New Information on Foods of the Spotted Seal, *Phoca largha*, in the Bering Sea in Spring

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ABSTRACT

Information on foods of spotted seals was obtained by analysis of stomach contents from specimens taken in spring in Karaginskii Gulf, Anadyr Gulf, and southeastern, central, and northern Bering Sea. Pollock was the major prey in central Bering Sea and ranked second in Anadyr Gulf. Capelin was the major food in southeastern Bering Sea and ranked second in northern Bering Sea. Arctic cod was the major food in Anadyr Gulf and northern Bering Sea. Sand lance was the major food in Karaginskii Gulf. Most of the fishes eaten were <20 cm in length and <50 g in weight. A comparison of the lengths of Arctic cod eaten by spotted seals and those caught in trawls in northern Bering Sea suggests that the seals may select the larger individuals of that species. Pups ate mostly small crustaceans. Older animals ate mostly fishes, shrimps, and octopus. Maximal quantities of food per stomach ranged from 2.7 to 5.9% of the seal's body weight.

РЕЗЮМЕ

Данные о питании ларги анализировались по содержимому желудков животных, взятых весной в Карагинском, Анадырском заливах и в юго-восточной, центральной и северной частях Берингова моря. Минтай являлся главным источником пищи в центральной части Берингова моря и занимает второе место в Анадырском заливе. Мойва составляла основу питания в юго-восточной части, и занимала второе место в северной части Берингова моря. Сайка преобладала в пище в Анадырском заливе и в северной части Берингова моря. Песчанка была главным источником пищи в Карагинском заливе. Большинство съеденных рыб было меньше 20 см. в длину и весило меньше 50 гр. Сравнение длины сайки, съеденной ларгой и пойманной тралом в северной части Берингова моря, даёт основание предполагать, что тюлени выбирают более крупную сайку. Ларги-сеголетки питались главным образом мелкими ракообразными. Взрослые животные питались в основном рыбами, креветками и осьминогами. В разных пробах максимальное количество найденной пищи в желудках ларги колебалось от 2,7 до 5,9 процентов веса тела.

INTRODUCTION

The spotted or larga seal, *Phoca largha*, is one of several species of phocine seals which frequent the waters of the Soviet Far East and Alaska. The natural history of this species has been discussed by Burns (1970), Burns et al. (1972), and Shaughnessy and Fay (1977). During February to May, these seals are found in the ice front of the Bering Sea. This is a broad swath of small, dispersed and moving floes in the southern part of the seasonal pack ice, which extends from Alaska to the Siberian coast. Spotted seals give birth, nurse their young, and mate in the ice front. The exact geographical position of the front varies widely between years, but usually is over the continental shelf. As the Bering Sea pack ice begins to break up in May and June, spotted seals concentrate on the remaining ice, where they molt and spend much of their time basking. After the Bering Sea ice has melted, these seals are found near shore, especially in and near estuaries.

The only previous information on the food of spotted seals was from studies in the Okhotsk Sea by Wilke (1954), Fedoseev and Bukhtiyarov (1972)[3], and Nikolaev and Skalkin (1975) and in the Bering Sea by Gol'tsev (1971). The results presented in this paper supplement and extend Gol'tsev's pioneering work.

MATERIALS AND METHODS

We collected information on the foods of spotted seals in March to June. Materials were obtained from seals collected in Karaginskii Gulf and Anadyr Gulf from Soviet research vessels in 1972 and 1973 and from seals collected in southeastern, central, and northern Bering Sea from American research vessels in 1976-78 (Fig.1).

Stomachs and intestines were obtained from seals collected in waters <200 m deep over the continental shelf. Stomachs were slit open longitudinally and the contents removed. In some cases, the contents were examined and analyzed immediately; in others, they were preserved for later analysis. For analysis, the contents were gently sieved on a fine mesh screen and sorted by species. Each component was quantified by weight in Soviet analyses and by volume in American analyses. Weight and volume can be considered identical, since the densities of the prey involved are all close to 1 g/ml. The number of each species (or higher taxon) in each stomach was determined by counts of intact food items or representative hard parts, such as otoliths and other skeletal parts of fishes and beaks of cephalopods. In American studies, otoliths and cephalopod beaks were obtained also from the small intestine, which was slit longitudinally (primarily for parasitological studies) and washed in a pail of water. The contents were allowed to settle and otoliths and beaks were separated from other materials. Counts of otoliths from stomachs and small intestines were combined in

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[3]Fedoseev, G. A., and Y. A. Bukhtiyarov. 1972. Food of seals of the Okhotsk Sea. Abstracts 5th all-union conf. stud. marine mammals, 1:110-112. Makhachkala.

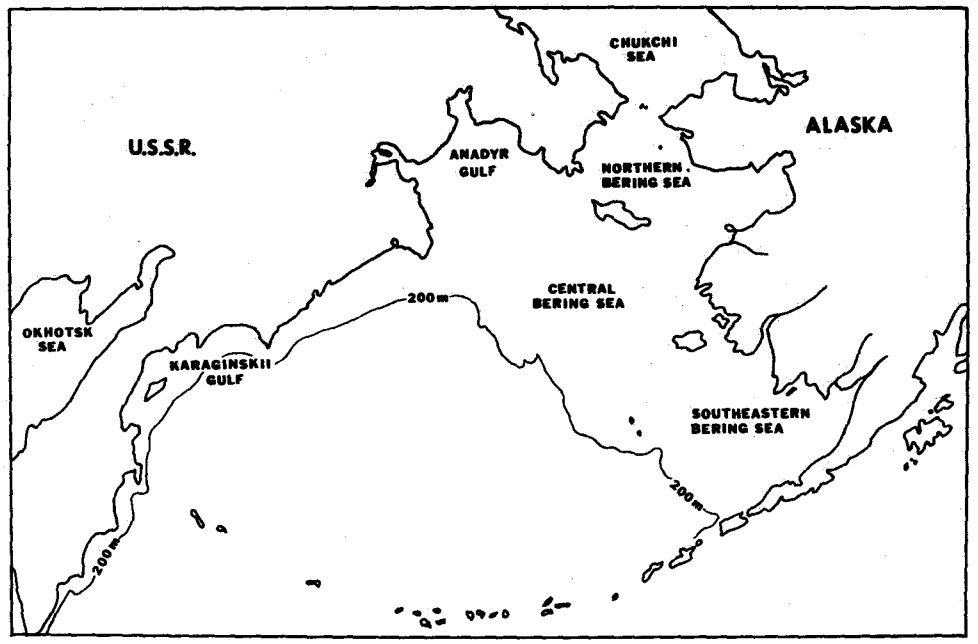

Figure 1.—Map of the Bering Sea showing areas in which spotted seals were collected.

analyses of the data. In some instances the lengths of fresh otoliths were measured to the nearest 0.1 mm with vernier calipers, as indices of size of the fishes.

In areas where seals were collected by American investigators, samples of available prey were collected by means of a 5.8 m headrope, semiballoon otter trawl. The contents of trawl catches were sorted, identified, and weighed. For fishes, the fork length, weight, and the length of the otoliths were measured. Otolith size/fish size relationships were calculated by means of regression analysis (Frost and Lowry 1980, 1981).

Common and scientific names of fishes are from Bailey et al. (1970).

RESULTS

Soviet Studies

Stomachs of over 500 spotted seals were examined, 110 of which contained food remains taken for analysis. Of the samples, 68 were from Karaginskii Gulf and 42 from Anadyr Gulf. A list of the species of prey found in the stomachs is given in Table 1.

In Karaginskii seals, the major food item was sand lance, which comprised 32.4% of the total weight of stomach contents. Other important foods included herring (13.2%) and octopus (10.3%). Unidentifiable fish remains accounted for 14.7%. Nine of the 18 species of prey were shrimps. However, crustaceans in total comprised < 5% of the stomach contents and only *Pandalus hypsinotus* was commonly represented. The largest number of items in a single stomach included 323 sand lance and 9 octopus.

In seals from Anadyr Gulf, fewer species of crustaceans were found, and these did not include large crangonid shrimps. Instead, brachyuran crabs (*Chionoecetes opilio* and *Hyas coarctatus*) and small shrimps of the family Hippolytidae were well represented. As in Karaginskii Gulf, crustaceans comprised < 5% of the total weight of food consumed. Arctic cod (29.5%), pollock (13.6%), and sand lance (9.1%) were the major prey. Remains of octopus occurred in 40% of the stomachs containing food.

Nine of 11 species of prey in stomachs of pups of the year were crustaceans (Table 2). Shrimps of the family Hippolytidae and immature shrimps of the families Pandalidae and Crangonidae were most commonly eaten. Sand lance occurred in approximately one-fourth, and algae occurred in more than one-half, of the stomachs of the seals in this age class.

Fishes and larger shrimps were present in greater quantities than small crustaceans in seals 1 to 4 yr old. Octopus occasionally were present; algae occurred rarely. The average weight of the food mass in this age group was 250 g/stomach with a maximum of 2,300 g.

In sexually mature animals, fishes made up the greatest proportion of the stomach contents. Analysis of the skeletal remains indicated that most of these were large individuals. Crabs as well as shrimps occasionally were present. Octopus occurred more often than in the younger animals.

American Studies

Of 51 seals collected, 31 from the central ($n=5$), southeastern ($n=14$), and northern ($n=12$) Bering Sea contained food remains in the stomach and/or intestine. The species of prey identified are given in Table 1.

Fishes comprised more than 95% of the stomach contents of seals from all areas; octopus comprised 2% in central and 3% in northern Bering Sea. Shrimps were found in only two seals from the northern Bering Sea and amounted to < 1% of the total stomach contents. In central Bering Sea, pollock and eelpout were the major foods; in southeastern Bering Sea, capelin was the major prey, followed by pollock and herring (Table 3). In northern Bering Sea, Arctic cod, capelin, and saffron cod were found most frequently and in the largest numbers.

Four of the spotted seals taken in southeastern Bering Sea were collected from a single locality (lat. 57°40′N, long. 165°01′W) on 20 April 1977. Partially digested remains of 55 capelin and otoliths from two pollock were found in the seal stomachs. In a 20-min tow with an otter trawl at this location, the fishes caught included 28 capelin, 16 pollock, 28 sculpins, and 4 fishes of other species.

Table 1.—Prey taxa identified in spotted seal stomachs in the Bering Sea.

Prey	Karaginskii Gulf	Anadyr Gulf	Northern Bering Sea	Central Bering Sea	Southeastern Bering Sea
Invertebrates					
Neomysis rayi	—	—	X	—	—
Thysanoessa sp.	—	X	—	—	—
Parathemisto libellula	—	—	—	X	—
Pandalus hypsinotus	X	—	—	—	—
Pandalopsis lamelligera	X	—	—	—	—
Sclerocrangon boreas	X	—	X	—	—
Sclerocrangon salebrosa	X	—	—	—	—
Sclerocrangon intermedia	X	—	—	—	—
Argis (=*Nectocrangon*) *lar*	X	—	—	—	—
Argis (=*Nectocrangon*) *crassa*	X	—	—	—	—
Crangon sp.	X	—	—	—	—
Lebbeus groenlandica	X	X	—	—	—
Eualus gaimardii	—	—	X	—	—
Pagurus sp.	X	X	—	—	—
Chionoecetes opilio	X	X	—	—	—
Hyas coarctatus	—	X	—	—	—
Bivalve mollusk	X	—	—	—	—
Octopus sp.	X	X	X	X	—
Fishes					
Clupea harengus (Pacific herring)	X	X	X	—	X
Mallotus villosus (capelin)	—	—	X	—	X
Boreogadus saida (Arctic cod)	X	X	X	—	X
Eleginus gracilis (saffron cod)	X	X	X	—	X
Theragra chalcogramma (walleye pollock)	—	X	X	X	X
Lycodes sp. (eelpout)	—	—	X	X	—
Lumpenus sp. (prickleback)	—	—	—	X	—
Ammodytes hexapterus (Pacific sand lance)	X	X	X	—	—
Hexagrammos sp. (greenling)	—	X	—	—	—
Family Cottidae (sculpins)	—	X	—	—	—
Gymnocanthus sp.	—	—	X	—	—
Icelus sp.	—	—	—	X	—
Myoxocephalus sp.	—	—	X	—	X
Triglops sp.	—	—	—	—	X
Family Pleuronectidae (flatfish)	—	X	X	—	X
Algae	X	X	—	—	—

Most of the fishes eaten by spotted seals in northern Bering Sea were < 20 cm in length and < 50 g in weight (Table 4). Larger fishes, particularly large sculpins, are sometimes eaten, but in such cases, the head of the fish may not be eaten.[4] Therefore, the otoliths of such fishes would not be present in the stomach or intestine. In our studies we did not find skeletal remains of fishes larger than those shown in Table 4.

The fresh condition of the stomach contents in 13 of the seals collected in southeastern Bering Sea indicated that they were actively feeding at the time of collection. In these, volumes of stomach contents ranged from 45 ml in a seal that had eaten capelin to 1,535 ml in a seal that had eaten herring. The mean volume of stomach contents in these seals was 491.5 ml, amounting to about 0.9% of the total body weight of the seals (range 0.08 to 2.7%).

[4]J. J. Burns, Game Biologist IV, Alaska Department of Fish and Game, Fairbanks, AK 99701, pers. commun. June 1979.

The range in size of Arctic cod caught by the otter trawl compared with those caught by the seals was very similar (Fig. 2). The cod eaten by the seals, however, tended to be slightly longer ($\bar{x}$=14.9 cm, n=326) than those caught in the trawls ($\bar{x}$=14.2 cm, n=121). Of the Arctic cod caught in the trawls, 38/121 (31.4%) were < 12 cm long, while only 33/326 (13.5%) of those eaten by the seals were < 12 cm long. These differences in proportions are highly significant (χ^2=21.353, P< 0.01) and indicate that the 1-yr-old Arctic cod (7-12 cm long), which were strongly represented in the trawl catches, were not commonly eaten by the seals.

DISCUSSION

At least 18 species of invertebrates and 15 species of fishes were identified from the stomach and intestinal contents of spotted seals collected in the Bering Sea in spring. Sixteen of the invertebrate species were crustaceans, 10 of which were shrimps. The number of prey species identified from seals collected in central and southeast-

Table 2.—Percentage frequency of occurrence of prey taxa in stomachs of spotted seals in relation to age class.

Prey	Age class of seals: Pups n=27	1 to 4 yr n=21	5 or more yr n=35
Thysanoessa sp.	—	—	2.8
Decapod crustaceans	—	4.8	—
Pandalus hypsinotus	7.4	4.8	5.7
Pandalus sp.	3.7	14.2	14.2
Pandalopsis lamelligera	—	4.8	—
Sclerocrangon boreas	—	—	2.8
Sclerocrangon salebrosa	—	—	2.8
Sclerocrangon intermedia	3.7	—	—
Sclerocrangon sp.	3.7	—	2.8
Argis (=*Nectocrangon*) *lar*	—	4.8	—
Argis (=*Nectocrangon*) *crassa*	3.7	—	—
Crangon sp.	3.7	—	—
Family Hippolytidae	7.4	—	—
Lebbeus groenlandica	—	4.8	—
Pagurus sp.	3.7	—	—
Chionoecetes opilio	3.7	—	8.5
Hyas coarctatus	—	—	2.8
Bivalve mollusks	—	4.8	2.8
Octopus sp.	—	9.5	31.4
Unidentified fishes	—	14.2	25.7
Clupea harengus	—	9.5	14.2
Ammodytes hexapterus	25.9	38.0	25.7
Eleginus gracilis	—	—	2.8
Boreogadus saida	—	4.8	11.4
Theragra chalcogramma	—	—	2.8
Family Cottidae	—	—	2.8
Family Pleuronectidae	—	4.8	—
Hexagrammos sp.	—	—	2.8
Algae	51.8	4.8	—

ern Bering Sea was less than in other areas. The largest number of prey species was identified in samples from Karaginskii Gulf. In general, the number of species identified was positively correlated with sample size. In northern Bering Sea, however, 14 prey species were found in 12 seals examined, while in southeastern Bering Sea only 8 prey species were found in 14 seals.

In spring in the Bering Sea, fishes, shrimps, and octopus comprised most of the food of spotted seals in all areas, but the principal species eaten differed among areas. Pollock was the major food in central Bering Sea and ranked second in Anadyr Gulf. Pollock have been reported to be the main prey of these seals in the Okhotsk Sea (Wilke 1954; Fedoseev and Bukhtiyarov footnote 3). Capelin was the primary food in southeastern Bering Sea and ranked second in northern Bering Sea. Arctic cod was the major prey in Anadyr Gulf and northern Bering Sea. Sand lance was the major food in

Table 4.—Size characteristics of fishes eaten by spotted seals in northern Bering Sea.

Prey	No. otoliths measured	Size of fishes estimated from otolith length: Length (cm) Mean	Length (cm) Range	Weight (g) Mean	Weight (g) Range
Boreogadus saida	326	14.9	7.6-20.5	24.9	2.2- 73.9
Eleginus gracilis	131	16.7	6.2-25.1	36.4	1.4-144.6
Theragra chalcogramma	21	10.9	8.0-15.0	8.4	3.3- 20.0
Lycodes sp.[1]	6	27.3	22.3-30.9	73.4	38.0-103.1
Family Cottidae[2]	19	10.0	3.3-16.5	14.5	0.3- 44.1
Mallotus villosus[3]	—	—	9.0-14.2	10.1	4.5- 16.1
Clupea harengus[3]	—	—	8.6-27.2	12.5	5.0-180.0
Ammodytes hexapterus[3]	—	—	6.6-11.9	2.3	0.5- 4.5

[1]Based on otolith length to fish length and weight relationships for *Lycodes palearis*.

[2]Based on otolith length to fish length and weight relationships for *Myoxocephalus* sp.

[3]Based on sizes of fishes caught by otter trawl in the area in which seals were collected.

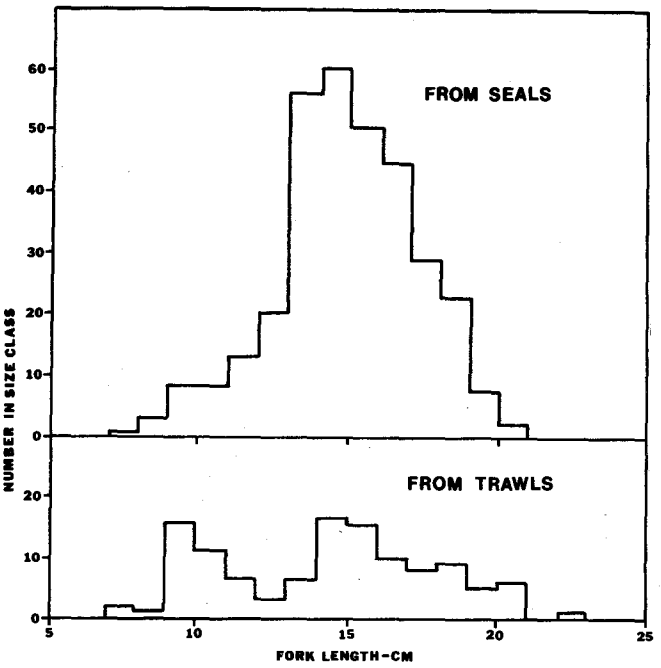

Figure 2.—Length-frequency distribution of Arctic cod, *Boreogadus saida*, obtained from trawl samples and from stomachs of spotted seals in the same areas of northern Bering Sea. Fork lengths of fishes from seal stomachs were estimated from otolith lengths.

Table 3.—Fishes identified from otoliths in stomachs and intestines of spotted seals taken in the Bering Sea.

Species	Central Bering (n=5): Total number of fishes (%)	Central Bering (n=5): Frequency of occurrence (%)	Southeastern Bering (n=14): Total number of fishes (%)	Southeastern Bering (n=14): Frequency of occurrence (%)	Northern Bering (n=12): Total number of fishes (%)	Northern Bering (n=12): Frequency of occurrence (%)
Theragra chalcogramma	88	80	5	43	2	8
Boreogadus saida	—	—	[1]	7	51	92
Eleginus gracilis	—	—	[1]	7	15	42
Clupea harengus	—	—	5	14	4	25
Mallotus villosus	—	—	89	86	19	42
Ammodytes hexapterus	—	—	—	—	4	25
Lycodes spp.	11	80	—	—	[1]	8
Lumpenus sp.	[1]	20	—	—	—	—
Family Cottidae	[1]	20	[1]	21	5	42
Family Pleuronectidae	—	—	[1]	7	[1]	25

[1]Less than 1%.

Karaginskii Gulf. Herring was of minor importance in all areas. Herring and rainbow smelt, *Osmerus mordax*, are major foods of spotted seals in southeastern Chukchi Sea in early summer and autumn (Frost and Lowry unpubl. data), as well as along southwestern Seward Peninsula in autumn (J. J. Burns footnote 4). In general, the regional and seasonal differences in foods of spotted seals appear to be related to the seasonal distribution and abundance of the principal species of forage fishes.

The comparison of seal stomach and otter trawl contents from southeastern Bering Sea suggests that selection of prey does occur. Capelin comprised 36.8% of the number of fishes caught in the trawl, while pollock and sculpins accounted for 21.0 and 36.8%, respectively. Since no pollock or sculpin bones were found in the stomachs, we concluded that the seals were feeding selectively on capelin when collected. Spotted seals sometimes eat pollock and sculpins in appreciable quantities (Table 3), but in this instance they apparently had selected for capelin or against pollock and sculpins.

Most of the fishes eaten by these seals are swallowed whole. The results in Figure 2 indicate that, given access to fishes of different sizes, the seals selected certain size classes, possibly those most easily caught and swallowed.

The quantity of food found in each stomach usually was small, relative to the weight of the seals. The maximal quantity from Soviet samples was about 4.1% of the average body weight and from the American samples, only 2.7%. Gol'tsev (1971) reported a maximum of 3,300 g, which would be about 5.9% of the body weight of a medium-sized seal. Keyes (1968) reported that phocid seals in captivity eat 6-10% of their body weight per day. Ashwell-Erickson et al. (1979) reported that the food intake of two captive spotted seals declined from 13% of the body weight per day during the first year of life to 3% at age 9 yr. The quantity of food in the stomach of a seal at any given time varies widely and does not appear to be directly related to the daily food requirement. More information is needed on the rate of food consumption, amount of time spent feeding, and rate of food passage through the stomach.

The differences found in this study between age classes in kinds of prey consumed were similar to those reported by Gol'tsev (1971) and Popov and Bukhtiyarov (1975)[5]. Spotted seals in their first year of life tend to eat mostly small crustaceans (amphipods, shrimps, and euphausiids) and commonly eat algae, sticks, and other debris. These kinds of items were not found in older animals. Animals 1 to 4 yr old mostly ate fishes, larger shrimps, and occasionally octopus. Those 5 yr or older fed more on benthic organisms, such as crabs and octopus. Similar changes in diet with age have been observed in ringed seals, *Phoca hispida*, in northern Bering and Chukchi Seas (Lowry et al. 1980).

Most of the prey species eaten by spotted seals in the Bering Sea also are eaten by other marine mammals and by seabirds and fishes (McAlister and Perez 1976)[6]. Many of the same species also are harvested in commercial fisheries (Lowry et al. 1979). A detailed understanding of the trophic interrelationships of major marine consumers in this area is essential for the design of national policies for marine resource utilization and conservation. Further studies of the foods of spotted seals and other Bering Sea pinnipeds by both Soviet and American scientists are needed to supply the information required for multispecies resource management.

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