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Historical Review of Capelin (*Mallotus villosus*) Consumption in the Gulf of Alaska and Eastern Bering Sea

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U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

Capelin (*Mallotus villosus*) is an important forage species in the marine ecosystem. In the Bering Sea and Gulf of Alaska, capelin has been documented as an important prey of seabirds and marine mammals. However, a thorough study of the capelin as prey of marine fish has not yet been done.

This study reviews the consumption of capelin by marine fishes in the eastern Bering Sea and Gulf of Alaska. Data from the years 1970 to 2001 in the eastern Bering Sea and data from 1981 to 2001 in the Gulf of Alaska are used to show annual geographic distributions of capelin in the stomach contents of different predators. These distributions suggest that capelin were a key diet item for groundfish in the inner domain area (< 50 m) of the eastern Bering Sea, and in the shelf area (< 100 m) of the Gulf of Alaska. Capelin, in the eastern Bering Sea, seem to prefer the colder areas where temperature was lower and the ice extent moved farther south.

The main fish predators of capelin included arrowtooth flounder (*Atheresthes stomias*), Pacific cod (*Gadus macrocephalus*), Pacific halibut (*Hippoglossus stenolepis*), and walleye pollock (*Theragra chalcogramma*). Indices of capelin abundance (expressed as percentage of total stomach contents weight) by sub-region were estimated to show the relative abundance of capelin consumed each year by groundfish in both the eastern Bering Sea and Gulf of Alaska. Capelin abundance ranged between 1.3% of Pacific cod stomach contents and 8.8% of arrowtooth flounder stomach contents in the eastern Bering Sea. In the Gulf of Alaska, capelin abundance ranged from 0.38% of Pacific cod stomach contents to 2.49% of Pacific halibut stomach contents.

Estimates of the total amount of capelin consumed by the groundfish population during each summer feeding season of each year ranged from 21,168 metric tons (t) in 1999 and 221,408 t in 1990 for the Gulf of Alaska. In the eastern Bering Sea, the estimate was between 19,155 t in 1994 and 47,988 t in 1993.

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INTRODUCTION

Capelin, *Mallotus villosus,* is distributed over much of the Arctic North Pacific and Atlantic Oceans. Along the coasts of North America, capelin ranges from across northern Canada to Point Barrow, Alaska, and south along Alaska and British Columbia to the Strait of Juan de Fuca in Washington state (Macy et al. 1978).

Capelin (*Mallotus villosus*) is an important forage fish in Alaskan waters. It is the prey of many marine fish (Roseneau and Byrd 1996, Yang and Nelson 2000), sea-birds (Maniscalco and Ostrand 1997, Hayes and Kuletz 1997), and marine mammals (Hansen 1997, Merrick et al. 1997).

In 1990, the Steller sea lion (*Eumetopias jubatus*) was listed as threatened, and in 1997 the western stock (west of 144° W long.) of Steller sea lion in Alaska was listed as endangered under the U.S. Endangered Species Act. Several studies designed to examine the role of forage fish such as capelin in marine food webs have been initiated in recent years in response to the listing of the Steller sea lion as endangered

Our objective was to do a historical review of capelin in the diets of marine fish in the eastern Bering Sea and Gulf of Alaska. Small forage species such as capelin are difficult and expensive to monitor using traditional survey techniques. Groundfish can be considered as a sampler of these prey. Using diet data from the Resource Ecology and Ecosystem Modeling (REEM) program of the Alaska Fisheries Science Center (AFSC), we describe the geographic distribution of the capelin, derive an index of abundance of capelin using stomach contents data from marine fishes, and estimate the biomass of the capelin consumed by marine fish in the Gulf of Alaska and the eastern Bering Sea.

METHODS

Study Area

Our study area covers the Alaskan waters of the eastern Bering Sea shelf and the Gulf of Alaska (Fig. 1). The eastern Bering Sea strata were devised by the Resource Assessment and Conservation Engineering (RACE) Division of the AFSC. In general, there are two subareas: the Northwest area and the Southeast area. Within each area, the strata boundaries were based on bottom depth. Strata 1 and 2 are considered the inner continental shelf (< 50 m), strata 3 and 4 are the middle shelf (50-100 m), and strata 5 and 6 are the outer shelf zones (101-200 m). The Gulf of Alaska was divided into three sub-areas: western (170°W-159°W), central (159°W-147°W), and eastern (147°W-130°W).

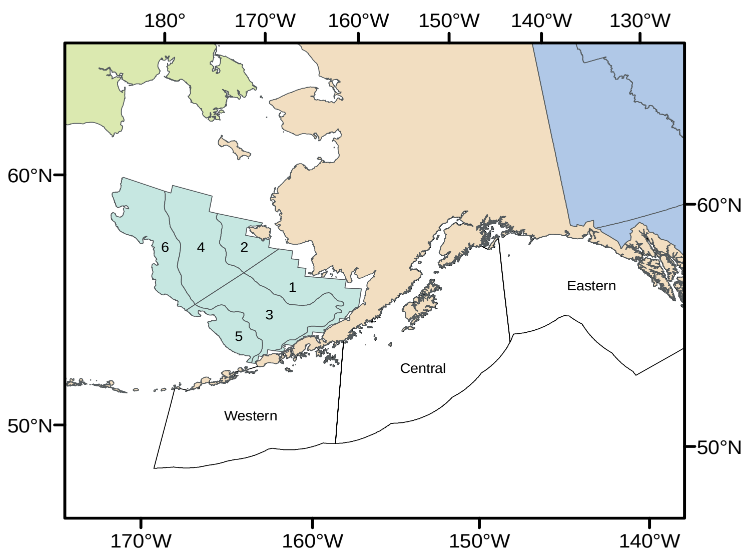

Figure 1.-- Six strata in the eastern Bering Sea and three subareas in the Gulf of Alaska described in this study.

Data Analysis

Stomach contents data from marine fish from REEM program were used. Data from 1970 to 2001 in the eastern Bering Sea and from 1990 to 2001 in the Gulf of Alaska were used.

These data were used to explore the geographical distribution of capelin, derive an index of abundance, and estimate population level consumption of capelin by marine fishes.

In addition, we used the standard length of capelin consumed by marine fish from the database to plot the general age distribution of capelin in different years.

Geographical Distribution of Capelin

Geographical distribution of capelin consumed by groundfish in the eastern Bering Sea and Gulf of Alaska was plotted to show locations where capelin were consumed by predators in every year. Predator categories included walleye pollock (*Theragra chalcogramma*) , Pacific cod (*Gadus macrocephalus*), arrowtooth flounder (*Atheresthes stomias*) , Pacific halibut (*Hippoglossus stenolepis*) , rockfish (short-spine thornyhead, *Sebastolobus alascanus*), sculpins (plain sculpin (*Myoxocephalus jaok*), great sculpin (*Myoxocephalus polyacanthocephalus*), butterfly sculpin (*Hemilepidotus papilio*)), other flatfish (flathead sole (*Hippoglossoides elassodon*), Bering flounder (*Hippoglossoides robustus*), Yellowfin sole (*Pleuronectes asper*), rock sole (*Lepidopsetta* sp.)), and other fish (sablefish (*Anoplopoma fimbria*, and unidentified skate). Only samples from May to September (the most vulnerable period for predation) were used in our analysis. This was to get a general idea of possible summertime capelin distribution.

To examine the relationship between ice cover, temperature, and the distribution of capelin, the last ice day after 15 March and the sea surface temperature (SST) at the 5° C isobar were also plotted (when data were available).

Maximum ice extent typically occurs between mid-February and late March (Overland and Pease 1982). The maximum ice extent of the last ice day after 15 March was plotted for each year. The area south of the line was ice free after 15 March.

Sea-surface temperatures for spawning capelin in the eastern Bering Sea have been determined to be between 5°C and 9°C (Pahlke 1985). Therefore, the 5°C SST (in June) isobar was plotted to show the possible relationships between capelin distribution and water temperatures.

Calculating an Index of Abundance

The relative amounts of capelin consumed per predator by key groundfish species were analyzed every year in different strata.

After initial data explorations of various indices of capelin abundance in groundfish stomachs, such as gram of capelin consumed per gram of predator, gram of capelin consumed per predator, gram of capelin consumed per stomach, and the percentage (by weight) of capelin in the diet, the percentage of capelin in the diet provided to be the best index of abundance.

The indices of abundance were expressed as weighted mean percent weights (%wt) of capelin consumed by each predator. For each stratum, the mean percent weights of capelin consumed by each 10 cm size group were first calculated. The weighted mean percent weights were then obtained by the mean values and the sample sizes in each size group. For each size group, the mean percent weight of capelin consumed in each stratum was first calculated. The weighted mean percent weights were then obtained by weighing the mean strata values by the sample sizes in each stratum.

If all size groups or all strata have zero values or the values were too small (< 0.2% weighted mean %wt), the data were not plotted. The data plotted for size groups varied for different predators and by the available data.

Gulf of Alaska--In the Gulf of Alaska, the key groundfish species included arrowtooth flounder, Pacific cod, Pacific halibut, and walleye pollock. The Gulf of Alaska was divided into three subareas: western (170° W–159° W), central (159° W–147° W), and eastern (147° W–130° W). Within each sub-area, there were three strata: shelf, gully, and slope. The depth of the slope was deeper than 200 m. The shelf depth was usually less than 100 m and the depth of gully was usually between 100 and 200 m. However, the depths of shelf and gullies varied depending on the bathymetry in the Gulf of Alaska.

Eastern Bering Sea--In the eastern Bering Sea, the key predatory groundfish species include arrowtooth flounder, walleye pollock, Pacific cod, and Pacific halibut. The eastern Bering Sea strata (Fig. 1) were devised by the Resource Assessment and Conservation Engineering (RACE)

Division of the AFSC. In general, the strata boundaries were based on bottom depth. Strata 1 and 2 are considered the inner continental shelf (< 50 m), strata 3 and 4 are the middle shelf (50-100 m), and strata 5 and 6 are the outer shelf zones (101-200 m).

Population Level Consumption of Capelin

The calculation of the population level consumption of capelin was based on the following formula

$$C_i = DR_i \times D \times B_i \times P_i,$$

where C_i is the consumption (by weight) of capelin by size group i of a predator species, DR_i is the daily ration (as a proportion of body weight per day) of predator size group i, D is the number of days in the sampling period (months 5-9) when the prey species was vulnerable to predation, B_i is the biomass of the predator size group i, and P_i is the proportion by weight of the capelin in the diet of predator size group i.

Daily ration (DR) estimates were derived using some basic bioenergetic considerations as an alternative to using rations estimated from gastric evacuation rate models and field-estimated stomach content weights. As Livingston et al. (1986) found, estimates derived from gastric evacuation rate models tend to be lower than expected based on known annual growth patterns of eastern Bering Sea groundfish species. Part of the problem with rations estimated in this fashion may be due to undetected regurgitation of stomach contents from field collections. In this study we assumed that more realistic rations can be derived using bioenergetic variables such as annual growth increments and food conversion efficiency estimates. Thus, daily growth in weight of each species size group was estimated from annual growth increments by length and length-weight relationships for each species. A gross conversion efficiency rate of food to somatic tissue for juvenile fish was assumed to be 25% and for adult fish was assumed to be 10% based on estimates presented by Brett and Groves (1979). Daily growth increments could thus be converted to the amount of food required to produce that growth. When the daily food requirements are divided by mean fish weight, the result is a daily ration expressed as a fraction of body weight. Daily rations of different size groups of each species are listed with the population level consumption of capelin (see Results).

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

RESULTS

Geographic Distribution of Capelin

The historical geographic distributions of capelin consumed by groundfish in the eastern Bering Sea and Gulf of Alaska are shown in Figures 2 to 33.

In the 1970s, only stomach content data from Japanese studies were available for the eastern Bering Sea. Pacific cod, walleye pollock, Pacific halibut, and plain sculpin were found preying on capelin. Capelin were consumed very sparsely in the eastern Bering sea throughout the 1970s (Figs. 2-11) except in 1975. In 1975, plain sculpin was the most common predator of capelin, in terms of the frequency of occurrence of capelin in groundfish species. No stomach content data were available in the Gulf of Alaska for the 1970s.

Starting in 1984, stomachs were collected annually in the eastern Bering Sea during the AFSC, RACE Division’s summer trawl surveys and by fishery observers on board the commercial fishing vessels. During the 1980s, capelin were found in the stomachs of the following species: Pacific cod, arrowtooth flounder, walleye pollock, plain sculpin, great sculpin, flathead sole, Bering flounder, and yellowfin sole (Figs. 12-21).

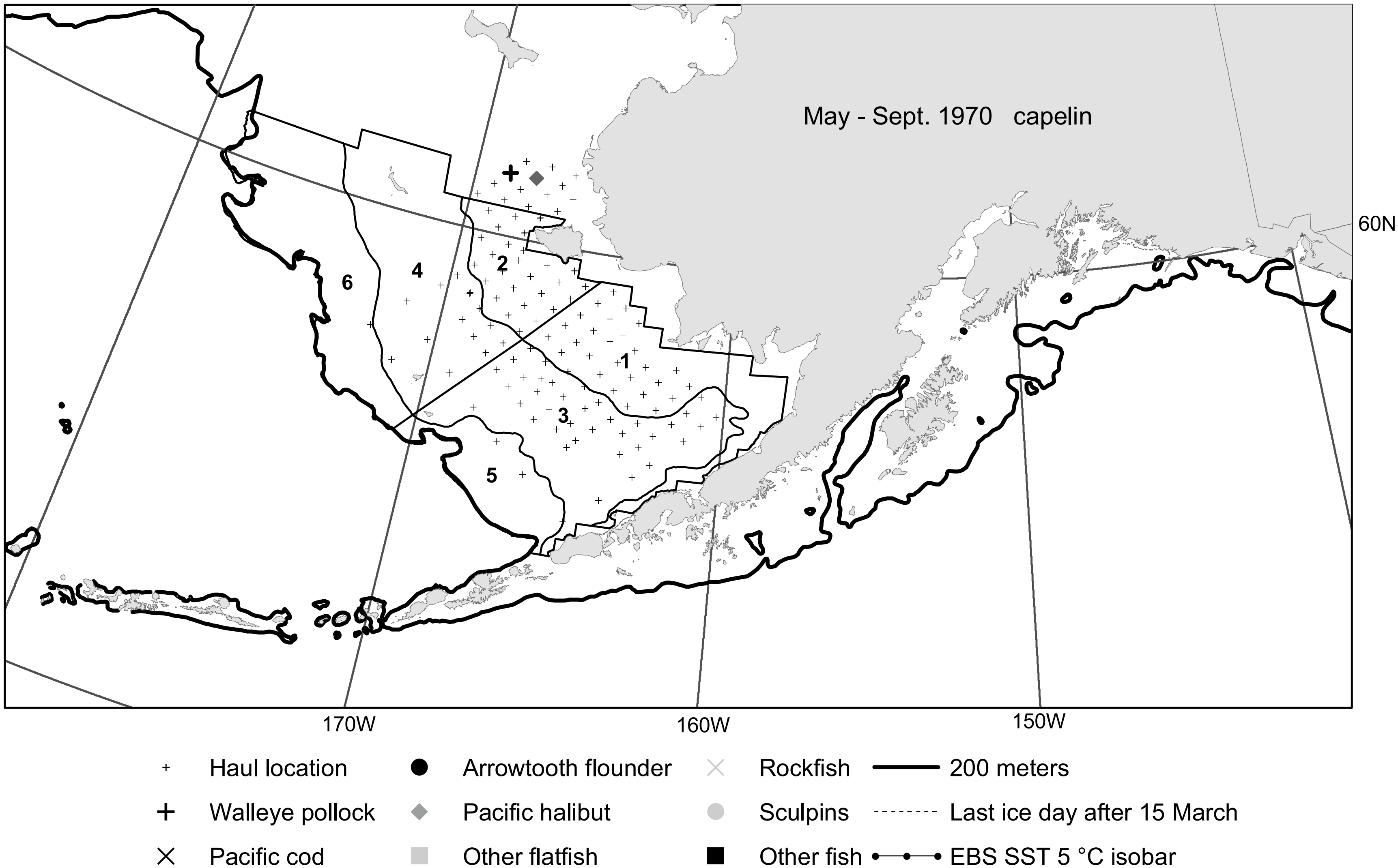

Figure 2.-- Geographic distribution of capelin consumed by groundfishes in 1970.
(no ice and temperature data available for this year)

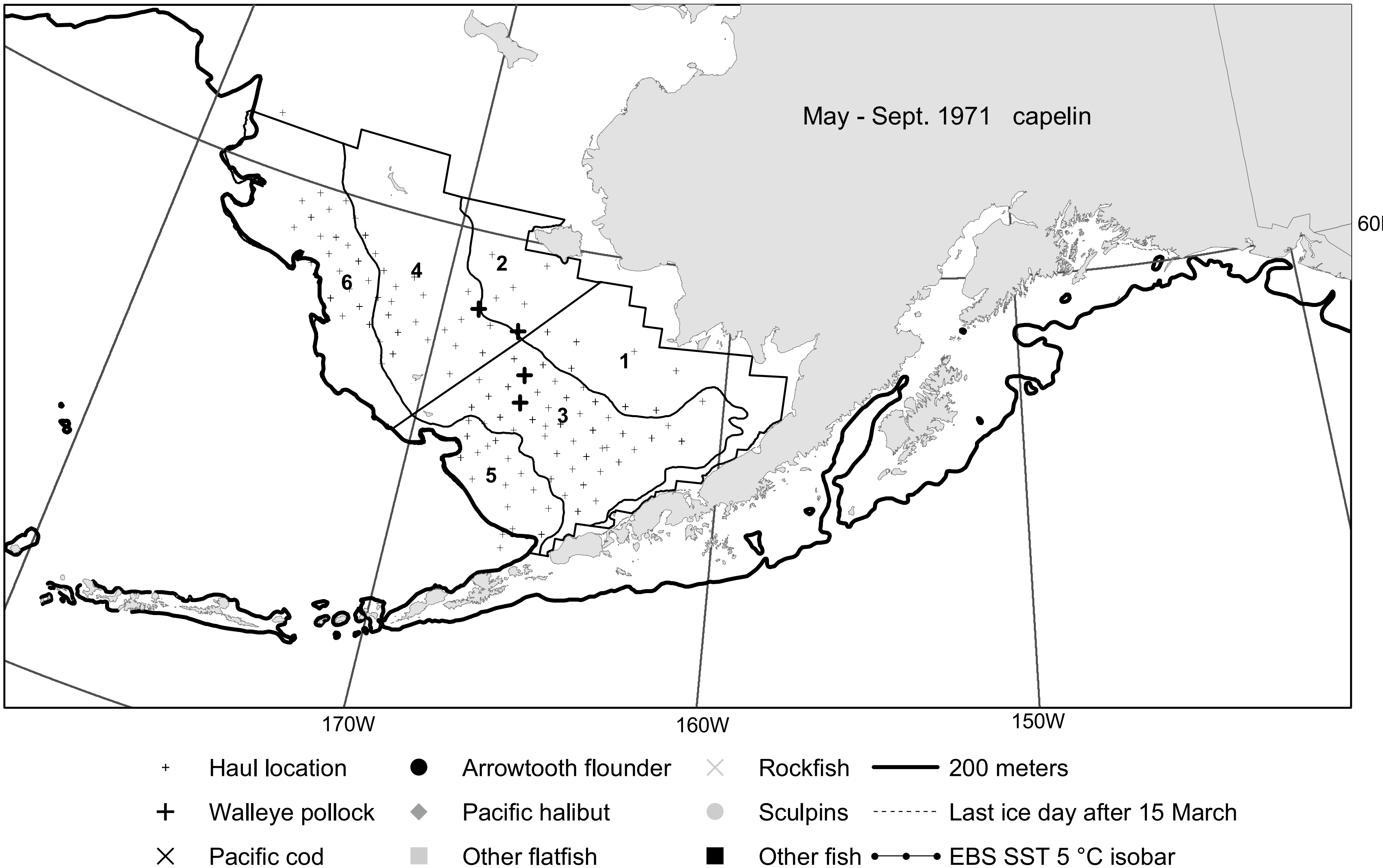

Figure 3.-- Geographic distribution of capelin consumed by groundfishes in 1971.
(no ice and temperature data available for this year)

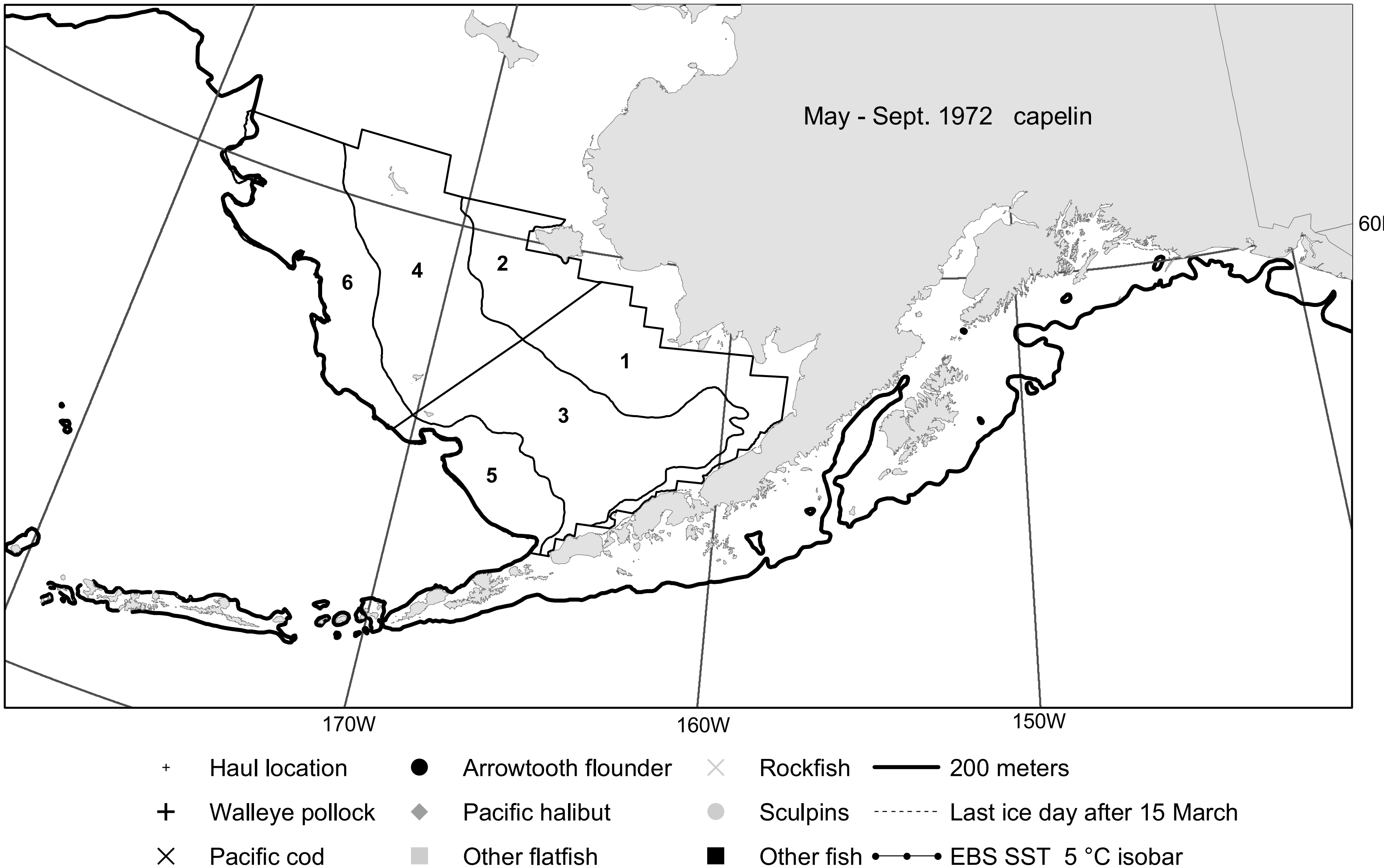

Figure 4.-- Geographic distribution of capelin consumed by groundfishes in 1972.
(no diet, ice, and temperature data available for this year)

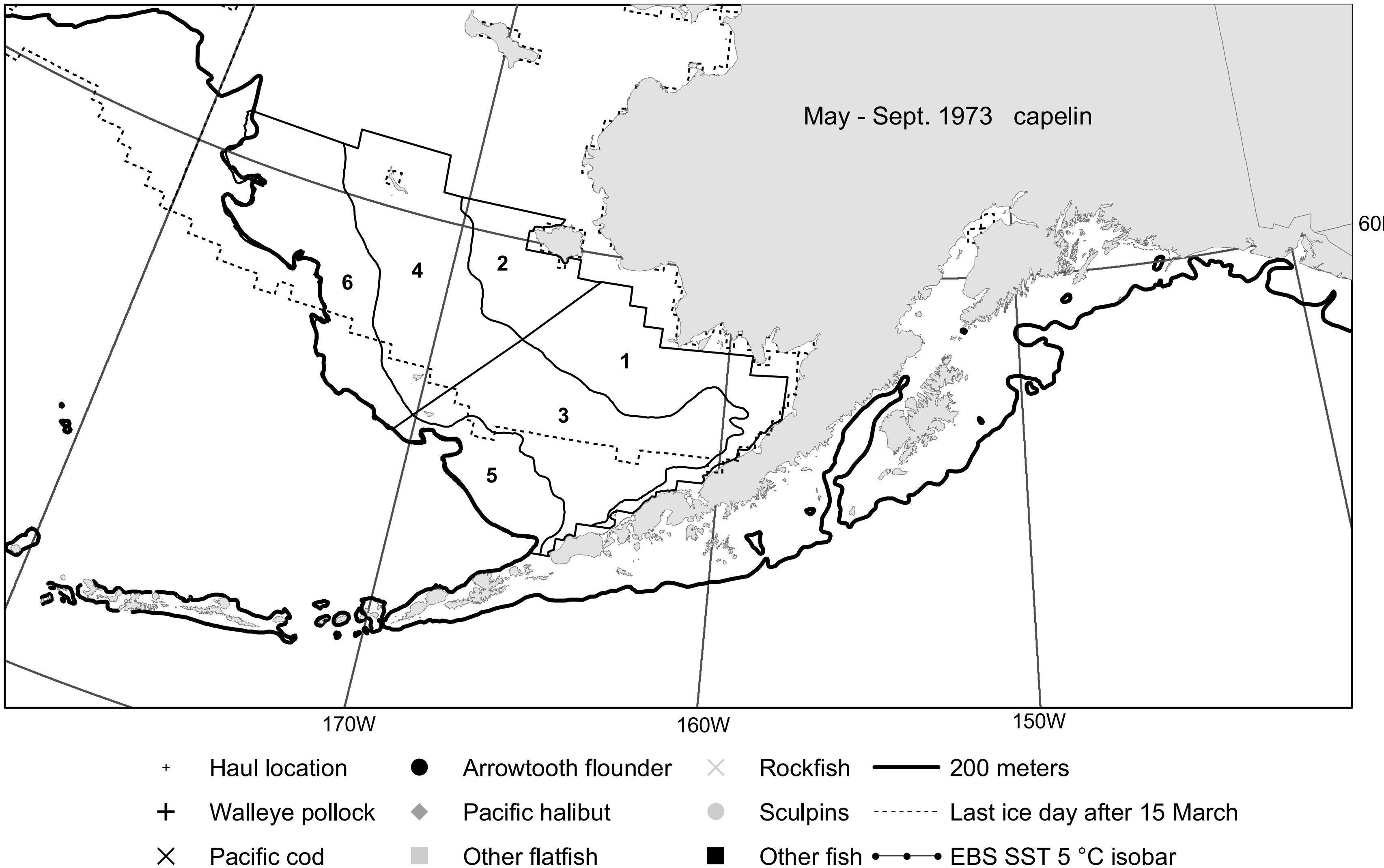

Figure 5.-- Geographic distribution of capelin consumed by groundfishes in 1973.
(no diet and temperature data available for this year)

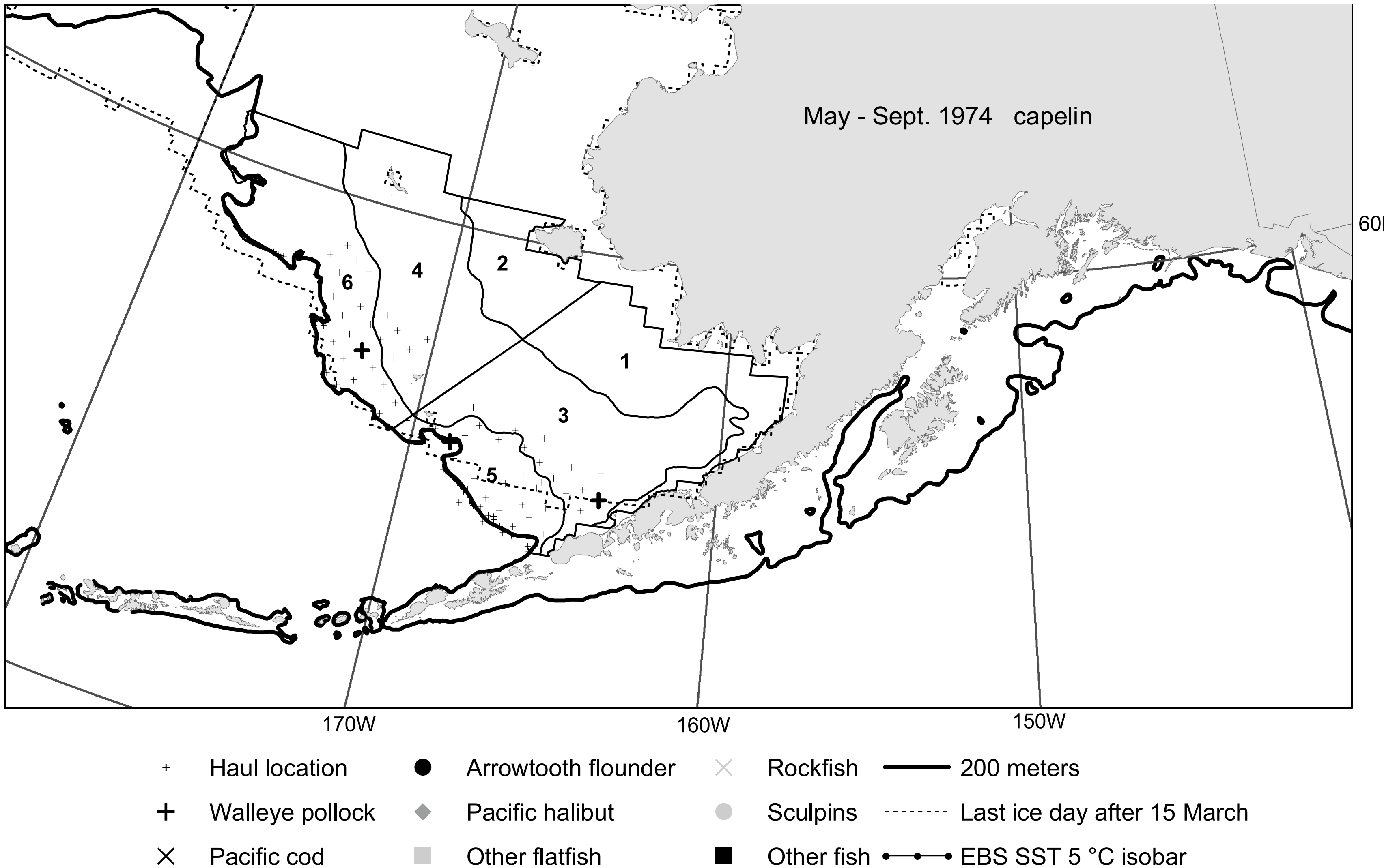

Figure 6.-- Geographic distribution of capelin consumed by groundfishes in 1974.

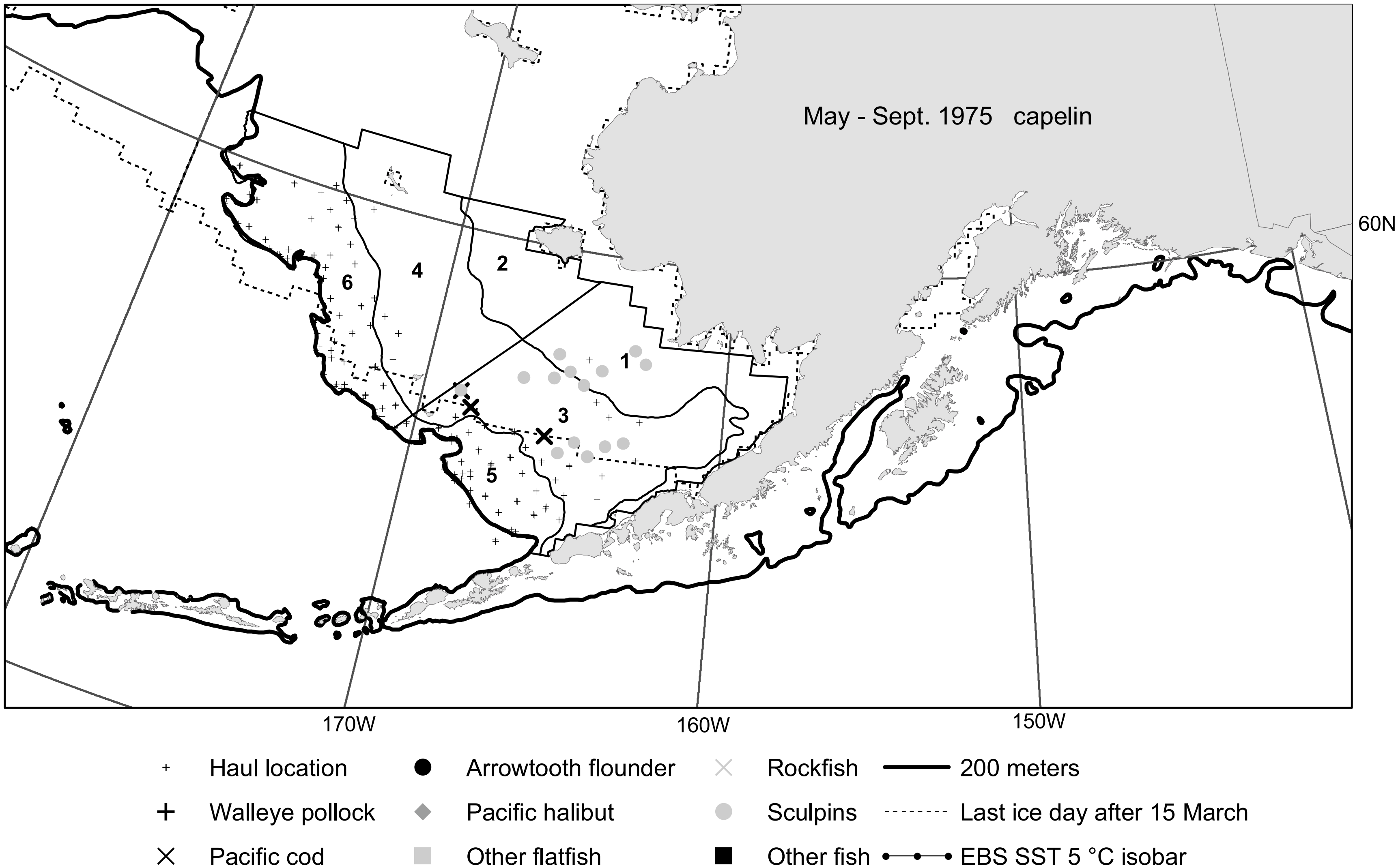

Figure 7.-- Geographic distribution of capelin consumed by groundfishes in 1975.

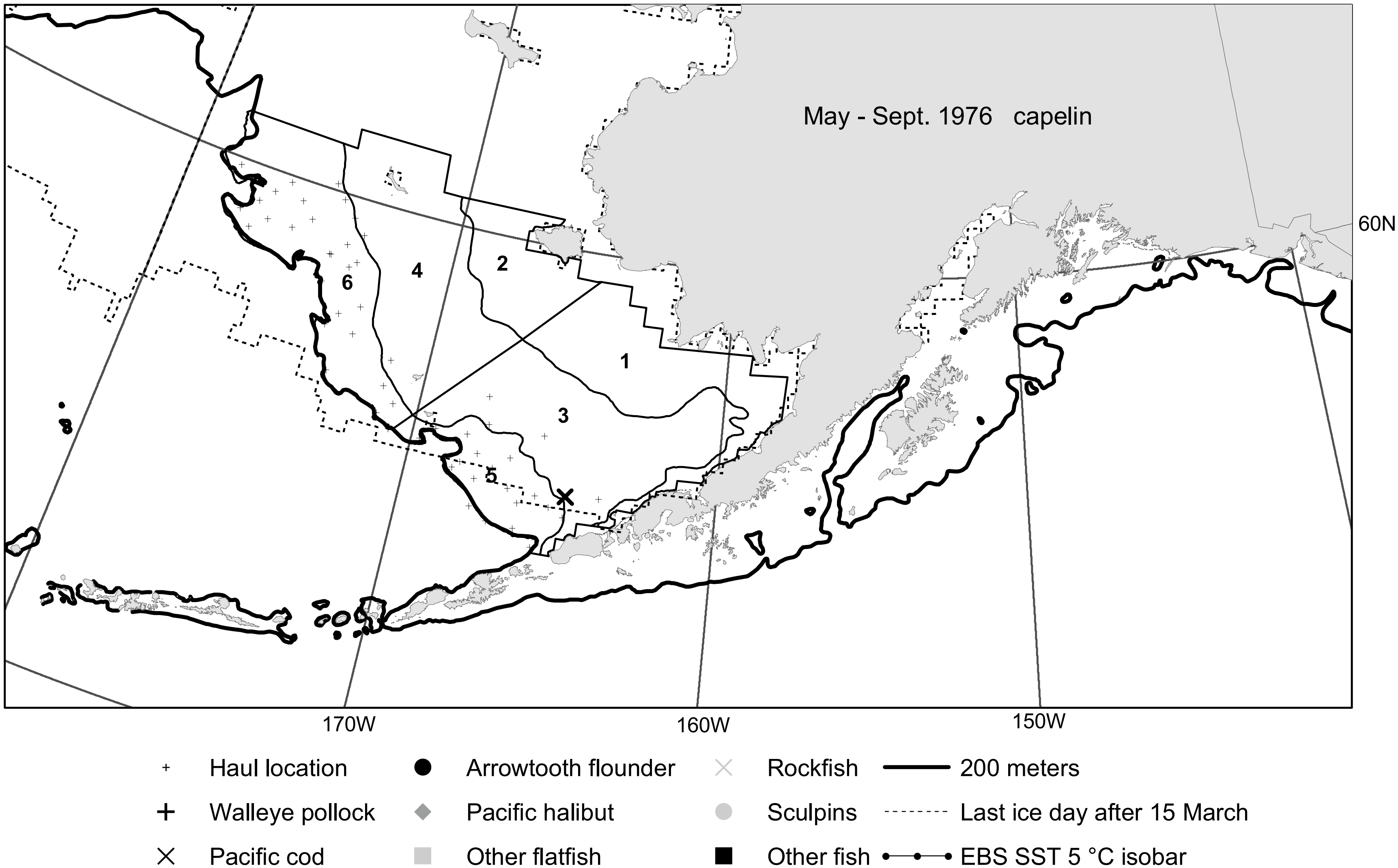

Figure 8.-- Geographic distribution of capelin consumed by groundfishes in 1976.

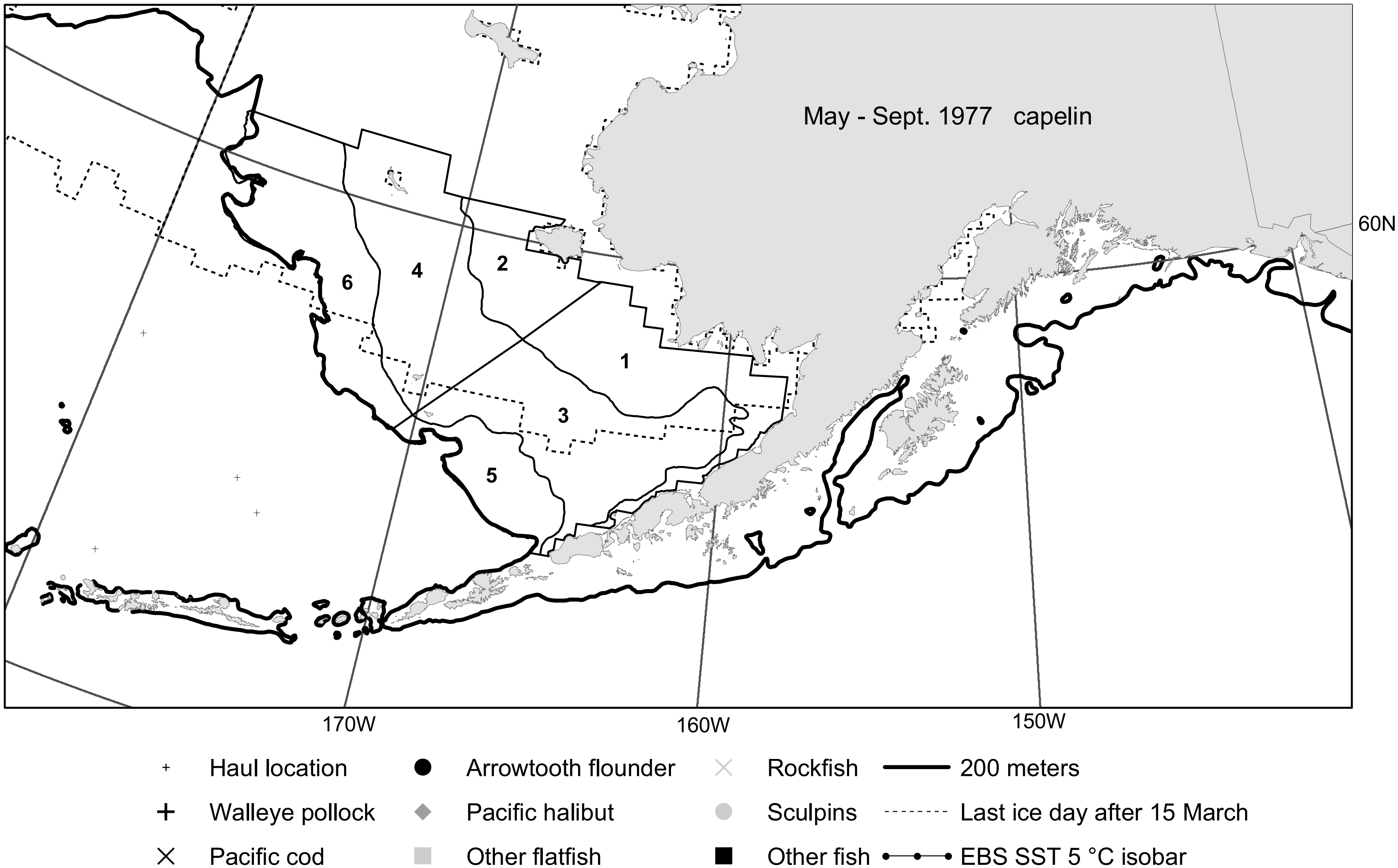

Figure 9.-- Geographic distribution of capelin consumed by groundfishes in 1977.

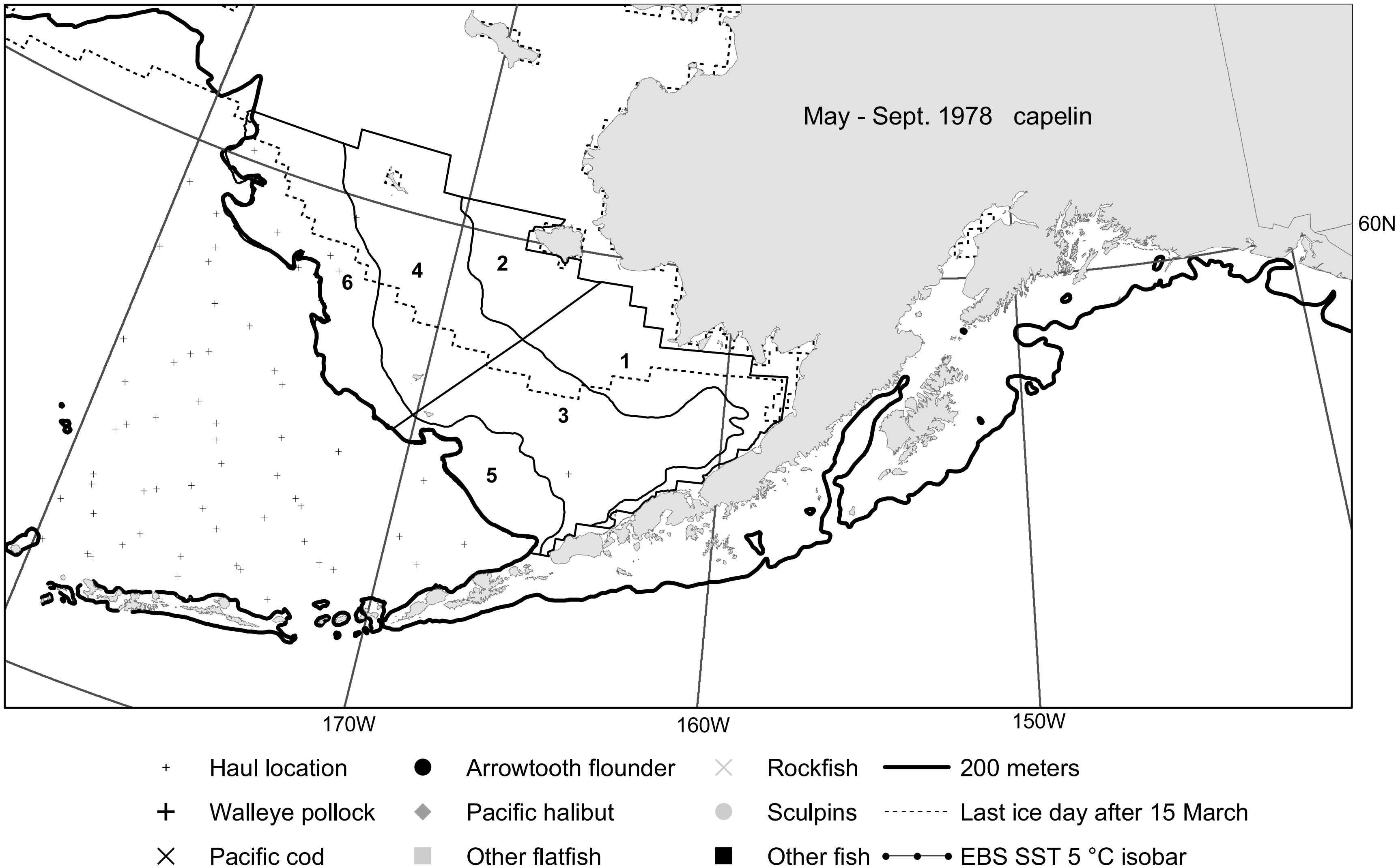

Figure 10.-- Geographic distribution of capelin consumed by groundfishes in 1978.

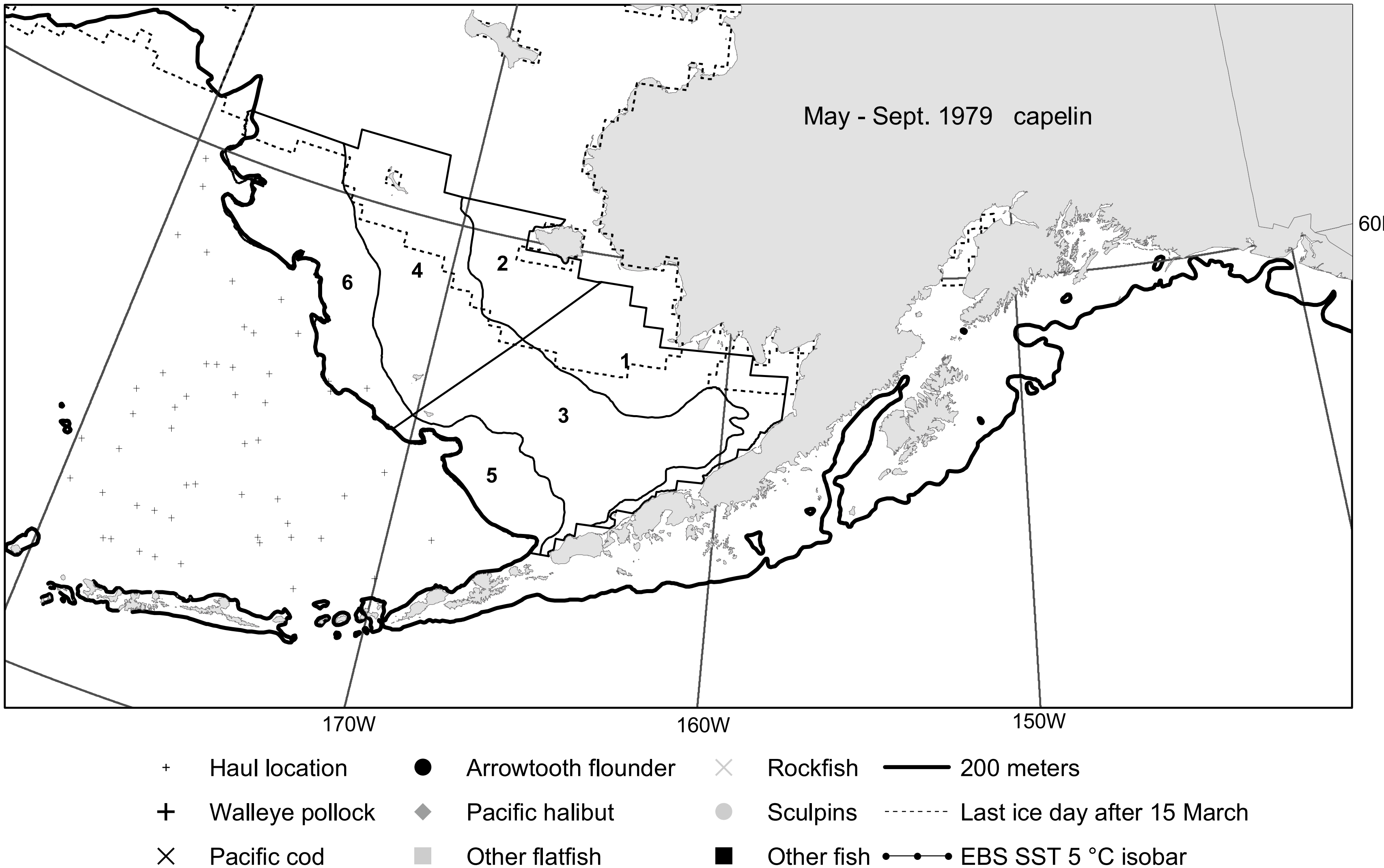

Figure 11.-- Geographic distribution of capelin consumed by groundfishes in 1979.

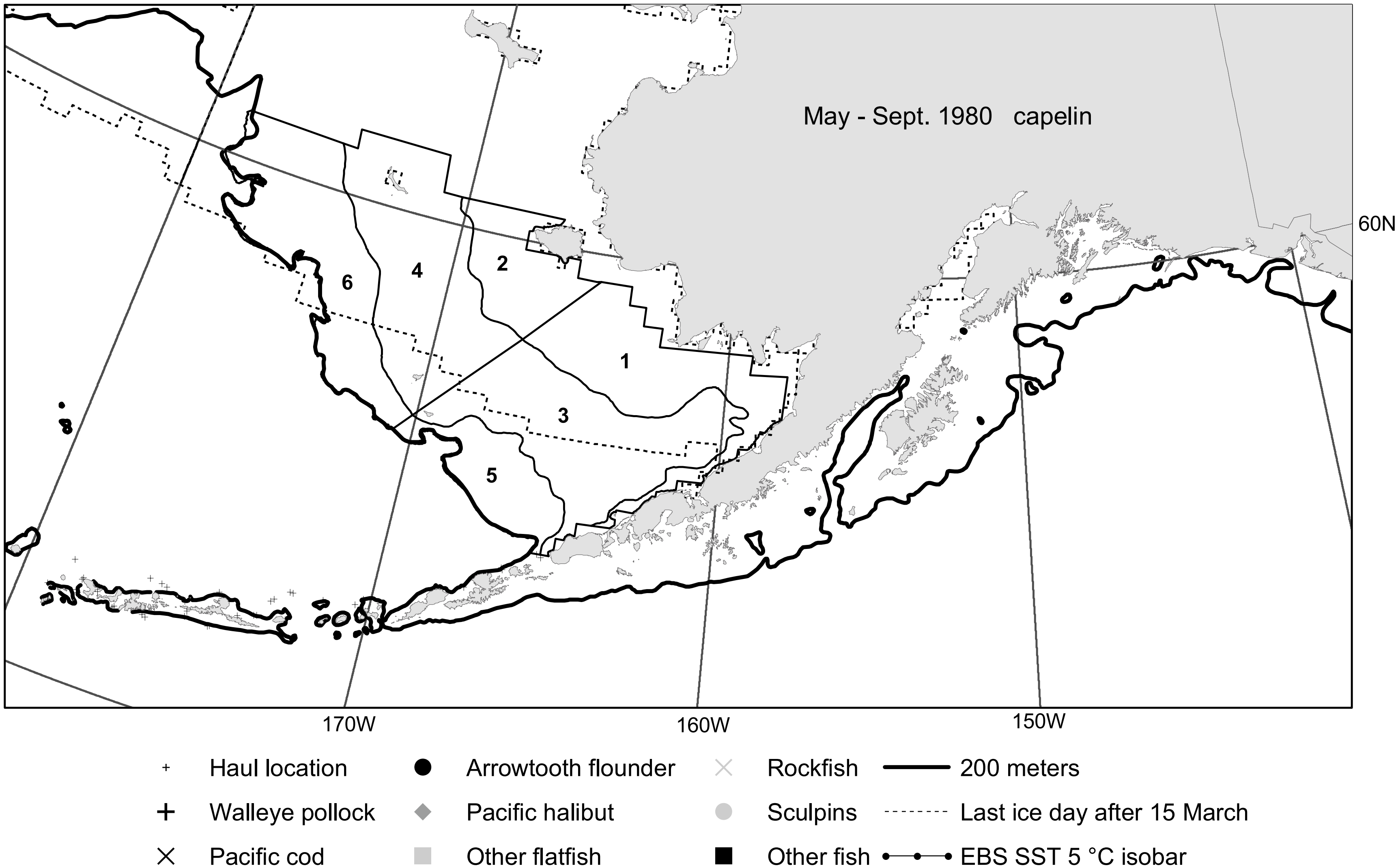

Figure 12.-- Geographic distribution of capelin consumed by groundfishes in 1980.

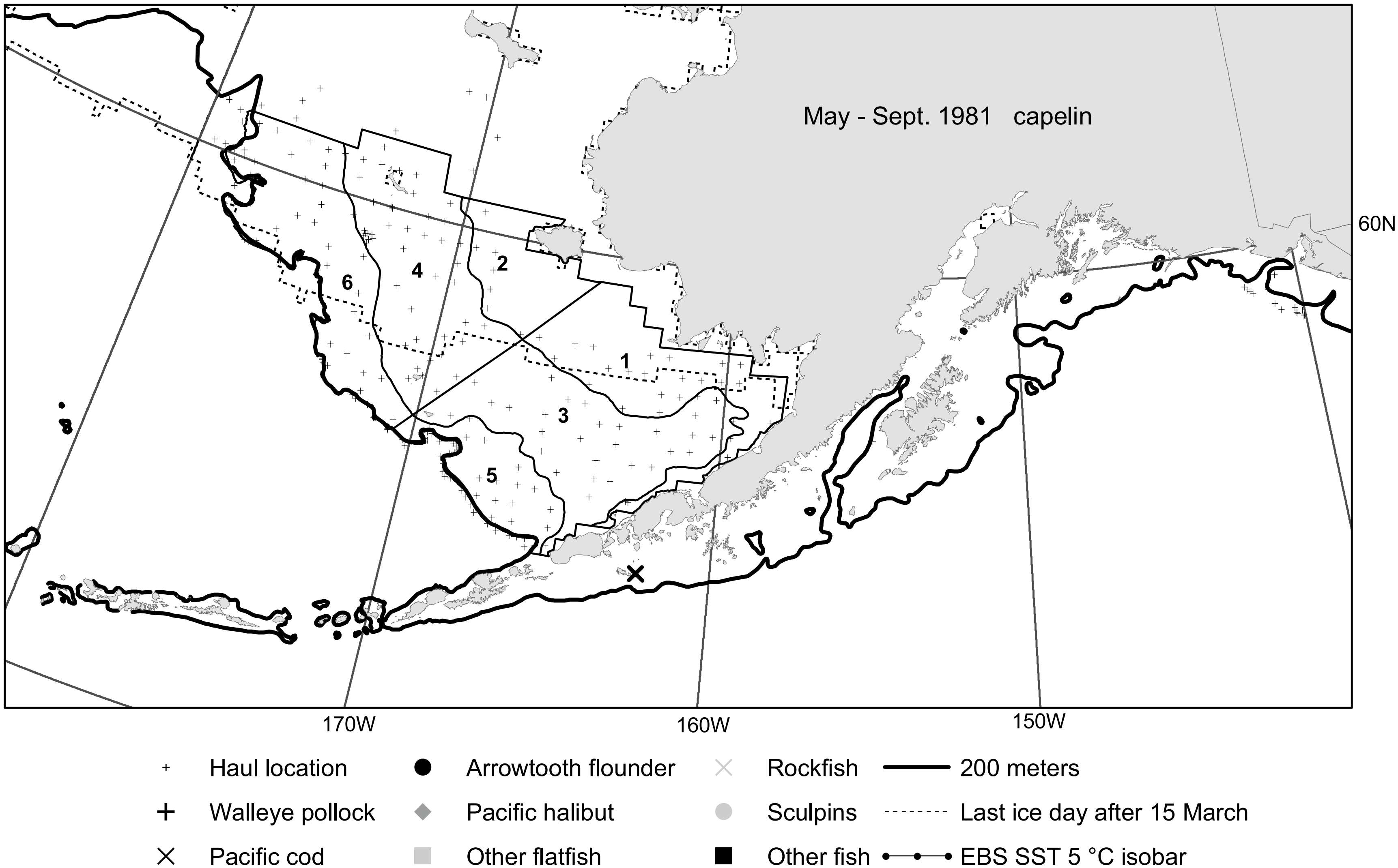

Figure 13.-- Geographic distribution of capelin consumed by groundfishes in 1981.

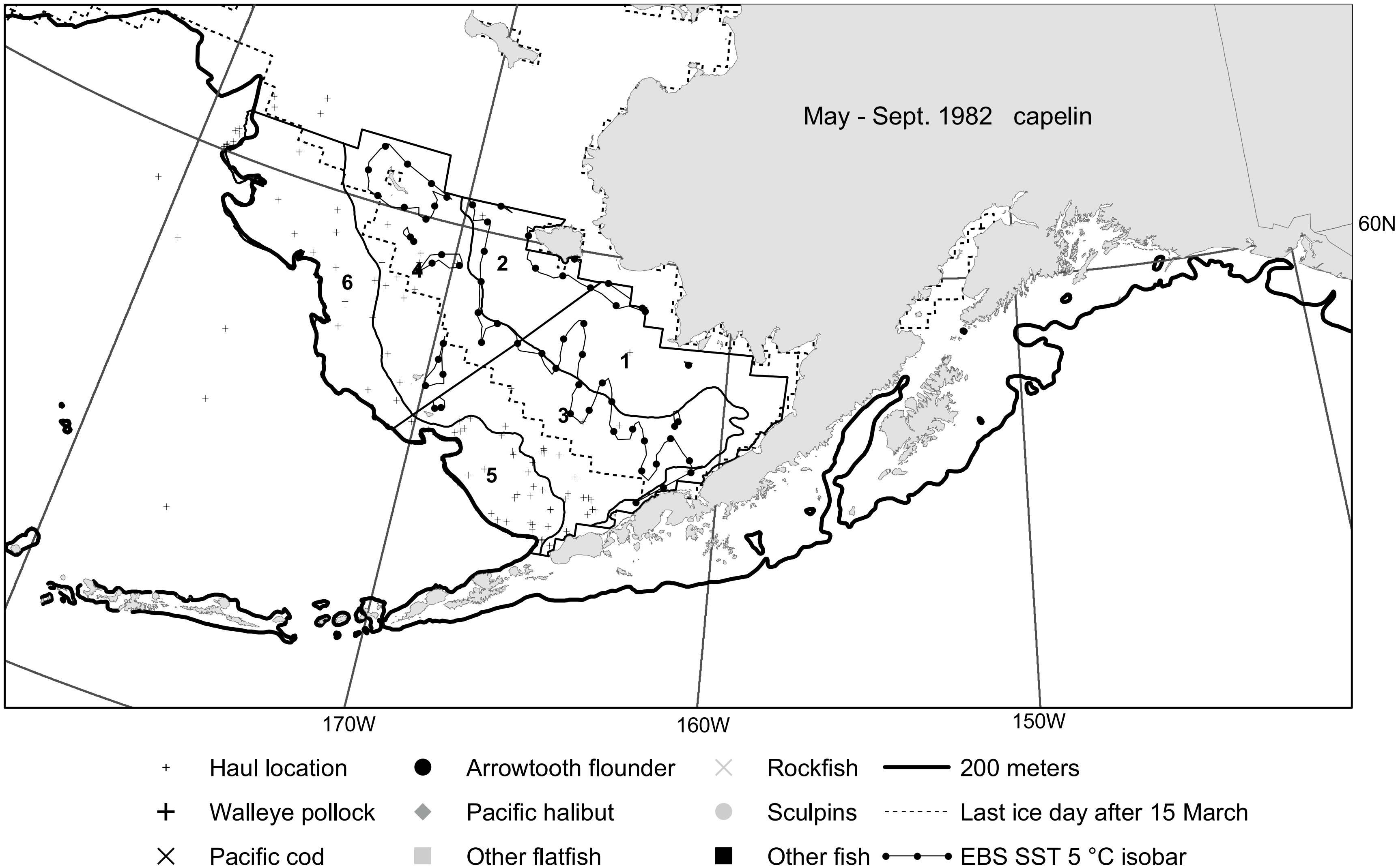

Figure 14.-- Geographic distribution of capelin consumed by groundfishes in 1982.

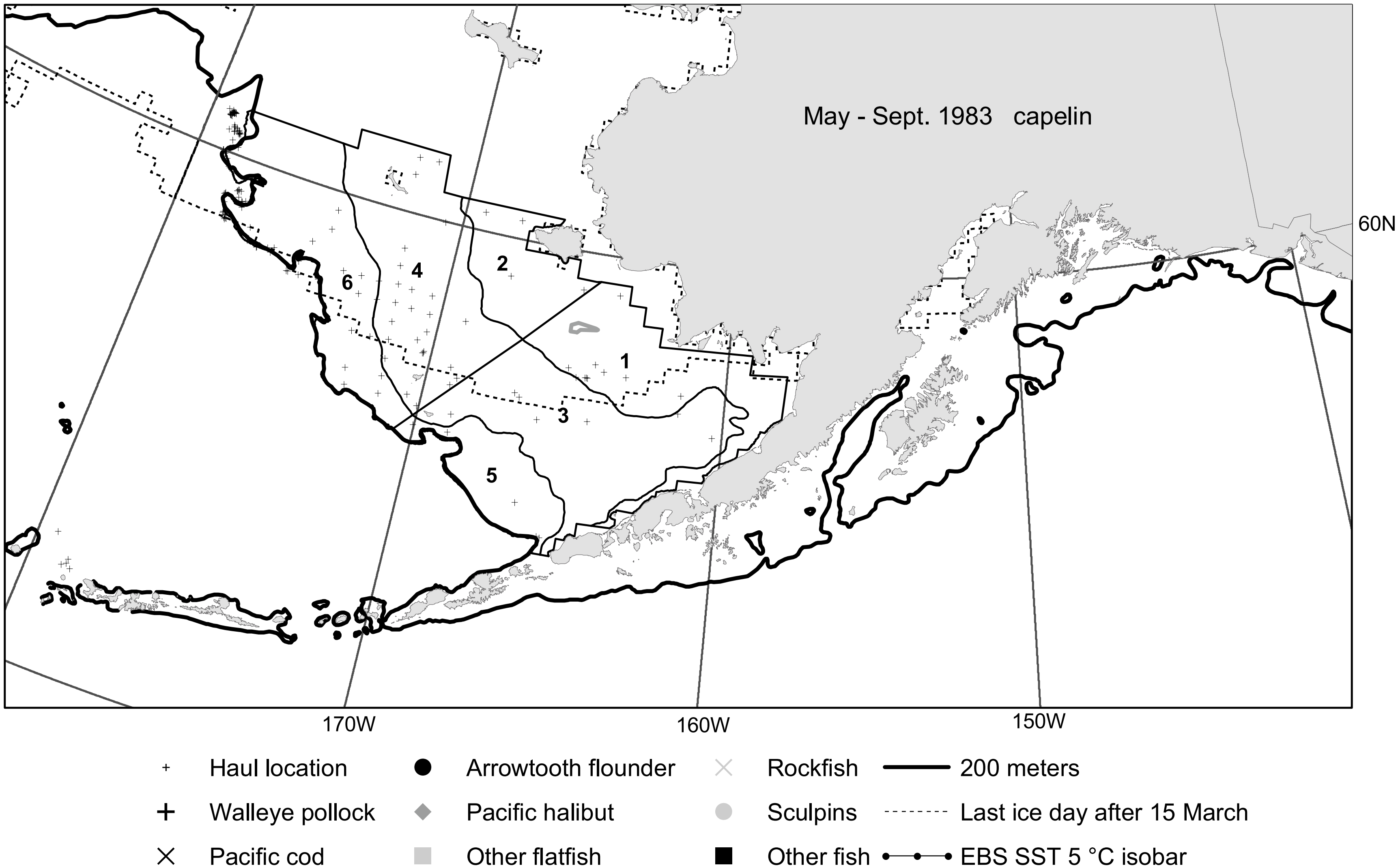

Figure 15.-- Geographic distribution of capelin consumed by groundfishes in 1983.

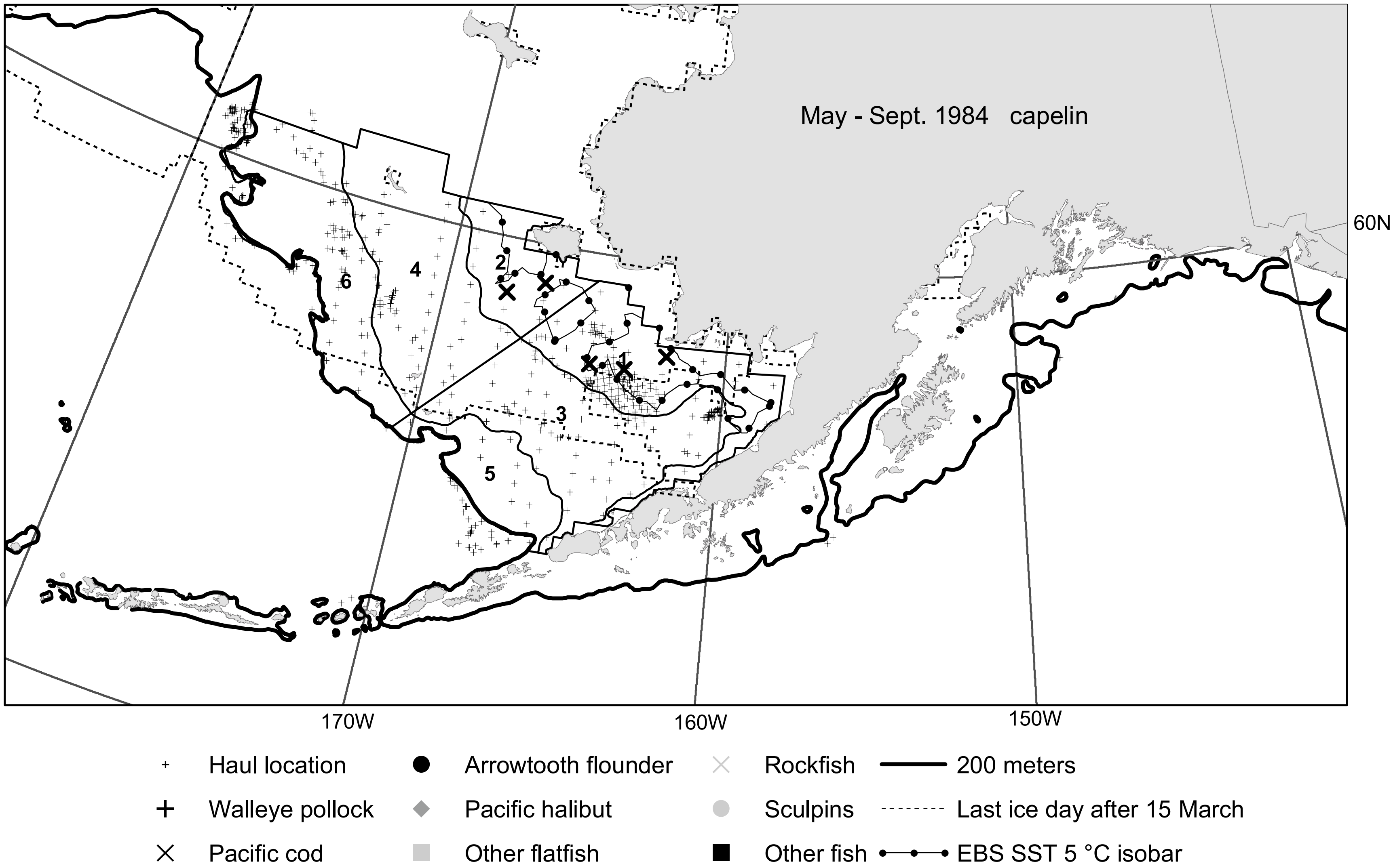

Figure 16.-- Geographic distribution of capelin consumed by groundfishes in 1984.

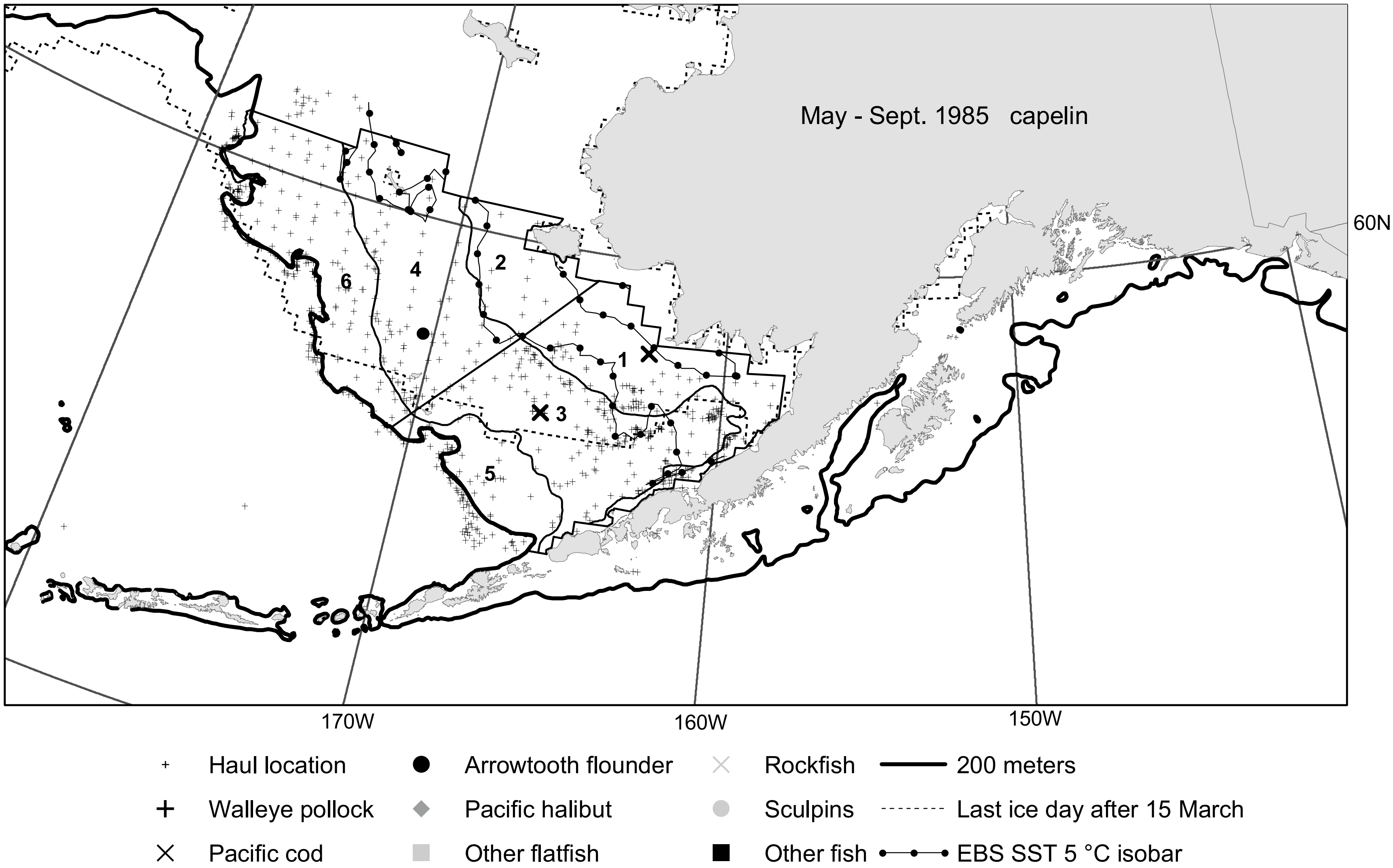

Figure 17.-- Geographic distribution of capelin consumed by groundfishes in 1985.

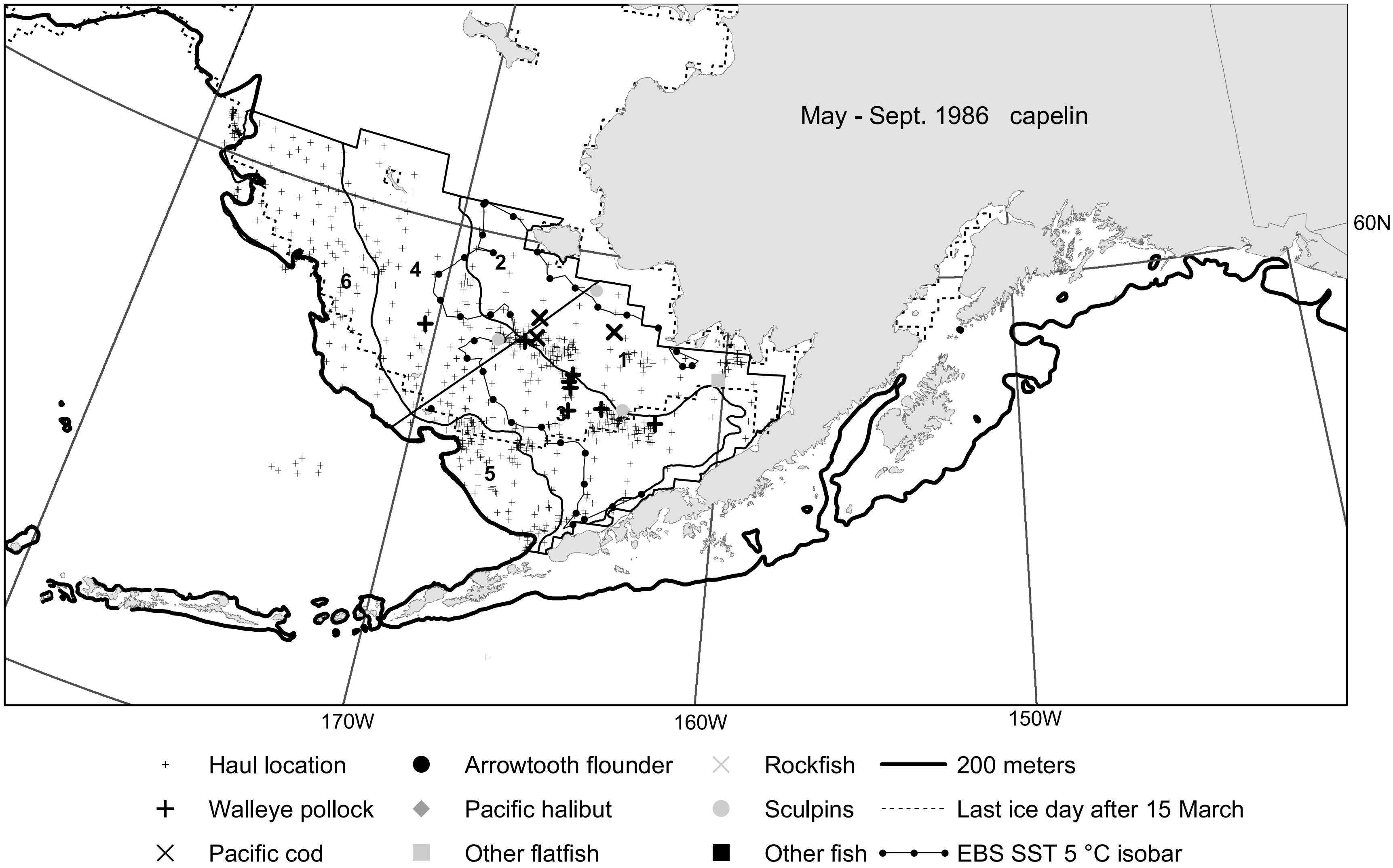

Figure 18.-- Geographic distribution of capelin consumed by groundfishes in 1986.

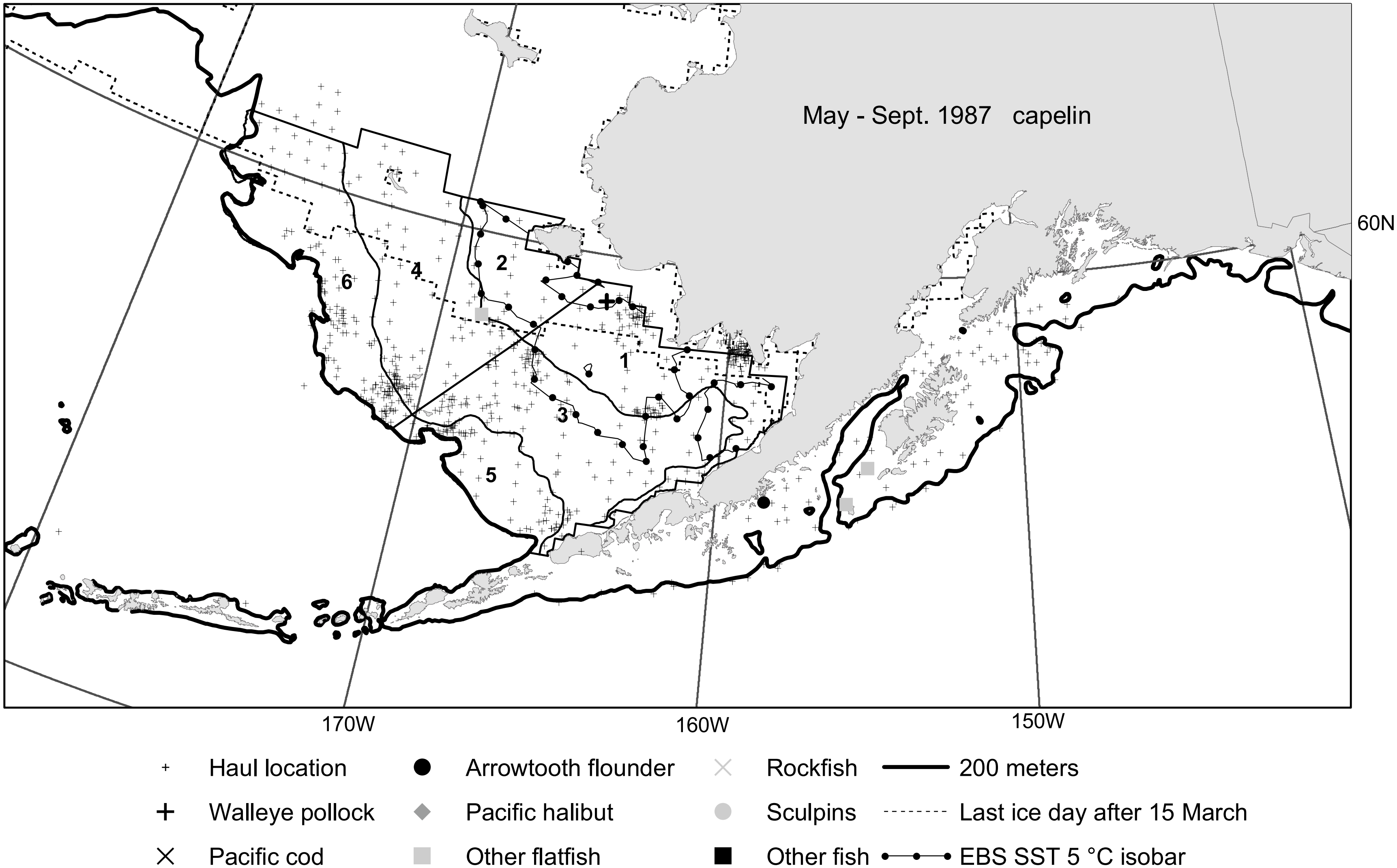

Figure 19.-- Geographic distribution of capelin consumed by groundfishes in 1987.

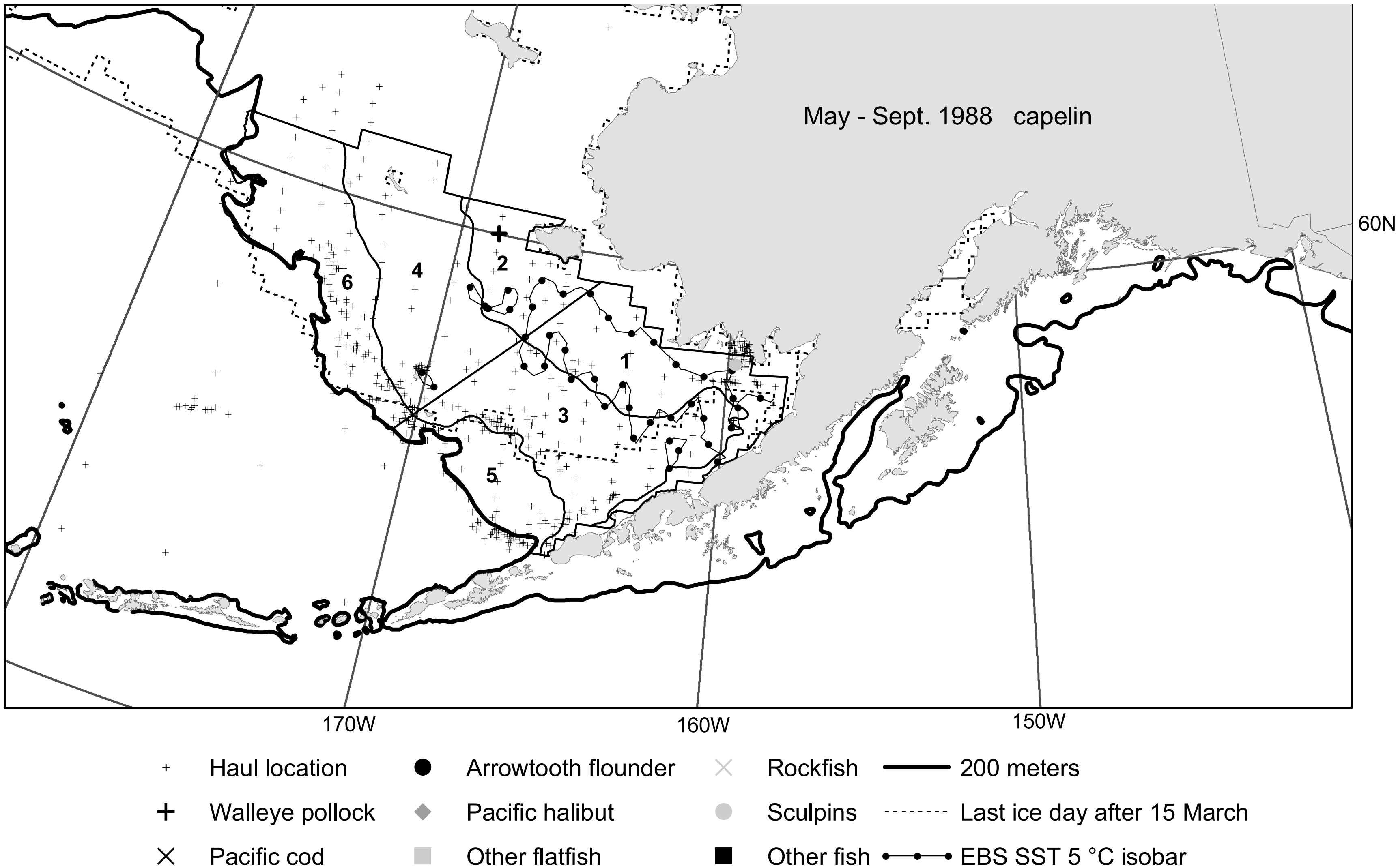

Figure 20.-- Geographic distribution of capelin consumed by groundfishes in 1988.

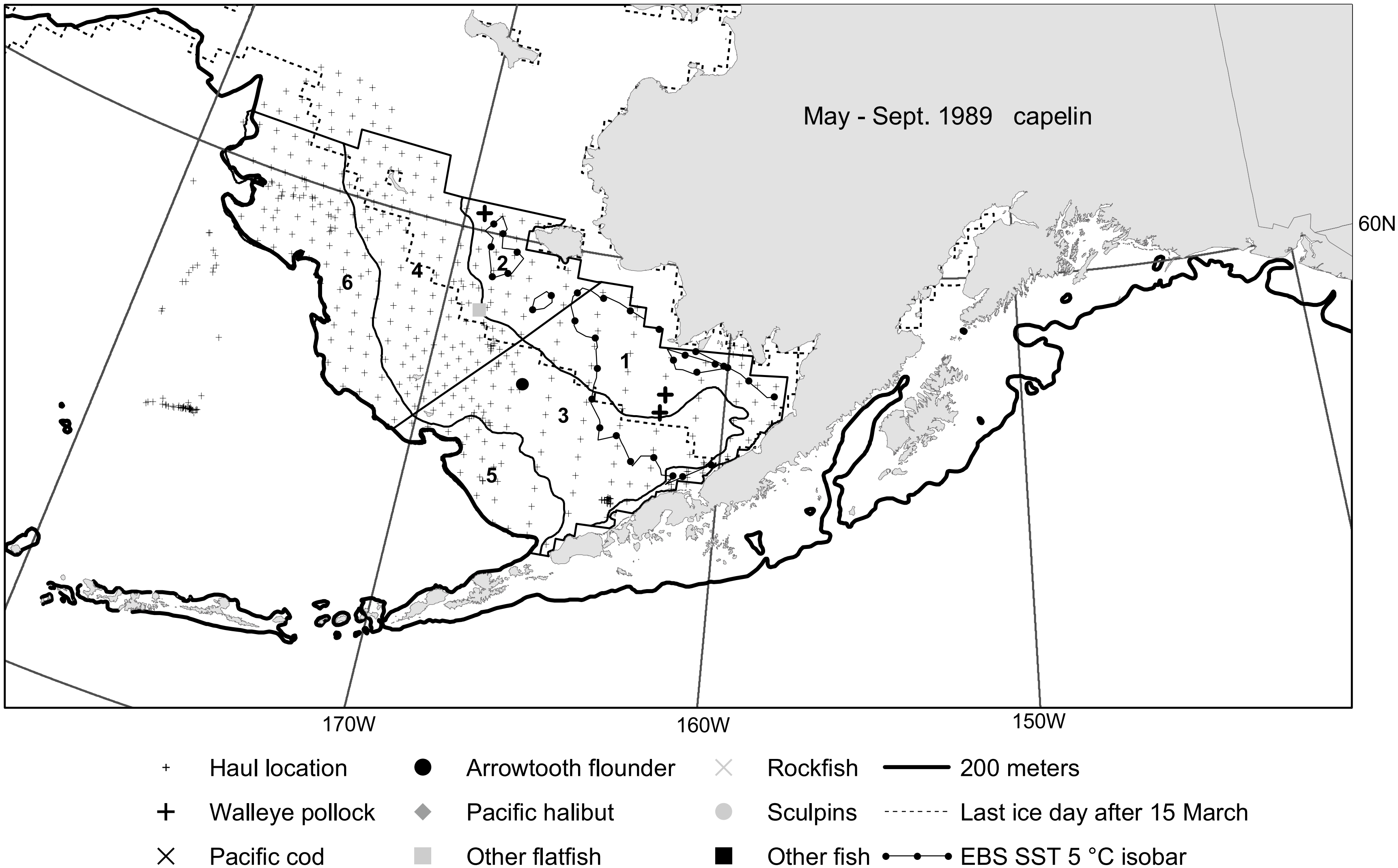

Figure 21.-- Geographic distribution of capelin consumed by groundfishes in 1989.

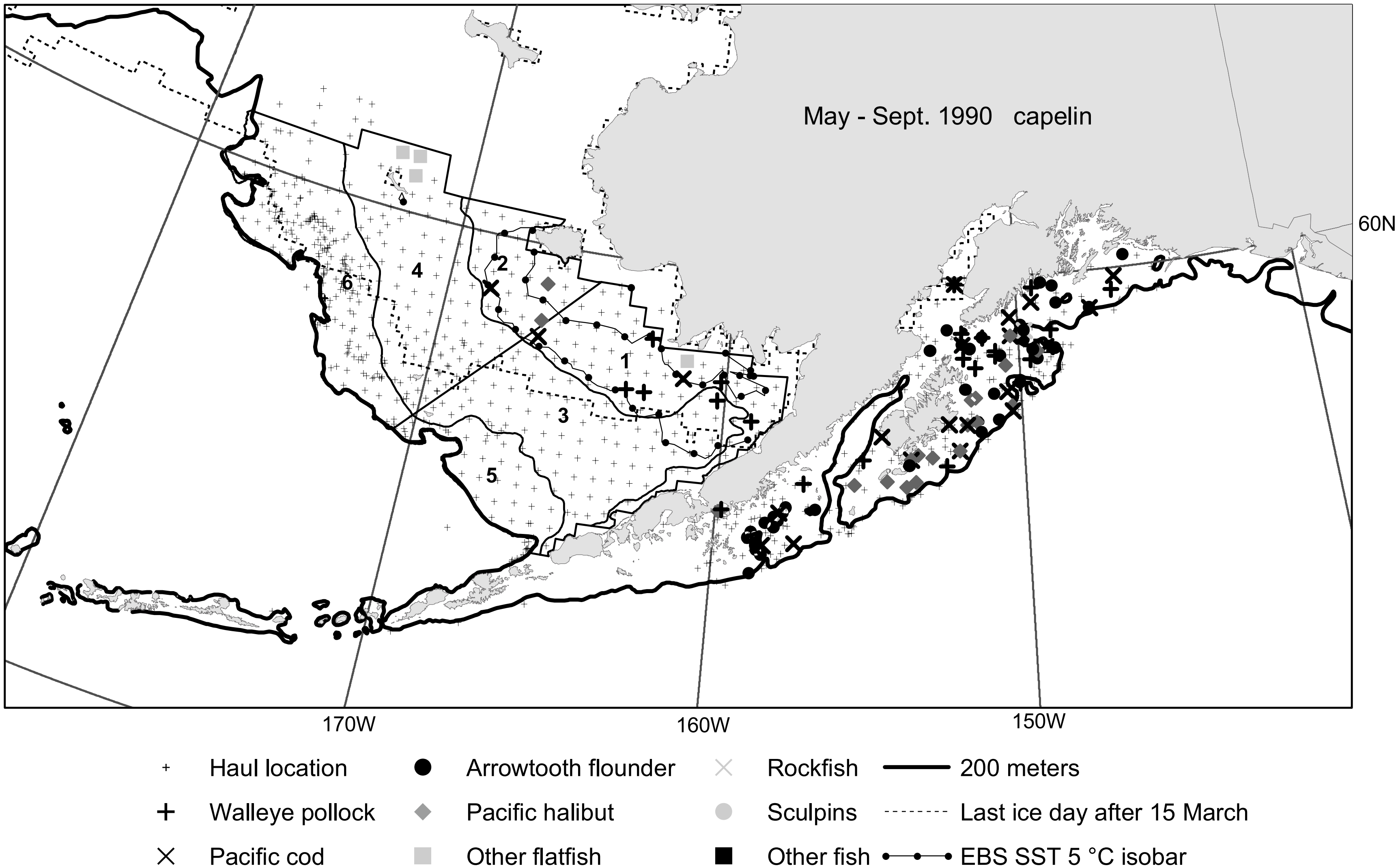

Figure 22.-- Geographic distribution of capelin consumed by groundfishes in 1990.

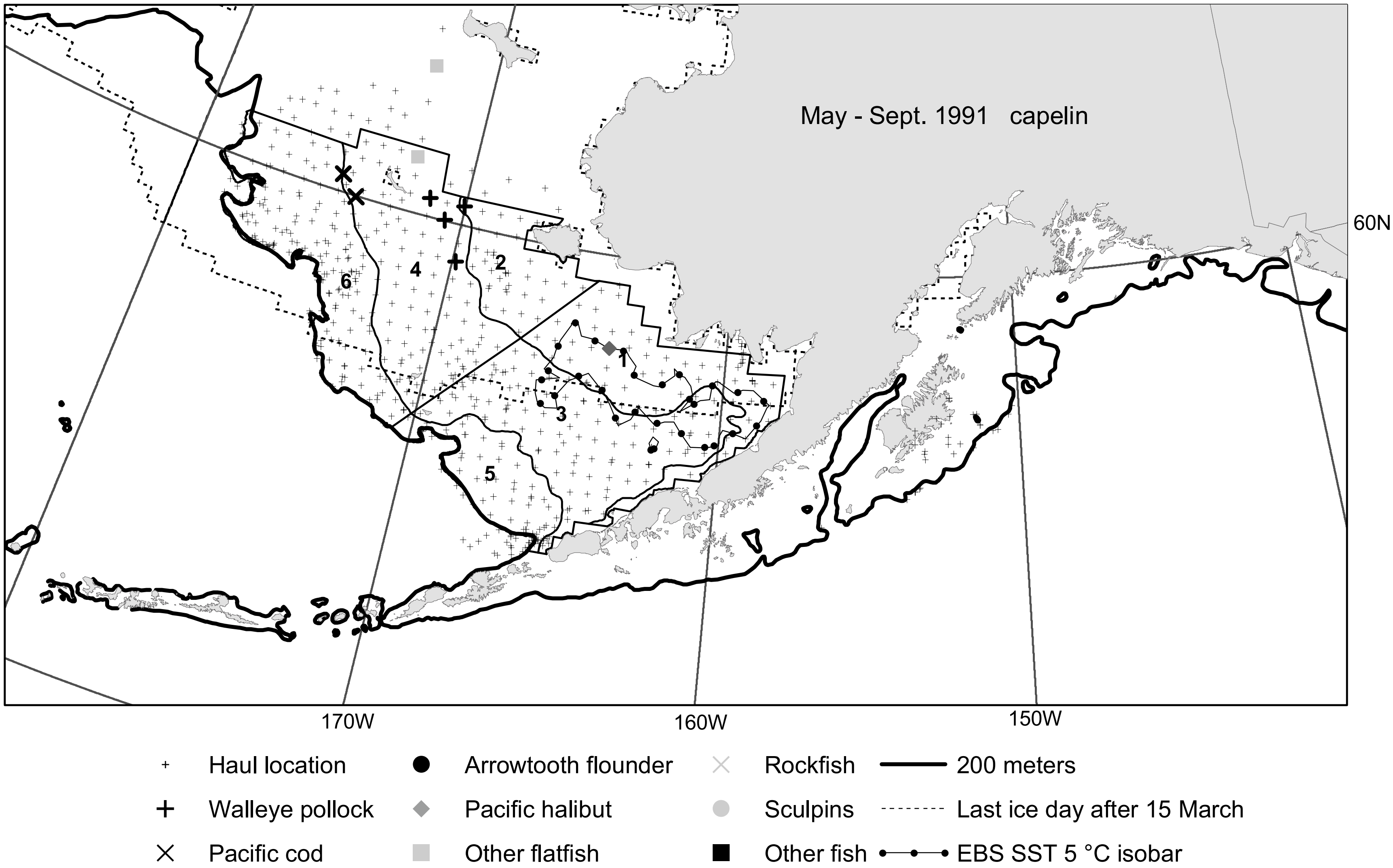

Figure 23.-- Geographic distribution of capelin consumed by groundfishes in 1991.

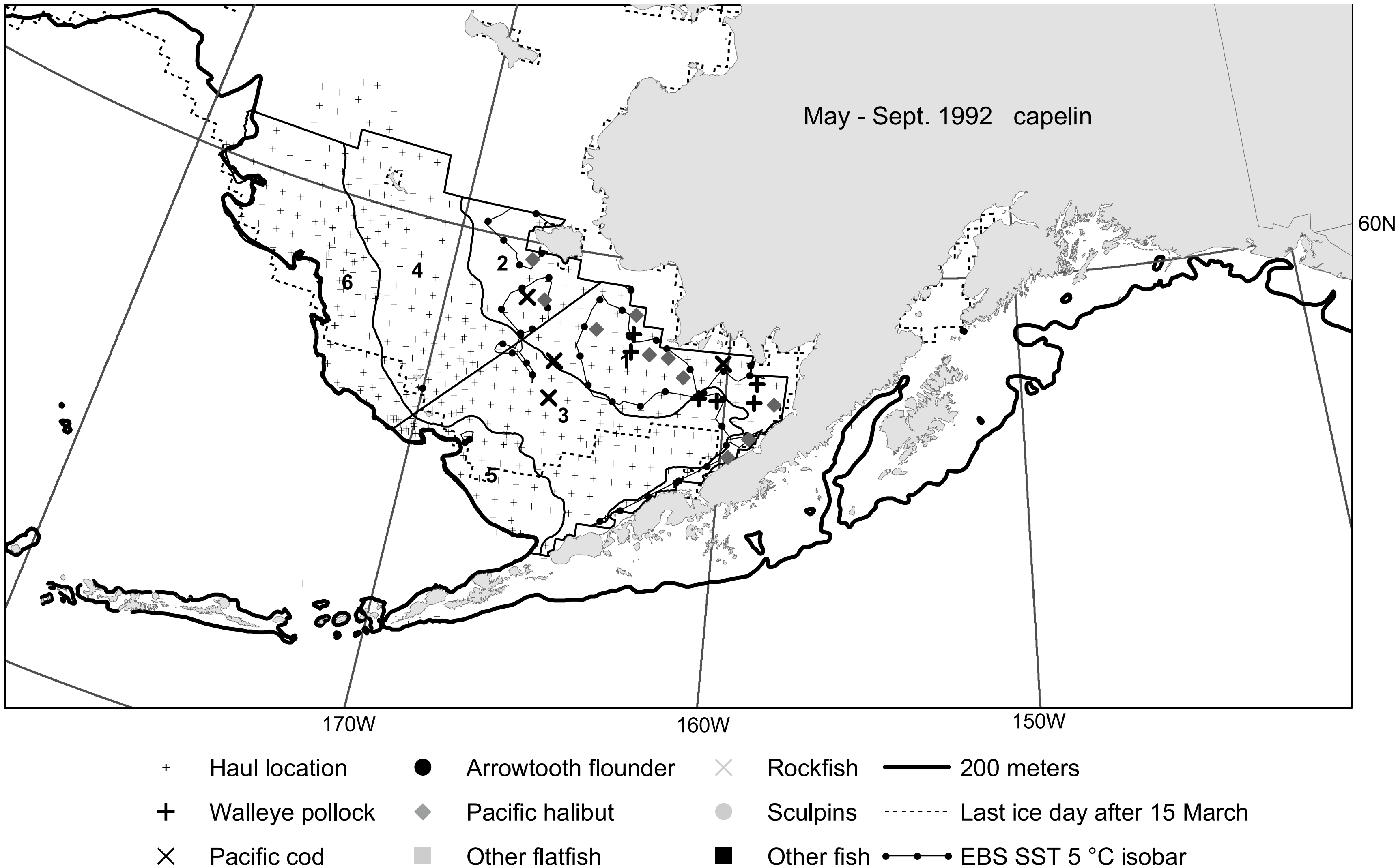

Figure 24.-- Geographic distribution of capelin consumed by groundfishes in 1992.

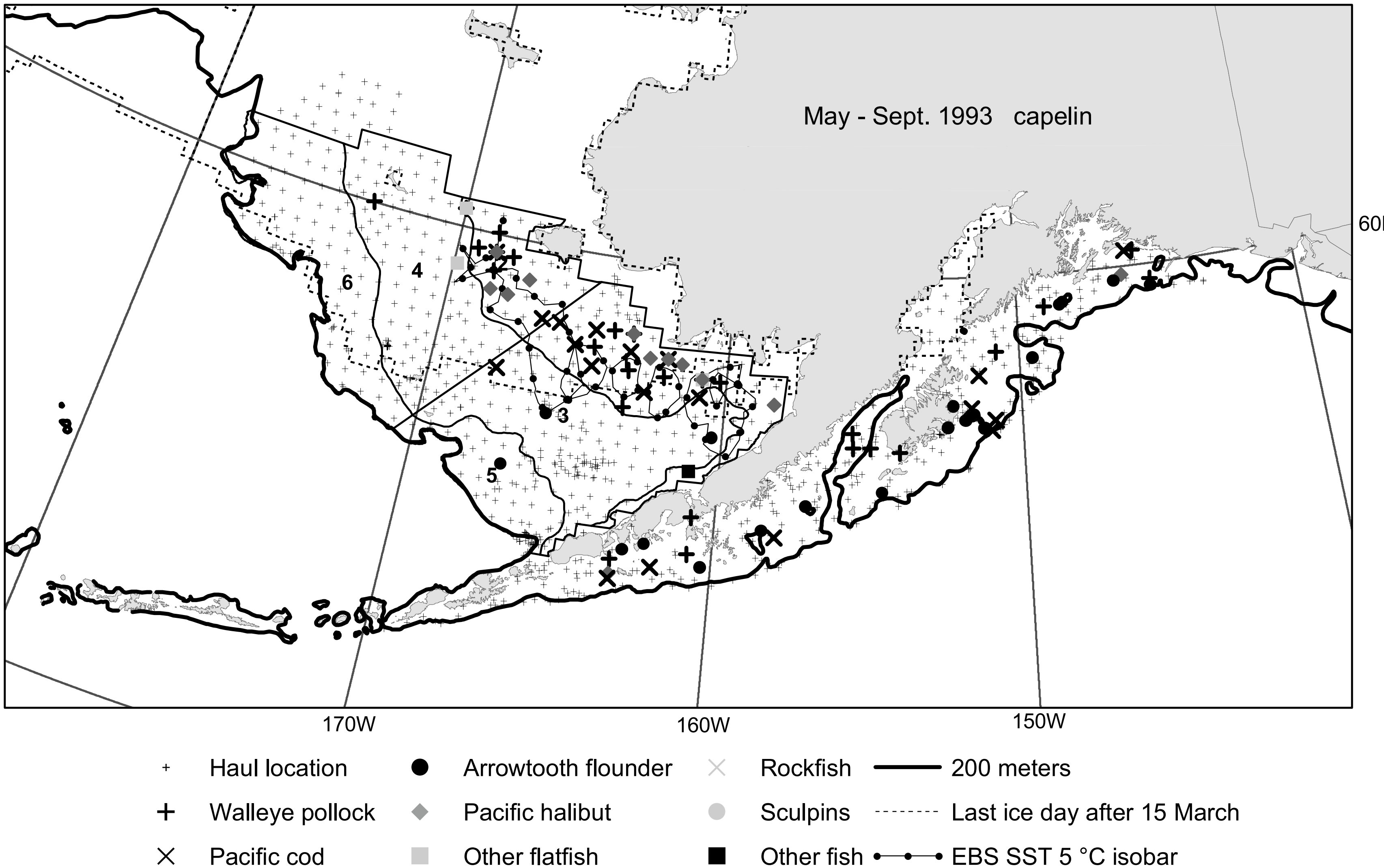

Figure 25.-- Geographic distribution of capelin consumed by groundfishes in 1993.

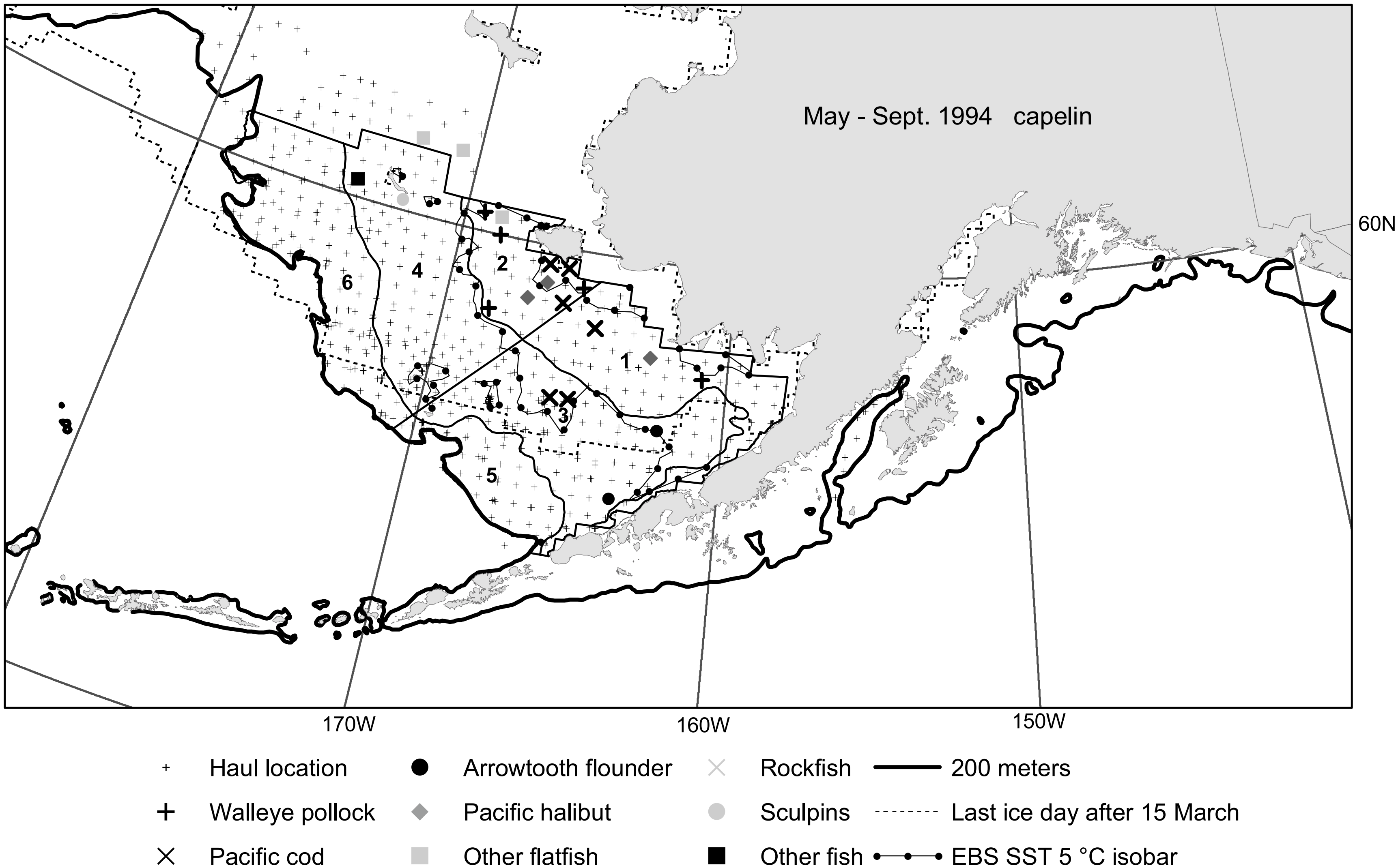

Figure 26.-- Geographic distribution of capelin consumed by groundfishes in 1994.

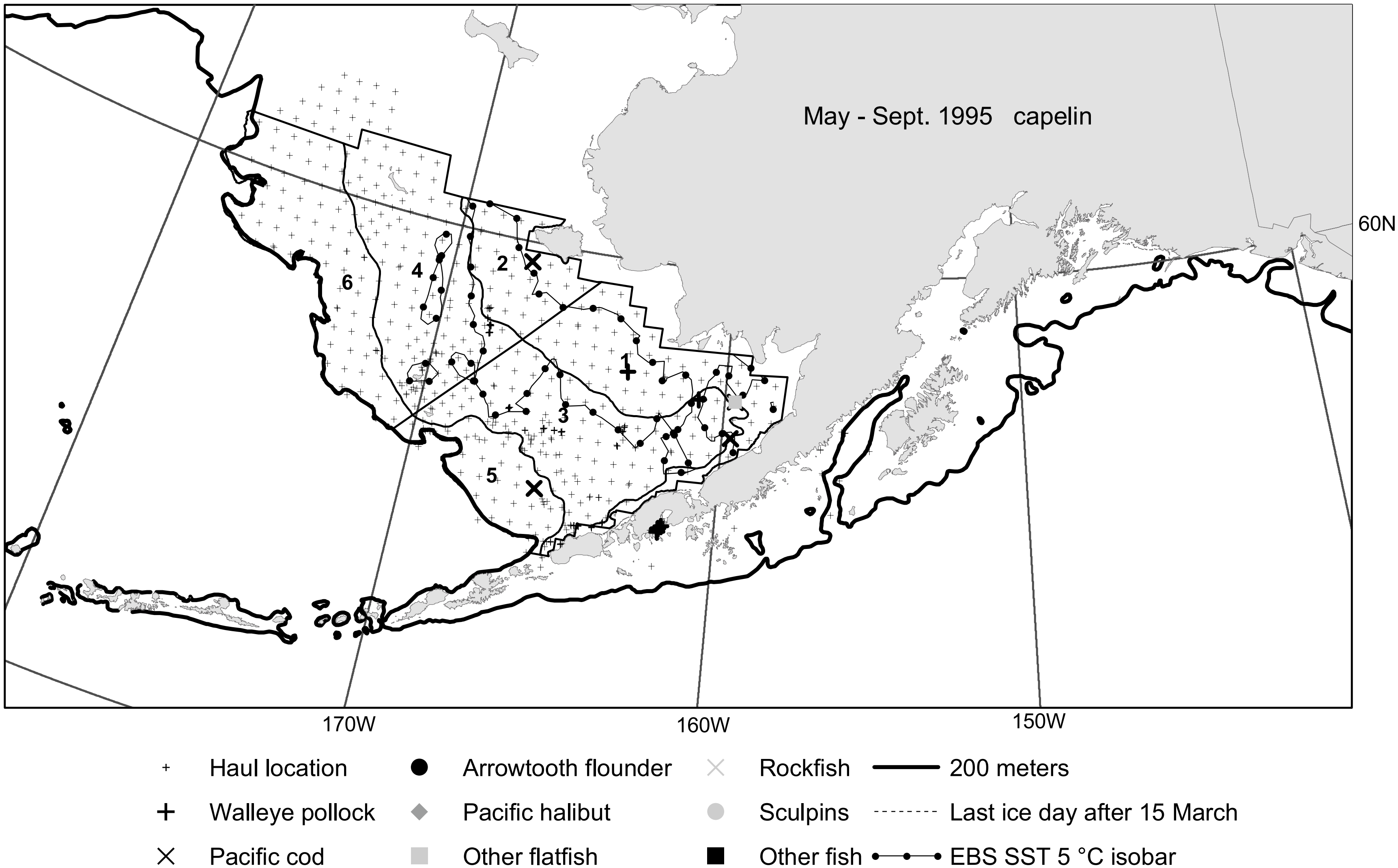

Figure 27.-- Geographic distribution of capelin consumed by groundfishes in 1995.
(no ice data available for this year)

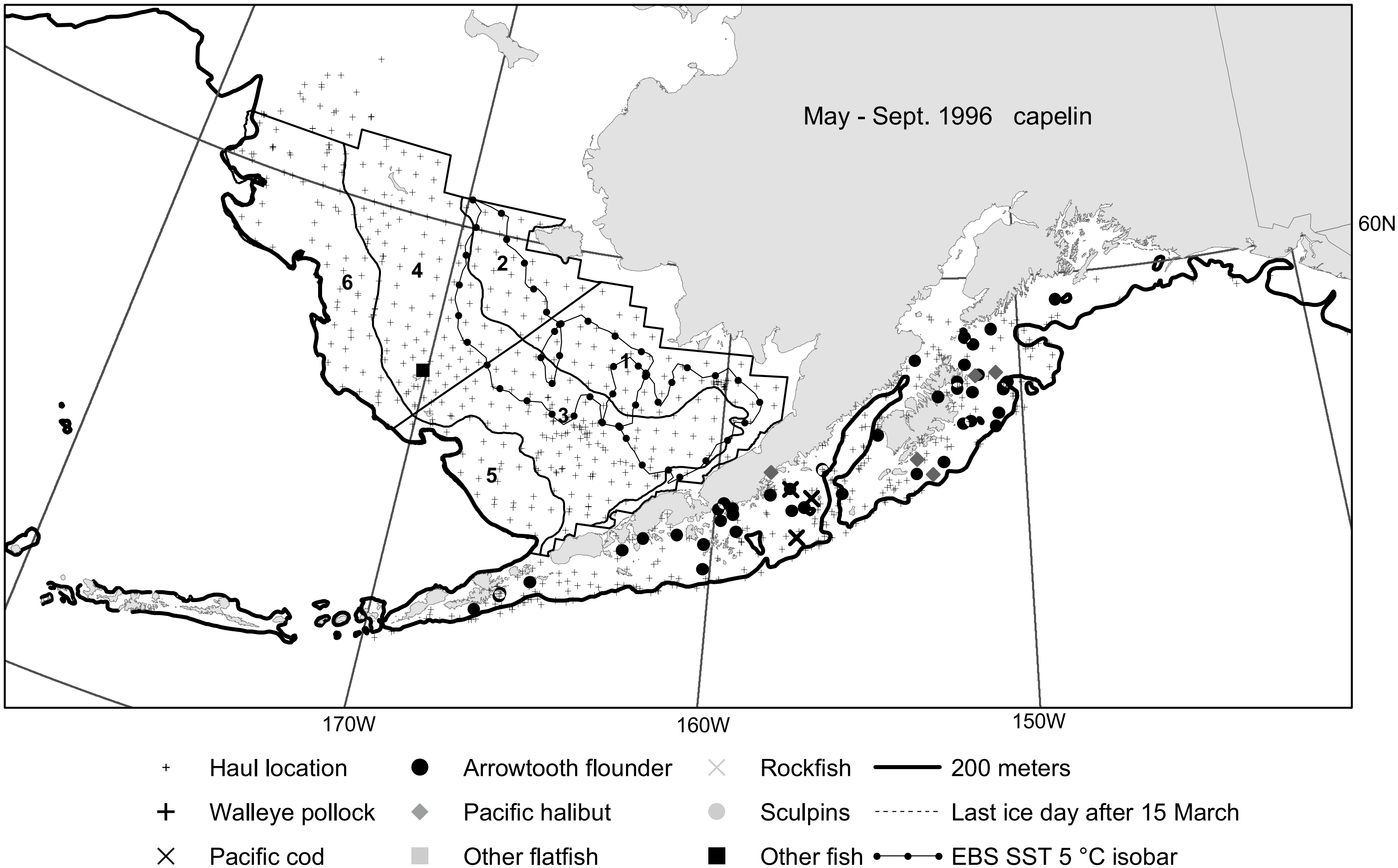

Figure 28.-- Geographic distribution of capelin consumed by groundfishes in 1996.

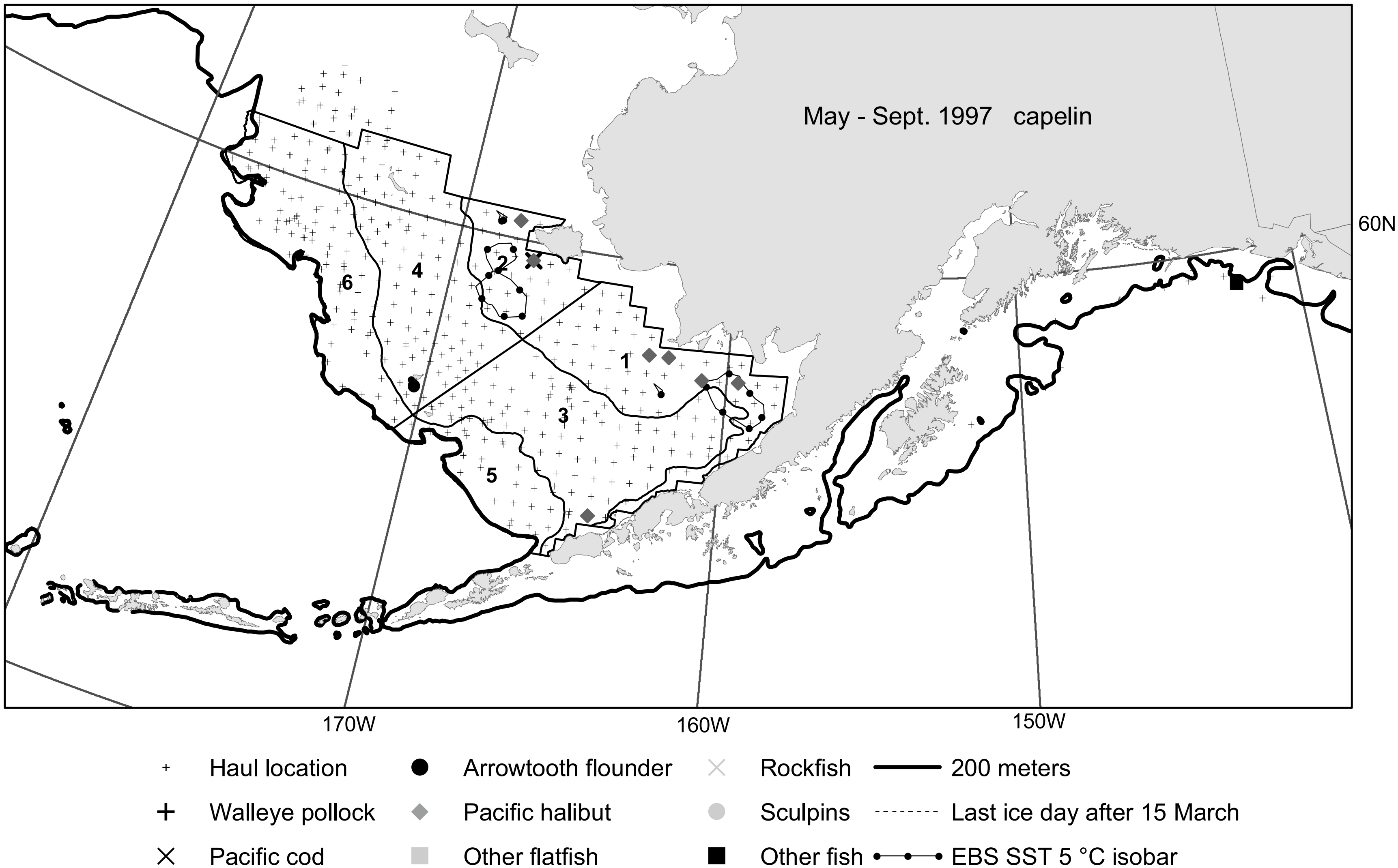

Figure 29.-- Geographic distribution of capelin consumed by groundfishes in 1997.

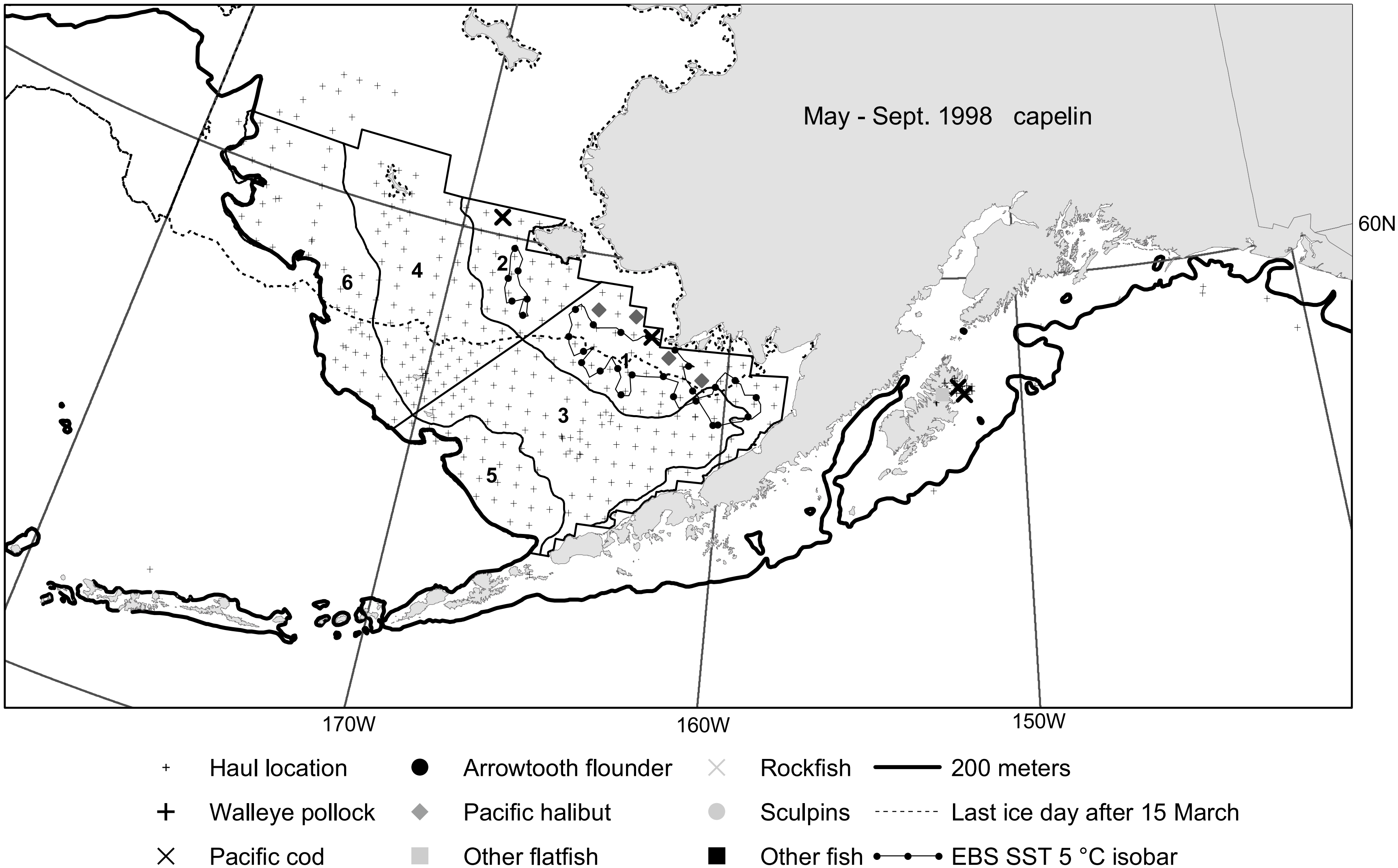

Figure 30.-- Geographic distribution of capelin consumed by groundfishes in 1998.

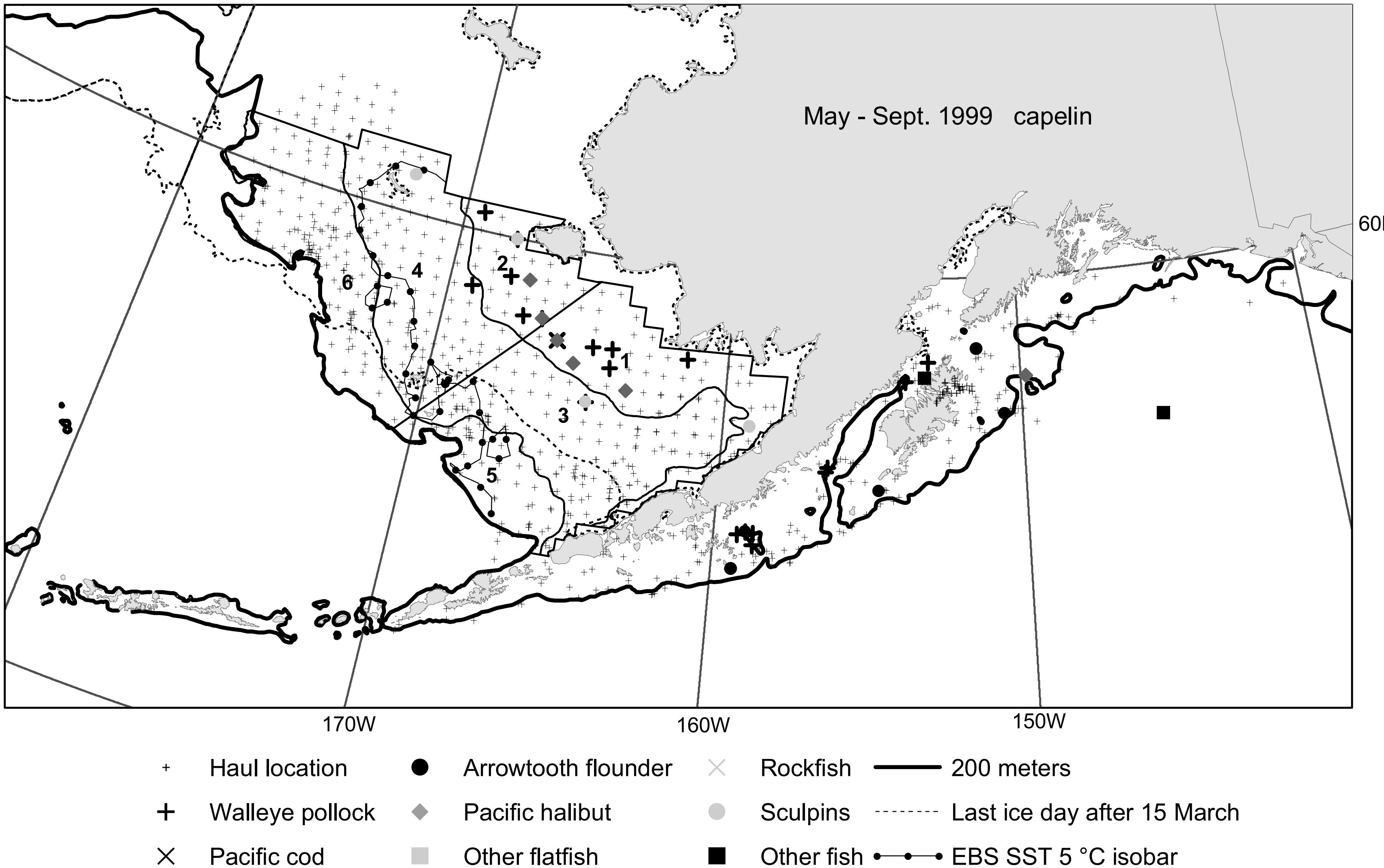

Figure 31.-- Geographic distribution of capelin consumed by groundfishes in 1999.

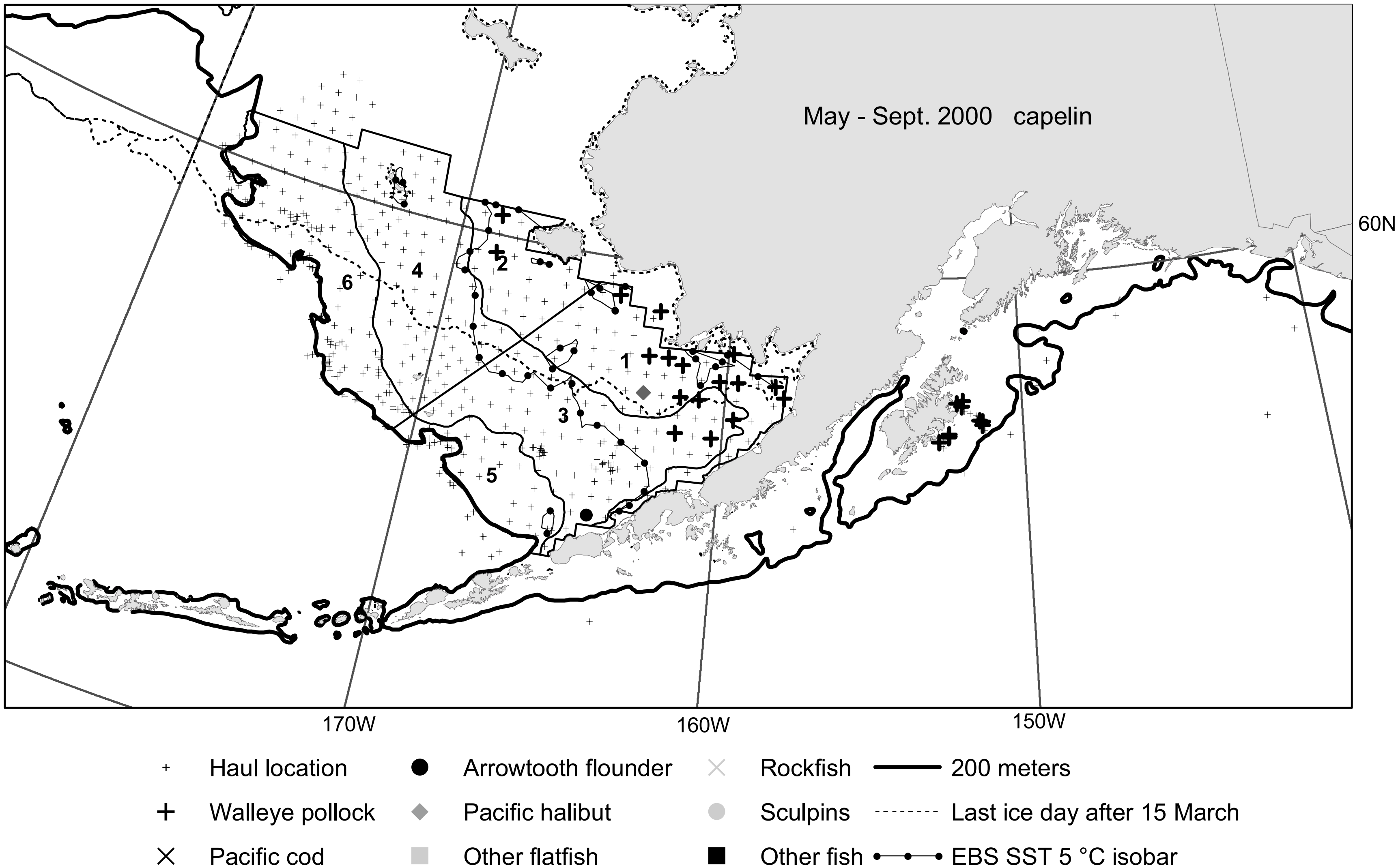

Figure 32.-- Geographic distribution of capelin consumed by groundfishes in 2000.

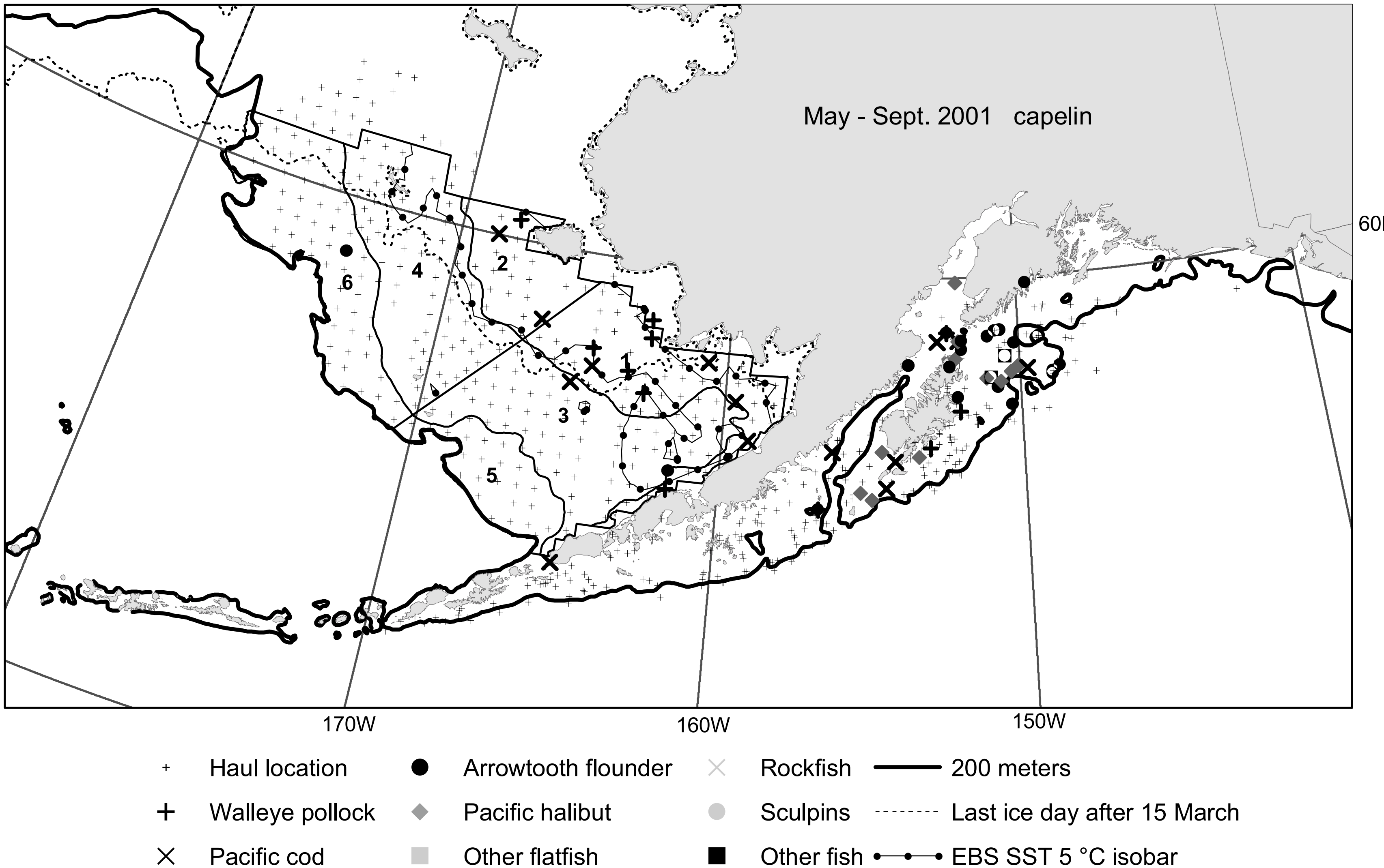

Figure 33.-- Geographic distribution of capelin consumed by groundfishes in 2001.

Beginning in 1990, stomach samples were also collected in the Gulf of Alaska every 3 years during the RACE summer trawl surveys (Figs. 22-31). During this period, capelin was found frequently in stomach samples. The occurrence of capelin in the stomachs decreased dramatically for GOA in 1999 (Fig. 31). Capelin was also found in the eastern Bering Sea area during the 1990s, especially in 1993 when higher survey catches of capelin were found (Walters 2003). Capelin was also found in the walleye pollock diet in 2000 in the Gulf of Alaska, based on samples collected in the Kodiak area from a RACE small-scale midwater trawl acoustic survey (Fig. 32). In the Gulf of Alaska, starting in 2001, stomachs were collected every other year during RACE summer bottom trawl surveys (Fig. 33). More capelin was observed in 2001 in Gulf of Alaska stomach samples than in 1999.

Index of Abundance: Weighted Mean Percent Weight (%wt)

Gulf of Alaska

In the Gulf of Alaska, regular stomach collections started in 1990 and were performed every 3 years before 1999 and every other year after 1999.

Arrowtooth flounder--When all predator size groups are combined, capelin comprised 31% (by weight) of the arrowtooth flounder diet in the Central-gully area in 1990 (Fig. 34). In the Central-shelf area, the greatest percentage (24%) of capelin consumed by arrowtooth flounder also occurred in 1990. In the West-gully stratum, the greater percentage (23%) of capelin consumed by arrowtooth flounder happened in 1993. In the East-shelf and West-shelf strata, capelin comprised no more than 10% of the diet of arrowtooth flounder in every year.

The overall index of abundance of capelin was 8.80%wt (weighted) of arrowtooth flounder diet with a range between 2.86% and 24.89% wt and a standard deviation of 8.68% (Table 1).

Overall, capelin comprised 44% of the diet of arrowtooth flounder 20-29 cm long in 1990. The diet of 10-19 cm arrowtooth flounder consisted of 28% of capelin in 1993. In 1990, the diet of 40-49 cm size group arrowtooth flounder consisted of 29% capelin. The greatest proportions of capelin consumed by the 30-39 and 50-59 cm size groups (20% and 16%, respectively) were also found in 1990.

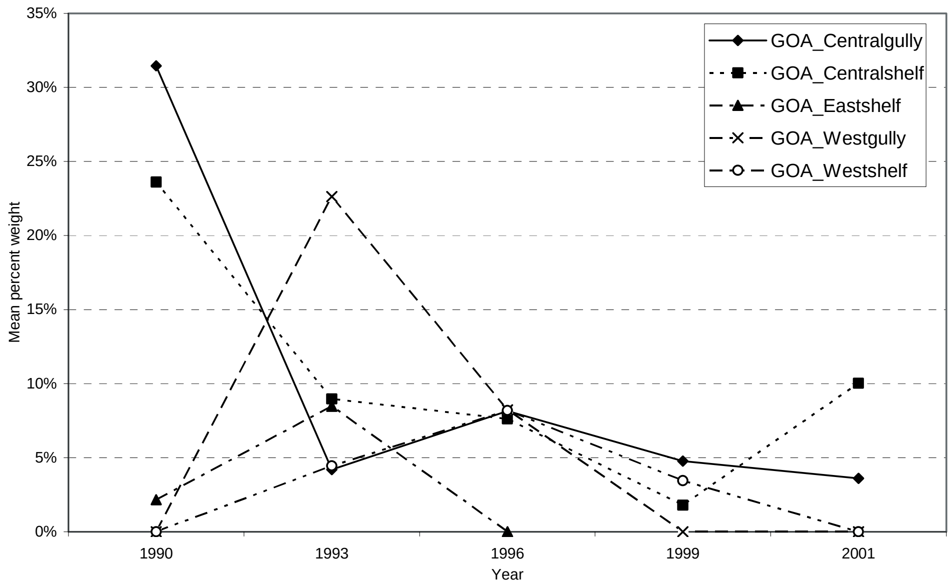

Fig. 34--Percent weight of capelin consumed by arrowtooth flounder in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

Pacific cod--Capelin made up a lower proportion of the stomach content weight of cod compared with arrowtooth flounder in the Gulf of Alaska area. Figure 35 shows that the greatest percentage (7%) of capelin found in Pacific cod stomach contents was in the West-gully strata in 1993. The second greatest amount (about 3-4%) was found in the East-shelf and Central-shelf strata in 1990. The diet of Pacific cod in the Central-gully and West-shelf strata contained less than 1% of capelin in their diet.

The overall index of abundance of capelin based on Pacific cod diet composition was 1.27% (weighted mean) with a range between 0.10% and 2.19%, and a standard deviation of 0.91% (Table 1).

Comparing the capelin consumed by different size groups, we found that the greatest amount of capelin consumed by Pacific cod was found in the 20-29 cm size group of fish in 1993 (23%wt); followed by 30-39 cm size group of fish in 1990 (18%wt). Pacific cod 40-49 cm size group had 8%wt of capelin in their diet in 2001. All other size groups of Pacific cod had less than 5% capelin in their diets, respectively.

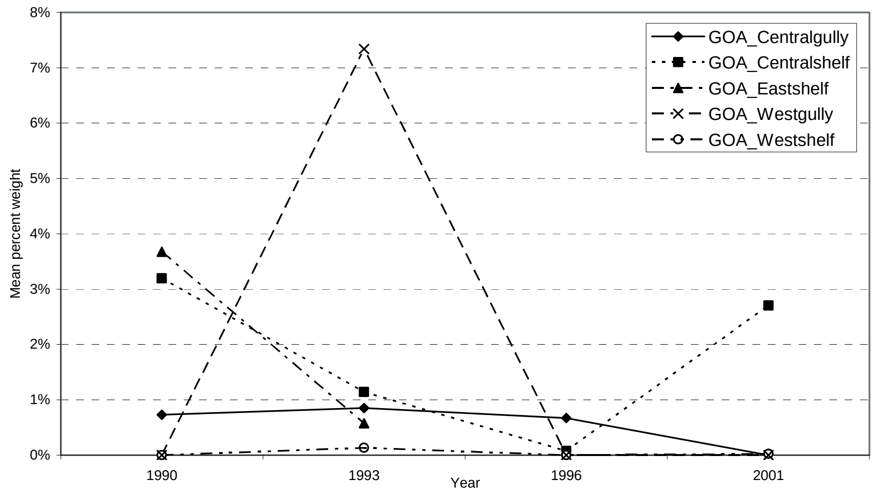

Fig. 35--Percent weight of capelin consumed by Pacific cod in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

Pacific halibut--The indices of abundance of capelin, expressed as the mean percent weight (%wt) in the diet of Pacific halibut, are shown in Figure 36. The greatest amount (23%) of capelin consumed was found in the East-shelf stratum in 1993; followed by 12% in Central-gully stratum in 2001. Capelin comprised less than 7% of Pacific halibut diets in each of the other strata in this study, respectively.

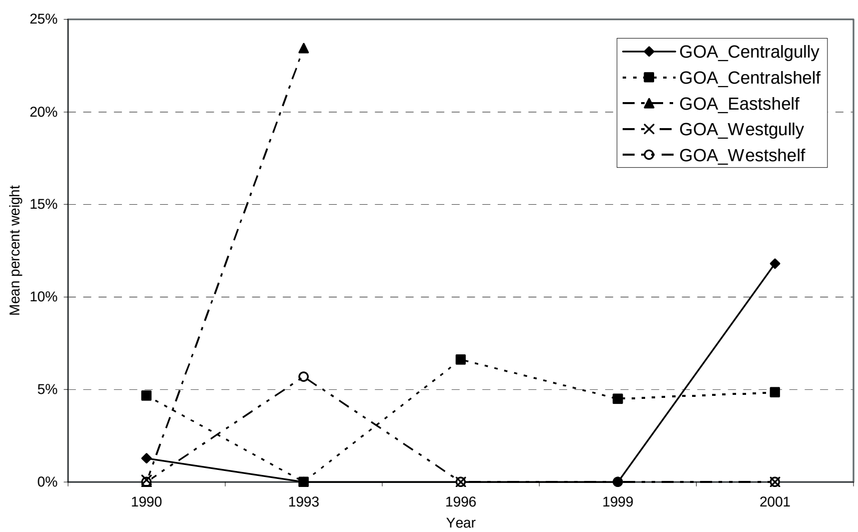

Fig. 36--Percent weight of capelin consumed by Pacific halibut in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

The overall index of abundance of capelin from Pacific halibut stomach contents was 3.70% (weighted mean) with a range between 3.34% and 4.17%, and a standard deviation of 0.33% (Table 1).

When calculating the indices of abundance of capelin consumed by different size groups of Pacific halibut, we found that the greatest amount of capelin consumed was found in 30-39 cm halibut in 1996 (19%); followed by the size group 60-69 cm in 1999 (17%). The greatest amount of capelin consumed by 50-59 cm and 70-79 cm halibut were found in 1996 (12%) and 2001 (12%), respectively. Capelin comprised less than 5% in the diets of other size groups of halibut.

Walleye pollock--Figure 37 shows the percent weight of capelin in the diets of walleye pollock in different strata in the Gulf of Alaska. The greatest amount of capelin consumed by walleye pollock was found in 1999 (25%) in the West-gully stratum; followed by the Central-gully stratum in 1999 (9%). Capelin comprised less than 7% of the diets of walleye pollock in all other strata in this study.

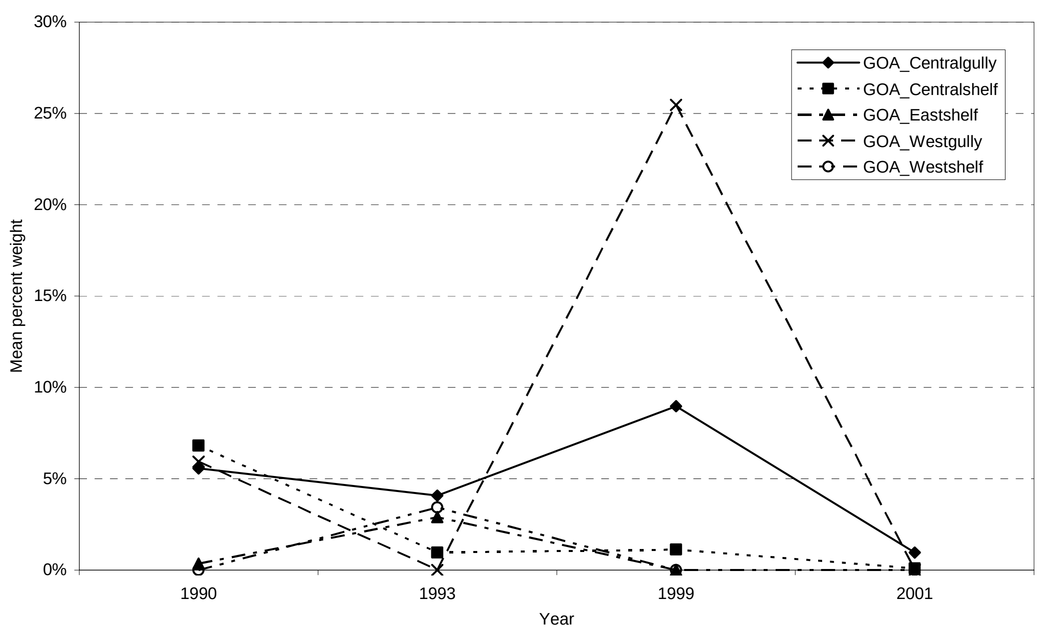

Fig. 37--Percent weight of capelin consumed by walleye pollock in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

The overall index of abundance of capelin from walleye pollock diet was 3.22% with a range between 0.25% and 5.95%, and a standard deviation of 2.4% (Table 1).

The indices of abundance of capelin from different size groups of walleye pollock were calculated. The greatest amount of capelin consumed was found in the 30-39 cm size group in 1990 (52%). The second greatest amount of capelin consumed was found in the diet of walleye pollock 60-69 cm long (15%) in 1990. Capelin comprised less than 10% of the diets of all other size groups of walleye pollock in this study.

Yearly trend in the Gulf of Alaska--Figure 38 shows the yearly trend of capelin found in the diets of marine fishes in the Gulf of Alaska. Capelin comprised the greatest percentage of the diet of arrowtooth flounder--usually more than 5% of the total stomach contents weight, whereas capelin comprised usually less than 5% of the diets of Pacific cod, Pacific halibut, and walleye pollock, respectively.

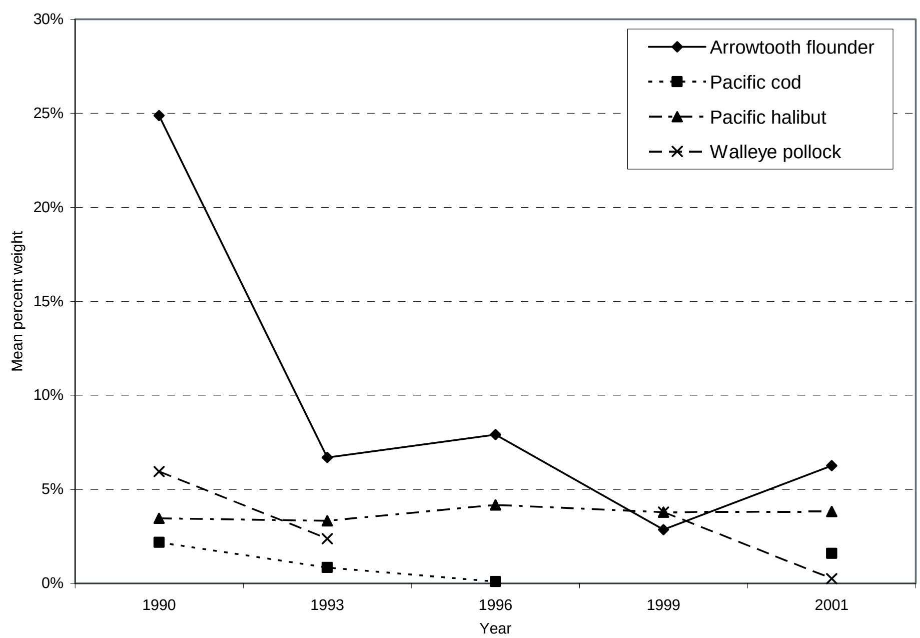

Fig. 38.--Yearly trend of capelin consumed by marine fish in the Gulf of Alaska.

In 1990, a very high percentage of capelin (up to 43% in the 40-49 cm size group in Central-gully stratum) was found in arrowtooth flounder diets in the Central-gully and Central-shelf strata, which resulted in the very high percentage (25%) of capelin in the diet of arrowtooth flounder that year. In 1996, no capelin was found in walleye pollock stomachs. There is some possibility that this might be due to errors in prey identification that year.

Table1.--Indices of abundance (%wt) of capelin in the Gulf of Alaska; expressed as the percent weight (weighted) of capelin in the diet of marine fishes.

Species	Year	No. of Stomachs	%Wt	%SD
Arrowtooth flounder	1990	624	24.89	x
Arrowtooth flounder	1993	1005	6.70	x
Arrowtooth flounder	1996	1558	7.91	x
Arrowtooth flounder	1999	540	2.86	x
Arrowtooth flounder	2001	1313	6.26	x
Arrowtooth flounder	**Total**	**5040**	**8.80**	**8.68**
Pacific cod	1990	834	2.19	x
Pacific cod	1993	991	0.85	x
Pacific cod	1996	514	0.10	x
Pacific cod	2001	800	1.59	x
Pacific cod	**Total**	**3139**	**1.27**	**0.91**
Pacific halibut	1990	368	3.47	x
Pacific halibut	1993	380	3.34	x
Pacific halibut	1996	241	4.17	x
Pacific halibut	1999	160	3.79	x
Pacific halibut	2001	822	3.82	x
Pacific halibut	**Total**	**1971**	**3.70**	**0.33**
Walleye pollock	1990	900	5.95	x
Walleye pollock	1993	809	2.37	x
Walleye pollock	1999	604	3.79	x
Walleye pollock	2001	705	0.25	x
Walleye pollock	**Total**	**3018**	**3.22**	**2.40**

Eastern Bering Sea

Regular stomach collections were performed annually starting in 1984 in the eastern Bering Sea. In the Gulf of Alaska, regular stomach collections started in 1990 and were performed every 3 years before 1999 and every other year after 1999. Therefore, more time series data were collected in the eastern Bering Sea than in the Gulf of Alaska.

Arrowtooth flounder--Figure 39 shows that capelin comprised 24% of the diet of arrowtooth flounder collected in stratum 1, eastern Bering Sea, in 2001. It was the greatest amount of capelin consumed by arrowtooth flounder in the eastern Bering Sea in this study; followed by 1997 and 1993 in stratum 3, with capelin comprising about 9% and 6%, respectively. Capelin comprised less than 5% in arrowtooth flounder diets in all other strata.

The overall index of abundance of capelin from arrowtooth flounder diets was 0.96% with a range between 0.06% and 2.01%, and a standard deviation of 0.79% (Table 2).

The indices of abundance of capelin from different size groups of arrowtooth flounder were calculated. The greatest amount of capelin consumed was found in the 20-29 cm size group in 2001 (8%); followed by the 30-39 cm size group in 1994 (7%), 40-49 cm size group in 1985 (5%), and 60-69 cm size group in 2001 (5%). Capelin comprised less than 4% in the diets of all other size groups of arrowtooth flounder in the eastern Bering Sea.

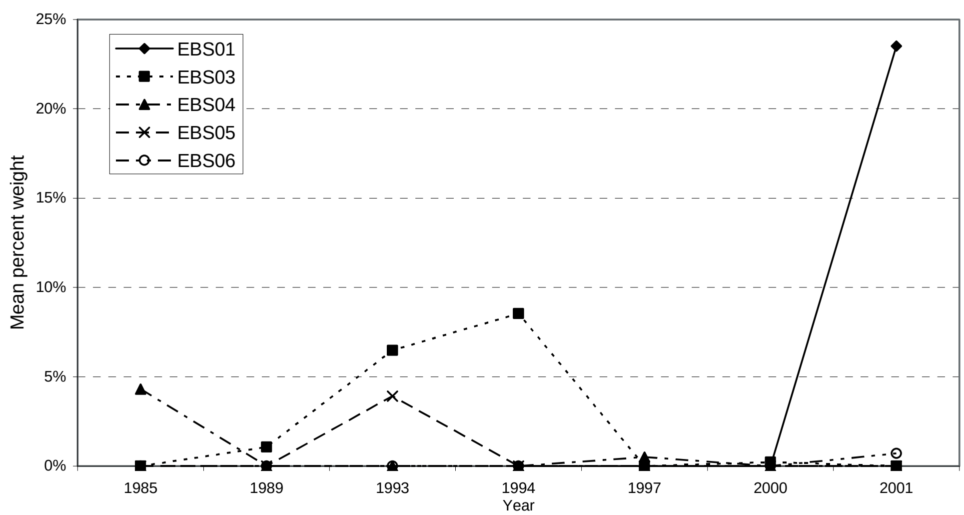

Fig. 39--Percent weight of capelin consumed by arrowtooth flounder in the eastern Bering Sea, by strata (all predator size groups combined) and by year.

Pacific cod--Figure 40 shows that the greatest amount (8%) of capelin consumed by Pacific cod was found in stratum 1 in 1993. The second greatest amount (7%) was found in stratum 2 in 1986. Capelin comprised less than 3% in Pacific cod diets in all other strata, respectively.

The overall index of abundance of capelin from Pacific cod diets was 0.38% with a range between 0.01% and 1.68% with a standard deviation of 0.43% (Table 2).

The indices of abundance of capelin consumed by different size groups were calculated. The greatest amount of capelin consumed by Pacific cod was found in the 20-29 cm size group fish in 1993 (14%wt). All other size groups of Pacific cod diets were comprised of less than 3% capelin.

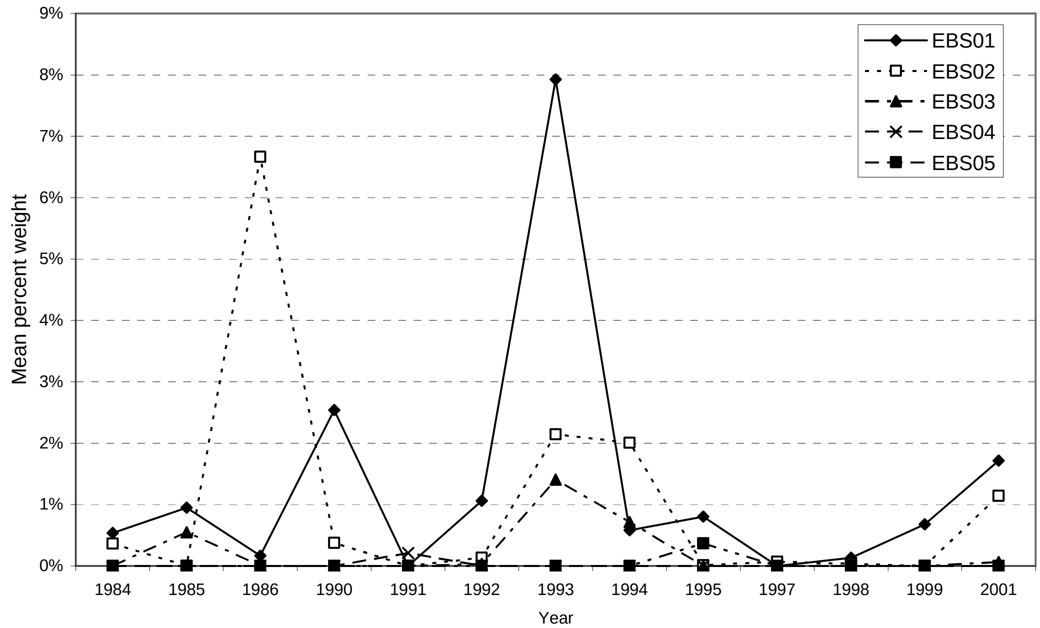

Fig. 40--Percent weight of capelin consumed by Pacific cod in the eastern Bering Sea, by strata (all predator size groups combined) and by year.

Pacific halibut--The indices of abundance of capelin from the diet of Pacific halibut are shown in Figure 41. The greatest amount (25%) of capelin consumed was found in stratum 2 in 1993, followed by 21% in stratum 2 in 1999, and 20% in stratum 1 in 1999. Capelin comprised 15% and 8% of the diets of Pacific halibut collected in stratum 1 in 1993 and 1992, respectively. Capelin was found in less than 6% of Pacific halibut diets in each of the other strata in this study.

The overall index of abundance of capelin from Pacific halibut diets was 2.49% (weighted mean) with a range between 0.03% and 7.33%, and a standard deviation of 2.88% (Table 2).

The indices of abundance of capelin consumed by different size groups were calculated. The greatest amount of capelin consumed by Pacific halibut was found in the 30-39 cm size group in 1999 (16%wt), followed by 50-59 cm size group in 1993 (15%), the 30-39 cm size group in 1993 (11%) and 40-49 cm size group in 1999 (10%). All other size groups of Pacific halibut comprised less than 6% of capelin in their diets, respectively.

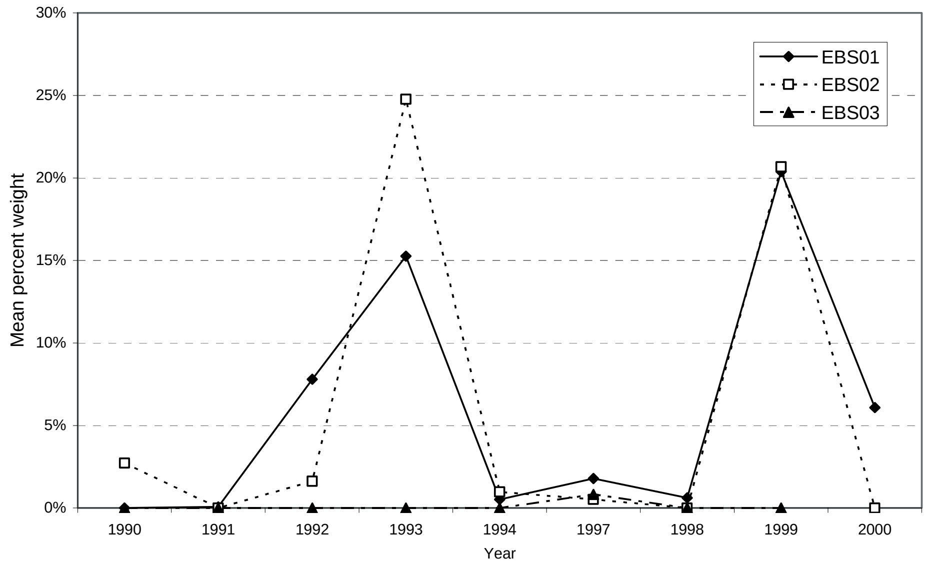

Fig. 41--Percent weight of capelin consumed by Pacific halibut in the eastern Bering Sea, by strata (all predator size groups combined) and by year.

Walleye pollock--Figure 42 shows the percent weight of capelin in the diets of walleye pollock in different strata in the eastern Bering Sea. It shows that the greatest amount of capelin consumed by walleye pollock was found in 1993 (8%) in stratum 2; followed by the amount found in stratum 1 in 2001 (7%), and in stratum 2 in 1999 (6%). Capelin was comprised less than 4% of the diets of walleye pollock in all other strata in this study.

The overall index of abundance of capelin from walleye pollock diet was 0.66% with a range between 0.06% and 1.64% with a standard deviation of 0.54% (Table 2).

The indices of abundance of capelin from different size groups of walleye pollock were calculated. The greatest amount of capelin consumed was found in the 70-99 cm size group in 2001 (11%). The second greatest amount of capelin consumed was found in the diet of walleye pollock 70-99 cm in 1990 (7%). Capelin comprised less than 6% in the diets of all other size groups of walleye pollock in this study.

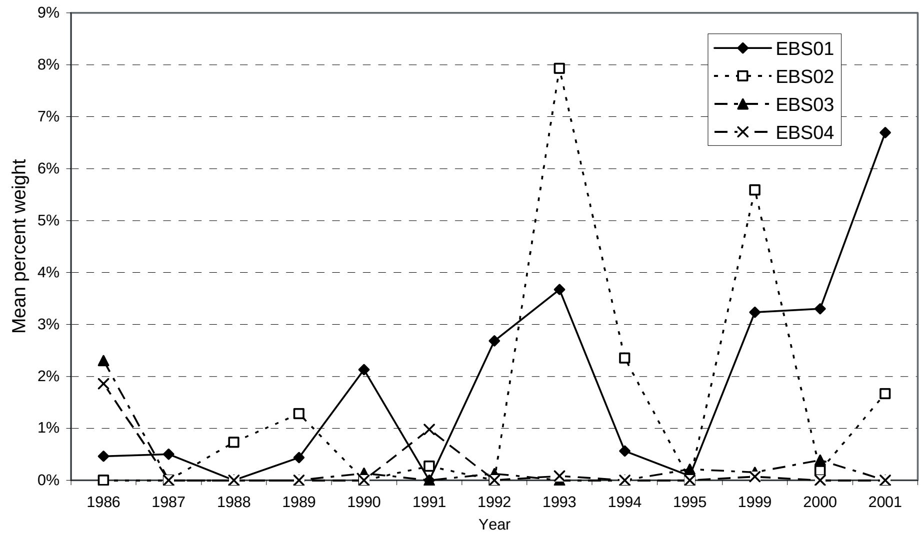

Fig. 42--Percent weight of capelin consumed by walleye pollock in the eastern Bering Sea, by strata (all predator size groups combined) and by year.

Yearly trend in the eastern Bering Sea--Figure 43 shows the yearly trend of capelin found in the diets of marine fishes in the eastern Bering Sea. It shows that capelin comprised the greatest percentage of the diet of Pacific halibut, usually between 4% and 8% of the total stomach contents weight. Capelin comprised less than 2% of the diets of arrowtooth flounder, Pacific cod, and walleye pollock, respectively.

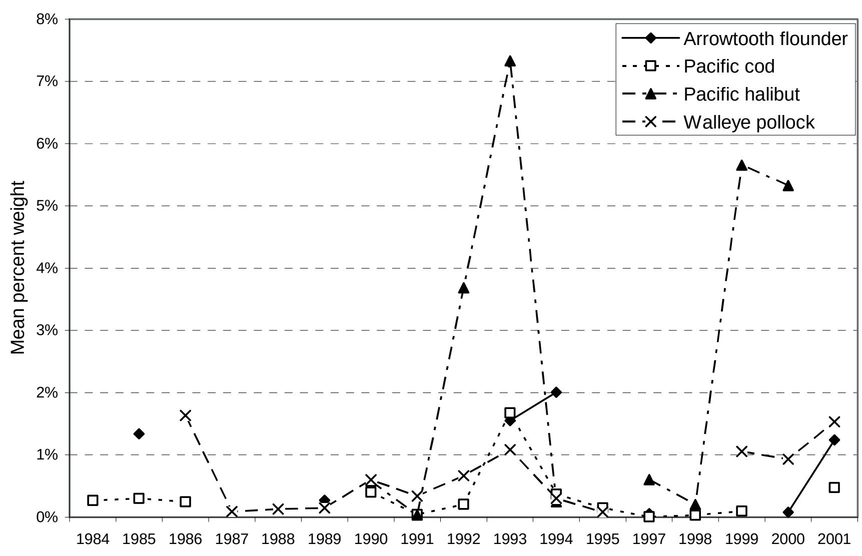

Fig. 43.--Yearly trend of capelin consumed by marine fish in the eastern Bering Sea.

Table 2.--Indices of abundance (%wt) of capelin in the eastern Bering Sea; expressed As the percent weight (weighted) of capelin in the diet of marine fishes.

Species	Year	No. of Stomachs	%Wt	%SD
Arrowtooth flounder	1985	396	1.34	x
Arrowtooth flounder	1989	364	0.27	x
Arrowtooth flounder	1993	384	1.55	x
Arrowtooth flounder	1994	315	2.01	x
Arrowtooth flounder	1997	295	0.06	x
Arrowtooth flounder	2000	274	0.08	x
Arrowtooth flounder	2001	213	1.24	x
Arrowtooth flounder	**Total**	**2241**	**0.96**	**0.79**
Pacific cod	1984	982	0.27	x
Pacific cod	1985	1342	0.30	x
Pacific cod	1986	1692	0.25	x
Pacific cod	1990	1199	0.40	x
Pacific cod	1991	1958	0.04	x
Pacific cod	1992	1935	0.21	x
Pacific cod	1993	2336	1.68	x
Pacific cod	1994	2510	0.37	x
Pacific cod	1995	2467	0.15	x
Pacific cod	1997	1055	0.01	x
Pacific cod	1998	1265	0.03	x
Pacific cod	1999	1216	0.10	x
Pacific cod	2001	1326	0.48	x
Pacific cod	**Total**	**21283**	**0.38**	**0.43**
Pacific halibut	1990	240	0.58	x
Pacific halibut	1991	179	0.03	x
Pacific halibut	1992	254	3.69	x
Pacific halibut	1993	351	7.33	x
Pacific halibut	1994	258	0.25	x
Pacific halibut	1997	252	0.61	x
Pacific halibut	1998	326	0.20	x
Pacific halibut	1999	203	5.66	x
Pacific halibut	2000	16	5.33	x
Pacific halibut	**Total**	**2079**	**2.49**	**2.88**
Walleye pollock	1986	910	1.64	x
Walleye pollock	1987	1429	0.09	x
Walleye pollock	1988	862	0.13	x
Walleye pollock	1989	1494	0.15	x
Walleye pollock	1990	1773	0.60	x
Walleye pollock	1991	1907	0.34	x
Walleye pollock	1992	1701	0.67	x
Walleye pollock	1993	2579	1.09	x
Walleye pollock	1994	2336	0.30	x
Walleye pollock	1995	2597	0.08	x
Walleye pollock	1999	2598	1.06	x
Walleye pollock	2000	2245	0.93	x
Walleye pollock	2001	1597	1.53	x
Walleye pollock	**Total**	**24028**	**0.66**	**0.54**

Population Consumption of Capelin by Marine Fish

In this section, the population consumption of capelin are described by area and species. Within each species, the consumption by size group and strata are discussed. The estimated biomass of capelin consumed by each 10 cm size group, each species, each stratum, in each year are listed in Appendix 1 for the Gulf of Alaska and Appendix 2 for the eastern Bering Sea. Daily rations, number of hauls, number of stomachs, mean percent weight of capelin in the diets, and biomass of predators are also listed in these appendices.

Gulf of Alaska

Arrowtooth flounder--Figure 44 shows that arrowtooth flounder consumed about 160,000 t of capelin in 1990, the largest amount consumed by arrowtooth flounder from 1990 to 2001. During this period, capelin were mainly consumed by arrowtooth flounder 40-59 cm except in 1999, in which the smallest size group (< 40 cm) consumed more capelin than the larger arrowtooth flounder.

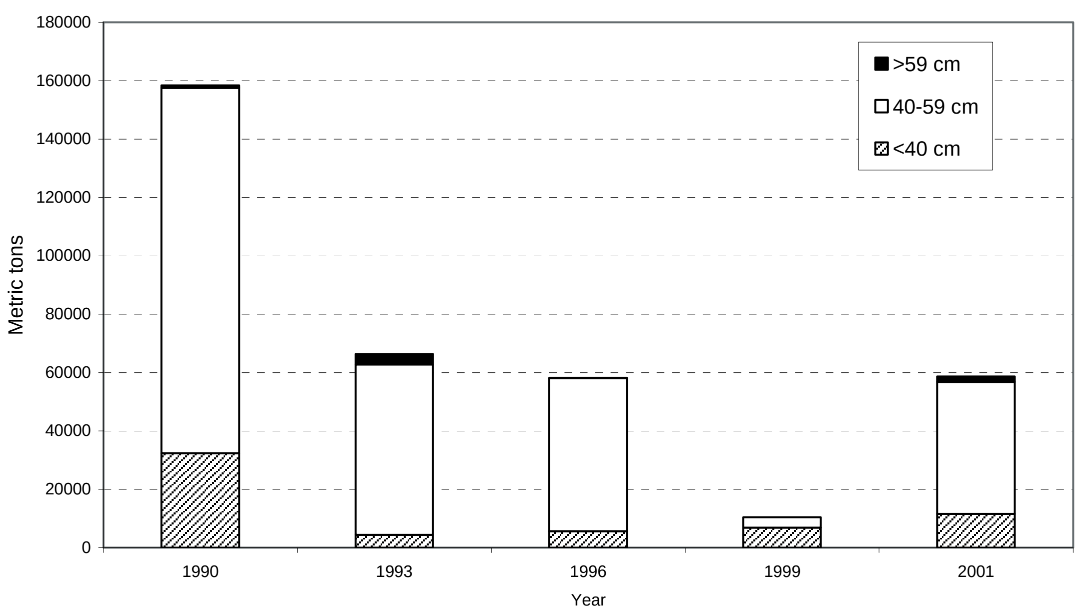

Fig. 44.--Population consumption of capelin by arrowtooth flounder in Gulf of Alaska, by predator size (all strata combined) and by year.

Figure 45 shows capelin consumed by arrowtooth flounder in different strata. Central-shelf stratum comprised the greatest amount of capelin consumed in all years except in 1999. The Central-gully stratum was the area that arrowtooth flounder consumed the second greatest quantity of capelin for almost every year (except 1999). Arrowtooth flounder consumed less capelin in the West-shelf, East-shelf, and West-gully strata.

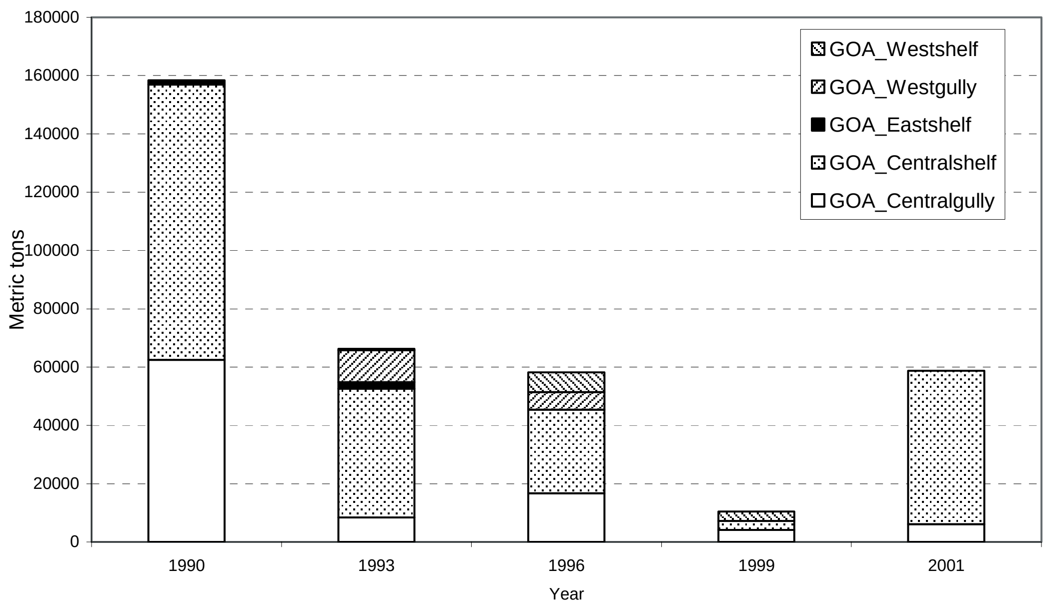

Fig. 45.--Population consumption of capelin by arrowtooth flounder in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

Pacific cod--Figure 46 shows that Pacific cod consumed less than 5,000 t of capelin in each of the 4 years from 1990 to 2001, respectively. In 1990, Pacific cod 30-59 cm consumed more than 4,500 t of capelin, whereas in 1993 and 1996, it was the ≥ 60 cm size group that consumed the largest amount (about 600 and 400 t, respectively) of capelin. Again, in 2001, the 30-59 cm size group was the dominant group that consumed the largest amount of capelin.

Figure 47 shows that Pacific cod in the Central-shelf stratum consumed the largest amount of capelin in every year except in 1996. Central-gully was the stratum where Pacific cod consumed the second greatest amount of capelin in the Gulf of Alaska. In the West-shelf, West-gully, and East-shelf strata, Pacific cod consumed relatively small amounts of capelin in every year.

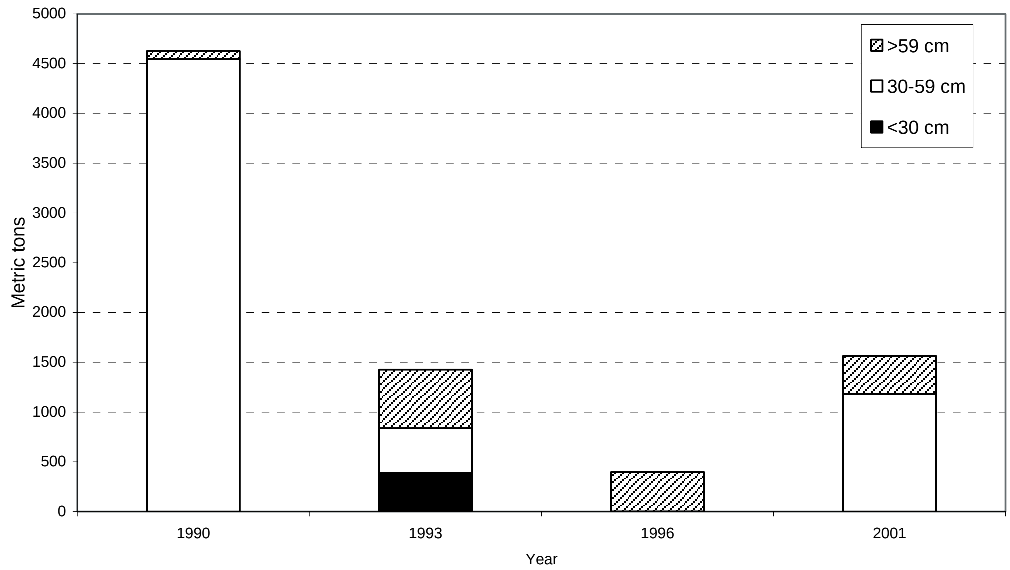

Fig. 46.--Population consumption of capelin by Pacific cod in the Gulf of Alaska, by predator size (all strata combined) and by year.

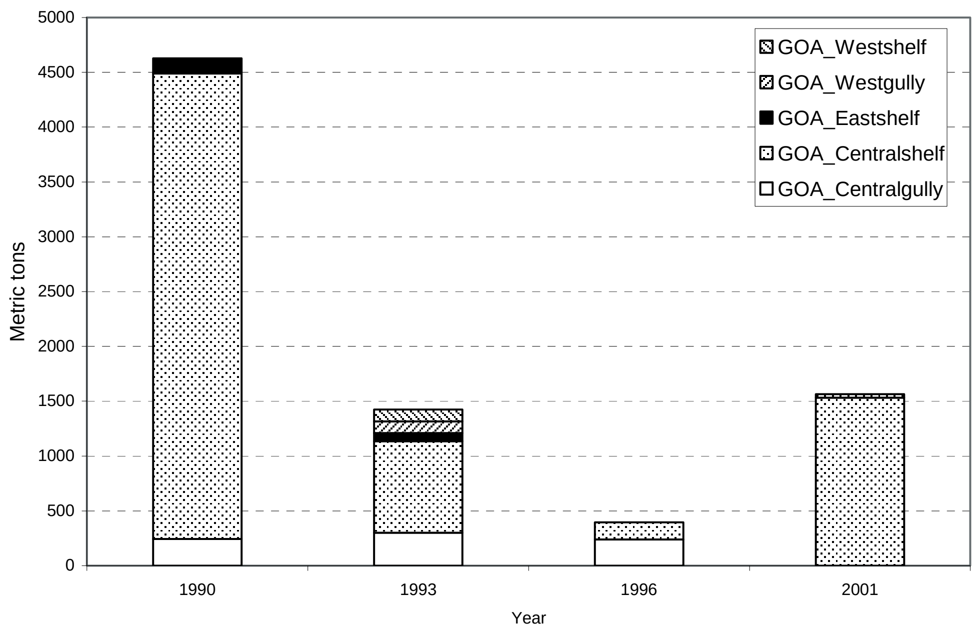

Fig. 47.--Population consumption of capelin by Pacific cod in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

Pacific halibut--In comparison to arrowtooth flounder and Pacific cod, Pacific halibut consumed less capelin in the Gulf of Alaska. About 3,500 t of capelin was consumed by Pacific halibut in 1996 and 1999, respectively (Fig. 48). Figure 48 also shows that the 50-69 cm size group of Pacific halibut dominated the predation of capelin in every year except in 2001, in which the dominant size group was the > 69 cm size group.

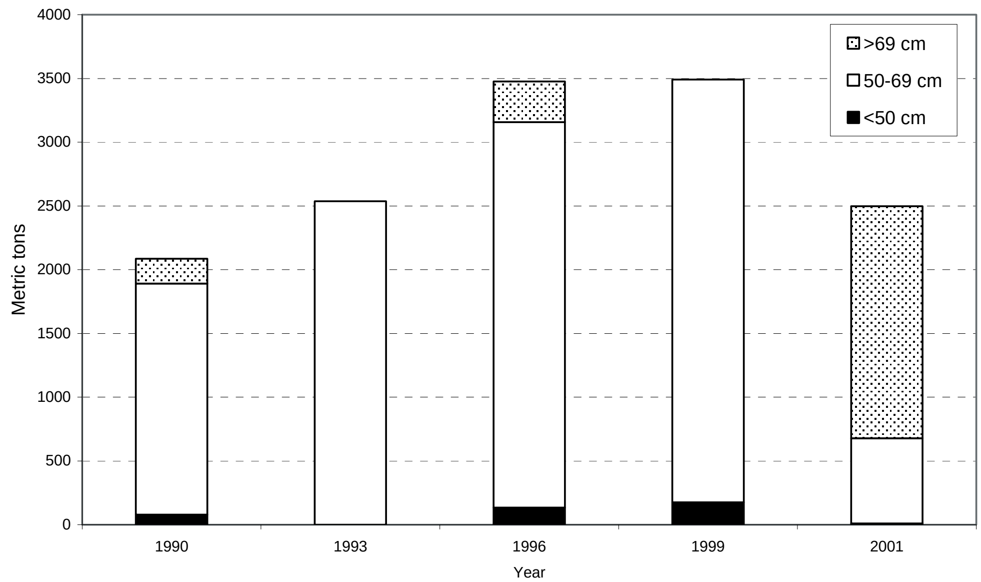

Fig. 48.--Population consumption of capelin by Pacific halibut in the Gulf of Alaska, by predator size (all strata combined) and by year.

The rate of consumption of capelin by Pacific halibut in different strata were similar to the consumption rates of other predator species. Capelin were consumed mainly in the Central-shelf stratum in most years (Fig. 49). Only in 1993, the West-shelf and East-shelf were the strata that comprised the greatest amounts of capelin consumption by Pacific halibut.

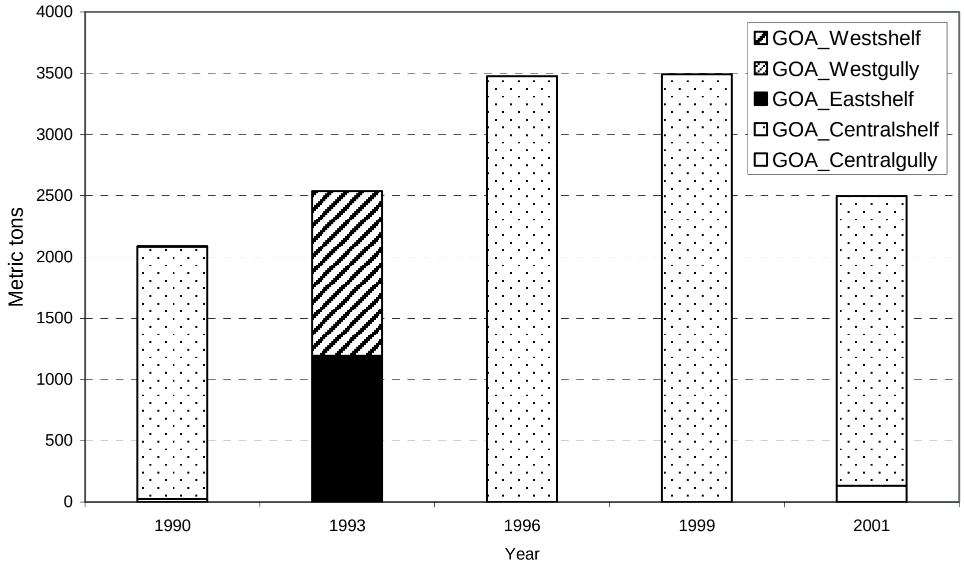

Fig. 49.--Population consumption of capelin by Pacific halibut in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

Walleye pollock--Walleye pollock consumed about 60,000 t of capelin in 1990 (Fig. 50). The dominant group of walleye pollock that consumed capelin was the ≥ 50 cm size group. It comprised about 60% of the total capelin consumed in 1990. The consumption of capelin by pollock has decreased considerably since 1993. In 2001, less than 300 t of capelin were consumed by walleye pollock in the Gulf of Alaska area.

Like other predators, the main areas where capelin were consumed by walleye pollock were the Central-shelf and Central-gully strata in 1990, whereas in 1993, capelin consumed in the West-shelf stratum comprised more than 55% of the total capelin consumption in that year (Fig. 51).

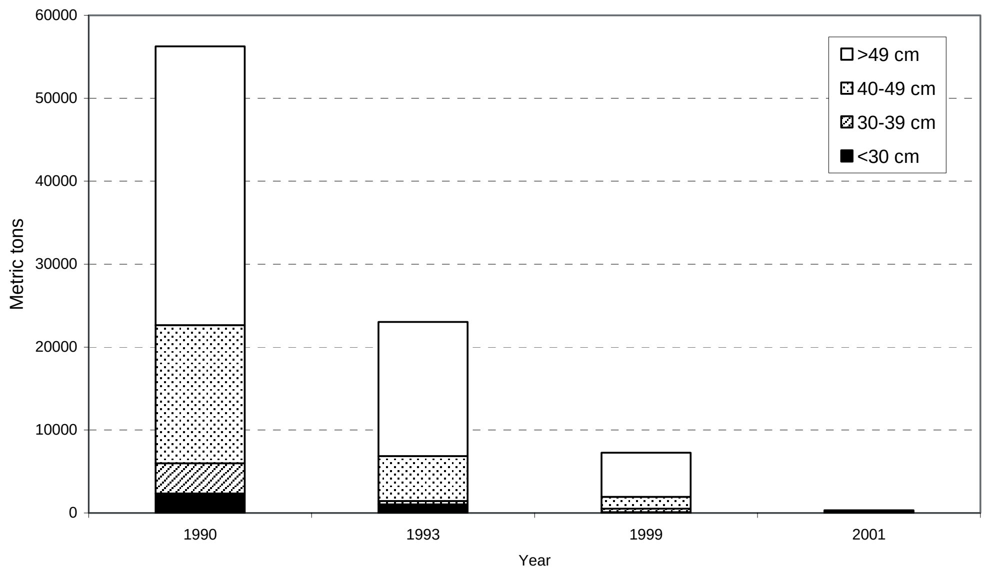

Fig. 50.--Population consumption of capelin by walleye pollock in the Gulf of Alaska, by predator size (all strata combined) and by year.

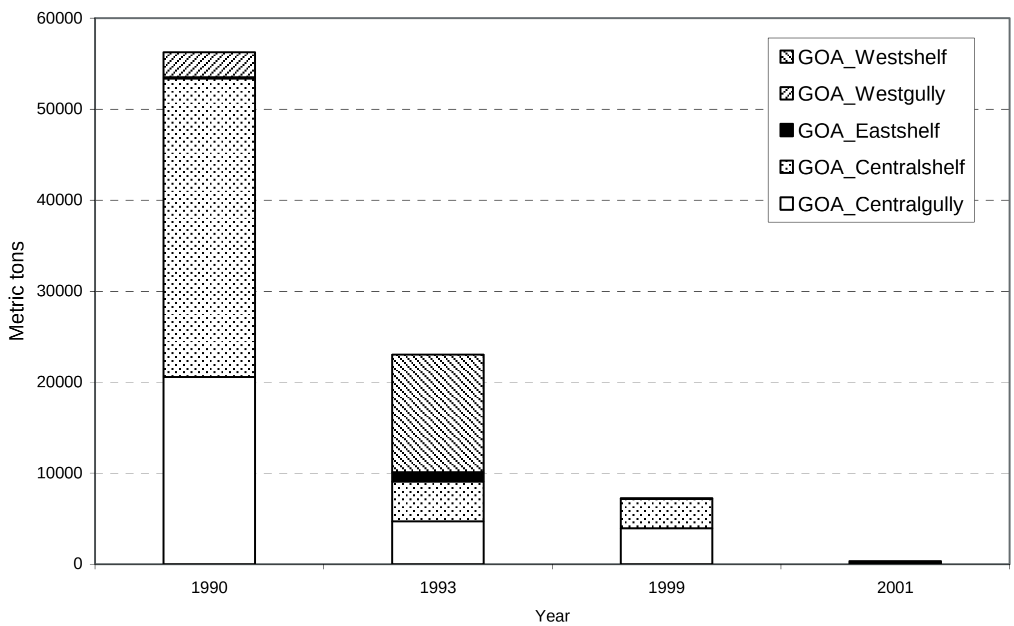

Fig. 51.--Population consumption of capelin by walleye pollock in the Gulf of Alaska, by strata (all predator size groups combined) and by year.

Yearly trend in the Gulf of Alaska--Figure 52 shows the yearly trend of consumption of capelin by marine fishes in the Gulf of Alaska. It shows the trends were similar to the yearly trend of the percent weight of capelin in the diet of marine fishes (Fig. 38). Arrowtooth flounder consumed the greatest amount (about 160,000 t) of capelin in 1990, decreased dramatically in 1993 (40,000 t), increased a little in 1996, and then decreased to the lowest level in 1999 (a little over 10,000 t). Walleye pollock was the next important consumer of capelin in the Gulf of Alaska. They consumed about 60,000 t of capelin in 1990 and then gradually decreased during the next 10 years. In 2001, the amount of capelin consumed by walleye pollock was only 320 t. Both Pacific cod and Pacific halibut consumed relatively less amounts (< 5,000 t) of capelin in all years in the Gulf of Alaska.

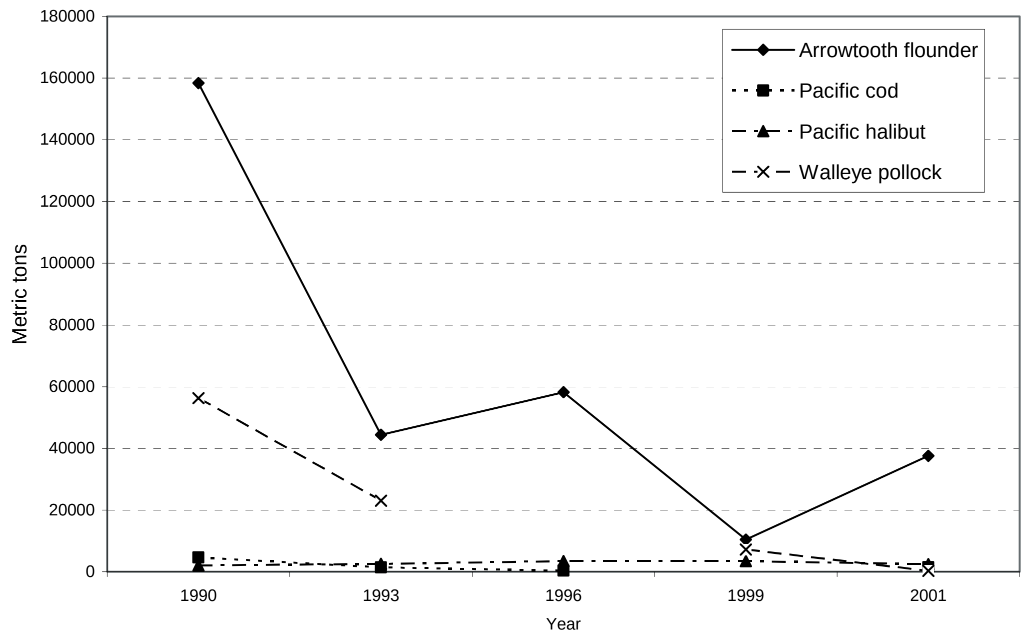

Fig. 52.--Yearly trend of population consumption of capelin by marine fish in the Gulf of Alaska.

Eastern Bering Sea

Arrowtooth flounder--Figure 53 shows that arrowtooth flounder consumed about 10,000 t of capelin in 1994, the greatest amount of capelin consumed from 1985 to 2000. The second greatest amount of capelin consumed by arrowtooth flounder was in 1993 (7,200 t). Capelin were mainly consumed by the 20-39 cm and ≥ 40 cm size groups of arrowtooth flounder in the eastern Bering Sea. Only a small amount (15 t) of capelin was consumed by arrowtooth flounder < 20 cm.

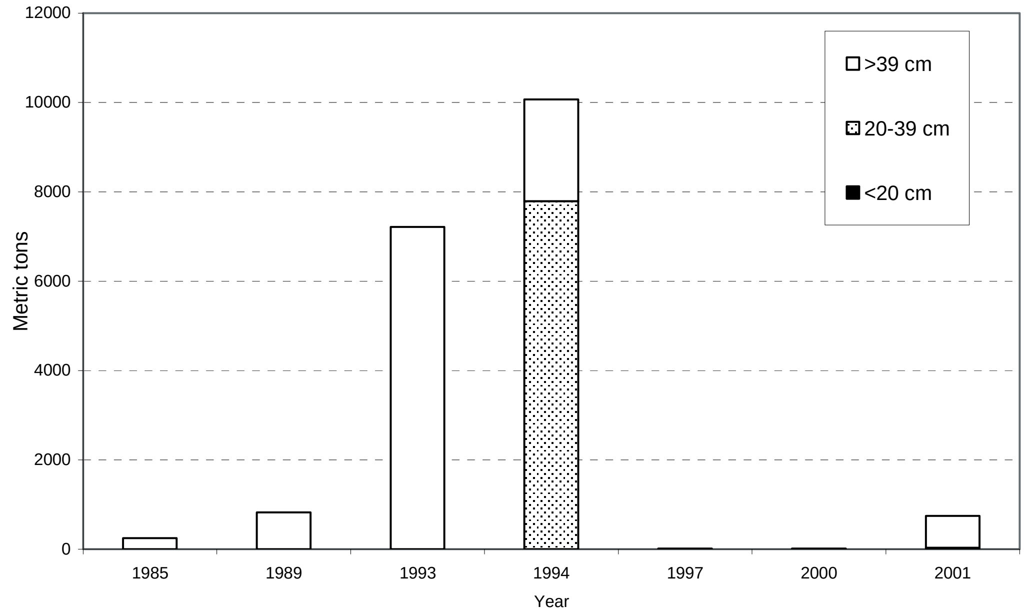

Fig. 53.--Population consumption of capelin by arrowtooth flounder in the eastern Bering Sea, by predator size (all strata combined) and by year.

As far as the locations where the capelin were consumed by arrowtooth flounder, strata 3 and 5 (middle and outer shelves) were the dominant areas of capelin consumption in the eastern Bering Sea (Fig. 54).

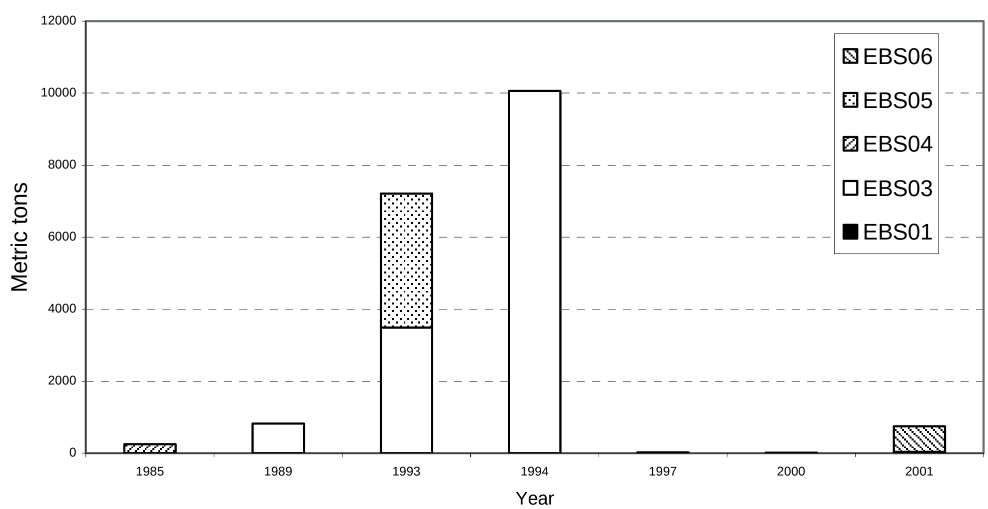

Fig. 54.--Population consumption of capelin by arrowtooth flounder in the eastern Bering Sea by strata (all predator size groups combined) and by year.

Pacific cod--The greatest consumption of capelin by Pacific cod (about 12,000 t) in the eastern Bering Sea was found in 1993 (Fig. 55), followed by 2,800 t in 1994. In 1984, 1985, 1992, 1995, and 2001, Pacific cod also consumed about

1,500t of capelin each year. Figure 60 shows that the size groups 30-59 cm and ≥ 60 cm Pacific cod dominated the consumption of capelin in the eastern Bering Sea.

Capelin occurred in the stomachs of Pacific cod in five out of six strata in the eastern Bering Sea. Strata 1 (EBS01) predominated most of the years from 1984 to 2001 (Fig. 56).

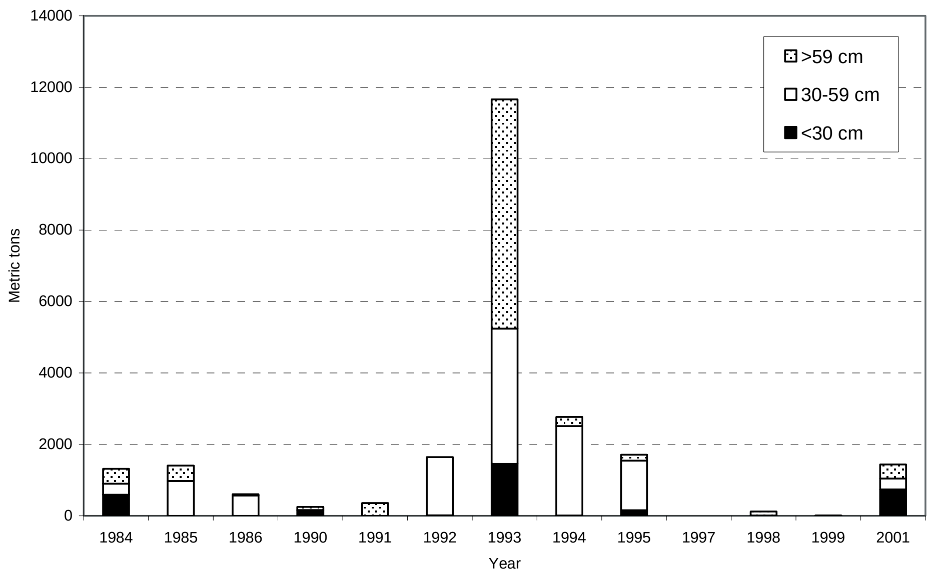

Fig. 55.--Population consumption of capelin by Pacific cod in the eastern Bering Sea by predator size (all strata combined) and by year.

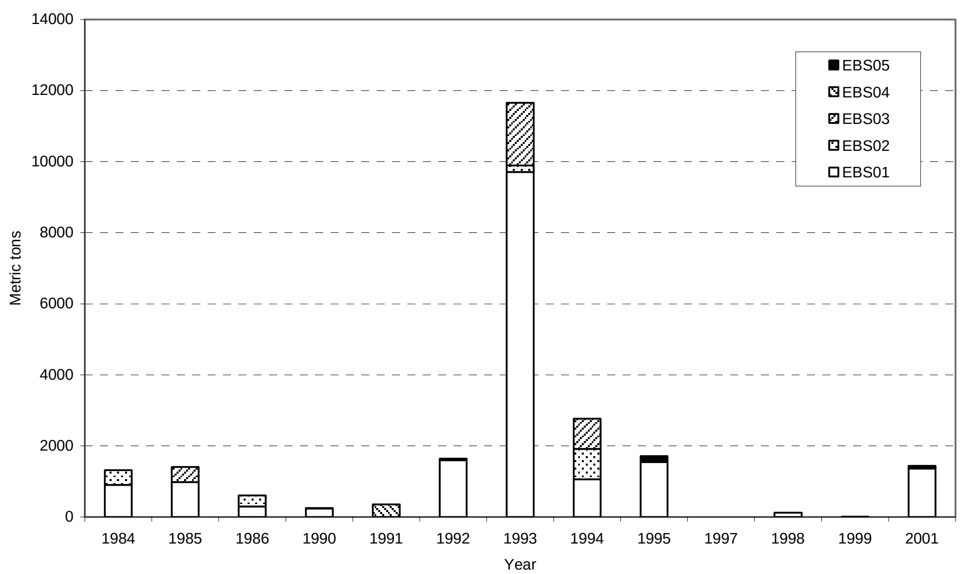

Fig. 56.--Population consumption of capelin by Pacific cod in the eastern Bering Sea by strata (all predator size groups combined) and by year.

Pacific halibut--Pacific halibut consumed small amounts of capelin in the eastern Bering Sea. The greatest consumption was found in 1993 (about 4,000 t), followed by about 500 t in 1992 and 1999, respectively (Fig. 57). The dominant size group of Pacific halibut that prey on capelin was between 50 and 69 cm long. Few were consumed by Pacific halibut less than 30 cm long; only < 0.1 t was found in 1998.

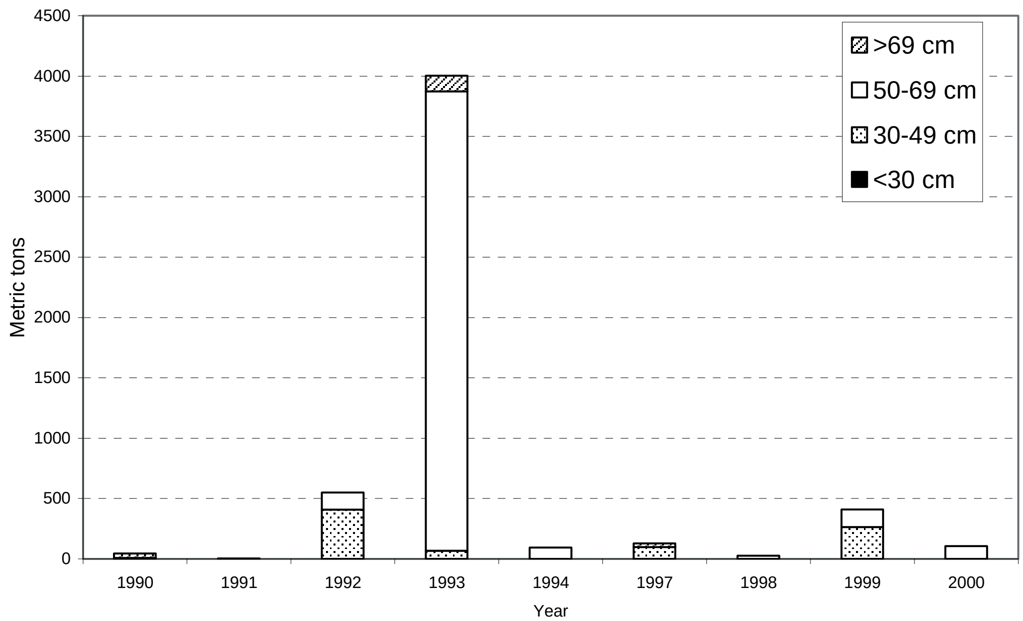

Fig. 57.--Population consumption of capelin by Pacific halibut in the eastern Bering Sea by predator size (all strata combined) and by year.

Figure 58 shows that capelin were mainly consumed by Pacific halibut in stratum 1 and stratum 2 areas, only 30 t of capelin were consumed by Pacific halibut in stratum 3 area in 1997.

Walleye pollock--Figure 59 shows that capelin were consumed by walleye pollock in different years. The greatest consumption (46,000 t) was found in 1986. The second greatest amount of capelin consumed (27,000 t) was in 1993. Figure 59 also shows that 50-59 cm and 60-69 cm size groups were the dominant groups that preyed upon capelin in the eastern Bering Sea. The smallest size group (< 50 cm) of walleye pollock consumed no more than 400 t of capelin in a single year.

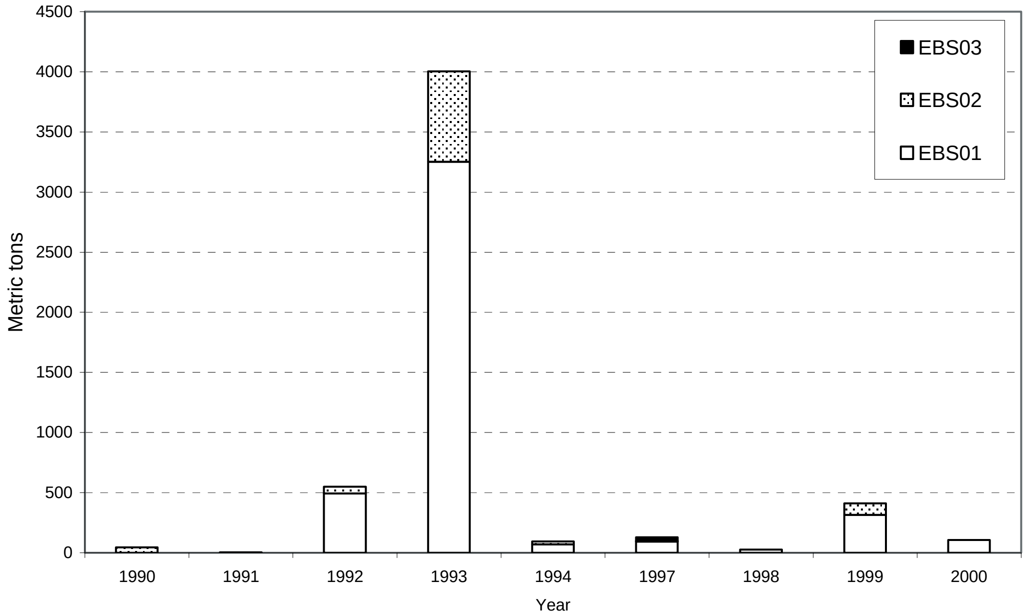

Fig. 58.--Population consumption of capelin by Pacific halibut in the eastern Bering Sea, by strata (all predator size groups combined) and by year.

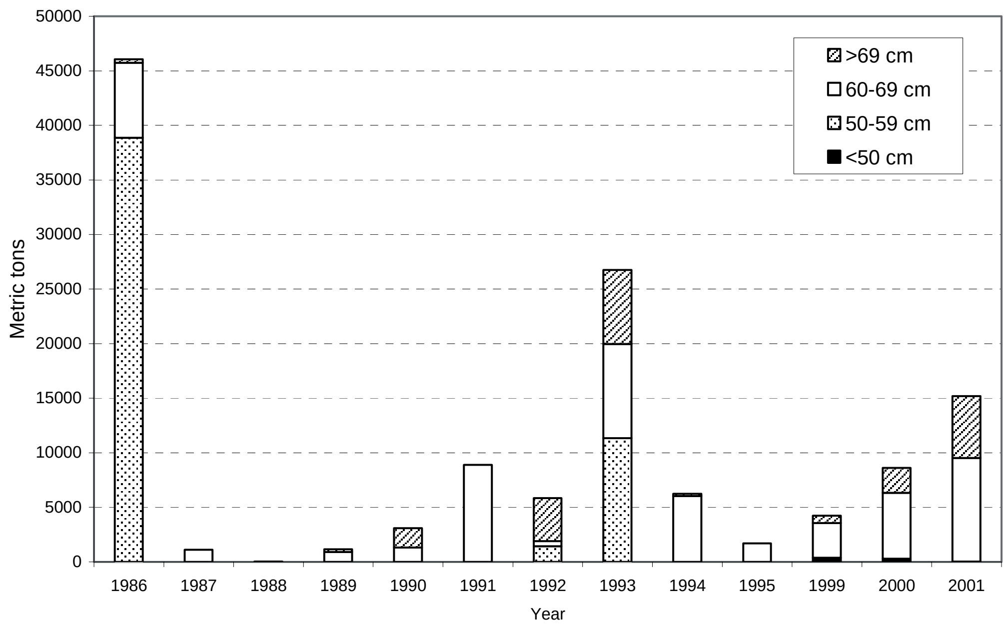

Fig. 59.--Population consumption of capelin by walleye pollock in the eastern Bering Sea, by predator size (all strata combined) and by year.

In 1986, 1991, and 1995 capelin were consumed by walleye pollock mainly in strata 3 and 4 (EBS03 and EBS04). In other years, capelin was found mainly in the stomachs of walleye pollock in strata 1 and 2 (EBS01 and EBS02) (Fig. 60).

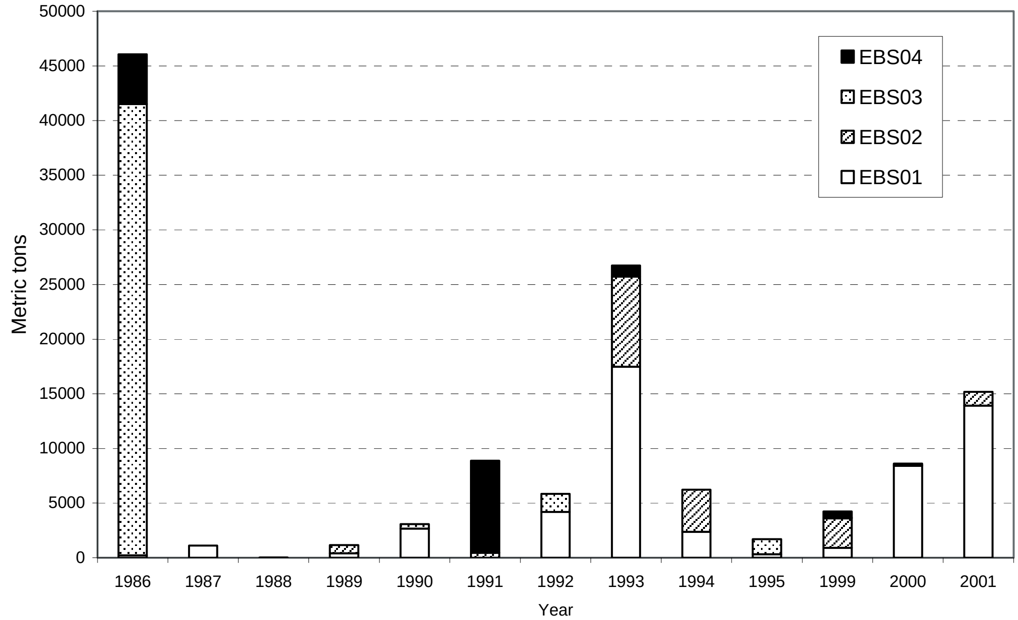

Fig. 60.--Population consumption of capelin by walleye pollock in the eastern Bering Sea, by strata (all predator size groups combined) and by year.

Yearly trend in the eastern Bering Sea--Figure 61 shows the yearly trend of capelin consumption by marine fishes in the eastern Bering Sea. Walleye pollock consumed the greatest amount (46,000 t) of capelin in 1986, the amount decreased dramatically in 1987 and 1988, and gradually increased to another peak in 1993 (27,000 t). Even though the percentage by weight of capelin consumed by walleye pollock was usually not as high as Pacific halibut (Fig. 43), the total amount (tonnage) of capelin consumed by walleye pollock was high because of the high biomass of walleye pollock in the eastern Bering Sea area. Pacific cod and arrowtooth flounder consumed their greatest amount (about 10,000 t) of capelin in 1993 and 1994, respectively. However, in other years, they did not consume large amounts of capelin in the eastern Bering Sea. Capelin consumed by Pacific halibut was no more than 2,500 t in any single year in the eastern Bering Sea.

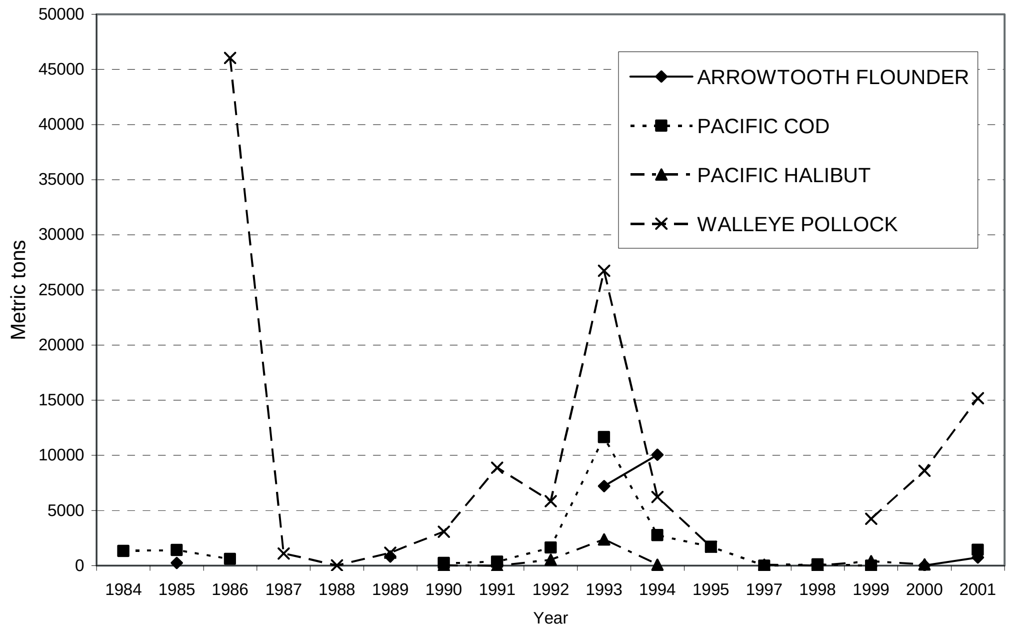

Fig. 61.--Yearly trend of population consumption of capelin by marine fish in the eastern Bering Sea.

Age-length Distribution of Capelin

The length of capelin by age varies greatly by area and by year (Pahlke, 1985; Brown, 2002; Naumenko, 2002). Based on Naumenko's (2002) study, we categorized the age groups as age 0 (< 70mm), age 1 (71-110 mm), age 2 (111-130 mm), and age 3+ (> 130mm) groups.

Eastern Bering Sea

Age-2 capelin were found in high frequencies in fish stomachs collected in 1986 in the eastern Bering Sea (Fig. 62). Compared to 1986, fewer capelin occurred in stomachs collected in 1987: five age-2 fish, four age-3 and older fish, and one age-1 fish. The greatest numbers of capelin (including age-3 and older) were found in stomachs collected in 1993 in which age-2 was the dominant age group consumed by fish. From 1999 to 2001, high numbers of capelin were found in fish stomachs. In 1999 and 2001, age-2 capelin occurred most frequently, whereas in 2000, age-0 was the dominant capelin consumed (Fig. 62).

Gulf of Alaska

Capelin occurred frequently in the stomach contents of marine fish in 1990, 1993, and 1996. Age-1 capelin was the dominant group consumed in those 3 years. The greatest number of capelin was found in stomachs collected in 2001, in which age-2 capelin was the dominant group consumed in that year (Fig. 63).

DISCUSSION

Two main factors (biological and physical) affect the consumption of capelin by marine fishes. Biological factors include the availability of capelin as prey, predator prey preferences, rations, and the abundance of the predators. Physical factors include the water temperature, ice cover (in Bering Sea), water column stratification, depths, and others (e.g., sunlight effect). We will discuss some of these effects.

The Availability of Capelin as Prey

Capelin are demersal spawners. In Alaska, they spawn mainly along beaches. Pahlke’s (1985) study of capelin in Alaska waters noted that spawning begins in late May along the Alaska Peninsula, Kodiak area, and in Togiak Bay and continues northward until late July, early August spawning at Point Barrow. He also noted that the trend for capelin to spawn later in more northern waters is associated with the breakup of the icepack and the warming of nearshore waters with temperatures between 5°C and 9°C. This may aid in understanding the distribution of capelin in different areas in specific times.

Gulf of Alaska

Capelin are captured incidentally in RACE bottom surveys. However, this survey is not designed to assess forage species and may only provide an index of abundance. The 2004 SAFE (Stock Assessment and Fishery Evaluation) report showed the CPUE of capelin reached a peak in 1996 in both the Central GOA and Western GOA (Brown, 2003). However, in the present study, neither the percentage of capelin in the diet of marine fishes (Fig. 42) nor the total consumption of capelin by marine fishes (Fig. 60) in 1996 showed the same peak of abundance.

Anderson and Piatt (1999) studied the climate and biological regime shift in the Gulf of Alaska and noted that the biomass of capelin (and other forage species such as pandalid shrimps) declined during the warmer years (between 1978 and 1997) while the abundance of predators such as

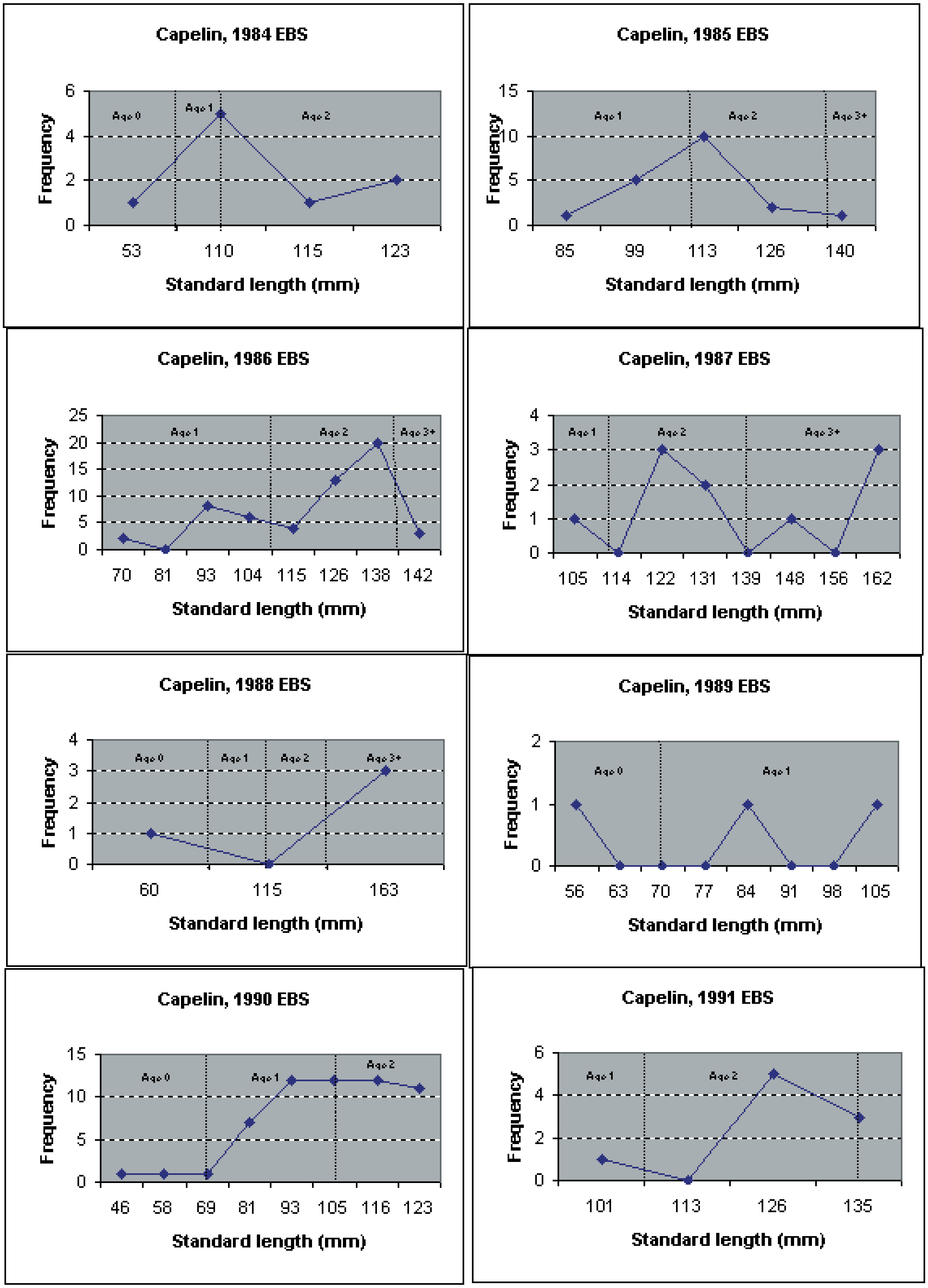

Fig. 62.--Age-length distribution of capelin as prey of marine fish in the eastern Bering Sea.

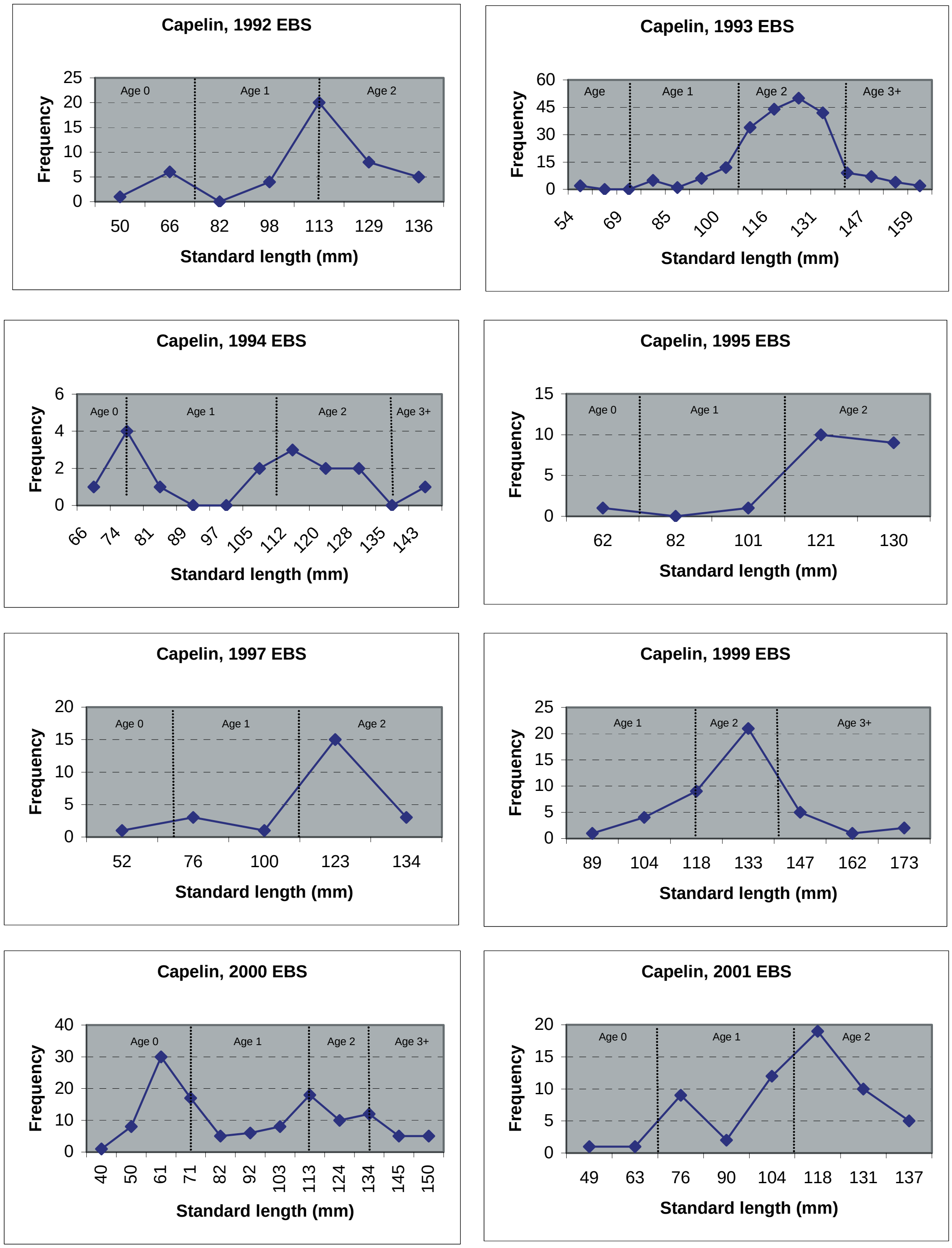

Fig. 62.--Continued.

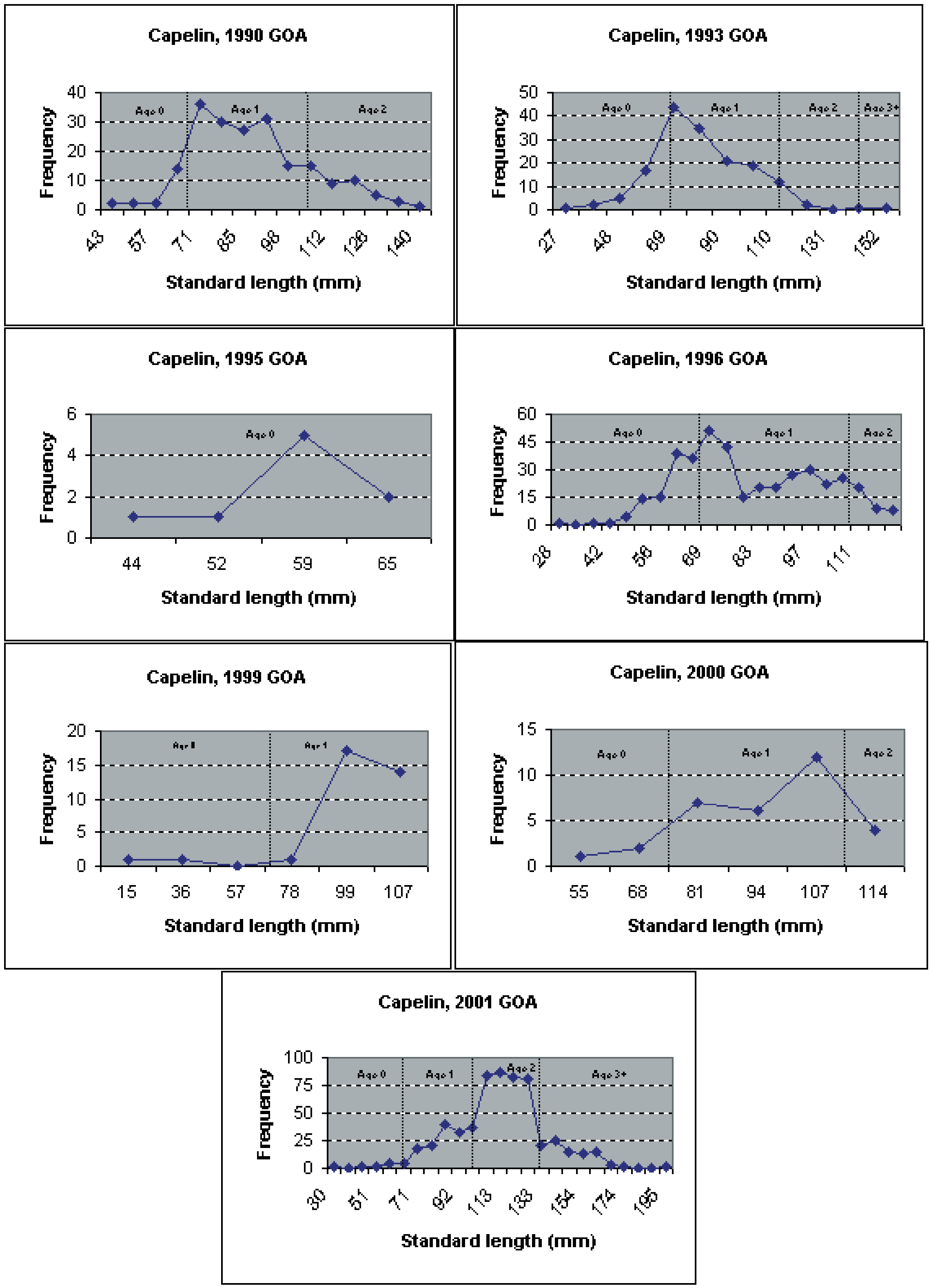

Fig. 63.--Age-length distribution of capelin as prey of marine fish in the Gulf of Alaska.

Pacific cod, walleye pollock, and flatfish increased. Hollowed et al. (in preparation) studied on the effect of ocean conditions on the distribution of walleye pollock and capelin and suggested that spatial distributions of capelin appear to be associated with the presence of cool slope waters over the shelf. They further suggested that this preference for cool water by capelin might explain the rapid disappearance of capelin in nearshore shrimp trawl surveys after the climate regime shifted to warmer coastal conditions.

Seasonal variations in larval abundance of capelin are significant in the Gulf of Alaska. In Kodiak bays, there is a summer peak (June-August). On the continental shelf, there is an autumn peak (September-November). Larvae are seen in low numbers in winter. Spring (March-May) has minimum numbers. This seasonal variation indicates a summer-autumn spawning season for capelin in the Kodiak area (Doyle et al. 2002). The abundance of capelin larvae in the Gulf of Alaska coincides with the summer peak in production of copepod nauplii (Cooney 1986). Doyle et al. (2002) suggest that capelin larvae migrate into the neuston (surface layer) at night to feed. Spawning mortality is high in the Kodiak area particularly in males. Female surviving the spawning period is generally accepted but survival to the next spawning season is believed to be negligible.

In Prince William Sound and the northern Gulf of Alaska, Brown (2002) found that the abundance of larval capelin in offshore areas (> 1 km) peaked in July, then declined. Larvae appeared to move inshore (< 1 km) because inshore abundance increased from July to October. Nursery areas are inshore since age 0 and 1 fish dominated the catches, and they were caught mostly within 400 m of the shore at bottom depths less than 100 m. Off-shore larval densities were greatest adjacent to the Gulf of Alaska and in southeastern Prince William Sound. Inshore larval densities were greatest in southeastern Prince William Sound. From aerial surveys, Brown (2002) found that schools of adult capelin were most abundant in outer beaches of the fjords closest to the Gulf of Alaska. They were never observed inside protected bays, seeming to prefer more exposed shorelines. The capelin made inshore migrations during their larval stage from offshore areas before metamorphosis. The nursery areas are in the inshore area. Immature capelin may overwinter in this area too. When they mature, they tend to move to offshore areas to spawn.

These findings may help us to understand the timing of where we would expect to find adult and juvenile capelin in offshore waters.

Eastern Bering Sea

Capelin, like other forage species, is captured incidentally in RACE bottom trawl surveys. The capelin survey catches in the eastern Bering Sea have been stable except in 1993 when catch biomass was very high (Walters, 2003). Our index of abundance data (Fig. 43) also showed high percentages of capelin in the diets of Pacific halibut, Pacific cod, arrowtooth flounder, and walleye pollock in 1993. The capelin survey catch in 1986 was the second greatest from 1982 to 2001. The relatively high percentage of capelin in the diet of walleye pollock in 1986 (Fig. 43) seemed to match the catch biomass of capelin from the RACE survey.

Naumenko (2002) indicates that, at the end of May, in the western part of the Bering Sea, capelin move inshore and concentrate in areas with bottom depths of 50-90 m to spawn. The spawning temperature is between 4-9°C sea surface temperature (SST). After spawning, the fish move away from shore. The non-spawning capelin stay offshore in bays. In late fall and early winter (November and December), capelin concentrate around St. Matthew Island and the Pribilof Islands at depths 60-100 m where the bottom temperature is -1.8° to 2.0°C. Capelin in the Pribilof Islands area had the fastest maturation rate. In the eastern part of Bering Sea, capelin fed on the broad shelf and moved 300 miles away offshore while in the western part, they stayed within embayments because of the narrowness of the shelf.

Predator Abundance

Predator biomass can have big effects on the total consumption of capelin. Detailed biomass information of each predator in different regions and in the time series is listed in Appendix 1 (Gulf of Alaska) and in Appendix 2 (eastern Bering Sea). The fluctuations or the trends of different predator biomass show that arrowtooth flounder total biomass, in the eastern Bering Sea, increased more than 2.5 times from 1976 to the 1996 value of 759,400 t (Wilderbuer and Sample 2004). Other groundfish population levels over different time periods also show different biomass fluctuations.

Maximum Ice Extent

Sea ice in the Bering Sea is an indicator of climate change and its effects on the marine ecosystem (McNutt 2004). Sea ice begins forming in the northern Bering Sea as late as November, as the ocean reaches a temperature of -1.7°C, the freezing point for salt water in this area, and ice may remain to June of the following year. Most of the sea ice forms in the northern portions of the shelf and is then blown southward due to the north-northeasterly winds. When the sea ice melts at the edge in the spring, the fresh water and nutrients in the ice are released onto the surface of the ocean on the Bering shelf.

Rodionov et al. (2003) studied ice cover and temperature in the eastern Bering Sea. They noted that, typically, the heavier the ice cover in a given winter, the later it retreats in the spring. Sea ice plays an important role in determining the timing of the spring phytoplankton bloom. If there is ice after mid-March, there is an associated ice-edge phytoplankton bloom (bloom starts when ice starts melt). If there is no ice after mid-March, the spring phytoplankton bloom occurs later in May or June when sunlight increases and water column becomes thermally stratified. The timing of the spring bloom is critical to supplying food to zooplankton. A phytoplankton bloom during March or April when the water is cold favors the benthic community since zooplanktons are temperature-limited and unable to fully consume the bloom. Alternately, a bloom in May is cropped by zooplankton ultimately favoring pelagic production. They hypothesize that warmer temperatures over the shelf would result in northward shift of the shelf ecosystem. Because most of the variability on the Bering Sea is inter-annual, it is difficult to pick out trends in climate patterns.

From our study (Figs. 2 to 33), we found that capelin were consumed mainly in the north of the maximum ice extent line. In 1986 (a cold year), the maximum ice extent reached to St. George Island (south of St. Paul Island), and more capelin were found in strata 3 and 4. In 1987 (warmer year), the maximum ice extent line was farther north than in 1986, therefore less capelin were consumed than in 1986 and only occurred in strata 1 and 2 (east and northeast of strata 3 and 4). Similar patterns occurred in 1998 (warmer year), when the maximum ice extent line was farther north, and capelin were consumed mainly in strata 1 and 2. In 1999 (cold year), ice reached St. Paul Island and more capelin were found in strata 3 and 4. These figures show the possible relationships between sea ice cover and the distribution of capelin.

In the Gulf of Alaska, the Alaska Current keeps the Gulf of Alaska ice-free and the average winter water temperature is several degrees warmer than the Bering Sea. Capelin stay in the bays of Kodiak Island in winter (Pahlke 1985).

Temperature Effect

Many studies have shown a relationship between water temperatures and capelin distributions. Brodeur et al. (1999) found that capelin in the eastern Bering Sea were associated with colder bottom temperatures (< 2°C). Naumenko (2002) noted that spawning temperature for capelin in the western Bering Sea was between 4°C and 9°C SST. Pahlke (1985) found that capelin were concentrated in the surface layer above the 5°C isotherm.

Figures 14 to 33 show the 5°C isobars in June in the eastern Bering Sea. There seems to be no relationship between the 5°C isobar and capelin distribution. However, the 5°C isobar and capelin distribution changes when the maximum ice extent changes. For example, in 1998, the capelin distribution seemed to match the 5°C isobar and the maximum ice extent. In 1999, when maximum ice extent moved farther south-west, the 5°C isobar and the capelin distribution also moved southwestward.

Brodeur et al. (1999) found that capelin were associated with colder bottom temperatures in the Bering Sea. Distributions of all species from the NMFS surveys during a cold year (1986) were more widespread and overlap among species was greater than during a warm year (1987). They suggested that the apparent decline in fish populations during the warm year of 1987 might actually be a shift in the distribution to the region north of that sampled during the annual surveys (e.g., near St. Lawrence Island and in the Gulf of Anadyr), whereas high biomasses of capelin were found in the 1987 Russian surveys.

Studying the temperatures in the Gulf of Alaska, Martin (2003) noted that the coolest years at depths between 51 and 150 m were in 1990 and 1999. From our study, we found that 1990 was the year that capelin comprised the greatest percentage of the diets of arrowtooth flounder, Pacific cod, and walleye pollock in all the years studied (Fig. 38). These results seem to match the reports that capelin prefer cooler temperatures and their distribution is more widespread during cooler years (Brodeur 1999, Hollowed in preparation).

Depth Effect

In addition to the effects of ice cover and temperature, depth seems also to affect the distribution of capelin. Figures 16 to 33 show that capelin occur mainly in the shallower inner-shelf area (< 50 m) in the eastern Bering Sea. Brodeur et al. (1999) also found that capelin were distributed in shallower areas in the eastern Bering Sea.

In our study, the depth range of capelin consumed by predators in the Gulf of Alaska area was between 24 and 294 m with a mean of 125.93 m $\pm$ 50.6 m. No capelin were found in fish stomachs collected deeper than 300 m in the Gulf of Alaska. The average depth of the hauls that capelin were consumed were 153.6 m for arrowtooth flounder, 111.7 m for Pacific cod, and 174.1 m for walleye pollock.

Methven and Piatt (1991) did a study on the seasonal abundance and vertical distribution of capelin in Newfoundland. They found most capelin at depths less than 50 m, generally above the cold (0°C) water layer in the Gulf of St. Lawrence and off Newfoundland. From hydro-acoustic surveys, they found that the vast majority of capelin were recorded near the surface (< 20-30 m). Feeding areas and spawning sites for Barents Sea capelin varies as a result of differences in annual temperatures. Many capelin might remain offshore rather than migrating inshore.

Sunlight Effect

Naumenko (2002) studied the spawning migration of capelin from the Okhotsk Sea to the coast of west Kamchatka and indicated that migration was related to changes in sunlight activity. When sunlight decreased, spawning began in late May; when sunlight activity increased, capelin approached spawning grounds in June, a couple weeks later.

Using an acoustic survey, Wilson et al. (2003) found that capelin dispersed from aggregated daytime layers and rose in the water column during darkness. This means that if predators tend to be at the bottom during the day and move up in the water column at night, they will have a greater chance to prey upon capelin.

Population Level Consumption of Capelin

The total estimate of the capelin consumed by sampled groundfish in Gulf of Alaska was between 22,000 (in 1999) and 222,000 t (in 1990). The amounts consumed by groundfish in the eastern Bering Sea was between 30 t (in 1988) and 47,000 t (in 1986). The large variations between different years are caused by variations in predator biomass, the capelin biomass, the availability of capelin during stomach collections, and many of the physical factors mentioned earlier. Among which, predator biomass appears to be the most important factor for the variations.

Bogstad and Gjosater (1994) estimated the consumption of capelin by Atlantic cod (*Gadus morhua* L.) in the Barents Sea. They estimated the amount of capelin consumed by Atlantic cod in the winter of 1991-93 was between 500,000 and 800,000 t. The method they used was based on stomach content data, a model for stomach evacuation rate, and various assumptions about temperature, stock size, age distribution of cod, initial stock size estimate of maturing capelin, and overlap between cod and capelin in space and time. In a later study, Bogstad and Gjosater (2001) indicated that their assessment method overestimated the consumption of mature capelin by cod. In our study, the greatest amount of capelin consumed by Pacific cod was 5,000 t in Gulf of Alaska and 12,000 t in the eastern Bering Sea.

Future Studies

This report was an initial exploration of the possible mechanisms influencing groundfish consumption of capelin and using groundfish as possible indicators of capelin abundance. Capelin distribution and consumption is associated with sunlight, ice cover, temperature, and the abundance of predators. These factors may interact with each other.

Future studies could include a long-term survey specifically for forage species in both the Gulf of Alaska and the eastern Bering Sea. Brown et al. (2002), using Lidar (Light Detection and Ranging) and video technology, did a remote sensing study for capelin. They noted that the advantage of this airborne remote sensing for fisheries research is its ability to collect physical and biological data over large regions quickly. However, the disadvantage of this survey is that it is restricted to the near surface only (the upper 50 m). Acoustic surveys may be the best way to study capelin distribution below 50 m. Small-scale studies that evaluate capelin distribution relative to zooplankton prey and groundfish predators using acoustic, trawl, and zooplankton sampling gear may aid in understanding the finer-scale distribution and overlap patterns of capelin and their predators and prey relative to physical factors.

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Appendix 1.-- Estimated biomass consumption (metric tons) of capelin by the marine fishes from May to September in the Gulf of Alaska, by year, predator species, strata, and predator size groups (PredLen). Daily ration (stomach contents weight as percent of body weight), number of hauls (N hauls), number of stomachs with food (N Stom), mean percent weight of capelin in diet (Mean %Wt), and predator biomass (metric tons) were also listed.

Year	Predator	Strata	PredLen	DailyRation	N hauls	N Stom	Mean %Wt	Pred Biomass	Consumption
1990	ARROWTOOTH FLOUNDER	GOA_Centralgully	20_29	0.0059	3	13	0.38	5589	1901
1990	ARROWTOOTH FLOUNDER	GOA_Centralgully	30_39	0.0048	6	67	0.33	54082	12994
1990	ARROWTOOTH FLOUNDER	GOA_Centralgully	40_49	0.0041	14	86	0.43	139529	37777
1990	ARROWTOOTH FLOUNDER	GOA_Centralgully	50_59	0.0036	5	37	0.12	135895	8905
1990	ARROWTOOTH FLOUNDER	GOA_Centralgully	60_69	0.0032	1	4	0.01	104192	380
1990	ARROWTOOTH FLOUNDER	GOA_Centralgully	70_99	0.0030	2	4	0.01	132214	518
1990	ARROWTOOTH FLOUNDER	GOA_Centralshelf	10_19	0.0082	1	4	0.21	315	84
1990	ARROWTOOTH FLOUNDER	GOA_Centralshelf	20_29	0.0059	5	62	0.45	15283	6272
1990	ARROWTOOTH FLOUNDER	GOA_Centralshelf	30_39	0.0048	11	88	0.16	96966	11131
1990	ARROWTOOTH FLOUNDER	GOA_Centralshelf	40_49	0.0041	15	140	0.22	345465	46695
1990	ARROWTOOTH FLOUNDER	GOA_Centralshelf	50_59	0.0036	5	62	0.22	255138	30201
1990	ARROWTOOTH FLOUNDER	GOA_Eastshelf	50_59	0.0036	1	5	0.06	44222	1572
1993	ARROWTOOTH FLOUNDER	GOA_Centralgully	20_29	0.0059	7	71	0.03	4507	125
1993	ARROWTOOTH FLOUNDER	GOA_Centralgully	30_39	0.0048	6	87	0.06	28325	1210

1993	ARROWTOOTH FLOUNDER	GOA_Centralgully	40_49	0.0041	13	101	0.05	105189	3306
1993	ARROWTOOTH FLOUNDER	GOA_Centralgully	50_59	0.0036	11	84	0.00	118210	232
1993	ARROWTOOTH FLOUNDER	GOA_Centralgully	60_69	0.0032	7	31	0.15	48707	3530
1993	ARROWTOOTH FLOUNDER	GOA_Centralshelf	10_19	0.0082	4	44	0.55	237	165
1993	ARROWTOOTH FLOUNDER	GOA_Centralshelf	20_29	0.0059	8	75	0.01	12171	164
1993	ARROWTOOTH FLOUNDER	GOA_Centralshelf	40_49	0.0041	12	140	0.04	253202	5906
1993	ARROWTOOTH FLOUNDER	GOA_Centralshelf	50_59	0.0036	11	100	0.09	329323	16033
1993	ARROWTOOTH FLOUNDER	GOA_Eastshelf	20_29	0.0059	1	7	0.48	5106	2197
1993	ARROWTOOTH FLOUNDER	GOA_Eastshelf	40_49	0.0041	6	23	0.02	60822	940
1993	ARROWTOOTH FLOUNDER	GOA_Westgully	40_49	0.0041	1	3	0.91	17749	10035
1993	ARROWTOOTH FLOUNDER	GOA_Westshelf	10_19	0.0082	2	16	0.18	727	160
1993	ARROWTOOTH FLOUNDER	GOA_Westshelf	20_29	0.0059	2	36	0.05	9389	385
1996	ARROWTOOTH FLOUNDER	GOA_Centralgully	10_19	0.0082	1	3	0.51	138	88
1996	ARROWTOOTH FLOUNDER	GOA_Centralgully	20_29	0.0059	3	30	0.01	5235	48
1996	ARROWTOOTH FLOUNDER	GOA_Centralgully	30_39	0.0048	5	70	0.04	37675	1216
1996	ARROWTOOTH FLOUNDER	GOA_Centralgully	40_49	0.0041	18	166	0.05	89728	2838
1996	ARROWTOOTH FLOUNDER	GOA_Centralgully	50_59	0.0036	16	105	0.19	118777	12534
1996	ARROWTOOTH FLOUNDER	GOA_Centralgully	70_99	0.0030	4	10	0.00	20151	20

1996	ARROWTOOTH FLOUNDER	GOA_Centralshelf	10_19	0.0082	2	32	0.11	580	82
1996	ARROWTOOTH FLOUNDER	GOA_Centralshelf	20_29	0.0059	21	159	0.14	14195	1798
1996	ARROWTOOTH FLOUNDER	GOA_Centralshelf	30_39	0.0048	9	97	0.02	58484	782
1996	ARROWTOOTH FLOUNDER	GOA_Centralshelf	40_49	0.0041	18	202	0.06	255240	10337
1996	ARROWTOOTH FLOUNDER	GOA_Centralshelf	50_59	0.0036	31	187	0.07	380651	15518
1996	ARROWTOOTH FLOUNDER	GOA_Centralshelf	70_99	0.0030	4	5	0.01	45949	104
1996	ARROWTOOTH FLOUNDER	GOA_Westgully	40_49	0.0041	5	15	0.13	27351	2182
1996	ARROWTOOTH FLOUNDER	GOA_Westgully	50_59	0.0036	2	9	0.37	18809	3841
1996	ARROWTOOTH FLOUNDER	GOA_Westgully	60_69	0.0032	3	9	0.02	7456	70
1996	ARROWTOOTH FLOUNDER	GOA_Westshelf	20_29	0.0059	16	112	0.08	5355	369
1996	ARROWTOOTH FLOUNDER	GOA_Westshelf	30_39	0.0048	6	65	0.09	20118	1321
1996	ARROWTOOTH FLOUNDER	GOA_Westshelf	40_49	0.0041	10	85	0.11	38256	2709
1996	ARROWTOOTH FLOUNDER	GOA_Westshelf	50_59	0.0036	8	45	0.13	33831	2364
1999	ARROWTOOTH FLOUNDER	GOA_Centralgully	20_29	0.0059	5	24	0.16	8697	1222
1999	ARROWTOOTH FLOUNDER	GOA_Centralgully	30_39	0.0048	7	46	0.09	42121	2907
1999	ARROWTOOTH FLOUNDER	GOA_Centralshelf	30_39	0.0048	7	76	0.06	59168	2721
1999	ARROWTOOTH FLOUNDER	GOA_Centralshelf	40_49	0.0041	19	69	0.00	131207	336

1999	ARROWTOOTH FLOUNDER	GOA_Westshelf	50_59	0.0036	4	10	0.23	25021	3227
2001	ARROWTOOTH FLOUNDER	GOA_Centralgully	10_19	0.0082	6	20	0.01	850	7
2001	ARROWTOOTH FLOUNDER	GOA_Centralgully	20_29	0.0059	5	79	0.05	13522	636
2001	ARROWTOOTH FLOUNDER	GOA_Centralgully	30_39	0.0048	6	87	0.06	59263	2476
2001	ARROWTOOTH FLOUNDER	GOA_Centralgully	40_49	0.0041	9	84	0.03	149468	2968
2001	ARROWTOOTH FLOUNDER	GOA_Centralshelf	10_19	0.0082	4	56	0.00	1110	6
2001	ARROWTOOTH FLOUNDER	GOA_Centralshelf	20_29	0.0059	23	222	0.14	20062	2479
2001	ARROWTOOTH FLOUNDER	GOA_Centralshelf	30_39	0.0048	12	132	0.16	51656	5971
2001	ARROWTOOTH FLOUNDER	GOA_Centralshelf	40_49	0.0041	15	127	0.04	172706	4628
2001	ARROWTOOTH FLOUNDER	GOA_Centralshelf	50_59	0.0036	10	112	0.12	255173	16498
2001	ARROWTOOTH FLOUNDER	GOA_Centralshelf	70_99	0.0030	2	6	0.07	58519	1889
1990	PACIFIC COD	GOA_Centralgully	50_59	0.0052	9	121	0.02	17338	238
1990	PACIFIC COD	GOA_Centralgully	70_99	0.0043	3	20	0.00	7859	6
1990	PACIFIC COD	GOA_Centralshelf	30_39	0.0070	4	19	0.26	2669	727
1990	PACIFIC COD	GOA_Centralshelf	40_49	0.0059	9	110	0.02	31606	683
1990	PACIFIC COD	GOA_Centralshelf	50_59	0.0052	9	138	0.05	64905	2760
1990	PACIFIC COD	GOA_Centralshelf	60_69	0.0047	13	147	0.00	71684	76
1990	PACIFIC COD	GOA_Eastshelf	50_59	0.0052	2	11	0.10	1647	137
1993	PACIFIC COD	GOA_Centralgully	50_59	0.0052	8	68	0.02	15594	301
1993	PACIFIC COD	GOA_Centralshelf	20_29	0.0086	1	18	0.23	1251	385
1993	PACIFIC COD	GOA_Centralshelf	40_49	0.0059	8	72	0.01	16092	152
1993	PACIFIC COD	GOA_Centralshelf	60_69	0.0047	13	159	0.01	77101	297
1993	PACIFIC COD	GOA_Eastshelf	70_99	0.0043	2	7	0.02	4870	74

1993	PACIFIC COD	GOA_Westgully	60_69	0.0047	1	6	0.07	1999	106
1993	PACIFIC COD	GOA_Westshelf	60_69	0.0047	7	55	0.01	24551	109
1996	PACIFIC COD	GOA_Centralgully	60_69	0.0047	3	26	0.01	23470	240
1996	PACIFIC COD	GOA_Centralshelf	50_59	0.0052	1	23	0.00	22491	2
1996	PACIFIC COD	GOA_Centralshelf	70_99	0.0043	7	44	0.00	74162	154
2001	PACIFIC COD	GOA_Centralshelf	30_39	0.0070	8	48	0.01	1961	23
2001	PACIFIC COD	GOA_Centralshelf	40_49	0.0059	10	87	0.12	9714	1069
2001	PACIFIC COD	GOA_Centralshelf	50_59	0.0052	7	72	0.01	19295	93
2001	PACIFIC COD	GOA_Centralshelf	70_99	0.0043	5	41	0.03	17937	347
2001	PACIFIC COD	GOA_Westshelf	60_69	0.0047	5	59	0.00	43274	33
1990	PACIFIC HALIBUT	GOA_Centralgully	70_99	0.0017	8	31	0.02	3705	24
1990	PACIFIC HALIBUT	GOA_Centralshelf	100_199	0.0012	8	29	0.00	19197	6
1990	PACIFIC HALIBUT	GOA_Centralshelf	20_29	0.0035	2	17	0.01	329	2
1990	PACIFIC HALIBUT	GOA_Centralshelf	30_39	0.0028	3	19	0.01	841	2
1990	PACIFIC HALIBUT	GOA_Centralshelf	40_49	0.0024	5	29	0.05	4175	74
1990	PACIFIC HALIBUT	GOA_Centralshelf	50_59	0.0021	3	23	0.11	12865	439
1990	PACIFIC HALIBUT	GOA_Centralshelf	60_69	0.0019	3	43	0.15	33139	1374
1990	PACIFIC HALIBUT	GOA_Centralshelf	70_99	0.0017	20	86	0.02	37428	163
1990	PACIFIC HALIBUT	GOA_Westgully	100_199	0.0012	1	8	0.00	1635	1
1993	PACIFIC HALIBUT	GOA_Eastshelf	60_69	0.0019	1	7	0.77	5440	1195
1993	PACIFIC HALIBUT	GOA_Westshelf	50_59	0.0021	4	44	0.17	25439	1341
1996	PACIFIC HALIBUT	GOA_Centralshelf	30_39	0.0028	1	12	0.19	1606	133
1996	PACIFIC HALIBUT	GOA_Centralshelf	50_59	0.0021	2	29	0.21	35106	2384
1996	PACIFIC HALIBUT	GOA_Centralshelf	60_69	0.0019	3	39	0.02	96507	641
1996	PACIFIC HALIBUT	GOA_Centralshelf	70_99	0.0017	10	47	0.01	90401	318
1999	PACIFIC HALIBUT	GOA_Centralshelf	40_49	0.0024	1	14	0.04	11947	175
1999	PACIFIC HALIBUT	GOA_Centralshelf	60_69	0.0019	3	27	0.20	57213	3317
2001	PACIFIC HALIBUT	GOA_Centralgully	70_99	0.0017	5	22	0.19	2637	132
2001	PACIFIC HALIBUT	GOA_Centralshelf	40_49	0.0024	13	100	0.00	8918	9
2001	PACIFIC HALIBUT	GOA_Centralshelf	50_59	0.0021	7	76	0.04	17960	237
2001	PACIFIC HALIBUT	GOA_Centralshelf	60_69	0.0019	4	64	0.05	30025	432
2001	PACIFIC HALIBUT	GOA_Centralshelf	70_99	0.0017	16	146	0.14	46199	1687
1990	WALLEYE POLLOCK	GOA_Centralgully	20_29	0.0149	3	16	0.15	3749	1309

1990	WALLEYE POLLOCK	GOA_Centralgully	30_39	0.0122	1	11	0.52	3784	3651
1990	WALLEYE POLLOCK	GOA_Centralgully	40_49	0.0104	7	119	0.00	78965	473
1990	WALLEYE POLLOCK	GOA_Centralgully	50_59	0.0093	11	132	0.06	174992	15138
1990	WALLEYE POLLOCK	GOA_Centralshelf	20_29	0.0149	6	58	0.02	21284	889
1990	WALLEYE POLLOCK	GOA_Centralshelf	40_49	0.0104	11	169	0.11	89181	16178
1990	WALLEYE POLLOCK	GOA_Centralshelf	50_59	0.0093	19	184	0.02	138220	4223
1990	WALLEYE POLLOCK	GOA_Centralshelf	60_69	0.0084	4	42	0.24	37056	11507
1990	WALLEYE POLLOCK	GOA_Eastshelf	20_29	0.0149	2	17	0.01	8664	150
1990	WALLEYE POLLOCK	GOA_Westgully	50_59	0.0093	2	23	0.10	19249	2747
1993	WALLEYE POLLOCK	GOA_Centralgully	40_49	0.0104	5	95	0.08	30086	4010
1993	WALLEYE POLLOCK	GOA_Centralgully	50_59	0.0093	13	101	0.01	56454	672
1993	WALLEYE POLLOCK	GOA_Centralshelf	30_39	0.0122	2	24	0.03	7582	398
1993	WALLEYE POLLOCK	GOA_Centralshelf	40_49	0.0104	9	94	0.01	81628	1405
1993	WALLEYE POLLOCK	GOA_Centralshelf	50_59	0.0093	12	144	0.01	148742	2602
1993	WALLEYE POLLOCK	GOA_Eastshelf	10_19	0.0202	3	14	0.03	662	61
1993	WALLEYE POLLOCK	GOA_Eastshelf	20_29	0.0149	1	10	0.20	2035	936
1993	WALLEYE POLLOCK	GOA_Westshelf	10_19	0.0202	2	17	0.04	431	55
1993	WALLEYE POLLOCK	GOA_Westshelf	50_59	0.0093	8	56	0.07	133500	12898
1999	WALLEYE POLLOCK	GOA_Centralgully	30_39	0.0122	2	11	0.18	1209	416
1999	WALLEYE POLLOCK	GOA_Centralgully	40_49	0.0104	4	61	0.04	7985	573
1999	WALLEYE POLLOCK	GOA_Centralgully	50_59	0.0093	4	38	0.25	8367	2935
1999	WALLEYE POLLOCK	GOA_Centralshelf	40_49	0.0104	11	129	0.01	56230	843
1999	WALLEYE POLLOCK	GOA_Centralshelf	50_59	0.0093	3	76	0.03	53110	2401
1999	WALLEYE POLLOCK	GOA_Westgully	10_19	0.0202	2	17	0.30	104	97
2001	WALLEYE POLLOCK	GOA_Centralgully	20_29	0.0149	2	45	0.03	1816	129
2001	WALLEYE POLLOCK	GOA_Centralshelf	50_59	0.0093	8	98	0.00	36766	188

Appendix 2.--Estimated biomass consumption (metric tons) of capelin by the marine fishes from May to September in the eastern Bering Sea, by year, predator species, strata, and predator size groups (PredLen). Daily ration (stomach contents weight as percent of body weight), number of hauls (N hauls), number of stomachs with food (N Stom), mean percent weight of capelin in diet (Mean %Wt), and predator biomass (metric tons) were also listed.

Year	Predator	Strata	PredLen	DailyRation	N hauls	N Stom	Mean %Wt	Pred Biomass	Consumption
1985	ARROWTOOTH FLOUNDER	EBS04	40_49	0.0041	3	27	0.20	2023	248
1989	ARROWTOOTH FLOUNDER	EBS03	40_49	0.0041	1	15	0.07	19991	827
1993	ARROWTOOTH FLOUNDER	EBS03	40_49	0.0041	11	37	0.11	52212	3486
1993	ARROWTOOTH FLOUNDER	EBS05	40_49	0.0041	4	18	0.11	53830	3728
1994	ARROWTOOTH FLOUNDER	EBS03	30_39	0.0048	2	16	0.28	37276	7791
1994	ARROWTOOTH FLOUNDER	EBS03	40_49	0.0041	6	32	0.06	66086	2273
1997	ARROWTOOTH FLOUNDER	EBS04	20_29	0.0059	2	6	0.03	735	19
2000	ARROWTOOTH FLOUNDER	EBS03	10_19	0.0082	4	22	0.01	1168	15
2001	ARROWTOOTH FLOUNDER	EBS01	20_29	0.0059	2	8	0.24	163	35
2001	ARROWTOOTH FLOUNDER	EBS06	60_69	0.0032	6	12	0.06	22640	713
1984	PACIFIC COD	EBS01	20_29	0.0086	7	52	0.03	15103	592
1984	PACIFIC COD	EBS01	40_49	0.0059	11	47	0.02	16390	307
1984	PACIFIC COD	EBS02	70_99	0.0043	2	7	0.02	29643	418
1985	PACIFIC COD	EBS01	50_59	0.0052	3	22	0.07	17098	975
1985	PACIFIC COD	EBS03	70_99	0.0043	11	105	0.02	27527	432
1986	PACIFIC COD	EBS01	50_59	0.0052	6	87	0.01	44857	249
1986	PACIFIC COD	EBS01	70_99	0.0043	9	70	0.00	32288	44
1986	PACIFIC COD	EBS02	30_39	0.0070	1	10	0.35	850	314
1990	PACIFIC COD	EBS01	10_19	0.0118	12	93	0.05	1790	150
1990	PACIFIC COD	EBS01	70_99	0.0043	5	15	0.01	9558	89
1990	PACIFIC COD	EBS02	20_29	0.0086	1	6	0.05	146	9
1991	PACIFIC COD	EBS04	60_69	0.0047	5	41	0.02	24812	332
1991	PACIFIC COD	EBS04	70_99	0.0043	11	45	0.00	17229	21
1992	PACIFIC COD	EBS01	30_39	0.0070	6	92	0.00	14737	6
1992	PACIFIC COD	EBS01	40_49	0.0059	3	62	0.06	29073	1589

1992	PACIFIC COD	EBS02	20_29	0.0086	1	14	0.01	1388	14
1992	PACIFIC COD	EBS03	50_59	0.0052	5	68	0.00	16603	30
1993	PACIFIC COD	EBS01	20_29	0.0086	2	55	0.34	2999	1325
1993	PACIFIC COD	EBS01	40_49	0.0059	5	85	0.04	51164	1884
1993	PACIFIC COD	EBS01	50_59	0.0052	6	46	0.00	33765	131
1993	PACIFIC COD	EBS01	60_69	0.0047	2	36	0.22	38415	6055
1993	PACIFIC COD	EBS01	70_99	0.0043	4	8	0.07	6422	315
1993	PACIFIC COD	EBS02	10_19	0.0118	3	67	0.04	1617	130
1993	PACIFIC COD	EBS02	50_59	0.0052	4	16	0.01	5281	55
1993	PACIFIC COD	EBS03	50_59	0.0052	5	68	0.07	28582	1716
1993	PACIFIC COD	EBS03	70_99	0.0043	10	55	0.00	14564	48
1994	PACIFIC COD	EBS01	30_39	0.0070	11	150	0.02	61282	1061
1994	PACIFIC COD	EBS02	10_19	0.0118	2	18	0.01	254	4
1994	PACIFIC COD	EBS02	50_59	0.0052	2	43	0.06	13442	598
1994	PACIFIC COD	EBS02	60_69	0.0047	5	56	0.02	19045	253
1994	PACIFIC COD	EBS03	30_39	0.0070	9	149	0.02	34854	739
1994	PACIFIC COD	EBS03	40_49	0.0059	7	75	0.00	29570	109
1995	PACIFIC COD	EBS01	20_29	0.0086	4	28	0.02	6229	151
1995	PACIFIC COD	EBS01	30_39	0.0070	3	46	0.06	23012	1393
1995	PACIFIC COD	EBS02	70_99	0.0043	3	13	0.00	2861	2
1995	PACIFIC COD	EBS05	70_99	0.0043	4	33	0.02	14431	163
1997	PACIFIC COD	EBS02	10_19	0.0118	5	56	0.00	1087	2
1998	PACIFIC COD	EBS01	70_99	0.0043	2	40	0.01	19427	119
1998	PACIFIC COD	EBS02	20_29	0.0086	2	23	0.00	1923	5
1999	PACIFIC COD	EBS01	10_19	0.0118	7	107	0.01	317	7
2001	PACIFIC COD	EBS01	10_19	0.0118	12	88	0.00	4158	23
2001	PACIFIC COD	EBS01	20_29	0.0086	3	45	0.08	6666	666
2001	PACIFIC COD	EBS01	50_59	0.0052	2	26	0.02	21331	306
2001	PACIFIC COD	EBS01	60_69	0.0047	7	56	0.02	27719	366
2001	PACIFIC COD	EBS02	10_19	0.0118	8	58	0.01	757	18
2001	PACIFIC COD	EBS02	70_99	0.0043	2	9	0.02	1958	30
2001	PACIFIC COD	EBS03	10_19	0.0118	5	31	0.01	2433	29
1990	PACIFIC HALIBUT	EBS02	30_39	0.0028	3	22	0.02	1060	8

1990	PACIFIC HALIBUT	EBS02	70_99	0.0017	2	2	0.50	283	36
1991	PACIFIC HALIBUT	EBS01	70_99	0.0017	8	18	0.00	3907	3
1992	PACIFIC HALIBUT	EBS01	30_39	0.0028	2	8	0.08	1071	38
1992	PACIFIC HALIBUT	EBS01	40_49	0.0024	11	56	0.11	8700	343
1992	PACIFIC HALIBUT	EBS01	50_59	0.0021	5	47	0.05	7655	114
1992	PACIFIC HALIBUT	EBS02	30_39	0.0028	1	1	0.23	277	27
1992	PACIFIC HALIBUT	EBS02	50_59	0.0021	2	9	0.02	4976	28
1993	PACIFIC HALIBUT	EBS01	50_59	0.0021	4	46	0.22	17750	1270
1993	PACIFIC HALIBUT	EBS01	60_69	0.0019	4	17	0.12	10493	357
1993	PACIFIC HALIBUT	EBS02	30_39	0.0028	2	12	0.15	1084	68
1993	PACIFIC HALIBUT	EBS02	50_59	0.0021	3	30	0.30	5879	553
1993	PACIFIC HALIBUT	EBS02	70_99	0.0017	2	4	0.69	720	129
1994	PACIFIC HALIBUT	EBS01	60_69	0.0019	5	23	0.01	18259	71
1994	PACIFIC HALIBUT	EBS02	50_59	0.0021	2	9	0.03	2078	20
1994	PACIFIC HALIBUT	EBS02	60_69	0.0019	2	13	0.00	3499	4
1997	PACIFIC HALIBUT	EBS01	30_39	0.0028	3	18	0.01	2220	11
1997	PACIFIC HALIBUT	EBS01	40_49	0.0024	3	7	0.10	956	35
1997	PACIFIC HALIBUT	EBS02	30_39	0.0028	3	14	0.01	439	1
1997	PACIFIC HALIBUT	EBS02	40_49	0.0024	1	16	0.01	999	5
1997	PACIFIC HALIBUT	EBS03	70_99	0.0017	7	21	0.01	9286	30
1998	PACIFIC HALIBUT	EBS01	10_19	0.0049	1	1	0.01	15	0
1998	PACIFIC HALIBUT	EBS01	30_39	0.0028	6	26	0.01	2527	14
1998	PACIFIC HALIBUT	EBS01	40_49	0.0024	5	32	0.01	3412	12
1999	PACIFIC HALIBUT	EBS01	30_39	0.0028	5	14	0.18	769	60
1999	PACIFIC HALIBUT	EBS01	40_49	0.0024	4	12	0.24	1266	108
1999	PACIFIC HALIBUT	EBS01	50_59	0.0021	1	4	0.33	1382	147
1999	PACIFIC HALIBUT	EBS02	30_39	0.0028	2	4	0.10	238	10
1999	PACIFIC HALIBUT	EBS02	40_49	0.0024	1	11	0.40	604	86
2000	PACIFIC HALIBUT	EBS01	50_59	0.0021	2	10	0.09	3969	108
1986	WALLEYE POLLOCK	EBS01	70_99	0.0077	13	64	0.02	10465	233
1986	WALLEYE POLLOCK	EBS03	50_59	0.0093	13	124	0.05	534461	38870
1986	WALLEYE POLLOCK	EBS03	60_69	0.0084	20	128	0.02	76191	2332
1986	WALLEYE POLLOCK	EBS03	70_99	0.0077	11	69	0.01	5347	74

1986	WALLEYE POLLOCK	EBS04	60_69	0.0084	12	71	0.05	72695	4540
1987	WALLEYE POLLOCK	EBS01	60_69	0.0084	10	124	0.01	82037	1110
1988	WALLEYE POLLOCK	EBS02	10_19	0.0202	5	72	0.02	625	30
1989	WALLEYE POLLOCK	EBS01	60_69	0.0084	11	61	0.00	36673	147
1989	WALLEYE POLLOCK	EBS01	70_99	0.0077	3	19	0.02	10796	266
1989	WALLEYE POLLOCK	EBS02	60_69	0.0084	5	50	0.03	17995	752
1990	WALLEYE POLLOCK	EBS01	60_69	0.0084	15	137	0.02	57644	1305
1990	WALLEYE POLLOCK	EBS01	70_99	0.0077	7	59	0.12	9424	1368
1990	WALLEYE POLLOCK	EBS03	70_99	0.0077	2	24	0.04	8794	407
1991	WALLEYE POLLOCK	EBS02	60_69	0.0084	7	83	0.01	41591	446
1991	WALLEYE POLLOCK	EBS04	60_69	0.0084	12	137	0.04	156534	8437
1992	WALLEYE POLLOCK	EBS01	60_69	0.0084	12	200	0.00	85991	241
1992	WALLEYE POLLOCK	EBS01	70_99	0.0077	8	83	0.12	27392	3942
1992	WALLEYE POLLOCK	EBS03	50_59	0.0093	14	250	0.00	462883	1434
1992	WALLEYE POLLOCK	EBS03	60_69	0.0084	14	168	0.00	151719	236
1993	WALLEYE POLLOCK	EBS01	50_59	0.0093	2	65	0.06	120782	10989
1993	WALLEYE POLLOCK	EBS01	60_69	0.0084	11	124	0.00	177143	488
1993	WALLEYE POLLOCK	EBS01	70_99	0.0077	9	57	0.13	40457	5994
1993	WALLEYE POLLOCK	EBS02	50_59	0.0093	2	21	0.03	9300	347
1993	WALLEYE POLLOCK	EBS02	60_69	0.0084	9	103	0.13	41726	7125
1993	WALLEYE POLLOCK	EBS02	70_99	0.0077	6	43	0.03	22359	780
1993	WALLEYE POLLOCK	EBS04	60_69	0.0084	11	217	0.00	196643	1017
1994	WALLEYE POLLOCK	EBS01	60_69	0.0084	9	168	0.01	169633	2388
1994	WALLEYE POLLOCK	EBS02	60_69	0.0084	5	118	0.04	69041	3632
1994	WALLEYE POLLOCK	EBS02	70_99	0.0077	7	61	0.01	32264	212
1995	WALLEYE POLLOCK	EBS01	60_69	0.0084	11	220	0.00	167778	306
1995	WALLEYE POLLOCK	EBS03	60_69	0.0084	12	197	0.01	116192	1394
1999	WALLEYE POLLOCK	EBS01	0_9	0.0391	1	23	0.37	97	214
1999	WALLEYE POLLOCK	EBS01	10_19	0.0202	4	18	0.01	77	1
1999	WALLEYE POLLOCK	EBS01	70_99	0.0077	8	105	0.02	33124	690
1999	WALLEYE POLLOCK	EBS02	0_9	0.0391	4	43	0.04	310	80
1999	WALLEYE POLLOCK	EBS02	60_69	0.0084	7	125	0.10	19789	2620
1999	WALLEYE POLLOCK	EBS03	10_19	0.0202	5	44	0.03	829	87

1999	WALLEYE POLLOCK	EBS04	60_69	0.0084	5	137	0.01	81362	551
2000	WALLEYE POLLOCK	EBS01	0_9	0.0391	9	73	0.02	817	87
2000	WALLEYE POLLOCK	EBS01	10_19	0.0202	8	94	0.02	1341	72
2000	WALLEYE POLLOCK	EBS01	60_69	0.0084	13	253	0.03	136842	6012
2000	WALLEYE POLLOCK	EBS01	70_99	0.0077	5	99	0.06	32215	2238
2000	WALLEYE POLLOCK	EBS02	0_9	0.0391	2	12	0.02	254	31
2000	WALLEYE POLLOCK	EBS02	70_99	0.0077	6	55	0.00	19743	52
2000	WALLEYE POLLOCK	EBS03	0_9	0.0391	3	22	0.08	100	51
2000	WALLEYE POLLOCK	EBS03	10_19	0.0202	4	106	0.01	1606	60
2001	WALLEYE POLLOCK	EBS01	10_19	0.0202	9	55	0.00	2560	33
2001	WALLEYE POLLOCK	EBS01	60_69	0.0084	9	180	0.06	112895	8228
2001	WALLEYE POLLOCK	EBS01	70_99	0.0077	4	69	0.17	28039	5667
2001	WALLEYE POLLOCK	EBS02	60_69	0.0084	4	61	0.04	27570	1265

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