Feeding of Ribbon Seals (*Phoca fasciata*) in the Bering Sea in Spring

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Abstract

Digestive tracts of 61 ribbon seals (*Phoca fasciata*) collected in the seasonal pack ice of the Bering Sea during March to June 1976-1979 were examined. Very little fresh food was found in stomachs; however, hard parts of prey, particularly fish otoliths, were found in stomachs and/or intestines of 28 seals. Few invertebrate remains were found. Based on counts of otoliths, pollock were the primary prey in southcentral and central Bering Sea, and arctic cod were the main prey in northern Bering Sea. Several other kinds of fishes (saffron cod, eelpout, capelin, pricklebacks, sculpins, flatfish, poachers, and snailfish) were eaten in much smaller numbers. Weights and lengths of fishes consumed by seals were estimated from measurements of otoliths. On the basis of estimated whole weight of prey consumed, eelpout were a major food of these seals in southcentral and central Bering Sea. The species composition of fishes caught in trawls and eaten by seals was compared. In central and northern Bering Sea seals appeared to select for pollock and arctic cod, respectively, and against sculpins and capelin. In southcentral Bering Sea seals were less selective; pollock was the most abundant fish in both seals and trawls. Seals were nonselective with regard to size of pollock consumed but appeared to select for large arctic cod. Based on prey selection, numbers of fishes caught in trawls, and the estimated weight of fishes consumed, feeding conditions are more

favorable for ribbon seals in southcentral Bering Sea than in more northern areas.

Introduction

The marine ecosystem of the Bering Sea presently supports large populations of mammals as well as large and in some cases expanding fisheries. In order to assess potential competition between marine mammals and fisheries, it is important that the food base of major consumers in this area be understood. The ribbon seal (*Phoca fasciata*) is one of the species of Bering Sea pinnipeds for which information about food habits is least available.

Ribbon seals are associated with the winter-early spring ice front and late spring ice remnants in the Bering Sea during which time they give birth, support young, mate, and molt. When the last of the sea ice disappears the ribbon seals become pelagic; their distribution during the open water season is largely unknown (Burns 1970). Population size in the Bering Sea is estimated at 90,000 to 100,000 (Burns, in press).

There are few published accounts of the foods of ribbon seals. Arseniev (1941) and Wilke (1954) reported on the stomach contents of seals taken in the Okhotsk Sea in spring. By far the most common food items there were pollock (*Theragra chalcogramma*) and cephalopods (squids and octopus). Shrimps (mostly *Pandalus goniurus*) and Pacific cod (*Gadus macrocephalus*) also were fairly common in the stomachs examined by Arseniev. In the Shantar region of the Okhotsk Sea, Fedoseev and Bukhtiyarov (1972) also found the main prey in spring to be pollock. They stated that cephalopods were a major food in some areas. Shustov (1965) reported the results of examination of 1,207 stomachs from ribbon seals taken in the central Bering Sea in March to July. Of this sample, only 32 contained food remains in stomachs, the majority of which was shrimps, mysids, crabs, cephalopods, and several species of fishes, including arctic cod (Boreogadus saida), pricklebacks (Lumpenus medius), sand lance (Ammodytes hexapterus), herring (Clupea harengus), and saffron cod (Eleginus gracilis). Burns (in press) reported stomach contents of six seals taken at St. Lawrence Island. Of four seals taken in April and May, two contained shrimps (Pandalus sp. and Sclerocrangon sp.), one contained a single large fish (Pholis sp.), and one, a pup, had only milk in its stomach. Of two seals taken in February, Burns found pollock in one and arctic cod in the other. We have examined the digestive tracts of 61 ribbon seals collected in the ice front of the Bering Sea during March through June 1976-1979.

Methods and Materials

Seals were collected on the ice in three general areas: southcentral, central, and northern Bering Sea (Figure 1). Each seal was photographed, weighed, measured, and necropsied. At necropsy the stomach was removed, slit open, and the contents gently washed onto a 1-mm mesh screen; the materials retained on the screen were preserved in 70% ethanol. In conjunction with parasitological examinations, the small intestine of each seal was slit along its entire length and flushed with water. Otoliths and other remains of prey were separated from other intestinal contents and preserved in 70% ethanol.

In the laboratory, contents from the stomachs and intestines were sorted and identified by comparison with reference materials taken from intact representatives of the various prey species. Otoliths were counted and those which were not broken or degraded were measured (maximum length) to the nearest 0.1 mm using vernier calipers.

The number of fishes eaten by a seal was estimated by counting all otoliths of each species from both the stomach and intestine and dividing by two. The weight of fishes which had been consumed was estimated in one of two ways. For common species with large, durable otoliths (pollock, arctic cod, saffron cod, and eelpout (*Lycodes* spp.)) regression equations relating otolith length to fish length and fish length to fish weight were calculated using measurements obtained from fishes collected in the Bering Sea (Frost and Lowry, unpublished data). Those equations were then applied to measurements of otoliths from the stomach and intestine of each seal. Since lengths of otoliths from stomachs and intestines did not differ significantly ($t=1.13$, $P > 0.05$), these data were combined for each seal. For species of infrequent occurrence in seals and those with small, fragile otoliths (capelin, Mallotus villosus; pricklebacks, Lumpenus spp.; sculpins, F. Cottidae; Greenland halibut, Reinhardtius hippoglossoides; poachers, F. Agonidae; and snailfish, F. Cyclopteridae) the average weight of a fish of that species as determined from fishes caught in trawls was used.

Bottom sampling for fishes and invertebrates was done in areas where seals were collected. A semi-balloon otter trawl constructed of 2.5-cm stretch mesh net with a 0.6-cm mesh cod end liner and a headrope length of 5.8 m was used to make tows of 20 minutes duration at a speed of 2-4 knots. Contents of trawls were sorted and identified using appropriate keys. The number of individuals caught and the total weight were determined for each taxon. Fishes were measured and weighed, and the otoliths removed and measured.

Results

None of the 61 seals we examined had been actively feeding at the time of collection; the greatest volume of contents in a stomach was 40 ml. We found food remains in 28 individuals. Seven of those had remains in both the stomach and intestine; the other 21 had remains only in the intestines. Small amounts of invertebrates were present in 11 seals. Octopus sp. (7 individuals, indicated by the presence of beaks) occurred in five seals, crustaceans in six, small clams in five, and a small snail in one (Table 1).

Most of the identifiable food remains were from fishes. Based on number and back-calculated weight of fishes, pollock were the major prey in southcentral Bering Sea, followed by eelpout and capelin. In central Bering Sea, based on number, pollock were again the major prey, followed by Greenland halibut, pricklebacks, eelpout, and capelin. However, on the basis of estimated weight, eelpout were the major prey. In northern Bering Sea the major prey, by number and weight, were arctic cod. Saffron cod comprised 9% of the total identified fishes there but were present in only one seal.

Back-calculated weight of fishes consumed ranged from 5 g in a seal containing otoliths from a single arctic cod to 3,102 g in a seal that had otoliths from 402 pollock, one eelpout, and one capelin. The calculated mean weight of fishes for all seals with food remains was 518.0 g. In southcentral Bering Sea the mean was 1,240 g; in central Bering Sea it was 163 g; and in northern Bering Sea it was 199 g. Mean weights in the three areas were compared using a one-way ANOVA and found to be significantly different ($F = 9.38 : F_{.01}[2,25] = 5.6$). Differences in mean weights between areas were tested with a Student-Newman-Keuls multiple-range test (Woolfe 1968). Means in central and northern Bering Sea were not significantly different ($P > 0.05$) while the mean in southcentral Bering Sea was significantly larger than that in either of the other areas ($P < 0.05$).

Of the seals collected in April, five of eight from south-central Bering Sea contained food remains with a calculated mean weight of 1,828.4 g while only one of 12 from central Bering Sea contained food remains representing 27 g of fishes consumed. Sample sizes were too small to evaluate statistical significance of mean weights.

The sizes of arctic cod and pollock caught in otter trawls were compared to those estimated from otoliths in seals from the same areas (Figure 2). Spearman rank correlation analysis showed a significant positive correlation between the size distributions of pollock from both sources ($r_s = 0.676$, $P < 0.01$). Pollock caught in the trawls and eaten by seals were mainly 1-year-old fishes (Pereyra et al. 1976). Although the ranges in size of arctic cod caught by trawls and eaten by seals were similar, size distributions of the two samples were not significantly correlated ($r_s = 0.404$, $P > 0.10$). Only 2% (2/92) of the arctic cod eaten by seals were 7-11 cm long compared to 32% (38/119) of trawl caught fishes. Those proportions were significantly different (Chi-square = 21.39, $P < 0.01$).

Spearman rank correlation analysis was also used to compare the abundance of fish species caught in otter trawls with that in the seals (Table 2). In central and northern Bering Sea the rank abundance of fishes in trawls and seals were not significantly correlated (r_s = 0.164 and 0.161, respectively, $P > 0.10$) while in southcentral they were similar (r_s = 0.746, $P < 0.02$), with the most abundant fish in trawls (pollock) also the most abundant in the seals. Eelpout in southcentral, Greenland halibut in central, and gadids (pollock, saffron cod, and arctic cod) in both central and northern areas were more highly ranked in seals than in trawls, while sculpins and capelin were ranked lower in seals in all areas.

Discussion

Little is known about the feeding of ribbon seals in the Bering Sea. During the open water season (July-November), when they probably feed intensively, their distribution is poorly known. In spring when the seals can be located and collected they are usually hauled out on ice and molting, and their stomachs are mostly empty (Arseniev 1941; Shustov 1965; Burns, in press). Thus, although the stomachs of many seals have been examined, there are few data on food utilization. Shustov (1965) found that only seals still wet had any food remains, and only those collected in the water had full stomachs containing undigested food. Further, he noted that the greatest number of seals entered the water at night or on cold, overcast days. Because it is difficult to collect ribbon seals in the water and at night, this and other studies may underestimate the proportion of seals feeding during spring (Shustov found food in 20% of the seals collected at night, in contrast to 3% for the total sample). It is also possible that during stormy weather when collecting is difficult, many seals are in the water and perhaps feeding.

As stomachs of ribbon seals we collected were mostly empty, standard methods for analyzing stomach contents contributed little to our knowledge of ribbon seal feeding. Food remains present in stomachs and intestines were comprised almost entirely of hard parts of prey. Consequently, we were unable to evaluate the importance of soft-bodied invertebrates in our samples. Previous studies indicate that at certain times and places crustaceans, mainly shrimps, are a major food of ribbon seals (Arseniev 1941; Shustov 1965; Burns, in press). The small clams (*Nuculana* sp.) we found in seals from southcentral Bering Sea probably were not directly ingested by the seals but were present in stomachs of eelpout which were eaten by seals.

Hard parts present in stomachs and intestines included mainly cephalopod beaks and otoliths. It is possible to identify cephalopods and estimate their size and weight from beaks (Clarke 1962; Pinkas et al. 1971). Pitcher (in press) found that in harbor seals (*Phoca vitulina*) beaks were probably underrepresented in intestines and overrepresented in stomachs. Miller (1978) observed that captive northern fur seals (*Callorhinus ursinus*) appeared to "trap" beaks in the stomach and regurgitate them at about 2-day intervals. It is possible that cephalopods were underrepresented in the food remains we examined.

In the 28 seals with food remains, otoliths comprised most of the contents. Since otoliths are diagnostic it was possible to identify the kinds and to estimate the numbers of fishes eaten (Fitch and Brownell 1968; Morrow 1979). Pitcher (in press) found that otoliths from intestines provided accurate information on the utilization of fishes (except large species such as salmon, Oncorhynchus spp.) by harbor seals. Pastukhov (1969), experimenting with Baikal seals (Phoca sibirica), found that in individuals fed on a regular basis most otoliths and other hard parts passed through the digestive tract in 15-17 hours. In fasted seals, retention time averaged 6-9 days and in one instance was as long as 55 days. In our studies we found that some otoliths appeared discolored and somewhat deteriorated, while others were indistinguishable from those taken directly from trawl caught fishes. Otoliths recovered from ribbon seals appeared to be of the latter type and we consider that they were recently ingested.

If these assumptions are correct, the otoliths and hard parts present in the stomach and intestine may represent food eaten in the previous 24-hour period, and the back-calculated weight of fishes is an estimate of the daily intake of food (not including invertebrates). In our samples, the mean quantity of fishes consumed calculated by this method was 0.7% (range 0.01 to 6.2%) of the body weight of a seal ($\overline{X}$ body weight = 68.8 kg, range 25.0 to 113.6 kg). This compares to a daily consumption of 4.6% in captive Baikal seals (Pastukhov 1969) and 3-13% in captive spotted seals (*Phoca largha*) (Ashwell-Erickson et al. 1979) depending on the age and sex of the seals. Thus, values obtained in this study by the back-calculation method appear reasonable, although somewhat low. As mentioned previously, our samples were collected during what is considered to be a period of overall reduced feeding. It is possible that significant amounts of soft-bodied prey may have been eaten by the seals but digested prior to collection. However, very few invertebrate remains were found in intestines examined.

Back-calculation of the weights provides a means of estimating the actual biomass of a particular species of fish consumed when relative importance, as determined by numerical abundance, may be misleading. For example, in our samples the mean weight of individual pollock consumed (9.8 g) was much smaller than that of individual eelpout (83.8 g). The importance of eelpout was therefore grossly underestimated in a numerical analysis of fishes consumed. Eelpout have not previously been reported as prey of ribbon seals although we found them to be major components of the diet in southcentral and central Bering Sea.

Bottom trawls were used to evaluate regional abundance of prey and prey selectivity by seals. Although our sampling gear may have been selective (large pollock and flatfishes (Family Pleuronectidae) were probably underrepresented), it appeared to catch the same species and size classes as the seals, and therefore to provide a good sample of potential prey. In contrast, the large commercial gear used in groundfish assessment surveys tends to catch large fishes. The smaller fishes eaten by seals are underrepresented in catches taken with this type of gear.

Regional differences in the distribution and abundance of fishes were reflected in differences in the fishes eaten by seals. For example, pollock were most commonly eaten in south-central Bering Sea where they were most abundant. Arctic cod, found mostly north of St. Lawrence Island, were commonly eaten only by seals taken in northern Bering Sea. Ribbon seals did not, however, always eat fish in proportion to their abundance. The overall composition and relative abundance of fishes from trawls and seals, while similar in southcentral Bering Sea, were different in the central and northern areas, where seals appeared to select certain "preferred" species. We suggest that in south-central Bering Sea where fishes were most numerous ($\overline{X}$ = 221 fishes/trawl) they were also overall more suitable prey. Small pollock of the sizes eaten by seals were the most abundant fishes caught in trawls. Consequently, the seals in that area appeared not to be selective. In central and northern Bering Sea, where fishes were less abundant ($\overline{X}$ = 106 fishes/trawl in central Bering

Sea and 26/trawl in northern Bering Sea), the most numerous species caught in trawls, sculpins and capelin, were not preferred prey. Seals in those areas were selective for less numerous pollock and arctic cod. In the case of arctic cod, seals selected larger fish. This apparent selectivity may be influenced by the distribution of size classes of arctic cod in the water column, which could affect the size composition of trawl catches.

Ribbon seals give birth, mate, support young, and molt during the period March through June when our samples were collected (Shustov 1965; Burns, in press). Throughout that period, especially the later months, they feed infrequently and spend much of their time hauled out on the ice. Feltz and Fay (1966) have proposed that such hauling out behavior, and the associated elevation of skin temperatures, is necessary for normal completion of the molt. The result is a presumed decrease in food intake, a marked loss of weight, and a 50-60% decrease in blubber thickness. Arseniev (1941) concluded that during the period when they are on the ice, ribbon seals do not search far for food, but feed only when concentrations of food are nearby. Assuming this is correct, we might expect a decrease in food intake as the seals move north with the receding pack ice into areas where prey are less abundant and less suitable. This appeared to be the case in our samples, where the calculated mean weight of fishes consumed was over six times greater in southcentral Bering Sea than in the central and northern areas even in seals collected during the same month. We suggest that during spring when feeding activity is greatly reduced and scarcity of prey is of less consequence, ribbon seals "tolerate" conditions in more northern areas where suitable prey is less abundant but ice is available as a substrate on which to bask and molt. During other times of year, ribbon seals probably seek out concentrations of food, perhaps along the Bering Sea shelf break as suggested by Burns (in press).

Most prey species of ribbon seals are also eaten by other marine mammals. In the central and southcentral Bering Sea large numbers of pinnipeds coexist during seasons when all are actively feeding. It is apparent (Table 3) that of the five pinniped species in the area which feed primarily on fishes, all feed mainly on pollock. In addition, numerous cetaceans, seabirds, other fishes, and commercial fisheries also remove pollock in large amounts (Pereyra et al. 1976; Divoky 1977; Frost and Lowry, in press). Some mammals, for example, sea lions (Eumetopias jubatus) and harbor seals, and the major commercial fisheries generally take larger pollock than do the ribbon seals. However, most pollock eaten by seabirds and over 90% of those eaten by spotted and ribbon seals are first-year class fishes (Bukhtiyarov et al. in press; Divoky 1977). In northern Bering Sea the major prey of both spotted and ribbon seals is arctic cod and both select the larger individuals (Bukhtiyarov et al., in press).

Eelpout and octopus are also important to both spotted and ribbon seals. This similarity of diet occurs for only part of the year. During summer and autumn ribbon seals probably are pelagic in southcentral Bering Sea (Burns, in press) and continue to eat pollock and eelpout. Spotted seals, however, move to the coast and eat fishes such as herring, capelin, and smelt (Osmerus mordax) (Bukhtiyarov et al., in press; Lowry and Frost, in press).

As commercial fisheries continue to be developed, their impact on marine mammals and the impact of the mammals on the fishery resources cannot be overlooked. A population of 100,000 ribbon seals averaging 75 kg/seal feeding in the southern and central Bering Sea for 8 months of the year at an average rate of 6% of their body weight/day would consume 110,000 mt of food. If 50% of that food is pollock, it would amount to about 55,000 mt/year or the equivalent of 7% of the current annual commercial harvest of pollock in eastern Bering Sea. Such considerations must be weighed as management plans are developed for fish and marine mammal populations.

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Table 1. Food items in stomachs and intestines of ribbon seals collected in the Bering Sea during March-June, 1976-1979

	Southcentral Bering March-April 1976, 1977 N = 9			Central Bering April-May 1978, 1979 N = 12			Northern Bering May-June 1978 N = 7		
Food Item	Percent of Total # of Fishes	Percent Total Wt. of Fishes	No. of Occurrences	Percent of Total # of Fishes	Percent Total Wt. of Fishes	No. of Occurrences	Percent of Total # of Fishes	Percent Total Wt. of Fishes	No. of Occurrences
Invertebrates									
Clam	--	--	5	--	--	--	--	--	--
Snail	--	--	1	--	--	--	--	--	--
Octopus	--	--	3	--	--	--	--	--	2
Mysid	--	--	--	--	--	1	--	--	--
Shrimp	--	--	3	--	--	--	--	--	1
Tanner crab	--	--	--	--	--	--	--	--	1
Fishes									
Pollock	89.4	49.7	9	54.9	27.8	11	1.1	0.6	1
Arctic cod	--	--	--	3.7	6.8	2	86.0	95.0	7
Saffron cod	--	--	--	--	--	--	9.7	2.6	1
Eelpout	6.0	45.1	7	8.8	31.3	6	--	--	--
Capelin	2.7	2.3	5	8.5	3.3	5	--	--	--
Prickleback	0.4	0.4	3	11.2	7.6	4	--	--	--
Sculpin	0.1	0.2	1	--	--	--	3.2	1.8	2
Flatfish	0.7	1.8	2	12.9	18.5	9	--	--	--
Poacher	0.3	0.1	1	--	--	--	--	--	--
Snailfish	0.4	0.4	2	--	--	--	--	--	--

Table 2. Ranking of abundance (based on number of individuals) of fishes eaten by ribbon seals and caught in otter trawls in three areas of the Bering Sea

Species	Southcentral Bering		Central Bering		Northern Bering	
	In Seals	In Trawls	In Seals	In Trawls	In Seals	In Trawls
Pollock	1	1	1	4	4	6
Arctic cod	--	10	6	9	1	4
Saffron cod	--	--	--	11	2	10
Capelin	3	2	4.5	1	--	2
Eelpout	2	6	4.5	5	--	7.5
Prickleback	5.5	4	3	3	--	5
Sculpin	7.5	5	--	2	3	1
Greenland halibut	4	3	2	8	--	--
Poachers	7.5	7	--	7	--	9
Snailfish	5.5	9	--	6	--	7.5
Herring	--	8	--	10	--	11
Sand lance	--	--	--	--	--	3

Table 3. Major foods of six species of pinnipeds in the southern Bering Sea, ranked in approximate order of decreasing importance

Ribbon Seal[a]	Spotted Seal[b]	Harbor Seal[c]	Fur Seal[d]	Sea Lion[e]
Pollock	Pollock	Pollock	Pollock	Pollock
Eelpout	Eelpout	Pacific cod	Squid	Squid
Capelin	Capelin	Octopus	Pacific cod	Capelin
Octopus	Octopus		Capelin	Flatfish
(Shrimp)				Sand lance

[a] Shustov 1965; Frost and Lowry, this paper.
[b] Bukhtiyarov et al., in press.
[c] Lowry and Frost, in press.
[d] Scheffer 1950.
[e] Fiscus and Baines 1966; Wilke and Kenyon 1952; Frost and Lowry, unpubl.

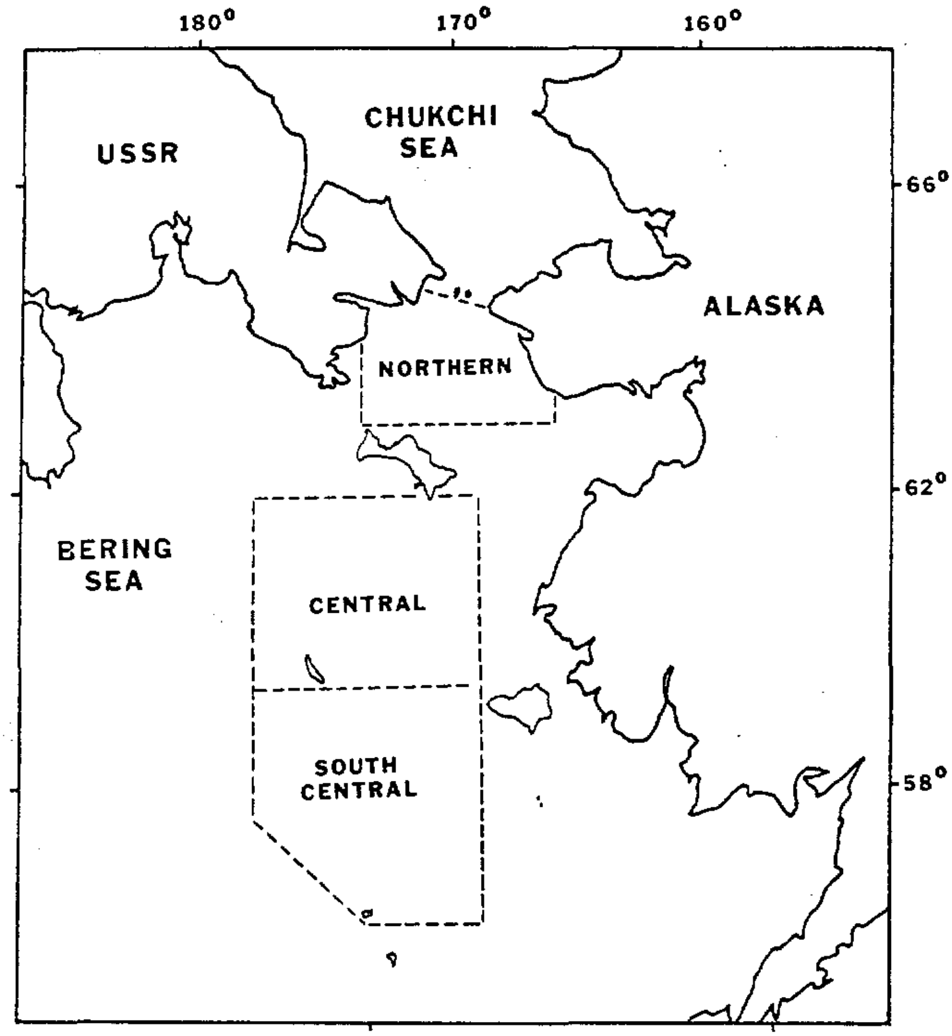

Figure 1. Map of the Bering Sea showing areas in which ribbon seals were collected.

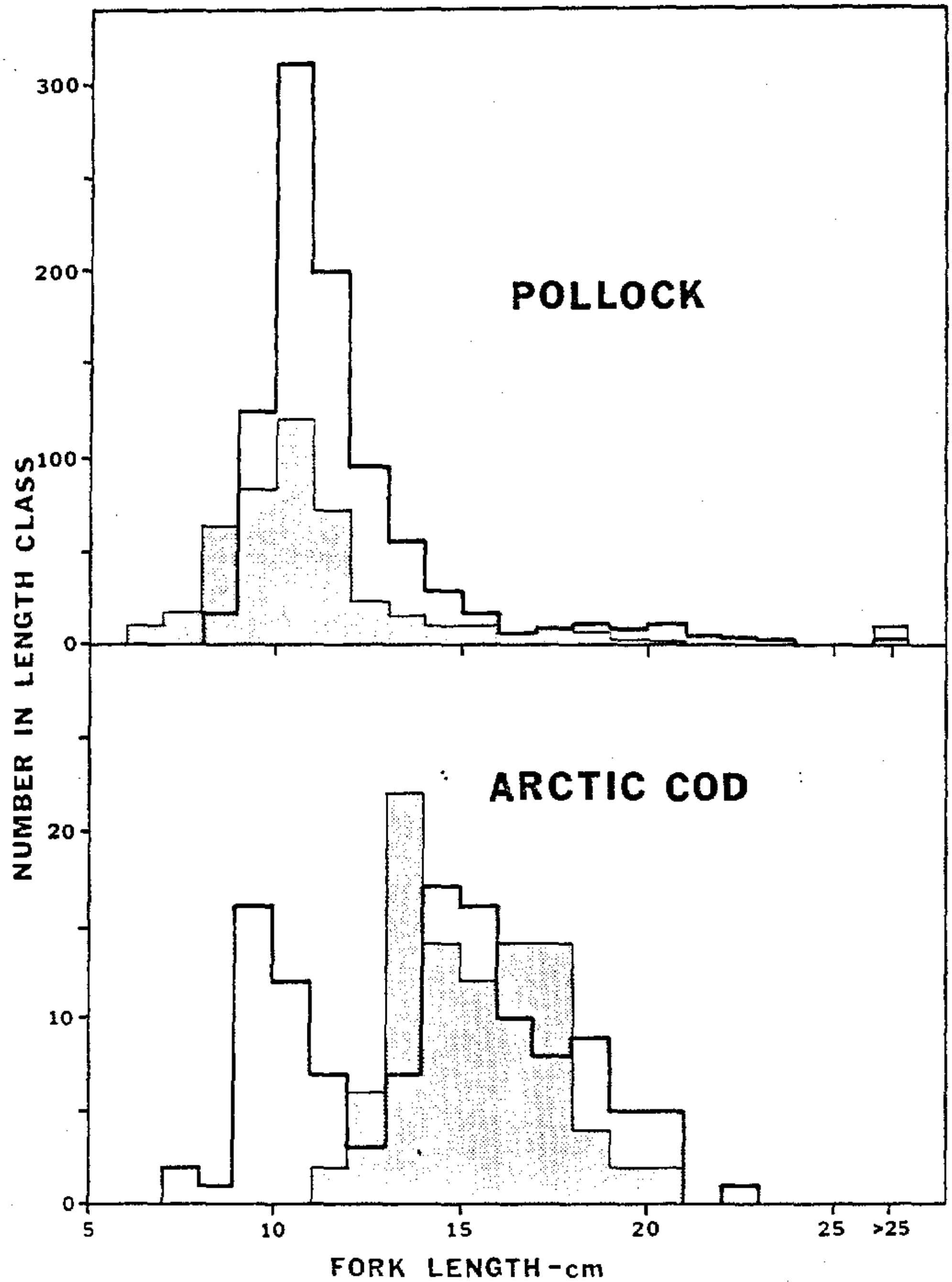

Figure 2. Size distribution of pollock and arctic cod caught in otter trawls (heavy line) and estimated from otoliths in ribbon seals (shaded). Pollock were from trawls and seals in southcentral and central Bering Sea. Arctic cod were from trawls and seals in northern Bering Sea.