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Food Habits of the Commerically Important Groundfishes in the Gulf of Alaska in 1990, 1993, and 1996

by
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ABSTRACT

A total of 13,928 stomachs from 13 species, walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), arrowtooth flounder (*Atheresthes stomias*), Pacific halibut (*Hippoglossus stenolepis*), sablefish (*Anoplopoma fimbria*), Pacific ocean perch (*Sebastes alutus*), northern rockfish (*Sebastes polyspinis*), dusky rockfish (*Sebastes ciliatus*), rougheye rockfish (*Sebastes aleutianus*), shortraker rockfish (*Sebastes borealis*), shortspine thornyhead (*Sebastolobus alascanus*), flathead sole (*Hippoglossoides elassodon*), and Atka mackerel (*Pleurogrammus monopterygius*), were analyzed to describe the food habits of the major groundfish species in the Gulf of Alaska in 1990, 1993, and 1996.

Arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and pollock were the main piscivores. Pollock were the dominant prey fish. The main predators that feed on Tanner crabs are Pacific halibut and Pacific cod. Pollock, shortspine thornyhead, shortraker rockfish, flathead sole, and rougheye rockfish are the main consumers of pandalid shrimp. Pacific ocean perch, northern rockfish, dusky rockfish, and Atka mackerel fed mainly on zooplanktons (mainly euphausiids and calanoid copepods).

A significant finding in this document is the predation on pandalid shrimp, capelin, and pollock. In 1990 and 1993, the

percentages of the pandalid shrimp consumed by pollock, Pacific cod, arrowtooth flounder, and sablefish were high (more than 10% by weight). However, in 1996, only Pacific cod still maintained 11% of pandalid shrimp in their diet. And the percentages of the pandalid shrimp in other predators declined dramatically to less than 10%. A similar trend was found in the consumption of capelin. A relatively large amount of capelin were consumed in 1990, and then declined in 1993 and 1996 by most species. However, during this period, the consumption of pollock increased dramatically in 1996 for most of the species.

The percent similarity index (PSI) was calculated by using the proportions of the prey items in the stomachs to show the diet overlap between groundfish species in the Gulf of Alaska in 1990, 1993, and 1996.

CONTENTS

INTRODUCTION

The estimated biomass of the groundfish resource in the Gulf of Alaska is about 5.8 million metric tons (t) (Martin 1997). Therefore, understanding the food habits of these fish and the interrelationships between them, their predators and their prey, becomes important when we try to understand the Gulf of Alaska ecosystem. In order to understand the multispecies implications of harvesting strategies, it is also important to understand the groundfish food web. These topics were the objective of this study.

In 1990, the Resource Ecology and Ecosystem Modeling (REEM) program of the Resource Ecology and Fishery Management (REFM) Division at the Alaska Fisheries Science Center (AFSC) began systematic collections of fish stomach samples in the Gulf of Alaska. The collections have continued on a triennial basis through REFM's participation in the bottom trawl survey performed by the Center's Resource Assessment and Conservation Engineering (RACE) Division in the Gulf of Alaska. This report includes information on the stomach collection procedures, data analysis and comparisons of the diet of groundfish species in the Gulf of Alaska for 1990, 1993, and 1996.

The western and central Gulf of Alaska regulatory areas of the North Pacific Fishery Management Council (NPFMC) were sampled for 12 predator species: Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), Pacific halibut

(*Hippoglossus 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*), shortspine thornyhead (*Sebastolobus alascanus*), and flathead sole (*Hippoglossoides elassodon*).

METHODS

Stomach Collection and Stomach Contents Analysis

The study area covered the area from the Islands of Four Mountains (170° W long.) to Cape St. Elias (144°30′W long.), which encompasses the NPFMC's western and central Gulf of Alaska regulatory areas.

Scientists on board chartered bottom trawl vessels collected stomachs from fish captured in AFSC survey trawls. Before excising a stomach, fish were examined for evidence of regurgitation or net feeding. If a fish had food in its mouth or around the gills, or if its stomach was inverted or flaccid, the fish was categorized as having regurgitated food, and the specimen was discarded. If a predator had fresh food (usually fish) sticking out of the mouth or the throat, it was categorized as a net-feeding fish and was also discarded. When a sampled stomach was retained, it was put in a cloth stomach bag. A field

tag with the species name, fork length (FL) of the fish, and haul data (vessel, cruise, haul number, specimen number) was also put in the bag. All of the samples collected were then preserved in buckets containing a 10% formalin solution. When the samples arrived at the laboratory, they were transferred into 70% ethanol before the stomach contents were analyzed. In the laboratory, the stomach was cut open, the contents were removed, then blotted with a paper towel. The wet weight was then recorded to the nearest 0.1 gm. After obtaining the total weight for a stomach's contents, the contents were placed in a Petri dish and examined under a 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 and carapace widths (CW) of Tanner crab (*C. bairdi*) 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 fishery offal if the parts (usually heads or tails) had an evident cut.

Data Analysis

The general diet of each species in each year was summarized to show the mean percent frequency of occurrence, and the mean percent of the total weight of each prey item found in the stomach (these values were calculated as the average of the values calculated from each haul)[1].

Change in diet by predator size in terms of percent by weight of main prey items was shown for each 10 cm FL group. The prey size frequency data of the commercially important fish and crabs, and some forage fish 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*

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[1] The values (means) of the 1990 data in this study are a little different from those shown in Yang (1993). In Yang's 1993 study, the values were calculated from the pooled data, not the means of the haul values.

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 other countries (e.g., Japan); therefore, data on these prey fish were also analyzed in this report.

GROUNDFISH FOOD HABITS

WALLEYE POLLOCK

by

Mei-Sun Yang

Walleye pollock (*Theragra chalcogramma*) ranked second (next to arrowtooth flounder) in biomass in the groundfish complex in the Gulf of Alaska in 1998. The exploitable biomass in 1998 was estimated at 1,156,000 t (NPFMC 1998). Walleye pollock feed mainly on euphausiids, calanoid copepods, and other crustaceans. As pollock increase in size, they also eat juvenile pollock and other teleosts. Therefore, it is important to understand the food habits of pollock and their possible impact on pollock and other commercially important fishes.

RESULTS

General Diet

Walleye pollock fed mainly on zooplankton. Euphausiids, shrimp, and calanoid copepods were the most important food. In addition, amphipods and planktonic tunicates (larvaceans) were also frequently found. Tables 1 - 3 (for the years 1990, 1993, and 1996, respectively) list the food items found in pollock stomachs, mean percentage of the prey weight to the total food weight, and the mean percentage of the frequency of occurrence of

Table 1.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Theragra chalcogramma* (walleye pollock) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	.51	3.30
Polynoidae (polychaete)	.05	.12
Pteropoda (snail)	.03	1.11
Bivalvia (clam)	.01	.29
Cephalopoda (unidentified)	.07	1.65
Teuthoidea (squid)	.30	2.26
Gonatidae (squid)	.47	.09
Berryteuthis magister (squid)	.20	.11
Octopoda (unidentified)	.14	.19
Calanoida (copepod unidentified)	1.58	31.71
Neocalanus cristatus	.01	.80
Eucalanus bungii (copepod)	.00	.18
Pseudocalanus sp. (copepod)	.00	.05
Mysidacea (mysid unidentified)	1.22	15.02
Acanthomysis marcropsis (mysid)	<.01	.09
Acanthomysis pseudomacropsis (mysid)	.03	.26
Holmesiella anomala (mysid)	.04	.59
Meterythrops robusta (mysid)	.18	2.44
Neomysis czerniawskii (mysid)	.01	.56
Neomysis rayii (mysid)	.10	.36
Pseudomma truncatum (mysid)	.02	.40
Cumacea (cumacean unidentified)	.15	1.39
Leucon sp. (cumacean)	.05	1.85
Isopoda (isopod)	.13	.31
Gammaridea (unidentified)	1.31	15.21
Ampeliscidae (amphipod)	.18	.71
Themisto sp. (amphipod)	2.11	34.98
Euphausiacea (unidentified)	45.42	77.67
Thysanoessa inermis (euphausiid)	.48	.42
Thysanoessa raschii (euphausiid)	<.01	.13
Thysanoessa spinifera (euphausiid)	.04	.19
Caridea (shrimp)	10.30	27.08
Pasiphaea pacifica (shrimp)	.88	.83
Hippolytidae (shrimp)	.10	.72
Spirontocaris arcuata (shrimp)	.12	.10
Eualus barbata (shrimp)	.01	.09
Eualus avinus (shrimp)	.06	.42
Pandalidae (shrimp)	11.90	12.16
Pandalus borealis (shrimp)	3.33	2.51
Pandalus goniurus (shrimp)	.05	.15
Pandalus jordani (shrimp)	.66	.67
Pandalopsis sp. (shrimp)	.45	.99
Crangonidae (unidentified)	1.92	6.40
Crangon communis (shrimp)	.13	.86
Paguridae (hermit crab)	1.38	12.64
Chaetognatha (arrow worm)	.03	1.78
Larvacea (tunicate)	.02	1.29
Teleostei (bony fish)	1.04	6.41
Non-gadoid fish remains	.72	2.95

Table 1.--Continued.

Prey name	Mean % Wt	Mean % FO
Clupea pallasi (Pacific herring)	.05	.09
Mallotus villosus (capelin)	6.93	4.73
Thaleichthys pacificus (eulachon)	.06	.48
Bathylagidae (deepsea smelts)	.01	.11
Chauliodontidae (viperfishes)	.01	.11
Stenobrachius leucopsarus (northern lampfish)	.01	.52
Gadidae (gadid fish)	.07	.50
Gadus macrocephalus (Pacific cod)	.01	.26
Theragra chalcogramma (walleye pollock)	2.07	4.14
Zoarcidae (eelpout)	.11	.63
Sebastes sp. (rockfish)	.05	.21
Cottidae (sculpin)	.18	.64
Cyclopteridae (snailfish)	.42	1.93
Stichaeidae (prickleback)	.21	.64
Lumpenus fabricii (slender eelblenny)	.06	.13
Lumpenus maculatus (daubed shanny)	.29	.50
Poroclinus rothrocki (whitebarred prickleback)	.02	.12
Cryptacanthodes aleutensis (dwarf wrymouth)	.29	.10
Ammodytes hexapterus (Pacific sand lance)	.19	.61
Pleuronectidae (flatfish)	.02	.37
Atheresthes stomias (arrowtooth flounder)	.05	.51
Hippoglossoides elassodon (flathead sole)	.25	.43
Microstomus pacificus (Dover sole)	.34	.10
Reinhardtius hippoglossoides (Greenland turbot)	.01	.12
Misc. unidentified materials	.05	.18
Total prey weight	2,746 g	
Total non-empty stomachs	985	
Total empty stomachs	74	
Total hauls	76	

Table 2.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Theragra chalcogramma* (walleye pollock) collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	.73	3.56
Gastropoda (snail)	.06	.40
Pteropoda (snail)	.09	.58
Bivalvia (clam)	.08	1.80
Cephalopoda (unidentified)	.07	.93
Teuthoidea (squid)	1.31	2.39
Octopoda (unidentified)	.17	.43
Crustacea (unidentified)	.27	.89
Calanoida (copepod)	3.58	23.47
Candacia columbiae (copepod)	.01	.18
Cirripedia (barnacle)	.02	.17
Mysidacea (mysid unidentified)	3.24	7.45
Pseudomma sp. (mysid)	<.01	.17
Cumacea (cumacean unidentified)	.05	1.06
Isopoda (isopod)	.00	.08
Gammaridea (amphipod)	1.24	5.03
Hyperiidea (amphipod)	.65	5.29
Themisto sp. (amphipod)	1.50	14.60
Euphausiacea (unidentified)	40.71	64.56
Caridea (shrimp)	1.88	10.04
Pasiphaea pacifica (shrimp)	.18	.26
Hippolytidae (shrimp)	.58	2.18
Pandalidae (shrimp)	16.93	17.05
Pandalus borealis (shrimp)	2.69	2.03
Crangonidae (shrimp)	3.37	6.47
Paguridae (hermit crab)	1.86	11.70
Majidae (spider crab)	.12	2.55
Oregonia sp. (decorator crab)	<.01	.09
Hyas sp. (lyre crab)	.01	.25
Atelecyclidae (crab)	.01	.30
Cancridae (crab)	.02	.56
Asteroidea (starfish)	.65	.07
Ctenodiscus crispatus (mud sea star)	.54	.12
Chaetognatha (arrow worm)	.15	1.61
Larvacea (tunicate)	6.82	13.25
Teleostei (bony fish)	.87	3.17
Non-gadoid fish remains	1.77	3.33
Osmeridae (smelts)	.72	.08
Mallotus villosus (capelin)	2.08	1.74

Table 2.--Continued.

Prey name	Mean % Wt	Mean % FO
Thaleichthys pacificus (eulachon)	1.28	.46
Myctophidae (lanternfish)	.16	.15
Theragra chalcogramma (walleye pollock)	1.24	.97
Zoarcidae (eelpout)	.02	.18
Cottidae (sculpin)	.10	.16
Stichaeidae (prickleback)	.48	.39
Ammodytes hexapterus (Pacific sand lance)	.78	1.59
Pleuronectidae (flatfish)	.05	.13
Atheresthes stomias (arrowtooth flounder)	.05	.36
Misc. unidentified materials	.69	1.70
Total prey weight	3,233 g	
Total non-empty stomachs	936	
Total empty stomachs	190	
Total hauls	84	

Table 3.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Theragra chalcogramma* (walleye pollock) collected in the Gulf of Alaska in 1996.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	.22	1.20
Tomopteridae (polychaete)	.01	.32
Pteropoda (snail)	.13	3.88
Cephalopoda (unidentified)	<.01	.28
Teuthoidea (squid unidentified)	.38	3.56
Calanoida (copepod)	17.73	34.02
Calanus sp. (copepod)	.03	.17
Mysidacea (mysid unidentified)	.33	.48
Cumacea (cumacean)	2.28	2.79
Gammaridea (amphipod)	.03	.55
Themisto sp. (amphipod)	1.40	18.60
Euphausiacea (unidentified)	56.43	66.70
Euphausia pacifica (euphausiid)	.09	.39
Thysanoessa sp. (euphausiid)	.80	.88
Thysanoessa spinifera (euphausiid)	.77	.80
Decapoda (unidentified)	.01	.45
Sergestidae (shrimp)	.17	1.20
Caridea (shrimp)	.16	2.04
Hippolytidae (shrimp)	.02	.17
Pandalidae (shrimp)	.29	.62
Pandalus borealis (shrimp)	1.82	2.12
Crangonidae (shrimp)	.46	.63
Crangon dalli (shrimp)	.05	.34
Crangon communis (shrimp)	.01	.22
Paguridae (hermit crab)	.03	.68
Chaetognatha (arrow worm)	.06	1.54
Larvacea (tunicate)	3.91	6.11
Teleostei (bony fish)	.23	.87
Chauliodontidae (viperfishes)	.01	.25
Myctophidae (lanternfish)	.08	.15
Theragra chalcogramma (walleye pollock)	10.24	10.31
Zoarcidae (eelpout)	.02	.22
Cottoidei (sculpin)	.02	.28
Ammodytes hexapterus (Pacific sand lance)	1.60	.70
Pleuronectidae (flatfish)	.02	.68
Atheresthes sp.	.14	.19
Total prey weight	2,162 g	
Total non-empty stomachs	434	
Total empty stomachs	57	
Total hauls	45	

the prey. Total number of stomachs with food, the number of total empty stomachs, and the number of the hauls were also listed in Tables 1 - 3. The percent by weight of the fish consumed was no more than 15% of the total stomach contents in each of the three years sampled (Tables 1 - 3). Juvenile walleye pollock and capelin were the most important prey fish consumed by pollock in this study. Other commercially important prey fish included Pacific herring, Pacific cod, arrowtooth flounder, flathead sole, Dover sole, Greenland turbot. Eulachon and Pacific sand lance were also consumed by pollock.

Comparing the diets from the three years indicates that the diet of walleye pollock in 1990 and 1993 was very similar. In both years, the diets included about 41-46% (by weight) euphausiids, 26-40% shrimp, and 9-13% fish. Compared to 1990 and 1993, the 1996 data showed a higher percentage of euphausiids (58% by weight), calanoid copepods (18%), and juvenile pollock (10%); and a smaller percentage of shrimp (only 3%) in pollock stomach contents.

Variation of Diet Based on Predator Size

Figure 1 illustrates the main prey items of walleye pollock by predator fork length. In 1990 and 1993, calanoid copepods and amphipods were mainly consumed by smaller (<40 cm FL) pollock. Euphausiids comprised the largest portion of pollock food through

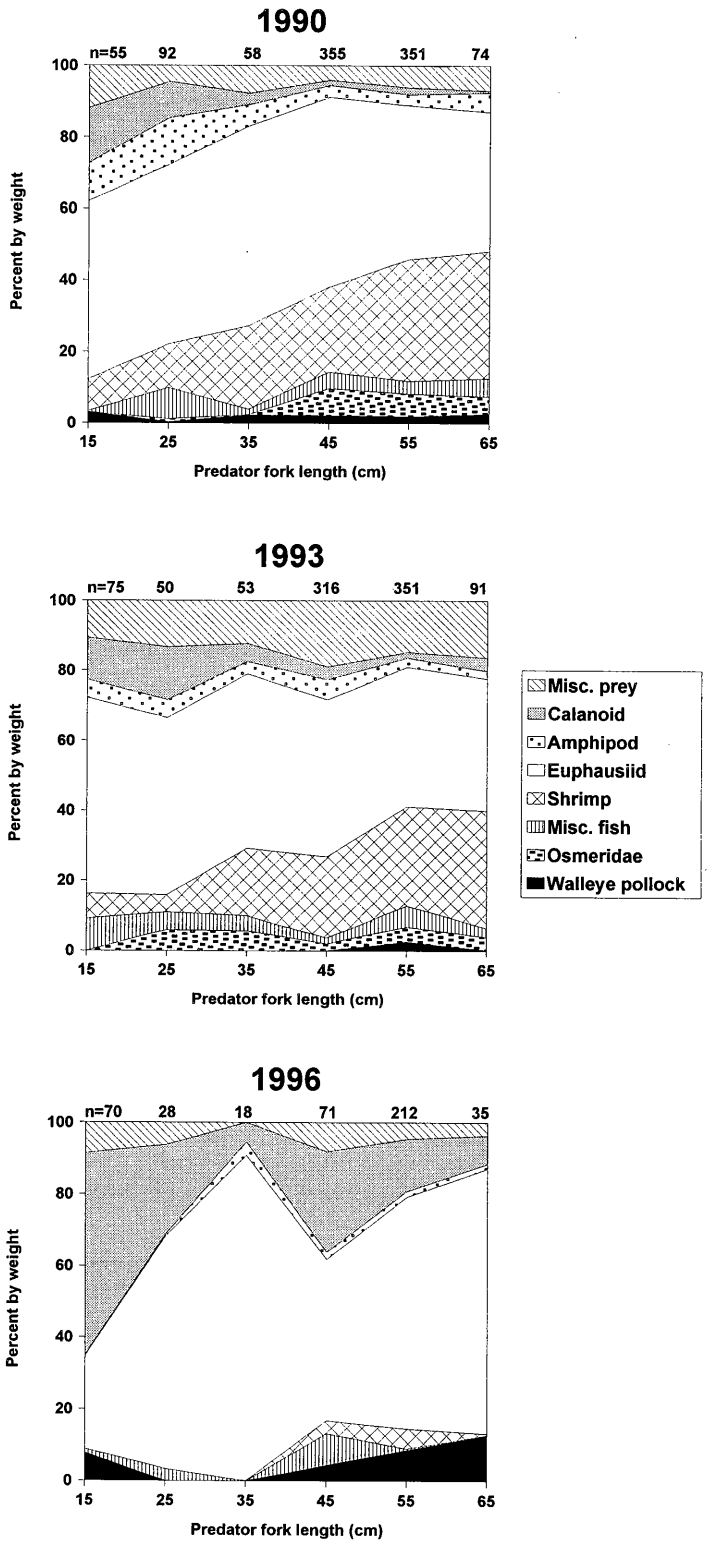


Figure 1.-- Variations in the main food items of walleye pollock, by predator size, in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size.

all size groups. Shrimp comprised the second largest portion of pollock food in all but the smallest (<20 cm FL) size group. For all size groups, walleye pollock consumed small amounts (<5%) of juvenile pollock.

In 1996, more calanoid copepods were consumed by smaller (<40 cm FL) pollock. Euphausiids made up the largest portion of the diet in all but the smallest (<20 cm FL) pollock size group. Juvenile pollock comprised about 13% of the diet of the largest size group (≥60 cm FL) of pollock.

Geographic Distribution of the Prey Consumed

Figures 2 - 4 show the percentage by weight of juvenile pollock, capelin, and pandalid shrimp consumed by walleye pollock in different locations in 1990, 1993, and 1996. Figure 2 illustrates that small amounts of juvenile pollock were consumed northeast of Kodiak Island in 1990 and 1993. It also shows that large amounts of pollock were consumed in the same area in 1996. Capelin were primarily consumed northeast of Kodiak Island in 1990 only (Fig. 3). Large amounts of pandalid shrimp were consumed both northeast and west of Kodiak Island in 1990 and 1993 (Fig. 4).

Sizes of the Commercially Important Prey Consumed

Prey size data of walleye pollock were divided into two predator size groups (<40 cm FL, and ≥40 cm FL) for analysis. The size frequencies of the walleye pollock, capelin, and Pacific sand

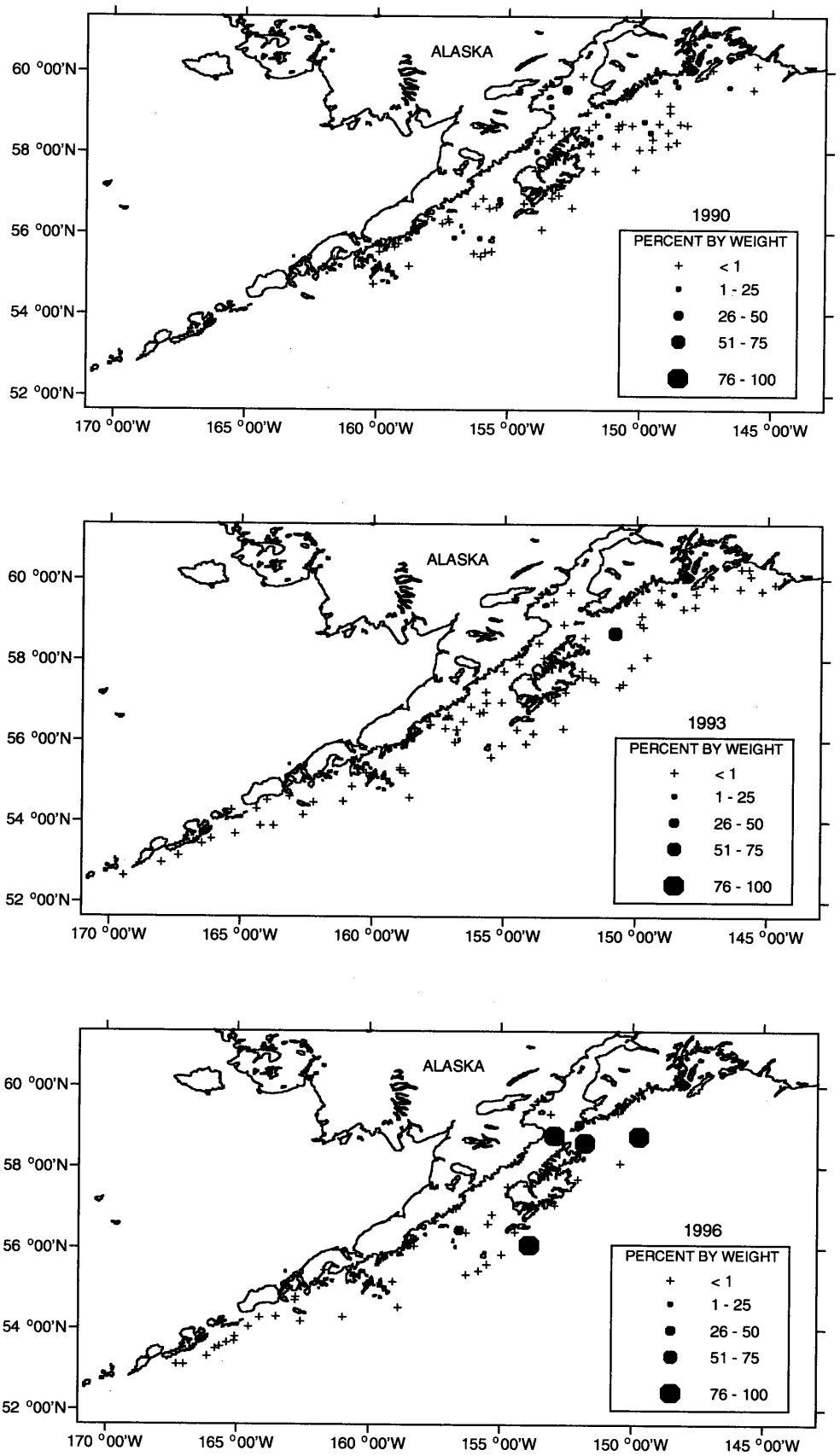


Figure 2.--Geographic distribution of juvenile walleye pollock consumed by walleye pollock in summer 1990, 1993, and 1996 in Gulf of Alaska.

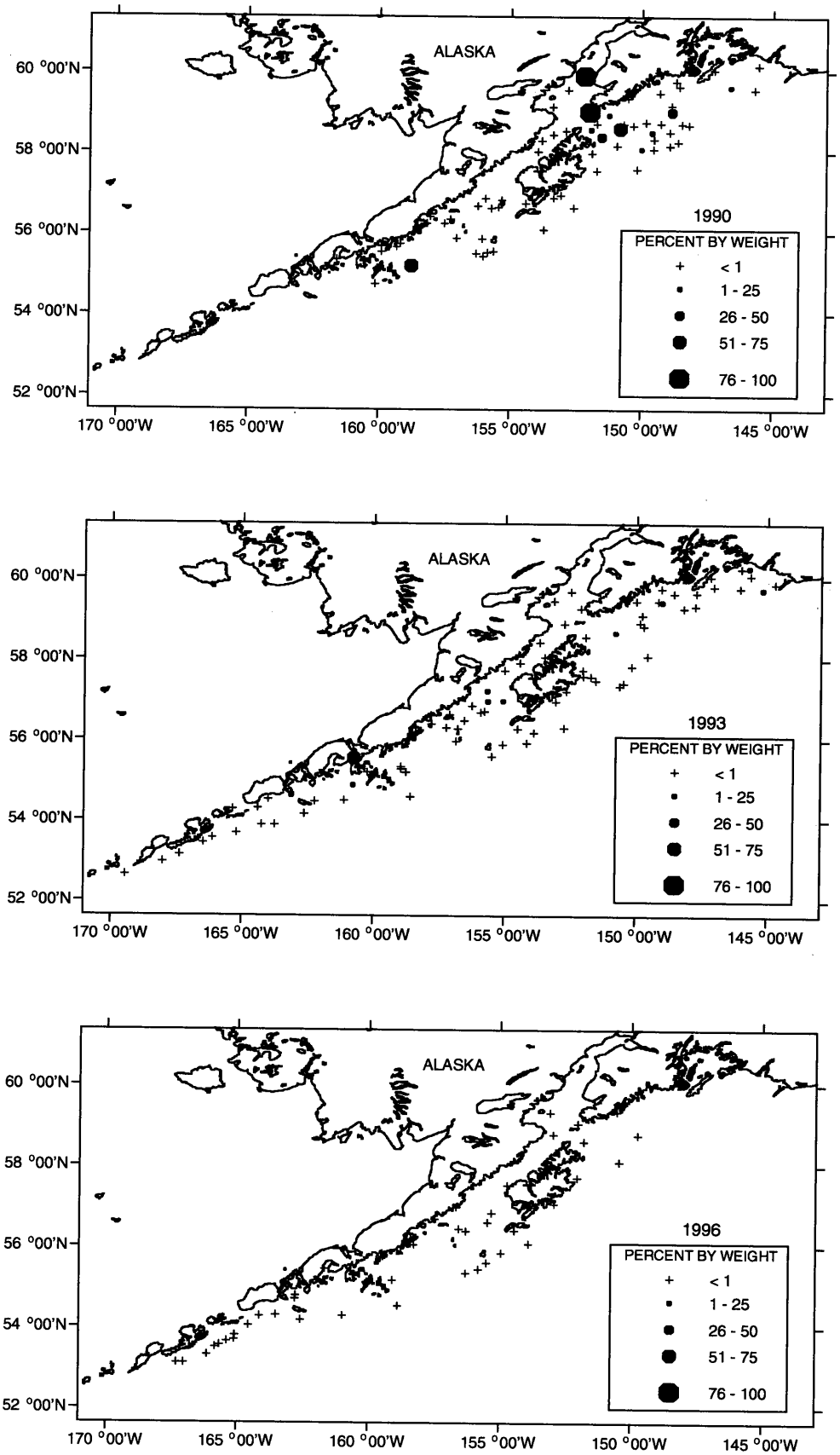


Figure 3.--Geographic distribution of capelin consumed by walleye pollock in summer 1990, 1993, and 1996 in Gulf of Alaska.

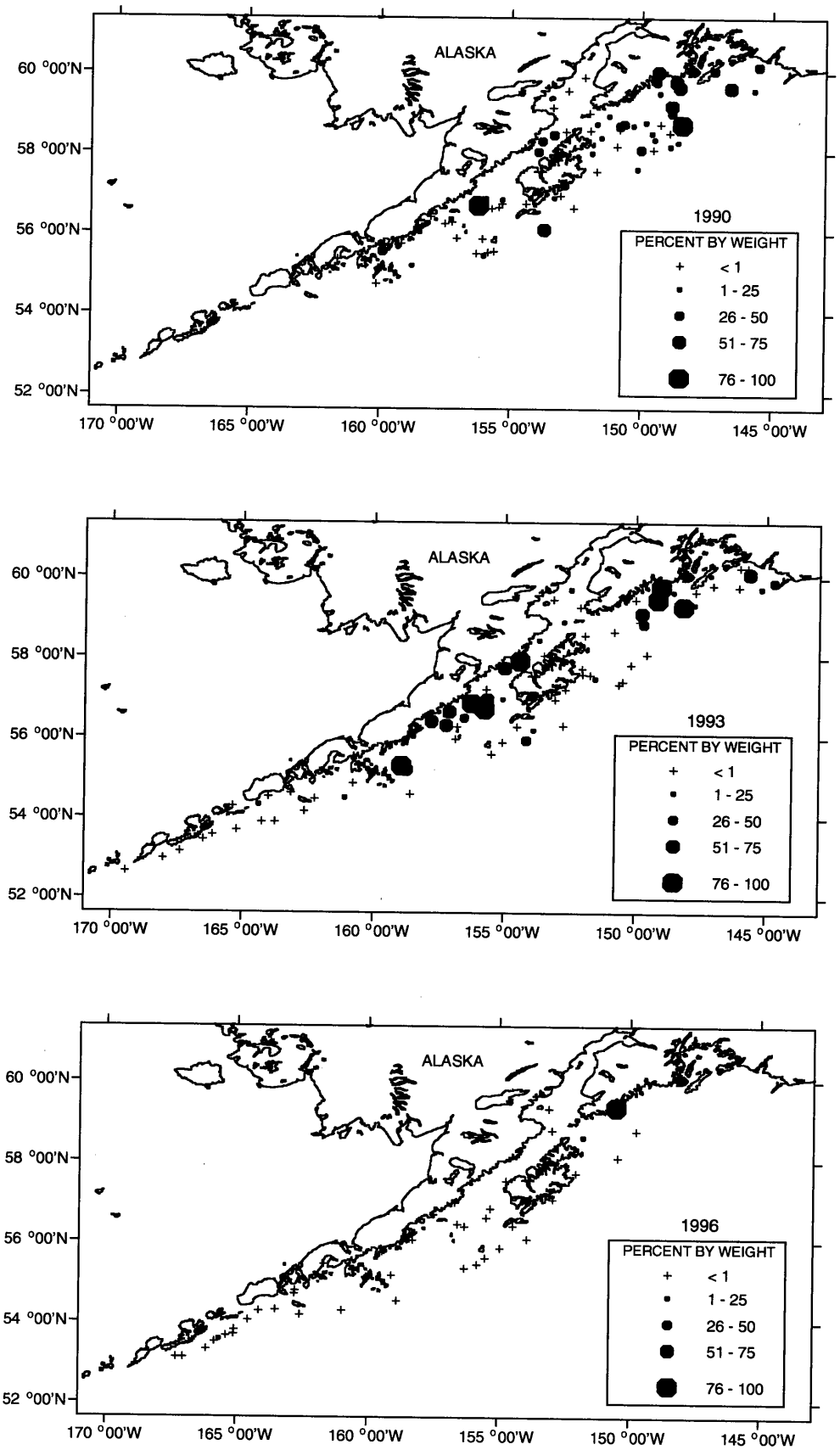


Figure 4.--Geographic distribution of pandalid shrimp consumed by walleye pollock in summer 1990, 1993, and 1996 in Gulf of Alaska.

lance consumed by walleye pollock are shown in Figures 5 - 7. Walleye pollock consumed mainly age-0 walleye pollock (< 140 mm SL) during the three sample years. The juvenile pollock consumed had a mean standard length and (±SD) of 71.5 ± 43.7 mm and ranged from 13 to 175 mm SL. In 1996, walleye pollock consumed relatively larger size juvenile pollock (around 120 mm SL) than in 1990 and 1993 (Fig. 5). Capelin were primarily consumed by the larger size group (≥40 cm FL) of pollock in 1990 and 1993 (Fig. 6). They had a mean standard length of 83.4 ± 25.7 mm and a range from 37 to 140 mm SL. Pacific sand lance were mainly consumed by larger pollock (≥40 cm FL) (Fig. 7), and they had a mean standard length of 45.1 ± 11.1 mm and a range from 28 to 118 mm SL. More Pacific sand lance was consumed by pollock in 1993 than in 1990, and 1996. Walleye pollock also consumed Pacific cod, arrowtooth flounder, Greenland turbot, flathead sole, Dover sole, snailfish, stichaeids, eulachon, myctophids, zoarcids, and cottids. The number, mean standard length, and the standard deviation of these prey fish are listed in Table 4.

DISCUSSION

Comparing the results for the three years, we found that fewer age-0 pollock were consumed (1-2% by weight) in 1990 and 1993 than in 1996 (10%)(Fig. 2 and Tables 1, 2, and 3). During the same time period, the consumption of capelin declined from 7% in 1990 to 2% in 1993 to nonexistence in 1996; and the

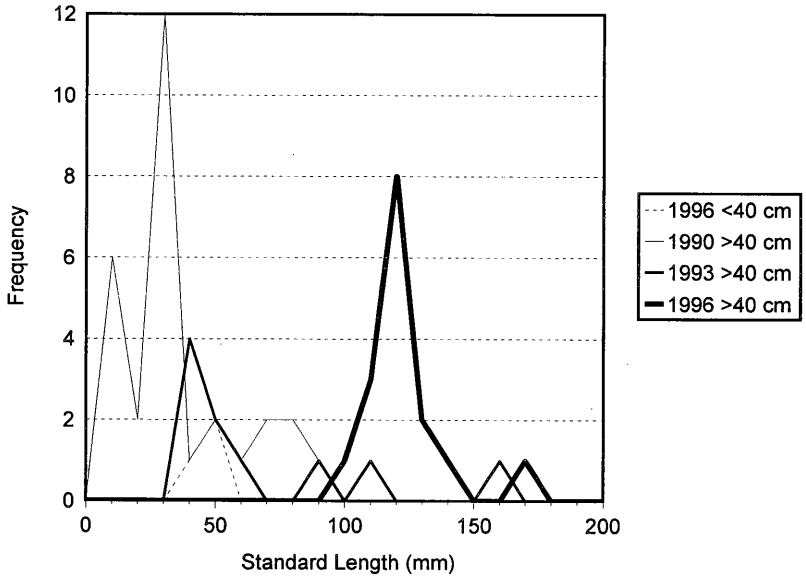


Figure 5.-- Size frequency distribution of juvenile walleye pollock consumed by walleye pollock in the Gulf of Alaska in 1990, 1993 and 1996.

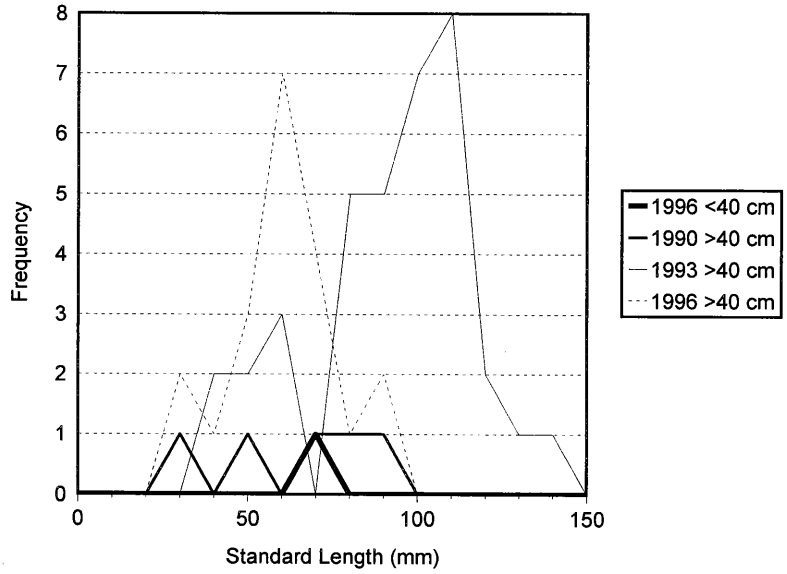


Figure 6.--Size frequency distribution of capelin consumed by walleye pollock in the Gulf of Alaska in 1990 and 1993.

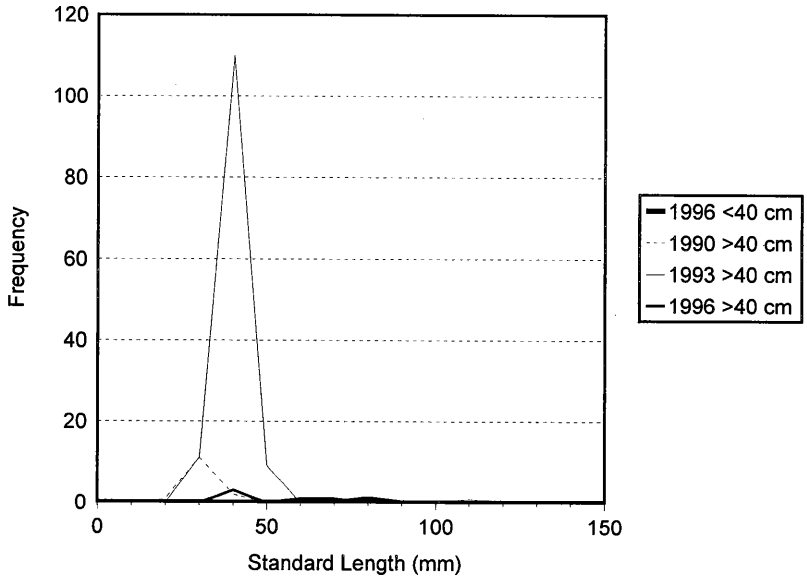


Figure 7.--Size frequency distribution of Pacific sand lance consumed by walleye pollock in the Gulf of Alaska in 1990, 1993 and 1996.

Table 4.--Mean standard length (SL) and standard deviation (SD) of the miscellaneous prey fish consumed by walleye pollock in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size

Prey name	n	Mean SL (mm)	SD (mm)	Range (mm)
Pacific cod	3	16.4	2.5	14-18
Arrowtooth flounder	20	24.1	8.7	13-46
Greenland halibut	1	23.0	0.0	23-23
Flathead sole	4	50.5	19.8	22-66
Dover sole	1	15.0	0.0	15-15
Snailfish	78	20.3	5.3	7-33
Stichaeids	21	58.9	22.9	27-126
Eulachon	8	101.6	61.4	33-180
Myctophids	6	28.2	24.4	13-74
Zoarcids	11	41.5	18.5	21-88
Cottids	10	24.0	19.0	13-70

consumption of pandalid shrimp declined from 16% in 1990 and 20% in 1993 to 2% in 1996. These observations were coincident with the declines in the populations of capelin and pandalid shrimp in Pavlof Bay found by Paul Anderson of the AFSC's Kodiak Laboratory (personal communication 1999). The cause for this decline is unknown. It appears that because of the declining pandalid shrimp and capelin populations, pollock consumed more euphausiids (56%) and calanoid copepods (17%) in 1996 than in 1990 (46% euphausiids and 2% calanoid copepods) and 1993 (41% euphausiids and 4% calanoid copepods).

PACIFIC COD

by

Mei-Sun Yang

Pacific cod (*Gadus macrocephalus*), with an exploitable biomass of 785,000 t (NPFMC 1998), ranks third in abundance in the Gulf of Alaska groundfish community. The landings of Pacific cod totaled 77,160 t in 1997. 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 crab.

RESULTS

General Diets

The long list of prey items presented in Tables 5 to 7 suggests that Pacific cod is an opportunistic feeder. These tables present the total number of stomachs with food, total empty stomachs, the mean percent frequency of occurrence, and the mean percent by weight of the prey items found in the stomachs in 1990, 1993, and 1996. Polychaetes and cephalopods were the most frequently found invertebrates in Pacific cod stomachs. However, shrimp (mainly pandalids) were relatively more important in terms of the percentage of the total stomach content weight. Pacific cod also consumed large amounts of Tanner crab (*C. bairdi*)(10%,

Table 5.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight)of *Gadus macrocephalus* (Pacific cod) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	5.02	46.44
Aphroditidae (polychaete)	3.11	5.95
Gastropoda (snail)	.26	8.11
Buccinum sp. (snail)	.06	.84
Neptunea sp. (snail)	.02	.33
Pteropod (snail)	.01	.21
Bivalvia (clam)	.32	7.91
Cephalopoda (unidentified)	.06	6.39
Teuthoidea (squid unidentified)	.77	1.80
Gonatidae (squid)	.30	.09
Octopoda (unidentified)	6.10	17.64
Calanoida (unidentified)	.04	2.44
Cirripedia (barnacle)	.02	.87
Mysidacea (mysid unidentified)	.08	8.23
Holmesiella anomala (mysid)	<.01	.10
Meterythrops robusta (mysid)	<.01	.10
Neomysis rayii (mysid)	<.01	.10
Pseudomma sp. (mysid)	<.01	.30
Cumacea (cumacean unidentified)	.09	.90
Leucon sp. (cumacean)	<.01	.37
Isopoda (isopod)	.17	3.21
Gammaridea (unidentified)	.75	34.91
Ampeliscidae (amphipod)	.19	5.48
Themisto sp. (amphipod)	.01	1.21
Caprellidea (amphipod)	<.01	.27
Euphausiacea (unidentified)	.88	21.64
Thysanoessa spinifera (euphausiid)	<.01	.26
Caridea (unidentified)	4.22	27.62
Pasiphaea pacifica (shrimp)	<.01	.18
Hippolytidae (shrimp)	.58	15.52
Spirontocaris sp. (shrimp)	.14	3.44
Spirontocaris lamellicornis (shrimp)	<.01	.09
Spirontocaris ochotensis (shrimp)	.01	.61
Spirontocaris arcuata (shrimp)	.01	.52
Lebbeus sp. (shrimp)	<.01	.17
Lebbeus groenlandicus (shrimp)	.11	.17
Eualus sp. (shrimp)	<.01	3.36
Eualus barbata (shrimp)	.03	.42
Eualus biunguis (shrimp)	<.01	.09
Eualus townsendi (shrimp)	<.01	.10
Eualus pusiolus (shrimp)	<.01	.31
Eualus stoneyi (shrimp)	<.01	.09
Eualus avinus (shrimp)	.05	2.39
Heptacarpus sp. (shrimp)	<.01	.09
Pandalidae (shrimp)	5.51	22.47
Pandalus sp. (shrimp)	2.92	12.13
Pandalus borealis (shrimp)	1.45	6.22
Pandalus goniurus (shrimp)	.31	.96
Pandalus jordani (shrimp)	<.01	.09
Pandalus montagui tridens (shrimp)	.19	1.15

Table 5.--Continued.

Prey name	Mean % Wt	Mean % FO
Pandalopsis sp. (shrimp)	.31	4.20
Pandalopsis dispar (shrimp)	.07	.09
Crangonidae (shrimp)	3.64	37.01
Crangon sp. (shrimp)	.23	2.03
Crangon alaskensis (shrimp)	.01	.09
Crangon stylirostris (shrimp)	.03	.09
Crangon dalli (shrimp)	<.01	.27
Crangon communis (shrimp)	1.79	15.97
Rhynocrangon alata (shrimp)	.09	.79
Argis sp. (shrimp)	.32	4.98
Argis lar (shrimp)	.05	.51
Argis dentata (shrimp)	.01	.17
Argis ovifer (shrimp)	.02	.32
Argis alaskensis (shrimp)	.03	.43
Metacrangon munita (shrimp)	.05	.51
Reptantia (crab)	.26	4.37
Anomura (unidentified)	.05	.40
Paguridae (hermit crab)	6.37	18.75
Pagurus sp. (hermit crab)	.22	1.25
Pagurus aleuticus (hermit crab)	.05	.18
Pagurus rathbuni (hermit crab)	.01	.24
Elassochirus sp. (hermit crab)	<.01	.09
Elassochirus tenuimanus (hermit crab)	.02	.27
Acantholithodes hispidus (fussy crab)	.14	.09
Lopholithodes sp. (box crab)	.11	.19
Lopholithodes foraminatus (brown box crab)	1.12	.19
Munida quadrispina (pinch bug)	.41	2.41
Majidae (spider crab)	.24	1.84
Oregonia sp. (decorator crab)	.01	.41
Oregonia gracilis (decorator crab)	.19	1.36
Oregonia bifurca (decorator crab)	.01	.26
Hyas sp. (lyre crab)	1.85	3.14
Hyas lyratus (lyre crab)	1.47	3.01
Hyas coarctatus (lyre crab)	.01	.26
Chionoecetes sp. (unidentified)	.99	5.78
Chionoecetes opilio (snow crab)	.12	.50
Chionoecetes bairdi (Tanner crab)	9.13	38.85
Erimacrus isenbeckii (Korean horse-hair crab)	<.01	.13
Cancer sp. (crab)	.05	.35
Cancer oregonensis (pygmy cancer crab)	.24	2.05
Pinnotheridae (pea crab)	.41	6.81
Pinnixa sp. (pea crab)	.33	4.89
Sipuncula (marine worm)	.10	.81
Echiura (marine worm)	.99	4.72
Asteroidea (starfish)	.02	.36
Ophiuroidae Ophiurida (brittle star)	.01	.80
Osteichthyes Teleostei (bony fish)	4.87	17.64
Non-gadoid Fish Remains	.61	11.19
Clupea pallasi (Pacific herring)	.43	.45
Mallotus villosus (capelin)	2.69	4.63

Table 5.--Continued.

Prey name	Mean % Wt	Mean % FO
Thaleichthys pacificus (eulachon)	1.22	1.42
Gadidae (gadid fish)	.24	1.76
Theragra chalcogramma (walleye pollock)	5.19	5.27
Zoarcidae (eelpout)	.90	2.67
Lycodes brevipes (shortfin eelpout)	.43	1.45
Cottidae (sculpin)	.98	9.08
Artedius sp. (sculpin)	.25	.09
Dasycottus setiger (spinyhead sculpin)	.63	.18
Icelinus borealis (Northern Sculpin)	<.01	.09
Agonidae (poacher)	.11	2.17
Asterotheca alascana (gray starsnout)	.01	.09
Asterotheca pentacanthus (bigeye poacher)	.02	.09
Sarritor frenatus (sawback poacher)	.09	1.05
Cyclopteridae (snailfish)	<.01	.48
Eumicrotremus orbis (Pacific spiny lumpsucker)	.03	.09
Bathymaster signatus (searcher)	.88	.81
Stichaeidae (prickleback)	1.41	7.68
Lumpenus fabricii (slender eelblenny)	<.01	.09
Lumpenus maculatus (daubed shanny)	.14	.95
Poroclinus rothrocki (whitebarred prickleback)	.14	.38
Cryptacanthodes aleutensis (dwarf wrymouth)	.54	1.75
Ammodytes hexapterus (Pacific sand lance)	1.23	2.05
Pleuronectidae (flatfish)	.98	2.88
Atheresthes stomias (arrowtooth flounder)	2.53	1.73
Errex zachirus (rex sole)	.05	.26
Hippoglossoides elassodon (flathead sole)	1.25	2.73
Pleuronectes bilineatus (rock sole)	.32	.27
Hippoglossus stenolepis (Pacific halibut)	<.01	.14
Fishery offal	5.49	3.22
Unidentified material	.02	.66
Total prey weight	20,872 g	
Total non-empty stomachs	892	
Total empty stomachs	24	
Total hauls	78	

Table 6.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight)of *Gadus macrocephalus* (Pacific cod) collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Anthozoa (anemone)	.03	.07
Polychaeta (unidentified)	3.72	15.98
Aphroditidae (polychaete)	3.30	8.60
Gastropoda (snail)	.44	3.60
Nudibranchia (nudibranch)	.02	.07
Bivalvia (clam)	.28	3.89
Pectinidae (scallops)	.01	.27
Cardiidae (cockle family)	<.01	.08
Cephalopoda (unidentified)	1.01	2.23
Teuthoidea (squid)	.56	1.38
Octopoda (octopus)	2.49	12.97
Copepoda (unidentified)	.01	.16
Calanoida (copepod)	<.01	.15
Cirripedia (barnacle)	.04	.08
Mysidacea (mysid unidentified)	.08	1.02
Cumacea (cumacean)	.18	.07
Isopoda (isopod)	.23	2.41
Amphipoda (amphipod)	.01	.07
Gammaridea (amphipod)	3.49	23.72
Themisto sp. (amphipod)	.02	.16
Caprellidea (amphipod)	.03	.19
Euphausiacea (euphausiid)	5.51	25.15
Caridea (shrimp)	.71	3.25
Hippolytidae (shrimp)	1.58	5.03
Pandalidae (shrimp)	12.96	31.72
Pandalus borealis (shrimp)	1.42	2.24
Pandalopsis dispar (shrimp)	.65	1.10
Crangonidae (shrimp)	6.93	28.15
Sclerocrangon sp. (shrimp)	.13	.08
Reptantia (crab)	.48	2.79
Paguridae (hermit crab)	6.68	16.06
Galatheidae (pelagic slip crabs)	.12	.38
Majidae (spider crab)	.10	.15
Oregonia sp. (decorator crab)	.12	.23
Hyas sp. (lyre crab)	3.80	6.22
Chionoecetes bairdi (Tanner crab)	6.57	20.65
Telmessus cheiragonus (hair crab)	.34	.24
Erimacrus isenbeckii (Korean Horse-hair crab)	.03	.09
Cancer oregonensis (pygmy cancer crab)	.74	1.47
Pinnotheridae (pea crab)	.64	3.36
Asteroidea (starfish)	.17	.52
Ophiuroidae (brittle star)	.07	.49
Larvacea Copelata	.02	.16

Table 6.--Continued.

Prey name	Mean % Wt	Mean % FO
Rajidae (skate)	.38	.28
Osteichthyes Teleostei (bony fish)	.35	2.00
Non-gadoid Fish Remains	.74	3.07
Mallotus villosus (capelin)	.83	1.06
Thaleichthys pacificus (eulachon)	.43	.41
Myctophidae (lanternfish)	.04	.16
Gadidae (gadid fish)	.08	.24
Theragra chalcogramma (walleye pollock)	18.61	9.24
Zoarcidae (eelpout)	.39	1.23
Lycodes palearis (wattled eelpout)	.43	.16
Cottidae (sculpin)	3.00	6.93
Agonidae (poacher)	.10	.37
Bathymaster signatus (searcher)	.21	.07
Stichaeidae (prickleback)	.82	2.24
Poroclinus rothrocki (whitebarred prickleback)	.09	.27
Ammodytes hexapterus (Pacific sand lance)	1.33	2.22
Pleuronectiformes (flatfish)	1.03	2.10
Atheresthes stomias (arrowtooth flounder)	2.50	1.00
Hippoglossoides elassodon (flathead sole)	.80	.67
Unidentified organic material	.37	.79
Fishery offal	1.75	.32

Total prey weight	26,043 g
Total non-empty stomachs	1,035
Total empty stomachs	47
Total hauls	89

Table 7.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight)of *Gadus macrocephalus* (Pacific cod) collected in the Gulf of Alaska in 1996.

Prey name	Mean % Wt	Mean % FO
Porifera (sponge)	1.39	.26
Anthozoa (anemone)	.02	.12
Polychaeta (unidentified)	3.15	30.23
Aphroditidae (polychaete)	2.29	5.69
Polynoidae (polychaete)	.58	5.37
Nephtyidae (polychaete)	.06	.65
Goniadidae (polychaete)	<.01	.15
Maldanidae (polychaete)	.01	.26
Pectinariidae (polychaete)	.01	.12
Mollusca (unidentified)	.07	.74
Gastropoda (snail)	.16	4.22
Fusitriton oregonensis (snail)	.01	.13
Neptuneidae (snail)	<.01	.12
Pteropoda (snail)	.03	.14
Bivalvia (clam)	.14	3.30
Nuculidae (clam)	.01	.74
Yoldia sp. (clam)	.03	.68
Mytilidae (mussel)	.01	.13
Pectinidae (scallops)	.01	.25
Chlamys sp. (scallop)	.01	.12
Cephalopoda (unidentified)	.03	.93
Teuthoidea (squid)	.02	1.39
Octopoda (unidentified)	1.20	9.46
Calanoida (copepod)	<.01	.66
Balanomorpha (barnacle)	.02	.13
Mysidacea (mysid unidentified)	.01	.21
Mysidae (mysid)	.02	1.70
Cumacea (cumacean)	.01	.50
Isopoda (isopod)	.14	3.35
Gammaridea (amphipod)	1.58	32.47
Hyperiidea (amphipod)	.10	.13
Themisto sp. (amphipod)	<.01	.35
Caprellidea (amphipod)	.01	.28
Euphausiacea (euphausiid)	4.37	30.81
Caridea (shrimp)	1.01	10.22
Hippolytidae (shrimp)	.95	8.88
Eualus sp. (shrimp)	.05	.42
Pandalidae (shrimp)	5.65	17.24
Pandalus sp. (shrimp)	.04	.12
Pandalus borealis (shrimp)	4.72	10.12
Pandalus goniurus (shrimp)	.32	.28
Pandalopsis dispar (sidestripe shrimp)	.05	.21
Crangonidae (shrimp)	2.10	15.10
Crangon sp. (shrimp)	.04	.28
Crangon alaskensis (shrimp)	.02	.12
Crangon dalli (shrimp)	.43	5.71
Argis sp. (shrimp)	.15	.52
Reptantia (crab)	.45	2.65
Paguridae (hermit crab)	10.69	26.86

Table 7.--Continued.

Prey name	Mean % Wt	Mean % FO
Lithodidae (king crab)	<.01	.12
Acantholithodes hispidus (fussy crab)	.16	.12
Galatheidae (pelagic slip crabs)	.01	.17
Munida quadrispina (pinch bug)	.03	.14
Majidae (spider crab)	.21	1.49
Oregonia sp. (decorator crab)	1.20	1.55
Oregonia gracilis (decorator crab)	<.01	.12
Hyas sp. (lyre crab)	3.97	7.66
Hyas lyratus (lyre crab)	2.44	4.69
Chionoecetes sp. (unidentified)	.63	2.53
Chionoecetes bairdi (Tanner crab)	10.77	25.25
Erimacrus isenbeckii (Korean horse-hair crab)	.22	.31
Cancer oregonensis (pygmy cancer crab)	.37	.70
Pinnotheridae (pea crab)	.21	3.61
Pinnixa sp. (pea crab)	.16	1.83
Sipuncula (marine worm)	.50	2.06
Echiura (marine worm)	.04	.23
Ectoprocta (bryozoan)	<.01	.25
Asteroidea (starfish)	.03	.60
Ophiuroidae (brittle star)	.18	.56
Stronglyocentrotus sp. (sea urchin)	.02	.15
Holothuroidea (sea cucumber)	.02	.25
Urochordata (tunicate)	.01	.37
Osteichthyes Teleostei (bony fish)	.73	6.45
Non-gadoid Fish Remains	.87	1.60
Osmeridae (smelts)	.01	.25
Mallotus villosus (capelin)	.12	.84
Thaleichthys pacificus (eulachon)	.03	.34
Gadidae (gadid fish)	.28	.39
Theragra chalcogramma (walleye pollock)	22.96	14.88
Zoarcidae (eelpout)	.32	1.33
Sebastes sp. (rockfish)	.50	.68
Hexagrammidae (greenling)	<.01	.12
Pleurogrammus monopterygius (Atka mackerel)	3.53	1.06
Cottoidei (sculpin)	1.14	8.25
Agonidae (poacher)	.50	1.50
Sarritor frenatus (sawback poacher)	.01	.25
Trichodon trichodon (Pacific sandfish)	1.88	.52
Bathymaster signatus (searcher)	.44	.25
Stichaeidae (prickleback)	.34	.71
Ammodytes hexapterus (Pacific sand lance)	.32	1.31
Pleuronectidae (flatfish)	.18	1.67
Atheresthes stomias (arrowtooth flounder)	1.24	.36
Pleuronectes bilineatus (rock sole)	.22	.82
Hippoglossus stenolepis (Pacific halibut)	.03	.41
Fishery offal	.98	.50
Total prey weight	26,004 g	
Total non-empty stomachs	588	
Total empty stomachs	17	
Total hauls	54	

7%, and 11% of the total stomach content weight in 1990, 1993, and 1996, respectively). Decorator crabs (*Oregonia* spp.),lyre crabs (*Hyas* spp.), hermit crabs, euphausiids, amphipods, and marine worms were the other invertebrates consumed by Pacific cod. Of the fish consumed by Pacific cod, walleye pollock made up the highest proportion of the total stomach contents weight for all three years (5%, 19%, and 23% in 1990, 1993, and 1996, respectively). Other commercially important prey fish include arrowtooth flounder, flathead sole, rock sole, Pacific halibut, Pacific herring, Atka mackerel (*Pleurogrammus monopterygius*), Pacific cod, and rex sole. Pacific cod also consumed many non-commercially important fish, such as capelin, eulachon, Pacific sand lance, zoarcids, cottids, agonids, cyclopterids, bathymasterids, and stichaeids. Fish processing offal (processed fish waste) was also consumed by Pacific cod in the Gulf of Alaska.

Variation of Diet Based on Predator Size

Figure 8 shows that Pacific cod ate more fish with increasing cod size, especially for larger cod ($\geq$70 cm FL). The fish consumed (including fish and fishery discards) comprised about 50% of the total stomach contents in this larger size group of Pacific cod the three years that were sampled. Only this group of larger Pacific cod ($\geq$70 cm FL) consumed a significant

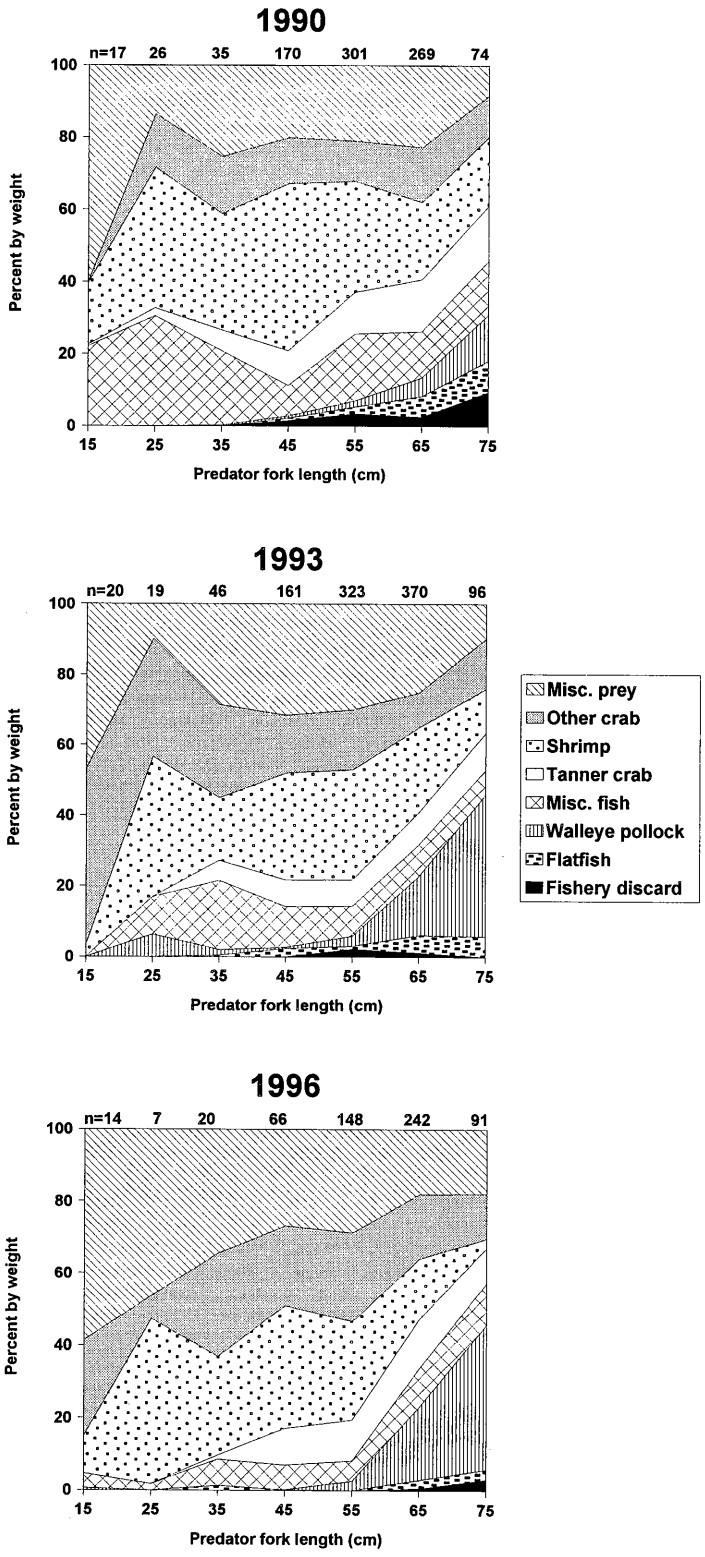


Figure 8.--Variations in the main food items of Pacific cod, by predator size, in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size.

amount of walleye pollock (13% in 1990, 40% in 1993, and 40% in 1996). Smaller size groups (<60 cm FL) consumed very small amounts of pollock (<5%). All but the smallest size group in 1993 and the largest size group in 1996 consumed a fair amount of shrimp (>10%). Tanner crabs were mainly consumed by Pacific cod between 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).

Geographic Distributions of the Prey Consumed

Figures 9 - 17 illustrate the geographic distributions of the important prey (percent by weight) consumed by Pacific cod in 1990, 1993, and 1996. Figure 9 shows that consumption of walleye pollock by Pacific cod was not widespread (26 out of 78 hauls) in 1990. In addition, the proportion of walleye pollock in the stomach content weights at each station was not high in 1990 either. However, in 1993 and 1996, walleye pollock were consumed by Pacific cod in many stations (mainly southwest of Kodiak Island) and high percentages (>75%) of pollock were found in many stomach content samples (Fig. 9). Capelin seemed to be consumed evenly throughout the sampling area (Fig. 10). There was only one station where capelin comprised more than 75% of the stomach contents of Pacific cod (Fig. 10). Tanner crab consumption was widespread in all the areas sampled, although the higher percentages by weight of Tanner crab in stomach contents seemed

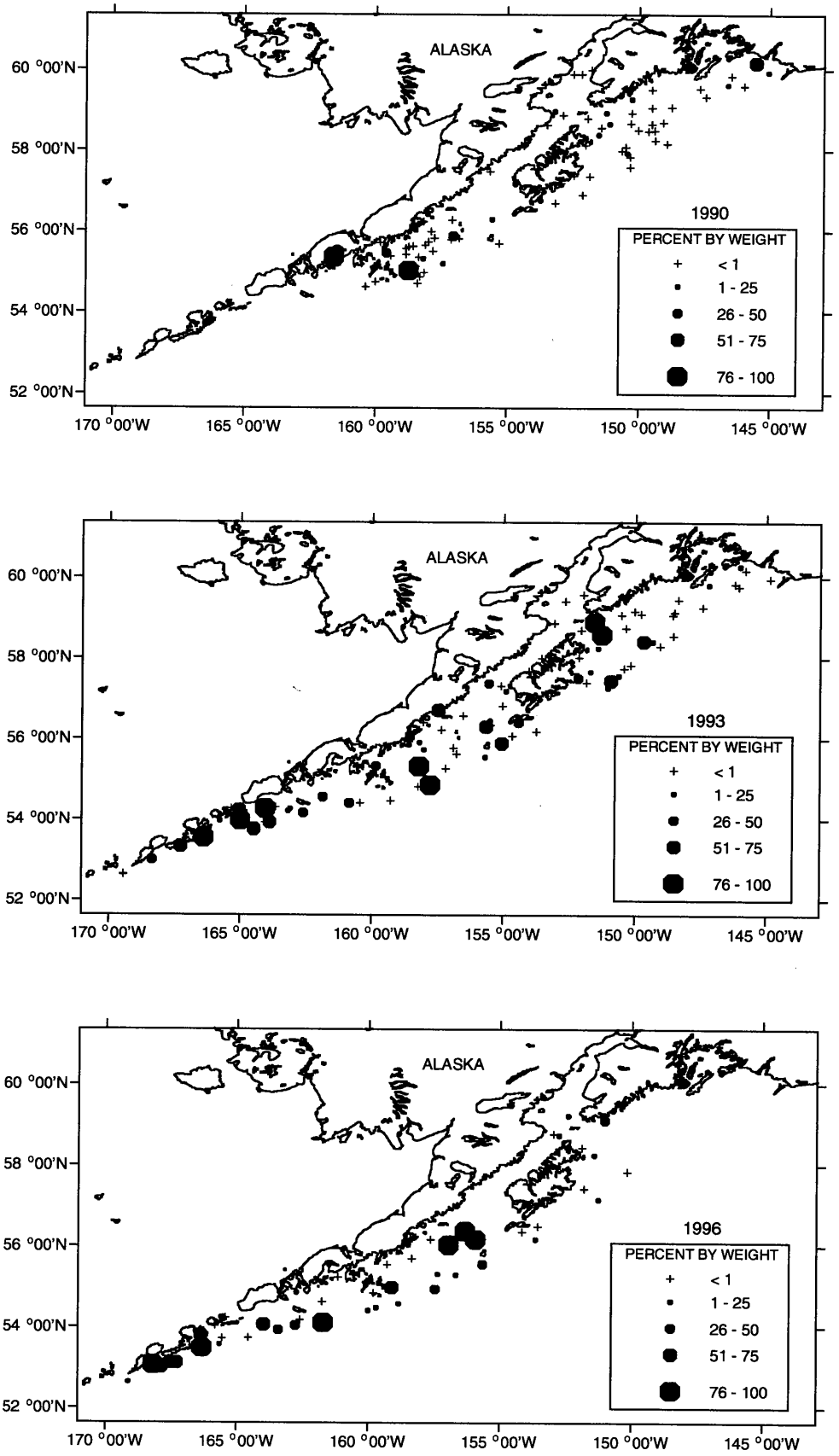


Figure 9.--Geographic distribution of walleye pollock consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

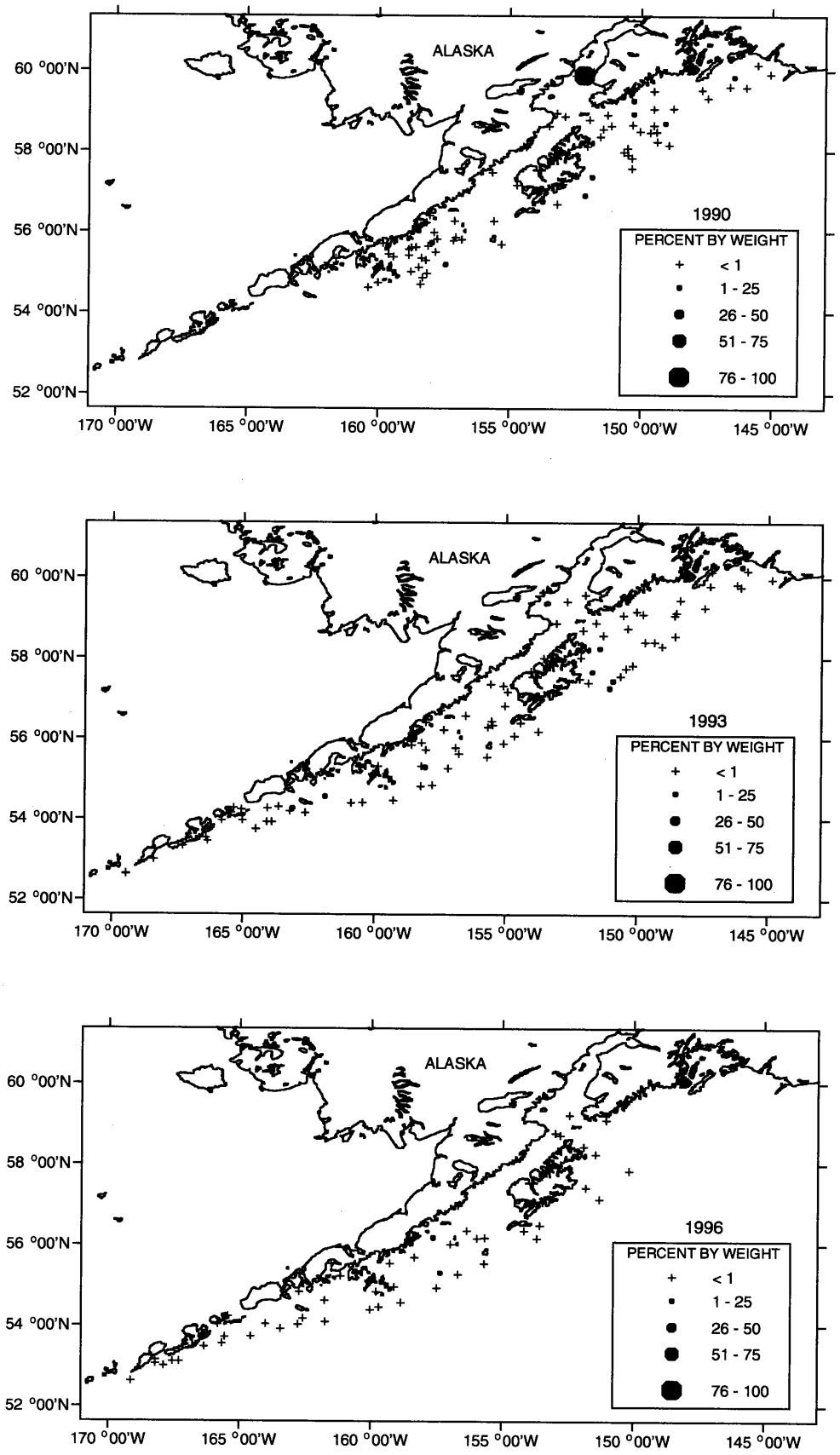


Figure 10.--Geographic distribution of capelin consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

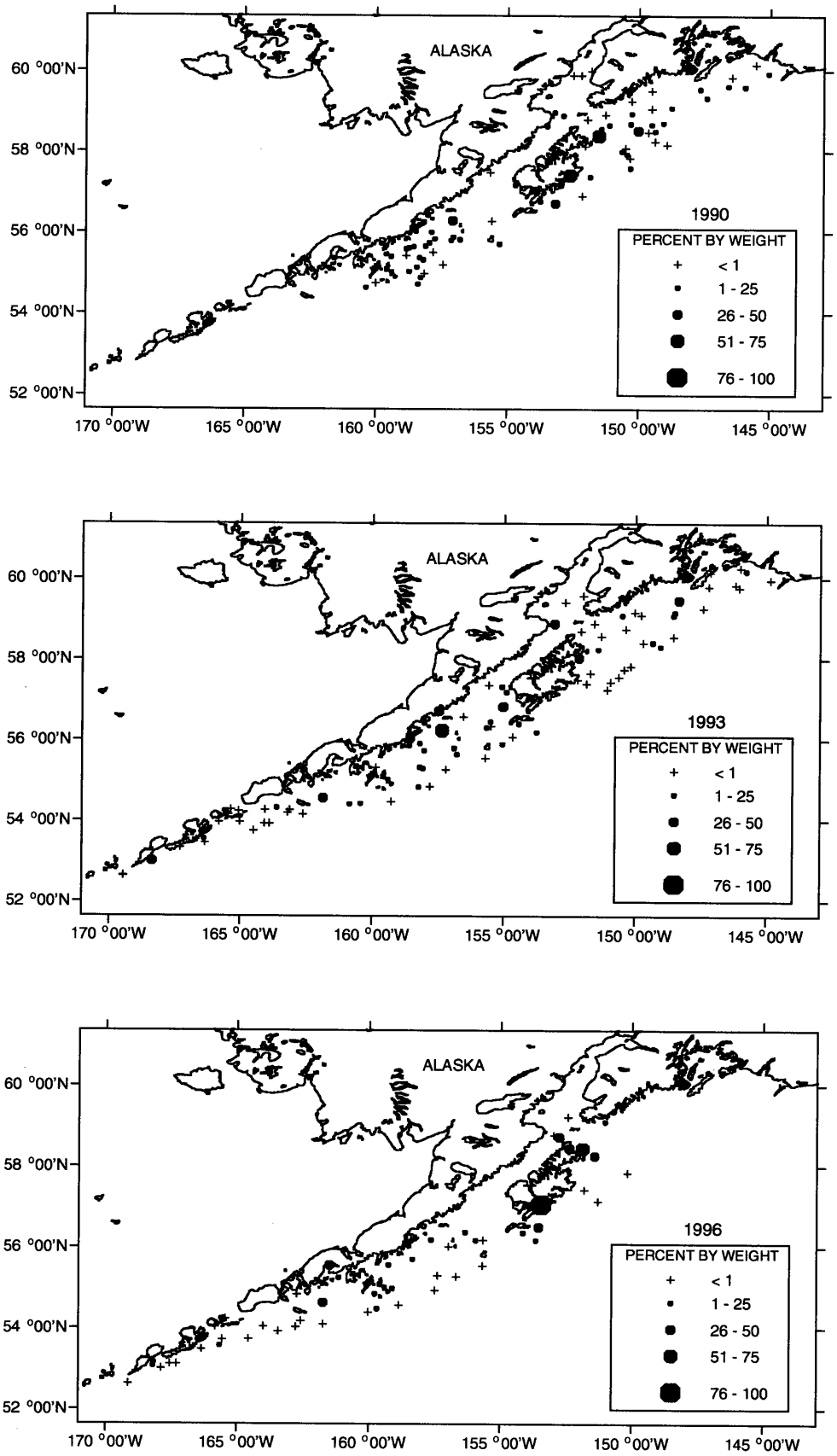


Figure 11.--Geographic distribution of Tanner crab consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

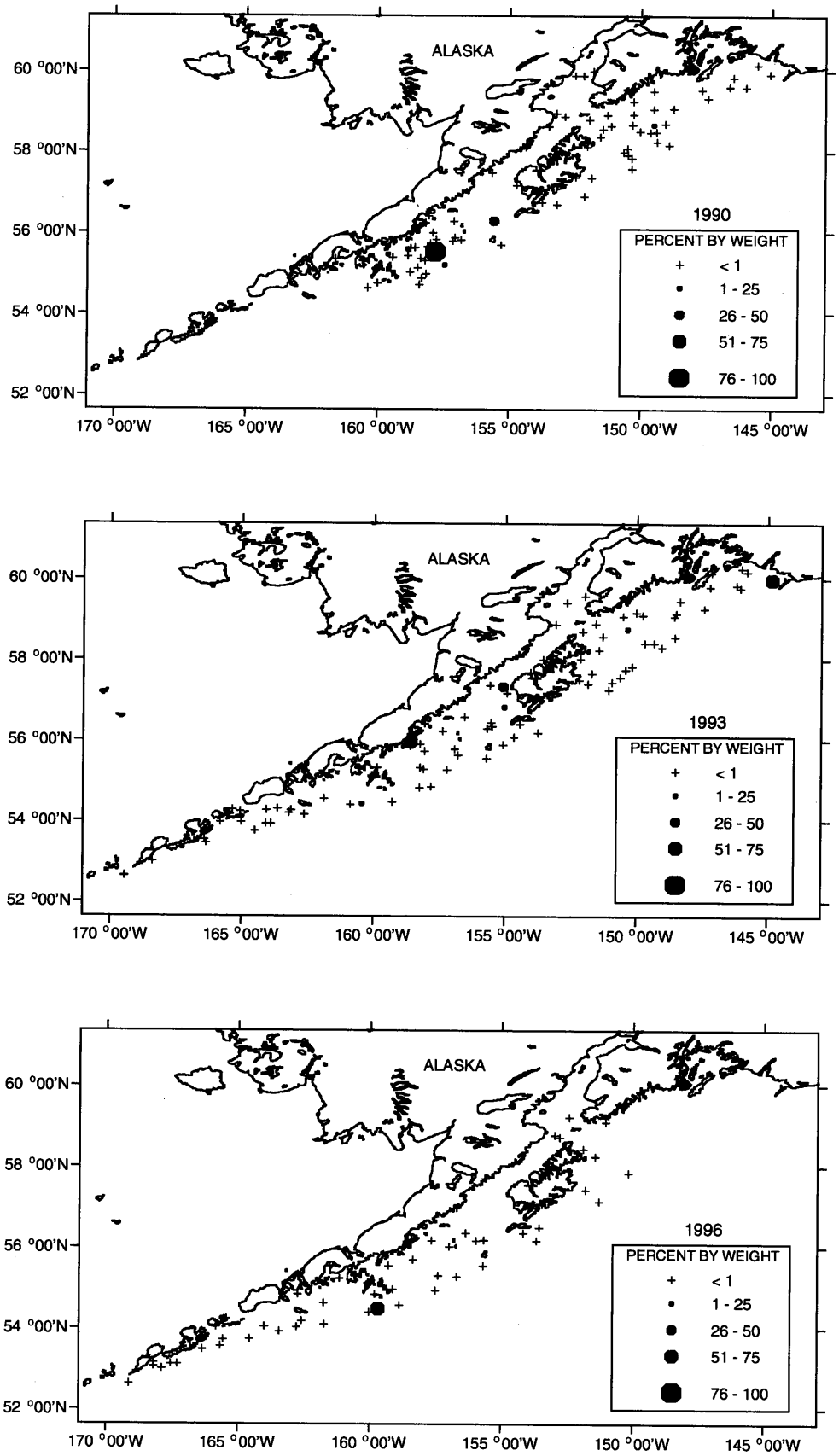


Figure 12.--Geographic distribution of arrowtooth flounder consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

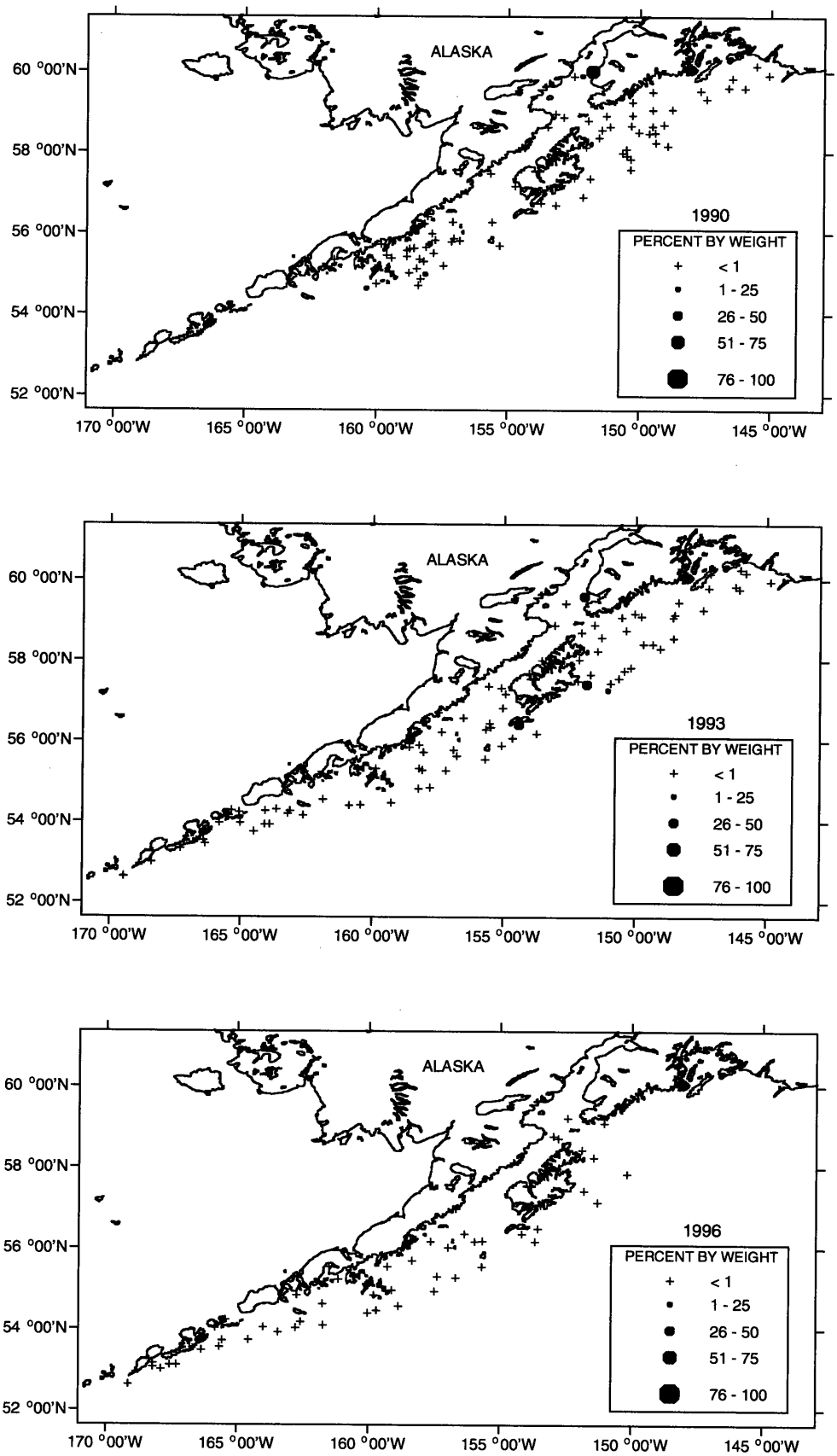


Figure 13.--Geographic distribution of Pacific sand lance consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

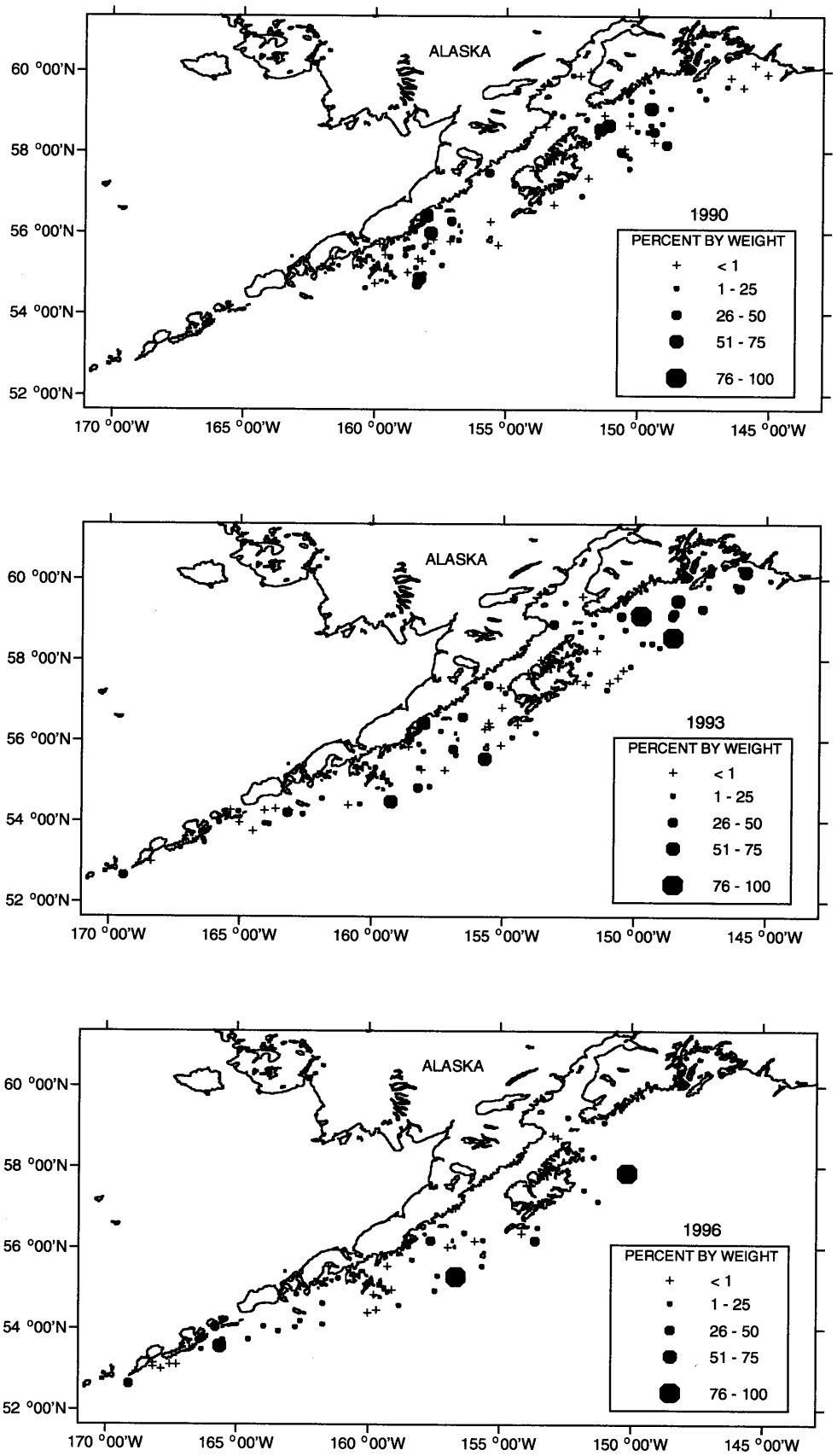


Figure 14.--Geographic distribution of pandalid shrimp consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

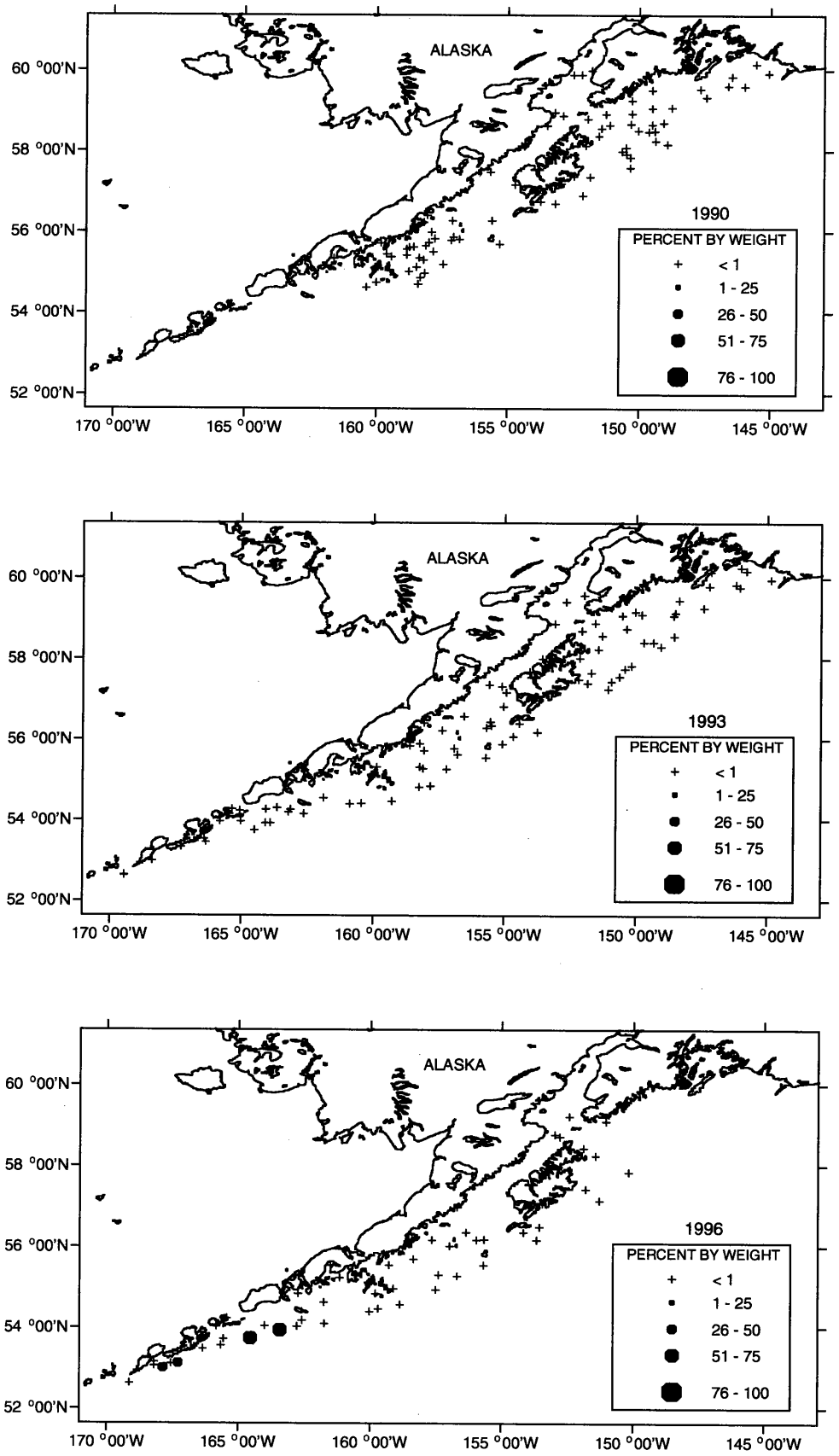


Figure 15.--Geographic distribution of Atka mackerel consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

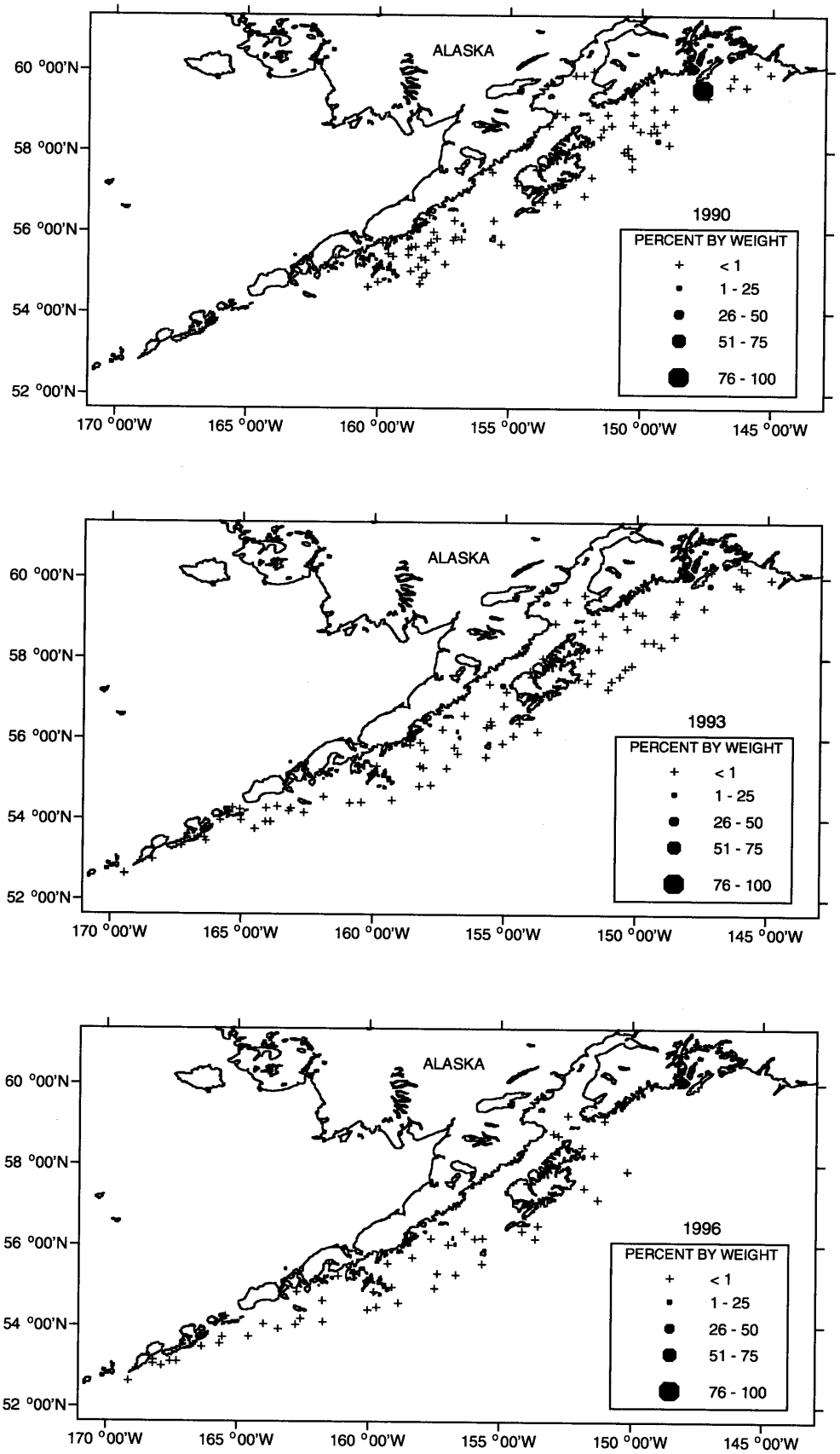
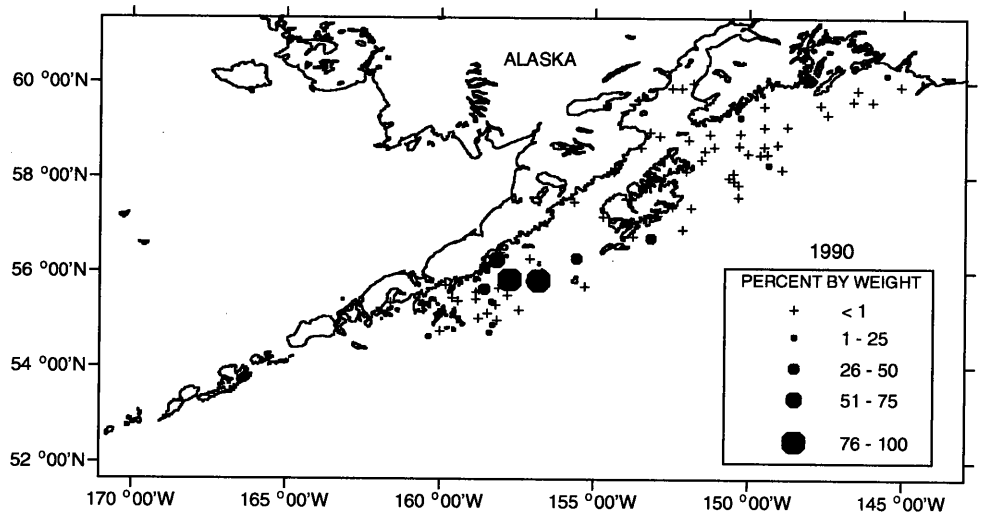
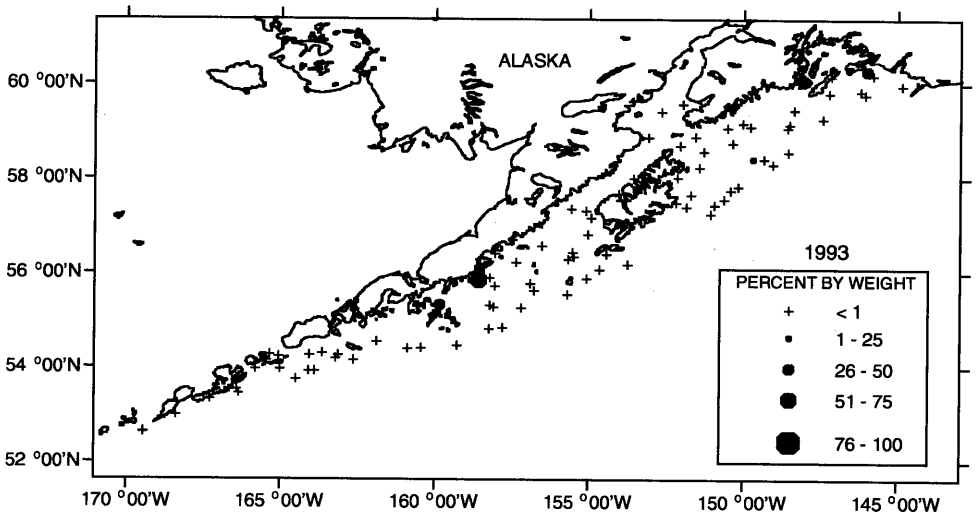


Figure 16.--Geographic distribution of eulachon consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.





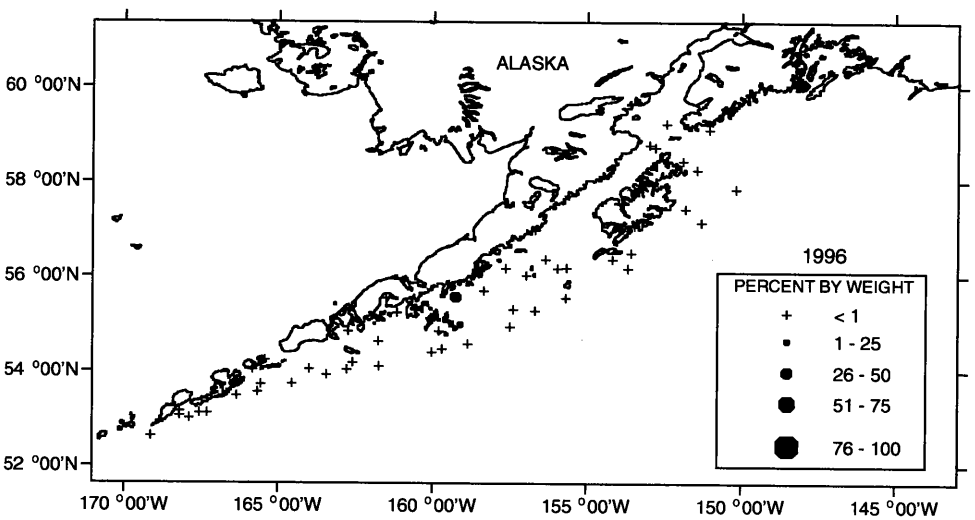


Figure 17.--Geographic distribution of fisheries offal consumed by Pacific cod in summer 1990, 1993, and 1996 in Gulf of Alaska.

to be focused near Kodiak Island (Fig. 11). The consumption of arrowtooth flounder by Pacific cod was found mainly in the area southwest of Kodiak Island (Fig. 12). Pacific sand lance were consumed primarily in the area southwest of Kodiak Island, although, in 1990, there was one station to the north of Kodiak Island where Pacific sand lance comprised more than 50% of the stomach contents (Fig. 13). Pandalid shrimp were consumed by Pacific cod in many different locations in the Gulf of Alaska area (Fig. 14). However, the higher percentages of pandalid shrimp consumption were found in the stations close to Kodiak Island. The consumption of Atka mackerel by Pacific cod was greatest in 1996 near Unimak Island area (Fig. 15). Eulachon consumption by Pacific cod was not widespread but a high percentage (>75%) of eulachon in the stomach contents was reported for one station (near Montague Island)(Fig. 16). Fishery offal was consumed by Pacific cod mainly in the area southwest of Kodiak Island (Fig. 17).

Sizes of the Commercially Important Prey Consumed

The commercially important prey consumed by Pacific cod were analyzed by two Pacific cod size groups (<60 cm and $\geq$60 cm FL) (Fig 18 - 24). Examination of Figures 18 and 19 suggests that the walleye pollock consumed by smaller Pacific cod (<60 cm FL) were mainly age-0 fish (<140 mm SL), whereas larger Pacific cod $\geq$60 cm consumed age-0, age-1 (140 - 222 mm SL), age-2 (223 - 296 mm SL),

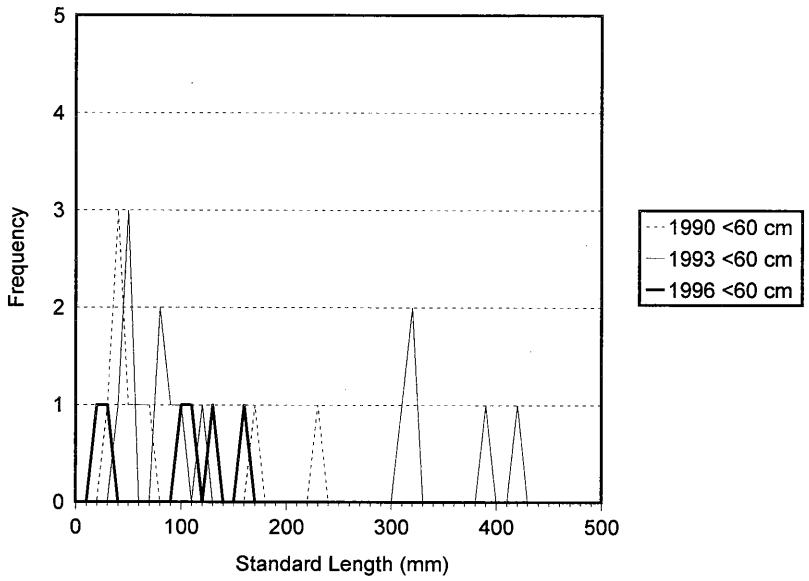


Figure 18.--Size frequency distribution of walleye pollock consumed by Pacific cod (<60 cm FL) in the Gulf of Alaska in 1990, 1993, and 1996.

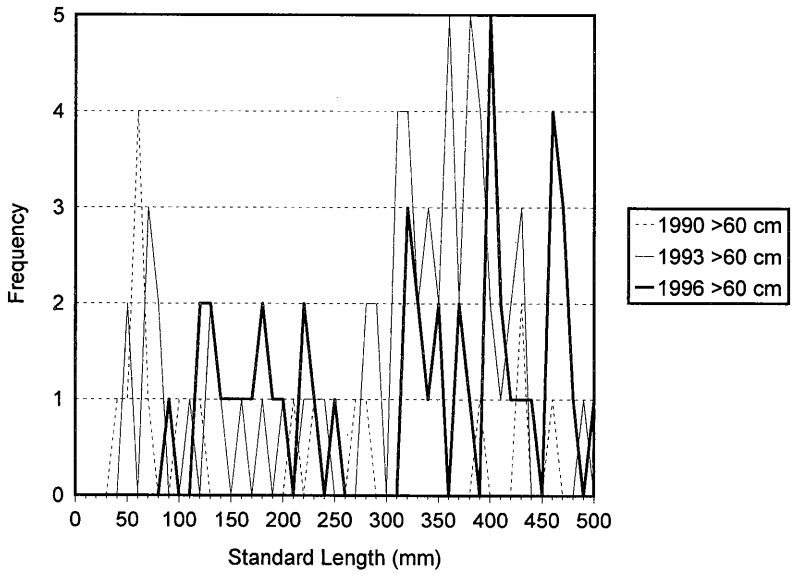


Figure 19.--Size frequency distribution of walleye pollock consumed by Pacific cod (>60 cm FL) in the Gulf of Alaska in 1990, 1993, and 1996.

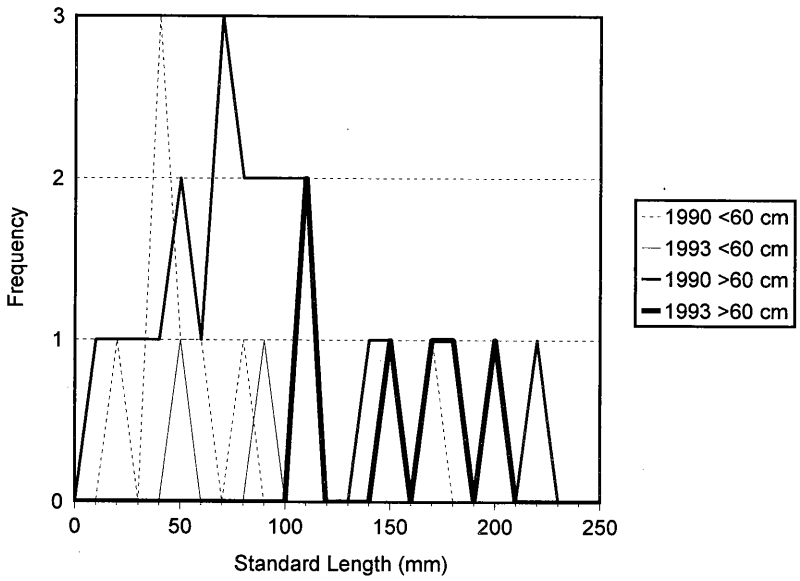


Figure 20.-- Size frequency distribution of flathead sole consumed by Pacific cod in the Gulf of Alaska in 1990 and 1993.

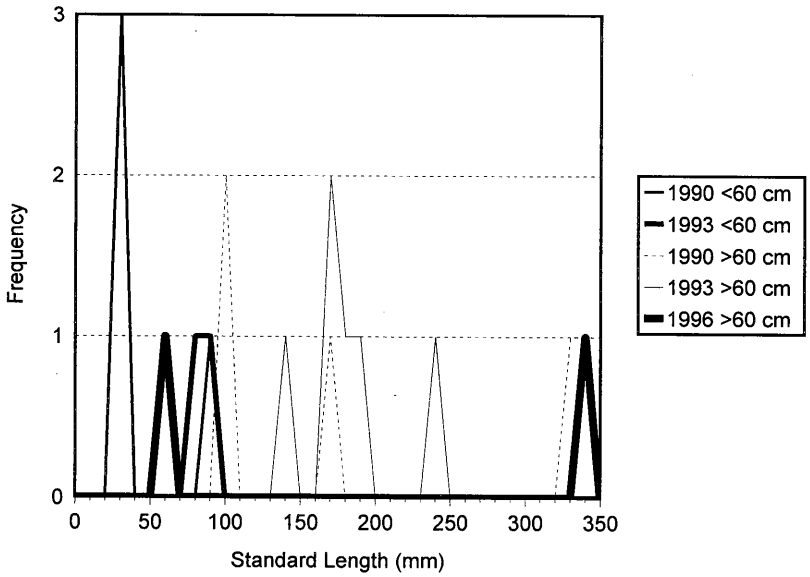


Figure 21.--Size frequency distribution of arrowtooth flounder consumed by Pacific cod in the Gulf of Alaska in 1990, 1993, and 1996.

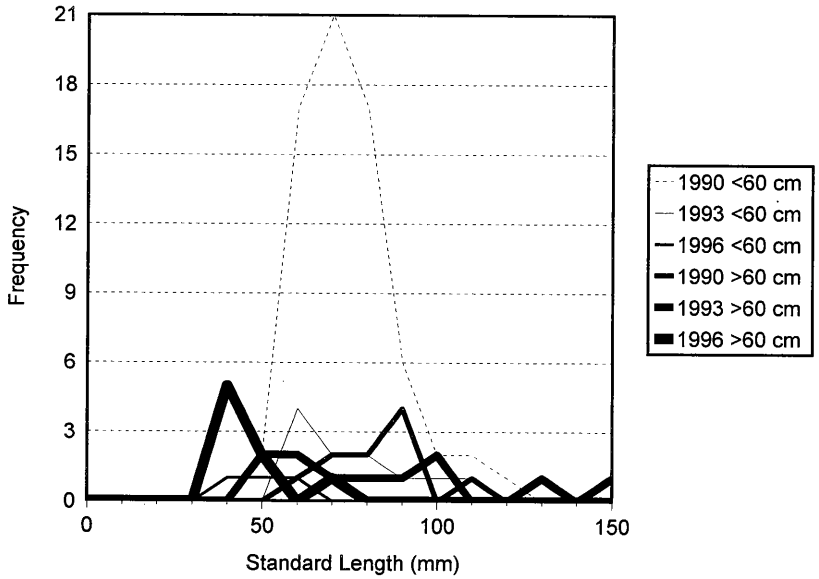


Figure 22.-- Size frequency distribution of capelin consumed by Pacific cod in the Gulf of Alaska in 1990, 1993, and 1996.

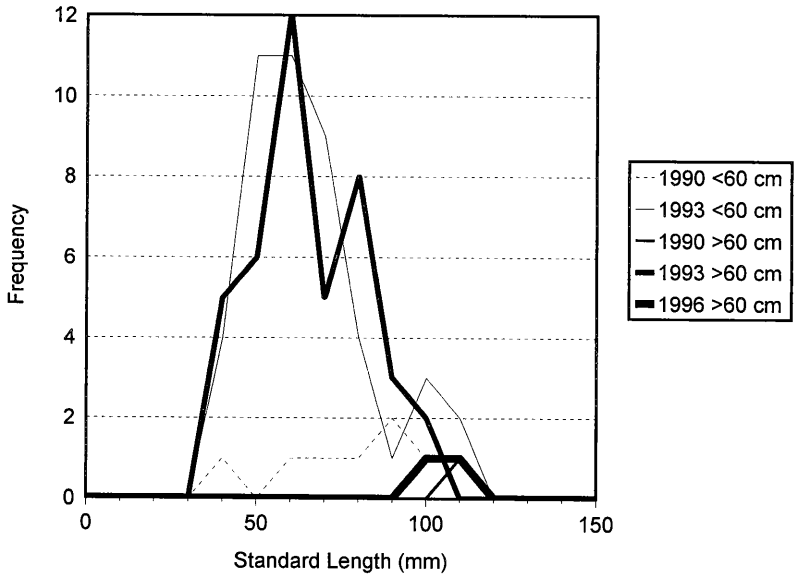


Figure 23.-- Size frequency distribution of Pacific sand lance consumed by Pacific cod in the Gulf of Alaska in 1990, 1993, and 1996.

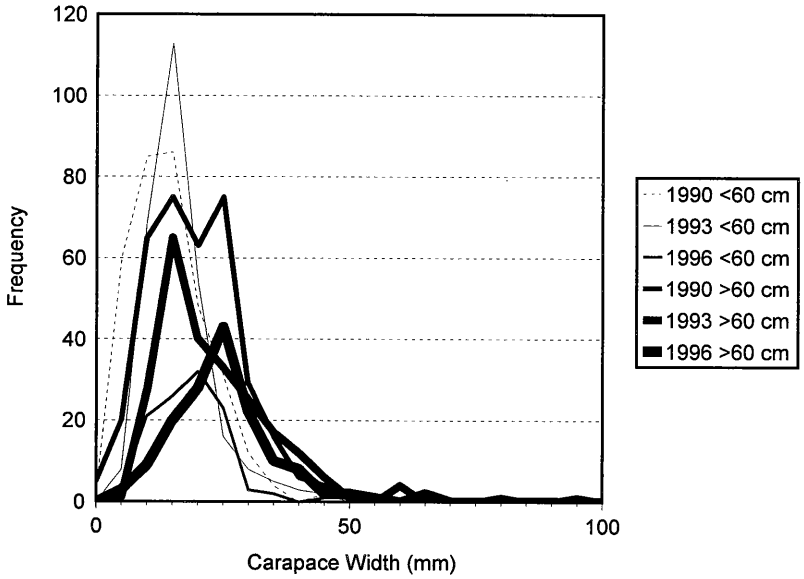


Figure 24.--Size frequency distribution of Tanner crab consumed by Pacific cod in the Gulf of Alaska in 1990, 1993, and 1996.

and age-3+ (≥297 mm SL) walleye pollock. The mean standard length (±SD) of pollock consumed by Pacific cod was 262.5 ± 142.1 mm with a range from 21 to 503 mm SL. The length distributions of flathead sole and arrowtooth flounder consumed by Pacific cod are shown in Figures 20 and 21. The mean standard length (±SD) of flathead sole consumed by Pacific cod was 92.3 ± 51.8 mm, with a range from 17 to 220 mm SL. The mean standard length (±SD) of arrowtooth flounder consumed was 161.3 ± 110.7 mm with a range between 33 to 390 mm. The mean standard length (±SD) of the capelin consumed was 77.6 ± 18.7 mm with a range from 42 to 152 mm SL. Figure 22 shows that large numbers of capelin were consumed by Pacific cod less than 60 cm FL in 1990. Figure 23 shows that more Pacific sand lance were consumed by Pacific cod in 1993 than in 1990 and 1996. The mean standard length (±SD) of all Pacific sand lance consumed by Pacific cod was 73.1 ± 21.1 mm with a range from 42 to 165 mm SL. Larger predators fed on larger prey. In general, Pacific cod greater than or equal to 60 cm FL fed on larger Tanner crabs than cod less than 60 cm FL in length (Fig. 24). The average carapace width (±SD) of the Tanner crabs consumed was 21.2 ± 9.9 mm with a range of 3 to 99 mm CW. Most of the Tanner crabs measured from Pacific cod stomach contents were age-0 and age-1 crab (<36 mm CW). Pacific cod also consumed Pacific halibut, rock sole, rex sole, Atka mackerel, stichaeids, eulachon, myctophids, zoarcids, and cottids. The

number, mean standard length, standard deviation and range ofthese fish are listed in Table 8.

DISCUSSION

Based on the data from 1990 we found pollock made up 6% (by weight) of the Pacific cod diet; however, the percentages of pollock in the Pacific cod diet increased to 19% and 23% for 1993 and 1996, respectively. The percentages of capelin consumed by Pacific cod were low: 3%, 1%, and <1% in 1990, 1993, and 1996, respectively. Like pollock, pandalid shrimp were also important food of Pacific cod. However, the amounts of pandalid shrimp consumed by Pacific cod during those three years were relatively similar (between 11% and 15%). The percentages of Tanner crab consumed were between 7% and 11% in those three years. Atka mackerel were only found in Pacific cod stomachs in 1996 (4%) and not in 1990 and 1993. Fish offal consumed by Pacific cod declined from 6% in 1990 to 2% in 1993, to 1% in 1996.

Table 8.--Mean standard length, standard deviation (SD), and range of standard length of the miscellaneous prey fish consumed by Pacific cod in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size.

Prey name	n	Mean SL (mm)	SD (mm)	Range (mm)
Eulachon	8	143.4	36.2	64-180
Pacific halibut	6	32.7	19.7	17-60
Rock sole	8	113.8	45.2	55-194
Flathead sole	4	50.5	19.8	22-66
Rex sole	1	121.0	0.0	121-121
Atka mackerel	8	253.8	60.9	200-370
Stichaeids	122	94.5	39.2	20-200
Myctophids	2	60.5	17.7	48-73
Zoarcids	49	106.7	45.7	30-252
Cottids	157	58.3	30.5	15-220

ARROWTOOTH FLOUNDER

by

Mei-Sun Yang

Arrowtooth flounder (*Atheresthes stomias*), with an exploitable biomass of 2,062,740 t in 1998, ranked first in the total groundfish biomass in the Gulf of Alaska(NPFMC 1998). Arrowtooth flounder is a large flatfish with a symmetrical mouth and sharp teeth that feeds on commercially important fish such as walleye pollock and capelin as well as shrimp and other crustaceans. Therefore, based on its feeding behavior and its high abundance in the Gulf of Alaska area, arrowtooth flounder is important to study because of its potential impact on commercially important species.

RESULTS

General Diets

Tables 9 to 11 display the total number of stomachs with food, total empty stomachs, the mean percent frequency of occurrence and the mean percent by weight of the prey items found in arrowtooth flounder stomachs in 1990, 1993, and 1996. Euphausiids and pandalid shrimp were the most important invertebrate food of arrowtooth flounder. However, fish

Table 9.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Atheresthes stomias* (arrowtooth flounder) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	.24	.66
Onuphidae (polychaete)	.04	.08
Bivalvia (clam)	.01	.25
Teuthoidea (squid unidentified)	.18	.71
Gonatidae (squid)	1.20	.21
Calanoida (copepod)	.01	.41
Mysidae (mysid)	.05	.84
Holmesiella anomala (mysid)	<.01	.21
Neomysis czerniawskii (mysid)	<.01	.08
Neomysis rayii (mysid)	.03	.10
Cumacea (cumacean)	.02	.29
Isopoda (isopod)	.01	.13
Gammaridea (unidentified)	.32	2.06
Ampeliscidae (amphipod)	.06	.33
Themisto sp. (amphipod)	.01	.55
Caprellidea (amphipod)	<.01	.10
Euphausiacea (unidentified)	16.20	28.48
Thysanoessa inermis (euphausiid)	1.01	4.80
Thysanoessa spinifera (euphausiid)	<.01	.10
Caridea (unidentified)	.10	1.31
Pasiphaea pacifica (shrimp)	.04	.36
Hippolytidae (shrimp)	<.01	.11
Eualus avinus (shrimp)	.10	.60
Pandalidae (unidentified)	5.78	11.92
Pandalus borealis (shrimp)	3.88	6.89
Pandalus jordani (shrimp)	.89	1.04
Pandalus montagui tridens (shrimp)	1.02	.76
Pandalus platyceros (shrimp)	.07	.18
Crangonidae (unidentified)	.38	1.51
Crangon communis (shrimp)	.61	1.85
Argis lar (shrimp)	.45	.31
Argis ovifer (shrimp)	.02	.10
Paguridae (hermit crab)	<.01	.18
Echiuridae (marine worm)	.02	.18
Chaetognatha (arrow worm)	.02	.48
Teleostei (unidentified fish)	1.01	3.06
Non-gadoid Fish Remains	.31	2.04
Clupea pallasi (Pacific herring)	6.23	4.17
Coregonus sp. (salmonidae)	1.14	.42
Mallotus villosus (capelin)	22.96	19.43
Thaleichthys pacificus (eulachon)	.31	.29
Gadidae (gadid fish)	1.62	5.83

Table 9.--Continued.

Prey name	Mean % Wt	Mean % FO
Theragra chalcogramma (walleye pollock)	26.48	15.47
Zoarcidae (eelpout)	.51	.63
Scorpaenidae	.23	.14
Pleurogrammus monopterygius (Atka mackerel)	.52	.16
Stichaeidae (prickleback)	1.18	1.22
Poroclinus rothrocki (whitebarred prickleback)	.58	.26
Ammodytes hexapterus (Pacific sand lance)	.40	.31
Pleuronectidae (unidentified flatfish)	1.97	1.30
Atheresthes stomias (arrowtooth flounder)	.01	.16
Hippoglossoides elassodon (flathead sole)	.15	.18
Fishery offal	1.59	1.39

Total prey weight	6,501 g
Total non-empty stomachs	655
Total empty stomachs	489
Total hauls	80

Table 10.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Atheresthes stomias* (arrowtooth flounder) collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	1.34	2.18
Gymnosomata (pteropod)	.01	.19
Bivalvia (clam)	.04	.55
Cephalopoda (unidentified)	.36	.56
Teuthoidea (squid unidentified)	2.60	3.29
Gonatus sp. (squid)	.56	.27
Cumacea (cumacean)	<.01	.21
Gammaridea (amphipod)	.07	.70
Themisto sp. (amphipod)	.02	.19
Vibilia sp. (isopod)	<.01	.07
Euphausiacea (unidentified)	21.00	45.53
Thysanoessa inermis (euphausiid)	1.01	.66
Caridea (unidentified)	.42	2.02
Pasiphaea pacifica (shrimp)	.06	.25
Pandalidae (shrimp)	16.80	15.69
Pandalus borealis (shrimp)	.77	.46
Pandalus jordani (shrimp)	.34	.24
Pandalopsis dispar (shrimp)	.05	.15
Crangonidae (shrimp)	3.02	4.54
Reptantia (crab)	.11	.49
Paguridae (hermit crab)	.06	.33
Pinnotheridae (pea crab)	.01	.21
Teleostei (unidentified fish)	3.06	7.72
Non-gadoid Fish Remains	7.78	7.75
Clupea pallasi (Pacific herring)	1.06	.53
Osmeridae (smelts)	.25	.22
Mallotus villosus (capelin)	3.22	2.03
Thaleichthys pacificus (eulachon)	2.73	.88
Myctophidae (lanternfish)	1.53	1.40
Gadidae (gadid fish)	1.06	1.05
Gadus macrocephalus (Pacific cod)	.33	.11
Theragra chalcogramma (walleye pollock)	14.70	8.60
Zoarcidae (unidentified)	2.31	2.25
Lycodes brevipes (shortfin eelpout)	.06	.08
Pleurogrammus monopterygius (Atka mackerel)	1.06	.28
Anoplopoma fimbria (sablefish)	1.53	.73
Cottidae (sculpin)	.39	1.00
Triglops sp. (sculpin)	.52	.15
Bathymaster signatus (searcher)	.44	.21
Stichaeidae (prickleback)	2.06	1.27
Lumpenus maculatus (daubed shanny)	.50	.35
Ammodytes hexapterus (Pacific sand lance)	1.26	.78
Pleuronectidae (flatfish)	2.26	1.16
Atheresthes stomias (arrowtooth flounder)	1.60	.55
Errex zachirus (rex sole)	.97	.35

Table 10.--Continued.

Prey name	Mean % Wt	Mean % FO
Pleuronectes bilineatus (rock sole)	.01	.43
Unidentified organic materials	.09	.76
Fishery offal	.59	.35
Total prey weight	5,296 g	
Total non-empty stomachs	647	
Total empty stomachs	728	
Total hauls	94	

Table 11.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Atheresthes stomias* (arrowtooth flounder) collected in the Gulf of Alaska in 1996.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	.08	.62
Bivalvia (clam)	<.01	.06
Cephalopoda (unidentified)	.08	.21
Teuthoidea (squid)	.54	.70
Calanoida (copepod)	<.01	.07
Mysidacea (mysid)	<.01	.07
Isopoda (isopod)	<.01	.03
Gammaridea (amphipod)	.06	.88
Themisto sp. (amphipod)	<.01	.03
Euphausiacea (unidentified)	10.06	20.16
Thysanoessa sp. (euphausiid)	.62	1.14
Thysanoessa inermis (euphausiid)	.82	.74
Caridea (unidentified)	.16	.76
Hippolytidae (shrimp)	.01	.06
Eualus sp. (shrimp)	.04	.05
Pandalidae (unidentified)	4.96	7.20
Pandalus borealis (shrimp)	.90	1.13
Pandalopsis dispar (shrimp)	<.01	.14
Crangonidae (unidentified)	.83	2.85
Crangon dalli (shrimp)	.02	.06
Crangon communis (shrimp)	.05	.36
Argis sp. (shrimp)	.55	.36
Paguridae (hermit crab)	<.01	.04
Echiura (marine worm)	<.01	.04
Ophiurida (brittle star)	.06	.12
Chaetognatha (arrow worm)	<.01	.05
Teleostei (unidentified fish)	2.49	5.27
Non-gadoid Fish Remains	3.57	6.24
Clupea pallasi (Pacific herring)	.23	.16
Oncorhynchus kisutch (coho salmon)	.37	.03
Osmeridae (smelts)	2.65	2.66
Mallotus villosus (capelin)	7.08	8.07
Thaleichthys pacificus (eulachon)	.61	.85
Bathylagidae (deepsea smelts)	.74	.56
Chauliodus macouni (Pacific viperfish)	.42	.42
Myctophidae (lanternfish)	.07	.24
Gadidae (gadid fish)	3.62	3.88
Gadus macrocephalus (Pacific cod)	.94	.93
Theragra chalcogramma (walleye pollock)	49.03	37.48
Zoarcidae (eelpout)	.62	1.19
Sebastes sp. (rockfish)	.02	.02
Pleurogrammus monopterygius (Atka mackerel)	.05	.04
Cottoidei (sculpin)	1.28	1.32
Agonidae (poacher)	<.01	.03
Aspidophoroides bartoni (Aleutian alligatorfish)	<.01	.10
Bathymasteridae (ronquils)	.32	.42
Bathymaster signatus (searcher)	.13	.07

Table 11.--Continued.

Prey name	Mean % Wt	Mean % FO
Ronquilis jordani (ronquil)	.03	.08
Stichaeidae (prickleback)	1.23	1.53
Lumpenus maculatus (daubed shanny)	.98	1.09
Ammodytes hexapterus (Pacific sand lance)	.18	.18
Pleuronectidae (unidentified flatfish)	.70	.56
Atheresthes stomias (arrowtooth flounder)	1.05	1.22
Hippoglossoides elassodon (flathead sole)	.17	.24
Pleuronectes bilineatus (rock sole)	.82	1.01
Pleuronectes asper (yellowfin sole)	.01	.04
Hippoglossus stenolepis (Pacific halibut)	.26	.26
Unidentified organic materials	.38	.36
Fishery offal	.08	.03
Total prey weight	61,782 g	
Total non-empty stomachs	1615	
Total empty stomachs	603	
Total hauls	239	

comprised the largest amounts of the total stomach contents of arrowtooth flounder (68%, 52%, and 80% by weight in 1990, 1993, and 1996, respectively). Walleye pollock was the most important prey fish of arrowtooth flounder; followed by capelin. Arrowtooth flounder also consumed some eulachon, Atka mackerel, Pacific herring, Pacific sand lance, arrowtooth flounder, flathead sole, fishery offal, and some non-commercially important species (e.g., zoarcids, stichaeids, and myctophids).

Variations of Diet Based on Predator Size

Figure 25 shows the percentage by weight of the main prey items for different arrowtooth flounder size groups in 1990, 1993, and 1996. In general, larger arrowtooth flounder ($\geq$ 40 cm FL) fed mainly on fish. Walleye pollock were the predominant prey fish for this size group of arrowtooth flounder. In 1996, pollock made up about 60% of the total stomach contents. Smaller arrowtooth flounder (<40 cm FL) fed mainly on euphausiids and shrimp (pandalids).

Geographic Distributions of the Prey Consumed

Figures 26 to 38 illustrate the geographic distributions of the important prey consumed by arrowtooth flounder in 1990, 1993, and 1996. Walleye pollock were extensively consumed by arrowtooth flounder all over the Gulf of Alaska in 1996 (Fig. 26). They comprised high percentages (>75 %) of the stomach

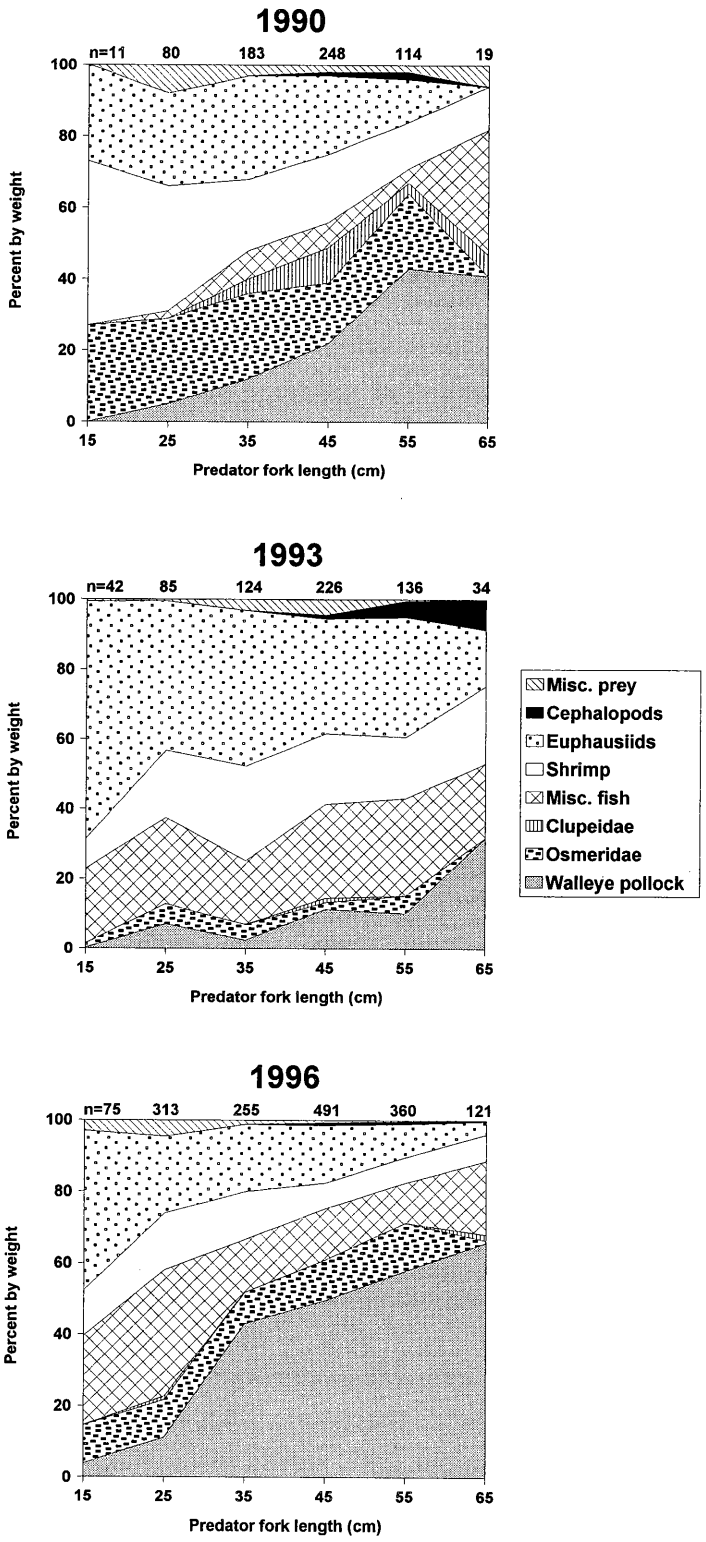
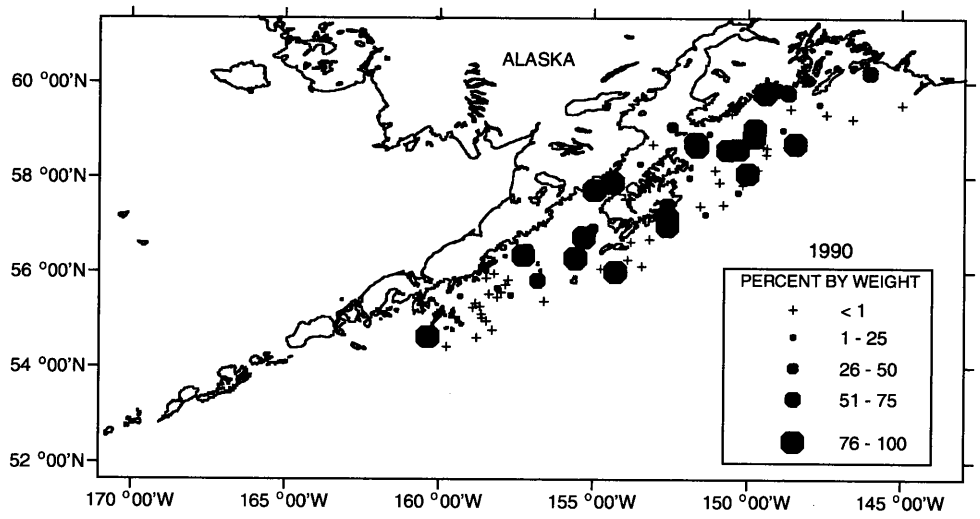
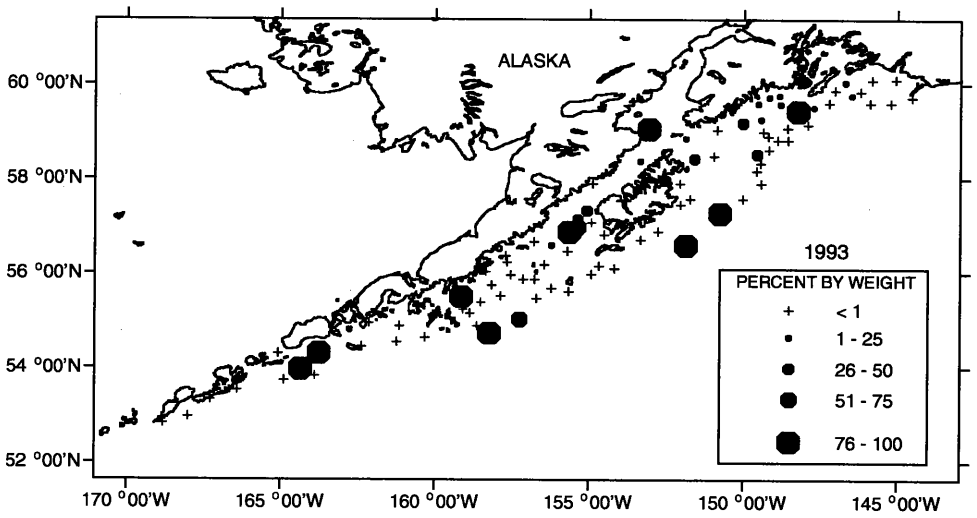


Figure 25.-- Variations in the main food items of arrowtooth flounder, by predator size, in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size.





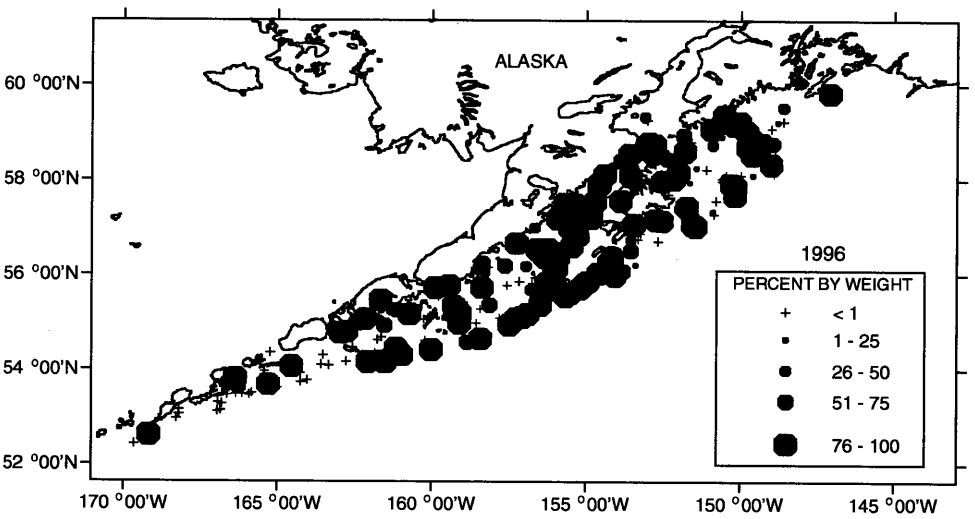


Figure 26.--Geographic distribution of walleye pollock consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

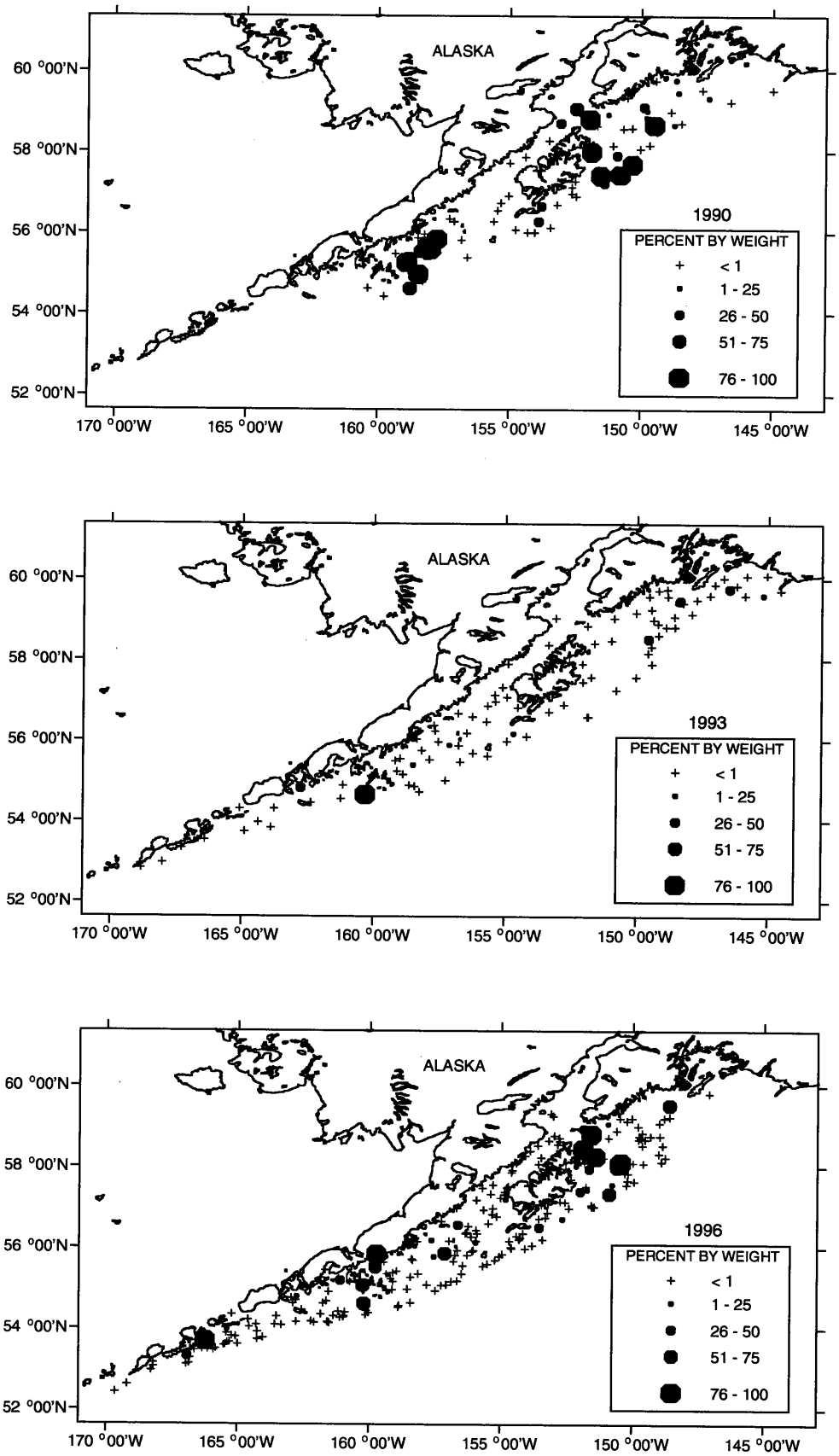


Figure 27.--Geographic distribution of capelin consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

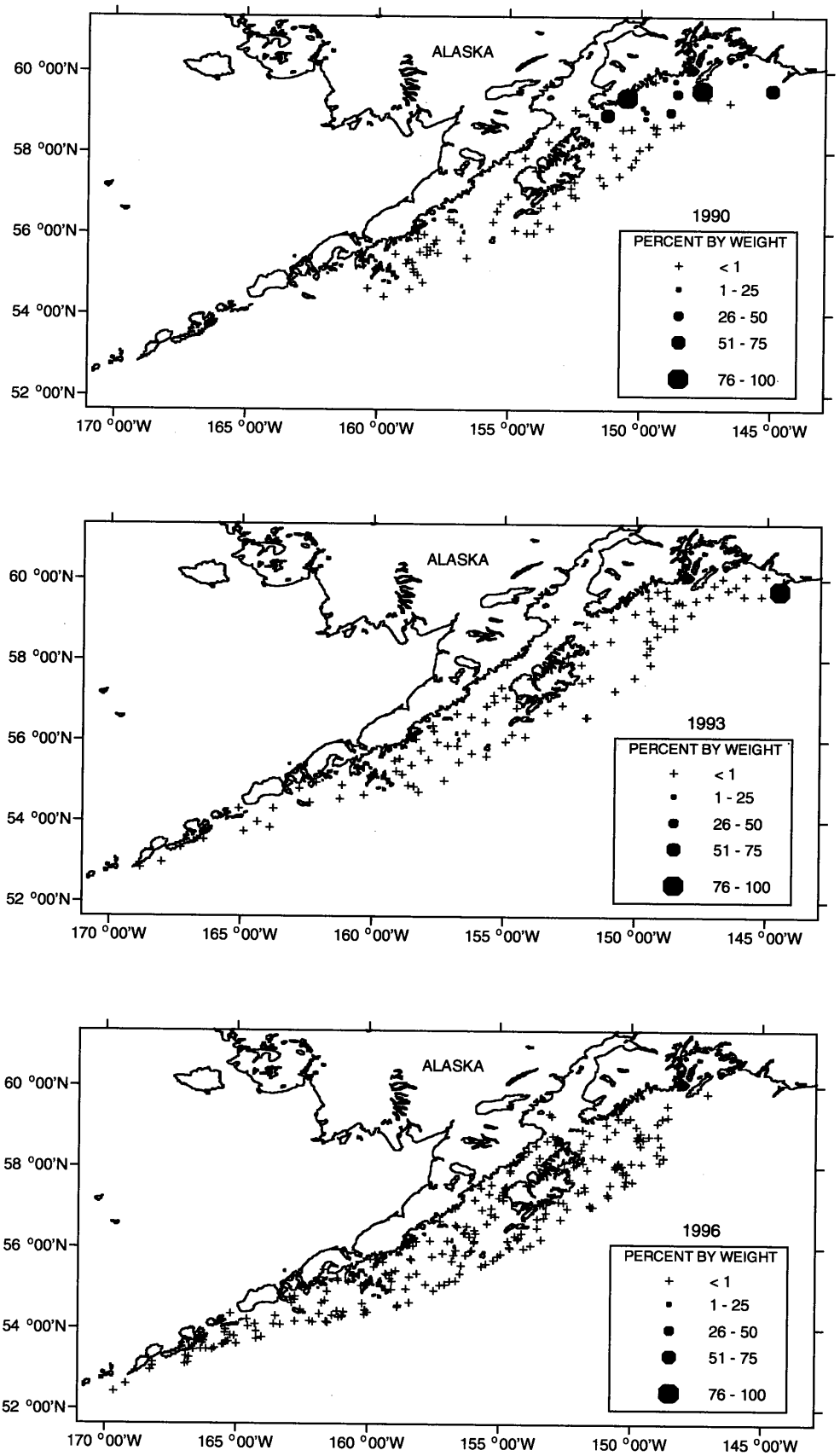


Figure 28.--Geographic distribution of Pacific herring consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

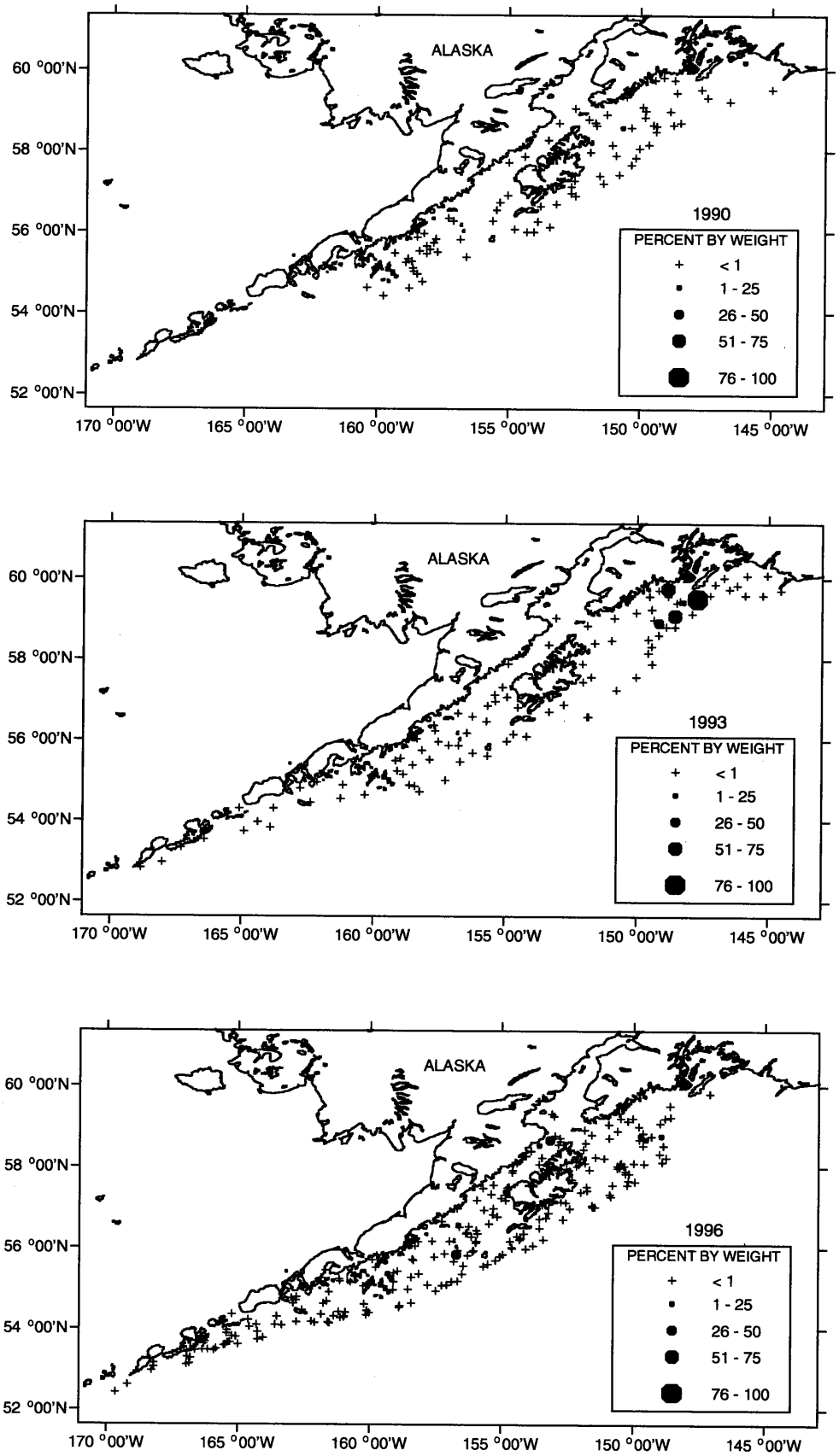


Figure 29.--Geographic distribution of eulachon consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

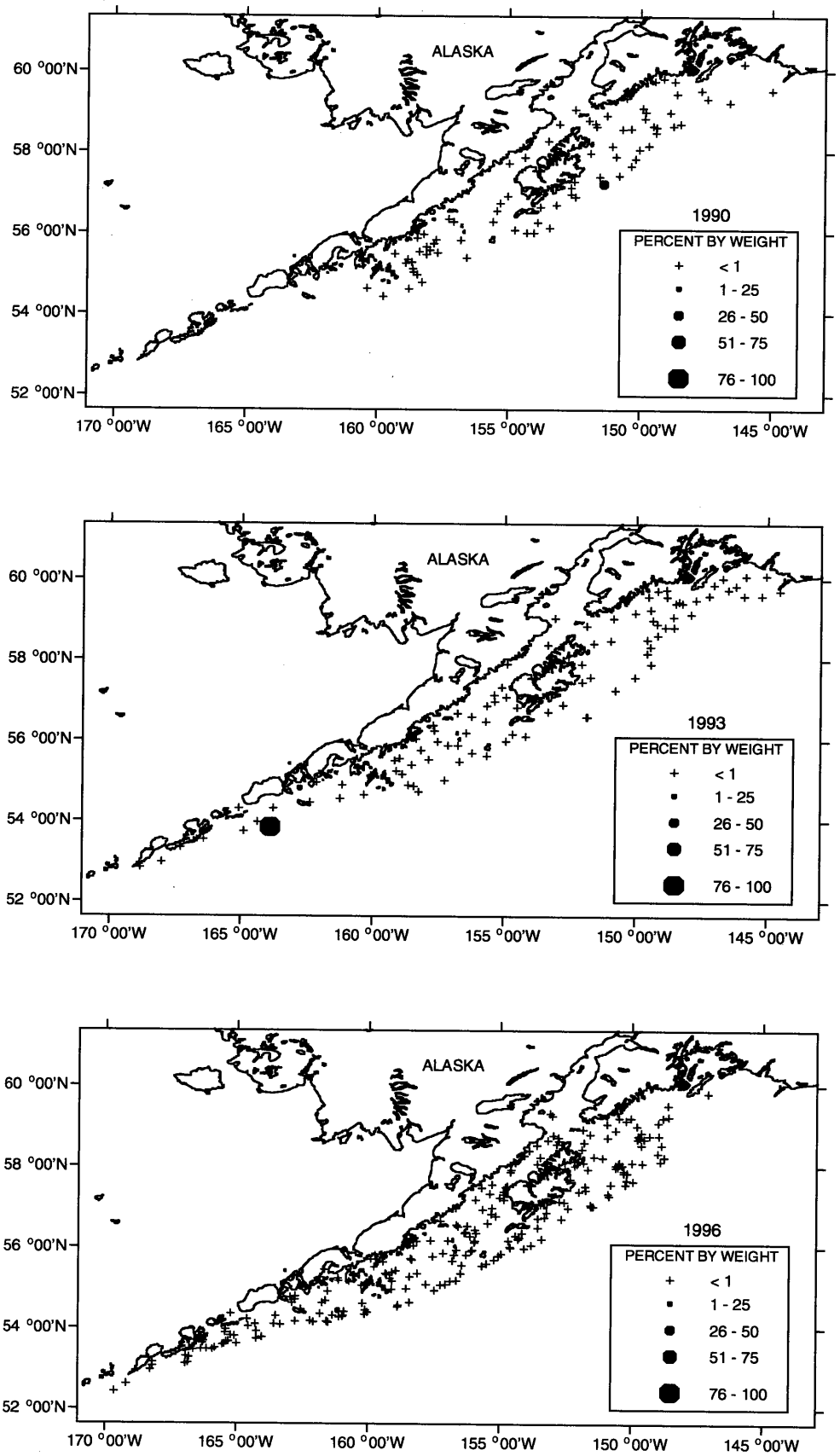


Figure 30.--Geographic distribution of Atka mackerel consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

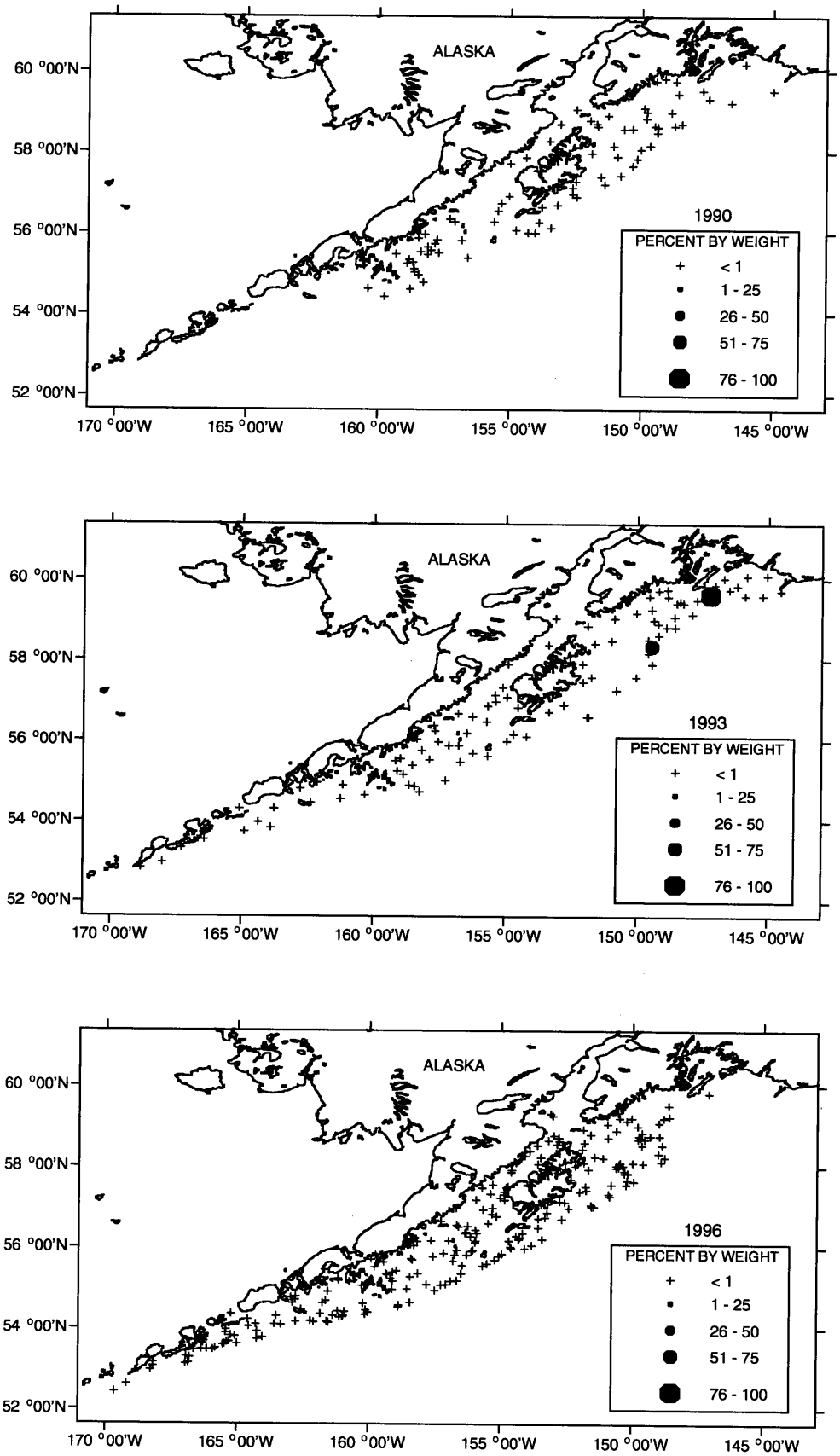
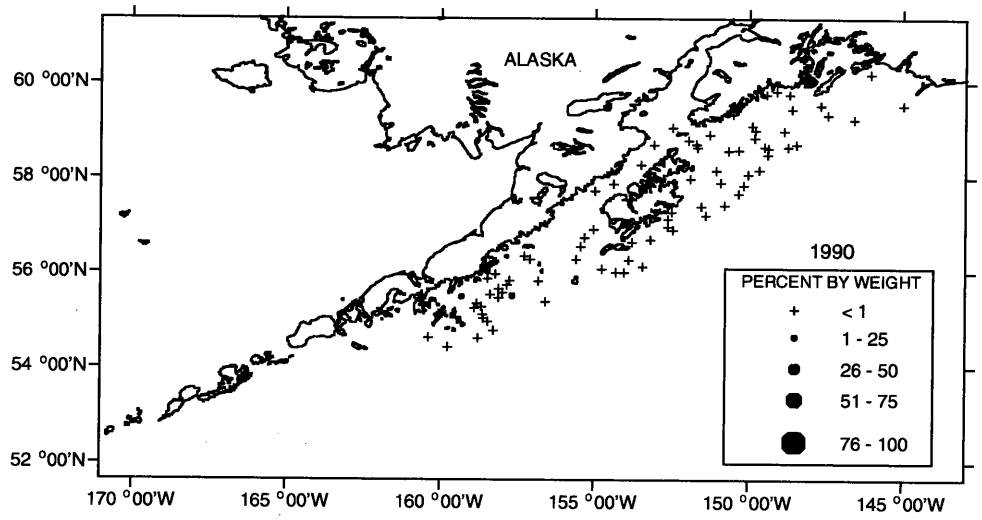
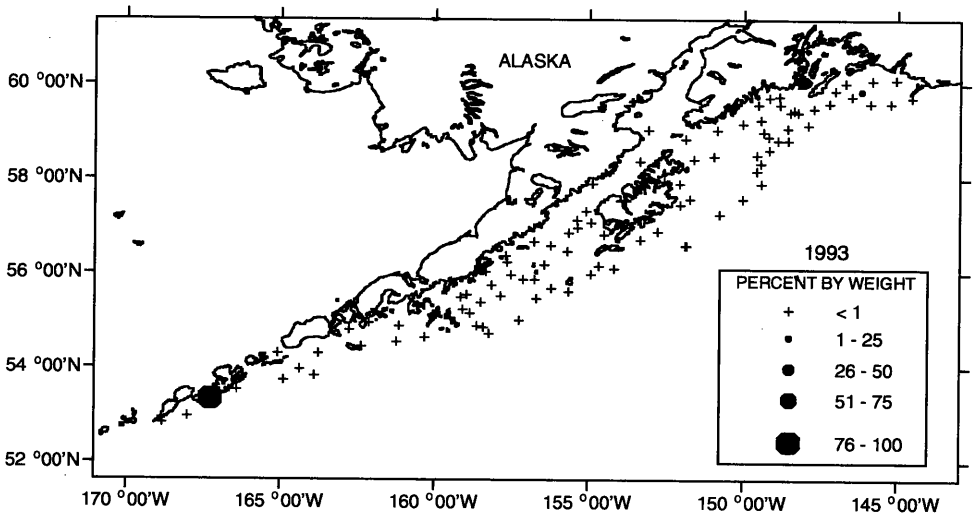


Figure 31.--Geographic distribution of sablefish consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.





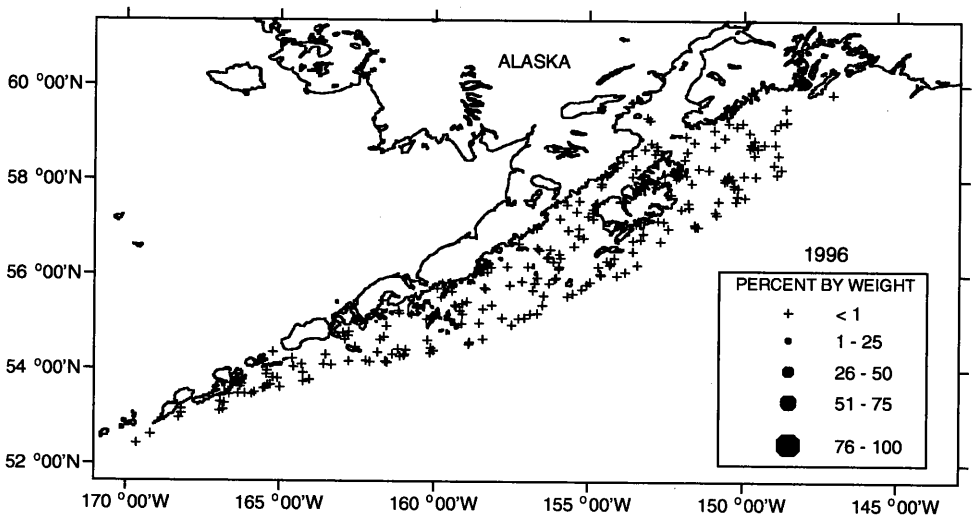


Figure 32.--Geographic distribution of Pacific sand lance consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

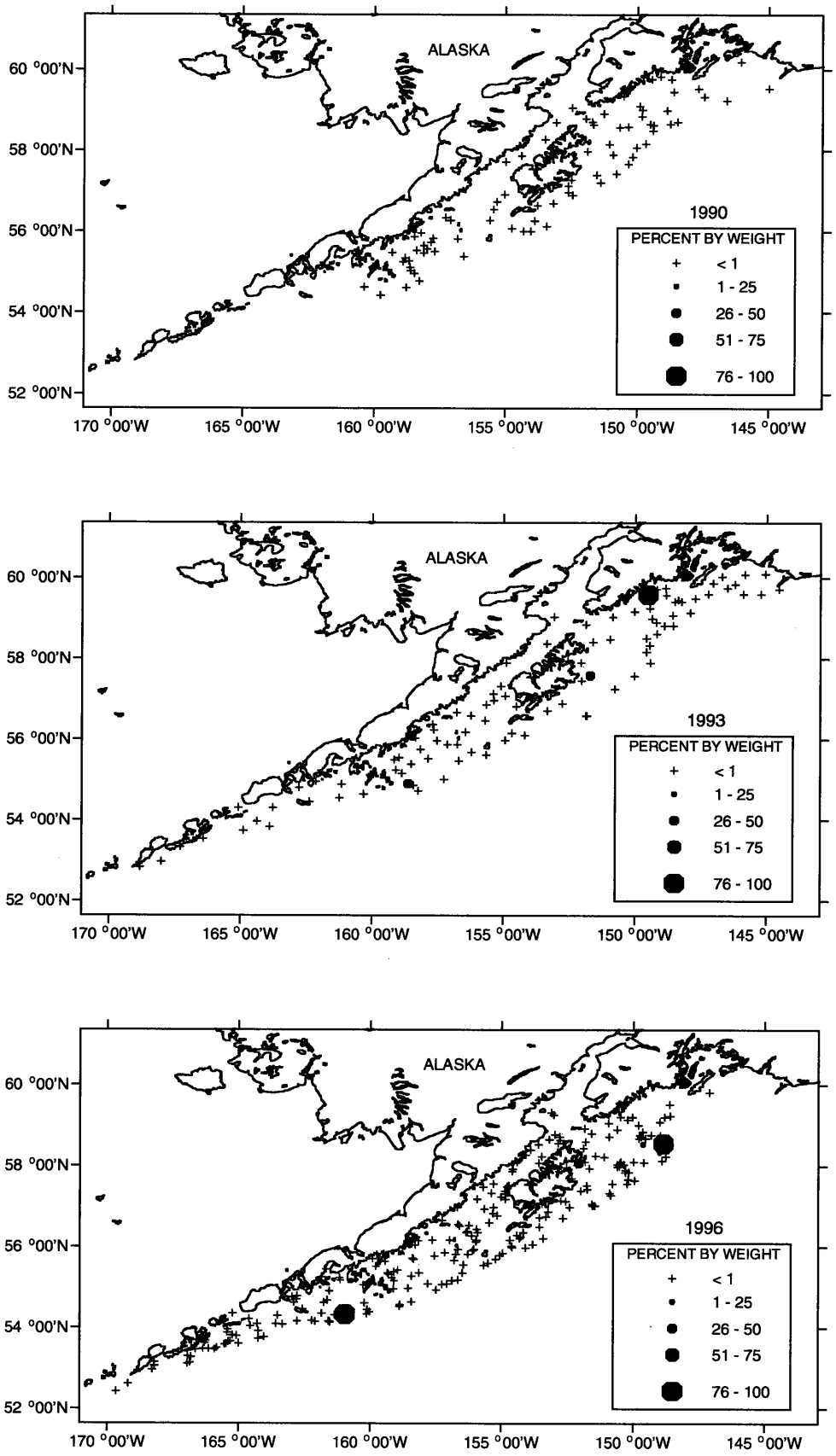
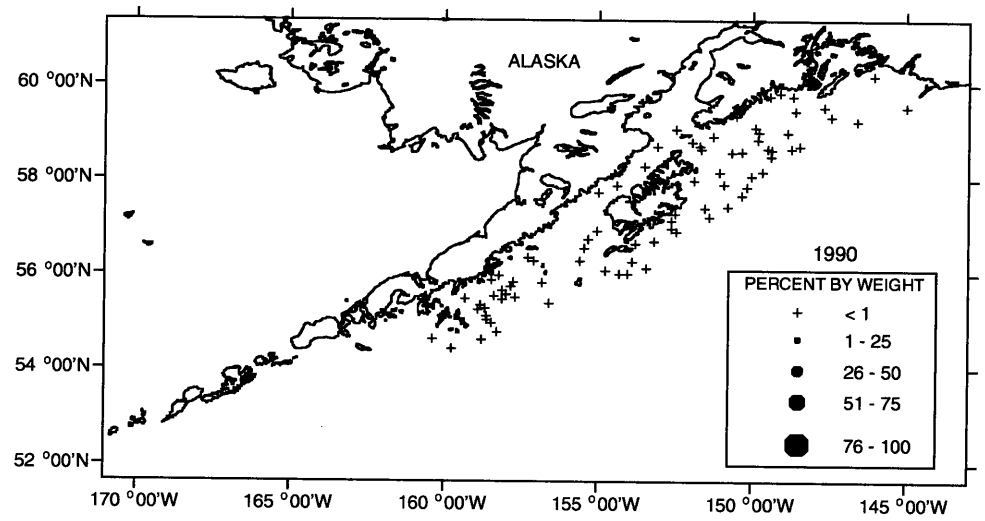
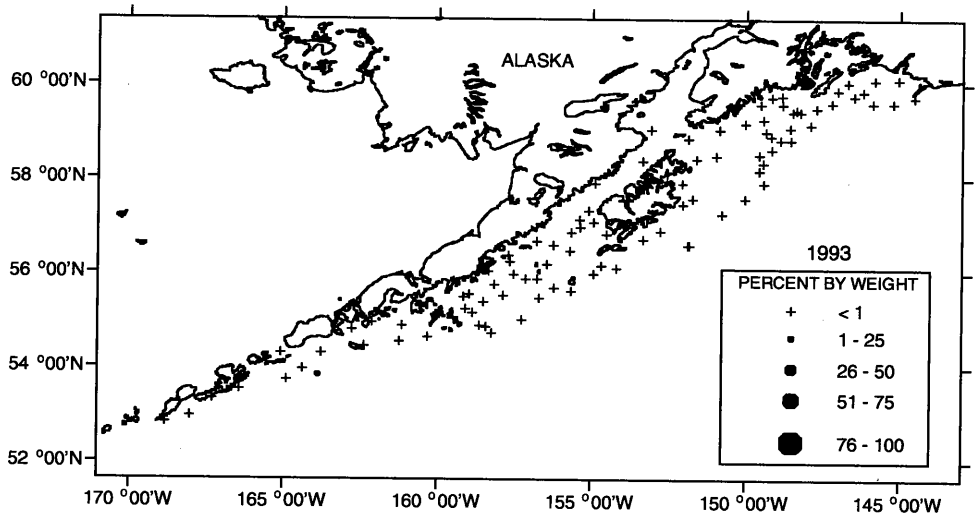


Figure 33.--Geographic distribution of arrowtooth flounder consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.





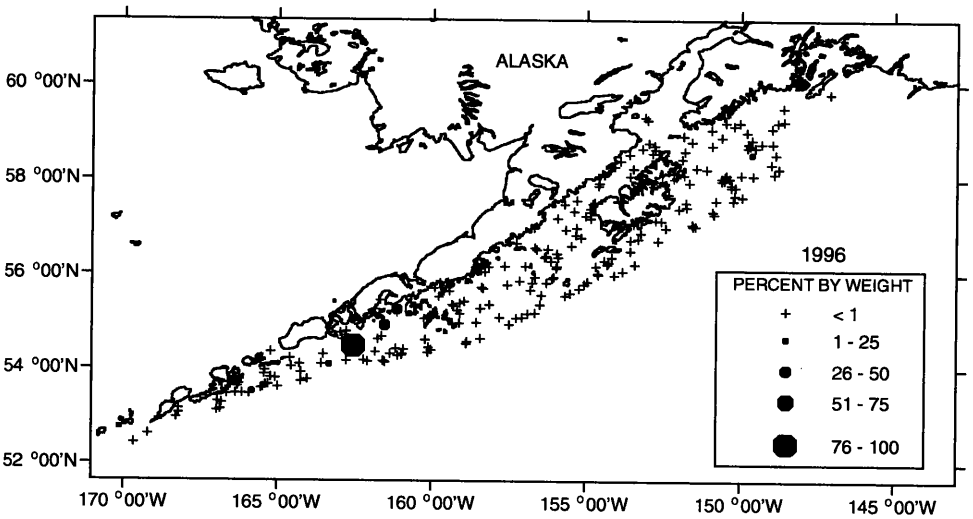


Figure 34.--Geographic distribution of rock sole consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

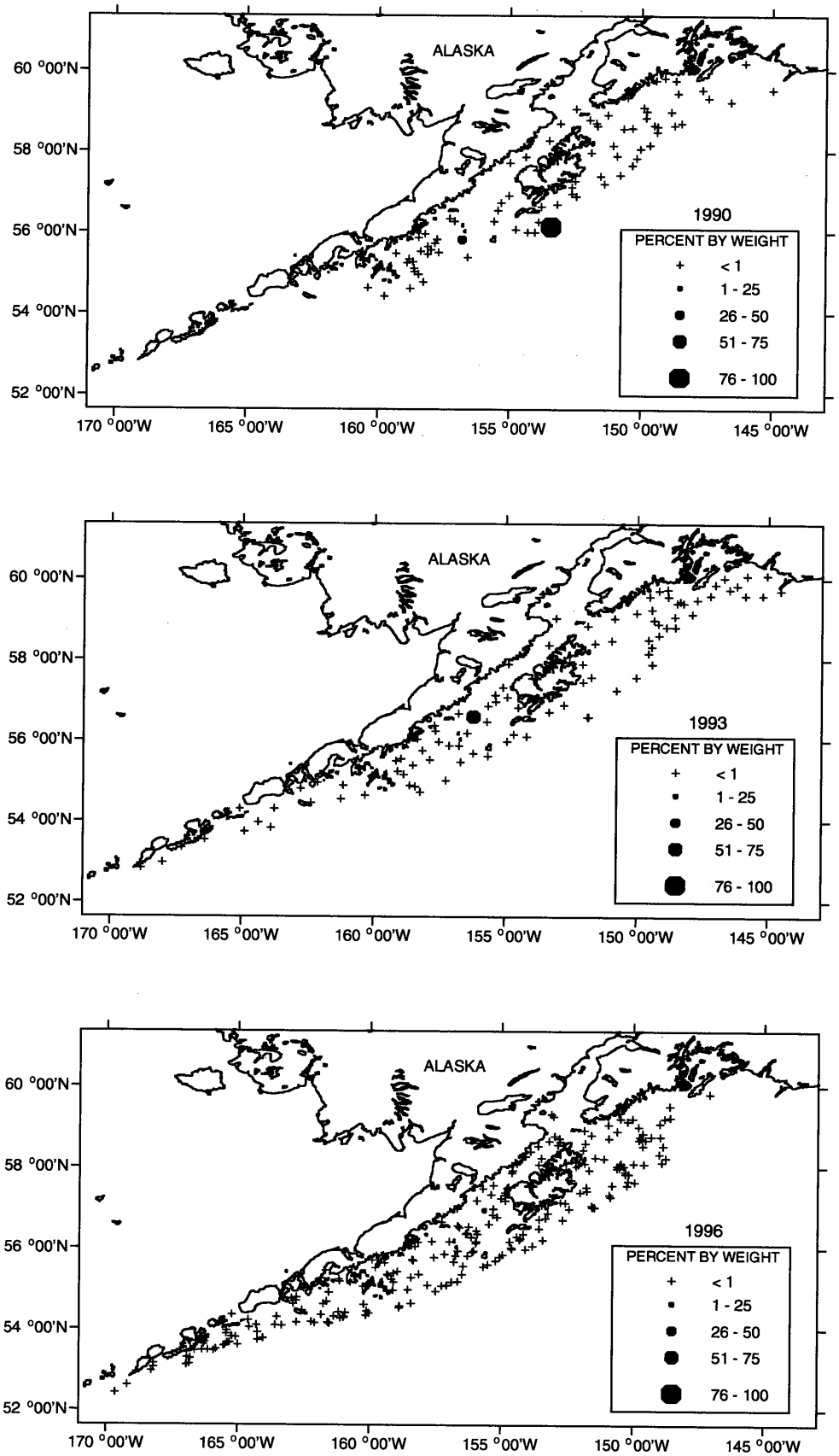


Figure 35.--Geographic distribution of fishery offal consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

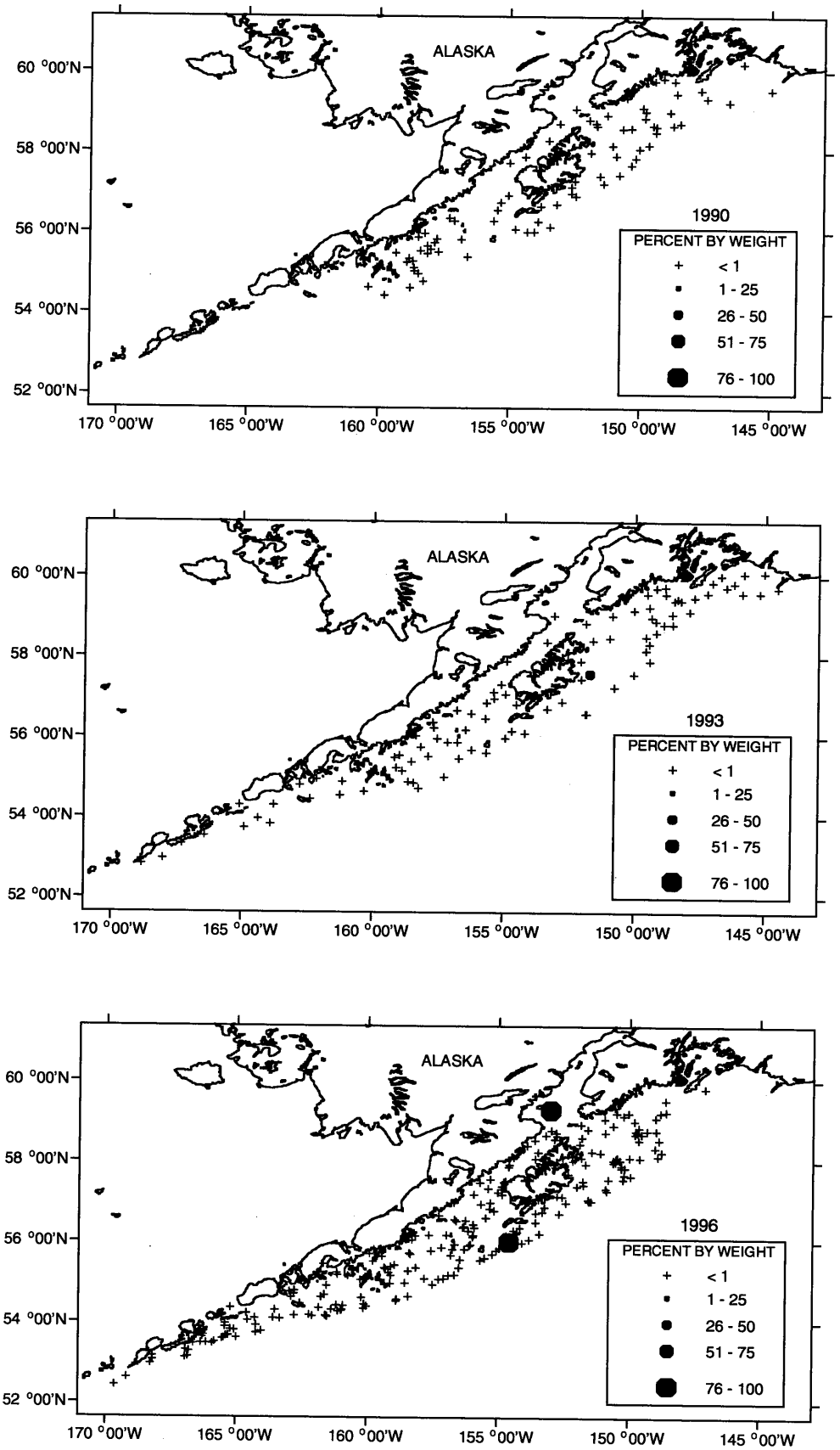


Figure 36.--Geographic distribution of Pacific cod consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

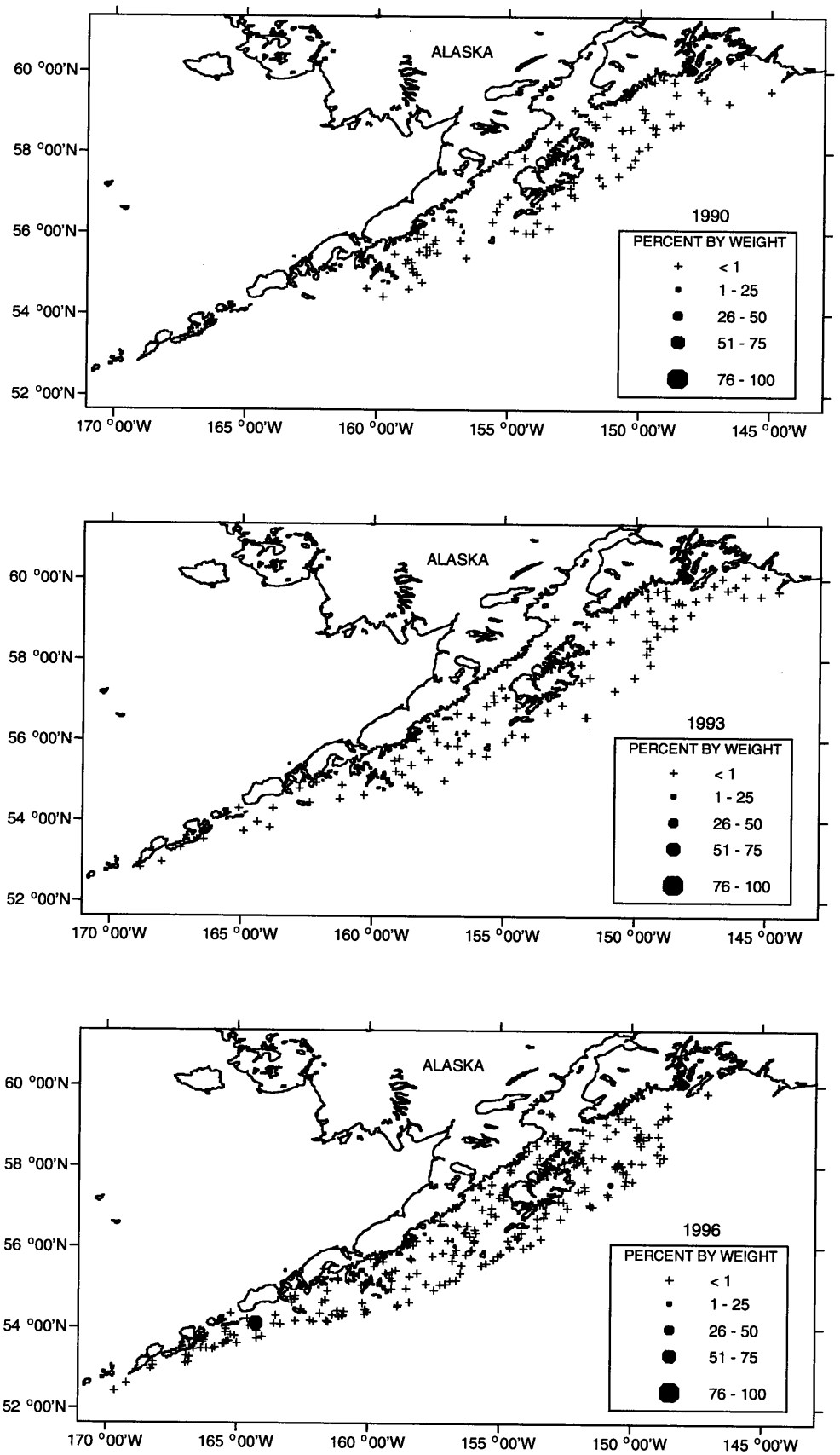


Figure 37.--Geographic distribution of Pacific halibut consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

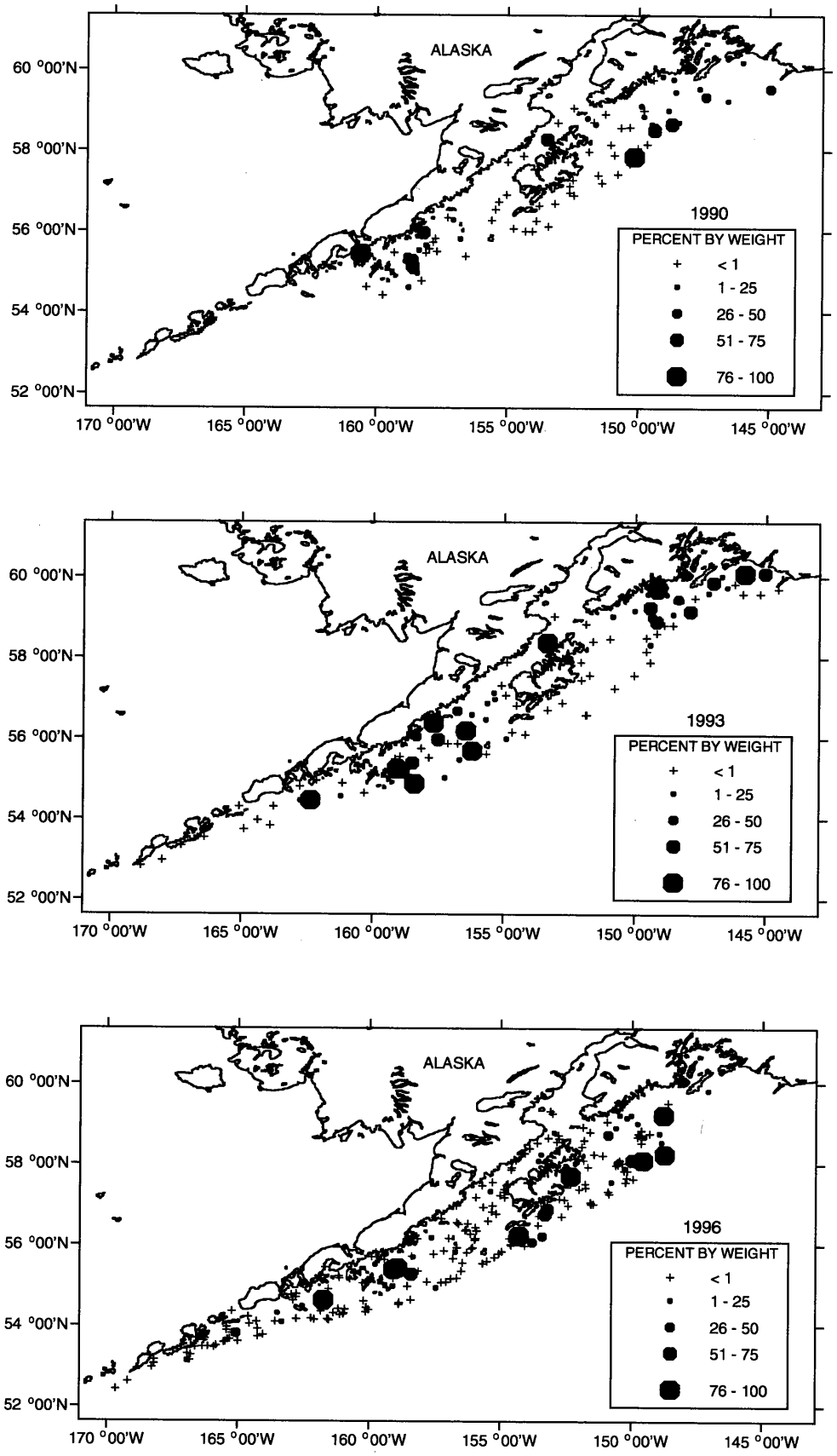


Figure 38.--Geographic distribution of pandalid shrimp consumed by arrowtooth flounder in summer 1990, 1993, and 1996 in Gulf of Alaska.

contents of arrowtooth flounder. In 1990 and 1993, fewer pollock were consumed by arrowtooth flounder, and most were consumed close to Kodiak Island. Figure 27 shows that in 1990 and 1996 most capelin consumed by arrowtooth flounder were on the east and southwest of Kodiak Island. Pacific herring consumption by arrowtooth flounder was limited to one location east of the Kenai Peninsula in 1990 (Fig. 28). Few eulachon were found in arrowtooth flounder in 1990 and 1996. However, in 1993 elevated quantities of eulachon were found east of the Kenai Peninsula (Fig. 29). Figure 30 shows that Atka mackerel consumed by arrowtooth flounder were found south of Unimak Island in 1993. Sablefish, Pacific sand lance, arrowtooth flounder, rock sole, fishery offal, Pacific cod, Pacific halibut, and pandalid shrimp were also consumed by arrowtooth flounder. Their geographic distributions were shown in Figures 31 to 38, respectively.

Sizes of the Commercially Important Prey Consumed

The commercially important prey consumed by arrowtooth flounder were analyzed by two predator size groups: less than 40 cm FL, and greater than or equal to 40 cm FL (Figs. 39 to 45). Figure 39 suggests that smaller arrowtooth flounder (<40 cm) consumed some age-0 and age-1 pollock. The larger-sized ($\geq$40 cm) arrowtooth flounder (especially in 1996) consumed many age-0, age-1, and age-2 pollock (<300 mm SL), and some age 3 and older

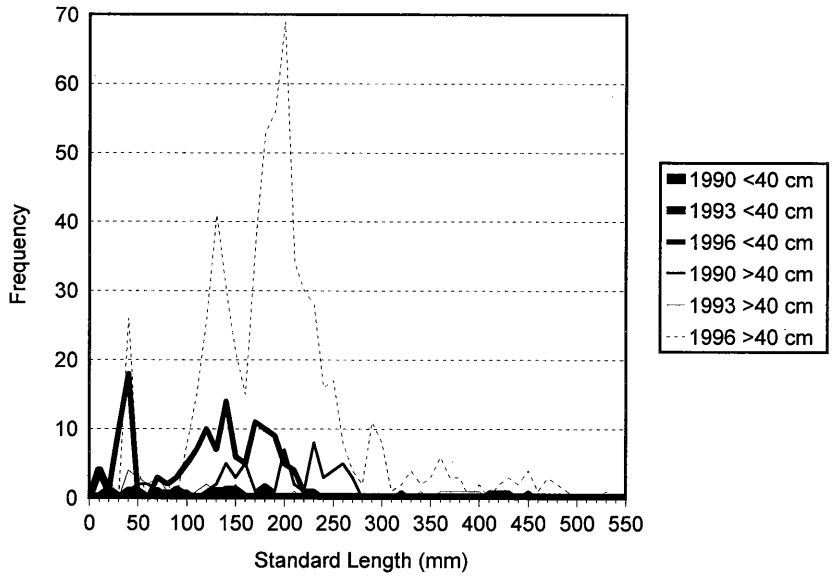


Figure 39.-- Size frequency distribution of walleye pollock consumed by arrowtooth flounder in the Gulf of Alaska in 1990, 1993, and 1996.

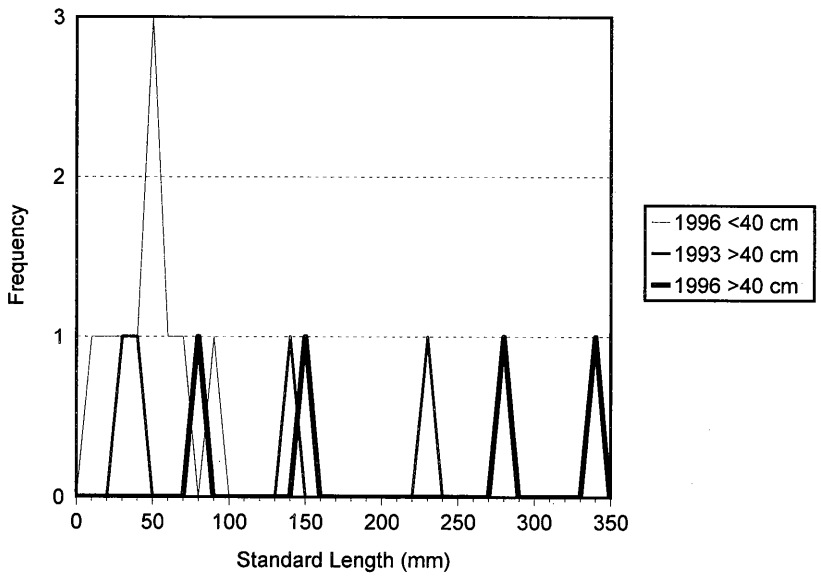


Figure 40.--Size frequency distribution of arrowtooth flounder consumed by arrowtooth flounder in the Gulf of Alaska in 1993, and 1996.

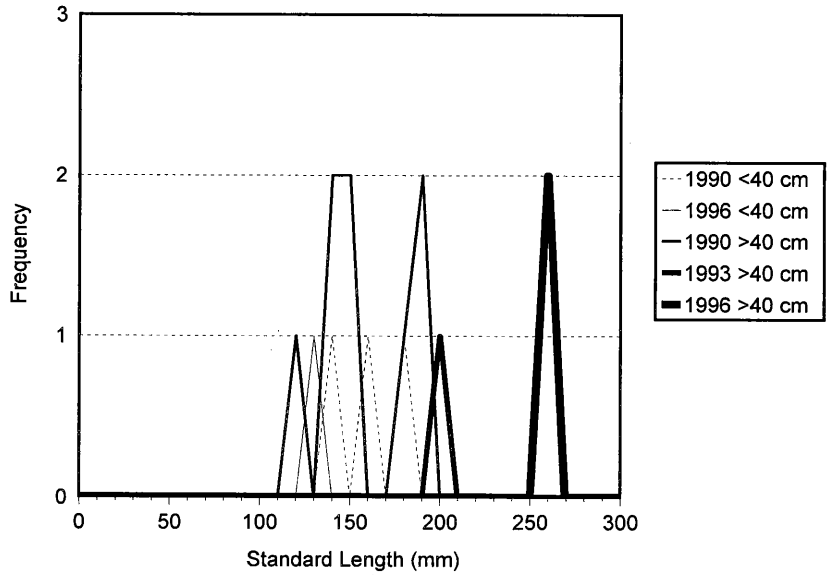


Figure 41.--Size frequency distribution of Pacific herring consumed by arrowtooth flounder in the Gulf of Alaska in 1990, 1993, and 1996.

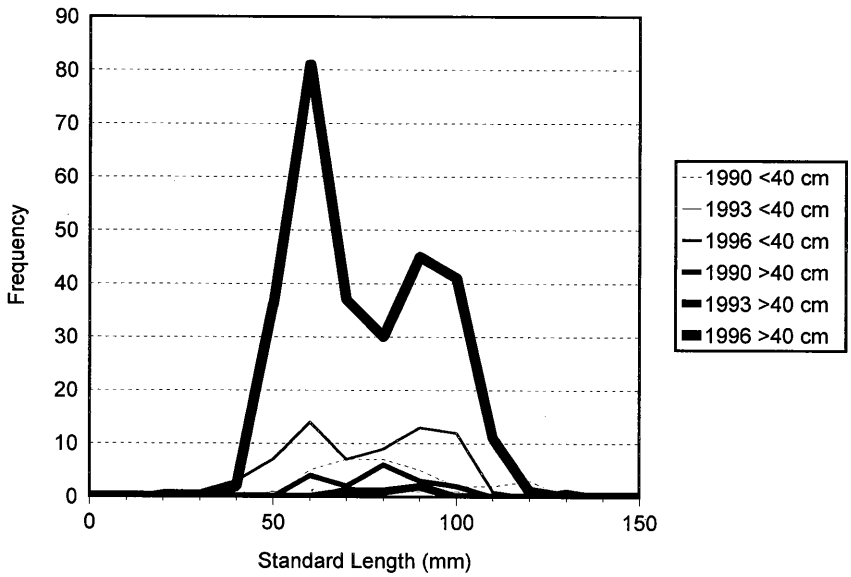


Figure 42.--Size frequency distribution of capelin consumed by arrowtooth flounder in the Gulf of Alaska in 1990, 1993, and 1996.

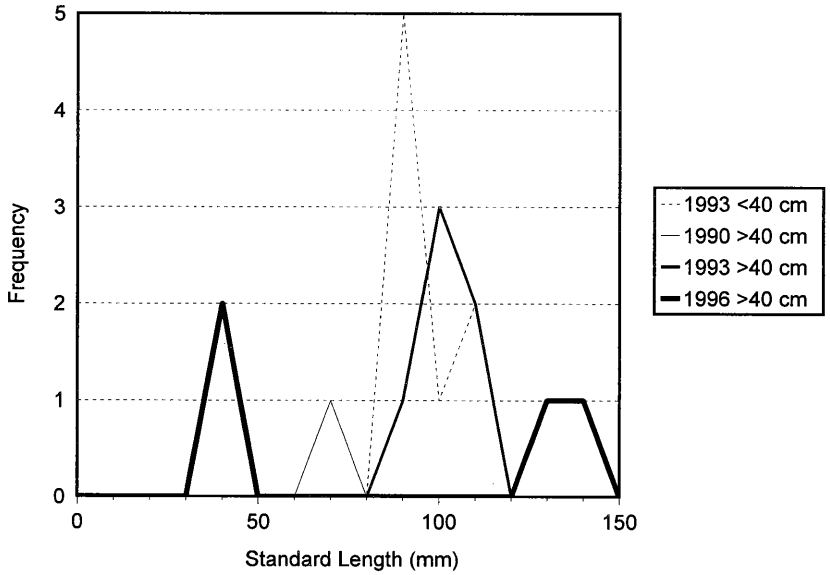


Figure 43.--Size frequency distribution of Pacific sand lance consumed by arrowtooth flounder in the Gulf of Alaska in 1990, 1993, and 1996.

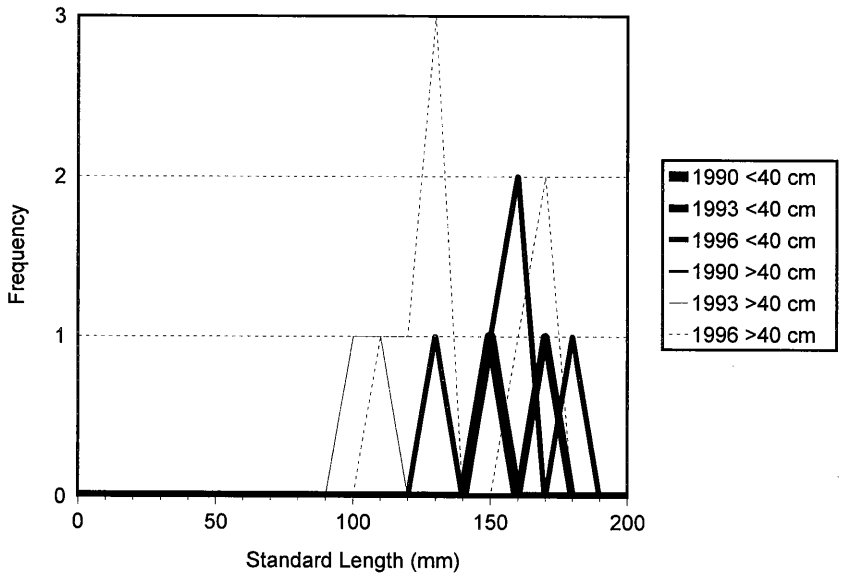


Figure 44.--Size frequency distribution of eulachon consumed by arrowtooth flounder in the Gulf of Alaska in 1990, 1993, and 1996.

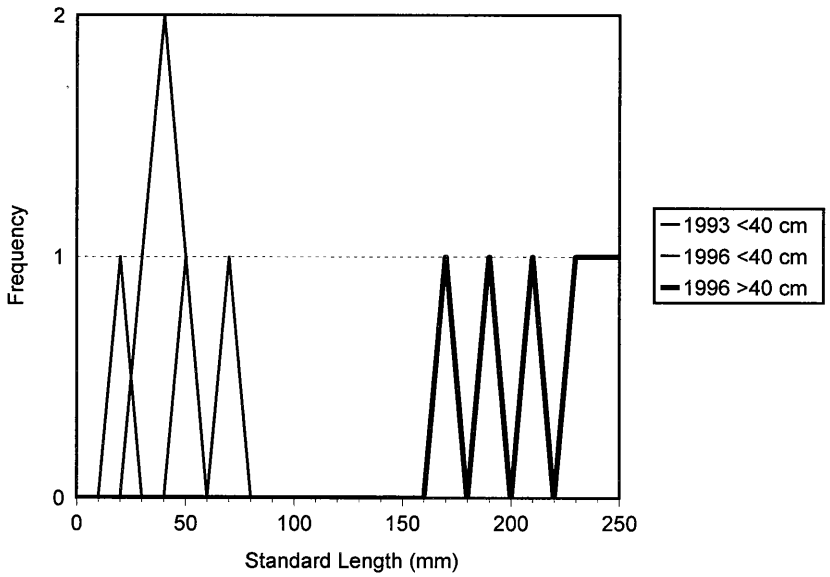


Figure 45.--Size frequency distribution of rock sole consumed by arrowtooth flounder in the Gulf of Alaska in 1993 and 1996.

pollock. The mean standard length (±SD) of the pollock consumed by arrowtooth flounder was 183.8 ± 84.8 mm with a range of 17 to 530 mm SL. Figure 40 shows that a few young arrowtooth flounder were also cannibalized by larger arrowtooth flounder. The mean standard length (±SD) of arrowtooth flounder consumed was 102.5 ± 93.1 mm with a range from 18 to 340 mm SL. Figure 41 displays the size frequency distribution of Pacific herring consumed by arrowtooth flounder. The mean standard length (±SD) of the Pacific herring was 174.2 ± 42.6 mm with a range from 127 to 263 mm SL. Figure 42 illustrates that many capelin were consumed by arrowtooth flounder collected in 1996. The mean standard length (±SD) of capelin consumed by arrowtooth flounder was 79.6 ± 18.9 mm with a range from 27 to 130 mm SL. The size frequency distributions of Pacific sand lance, eulachon, and rock sole were shown in Figures 43, 44, and 45, respectively.

Arrowtooth flounder also consumed salmonids, Pacific cod, Pacific halibut, rex sole, flathead sole, yellowfin sole, Atka mackerel, stichaeids, bathymasterids, bathylagids, viperfish, agonids, eulachon, myctophids, zoarcids, rockfish, and cottids. The number, mean standard length, and the standard deviation of these prey fish are listed in Table 12.

Table 12.--Mean standard length and standard deviation (SD) of the miscellaneous prey fish consumed by arrowtooth flounder in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size

Prey name	n	Mean SL(mm)	SD (mm)	Range(mm)
Pacific cod	3	284.7	103.1	184-390
Flathead sole	6	114.5	71.1	54-250
Atka mackerel	5	161.8	92.7	16-250
Salmonid	2	166.5	118.1	83-250
Stichaeids	67	96.1	48.1	43-310
Rex sole	1	91.0	0.0	91-91
Zoarcid	15	150.8	53.4	57-250
Cottid	11	82.8	45.4	23-180
Agonid	2	70.0	2.1	68-71
Pacific halibut	2	45.5	2.1	44-47
Yellowfin sole	1	62.0	0.0	62-62
Myctophid	9	88.0	9.7	79-109
Rockfish	2	56.0	8.5	50-62
Bathymasterid	5	150.8	81.4	42-250
Bathylagid	5	141.4	22.4	116-160
Viperfish	1	91.0	0.0	91-91

DISCUSSION

The percentage of pollock in the diet of arrowtooth flounder was 28% and 16% in 1990 and 1993, respectively. This percentage jumped to 53% in 1996. This phenomenon of having a high percentage of pollock as food in the diet of arrowtooth flounder in 1996 was similar to what was observed in the diets of pollock and Pacific cod in the same year. Capelin made up a high percentage (23%) of the diet of arrowtooth flounder in 1990 but they comprised only 4% and 10% in 1993 and 1996, respectively. The percentages of pandalid shrimp in the diet of arrowtooth flounder was 12% in 1990 and 18% in 1996. This value declined to only 6% in 1996. This low consumption of pandalid shrimp by arrowtooth flounder in 1996 (compared to 1990 and 1993) was also observed for pollock.

PACIFIC HALIBUT

by

Mei-Sun Yang

Pacific halibut (*Hippoglossus stenolepis*) had an exploitable biomass of about 300,000 t in the Gulf of Alaska (NPFMC Regulatory areas 3A and 3B) in 1997. In that same year the commercial catch in the Gulf of Alaska (areas 3A and 3B) was 20,379 t (NPFMC 1998). Pacific halibut are important predators feeding on fish, crab and squid. Knowledge of their food habits is needed to describe their potential impact on other commercially important species in the Gulf of Alaska area.

RESULTS

General Diets

Tables 13 to 15 list the total number of stomachs containing food, the empty stomachs, the mean percent frequency of occurrence of the prey, and the mean percent by weight of the prey found in Pacific halibut stomachs collected in 1990, 1993, and 1996. Walleye pollock was the most important prey. In terms of weight, pollock comprised 38%, 31%, and 32% of the total stomach contents in 1990, 1993, and 1996, respectively. Capelin made up about 2% of the total stomach contents weight in each

Table 13.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Hippoglossus stenolepis* (Pacific halibut) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	<.01	.46
Polynoidae (polychaete)	<.01	.29
Mollusca (unidentified)	.60	.60
Gastropoda (snail)	<.01	.53
Naticidae (snail)	<.01	.29
Fusitriton oregonensis (snail)	.01	.72
Buccinum sp. (snail)	<.01	.72
Bivalvia (clam)	.02	2.43
Nuculana fossa (clam)	.04	.97
Mytilidae (unidentified)	.02	.39
Modiolus modiolus (horse mussel)	.04	.43
Cephalopoda (unidentified)	.11	.12
Teuthoidea (squid unidentified)	.07	.21
Gonatus magister (squid)	.42	.36
Octopoda (octopus)	4.79	9.56
Acanthomysis dybowskii (mysid)	.01	.16
Diastylis sp. (cumacean)	.29	.66
Gammaridea (unidentified)	.19	1.95
Lysianassidae (amphipod)	<.01	.16
Pasiphaea pacifica (shrimp)	<.01	.16
Hippolytidae (shrimp)	<.01	.72
Spirontocaris sp. (shrimp)	.01	.12
Spirontocaris lamellicornis (shrimp)	.01	.32
Spirontocaris arcuata (shrimp)	<.01	.29
Pandalidae (unidentified)	.11	.69
Pandalus borealis (shrimp)	.05	.89
Pandalus montagui tridens (shrimp)	.05	.32
Crangonidae (unidentified)	.04	1.41
Crangon alaskensis (shrimp)	.39	.24
Crangon alba (shrimp)	.28	.26
Crangon dalli (shrimp)	<.01	.16
Crangon communis (shrimp)	.03	.48
Rhynocrangon alata (shrimp)	<.01	.12
Argis dentata (shrimp)	.22	.93
Argis levior (shrimp)	.56	1.22
Paguridae (hermit crab)	5.53	13.86
Pagurus aleuticus	.09	.31
Pagurus rathbuni (hermit crab)	.03	.32
Elassochirus tenuimanus (hermit crab)	1.82	1.18
Acantholithodes hispidus (crab)	.03	.29
Phyllolithodes papillosus (crab)	.07	.14
Lopholithodes mandtii (crab)	.02	.36
Lopholithodes foraminatus (crab)	.68	.24
Rhinolithodes wosnessenskii (crab)	<.01	.14
Munida quadrispina (crab)	.01	.18
Majidae (unidentified)	.01	.29
Oregonia gracilis (crab)	1.74	5.52
Hyas lyratus (crab)	5.97	12.74

Table 13.--Continued.

Prey name	Mean % Wt	Mean % FO
Chionoecetes bairdi (Tanner crab)	5.73	17.23
Pugettia gracilis (crab)	.02	.14
Cancer oregonensis (crab)	4.37	9.97
Pinnotheridae (pea crab)	.00	.13
Pinnotheridae (crab)	<.01	.48
Echiuroid (marine worm)	.01	.48
Asteroidea (starfish)	.01	1.45
Holothuroidea (sea cucumber)	.01	.29
Teleostei (unidentified fish)	.77	11.31
Non-gadoid Fish Remains	.31	1.42
Oncorhynchus sp. (salmon)	.03	.16
Oncorhynchus kisutch (coho salmon)	1.18	.24
Mallotus villosus (capelin)	2.32	10.07
Thaleichthys pacificus (eulachon)	<.01	.16
Gadidae (gadid fish)	2.72	2.90
Gadus macrocephalus (Pacific cod)	1.18	.53
Theragra chalcogramma (walleye pollock)	35.67	34.70
Lycodes brevipes (shortfin eelpout)	.76	1.18
Lycodes palearis (wattled eelpout)	.38	.81
Scorpaenidae (unidentified)	.01	.24
Sebastes alutus (Pacific ocean perch)	.88	.18
Cottidae (sculpin)	.17	1.46
Artediellus sp. (sculpin)	.01	.16
Hemilepidotus sp. (sculpin)	.94	.16
Hemilepidotus jordani (sculpin)	.74	.99
Icelinus borealis (Northern Sculpin)	.09	.86
Malacocottus kincaidi (blackfin sculpin)	.00	.29
Triglops pingeli (ribbed sculpin)	.18	.14
Agonidae (poacher)	.01	.14
Anoplagonus inermis (poacher)	.02	.14
Sarritor frenatus (sawback poacher)	.06	1.15
Cyclopteridae (snailfish)	.00	.13
Liparis sp. (snailfish)	.20	.16
Bathymaster signatus (searcher)	.18	.41
Stichaeidae (prickleback)	.47	1.14
Zaprora silenus (prowfish)	.11	.72
Ammodytes hexapterus (Pacific sand lance)	3.58	3.78
Pleuronectidae (flatfish)	1.76	4.19
Atheresthes stomias (arrowtooth flounder)	5.09	5.61
Hippoglossoides elassodon (flathead sole)	.46	.93
Pleuronectes bilineatus (rock sole)	.44	.14
Pleuronectes asper (yellowfin sole)	.01	.36
Microstomus pacificus (Dover sole)	.63	.36
Hippoglossus stenolepis (Pacific halibut)	.02	.40
Fishery offal	3.86	2.10
Total prey weight	50,417 g	
Total non-empty stomachs	388	
Total empty stomachs	79	
Total hauls	69	

Table 14.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Hippoglossus stenolepis* (Pacific halibut) collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	.14	1.45
Aphroditidae (polychaete)	.17	.91
Gastropoda (snail)	.45	5.76
Bivalvia (clam)	.38	1.70
Cephalopoda (unidentified)	.34	.30
Teuthoidea (squid)	.05	.17
Octopoda (octopus)	2.11	7.07
Cirripedia (barnacle)	.07	.27
Isopoda (isopod)	.02	.15
Gammaridea (amphipod)	.01	.17
Hyperiidae (amphipod)	<.01	.14
Euphausiacea (unidentified)	1.28	3.10
Caridea (shrimp)	.02	.79
Hippolytidae (shrimp)	.02	.50
Pandalidae (shrimp)	2.33	4.73
Pandalopsis dispar (shrimp)	.40	1.03
Crangonidae (shrimp)	.88	2.84
Reptantia (crab)	.17	1.23
Paguridae (hermit crab)	21.61	42.07
Lopholithodes sp. (box crab)	.02	.27
Rhinolithodes wosnessenskii (rhinoceros crab)	.08	.30
Majidae (unidentified)	.30	.31
Oregonia sp. (decorator crab)	.93	1.41
Hyas sp. (lyre crab)	8.19	16.28
Chionoecetes bairdi (Tanner crab)	8.79	20.07
Cancridae (crab)	.11	.50
Cancer oregonensis (pygmy cancer crab)	2.74	8.31
Pinnotheridae (pea crab)	<.01	.15
Ophiurida (brittle star)	.04	.17
Holothuroidea (sea cucumber)	.18	.15
Rajidae (skate)	1.35	1.66
Teleostei (unidentified fish)	.36	2.24
Non-gadoid Fish Remains	.23	1.28
Clupea pallasi (Pacific herring)	1.99	2.05
Mallotus villosus (capelin)	1.96	2.16
Gadidae (gadid fish)	.30	.11
Gadus macrocephalus (Pacific cod)	1.78	1.67
Theragra chalcogramma (walleye pollock)	30.60	20.95
Zoarcidae (eelpout)	.39	.79
Sebastes sp. (rockfish)	.03	.15
Pleurogrammus monopterygius (Atka mackerel)	.57	.23
Anoplopoma fimbria (sablefish)	.83	.68
Cottidae (sculpin)	.81	1.89
Stichaeidae (prickleback)	.11	.32
Ammodytes hexapterus (Pacific sand lance)	2.95	4.82

Table 14.--Continued.

Prey name	Mean % Wt	Mean % FO
Pleuronectidae (flatfish)	.08	.42
Atheresthes stomias (arrowtooth flounder)	2.89	2.36
Pleuronectes bilineatus (rock sole)	.62	.44
Misc. unidentified organic materials	.04	.93
Fishery offal	.23	.34
Total prey weight	40,067 g	
Total non-empty stomachs	409	
Total empty stomachs	150	
Total hauls	73	

Table 15.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Hippoglossus stenolepis* (Pacific halibut) collected in the Gulf of Alaska in 1996.

Prey name	Mean % Wt	Mean % FO
Anthozoa (anemone)	.04	.68
Aphroditidae (polychaete)	.14	.19
Polynoidae (polychaete)	<.01	.23
Nereidae (polychaete)	.01	.39
Trichobranchidae (polychaete)	<.01	.19
Capitellida (polychaete)	.02	.27
Mollusca (unidentified)	.12	1.16
Gastropoda (snail)	.04	1.60
Neptuneidae (snail)	<.01	.27
Bivalvia (clam)	.65	6.12
Pectinidae (scallops)	.02	1.17
Cephalopoda (unidentified)	.39	.93
Teuthoidea (squid)	.16	.79
Octopoda (octopus)	2.37	4.06
Mysidae (mysid)	<.01	.30
Isopoda (isopod)	<.01	.27
Gammaridea (amphipod)	.01	.77
Euphausiacea (unidentified)	.20	.61
Thysanoessa sp. (euphausiid)	<.01	.27
Hippolytidae (shrimp)	<.01	.55
Spirontocaris sp. (shrimp)	.04	.85
Spirontocaris prionota (shrimp)	.01	.16
Spirontocaris ochotensis (shrimp)	.01	.39
Spirontocaris arcuata (shrimp)	.03	1.09
Lebbeus groenlandicus (shrimp)	.45	1.61
Lebbeus grandimanus (candystripe shrimp)	.01	.45
Eualus sp. (shrimp)	<.01	.19
Eualus barbata (shrimp)	.03	.54
Eualus suckleyi (shrimp)	.01	.90
Eualus avinus (shrimp)	.01	.90
Heptacarpus tridens (shrimp)	.04	.39
Heptacarpus stylus (shrimp)	.03	.39
Pandalus sp. (shrimp)	.12	.72
Pandalus borealis (shrimp)	.01	.68
Pandalus stenolepis (rough patch shrimp)	.13	1.02
Crangonidae (shrimp)	.04	1.17
Crangon sp. (shrimp)	.02	.34
Crangon dalli (shrimp)	.02	.30
Rhynocrangon alata (saddle-back shrimp)	.06	.16
Argis sp. (shrimp)	.14	2.03
Metacrangon sp. (spinyhead shrimp)	.01	.16
Reptantia (crab)	.14	2.70
Paguridae (hermit crab)	5.49	16.58
Pagurus sp. (hermit crab)	2.73	15.28
Pagurus ochotensis (hermit crab)	.50	.30
Pagurus kennerlyi (hermit crab)	.01	.15
Elassochirus tenuimanus (hermit crab)	6.26	14.02
Elassochirus cavimanus (purple hermit crab)	.14	1.17
Acantholithodes hispidus (fussy crab)	.46	1.35

Table 15.--Continued.

Prey name	Mean % Wt	Mean % FO
Lopholithodes mandtii (red box crab)	.04	.27
Decapoda brachyura (crab)	.01	.19
Majidae (spider crab)	1.12	8.12
Oregonia sp. (decorator crab)	.19	.80
Oregonia gracilis (decorator crab)	2.34	6.22
Hyas lyratus (lyre crab)	6.00	18.07
Chionoecetes sp. (snow and Tanner crab)	.57	4.69
Chionoecetes bairdi (Tanner crab)	8.29	31.00
Erimacrus isenbeckii (Korean horse-hair crab)	<.01	.19
Cancridae (crab)	.19	.80
Cancer sp. (crab)	.01	.77
Cancer oregonensis (pygmy cancer crab)	2.39	5.90
Pinnixa sp. (pea crab)	.01	.45
Sipuncula (marine worm)	<.01	.34
Echiura (marine worm)	.02	1.01
Ectoprocta (bryozoan)	<.01	.39
Ophiurida (brittle star)	.01	.25
Holothuroidea (sea cucumber)	.39	1.35
Teleostei (unidentified fish)	.18	4.58
Non-gadoid Fish Remains	1.02	10.29
Clupea pallasi (Pacific herring)	.17	.39
Osmeridae (smelts)	1.27	2.90
Mallotus villosus (capelin)	2.23	3.60
Gadidae (gadid fish)	.44	6.63
Gadus macrocephalus (Pacific cod)	.56	.34
Theragra chalcogramma (walleye pollock)	32.00	23.95
Zoarcidae (eelpout)	.24	.23
Pleurogrammus monopterygius (Atka mackerel)	5.98	2.48
Cottoidei (sculpin)	.02	.16
Agonidae (poacher)	.01	.88
Aspidophoroides bartoni (Aleutian alligatorfish)	.02	.42
Hypsagonus quadricornis (4 horn poacher)	.02	.25
Trichodon trichodon (Pacific sandfish)	1.54	.23
Bathymaster signatus (searcher)	.47	.25
Stichaeidae (prickleback)	.06	.77
Lumpenus sagitta (snake prickleback)	.27	.30
Pholis clemensi (longfin gunnel)	.03	.25
Ammodytes hexapterus (Pacific sand lance)	3.19	6.47
Pleuronectidae (flatfish)	.19	1.32
Atheresthes stomias (arrowtooth flounder)	.99	1.24
Pleuronectes bilineatus (rock sole)	2.00	.61
Pleuronectes asper (yellowfin sole)	1.46	.64
Microstomus pacificus (Dover sole)	.96	.54
Fishery offal	1.85	1.80
Total prey weight	25,340 g	
Total non-empty stomachs	296	
Total empty stomachs	71	
Total hauls	37	

year. Arrowtooth flounder comprised between 1% and 5% of the total stomach contents weights in the three years collections. Atka mackerel comprised 6% of the total stomach contents weight in 1996. Other commercially important fish consumed by Pacific halibut included Pacific cod, eulachon, Pacific sand lance, Pacific ocean perch, flathead sole, rock sole, yellowfin sole, Dover sole, and young Pacific halibut. Pacific halibut also consumed some fishery offal. 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 were the most important invertebrate prey of Pacific halibut; they comprised about 6-9% of the total stomach contents weight in 1990, 1993, and 1996. Less important invertebrate prey included cephalopods (3-5%), lyre crab (*Hyas* sp.) (6-8%), cancer crab (*Cancer oregonensis*) (2-4%), hermit crab (7-22%), and decorator crab (*Oregonia gracilis*) (1-2%). 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 varied greatly by predator size (Fig. 46). Miscellaneous prey fish (mainly capelin, Pacific sand

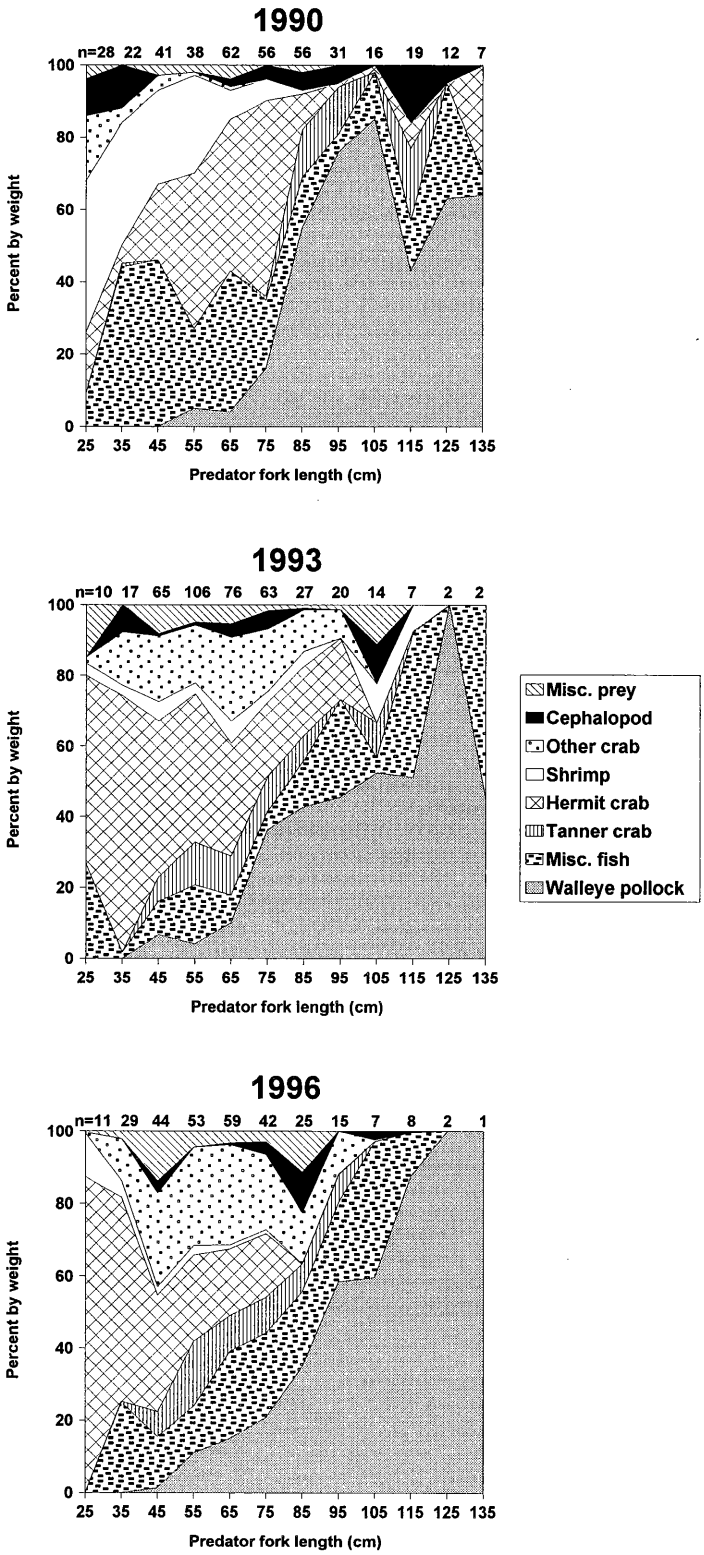


Figure 46.-- Variations in the main food items of Pacific halibut, by predator size, in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size.

lance, cottids, zoarcids, stichaeids, and flatfish) were important food for all sizes of Pacific halibut, whereas walleye pollock were mainly consumed by larger Pacific halibut (≥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. Hermit crabs (pagurids) were important food (≥25% by weight) for Pacific halibut less than 60 cm FL, especially for fish less than 30 cm long (they comprised 38%, 53%, and 87% of the total stomach contents weight in 1990, 1993, and 1996, respectively).

Geographic Distributions of the Prey Consumed

The distributions of the commercially important prey consumed by Pacific halibut are shown in Figures 47 to 54. Figure 47 illustrates that walleye pollock were consumed by Pacific halibut at most of the sampling stations in 1990, 1993, and 1996, 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 east and southeast of Kodiak Island in 1990 and 1996; however, in 1993, they were found in samples from Middleton Island and Unimak Island areas (Fig. 48). The amount of capelin consumed in all but one station was low (<25%). Tanner crabs were found in Pacific halibut stomachs

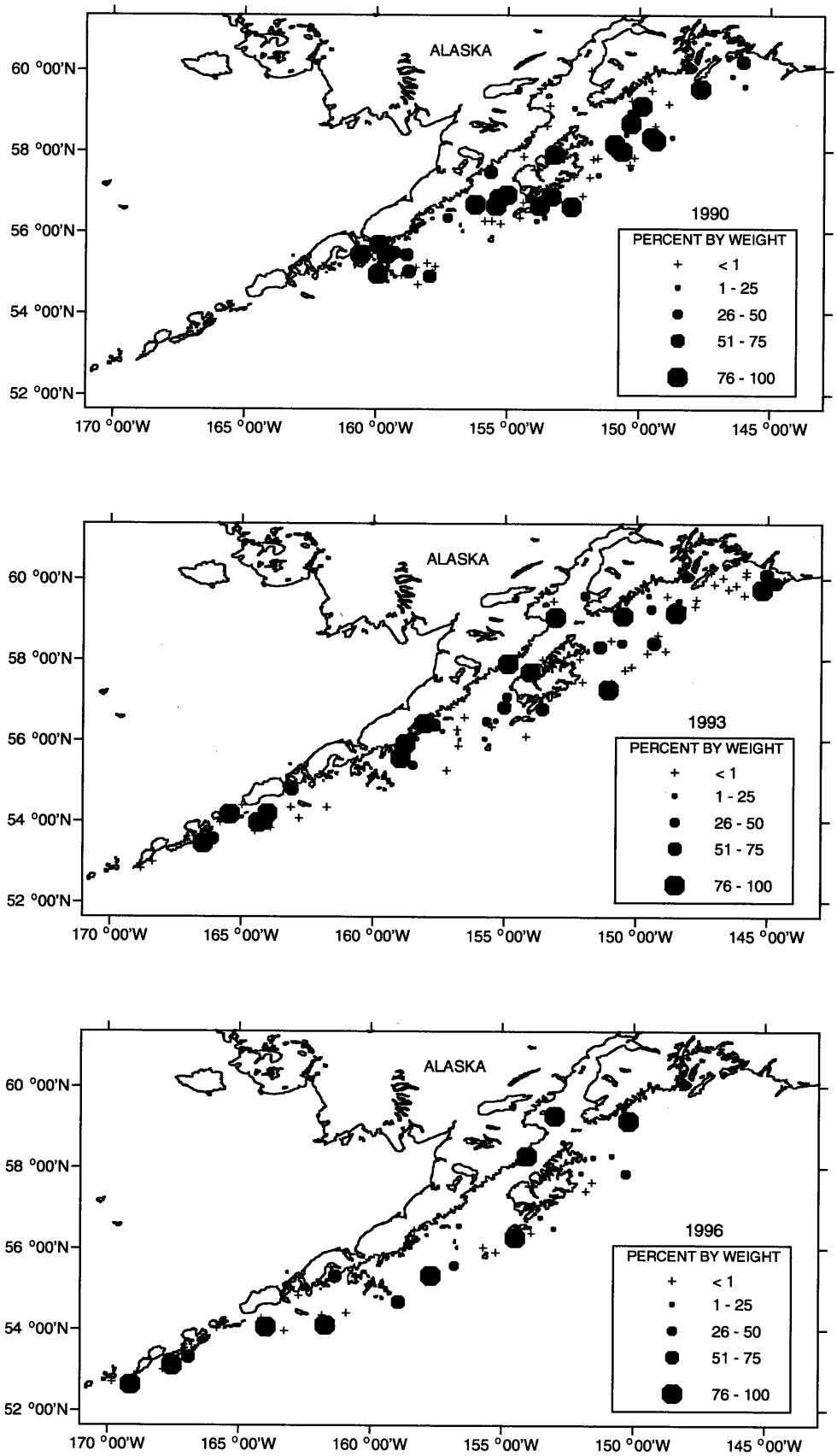


Figure 47.--Geographic distribution of walleye pollock consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.

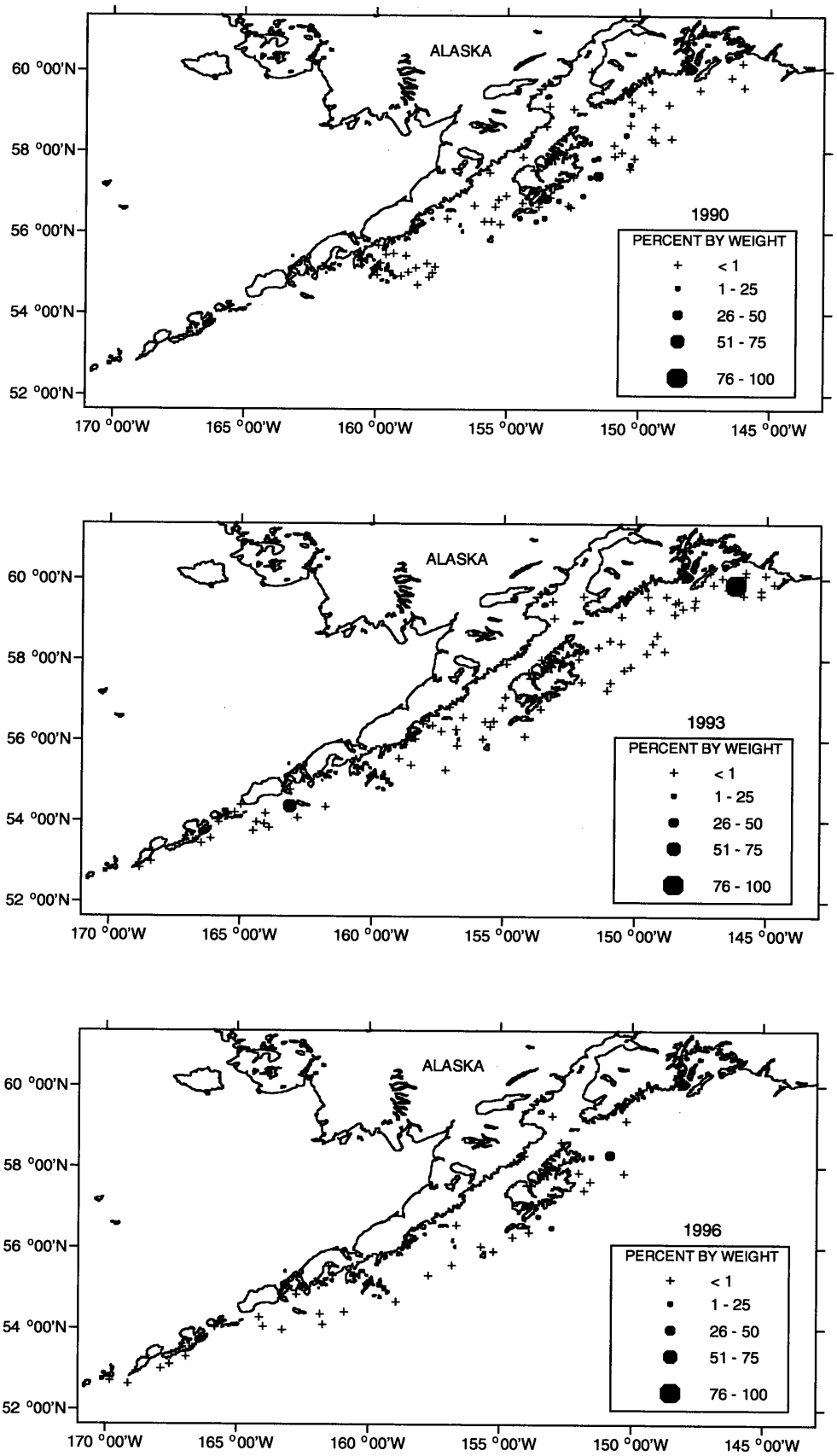


Figure 48.--Geographic distribution of capelin consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.

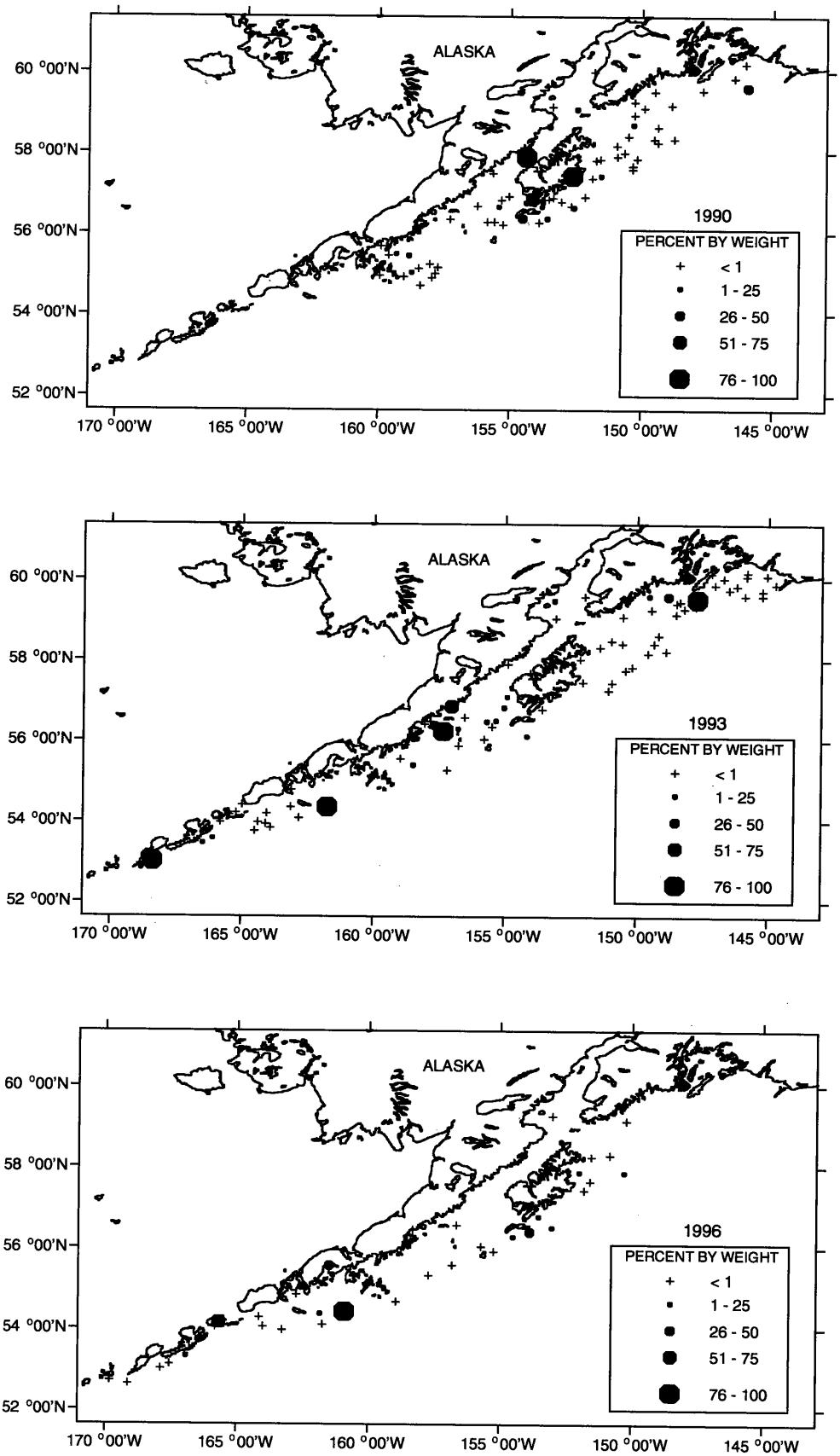


Figure 49.--Geographic distribution of Tanner crab consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.

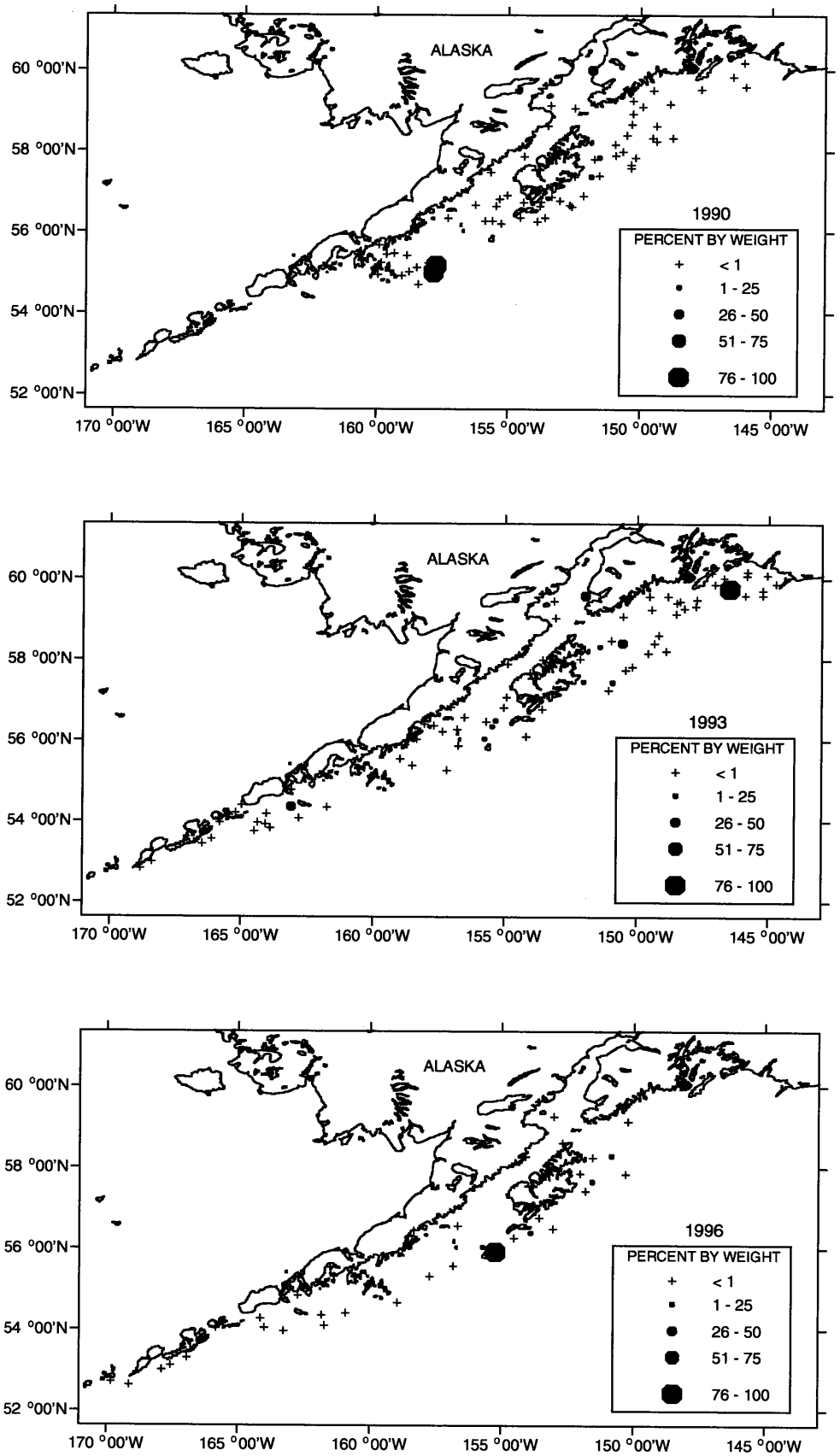


Figure 50.--Geographic distribution of Pacific sand lance consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.

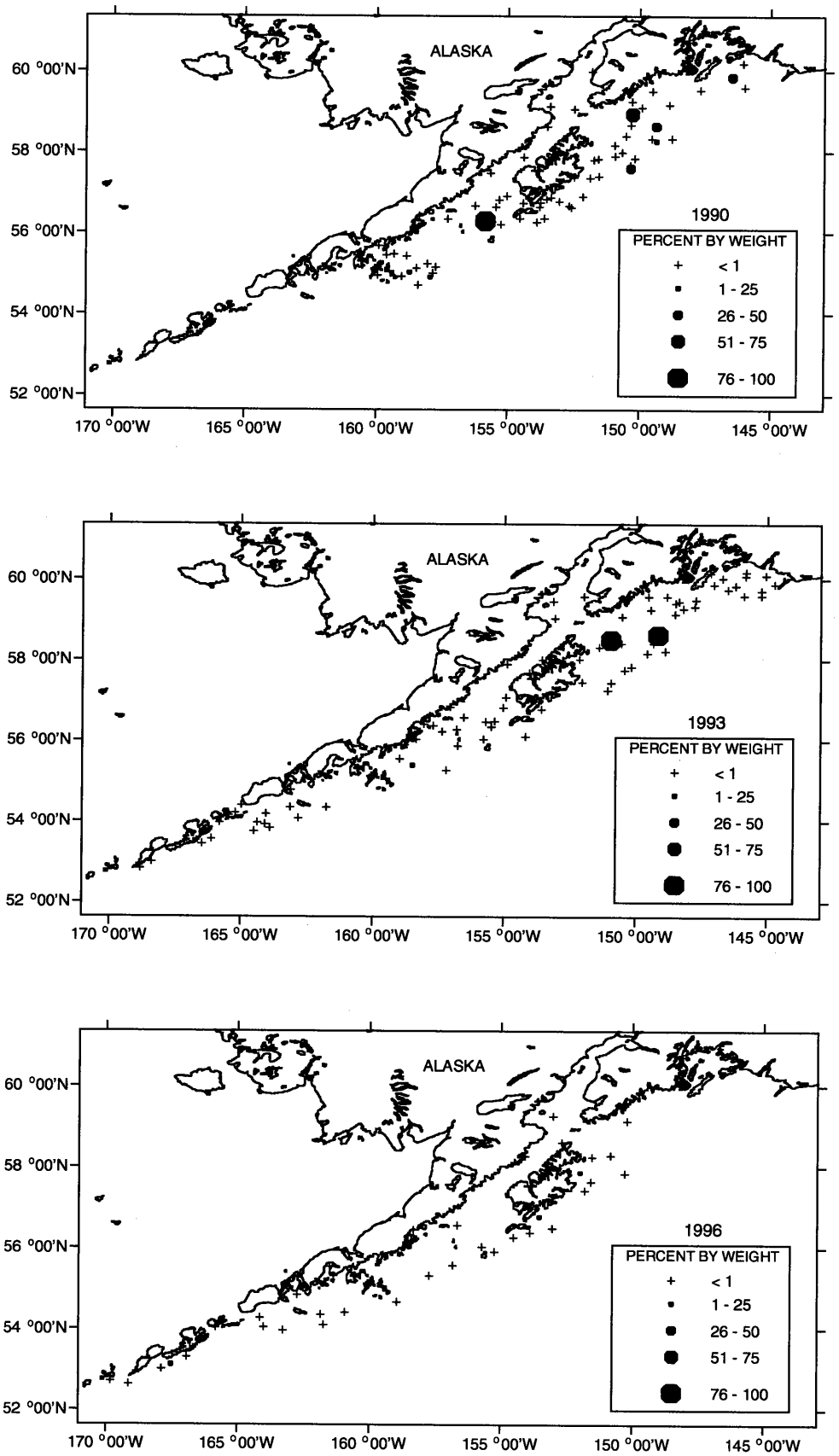
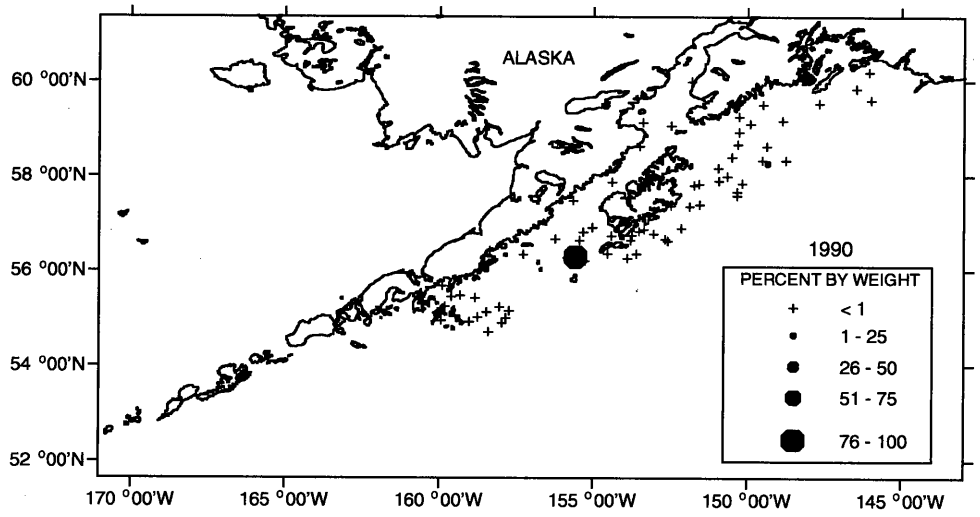
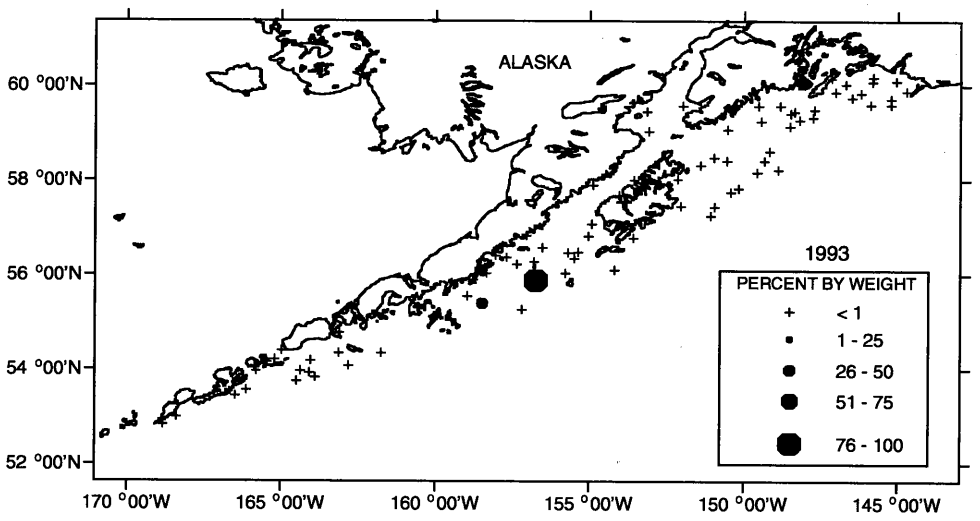


Figure 51.--Geographic distribution of arrowtooth flounder consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.





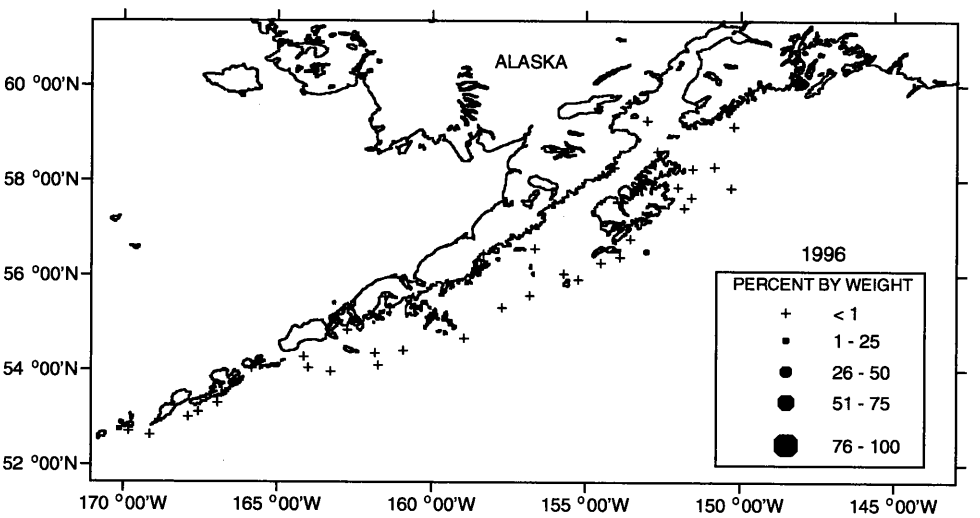


Figure 52.--Geographic distribution of Pacific cod consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.

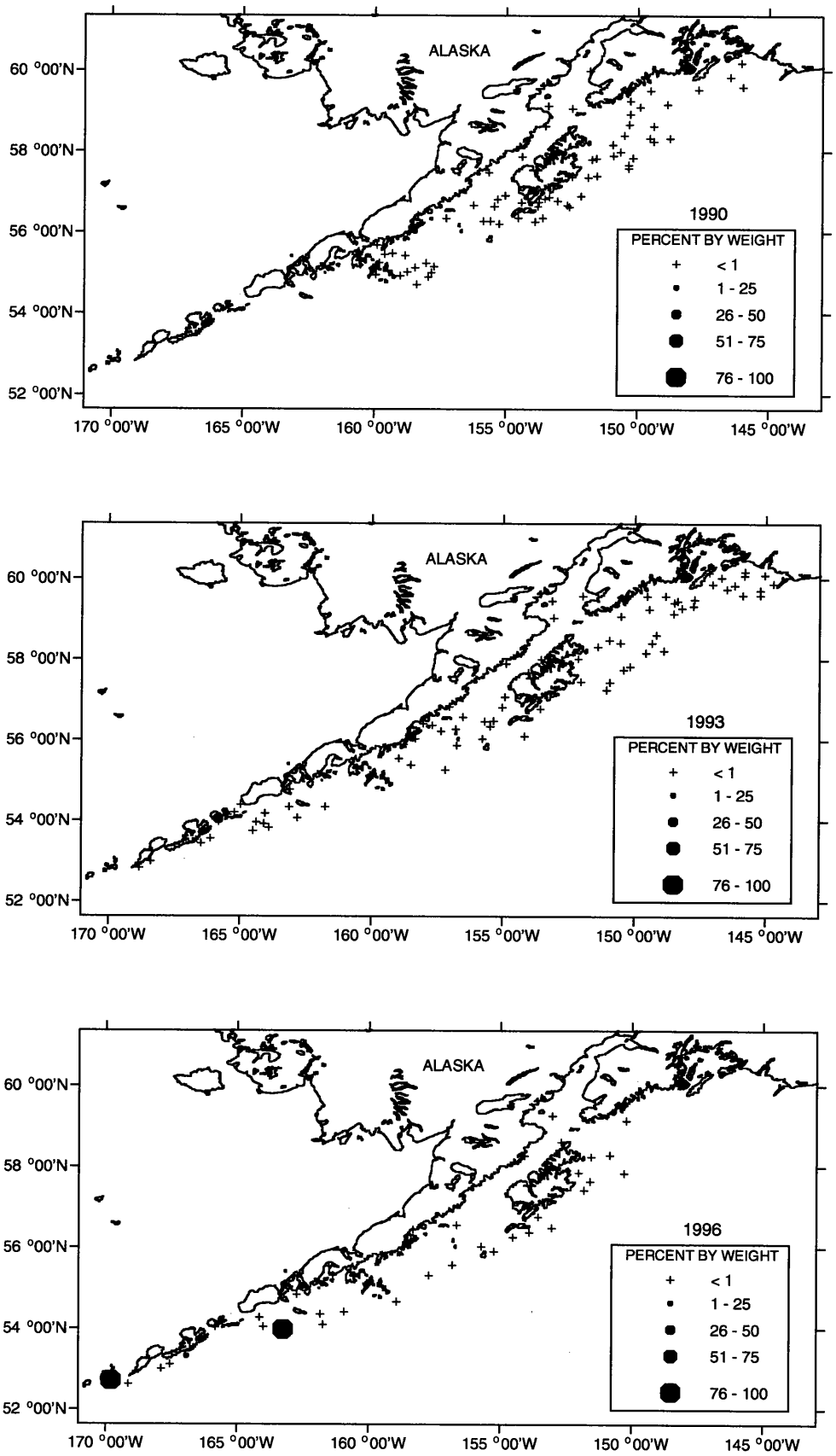
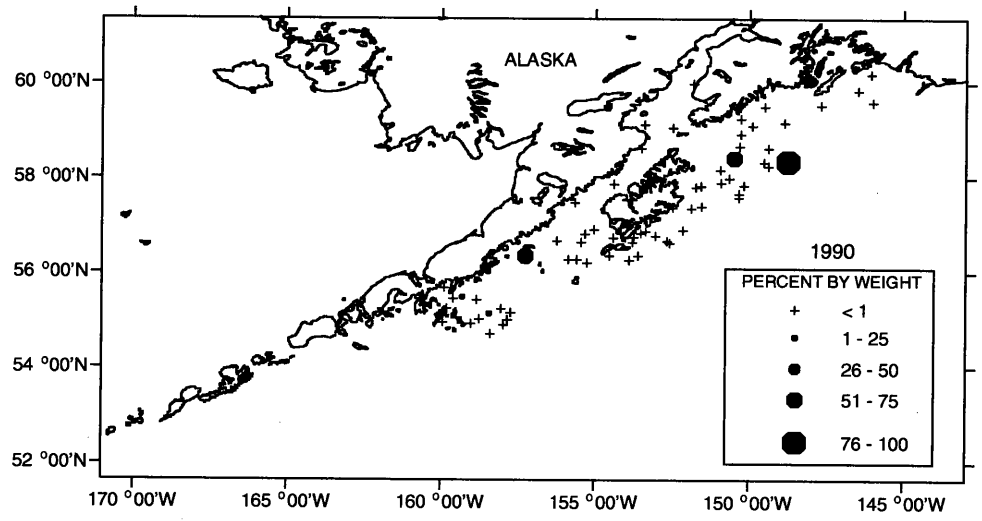
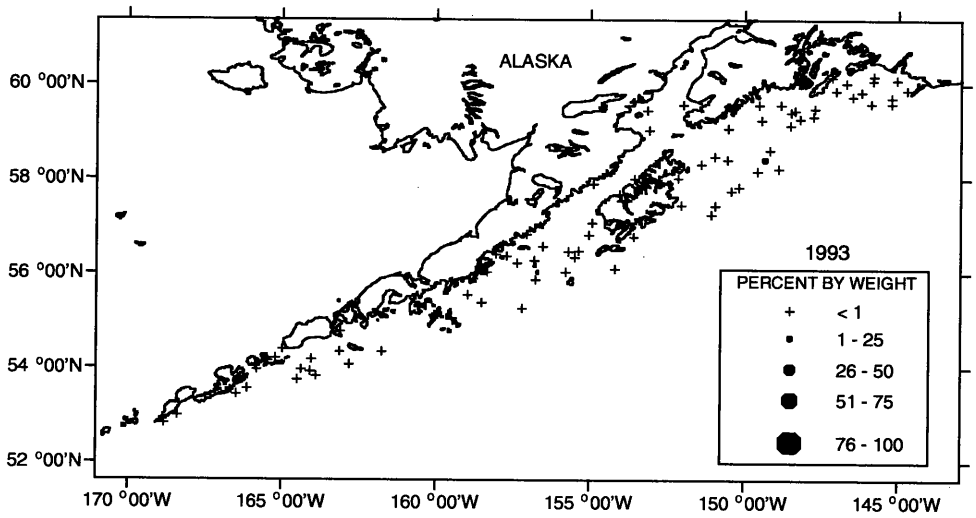


Figure 53.--Geographic distribution of Atka mackerel consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.





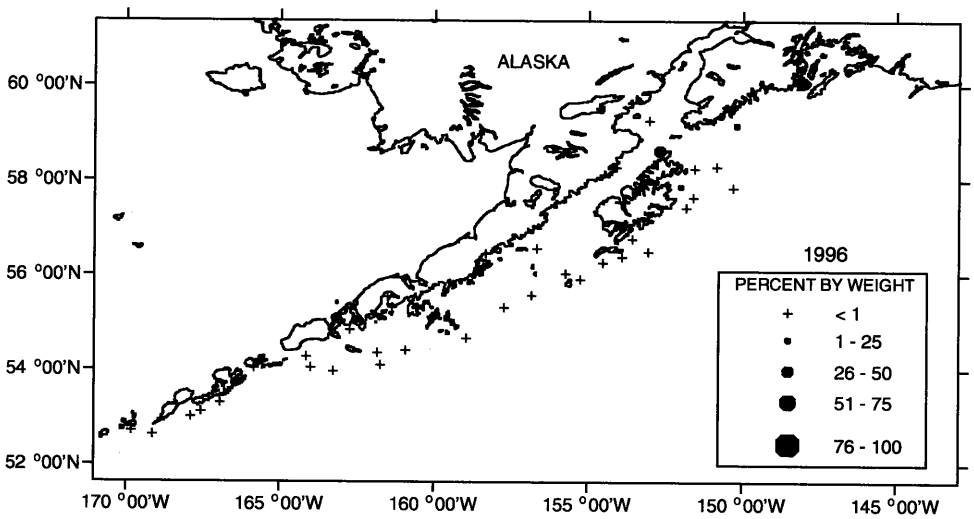


Figure 54.--Geographic distribution of fishery offal consumed by Pacific halibut in summer 1990, 1993, and 1996 in Gulf of Alaska.

collected in the Kodiak Island area in 1990; however, Tanner crabs were consumed by Pacific halibut in more stations in the sampling area in 1993; and only one station comprised a high percent (>75%) of Tanner crab in Pacific halibut diet in 1996 sampling area (Fig. 49). Pacific sand lance were consumed by Pacific halibut in the areas southwest of Kodiak Island in 1990 and 1996, and in the Middleton Island area in 1993 (Fig. 50). Arrowtooth flounder consumed by Pacific halibut were found mainly around the Kodiak Island area (Fig. 51). The locations where Pacific halibut consumed Pacific cod, and Atka mackerel are shown in Figures 52 and 53, respectively. Figure 54 illustrates the locations where fishery offal was consumed by Pacific halibut.

Sizes of the Commercially Important Prey Consumed

The prey length data for Pacific halibut were divided into two predator size groups (<80 cm and ≥80 cm FL) for analysis (Figs. 55 to 61). Figure 55 shows that smaller Pacific halibut (<80 cm FL) consumed mainly age-0 walleye pollock (<140 mm SL) plus a few age-1 to age-3 fish. The larger-sized Pacific halibut (≥80 cm FL) consumed many different sizes of walleye pollock including both pre-recruits (<300 mm SL) and recruits (≥300 mm SL) (Fig. 56). Most pre-recruit pollock consumed were age-1 and age-2 fish, whereas most recruited pollock consumed were age-3 and age-4 fish. A few large pollock (≥50 cm SL) were consumed by

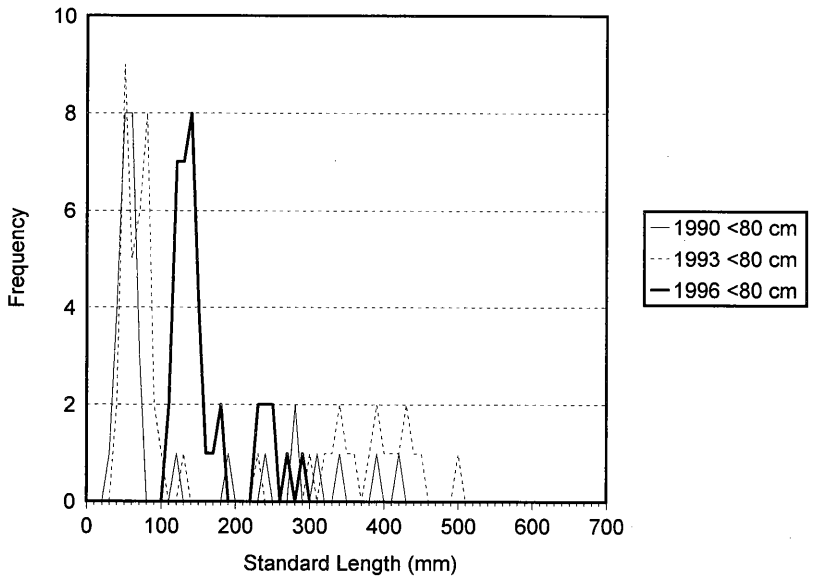


Figure 55 .--Size frequency distribution of walleye pollock consumed by Pacific halibut (<80 cm FL) in the Gulf of Alaska in 1990,1993 and 1996.

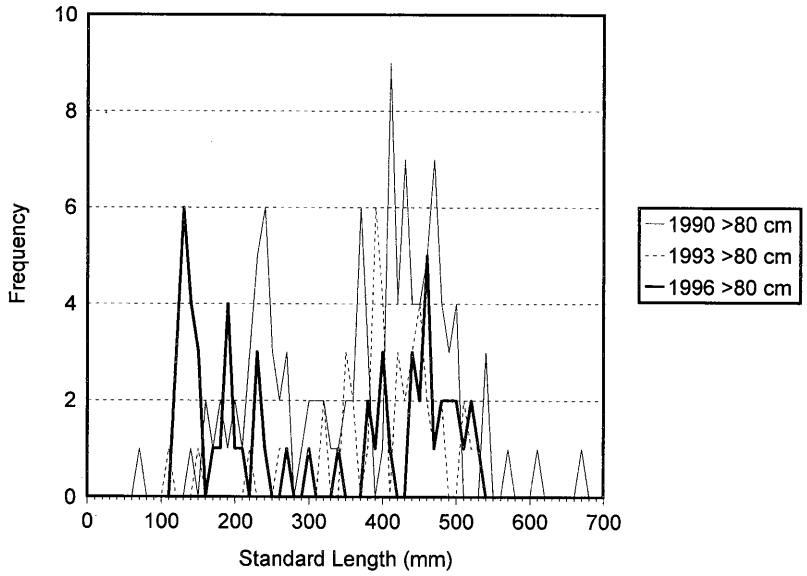


Figure 56.--Size frequency distribution of walleye pollock consumed by Pacific halibut (>80 cm FL) in the Gulf of Alaska in 1990,1993 and 1996.

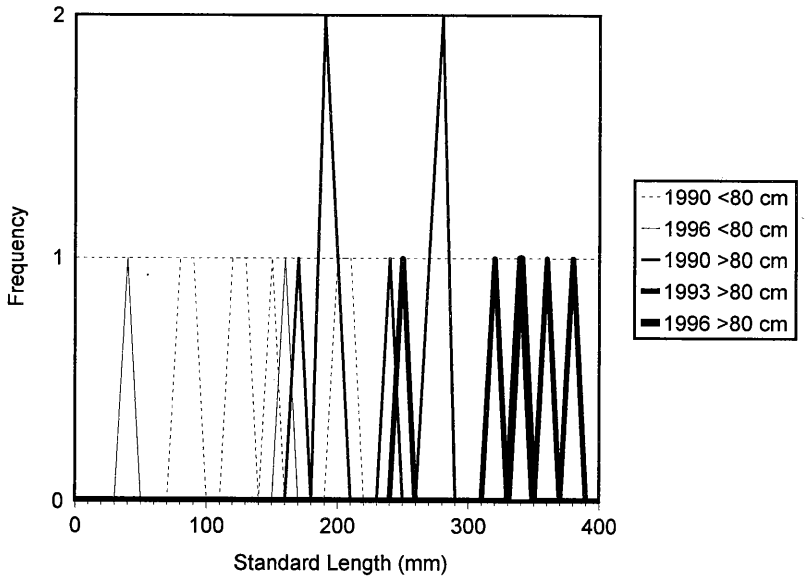


Figure 57.-- Size frequency distribution of arrowtooth flounder consumed by Pacific halibut in the Gulf of Alaska in 1990, 1993, and 1996.

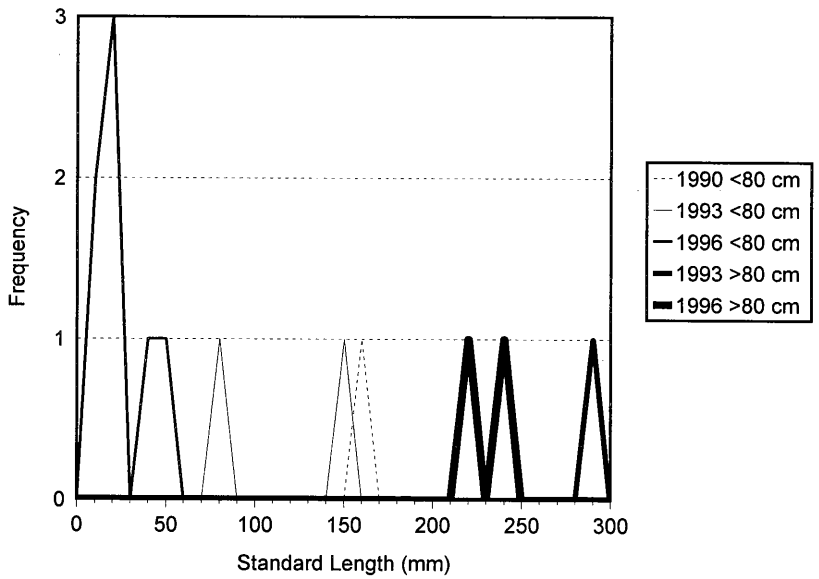


Figure 58.-- Size frequency distribution of rock sole consumed by Pacific halibut in the Gulf of Alaska in 1990, 1993, and 1996.

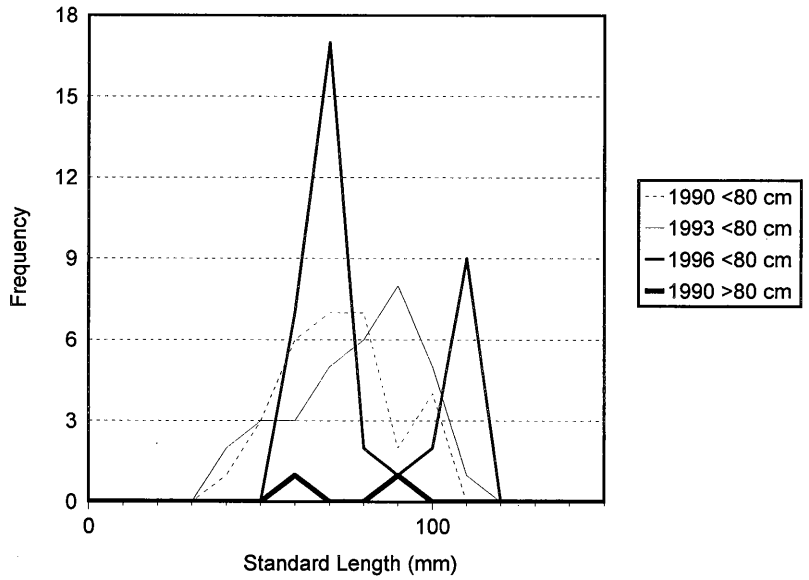


Figure 59.--Size frequency distribution of capelin consumed by Pacific halibut in the Gulf of Alaska in 1990, 1993, and 1996.

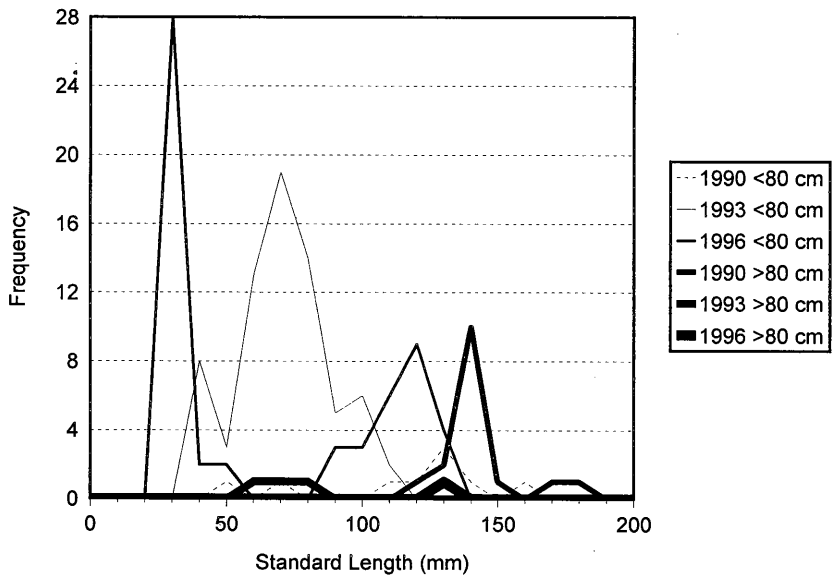


Figure 60.-- Size frequency distribution of Pacific sand lance consumed by Pacific halibut in the Gulf of Alaska in 1990, 1993, and 1996.

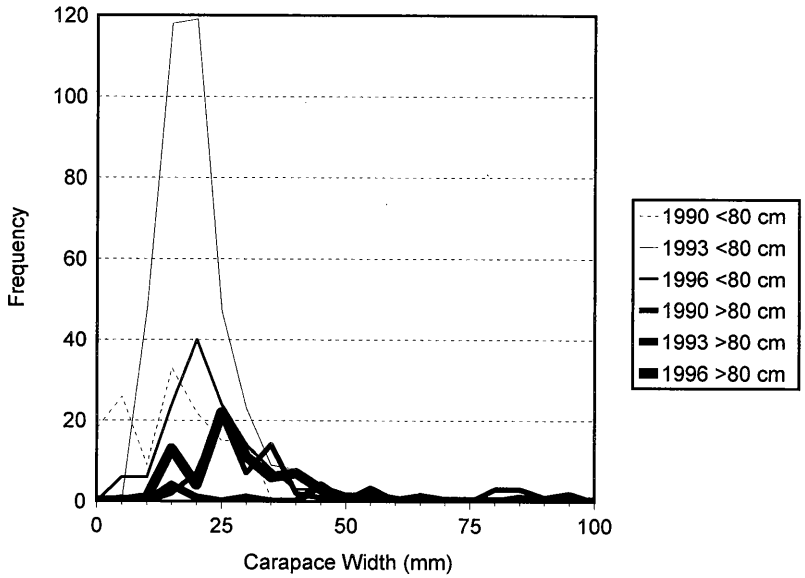


Figure 61.--Size frequency distribution of Tanner crab consumed by Pacific halibut in the Gulf of Alaska in 1990, 1993, and 1996.

some Pacific halibut larger than 100 cm FL; one 151 cm FL female Pacific halibut had consumed a 670 mm SL walleye pollock. The mean standard length (±SD) of pollock consumed by Pacific halibut was 287.8 ± 156.6 mm with a range from 34 to 670 mm SL.

Figure 57 shows that larger Pacific halibut consumed more larger-sized arrowtooth flounder. The mean standard length (±SD) of arrowtooth flounder was 229.0 ± 88.4 mm with a range from 85 to 382 mm SL. Figure 58 shows the size frequency distribution of rock sole consumed by Pacific halibut. They had a mean standard length (±SD) of 105.0 + 98.6 mm with a range from 17 to 296 mm SL. Consumption of capelin occurred mainly in smaller (<80 cm FL) Pacific halibut, and only a few were found in the stomachs of large (≥80 cm) Pacific halibut (Fig. 59). The mean standard length (±SD) of the capelin consumed was 81.6 ± 17.7 mm with a range from 46 to 119 mm SL. Figure 60 shows the size frequency distribution of Pacific sand lance consumed by Pacific halibut. They had a mean standard length (±SD) of 84.4 ± 37.6 mm with a range from 30 to 187 mm SL.

The *C. bairdi* consumed by Pacific halibut less than 80 cm FL were mainly age-0 and age-1 (<36 mm CW) crabs, whereas large Pacific halibut (≥80 cm) consumed mainly age-1 *C. bairdi* and some age-2 and older crabs (Fig. 61). The mean carapace width (±SD) of the *C. bairdi* consumed was 24.3 ± 13.1 mm with a range from 3 to 103 mm CW.

Pacific halibut also consumed Pacific cod, Pacific salmon, flathead sole, Dover sole, yellowfin sole, snailfish, juvenile Pacific halibut, agonids, stichaeids, eulachon, rockfish, zoarcids, and cottids. The number, mean standard length, and the SD of these prey fish are listed in Table 16.

DISCUSSION

Walleye pollock, Tanner crab, and other crabs (including lyre crabs, cancer crabs, and decorator crabs) were the three main prey groups of Pacific halibut. The percentages of these three main prey groups in the diets of Pacific halibut in 1990, 1993, and 1996 were very similar. Pollock comprised 38%, 31%, and 32% of the stomach contents in 1990, 1993, and 1996, respectively. Tanner crab ranged between 6% and 9% in those three years. And the other crabs category comprised 13% of the stomach contents of Pacific halibut in each of those three years. Larger variations of the stomach contents of the Pacific halibut showed in the percentages of the hermit crab in those three years (7% in 1990, 22% in 1993, and 15% in 1996).

Table 16.--Mean standard length (SL) and standard deviation (SD) of the miscellaneous prey fish consumed by Pacific halibut in the Gulf of Alaska in 1990, 1993, and 1996. n = sample size

Prey name	n	Mean SL(mm)	SD (mm)	Range(mm)
Pacific cod	6	378.8	85.4	215-461
Flathead sole	4	146.5	96.1	58-280
Dover sole	2	225.0	169.7	105-345
Snailfish	2	73.6	79.8	17-130
Stichaeids	17	121.9	72.2	46-245
Eulachon	1	120.0	0.0	120-120
Zoarcids	15	150.8	53.4	57-250
Cottids	19	58.4	47.4	13-215
Agonids	11	58.8	35.5	17-102
Pacific halibut	2	24.8	6.1	21-30
Yellowfin sole	4	112.2	98.6	61-260
Salmonids	3	463.3	32.2	440-500
Rockfish	2	112.0	135.8	16-208

SABLEFISH

by

Mei-Sun Yang

Sablefish, *Anoplopoma fimbria*, ranked sixth in total groundfish biomass in the Gulf of Alaska in 1997 with an exploitable biomass of 199,920 t (NPFMC 1998). The commercial catch of sablefish in 1997 was 14,129 t. 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 Diet

Tables 17 to 19 list the total number of stomachs with food, the total empty stomachs, the mean percent frequency of occurrence, and the mean percent by weight of the prey found in sablefish stomachs collected in 1990, 1993, and 1996. Walleye pollock was the predominate fish prey consumed by sablefish. Pollock comprised about 14%, 26%, and 11% by weight of the total

Table 17.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Anoplopoma fimbria* (sablefish) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Scyphozoa (jellyfish)	9.54	13.68
Polychaeta (worm)	.04	.75
Gastropoda (snail)	.06	.25
Bivalvia (clam)	<.01	.25
Teuthoidea (squid unidentified)	.97	1.25
Berryteuthis magister (squid)	2.99	1.88
Octopoda (octopus)	.01	.25
Calanoida (copepod)	<.01	4.03
Mysidacea (unidentified)	.11	4.17
Holmesiella anomala (mysid)	<.01	.67
Neomysis czerniawskii (mysid)	<.01	.31
Diastylis sp. (cumacean)	<.01	.83
Gammaridea (amphipod)	.54	15.24
Themisto sp. (amphipod)	.03	12.61
Themisto abyssorum (amphipod)	.02	.77
Euphausiacea (unidentified)	6.35	22.09
Thysanoessa inermis (euphausiid)	3.83	12.60
Caridea (unidentified shrimp)	<.01	.50
Pasiphaea pacifica (shrimp)	.16	2.00
Eualus avinus (shrimp)	<.01	.36
Pandalidae (unidentified)	2.42	8.50
Pandalus borealis (shrimp)	6.68	10.71
Pandalus goniurus (shrimp)	.63	2.02
Pandalopsis dispar (sidestripe shrimp)	1.36	1.88
Crangonidae (unidentified)	.04	1.81
Crangon communis (shrimp)	<.01	.23
Paguridae (hermit crab)	1.85	4.52
Majidae (spider crab)	.74	.92
Chionoecetes bairdi (Tanner crab)	4.62	3.33
Sipuncula (marine worm)	.08	.67
Sagitta sp. (arrow worm)	<.01	.81
Teleostei (unidentified fish)	10.17	18.09
Non-gadoid Fish Remains	.05	.63
Clupea pallasi (Pacific herring)	1.48	2.58
Mallotus villosus (capelin)	1.95	1.33
Thaleichthys pacificus (eulachon)	1.78	3.88
Stenobrachius leucopsarus (northern lampfish)	.12	.36
Gadidae (gadid fish)	8.45	7.62
Gadus macrocephalus (Pacific cod)	1.04	.21
Theragra chalcogramma (walleye pollock)	13.90	8.40
Zoarcidae (eelpout)	.33	1.25
Cottidae (sculpin)	.12	.31

Table 17.--Continued.

Prey name	Mean % Wt	Mean % FO
Hemitripterus bolini (bigmouth sculpin)	2.50	2.50
Cyclopteridae (snailfish)	.07	.98
Stichaeidae (prickleback)	.25	1.33
Ammodytes hexapterus (Pacific sand lance)	.64	.50
Pleuronectidae (flatfish)	.01	.23
Fishery offal	13.80	11.78

Total prey weight	4,354 g
Total non-empty stomachs	239
Total empty stomachs	92
Total hauls	40

Table 18.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Anoplopoma fimbria* (sablefish) collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Scyphozoa (jellyfish)	8.89	8.83
Anthozoa (anemone)	.29	.98
Polychaeta (unidentified)	.98	1.96
Aphroditidae (polychaete)	.24	.39
Gastropoda (snail)	1.96	2.24
Cephalopoda (unidentified)	.65	2.11
Teuthoidea (squid)	6.00	7.81
Octopoda (octopus)	3.87	5.57
Cirripedia (barnacle)	.05	.39
Mysidacea (mysid)	.03	.54
Isopoda (isopod)	.06	1.05
Gammaridea (amphipod)	3.13	9.19
Themisto sp. (amphipod)	.16	4.25
Caprellidea (amphipod)	<.01	.18
Euphausiacea (euphausiid)	5.55	13.18
Caridea (unidentified)	.09	1.96
Hippolytidae (shrimp)	.14	.61
Pandalidae (shrimp)	4.83	8.91
Pandalus borealis (shrimp)	4.51	3.49
Pandalopsis dispar (sidestripe shrimp)	.27	.53
Crangonidae (shrimp)	.06	1.06
Paguridae (hermit crab)	4.27	4.53
Asteroidea (starfish)	.05	.49
Ophiuroidae (brittle star)	.36	.33
Teleostei (unidentified fish)	1.86	3.21
Non-gadoid Fish Remains	2.63	3.98
Thaleichthys pacificus (eulachon)	.79	.56
Gadidae (gadid fish)	.55	.49
Theragra chalcogramma (walleye pollock)	26.25	23.02
Cottidae (sculpin)	.26	1.15
Pleuronectidae (flatfish)	2.48	1.46
Atheresthes stomias (arrowtooth flounder)	1.78	1.96
Misc. organic materials	.02	.98
Fishery offal	16.93	16.06

Total prey weight	5,854 g
Total non-empty stomachs	250
Total empty stomachs	105
Total hauls	51

Table 19.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Anoplopoma fimbria* (sablefish) collected in the Gulf of Alaska in 1996.

Prey name	Mean % Wt	Mean % FO
Scyphozoa (jellyfish)	13.50	16.62
Polychaeta (worm)	1.06	7.88
Gastropoda (snail)	.03	.91
Teuthoidea (squid)	2.46	6.97
Octopoda (octopus)	<.01	1.52
Calanoida (copepod)	.03	2.12
Mysidae (mysid)	.06	3.03
Isopoda (isopod)	.03	3.03
Gammaridea (amphipod)	10.72	25.51
Euphausiacea (unidentified)	9.64	12.71
Thysanoessa inermis (euphausiid)	0.37	.61
Caridea (shrimp)	.02	1.21
Hippolytidae (shrimp)	.03	.91
Pandalidae (shrimp)	4.99	3.64
Pandalus borealis (shrimp)	.36	3.03
Paguridae (hermit crab)	.64	6.15
Sipuncula (marine worm)	3.47	1.30
Ophiurida (brittle star)	.03	1.01
Teleostei (unidentified fish)	1.30	8.57
Theragra chalcogramma (walleye pollock)	10.44	18.17
Unidentified organic material	9.09	9.09
Fishery offal	31.74	22.22

Total prey weight	1,036 g
Total non-empty stomachs	58
Total empty stomachs	14
Total hauls	11

sablefish stomach contents in 1990, 1993, and 1996, respectively. Most of the unidentified gadid fish (about 9% by weight of the total stomach contents, Table 17) were probably walleye pollock. Eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and some flatfish (Family Pleuronectidae) were also important commercial species consumed by sablefish. Sablefish also consumed fish such as northern lampfish (*Stenobrachius leucopsarus*), eelpout (Family Zoarcidae), sculpin (Family Cottidae), and prickleback (Family Stichaeidae). It is worth noting that fishery offal (fish carcasses) made up to 14%, 17%, and 32% by weight of the sablefish diet in 1990, 1993, and 1996, respectively.

Jellyfish was the most important invertebrate prey of sablefish. They comprised 10%, 9%, and 14% of the total stomach content weights in 1990, 1993, and 1996, respectively. Euphausiids were found frequently in stomachs. They comprised about 6-10% by weight of the stomach contents in 1990, 1993, and 1996. Pandalid shrimps comprised 11%, 10%, and 5% of the total stomach contents weight in 1990, 1993, and 1996, respectively. Squid (mainly *Berryteuthis magister*) were also important invertebrate prey of the sablefish. They comprised about 3-10% by weight of the total stomach content in the three years. Tanner crabs (*C. bairdi*) were found in sablefish stomachs in 1990 when they comprised 5% of the total stomach contents weight.

Sablefish also consumed low amounts of polychaetes, snails, mysids, amphipods, crangonids, pagurids, and some marine worms.

Variation of Diet Based on Predator Size

Figure 62 illustrates that larger sized (≥60 cm FL) sablefish consumed more fish (walleye pollock, miscellaneous fish, and fishery discards) than the smaller-sized fish (<60 cm FL). The smaller-sized sablefish (<60 cm FL) consumed more euphausiids, shrimp, and cephalopods. Sablefish 50-59 cm FL consumed a high percentage (19%, and 30%) of fishery offal in 1990 and 1993, respectively. However, in 1996, larger sablefish (≥60 cm FL) consumed the highest percentage (25%) of fishery offal. The miscellaneous prey consumed by the smallest size group (<50 cm FL) of sablefish in 1996 was made up of mainly gammarid amphipods (59% by weight).

Geographic Distributions of the Prey Consumed

The distributions of the commercially important prey consumed by sablefish are shown in Figures 63 to 67. Walleye pollock were consumed by sablefish at many of the sampled stations in 1990 and 1993, and that the percent by weight in many stations was greater than 50% (Fig. 63). However, in 1996, pollock were not consumed by sablefish in many stations, and the percent by weight in many stations was low. The distribution of

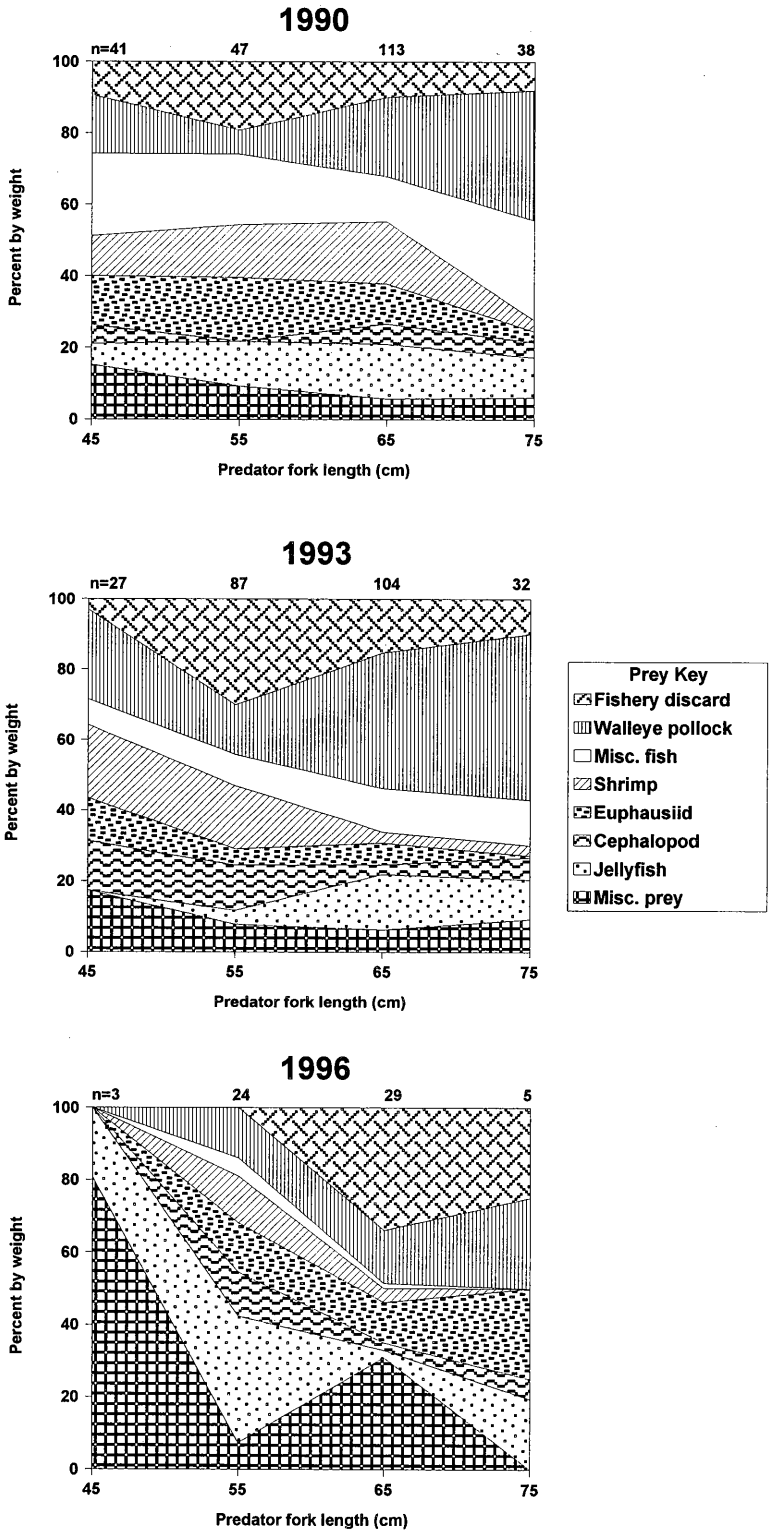
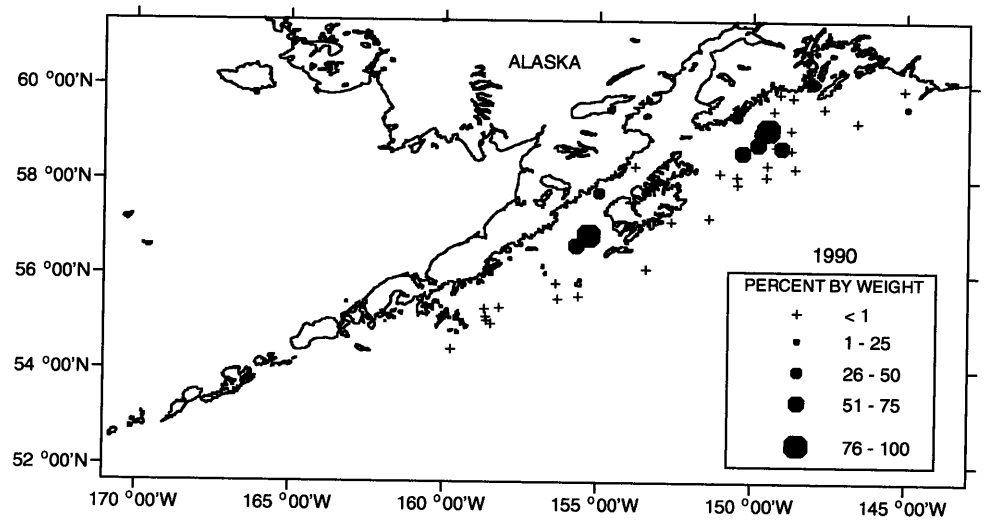
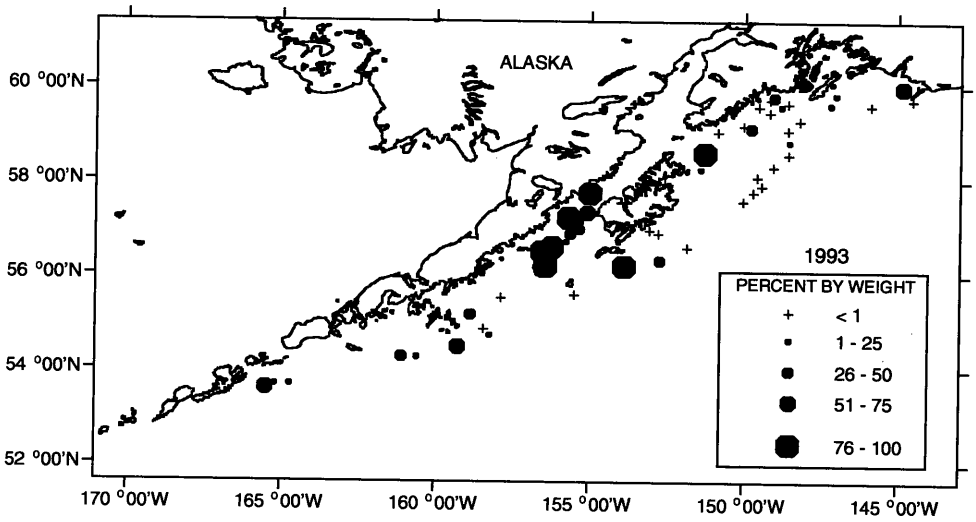


Figure 62.-- Variations in the main food items of sablefish, by predator size, in the Gulf of Alaska in 1990, 1993 and 1996. n = sample size.





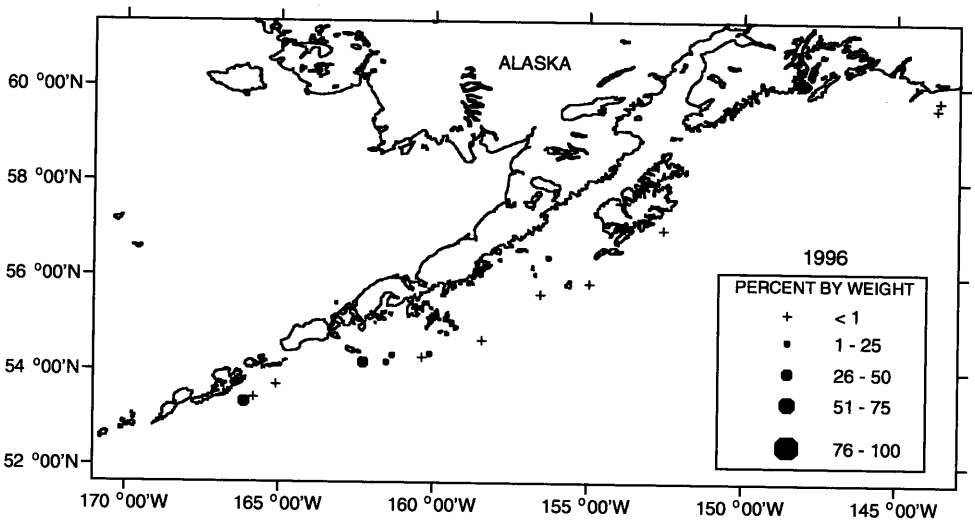
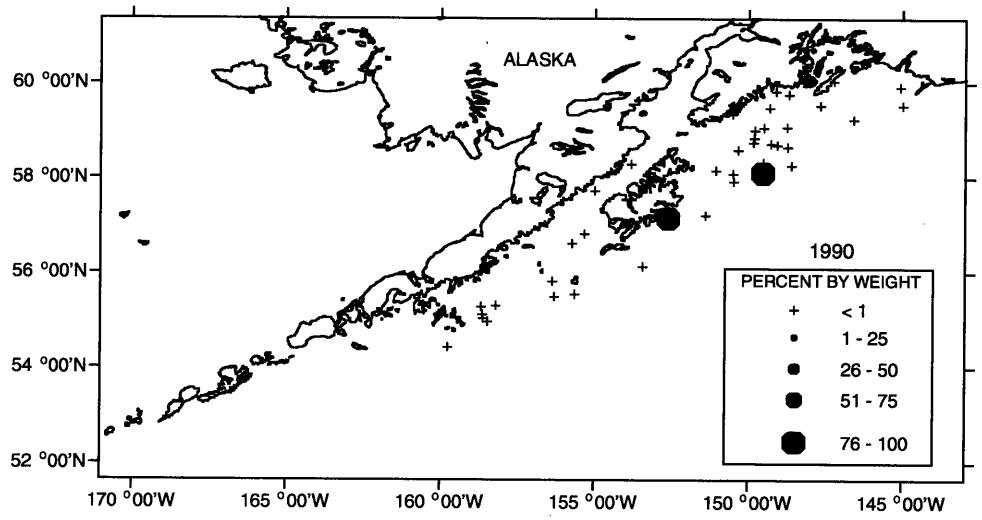
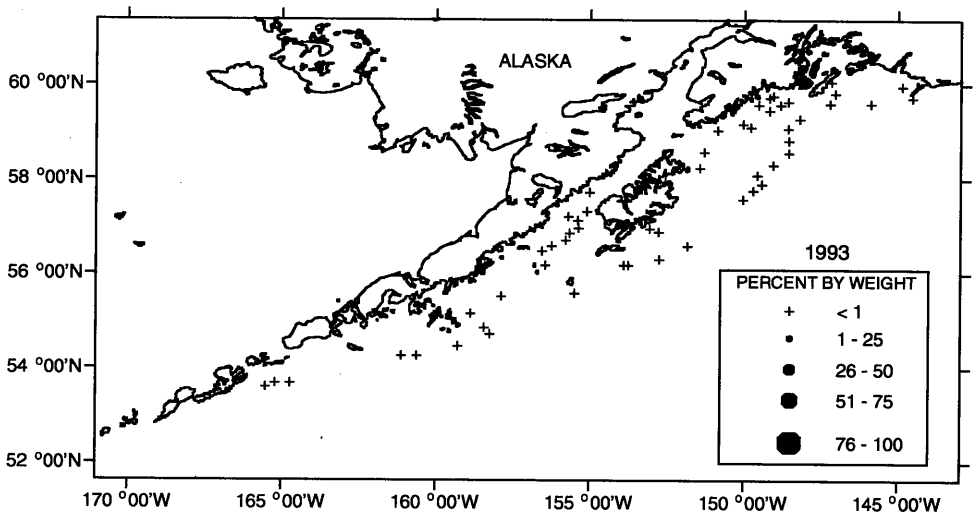


Figure 63.--Geographic distribution of walleye pollock consumed by sablefish in summer 1990, 1993, and 1996 in Gulf of Alaska.





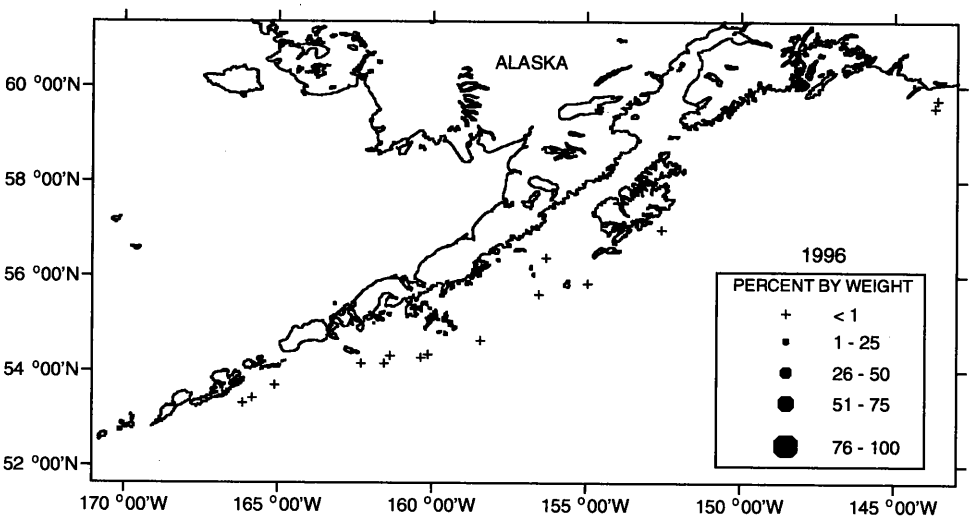


Figure 64.--Geographic distribution of Tanner crab consumed by sablefish in summer 1990, 1993, and 1996 in Gulf of Alaska.

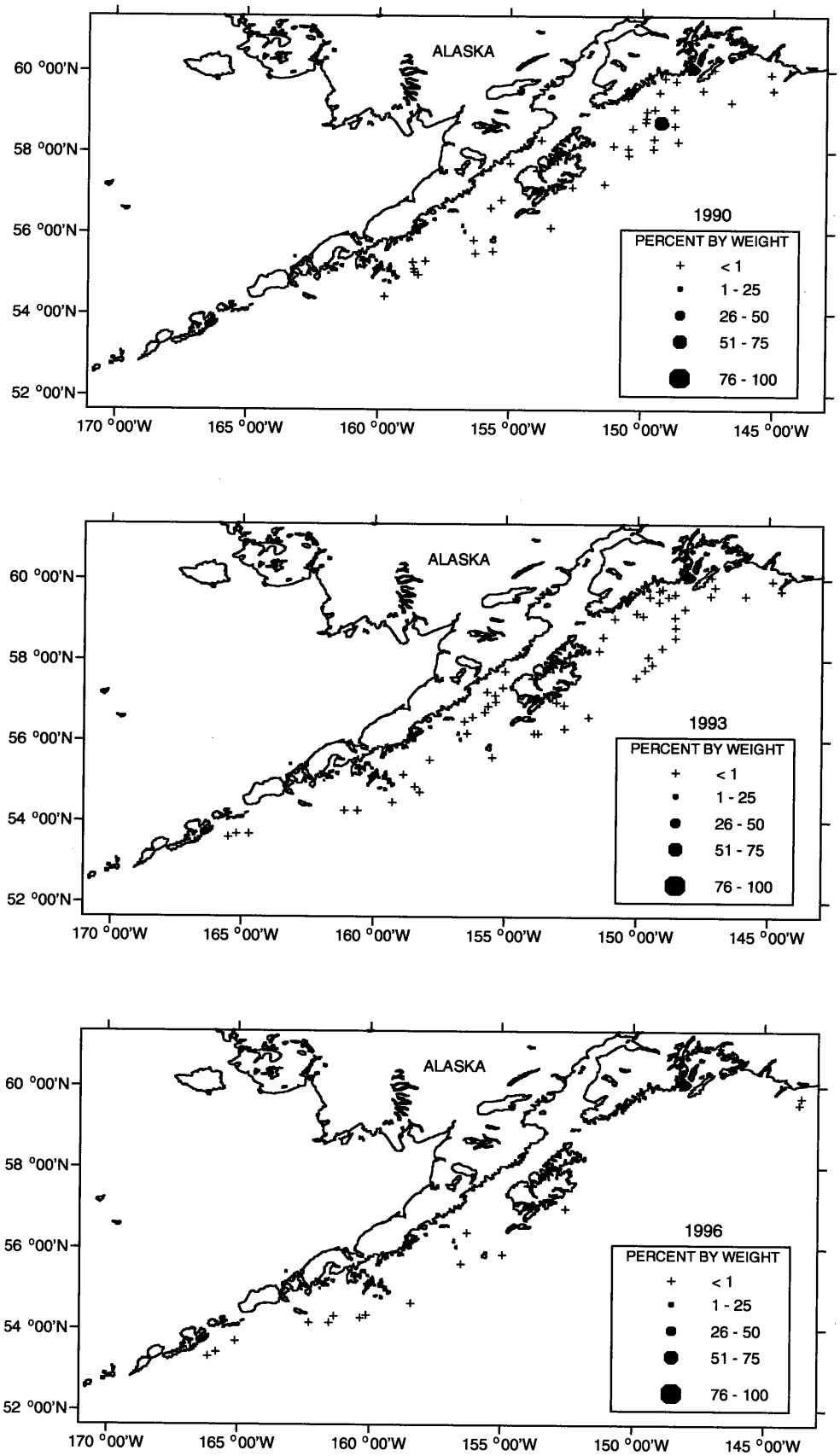


Figure 65.--Geographic distribution of capelin consumed by sablefish in summer 1990, 1993, and 1996 in Gulf of Alaska.

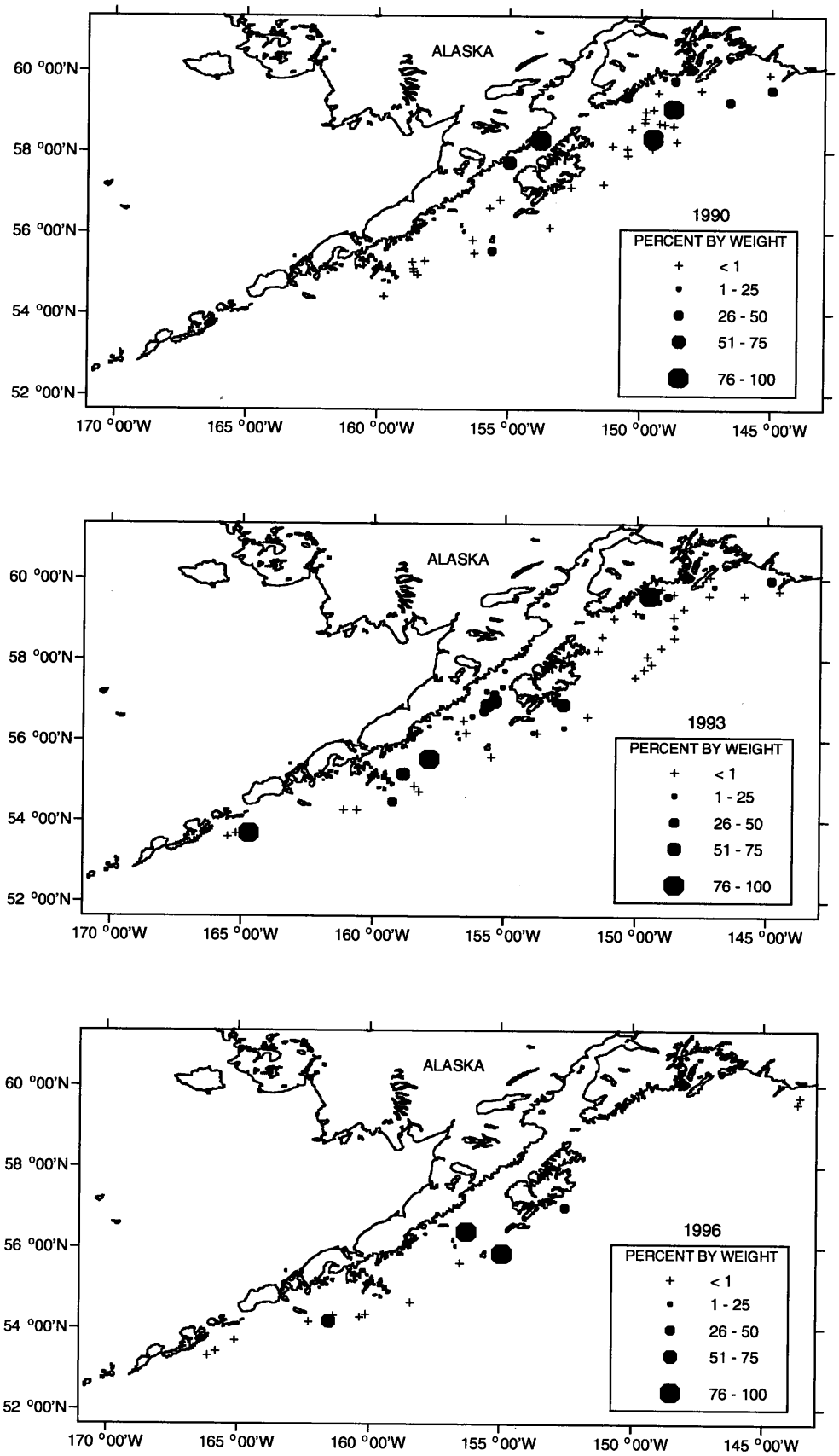


Figure 66.--Geographic distribution of fishery offal consumed by sablefish in summer 1990, 1993, and 1996 in Gulf of Alaska.

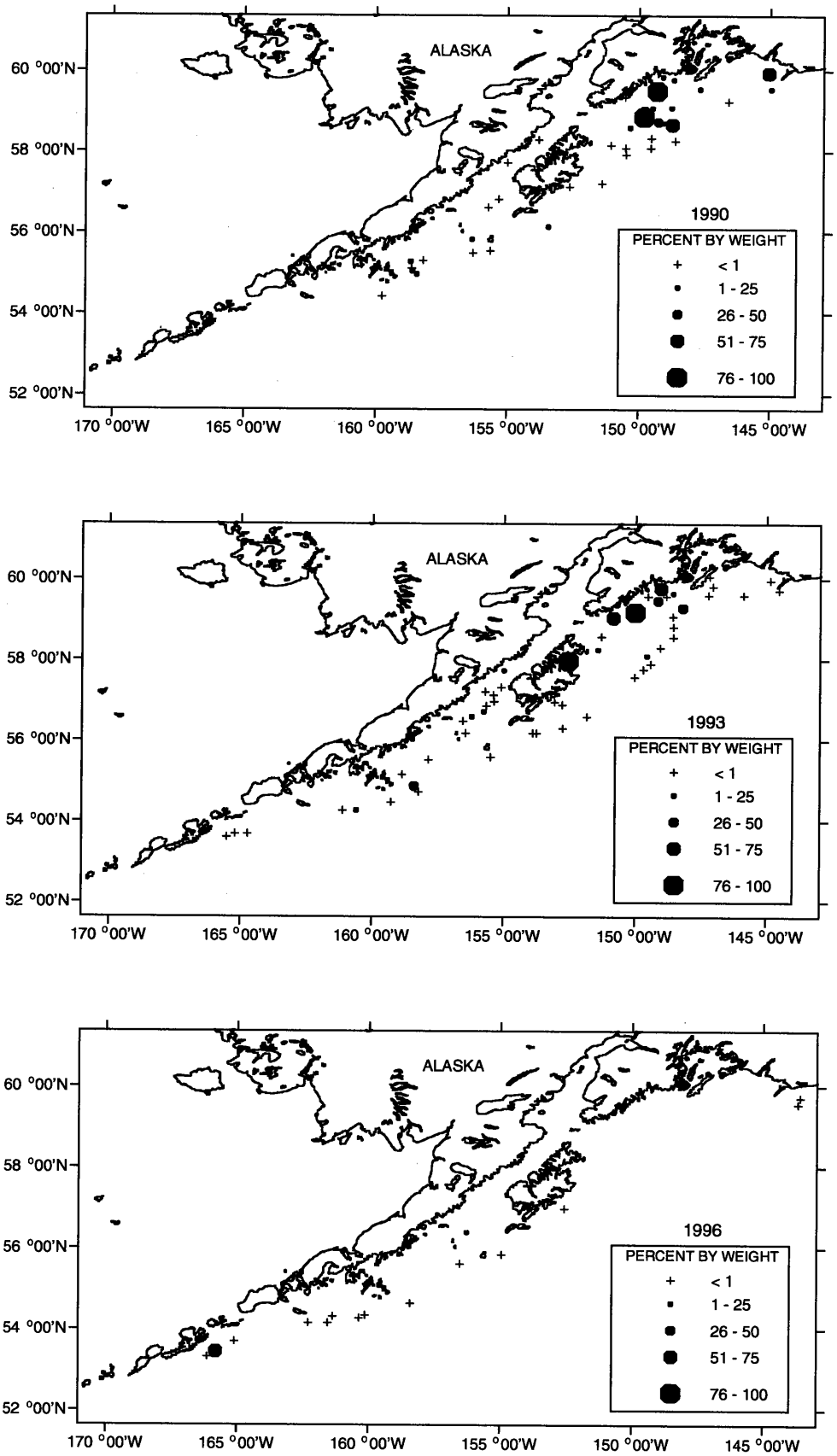


Figure 67.--Geographic distribution of pandalid shrimp consumed by sablefish in summer 1990, 1993, and 1996 in Gulf of Alaska.

the consumption of Tanner (*C. bairdi*) crabs by sablefish is shown in Figure 64. It shows that Tanner crabs were only consumed by the sablefish caught in 1990. 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. Figure 65 illustrates that capelin were only consumed by sablefish at one station in 1990. The consumption of fishery offal by sablefish is illustrated in Figure 66. The consumption of fishery offal was primarily distributed around Kodiak Island in 1990 and 1996; however, in 1993, it was widespread in the sampling area. Figure 67 illustrates the sporadic distribution of pandalid shrimp consumption by sablefish.

Sizes of the Commercially Important Prey Consumed

The prey length data of the sablefish were divided into two predator size (<55 cm and $\geq$55 cm FL) groups for analysis (Figs. 68 to 69). The walleye pollock consumed by both size groups were mainly pre-recruits (<300 mm SL), though the larger-sized sablefish also consumed a few pollock larger than or equal to 400 mm SL (Fig. 68). Figure 68 also shows that more pollock were consumed by sablefish in 1993 than in 1990. The mean standard length ($\pm$SD) of pollock consumed by sablefish was 278.2 $\pm$ 94.0 mm with a range from 56 to 445 mm SL. Figure 69 shows that smaller-sized sablefish only consumed smaller eulachon (<100 mm SL),

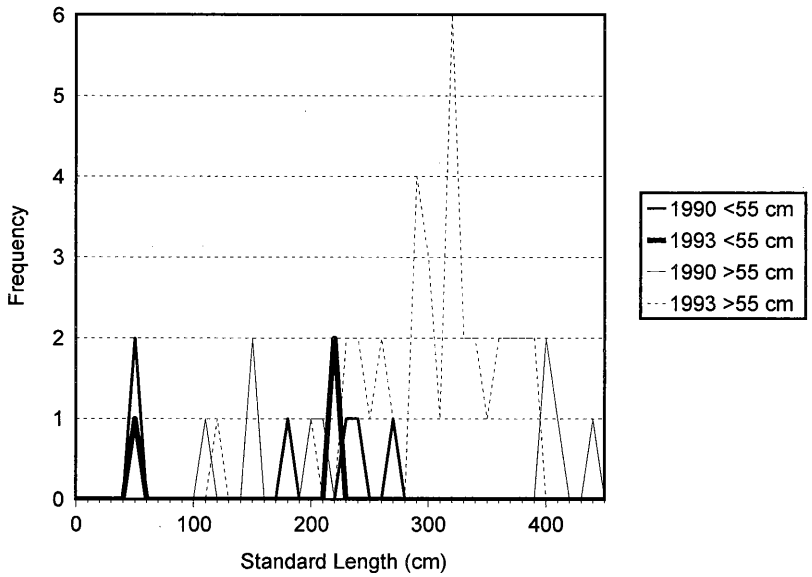


Figure 68.-- Size frequency distribution of walleye pollock consumed by sablefish in the Gulf of Alaska in 1990 and 1993.

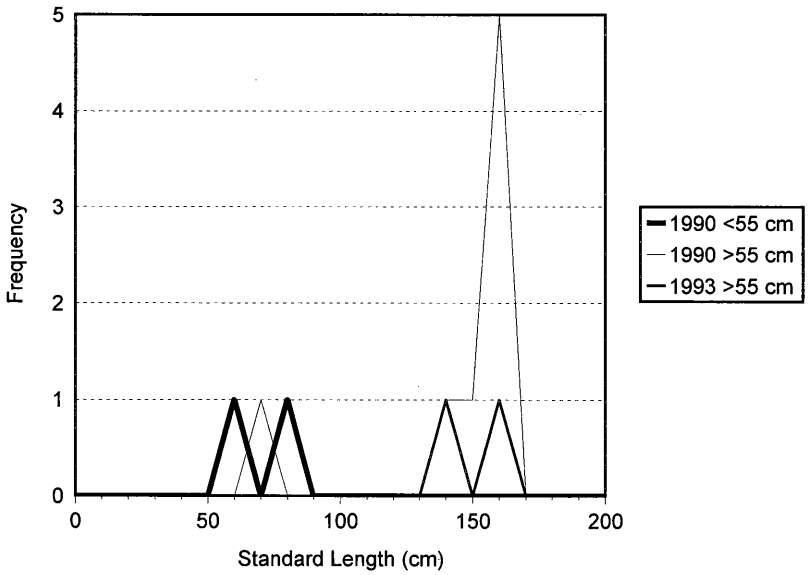


Figure 69.-- Size frequency distribution of eulachon consumed by sablefish in the Gulf of Alaska in 1990 and 1993.

whereas larger sablefish (≥55 cm FL) also consumed some larger eulachon (about 160 mm SL). The mean standard length (±SD) of the eulachon consumed was 137.5 ± 38.1 mm standard length with a range from 68 to 165 mm SL.

Other fish consumed by sablefish included three capelin (82, 96, 106 mm SL), two Pacific herring (154 and 170 mm SL), one arrowtooth flounder (236 mm SL), one myctophid (79 mm SL), one Pacific sand lance (97 mm SL), and three Tanner crabs (*C. bairdi*) (5, 21, 54 mm CW).

DISCUSSION

Comparing the three years of data, we noticed that the percentages of the main food in sablefish stomachs were similar between 1990 and 1993. For example, pollock comprised 22% and 27% in 1990 and 1993, respectively. Pandalid shrimp comprised 11% and 10% in those two years. Jellyfish ranged 10% and 9% in the stomach contents of sablefish in those two years, respectively. Fish offal comprised 14% and 17% in 1990 and 1993, respectively. However, the compositions of the food of sablefish varied greatly in 1996. The percentages of pollock and pandalid shrimp declined to 10% and 5%, respectively. Amphipods increased to 11% and fish offal jumped to 32%. The possible reason for these apparent changes in the diet of sablefish in 1996 is probably caused by the small sample size (Fig. 62). Comparing the diets of other groundfish species, we noticed that sablefish fed more on fish

offal than walleye pollock, Pacific cod, arrowtooth flounder, and Pacific halibut did. This may indicate highly opportunistic feeding behavior by sablefish.

ROUGHEYE ROCKFISH

by

Mei-Sun Yang

The rougheye rockfish (*Sebastes aleutianus*) had an exploitable biomass of 48,710 t in the Gulf of Alaska in 1997 (NPFMC 1998). It ranked third in abundance of the rockfish complex in the Gulf of Alaska. The reported catch of rougheye rockfish has been combined with shortraker rockfish since 1994. The total catch of these two species in the Gulf of Alaska in 1997 was 1,609 t.

RESULTS

General Diet

Tables 20 and 21 show the total number of stomachs containing food, the total empty stomachs, the mean percent frequency of occurrence, and mean percent by weight of the prey items of rougheye rockfish in 1990 and 1993, respectively. Shrimp, including *Pandalus borealis*, *Pandalus montagui tridens*, hippolytids, and crangonids, were the main food of rougheye rockfish (44% and 62% by weight of the total stomach contents weight in 1990 and 1993, respectively). Prey fish consumed by rougheye rockfish included walleye pollock, Pacific herring,

Table 20.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Sebastes aleutianus* (rougheye rockfish) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Polychaeta (worm)	.42	3.68
Cephalopoda (unidentified)	3.97	5.88
Teuthoidea (squid)	5.89	5.88
Mysidacea (mysid)	1.42	7.82
Gnathophausia gigas (mysid)	.54	2.94
Holmesiella anomala (mysid)	.80	2.31
Meterythrops robusta (mysid)	3.07	14.62
Neomysis czerniawskii (mysid)	.73	8.28
Neomysis rayii (mysid)	.22	1.96
Pseudomma truncatum (mysid)	.39	11.96
Cumacea (cumacean)	<.01	.74
Isopoda (isopod)	3.36	6.03
Gammaridea (unidentified)	5.49	21.31
Ampeliscidae (amphipod)	.58	3.78
Lysianassidae (amphipod)	1.84	1.96
Themisto sp. (amphipod)	.56	5.55
Themisto abyssorum (amphipod)	.40	4.41
Euphausiacea (unidentified)	1.89	3.92
Thysanoessa inermis (euphausiid)	.33	2.94
Caridea (unidentified shrimp)	.65	3.64
Hippolytidae (shrimp)	.23	3.15
Eualus avinus (shrimp)	1.97	2.52
Pandalidae (shrimp)	12.47	25.59
Pandalus borealis (shrimp)	19.12	10.08
Pandalus montagui tridens (shrimp)	.08	1.47
Crangonidae (unidentified)	1.06	7.95
Crangon communis (shrimp)	6.17	6.72
Argis lar (shrimp)	2.22	1.91
Paguridae (hermit crab)	.04	.84
Chionoecetes bairdi (Tanner crab)	5.01	1.72
Pinnotheridae (pea crab)	.21	.74
Sagitta sp. (arrow worm)	.55	9.31
Teleostei (unidentified fish)	8.45	11.47
Non-gadoid Fish Remains	9.67	5.46
Cyclopteridae (snailfish)	.13	.84
Pleuronectidae (flatfish)	.05	1.96

Total prey weight	211 g
Total non-empty stomachs	84
Total empty stomachs	57
Total hauls	17

Table 21.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Sebastes aleutianus* (rougheye rockfish) collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Polychaeta (worm)	.25	2.50
Gastropoda (snail)	.37	.36
Pteropod (snail)	.01	.31
Bivalvia (clam)	.18	1.69
Cephalopoda (unidentified)	.18	3.13
Teuthoidea (squid)	.42	2.32
Octopoda (octopus)	1.50	1.25
Mysidacea (mysid)	2.81	15.50
Cumacea (cumacean)	.02	.94
Isopoda (isopod)	1.87	4.61
Gammaridea (unidentified)	2.05	15.90
Ampeliscidae (amphipod)	.56	1.67
Themisto sp. (amphipod)	.16	4.17
Caprellidea (amphipod)	.05	1.25
Euphausiacea (unidentified)	8.39	16.40
Thysanoessa inermis (euphausiid)	2.34	2.44
Thysanoessa raschii (euphausiid)	.11	1.25
Caridea (shrimp)	.53	4.32
Pasiphaeidae (shrimp)	1.57	2.50
Hippolytidae (shrimp)	4.27	6.63
Pandalidae (shrimp)	49.23	52.18
Pandalus borealis (shrimp)	.31	.21
Crangonidae (shrimp)	4.09	9.49
Argis sp. (shrimp)	1.65	.63
Reptantia (crab)	.09	.63
Paguridae (hermit crab)	1.48	.63
Chionoecetes bairdi (Tanner crab)	1.23	1.15
Chaetognatha (arrow worm)	.91	4.17
Teleostei (unidentified fish)	2.80	4.26
Clupea pallasi (Pacific herring)	.45	.63
Osmeridae (smelts)	2.73	1.46
Thaleichthys pacificus (eulachon)	2.59	1.88
Myctophidae (lanternfish)	2.28	.63
Theragra chalcogramma (walleye pollock)	.32	.50
Zoarcidae (eelpout)	1.34	.83
Cottidae (sculpin)	.34	1.25
Ammodytes hexapterus (Pacific sand lance)	.06	.36
Misc. unidentified materials	.46	.83

Total prey weight	312 g
Total non-empty stomachs	154
Total empty stomachs	125
Total hauls	40

eulachon, Pacific sand lance, myctophids, zoarcids, cottids, snailfish, flatfish, and some unidentifiable fish. Fish made up 18% and 13% of the total stomach contents weight in 1990 and 1993, respectively. The commercially important Tanner crab (*C. bairdi*) was also consumed by rougheye rockfish, it comprised 5% and 1% of the total stomach contents weight in 1990 and 1993, respectively. Other food items included cephalopods, amphipods, mysids, euphausiids, cumaceans, isopods, and polychaetes.

Variation of Diet Based on Predator Size

Figure 70 shows the variations of the main food items of different size groups of rougheye rockfish. All size groups consumed a large amount of shrimp (>25% and 45% by weight in 1990 and 1993, respectively). The smallest size group (<30 cm FL) consumed more amphipods whereas the larger-sized rougheye rockfish ($\geq$30 cm FL) consumed more fish. More mysids (26% by weight) were consumed by the smallest size group (<30 cm FL) in 1990 than in 1993 (7%); however, more euphausiids were consumed by the same size group of rougheye rockfish in 1993 (22% by weight) than in 1990 (0%).

Sizes of the Important Prey Consumed

The Tanner crabs consumed by rougheye rockfish had a mean carapace width ($\pm$SD) of 21.2 mm $\pm$ 8.0 mm with a range from 12 to

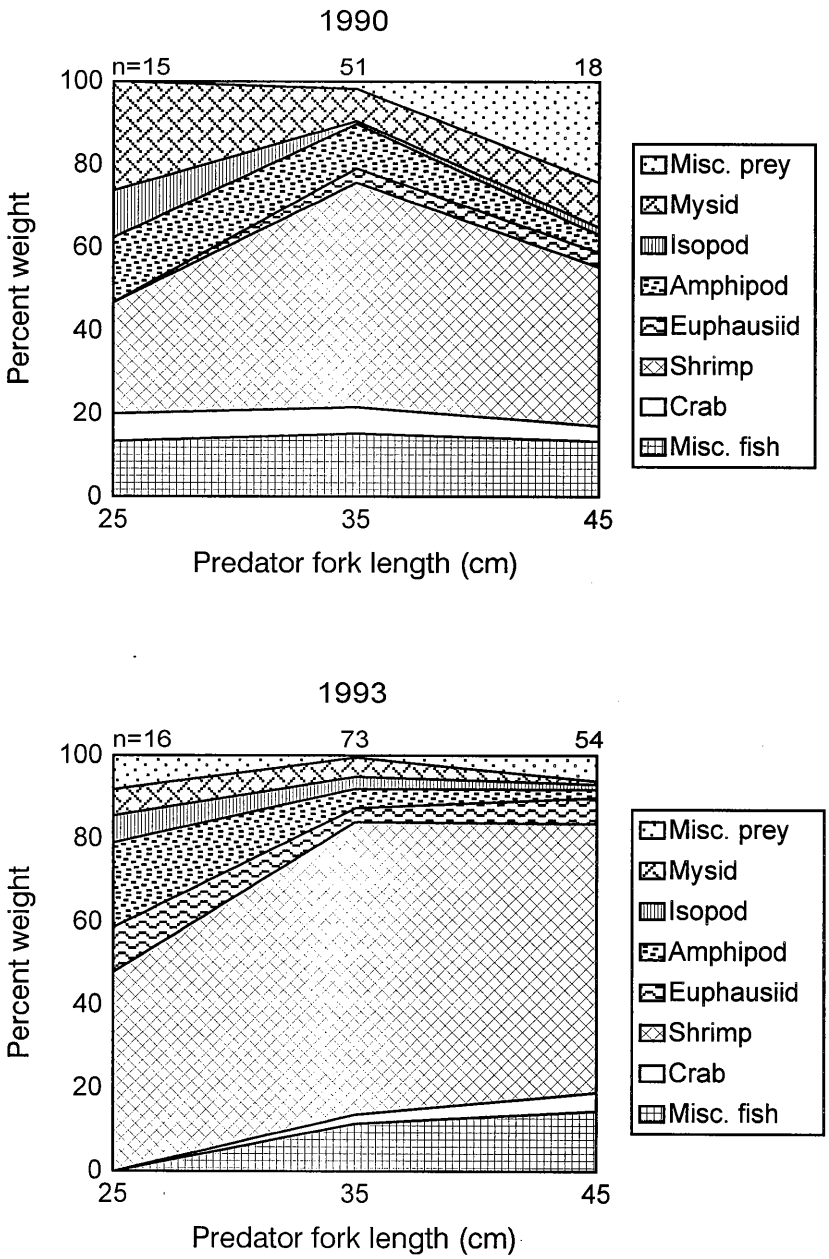
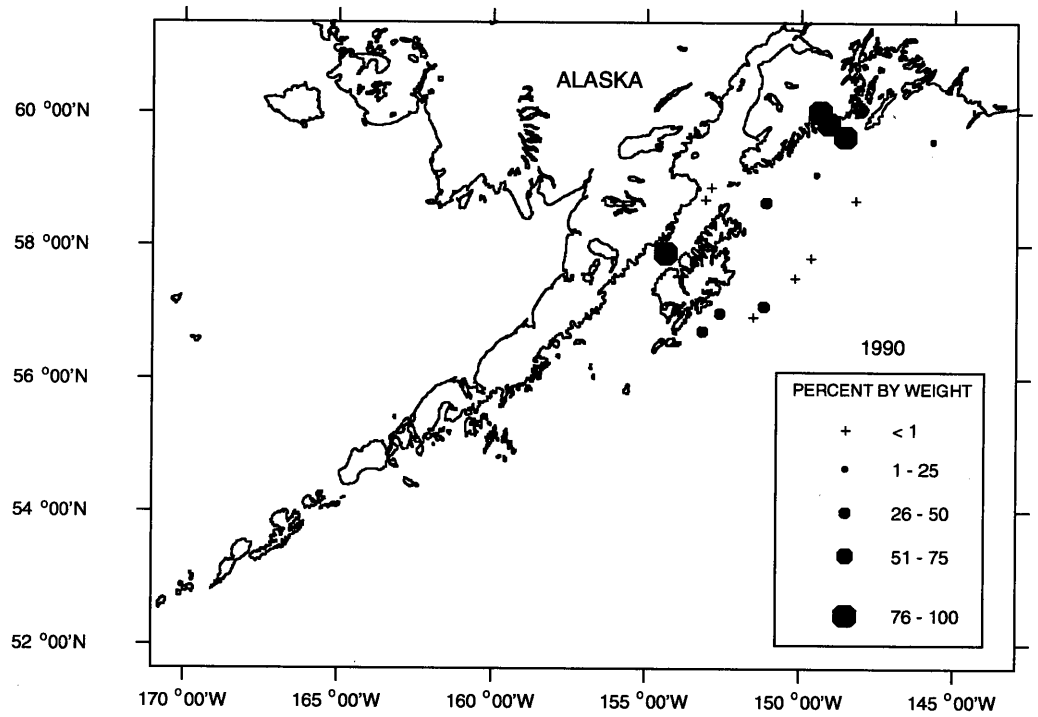


Figure 70.--Variations in the main food items of rougheye rockfish by predator size, in the Gulf of Alaska in 1990 and 1993. n = sample size.

27 mm CW. One of each of the following species were also consumed by rougheye rockfish: walleye pollock (55 mm SL), eulachon (64 mm SL), snailfish (41 mm SL), zoarcid (133 mm SL), and cottid (23 mm SL).

Geographic Distributions of the Prey Consumed

The distributions of the commercially important prey consumed by rougheye rockfish is shown in Figure 71. Pandalid shrimp were consumed by rougheye rockfish at many of the sampled stations in 1990 and 1993 and the percent by weight in many stations in 1993 was high (>75%).



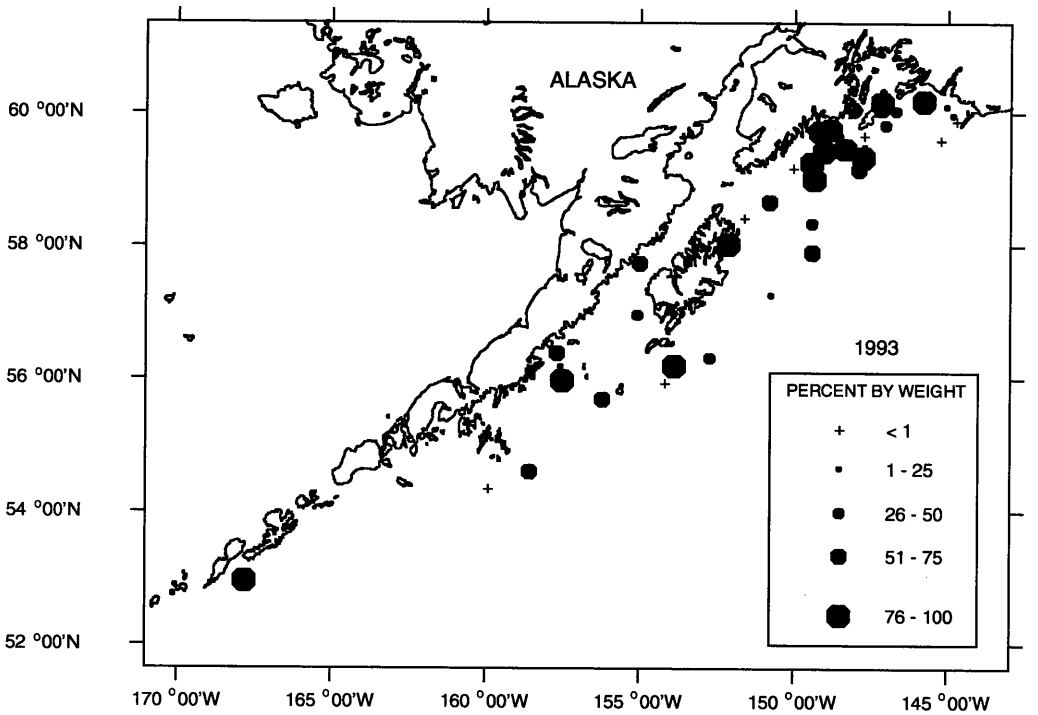


Figure 71.--Geographic distribution of pandalid shrimp consumed by rougheye rockfish in the Gulf of Alaska in summer 1990 and 1993.

SHORTSPINE THORNYHEAD

by

Mei-Sun Yang

Shortspine thornyhead (*Sebastolobus alascanus*) had an exploitable biomass of 46,108 t in the Gulf of Alaska in 1997 (NPFMC 1998). Since 1980, the shortspine thornyhead resource has been managed as a separate 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 1997, the catch of this species in the Gulf of Alaska area was 1,240 t.

RESULTS

General Diet

Tables 22 and 23 list the total number of stomachs with food, the total empty stomachs, the mean percent frequency of occurrence, and mean percent by weight of the prey items found in the stomachs of shortspine thornyhead in 1990 and 1993, respectively. Shrimp (mainly pandalids) were the most important food of the thornyhead (52% and 61% by weight in 1990 and 1993, respectively) (Tables 22 and 23). Tanner crabs (*C. bairdi*) comprised 1% and 7% (by weight) of the food of thornyheads in 1990 and 1993, respectively. Fish (walleye pollock, capelin,

Table 22.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Sebastolobus alascanus* (shortspine thornyhead) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Polychaeta (worm)	12.11	8.80
Gastropoda (snail)	1.85	1.14
Teuthoidea (squid)	.97	3.32
Calanoida (copepod)	.02	2.60
Mysidae (unidentified mysid)	.47	8.32
Holmesiella anomala (mysid)	.82	9.68
Meterythrops robusta (mysid)	.04	1.14
Pseudomma truncatum (mysid)	.35	4.58
Gammaridea (unidentified amphipod)	1.02	12.77
Ampeliscidae (amphipod)	.23	2.60
Lysianassidae (amphipod)	.35	1.30
Caridea (shrimp)	2.87	6.23
Pasiphaeidae (shrimp)	.68	1.30
Hippolytidae (shrimp)	5.95	14.07
Eualus barbata (shrimp)	.73	2.31
Eualus biunguis (shrimp)	.90	3.90
Eualus avinus (shrimp)	.85	5.03
Heptacarpus sp. (shrimp)	.25	2.60
Pandalidae (unidentified)	19.61	26.16
Pandalus borealis (shrimp)	3.95	3.84
Pandalus jordani (shrimp)	9.80	3.12
Pandalus montagui tridens (shrimp)	1.06	2.44
Crangonidae (shrimp)	1.49	6.50
Crangon communis (shrimp)	3.42	8.16
Argis ovifer (shrimp)	.16	1.30
Paguridae (hermit crab)	2.44	2.27
Lithodidae (king crab)	1.58	1.30
Oregonia gracilis (decorator crab)	4.49	2.31
Chionoecetes bairdi (Tanner crab)	.99	3.18
Cherilia longipes (decorator crab)	5.57	3.03
Pinnotheridae (pea crab)	.22	1.30
Teleostei (unidentified fish)	1.84	2.31
Non-gadoid Fish Remains	10.63	7.86
Mallotus villosus (capelin)	.47	1.01
Theragra chalcogramma (walleye pollock)	1.29	1.30
Zoarcidae (eelpout)	.06	1.14
Icelinus borealis (northern sculpin)	.45	2.15

Total prey weight	147 g
Total non-empty stomachs	81
Total empty stomachs	39
Total hauls	11

Table 23.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Sebastolobus alascanus* (shortspine thornyhead) collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Polychaeta (unidentified)	4.16	4.88
Aphroditidae (polychaete)	3.77	1.64
Pteropod (snail)	.03	.46
Cephalopoda (unidentified)	.29	1.06
Teuthoidea (squid)	.33	.46
Octopoda (octopus)	1.70	1.04
Mysidacea (mysid)	3.17	17.38
Isopoda (isopod)	.26	3.49
Gammaridea (amphipod)	3.01	13.33
Themisto sp. (amphipod)	.03	1.39
Caprellidea (amphipod)	.09	.60
Euphausiacea (euphausiid)	.20	2.60
Caridea (shrimp)	.58	.69
Hippolytidae (shrimp)	7.57	12.17
Eualus avinus (shrimp)	.08	1.12
Pandalidae (shrimp)	43.87	45.99
Pandalus borealis (shrimp)	1.02	.69
Crangonidae (shrimp)	7.49	13.70
Argis sp. (shrimp)	.36	.60
Reptantia (crab)	.03	.60
Paguridae (hermit crab)	1.94	3.82
Majidae (spider crab)	.14	.46
Hyas sp. (lyre crab)	.12	1.06
Hyas lyratus (lyre crab)	.18	.69
Chionoecetes bairdi (Tanner crab)	6.72	4.40
Pugettia richii (kelp crab)	.19	.60
Cherilia longipes (decorator crab)	.41	.46
Pinnotheridae (pea crab)	.16	1.22
Teleostei (unidentified fish)	.26	1.06
Non-gadoid Fish Remains	2.00	2.08
Zoarcidae (eelpout)	5.99	3.72
Agonidae (poacher)	1.31	1.65
Cyclopteridae (snailfish)	.15	.60
Stichaeidae (prickleback)	.06	.52
Fishery offal	2.36	.60

Total prey weight	392 g
Total non-empty stomachs	141
Total empty stomachs	72
Total hauls	24

zoarcids, and sculpins) comprised 15% and 12% (by weight) of the food of the thornyhead in 1990 and 1993, respectively. Other prey items included polychaetes, mysids, amphipods, and other crabs (mainly decorator crab).

Variation of Diet Based on Predator Size

Figure 72 shows the variations of the main food items of different size groups of shortspine thornyhead. All shortspine thornyhead size groups consumed a large amount of shrimp (>40% by weight). Thornyheads smaller than 35 cm FL consumed more polychaetes in 1990 than in 1993; however, the same size group of thornyheads consumed more mysids in 1993 than in 1990. The largest size group of thornyheads (>35 cm FL) consumed more crabs (mainly decorator crab) than the smaller size groups.

Geographic Distributions of the Prey Consumed

The distributions of the commercially important prey consumed by shortspine thornyhead are shown in Figures 73 and 74. Figure 73 shows that the pandalids consumed by the thornyhead were distributed in many stations, and the percentage (by weight) consumed in many stations was high (>75%). Figure 74 shows that the Tanner crabs consumed by the thornyhead were mainly distributed around the Montague Island area for both years.

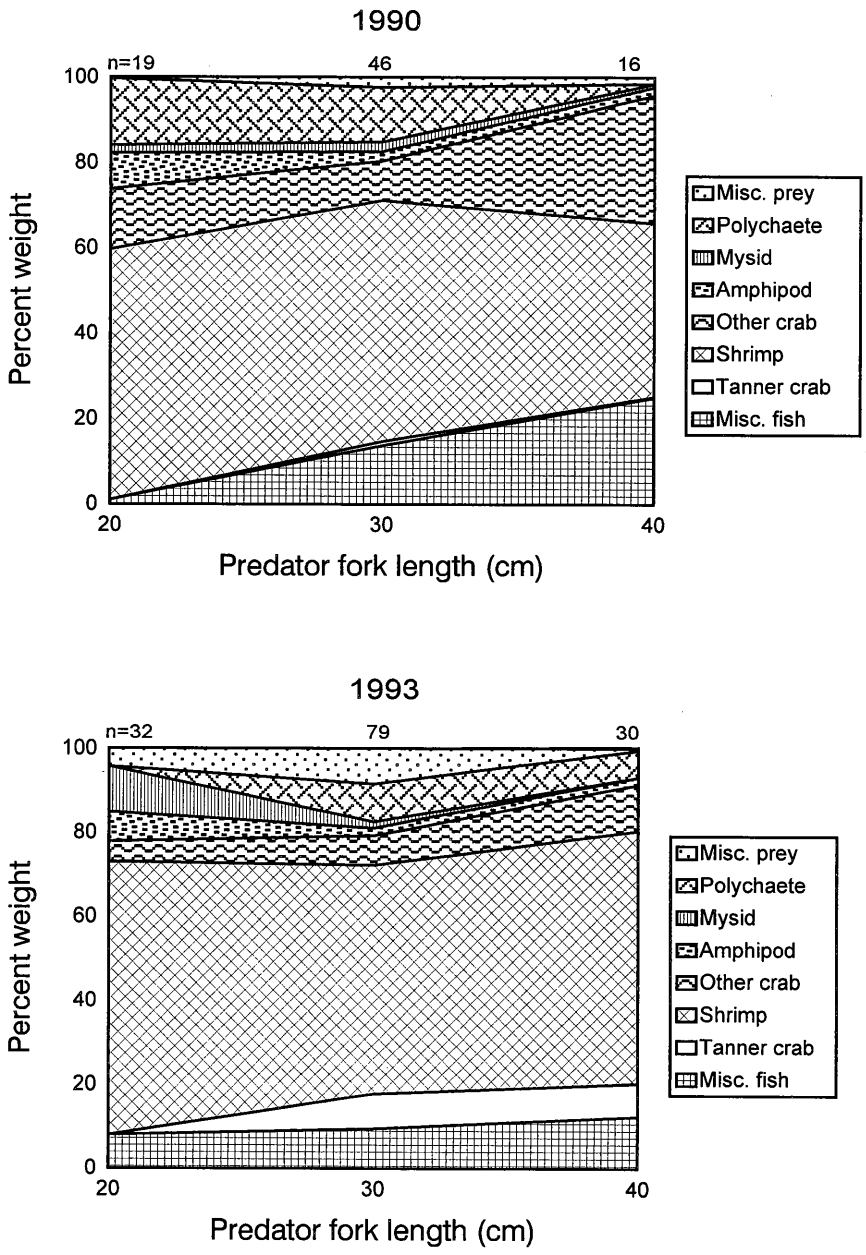
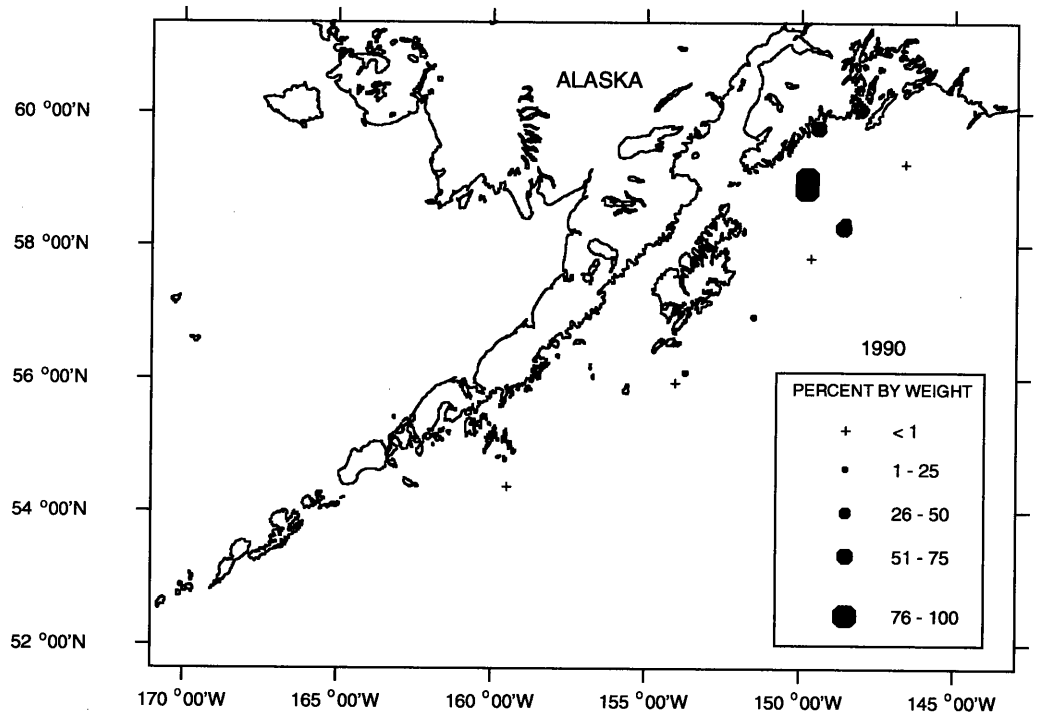


Figure 72.--Variations in the main food items of shortspine thornyhead by predator size, in the Gulf of Alaska in 1990 and 1993. n = sample size.



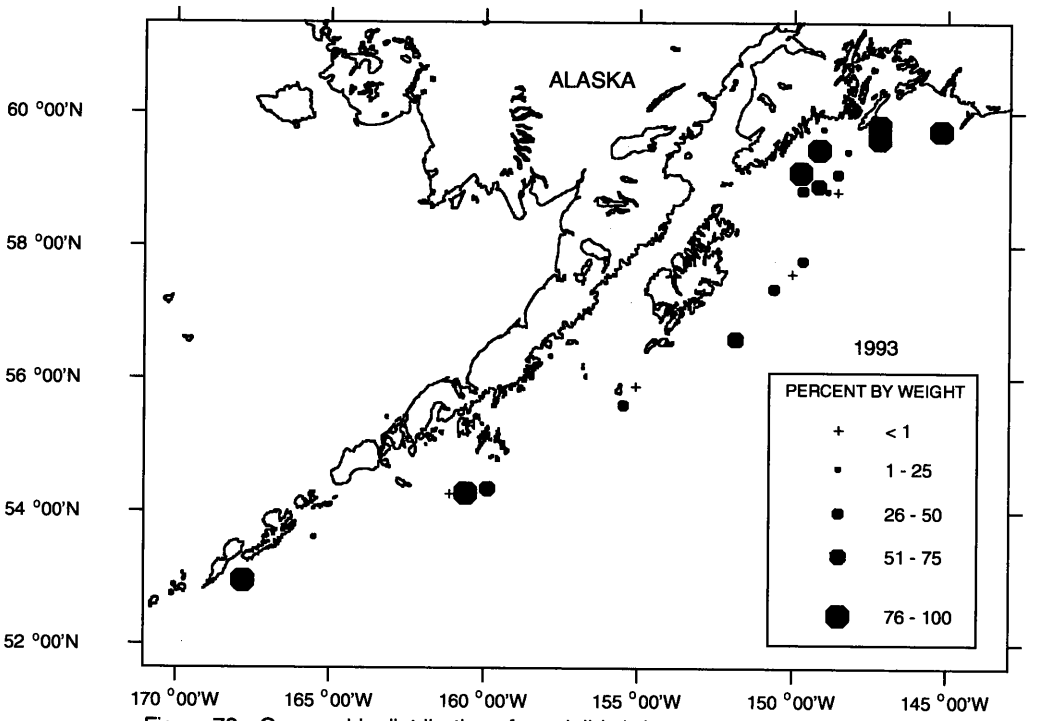
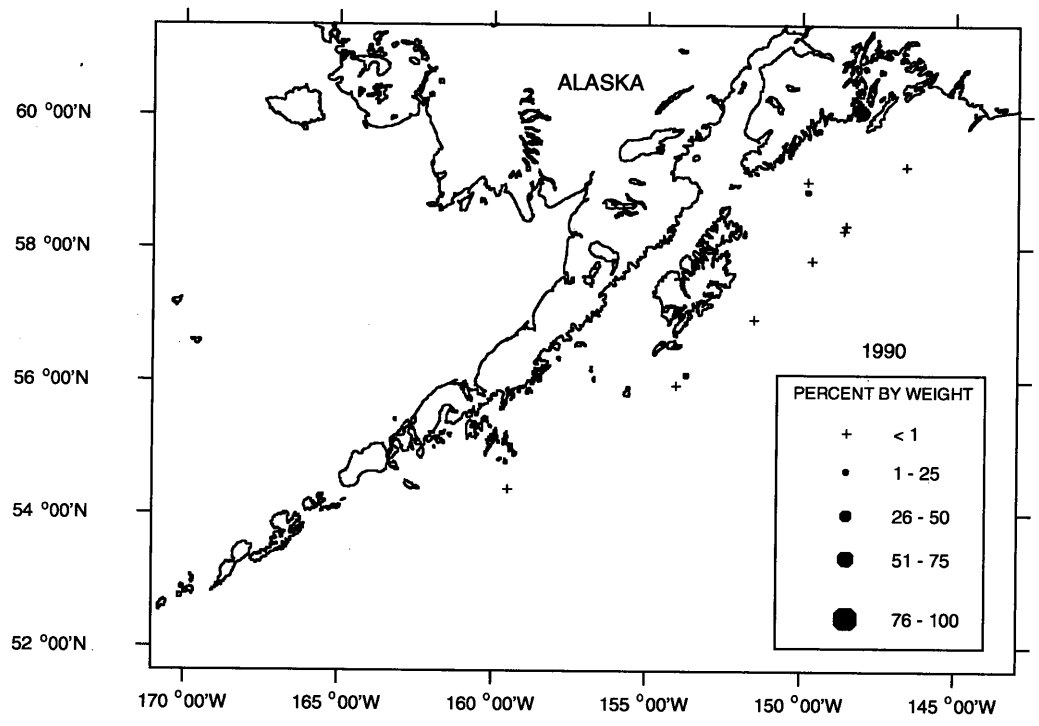


Figure 73.--Geographic distribution of pandalid shrimp consumed by shortspine thornyhead in the Gulf of Alaska in summer 1990 and 1993.



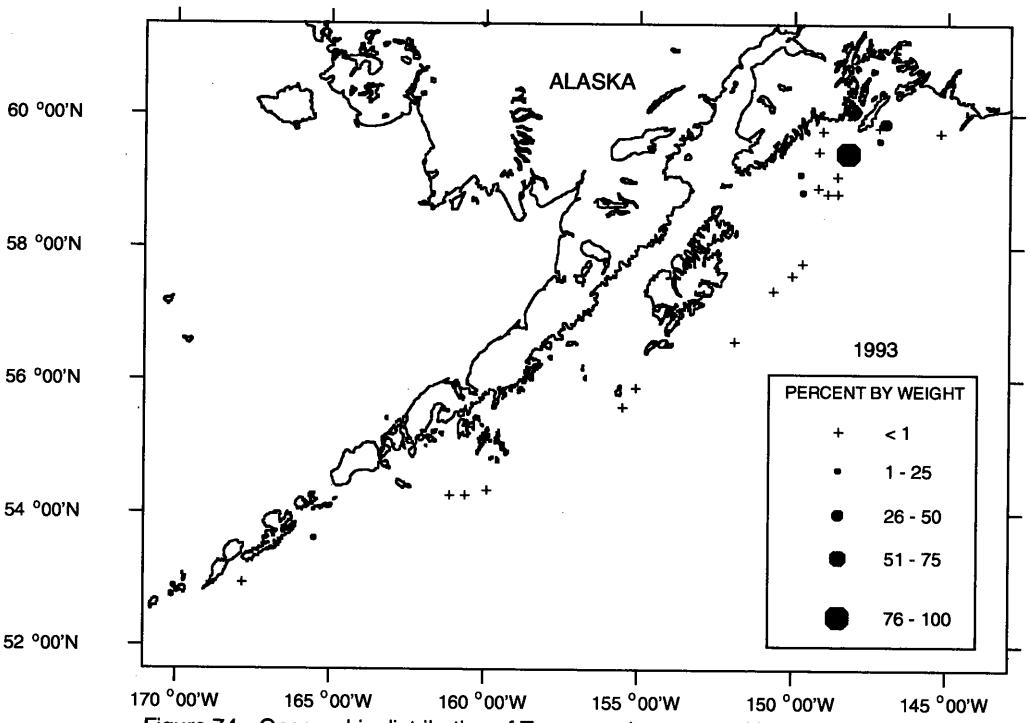


Figure 74.--Geographic distribution of Tanner crab consumed by shortspine thornyhead in the Gulf of Alaska in summer 1990 and 1993.

Sizes of the Commercially Important Prey Consumed

The sizes of the Tanner crabs consumed ranged from 13 to 43 mm CW with a mean carapace width (±SD) of 22.7 ± 8.4 mm. Among the prey fish consumed, one 49 mm SL walleye pollock was found in the stomach of a 37 cm FL thornyhead. The mean standard length (±SD) of the 6 zoarcids consumed was 109.6 ± 64.7 mm with a range from 21 to 210 mm SL. Shortspine thornyhead also consumed one sculpin (32 mm SL), one agonid (81 mm SL), one snailfish (35 mm SL), and one stichaeid (30 mm SL). One unmeasurable capelin was also found in a thornyhead stomach.

SHORTRAKER ROCKFISH

by

Mei-Sun Yang

Shortraker rockfish (*Sebastes borealis*) had an exploitable biomass of 16,670 t in the Gulf of Alaska in 1997 (NPFMC 1998). This species has been classified and managed as part of the slope assemblage rockfishes since 1988 (Heifetz et al. 1998). 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

Tables 24 and 25 show the total number of stomachs with food, the total empty stomachs, the mean percent frequency of occurrence, and mean percent by weight of the prey items of shortraker rockfish in 1990 and 1993, respectively. Cephalopods (mainly squid) were important food of shortraker rockfish (82% and 35% by weight in 1990 and 1993, respectively). However, pandalid shrimp, comprising 50% of the total stomach contents weight, was the most important food of shortraker rockfish in

1993 (Table 25). Shortraker rockfish also consumed mysids, bathylagids, and myctophids.

Table 24.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Sebastes borealis* (shortraker rockfish) collected in the Gulf of Alaska in 1990.

Prey name	Mean % Wt	Mean % FO
Teuthoidea (squid)	81.71	66.67
Myctophid (deepsea smelts)	18.29	33.33
Total prey weight	3.5 g	
Total non-empty stomachs	3	
Total empty stomachs	7	
Total hauls	1	

Table 25.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Sebastes borealis* (shortraker rockfish)collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Cephalopoda (squid & octopus)	35.47	50.00
Mysidacea Mysida (mysid)	13.67	33.33
Pandalidae (shrimp)	50.00	50.00
Bathylagidae (deepsea smelts)	.86	16.67
Total prey weight	8.4 g	
Total non-empty stomachs	4	
Total empty stomachs	16	
Total hauls	2	

FLATHEAD SOLE

by

Mark Nelson

In 1997, the estimated exploitable biomass of flathead sole (*Hippoglossoides elassodon*) was 206,340 t in the Gulf of Alaska (Turnock et al. 1998). This is a decrease from the estimated exploitable biomass of 247,250 t found in 1993 (Wilderbuer and Brown 1995). The catches of flathead sole also decreased from 2,824 t in 1993 to 2,446 t in 1997 (Wilderbuer and Brown 1995, Turnock et al. 1998). Flathead sole, ranked third (after arrowtooth flounder and Pacific halibut) in the total flatfish biomass in the Gulf of Alaska area. Their diet included commercially important species like walleye pollock and Tanner crabs (*C. bairdi*). Because of their predation on commercially important species the food habits of flathead sole are reviewed in this document.

RESULTS

General Diet

A total of 692 flathead sole stomachs collected in 1993 were analyzed, of which 383 stomachs (55%) contained food and 309 (45%) were empty. The size of the fish ranged from 7 cm to 51 cm SL, the mean standard length (+SD) being 32.8 ± 7.0 cm.

Table 26 lists the mean percent weight and mean frequency of occurrence of the prey items found in the flathead sole stomachs. Pandalid shrimp and brittle stars (39% and 25% mean weight, respectively) were the most important food sources in the diet of flathead sole. Other food items included polychaetes, mollusks, calanoid copepods, mysids, amphipods, euphausiids, pagurid crabs and chaetognaths. Prey fish consumed included pollock, zoarcids, cottids and unidentifiable fish remains. In terms of percentage by weight, fish were not an important food item for flathead sole. All fish combined amounted to less than 3% of the total stomach content weight. Variations in the diet of flathead sole of different sizes are shown by Figure 75. This figure illustrates that consumption of brittle stars increased (from 13% to 47% by weight) with size in flathead sole. Conversely, consumption of shrimp decreased (from 42% to 20% by weight) with size.

Sizes of Commercially Important Prey Consumed

The size frequency of pollock consumed by flath

ead sole is shown in Figure 76. Flathead sole fed exclusively on age 0 pollock ($\leq$140 mm SL). Flathead sole also consumed small amounts of Tanner crab (3% by weight). They were primarily from the age-0 cohort (<19 mm CW) although four crabs from the age-1 cohort (19-36 mm CW) were also consumed (Fig. 77).

Table 26.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Hippoglossoides elassodon* (flathead sole)collected in the Gulf of Alaska in 1993.

Prey name	Mean % Wt	Mean % FO
Polychaeta (worm)	1.31	2.52
Maldanidae (polychaete)	.65	.21
Gastropoda (snail)	.06	.39
Bivalvia (unidentified)	3.91	6.23
Nuculidae (clam)	3.62	4.17
Tapes sp. (clam)	1.41	.63
Calanoida (copepod)	<.01	.11
Mysidacea (unidentified)	2.17	2.21
Holmesiella anomala (mysid)	.01	.11
Meterythrops robusta (mysid)	.02	.37
Pseudomma sp. (mysid)	.02	.42
Isopoda (isopod)	1.80	2.45
Gammaridea (unidentified)	.13	.71
Lysianassidae (amphipod)	.03	.21
Euphausiacea (unidentified)	3.58	7.06
Thysanoessa inermis (euphausiid)	.02	.32
Caridea (shrimp)	1.99	3.03
Hippolytidae (shrimp)	.14	1.00
Pandalidae (shrimp)	25.17	27.37
Pandalus borealis (shrimp)	6.87	3.10
Crangonidae (shrimp)	5.25	9.69
Paguridae (hermit crab)	9.79	7.86
Munida quadrispina (pinch bug)	.06	.15
Chionoecetes bairdi (Tanner crab)	3.06	7.12
Cancer magister (Dungeness crab)	.02	.15
Pinnotheridae (pea crab)	.07	.58
Echiura (marine worm)	.94	1.04
Ophiurida (brittle star)	25.27	28.16
Chaetognatha (arrow worm)	<.01	.16
Teleostei (unidentified fish)	.02	.11
Non-gadoid Fish Remains	.49	.49
Theragra chalcogramma (walleye pollock)	.36	1.44
Zoarcidae (eelpout)	1.01	.37
Cottidae (sculpin)	.57	1.31
Unidentified organic material	.19	.37

Total prey weight	981 g
Total non-empty stomachs	383
Total empty stomachs	309
Total hauls	68

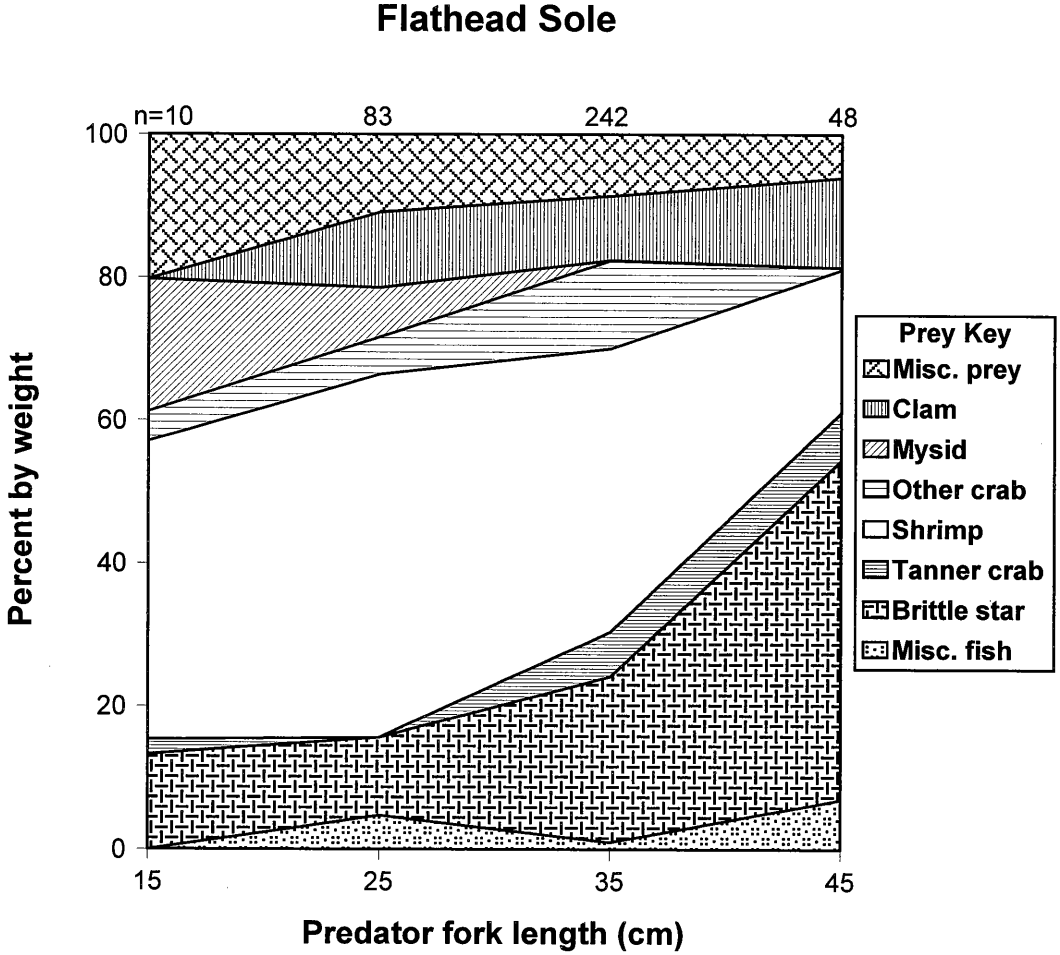


Figure 75.--Variations in the main food items of flathead sole, by predator size, in the Gulf of Alaska in 1993. n = sample size.

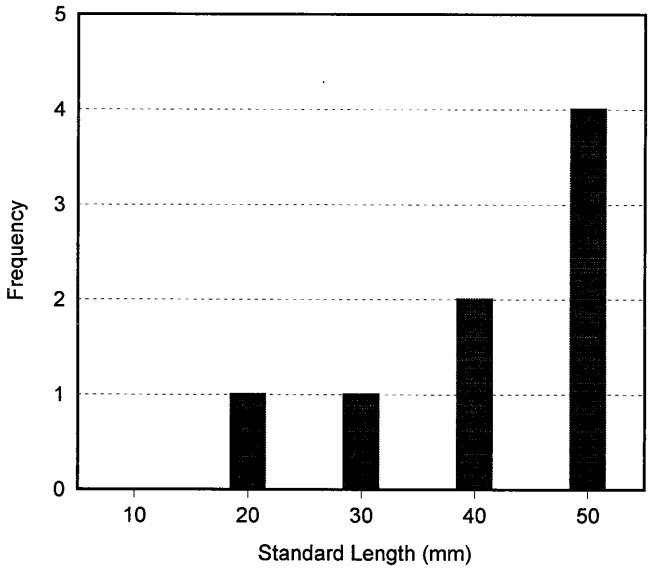


Figure 76.-- Size frequency distribution of walleye pollock consumed by flathead sole in the Gulf of Alaska in 1993.

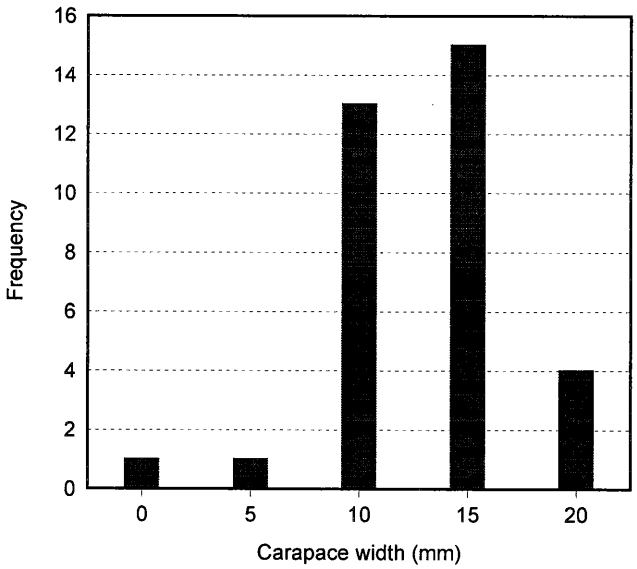


Figure 77.-- Size frequency distribution of Tanner crab consumed by flathead sole in the Gulf of Alaska in 1993.

DISCUSSION

A similar study was performed in the Bering Sea by Pacunski (1990). He found the same trend of smaller flathead sole consuming more decapods and larger flathead sole consuming more brittle stars. However, in Pacunski's study, brittle stars were consumed in greater overall abundance (42% total by weight compared to 25% in this study). Compared to the consumption of pollock (20% by weight) in the Bering Sea, flathead sole consumed less pollock (<1% by weight) in the Gulf of Alaska area. Similar to our study, *Chionoecetes* spp. (ranging from 3 to 46 mm CW) were of little importance (less than 2% by weight) as food for flathead sole in the Bering Sea area (Pacunski 1990).

ATKA MACKEREL

by

Mark Nelson

In 1996, the estimated biomass of Atka mackerel was 345,990 t (Martin 1997). This estimate is highly variable due to extreme catch variances in the survey. Approximately 99% of the catch came from a single haul in the eastern Gulf of Alaska. Atka mackerel is a schooling species with a patchy distribution, which leads to this type of sampling problem. Catches in 1996 were 1,586 t (Lowe and Fritz 1997).

RESULTS

In 1993 a total of 42 stomachs from 4 hauls were collected and analyzed. A total of 23 stomachs (55%) were full and 19 (45%) were empty. The size range of the Atka mackerel sampled was 38 - 50 FL cm with an mean fork length ($\pm$SD) of 44.36 $\pm$ 2.95 cm. The mean percent weight (% wt) and mean percent frequency of occurrence (% FO) of prey consumed by Atka mackerel is presented in Table 27. Calanoid copepods (64% by wt) were the main prey for the Atka mackerel analyzed. The geographic distribution of calanoid copepods is shown in Figure 78. Jellyfish (19%) ranked second in percent weight but were consumed infrequently (8% FO). Gastropods on the other hand comprised less than 10% of the mean weight but were found in over 71% of the stomachs. Other prey

Table 27.--Prey items (expressed in mean percent frequency of occurrence (%FO), and mean percent total weight) of *Pleurogrammus monopterygius* (Atka mackerel) collected in the Gulf of Alaska in 1996.

Prey Name	Mean % Wt	Mean % FO
Scyphozoa (jellyfish)	19.00	8.33
Polychaeta (worm)	.03	1.92
Gastropoda (snail)	9.55	71.15
Pteropoda (snail)	.30	24.36
Bivalvia (clam)	2.00	8.33
Calanoida (copepod)	64.21	54.33
Themisto sp. (amphipod)	.77	32.05
Euphausiacea (euphausiid)	4.08	53.04
Teleostei (unidentified fish)	.01	1.92
Cottidae (sculpin)	.03	1.92
Pleuronectidae (flatfish eggs)	.03	5.77

Total prey weight	82.4 g
Total non-empty stomachs	23
Total empty stomachs	19
Total hauls	4

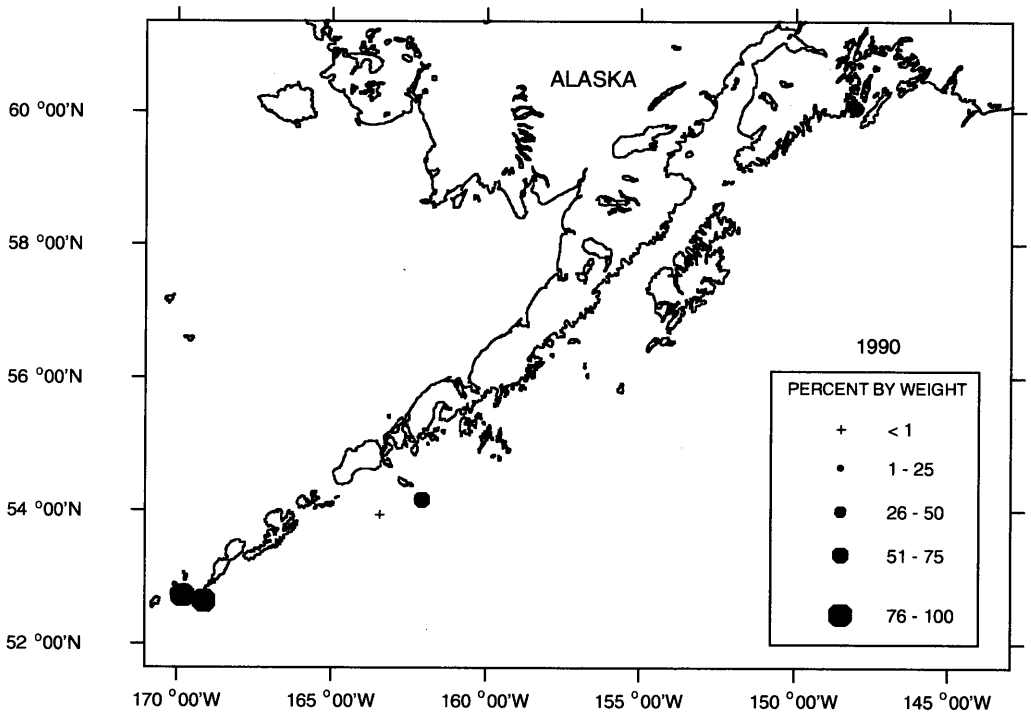


Figure 78.--Geographic distribution of calanoid copepods consumed by Atka mackerel in the Gulf of Alaska in summer 1996.

items included bivalves, polychaetes, pteropods, hyperiid amphipods, euphausiids, sculpins, unidentified fish, and flatfish eggs.

DISCUSSION

Yang (1996) found the main prey of Atka mackerel in the Aleutian Islands were euphausiids (55%). However, euphausiids were only 4% of the diet weight in the current study. Also, in Yang's study, calanoid copepods comprised only 17% by weight as opposed to the 64% by weight found by this study. Simenstad (1977) found Atka mackerel most frequently consumed pelagic crustaceans such as amphipods, mysids and copepods. Differences in the findings of these studies could be attributed to the different study areas for Atka mackerel and to the small sample size of the current study.

SUMMARY

Important Prey of Groundfish

A total of 13,928 stomachs from 13 species were analyzed to describe the food habits of the major groundfish species in the Gulf of Alaska in 1990, 1993, and 1996. The food habits data of Pacific ocean perch, dusky rockfish, and northern rockfish collected in 1990 have been described in a separate publication (Yang 1993). No stomach samples from these three species were collected in 1993 or 1996 but the data from 1990 are included in this document. Our analysis emphasized groundfish predation on commercially important fish, crab, and shrimp. The predator sizes and the number of the stomachs collected for each species are summarized in Tables 28 to 30 for 1990, 1993, and 1996, respectively. Although juveniles of some species (walleye pollock, Pacific cod, Pacific halibut, and arrowtooth flounder) were sampled, the main focus of our study was the food habits of adult fish.

Tables 31, 32, and 33 list the percent by weight of the commercially important fish, crab, shrimp, and other major prey or prey groups consumed by groundfish in 1990, 1993, and 1996, respectively. Arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and pollock were the main predators that consumed fish. The main predators that consumed Tanner crabs were Pacific

Table 28.--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 29.--Number of stomachs and fish size analyzed in the Gulf of Alaska in 1993. 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	647	728	1,375	11-80	43.1 ± 12.5
Pacific halibut	409	150	559	20-155	65.8 ± 19.0
Sablefish	250	105	355	24-82	59.4 ± 8.7
Pacific cod	1,035	47	1,082	13-100	55.9 ± 12.3
Pollock	936	190	1,126	9-70	45.2 ± 13.2
Shortspine thornyhead	141	72	213	13-48	29.2 ± 6.7
Rougheye rockfish	154	125	279	8-64	34.5 ± 10.4
Shortraker rockfish	4	16	20	30-69	52.4 ± 11.6
Flathead sole	383	309	692	7-51	32.8 ± 7.0
Total	3,959	1,742	5,701		

Table 30.--Number of stomachs and fish size analyzed in the Gulf of Alaska in 1996. 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	1,615	603	2,218	12-84	41.7 ± 13.7
Pacific halibut	296	71	367	18-148	63.0 ± 20.4
Sablefish	61	14	75	42-82	61.4 ± 7.0
Pacific cod	588	17	605	14-105	59.0 ± 13.4
Pollock	434	57	491	8-72	44.4 ± 16.0
Atka mackerel	23	0	18	49-87	63.8 ± 10.6
Total	3,017	781	3,798		

Table 31.--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%. NOR, northern rockfish; POP, Pacific Ocean perch; DUS, Dusky rockfish; SHR, shortraker rockfish; ROU, rougheye rockfish; SST, short spine thornyhead; PLK, pollock; COD, Pacific cod; SAB, sablefish; PH, Pacific halibut; ATF, arrowtooth flounder; JFH, jellyfish; POL, polychaete; MOL, molluska; CHA, chaetognath; LAR, larvacean; CAL, calanoid; MYS, mysid; AMP, amphipod; EUP, euphausiid; OSH, other shrimp; PAN, pandalid; OCR, other crabs; PAG, pagurid; TAN, Tanner crab; CEP, cephalopod; SAL, salmonid; ZOA, zoarcid; COT, cottid; STI, stichaeid; RF, rockfish; BAS, bathymasterid; ATK, Atka mackerel; EUL, eulachon; MYC, myctophid; SAN, Pacific sand lance; FHS, flathead sole; RS, rock sole; DOV, Dover sole; CAP, capelin; HER, Pacific herring.

	Predator										
Prey	NOR	POP	DUS	SHR	ROU	SST	PLK	COD	SAB	PH	ATF
JFH	0	0	0	0	0	0	0	0	10	0	0
POL	0	0	0	0	-	12	1	8	-	-	-
MOL	0	-	-	0	-	2	-	1	-	1	-
CHA	3	4	8	0	0	0	-	0	-	0	-
LAR	0	0	14	0	1	0	-	0	0	0	0
CAL	4	7	1	0	-	-	2	-	-	0	-
MYS	0	6	-	0	7	2	2	-	-	-	-
AMP	4	11	1	0	9	2	4	1	1	-	-
EUP	88	60	61	0	2	0	46	1	10	0	17
OSH	-	2	2	0	12	17	14	12	-	2	2
PAN	0	5	4	0	32	34	16	11	11	-	12
OCR	0	0	-	0	-	12	-	7	1	13	0
PAG	-	-	8	0	-	2	1	7	2	7	-
TAN	-	-	0	0	5	1	-	10	5	6	0
CEP	1	1	2	82	10	1	1	7	4	5	1
SAL	0	0	0	0	0	0	0	0	0	1	1
ZOA	0	0	0	0	0	1	1	1	0	1	1
COT	0	0	0	0	0	1	1	2	3	2	1
STI	0	0	0	0	0	0	1	2	1	1	0
RF	0	0	0	0	0	0	1	0	0	1	0
BAS	0	0	0	0	0	0	0	1	0	0	0
ATK	0	0	0	0	0	0	0	0	0	0	1
EUL	0	0	0	0	0	0	-	1	2	-	-
MYC	0	1	0	18	0	0	-	0	-	0	0
SAN	0	0	0	0	0	0	-	1	1	4	-
ATF	-	2	0	0	0	0	-	2	0	5	-
FHS	0	0	0	0	0	0	-	1	0	1	-
RS	0	0	0	0	0	0	0	-	0	1	0
DOV	0	0	0	0	0	0	-	0	0	1	0
COD	0	0	0	0	0	0	0	0	1	1	0
CAP	0	0	0	0	0	1	7	3	2	2	23
HER	0	0	0	0	0	0	-	-	2	0	6
PLK	0	0	0	0	0	1	2	6	22	38	28

Table 32.--Percent by weight of the important prey or prey group consumed by the groundfish in the Gulf of Alaska in 1993. "-" means less than 1%. FHS, flathead sole; SHR, shortraker rockfish; ROU, rougheye rockfish; SST, short spine thornyhead; PLK, pollock; COD, Pacific cod; SAB, sablefish; PH, Pacific halibut; ATF, arrowtooth flounder; JFH, jellyfish; POL, polychaete; MOL, molluska; CHA, chaetognath; LAR, larvacean; CAL, calanoid; MYS, mysid; AMP, amphipod; EUP, Euphausiid; OSH, other shrimps; PAN, pandalid; OCR, other crabs; PAG, pagurid; TAN, Tanner crab; BRI, brittle star; CEP, cephalopod; AGO, agonid; ZOA, zoarcid; COT, cottid; STI, stichaeid; RAJ, skate; BAS, bathymasterid; ATK, Atka mackerel; EUL, eulachon; MYC, myctophid; SAN, Pacific sand lance; RS, rock sole; REX, rex sole; CAP, capelin; HER, Pacific herring.

	Predator								
Prey	FHS	SHR	ROU	SST	PLK	COD	SAB	PH	ATF
JFH	0	0	0	0	0	0	9	0	0
POL	2	0	-	8	1	7	1	-	1
MOL	9	0	1	-	-	1	2	1	-
CHA	-	0	1	0	-	0	0	0	0
LAR	0	0	0	0	6	-	0	0	0
CAL	-	0	0	0	4	-	0	0	0
MYS	2	14	3	3	3	-	-	0	0
AMP	-	0	3	3	3	4	3	-	-
EUP	4	0	11	-	41	6	6	1	22
OSH	7	0	12	16	6	9	-	1	4
PAN	32	50	50	45	20	15	10	3	18
OCR	-	0	-	1	-	6	0	13	-
PAG	10	0	2	2	2	7	4	22	-
TAN	3	0	1	7	0	7	0	9	0
BRI	25	0	0	0	0	0	-	-	0
CEP	0	35	2	2	2	4	11	3	4
AGO	0	0	0	1	0	1	0	0	0
ZOA	1	0	1	6	1	1	0	1	3
SAB	0	0	0	0	0	0	0	1	2
COT	1	0	1	0	1	3	1	1	1
STI	0	0	0	1	1	1	0	1	3
RAJ	0	0	0	0	0	1	0	1	0
BAS	0	0	0	0	0	1	0	0	1
ATK	0	0	0	0	0	0	0	1	1
EUL	0	0	5	0	1	-	1	0	3
MYC	0	0	2	0	-	-	0	0	2
SAN	0	0	-	0	1	1	0	3	1
ATF	0	0	0	0	-	3	2	3	2
FHS	0	0	0	0	0	1	0	1	0
RS	0	0	0	0	0	0	0	1	-
REX	0	0	0	0	0	0	0	-	1
COD	0	0	0	0	0	0	0	2	1
CAP	0	0	0	0	3	1	0	2	4
HER	0	0	1	0	0	-	0	2	1
PLK	-	0	-	0	1	19	27	31	16

Table 33.--Percent by weight of the important prey or prey group consumed by the groundfish in the Gulf of Alaska in 1996. "-" means less than 1%. ATK, Atka mackerel; PLK, pollock; COD, Pacific cod; SAB, sablefish; PH, Pacific halibut; ATF, arrowtooth flounder; JFH, jellyfish; POL, polychaete; MOL, molluska; CHA, chaetognath; LAR, larvacean; CAL, calanoid; MYS, mysid; AMP, amphipod; EUP, euphausiid; OSH, other shrimp; PAN, pandalid; OCR, other crabs; PAG, pagurid; TAN, Tanner crab; CEP, cephalopod; RF, rockfish; BAT, bathylagid; SAL, salmonid; ZOA, zoarcid; COT, cottid; BAS, bathymasterid; STI, stichaeid; EUL, eulachon; SAN, Pacific sand lance; FHS, flathead sole; RS, rock sole; YFS, yellowfin sole; DOV, Dover sole; CAP, capelin; HER, Pacific herring.

	Predator					
Prey	ATK	PLK	COD	SAB	PH	ATF
JFH	19	0	0	14	0	0
POL	-	-	6	1	-	-
MOL	12	-	1	-	1	-
CHA	0	-	0	0	0	-
LAR	0	4	0	0	0	0
CAL	64	18	-	-	0	-
MYS	0	-	-	-	-	-
AMP	1	1	2	11	-	-
EUP	4	58	4	10	-	12
OSH	0	1	5	-	1	2
PAN	0	2	11	5	-	6
OCR	0	0	9	-	13	0
PAG	0	-	11	1	15	-
TAN	0	0	11	0	9	0
CEP	0	-	1	3	3	1
RF	0	0	1	0	0	0
BAT	0	0	0	0	0	1
SAL	0	0	0	0	0	1
ZOA	0	1	1	0	1	1
COT	0	1	1	0	1	1
BAS	0	0	1	0	1	1
STI	0	0	1	0	1	2
ATK	0	0	4	0	6	-
EUL	0	0	-	0	0	1
SAN	0	2	-	0	3	-
ATF	0	-	1	0	1	1
FHS	0	0	0	0	0	-
RS	0	0	-	0	2	1
YFS	0	0	0	0	2	-
DOV	0	0	0	0	1	0
COD	0	0	0	0	1	1
CAP	0	0	-	0	4	10
HER	0	0	0	0	-	-
PLK	0	10	23	10	32	53

halibut and Pacific cod. Pollock, shortspine thornyhead, shortraker rockfish, flathead sole, and rougheye rockfish were the primary consumers of pandalid shrimp. Pacific ocean perch, northern rockfish, dusky rockfish, and Atka mackerel are thought to not have substantial impact on the commercially important species in the Gulf of Alaska since they feed mainly on zooplankton (primarily euphausiids and calanoid copepods). The data in Tables 31, 32, and 33 indicate that pollock were the dominant prey fish every year and were consumed predominately by arrowtooth flounder, Pacific halibut, sablefish, and Pacific cod. Pollock cannibalism, which accounted for only 2% in 1990 and 1% in 1993, but increased to 10% in 1996 of the total stomach contents weight, were not an important phenomenon in the Gulf of Alaska compared with the Bering Sea (Livingston 1991). Other forage fish such as Pacific herring, capelin, eulachon, Pacific sand lance, and Atka mackerel can be categorized as the next most important prey fishes. Arrowtooth flounder was the main predator of Pacific herring in 1990 (6% of the total stomach content weight), whereas arrowtooth flounder and pollock both consumed relatively large amounts of capelin (23% and 7% by weight, respectively) in the same year. The only other large amount (10% by weight) of capelin consumed was in 1996 by arrowtooth flounder. Pacific sand lance and eulachon were consumed by the main piscivorous species (arrowtooth flounder, Pacific halibut,

sablefish, Pacific cod, and pollock) but each comprised no more than 5% of the stomach content weight of each of the predator species in every year. Atka mackerel were found in arrowtooth flounder, Pacific halibut, and Pacific cod stomachs. The highest percent by weight of Atka mackerel (6%) was found in Pacific halibut stomachs collected in 1996. Flatfish consumed by 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, Pacific cod, and sablefish. Pacific cod (<3% each) were consumed by Pacific halibut, arrowtooth flounder, and sablefish. Coho salmon (1% stomach content weight) were found in Pacific halibut and arrowtooth flounder stomachs. *Sebastes* spp. were found in pollock, Pacific halibut, and Pacific cod stomachs. Tanner crabs were mainly consumed by Pacific cod and Pacific halibut though they were also consumed by rougheye rockfish, sablefish, shortspine thornyhead, and flathead sole. Tables 31, 32, and 33 show that almost all predator species consumed a certain amount of cephalopods (squid and octopus) but shortraker rockfish was the main predator of the cephalopods. All predators, except northern rockfish and Atka mackerel, preyed on pandalid shrimp, which includes all the *Pandalus* and *Pandalopsis* species. The shortspine thornyhead, rougheye rockfish, shortraker rockfish, flathead sole, and pollock were the primary predators of the pandalids.

Diet Overlap

The percent similarity index (PSI) was calculated by using the proportions of the prey items in the stomachs (values in Tables 31, 32, and 33) to show the diet overlap between groundfish species in the Gulf of Alaska in 1990, 1993, and 1996 (Fig. 79). The PSI is calculated as

$$PSI = \Sigma \text{ (the smallest of } P_{xi} \text{ and } P_{yi}),$$

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

The upper diagonal section of each year in Figure 79 shows the percent similarity indices (percentage) between different species. The lower diagonal section shows the diet overlap between species by categorizing the percent similarity indices into low (<30%), medium (30-50%), and high (>50%) values.

In 1990, the overlap values between arrowtooth flounder, Pacific halibut, and sablefish were medium (30-50%) since they all fed mainly on fish plus different proportions of shrimp, crab, and cephalopods. Pacific cod had low overlap value (26%) with arrowtooth flounder but medium (30-50%) overlap values with Pacific halibut and sablefish. Figure 79 shows that pollock holds a special position in the food web of the Gulf of Alaska. It had medium (from 31% to 43%) overlap values with the primary piscivorous fish, arrowtooth flounder, sablefish, and Pacific

1990

	ATF	PH	SAB	COD	PLK	SST	ROU	SHR	DUS	POP	NOR
ATF		36	49	26	43	19	17	1	24	25	18
PH			42	44	12	23	12	5	11	5	1
SAB				39	31	21	23	4	19	17	12
COD					36	48	37	7	17	12	3
PLK						41	37	1	56	62	53
SST							50	1	10	12	3
ROU								10	12	25	7
SHR									2	2	1
DUS										73	67
POP											72
NOR											

1993

	ATF	PH	SAB	COD	PLK	SST	ROU	SHR	FHS
ATF		36	41	54	56	29	43	22	29
PH			42	58	16	18	13	6	21
SAB				51	27	18	26	21	22
COD					41	49	41	19	41
PLK						39	50	25	37
SST							69	50	49
ROU								55	51
SHR									34
FHS									

1996

	ATF	PH	SAB	COD	PLK	ATK
ATF		45	26	41	27	4
PH			14	64	15	1
SAB				24	23	19
COD					20	6
PLK						23
ATK						

Diet Overlap: <30% Low; 30-50% Medium; >50% High

Figure 79.--Percent Similarity Index (%) of dietary overlap of groundfish species in the Gulf of Alaska in 1990, 1993, and 1996. ATF, arrowtooth flounder; PH, Pacific halibut; SAB, sablefish; COD, Pacific cod; PLK, pollock; SST, shortspine thornyhead; ROU, rougheye rockfish; DUS, dusky rockfish; POP, Pacific ocean perch; NOR, northern rockfish; FHS, flathead sole; ATK, Atka mackerel.

cod. Pollock also had relatively high (from 37% to 62%) overlap values with all rockfish except shortraker rockfish. This can be easily explained since the pollock's diet included not only large amounts (49%) of euphausiids (like many rockfishes) and shrimp (30%), but also some fish (e.g., capelin and pollock). The combination of euphausiids, shrimp, and fish as prey made pollock the groundfish whose diet has moderate overlaps with both piscivorous and planktivorous groundfish species in the Gulf of Alaska. The shortspine thornyhead and rougheye rockfish had a high dietary overlap value (50%) because they both fed on large amounts (51% and 44%, respectively) of shrimp (Fig. 79). Dusky rockfish, Pacific ocean perch, and northern rockfish also had high overlap values since they all fed largely ($\geq$60%) on euphausiids.

In 1993, the general trend of the diet overlap between the groundfish species are similar to those in 1990. The diet overlap values between the piscivorous species, arrowtooth flounder, Pacific halibut, and sablefish were medium (30-50%). In 1990, Pacific cod had high (>50%) diet overlap values with arrowtooth flounder, Pacific halibut, and sablefish. Arrowtooth flounder also had high (56%) diet overlap with pollock in 1993 comparing to that in 1990. Diet overlap between the rockfishes (short spine thornyhead, rougheye rockfish, shortraker rockfish) in 1993 were all high (>50%). Flathead sole had low diet overlap

with the heavy piscivores like arrowtooth flounder, Pacific halibut, and sablefish. It had medium diet overlap with Pacific cod and pollock and high overlap with rougheye rockfish. Flathead sole is the only epibenthic eater that consumed a high proportion of brittle stars (25%) in their diet.

In 1996, only the main piscivorous fish, arrowtooth flounder, Pacific halibut, Pacific cod, sablefish, pollock, plus the planktivorous Atka mackerel were collected. The diet overlap values between these species were relatively low except the overlap (64%) between Pacific cod and Pacific halibut. Both pollock and sablefish had low diet overlap values with other species. This is quite different from those reported for 1990 and 1993. The reduced diet overlap values may be attributed to the low consumption of shrimp (pandalids and other shrimp) by all of the species in 1996 (Table 30).

Prey Sizes Consumed by Predators

Table 34 lists the size of the commercially important prey consumed by each predator species in the Gulf of Alaska. 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 34 lists prey pollock size as it varies from species to species. The mean standard length ($\pm$SD) of the prey pollock

Table 34.--The standard length (mm) of the commercially important prey consumed by the groundfish in the Gulf of Alaska. "+" indicates prey not measurable. "*" indicates no data. PLK, pollock; HER, Pacific 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; EUL, eulachon; COD, Pacific cod, COH, coho salmon; RF, rockfish; ATK, Atka mackerel; SAB, sablefish; TAN, Tanner crab; ROU, rougheye rockfish, SST, short spine thornyhead; POP, Pacific ocean perch; NOR, northern rockfish.

Prey	Predator								
	ATF			PH			SAB		
	Range	Mean ±	SD	Range	Mean ±	SD	Range	Mean ±	SD
PLK	17-530	184 ±	85	34-670	288 ±	157	56-445	278 ±	94
HER	127-263	174 ±	43	*	*		154-170	162 ±	8
CAP	27-130	80 ±	19	46-119	82 ±	18	82-106	95 ±	12
ATF	18-340	103 ±	93	85-382	229 ±	88	236	236	
FHS	54-250	115 ±	71	58-280	147 ±	96	*	*	
GT	*	*		*	*		*	*	
RS	28-250	125 ±	90	17-296	105 ±	99	*	*	
REX	91	91		*	*		*	*	
YFS	62	62		61-260	112 ±	99	*	*	
PH	44-47	46 ±	2	21- 29	25 ±	6	*	*	
DOV	*	*		105-345	225 ±	170	*	*	
SAN	46-146	99 ±	24	30-187	84 ±	38	97	97	
EUL	108-183	149 ±	24	120	120		68-165	138 ±	38
COD	184-390	285 ±	103	215-461	379 ±	85	+	+	
COH	83-250	167 ±	118	440-500	463 ±	32	*	*	
RF	50-62	56 ±	9	16-208	112 ±	136	*	*	
ATK	16-250	162 ±	93	*	*		*	*	
TAN	*	*		3-103	24 ±	13	5- 54	27 ±	25

Table 34.--Continued.

Prey	Predator								
	COD			PLK			SST		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
PLK	21-503	263	142	13-175	72	44	49	49	
HER	*	*		*	*		*	*	
CAP	42-152	78	19	37-140	83	26	+	+	
ATF	33-390	161	111	13- 46	24	9	*	*	
FHS	17-220	92	52	22- 66	51	20	*	*	
GT	*	*		23	23		*	*	
RS	55-194	114	45	*	*		*	*	
REX	121	121		*	*		*	*	
YFS	*	*		*	*		*	*	
PH	17- 60	33	20	*	*		*	*	
DOV	*	*		115	115		*	*	
SAN	42-165	73	21	28-118	45	11	*	*	
EUL	64-180	143	36	33-180	102	61	*	*	
COD	*	*		14- 18	16	3	*	*	
COH	*	*		*	*		*	*	
RF	25-210	98	87	*	*		*	*	
ATK	*	*		*	*		*	*	
TAN	3- 99	21	10	*	*		13- 43	23	8

Table 34.--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	*	*		*	*		*	*	
RF	*	*		*	*		*	*	
ATK	*	*		*	*		*	*	
TAN	12-27	21 ±	8	+	+		+	+	

Table 34.--Continued.

Prey	Predator					
	FHS			ATK		
	Range	Mean ±	SD	Range	Mean ±	SD
PLK	24-59	46 ±	12	*	*	
HER	*	*		*	*	
CAP	*	*		*	*	
ATF	*	*		*	*	
FHS	*	*		*	*	
GT	*	*		*	*	
RS	*	*		*	*	
REX	*	*		*	*	
YFS	*	*		*	*	
PH	*	*		*	*	
DOV	*	*		*	*	
SAN	*	*		*	*	
EUL	*	*		*	*	
COD	*	*		*	*	
COH	*	*		*	*	
RF	*	*		*	*	
ATK	*	*		*	*	
TAN	4-22	15 ±	4	*	*	

consumed by Pacific halibut (288 ± 157 mm) was the largest, whereas flathead sole only consumed smaller pollock (46 ± 12 mm). The herring consumed were mainly age-1 (10-16 cm FL) or age-2 (17-20 cm FL) fish. The length of the capelin consumed by different predator ranged from 78 to 95 mm SL. Most of the flatfish consumed were less than 200 mm SL. The mean standard length (±SD) of Pacific sand lance consumed varied greatly from 45 ± 11 mm consumed by pollock, to 73 ± 21 mm consumed by Pacific cod, to 99 ± 24 mm consumed by arrowtooth flounder. The mean standard length of eulachon consumed by the predator species ranged from about 100 to 150 mm SL. The mean carapace width (±SD) of the Tanner crabs ranged from 15 ± 4 mm (flathead sole) to 27 ± 25 mm CW (sablefish). Pacific cod larvae (14-18 mm SL) were consumed by pollock. One adult Pacific cod (460 mm SL) was also consumed by a Pacific halibut. The mean lengths of coho salmon consumed by the predator species ranged from 83 to 500 mm SL. The mean length (±SD) of rockfish (*Sebastes* spp.) consumed varied from 56 ± 9 mm SL consumed by arrowtooth flounder, to 98 ± 87 mm SL consumed by Pacific cod, to 112 ± 136 mm SL consumed by Pacific halibut.

Overall, within the same predator species, prey size increased as the predator size increased. Among all the species in this study, piscivorous predators (e.g., Pacific halibut, arrowtooth flounder, and Pacific cod) ate larger sized prey than

planktivorous fish such as rockfish and Atka mackerel. Table 34 also shows that the prey fish consumed by walleye pollock and sablefish were mainly forage fish like herring, capelin, Pacific sand lance, eulachon, and the larvae or juvenile pollock.

Pandalid Shrimp Consumption

A significant finding in our research was the level of predation on pandalid shrimp. In 1990 and 1993, the percentages of the pandalid shrimp consumed by pollock, Pacific cod, arrowtooth flounder, and sablefish were high (more than 10% by weight) (Tables 31 and 32). However, in 1996, only Pacific cod still maintained of pandalid shrimp (11% by weight) in their diet. The percentages (by weight) of the pandalid shrimp in the stomachs of other predators declined dramatically to less than 10% (Table 33). Albers and Anderson (1985) reported that predation on pink shrimp (*Pandalus borealis*) by Pacific cod in Pavlof Bay, Alaska, was probably one reason that the pink shrimp stock still can not rebuild since the closure of the pink shrimp fishery in 1979. Based on our study, it seems that there was a strong predator-prey relationships between groundfish species and pandalid shrimp. However, this study can not make any conclusions about the pandalid shrimp population dynamics in this region.

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