INVESTIGATIONS OF BELUKHA WHALES IN COASTAL WATERS OF WESTERN AND NORTHERN ALASKA

III. FOOD HABITS

by

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SUMMARY

The stomachs of 242 belukha whales from the Bering and Chukchi seas were examined. Of those, 141 contained food remains. Foods eaten during the spring migration in the Chukchi Sea included arctic cod, shrimps, and octopus. In coastal areas of the northern Bering and Chukchi seas summer foods were saffron cod, sculpins, herring, smelt, capelin, char, shrimps, squid, and octopus. Primary foods in Bristol Bay were salmon and smelt. No samples are available from autumn or winter. During those seasons it is probable that pollock are the main prey in the southeastern and southcentral Bering Sea, while saffron cod and arctic cod are major foods in more northern areas.

In Eschscholtz Bay young belukhas ate smaller saffron cod than did older animals, and males ate proportionately more sculpins than did females.

Belukha whales are large animals and where they are abundant they will consume substantial quantities of fishes. In the Kvichak River in 1983, belukha predation accounted for 5% of the red salmon smelt outmigration, 1% of the commercial catch of red salmon, and 9% of the commercial catch of other salmon species. Prey eaten by belukhas are similar to those eaten by several other marine mammals species, and harvested by commercial fisheries. Competition for food with other marine mammals and fisheries may influence population size and productivity of belukhas.

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INTRODUCTION

The belukha whale (Delphinapterus leucas) is a major component of the marine mammal fauna of Alaskan waters. It is the only ice-associated small cetacean commonly found in Alaska and as such occupies areas in which the mammal fauna is dominated by pinnipeds. Although the foods utilized by belukha whales in some parts of their range have been described in detail (e.g., Vladykov 1946; Kleinenberg et al. 1964) , the only significant recent information on foods utilized in Alaskan waters is from studies in inner Bristol Bay (summarized in Lensink 1961). As part of a comprehensive investigation of the trophic relationships of marine mammals in the Bering, Chukchi, and Beaufort seas, we have obtained and examined samples of the stomach contents of belukha whales taken by Eskimo subsistence hunters. In addition, we have obtained some specimens from animals killed in fishing nets or dead from natural causes.

An understanding of the trophic relationships of this species is important for at least two reasons. First, major developments such as oil and gas exploration will soon occur in coastal and offshore waters of Alaska. Such development is presently underway in the Mackenzie River delta in Canada, an important part of the belukha whale's range. If potential effects of such development are to be fully assessed, an understanding of the food web of which belukhas are a part must be achieved. Second, management of marine mammals based on ecosystem concepts is mandated by the Marine Mammal Protection Act of 1972. Carrying capacity, defined as the maximum number of animals of a given species which the environment can support, is one such concept. Since major food resources are always shared by more than one consumer, carrying capacity in terms of food is not a single species parameter, but rather is related to the characteristics of all species which share the resource base. In order to understand the complex and dynamic nature of carrying capacity, the types of foods utilized by major consumers must be documented.

The results of our analysis of belukha whale stomach contents have been reported in part elsewhere (Lowry et al. 1981a, b; Seaman et al. 1982) . In this report we present the results of all specimens examined from the initiation of this study in 1977 through the summer of 1982.

METHODS AND MATERIALS

Most belukha stomachs were obtained from whales taken in Eskimo subsistence harvests at various sites in the northern Bering and Chukchi seas from 1977 through 1981. One stomach was obtained from an animal that was accidentally caught in a fishing net and two were from animals found dead on or near shore. Sex was determined for each animal sampled by examination of the genital slit. Age determinations were based on counts of dentinal growth layers in thin longitudinal sections of mandibular teeth (Burns and Seaman 1985) .

Stomachs were collected whole or slit longitudinally and the contents removed. In some instances when stomachs contained small amounts of a single type of prey, the contents were examined and quantified in the

field. In all other stomachs the contents were preserved in a 10% buffered formalin solution for later analysis. Stomachs of animals taken in Eschscholtz Bay in 1982 were very full, and we collected only subsamples that ranged in volume from 10 to about 900 ml. Although formalin can degrade otoliths, we do not think that was an important factor in this study since we regularly recovered small otoliths with surface features intact.

In the laboratory, stomach contents were gently washed on a I.O-mm mesh sieve. Components of the stomach contents were identified using appropriate keys and reference specimens and sorted to the lowest possible taxonomic level. The water displacement volume of each invertebrate taxon and of all fish material combined was determined. The number of fishes of each taxon consumed was estimated based on identification and counts of characteristic hard parts, particularly otoliths. For major prey species, a sample of otoliths that did not appear degraded was measured from each stomach (maximum length to 0.1 mm) . The lower crest length of octopus beaks was measured (Clarke 1962) to the nearest 0.1 mm. These measurements were used to estimate lengths and weights of fishes and weights of octopus consumed using relationships determined from intact fishes and octopus collected in the Bering and Chukchi seas (Table 1).

We present our findings in three ways: (1) the percent of the total volume of stomach contents which was composed of a particular type of item (percent volume) was used for invertebrate taxa and all fish material in aggregate; (2) the percent of the total number of identified fishes represented by each taxon (percent number) for fish taxa; (3) the percent of all stomachs in a sample which contained each particular item (percent frequency) for all items.

RESULTS

Stomachs from a total of 242 whales were examined, of which 141 contained food remains. Three were from whales found dead in northeastern Bristol Bay, three were from whales taken at Elim in Norton Sound, and the remainder were from four locations along the Chukchi Sea coast (Figure 1) . Samples *were* collected during the months of April-July.

A minimum of 18 species of invertebrates and 13 species of fishes were identified from the stomach contents (Table 2) . The greatest variety of prey (minimum of 19 species) was found at Eschscholtz Bay, the area from which the largest number of stomachs was collected.

The volume of contents in stomachs we examined ranged from a few milliliters to over 5 liters. The great majority of stomachs contained less than 500 ml of food, usually consisting of bones and otoliths from fishes, beaks from cephalopods, carapaces from crustaceans, and inorganic material, particularly pebbles and sand.

The stomach of the belukha caught in a salmon net in Kvichak Bay in May 1980 contained remains of 70 rainbow smelt (490 ml), 2 flatfish (77 ml), and 10 shrimp (13 ml). On 29 June 1982 we found a subadult

Table 1. Regression equations used to estimate sizes of prey consumed by belukha whales (from Frost and Lowry 1981a and unpublished).

Prey Item	Otolith length range (mm)	Regression Equation
Eleginus gracilis (saffron cod)	≤ 8.5	fish length (cm) = 1.740 (otolith length (mm)) - 0.090
	> 8.5	fish length = 2.323 (otolith length) – 4.839
	--	fish weight (gins) = 0.0050 (fish length (cm)) $^{3.095}$
Family Cottidae (sculpins)	all	fish length = 4.009 (otolith length) - 4.364
	--	fish weight = 0.0088 (fish length) $^{3.038}$
Oncorhynchus nerka [1] (red salmon)	all	fish length = 8.635 (otolith length) + 17.723
	--	fish weight = 0.00046 (fish length) $^{3.776}$
octopus Sp.	--	octopus weight (gins) = 0.0281 (lower crest length (mm)) $^{3.389}$

[1] equations are preliminary based on measurements from 8 fishes

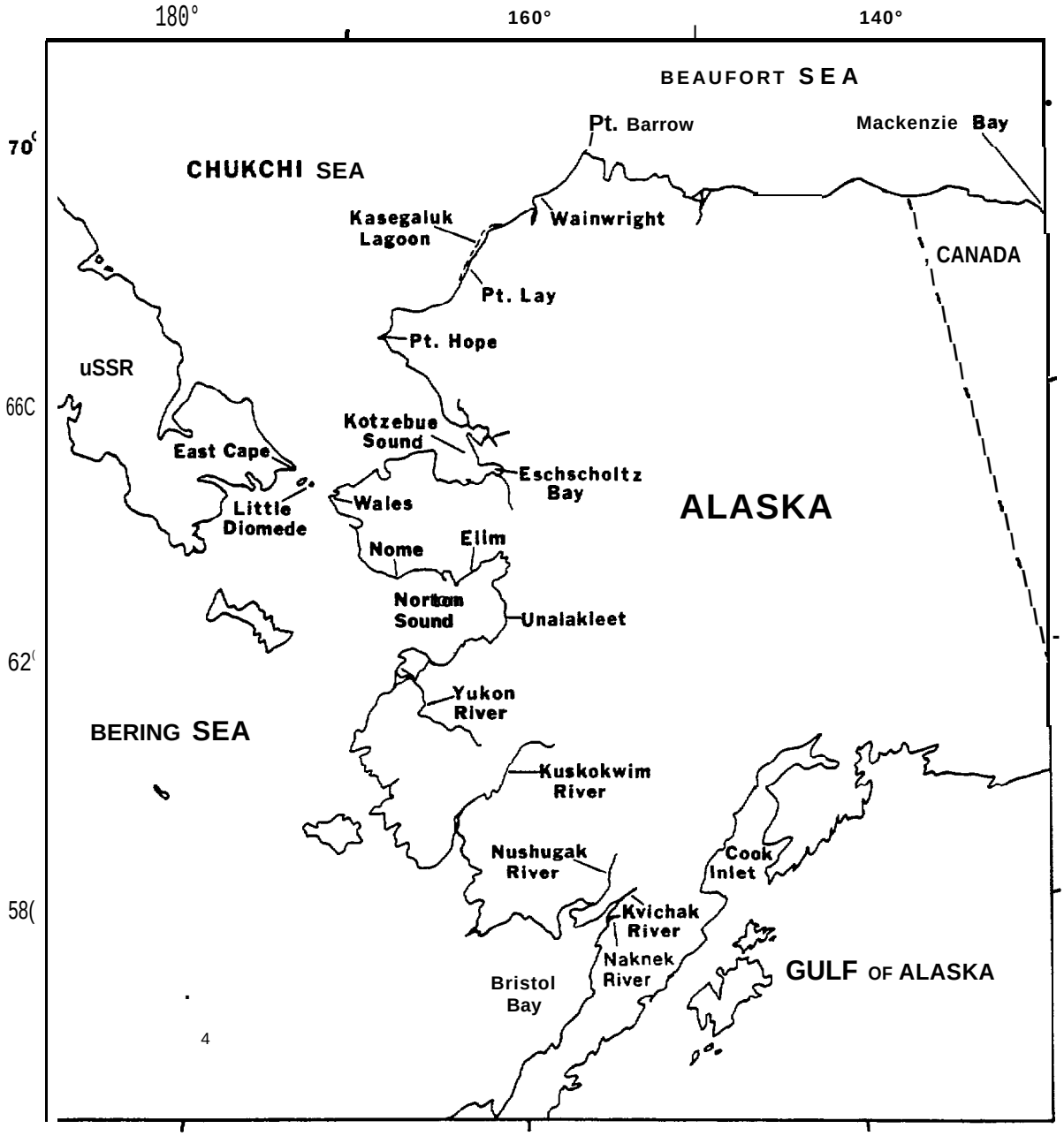

Figure 1. Map of Alaska showing major locations referred to in the text.

Table 2. Prey species identified from stomachs of belukha whales taken at 5 locations in western Alaska. Sample sizes indicated include only stomachs containing food remains.

TAXON	northeastern Bristol Bay May-July n=3	Elim June n=3	Eschscholtz Bay June n=113	Point Hope April-May n=18	Wainwright July n=3	Barrow May n=1
CEPHALOPODS						
Family Gonatidae (squid)				X	X	
octopus Sp.			X	X	X	
SNAILS						
Margaritas sp.				X		
Polinices sp.			X		X	
CLAMS (unidentified)			X			
MYSIDS						
Mysis sp.			X			
Neomysis sp.			X			
AMPHIPODS						
Gammarus sp.			X			
SHRIMPS						
Argis sp.				X		
Crangon SP.				X		
Crangon septemspinosa	X		X			
Eualus sp.				X		
HERMIT CRABS						
Pagurus trigonochierus				X		
ISOPODS						
Saduria entomon			X		X	
Saduria sabini			X			
ECHIUROID WORMS						
Echiurus echiurus				X		
POLYCHAETE WORMS (unidentified)			X			
TUNICATES (unidentified)			X			
FISHES						
Boreogadus saida (arctic cod)			X	X		X
Catostomus catostomus (sucker)			X			
Clupea harengus (Pacific herring)		X				X
Coregonus sp. (whitefish)			X			
Eleginus gracilis (saffron cod)		X	X		X	
Family Cottidae (sculpins)	X	X	X			
Lycodes sp. (eelpout)			X			
Hypomesus olidus (pond smelt)	X					
Osmerus mordax (rainbow smelt)	X		X		X	
Family Pleuronectidae (flatfish)	X					
Pungitius pungitius (sticklebacks)						X
Oncorhynchus nerka (sockeye salmon)	X					
Salvelinus malma (arctic char)			X			
PEBBLES		X	X	X		

male belukha floating in the Snake River (Nushagak Bay) approximately 3 km upstream from the river mouth. The animal was freshly dead and was spewing remains of red salmon. In the stomach were remains of four salmon; based on sizes of otoliths, two of the fishes were 54.9 and 73.8 cm long and weighed approximately 1,715 and 5,240 g. On 1 July 1982 we located another subadult male belukha which had obviously been dead for several days. The carcass was above the high tide line about 10 km upstream from the mouth of the Snake River. In its stomach were a few fragments of a shrimp and otoliths from 68 rainbow smelt, 2 pond smelt, 7 sculpins, and 1 flatfish.

The stomach contents of three belukhas taken at Elim on 12 June 1977 were similar to one another and consisted of a combined total of 887 ml of partially digested fish and 381 ml of pebbles, mostly 2 cm or less in diameter. Fishes eaten by the three whales included at least 3,900 saffron cod, 55 sculpins, and 5 herring. Saffron cod eaten averaged 16.5 cm long (range 6.5-29.1 cm) and 40.0 g in weight (range 1.6-168.4 g); sculpins averaged 35.6 cm (range 22.9-51.0 cm) and 524.6 9 (range 119.6-1,362.2 g).

We examined the stomach contents of 65 belukhas taken in Eschscholtz Bay in June 1978 (Table 3) . Stomachs from three animals were empty; the remainder contained bones and otoliths of fishes, primarily saffron cod and sculpins, and small amounts of shrimp, isopods, snails, polychaetes, and octopus. Saffron cod eaten averaged 12.4 cm long (range 5.0-30.2 cm) and 17.7 g (range 0.7-188.9g); sculpins averaged 22.5 cm (range 10.5-28.9 cm) and 131.7 g (range 11.2-242.5 g). In 1979 we examined the stomach contents of three whales taken between 16 and 23 June. Two were taken in Eschscholtz Bay and contained numerous saffron cod otoliths and traces of shrimp and snails. The third, taken near the village of Buckland (about 38 km up the Buckland River from Eschscholtz Bay) , contained 5,810 ml of partially digested fish, most of which was the remains of 11 arctic char up to 50 cm long. Otoliths and bones representing 7 whitefish, 5 suckers, 50 sculpins, 22 smelt, and 1 arctic cod were also present. In June 1980 we examined the stomachs of 53 belukhas, 28 of which contained food remains. Food items identified were generally similar to previous years (Table 3). In comparison with 1978, whales taken in 1980 ate invertebrates, sculpins, and rocks less frequently and had eaten more rainbow smelt. In 1981 the stomachs of 11 whales taken on 15 June were examined. All of those stomachs were empty. In 1982, subsamples of stomach contents were collected from a sample of 20 whales. The animals had been actively feeding prior to being hunted and were observed feeding in the Bay again on the day after the hunt (Burns, field notes) . Based on frequency of occurrence in the subsamples (Table 3) foods eaten were very similar to those found in previous years.

At Point Hope we examined the stomachs of 35 whales taken 22-27 May 1977 and 15 whales taken 25-26 April 1978. In 1977 30 stomachs were empty, and in 1978 six stomachs were empty. Stomachs of the whales taken in April 1978 contained mostly crangonid shrimp (Table 4). One stomach contained otoliths from 43 arctic cod. A total of 34 octopus beaks was found with a maximum of 15 in a single stomach. The animals examined in May 1977 contained almost exclusively octopus beaks and small pebbles.

Table 3. Stomach contents of belukha whales collected in Eschscholtz Bay.

Prey Item	13–18 June 1978, n=62 Percent Volume	Percent Number	Percent Frequency	16-24 June 1980, n=28 Percent Volume	Percent Number	Percent Frequency	22-23 June 1982 n=20 Percent Frequency
Shrimp	4	--	76	3	--	50	90
Isopod	6	--	34	1	--	14	35
octopus	<1	--	52	<1	--	14	5
Other Invertebrate	<1	--	41	<1	--	29	40
TOTAL INVERTEBRATE	11		90	5	--	82	95
Rocks and Pebbles	1	--	66	<1	--	4	5
TOTAL FISHES	87		94	95	--	96	**100**
Saffron Cod	--	88	94	--	90	86	**100**
Sculpins	--	11	42	--	2	25	10
Rainbow Smelt	--	<1	29	--	7	39	55
Pacific Herring	--	<1	3	--	1	7	5
Eelpout	--	<1	2	--	--	--	--
Mean Volume of Contents (ml)		47.2			81.1		410.7[1]
Total Number Identified Fishes		4,346			434		1,250 ,

[1]mean volume of subsamples

Table 4. Stomach contents of belukha whales collected at Point Hope.

Prey Item	22-27 May 1977, n=5 Percent Volume	Percent Number	Percent Frequency	25-26 April 1978, n=9 Percent Volume	Percent Number	Percent Frequency
Shrimp	<1	--	20	99	--	67
Squid	0	--	0	<1	--	11
octopus	75	--	100	<1	--	78
Other Invertebrate	<1	--	60	<1	.-	11
TOTAL INVERTEBRATE	75	--	**100**	100	--	100
Rocks and Pebbles	25	--	40	<1	.-	22
TOTAL FISHES	0	--	0	<1	--	11
Arctic Cod	--	**0**	**0**	**--**	**100**	**11**
Mean Volume of Contents (ml)	53.3			48.4		
Total Number Identified Fishes	O			43		

A total of 823 beaks was found with a maximum of 625 in a single stomach. Thirteen additional whales taken at Point Hope in 1979 and 1980 were examined. Stomachs of two of six taken on 6 and 8 May 1979 contained food in the stomach; one containing otoliths from three arctic cod; the other, one octopus beak, one saffron cod otolith, and two small unidentifiable fishes. Two of seven taken on 19 May 1980 contained traces of food; one had only beaks of two octopus, the other had beaks from seven octopus and fragments of a shrimp, the operculum from a snail, and a small pebble.

Three of 20 belukhas we examined at Wainwright contained food. One taken 22 July 1976 contained beaks from three octopus and four gonatid squids (probably Gonatopsis borealis) . Two whales taken on 18 July 1979 contained 12 partially digested rainbow smelt, otoliths from two saffron cod, and trace amounts of snails and isopods.

The stomach of a belukha taken 17 May 1979 at Barrow contained one intact nine-spined sticklebacks (3.2 cm long) , two intact herring (6-7 cm long), and otoliths from two arctic cod.

The large sample of belukha stomachs collected from Eschscholtz Bay in 1978 was examined for age- and sex-related differences in foods. The components of the stomach contents of young and older whales were very similar (Table 5). The range in size of saffron cod eaten was also similar (Figure 2). However, only 8.6% (9/104) of the saffron cod eaten by young animals were over 15 cm in length while 27.0% (115/426) of the saffron cod eaten by older animals were longer than 15 cm. This difference is highly significant ($\chi^2 = 10.749$, $P < 0.01$).

The composition of the stomach contents of male and female belukhas was slightly different (Table 6). Shrimp accounted for a greater proportion of the contents and occurred more frequently in females than in males; the opposite was true for isopods. The most obvious difference occurred in the consumption of sculpins which were eaten by 4 of 28 females and 21 of 29 males, a highly significant difference ($\chi^2 = 8.012$, $P < 0.01$).

DISCUSSION

Biases in Stomach Content Analysis

Over 100 kinds of organisms have been identified in the diet of belukha whales (Kleinenberg et al. 1964) . We found several general types of prey in the belukha stomachs we examined, including benthic invertebrates (crustaceans, worms, molluscs, and tunicates) , nektonic invertebrates (squids) , pelagic and semidemersal fishes (arctic cod, saffron cod, herring, whitefish, smelt, char) , and demersal fishes (sculpins, suckers, and eelpout) . With the exception of octopus, many of the benthic invertebrates found in the belukha stomachs may have been released from the stomachs of fishes consumed and digested by the whales. Both saffron cod and sculpins commonly feed on benthic invertebrates (Andriyashev 1954). We examined the stomachs of 79 saffron cod caught in Kotzebue Sound in March 1978 and found that they had eaten mostly polychaetes, shrimps, amphipods, and mysids. Forty sculpins (Myoxocephalus spp.) caught in the northern Bering Sea and Norton Sound

Table 5. Stomach contents of belukha whales collected in Eschscholtz Bay, June 1978, separated by age categories.

Prey Item	less than 6 years old, n=9			6 or more years old, n=47		
	Percent Volume	Percent Number	Percent Frequency	Percent Volume	Percent Number	Percent Frequency
Shrimp	15	--	78	5	--	77
Isopod	7	--	22	7	--	38
octopus	3	--	56	<1	--	47
Other Invertebrate	<1	--	44	<1	--	30
TOTAL INVERTEBRATE	25	--	**100**	12	--	89
Rocks and Pebbles	2	--	67	1	--	68
TOTAL FISHES	72	--	**100**	86	--	94
Saffron Cod	--	92	**100**	--	89	94
Sculpins	--	7	44	--	10	40
Rainbow Smelt	--	<1	33	--	<1	32
Pacific Herring	--	0	0	--	<1	4
Eelpout	--	0	0	--	<1	2
Mean Volume of Contents (ml)		9.9			44.3	
Total Number Identified Fishes		571			3,562	

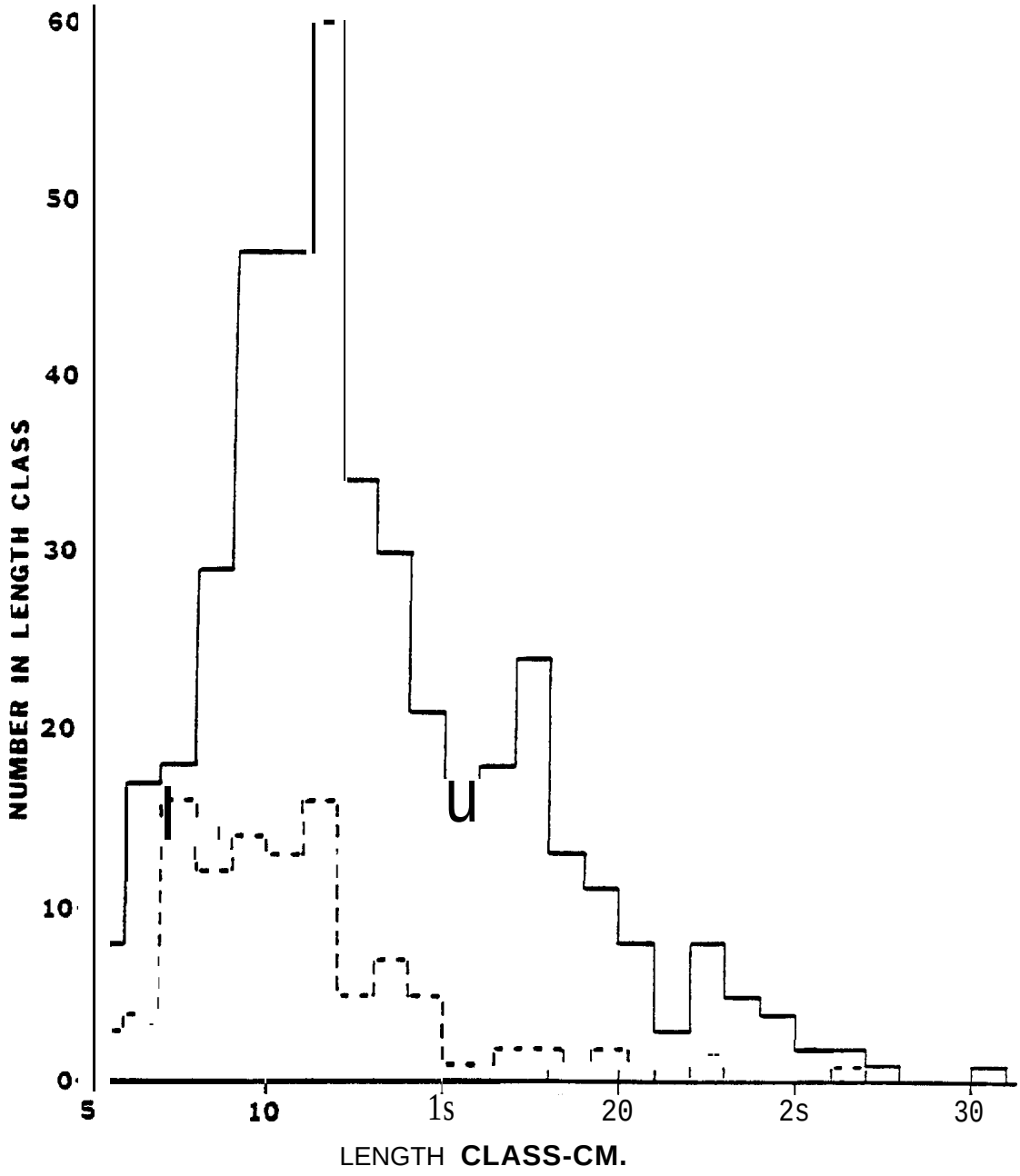

Figure 2. Length distribution of saffron cod eaten by belukha whales based on measurements of otoliths in stomachs. Dotted lines represent fishes eaten by whales five years old and younger; solid lines represent fishes eaten by older whales.

Table 6. Stomach contents of belukha whales collected in Eschscholtz Bay, June 1978, separated by sex.

Prey Item	Females, n = 28 Percent Volume	Percent Number	Percent Frequency	Males, n=29 Percent Volume	Percent Number	Percent Frequency
Shrimp	11	--	82	2	--	72
Isopod	2	--	25	8	--	48
octopus	<1	--	64	<1	--	34
Other Invertebrate	<1	--	21	<1	--	38
TOTAL INVERTEBRATE	14	--	93	10	--	86
Rocks and Pebbles	<1	--	64	1	--	69
TOTAL FISHES	85		89	88	--	97
Saffron Cod	--	98	89	--	82	97
Sculpins	--	<1	14	--	17	72
Rainbow Smelt	--	2	39	--	<1	24
Eelpout	--	<1	4	--	0	0
Mean Volume of Contents (ml)		24.8			73.0	
Total Number Identified Fishes		1,648			2,588	

in October 1976 had eaten shrimps, amphipods, crabs, and fishes (Frost, unpublished) . In belukhas taken in Eschscholtz Bay, snails, clams, amphipods, mysids, tunicates, and polychaetes were found only in stomachs which also contained fishes. Of 27 stomachs containing isopods 20 also contained sculpins. Kleinenberg et al. (1964) found a similar situation in the White Sea where certain benthic invertebrates were present only in belukha stomachs which contained flatfish. At Point Hope three of the whales examined in 1978 contained over 100 ml of shrimp and no fresh fish remains. We conclude that although many of the invertebrates we found were secondary prey, octopus, shrimps, and sometimes isopods are directly consumed by belukhas. Hay and McClung (1976) found a young belukha in Cumberland Sound with a stomach full of amphipods and seaweed.

Since most of the stomachs we examined contained little or no freshly ingested food, our measures of volume of food items in the stomachs are probably biased in several ways and may be of little value in determining the actual importance of the various prey. For fishes, we were able to determine the number of each species (or taxon) consumed during recent meals based on characteristic hard parts. This measure may be biased if parts of different fish species persist in the stomach for different lengths of time. However, we know of no data to indicate that such is the case, therefore we consider that our counts of fish parts reflect recent consumption. Miller (1978) noted that fur seals (Callorhinus ursinus) accumulate and later regurgitate squid beaks and Pitcher (1980) presents data which suggest that the same may occur in harbor seals (Phoca vitulina richardsi). Octopus flesh was not found in any of the belukhas we examined suggesting that they had been eaten some time before the whales were killed.

We found no evidence to suggest that stomach contents were regurgitated by belukhas during the course of their being pursued and killed. One pod of more than 200 whales was slowly driven for over two hours in Eschscholtz Bay. When a suitable location was reached, 45 of them were killed, of which 43 contained food in the same state of digestion. One belukha in the Buckland River was chased for several hours and when killed contained the largest volume of contents we encountered. However, our data from Eschscholtz Bay in 1981 suggest a limit on the persistence of food remains in the stomach. The whales were driven for about 3.2 hours before being killed and all 11 examined had empty stomachs. This indicates that either they had not fed prior to entering the Bay or all food remains were cleared from the stomachs during the drive.

Feeding During Spring Migration

Arctic cod, the most abundant semidemersal fish in northern ice-covered waters (Blacker 1968) , was the fish species we found eaten in greatest numbers by belukhas taken in the spring. However, the presence of otoliths from 48 arctic cod in 19 belukha stomachs containing food indicates that arctic cod were not abundantly available or the whales chose not to feed intensively on them.

Shrimps were eaten in small but perhaps significant quantities by whales taken at Point Hope in April. Johnson et al. (1966) examined stomachs from two belukhas taken in May 1961 at Point Hope which contained arctic cod and shrimp of at least three species. We found shrimp in only trace amounts in two of nine belukhas taken at Point Hope in May. Shrimps, particularly the family Crangonidae, are widely distributed and quite abundant in arctic waters (Squires 1969; Lowry and Frost, unpublished).

Octopus beaks were more prevalent in belukha stomachs from Point Hope than elsewhere, occurring in 15 of the 18 stomachs examined. Although the beaks may persist in the stomachs for some time, the prevalence of beaks in the whales strongly indicates an abundance of octopus in the vicinity of Point Hope, although perhaps some distance to the south. The maximum number of beaks in a single whale was 625. Based on measurements of lower crest length, the mean weight of the octopus consumed by that belukha was 205 g; therefore, approximately 128 kg of octopus was consumed, enough to supply the food intake requirements of a belukha weighing 700 kg for four days. We conclude that octopus are a potentially significant food of belukhas during the spring migration.

The percentage of empty stomachs during the spring migration was high. Overall, at Point Hope 45 of 63 stomachs we examined were empty. At the same time of year nearly all stomachs of belukhas taken at Wainwright and Barrow are usually empty (R. Tremaine, personal communication). At Point Hope a much higher proportion of stomachs was empty in 1977 than in 1978. The difference is not significant ($\chi^2 = 2.016$ $P > 0.10$) but nonetheless suggests a difference in conditions which affect feeding. In 1977 most of the whales were taken during periods with unobstructed leads south of Point Hope which allowed belukhas to move steadily northward. Stomach contents of those whales were dominated by octopus beaks which may represent prey eaten several days earlier. In 1978 all the belukhas were taken in 12 hours immediately following the formation of a nearshore lead which had previously been kept closed by southerly winds. Numerous belukhas were seen in openings in the ice southeast of Point Hope. Whales taken immediately following the opening of the lead contained small amounts of recently eaten prey, largely crangonid shrimp. It appears that belukhas sometimes feed during their spring migration when their northward movement is prevented by ice.

Sumner Feeding in Coastal Areas

Fishes were the dominant item in the stomachs of belukhas taken in coastal waters during summer. In the northern Bering and southern Chukchi seas, saffron cod were by far the most commonly eaten species, occurring in 104 of 113 belukhas taken at Eschscholtz Bay and in all three belukhas taken at Elim. Sculpins were eaten less commonly, occurring in 37 of the whales from Eschscholtz Bay and in two of the whales from Elim. The total quantity of sculpins and saffron cod represented by otoliths in belukha stomachs from Elim in 1977 and Eschscholtz Bay in 1978 was calculated (Table 7). The estimated amount consumed was about 28 times larger at Elim due to the greater number of otoliths in the stomachs and the larger individual size of fishes consumed. The differences in numbers of otoliths found in belukhas from the two areas may be the result of differences in location of feeding,

Table 7. Estimated quantities of fishes consumed by an average belukha whale taken near Elim (June 1977) and in Eschscholtz Bay (June 1978).

Location	Saffron Cod			Sculpins			Total
	Mean Number Consumed	Mean Weight (g)	Estimated Amount Consumed (kg)	Mean Number Consumed	Mean Weight (g)	Estimated Amount Consumed (kg)	Estimated Amount Consumed (kg)
Elim	1,300	40.0	52.0	18	524.6	9.4	61.4
Eschscholtz Bay	63	17.7	1.1	8	131.7	1.1	2.2

time when killed, and feeding conditions. The hunters from Elim said the belukhas were actively feeding when first sighted, as further indicated by the presence of several intact fish in the stomachs. The belukhas were moving westward away from Norton Bay. In most instances, belukhas taken in Eschscholtz Bay had probably eaten in Kotzebue Sound before entering the bay, though in 1982 they were feeding in the bay as indicated by the larger than usual quantities of food in their stomachs. In June belukhas enter Eschscholtz Bay on the rising tide and are normally intercepted and hunted within about one to two hours after entering. It is also noteworthy that because of their much larger size, sculpins are more important in the diet than is indicated by the relative numbers consumed (Table 7).

All our samples from Kotzebue Sound were obtained in June from Eschscholtz Bay. Curtis (19301 found that saffron cod *was the most* common item in belukhas taken in northern Kotzebue Sound near Sheshalik mostly in late June. Hunters from Kotzebue who have hunted many years near Sheshalik informed us that saffron cod were common in belukha stomachs and that shrimp and salmon were occasionally found. Belukha hunting at that locale usually ended before salmon arrived. Belukhas sometimes return to Eschscholtz Bay after the June-early July hunt and are occasionally seen in large numbers (Seaman, unpublished) . They may feed on salmon in late July and August. Hunters in Eschscholtz Bay report that saffron cod, sculpins, and herring are common items in belukha stomachs. Herring normally appear in mid-June to July, generally after the hunts from which we obtained samples in 1978-82. Smelt appear in Eschscholtz Bay and the Buckland River in greatest numbers in May and early June.

The feeding of belukha whales inhabiting Bristol Bay in spring and summer was studied by Brooks (1954-1956) and summarized by Klinkhart (1966) . Brooks (1954) and Lensink (1961) found a close relationship between prey abundance and belukha distribution and movements. Belukhas are present in Kvichak and Nushagak bays in large numbers in May through August . They are attracted to these rivers in early May by large concentrations of outmigrating smelt. As soon as ice cover on the rivers breaks up, belukhas frequently move upstream on flooding tides, apparently in pursuit of smelt. At the end of May whales shift from eating smelt to sockeye salmon fingerlings, which continue to be the predominant food items until about mid-June. In mid-June adult salmon become the primary prey. The frequency of occurrence of different species of salmon is directly correlated to their abundance; sockeye salmon predominating in stomachs in the first three weeks of July and other salmon species in late July and August (Brooks 1955). In addition to salmon and smelt, flounder, sole, sculpin, blenny, lamprey, two types of shrimp, and mussels were also reported in the stomachs examined. The three belukha stomachs we examined generally agree with the pattern described by Brooks.

Nelson (1887) reported on feeding of belukhas along the Yukon-Kuskokwim Delta. Near Saint Michael (southern Norton Sound), the first belukhas seen *in* spring arrived 5-10 June, coinciding with the arrival of spawning herring which they followed into bays and inlets. These observations are in agreement with those of Giddings (1967) who

frequently saw belukhas near Cape Denbigh (northeastern Norton Sound) following schools of herring in June. Also, the people of Stebbins, Unalakleet, and Shaktoolik reported that they frequently see belukhas following schools of herring into Norton Bay. While surveying herring schools, Barton (personal communication) saw numerous belukhas associated with herring concentrations on 30 May 1978 near Golovnin Bay (northern Norton Sound), and somewhat later near Nome.

Nelson (1887) found that belukhas fed heavily on saffron cod in the mouths of many tidal creeks between Saint Michael and the Kuskokwim River. He found the mouths of these tidal creeks to abound in saffron cod between midsummer and freezeup. Whales actively fed on saffron cod throughout this period, ascending rivers after darkness and returning by daylight. We observed numerous belukhas in association with schools of saffron cod near Golovnin Bay in late September 1981. Informants from several villages in Norton Sound have reported salmon in belukha stomachs in July and early August. Fishermen from Elim who annually fish near the northern Yukon Delta frequently see belukhas near the mouths of this river while salmon are present. One fisherman reported taking belukhas with recently ingested chum salmon (Oncorhynchus keta) in their stomachs. It appears that salmon are important to belukhas when available, but that saffron cod are probably of greater importance because they are available and abundant *over* a longer period of time.

Large numbers of belukhas utilize the coastal and lagoon waters adjacent to Kasegaluk Lagoon (northern Chukchi Sea) from late June to August. No stomachs have been examined from whales in this region but observations of fish abundance, belukha behavior and movements, and past examination of stomach contents by hunters suggests some species which may be important food items. Fish frequently caught by subsistence fishermen in this area in June, July, and August include sculpins, arctic char, smelt, saffron cod, whitefish, and capelin (Mallotus villosus) . In addition, salmon are caught in July and August. Certain regions of Kasegaluk Lagoon such as Utukok and Akoliakatat Passes are known for better fishing. Large concentrations of spotted seals (Phoca largha) are found in July and August in those areas.

The hunters of Point Lay believe that belukhas come to the Kasegaluk Lagoon area to feed. According to hunters, the stomachs from whales arriving in the area in late June or early July frequently contain shrimp, octopus or squid, and small fish. The first belukhas discovered and killed in the lagoon have usually eaten fish; at least sculpins, smelt, and char. The hunters reported that contents were highly digested and difficult to identify. Stomachs of whales taken from large localized concentrations in the passes of the lagoon were usually empty or contained digested fish remains.

On 10 July 1979 one of us (G. Seaman) observed several hundred belukhas for a period of six hours. The whales followed the coast within 50 m of shore, near Point Lay. They characteristically surfaced two to four times, then dove and remained submerged for 30 to 180 seconds. Occasionally a whale would remain near the observation site for five minutes making several dives and then continuing northward. On 9 and 10 July large schools of capelin were observed near the beach and

occasionally washed up on shore. It appeared that belukhas were following and feeding on capelin. The residents of Point Lay said capelin occur off Kasegaluk Lagoon in very large numbers for a short period in mid-July of most years. Capelin are probably very important to belukhas during periods when they are present in the area, but they do not occur every year. A similar condition of occasional importance of capelin to belukhas was observed by Vladykov (1946) in the Saint Lawrence estuary, Doan and Douglas (1953) in Hudson Bay, and Kleinenberg et al. (1964) in Soviet waters.

After belukhas leave Kasegaluk Lagoon they often move northward along the coast and pass Wainwright. Our samples indicate that rainbow smelt may be a major food near there. Capelin also spawn on the beaches near Wainwright. We have received specimens collected on the beach in front of the village on 16 July 1978 (Lowry and Frost, unpublished) .

Sex- and Age-related Differences in Foods

Our collections from Eschscholtz Bay give strong evidence of a difference in the selection of food by belukhas of different ages and sexes. Sexual dimorphism occurs in belukhas with females substantially smaller than males of the same age (Sergeant and Brodie 1969). Although the components of the food found in younger and older whales of both sexes were similar, older belukhas had eaten significantly larger saffron cod and males had eaten significantly more sculpins which were of a much larger size than saffron cod. This suggests that the smaller whales prefer smaller fish and the larger belukhas select for larger fish. Vladykov (1946) found the same to be true in the Gulf of Saint Lawrence where young belukhas and females ate small fish and shrimp, and adult males, in addition to the smaller prey, had eaten large cods (Gadus spp.) which were rarely eaten by small belukhas and females. Kleinenberg et al. (1964) showed a similar preference for prey by belukhas of different size and sex classes in waters of the Soviet Union.

Autumn and Winter Foods

Although no stomach samples are available from belukha whales in autumn and winter, their probable foods can be inferred from distribution and abundance of potential prey. Pollock (Theragra chalcogramma) is the most abundant species of finfish in the vicinity of the ice front (Pereyra et al. 1976) and is probably a major belukha food in this area. Based on the stomach contents of ringed seals (Phoca hispida), arctic and saffron cods are by far the most abundant forage fishes in the northern Bering Sea in autumn and winter (Lowry et al. 1980) . Arctic cod are the most important single item in the winter diet of belukhas over much of their range, and thus the winter movements of belukhas are closely tied to the distribution of arctic cod (Lønø and Øynes 1961; Kleinenberg et al 1964; Tarasevich 1974). Saffron cod may also be an important autumn and winter food of belukhas in some portions of the Bering Sea. Residents of Gambell note that belukhas are frequently seen along the western and southern shores of Saint Lawrence Island where prevailing northeasterly winds keep the coast free of ice throughout

most of the winter. The presence of belukhas in this area in winter is closely linked to abundance of saffron cod along the shores.

In addition to pollock and arctic cod, many other species of demersal, semidemersal, and pelagic fishes occur in the Bering Sea in autumn and winter and are certainly eaten at times by belukhas. Spawning smelt are abundant in some coastal areas in autumn. Shrimps and octopus may be eaten in quantities in some areas. However, based on observations of belukha foods in other areas and seasons, and the winter distribution and abundance of potential prey, we speculate that in the Bering Sea the bulk of their autumn and winter diet is composed of arctic and saffron cods in northern areas and pollock in southeastern and southcentral regions.

Trophic Interactions

Belukha whales are large and may be locally very abundant. Their foraging activities might therefore be expected to affect stocks of fishes on which they feed. Brooks (1955) estimated the number of adult salmon consumed by belukhas in Kvichak Bay as approximately 196,000 in 1954 and 99,000 in 1955. He also estimated that about three million red salmon smelt were eaten each season. This predation was considered significant in light of the depleted red salmon stocks. Frost et al. (1984) estimated that in 1983, belukhas in the Kvichak River consumed about six million red salmon smelt and 283,000 adult salmon (182,000 red salmon and 101,000 other species) . This consumption amounted to about 5% of the average annual smelt outmigration, 1% of the commercial catch of adult red salmon, and 9% of the commercial catch of other salmon species.

The species of prey consumed by belukha whales are also major foods of other species of cetaceans and pinnipeds in the Bering and Chukchi seas (Johnson et al. 1966; Frost and Lowry 1981b; Lowry and Frost 1981). Gadid fishes (arctic and saffron cods and pollock), herring, capelin, and smelt are of particular importance in the diet of at least six species of pinnipeds and four species of cetaceans. Sculpins, shrimps, and octopus are of secondary importance in the diet of both seals and belukhas. Saffron cod and sculpins eaten by belukhas are generally larger than those eaten by seals (Lowry and Frost, unpublished), while arctic cod, capelin, smelt, and herring consumed by belukhas and seals are probably of similar size classes. Potential competition for food may be particularly great between belukhas and spotted seals since the distribution and food habits of these species overlap broadly throughout much of the year (Lowry and Frost 1981 and unpublished) . The number of fish-eating pinnipeds in the Bering and Chukchi seas is difficult to estimate at present, but certainly exceeds two million. Given the broad dietary overlap with pinnipeds and the relatively much smaller population of belukha whales, limitation of the belukha population through competition for food appears to be a possibility. If so, the carrying capacity of the Bering-Chukchi system for belukha whales (as expressed by population size and productivity) may be influenced by foraging activities and population sizes of other species of marine mammals. In addition, commercial fisheries, particularly for herring and salmon in coastal areas of the Bering and Chukchi seas and for

groundfish in the southeastern and central Bering Sea, remove great quantities of some marine mammal forage fishes (e.g., Pruter 1976; Lowry et al. 1979). The combined effects of predation and commercial fishing on fish stocks and the possible resultant effects on marine mammal populations remain unclear at present. However, a significant potential exists for interactions between belukha whales and commercial fisheries (Lowry et al. 1984).

LITERATURE CITED

Andriyashev, A. P. 1954. Fishes of the northern seas of the U.S.S.R. Keys to the Fauna of the U.S.S.R. , No. 53. 617 p. (In Russian, transl. by Israel Program for Sci. Transl. Jerusalem, 1964.)

Blacker, R. W. (cd.). 1968. Symposium on the ecology of pelagic fish species in arctic waters and adjacent seas. International Council for the Exploration of the Sea, Copenhagen. Rapports et Proces-Verbaux de Reunions, 158. 148 p.

Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whale in the Bering, Chukchi, and Beaufort seas. NOAA, Northwest and Alaska Fisheries Center, Seattle, WA. Processed Rep. 29 p.

Brodie, P. F. 1969. Mandibular layering in Delphinapterus leucas and age determination. Nature 221:956-958.

Brooks, J. W. 1954. Beluga investigations 1954. Ann. Rep. Alaska Dept. Fisheries, Juneau. 6:51-57.

_____. 1955. Beluga investigations 1955. Ann. Rep. Alaska Dept. Fisheries, Juneau. 7:98-106.

_____. 1956. Beluga investigations 1956. Ann. Rep. Alaska Dept. Fisheries, Juneau. 8:52-58.

Burns, J. J., and G. A. Seaman. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska. II. Biology and ecology. Final Rep., Outer Continental Shelf Environmental Assessment Program, Contract No. NA 81 RAC 00049. Alaska Dept. Fish and Game, Fairbanks. 129 p.

Clarke, M. R. 1962. The identification of cephalopod "beaks" and the relationship between beak size and total body weight. Bull . British Museum (Natural History) Zoology 8:419-480.

Curtis, E. S. 1930. The North American Indian. Volume 20. The University Press, Cambridge, MA. 320 p.

Doan, K. H., and C. W. Douglas. 1953. Beluga of the Churchill Region of Hudson Bay. Fish. Res. Board Can. Bull. No. 98:27 p.

Fraker, M. A., D. E. Sergeant, and W. Hock. 1978. Bowhead and white whales in the southern Beaufort Sea. Beaufort Sea Proj. Tech. Rep. No. 4. Dept. Fish. and Environ. Canada, Sidney, B.C. 114 p.

Frost, K. J., and L. F. Lowry. 1981a. Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. Fish. Bull. 79(1) :187-192.

_____, and _____. 1981b. Foods and trophic relationships of cetaceans in the Bering Sea. Pages 825-836 in D. W. Hood, (cd.). The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. 2. Univ. Washington Press, Seattle. 1339 p.

Frost, K. J., L. F. Lowry, and R. R. Nelson. 1984. Belukha whale studies in Bristol Bay, Alaska. Pages 187-200 in Proceedings of the workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea, Oct. 18-21, 1983, Anchorage, AK. Alaska Sea Grant Rep. 84-1.

Giddings, J. L. 1967. Ancient men of the arctic. Alfred A. Knopf, New York. 391 p.

Harrison, C. S., and J. D. Hall. 1978. Alaskan distribution of the beluga whale, Delphinapterus leucas. Can. Field-Nat. 92:235-241.

Hay, K., and R. McClung. 1976. Observations on beluga and narwhal in the Canadian high arctic summer 1974. Fish. Res. Board Can. Man. Rep. Ser. 1385:55 p.

Johnson, M. L., C. H. Fiscus, B. T. Ostenson, and M. L. Barbour. 1966. Marine Mammals. Pages 897-924 in N. J. Wilimovsky and J. N. Wolfe (eds.). Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Comm., Oak Ridge, TN. 1250 p.

Kleinenberg, S. E., A. V. Yablokov, B. M. Belkovich, and M. N. Tarasevich. 1964. Beluga (Delphinapterus leucas) : Investigation of the species. Akad. Nauk SSSR, Moscow. 376 p. (In Russian, transl. by Israel Program for Sci. Transl., Jerusalem, 1969.)

Klinkhart, E. G. 1966. The beluga whale in Alaska. Alaska Dept. Fish and Game, Juneau. 11 p.

Lensink, C. J. 1961. Status report: beluga studies. Unpubl. Rep. Alaska Dept. Fish and Game, Juneau. 20 p.

Lønø, O., and P. Øynes. 1961. White whale fishery at Spitsbergen. Norsk Hvalfangst-Tidende 1961, 7:267-287.

Lowry, L. F. 1984. A conceptual assessment of biological interactions among marine mammals and commercial fisheries in the Bering Sea. Pages 101-117 in Proceedings of the workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea, Oct. 18-21, 1983, Anchorage, AK. Alaska Sea Grant Rep. 84-1.

Lowry, L. F., and K. J. Frost. 1981. Feeding and trophic relationships of phocid seals and walruses in the eastern Bering Sea. Pages 813-824 in D. W. Hood (cd.). The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. Two. Univ. Washington Press, Seattle. 1339 p.

_____, _____, and J. J. Burns. 1979. Potential resource competition in the southeastern Bering Sea: Fisheries and phocid seals. Pages 287-296 in Proceedings 29th Alaska Science Conference, Fairbanks. '15-17 August 1978.

_____, _____, and _____. 1980. Variability in the diet of ringed seals, Phoca hispida, in Alaska. Can. J. Fish. Aquat. Sci. 37:2254-2261.

_____, _____, and _____. 1981a. Trophic relationships among ice inhabiting phocid seals and functionally related marine mammals in the Chukchi Sea. Pages 37-95 in Environmental Assessment of the Alaskan Continental Shelf, Final Rep. of Principal Investigators, Vol. 11. NOAA, Outer Continental Shelf Environmental Assessment Program, Boulder, CO.

_____, _____, and _____. 1981b. Trophic relationships among ice inhabiting phocid seals and functionally related marine mammals in the Bering Sea. Pages 97-173 in Environmental Assessment of the Alaska Continental Shelf, Final Rep. of Principal Investigators, Vol. 11. NOAA, Outer Continental Shelf Environmental Assessment Program, Boulder, CO.

Miller, L. K. 1978. Energetic of the northern fur seal in relation to climate and food resources of the Bering Sea. Final Report Marine Mammal Commission, Contract No. MM5AC025. 27 p.

Nelson, E. W. 1887. Report upon natural history collections made in Alaska between the years 1877 and 1881. Arctic Series Publ. No. 3. Signal Service, U.S. Army. Washington, D.C.

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 1975. Processed Rep. NOAA, Northwest and Alaska Fisheries Center, Seattle, WA. 619 p.

Pitcher, K. 1980. Stomach contents and feces as indicators of harbor *seal,* Phoca vitulina, foods in the Gulf of Alaska. Fish. Bull. 78:797-798.

Pruter, A. T. 1976. Soviet fisheries for bottomfish and herring off the Pacific and Bering Sea coasts of the United States. Mar. Fish. Rev. 38:1-14.

Seaman, G. A., L. F. Lowry, and K. J. Frost. 1982. Foods of belukha whales (Delphinapterus leucas) in western Alaska. Cetology 44:1-19.

Sergeant, D. E. 1973. Biology of white whales (Delphinapterus leucas) in western Hudson Bay. J. Fish. Res. Board Can. 30:1065-1090.

_____, and P. F. Brodie. 1969. Body size of white whales (Delphinapterus leucas). J. Fish. Res. Board Can. 26:2561-2580.

_____, and W. Hock. 1974. Seasonal distribution of bowhead and white whales in the eastern Beaufort Sea. Pages 705-719 in J. C. Reed and J. E. Sater (eds.). The coast and shelf of the Beaufort Sea. Arct. Inst. N. Am., Arlington, VA. 750 p.

Squires, H. J. 1969. Decapod crustacea of the Beaufort Sea and arctic waters eastward to Cambridge Bay, 1960-65. J. Fish. Res. Board Can. 26:1899-1918.

Tarasevich, M. M. 1974. Characteristics of white whale migration toward the coast. (In Russian, transl. by National Technical Information Service, U.S. Department of Commerce, Springfield, VA. Report No. NOOT-1. 11 p.)

Tomilin, A. G. 1957. Cetacea. In V. G. Heptner (cd.). Mammals of the U.S.S.R. and adjacent countries. vol. 9. 717 p. (In Russian, transl. by Israel Program for Sci. Transl., Jerusalem, 1967.)

Vladykov, V. D. 1946. Nourriture du Marsouin Blanc ou Beluga (Delphinapterus leucas) du fleuve Saint-Laurent. Contribution du Department des Pecheries Quebec, No. 17. 157 p. (In French.)