SIZES OF WALLEYE POLLOCK, *THERAGRA CHALCOGRAMMA*, CONSUMED BY MARINE MAMMALS IN THE BERING SEA

In the Bering Sea at least 11 species of marine mammals, 13 seabirds, and 10 fishes are known to feed on walleye pollock, *Theragra chalcogramma* (Frost and Lowry 1981a). Walleye pollock are a major food of most pinnipeds, particularly in the southern Bering Sea (Lowry and Frost 1981), and are sometimes eaten by several species of baleen and toothed whales (Frost and Lowry 1981b).

In recent years, walleye pollock have been the principal target species in the Bering Sea commercial groundfish fishery. Annual catches have been as high as 1,840,000 t in 1972 (Bakkala et al. 1981). While there can be little doubt that both the fishery and marine mammal predation affect pollock stocks and perhaps also one another, the interactions are poorly understood at present (Lowry et al.[1]; Swartzman and Harr 1983).

An important aspect of marine mammal-fishery interactions is the size composition of fishes eaten in relation to that of the commercial catch. For example, if a marine mammal consumes fishes smaller than those taken by the fishery, the fishery would be unlikely to influence availability of food to the predator unless it affected recruitment. If marine mammals and the fishery remove fishes of similar sizes, competition would be expected (IUCN[2]).

Stomach contents of marine mammals seldom contain intact fishes in a condition suitable for measuring. However, the sagittal otoliths of species such as walleye pollock are easily identified (Frost 1981), and equations are available that estimate the length and weight of fishes from otolith lengths (Frost and Lowry 1981a). We present here information on the sizes of walleye pollock consumed by marine mammals in the Bering Sea, based on otoliths from gastrointestinal tracts.

Methods

Specimens were collected during the months of March to October 1975-81, at the locations shown in Table 1. With the exception of a minke whale, *Balaenoptera acutorostrata*, which was stranded on shore, all specimens were from animals collected for scientific purposes. Stomachs were removed and opened, and the contents gently washed on a 1 mm mesh sieve. Otoliths were sorted from other ingesta and identified using the descriptions of Morrow (1979) and Frost (1981). Since fresh walleye pollock otoliths have fine lobulations around their perimeter (Frost 1981) which disappear during digestion, degraded otoliths were easily detected by compari-

[1]Lowry, L. F., K. J. Frost, D. G. Calkins, G. L. Swartzman, and S. Hills. 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. North Pac. Fish. Manage. Counc. Doc. 19 and 19A, Anchorage, Alaska, Contract 81-4, 574 p.

[2]IUCN. 1981. Report of IUCN workshop on marine mammal-fishery interactions, La Jolla, Calif., 30 March-2 April. IUCN, Gland, Switzerland, 68 p.

TABLE 1.—Location and dates of capture of marine mammals from which otoliths of walleye pollock were obtained.

Species	Dates	Location	No. of specimens	No. of otoliths measured
Harbor seal,	13 Apr. 1979	Otter Island	4	23
Phoca vitulina richardsi	9 Oct. 1981	Port Heiden	1	12
Spotted seal,	6 May 1978	61°42.3N, 175°36.0W	1	11
Phoca largha	23 May 1978	63°25.8N, 173°05.6W	1	10
Ribbon seal, *Phoca fasciata*	19-20 Apr. 1976	57°20.1N-57°28.0N 172°30.9W-173°07.5W	5	256
	21-22 Mar. 1977	58°51.0N-58°56.0N 172°40.0W-173°08.0W	4	67
	5-31 May 1978	61°23.0N-64°39.4N 169°07.0W-176°08.8W	10	145
Steller sea lion,	20 Mar. 1976	56°04.8N, 168°32.9W	1	274
Eumetopias jubatus	13 Apr. 1979	Otter Island	1	6
	24 Mar., 10-11 Apr. 1981	59°30.0N-60°11.5N 176°43.5W-179°55.0W	32	497
	30 Mar.-4 Apr. 1981	59°08.0N-60°13.0N 165°45.0E-170°46.0E	56	638
Minke whale, *Balaenoptera acutorostrata*	5 Aug. 1975	Unalaska Island	1	121

son with those taken from trawl-caught fishes. The maximum length of nondegraded otoliths was measured to the nearest 0.1 mm using vernier calipers. When more than 20 otoliths occurred in a single stomach, a subsample of 20 was measured.

Very few otoliths were found in the stomachs of ribbon, *Phoca fasciata*, and spotted, *P. largha*, seals. For those species, additional otoliths were obtained from small intestines which were split along their entire length and examined for parasitological studies. There was no significant difference between sizes of otoliths obtained from stomachs and intestines of ribbon seals (Frost and Lowry 1980). Too few otoliths were retrieved from spotted seal stomachs to test their sizes relative to otoliths from intestines. However, otoliths from intestines were of the same general size range and condition as those from stomachs. We therefore pooled the measurements of otoliths from stomachs and intestines.

The fork lengths and weights of walleye pollock consumed were estimated from equations in Frost and Lowry (1981a).

Results

We measured a total of 2,060 otoliths from 117 individual marine mammals belong to 5 species (Table 1). Most of the otoliths were from the stomachs and small intestines of 19 ribbon seals and 90 Steller sea lions, *Eumetopias jubatus*. Ribbon seals, spotted seals, and a minke whale fed primarily on walleye pollock <20 cm long (Table 2, Fig. 1). Harbor seals, *Phoca vitulina richardsi*, fed on a wide size range of pollock, including equal numbers of fishes 8-15 cm and 20-35 cm long and a few individuals 45-56 cm in length. Most pollock eaten by sea lions (76%) were 20 cm or longer. Young sea lions (≤4 yr) collected in 1981 (all were males) ate significantly smaller fish ($\bar{x}$ = 22.4 cm, n = 37) than did older animals ($\bar{x}$ = 26.9 cm, n = 51; P < 0.005).

There were some differences in sizes of pollock consumed at different localities and in different years. The sizes of pollock eaten by harbor seals collected at Otter Island in 1979 ranged from 10.3 to 56.3 cm ($\bar{x}$ = 31.8 cm), while those eaten by a seal collected at Port Heiden in 1981 were all <12.6 cm long ($\bar{x}$ = 10.6 cm). Two sea lions collected in 1976 and 1979 near the Pribilof Islands had eaten pollock averaging 46.9 cm in length (range 18.4-61.4 cm), while those collected in 1981 to the west had eaten substantially smaller pollock averaging 25.2 cm in length (range 8.3-64.2 cm). In Figure 1, the smaller size mode corresponds to 1981 collections and the larger mode to those from 1976 and 1979. In 1981 sea lions collected in the central Bering had eaten larger pollock than those off the Kamchatka Peninsula ($\bar{x}$ = 26.8 cm vs. 23.5 cm; P < 0.001). This was not attributable to different age or size composition of the samples, since the difference was apparent for older sea lions (≥5 yr; $\bar{x}$ = 27.8 cm vs. 25.6 cm; P < 0.01) as well as the samples as a whole, and the mean age and standard length of all sea lions ≥5 yr in the Kamchatka sample ($\bar{x}$ age = 9.1 yr, $\bar{x}$ SL = 297 cm, n = 27) was greater than that of the central Bering sample ($\bar{x}$ age = 8.2 yr, $\bar{x}$ SL = 282 cm, n = 25).

Discussion

Of the marine mammal species we examined, ribbon seals, spotted seals, and a minke whale ate almost exclusively small pollock, whereas Steller sea lions and harbor seals ate pollock of a wide range of sizes. There are few other data available on the sizes of pollock consumed by marine mammals in the Bering Sea. Nemoto (1959) indicated that the length of pollock eaten by fin whales, *Balaenoptera physalus*, never exceeded 30 cm, while larger pollock were sometimes eaten by humpback whales, *Megaptera novaeangliae*. Fiscus et al. (1964) reported that in 1962 northern fur seals, *Callorhinus ursinus*, ate mostly whole pollock <30-35 cm long. McAlister et al.[3] found intact pollock in fur seal stomachs collected in the eastern Bering Sea, July-September 1974, to range from 10 to 35 cm, with a mean length of 19.3 cm. Most specimens were between 16 and 21 cm long. In 1981, Loughlin[4] collected fur seals north of Unalaska Island and found the average size of pollock consumed to be 30.4 cm. Antonelis[5] found that bearded seals, *Erignathus barbatus*, collected near St. Matthew Island in the central Bering Sea had eaten only small pollock ($\bar{x}$ length = 8.2 cm).

It is unknown whether the consumption patterns described above are a result of actual size selection of prey or if they result from coincidental distribution of predators and prey size classes. The overall density of pollock and distribution by age classes are far from uniform in the southern Bering Sea (Smith 1981; Bakkala and Alton[6]). The sizes of fishes con-

[3]McAlister, W. B., G. A. Sanger, and M. A. Perez. 1976. Preliminary estimates of pinniped-finfish relationships in the Bering Sea. Unpubl. background paper, 19th meeting North Pac. Fur Seal Comm., Moscow, 1976.

[4]T. R. Loughlin, National Marine Mammal Laboratory, 7600 Sand Point Way N.E., Seattle, WA 98115, pers. commun. November 1983.

[5]G. Antonelis, National Marine Mammal Laboratory, 7600 Sand Point Way N.E., Seattle, WA 98115, pers. commun. December 1983.

[6]Bakkala, R., and M. Alton. 1983. Evaluation of demersal trawl survey data for assessing the condition of eastern Bering Sea

TABLE 2.—Summary of sizes of walleye pollock consumed by marine mammals in the Bering Sea.

Marine mammal species	Size of walleye pollock consumed			
	Fork length		[1]Weight of mean length fish (g)	[1]Mean weight of fishes consumed (g)
	Mean (cm)	Range (cm)		
Ribbon seal	11.2	6.5-34.4	8.6	11.2
Spotted seal	10.9	8.0-15.0	7.9	8.4
Harbor seal	24.5	8.2-56.3	83.8	174.3
Steller sea lion	29.3	8.2-64.2	140.5	204.3
Minke whale	14.5	11.8-17.5	18.3	18.7

[1]The weight of the mean length fish does not correspond to the mean weight of fishes consumed due to the exponential nature of the length-weight relationship for fishes and the distribution of lengths of fishes consumed.

sumed generally agree with the basic distribution pattern for pollock in that sea lions collected near the continental slope ate many large pollock, while ribbon and spotted seals collected north of St. Matthew Island ate almost entirely small pollock. However, concurrent sampling of prey in stomachs and those available in the environment suggest that some selection does occur. Fur seals were found to eat smaller pollock than those caught in otter trawls taken nearby ($\bar{x}$ length = 30.4 cm in seals, 38.3 cm in trawls), while sea lions appeared to select larger fishes ($\bar{x}$ length = 29.9 cm in sea lions, 25.5 cm in trawls) (Loughlin fn. 4). Such comparisons must be interpreted with caution since demersal trawl samples underestimate the abundance of young pollock, most of which occur several meters off the bottom (Traynor[7]).

Other information also indicates that marine mammals sometimes select fishes of certain size classes. The sizes of arctic cod, *Boreogadus saida*, caught in otter trawls in the northern Bering Sea were compared with the estimated lengths of fishes eaten by spotted and ribbon seals collected in the same area and time period (Frost and Lowry 1980; Bukhtiyarov et al. 1984). While the distribution of trawl-caught fishes was distinctly bimodal, seals ate predominantly fishes of the larger size classes. Saffron cod, *Eleginus gracilis*, eaten by adult white whales, *Delphinapterus leucas*, in the Kotzebue Sound region of the southern Chukchi Sea were larger than those eaten by younger animals collected at the same location on the same dates (Seaman et al. 1982). We obtained similar results in this study for young versus old sea lions. Pitcher (1981) found that pollock eaten by sea lions were significantly longer ($\bar{x}$ = 29.8 cm) than those eaten by harbor seals ($\bar{x}$ = 19.2 cm; $P < 0.001$) collected in the same general locations in the Gulf of Alaska.

The factors involved in the apparent size selection of prey are poorly known for marine mammals. A strict relationship between the size of predators and the size of their prey is not to be expected in such behaviorally complex and morphologically diverse animals. For example, the prey of ringed seals, *Phoca hispida*, range in length from 1 cm (euphausiids) to at least 121 cm (wolffish, *Anarhichas* sp.) (Frost and Lowry 1981c). The largest animal we examined in this study, a minke whale 7.3 m long, ate uniformly small pollock. Age-related differences in sizes of fishes eaten by sea lions and belukha whales are more likely due to morphological and behavioral development than to size relationships per se. Although size may affect a sea lion's ability to catch large pollock, and old sea lions are larger than young ones ($\bar{x}$ SL = 212 cm for sea lions age 1-4 yr, n = 33 vs. $\bar{x}$ SL = 289 cm for those ≥5 yr, n = 52), the size range of pollock eaten by both young and old sea lions was similar. The largest pollock (64 cm) represented in our samples was eaten by a 215 cm long, 3-yr-old sea lion which indicates that physical differences due strictly to predator size are not the sole factor influencing preference for a particular prey size. Aspects of feeding strategy, including size selectivity, are the result of a complex and interacting suite of morphological, physiological, and behavioral adaptations which allow an organism to gather food in the most efficient manner (Schoener 1971).

Size-specific feeding may have important consequences for predators. For example, the length of 1-yr-old pollock fluctuates markedly among years, as does the numerical abundance of the first year class. In 1976 abundance was low (729 million individuals in the NMFS Bering Sea survey area) and fishes were small ($\bar{x}$ = 11.6 cm), while in 1974 abundance was high (2,840 million individuals) and fishes were

pollock. Unpubl. Rep., 43 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA.

[7]Traynor, J. J. 1983. Midwater pollock (*Theragra chalcogramma*) abundance estimation in the eastern Bering Sea. Unpubl. Rep., 7 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA.

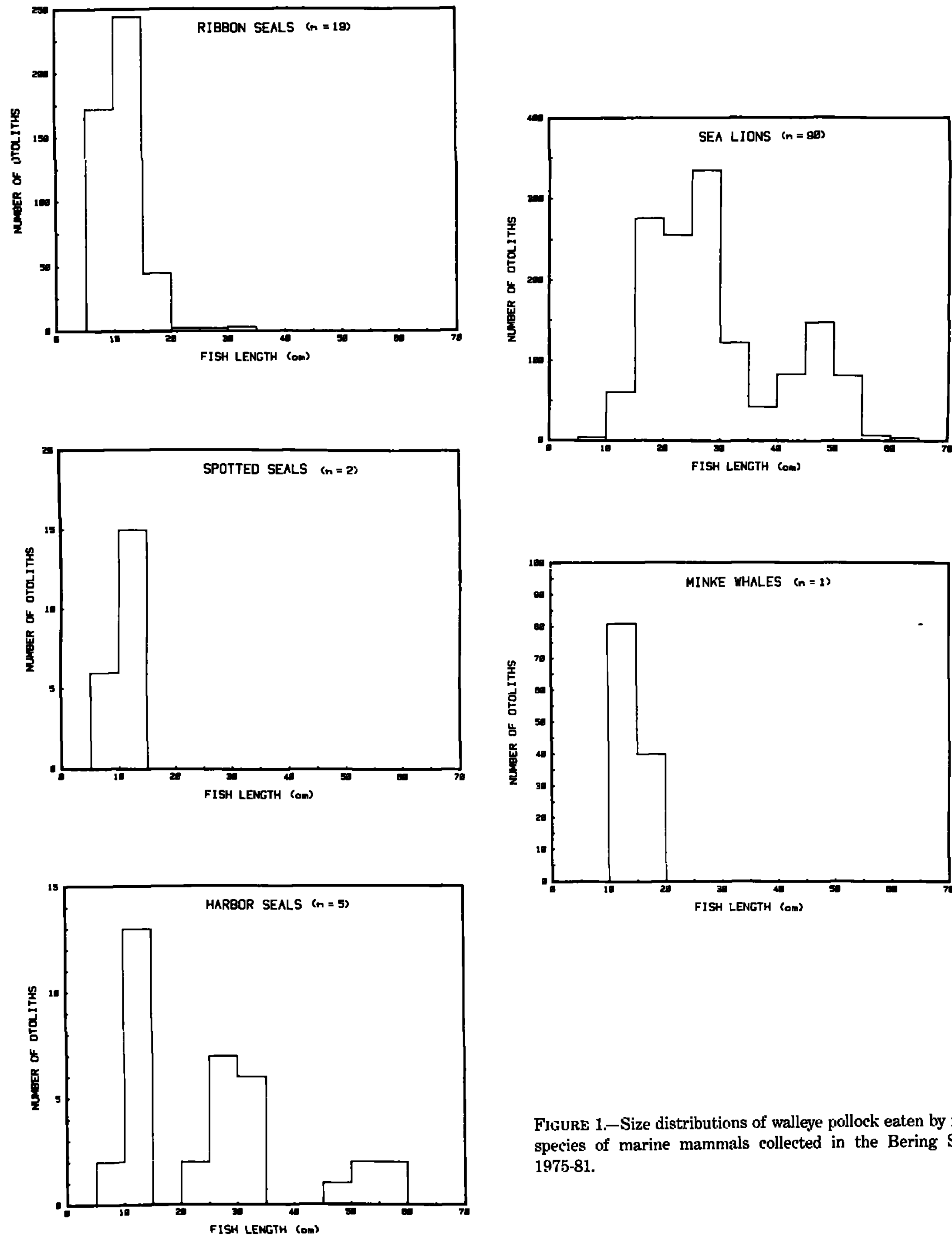

FIGURE 1.—Size distributions of walleye pollock eaten by five species of marine mammals collected in the Bering Sea, 1975-81.

considerably larger ($\bar{x}$ = 15.9 cm) (Smith 1981). The corresponding average individual weights can be estimated as 9.5 and 23.7 g, giving an estimated biomass of age 1 pollock about 10 times greater in 1974 than in 1976. Therefore, the total food available to predators that specialize on small pollock can vary markedly, as can the energy obtained from each fish consumed. Lengths and population sizes of older pollock also vary somewhat among years (Smith 1981); however, predators feeding on large pollock will undoubtedly be exploiting several age classes.

Three species of marine mammals—harbor seals, sea lions, and fur seals—consume age classes of pollock that are also exploited by the commercial fishery (Table 3). A major effect of the pollock fishery has been a reduction in the abundance of older, larger individuals (Pereyra et al.[8]). Major declines in abundance of sea lions and fur seals in the eastern Bering Sea have been reported since the 1950's (Braham et al. 1980; Fowler 1982). Although the evidence is equivocal, especially for the fur seal (see Swartzman and Haar 1983), reduced food availability due to expansion of the pollock fishery has been suggested as a possible cause of the decline in populations. The present population status of other pollock-eating marine mammals in the Bering Sea is not known.

The sizes of fishes consumed by marine mammals are obviously very important for determining the nature and magnitude of marine mammal-fishery interactions. It is particularly important to recognize that because of different feeding strategies, changes in fish stock characteristics caused by fishing may benefit some marine mammal species while having no effect or being detrimental to others.

[8]Pereyra, W. T., J. E. Reeves, and R. G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1976. Processed Rep., 619 p. Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA.

TABLE 3.—Age-class distribution of walleye pollock consumed by marine mammals in the Bering Sea, and caught in the commercial fishery in 1978, based on length-at-age data from Smith (1981).

	Percent of fishes in age class									
Predator species	1	2	3	4	5	6	7	8	9	≥10
Harbor seal	43	20	23	—	—	3	0	3	3	6
Spotted seal	100	—	—	—	—	—	—	—	—	—
Ribbon seal	98	1	1	—	—	—	—	—	—	—
Steller sea lion	21	40	14	3	5	6	4	2	2	3
Fur seal[1]	49	44	7	—	—	—	—	—	—	—
Minke whale	100	—	—	—	—	—	—	—	—	—
Commercial fishery[2]	2	20	40	18	20 (>5 yr old)					

[1]from McAlister et al. 1976.
[2]from Smith 1981.

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OCCURRENCE OF SOME PARASITES AND A COMMENSAL IN THE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, FROM THE MID-ATLANTIC BIGHT[1]

Larvae of the nematode *Ascarophis* sp. were reported by Uzmann (1967b) from American lobsters collected from Hudson, Block, Veatch, and Corsair Canyons on the edge of the continental shelf east and south of southern New England (Fig. 1). Following parasitological examinations of over 3,000 coastal and offshore lobsters, Uzmann (1970) reported that the nematode larvae were restricted almost exclusively to offshore lobsters. Adult *Ascarophis* sp. are intestinal parasites of fishes (Uspenskaya 1953).

Although coastal and offshore lobsters occur off northern and central New Jersey, coastal lobsters are scarce or absent south of Cape May, NJ. There is an active offshore commercial lobster fishery along the edge of the continental shelf south to Norfolk Canyon (Fig. 1).

Materials and Methods

To determine whether offshore lobsters in the Mid-Atlantic Bight have larval *Ascarophis* sp., we examined the guts of 218 American lobsters, *Homarus americanus*, collected from August 1975 through March 1977. Lobsters from this region had not been examined previously for parasites.

One hundred and ninety-seven of the lobsters examined were caught in lobster traps or trawl nets by commercial and research vessels in Norfolk and Washington Canyons and from the shelf and slope between and adjacent to those canyons (areas III-V, Fig. 1) at depths of 73-402 m. The remaining 21 lobsters were caught by trawl nets from research vessels off the coasts of Delaware and New Jersey at depths of 57-95 m (area VIII, Fig. 1).

The intestines and rectum were excised from live lobsters on shipboard (70% of the samples) or in the laboratory at the Virginia Institute of Marine Science, split longitudinally, and fixed in 10% Formalin[2] or in Davidson's fixative. No free parasites were found in the gut contents. In the laboratory, the gut was transferred to 35% glycerine in 70% ethanol, and part of the ethanol evaporated in a 55°C oven. Pieces of the gut were then laid open, pressed between two 35 × 50 mm slides, and examined for the presence of cysts. This procedure followed the recommendation of J. R. Uzmann[3].

Results

Thirty-nine American lobsters were infected with larval *Ascarophis* sp., encapsulated in the anterior wall of the rectum (Table 1). The proportion of infection in 218 lobsters (17.9%) from the Mid-Atlantic Bight was similar to that reported by Uzmann (1967b), when examined in a 2 × 2 contingency table and using Yates' correction for continuity (Elliott 1971). Uzmann (1967b) reported 77 infections in 314 lobsters (24.5%) collected east and south of southern New England. However, Boghen (1978) reported infection in the gills of 82 out of 233 lobsters (35.2%)

[1]Contribution No. 1277, Virginia Institute of Marine Science, Gloucester Point, VA 23062.

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[3]J. R. Uzmann, Northeast Fisheries Center Woods Hole Laboratory, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543, pers. commun. June 1974.