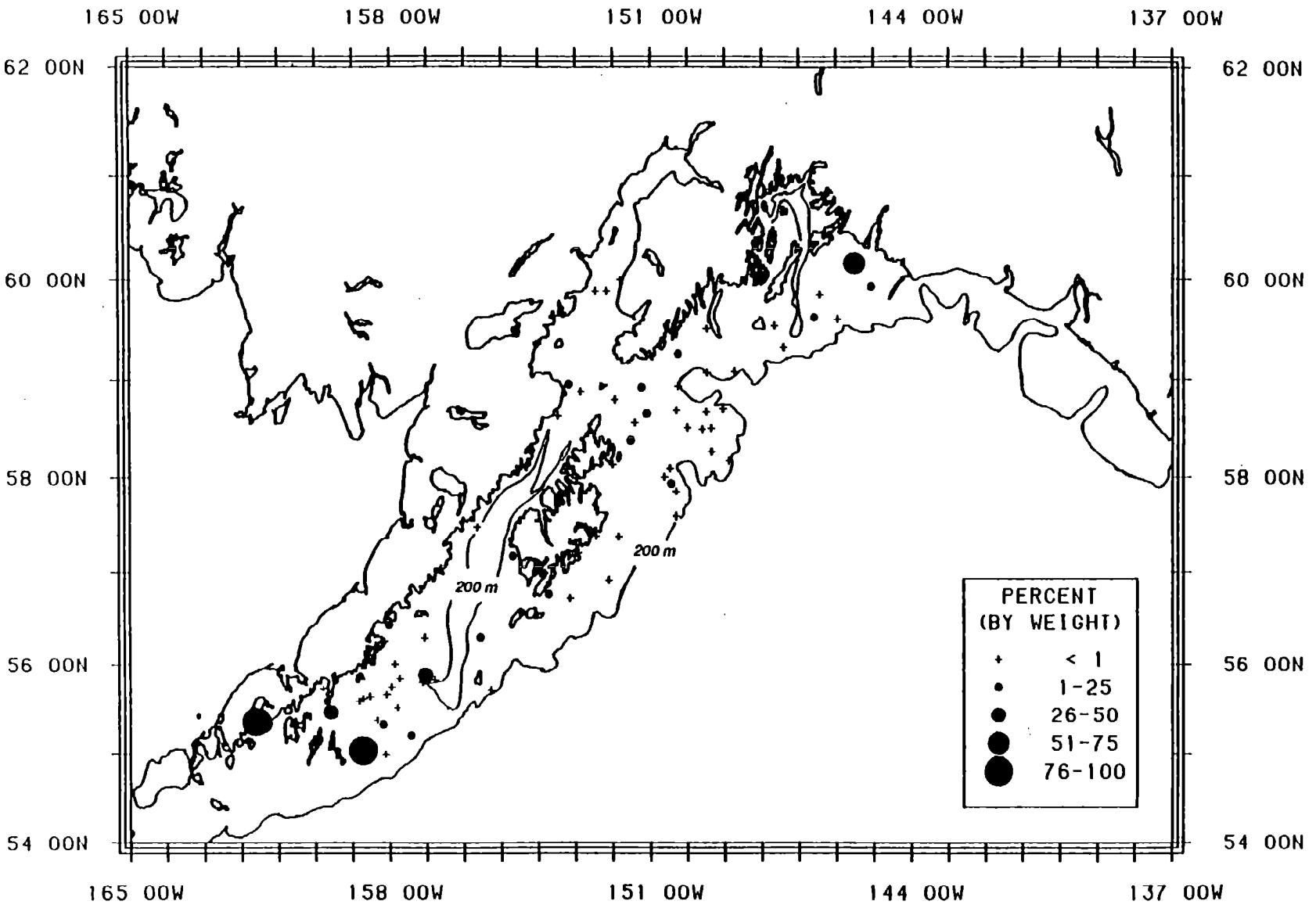

Figure 2-6. --Geographic distribution of walleye pollock consumed by Pacific cod in the Gulf of Alaska in 1990.

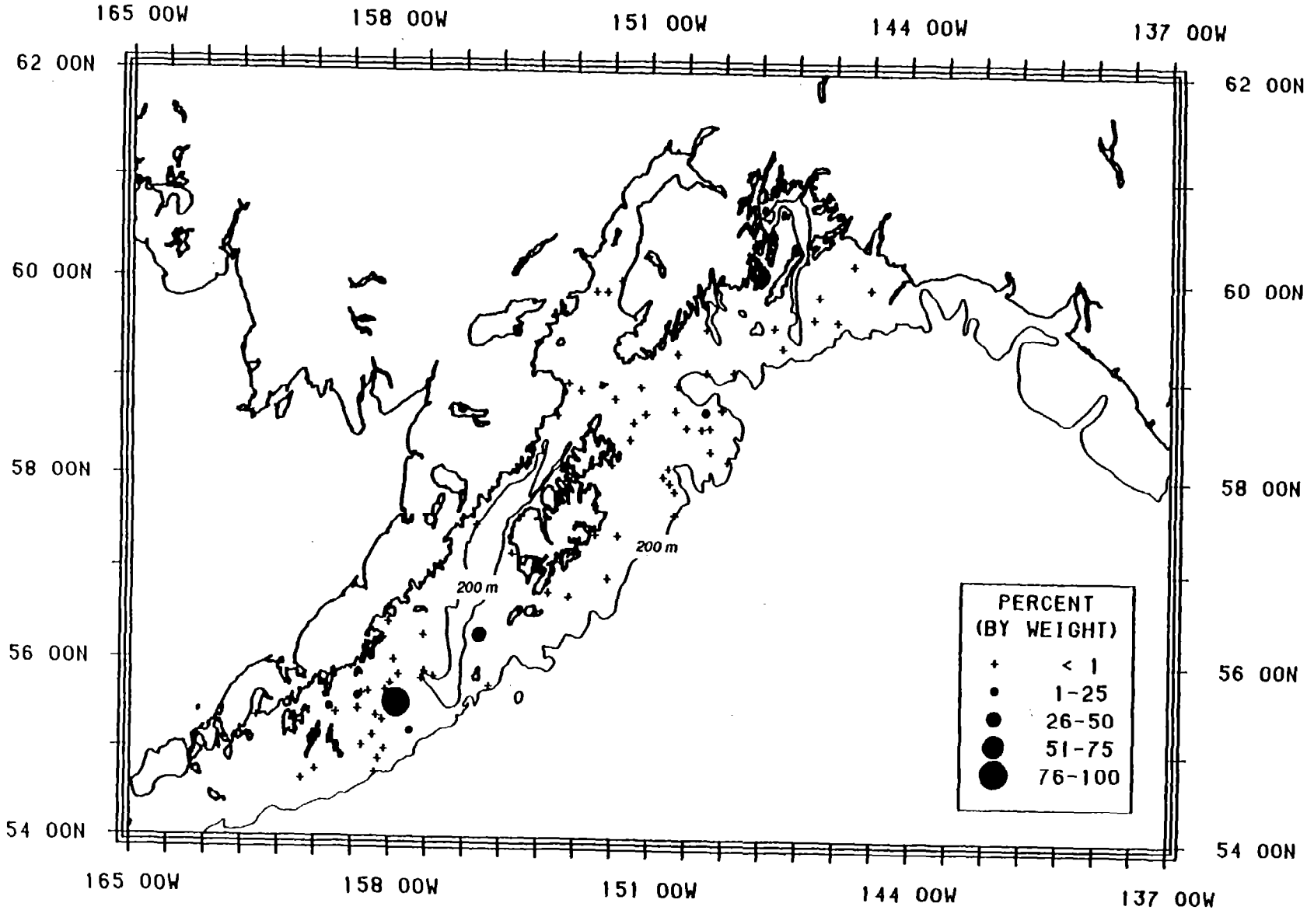

Figure 2-7.--Geographic distribution of arrowtooth flounder consumed by Pacific cod in the Gulf of Alaska in 1990.

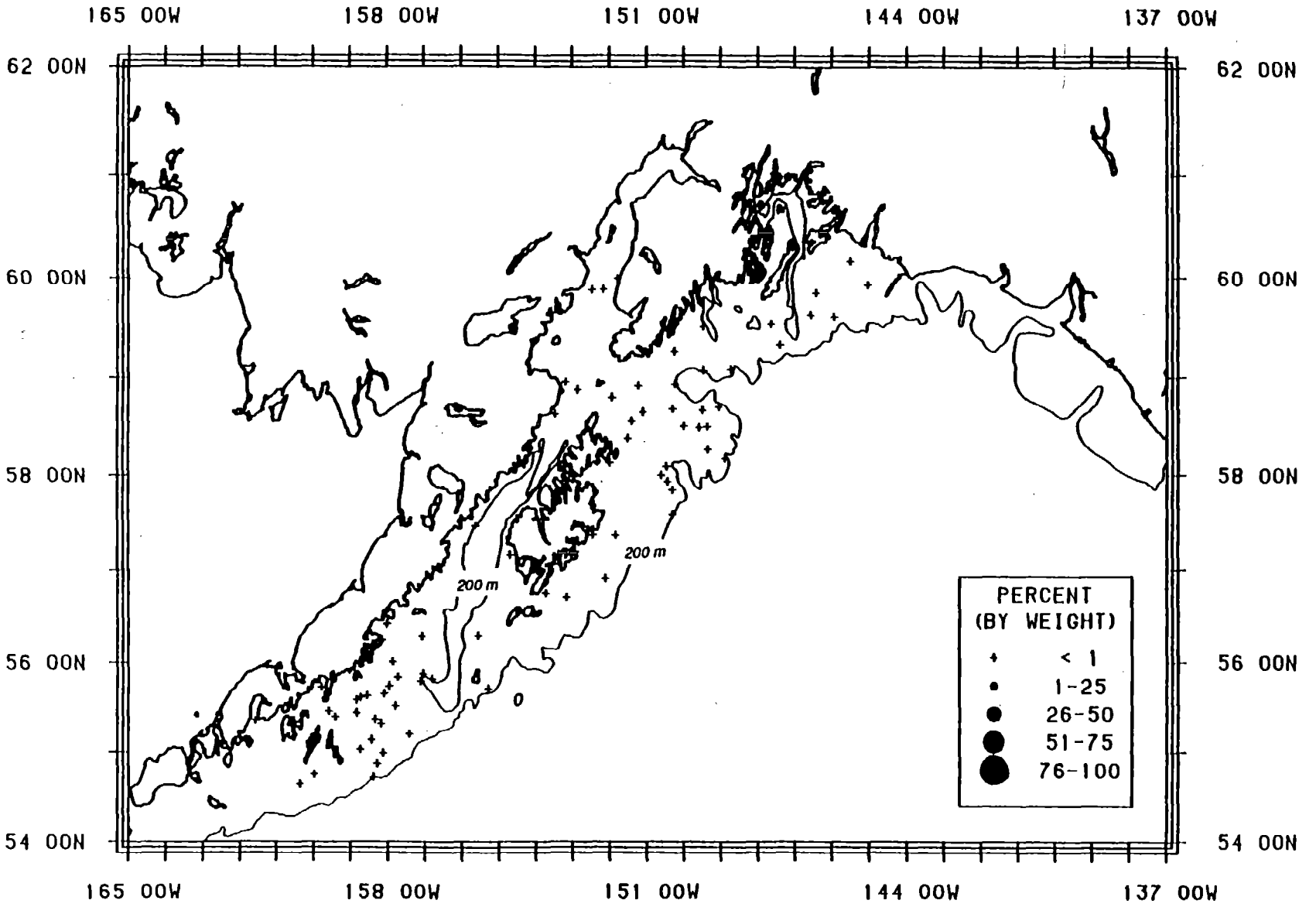

Figure 2-8.--Geographic distribution of Pacific halibut consumed by Pacific cod in the Gulf of Alaska in 1990.

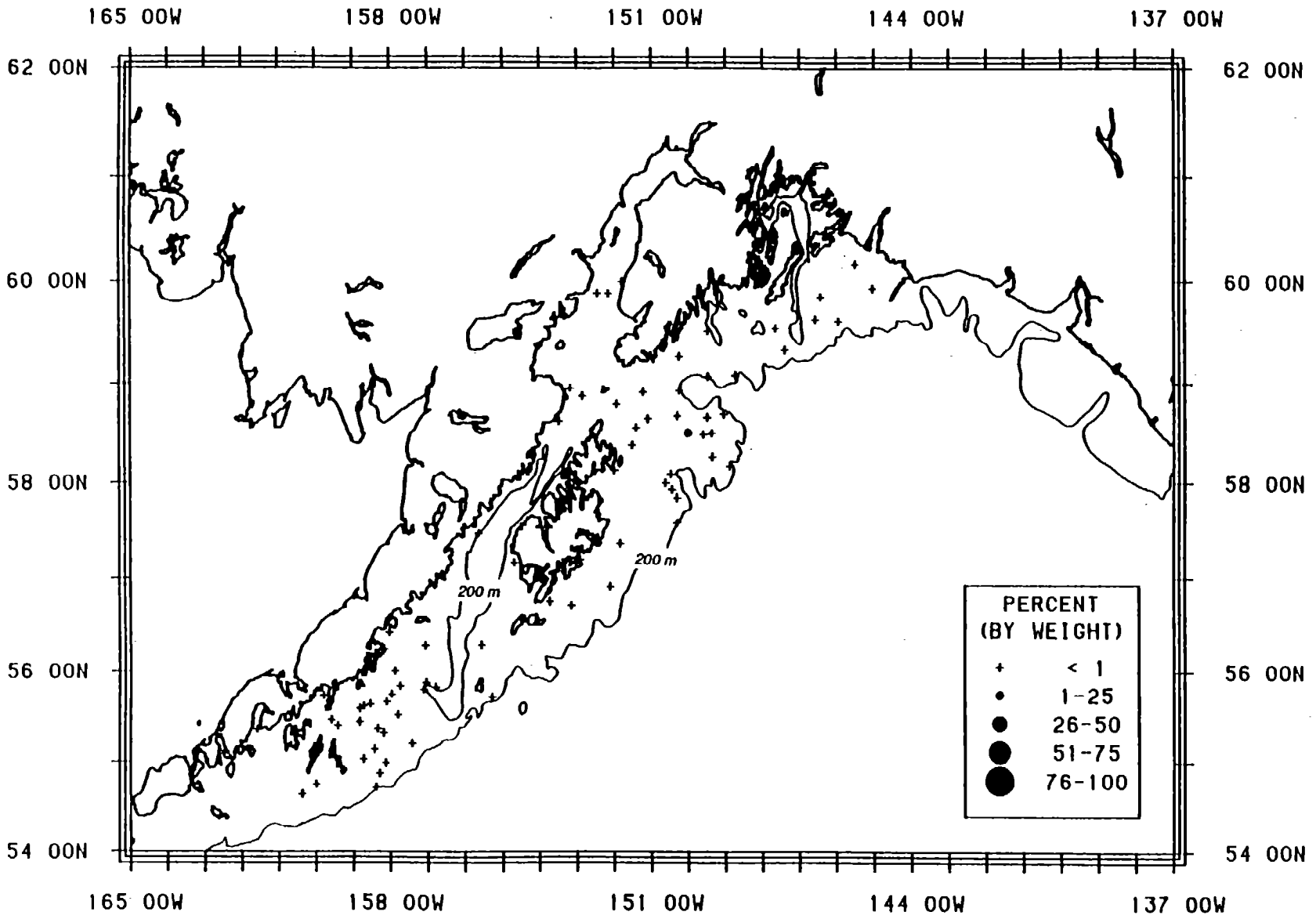

Figure 2-9.--Geographic distribution of rock sole consumed by Pacific cod in the Gulf of Alaska in 1990.

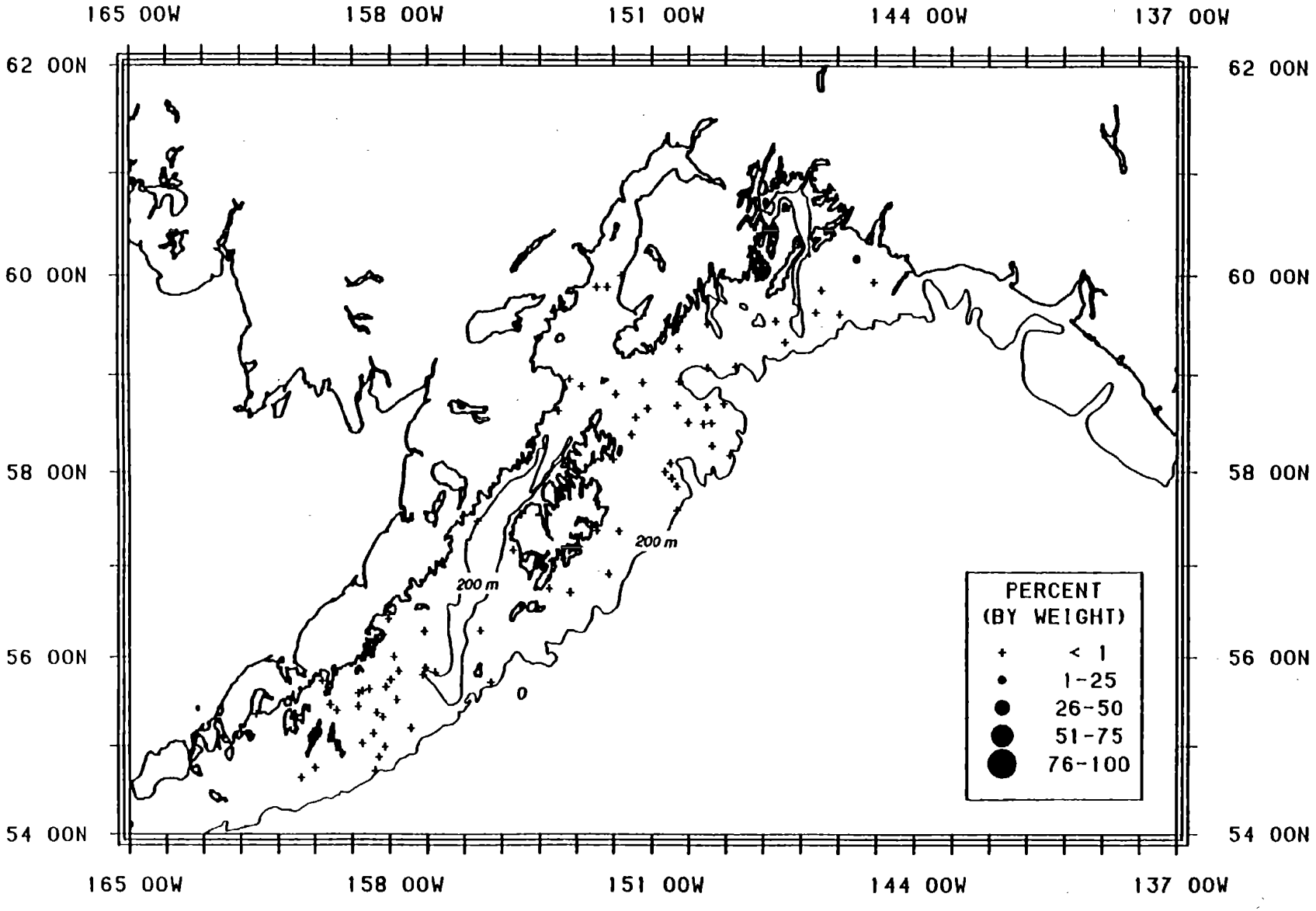

Figure 2-10.--Geographic distribution of rex sole consumed by Pacific cod in the Gulf of Alaska in 1990.

three flatfish mentioned above, flathead sole were eaten more frequently by the Pacific cod and were found in the area southwest of Kodiak Island (Fig. 2-11).

Capelin seemed to be consumed evenly throughout the sampling area. There was only one station where capelin comprised more than 75% of the stomach contents of Pacific cod (Fig. 2-12).

Pacific sand lance were consumed primarily in the area southwest of Kodiak Island, although there was one station to the north of Kodiak Island where Pacific sand lance comprised more than 50% of the stomach contents (Fig. 2-13).

Tanner crab consumption was widespread in all the areas sampled, although the higher percent by weight of Tanner crab in stomach contents seemed to be focused only on the east side of Kodiak Island (Fig. 2-14).

Fishery discards were consumed by Pacific cod mainly in the area southwest of Kodiak Island (Fig. 2-15).

DISCUSSION

Previous studies indicated that fish, crab, and shrimp were the main food components of Pacific cod found in the Gulf of Alaska (Jewett 1978, Clausen 1981). Jewett found that, in the Kodiak area, walleye pollock was the most common (3.9% frequency of occurrence) prey fish eaten by cod, followed by some unidentified flatfish and Pacific sand lance. Jewett also reported that Tanner crabs occurred in 36.7% and pandalid shrimp occurred in 4.7% of the Pacific cod stomachs sampled. In Clausen's (1981) study, Pacific herring and pollock (9.6 and 8.7%

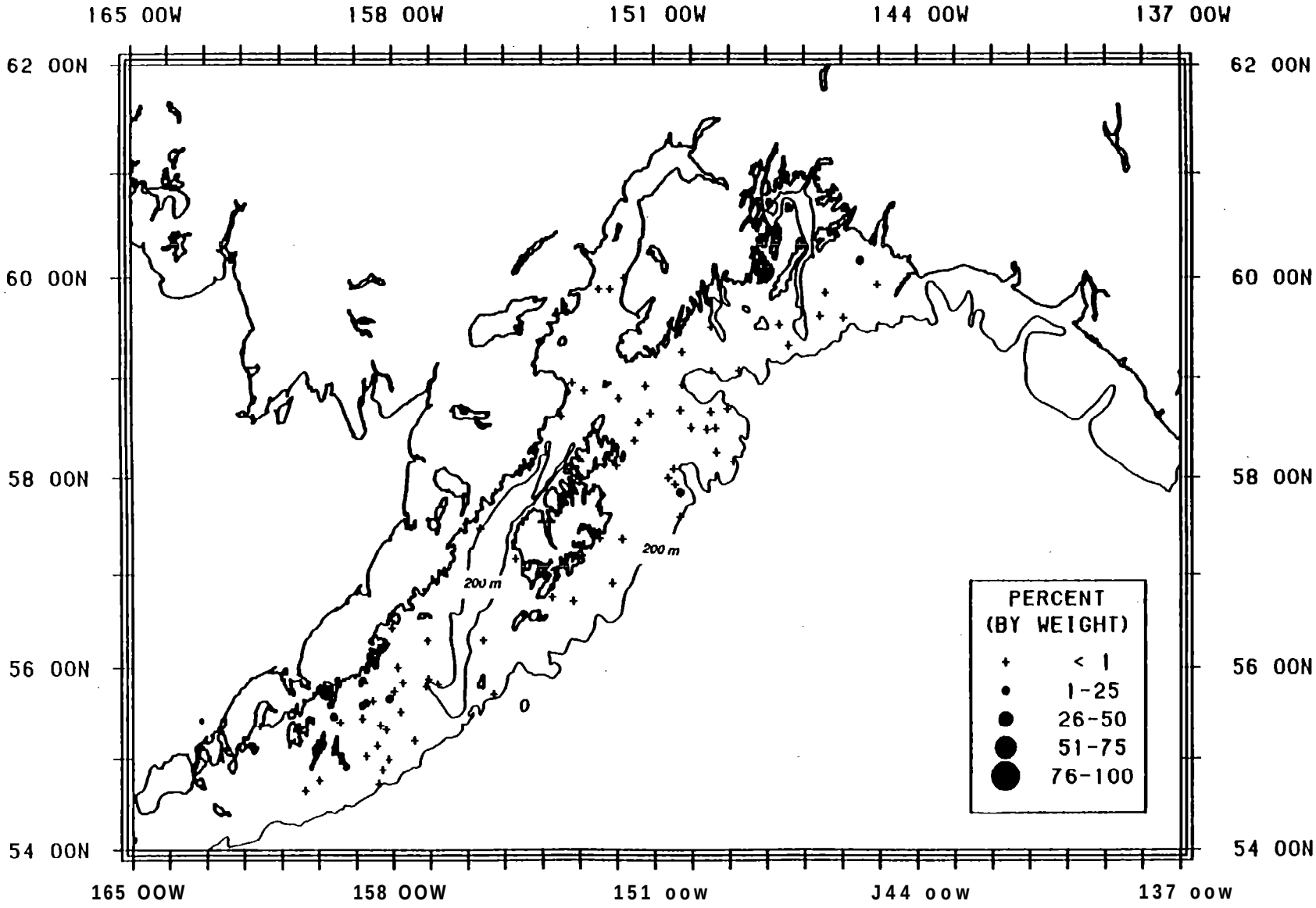

Figure 2-11. --Geographic distribution of flathead sole consumed by Pacific cod in the Gulf of Alaska in 1990.

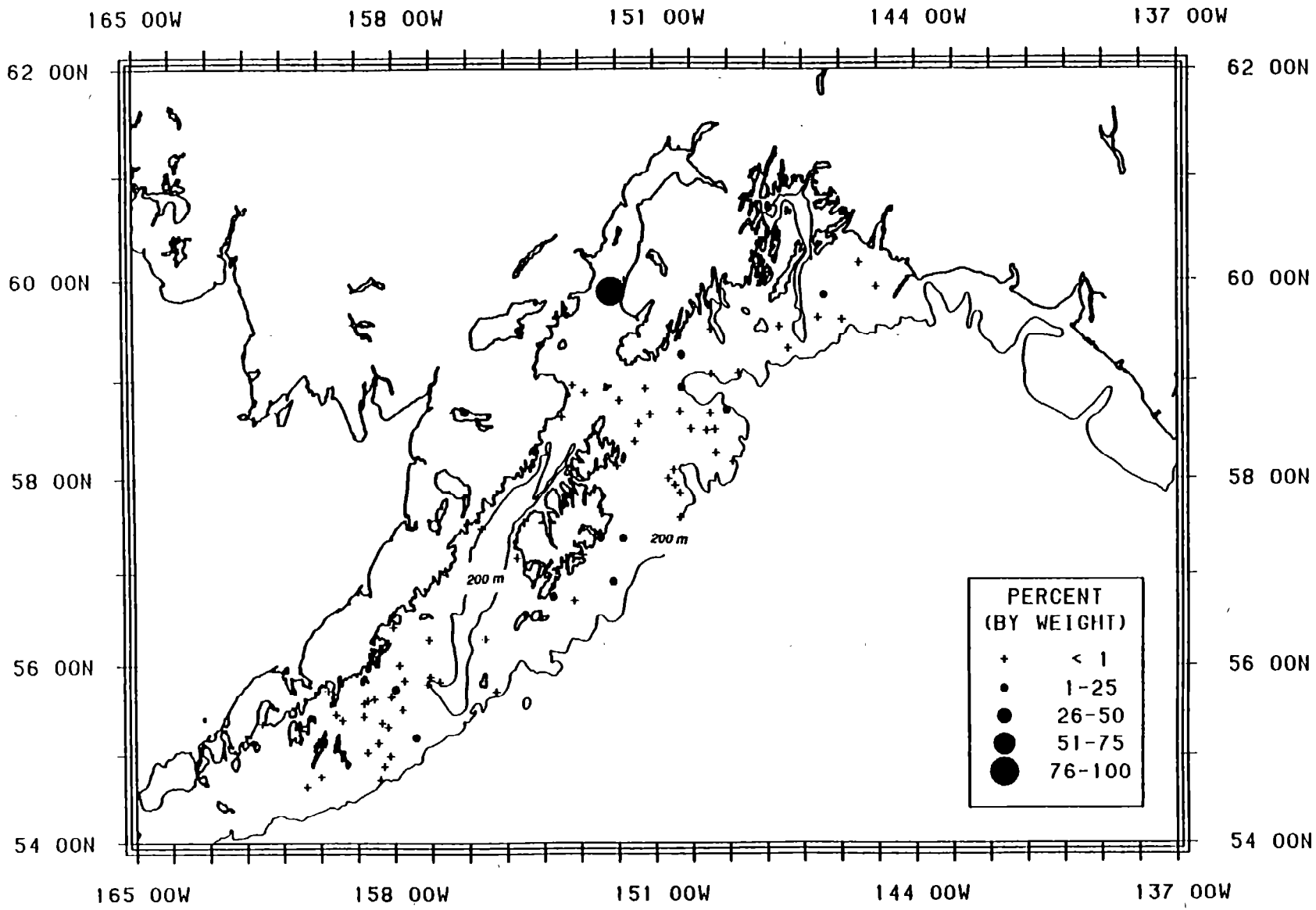

Figure 2-12.--Geographic distribution of capelin consumed by Pacific cod in the Gulf of Alaska in 1990.

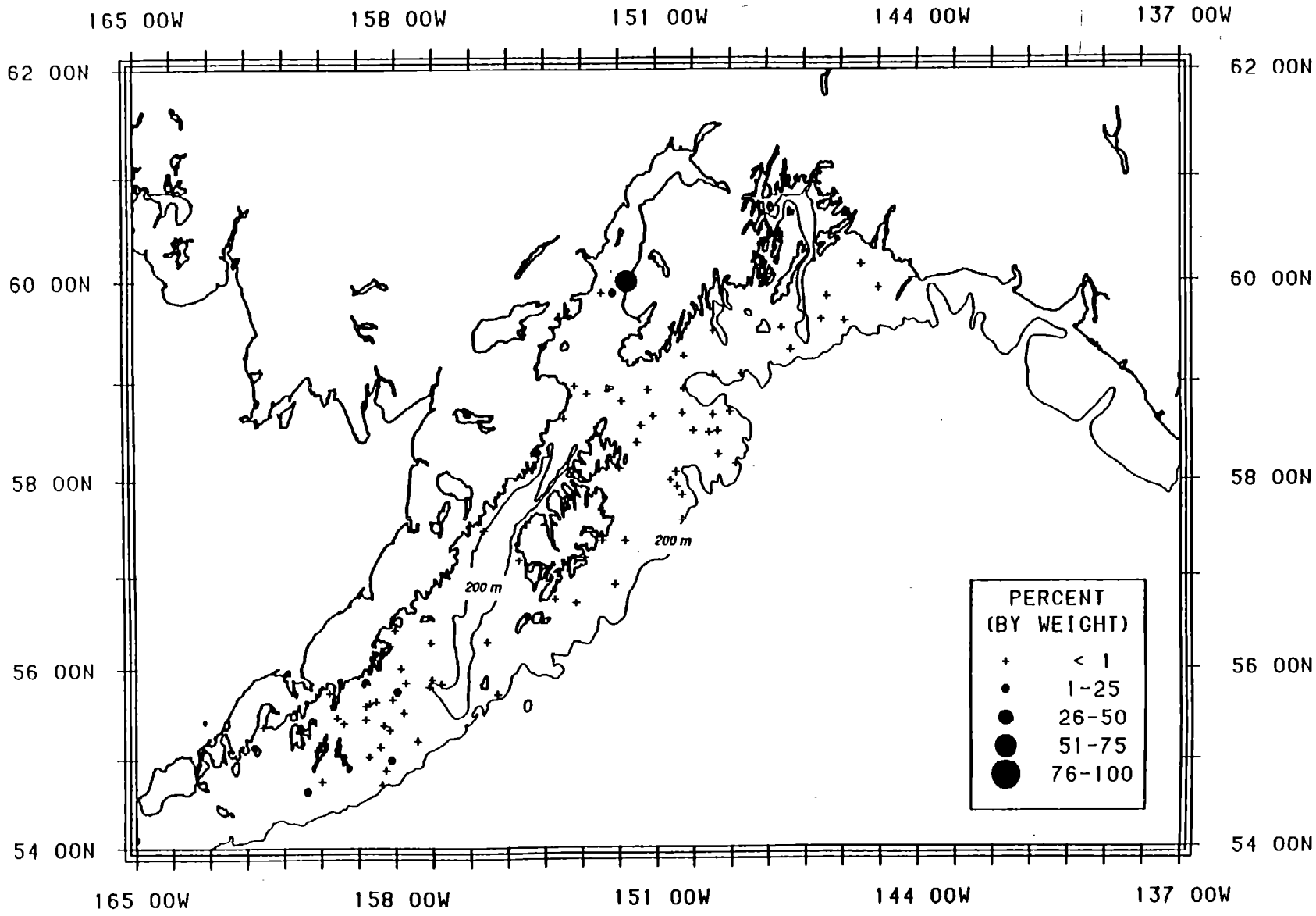

Figure 2-13.--Geographic distribution of Pacific sand lance consumed by Pacific cod in the Gulf of Alaska in 1990.

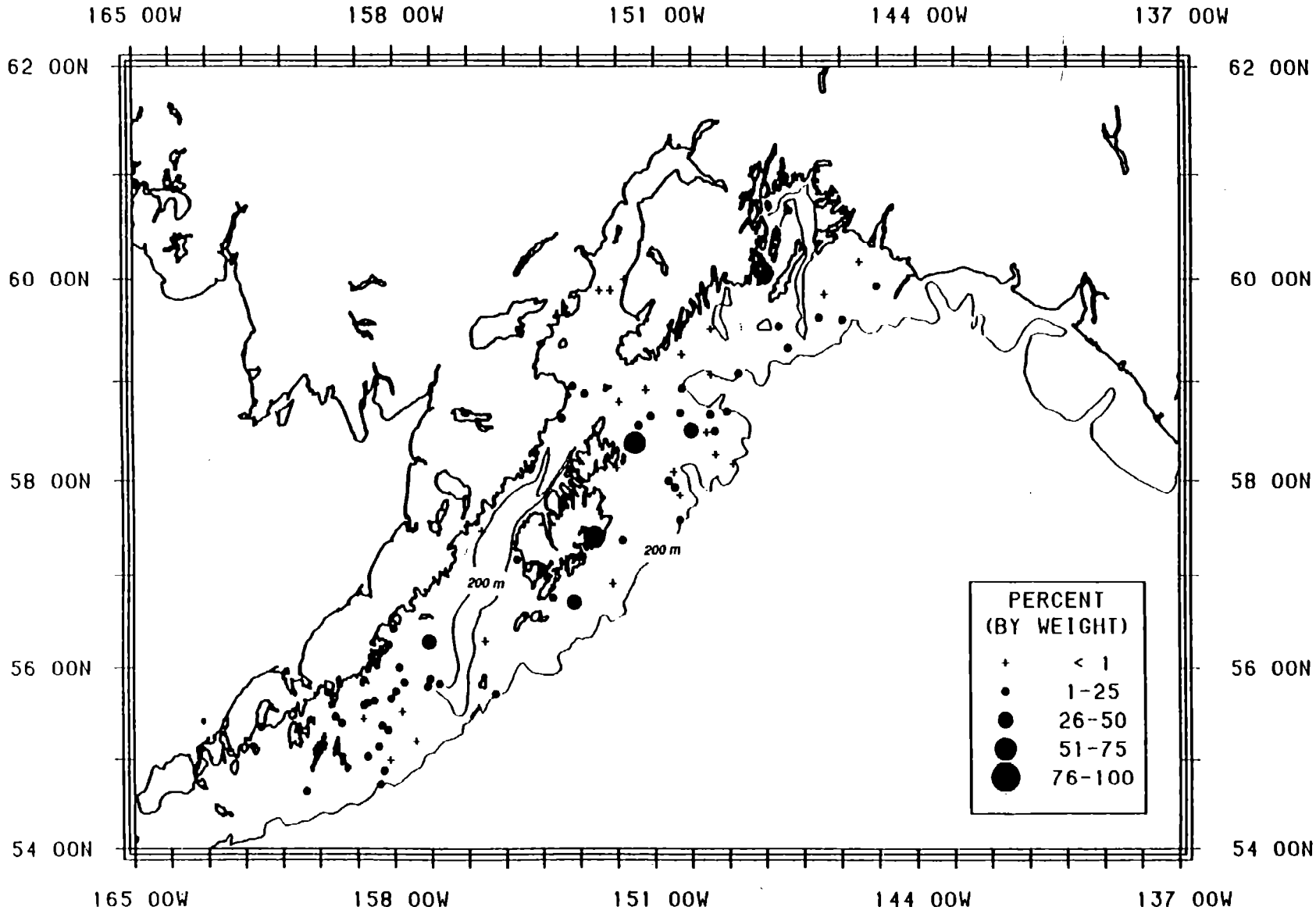

Figure 2-14.--Geographic distribution of Tanner crab consumed by Pacific cod in the Gulf of Alaska in 1990.

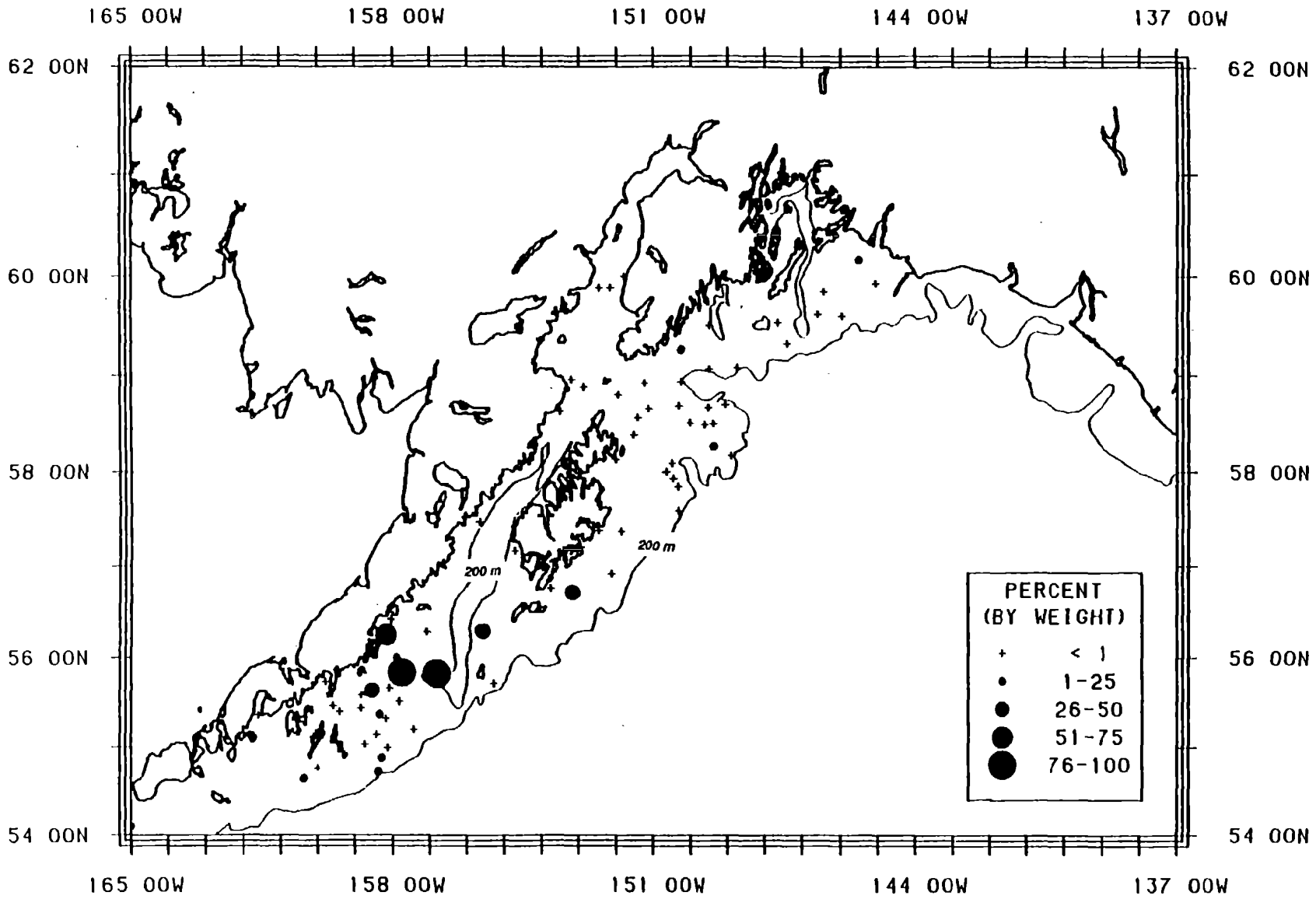

Figure 2-15.--Geographic distribution of fishery discard consumed by Pacific cod in the Gulf of Alaska in 1990.

frequency of occurrence, respectively) were the most common prey fish found in cod stomachs and Tanner crabs (26.2%) were the most common prey of Pacific cod in Southeast Alaskan waters. Pandalid shrimp were found in 25.4% of the cod stomachs sampled. The main difference between the present study and earlier studies in the Gulf of Alaska area is that fishery discards now comprise a significant proportion (13%) of the total stomach content weights in this study, whereas no fishery discards were reported as food in the earlier studies. Another significant difference is that in both Jewett (1978) and Clausen's (1981) studies, reported a high percentage (35%) of unidentified fish, whereas this unidentified category was only 7% in this study.

In another comparison, walleye pollock comprised 40% by weight of the total stomach contents of Pacific cod in the Bering Sea (Livingston 1991), whereas only 7% of the total stomach contents were pollock from this study. More prey fish species were consumed by Pacific cod in the Gulf of Alaska area compared with the Bering Sea. In addition, king crabs (*Paralithodes* spp.) were consumed in the Bering Sea area, but they were not found in the stomachs of Pacific cod in the Gulf of Alaska area.

CITATIONS

Clausen, D. M. 1981. Summer food of Pacific cod, Gadus macrocephalus, in coastal waters of southeastern Alaska. Fish. Bull., U.S. 78:968-973.

Jewett, S. C. 1978. Summer food of the Pacific cod, Gadus macrocephalus, near Kodiak Island, Alaska. Fish. Bull., U.S. 76:700-706.

Livingston, P. A. 1991. Pacific cod, p. 31-88. In P. A. Livingston (ed.), Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-207.

Zenger, H. H., and G. G. Thompson. 1991. Pacific cod. In Stock assessment and fishery evaluation report for the 1992 Gulf of Alaska groundfish fishery. November 1991, prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.B. Box 103136, Anchorage, AK 99510.

ARROWTOOTH FLOUNDER

Arrowtooth flounder (Atheresthes stomias), with an exploitable biomass of 1,144,242 t in 1990, ranked first in the total groundfish biomass (North Pacific Fishery Management Council 1991). However, because of the species' low commercial value, catches have been low (Wilderbuer and Brown 1990). Arrow-tooth flounder is a large flatfish with a symmetrical mouth and sharp teeth that feeds on commercially important fish like walleye pollock (Theragra chalcogramma), capelin (Mallotus villosus), and other fish, as well as shrimp and other crustaceans (Smith et al. 1978). Therefore, with the feeding behavior and the high abundance of arrowtooth flounder in the Gulf of Alaska area, it is important to study its food habits and its impact on commercially important prey.

RESULTS

General Diets

A total of 1,144 arrowtooth flounder stomachs were analyzed. Of this total, 489 were empty and 655 (57%) contained food. Arrowtooth flounder sizes ranged from 12 to 80 cm FL with a mean and SD of 42.1 and +. 10.1 cm, respectively. The average depth of the 62 hauls where stomachs were collected was 164 + 69 m with a range from 66 to 432 m.

Table 3-l displays all the prey 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

Table 3-l. --Prey items (expressed in percent frequency of occurrence, and percent total weight) of Atheresthes stomias (arrowtooth flounder) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Total weight
Polychaeta (unidentified)	0.80	0.02
Bivalvia (clam)	0.20	co.01
Teuthoidea (squid unidentified)	0.80	0.21
Gonatidae (squid)	0.20	1.80
Calanoida (copepod)	0.80	co.01
Mysidae (mysid)	0.60	0.01
Holmesiella anomala (mysid)	0.20	co.01
Neomysis czerniawskii (mysid)	0.20	co.01
Neomysis ravii	0.20	co.01
Cumacea (cumacean)	0.30	co.01
Isopoda (isopod)	0.20	0.02
Gammaridea (unidentified)	1.40	0.02
Ampeliscidae (amphipod)	0.30	0.01
Themisto sp.	0.60	co.01
Caprellidea (amphipod)	0.20	co.01
Euphausiacea (unidentified)	34.80	2.84
Thysanoessa inermis (euphausiid)	4.90	0.15
Thysanoessa soinifera (euphausiid)	0.20	co.01
Caridea (unidentified)	1.40	0.05
Pasinhaea oacifica (shrimp)	0.50	0.11
Hippolytidae (unidentified)	0.20	0.01
Eualus avinus (shrimp)	0.70	0.02
Pandalidae (unidentified)	12.00	1.67
Pandalus borealis (northern shrimp)	7.00	1.80
Pandalus iordani (shrimp)	0.80	0.27
Pandalus montasui tridens (shrimp)	0.60	0.15
Pandalus olatyceros (shrimp)	0.20	0.01
Crangonidae (unidentified)	1.40	0.08
Cranson communis (shrimp)	1.80	0.12
Arsia r	0.60	0.06
Arsis ovifer (shrimp)	0.20	co.01
Paguridae (hermit crab)	0.20	co.01
Echiuridae (marine worm)	0.20	0.03
Chaetognatha (arrow worm)	0.60	co.01
Teleostei (unidentified fish)	2.70	0.06
Non-gadoid fish remains	1.50	0.38
Cluoea harensus oallasi (Pacific herring)	4.40	9.15
Coresonus sp. (salmonidae)	0.20	0.12
Mallotus villosus (capelin)	19.70	8.18
Thaleichthys pacificus (eulachon)	0.30	0.78
Gadidae (unidentified gadid)	5.50	1.73
Therasra chalcogramma (walleye pollock)	15.30	66.43

Table 3-l. --Continued.

Prey Name	% Freq. occur.	% Total weight
Zoarcidae (unidentified eelpout)	0.60	0.36
Scorpaenidae (unidentified)	0.40	0.26
Pleurosrammus monopteryaius (Atka mackerel)	0.20	0.50
Stichaeidae (prickleback)	1.20	0.33
Poroclinus rothrocki (whitebarred prickleback)	0.30	0.16
Ammodytes hexapterus (Pacific sand lance)	0.30	0.02
Pleuronectidae (unidentified flatfish)	0.90	1.21
Atheresthes stomias (arrowtooth flounder)	0.20	<0.01
Hippoglossoides elassodon (flathead sole)	0.20	0.26
Fishery discard	0.30	0.56

Total prey weight	6,501 g
Number of stomachs with food	655
Number of empty stomachs	489

flounder, they comprised only 10% by weight of the total stomach contents. The remaining 90% of stomach content weight was made up of fish. Walleye pollock was the most important prey of arrowtooth flounder; they comprised 66% by weight of the total stomach contents. Pacific herring (Clupea pallasi) and capelin comprised 9% and 8% of the total stomach contents by weight, respectively. Arrowtooth flounder also consumed some eulachon (Thaleichthys pacificus), Atka mackerel (Pleurogrammus monopterygius), Pacific sand lance (Ammodytes hexapterus), arrowtooth flounder, flathead sole (Hipposlossoides elassodon), fishery discard, and some non-commercially important species (zoarcids and stichaeids).

Variation of Diet Based on Predator Size

Figure 3-l shows the percentage by weight of the main prey items for different arrowtooth flounder size groups. With the exception of the smallest size group (<20 cm FL), all size groups had at least 70% fish by weight in their stomach contents. Walleye pollock were the predominant prey fish (60 to 90%) for arrowtooth flounder greater than or equal to 40 cm, whereas capelin predominate in the diets of fish between 20 and 40 cm long. Pacific herring comprised about 20% of the food for fish between 30 and 50 cm. Shrimp were the predominant food of fish less than 20 cm.

Sizes of the Commercially Important Prey Consumed

The commercially important prey consumed by arrowtooth flounder were analyzed by three different size groups: less than

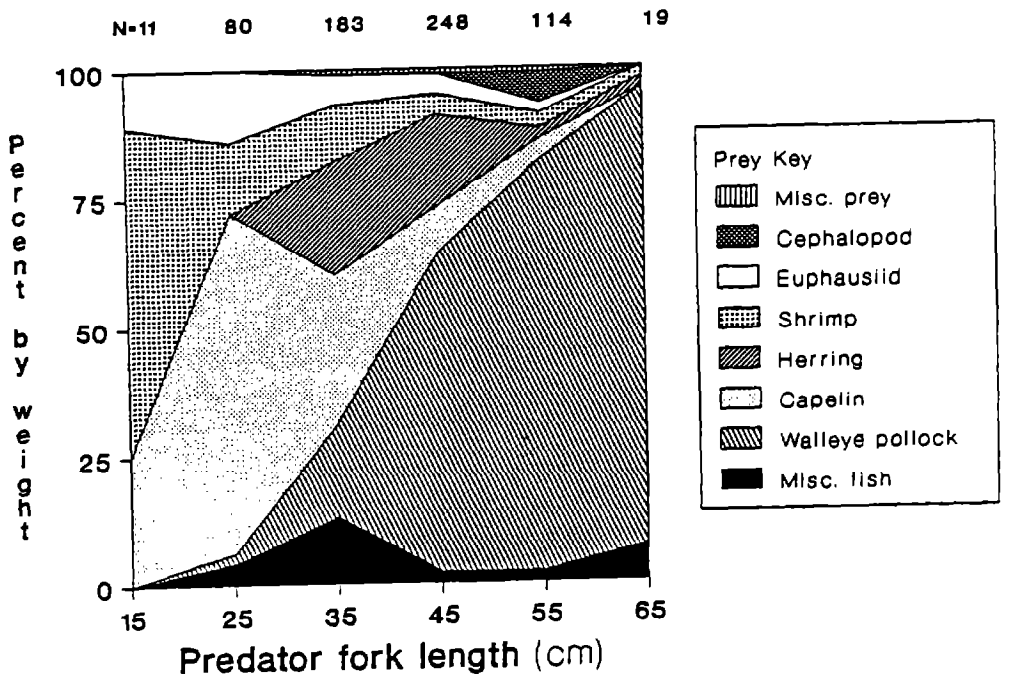

Figure 3-1. --Variations in the main food items of arrowtooth flounder, by predator size, in the Gulf of Alaska in 1990. N = sample size.

20 cm, 20-39 cm, and greater than or equal to 40 cm FL (Figs. 3-2 and 3-3). Figure 3-2 (left side) shows that pollock were not consumed by arrowtooth flounder less than 20 cm long. The medium-sized fish (20-39 cm) consumed some age-0 and age-l pollock. The larger-sized (>40 cm) arrowtooth flounder contained many age-O, age-l, and age-2 pollock (approximately <300 mm), and some age 3 and older pollock. The average SL (mean + SD) of the pollock consumed by arrowtooth flounder was 196.1 + 89.2 mm with a range of 21 to 450 mm. The relationship between the arrow-tooth flounder size and the size of the pollock that they consumed is shown in Figure 3-4. Figure 3-2 (right side) displays the consumption of Pacific herring by arrowtooth flounder. It illustrates that no Pacific herring were found in arrowtooth flounder smaller than 20 cm long. And the medium-sized and the larger-sized fish consumed only a few Pacific herring. The mean length of the 11 Pacific herring consumed was 159.9 + 23.0 mm SL with a range from 127 to 195 mm SL. Figure 3-3 shows that many capelin were consumed by arrowtooth flounder larger than 20 cm long. The average SL of capelin consumed by arrowtooth flounder was 85.3 + 18.1 mm with a range from 43 to 130 mm SL. Arrowtooth flounder also consumed one flathead sole (130 mm SL), one Atka mackerel (128 mm SL), two eulachons (130 and 154 mm SL), and one Pacific sand lance (70 mm SL).

Geographic Distributions of the Prey Consumed

Figures 3-5, 3-6, and 3-7 describe the geographic distributions of the pollock, capelin, and Pacific herring consumed by arrowtooth flounder. It shows that pollock were

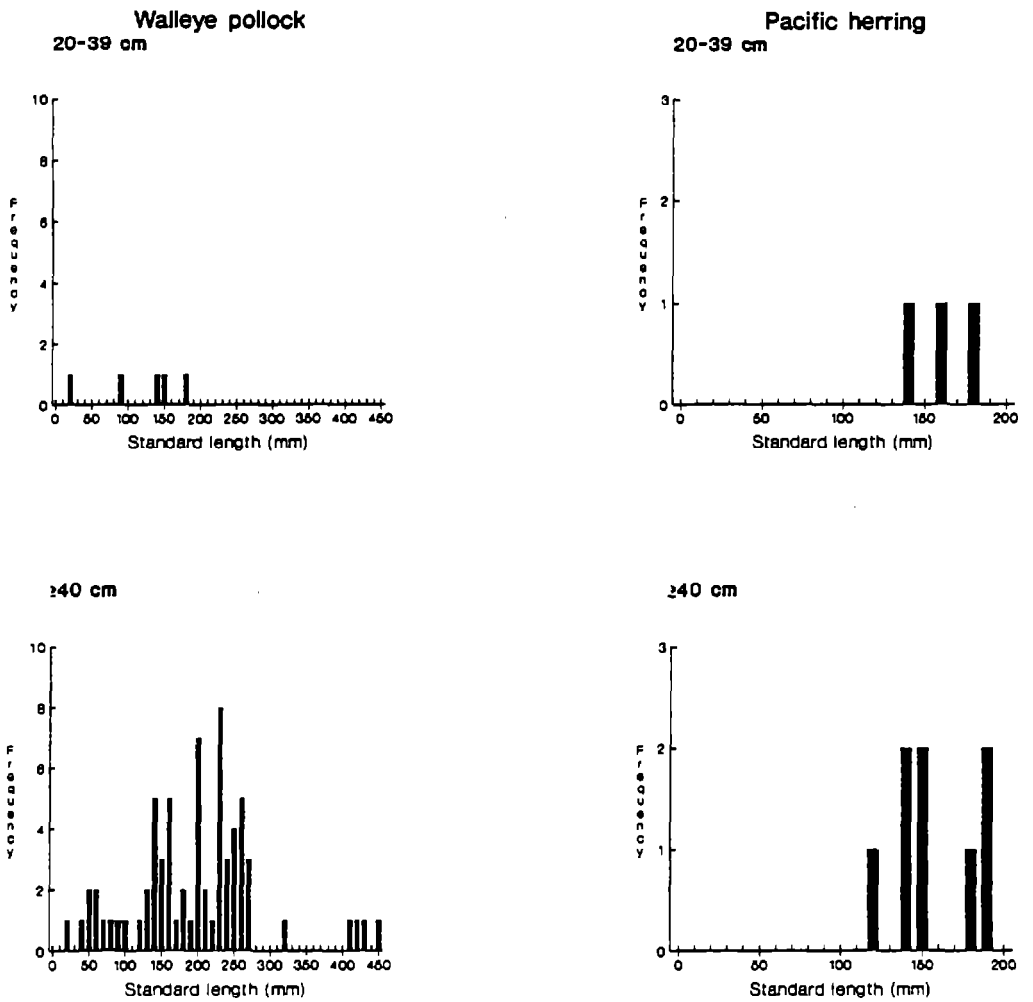

Figure 3-2.--Size frequency distributions of walleye pollock and Pacific herring consumed by two size groups of arrow-tooth flounder in the Gulf of Alaska in 1990.

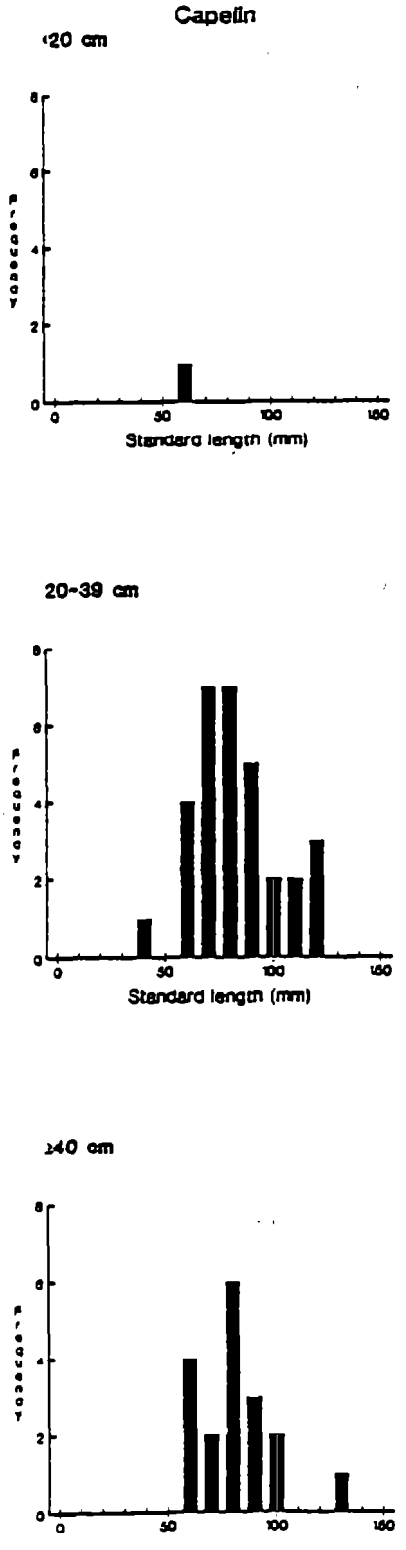

Figure 3-3. --Size frequency distributions of capelin consumed by three size groups of arrowtooth flounder in the Gulf of Alaska in 1990.

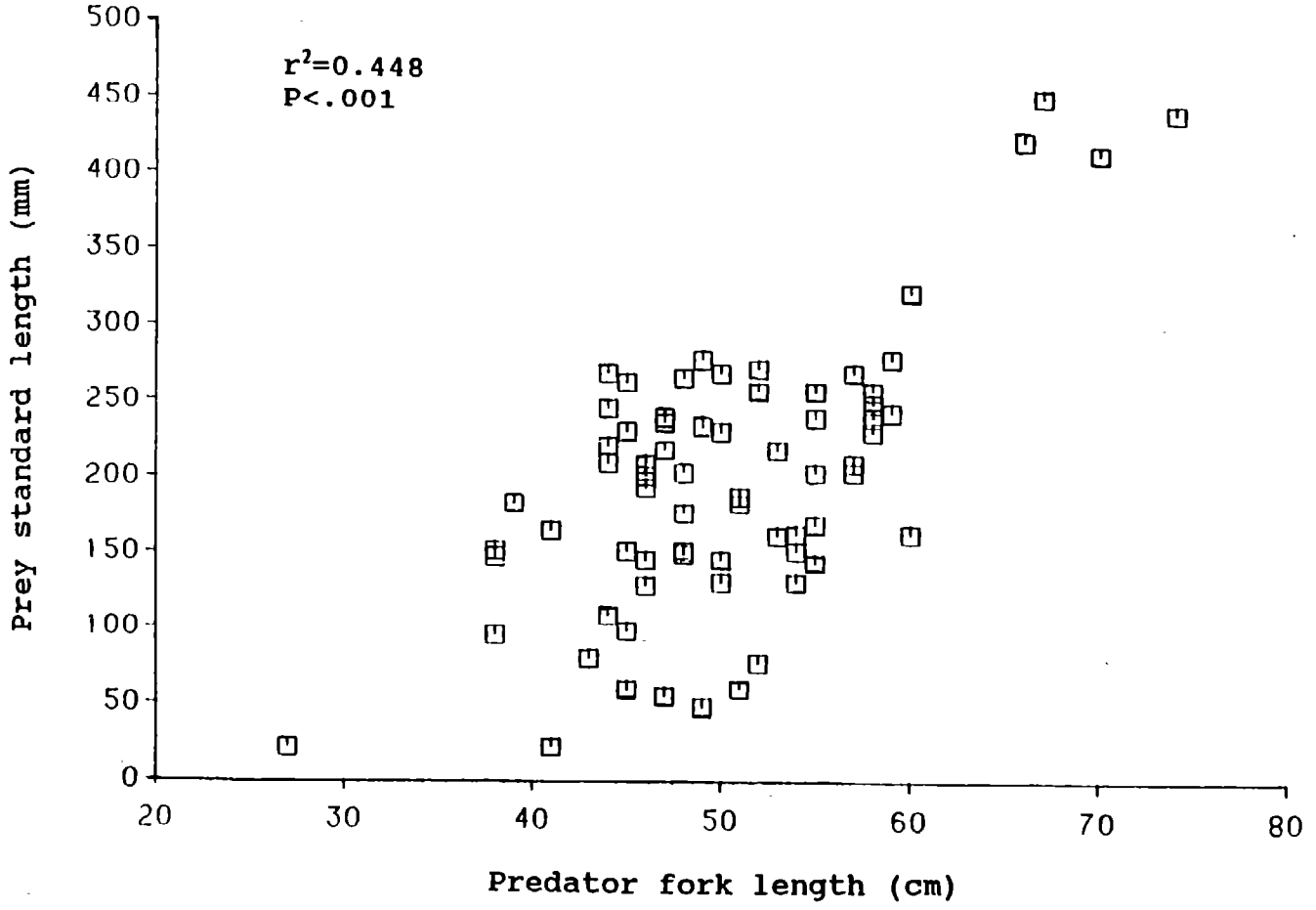

Figure 3-4.--scatterplot of walleye pollock prey size versus arrowtooth flounder in the Gulf of Alaska in 1990.

primarily consumed around Kodiak Island (Fig. 3-5). Figure 3-6 shows that most capelin consumed by arrowtooth flounder were on the east and southwest of Kodiak Island. Most Pacific herring consumed by arrowtooth flounder were located east of the Kenai Peninsula (Fig. 3-7).

DISCUSSION

Smith et al. (1978) found that similar prey items (pollock, euphausiids, shrimp, and miscellaneous fish) were consumed by arrowtooth flounder in the Gulf of Alaska area, although euphausiids comprised a higher percentage by volume in their study compared with this study. This discrepancy is probably due to the fact that 85% of the arrowtooth flounder in their study were less than or equal to 35 cm long, whereas most fish in our study were greater than or equal to 40 cm. In the Bering Sea area, arrowtooth flounder also consumed a high percentage (56% by weight) of pollock (Yang 1991). The other prey items consumed in the Bering Sea area were similar to those in the Gulf of Alaska area. The main difference is that capelin made up 8% by weight of the diet in the Gulf of Alaska area, whereas less than 1% of the diet of arrowtooth flounder in the Bering Sea area was capelin.

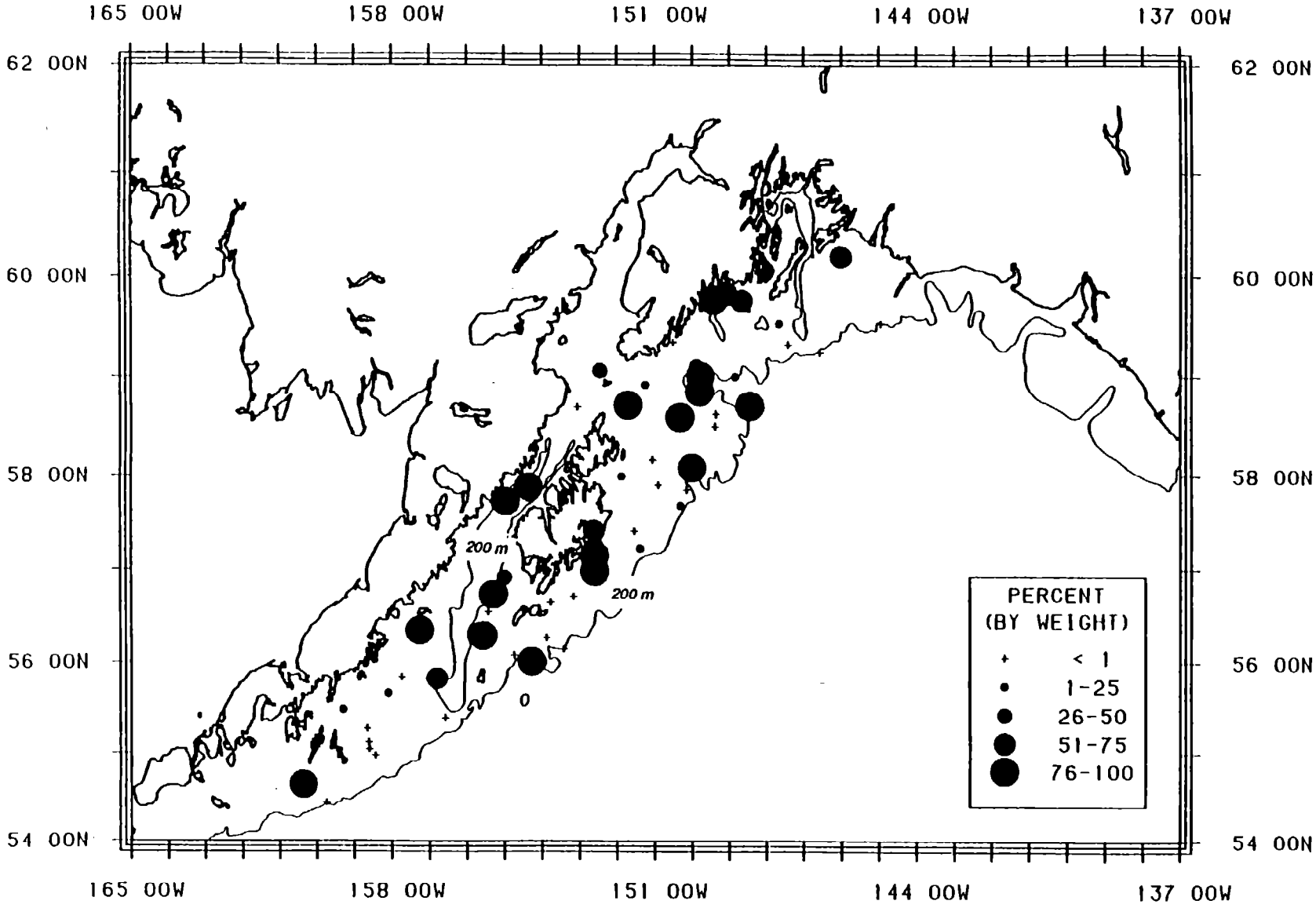

Figure 3-5.--Geographic distribution of walleye pollock consumed by arrowtooth flounder in the Gulf of Alaska in 1990.

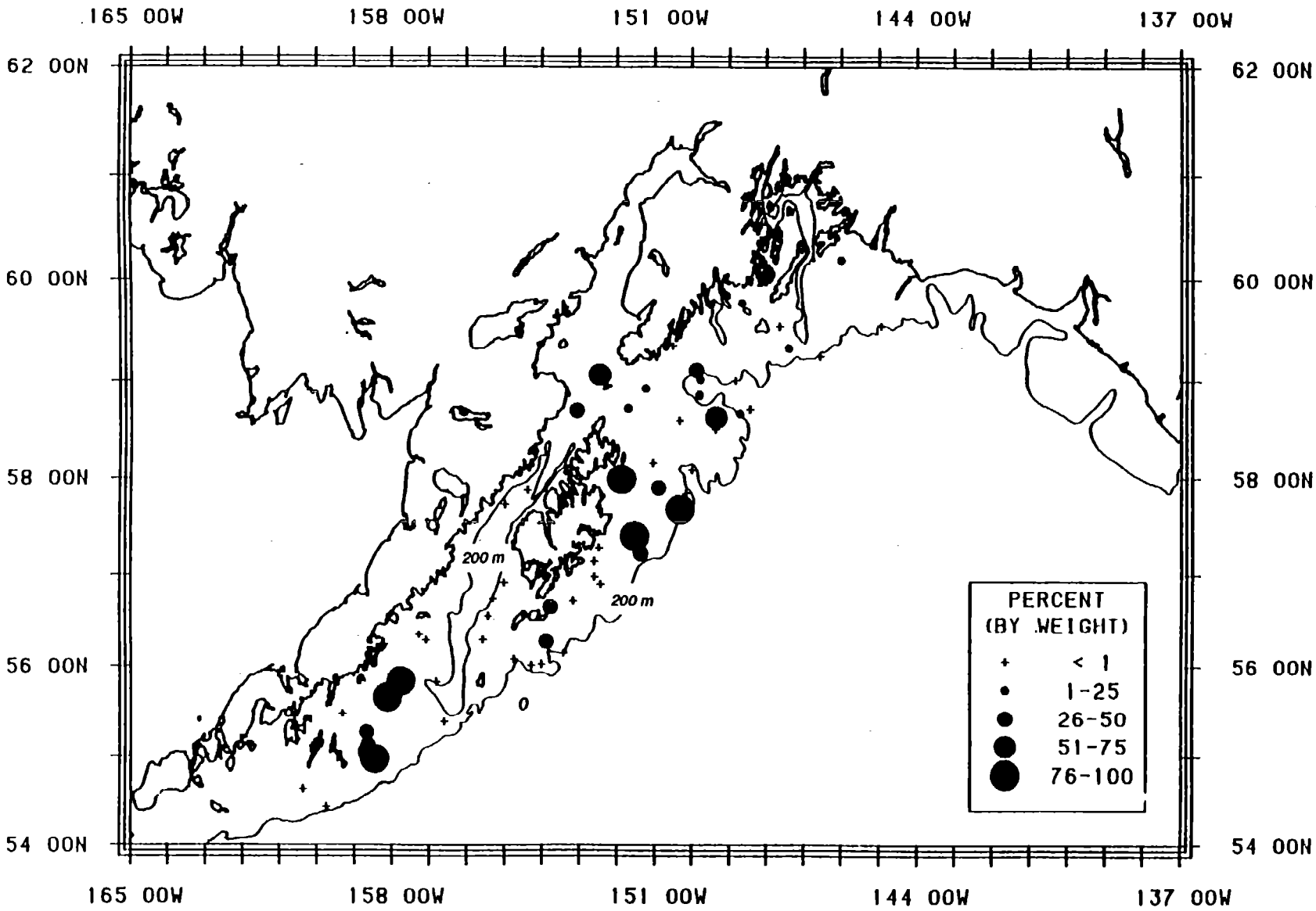

Figure 3-6.--Geographic distribution of capelin consumed by arrowtooth flounder in the Gulf of Alaska in 1990.

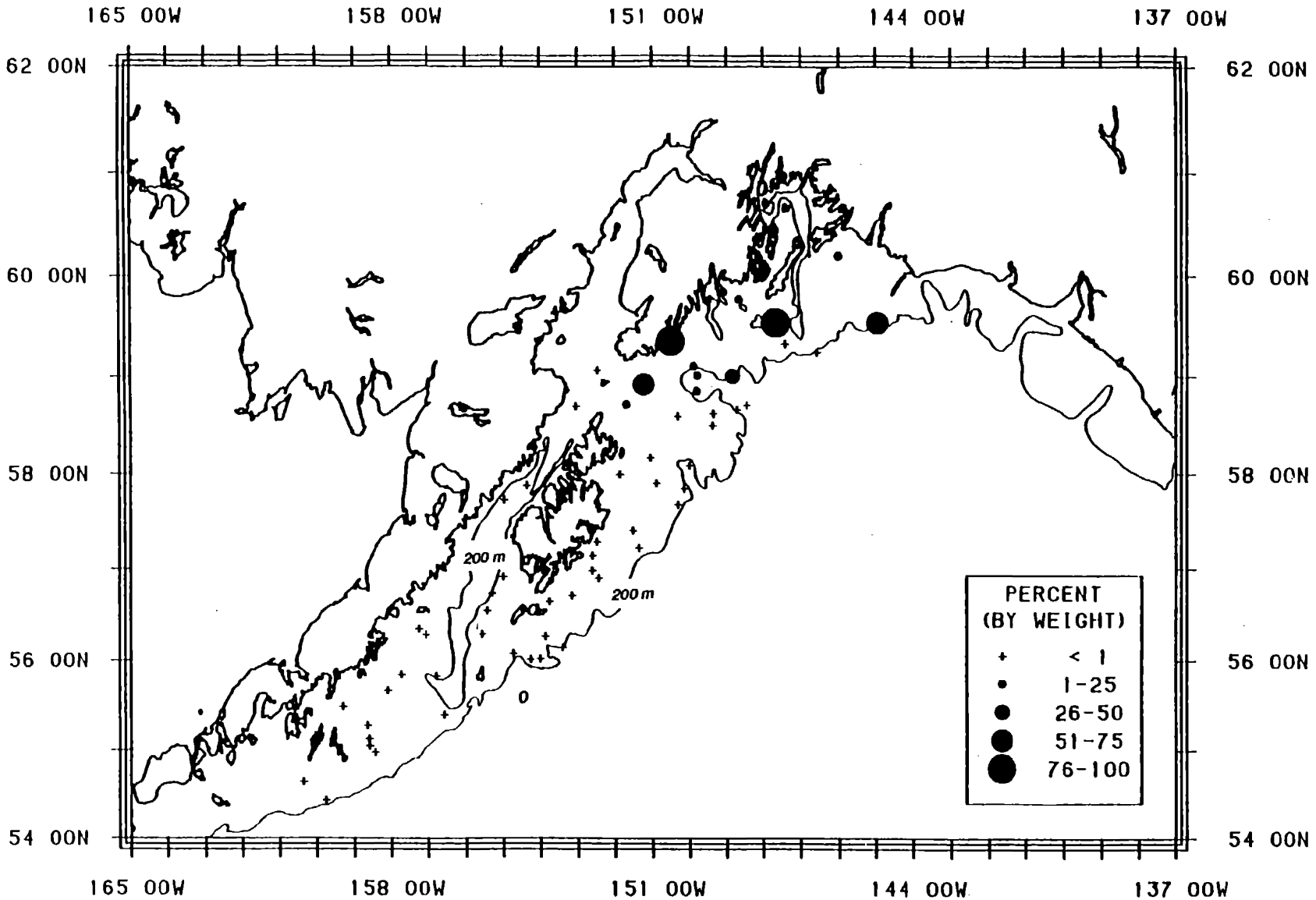

Figure 3-7.--Geographic distribution of Pacific herring consumed by arrowtooth flounder in the Gulf of Alaska in 1990.

CITATIONS

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PACIFIC HALIBUT

Pacific halibut (Hippoglossus stenolenis) had an exploitable biomass of 216,888 t in the Gulf of Alaska (3A, 3B, and 4A North Pacific Fishery Management Council Regulatory areas) in 1990 (P. J. Sullivan, International Pacific Halibut Commission, P.O. Box 95009, Seattle, WA 98145-2009. Pers. commun., September 1993). The commercial catch in the Gulf of Alaska area in 1990 was 23,836 t (data compiled from International Pacific Halibut Commission). Because the 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 Gulf of Alaska area.

RESULTS

General Diets

A total of 467 Pacific halibut stomachs were analyzed, of which 79 were empty and 388 (83%) contained food. The size range of the Pacific halibut was between 11 to 151 cm FL with a mean and SD of 71.5 + 25.9 cm. The average depth of the 71 haul locations was 109 + 48 m with a range from 20 to 234 m. Table 4-l lists the percent of frequency of occurrence, the percent by number, and the percent by weight of the prey found in Pacific halibut stomachs. Nearly 80% of the total stomach contents weight were fish and invertebrates comprised only 20% by weight. Walleye pollock (Theragra chalcogramma) was the. most important prey item. They were the most frequently occurring prey in the stomachs (28%). In terms of weight, they comprised

Table 4-l. --Prey items (expressed in percent frequency of occurrence, numerical percentage, and percent total weight) of Pacific halibut (Hippoglossus stenolepis) collected in the Gulf of Alaska in 1990.

'Prey Name	% Freq. occur.	% Number	% Total weight
Polychaeta (unidentified)	0.80	0.15	<0.01
Polynoidae (polychaete)	0.30	0.03	<0.01
Mollusca (unidentified)	0.50	0.06	0.05
Gastropoda (snail)	0.80	0.09	0.01
Modulus modulus (horse mussel)	0.80	0.21	0.03
Naticidae (snail)	0.30	0.03	<0.01
Fusitriton oregonensis (snail)	0.30	0.03	<0.01
Buccinum sp. (snail)	0.30	0.03	<0.01
Bivalvia (clam)	3.90	0.77	0.01
Nuculana fossa (clam)	1.80	3.31	0.03
Mytilidae (clam)	0.50	0.06	0.01
Teuthoidea (squid unidentified)	0.50	0.06	0.05
Gonatus magister (squid)	0.30	0.03	0.18
Octopoda (octopus)	7.20	1.18	4.77
Acanthomysis dybowskii (mysid)	0.30	0.06	<0.01
Holmesiella anomala (mysid)	0.80	0.02	0.01
Neomysis czerniawskii (mysid)	0.40	0.01	0.01
Diastylis sp. (cumacean)	1.30	31.01	0.01
Gammaridea (unidentified)	2.60	6.71	<0.01
Lysianassidae (amphipod)	0.30	0.06	<0.01
Pasiphaea pacifica (shrimp)	0.30	0.03	<0.01
Hippolytidae (shrimp)	0.50	0.06	<0.01
Spirontocaris sp. (shrimp)	0.30	0.03	<0.01
Spirontocaris lamellicornis (shrimp)	0.50	0.06	<0.01
Spirontocaris arcuata (shrimp)	0.30	0.06	0.01
Pandalidae (unidentified)	1.30	0.50	0.01
Pandalus borealis (northern shrimp)	0.80	0.12	0.02
Pandalus montagui tridens (shrimp)	0.50	0.09	0.01
Crangonidae (unidentified)	2.10	0.27	<0.01
Crangon alaskensis (shrimp)	0.30	0.03	<0.01
Crangon alba (shrimp)	0.50	0.15	0.01
Crangon dalli (shrimp)	0.30	0.03	<0.01
Crangon communis (shrimp)	0.50	0.71	0.02
Rhynocrangori alata (shrimp)	0.03	0.03	<0.01
Argis dentata (shrimp)	0.50	0.06	0.02
Argis levior (shrimp)	1.00	0.12	0.02
Paguridae (hermit crab)	23.50	4.11	1.29
Pagurus aleuticus (hermit crab)	0.50	0.06	0.02
Pagurus rathbuni (hermit crab)	0.50	0.06	0.02
Elassachirus tenuimanus (hermit crab)	2.50	1.03	0.13
Acantholithodes hispidus (crab)	0.50	0.06	0.04
Phyllolithodes papillosus (crab)	0.30	0.15	0.04

Table 4-l. --Continued.

Prey Name	% Freq. occur.	% Number	% Total weight
Lopholithodes mandtii (crab)	0.30	0.03	0.01
Lopholithodes foraminatus (crab)	0.30	0.06	0.53
Rhinolithodes wosnessenskii (crab)	0.30	0.03	<0.01
Munida quadrispina (crab)	0.30	0.03	<0.01
Majidae (unidentified)	0.30	0.03	<0.01
Oregonia gracilis (crab)	8.50	4.70	0.89
Hyas lyratus (crab)	17.00	6.06	2.72
Chionoecetes bairdi (Tanner crab)	17.60	8.10	5.96
Pugettia gracilis (crab)	0.30	0.03	<0.01
Cancer oregonensis (crab)	16.00	8.31	2.00
Pinnotheridae (crab)	0.50	0.06	<0.01
Echruoid (marine worm)	0.30	0.03	<0.01
Asteroidea (starfish)	0.30	0.03	<0.01
Holothuroidea (sea cucumber)	0.30	0.03	0.01
Teleostei (unidentified fish)	11.90	2.04	0.56
Non-gadoid fish remains	1.80	0.27	0.11
Oncorhynchus sp. (salmon)	0.30	0.03	0.16
Oncorhynchus kisutch (coho salmon)	0.30	0.06	5.15
Mallotus villosus (capelin)	14.20	6.03	0.89
Thaleichthys pacificus (eulachon)	0.30	0.03	0.02
Gadidae (gadid fish)	1.30	0.24	0.68
Gadus macrocephalus (Pacific cod)	0.50	0.06	0.98
Theragra chalcogramma (walleye pollock)	28.10	5.44	57.43
Lycodes brevipes (shortfin eelpout)	0.80	0.15	0.11
Lycodes palearis (wattled eelpout)	1.30	0.27	0.31
Scorpaenidae (unidentified)	0.30	0.03	<0.01
Sebastes alutus (Pacific ocean perch)	0.30	0.03	0.34
Cottidae (unidentified)	2.40	0.36	0.11
Artediellus sp. (sculpin)	0.30	0.03	<0.01
Hemilepidotus sp. (sculpin)	0.30	0.06	0.30
Hemilepidotus jordani (sculpin)	0.80	0.18	0.02
Icelinus borealis (northern sculpin)	1.30	0.21	0.03
Malacocottus kincaidi (blackfin sculpin)	0.30	0.03	<0.01
Triglops pingeli (ribbed sculpin)	0.30	0.06	0.05
Agonidae (poacher)	0.30	0.03	<0.01
Agoplagonus inermis (fish)	0.30	0.03	0.01
Sarritor frenatus (sawback poacher)	1.80	0.27	0.02
Cyclopteridae (snailfish)	0.30	0.03	<0.01
Liparis sp. (snailfish)	0.30	0.03	0.06
Bathymaster signatus (searcher)	0.80	0.09	0.06
Stichaeidae (prickleback)	1.80	0.33	0.06
Zaprora silenus (prowfish)	0.30	0.03	0.03
Ammodytes hexapterus (Pacific sand lance)	6.20	1.57	0.62
Pleuronectidae (flatfish)	4.10	0.52	0.83
Atheresthes stomias (arrowtooth flounder)	3.90	0.62	4.16

Table 4-l. --Continued.

Prey Name	% Freq. occur.	% Number	% Total weight
Hippoglossoides elassodon (flathead sole)	0.10	0.12	0.56
Pleuronectes bilineatus (rock sole)	0.30	0.03	0.13
Pleuronectes asper (yellowfin sole)	0.30	0.06	0.01
Microstomus pacificus (Dover sole)	0.30	0.03	0.03
Hippoglossoides stenolepis (Pacific halibut)	0.80	0.09	<0.01
Fishery discards	2.10	0.47	7.07

Total prey count	3,383
Total prey weight	50,417 g
Number of stomachs with food	388
Number of empty stomachs	79

57% of the total stomach contents. Coho salmon (Oncorhynchus kisutch) made up 5% of the total stomach contents by weight, but they did not often occur in the Pacific halibut sampled. Capelin (Mallotus villosus) were consumed quite frequently (14%) but they comprised less than 1% of the total stomach contents weight. Other commercially important fish consumed by Pacific halibut include Pacific cod (Gadus macroceDhalus), eulachon (Thaleichthvs pacificus), Pacific sand lance (Ammodvtes hexapterus), Pacific ocean perch (Sebastes alutus), arrowtooth flounder (Atheresthes stomias), flathead sole (Hippoglossides elassodon), rock sole (Pleuronectes bilineatus), yellowfin sole (Pleuronectes asper), Dover sole (Microstomus pacificus), and young Pacific halibut. Pacific halibut also consumed 7%, by weight, of fishery discards (processed fish carcasses). Many non-commercially important fish (cottids, agonids, cyclopterids, bathymasterids, and stichaeids) were also consumed by Pacific halibut; however, they played a minor role as food of the Pacific halibut.

Tanner crabs (Chionoecetes bairdi) were the most important invertebrate prey of Pacific halibut; they comprised about 6% of the total stomach contents weight. Less important invertebrate prey included octopus (4.8%), lyre crab (Hyas lyratus) (2.7%), cancer crab (Cancer oregonensis) (2%), hermit crab (1.3%), and decorator crab (Oresonia gracilis) (1%). All of the other invertebrates consumed (polychaetes, gastropods, clams, squid, shrimp, and other crustaceans) were found less frequently and were considered to be relatively less important as food of Pacific halibut.

Variation of Diet Based on Predator Size

The diet of Pacific halibut varies greatly by predator size (Fig. 4-l). Miscellaneous prey fish (mainly capelin, Pacific sand lance, cottids, zoarcids, stichaeids, and flatfish) were important food for Pacific halibut between 30 and 70 cm FL long, whereas walleye pollock were mainly consumed by Pacific halibut greater than or equal to 80 cm FL. Crabs (Tanner crabs, decorator crabs, lyre crabs, and cancer crabs) were the main food of Pacific halibut between 50 and 80 cm FL (they comprised more than 40% by weight of the total stomach contents weight in this size group). Hermit crabs (pagurids) were important food (225% by weight) for Pacific halibut less than 60 cm FL, especially for fish less than 30 cm long. Cephalopods (mainly octopus) were important food for fish less than 40 cm FL.

Sizes of the Commercially Important Prey Consumed

The prey length data of the Pacific halibut were divided by predator size into two groups (<80 cm and 280 cm FL) for analysis (Figs. 4-2 to 4-4). Figure 4-2 (left) shows that walleye pollock consumed by Pacific halibut less than 80 cm were mainly age-0 (<140 mm SL) fish plus a few age-l to age-3 fish. The larger-sized Pacific halibut (<80 cm) consumed many different sizes of walleye pollock including both pre-recruits (<300 mm SL) and recruits (>300 mm SL). Figure 4-2 (top left) shows that most pre-recruit pollock consumed were age-l and age-2 fish, whereas most recruited pollock consumed were age-3 and age-4 fish. A few large pollock (250 cm SL) were consumed by some Pacific halibut larger than 100 cm FL; one 151 cm female Pacific halibut consumed

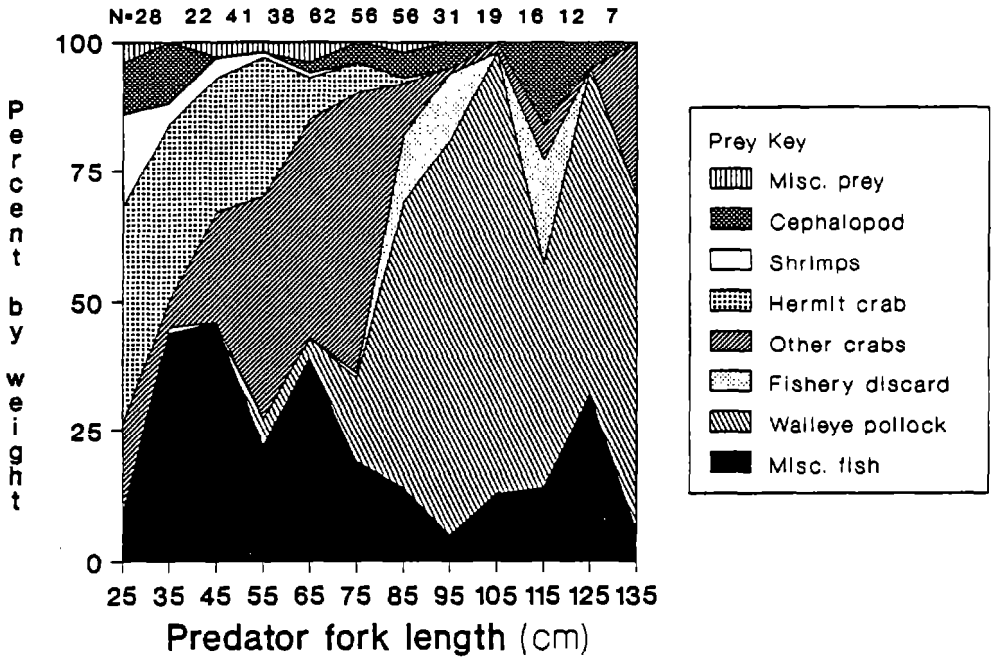

Figure 4-1. --Variation in the main food items of Pacific halibut, by predator size, in the Gulf of Alaska in 1990. N = sample size.

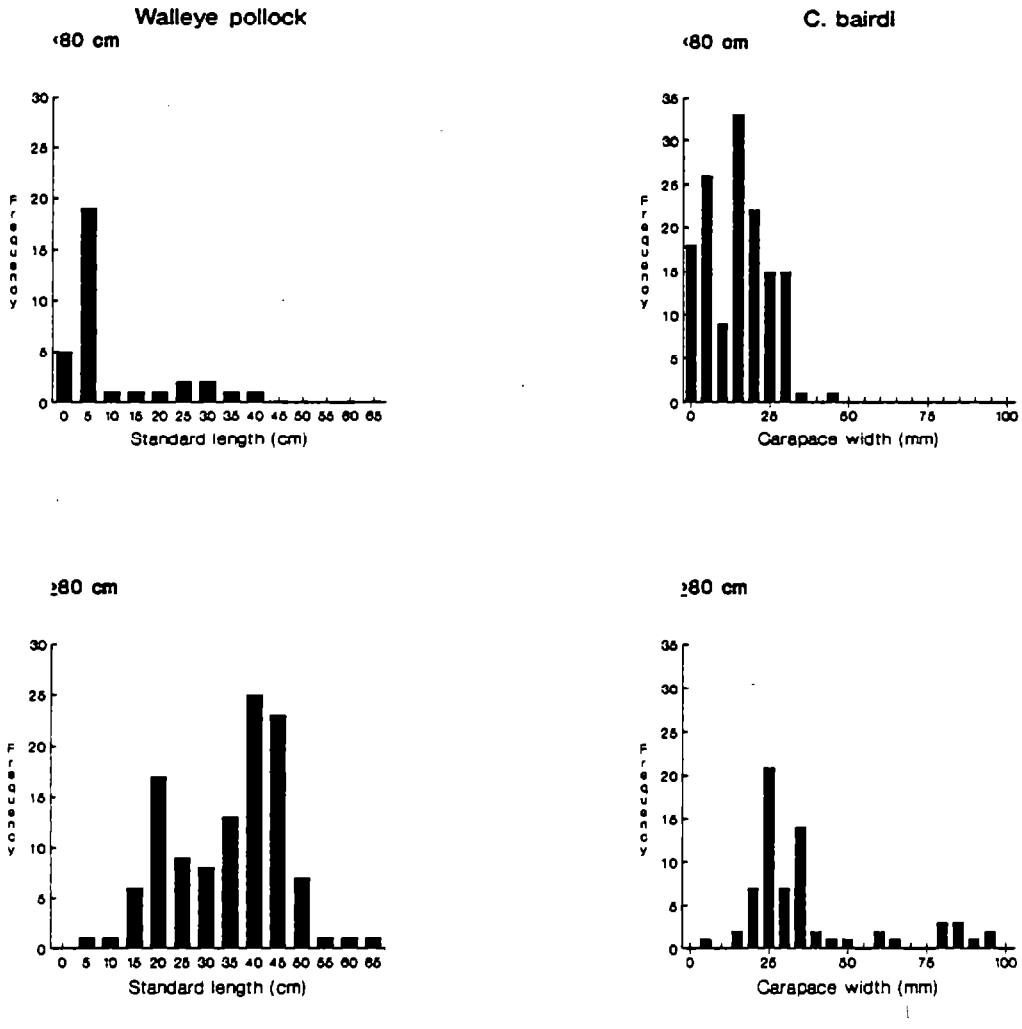

Figure 4-2 .--Size frequency distributions of walleye pollock and Tanner crabs consumed by two size groups of Pacific halibut in the Gulf of Alaska in 1990.

a 670 mm walleye pollock. The average (mean + SD) standard length of pollock consumed by Pacific halibut was 315.9 + 155.0 mm with a range from 34 to 670 mm long. The relationship between the Pacific halibut size and the size of the pollock they consumed is shown in Figure 4-5.

The size of Chionoecetes bairdi consumed by Pacific halibut less than 80 cm (Fig. 4-2, top right) were mainly age-0 (<9 mm CW) and age-l (9-34 mm CW) crabs, whereas large Pacific halibut (180 cm) consumed mainly age-l C. bairdi and some age-2 and older crabs (Fig. 4-2, bottom right). The mean CW of the C. bairdi consumed 24.7 + 18.0 mm with a range from 3 to 97 mm.

Figure 4-3 shows that large Pacific halibut consumed more larger-sized arrowtooth flounder. Consumption of capelin occurred mainly in smaller (<80 cm FL) Pacific halibut, and only a few were found in large (280 cm) Pacific halibut (Fig. 4-4, left). The mean SL of the capelin consumed was 78.8 + 15.3 mm with a range from 46 to 108 mm. Figure 4-4 (right) shows that the Pacific sand lance consumed by Pacific halibut were mainly between 100 and 150 mm SL. They had a mean SL of 136.5 + 26.5 mm with a range from 55 to 187 mm.

Pacific halibut also consumed two coho salmon (450 and 500 mm SL, respectively), one Pacific cod (380 mm SL), one eulachon (120 nun SL), one Pacific ocean perch (208 mm SL), four flathead sole (58, 101, 147, and 280 mm SL), one rock sole (160 mm SL), two yellowfin sole (61, 64 mm SL), one Dover sole (105 mm SL.), and two Pacific halibut larvae (21 and 30 mm SL).

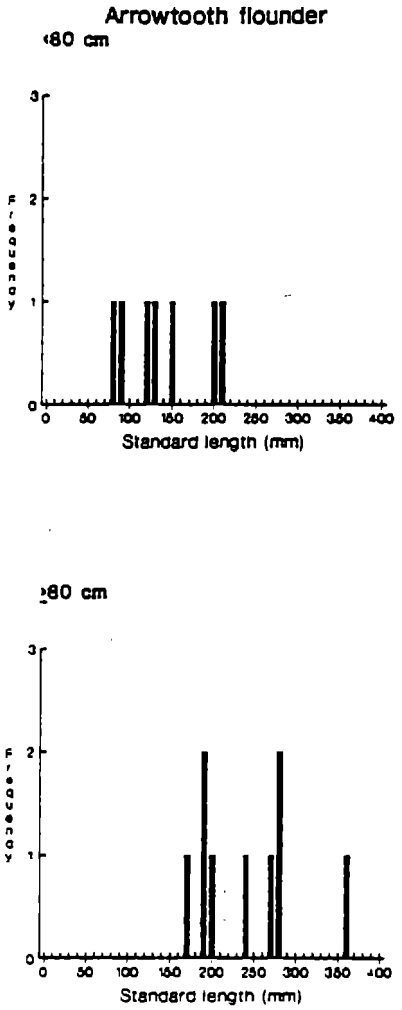

Figure 4-3.--Size frequency distributions of arrowtooth flounder consumed by two size groups of Pacific halibut in the Gulf of Alaska in 1990.

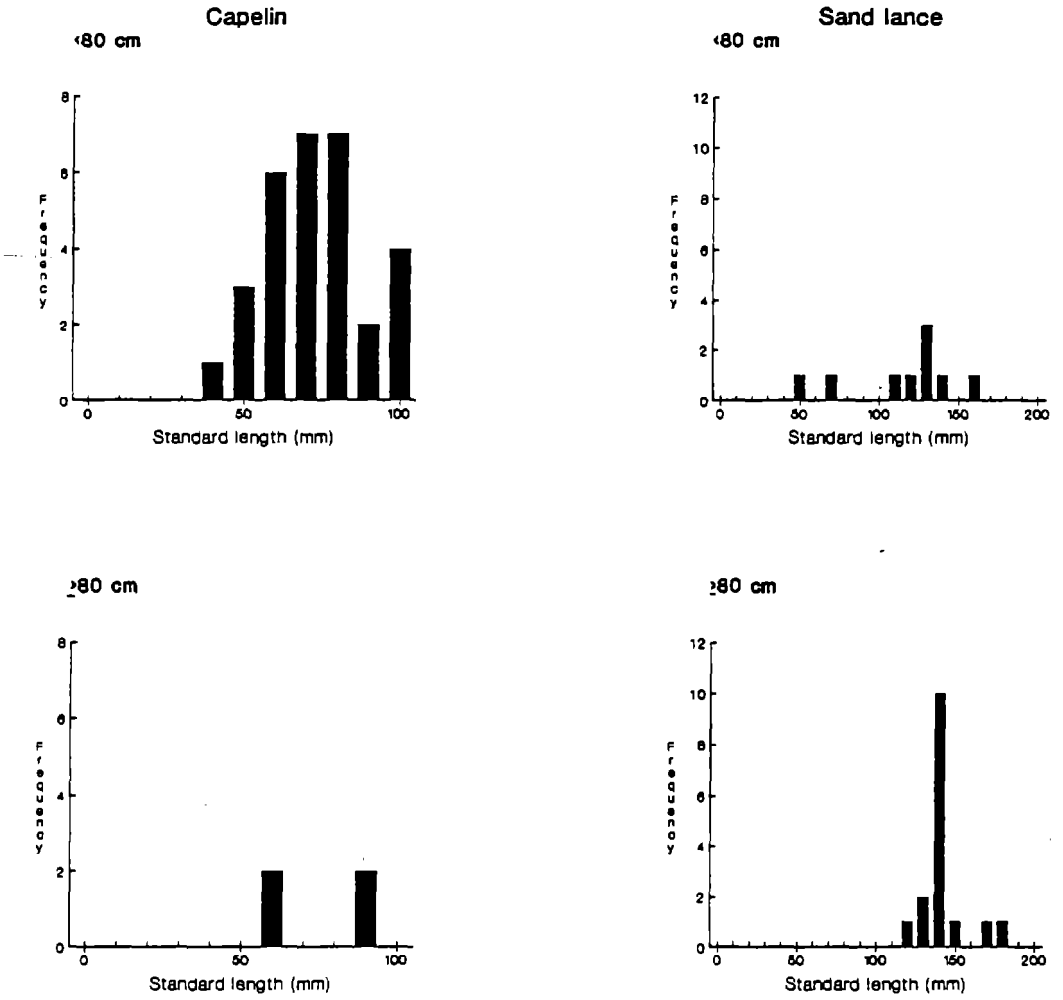

Figure 4-4. --Size frequency distributions of capelin and Pacific sand lance consumed by two size groups of Pacific halibut in the Gulf of Alaska in 1990.

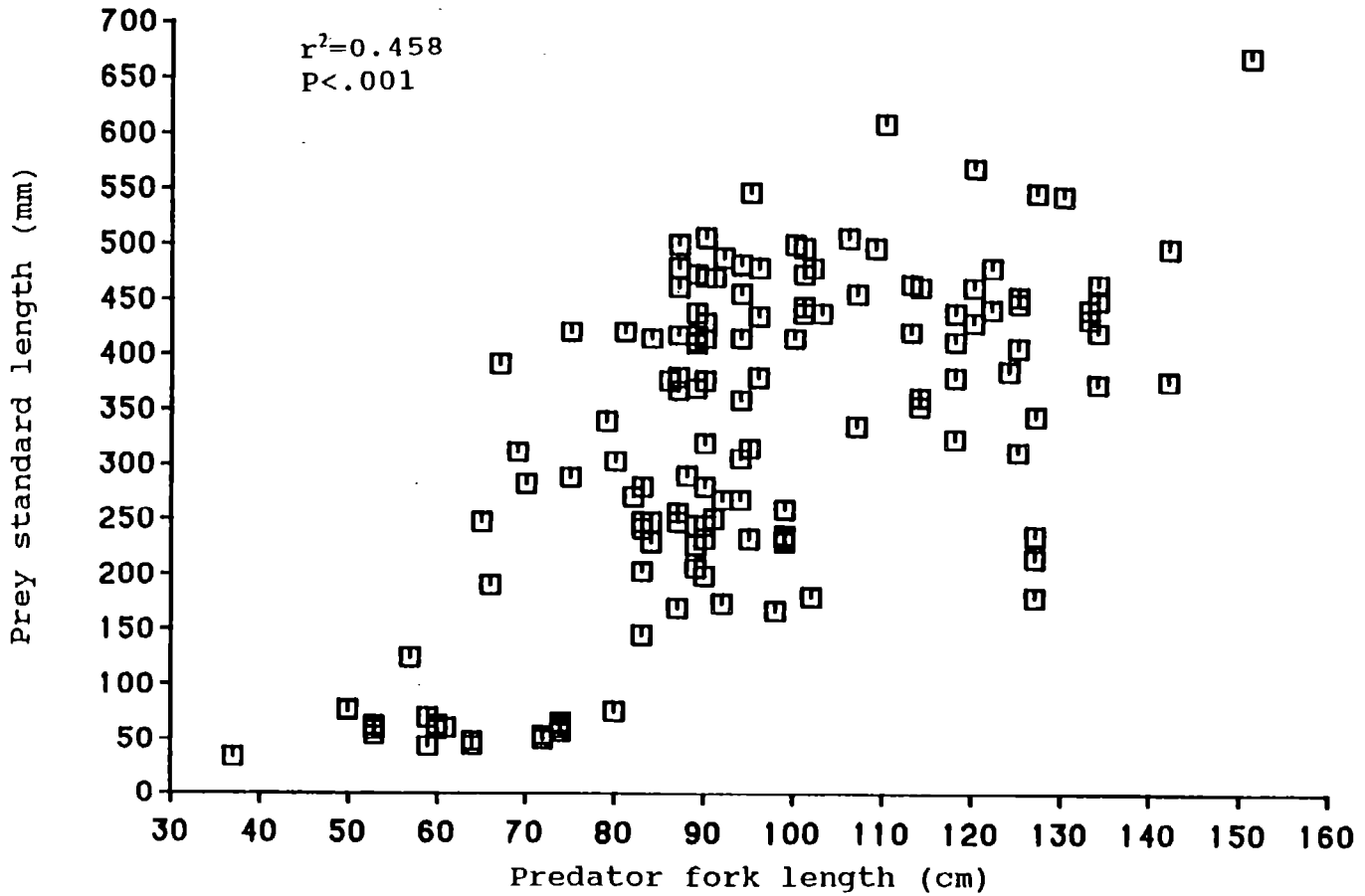

Figure 4-5. --Relationship between the Pacific halibut fork length (cm) and the walleye pollock standard length (mm) in the Gulf of Alaska in 1990.

Geographic Distributions of the Prey Consumed

The distributions of the commercially important prey consumed by Pacific halibut are shown in Figures 4-6 to 4-14. Figure 4-6 illustrates that walleye pollock were consumed by Pacific halibut at most of the survey stations, and the percent by weight of the pollock in most of the stations was high (>75%). Capelin were consumed by Pacific halibut primarily in the areas to east and southeast of Kodiak Island (Fig. 4-7). The amount of capelin consumed in each station was low (<25%). Tanner crabs were also consumed in the Kodiak area (Fig. 4-8). Pacific sand lance were only found in samples from areas southwest of Kodiak Island (Fig. 4-9). Figure. 4-10 shows that the arrowtooth flounder consumed by Pacific halibut were found mainly around the Kodiak area. The locations where Pacific halibut consumed coho salmon, Pacific cod, and Dover sole are shown in Figures 4-11 to 4-13, respectively. Figure 4-14 shows the locations where fishery discards (mainly fish carcasses) were consumed by Pacific halibut.

DISCUSSION

The earlier food habits studies of Pacific halibut showed that the diet was primarily composed of fish, crustaceans, and mollusks (Novikov 1968). Novikov found that, in the Bering Sea area, the frequency of occurrence and the species composition of the diet depended on the locations inhabited and the size of the Pacific halibut. The smaller fish (<30 cm) fed mainly on crustaceans. The medium-sized fish (30-60 cm) switched to feed

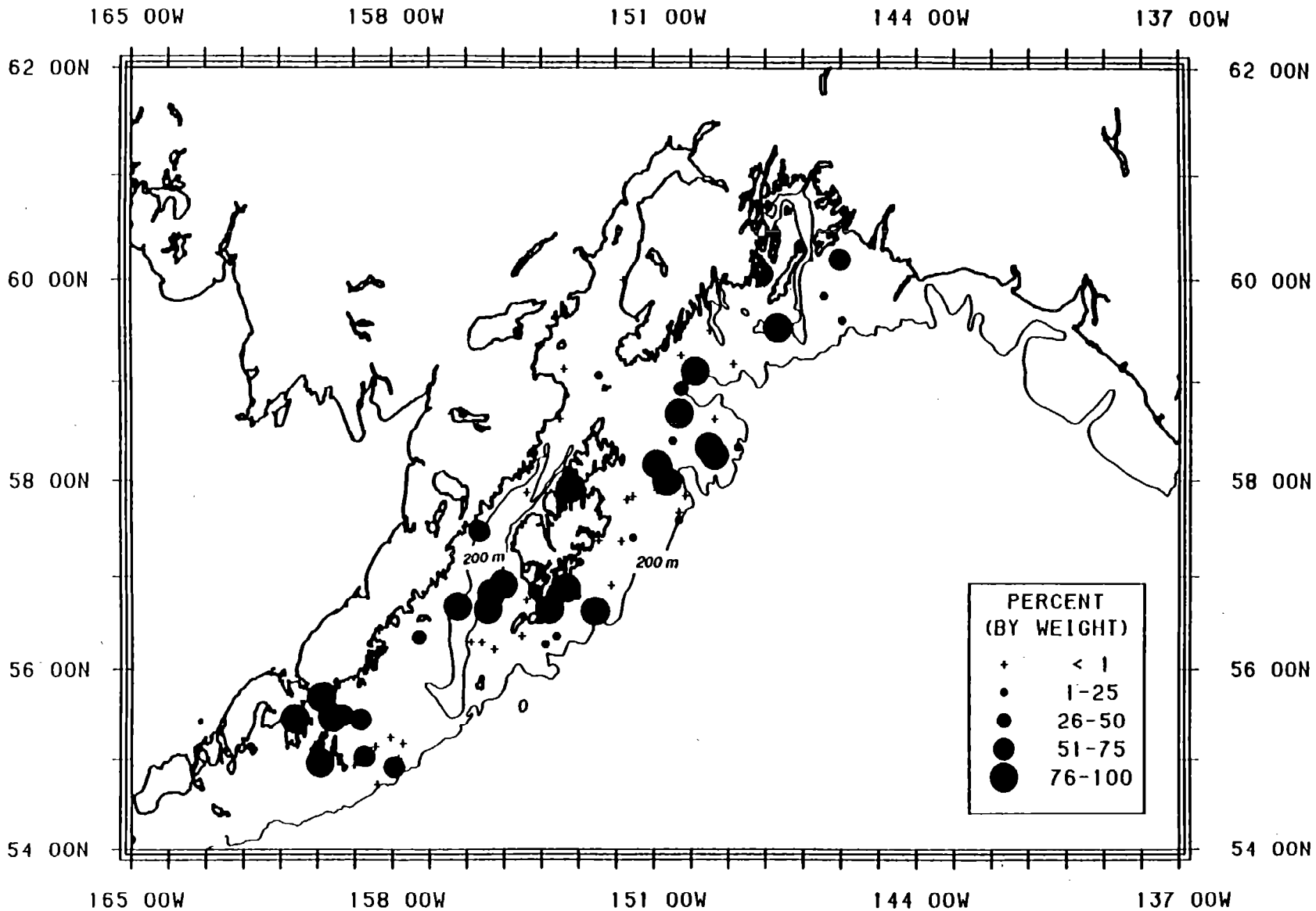

Figure 4-6. --Geographic distribution of walleye pollock consumed by Pacific halibut in the Gulf of Alaska in 1990.

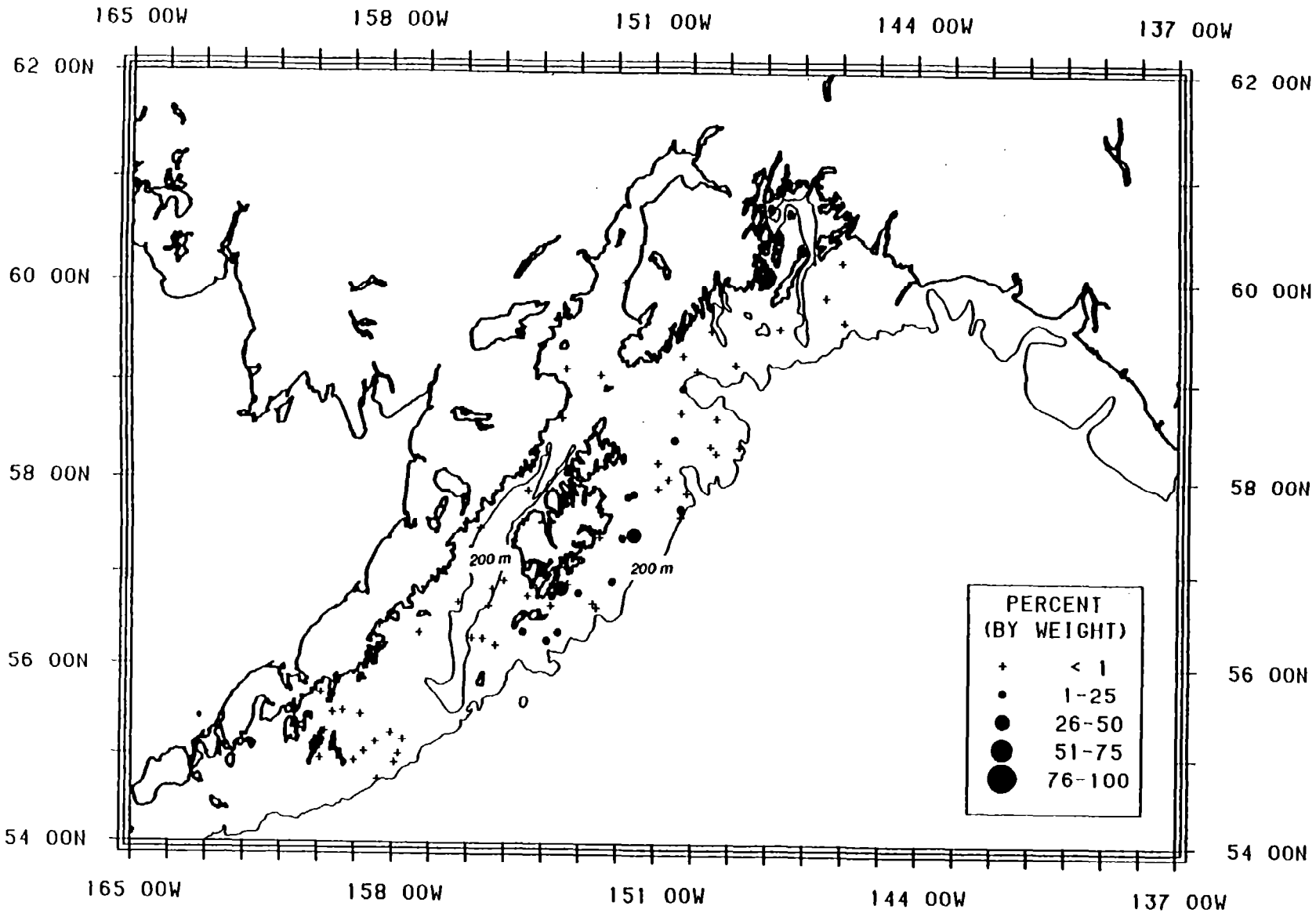

Figure 4-7 .--Geographic distribution of capelin consumed by Pacific halibut in the Gulf of Alaska in 1990.

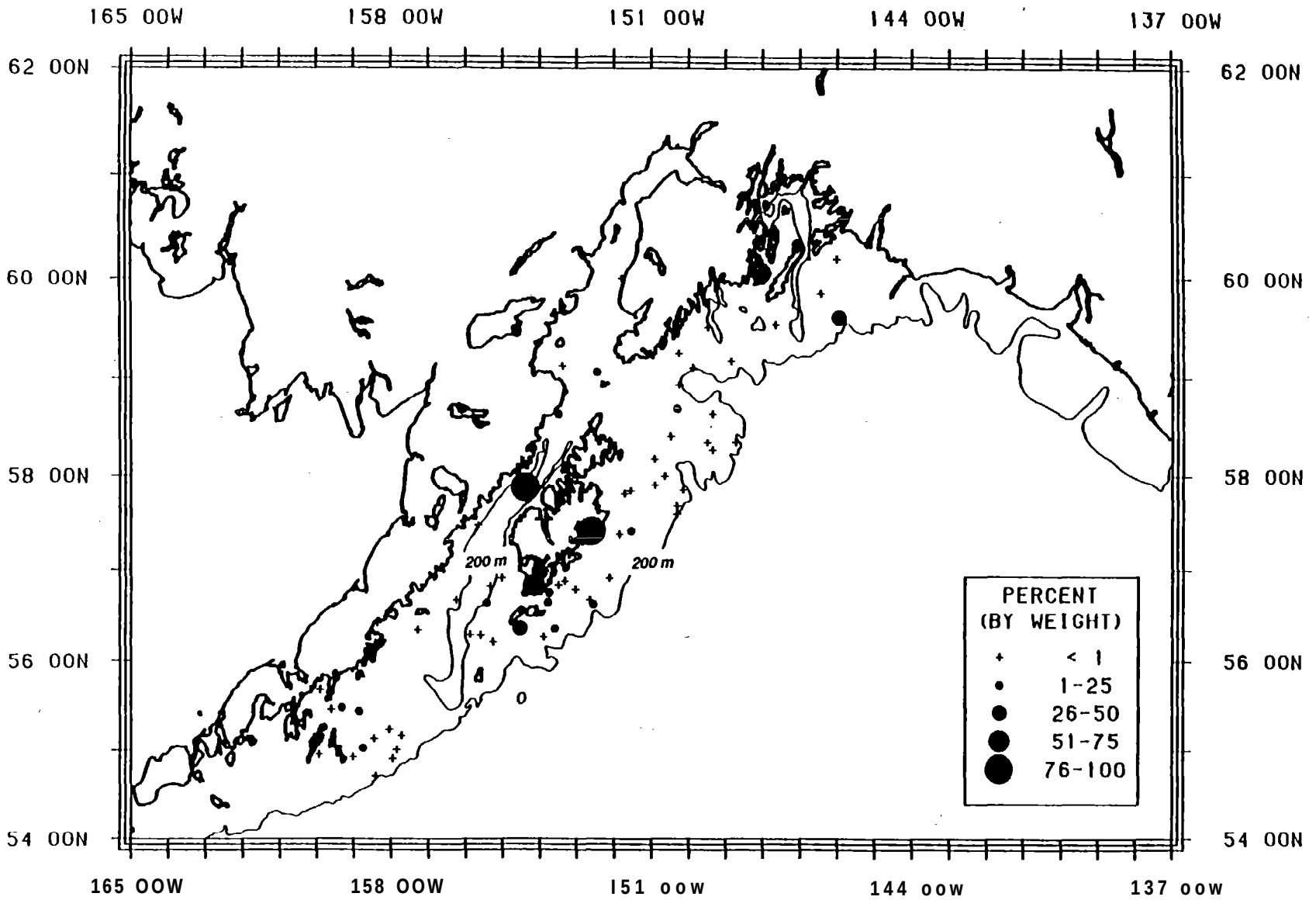

Figure 4-0. --Geographic distribution of Tanner crabs (Chionoecetes bairdi) consumed by Pacific halibut in the Gulf of Alaska in 1990.

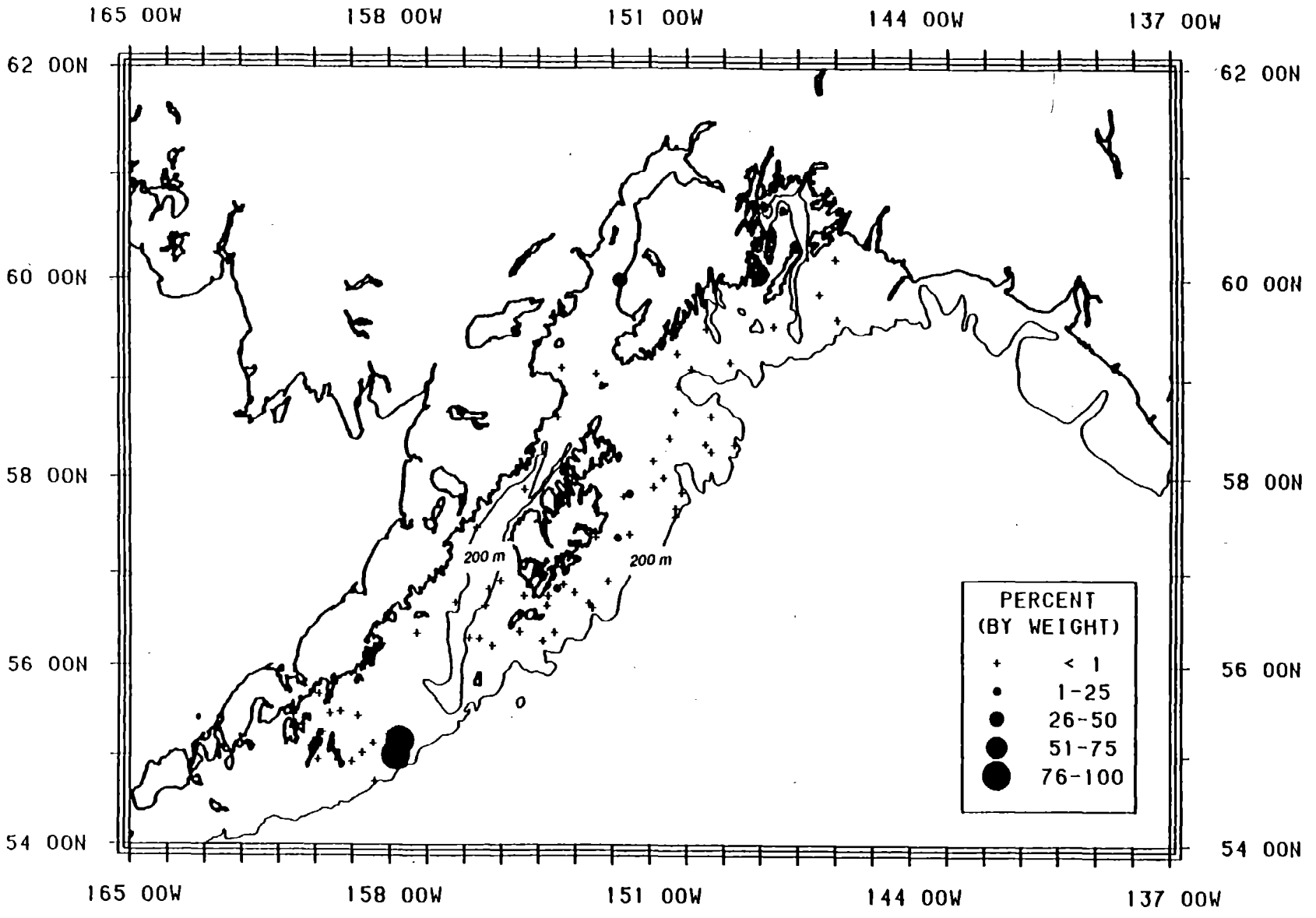

Figure 4-9.--Geographic distribution of Pacific sand lance consumed by Pacific halibut in the Gulf of Alaska in 1990.

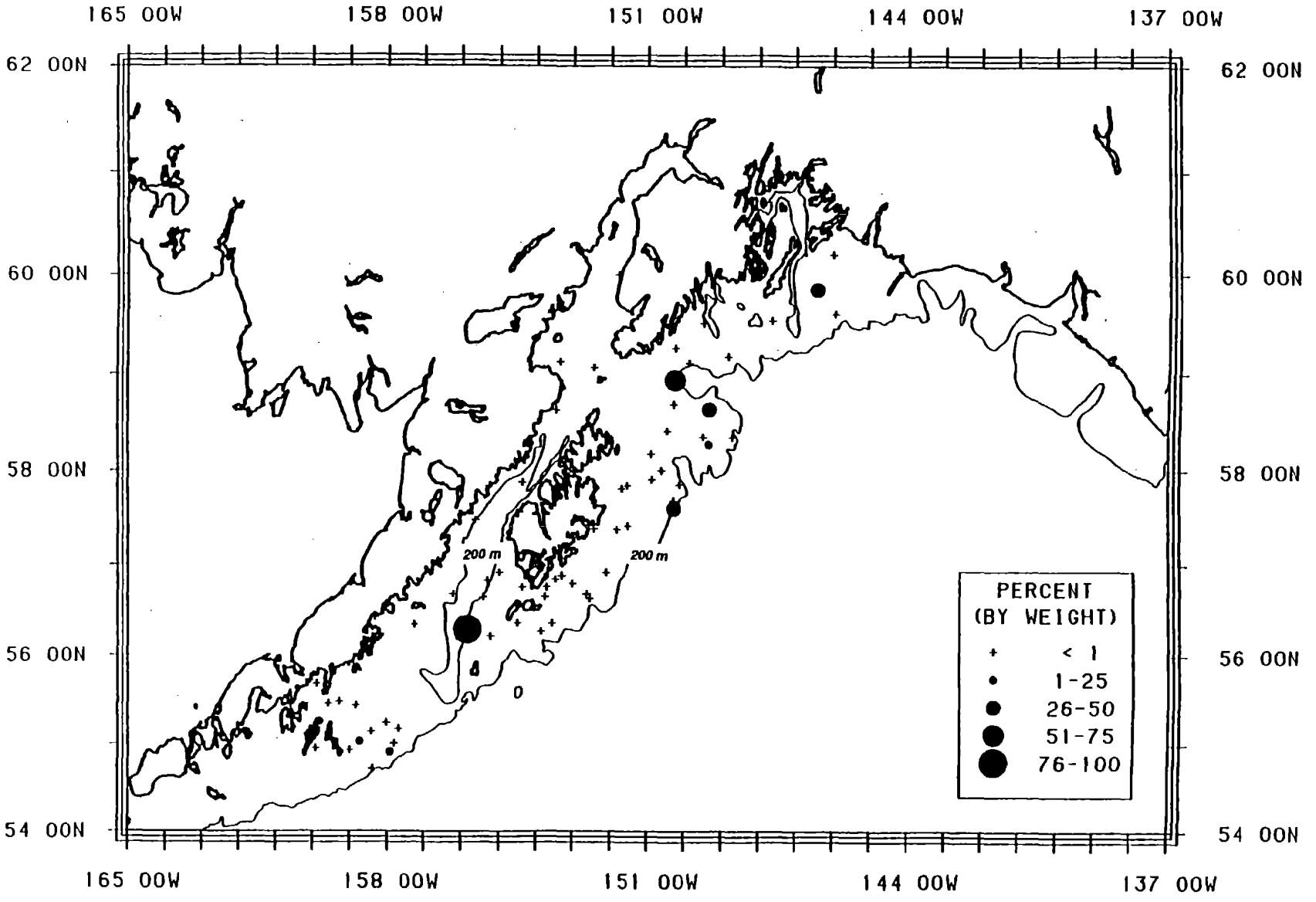

Figure 4-10.--Geographic distribution of arrowtooth flounder consumed by Pacific halibut in the Gulf of Alaska in 1990.

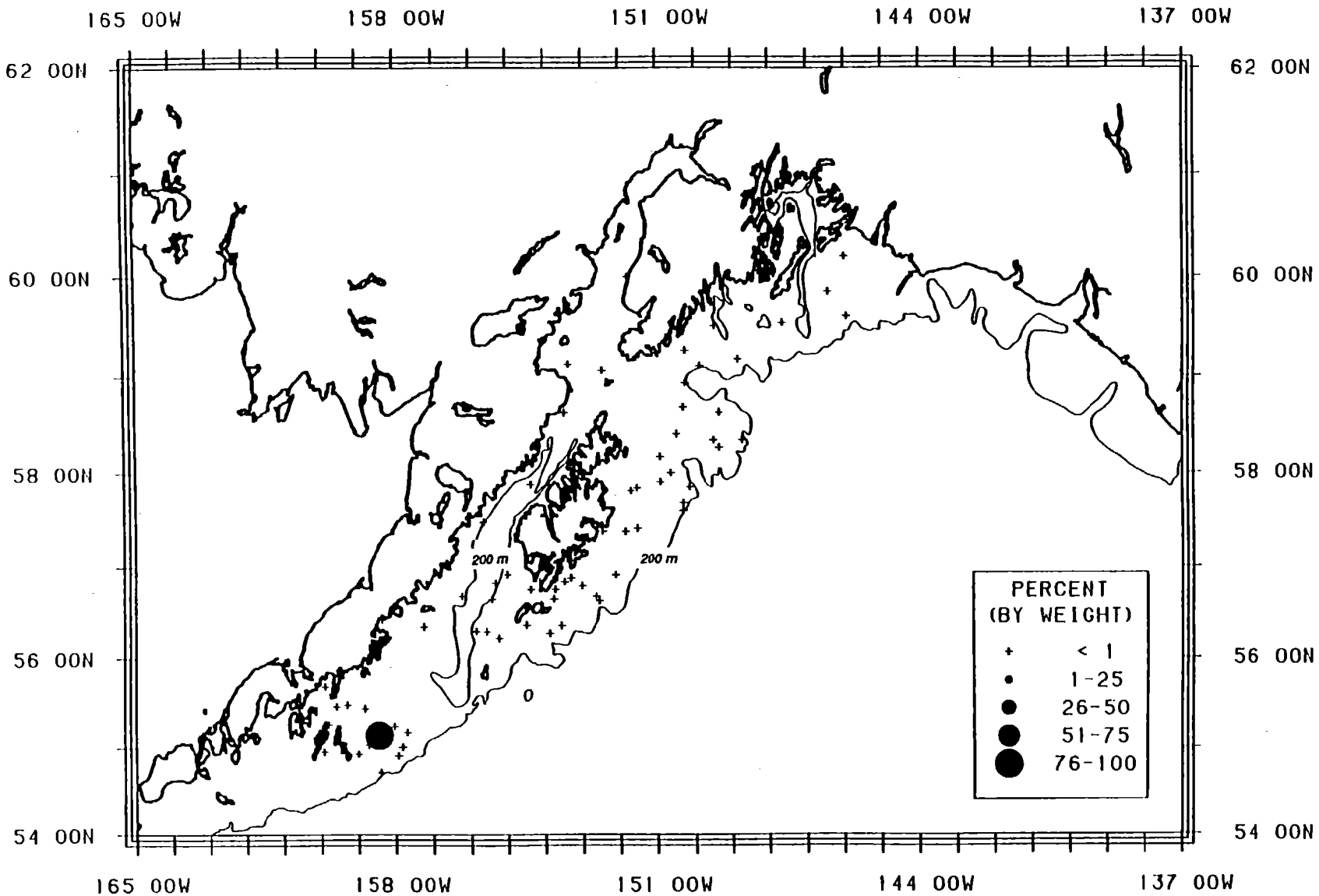

Figure 4-11.--Geographic distribution of coho salmon consumed by Pacific halibut in the Gulf of Alaska in 1990.

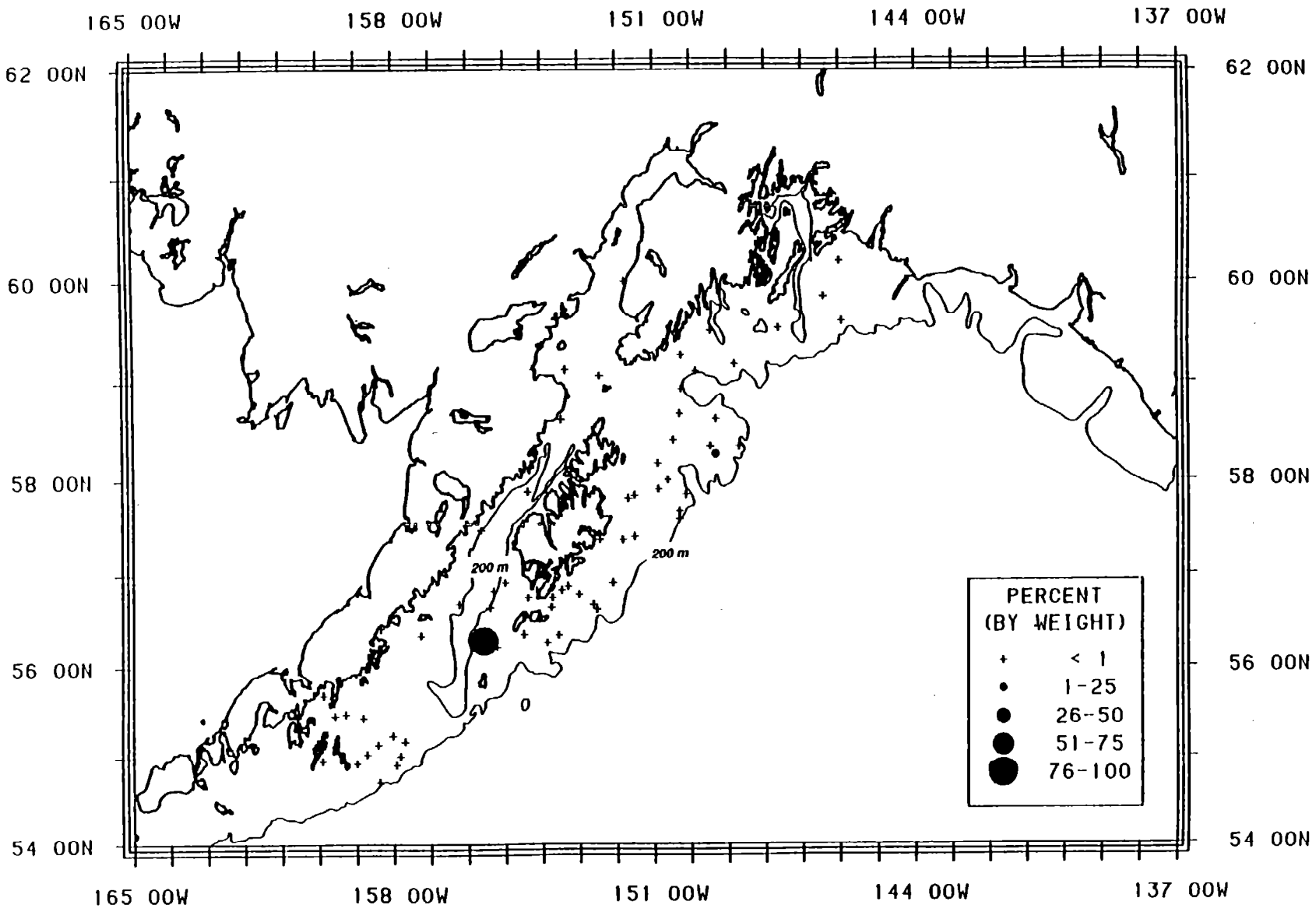

Figure 4-12.--Geographic distribution of Pacific cod consumed by Pacific halibut in the Gulf of Alaska in 1990.

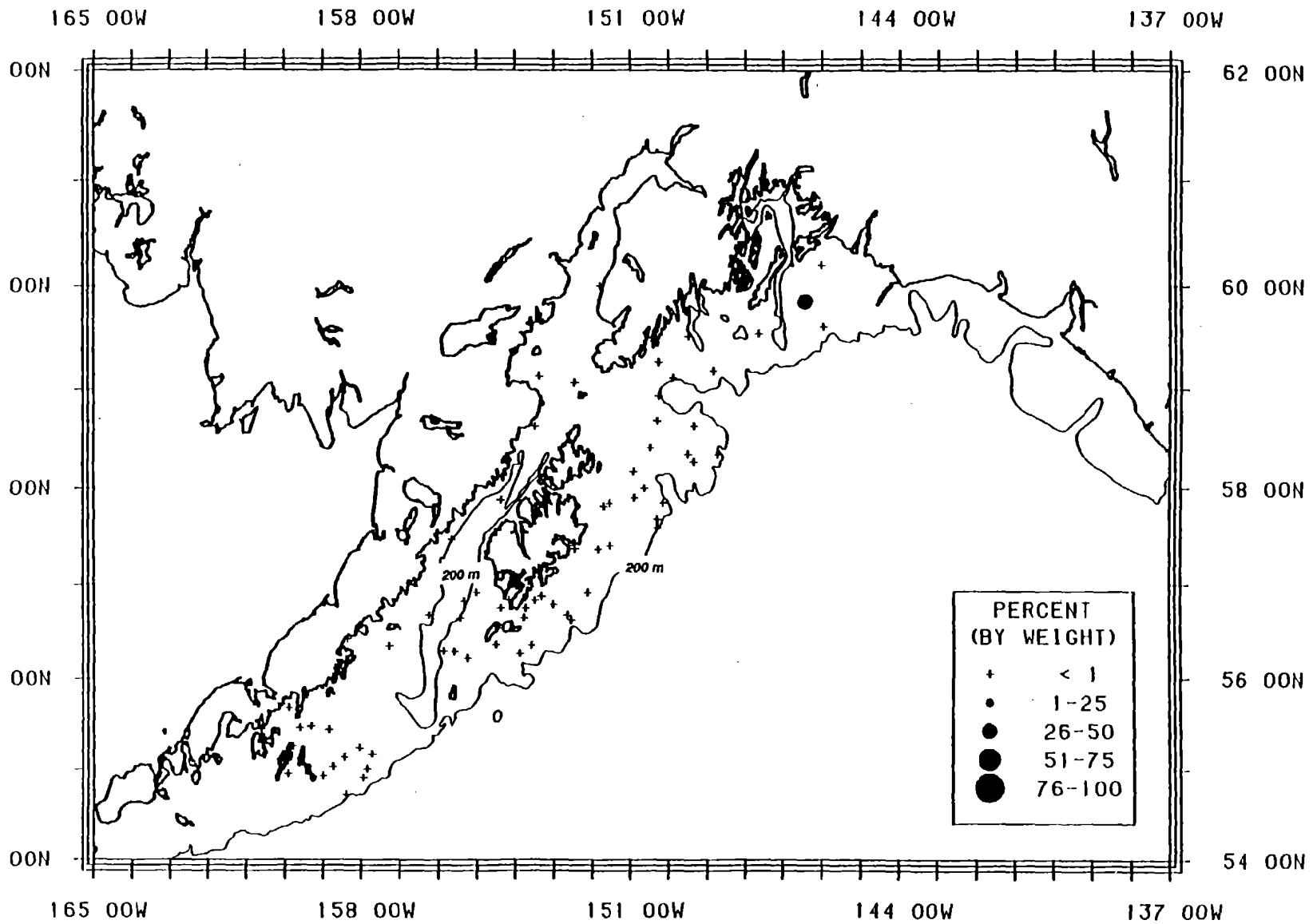

Figure 4-13.--Geographic distribution of Dover sole consumed by Pacific halibut in the Gulf of Alaska in 1990.

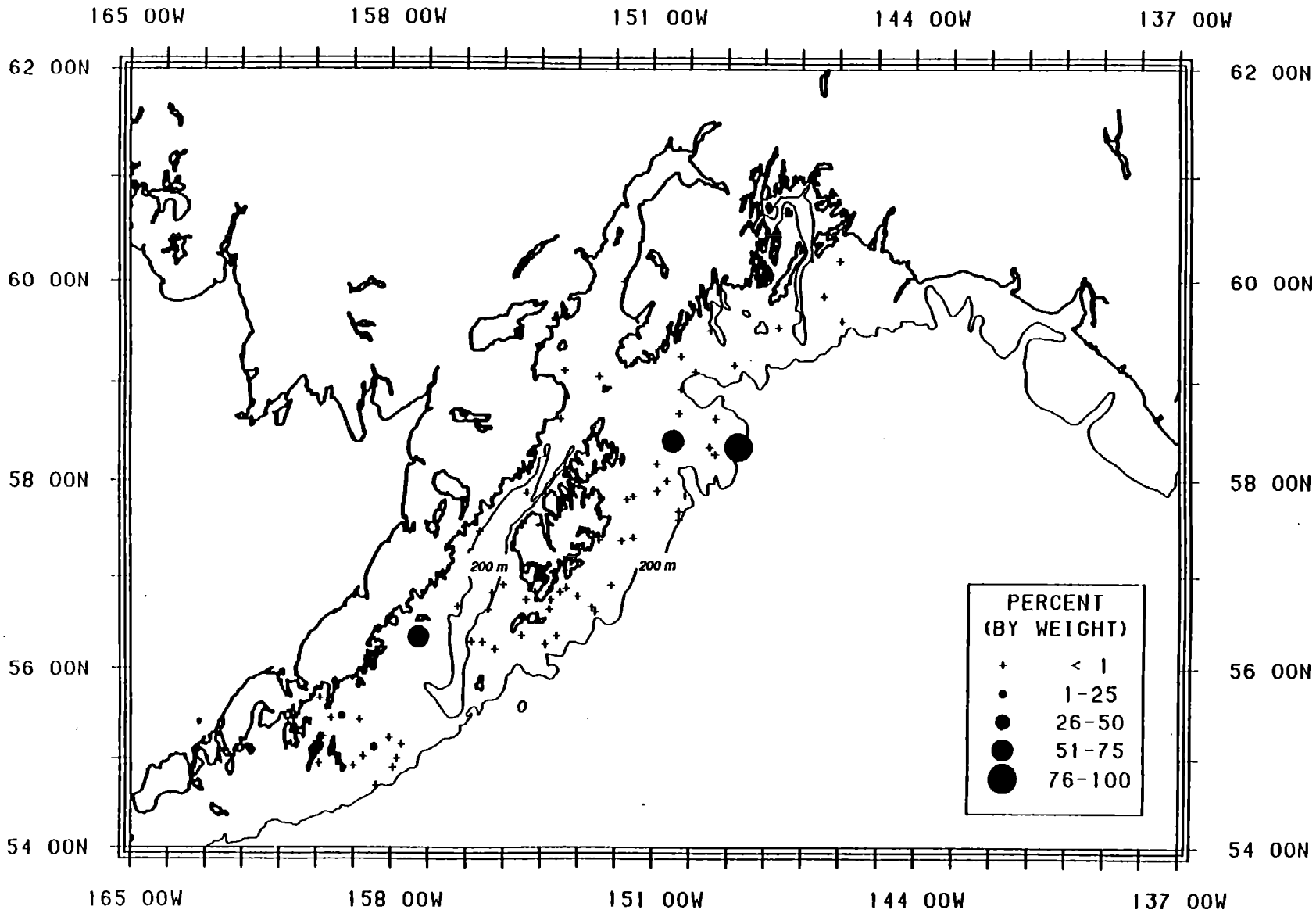

Figure 4-14.--Geographic distribution of fishery discard consumed by Pacific halibut in the Gulf of Alaska in 1990.

on larger crustaceans and fish. Pacific halibut larger than 60 cm fed mainly on fish. Novikov also pointed out the importance of some flatfish as prey of Pacific halibut, especially the connection between the yellowfin sole and the Pacific halibut. Livingston et al. (1993) also reported that, in addition to the large amount of walleye pollock, Tanner crabs, and snow crabs (Chionoecetes opilio) consumed, Pacific halibut also consumed relatively high proportions of Pacific cod, yellowfin sole, and flathead sole in some areas in the eastern Bering Sea.

Best and Pierre (1986) analyzed the stomach contents of Pacific halibut collected in the Gulf of Alaska and characterized the species as opportunistic feeders. When Pacific halibut are young, they feed mainly on crustaceans. The Pacific halibut's diet changes to primarily fish as they grow and increase in size. They found that walleye pollock, Pacific sand lance, octopus, and Tanner crabs were the main food of the Pacific halibut.

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Novikov, N. P. 1968. Basic elements of the biology of the Pacific halibut (Hippoglossoides Hippoglossoides stenolepis Schmidt) in the Bering Sea. In: Sov. Fish. Inv. N. Pac. Pt. II, 175-219. Isr. Prog. Sci. Transl. TT67-51204. Available from the Department of Commerce, Clearinghouse for Federal Scientific and Technical Information, Springfield, VA 22151.

SABLEFISH

Sablefish, Anoplonoma fimbria, ranked sixth in total groundfish biomass in the Gulf of Alaska in 1990 with an exploitable biomass of 226,000 t (North Pacific Fishery Management Council 1991). Annual catches of sablefish from 1986 to 1990 ranged from 20,000 to 30,000 t (Fujioka 1990). Sablefish has been found to feed opportunistically on fish, crustaceans, and worms (Grinols and Gill 1968). Because sablefish is an important commercial species and it probably feeds on some other commercially important fish, it is included in this study on food habits and potential impacts on the other marine fishes in the Gulf of Alaska.

RESULTS

General Diets

A total of 331 sablefish stomachs were analyzed, of which 92 were empty and 239 (72%) contained food. Sablefish ranged in size from 40 cm to 80 cm FL with a mean and of 60.3 and + 9.1 cm, respectively. The average depth of the 40 haul locations sampled was 201 + 63 m with a range from 101 to 432 m. Table 5-l lists the percent frequency of occurrence, the percent by number, and the percent by weight of the prey items found in sablefish stomachs. Approximately 74% of the weight of the total stomach contents was fish, with invertebrates making up only one-quarter of the total stomach contents weight. Walleye pollock was the predominate fish-prey consumed by sablefish. Pollock comprised about 24% by weight of the total sablefish stomach contents.

Table 5-l.--Prey items (expressed in percent frequency of occurrence, numerical percentage, and percent total weight) of sablefish (Anonloooma fimbria) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Number	% Total weight
Scyphozoa (jellyfish)	20.50	0.63	5.35
Polychaeta (worm)	0.80	0.02	0.05
Gastropoda (snail)	0.80	0.02	0.08
Bivalvia (clam)	0.40	0.01	0.03
Teuthoidea (squid unidentified)	2.10	0.05	0.26
Berryteuthis magister (squid)	1.70	0.04	7.77
Octopoda (octopus)	0.40	0.01	0.01
Calanoida (copepod)	3.30	0.14	0.01
Mysidacea (unidentified)	2.90	0.68	0.02
Holmesiella anomala (mysid)	0.80	0.02	0.01
Neomysis czerniawskii (mysid)	0.40	0.01	0.01
Diastylis sp. (cumacean)	0.40	0.01	0.01
Gammaridea (unidentified)	12.10	0.87	0.06
Themisto sp. (amphipod)	13.40	0.90	0.01
Themisto abyssorum (amphipod)	0.80	0.09	0.01
Euphausiacea (unidentified)	19.70	73.82	4.86
Thysanoessa inermis (euphausiid)	13.00	19.77	1.80
Caridea (unidentified shrimp)	0.40	0.01	0.01
Pasiphaea pacifica (shrimp)	1.70	0.04	0.12
Eualus avinus (shrimp)	0.40	0.01	0.01
Pandalidae (unidentified)	8.80	0.26	0.65
Pandalus borealis (northern shrimp)	11.70	0.33	1.95
Pandalus goniurus (shrimp)	2.10	0.05	0.27
Pandalopsis dispar (sidestripe shrimp)	1.70	0.04	0.71
Crangonidae (unidentified)	1.70	0.04	0.02
Crangon communis (shrimp)	0.40	0.01	0.01
Paguridae (hermit crab)	3.30	0.08	0.61
Majidae (decorator crab)	0.80	0.02	0.12
Chionoecetes bairdi (Tanner crab)	3.00	0.07	0.42
Sipuncula (marine worm)	0.80	0.02	0.10
Sagitta sp. (arrow worm)	0.80	0.03	0.01
Teleostei (unidentified fish)	15.10	0.34	4.08
Non-gadoid fish remains	0.80	0.02	0.04
Clupea pallasi (Pacific herring)	3.30	0.10	2.21
Mallotus villosus (capelin)	1.30	0.03	0.33
Thaleichthys pacificus (eulachon)	2.90	0.10	5.53
Stenobrachius leucopsarus (myctophid)	0.40	0.31	0.17
Gadidae (gadid fish)	10.50	0.31	7.67
Gadus macrocephalus (Pacific cod)	0.40	0.01	0.83
Theragra chalcogramma (walleye pollock)	9.60	0.24	23.95
Zoarcidae (eelpout)	0.80	0.04	0.12
Cottidae (sculpin)	0.40	0.01	0.12

Table 5-l. --Continued.

Prey Name	% Freq. occur.	% Number	% Total weight
Hemitripterus bolini (bigmouth sculpin)	0.80	0.02	0.05
Cyclopteridae (snailfish)	1.30	0.05	0.03
Stichaeidae (prickleback)	0.80	0.02	0.02
Ammodytes hexapterus (Pacific sand lance)	0.40	0.01	0.08
Pleuronectidae (flatfish)	0.40	0.01	0.05
Fishery discards	12.10	0.38	29.08

Total prey count	10,493
Total prey weight	4,354 g
Number of stomachs with food	239
Number of empty stomachs	92

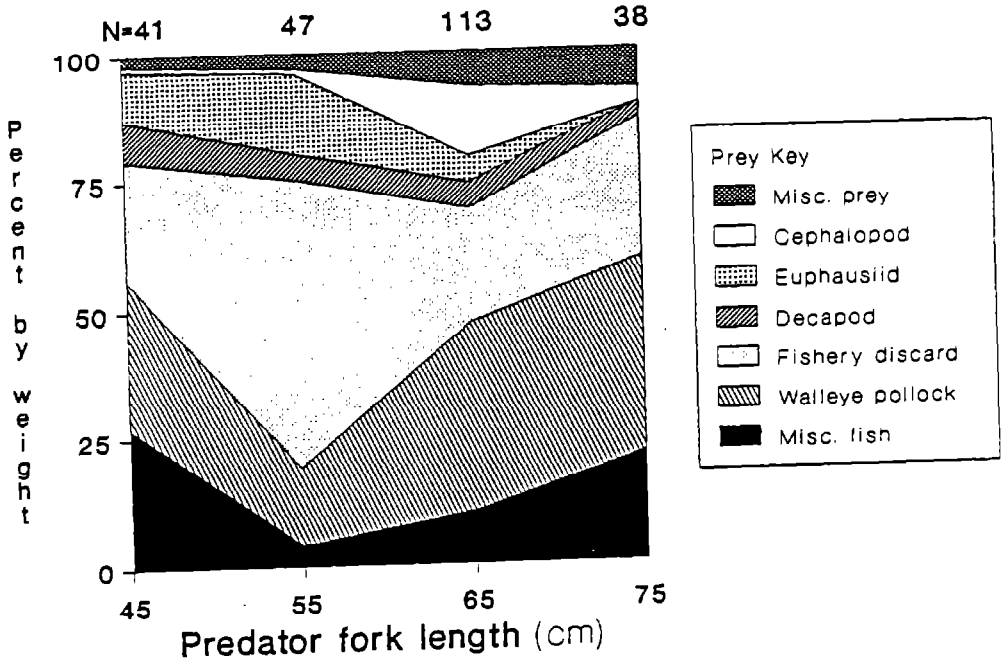

Figure 5-l. --Variations in the main food items of sablefish, by predator size, In the Gulf of Alaska in 1990.
N = sample size.

40 cm FL were available. Figure 5-1 illustrates that the diet did not vary much by size of sablefish for the fish examined in this study. Cephalopods (14%) were primarily consumed by the 60-69 cm FL size group and more euphausiids and decapods were consumed by the two smaller-sized groups (40-49 cm and 50-59 cm FL). The miscellaneous fish category comprised higher percentages in both the smallest size group (40-49 cm FL) and largest size group (<70 cm FL). Sablefish 50-59 cm FL consumed a high percentage (56%) of fishery discards, though all other size-groups also consumed a fairly large amount (about 20% by weight) of fishery discard. Walleye pollock were consumed more by the two larger size groups (60-69 cm and >70 cm FL) than the two smaller size groups.

Sizes of the Commercially Important Prey Consumed

The prey length data of the sablefish were divided by predator size into less than 55 cm and greater than or equal to 55 cm size groups for analysis (Fig. 5-2). Figure 5-2 (left) shows that walleye pollock consumed by both size groups were mainly the pre-recruits (<300 mm SL), though the larger size group also consumed a few pollock greater than or equal to 400 mm. The average (mean + SD) SL of pollock consumed by sablefish was 234.9 1 124.9 mm with a range from 56 to 445 mm. The relationship between the size of the sablefish and the size of the pollock that they consumed is shown in Figure 5-3.

The size of the eulachon consumed by sablefish is shown in Figure 5-2 (right). It shows that sablefish less than 55 cm FL only consumed smaller eulachon (<l00 mm SL), whereas larger

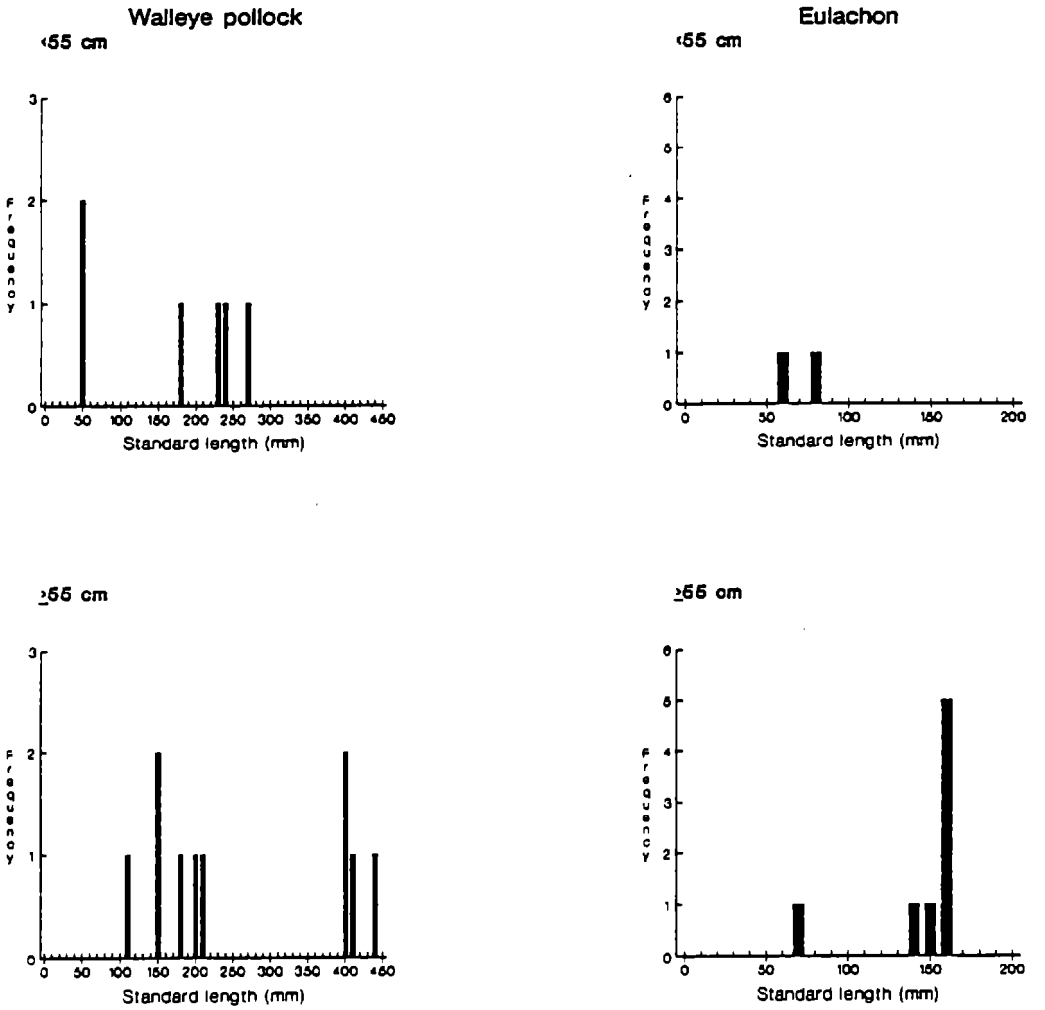

Figure 5-2.--Size frequency distributions of walleye pollock and eulachon consumed by two size groups of sablefish in the Gulf of Alaska in 1990.

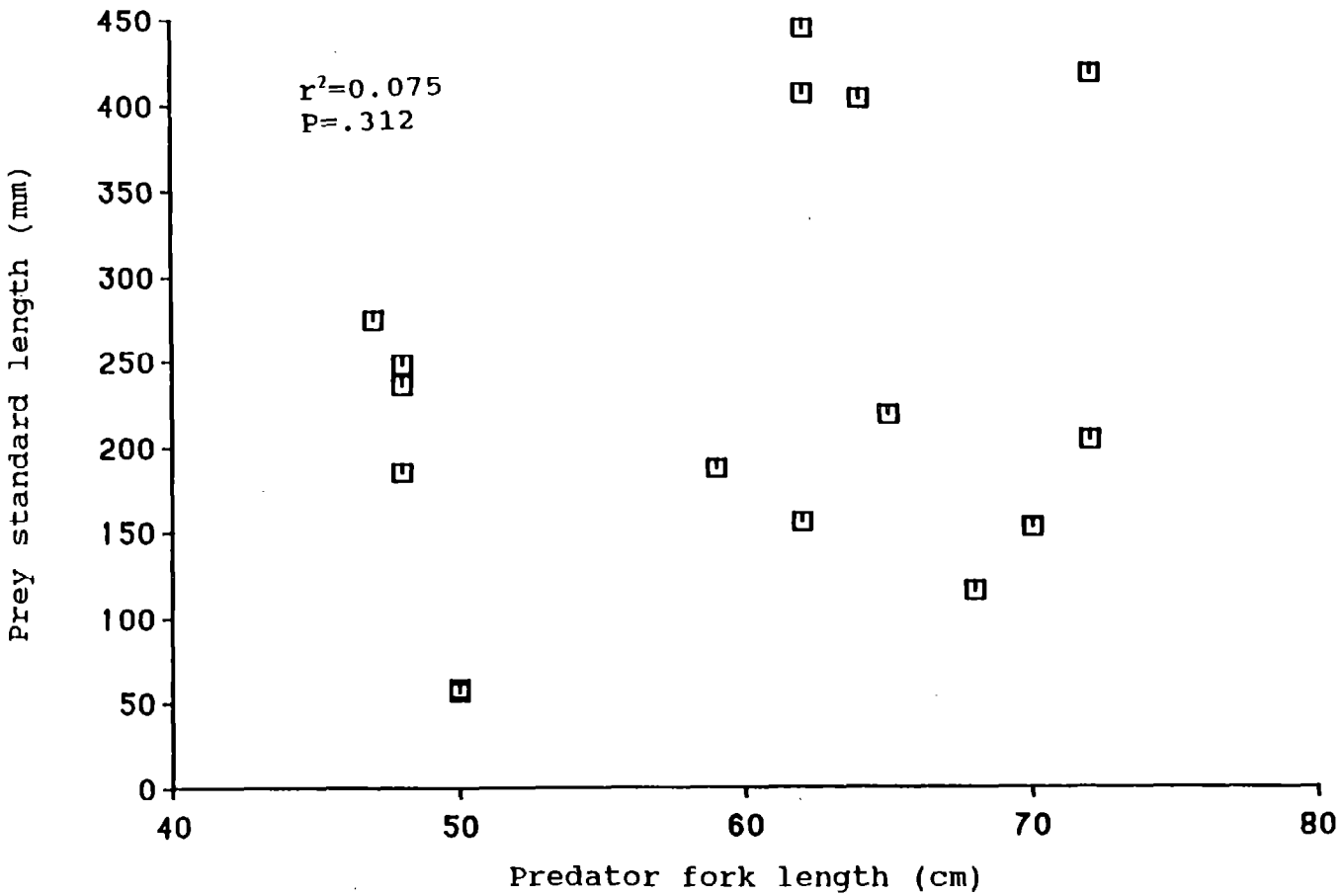

Figure 5-3. --Relationship between the sablefish fork length (cm) and the walleye pollock standard length (mm) in the Gulf of Alaska in 1990.

sablefish (>55 cm FL) also consumed some larger eulachon (about 150 mm SL). The average length of the eulachon consumed was 134.1 +. 41.0 mm SL with a range from 68 to 165 mm SL.

Sablefish also consumed three capelin (82, 96, 106 mm SL), two Pacific herring (154 and 170 mm SL), one Pacific sand lance (97 mm SL), and three Tanner crabs (5, 21, 54 mm CW).

Geographic Distributions of the Prey Consumed

The distributions of the commercially important prey consumed by sablefish are shown in Figures 5-4 to 5-7. Figure 5-4 shows that walleye pollock were consumed by sablefish at many of the sampled stations, and that the percent by weight in many stations was high (>50%). Figure 5-5 illustrates that capelin were consumed by sablefish in quite a few stations even though they usually did not comprise a high proportion of the stomach contents at any station. The distribution of the consumption of Tanner crabs by sablefish is shown in Figure 5-6. Even though Tanner crabs were consumed at only two stations, their high percentages of occurrence in stomach contents indicates that they were heavily targeted by the sablefish in those areas. The consumption of fishery discard by sablefish was primarily distributed around Kodiak Island (Fig. 5-7).

DISCUSSION

Shubnikov (1963) found that fish (including pollock, capelin and herring) made up the major part of the Bering Sea sablefish diet in spring and autumn; during the summer months the sablefish switch to a diet including shrimp, jellyfish, and some benthic

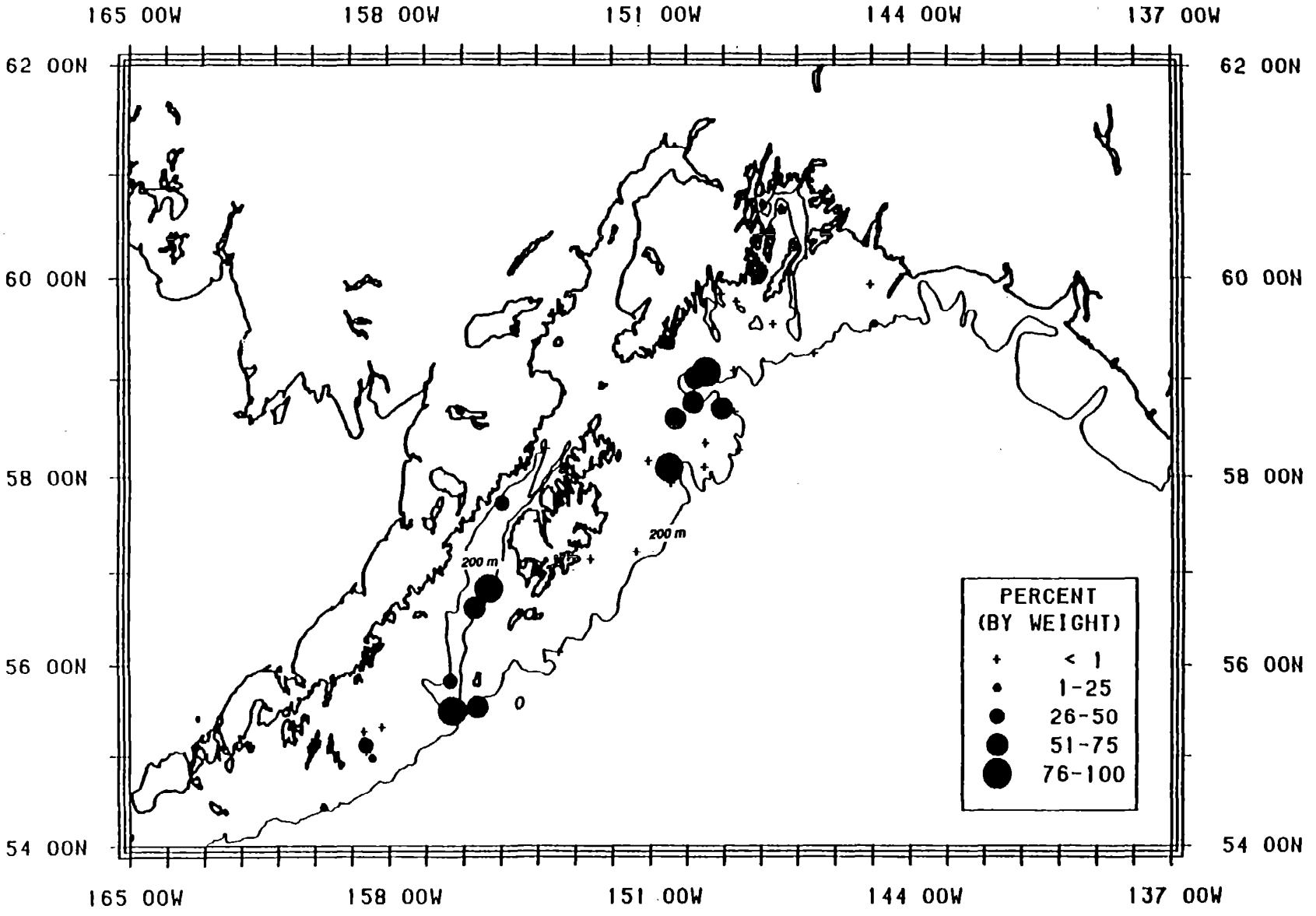

Figure 5-4. -,-Geographic distribution of walleye pollock consumed by sablefish in the Gulf of Alaska in 1990.

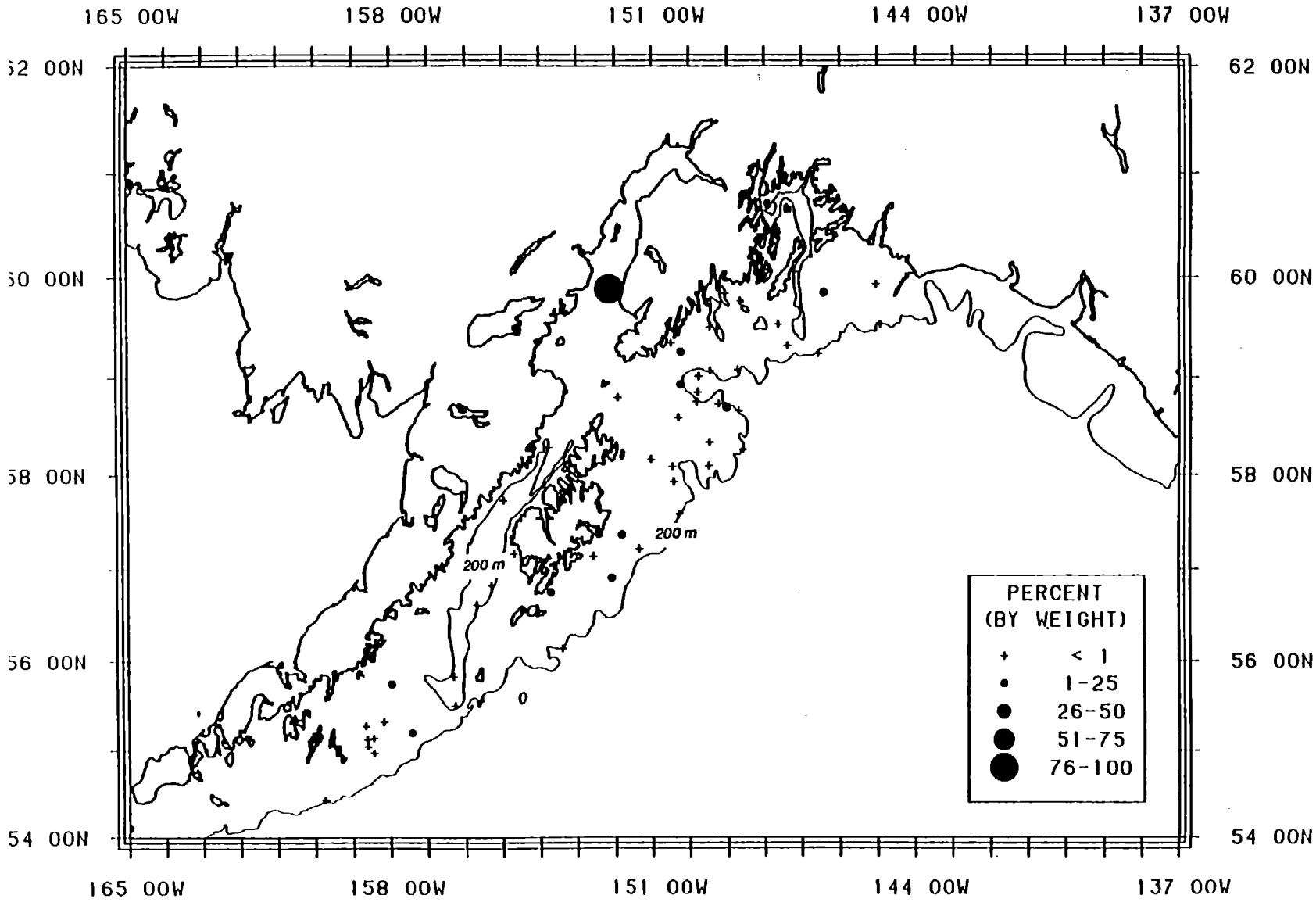

Figure 5-5.--Geographic distribution of capelin consumed by sablefish in the Gulf of Alaska in 1990.

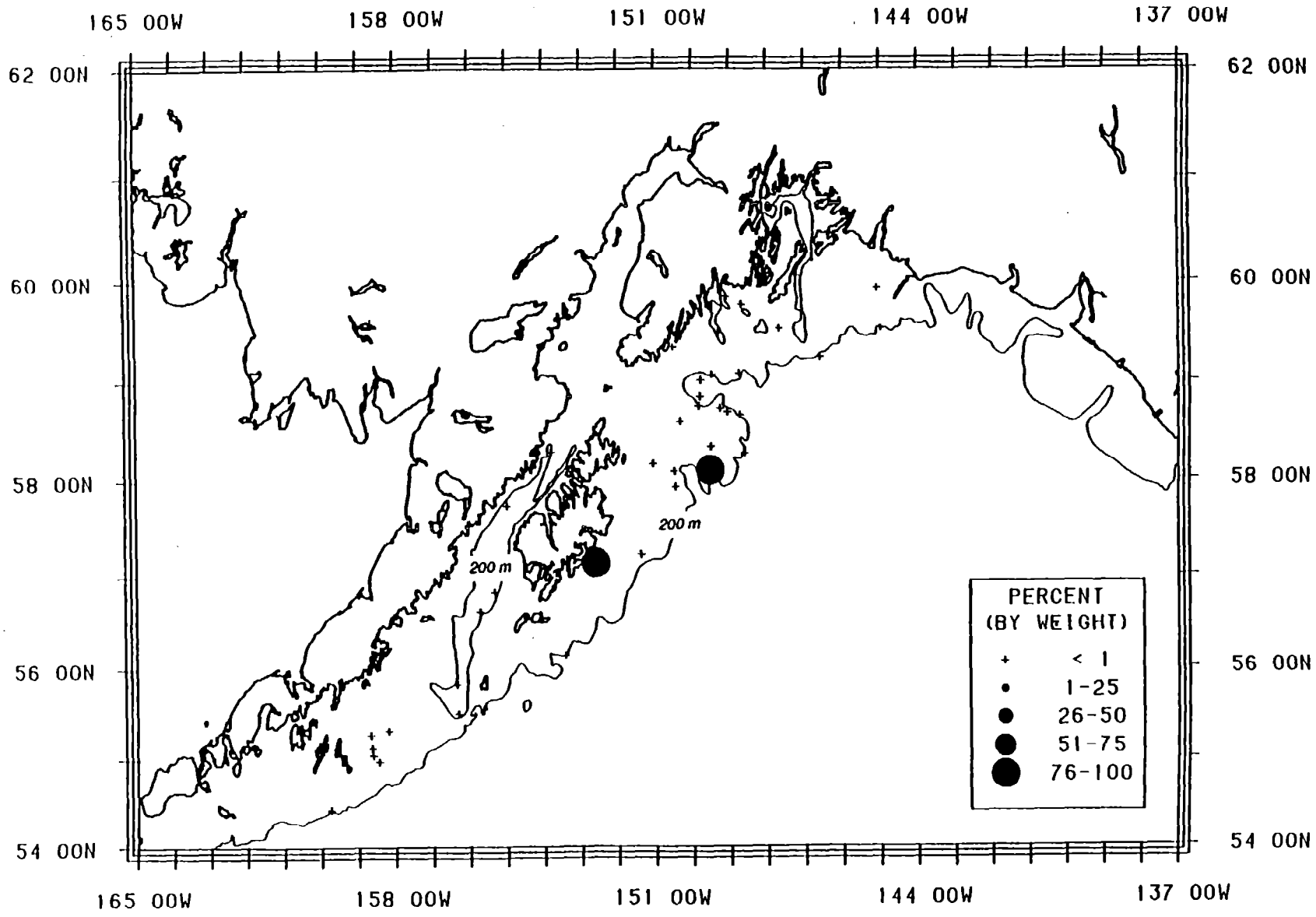

Figure 5-6.--Geographic distribution of Chionoecetes bairdi consumed by sablefish in the Gulf of Alaska in 1990.

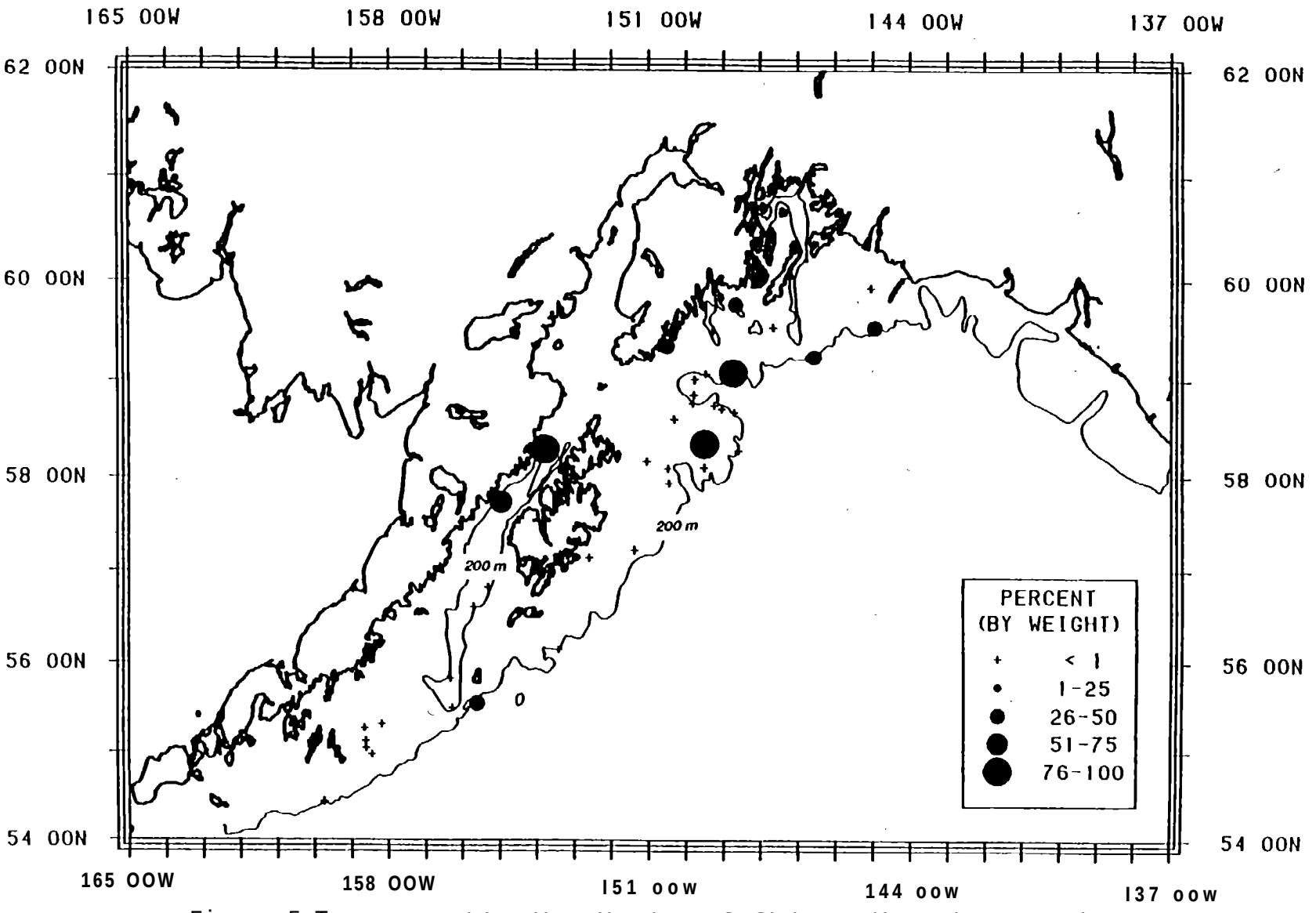

Figure 5-T.--Geographic distribution of fishery discard consumed by sablefish in the Gulf of Alaska in 1990.

invertebrates. Mito (1974) found that pollock was the predominate food of sablefish in the eastern Bering Sea (in some areas pollock made up as much as 97% of the diet of sablefish). Brodeur and Livingston (1988) found gadid fish (mainly pollock) accounted for about 50% of the total stomach content weight. They also reported that 8.5% of the sablefish diet was fishery discards.

Comparing Mito's (1974) study, Brodeur and Livingston's (1988) study, and this study, I found that sablefish consumed more pollock in the eastern Bering Sea than in the Gulf of Alaska. On the other hand, fishery discards comprised a higher percentage (29%) of the food of sablefish in the Gulf of Alaska area than in the eastern Bering Sea (8.5%).

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PACIFIC OCEAN PERCH

The estimated 1990 exploitable biomass of Pacific ocean perch (Sebastes alutus) in the Gulf of Alaska area was 129,734 t (Heifetz and Clausen 1991). It ranked eighth (first of all of the rockfishes) in total biomass of the Gulf of Alaska groundfish complex. Pacific ocean perch is a commercially important fish in the Gulf of Alaska area. Trawl fisheries by the U.S.S.R. and Japan for this species began in the early 1960s and overexploited the stock (Heifetz and Clausen 1991). Since the mid-1960s the catches have fluctuated. In 1990 the total catch' was about 21,114 t (Heifetz and Clausen 1991). The objective of this study was to understand the food habits of Pacific ocean perch and their relation to other marine fishes in the Gulf of Alaska area.

RESULTS

A total of 143 Pacific ocean perch stomachs were analyzed, of which 41 were empty and 102 (71%) contained food. Pacific ocean perch sizes ranged from 14 to 48 cm FL with a mean and SD of 32.3 + 7.2 cm. Figure 6-l shows the haul locations for the collected stomach samples of the Pacific ocean perch in the Gulf of Alaska in 1990. The average depth of the 16 haul locations was 183 + 71 m with a range from 101 to 346 m.

l/ The total catch included the 18 slope rockfish species, in which Pacific ocean perch was the dominant species.

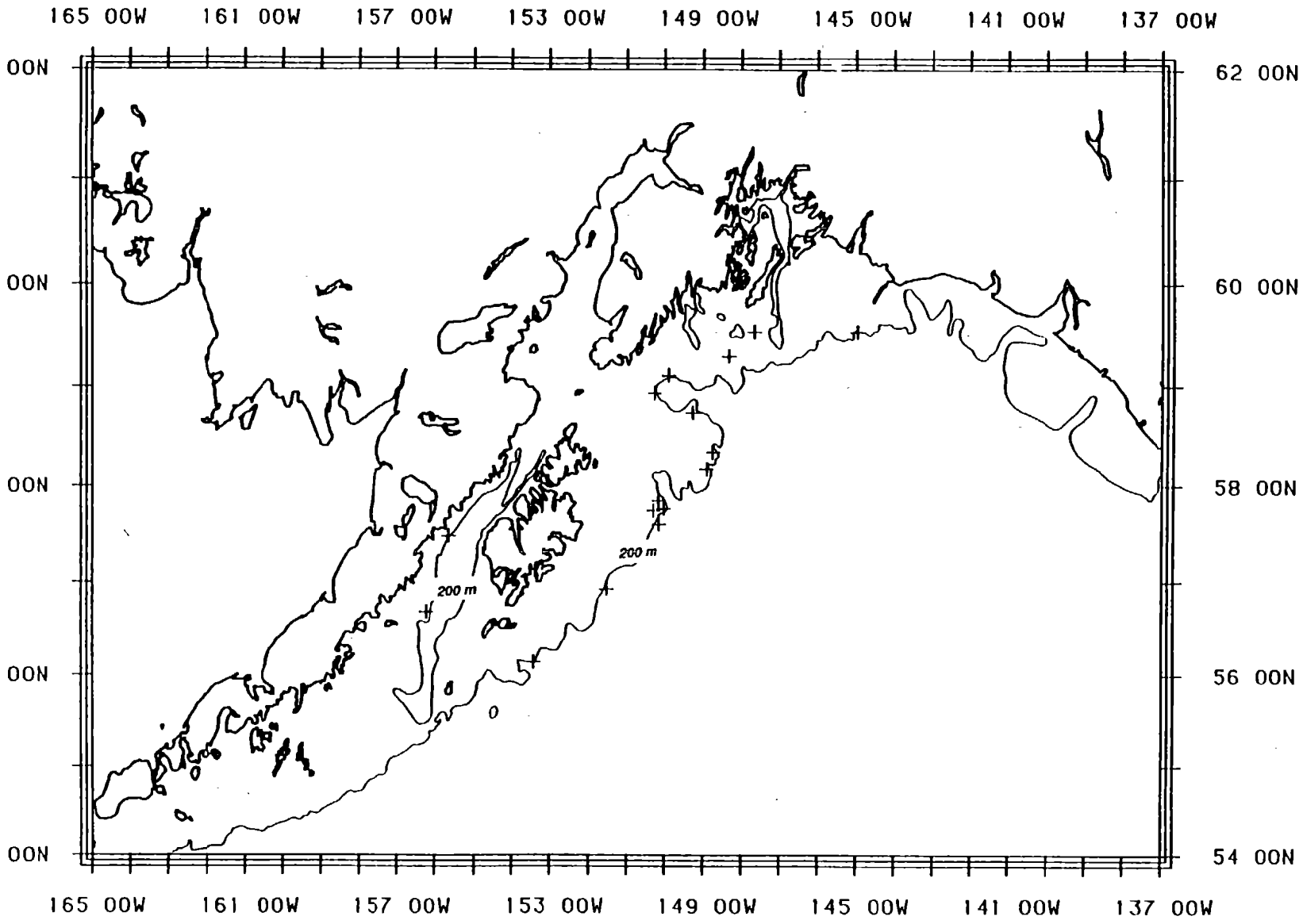

Figure 6-1.--Haul locations (+) of the stomach samples of Pacific ocean perch collected in Gulf of Alaska in 1990.

Table 6-1 lists the percent frequency of occurrence, the percent by number, and the percent total weight of the prey items of Pacific ocean perch. Fish comprised only 2% by weight of the diet of Pacific ocean perch in which arrowtooth flounder (Atheresthes stomias) was the only major groundfish species consumed. The SLs of the two measurable arrowtooth flounder were 12.1 mm and 22.0 mm. Other fish consumed by Pacific ocean perch included myctophids, snailfish, and stichaeids. Euphausiids (mainly Thysanoessa inermis) were the most important prey of Pacific ocean perch; they comprised about 87% by weight of the total stomach contents. Calanoid copepods, amphipods, and arrow worms were found frequently in Pacific ocean perch stomachs. However, they comprised very low percentages by weight of the total diet of Pacific ocean perch. Pacific ocean perch stomachs also contained 0.5% by weight of Tanner crabs (Chionoectes. bairdi). However, no Tanner crabs were measurable. Shrimp, including pasiphaeids, pandalids, and crangonids comprised 2.5% by weight of the diet of Pacific ocean perch.

Figure 6-2 illustrates that there were no large diet variations between the different size groups of the Pacific ocean perch except the smallest size group ((25 cm FL) consumed more euphausiids.

DISCUSSION

Because of the wide range distributions (from southern California to the Bering Sea) of the Pacific ocean perch, the diets of this species have been documented in many areas

Table 6-l.--Prey items (expressed in percent frequency of occurrence, numerical percentage, and percent total weight) of Pacific ocean perch (*Sebastes alutus*) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Number	% Total weight
Gymnosomata (pteropod)	2.90	0.10	0.04
Teuthoidea (squid)	1.00	0.03	0.77
Octopoda (octopus)	1.00	0.01	0.20
Calanoida (unidentified)	23.50	6.32	1.55
Neocalanus cristatus (copepod)	3.90	0.14	0.06
Mysidacea (unidentified)	2.00	0.03	0.04
Acanthomysis dybowskii (mysid)	1.00	0.06	0.06
Acanthomysis pseudomacropsis (mysid)	1.00	0.01	0.01
Holmesiella anomala (mysid)	2.00	0.04	0.05
Meterythrops robusta (mysid)	2.00	0.76	1.20
Neomysis czerniawskii (mysid)	2.90	0.16	0.22
Diastylis sp. (cumacean)	1.00	0.01	0.01
Gammaridea (unidentified)	9.80	0.38	0.72
Ampeliscidae (amphipod)	3.90	0.06	0.04
Themisto sp. (amphipod)	20.60	3.21	0.98
Euphausiacea (unidentified)	55.90	22.08	32.81
Thysanoessa inermis (euphausiid)	26.50	61.27	53.09
Thysanoessa raschii (euphausiid)	2.00	0.04	0.08
Thysanoessa spinifera (euphausiid)	6.90	0.20	1.37
Caridea (unidentified shrimp)	7.80	0.18	0.42
Pasiphaeidae (shrimp)	1.00	0.01	0.01
Pandalidae (unidentified)	9.80	0.48	0.99
Pandalus borealis (northern shrimp)	1.00	0.01	0.07
Pandalus montagui tridens (shrimp)	1.00	0.01	0.95
Crangonidae (shrimp)	2.00	0.03	0.02
Paguridae (hermit crab)	8.80	0.38	0.12
Chionoecetes bairdi (Tanner crab)	2.00	0.03	0.01
Sagitta sp. (arrow worm)	17.60	3.42	2.17
Teleostei (unidentified fish)	1.00	0.01	0.01
Non-gadoid fish remains	2.00	0.03	0.18
Chauliodus macouni (Pacific viperfish)	1.00	0.01	0.24
Stenobrachius leucopsarus (myctophid)	6.90	0.41	1.08
Cyclopteridae (snailfish)	1.00	0.01	0.08
Stichaeidae (prickleback)	1.00	0.01	0.27
Atheresthes stomias (arrowtooth flounder)	2.00	0.03	0.11
Total prey count		7,074	
Total prey weight		118 g	
Number of stomachs with food		102	
Number of empty stomachs		41	

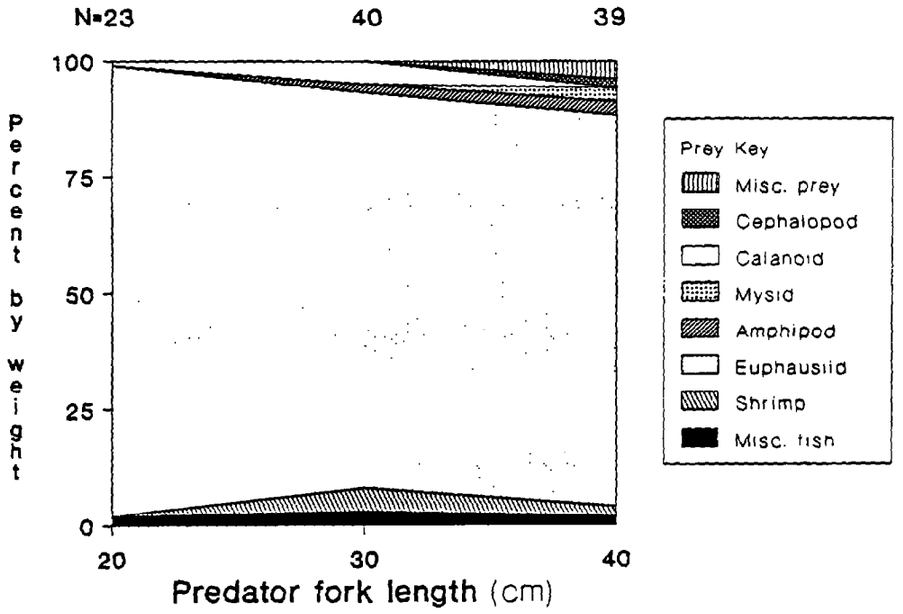

Figure 6-2. --Variations in the main food items of Pacific ocean perch, by predator size, in the Gulf of Alaska in 1990. N = sample size.

(Lyubimova 1963 and Somerton et al. 1978 in the Gulf of Alaska; Skalkin 1964 and Mito 1974 in the Bering Sea; Brodeur and Pearcy 1984 along the West Coast). All of these previous studies showed similar results to this study. That is, Pacific ocean perch is mainly planktivorous; the smaller fish eat a higher percent of canlanoid copepods and the larger fish eat a higher percent (usually more than 85%) of euphausiids and some shrimp. The structure of the gill rakers also supports the belief that Pacific ocean perch is planktivorous. The outer rakers (about 35 to 39 counts based on my study) on the first gill arch are slender and long, the inner rakers on the first gill arch interlock with the outer rakers on the second gill arch, and so on for the rest of the gill arches. In this way the gill arches form a screen to filter planktonic organisms.

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ROUGHEYE ROCKFISH

The rougheye rockfish (Sebastes aleutianus) had an exploitable biomass of 36,794 t in the Gulf of Alaska in 1990 (Heifetz and Clausen 1991). It ranked third in abundance of the rockfish complex in the Gulf of Alaska. The catch of the rougheye rockfish was not available since it was combined with 17 other rockfish species of the slope rockfish assemblage. Slope rockfish are defined as those Sebastes species that inhabit the Gulf of Alaska area at depths greater than 150-200 m (Heifetz and Clausen 1991).

RESULTS

A total of 141 rougheye rockfish stomachs were analyzed, of which 57 were empty and 84 stomachs (60%) contained food. The average size of the rougheye rockfish was 36.4 cm FL with a SD of 5.9 cm. Fish size ranged from 21 to 56 cm FL. The average depth of the 17 haul locations was 234 + 82 m with a range from 148 to 368 m.

Table 7-l shows the percent frequency of occurrence, percent by number, and percent by weight of the prey items of rougheye rockfish. It shows that shrimp, including Pandalus borealis, Pandalus montaaui tridens, hippolytids, and crangonid, are the main food (more than 50% of the total stomach contents weight) of rougheye rockfish. The area and amount (percent by weight) of pandalid shrimp consumed by rougheye rockfish is shown in Figure 7-l. Squid also comprised a high proportion (21%) of the stomach contents weight. This was mostly due to one large rougheye

Table 7-l.--Prey items (expressed in percent frequency of occurrence, numerical percentage, and percent total weight) of rougheye rockfish (Sebastes aleutianus) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Number	% Total weight
Polychaeta (worm)	6.00	0.59	1.43
Cephalopoda (unidentified)	2.40	0.24	0.17
Teuthoidea (squid)	2.40	0.24	20.49
Mysidacea (unidentified)	7.10	1.18	0.20
Gnathophausia gigas (mysid)	1.20	0.24	0.02
Holmesiella anomala (mysid)	2.40	0.36	0.09
Meterythrops robusta (mysid)	11.90	8.18	0.78
Neomysis czerniawskii (mysid)	10.70	3.55	0.41
Neomysis rayii (mysid)	2.40	2.49	0.19
Pseudomma truncatum (mysid)	14.30	11.37	0.42
Cumacea (cumacean)	1.20	0.12	0.00
Isopoda (isopod)	9.50	0.95	1.81
Gammaridea (unidentified)	22.60	9.00	1.41
Ampeliscidae (amphipod)	3.60	1.66	0.18
Lysianassidae (amphipod)	1.20	1.18	0.46
Themisto sp. (amphipod)	7.10	3.67	0.25
Themisto abyssorum (amphipod)	7.10	8.53	1.70
Euphausiacea (unidentified)	4.80	8.06	1.61
Thysanoessa inermis (euphausiid)	2.40	0.95	0.10
Caridea (unidentified shrimp)	3.60	0.36	0.08
Hippolytidae (unidentified)	4.80	0.83	0.12
Eualus avinus (shrimp)	3.60	0.59	0.30
Pandalidae (unidentified)	32.10	6.64	19.50
Pandalus borealis (northern shrimp)	15.50	2.37	31.65
Pandalus montagui tridens (shrimp)	1.20	0.12	0.03
Crangonidae (unidentified)	10.70	9.36	1.30
Crangon communis (shrimp)	8.30	1.54	4.46
Argis lar (shrimp)	2.40	0.24	1.20
Paguridae (hermit crab)	1.20	0.12	0.01
Chionoecetes bairdi (Tanner crab)	3.60	0.36	2.00
Pinnotheridae (pea crab)	1.20	0.12	0.22
Sagitta sp. (arrow worm)	8.30	13.03	0.40
Teleostei (unidentified fish)	6.00	0.71	2.00
Non-gadoid fish remains	4.80	0.59	4.65
Cyclopteridae (snailfish)	1.20	0.12	0.32
Pleuronectidae (flatfish)	1.20	0.12	0.01
Total prey count		844	
Total prey weight		211 g	
Number of stomachs with food		84	
Number of empty stomachs		57	

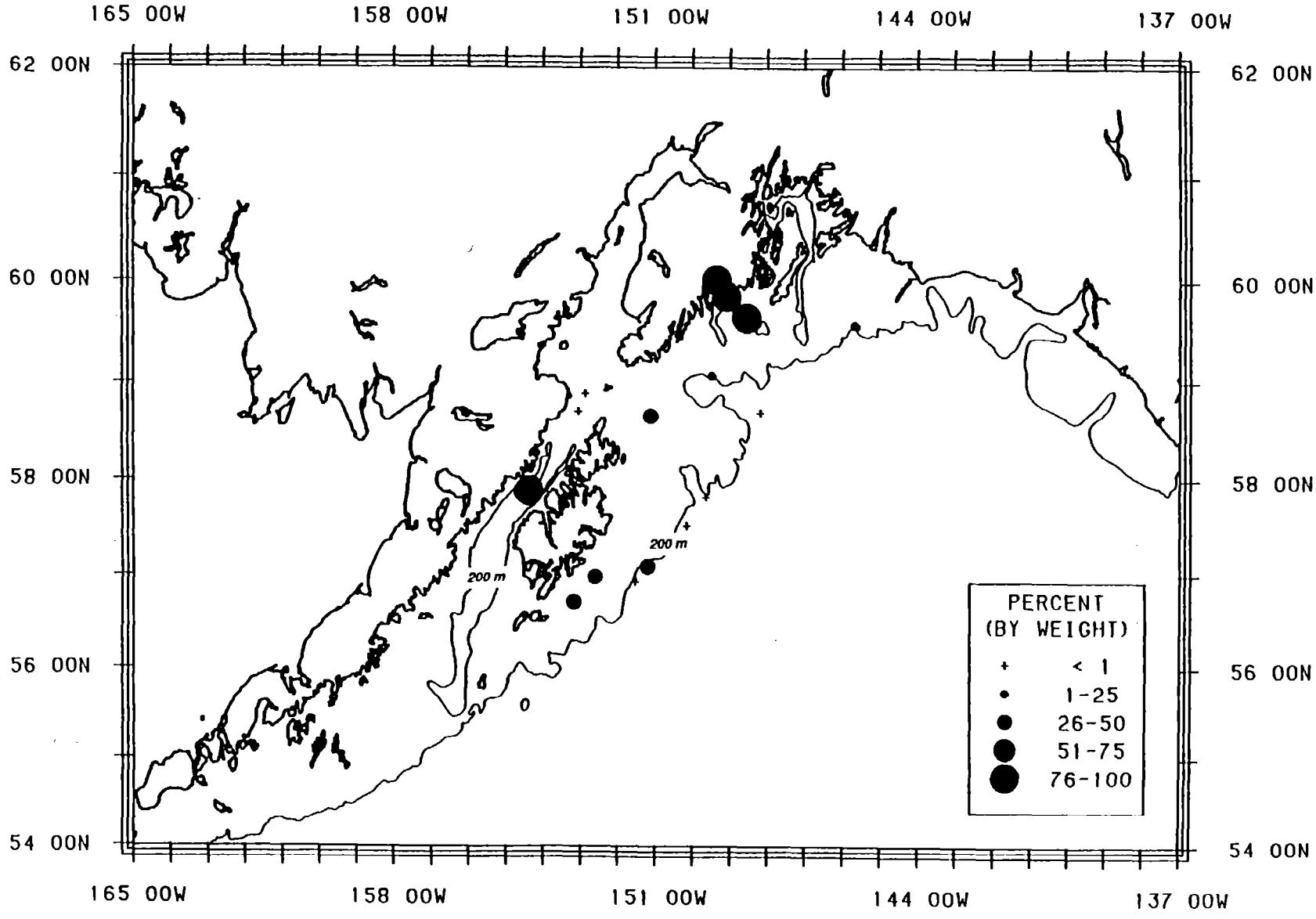

Figure 7-1.--Geographic distribution of the pandalid shrimp consumed by rougheye rockfish in the Gulf of Alaska in 1990.

rockfish (56 cm) that ate one squid weighing 43.1 g; however, squid were not the common food of rougheye rockfish (only 2.4% of the frequency of occurrence). Other food items included amphipods, mysids, euphausiids, cumaceans, isopods, and polychaetes. Prey fish consumed by rougheye rockfish included non-gadoid fish, snailfish, flatfish, and some unidentifiable fish. They comprised about 7% of the total stomach contents weight. The commercially important Tanner crab (Chionoecetes bairdi) was also consumed by rougheye rockfish, it comprised about 2% of the total stomach contents weight. One measurable Tanner crab, 26.5 mm CW, was consumed by one 39 cm rougheye rockfish.

Figure 7-2 shows the variations of the main food items of different size groups of rougheye rockfish. It shows that all size groups consumed a large amount of shrimp (>50% by weight). The smallest size group (<30 cm FL) consumed more amphipods whereas the largest size group (40-49 cm FL) consumed more fish than the other size groups. The medium-sized (30-39 cm FL) rougheye rockfish consumed relatively more crab compared to other groups. Diet of rougheye rockfish larger than 50 cm FL (only one) was not included in Figure 7-2 because of the small sample size.

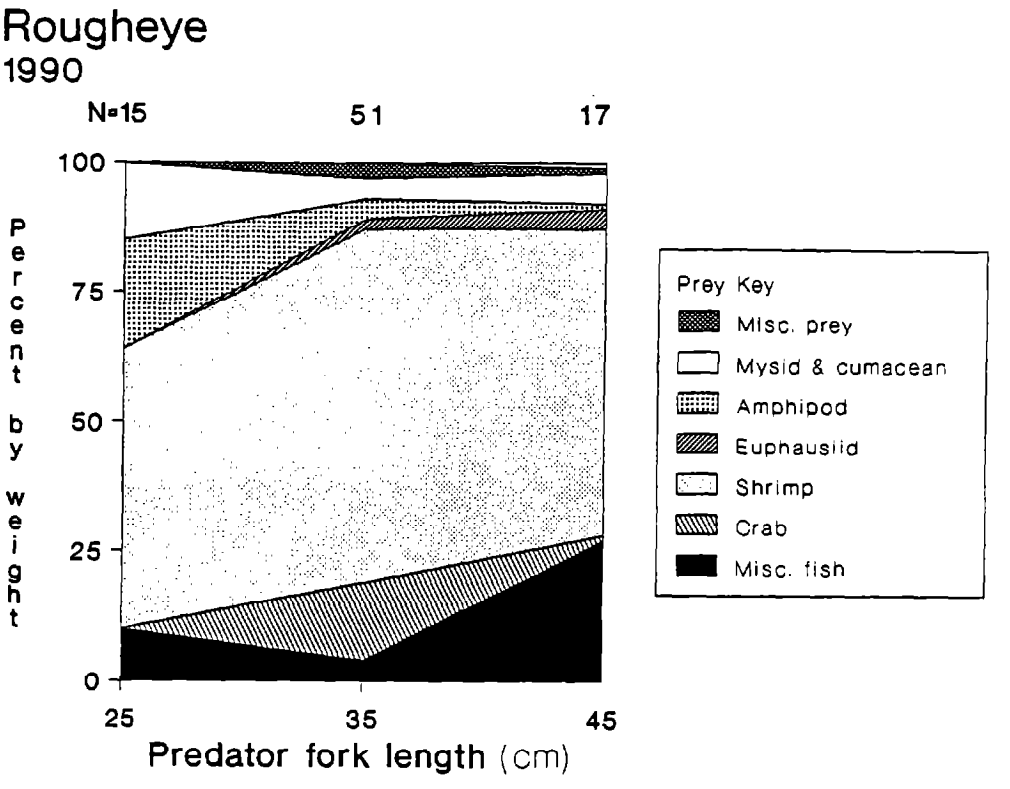

Figure 7-2.--Variations in the main food items of rougheye rockfish, by predator size, in the Gulf of Alaska in 1990. N = sample size.

DISCUSSION

Feder (1980) found that shrimp were the most important food of rougheye rockfish (occurred in 75% of the stomachs) in the southeastern Gulf of Alaska. He also reported that fish, squid, and mysids were found occasionally in rougheye stomachs. Feder's (1980) results are similar to this study.

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NORTHERN ROCKFISH

Northern rockfish (Sebastes polyspinis) had an exploitable biomass of 74,626 t in the Gulf of Alaska in 1990 (Heifetz and Clausen 1991). It was the second largest group of rockfish (next to Pacific ocean perch) in the Gulf of Alaska in terms of biomass. Along with Pacific ocean perch (S. alutus), rougheye rockfish (S. aleutianus), shortraker rockfish (S. borealis), and the northern rockfish were categorized as members of the Pacific ocean perch (POP) complex between 1979 and 1987. Since 1988, however, northern rockfish has been classified and managed as one of the 18 Sebastes species within the slope rockfish assemblage. Slope rockfish are defined as those species of Sebastes that inhabit depths greater than 150-200 m (Heifetz and Clausen 1991).

RESULTS

A total of 57 northern rockfish stomachs were analyzed, of which 18 stomachs were empty and 39 stomachs (68%) contained food. The average size of the northern rockfish was 35.1 cm FL with a SD of 2.3 cm. Fish size ranged from 30 to 41 cm FL. The average depth of the seven haul locations was 116 + 9 m with a range between 102 and 126 m.

Table 8-l shows the percent frequency of occurrence, the percent by number, and the percent by weight of the prey items consumed by northern rockfish. It shows that euphausiids (mainly Thysanoessa inermis) were the most important (95% by weight) food of northern rockfish. Other food included calanoid copepods, cephalopods, gastropods, amphipods, Chionoecetes sp., pagurid

Table 8-l.--Prey items (expressed in percent frequency of occurrence, numerical percentage, and percent total weight) of northern rockfish (Sebastes polyspinis) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Number	% Total weight
Gastropods (snail)	2.60	0.01	0.01
Cephalopoda (unidentified)	7.70	0.03	0.30
Teuthoidea oegopsida (squid)	5.10	0.01	0.01
Calanoida (unidentified)	10.30	0.06	0.02
Neocalanus cristatus (copepod)	28.20	3.82	2.43
Gammaridea (unidentified)	12.80	0.05	0.08
Themisto sp. (amphipod)	35.90	0.21	0.05
Euphausiacea (unidentified)	89.70	94.65	95.41
Thvsanoessa inermis (euphausiid)	10.30	0.50	0.82
Thvsanoessa soinifera (euphausiid)	2.60	0.01	0.05
Caridea (unidentified shrimp)	2.60	0.01	0.01
Paguridae (hermit crab)	5.10	0.01	0.01
Chionoecetes sp. (snow and Tanner crab)	5.10	0.01	0.01
Sasitta sp. (arrow worm)	35.90	0.60	0.41
Non-gadoid fish remains	2.60	0.01	0.32
Atheresthes stomias (arrowtooth flounder)	7.70	0.03	0.07

Total prey count	14,772
Tota- prey weight	142 g
Number of stomachs with food	39
Number of empty stomachs	18

crabs, and arrow worms. Prey fish found in northern rockfish stomachs were arrowtooth flounder (Atheresthes stomias) and some non-gadoid fish remains. The four arrowtooth flounder consumed had a mean and SD of 12.8 + 2.0 mm SL with a range from 11.5 to 15.7 mm. The locations where the arrowtooth flounder were consumed are shown in Figure 8-l. Because of the small sample size and the small size range (30 to 41 cm FL) of the northern rockfish collected, variation of the diet of different size groups is not available.

'DISCUSSION

Skalkin (1964) found that northern rockfish in the Bering Sea area consumed large amounts of euphausiids, as well as cephalopods, copepods, arrow worms, and larvaceans. Mito (1974) also found a similar diet: euphausiids, hermit crabs, northern shrimp Pandalus borealis, and squid in northern rockfish stomachs in the Bering Sea. Skalkin (1964), Mito (1974), and this study indicate that northern rockfish is mainly planktivorous. This fact is supported by the similarities noted in the gill arch structures of northern rockfish to the Pacific ocean perch gill arch structures described earlier in the food habits section for that species.

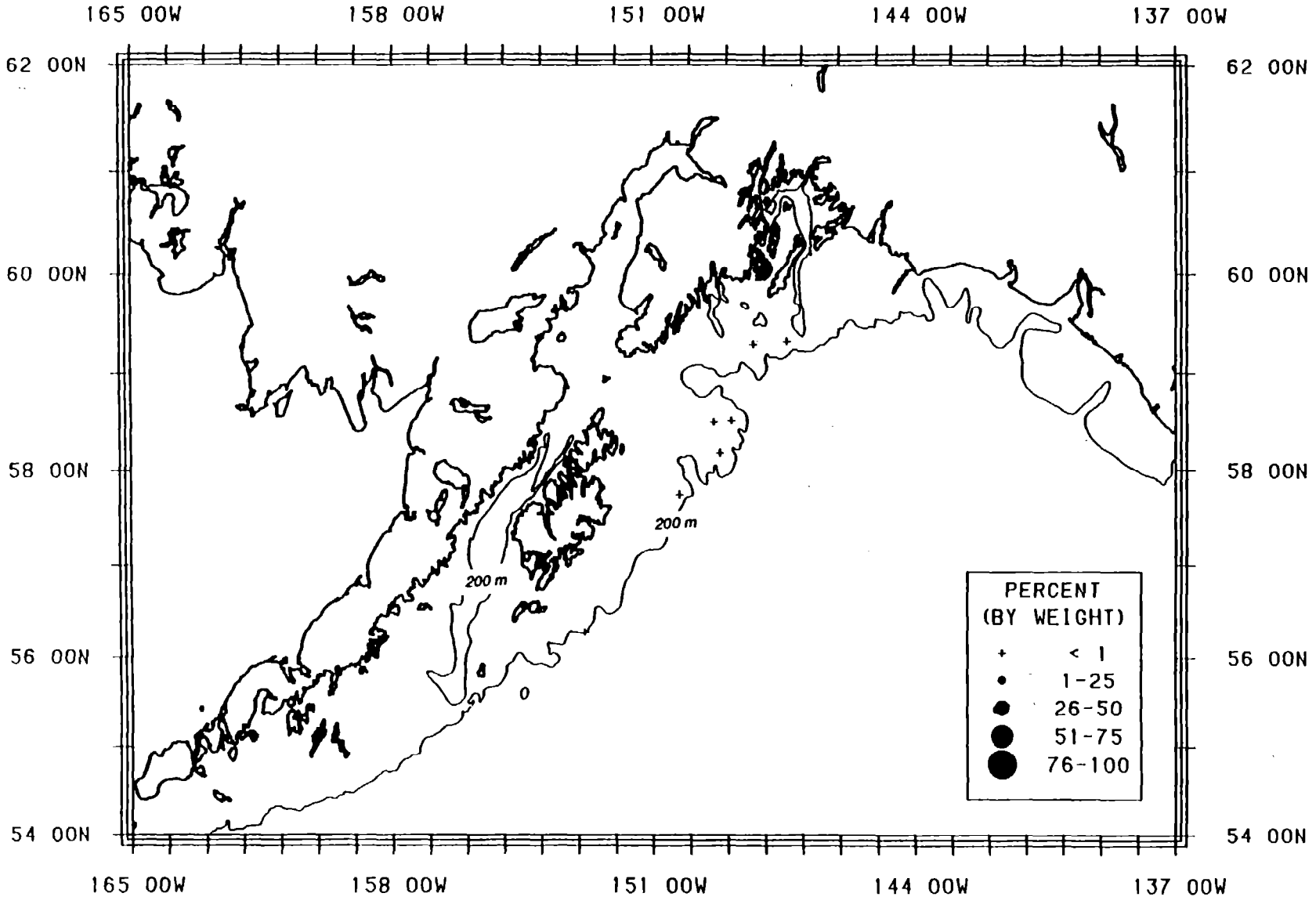

Figure 8-l. --Geographic distribution of the arrowtooth flounder consumed by northern rockfish in the Gulf of Alaska in 1990.

CITATIONS

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DUSKY ROCKFISH

Dusky rockfish (Sebastes ciliatus) had an exploitable biomass of 24,141 t in the Gulf of Alaska in 1990 (Clausen and Heifetz 1991). It ranked fifth in abundance among the rockfish complex in the Gulf of Alaska in 1990. Along with black rockfish (S. melanops), widow rockfish (S. entomelas), blue rockfish (S. mystinus), and yellowtail rockfish (S. flavidus), dusky rockfish is one of the five Sebastes spp. in the pelagic shelf rockfish assemblage. This assemblage is defined as those species of Sebastes that inhabit waters of the continental shelf of the Gulf of Alaska and exhibit a midwater schooling behavior (Clausen and Heifetz 1991). The catch of this assemblage in 1990 (1,647 t) was much less than the quota (8,200 t) assigned by the North Pacific Fishery Management Council, 'indicating this assemblage was underutilized by the commercial fishery.

RESULTS

A total of 41 dusky rockfish stomachs were analyzed, of which 19 were empty and 22 (54%) contained food. The average size of the dusky rockfish was 39.7 cm FL with a SD of 7.7 cm. Fish size ranged from 16 to 47 cm FL. The average depth of the five haul locations (Fig. 9-1) was 99 + 27 m with a range between 51 and 117 m.

Table 9-l lists the percent frequency of occurrence, the percent by number, and the percent by weight of the prey items found in dusky rockfish stomachs. It shows that euphausiids (mainly Thysanoessa inermis) were the most important food (67% by

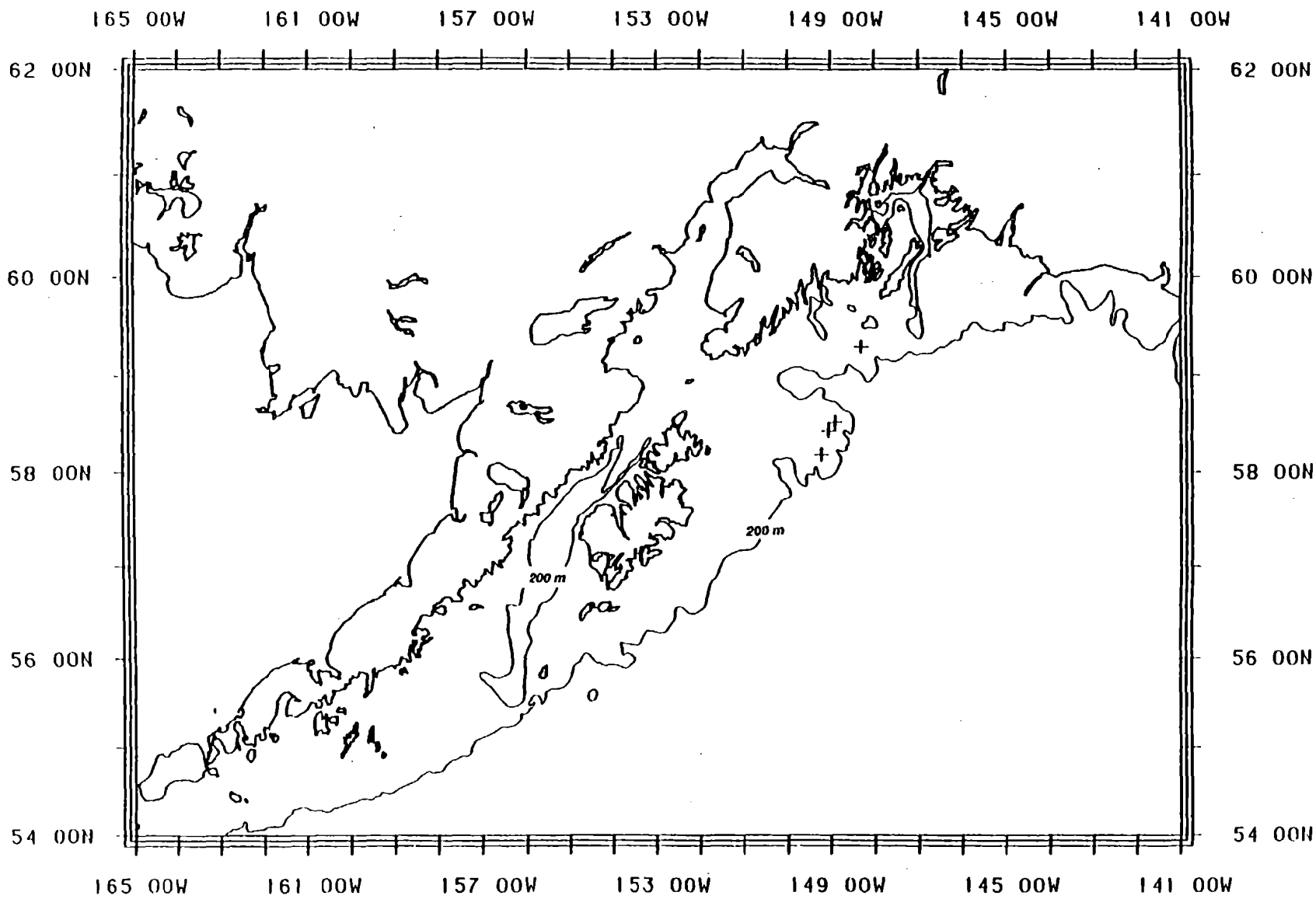

Figure 9-1.--Haul locations of the stomachs of dusky rockfish collected in the Gulf of Alaska in 1990.

Table 9-l. --Prey items (expressed in percent frequency of occurrence, numerical percentage, and percent total weight) of dusky' rockfish (Sebastes ciliatus) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Number	% Total weight
Gastropods (snail)	4.50	0.05	0.08
Cephalopoda (unidentified)	22.70	0.83	6.07
Teuthoidea oegopsida (squid)	4.50	0.05	0.07
Calanoida (unidentified)	18.20	0.68	0.11
Neocalanus cristatus (copepod)	9.10	2.43	1.82
Gammaridea (unidentified)	4.50	0.05	0.13
Ampeliscidae (amphipod)	9.10	0.10	0.20
Euphausiacea (unidentified)	59.10	26.19	55.89
Thvsanoessa inermis (euphausiid)	31.80	4.47	10.92
Thvsanoessa sninifera (euphausiid)	4.50	0.24	2.04
Caridea (unidentified shrimp)	9.10	1.55	0.71
Hippolytidae (shrimp)	4.50	0.05	0.01
Pandalidae (shrimp)	9.10	0.15	3.46
Paguridae (hermit crab)	18.20	8.41	3.10
Cancer sp. (crab)	4.50	0.05	0.02
Sasitta sp. (arrow worm)	36.40	8.21	3.34
Larvacea (tunicate)	22.70	45.29	11.64

Total prey count	2,058
Total prey weight	24 g
Number of stomachs with food	22
Number of empty stomachs	19

weight) of dusky rockfish. Larvaceans were the second most important prey of dusky rockfish; they comprised 12% of the total stomach contents weight. Cephalopods, calanoid copepods, arrow worms, and hermit crabs were also found-quite frequently; however, they all comprised less than 10% by weight of the stomach contents. Dusky rockfish also consumed small amounts of gammarid amphipods, pandalids, hippolytids, and snails. Cancer sp. (one megalops larvae) was the only commercially important prey consumed by dusky rockfish. It comprised less than 1% of the total stomach contents weight.

Diet variations between different size groups were not available because of the small sample size (n=41) in this study.

DISCUSSION

Simenstad et al. (1977) reported that mysids, amphipods, copepods, and sand lance were the main food of dusky rockfish near Amchitka Island in the Aleutian Islands. Blackburn et al. (1981) found that crab megalops, chaetognaths, and calanoid copepods were important as food items for dusky rockfish in the Cook Inlet estuary. Rosenthal et al. (1988) found that dusky rockfish consumed large amounts (25.4% by volume of the total stomach content) of brachyuran crab larvae in the southeastern Gulf of Alaska. Calanoid copepods, amphipods, jellyfish, and pteropods were also consumed. Rosenthal et al. (1988) also reported that some gadid larvae and Pacific sand lance were found in dusky rockfish stomachs.

Based on this study and similar studies, dusky rockfish, like Pacific ocean perch and northern rockfish, is mainly a planktivore. The compositions of the prey might vary depending on different study areas and different sampling seasons.

CITATIONS

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SHORTSPINE THORNYHEAD

Shortspine thornyhead (Sebastolobus alascanus) had an exploitable biomass of 25,697 t in the Gulf of Alaska in 1990 (Dawson 1991). It ranked seventh in abundance of the total rockfish complex in the Gulf of Alaska. Since 1980, the shortspine thornyhead resource has been managed as a unit in the Gulf of Alaska. In the past, thornyheads were not the primary target of the rockfish fleet. Today, thornyheads are one of the most commercially valuable rockfish species. In 1990, the catch of this species in the Gulf of Alaska area was 1,646 t (Dawson 1991).

RESULTS

A total of 120 shortspine thornyhead stomachs were analyzed, of which 39 were empty and 81 (68%) contained food. The average size of the shortspine thornyhead was 29.7 cm FL with a SD of 6.6 cm. Fish size ranged from 13 to 48 cm FL. The average depth of the 11 haul locations was 310 + 77 m with a range from 212 to 439 m.

Table 10-l lists the percent frequency of occurrence, the percent by number, and the percent by weight of the prey items found in the stomachs of shortspine thornyhead. It shows that shrimp (mainly pandalids) were the most important food of the thornyhead (67% by weight). The geographic distribution and the amount of the pandalids (including Pandalus borealis, p. jordani, p. montagui tridens) is shown in Figure 10-l. Tanner crabs (Chionoecetes bairdi) comprised about 1% (by weight) of the food

Table 10-l.--Prey items (expressed in percent frequency of occurrence, numerical percentage, and percent total weight) of shortspine thornyhead (Sebastolobus alascanus) collected in the Gulf of Alaska in 1990.

Prey Name	% Freq. occur.	% Number	% Total weight
Polychaeta (worm)	6.20	2.37	1.18
Gastropoda (snail)	1.20	0.95	1.54
Teuthoidea (squid)	3.70	1.42	0.72
Calanoida (copepod)	2.50	0.95	0.01
Mysidacea (unidentified mysid)	7.40	3.32	0.17
Holmesiella anomala (mysid)	8.60	8.06	0.41
Metervthrops robusta (mysid)	1.20	0.47	0.03
Pseudomma truncatum (mysid)	3.70	1.42	0.07
Gammaridea (unidentified amphipod)	13.60	9.00	0.84
Ampeliscidae (amphipod)	3.70	3.32	0.11
Lysianassidae (amphipod)	1.20	0.47	0.25
Caridea (unidentified shrimp)	4.90	1.90	0.38
Pasiphaeidae (shrimp)	1.20	0.47	1.04
Hippolytidae (unidentified shrimp)	13.60	8.06	3.46
Eualus barbata (shrimp)	2.50	1.42	0.52
Eualus biunquis (shrimp)	3.70	1.42	0.64
Eualus avinus (shrimp)	4.90	2.84	0.59
Heptacarpus sp. (shrimp)	2.50	0.95	0.38
Pandalidae (unidentified shrimp)	33.30	23.69	27.86
Pandalus borealis (northern shrimp)	4.90	1.90	7.38
Pandalus jordani (shrimp)	3.70	2.37	18.39
Pandalus montaqui tridens (shrimp)	2.50	0.95	0.81
Crangonidae (unidentified shrimp)	7.40	3.32	1.22
Cranaon communis (shrimp)	9.90	5.21	4.12
Arais ovifer (shrimp)	1.20	0.47	0.11
Paguridae (hermit crab)	2.50	0.95	2.04
Lithodidae (crab)	1.20	0.47	1.12
Oresonia sracilis (decorator crab)	2.50	0.95	2.19
Chionoecetes bairdi (Tanner crab)	3.70	1.90	1.16
Cherilia longioes (decorator crab)	3.70	1.42	3.96
Pinnotheridae (pea crab)	1.20	0.47	0.10
Teleostei (unidentified fish)	2.50	0.95	1.30
Non-gadoid fish remains	7.40	2.84	13.75
Mallotus villosus (capelin)	1.20	0.47	0.72
Theragra chalcogramma (walleye pollock)	1.20	0.47	0.85
Zoarcidae (eelpout)	1.20	0.47	0.04
Icelinus borealis (northern sculpin)	2.50	0.95	0.51
Total prey count		211	
Total prey weight		147 g	
Number of stomachs with food		81	
Number of empty stomachs		39	

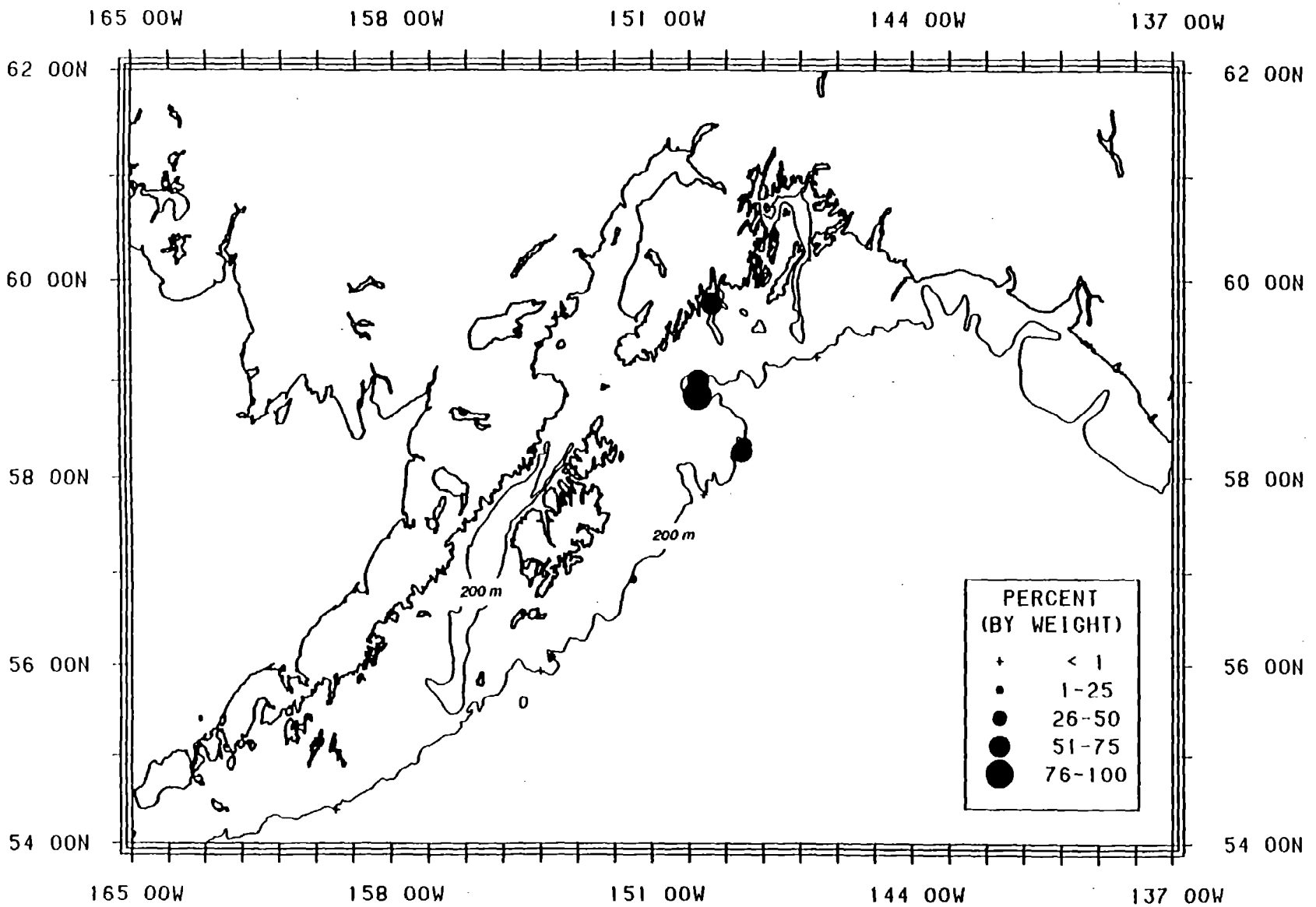

Figure 10-1.--Geographic distribution of pandalid shrimp consumed by shortspine thornyhead in the Gulf of Alaska in 1990.

of thornyheads. The sizes of the four Tanner crabs consumed were between 13 and 18 mm carapace width with a mean and standard deviation of 16.4 + 2.5 mm. Fish comprised about 17% (by weight) of the food of the thornyhead. Although the thornyhead stomach did not contain a large amount of prey fish, they had the highest proportion of prey fish as food between all the rockfish species. Among the prey fish consumed, one 49 mm SL walleye pollock (Theragra chalcogramma) was found in a 37 cm thornyhead stomach. One capelin (Mallotus villosus) was also found in a thornyhead stomach; however, the fish size was not measurable. Shortspine thornyhead also consumed a zoarcid, sculpin, and some unidentifiable fish.

DISCUSSION

Feder (1980) found that shrimp (occurred in 90% stomachs) were the most important food for shortspine thornyhead in the southeastern Gulf of Alaska area, followed by fish (15% frequency of occurrence). His results basically agreed with this study. However, in the Bering Sea area, Mito (1974) found that fish, euphausiids, Chionoecetes opilio, and macrura were important food, whereas shrimp were not. This difference was probably because of the differences of the prey abundances and prey availabilities in the different areas.

Compared to most other rockfish, shortspine thornyhead has a more elongated body and a relatively large terminal mouth. It has 18 to 23 gill rakers on the first gill arch (fewer than most of the other rockfishes), and the gill rakers are stout and not

very long. All of these contributed to their feeding mainly on epibenthic shrimp and fish and not much on the planktons.

CITATIONS

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SHORTRAKER ROCKFISH

Shortraker rockfish (Sebastes borealis) had an exploitable biomass of 9,449 t the Gulf of Alaska in 1990 (Heifetz and Clausen 1991). It ranked 10th in abundance of the rockfish complex in-the Gulf of Alaska in 1990. This species has been classified and managed as one of the 18 slope assemblage rockfishes since 1988 (Heifetz and Clausen 1991). Because of their special morphological characteristics (large mouth, short gill rakers, and low gill raker number), they are 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

Ten stomachs of shortraker rockfish collected from one haul (361 m deep) in the Gulf of Alaska were analyzed, of which seven were empty, and three contained food. The average size of the shortraker rockfish was 57.3 cm FL with a SD of 5.4 cm. Fish length ranged between 50 and 68 cm FL. The diet of the shortraker rockfish was comprised of 82% (by weight) of squid and 18% myctophids. Since the sample size and the size range of the fish were too small, the data was insufficient to describe the food habits of shortraker rockfish. More samples should be collected for the future study of this species.

CITATIONS

Heifetz, J., and D. M. Clausen. 1991. Slope rockfish. In Stock assessment and fishery evaluation report for the 1992 Gulf of Alaska groundfish fishery. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

SUMMARY

A total of 4,429 stomachs from 11 species were analyzed to describe the food habits of the major groundfish species in the Gulf of Alaska. 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 (walleye pollock, Pacific cod, Pacific halibut, and arrow-tooth flounder) were sampled, the main focus was on the food habits of the adult fish.

A Table 2 lists the percent by weight of the commercially important fish, crab, shrimp, and other major prey or prey groups consumed by groundfish. It shows that arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and pollock are the main predators that consume fish. The main predators that feed on Tanner crabs are Pacific halibut and Pacific cod. Pollock, shortspine thornyhead, and rougheye rockfish are the main consumers of pandalid shrimp. Pacific ocean perch, northern rockfish, and dusky rockfish did not have too much impact on the commercially important species in the Gulf of Alaska since they feed mainly on zooplankton (mainly euphausiids). Although there was not enough data (only three stomachs with food) to describe the diet of the shortraker rockfish, based on their morphological characteristics (large mouth, short gillrakers, and less gillraker numbers), they probably also consume some fish and crab in addition to the cephalopods found in this study.

Table 1.--Number of stomachs and fish size analyzed in the Gulf of Alaska in 1990. 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	655	489	1,144	12-80	42.1 ± 10.1
Pacific halibut	388	79	467	11-151	71.5 ± 25.9
Sablefish	239	92	331	40-80	60.3 ± 9.1
Pacific cod	892	24	916	7-90	54.7 ± 12.1
Pollock	985	74	1,059	8-70	45.4 ± 13.0
Shortspine thornyhead	81	39	120	13-48	29.7 ± 6.6
Rougheye rockfish	84	57	141	21-56	36.4 ± 5.9
Shortraker rockfish	3	7	10	50-68	57.3 ± 5.4
Dusky rockfish	22	19	41	16-47	39.7 ± 7.7
Pacific ocean perch	102	41	143	14-48	32.3 ± 7.2
Northern rockfish	39	18	57	30-41	35.1 ± 2.3
Total	3,490	939	4,429		

Table 2.--Percent by weight of the important prey or prey group consumed by the groundfish in the Gulf of Alaska in 1990. "-" means less than 1%. PLK, pollock; HER, herring; CAP, capelin; ATF, arrowtooth flounder; FHS, flathead sole; GT, Greenland turbot; RS, rock sole; REX, rex sole; YFS, yellowfin sole; PH, Pacific halibut; DOV, Dover sole; SAN, Pacific sand lance; EUL, eulachon; COD, Pacific cod; COH, coho salmon; POP, Pacific ocean perch; ATK, Atka mackerel; TAN, Tanner crab; PAN, pandalids; CEP, cephalopods; SST shortspine thornyhead; ROU, rougheye rockfish; NOR, northern rockfish; SHR, shortraker rockfish; DUS, dusky rockfish; MSF, miscellaneous fish; FSD, fishery discard; EUP, euphausiids; PAG, paguid; OCR, other crabs; OSH, other shrimps; JFH, jellyfish; POL, polychaete; CAL, calanoid; MSP, miscellaneous prey.'

	Predator										
Prey	ATF	PH	SAB	COD	PLK	SST	ROU	SHR	DUS	POP	NOR
PLK	66	57	24	7	2	1	0	0	0	0	0
HER	9	0	2	-	-	0	0	0	0	0	0
CAP	8	1	-	2	13	1	0	0	0	0	0
ATF	-	4	0	6	-	0	0	0	0	-	-
FHS	-	1	0	2	-	0	0	0	0	0	0
GT	0	0	0	0	-	0	0	0	0	0	0
RS	0	-	0	-	0	0	0	0	0	0	0
REX	0	0	0	-	0	0	0	0	0	0	0
YFS	0	-	0	0	0	0	0	0	0	0	0
PH	0	-	0	-	0	0	0	0	0	0	0
DOV	0	-	0	0	1	0	0	0	0	0	0
SAN	-	-	-	-	-	0	0	0	0	0	0
EUL	1	-	6	-	0	0	0	0	0	0	0
COD	0	1	1	0	-	0	0	0	0	0	0
COH	0	5	0	0	0	0	0	0	0	0	0
POP	0	-	0	0	0	0	0	0	0	0	0
ATK	1	0	0	0	0	0	0	0	0	0	0
TAN	0	6	-	12	0	1	2	0	0	-	-
PAN	4	-	4	9	19	54	51	0	4	2	0
OSH	0	0	1	8	14	13	8	0	1	1	0
CEP	2	5	8	10	3	1	21	82	6	1	-
MSF	2	4	4	15	4	15	7	18	0	2	1
FSD	1	7	29	13	0	0	0	0	0	0	0
EUP	3	0	7	1	39	0	2	0	69	87	96
PAG	0	2	0	4	1	2	0	0	3	1	0
OCR	0	6	0	7	0	7	0	0	0	0	0
JFH	0	0	5	0	0	0	0	0	0	0	0
POL	0	0	0	4	1	1	1	0	0	0	0
CAL	0	0	0	0	1	0	0	0	2	2	3
MSP	1	1	1	0	2	4	8	0	15	4	0

The data in Table 2 indicates that pollock were the dominant prey fish and were consumed mainly by arrowtooth flounder (66%), Pacific halibut (57%), sablefish (24%), and Pacific cod (7%). Pollock cannibalism, which accounted for only 2% of the total stomach contents weight, was not an important phenomenon in the Gulf of Alaska compared with the Bering Sea (Livingston 1991). Pacific herring and capelin can be categorized as the next most important prey fishes. Arrowtooth flounder was the main predator of Pacific herring (herring comprised 9% of their total stomach contents weight), whereas arrow-tooth flounder and pollock both consumed relatively large amounts of capelin (8% and 13 % by weight, respectively). The flatfish consumed by the groundfish include arrowtooth flounder, flathead sole, Greenland turbot, rock sole, rex sole, yellowfin sole, Pacific halibut, and Dover sole. Arrowtooth flounder and flathead sole were consumed mostly by Pacific halibut and Pacific cod (Table 2). Pacific sand lance were consumed by the main predator species (arrow-tooth flounder, Pacific halibut, sablefish, Pacific cod, and pollock) but comprised less than 1% of the stomach content weight of each species. Although eulachon comprised 6% of the stomach content weight of sablefish, some might be due to undetected net feeding because we found evidence of net feeding by sablefish at some stations. Pacific cod (1% each) were consumed by Pacific halibut and sablefish. Coho salmon (5%) and Pacific ocean perch (less than 1%) were also found in Pacific halibut stomachs. Atka mackerel (1%) were only found in arrowtooth flounder stomachs. The commercially important Tanner crabs were mainly consumed by

Pacific cod and Pacific halibut (12% and 6% of the total stomach contents weight, respectively), though they were also consumed by rougheye rockfish (2%) and shortspine thornyhead (1%). Table 2 shows that almost all predator species consumed a certain amount of cephalopods (squid and octopus), of which rougheye rockfish and shortraker rockfish were the two main predators of the cephalopods. All predators, except northern rockfish and shortraker rockfish, preyed on pandalid shrimp, which includes all the Pandalus and Pandalopsis species. Among them, shortspine thornyhead (54%), rougheye rockfish (51%), pollock (19%), and Pacific cod (9%) were the main predators of the pandalids.

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 diet overlap between groundfish species in the Gulf of Alaska (Fig. 1). Schoener's index (Cxy) is calculated as

$$cxy = 1 - 0.5 (Px,i - Py,i),$$

where Px,i and Py,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 64 in column 3 and row 2 means the diet overlap between arrowtooth flounder (ATF) and Pacific halibut (PH) was 64% in term of the 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 (30-60%), and high (>60%) values. These values are denoted as blank cells

	ATF	PH	SAB	COD	PLK	SST	ROU	SHR	DUS	POP	NOR
ATF		64	48	19	22	10	11	4	10	9	4
PH			50	43	19	12	12	9	8	5	1
SAB				38	22	12	20	12	19	14	8
COD					31	46	38	25	15	8	2
PLK						43	39	7	47	49	41
SST							73	16	12	11	1
ROU								28	21	12	3
SHR									6	3	1
DUS										80	69
POP											90
NOR											

Diet Overlap

<30 % Low

30-60 % Medium

>60 % High

Figure 1.--Schoener's index (%) of dietary overlap of groundfish species in the Gulf of Alaska. ATF, arrowtooth flounder: PH, Pacific halibut: SAB, sablefish; COD, Pacific cod; PLK, pollock; SST, shortspine thornyhead; ROU, rougheye rockfish; SHR, shortraker rockfish; DUS, dusky rockfish: POP, Pacific ocean perch; NOR, northern rockfish.

(for <30% overlap), gray cells (for 30-60% overlap) and black cells (for >60% overlap). For example, in -column 2, it shows that arrowtooth flounder has high diet overlap (black cell) with Pacific halibut, medium diet overlap (gray cell) with sablefish and low diet overlap (blank cells) with all other species in this study. Overall, Figure 1 shows that two flatfish, arrowtooth flounder, and Pacific halibut that feed mainly on pollock had a high (>60% in this study) dietary overlap value of 64%. The overlap values between the Pacific halibut, sablefish, and Pacific cod were medium (30-60%) since they all fed on different proportions of shrimp, crab, and cephalopods even though they fed mainly on fish. It is very obvious from Figure 1 that pollock holds a very special position in the food web of the Gulf of Alaska. It had minimal (from 19 to 31%) overlap values with the primary piscivorous fish, arrowtooth flounder, Pacific halibut, sablefish, and Pacific cod. Pollock also had relatively high (39 to 49%) overlap values with all but the shortraker rockfish. This can be easily explained since the pollock's diet included not only large amounts (39%) of euphausiids (like many rockfishes) and shrimp (33%), but also some fish (e.g., capelin and pollock). The combination of euphausiids, shrimp, and fish as prey made pollock the most competitive (overlap diet with most of other species) groundfish species in the Gulf of Alaska. Figure 1 also shows that shortspine thornyhead and rougheye rockfish had a high dietary overlap value (73%) because they both fed on large amounts (54 and 51%, respectively) of pandalids. Dusky rockfish, Pacific ocean perch, and northern rockfish also

had high overlap values since they all fed largely (269%) on euphausiids.

Table 3 lists the size of the commercially important prey consumed by each predator species. While details of the prey size of each of the predators were presented in the different sections describing each species, this summary compares the prey size of the same prey species consumed by different predators.

Table 3 shows that prey pollock size varies from species to species. The average size (316 + 155 mm SL) of the prey pollock consumed by Pacific halibut was the highest, whereas predator pollock only consume smaller prey pollock (44 + 25 mm). The herring consumed were mainly age-l or age-2 fish. The mean length of the capelin consumed by different predator ranged from 79 to 95 mm SL. Most of the flatfish consumed were less than 200 mm. The mean size of Pacific sand lance consumed varied greatly from 41 + 22 mm SL consumed by pollock, to 94 +. 33 mm SL consumed by Pacific cod, to 137 + 27 mm SL consumed by Pacific halibut. The mean lengths of eulachon consumed by the predator species ranged from about 120 to 150 mm SL. The mean carapace widths of the Tanner crabs ranged from 16 + 3 mm (shortspine thornyhead) to 27 + 25 mm (sablefish). Prey Pacific cod included larvae 14-18 mm in length consumed by pollock and the 380 mm adult consumed by the Pacific halibut. Coho salmon (450, 500 mm SL) and Pacific ocean perch (208 mm SL) were only found in Pacific halibut stomachs. The only prey fish found in Pacific ocean perch and northern rockfish were larval arrowtooth flounder (about 20 mm SL).

Table 3.--The standard length (mm) of the commercially important prey consumed by the groundfish in the Gulf of Alaska in 1990. "+" indicates prey not measurable. "*" indicates no data. PLK, pollock; HER, Pacific herring; CAP, capelin; ATF, arrow-tooth flounder; FHS, flathead sole; GT, Greenland turbot; RS, rock sole; REX, rex sole; YFS, yellowfin sole; PH, Pacific halibut; DOV, Dover sole; EUL, eulachon; COD, Pacific cod, COH, coho salmon; POP, Pacific ocean perch; ATK, Atka mackerel; TAN, Tanner crab.

Prey	Predator									
	ATF				PH				SAB			
	Range	Mean	±	SD	Range	Mean	±	SD	Range	Mean	±	SD
PLK	21-450	196	±	89	34-670	316	±	155	56-445	235	±	125
HER	127-195	160	±	23	*	*			154-170	162	±	8
CAP	43-130	85	±	18	46-108	79	±	15	82-106	95	±	12
ATF	+	+			85-360	200	±	74	*	*		
FHS	130	130			58-280	147	±	96	*	*		
GT	*	*			*	*			*	*		
RS	*	*			160	160			*	*		
REX	*	*			*	*			*	*		
YFS	*	*			61- 64	63	±	2	*	*		
PH	*	*			21- 29	25	±	6	*	*		
DOV	*	*			105	105			*	*		
SAN	70	70			56-187	137	±	27	97	97		
EUL	130-154	142	±	17	120	120			68-165	134	±	41
COD	*	*			380	380			+	+		
COH	*	*			450-500	475	±	35	*	*		
POP	*	*			208	208			*	*		
ATK	128	128			*	*			*	*		
TAN	*	*			3- 97	25	±	18	5- 54	27	±	25

Table 3.--Continued.

Prey	Predator								
	COD			PLK			SST		
	Range	Mean ±	SD	Range	Mean ±	SD	Range	Mean ±	SD
PLK	33-468	161 ±	133	14-110	44 ±	25	49	49	
HER	*	*		*	*		*	*	
CAP	57-125	79 ±	14	43-140	95 ±	24	+	+	
ATF	33-390	153 ±	135	13- 35	27 ±	9	*	*	
FHS	17-220	81 ±	46	22- 66	51 ±	20	*	*	
GT	*	*		23	23		*	*	
RS	95-150	128 ±	29	*	*		*	*	
REX	121	121		*	*		*	*	
YFS	*	*		*	*		*	*	
PH	21- 60	41 ±	27	*	*		*	*	
DOV	*	*		115	115		*	*	
SAN	46-165	94 ±	33	28-118	41 ±	22	*	*	
EUL	132-180	156 ±	34	*	*		*	*	
COD	*	*		14- 18	16 ±	3	*	*	
COH	*	*		*	*		*	*	
POP	*	*		*	*		*	*	
ATK	*	*		*	*		*	*	
TAN	3- 99	20 ±	9	*	*		13- 18	16 ±	3

Table 3. --Continued.

Prey	Predator											
	ROU				POP				NOR			
	Range	Mean	±	SD	Range	Mean	±	SD	Range	Mean	±	SD
PLK	*	*			*	*			*	*		
HER	*	*			*	*			*	*		
CAP	*	*			*	*			*	*		
ATF	*	*			12-22	17	±	7	12-16	13	±	2
FHS	*	*			*	*			*	*		
GT	*	*			*	*			*	*		
RS	*	*			*	*			*	*		
REX	*	*			*	*			*	*		
YFS	*	*			*	*			*	*		
PH	*	*			*	*			*	*		
DOV	*	*			*	*			*	*		
SAN	*	*			*	*			*	*		
EUL	*	*			*	*			*	*		
COD	*	*			*	*			*	*		
COH	*	*			*	*			*	*		
POP	*	*			*	*			*	*		
ATK	*	*			*	*			*	*		
TAN	27	27			+	+			+	+		

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