FINAL REPORT OF CHUKCHI SEA ACTIVITIES

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Trophic Relationships Among Ice-Inhabiting Phocid Seals and Functionally Related Marine Mammals in the Chukchi Sea

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I. Summary

A total of 41 spotted seal, 581 ringed seal, and 243 bearded seal stomachs containing food and collected in the Chukchi Sea were analyzed. In addition, we examined 83 belukha whale and 4 walrus stomachs containing food. Most of the specimens were obtained from Eskimo subsistence hunters at three coastal villages: Shishmaref, Point Hope, and Wainwright. Most of the belukhas were collected in Eschscholtz Bay (inner Kotzebue Sound). Samples were collected at several times of year in order to assess seasonal changes in feeding patterns. The best sample coverage was near the coast in spring and summer when native hunting activity is greatest. Poorest sample coverage was in winter, and in offshore areas that are not accessible to coastal based hunters.

The diet of ringed seals in the Chukchi Sea shows pronounced seasonal variation. In most seals collected in fall, winter, and early spring, arctic cod were the main food. Near Shishmaref saffron cod were important in the fall and spring periods, with arctic cod most important in midwinter. During spring and summer crustaceans, mostly shrimps, amphipods and mysids, were the major prey. Age-related differences in diet were found in seals from Shishmaref. Almost one-third of the diet of pups was comprised of small crustaceans such as mysids, amphipods, and euphausiids, and the fish they ate were entirely cod. Older seals ate proportionately less crustacean material and a much greater variety of fishes.

Bearded seals are primarily benthic feeders, eating mostly crabs, shrimps, and clams. The vast Chukchi Platform provides extensive shallow water feeding habitat for them. Clams are found in the diet only during summer months. Pup bearded seals eat more shrimps and isopods than do older seals which eat more clams, crabs, and echuiroid worms.

Based on very limited samples, spotted seals and belukhas forage primarily on several species of coastal and anadramous fishes including herring, saffron cod, capelin, and rainbow smelt.

Clams comprised most of the contents of the four walrus stomachs exmained.

During much of the year the distribution of marine mammals is determined by the distribution and abundance of their prey. In order to assess the probable effects of OCS development on marine mammals, data must be available on the distribution, abundance, and hydrocarbon sensitivity of their principal prey species. Available data are reviewed in this report and found to be inadequate. Recommendations for further studies of the foods and feeding habits of marine mammals as well as the biology and hydrocarbon sensitivity of prey species are given.

II. Introduction

During the last 5 years there has been a continually changing series of oil and gas leasing schedules proposed for areas of "promising" oil and gas potential on the continental shelf off Alaska. Among these areas are the nearshore waters of the Chukchi Sea. The present leasing schedule calls for sale #85 (Chukchi Sea) in February 1985 and sale #86 (Hope Basin) in May 1985. Final Environmental Impact Statements for those areas are due in July and October 1984, respectively.

Since 1975, as a part of the Alaskan Outer Continental Shelf Environmental Assessment Program (OCSEAP), this research unit has been investigating trophic relationships of ice-associated marine mammals, primarily phocid seals, of western and northern Alaska. This final report presents the information collected in the Chukchi Sea during a 4-year field program in order to make it available to resource managers for consideration during tract selection, EIS preparation, and policy formulation.

The waters off the coast of Alaska support a tremendous abundance and diversity of marine mammals. Some species occur only during ice-free months while others are more or less dependent on sea ice as a habitat in which to whelp, breed, molt, and feed. The relationship between northern marine mammals and sea ice has been well summarized by Burns (1970) and Fay (1974).

Several species of marine mammals regularly occur in the Chukchi Sea. From April to June bowhead whales pass through leads in the nearshore ice of the Chukchi Sea on their way from wintering areas in the Bering Sea to their summer feeding grounds in the eastern Beaufort Sea. These whales leave the Beaufort Sea when ice reforms in September and October and once again pass through the Chukchi on their way to overwintering areas. Belukha or white whales accompany the bowheads north in spring. Some of these small whales may bear their young in coastal lagoons and estuarine systems of the Chukchi. They, too, usually leave in autumn as the ice forms. Belukhas winter primarily in areas of moving ice. Occasionally they are trapped in polynyi where they overwinter or perish as the ice cover becomes complete.

As the pack ice disintegrates and recedes north in the spring, most of the Pacific walrus population leaves its wintering grounds in the Bering Sea and moves north. The majority of these animals summer in the northern Chukchi Sea and off the coast of northeast Siberia. Some walruses penetrate the western and central Beaufort Sea. They move south in the early autumn, passing through the Bering Strait mainly in the months of October, November, and December.

Spotted seals utilize the ice front of the Bering Sea for whelping and molting in late winter and spring. They move north and toward the coast as the ice recedes in May and June. Many are found along the Chukchi coast during summer and early fall. They are not adapted to wintering in this area, and so move south in early fall with the onset of freezeup.

Only three species of marine mammals can be considered year-round residents of the Chukchi Sea. These are ringed seals, bearded seals, and polar bears. Although arctic foxes range widely over all types of sea ice, it is debatable whether they can be considered truly marine.

Polar bears are distributed throughout ice-covered arctic waters. In summer they are found on the pack ice, with greatest densities along the edge. They are primarily found in areas of high abundance and availability of ringed and bearded seals which are their main prey.

Bearded seals are year-round residents of the Chukchi Sea. They are able to maintain breathing holes in ice, but appear to do so only rarely, and are thus largely excluded from the fast ice zone. Rather, they are most common in the transition zone and offshore pack ice (Burns 1967, Burns and Harbo 1972, Stirling et al. 1975). The Chukchi Sea is underlain by the Chukchi Platform, a vast area of continental shelf with water depths less than 100 m. As bearded seals can feed at depths up to 100 m, the Chukchi Sea offers an extensive foraging area. During the summer there is an influx of bearded seals from the Bering Sea as the ice there melts and recedes north. Although some seals move into the Beaufort Sea in summer, the majority appear to remain over the shallow Chukchi Platform.

Ringed seals are found almost throughout ice-covered seas of the northern hemisphere, and they are overall the most common species of seal in the Chukchi Sea. Their density in any given area and at any given time is closely related to ice conditions. In late March and early April ringed seal pups are born in lairs excavated in snow-covered ice (McLaren 1958, Burns 1970, Smith and Stirling 1975). Although stable landfast ice is the preferred area for pupping, and the greatest density of seals occurs there, some pups are born on drifting ice. There are some indications that older, more experienced females may occupy the preferred breeding habitat (McLaren 1958, Burns 1970). Subadult animals are often found congregated along transient lead systems (Stirling et al. 1975; Burns, unpubl.).

Subsequent to pupping and breeding, ringed seals undergo a period of molting during which they spend a large amount of time hauled out on the ice. During this period feeding intensity is quite low (McLaren 1958, Johnson et al. 1966). As the ice melts in the Bering Sea in May and June, seals move into the Chukchi and Beaufort Seas where they spend the summer dispersed throughout ice-covered areas. With the onset of winter and the increase in ice cover, the area occupied by ringed seals expands accordingly. Specific details of these movements are largely unknown.

Ringed, spotted, and bearded seals, as well as the other species of marine mammals, are of cultural and economic importance to residents of the Chukchi coast. Seal hunting occurs regularly at the villages of Shishmaref, Point Hope, and Wainwright where seals are hunted for human and dog food, and for the skins which have traditionally been used for clothing, equipment, and crafts. National interest in these animals and the habitats they utilize is high. This interest is perhaps best exemplified by the Marine Mammal Protection Act of 1972 (Public Law 92-522) passed by the Congress of the United States which states that "marine mammals have proven themselves to be resources of great international significance, esthetic and recreational as well as economic, and it is the sense of the Congress that they should be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management."

These factors and others make it imperative that the potential effects of oil and gas exploration and development in the Chukchi Sea on ice-inhabiting marine mammals be anticipated and minimized to whatever degree possible. Such an evaluation requires an understanding of the biology of the species involved, as well as how they affect and are affected by their environment. This study of the trophic relationships of ice-inhabiting phocid seals of the Chukchi Sea will contribute to such an understanding. We have dealt in greatest detail with the two resident and most abundant species, ringed seals and bearded seals. In addition, preliminary data are presented for three summer residents, spotted seals, walruses, and belukha whales.

The intricacy of biological systems is such that even gross simplifications are difficult to render verbally and/or graphically. However, through this study of trophic relationships of marine mammals we have attempted to identify key species, those organisms which are the most tightly woven into the web of trophic interdependencies. It is our hope that identification of these key species and important interdependencies will provide a focus of attention and contribute to the assessment of anticipated ecological effects. When integrated with other OCSEAP research it should be possible to identify potential differential sensitivity of parts of the system and to evaluate which times, places, or species appear to be most or least vulnerable.

In the discussions that follow it will be necessary to give the names of many species of marine animals. The authors realize that there are advantages to the use of either common or scientific names. In this report we will use common names whenever such are available and appropriate. For purposes of clarity and ease of reference, the accepted scientific names of most species for which we will use common names are given in Table 1. For species mentioned seldom in this report, both common and scientific names are given at the first mention of that species.

Table 1. Common and scientific names of species commonly mentioned in this report.

Common Name	Scientific Name
Pollock	Theragra chalcogramma
Arctic cod	Boreogadus saida
Saffron cod	Eleginus gracilis
Herring	Clupea harengus
Rainbow smelt	Osmerus mordax
Sand lance	Ammodytes hexapterus
Capelin	Mallotus villosus
Sculpin	Family Cottidae
Flatfish	Family Pleuronectidae
Tanner crab	Chionoecetes opilio
Spider crab	Hyas coarctatus

III. Current State of Knowledge

We know of only two accounts of the food habits of marine mammals in the Chukchi Sea published prior to this OCSEAP study. An extensive study was conducted as a part of Project Chariot by Johnson et al. (1966) at Point Hope and Kivalina from November 1960 through June 1961. They examined 1,923 stomachs from ringed seals. During the months of November, December, January, and February, fishes (mostly sculpins, arctic cod, and saffron cod) made up 90 percent or more of the contents. During March, April, May, and June, invertebrates, mostly shrimp and amphipods, were the predominant food, making up more than half and occasionally more than 80 percent of total stomach contents.

The stomach contents of 164 bearded seals were examined in that study. The only month in which a large sample (129) was obtained was June. Shrimp, crabs, and clams were the most common food items with other benthic invertebrates found in small quantities and fishes (sculpins and arctic cod) usually comprising less than 10 percent of the total volume.

Burns (1967), in his summary of the biology of the bearded seal, reported on his examination of stomachs from seals collected at Nome, Gambell, and Wainwright. In May he found that brachyuran and anomuran crabs (Hyas coarctatus alutaceus and Pagurus sp.) accounted for 57 percent of the contents with shrimp, fishes (saffron cod, arctic cod, and sculpins), and sponges comprising most of the remainder. In July and August clams (Serripes groenlandicus, Spisula sp. and Clinocardium sp.) were the most abundant food item, with shrimp, crabs, and isopods also quite commonly found.

Results of our OCSEAP studies of the food habits of bearded seals in the Bering and Chukchi Seas have been compiled and are currently in press (Lowry et al. 1980).

There are no published accounts of the foods of spotted seals, walruses, or belukha whales in the Chukchi Sea.

Published accounts of the food habits of ringed, bearded, and spotted seals, as well as belukha whales, in other parts of the world have been reviewed in 1978 and 1979 annual reports for this research unit (Lowry et al. 1978a, Lowry et al. 1979a).

IV. Study Area

The study area encompasses the Alaskan sector of the Chukchi Sea from Bering Strait to Point Barrow (Figure 1). Data we have collected from the Bering Strait (Wales and Diomede) will be presented in a future report dealing with the Bering Sea. In the Chukchi Sea we collected specimens from the villages of Shishmaref, Point Hope, and Wainwright. The region between Bering Strait and Point Hope is referred to as Hope Basin. The region between Cape Lisburne and Wainwright is referred to simply as "the Chukchi," or Sale #85.

V. Sources, Methods, and Rationale of Data Collection

Field Collections

OCSEAP sponsored collection efforts began in 1975 and intensified in 1976-1979. Collectors were sent to the coastal hunting villages during predictably good hunting periods. Specimen material, including jaws and claws for age determination, reproductive tracts, and stomachs were purchased from hunters. Sampling was done by the principal investigators and other ADF&G employees. A schedule of field activities and summary of specimens obtained is presented in Table 2.

Whenever possible seals from which specimen material was taken were weighed, sex was determined, and a series of standard measurements was made for use in this and other ongoing studies of ice-inhabiting seals. Tissue and blood samples were collected in some cases and made available to other investigators for heavy metal, hydrocarbon, PCB, and pathogen analysis. (See methods section in RU #230, Annual Report, for detailed description of standard measurements and collection of additional specimen material.)

Only stomachs containing food were collected. Stomachs were tied at the cardiac and pyloric sphincters and severed from the remainder of the alimentary canal near these ties. They were then either injected with 10 percent formalin, labeled and placed intact in plastic bags

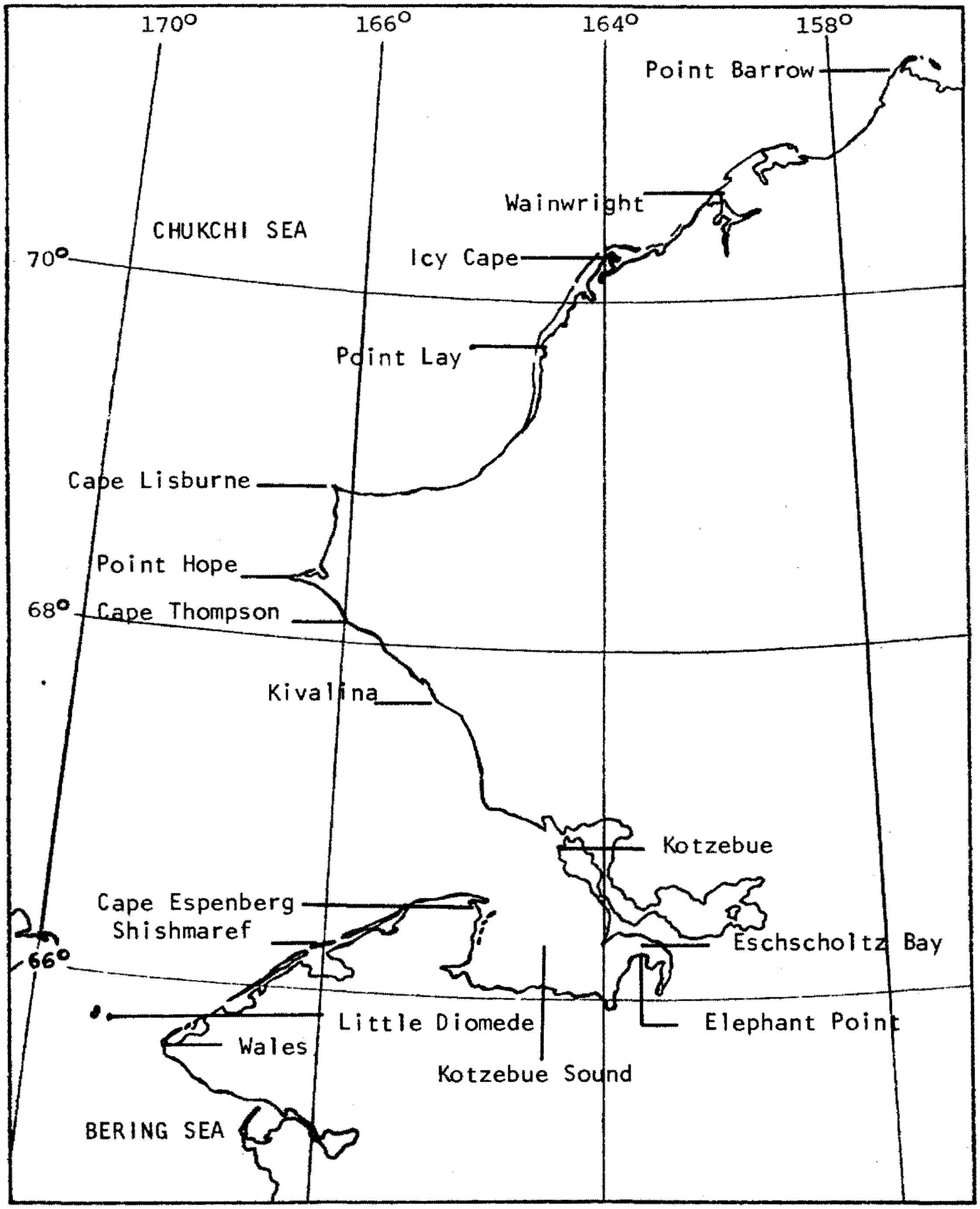
170°
166°
164°
158°
Point Barrow
Wainwright
CHUKCHI SEA
70°
Icy Cape
Point Lay
Cape Lisburne
Point Hope
68°
Cape Thompson
Kivalina
Kotzebue
Cape Espenberg
Shishmaref
Eschscholtz Bay
66°
Little Diomede
Wales
Elephant Point
Kotzebue Sound
BERING SEA

Table 2. Schedule of field activities in the Chukchi Sea and summary of specimens obtained. Only stomachs with food are included.

		Specimens Obtained				
Location/Platform	Dates	Spotted Seals	Ringed Seals	Bearded Seals	Belukha Whales	Walrus
Wainwright	24 July-11 Aug 1975	3	17	22		
Cape Lisburne	10 Mar-20 Apr 1976		3			
Point Hope	19 Apr-1 June 1976		33			
Shishmaref	22 June-15 July 1976	3	106	40		
Wainwright	22 July-1 Aug 1976			7		
DISCOVERER	17 Aug-3 Sept 1976		2	1		
Point Hope	15 Apr-2 June 1977		26		5	
Shishmaref	24 June-21 July 1977	10	235	112		3
Wainwright	22 July-24 July 1977			3		
GLACIER	1 Aug-5 Aug 1977			2		
Shishmaref	15-31 October 1977	14	6	13		
Shishmaref	4-11 November 1977	1	7			
Shishmaref	6 Jan-10 Feb 1978		24			
Kotzebue	February 1978		3			
Point Hope	10-28 Apr 1978		15	1	9	
Wainwright	25 Apr-22 May 1978		4	1		
Shishmaref	20 May-21 June 1978	10	56	17		
Elephant Point	13-18 June 1978		3		62	
Wainwright	1-12 July 1978		24	4		
Point Hope	6-8 May 1979				2	
Shishmaref	24 May-8 June 1979		12	4		
Wainwright	25 June-13 July 1979		5	16	2	1
Elephant Point	16-23 June 1979				3	
Totals		41	581	243	83	4

containing 10 percent formalin, or placed in bags and frozen. All stomachs were shipped to the ADF&G lab in Fairbanks. Upon arrival in the lab those stomachs containing large numbers of small otoliths, which degrade rapidly in formalin, underwent a preliminary sort in which the otoliths were removed and stored in 95 percent ethanol.

Laboratory Procedures and Identification

The preserved contents of stomachs were washed onto a 1.0-mm mesh screen. Contents were sorted and identified to the lowest taxonomic level permitted by their condition, using appropriate taxonomic keys and reference specimens. In the majority of cases identifications entailed the sorting and recognition of small bits and pieces of organisms. Crustaceans were frequently identified by claws, carapaces, or abdomens. Fishes were identified on the basis of otoliths and bone fragments. The volume and number of each type of prey item were determined by water displacement and counts of individuals or otoliths. Size ranges of various prey items were determined when possible.

Virtually all identifications were made by project personnel. Necessary taxonomic keys and references, both published and unpublished, were accumulated. Much use was made of the University of Alaska Marine Museum/Sorting Center reference collection and of the expertise of Sorting Center personnel. A reference and voucher collection of invertebrates and fishes was established at ADF&G. In addition, an otolith collection was compiled. Considerable interchange of specimen material and ideas occurred among personnel of this project, Dr. James Morrow, OCSEAP RU# 285, and John Fitch, California Department of Fish and Game (retired).

VI. Results

Spotted Seals

Most of the spotted seal specimens we have examined were from seals taken at Shishmaref. Foods found in specimens collected in the spring-summer varied widely among the 3 years sampled (Table 3). Largest volumes of food were found in seals taken 8-19 July 1977 which had eaten mostly herring. Our results are obviously influenced by the timing of seal collections in relation to the appearance of schools of spawning herring. Barton (1979) reported schools of herring off Shishmaref on 25 July 1976. Herring were obviously abundant in the vicinity from 8-19 July 1977 when our spotted seal samples were collected, but apparently had not yet arrived when seals were taken in early July 1976 and June 1978. Spotted seals taken at Shishmaref in October 1977 had also eaten mostly herring (Table 4). A seal taken there in early November had eaten only arctic cod. Three spotted seals taken at Wainwright in summer 1975 had eaten small amounts of sculpins and cod (arctic or saffron) and traces of shrimp and isopods.

Ringed Seals

Most of the ringed seal specimens we examined were collected at Shishmaref, Point Hope, and Wainwright. Foods eaten by ringed seals during the late spring-early summer period at Shishmaref were similar in 1976, 1977, and 1978 (Table 5). Fishes (mostly saffron cod) and shrimps (mostly Crangon septemspinosa) were the major foods in all 3 years with amphipods, mysids, euphausiids, and isopods also eaten. Seals taken at Shishmaref in spring 1979, slightly earlier than previous years, had eaten almost entirely fishes: saffron and arctic cods, and rainbow smelt. Seals collected at Shishmaref in October had eaten mostly hyperiid amphipods while arctic cod were the primary food item in November, January, and February (Table 6).

Four ringed seal stomachs containing food were collected at Point Hope during January-March. Foods eaten included arctic cod, sand lance, gammarid amphipods (mostly Ampelisca spp.), and hyperiid amphipods (Table 7). Stomach contents of seals collected in April varied widely among the 3 years sampled. Overall during April, fishes (several species) Ampelisca spp., and shrimps (primarily Pandalus goniurus) were the main foods (Table 8). Foods eaten by seals collected in May 1976 and 1977 were similar (Table 9). Several types of prey were identified from the stomachs including shrimps (mostly Argis lar), gammarid amphipods (mostly Ampelisca spp., some Anonyx nugax), mysids (Mysis litoralis and Neomysis rayi), euphausiids (Thysanoessa spp.), and several species of fishes, mainly saffron cod and sand lance.

Four seals collected at Wainwright during winter and spring 1978 had eaten small amounts of primarily gammarid amphipods (mostly Anonyx nugax, some Ampelisca spp.) and shrimps (Argis lar, Sclerocrangon boreas, and Pandalus goniurus). Seals taken in winter had eaten arctic cod also. Stomach contents varied greatly in seals collected during summer 1975, 1978, and 1979 (Table 10). Overall the stomach contents consisted mostly of fishes (primarily arctic cod), gammarid amphipods (Gammarus sp. and Onisimus sp.), and shrimps (Eualus gaimardii and Sclerocrangon boreas).

Stomach contents of 11 ringed seals collected at miscellaneous locations in the Chukchi Sea were examined (Table 11). The presence of herring in seals taken near Kotzebue in February was of interest since overwintering of herring in that area was not previously documented. The two seals collected on the DISCOVERER cruise provided the only data collected on summer foods of ringed seals in offshore waters of the northern Chukchi Sea. Those seals had eaten mostly shrimps (Eualus gaimardii, E. macilenta, and Pandalus goniurus) and arctic cod.

The large samples of ringed seals collected at Shishmaref during June-July 1976-1978 were examined for age- and sex-related differences in foods (Table 12). Foods of male and female seals were very similar. Small crustaceans (amphipods, mysids, and euphausiids) make up 28 percent of the stomach contents of pups but only 4-9 percent of the contents of older seals. The proportion of fish in the stomach contents increased

Table 3. Spotted seal stomach contents data from Shishmaref. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Shishmaref	Shishmaref	Shishmaref		
Dates:		4-6 July 1976	8-19 July 1977	6-21 June 1978	All years combined 1976-1978	
Sample Size:		3	10	10	23	
Mean Volume (ml)		402.9	632.0	49.7	359.7	
Food Items	1	Shrimp 87	Fish 99 Herring 96 Saffron cod 4	Fish 80 Sand Lance 94 Saffron cod 3 Sculpins 2	Fish 85 Sand Lance 48 Herring 36 Saffron cod 8 Flatfish 7	
	2	Fish 13 Flatfish 62 Saffron cod 38	Shrimp 1	Shrimp 8	Shrimp 14	
	3			Hyperiid amphipod 7		
	4			Mysid 3		
	5			Gammarid amphipod 1		

Table 4. Spotted seal stomach contents data from Shishmaref. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Shishmaref	Shishmaref			
Dates:		10-24 Oct 1977	4 Nov 1977			
Sample Size:		14	1			
Mean Volume (ml)		432.9	751.0			
Food Items	1	Fish 99 Herring 83 Saffron cod 17	Fish 100 Arctic cod 100			
	2					
	3					
	4					
	5					

Table 5. Ringed seal stomach contents data from Shishmaref. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:	Shishmaref	Shishmaref	Shishmaref	Shishmaref	Shishmaref
Dates:	4 June-12 July 1976	10 June-19 July 1977	9-21 June 1978	24 May-8 June 1979	All years combined 20 May-19 July
Sample Size:	106	235	56	12	409
Mean Volume (ml)	96.1	97.6	104.2	102.4	98.3
Food Items 1	Shrimp 47	Fish 57 Saffron cod 83 Arctic cod 8 Sand lance 4 Flatfish 3	Fish 44 Saffron cod 89 Sand lance 8 Arctic cod 1	Fish 95 Saffron cod 77 Rainbow smelt 13 Arctic cod 8	Fish 52 Saffron cod 86 Arctic cod 5 Sand lance 4 Flatfish 3
Food Items 2	Fish 41 Saffron cod 91 Flatfish 6 Herring 1	Shrimp 31	Shrimp 27	Shrimp 2	Shrimp 29
Food Items 3	Mysid 4	Euphausiid 3	Hyperiid amphipod 16	Echiuroid worm 2	Mysid 4
Food Items 4	Isopod 4	Mysid 3	Mysid 6	Mysid 1	Hyperiid amphipod 2
Food Items 5	Gammarid amphipod 2	Gammarid amphipod 2	Gammarid amphipod 3		Gammarid amphipod 2

Table 6. Ringed seal stomach contents data from Shishmaref. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Shishmaref	Shishmaref	Shishmaref		
Dates:		23-28 Oct 1977	4-5 Nov 1977	6 Jan-2 Feb 1978		
Sample Size:		6	7	24		
Mean Volume (ml)		122.0	272.7	314.9		
Food Items	1	Hyperiid amphipod 88	Fish 100 Arctic cod 86 Saffron cod 14	Fish 99 Arctic cod 83 Saffron cod 10 Sculpins 3		
Food Items	2	Fish 7 Saffron cod 100				
Food Items	3	Shrimp 5				
Food Items	4					
Food Items	5					

Table 7. Ringed seal stomach contents data from Point Hope. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Point Hope	Point Hope	Point Hope		
Dates:		January 1977	February 1978	March 1976		
Sample Size:		2	1	1		
Mean Volume (ml)		149.5	140.0	15.6		
Food Items	1	Fish 84 Arctic cod 96 Sand lance 4	Gammarid amphipod 100	Gammarid amphipod 59		
	2	Hyperiid amphipod 16		Fish 32 Sand lance 100		
	3			Shrimp 5		
	4					
	5					

Table 8. Ringed seal stomach contents data from Point Hope. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

	Point Hope	Point Hope	Point Hope	Point Hope	
Area:	Point Hope	Point Hope	Point Hope	Point Hope	
Dates:	April 1976	April 1977	April 1978	Combined April 1976-78	
Sample Size:	12	17	15	44	
Mean Volume (ml)	118.9	42.3	59.9	67.3	
Food Items 1	Fish 75 Arctic cod 78 Sculpins 9 Sand lance 6 Saffron cod 5	Hyperiid Amphipod 52	Gammarid Amphipod 32	Fish 46 Arctic cod 49 Sand lance 29 Sculpins 16 Saffron cod 3	
Food Items 2	Hyperiid amphipod 16	Shrimp 36	Fish 33 Sand lance 64 Sculpins 26 Arctic cod 6 Saffron cod 2	Gammarid amphipod 29	
Food Items 3	Shrimp 4	Fish 7 Arctic cod 64 Sand lance 16 Sculpins 12 Pricklebacks 8	Shrimp 27	Shrimp 19	
Food Items 4	Echiuroid worm 3	Euphausiid 4	Hyperiid amphipod 8	Hyperiid amphipod 2	
Food Items 5				Echiuroid worm 1	

Table 9. Ringed seal stomach contents data from Point Hope. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area: Dates: Sample Size:		Point Hope May 1976 20	Point Hope May 1977 7	Point Hope Combined May 1976-77 27		
Mean Volume (ml)		27.9	55.8	35.1		
Food Items	1	Shrimp 36	Shrimp 42	Shrimp 38		
	2	Gammarid amphipod 30	Gammarid amphipod 22	Gammarid amphipod 27		
	3	Euphausiid 11	Mysid 22	Mysid 11		
	4	Fish 8 Sand lance 69 Arctic cod 19	Fish 13 Saffron cod 65 Sand lance 17 Arctic cod 14 Sculpins 4	Fish 10 Saffron cod 42 Sand lance 37 Arctic cod 16 Sculpins 5		
	5			Euphausiid 7		

Table 10. Ringed seal stomach contents data from Wainwright. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Wainwright	Wainwright	Wainwright	Wainwright	
Dates:		8 July-7 August 1975	1-2 July 1978	25 June-13 July 1979	All years combined 25 June-7 August 1975-1979	
Sample Size:		17	24	5	46	
Mean Volume (ml)		26.3	117.7	63.8	78.1	
Food Items	1	Shrimp 42	Fish 71 Arctic cod 99 Sand lance 1	Gammarid amphipod 75	Fish 61 Arctic cod 96 Sculpin 2 Sand lance 1	
	2	Fish 22 Sculpins 50 Cod 25 Capelin 17	Gammarid amphipod 27	Fish 21 Arctic cod 93 Sculpin 7	Gammarid amphipod 29	
	3	Gammarid amphipod 8	Shrimp 1	Mysid 1	Shrimp 6	
	4	Isopod 5			Isopod 1	
	5	Hyperiid amphipod 2			Mysid 1	

Table 11. Ringed seal stomach contents data from misc. areas in the Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Kotzebue	Elephant Point	Cape Lisburne	DISCOVERER	
Dates:		February 1978	June 1978	March-April 1976	27-28 August 1976	
Sample Size:		3	3	3	2	
Mean Volume (ml)		212.3	21.9	36.6	75.9	
Food Items	1	Fish 100 Herring 51 Saffron cod 37 Smelt 6 Arctic cod 3	Fish 62 Saffron cod 71 Sculpins 29	Fish 31 Arctic cod 96 Sculpins 4	Shrimp 84	
	2		Mysid 17	Shrimp 29	Fish 13 Arctic cod 100	
	3		Shrimp 15	Gammarid amphipod 20	Gammarid amphipod 2	
	4		Isopod 2	Mysid 1		
	5		Gammarid amphipod 1			

Table 12. Major food items of ringed seals collected at Shishmaref in June-July 1976-1978. Results are presented by age and sex categories. Numbers indicate percent of total volume for invertebrates and total fish, and percent of total number for species of fishes.

Food Item	Sexes Combined				Seals ≥5 yrs old	
	Pups N=99	Yrlgs N=24	2-4 yrs old N=36	≥5 yrs N=212	Males N=100	Females N=126
Shrimp	19	37	38	30	31	33
Hyperiid Amphipod	9	*	*	2	1	*
Gammarid Amphipod	8	*	1	2	2	2
Mysid	7	6	3	3	4	3
Euphausiid	4	-	*	2	3	1
Total Fish	45	42	48	52	49	53
Saffron Cod	92	60	75	90	85	93
Arctic Cod	7	38	11	3	2	3
Sand Lance	1	-	-	2	*	-
Sculpin	*	*	1	*	1	*
Flatfish	-	1	1	4	11	3
Mean Volume of Contents (ml)	39.3	98.9	111.6	121.9	120.7	111.1

* Indicates values less than 1 percent.

slightly with age. Pups ate almost exclusively cod while other fishes occurred more frequently in stomachs of older seals. The mean volume of stomach contents showed a steady increase with age.

Bearded Seals

Most of the bearded seal specimens we examined were collected at Shishmaref and Wainwright. At Shishmaref during June and July shrimps (mostly *Crangon septemspinosa* and some *Argis lar*) were the main food in all 4 years sampled (Table 13). Brachyuran crabs (mostly *Telmessus cheiragonus*), clams (mostly *Spisula polynyma* and *Serripes groenlandicus*), isopods (*Saduria entomon*), and fishes were also major foods. In 13 bearded seals taken at Shishmaref 16-30 October 1977, the stomach contents averaged 631.8 ml and was comprised of 87 percent shrimps and 13 percent fishes (flatfish, sculpins, and saffron cod).

Stomachs of bearded seals were collected at Wainwright during five summers (Table 14a). Clams (*Spisula* and *Serripes*) were the primary prey during 1975-1977. Shrimp (*Sclerocrangon boreas* and *Eualus gaimardii*) were the major food in 1978 and 1979. Overall for the 5 years sampled, clams were the major food followed by shrimp, crabs (*Chionoecetes opilio* and *Hyas coarctatus*), fishes, and *Saduria* (Table 14b). The stomach of one bearded seal collected at Wainwright on 18 May 1978 contained 1171.7 ml of food consisting of 52 percent shrimp, 34 percent fishes (98% sculpins, 2% arctic cod), 9 percent gammarid amphipods, and 2 percent clams (*Musculus* sp.).

Only four bearded seal stomachs containing food were obtained from other locations in the Chukchi Sea (Table 15). Little can be said about those small, scattered samples. It is interesting and perhaps significant that three types of prey which were not important foods at Shishmaref and Wainwright (eelpout, priapulids, and snails) were major foods of seals collected in the northern Chukchi Sea ice edge in August.

Age- and sex-related differences in the bearded seal diet were examined using data from seals collected at Shishmaref in June-July 1976-1978 (Table 16). Foods of males and females were generally similar although shrimp and isopods were proportionately more important in the diet of females while males ate more echiuroid worms. The importance of clams, brachyuran crabs, and echiuroid worms in the diet increased with age while shrimp and isopods were of lesser importance in the diet of older seals.

Walruses

We obtained and examined stomach contents of only four walruses taken in the Chukchi Sea. Small amounts of food (mean volume 48.5 ml) were found in three walruses taken at Shishmaref on 25 October 1977. The contents consisted of 75.7 percent clams (*Siliqua* sp. and *Tellina* sp.), 11.7 percent priapulid, 6.5 percent shrimp (*Crangon septemspinosa*), and 4.2 percent snail (*Natica* sp. and *Polinices* sp.). One walrus taken

Table 13. Bearded seal stomach contents data from Shishmaref. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Shishmaref	Shishmaref	Shishmaref	Shishmaref	Shishmaref
Dates:		4 June-11 July 1976	24 June-20 July 1977	9-21 June 1978	3-8 June 1979	3 June-20 July 1976-1979
Sample Size:		40	112	17	4	173
Mean Volume (ml)		415.2	460.4	407.9	433.8	444.5
Food Items	1	Shrimp 51	Shrimp 35	Shrimp 41	Shrimp 65	Shrimp 40
	2	Brachyuran Crab 19	Brachyuran Crab 21	Clam 17	Isopod 17	Brachyuran Crab 20
	3	Clam 16	Clam 14	Echiuroid 16	Echiuroid 4	Clam 14
	4	Isopod 4	Isopod 13	Brachyuran Crab 13	Snail 3	Isopod 10
	5	Fish 3 Flatfish 54 Saffron cod 15 Sculpins 14 Sand lance 7	Echiuroid worm 6	Fish 4 Sculpins 45 Flatfish 34 Sand lance 14 Saffron cod 6	Clam 3	Fish 6 Sculpins 34 Saffron cod 32 Flatfish 30

Table 14a Bearded seal stomach contents data from Wainwright. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Wainwright		Wainwright		Wainwright		Wainwright		Wainwright	
Dates:		24 July- 7Aug 1975		28-29 July 1976		23 July 1977		8 July 1978		27 June-1 July 1979	
Sample Size:		22		7		3		4		16	
Mean Volume (ml)		530.7		848.3		367.6		761.0		593.4	
Food Items	1	Clam	55	Clam	66	Clam	75	Shrimp	81	Shrimp	39
	2	Shrimp	12	Shrimp	25	Shrimp	13	Isopod	9	Clam	32
	3	Fish Sculpin Cod	10 96 4	Brachyuran Crab	5	Brachyuran Crab	7	Brachyuran Crab	5	Brachyuran Crab	12
	4	Brachyuran Crab	4	Isopod	2	Snail	2	Clam	4	Gammarid amphipod	3
	5	Snail	4	Fish Sculpin Sand lance Arctic cod	1 60 26 14					Fish Sculpin Arctic cod Saffron cod	1 77 21 1

Table 14b. Bearded seal stomach contents data from Wainwright. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area: Dates: Sample Size:		Wainwright All years combined 27 June-7 August 1975-1979 52				
Mean Volume (ml)		601.1				
Food Items	1	Clam 46				
	2	Shrimp 29				
	3	Brachyuran Crab 7				
	4	Fish 4 Sculpin 74 Arctic cod 15 Sand lance 10				
	5	Isopod 2				

Table 15. Bearded seal stomach contents data from misc. areas in the Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Point Hope		DISCOVERER		GLACIER			
Dates:		16 April 1978		27 August 1976		1-5 August 1977			
Sample Size:		1		1		2			
Mean Volume (ml)		1172.4		655.5		454.5			
Food Items	1	Shrimp	88	Fish Eelpout Sculpins	29 91 9	Snails	48		
	2	Fish Sculpins	6 100	Brachyuran Crabs	26	Shrimp	9		
	3	Brachyuran Crab	5	Shrimp	6	Priapulids	6		
	4			Priapulids	3	Amphipods	4		
	5					Brachyuran Crabs	3		

Table 16. Major food items of bearded seals collected at Shishmaref in June-July 1976-1978. Results are presented by age and sex categories. Numbers indicate percent of total volume for invertebrates and total fish, and percent of total number for species of fishes.

	Sexes Combined			Seals ≥3 yrs old	
Food Item	Pups N=38	1&2 yrs old N=21	≥3 yrs old N=91	Males N=27	Females N=64
Shrimp	59	30	30	26	32
Isopod	18	18	8	2	11
Clam	4	11	19	20	18
Brachyuran Crab	6	20	24	23	25
Echiuroid Worm	*	*	9	19	4
Total Fish	7	11	6	6	5
Saffron Cod	51	18	30	28	31
Sculpin	28	55	25	24	25
Flatfish	20	25	37	46	38
Mean Volume of Contents (ml)	324.8	462.4	492.4	539.7	472.5

* Indicates values less than 1 percent.

at Wainwright on 28 June 1979 contained 2039 ml of food comprised of 99.7 percent clam and trace amounts of priapulids and polychaete worms. Of the identifiable clams in that walrus, 50.3 percent (by volume) were Mya truncata, 48.6 percent were Spisula polynyma, and 1.1 percent were Serripes groenlandicus.

Belukha Whales

Stomach contents of 62 belukhas collected at Elephant Point (eastern Kotzebue Sound) in June 1978 were examined (Table 17). Small amounts of shrimp (Crangon septemspinosa), isopods (Saduria entomon), snails (Polinices sp.), polychaetes, and octopus were found in the stomachs. Most of the stomach contents consisted of bones and otoliths of fishes, primarily saffron cod and sculpins. Stomachs of three whales taken in Kotzebue Sound in June 1979 contained food. Two were taken in Eschscholtz Bay and contained numerous saffron cod otoliths and traces of shrimp and snails. The third was taken near the village of Buckland and contained 5810 ml of partially digested fish, most of which was 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 that stomach.

At Point Hope we found food remains in stomachs of five belukhas taken in May 1977 and 9 taken in April 1978 (Table 18). Most of the stomach contents in April was fragments of crangonid shrimps and arctic cod otoliths. Octopus beaks were very common in stomachs collected in May 1977, occurring in all five stomachs containing food. Stomachs of two belukhas taken on 6 and 8 May 1979 at Point Hope contained food. One stomach contained otoliths from 3 arctic cod; the other contained 1 octopus beak, 1 saffron cod otolith, and 2 small unidentifiable fishes.

One belukha taken at Wainwright on 22 July 1976 contained beaks from three octopus and four gonatid squids. Two belukhas taken at Wainwright on 18 July 1979 contained 12 partially digested rainbow smelt, otoliths from 2 saffron cod, and trace amounts of snails and isopods.

Possible age- and sex-related differences in belukha foods were examined using data from whales collected at Elephant Point in June 1978. The composition of the stomach contents in young and older belukhas was quite similar (Table 19). The composition of the stomach contents of male and female whales was slightly different (Table 20). Shrimp accounted for a greater proportion of the contents and occurred more frequently in females while the converse 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.

VII. Discussion

A. Foods of Marine Mammals

We investigated the foods utilized by marine mammals in the Chukchi Sea based on stomachs collected during 1975-1979. During 1975-1977,

Table 17. Stomach contents of belukha whales collected at Eschscholtz Bay, 13-18 June 1978 (N=62).

Prey Item	% of total volume	% of total number	% frequency of occurrence
Shrimp	4	--	76
Isopod	6	--	34
Octopus	<1	--	52
Other Invertebrate	<1	--	41
Total Invertebrate	11	--	90
Rocks and Pebbles	1	--	66
Total Fishes	87	--	94
Saffron Cod	--	88	94
Sculpins	--	11	42
Rainbow Smelt	--	<1	29
Pacific Herring	--	<1	3
Eelpout	--	<1	2
Mean Volume of Contents (ml)		47.2	
Total # Identified Fishes		4346	

Table 18. Stomach contents of belukha whales collected at Point Hope.

Prey Item	22-27 May 1977, N = 5			25-26 April 1978, N = 9		
	% of total volume	% of total number	% frequency of occurrence	% of total volume	% of total number	% frequency of occurrence
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 # Identified Fishes		0			43	

Table 20. Stomach contents of belukha whales collected at Eschscholtz Bay, June 1978, separated by sex.

Prey Item	Females, N = 28			Males, N = 29		
	% of total volume	% of total number	% frequency of occurrence	% of total volume	% of total number	% frequency of occurrence
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 # Identified Fishes		1648			2588	

collection efforts concentrated only on seals. In 1978 and 1979 we systematically attempted to collect stomachs from belukha whales also. Stomach contents of belukhas and walruses were obtained on an opportunistic basis throughout the collection period.

Virtually all marine mammal stomachs were obtained from animals killed by Eskimo subsistence hunters. The distribution of our sample collections reflects locations and times where active subsistence marine mammal hunting occurs. Most of the seal specimens were collected at Shishmaref and Wainwright in the late spring-summer period. Most of the belukha specimens were collected at Point Hope in spring and Elephant Point in June. Therefore, our results cannot be extrapolated to and should not be considered representative of the entire Chukchi Sea. Rather, they represent the feeding patterns of marine mammals in localized areas of the nearshore zone. This is unfortunate since marine mammals occur and feed throughout the vast area of the Chukchi Sea. In order to allow a broader interpretation of our findings and a description of overall feeding patterns in the Chukchi Sea, many more animals (ringed and bearded seals and walruses) must be collected from offshore areas and systematic collections of spotted seals must be made in certain coastal areas. Offshore collections can be made from ice-strengthened vessels and shore-based helicopters. Adequate ship and helicopter support have not yet been provided by OCSEAP in the Chukchi Sea, although in the Bering and Beaufort Seas we have had great success in using such logistics. With the background data presented in this report, an adequate understanding of feeding of marine mammals in the Chukchi Sea can be developed when appropriate support and logistics are made available.

Spotted Seals

Spotted seals forage in coastal waters of the Chukchi Sea primarily during June-October. Major concentrations of spotted seals occur in Kotzebue Sound and the coastal lagoons and barrier islands between Point Lay and Point Barrow. Based on our samples from Shishmaref, herring are a major food of spotted seals at least in July and October. Other fishes and shrimps may be the main foods earlier and later in the year. Concentrations of herring have not been documented north of Kotzebue Sound and the few seal specimens we obtained at Wainwright do little to identify major prey in the northern Chukchi. Based on results from other areas (Bukhtiyarov et al. in press), capelin, smelt, arctic cod, saffron cod, and sculpins, in addition to herring, are probably all significant prey of spotted seals in the Chukchi Sea. Identification of specific seasonal and geographical prey utilization patterns will require systematic sampling.

Ringed Seals

Ringed seals are abundant throughout the Chukchi Sea, particularly in coastal waters, from late October through July. During August through mid-October when much of the Chukchi Sea is ice-free, many ringed seals are thought to be associated with the pack ice in the northern Chukchi.

At Shishmaref, arctic cod and some saffron cod were the main foods of ringed seals in November-February. Saffron cod and several types of crustaceans were the primary foods in late spring and early summer as were hyperiid amphipods in October. A similar pattern was documented at Point Hope by Johnson et al. (1966) based on 1,432 stomachs containing food. Fishes were the main food there in November-February. Arctic cod were eaten throughout that period but were proportionately most important in December-February. Saffron cod were most commonly eaten in November, December, April, and June. Crustaceans (amphipods, shrimp, and mysids) were the primary food in March-June. The results of our limited collections from Point Hope generally agree with those of Johnson et al. The foods eaten at Wainwright in summer were slightly different from those found further south. Arctic cod were overall the dominant food. This is probably due to the fact that the pack ice edge usually remains close to Wainwright during the summer. Our data from Wainwright at other times of year are inadequate. However, it seems likely that the seasonal pattern of food utilization would be similar to other areas, i.e. primarily arctic cod in winter and mostly crustaceans in spring.

The feeding pattern of ringed seals near coastal villages in the Chukchi Sea is similar to what we observed in the Beaufort Sea (Lowry et al. 1979b) with the following exceptions: 1) more species of fishes are regularly eaten, and saffron cod are of considerable importance in the diet especially at Point Hope and Shishmaref; 2) shrimp (*Crangon septemspinosa*, *Eualus gamardii*, *Pandalus goniurus*, and *Sclerocrangon boreas*) are proportionately more important in the spring-early summer diet in the Chukchi Sea. In general, more species are of importance in the diet in the Chukchi Sea than in the Beaufort Sea. In August-October in the Beaufort Sea, ringed seals forage intensively on nektonic crustaceans (euphausiids and hyperiid amphipods) associated with pack ice. The only two seals we examined from the summer pack ice of the northern Chukchi had eaten mostly shrimp. That is not surprising since nektonic crustaceans appear to occur in patches, perhaps related to oceanographic conditions. Relatively large amounts of hyperiids in ringed seal stomachs collected in October at Shishmaref indicate that patches of nekton do occur in the Chukchi. The distribution and causes of such concentrations of nekton are of great interest since they appear to be of major importance in the annual feeding cycle of ringed seals (Lowry et al. in prep.).

Bearded Seals

Bearded seals forage throughout the Chukchi Sea. During winter months they are most common in areas of regular ice movement. They are generally absent from open water areas in summer.

The foods of bearded seals in the late spring-summer period at Shishmaref and Wainwright were generally similar to those found at other locations (Lowry et al. 1980). Shrimp, brachyuran crabs, and clams made up the majority of the stomach contents. The composition of the diet was relatively stable over the several years sampled; however, clams made up a smaller proportion of the diet at Wainwright in 1978 and 1979 than in previous years.

There are very few data available on foods of bearded seals nearshore during fall, winter, and early spring or offshore at any time of year. Distinct seasonality was observed in foods of bearded seals collected at Point Hope; clams were important in the diet only in June (Johnson et al. 1966). A similar seasonal pattern occurs in the Bering Sea (Lowry et al. 1980).

Walruses

A large portion of the Pacific walrus population summers and feeds along the pack ice edge in the northern Chukchi Sea (Estes and Gilbert 1978). Walruses are not common in the Chukchi Sea during winter months.

Foods of walruses in the Chukchi Sea are poorly documented. The stomach contents of the four walruses we examined was mostly clams. Clams appear to make up most of the walrus diet in all areas of the Bering and Chukchi Seas (Fay et al. in press).

Belukha Whales

Belukha whales migrate through the Chukchi Sea in spring and fall. Some belukhas spend summer months in and near coastal lagoons and estuaries in Kotzebue Sound and between Point Lay and Wainwright and along the edge of pack ice in the northern Chukchi Sea.

The intensity with which belukhas feed during migration is not known. Our results from Point Hope indicate that some feeding does occur during the spring migration: octopus, shrimps, and arctic cod are eaten.

Belukhas taken at Elephant Point (which had probably fed in the Eschscholtz Bay portion of Kotzebue Sound) had eaten saffron cod, sculpins, shrimps, isopods, snails, polychaetes, and octopus. Based on food remains in stomachs, saffron cod were the major prey. Belukhas we examined were taken in mid-June. Interviews with local residents indicated that later in the summer (July and August) belukhas in the area feed extensively on herring and occasionally on salmonids. Less is known about the foods of belukhas summering in the Point Lay-Wainwright areas. The few stomachs we have examined contained mostly rainbow smelt, saffron cod, octopus, and squids. Belukhas observed near Point Lay in summer appeared to be feeding on capelin (Seaman and Lowry, in prep.).

There are no data available on foods of belukhas in the summer Chukchi Sea pack ice. Based on other studies (Kleinenberg et al. 1964), arctic cod may be a major food in that region.

B. Biology of Major Prey Species

The probable effects of OCS exploration and development on marine mammals in the Chukchi Sea will depend to a large degree on the effects such activities may have on populations of prey species. In this section we review the available information on the biology of major marine mammal prey with particular respect to distribution and abundance, reproductive strategy, and food habits. Since little data for most species have been collected in the Chukchi Sea, we have had to draw on data collected in other areas in many instances.

Arctic Cod

Arctic cod is the single most important forage fish in far northern waters (Klumov 1937, Tomilin 1957, Tuck 1960, Lowry et al. 1979a&b). In the southeastern Chukchi Sea in September-October, Wolotira et al. (1977) found them to be the most widely distributed of all species of fishes, with the greatest abundance in the Hope Basin area, excluding Kotzebue Sound. Alverson and Wilimovsky (1966) noted that arctic cod were the most common species near Point Hope in August 1959. Over a thousand individuals were caught at a single station approximately 80 km northeast of Cape Lisburne. Lowry et al. (1978a) found arctic cod to be the most numerous fish in 10 trawls conducted in the northeastern Chukchi Sea in August. Quast (1974) sampled surface and mid-depth waters between Cape Lisburne and Icy Cape at night during September and October 1970 and found juvenile arctic cod to be ubiquitous and at least 10 times more numerous than sand lance, the only other species caught. Quast estimated an average density of 28 juvenile cod/1000 m^3.

The distribution of adult arctic cod is closely related to low temperatures and/or the presence of sea ice, with much of the population believed to stay under or near the edge of compact ice for most of the year (Svetovidov 1948, Andriyashev 1954, Ponomarenko 1968). Andriyashev (1954) indicated that in autumn large schools may be found nearshore, especially in warm, relatively fresh water near river mouths. Recent OCSEAP research in the Beaufort Sea has also documented large concentrations of arctic cod in nearshore areas in late summer and autumn (Bendock 1979, Craig and Haldorson 1979). The precise time and location of spawning for arctic cod in Alaska is unknown. In the Beaufort Sea individuals caught nearshore during November were gravid, and by the next sampling period in February all individuals had spawned. This coincides closely with spawning periods in the Barents and Kara Seas and eastern Siberia (Moskalenko 1964, Rass 1968, Ponomarenko 1968). Spawning probably occurs in coastal areas.

Arctic cod have the largest and fewest eggs of all cods (Svetovidov 1948, Andriyashev 1954). The eggs develop in surface waters under the ice and probably hatch in May or June. Larvae live in surface waters until August or September when transition to the juvenile stage takes place and the fry descend to the bottom (Rass 1968, Baranenkova et al. 1966). Association with the ice is thought to begin after the first year. Individuals mature at 3 to 4 years and probably do not live much longer than 6 years (Gjosaeter 1973).

Arctic cod eat a variety of euphausiids, copepods, benthic amphipods, shrimps, mysids, hyperiid amphipods, and small fish (Lowry and Frost unpubl., Klumov 1937, Craig and Haldorson 1979). Planktonic forms--

copepods (mostly _Calanus hyperboreas_, _C. glacialis_, and _Euchaeta glacialis_) and gammarid amphipods (_Apherusa glacialis_)--were the major prey of arctic cod from the northeastern Chukchi Sea (Lowry et al. 1978a).

Saffron Cod

Saffron cod are important prey of seals, belukha whales, and seabirds (Lowry et al. 1978a, 1979a; Tomilin 1957; Springer and Roseneau 1978). Alverson and Wilimovsky (1966) and Wolotira et al. (1977) found them to be much less abundant in central and southeastern Chukchi Sea and Kotzebue Sound than in the northern Bering Sea and Norton Sound. Greatest densities were in relatively shallow water near the mouth of Kotzebue Sound, offshore from the northern Seward Peninsula, and in waters less than 25 m deep between Cape Lisburne to Point Hope. Most saffron cod caught north of Bering Strait were small (less than 10 cm in length).

Saffron cod are thought to reside in the coastal zone coming close to shore in the fall to spawn in river mouths, bays, and inlets, and moving into deeper water (30-50 m) in summer to feed (Svetovidov 1948, Andriyashev 1954). Such movements may not occur in the Chukchi Sea. Saffron cod are present and abundant in nearshore shallow waters in June and July, as indicated by their importance in the diets of seals and belukhas at Shishmaref and Eschscholtz Bay at that time. No trawl surveys have been conducted in offshore waters in June and July, but by August-October saffron cod are not numerous there. It is probable that they remain nearshore throughout the year. Spawning probably takes place between December and February (February in Norton Sound) at subzero temperatures (-1.0 to -1.8°C). The eggs are demersal and are spawned on clean sandy or pebbly bottoms (Andriyashev 1954). Most larvae hatch in April. Normal embryonic development occurs at temperatures of -3.8° to 8°C and salinities of 28-30 ppt. Development is suspended below -3.8°C; however, eggs will resume growth even after freezing in ice once temperatures are greater than -3.8°. Larvae perish en masse in water warmer than 8°C (Mukhacheva 1959). Larvae stay near the surface after hatching and are often associated with the jellyfish _Cyanea_ sp. (they live inside the protection of the mantle and tentacles). Growth is probably very slow until August when larvae are fully transformed into fry and descend to the bottom to assume a demersal life similar to the adults. Maximal growth occurs in the first 3 years of life, and almost all of each year's growth occurs in September-October. Sexual maturity occurs at 2-3 years and individuals probably live at least 12 years (Svetovidov 1948). Saffron cod eat a variety of benthic organisms including polychaetes, shrimps, crabs, mysids, and amphipods.

Herring

Herring are present and locally abundant in nearshore areas of the southern Chukchi Sea. Barton (1979) reported peak herring abundance along the northern coast of the Seward Peninsula and southern Kotzebue Sound (Eschscholtz Bay) in late July and August. Both pre- and post-spawning segments of the population remain nearshore during spring and summer. Barton also noted that herring were present in autumn and winter near Shishmaref (October, March, April) and in Kotzebue Sound (November). We have found herring in the stomachs of spotted and ringed seals from Shishmaref in October, January, and February. Wolotira et al. (1977) reported that herring made up 22 percent of the total catch of fish in the southeastern Chukchi and Kotzebue Sound. Catch rates were highest in outer Kotzebue Sound and lowest in inner Kotzebue Sound. Relatively few herring were caught by Alverson and Wilimovsky (1966) in their 1959 trawl survey. Highest relative abundance was near Cape Thompson. In all of the Chukchi trawl surveys very few young fish (less than 2 years) were caught. In the Bering Sea herring make large scale onshore-offshore movements in summer and winter. Major wintering concentrations occur northwest of the Pribilofs and at the seasonal ice edge. Herring move to the coast in summer to spawn and feed (Barton 1979). It is unknown whether Chukchi and Bering Sea herring are part of the same stocks. Barton suggests that there may be an overwintering population in Kotzebue Sound. Percy (1975) working in the MacKenzie Delta found herring to congregate nearshore during winter and spawn in spring and summer in coastal bays and river mouths.

Herring spawn in late July or August in the Chukchi Sea (spawning occurs earlier farther south). Most spawning occurs subtidally in relatively shallow bays, lagoons, or inlets such as Shishmaref Inlet and Kugruk and Kiwalik lagoons in Kotzebue Sound (Barton 1979). Spawning is also known to occur along rocky headlands of eastern Eschscholtz Bay. Eggs develop in about 23 days at 6-8°C (Andriyashev 1954). Barton found Chukchi Sea herring to be euryhaline and believed they are also eurythermal if they in fact overwinter north of Bering Strait. Sexual maturity probably occurs between 3 and 6 years of age. Herring feed on euphausiids, copepods, hyperiids, mysids, amphipods, and fish fry (Andriyashev 1954, Percy 1975, Rumyantsev and Darda 1970). Feeding is probably most intensive during the period following spawning.

Sand Lance

The distribution and abundance of sand lance in the Chukchi Sea are poorly known. Alverson and Wilimovsky (1966), Wolotira et al. (1977), and Barton (1979) make no mention of them in any of their Chukchi Sea fish surveys. They were one of two species caught by Quast (1974) in a midwater survey of the eastern Chukchi Sea in 1970. In that survey sand lance were taken mostly near the surface and were about one-tenth as abundant as arctic cod. Swartz (1966) reported sand lance as a major food of murres, kittiwakes, and gulls in the Cape Thompson region. They did not appear in the diets, however, until mid-June or early July. According to Andriyashev (1954) sand lance form schools near the bottom in sandy areas, sometimes burrowing into the sand. They inhabit deep water in winter and move close to the coast in June. Spawning occurs from November-February at 50-75 m on sandy bottoms. Sand lance mature in their third year of life. Their main foods include copepods, barnacle larvae, euphausiids, and amphipods.

Sculpins

Many species of sculpins are present in the Chukchi Sea. Five species were among the 20 most abundant fishes caught in the southeastern Chukchi and Kotzebue Sound (Wolotira et al. 1977). They were, in relative order of abundance, *Myoxocephalus scorpius*, *Gymnocanthus tricuspus*, *Enophrys diceraus*, *Triglops pingeli*, and *Megalocottus platycephalus*. *Myoxocephalus* (averaging 25 g in weight) were most abundant slightly north of Bering Strait in water deeper than 25 m, and farther north near Kivalina and Point Hope. Alverson and Wilimovsky (1966) listed the genera *Gymnocanthus*, *Artediellus*, *Triglops*, and *Myoxocephalus* among the 10 most common fishes near Cape Lisburne and Point Hope. Together they comprised almost 20 percent of the total catch.

Sculpins are demersal and most prefer water temperatures around 0°C. Most species spawn in fall or winter (Andriyashev 1954). In general they feed on benthic or epibenthic organisms such as shrimps, amphipods, polychaete worms, isopods, mysids, and molluscs.

Flatfishes

Flatfishes (F. Pleuronectidae) were the most abundant group of fishes in southeastern Chukchi Sea and Kotzebue Sound, comprising 30 percent of the total fish biomass (Wolotira et al. 1977). They were less abundant in Kotzebue Sound (10%) than in offshore waters (42%). Starry flounder (*Platichthys stellatus*), mostly large, older fish, was the most abundant species in this group in the southern portion of the Chukchi Sea. Alaska plaice (*Pleuronectes quadrituberculatus*) were locally abundant along the north coast of the Seward Peninsula, with small individuals closest to shore and larger fish offshore. Yellowfin sole (*Limanda aspera*) were most abundant in inner Kotzebue Sound (mostly small fish) and along the north coast of the Seward Peninsula. They were absent farther north. Bering flounder (*Hippoglossoides robustus*) were found mostly north of Kotzebue Sound. None were caught in inner Kotzebue Sound. Arctic flounder (*Liopsetta glacialis*) were restricted to very shallow waters in Kotzebue Sound, and near Kivalina. Mean size of individuals was quite small (less than 14 cm). Flatfishes feed on a variety of benthic organisms including polychaetes, molluscs, and small crustaceans, and on small fishes.

Hyperiid Amphipods

Parathemisto libellula is very common in arctic waters. According to Dunbar (1942) "*P. libellula* is without doubt one of the most important organisms in the Arctic, in any habitat, terrestrial or aquatic." He later stated (Dunbar 1957) that "it forms the most important link in the food chain between the copepods and other smaller planktonic forms on the one hand, and the vertebrates on the other, and in fact it takes the place, in cold water, of the euphausiids in this respect." Although *Parathemisto* is probably somewhat less "important" in more southern waters, it is nonetheless a major food of ringed seals at some locations and during certain times. It may be relatively more important in far northern Chukchi waters than in more southern areas with warmer water. Information on the distribution and relative abundance of Parathemisto in the Chukchi Sea is virtually nonexistent, except by inference from stomach contents of predators.

Parathemisto is a pelagic species which spends its life in the water column. It is often considered to be an indicator of cold arctic waters. Individuals are found closer to the surface during the day due to a positive phototropic response (Tencati and Leung 1970). The young develop directly in brood pouches in the female rather than as free swimming larvae. Individuals probably breed only once in their 18-month to 2-year lifetime (Dunbar 1957). Breeding takes place over an extended period lasting from September until April. There may be two breeding periods during this time: September-October and March-April. Foods include small crustaceans such as copepods and barnacle, crab, and shrimp larvae.

Gammarid Amphipods

Gammarid amphipods are a diverse element of the Chukchi Sea fauna. They are the predominant food of many demersal fishes, and regular prey of seabirds, arctic cod, ringed and bearded seals, and bowhead and gray whales. Although primarily benthic, several species make use of the inverted substrate provided by the undersides of ice floes (Barnard 1959, George and Paul 1970, Tencati and Leung 1970). Ampelisca, Anonyx, and Gammarus are all important genera to seals and whales. Based on scattered samples collected in the Chukchi Sea, Anonyx is widespread though apparently not present in large numbers. We found Ampelisca to be much less abundant, but because they are tube dwellers, trawls probably do not provide a true reflection of their abundance. Stoker (pers. comm.) found Anonyx, Rhacotropis, and Stegocephalus to be the most ubiquitous genera in the Chukchi Sea. Sparks and Pereyra (1966) also found Stegocephalus to be very abundant in the Point Hope region. This species is large and heavily armored and is probably poorly suited as food.

Ampelisca is probably the single most important species to marine mammals. Ampelisca macrocephala lives 1-1/2 to 2 years, with some females living to age 3 and reproducing a second time (Kanneworff 1965). Maximum growth occurs in spring and early summer and breeding takes place in the fall (October). Females carry eggs in a brood pouch until the young are released in about April when feeding conditions are good. Ampelisca is both an active predator and a detritus feeder. Prey includes copepods, other small crustaceans, and various detrital plant and animal material. Feeding (as well as growth and gonad development) is most intense during spring and summer when phyto- and zooplankton are abundant.

Mysids

Mysids (Mysis litoralis and Neomysis rayii) occurred as major prey in samples from May and June near Shishmaref, Point Hope, and Elephant Point. Redburn (1974) encountered mysids only rarely in his collections from the Chukchi Sea near Point Barrow. Geiger (1969) did not catch mysids in 13 tows from the southwestern Chukchi, but cautioned that this should not be interpreted as complete absence of the group from the Chukchi Sea. Broad (1978) listed Mysis as one of the principal genera at 4 of 18 nearshore stations between Point Hope and Point Barrow and at 2 of 23 between Bering Strait and Point Hope. Neomysis was one of the principal genera at 13 of 23 more southern stations. In general Mysis and Neomysis are found throughout shallow waters of the Alaskan continental shelf. Mysis is tolerant of low salinities and is often found nearshore (Geiger 1969). They live on or near the bottom and are probably detritus feeders.

Isopods

The isopod Saduria entomon is locally abundant in shallow nearshore waters of the continental shelf (McCrimmon and Bray 1962, Mohr and Geiger 1968). This species is extremely euryhaline (0-31.6 ppt) and eurythermal (-1.4-11.0°C) (Bray 1962). Sparks and Pereyra (1966) reported cosmopolitan distribution of Saduria in the eastern Chukchi. The life cycle probably requires 2-3 years; individuals spawn once and then die. Spawning activity takes place throughout the summer in the western Canadian Arctic, with females moving inshore to release the young. Young are borne in a brood pouch and released when 3-4 mm long. Saduria is an omnivorous scavenger, eating a variety of plant and animal material and occasionally preying on small crustaceans (Green 1957).

Shrimps

Three families of shrimps are present and important as marine mammal prey in the Chukchi Sea: F. Hippolytidae, F. Crangonidae, and F. Pandalidae. The pandalids are of commercial importance in the Gulf of Alaska and Bering Sea, but no species are commercially harvested in the Chukchi. Information on the distribution and abundance of shrimps in the Chukchi Sea is scarce.

Eualus gaimardii is the most widespread and abundant of the hippolytids. MacGinitie (1955) found it to be the most numerous shrimp near Point Barrow. We caught this species throughout the Chukchi, both nearshore and offshore, in depths of 5-55 m on muddy and rocky bottoms. It was usually the most numerous shrimp species in our trawls. In the Canadian arctic individuals probably spawn biennially (Squires 1969). Spawning frequency in the Chukchi is unknown. Many ovigerous females were found in spring-summer when most of our trawls were made. Eualus eat ostracods, euphausiids, copepods, and phytobenthos.

Pandalus goniurus is the most abundant pandalid shrimp in the Chukchi Sea. We caught them in trawls from Bering Strait to Barrow.

Most individuals we caught were small, and none were ovigerous. Pandalid shrimps are protandrous hermaphrodites, that is they reproduce first as males (probably during the first year), then become females and produce eggs when large (1-1/2 to 2-1/2 years) (Butler 1964). Breeding takes place in the fall and the eggs are carried until they hatch in spring. Larvae are planktonic during summer and settle to the bottom in late summer or early fall (Charnov 1979). Adult shrimps eat small crustaceans, polychaete worms, and detritus.

Crangonid shrimps which are major prey of seals include Crangon septemspinosa, Argis lar, and Sclerocrangon boreas. Crangon septemspinosa is euryhaline and eurythermal, and is especially common in very shallow waters (Price 1962). Broad (1978) found them to be abundant between Wales and Point Hope in water 0-5 m deep. Argis lar is one of the most abundant and widespread shrimps throughout the Chukchi Sea (Feder and Jewett 1978, Lowry et al. 1978a, Stoker unpublished). Sclerocrangon boreas is apparently less abundant there, being found at only a few stations, mostly in the northeastern Chukchi near Wainwright (Lowry and Frost unpublished, Stoker unpublished). It is a relatively large, heavily armored shrimp which occurs at temperatures of -1.5 to -5°C (Squires 1967). Spawning in the three species may occur over a broad time span, although all probably carry eggs through the winter and hatch them in spring-summer. Sclerocrangon and Argis females carrying eggs were caught in October (Feder and Jewett 1978). During June-July very few Crangon females had eggs, whereas many Argis and Sclerocrangon either had large eggs ready to hatch, recently hatched eggs, or recently extruded eggs (Squires 1968, Lowry and Frost unpublished). Crangonid shrimps eat a variety of organisms including phytobenthos and detritus, polychaete worms, small crustaceans, crustacean eggs and larvae, and to a lesser degree foraminiferans, gastropods, and ophiuroids (Squires 1967).

Crabs

Brachyuran crabs are widely distributed in the Chukchi Sea. Three species are important to bearded seals--Hyas coarctatus, Telmessus cheiragonus, and Chionoecetes opilio. Feder and Jewett (1978) and Wolotira et al. (1977) found Chionoecetes and Hyas to be nearly ubiquitous in southeastern Chukchi Sea and outer Kotzebue Sound. Telmessus was found mostly nearshore and in Kotzebue Sound. Chionoecetes was over 4 times more abundant than either of the other two species. Sparks and Pereyra (1966) listed Chionoecetes as one of the dominant organisms in trawls near Point Hope/Cape Lisburne. Lowry et al. (1978a) found both Hyas and Chionoecetes in the northeastern Chukchi. Hyas was the most abundant of the two.

Watson (1970) found that Chionoecetes males mature at about 5.7 cm and females at about 5.0 cm. Since most individuals caught in the Chukchi Sea were smaller than 5 cm, the number of reproductively mature specimens there is probably very low (Feder and Jewett 1978, Lowry and Frost unpublished). In contrast, reproductively mature Hyas are common in the Chukchi. Many females with eggs were found in July-August and

October. In Canada Squires (1957) found eggs only in July and August. Telmessus were ovigerous in June-July but not in October (Feder and Jewett 1978, Frost and Lowry unpublished).

Brachyuran crabs are scavengers or predators. They eat a variety of detritus, phytobenthos, crustaceans such as amphipods, euphausiids, copepods, and shrimps, molluscs, ophiuroids, polychaetes, hydroids, and in some cases, fishes (Feder and Paul 1979, Squires 1967).

Clams

Two genera of clams, *Serripes* and *Spisula*, are especially important as food for bearded seals and walruses in the Chukchi Sea. Virtually nothing is known about the distribution or abundance of either species there. Filatova (1957) lists *Serripes* as one of the abundant bivalves in the southwestern Chukchi and *Spisula* as common along the Alaska shore from Bering Strait to the MacKenzie River. Neither of these clams was mentioned in his biomass calculations, perhaps because of sampling difficulties and patchy distribution.

Serripes is hermaphroditic and probably spawns in spring after the phytoplankton bloom has begun (Petersen 1978). Settling of larvae probably occurs in late summer-autumn. In Greenland waters some examples of size at age are as follows: 1 yr, 3-10 mm; 11 yrs, 53.4 mm; 14 yrs, 58.3 mm. They probably grow as large as 10 cm (Clench and Smith 1944).

Little is known about the life history of *Spisula*. They seem to prefer medium grade sediments of sand and gravel mixture. In southeastern Bering Sea they are found primarily in coastal waters 24-33 meters deep. *Spisula* is probably patchy in distribution, with given patches consisting of clams of a single year class (due to favorable larval settlement and survival in specific areas in a particular year). They are active burrowers, sometimes living as deep as 22 cm. Individuals reach about 13.5 cm, or 16 years of age, with growth until age 8 occurring at a rate of 10-12 mm/year (North Pacific Fishery Management Council, in preparation). There is no information on reproduction of *Spisula* in Alaska. *Spisula* in the North Atlantic are dioecious (sexes separate), unlike *Serripes*, and spawning probably occurs in summer. Larvae are planktonic for some unknown period of time, then settle to the bottom as miniature adults.

Spisula and *Serripes* are both filter feeders, removing small particles from seawater.

C. Food Webs and Trophic Relationships

The food webs which support marine mammal populations in the Chukchi Sea are considerably more complex than in the Beaufort Sea. More species of marine mammals regularly feed in the Chukchi Sea and they utilize a greater number of prey species. Major prey dependencies of the marine mammals we have studied are summarized in Table 21.

Table 21. Major prey of marine mammals in nearshore waters of the Chukchi Sea. Items which are probably major prey but have not occurred in samples examined during this project are followed by a question mark.

SEASON	SPOTTED SEALS	RINGED SEALS	BEARDED SEALS	WALRUSES	BELUKHA WHALES
SPRING	Not present	Gammarid Amphipods Shrimps Mysids Arctic Cod Saffron Cod	Shrimps Brachyuran Crabs? Sculpins	Not present	Octopus Shrimps Arctic Cod
SUMMER	Herring Saffron Cod Sand Lance Shrimps Rainbow Smelt? Capelin?	Hyperiid Amphipods? Euphausiids? Shrimps Gammarid Amphipods Arctic Cod	Clams Shrimps Brachyuran Crabs Isopods Sculpins	Clams Snails Priapulids Polychaetes	Saffron Cod Herring Rainbow Smelt Sculpins Salmonids Arctic Cod? Shrimps
AUTUMN	Herring Saffron Cod Arctic Cod Rainbow Smelt?	Hyperiid Amphipods Saffron Cod Arctic Cod	Shrimps Brachyuran Crabs? Sculpins Flatfish	Clams Priapulids Shrimps Snails	Saffron Cod? Arctic Cod? Rainbow Smelt? Shrimps?
WINTER	Not present	Arctic Cod Saffron Cod Sculpins Gammarid Amphipods Shrimps	Shrimps? Brachyuran Crabs? Sculpins?	Not present	Not present

Bearded seals and walruses feed primarily on benthic organisms. Much of the bearded seal diet is comprised of epifauna (shrimp and crabs) while infaunal species, particularly clams, are the most important foods of walruses. In some areas clams are a major component of the bearded seal diet, and in such instances seals compete with walruses for food since the species of clams eaten by the two are the same (Serripes groenlandicus, Clinocardium ciliatum, Spisula polynyma). Available information is not adequate to address the magnitude and effects of such competition in detail. However, it presently appears that competition may have a greater effect on walruses than on more euryphagous bearded seals (Lowry et al. 1980). The prey utilized by walruses and bearded seals are generally benthic omnivores (crabs and shrimps), detritus feeders (some clams and polychaetes), or filter feeders (priapulids and some clams). A relatively small portion of the diet is made up of predators of other benthic organisms (snails, sculpins, and some polychaetes).

Based on our samples belukhas and spotted seals in coastal waters utilize very similar prey, the majority of which are small to medium sized forage fishes. It appears that aggregations of the forage fishes which occur in coastal waters in summer and fall are of major importance in the diet of spotted seals and belukhas and influence their summer distributions. The distribution, abundance, and phenology of forage fishes in the Chukchi, and their importance in marine mammal diets, warrants considerable further study. The food habits of forage fishes in the Chukchi Sea have not been studied.

Ringed seals also eat considerable quantities of the same fish species consumed by spotted seals and belukhas. However, they also feed to a large extent on crustaceans and therefore have a more diverse food resource base, and utilize organisms from more points in the trophic structure. Nektonic crustaceans eaten by ringed seals feed on other, smaller crustaceans and phytoplankton, while benthic crustaceans consumed are detritivores, predators, and omnivores.

Bowhead whales migrate through the Chukchi Sea in spring and autumn. While it is known that they seldom feed during the spring migration, the extent of their summer and autumn foraging in the Chukchi is not known. In some areas of the Beaufort Sea, ringed seals and bowhead whales feed on the same prey (Lowry et al. 1978b, Lowry and Burns 1980).

In summer grey whales forage throughout the Chukchi Sea. Foods of grey whales in the Chukchi are poorly documented. In the Bering Sea they feed primarily on benthic crustaceans, mostly gammarid amphipods (Zimushko and Lenskaya 1970). They may be significant trophic competitors with ringed seals which also feed considerably on gammarid amphipods in some areas.

Seabirds compete to some extent with marine mammals for food. In particular, murres (Uria spp.) which are very abundant near Cape Lisburne feed on many of the fish species which are consumed by marine mammals (Swartz 1966).

In some areas such as the Bering Sea, commercial fisheries harvest considerable quantities of the same species eaten by marine mammals (Lowry et al. 1979c). In the Chukchi Sea, few species of marine mammal prey are of potential commercial value. The primary exception is herring which in the Bering Sea have been harvested at increased levels in recent years. Considering the importance of herring to marine mammals, any commercial fishing of stocks occurring in the Chukchi Sea should be approached very cautiously.

D. Potential Effects of Petroleum Development

This study was designed to develop an understanding of the feeding and trophic interactions of marine mammals, particularly ringed, bearded, and spotted seals, in the Chukchi Sea and to assess the possible and/or probable effects of petroleum exploration and development on the ability of those animals to meet their nutritional requirements. Possible effects fall into two categories: 1) those directly affecting the seals and their access to feeding habitat and 2) those affecting the availability of prey. The potential for and severity of any effects will vary by season and geographic area. For that reason we have organized the following discussion of effects by time period and, when appropriate, by area.

Winter exploration and development activities are likely to include such things as seismic profiling, construction and operation of drilling facilities, and maintenance activities such as supply and service of facilities. In the immediate future most activity will probably occur nearshore using landfast ice as a stable platform from which to operate. During this time period ringed and bearded seals and polar bears are the only resident marine mammals. Bearded seals and polar bears are found mostly offshore in areas of moving broken ice. Ringed seals are also present in the offshore area; however, preferred breeding habitat is the shorefast ice. It is this nearshore area where direct effects on feeding seals are most likely to occur and be of significance.

Prime ringed seal habitat coincides with and may be determined by the availability of arctic cod which are abundant nearshore under the fast ice during winter. Spilled oil or high noise levels which may displace ringed seals from this area would in fact be excluding them from their major food source at a time of year when energetic requirements are high and alternate prey are least available.

The nearshore area is important in winter, not only to ringed seals but to several major prey species. Arctic cod aggregate in autumn-winter and move onshore to spawn during January-February. The schooling of adult arctic cod at spawning time, particularly near narrow cracks in the ice and in slushy "frazil" ice, places them in areas most likely to be contaminated by winter oil spills. It also suggests that in the event of a catastrophic spill or blowout a large proportion of the breeding segment of the population might be affected. Preliminary toxicity studies have shown adult arctic cod to be very sensitive to crude oil at less than 2 ppm (NAFC 1979).

Both the eggs and larvae of arctic cod are pelagic, developing near the undersurface of the ice. The egg stage lasts 1.5-3.0 months, and the larval stage lasts about 2 months. Because the eggs and larvae are in the upper portion of the water column, they are likely to be exposed to surface and under ice spills, emulsions, and dispersions. Studies of other members of the cod family have shown eggs and larvae to be highly sensitive to even short-term exposure (5-30 hrs) to crude oil and crude oil extracts (Mironov 1967, Kuhnhold 1970).

Saffron cod also spawn nearshore under the ice in winter. Spawning aggregations form in autumn-early winter near river mouths, bays, and inlets in such places as Shishmaref, Kotzebue Sound, and the area near Point Hope. Unlike arctic cod the eggs are demersal and are laid on clean, sandy gravel bottoms. The presence of sinking oil in areas where saffron cod spawn could kill or cause abnormal development of eggs and larvae. Adult mortality occurs within 24 hours when individuals are exposed to the soluble fractions of crude oil at less than 2ppm at 3°C (Devries 1976).

Other major prey species reproduce in deeper offshore waters during autumn-winter. Sand lance spawn then as do many species of sculpins. Percy and Mullin (1975) found fry of the sculpin *Myoxocephalus quadricornis* to be the most sensitive organisms they tested, with 100 percent mortality occurring after 24 hours in a heavy dispersion of oil. *Parathemisto* breeds in autumn-winter and broods its eggs until spring. A similar pattern occurs in many gammarid amphipods, including *Ampelisca* and *Gammarus*, and some shrimps such as *Pandalus*, *Argis*, and *Sclerocrangon*. The crabs *Hyas* and *Chionocetes* carry eggs in autumn and perhaps winter. Time of hatching in the Chukchi is unknown. Water soluble fractions of crude oil can cause loss of eggs by gravid female amphipods (Busdosh and Atlas 1977) and may cause similar effects in shrimps and crabs.

The spring-summer period is a time of increased biological activity. Ringed and bearded seals bear their pups in April. As the ice melts in the Bering Sea there is an influx of ringed, bearded, and spotted seals, as well as walruses and belukhas, into the Chukchi. Walruses remain associated with pack ice in the northern Chukchi while belukhas move inshore to calve and feed in nearshore lagoons, bays, or inlets. Some prey species also undergo major movements at this time, moving into or out of nearshore areas to feed and/or reproduce.

The two major forage fishes of ringed seals, arctic and saffron cod, have already spawned. Larvae of both species develop in surface waters where exposure to toxic pollutants is most likely, then descend to the bottom in late summer and assume a demersal life similar to adults. Adult arctic cod disperse offshore during spring/summer and are probably least sensitive to oil spills and pollutants at this time. Most saffron cod apparently remain nearshore in areas where exploration and development are likely to occur.

Herring form pre-spawning concentrations in spring and move en masse into lagoons, bays, and inlets (for example the north coast of the Seward Peninsula, Shishmaref Inlet, Eschscholtz Bay, and outer Kotzebue Sound) to spawn at about the time the ice breaks up. After spawning they remain aggregated and feed intensively throughout the remainder of the summer.

Spawning takes place in two very different habitats: on kelp growing near exposed rocky headlands (such as Cape Espenberg in Kotzebue Sound) and on eelgrass (*Zostera* sp.) growing in shallow, brackish bays, lagoons, or inlets (such as the inlets near Shishmaref). The latter of these types is probably the most important spawning habitat in the Chukchi and the most vulnerable to either large or small scale discharges of pollutants. Rocky headlands are quite rapidly cleansed of oil as a result of wind and wave action. Such cleansing action occurs more slowly in lagoons, bays, or inlets where wind and wave action are more moderate and hydrocarbons can become entrained in sediments.

In herring, hydrocarbons cause reduced survival of ovarian eggs prior to spawning, of embryos from the time of fertilization to hatching, and of larvae through the yolk absorption stage (Struhsaker 1977; Kuhnhold 1970; Mironov 1970; Eldridge et al. 1978; Smith and Cameron 1977). In addition, hatching may be delayed and a significant proportion of the larvae may develop abnormally. In the natural environment only 5-10 percent of the herring are estimated to survive beyond the larval stage. The presence of hydrocarbons may aggravate a natural tendency toward embryonic mortality, and it is possible that an entire year class could be eliminated in localized areas. In addition to effects on eggs and larvae, benzene has been shown to cause aberrant swimming and disequilibrium in adults (Struhsaker 1977).

Many invertebrates release their young during spring and summer. Among the major species are the amphipods *Ampelisca* and *Gammarus*, the isopod *Saduria*, the shrimps *Eualus*, *Pandalus*, *Crangon*, *Argis*, and *Sclerocrangon*, and the clams *Serripes* and *Spisula*. The eggs of *Hyas* and *Chionocoetes* crabs may also hatch then. Growth and molting of crab larvae are impaired by hydrocarbons even in species in which adults are highly resistant (Mironov 1970; Parker and Menzel 1974; Rice et al. 1976). Pandalid and hippolytid shrimp larvae are sensitive to hydrocarbons. Low concentrations (1-5ppm) of water soluble fractions cause mortality and cessation of swimming activity (Malins et al. 1977; Brodersen et al. 1977; Craddock 1977).

Water soluble fractions of crude oil cause reduced fertilization of eggs, decreased survival of eggs, sperm, and larvae, and abnormal development of embryos in bivalve molluscs (Scarratt and Zitko 1972; Renzoni 1975). Growth, survival, and recruitment rates in local clam populations remained depressed for 3-6 years after the occurrence of oil spills in Nova Scotia and Maine (Gilfillan and Vandermeulen 1978).

Young amphipods may not colonize oiled sediments. Atlas et al. (1978) found that arctic amphipods occurred less frequently in oiled sediments than in unoiled (control) sediments. Although contaminated sediments were later recolonized, species composition was quite different. If colonization of a species such as Ampelisca, which is a major food not only of ringed seals but also of grey whales and numerous fishes, were discouraged it could have major implications for predators.

In general the literature indicates that many of the fishes, crustaceans, and bivalves (especially their eggs and larvae) which are important prey species in the Chukchi are sensitive to the presence of hydrocarbon in water. Summer is probably the period when reproductive products are most abundant; however, it is also the time of open water and warmer temperatures, which may facilitate dispersal, dilution, and degradation of contaminants. Consequently, the occurrence of an oil spill in summer may be less critical from the standpoint of prey species than a similar spill in winter. The probable exception is a summer spill in areas such as bays, inlets, and lagoons, where water circulation is sluggish, flushing time slow, and abundance of spawning and/or juvenile organisms is very high. Such spawning/nursery areas are very important to maintenance of prey species populations.

Fewer species reproduce during winter but many of the ones that do are major prey of marine mammals. The winter ice cover and accompanying colder water act to reduce dispersion rates, evaporative loss of toxic fractions, and biodegradation rates, and may concentrate pollutants in places of high biological activity such as leads and slush ice.

Pollutant levels high enough to cause large-scale die-offs of individuals will probably occur only on a very localized basis (except where oil or pollutants are trapped under the ice and transported long distances in a relatively unweathered state). The greatest concern may not be with local catastrophic events but with long-term sublethal effects of pollutants. Individuals may not be killed directly, but instead very low concentrations of pollutants may affect locomotion, metabolism, or reproduction and lead to substantial reduction of populations over several generations (Percy and Mullin 1975). These long-term reductions are of special concern in considering food availability to consumers.

VIII. Conclusions

Spotted seals are summer residents in the Chukchi Sea. They feed mostly on fishes, although at certain times and places shrimps are a major food. Among the fishes eaten are herring, arctic and saffron cods, sculpins and sand lance, and probably capelin and rainbow smelt.

Belukha whales are also summer residents in the Chukchi Sea. Based on our samples from coastal waters they utilize much the same prey as spotted seals; small to medium-sized forage fishes make up most of the diet. Aggregations of those fishes which occur in coastal waters during summer and fall probably influence the distribution of both spotted seals and belukhas.

Bearded seals are abundant year round residents in the Chukchi. They eat mostly shrimps, brachyuran crabs, and clams. The diet appears to vary on a seasonal basis with clams important only during summer. Young seals eat more shrimps and isopods while older seals eat more clams, crabs, and echiuroid worms.

A large proportion of the Pacific walrus population summers and feeds in the Chukchi Sea but they are not common there during winter. Foods of walruses in the Chukchi are poorly documented. They probably eat mostly clams, as they do elsewhere in their range. Walruses may compete for food with bearded seals in areas such as Wainwright where clams are a major component of the bearded seal diet.

Ringed seals are the most abundant marine mammal in the Chukchi Sea and they compete with and provide food for other marine species. Arctic cod and some saffron cod (at Shishmaref) are their main foods in winter. Crustaceans (amphipods, shrimps, and mysids) are the main food in March through June. Ringed seal pups eat more small crustaceans (amphipods, mysids, and euphausiids) than older seals, while older seals eat slightly more fish. Ringed seals eat many of the same fish species consumed by spotted seals and belukhas. However, they also utilize crustaceans in significant quantities and therefore have a more diverse food resource base.

Available information on the distribution, abundance, and natural history of most major prey species is inadequate. Information on hydrocarbon sensitivity of all but a few species is totally lacking. Without such information the potential effects of OCS development in the Chukchi Sea on marine mammals cannot be quantified. However, based on what information is available, a real potential for detrimental effects on prey populations exists. Changes in the abundance of prey can be expected to influence populations of marine mammals.

IX. Needs for Further Study

The data summarized in this report pertain almost exclusively to the nearshore waters of the Chukchi Sea in spring and summer. Virtually nothing is known about foods of marine mammals in offshore waters in either summer or winter, or about winter food habits in coastal areas. With adequate logistic support the necessary data could be obtained.

The Chukchi Sea is the major summering and feeding area for much of the Pacific walrus population yet virtually nothing is known of either food habits or distribution of potential prey in that region. Of particular interest are areas where bearded seals and walruses are found together and appear to compete for the same major prey (clams). Very little is known about utilization of the Chukchi coast by belukha whales. Although many belukhas migrate through the Chukchi to other areas, some spend summer months in and near coastal lagoons and estuaries in Kotzebue

Sound and between Point Lay and Wainwright. Future studies should address the distribution of whales in relation to available food resources such as herring, saffron cod, capelin, and anadromous fishes.

Distribution and abundance of arctic cod are virtually unknown in the Chukchi Sea. Spawning time and locations are unknown. Very limited data are available on arctic cod foods. Prey specificity, seasonal variation in prey, availability of alternate prey items and sensitivity of prey to hydrocarbons should be studied. Arctic cod are one of the most important forage species in the Chukchi Sea. Research should be undertaken immediately to fill these data gaps.

Data are needed on a seasonal basis on the distribution and abundance of other important prey species, the factors determining their presence or absence and the timing of important life history events. Some information on these species is available in the literature. It should be compiled and analyzed in light of questions pertaining to petroleum development. Critical feeding areas for marine mammals in the Chukchi Sea will be determined in part by the distribution of these organisms. The species include:

Fishes - Herring, saffron cod, sand lance
Gammarid amphipods - *Ampelisca* spp.
Mysids - *Mysis litoralis*, *Neomysis rayii*
Shrimps - *Crangon septemspinosa*, *Argis lar*, *Sclerocrangon boreas*, *Pandalus goniurus*, *Eualus gaimardii*
Brachyuran crabs - *Hyas coarctatus*, *Chionoecetes opilio*, *Telmessus cheiragonus*
Clams - *Serripes groenlandicus*, *Spisula polynyma*
Hyperiid amphipods - *Parathemisto libellula*

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