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Demersal Fishes and Invertebrates Trawled in the Northeastern Chukchi and Western Beaufort Seas, 1976-77

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ABSTRACT

Thirty-five successful otter trawl tows were conducted in the northeastern Chukchi and western Beaufort Seas in August-September of 1976 and 1977. Nineteen species or species groups of fishes and 238 invertebrate taxa were identified. Three of the fishes (*Boreogadus saida*, *Lycodes polaris*, and *Icelus bicornis*) accounted for 65% of all fishes caught. Information on size, reproductive condition, and food habits is presented fur those three as well as for *Artediellus scaber*, *Aspidophoroides olriki*, *Liparis* spp., *Eumicrotremus derjugini*, *Gymnelis viridis*, and *Icelus spatula*. The first Beaufort Sea records are reported for three species: *Arctogadus glacialis*, *Lycodes raridens*, and *Eumesogrammus praecisus*. Of the invertebrate taxa, echinoderms (mainly brittle stars and crinoids) were the most abundant, and in most cases comprised more than 75% of the total trawl biomass. West of long. 154°W, brittle stars, *Ophiura sarsi*, were predominant whereas east ld long. 150°W, the invertebrate community was characterized by crinoids (*Heliometra glacialis*) and small scul 1ops (*Delectopecten groenlandicus*). Information un sire. reproductive condition, and depth distribution is presented for brachyuran crabs and shrimps and the occurrence of other major invertebrate groups is summarized. A complete list of species and stations at which each was caught is included.

INTR()[)UCTION

Since 1975. as a prelude to offshore petroleum exploration, biological research in the Alaskan sector of the Beaufort Sea has been intensified under the auspices of the Alaskan Outer Continental Shell Environmental Assessment Program (OCSEAP). In the course of these studies, it became evident that information on the distribution, abundance, and life history characteristics of offshore fishes and epibenthic invertebrates was almost totally lucking. Since certain of those organisms were known 10 be important prey of marine mammals, seabirds, and other fishes, a trawl survey wirs conducted in the northeastern Chukchi and western Beaufort Seas to begin 10 obtain such information. Since trawls were made in conjunction with an investigation of the feeding and trophic relationships of ringed seals, *Phoca hispida*, and bearded seals, *Erignathus barbatus*, more detailed attention was paid to species or groups which were ol" potential importance to these seals.

Walters (1955) summarized information available prior to 1955 on the marine fish fauna of arctic Alaska and included a discussion of taxonomy and zoogeography. Alverson and Wilimovsky (1966) and Quast (1972) conducted trawl surveys in the Chukchi Sea south of Icy Cape. Quast and Hall (1972) published a list of fishes of Alitskit and included some new records from Icy Cape and Point Bitrrow. Pfeifer (1977) compiled an extensive bibliography of fishes Of the Beaufort Sea but most of the literature cited therein deals with freshwater, anadromous, and nearshore species. References to offshore demersal fishes of the northeastern Chukchi and western Beaufort Seas are restricted In distributi mid records (primarily from near Point Barrow), taxonomic studies. or anecdotal accounts. Life history information for widely distributed species cim be found in studies from coastal arctic Alaska (e. g.. Bendock 1979) and Soviet and Canadian waters (Andriyashev 1954: McAllister 1962).

Information on epifaunal invertebrates is restricted largely to the Barrow area and nearshore waters. Most reports are nf strictly taxonomic nature. The report 01" MacGinitie (1955] provides the mnst complete in formation available on the distribution, abundance, and life history of invertebrates near Point Barrow. MacGinitie (1959) described the distribut ion and taxonomy of gastropods in that area and Hulsemann (1962) gave a simil ill' treatme 111 (11" bivalve molluscs. Shoemaker (1955) reported on distribution of amphipods and Menzies and Mohr (1962) examined collections of isopods and tanaids. Hedgpeth (1963) reported on pycnogonids nf arctic America and Hulsemann and Soule (1962) listed some bryozoans found along the arctic coast of Alaska. Squires (1960) described the distribution and life history of decapod crustaceans in the Canadian Arctic. Recent benthic sampling hy Carey (1977) in the western Beaufort Sea has dealt mainly with distribution and abundance of infaunal organisms. Also included in that work is a valuable compilation of distributional information and an exhaustive literature survey.

METHODS

In 1976 two tows were made in the western Beaufort Sca between long. 152° and 153°W and lat. 710 and 72°N in water 40 m and 123 m deep. In 1977 tows were made in the northeastern Chukchi and western Beaufort Seas between long. 164° and 1-1 1"W and lat. 700 and 72°N in waters 40 to 400 m deep. Many were conducted near the southern edge of pack ice. Wc sampled with semiballoon otter trawls of two sizes. Headropes were 4.9 and 5.8 m (16 and 19 ft). Nets were constructed of 3.2 cm (1¼ in) stretch mesh webbing with 0.6 cm (¼ in) stretch mesh liners in the cod ends. Tows were 5-10 min bottom time at a speed uf 5-8 km/h.

Organisms were sorted from debris and readily identifiable species were counted and weighed. The occurrence of rocks, pebbles, or mud in the net was noted. All organisms were preserved in 10% Formalin. Stomachs of fishes were injected with 10% Formalin.

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In the laboratory, fishes were measured to Ihc nearest (). I cm fork length (FL). or total length ("I-L) if fork length was not appropriate, and weighed to Ihc nearest 0. I g. Otoliths were polished and cleared in xylene; the annuli wet-c counted to estimate age. Stomach contents Of each fish were classfied by major taxonomic group ;Ind volumetric abundance of each group was assigned a ranked ıc. Invertebrates from each trawl were identified to Ihc lowest possible taxonomic level. Members of each species or taxon were weighed irnd enumerated. Carapace lengths (CL) of decapod crustaceans were measured to the nearest 0. I cm. The numbcrx of nvigerous critbs and shrimps in each trawl were noted.

RESULTS AND DISCUSSION

Thirty -three successful tows were conducted from 2 August to 3 September 1977; iwo (indicated by A and 0. Fig. i) were made on 30 irnd 3 I August 1976. Ten were west of Point Barrow, 10 between Barrow and Prudhoe Bay, and 15 between Prudhoe Bay and Ihc U. S.-Canada demarcation line (long. 14 1'W). Depth distribution Of tows WilS itS follows: 14 itt 40-50" III. I 1 at 5 I - I (M) III. 9 at 10 I-I5O m. and 1 at 400 m (Table 1).

Nineteen species or species groups of fishes and 238 species or species groups 01' invertebrates were identified (Appendix A). The natural history infurmatitm prcscntcd in this report is only from collections made in 1977: material from the 1976 tows was identified and enumerated hut riot further worked up. Representative specimens uf invertebrates arc catalogued and located at the University of Alitskit Marine Museum. Those fishes representing range cxlcnsions are held in the Ichthyology Collect ion. National Museum of Natural Sciences, National Museums of Canada, Ottawa, Canada (NMC).

Fishes

We caught 13.7 fishes belonging to 14 species[1] in trawls made in 1976. In the more extensive trawl series done in i 977, 5 I 2 fishes *were* caught belonging tn 17 species (Table 2). Three species (*Boreogadus saida*, *Lycodes polaris*, nnd *Icelus bicornis*) accounted for 65 % of all fishes caught. Eight species were represented by I"ivc or fewer specimens.

Previous records of" fishes of northern Alaska have been compiled by Walters (1955), Quast and Hall (1972), :111(1 Carcy (I ')78). A list of all marine species reported in those compilations to occur in the northeastern Chukchi and Beaufort Seas is given in Table 3 along with the species recorded in this report and by McAllister (1962) for the eastern Beaufort Sea. of the 41 species listed, 5 (*Limanda aspera*, *Lumpenus maculatus*, *Myoxocephalus scorpius*, *Nautichthys pribilovius*, and *Podothecus acipenserinus*) are primarily Bering Sea forms which only rarely occur as far north as Point Barrow. The remaining 36 species appear to be fairly widcly distributed and can be considered characteristic ol" the fauna of Ihc

[1]In the following presentation of results and discussion, all snailfishes are considered as *Liparis* spp. and counted as one form. The number of species inhabiting the northeastern Chukchi and Beaufort Seas cannot at present be determined due to taxonomic confusion in the group.

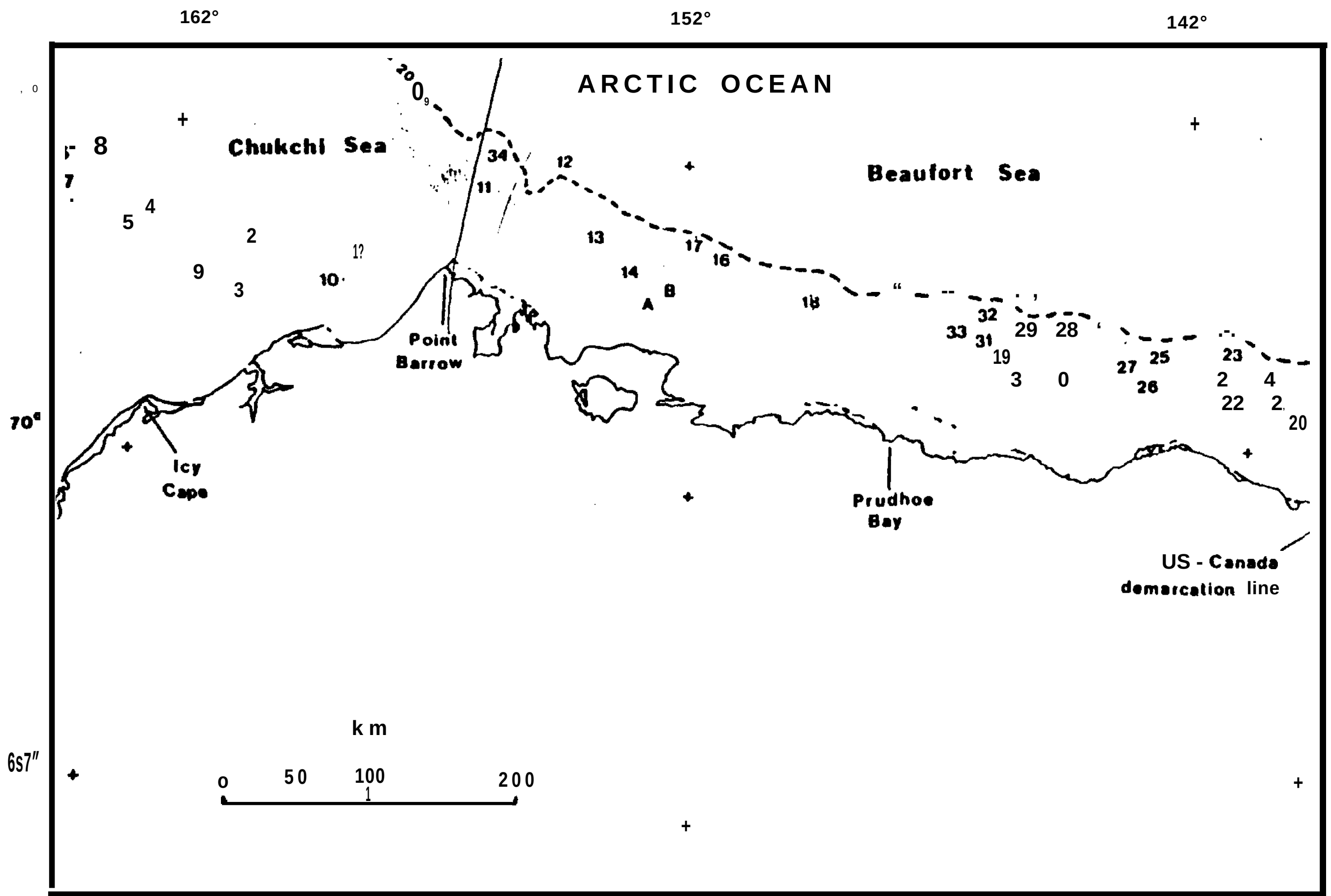

Figure I.—Locations of otter trawl stations in the northeastern Chukchi 111111 western Beaufort Seas, August-September 1976 and 1977.

Table 1.—Station locations of 35 tows from the northeastern Chukchi and western Beaufort Seas during August–September 1976 and 1977.

Tow no.	Date	Depth (m)	Latitude (N)	Longitude (W)	Comments
A	30 Aug. 1976	123	71 "IV'	152°34'	Pebbles
B	31 Aug. 1976	40	71 "13.s'	152°47.9'	Rocks, pebbles, shells
1	2 Aug. 1977	64	71°27'	158°02'	Mud, gravel
2	2 Aug. 1977	4s	71 "19'	100"01'	Mud
3	2 Aug. 1977	62	71 "05"	160"08'	Rocks
4	3 Aug. 1977	43	71°26'	16?"01'	Mud
5	3 Aug. 1977	40	71°20'	162°30'	
6	3 Aug. 1977	48	71°35'	163°58'	
7	4 Aug. 1977	44	711,~~.	163°47'	Mud
8	4 Aug. 1977	44	71"4.s'	162°59'	Mud
9	5 Aug. 1977	50	71 "07'	161 "(w	
10	6 Aug. 1977	102	71 [illegible]	158°35'	Gravel, rocks
11	7 Aug. 1977	100-120	71°45'	155°43'	Mud
12	9 Aug. 1977	400	71"s?.5'	154" 16'	Mud
13	10 Aug. 1977	5?-58	71°35.'r'	153°41.0'	Mud
14	11 Aug. 1977	50	71°16'	153"01.9'	Rocks
16	12 Aug. 1977	50	71°13.1'	151°23'	Rocks
17	12 Aug. 1977	50	71°16.s'	151°33'	Rocks
18	16 Aug. 1977	40	71°06'	149°42'	Rocks, mud
19	18 Aug. 1977	"55	70°46'	146"30'	No mud
20	26 Aug. 1977	56	70°09'	141 "17"	Rocks
21	27 Aug. 1977	s4)	70°17'	141°39'	Rocks
22	27 Aug. 1977	5(1	7(I" 18.4'	142°37'	Rocks
23	27 Aug. 1977	7s	7(I"W s'	I-r: °21'	Gravel, rocks
24	27 Aug. 1977	I(I5	70°36.5'	143°55'	
25	28 Aug. 1977	110	70°43.K'	145°02'	Rocks
26	29 Aug. 1977	50	70'35 .5"	145" I .r'	Rocks
27	29 Aug. 1977	54	70°40'	145°32'	
28	29 Aug. 1977	110	71}" 50'	145°31'	
29	30 Aug. 1977	130	71)" .$(1'	146°00'	
30	30 Aug. 1977	54	70°38'	146°04'	Rocks
31	30 Aug. 1977	56	7{)".s7"	146°33'	
32	30 Aug. 1977	90-110	70°56.5'	140" 3?"	
33	31 Aug. 1977	70	7(I' 53'	147"01'	Rocks
34	3 Sept. 1977	150	71°59'	155°42'	

northeastern Chukchi and Beaufort Seas. For three of those species (*Arctogadus glacialis* (NMC82-0027), *Lycodes raridens* (NMC78-0296), and *Eumesogrammus praecisus* (NMC82-0026)), the first Beaufort Sea records are from our trawls. our records of *Lycodes rossi* (NMC78-0289) fill ir major gap in the known distribution of the species which turd been previously reported only from the Kara Sea, Spitsbergen, and Herschel [slid. Canada.

Many of the species listed hy other authors were not encountered in our lows since pelagic species such as salmonids and osmerids were not adequately sampled by our otter (raw I and some species such as *Myoxocephalus quadricornis* and *Liopsetta glacialis* are restricted in distribution to coastal, brackish waters (Walters 1955; Alverson ilnd Wilimovsky 1966).

All of the primarily marine species reported from western arctic Canada by McAllister (1962) hirve been recorded frum arctic waters of the northeastern Chukchi or western Beaufort Seas (Table 3). McAllister suggested that this low arctic fauna, which he termed the Inuit fauna, extends continuously from the Boothia Peninsula region of the central Canadian Arctic westward through the Beaufort, Chukchi, East Siberian, Laptev, Kara, and Barents Seas. Faunal connections with the eastern Canadian Arctic and North Atlantic are restricted. probably because of differences in water temperature, salinity, and ice cover.

Alverson and Wilimovsky (1966) and Quast (1972) reported the results of" trawl surveys in the Chukchi Sea south and west of Icy Cape in which they found approximately 43 species of mist-kc fishes. Fourteen of those, including 3 species of" Pleuronectidae itnrl 6 species of Cottidae, have not been reported from the northeastern Chukchi and Beaufort Seas (Table 3). Those species are idf primirr-ily North Pacific/Bering Sea forms which apparently reach the northern limit of their distribution in the central Chukchi Sea near Icy Cape. As mentioned previously, an additional five species reach only to the vicinity of Point Barrow.

Table 2.—Fishes caught in waters 40 m and deeper in the northeastern Chukchi and western Beaufort Seas during August–September 1976 and 1977, ranked in order of decreasing numerical abundance in tows.

Latin name	Common name	No. of individuals 1976	No. of individuals 1977	No. of stations Chukchi 1976	No. of stations Beaufort 1976	No. of stations Beaufort 1977	Depth range (m)
Boreogadus saida	Arctic cod	33	191	10	2	1n	40-400
Lycodes /1,1/' 11.1.$	Canadian eelpout	40	81	3	2	1	40-150
Icelus bicornis	Twohorn sculpin		?1			13	50-130
Artediellus scaber	Hamecon	6	30	5	1	5	40-70
Aspidophoroides olriki	Arctic alligatorfish	17	19	1	2	3	40-4(K)
Liparis sp.	Snailfish	5	29	3	2	Is	40-400
Eumicrotremus derjugini	Leatherfin lumpsucker		29			//	50-1In
Gymnelis viridis	Fish doctor	4	23	4	1	7	40-130
Icelus spatula	Spatulate sculpin	6	14	1	1	2	56-123
Lumpenus fabricii	Slender eelblenny	11			2		40-123
Lycodes raridens	Eelpout	.r	7	1	1	1	6?-123
Gymnocanthus tricuspis	Arctic staghorn sculpin	3	2		1	2	40-58
Eumesogrammus praecisus	Fourline snakeblenny	1	3	2	1	1	40 M
Triglops pingeli	Ribbed sculpin	1	2	0	1	2	40-t10
Lycodes mucosus	Saddled eelpout	1	2		1	2	40-11)5
Lycodes rossi	Threespot eelpout	2			1		123
Arctogadus glacialis	Polar cod		1			1	150
Lumpenus medius	Stout eelbenny		1			1	40
Lumpenus maculatus	Daubed shanny		1	1			44

Table 3.—Fishes recorded from the northeastern Chukchi and Beaufort Seas in this and previous studies.

Species	Walters 1955	Quast & Hall 1972	Carey 1978	This report	McAllister 1962
Petromyzonidae					
Lampetra japonica	x				x
Clupeidae					
Clupea harengus	x		x		x
Salmonidae					
Salvelinus alpinus	x	x	x		x
Oncorhynchus gorbuscha	x		x		
Oncorhynchus keta	x	x	x		
Osmeridae					
Mallotus villosus	x	x	x		x
Osmerus mordax	x	x	x		x
Myctophidae					
Benthosoma glaciale	x				
Gadidae					
Arctogadus borisovi	x	x			
Arctogadus glacialis				x	
Boreogadus saida	x	x	x	x	x
Eleginus gracilis	x				x
Gadus morhua ogac	x		x		
Zoarcidae					
Gymnelis viridis	x	x		x	
Lycodes jugoricus	x				x
Lycodes mucosus		x		x	
Lycodes pallidus	x		x		x
Lycodes polaris	x	x		x	x
Lycodes rarudens				x	
Lycodes rossi				x	x
Ammodytidae					
Ammodytes hexapterus	x				x
Cottidae					
Artediellus scaber		x		x	x
Artediellus uncinatus	x	x			
Gymnocanthus tricuspis	x	x		x	x
Icelus bicornis	x	x		x	x
Icelus spatula		x		x	x
Myoxocephalus quadricornis	x		x		x
Myoxocephalus scorpiodes		x	x		x
Myoxocephalus scorpius	x	x			
Nautichthys pribilovius		x			
Triglops pingeli	x	x		x	x
Agonidae					
Aspidophoroides olriki	x	x		x	x
Podothecus acipenserinus	x	x			
Cyclopteridae					
Eumicrotremus derjugini		x		x	
Liparis spp.	x	x	x	x	x
Stichaeidae					
Eumesogrammus praecisus				x	
Lumpenus fabricii	x		x	x	x
Lumpenus maculatus				x	
Lumpenus medius			x	x	
Pleuronectidae					
Limanda aspera	x				
Liopsetta glacialis		x	x		x
Platichthys stellatus			x		

***Boreogadus saida*.**—Arctic cod were the most abundant and consistently present fish in our survey. They were caught in each of 20 tows west of Prudhoe Bay with an average of 9 fish caught per tow (range 1-26). However, they were caught in only 10 of 15 tows east of Prudhoe Bay with an average of only 2 fish caught per tow (range 0-11). Arctic cod were caught in all depths between 40 and 100 m and we saw no obvious correlation between abundance and depth of tow.

Individuals were 4.5-18.0 cm FL with a distinct mode at about 8.0 cm (Fig. 2). The length-weight relationship in Arctic cod is $W = 0.0018\,L^{[illegible]}$ (N = [illegible], r = 0.9[illegible]7) (Frost and Lowry 1981). Fishes caught in waters deeper than 100 m were larger ($\bar{x}$ = 11.4 cm FL) than those caught in shallower water ($\bar{x}$ = 8.1 cm FL). In waters 100 m or less deep, 89% of the fishes caught were < 10.5 cm FL while in deeper water 24% of fishes caught were > 14.0 cm long. Similar size (or age) segregation has been observed in the Barents Sea (Hognestad 1968). It is probable that the length-frequency distribution for all tows combined was influenced by the depth distribution of the tows. In a series of midwater tows in the eastern Chukchi Sea, Quast (1974) found the abundance of juvenile cod was strongly correlated with depth, presumably due to a negative phototactic response.

Length at age of fishes caught by us was compared with that in other geographic areas (Table 4). It is unknown whether results for other studies were for fresh or preserved specimens. We measured preserved specimens. Arctic cod we examined had grown about 5 cm the first year and 3-4 cm in each of the following 2 yr. These rates are similar to but slightly less than those found by other investigators. There is considerable variation in size at age, which may be caused by an extended spawning period (Rass 1968) or patchy food resources with resulting variable growth.

In other geographic areas Arctic cod mature when they are 3-4 yr old or about 14-19 cm long (Gjosaeter 1973; Andriyashev 1954). We found no development of eggs in specimens smaller than 11 cm; gonads made up about 1% of body wieght. In specimens > 11.5 cm, eggs were clearly visible in the ovaries, and gonads made up 2-2.5% of the body weight. Based on size at age, Arctic cod in the Beaufort Sea probably first spawn at an age of 3 yr and a length of at least 12.5 cm. Spawning probably occurs in January and February (Klimov 1937; Svetovidov 1948; Andriyashev 1954; Hognestad 1968; Rass 1968).

In 187 Arctic cod, 157 stomachs had identifiable contents, 13 were empty, and 17 contained only unidentifiable food remains (Table 5). Copepods (mostly *Calanus hyperboreus*, *C. glacialis*, and *Euchaeta glacialis*) and the amphipod *Apherusa glacialis* were the most important prey. Mysids, the primary food of Arctic cod in nearshore waters (inside the barrier islands) of the Beaufort Sea (Bendock 1979), were a minor item in the diet of the fishes we examined from 40 m and deeper.

***Lycodes polaris*.**—Canadian eelpout are benthic fishes common on muddy bottoms (Andriyashev 1954). They were the second most numerous species in this study and were caught at 16 stations. Forty-one of the 121 individuals were caught in tow No. 1. That trawl was on the bottom for about 1 h while the ship drifted and made mechanical repairs, and it is possible that eelpout swam into the net to feed on the contents. They occurred at 40-150 m and showed no obvious relationship between abundance and depth.

Individuals ranged from 3.8 to 24.5 cm TL with most specimens measuring < 15 cm TL (Fig. 3). A mode was present at about 8.0 cm. The length-weight relationship of Canadian eelpout is $W = 0.0054\,L^{[illegible]}$ (N = [illegible]76, r = 0.993).

Due to the small size and opaque nature of the otoliths, this species was poorly suited for age determinations. The mode at about 8

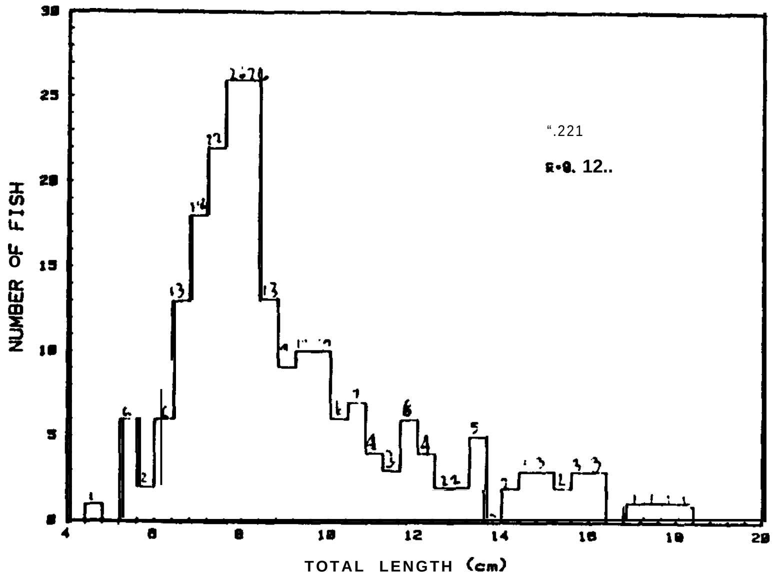

Figure 2.—Length-frequency distribution of Arctic cod caught in the northeastern Chukchi and western Beaufort Seas, August-September 1976 and 1977.

Table 4.—Mean and range of length (FL) at various ages for Arctic cod in this and other studies.

	This study		Bendock 1979[1]		Hognestad 1968		Gjosaeter 1973		Andriyashev 1954	
Location	NE Chukchi and offshore Beaufort Seas		Prudhoe Bay		Barents Sea		Barents Sea		Bering and Chukchi Seas	
Time of year	August		August		August-September		July - September		Summer?	
Age class	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range
0+			2.4		4.2	2.0 6.2			3.1	
1+	7.2	4.5 11.7	9.9		9.3	5.0 13.1	9.3		8.8	7.5 - 10.0
2+	11.6	9.7 14.4	13.1		14.9	8.0 22.0	13.4		15.1	14.4-15.8
3+	14.1	12.9- 16.0	16.1		17.9	13.0 24.5	16.6		19.5	19.0-20.0
4+	17.1	16.1-18.0			19.5	15.5 27.0	19.1		22.5	22.0 23.0
5+					22.7	17.3 25.2	21.2			
6+					24.3	19.0 28.8	22.9			

[1]See footnote 2 in text

Table 5.—Foods from stomachs of 157 Arctic cod collected in offshore waters of the northeastern Chukchi and western Beaufort Seas during August-September 1977.

Food item	No. of occurrences in tank 1	2	3	4	Total no. of occurrences	Frequency of occurrence (%)
Copepods	86	22	2		110	70.1
Apherusa glacialis	44	31	7		82	52.2
Other gammarid amphipods	3	9	3		15	10.2
Parathemisto sp.	2	7	4	3	16	10.2
Mysids	4	9	1		14	8.9
Euphausiids	2	2	1		5	3.2
Shrimp	1	2			3	1.9
Chaetognaths	4	3			7	4.5
Medusae	1				1	0.6

cm represented individuals 2+ yr old. The largest individual caught (24.5 cm) was probably 5+ yr old.

Ovaries of specimens <15 cm contained only small (<1 mm) eggs while those of individuals 15.5 cm and longer contained eggs of two or three size classes. Eggs of the largest size class ranged from 2.7 to 4.5 mm in diameter. The ovaries of individuals 15.5 and 18.9 cm long contained 66 and 135 "large" eggs, respectively, and the gonads made up 8.2 and 19.2% of the body weight. These measurements correspond closely with those of Andriyashev (1954). This species probably spawns in fall or early winter.

In 74 stomachs examined, 9 were empty and 12 contained only unidentifiable food remains. Of the stomachs containing identifiable food, gammarid amphipods occurred in 27, polychaete worms in 12, cumaceans and caprellids each in 4, and isopods, mysids, shrimp, brittle stars, and Arctic cod in 1 stomach each.

Icelus bicornis.—Seventy-four twohorn sculpins were caught during the 1977 survey. Only two were caught in the 18 tows made west of Prudhoe Bay. A total of 49 were caught at three stations (24, 25, 28), indicating patchy abundance. These sculpins occurred at stations ranging from 50 to 130 m. The three stations of abundance were in 105, 110 m.

Twohorn sculpins ranged in length from 3.0 to 7.0 cm TL (Fig. 4). Most specimens >6 cm were females (20 of 23) and most <6 cm were males (33 of 47). Sexual dimorphism in size is not uncommon in sculpins (Andriyashev 1954). Such differences in size may be due to faster growth or differential survival of females. Nine of 11 individuals 5 yr or older were females. The length-weight relationship was similar for males and females although there was a tendency for females with well-developed ovaries to fall above the indicated line. That relationship is described by the equation $W = 0.0082 L^{3.26}$ (N = 71, r = 0.955). Length at a given age varied widely; however, the mean length of fishes increased about 2 mm/yr from the age of 2 to about 5 yr old. Eight 3+-yr-old fish averaged 5.45 cm (range 4.6-6.3, SD = 0.583), ten 4+-yr-old fish

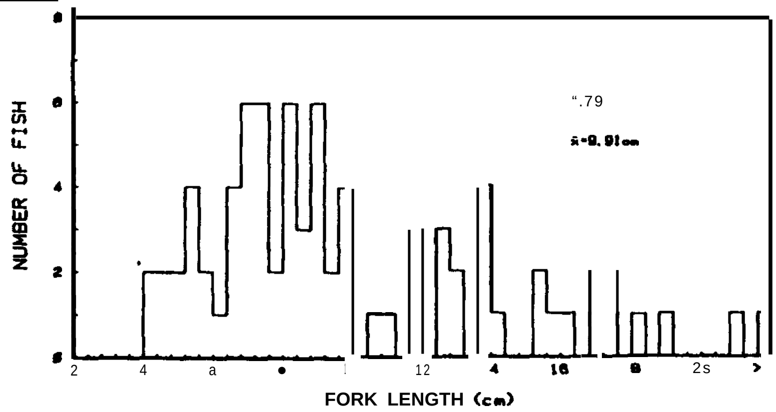

Figure 3.—Length-frequency distribution of **Canadian eelpout caught** in the **northeastern Chukchi and western Beaufort** Seas in **August-September** 1977.

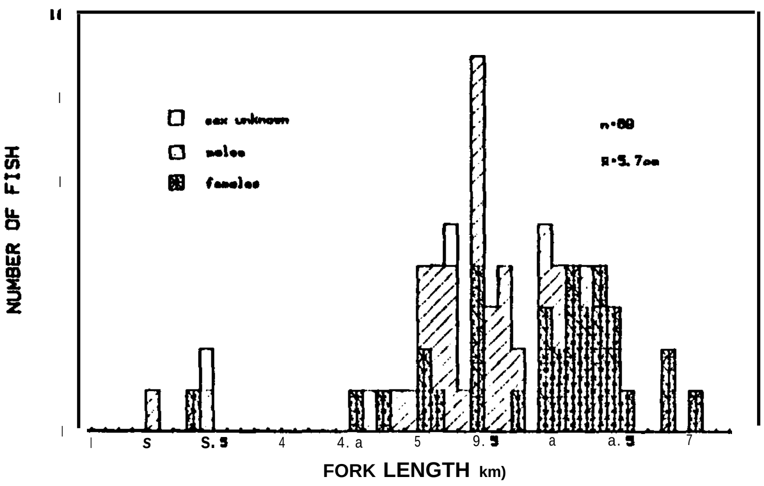

Figure 4.—Length-frequency distribution of twohorn sculpins caught in the northeastern Chukchi and western Beaufort Seas in August-September 1977.

averaged 5.65 cm (range 5.0-7.0, SD = 0.650), and six 5+-yr-old fish averaged 5.87 cm (range 5.4-6.8, SD = 0.557).

Females appeared to mature at about 4 yr of age and a size of about 6 cm. The eggs of mature females were 1.4 to 1.9 mm in diameter and ranged in number from 79 to 180. Andriyashev (1954) reported that this species spawns in August to October at which time the ovaries contain 147 to 340 eggs up to 3.1 mm in diameter.

Stomachs of 38 fishes contained identifiable remains. Gammarid amphipods occurred in 23, polychaetes in 11, mysids and isopods each in 3, euphausiids and hyperiid amphipods each in 2, and shrimp and cumaceans each in 1.

***Artediellus scaber*.**—Thirty-six hamecon were caught at 11 stations. All stations at which they occurred were in water depths ≤ 70 m. Specimens ranged in size from 2.7 cm TL (0.3 g) to 7.6 cm TL (6.6 g). Females >5.6 cm (about 3 or 4 yr old) appeared reproductively mature and had 50 to 100 eggs ranging in size from 0.6 to 1.6 mm. The oldest specimen for which age could be determined was 7 yr old. Growth from the age of 1-5 yr was about 0.8 cm/yr.

Stomachs of 24 fishes contained identifiable food. Polychaete worms and gammarid amphipods each occurred in 15 stomachs, mysids in 6, cumaceans in 2, and euphausiids, hyperiid amphipods, and isopods each in 1.

***Aspidophoroides olriki*.**—Thirty-six Arctic alligatorfish were caught at six stations ranging from 40 to 400 m. Most were caught near and to the east of Point Barrow. Specimens ranged from 4.0 cm TL (0.3 g) to 6.7 cm TL (2.3 g). A 6.3 cm female had 260 eggs 0.8 to 1.2 mm in diameter. Six stomachs contained identifiable food. Gammarid amphipods occurred in four stomachs and polychaete worms in two.

***Liparis* spp.**—Thirty-four snailfish were caught at 20 stations. No more than four individuals occurred in any tow. Most of the specimens could not be identified to species due to damage caused by the large quantities of mud and small rocks present in many of the tows. Three specimens were identified as *L. herschelinus* and four as *L. koefoedi*.

The liparids ranged from 3.8 cm TL (0.4 g) to 12.2 cm TL (34.5 g). Age determination was not possible because of minute size and opaque nature of the otoliths. Two specimens (8.5 and 9.7 cm TL) had numerous large (up to 2 mm) eggs which appeared nearly ripe. Of 16 stomachs containing identifiable food, gammarid amphipods occurred in 12, caprellids, hyperiid amphipods, isopods, and polychaetes each in 2, and copepods and euphausiids each in 1.

***Eumicrotremus derjugini*.**—Twenty-nine leatherfin lumpsuckers were caught in 50-110 m; 3 west of Prudhoe Bay and 26 east of Prudhoe Bay.

Specimens ranged from 2.5 cm TL (0.7 g) to 8.5 cm TL (35.8 g). Only four were larger than 4.0 cm; these were females. Of 21 individuals for which sex was determined, 15 were females and 6 were males. Females > 6.5 cm long appeared to be reproductively mature and had eggs of two size classes, 0.4 to 0.8 mm and 3.0 to 4.0 mm diameter. No age determinations were made for this species.

The main prey of leatherfin lumpsuckers were hyperiid amphipods (*Parathemisto libellula*) which occurred in 23 of 25 stomachs containing identifiable tired. Gammarid amphipods occurred in six stomachs and mysids itnd polychaetes each in one.

Gymnelis vin"dis.-Twurty-scvcn fish doctors were caught at 12 stations throughout the survey area in 43-130 m. They ranged from 7.0 cm TL (1.2 g) to I I.4 cm TL (5.3 g). Three females longer than 9.0 cm were reproductively mature. The ovaries nf each contained about 60 eggs ().6 to 4.0 mm in diameter. No ages were determined for [his species.

Thirteen stomachs contained identifiable fond. Gammarid amphipuds occurred in nine. caprellids in two, itnd mysids, polychitetes, and copepods each in one.

***Icelus spatula*.**—Twenty spccimcns of the spatulate sculpin were caught at four stations ranging from 56 to 123 m. Eight were females with a mean length of 8.3 cm TL (range 5.5-II .0). Six were mitles with a mean length of 6.6 cm (range 5.6–7.5). Specimens ranged in weight from 1.6 to i4. I g. No ages could be determined due to degraded otoliths. Eggs in the ovaries ranged from ().2 to 1.2 mm and numbered 110- 1.(NM). Eggs were more numerous and smidlcr than those of *I. bicornis*.

Of 10 stomitchs containing identifiable food, 4 contained mysids. 3 gammarid itmphipods, 2 shrimp. and I polychaetes.

Epifaunal Invertebrates

The following includes only data collected from the 33 trawls made in I 977. Invertebrates from the two I 976 trawls were not worked up in comparable detail.

We identified 238 species or species groups of invertebrates including 49 gastropods, 34 amphipods, 28 polychaetes, 27 echinoderms, 25 bivalves, I 6 ectoprocts, and I-1 shrimps. only 14 species occurred in more than 20 trawls. All except the scallop *Delectopecten groenlandicus* (which was caught only east of long. 1 54°W) were found throughout the study area. Forty-one species occurred in 10 or more trawls and almost half of the 238 species occurred in fewer than 5 trawls. At260133 stations, echinoderms. mainly brittle stars and crinoids, were the most abundant invertebrate group. In most cases they composed more than 75% of the total trawl biomass.

At least two major community types seemed to exist. West of long. 154°W, brittle stars (usually *Ophiura sarsi*) were predominant. Associated species included soft corals (*Eunephthya* spp.) and sea cucumbers (*Psolus* sp. and *Cucumaria* sp.). Al all stat ions where this brittle star community was found the bottom was muddy.

East 01" long. 150°W the invertebrate community was characterized by Ihc scallop *Delectopecten groenlandicus* and the crinoid *Heliometra glacialis*. Sea cucumbers (*Psolus* sp.), sea urchins (*Strongylocentrotus droebachiensis*), several species of brittle stars (roll *Ophiura sarsi*), and the shrimp *Sabinea septemcarinata* were usually among the most abundant species. Most trawls in which this species assemblage occurred were in rocky (cobble) areas.

Some trawls fell into neither of the above community types. Those trawls were generally in rocky areas between long. 158° and 162°W and between long. 150° and 154°W.

Brachyuran crabs.—The spider crabs *Chionoecetes opilio* and *Hyas coarctatus* are probably the two single most important forage species of bearded seals in Alaskan waters and are the most common food items of bearded seals in the Beaufort Sea (Lowry et al. 1979). *Chionoecetes opilio* is found from [hc Aleutian Peninsula north to the Beaufort Sea, across the Canadian Arctic and into the North Atlantic as far south as Maine. *Hyas coarctatus alutaceus* occurs from the Shumagin Islands south of the Alaska Peninsula north to the Beaufort Scis, throughout the Canadian Arctic, and off Newfoundland, Labrador, and Greenland (Garth 1958).

Forty-nine C. *opilio* were caught in eight trawls, all west of long. 155°W. Mirximum carapace length was 7,5 cm. I'hc largest male was 7.5 cm CL and the largest female was 6.8 cm CL. That female wils the only ovigerous individual. The next largest female was 3.8 cm. MacGinitie (1955) reported catching no ovigerous females off Point Barrow. According to Watson (1970), 50% of males are mature at 5.7 cm and 50% nf females at 5.0 cm, If maturation sizes are similar in the Chukchi itnd Beaufort Scits, the number of reproductively mature specimens in those areas is low. The ratio of males to females was about 2: I .

onc hundred imd ninety-twn H. *coarctatus* were caught in 28 trawls. Maximum CL wits 7.3 cm with an average length of4.9 cm. The largest female was 4.6 cm, the largest male was 7.3 cm. MacGinitie [1955) reported similar maximum lengths of 4.9 cm for females and 7.5 cm for males. Approximately equal numbers of males and females were caught. Twenty-eight pcrecnt of all fcmalcs were ovigerous with the smallest ovigerous female having a carapace length of 3.2 cm. Percent of ovigerous fcmisles varied from S()% west of Point Barrow to 18% east of there.

Shrimps.—Shrimps itrc major prey of bearded seals in the western Beaufort and northeastern Chukchi Seas and itre sometimes eaten by ringed seals in those areas (Lowry et al. 1979). Fourteen species belonging to the families H ippolytidae (8 species). Crangonidae (5 species), and Pond; lidae (I species) were identified. All 1-l species were ;dso reported by MacGinitie (1955) from the Point B: urow region and by Carey (1977). MacGinitie and Carey together listed an additional livc species fnnn the Beaufort Sca which were not found in this study. shrimp were present in all trawls with 2 -8 species pcr trawl. In 22 lnws. shrimp hinmass was greater than fish biomass. This was especially true cast of Point Barrow. A summary of distribution, abundance, and biological data for each species is given in Table 6.

Family Hippolytidae. - *Eualus gaimardii belcheri* was the most numerous shrimp in our trawls and occurred at 40-150 m on both muddy and rocky bottoms. It was tbc most numerous species by number and biomass at 10 stations, all of u hich wcrc west of Prudhoe Bay. Although they were present Throughout the study area, numbers decreased noticeably east of Prudhoe flay. Minimum length was 5 mm Cf. and maximum was 14 [11111 CL. Maximum size of our specimens is considerably smaller th:m that (22 mm) reported by Squires (1970) for the eastern Canadian Arctic. Twenty-nine percent of the total number was ovigerous. The smallest {t\ igerous female measured 8 mm.

Eualus macilenta occurred iit 28 Stilt ions in water depths Of 40-400 m. It was the most numerous shrimp at three stations deeper than 100 m. *Eualus macilenta* irnd *E. g. belcheri* frequently cooccurred in trawls, with *E.* g. *belcheri* the most numerous in water shallower than 100" m and *E. macilenta* usually tbc mnst numerous deeper than 100 m. *Eualus macilenta* was present in all of the deeper traw 1s whereas *E. gaimardii* was often irbscnt. Squires (1970) reported that it was most abundant in deeper, colder waters. Carapace lengths ranged from 6 to I 2 mm witb it mode at 9 mm. There were 110 ovigerous females; however. many females carried large, visible eggs under the carapace.

Eualus macilenta ranges in the west Atlantic from Greenland to Nova Scotia and in the North Pacific from the Okhotsk and Bering Seas to the Arctic Ocean at depths of S5 -S-N) m (Squires 1970).

Table 6.—Summary of data collected on shrimps caught in the northeastern Chukchi and western Beaufort Seas during August-Septem-lwr 1977.

Species	Depth (m)	No.	Size Range (mm)	Size Mode(s)	% ovig.	Smallest ovig.	No. of occurrences	Comments
Eualus gaimardii	40-1 so	1.302	5- i4	9	29.4	8	23	Less numerous east of Prudhoe Bay
Sabirrra *septemcarinata*	40-400	912	fr-19	10.16	71	16	2tl	Most numerous east of Point Barrow
Eualus macilenta	40-400	542	6-12	9	0		28	Must numerous in water > lon n)
Spirorrmcaris spirrrr	45-400	80	5-16	9	35.7	7	14	
Sclerocrangon boreas	44-102	fr7	13-25	15.20	0		4	Only west of Point Burrow
Pandalus goniurus	.U-400	59	7-25	9.13.19	6.8	16	12	Mainly west of Prudhoe Bay
Lebbeus polaris	50-1s0	.t7	4-16	6.10	2.7	12	12	Mainly east nl Point Borrow
L *groenlandicus*	50-80	6	13-22		16.6	22	3	
Argis lar	.$0-.s0	5	12-20		0		4	Only west of Point Barrow
Eualus fabricii	50-60	4	1.10		0		2	
Crangon communis	40-so	3	10-13		0		3	West nf Prudhoe lily
Spirontocaris phippsi	50	1					1	
Eualus suckleyi	so- 110						4	Only presence or absence information available
Argis dentata	48-110	2			0		2	Only presence or absence information available

Eualus fabricii was caught in only two trawls at depths of 50 and 60 m. Size range wits 7-10 mm CL. None was ovigerous. Elsc-where they are reported from the Japan Sea itrsd the east Siberian crust tn Alaska, the Arctic Ocean off Alaska, and the northwest Atlantic, at 4-200 m (Squires 1970).

Eualus suckleyi was identified from four trawls at depths of 50-110 m. No further information was noted for these specimens.

Lebbeus polaris was present in 12 trawls at depths of 50-150 m. Size range was 4-16 mm CL with modal sizes in 6 and 10 mm. Thrcc percent of all individuals were ovigerous with the smallest ovigerous female measuring 12 mm. Squires (1970) in the Cana-diirn Arctic reported the smallest ovigerous female to be 10 mm. In this trawl series L.. *polaris* was found mainly east of Barrow. MitcGinitie (1955) caught three specimens off Barrow. squires (1970) summarized distributional information fur f,. *polaris* 0s fol-lows: in the North Atlantic from the polar regions tu Skaggerak and the Hebrides in Eurnpc. to Cape Cod in America, in the North Pacific from the Aleutians, and Bering and Okhotsk Seas, at ()-93() m.

Six specimens of *Lebbeus groenlandicus* were caught :11 three stations in depths of 50-80 m. Carapace length ranged from 13 to 22 mm. A single individual (22 mm Cl,) was ovigerous. *Lebbeus groenlandicus* is present in the North Atlantic from east and west Greenland and from the Canadian Arctic to Cape Cod, in the North Pacific from arctic Alaska, the Bering Sea to Puget Sound, and the Sea of Okhotsk at depths < 200 m (Squires 1970).

Spirontocaris spina was caught in 21 trawls at depths of 45 -MM) m. It was the fourth most numerous species of shrimp. Carapace lengths ranged from 5 to 16 mm with the main size mode at 9 mm. Thirty-six percent uf all individuals were ovigerous and the small-est ovigerous female measured 7 mm ("L. This species seemed tu prefer rocky bottoms although it occurred at least once on it hard mud bottom. *Spirontocaris spina* is circumpolar. II is widespread in the North Atlantic, in the North Pacific from arctic Alaska, Bering Strait, Wing Sea, the Siberiiur east coast to the Alaska Peninsula and Vancouver, B.C. (Rathbun 1904; Squires 1970).

A single specimen of *Spirontocaris phippsi* was caught in 1977 in 50 m of water in the eastern part of' the study area. Twenty-four individuals were caught in it single trawl off Pitt Point in 1976 at 40 m. Distribution is circumpolar. It occurs from arctic Alaska 10 the Shumagins, the Atlantic coast of America southward to Cape Cnd, off northern Europe, in 10-2S0 m (Rathbun 1904).

Family Pandalidae.—We caught ii single species of pandalid shrimp. *Pandalus goniurus. Pandalus borealis* was also reported near Point Barrow by MacGinitie (1955). *Pandalus goniurus* occurred in 12 trawls at depths of 40- 4(M) m. only 3% of the irrdi-viduals were caught east of Prudhoe Bay. Indi viduals ranged from 7 to 2S mm CL. Although total sample size was relatively small (59) there appeared to be three size modes iit 9, 13, and 1 9111111. Seven percent of all individuals were ovigerous, the smallest ovigerous female measuring 16 mm c1,. According to Rathbun (1904) *P. goniurus* ranges from the arctic coast of Alaska southward to thC Okhotsk Sea and Puget S{)und, in 5-250 m. Occurrence in water > 100 m is unusual.

Family Crangonidae.—Five species of crangonid shrimps were identified. ( )1' these five, only one, *Sabinea septemcarinata*, was widespread and abundant.

Sabinea septemcarinata, the second most numerous shrimp in our samples s, was collected in 28 trawls at depths III' 40 400 m. II was the m(isi numerous shrimp species in 15 trawls, all Of which were east of Barrow. *Sabinea* occurred west of Point Burrow. but only in very low numbers (< 3% of the total shrimp c; itches). Car-apace lengths ranged from 6 to 19 111111, with modes at 10 and 16 mm. ( )nly 7 % of all individuals were f)\ igerous and the smallest ovigerous female was 16 111111. considerably larger than the smallest ovigerous female (10 nnn) reported by Squires (1970) lor the east-ern Canadian Arctic. *Sabinea septemcarinata* is widely distributed throughout the North Atlantic. It occurs in the Beaufort Sea and the east Siberian Sea at 45 3-45111 (Squirm 1970).

Sclerocrangon boreas was present in only four trawls, all west of Point Barrow, in 44-102 m. only two rocky bottom stations occurred west of Barrow and *S. boreas* was the dominant shrimp at both of those stations. Carapace lengths ranged from 13 to 25 mm with modes at 15 and 20 nnn. No ovigerous females were present. Leech egg cases, reported by MacGinitie (1955) to be *Crangonob-della murmanica*, were present on the pleopods of several individ-uals. *Sclerocrangon boreas* is primarily an arctic species. h is present throughout lbc North Atlantic, in the Nurtb Pacific from

Bering Strait and Kilesnov 10 the Straits of Georgia, B. C., in the Arctic Ocean from Siberia to Point Barrow, at 0-400 m (Squires 1970), Squires (1969) reported this species from one shallow water station in the western Canadian Arctic (Franklin Bay).

Argis lar was present in four trawls west of Barrow, in 40-50 m. Carapace lengths were 12-20 mm. No ovigerous females were present. Carey (1977) reported *A. lar* from north of Camden Bay. It occurs from the arctic coast of Alaska and Siberia southward to Sitka and the Kuril Islands, and off Greenland, in 0-90 m (Rathbun 1904). only two specimens of *Argis dentata* were identified. No further information is available on those specimens.

Crangon communis was identified from three trawls, all west of Prudhoe Bay, in 40-50 m. Range of carapace lengths was 10-13 mm. No ovigerous individuals were present. A single specimen of *C. communis* was taken by MacGinitie in 1949 (MacGinitie 1955). That was the first report of this species north of Bering Strait. Rathbun (1904) reported *C. communis* from the Bering Sea to San Diego, Calif., at 40-600 m.

Amphipods.—Gammarid amphipods are prey of many demersal fishes, seabirds, Arctic cod, ringed and bearded seals, and bowhead whales, *Balaena mysticetus* (Lowry et al. 1979). They occurred in 34 trawls, but seldom made up more than 2% of the total trawl biomass. Fifteen families and 34 species were identified. The families Lysianassidae and Ampeliscidae were represented by the greatest number of species, eight and five, respectively. Most species occurred at 1-3 stations. Seven including *Ampelisca eschrichti*, *Acanthostepheia behringiensis*, *Rhacotropis aculeata*, *Anonyx nugax*, *Socarnes bidentata*, *Stegocephala inflatus*, and *Stegocephalopsis ampulla* occurred at more than 10. Only *Rhacotropis aculeata* showed any obvious geographic variation in abundance; it was by far more numerous between Point Barrow and Prudhoe Bay than elsewhere.

Gastropods.—Snails are a regular prey item of bearded seals and walruses (*Odobenus rosmarus*) (Fay et al. 1977; Lowry et al. 1979). Thirteen families and 49 species were identified from our trawls. The families Buccinidae and Neptunidae were represented by the greatest number of species.

Margarites costalis occurred at all but six stations. It was the most numerous snail in the trawl survey.

Seven species of *Buccinum* occurred in the trawls. *Buccinum polare* and *B. scaliforme* were most numerous. Buccinid snails were in general more abundant west of Prudhoe Bay.

Ten species of the family Neptunidae occurred in the trawls. Snails of the genus *Colus* were most common, especially east of Prudhoe Bay. The genera *Plicifusus* and *Neptunea* were present mainly west of Prudhoe Bay.

East-west distributional patterns were indicated for several other species and genera. *Natica clausa* was found only west of Prudhoe Bay, and 9 of 10 tows in which *Polinices pallida* occurred were west of Prudhoe Bay. *Admete couthouyi* and two species of the genus *Trichotropsis* were present only west of Point Barrow.

Three species of the genus *Trophonopsis* (*Boreotrophon*) were represented in the trawls. Although these species occurred both east and west of Point Barrow, most specimens were caught east of Prudhoe Bay.

Bivalves.—Bivalve molluscs are generally abundant and diverse in the benthos. Carey (1977) listed X5 species in his arctic species list. Bivalves are a major food of walruses and bearded seals (Lowry et al. 1979).

Twenty-five species belonging to 12 families were identified from our trawls. Only seven species occurred in more than five trawls. The small transparent scallop *Delectopecten groenlandicus* was by far the most abundant species, although it was found only east of long. 150°W. It was abundant where it was present.

A small, chalky, heavy-shelled species, *Bathyarca glacialis*, was the second most numerous bivalve. It was caught only east of Prudhoe Bay and was patchy in occurrence.

Nuculana pernula occurred only east of the Prudhoe Bay area. Its occurrence coincided closely with that of *B. glacialis* and *D. groenlandicus*.

Cyclocardia crassidens was present throughout the area sampled, as was *Nucula tenuis*. Two species of *Astarte* were common. *Astarte montegui* was present in greatest numbers west of Prudhoe Bay whereas *A. crenata* was most numerous east of Prudhoe Bay.

Polychaetes.—Polychaetes are a major component of Beaufort Sea infauna (Carey 1977). They were also a regular component of the epifauna. Most specimens we collected were fragmented and in very poor condition, Nonetheless, 15 families and 27 species were identified. The scaleworms, Family Polynoidae, were the most widespread and numerous, occurring in 24 trawls. Three species, *Antinoella sarsi*, *Eunoe nodosa*, and *Gattyana cirrosa*, were most common

Only two other species occurred in more than five stations. These were *Nereis zonata*, most numerous west of Prudhoe Bay, and *Brada granulata*, present in all areas.

Echinoderms.-Echinoderms were by far the most abundant invertebrates in the western Beaufort and northeastern Chukchi Seas, We found 27 species: 15 asteroids, 7 ophiuroids, 1 echinoid, 1 crinoid, and 3 holothuroids.

Ophiuroids were most abundant but least diverse west of long. 151°W. *Ophiura sarsi* was the only species identified. East of long. 154°W numbers of ophiuroids decreased but at least six species occurred. *Ophiura* [illegible] *bidentata* was the most common.

The sea urchin, *Strongylocentrotus droebachiensis*, was present at rocky stations and absent from all muddy stations. It occurred in 14 trawls in relatively low numbers (usually fewer than 10/trawl).

Heliametra glacialis, a crinoid, was the dominant organism at 8 of 15 stations east of Prudhoe Bay. It was abundant at most of the other eastern stations, but did not occur at all west of Point Harrow.

Sea cucumbers were extremely numerous and widespread. *Cucumaria* sp. was present at 17 stations and *Psolus* sp. at 16. The two species often cooccurred.

Sea stars were the most diverse of the echinoderms, though never so abundant as other groups. *Crossaster papposus* and *Leptasterias groenlandicus* were the most common, each occurring in more than 20 trawls. The average number of species per trawl increased from [illegible] in the west to 3.7 in the east. The maximum number of species per trawl west of Point Barrow was three whereas east of Prudhoe [illegible] it was [illegible]. This difference may be related to the increased number of small bivalves in the eastern area.

Other groups.—Sponges, anemones, flatworms, nemerteans, bryozoans, and tunicates were present in many trawls. The taxonomy of many of these groups is poorly known for arctic waters and thus the species lists presented in this report are incomplete.

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Appendix A. Fishes and invertebrates collected in the northeastern Chukchi and western Beaufort Seas in August-September 1977. Letters and numbers indicate stations (Figure 1).

PHYLUM PORIFERA

Unidentified sponge - 1, 16, 23, 26, 27, 31, 33, 34

FAM. AXINELLIDAE

Phakettia cribosa - 22

FAM. POLYMASTIIDAE

Polymastia mammilaris - 16, 20, 21, 24, 29

FAM. CRANIELLIDAE

Craniella crania - 17, 20

PHYLUM CNIDARIA

Thuiaria sp. - 3, 4

Lucernosa sp. - 3

Eunephthya sp. - 4, 5, 6, 8, 9, 13, 34

**Eunephthya rubiformes* - 1, 3, 10, 28

**Eunephthya fruticosa* - 1, 3, 7, 10, 22, 27

Unidentified anemone - 1, 3-6, 10, 11, 12, 14, 16-25, 27-34

PHYLUM PLATYHELMINTHES

Turbellaria - 22, '24," 27

PHYLUM RHYNCHOCOELIA

Nemertean - 4, 11, 24, 25, 27, 32

Cerebratulus sp. - 24, 2s, 3z

PHYLUM ANNELIDA

CLASS POLYCHAETA

FAM. POLYNOIDAE

Antinoella sarsi - 2, 6, 8, 19, 25, 27, 29, 30, 31

Eunoe nodosa - 1, 4-7, 9, 10, 14, 16, 20, 22, 24, 25, 27, 28,, 32

Gattyana cirrosa - 1, 2, 4-9, 12, 17, 27, 29, 31

Hannothoe imbricata - 2

FAM. SPINTHERIDAE

Spinther sp. - 10

FAM. PHYLLODOCIDAE

Anaitides mucosa - 27

Anaitides maculata - 7

Phyllodoce groenlandica - 6, 12

Genetyllis castanea - 20

FAM. SYLLIDAE

Typosyllis fasciata - 1 0

FAM. NERIDAE

Nereis pelagica - 3

Nereis zonata -1, 14, 16, 17, 20, 22, 24, 27, 28

FAM. NEPHTYIDAE

**Nephtys* Sp. 1 0

Nephtys ciliata - 17

AgIaophomus malmgreni.19,20,22, 27

FAM. ONUPHIDAE

Onuphis sp. - 29

FAM. LUMBRINERIDAE

Lumbrinereis sp. ' - 7, 19

**Lulnbrinerels fragilis* 2 9

FAM. SPIONIDAE

Laonice cirrata - 31

FAM. FLABELLIGERIDAE

**Brada granulata* - 1, 2, 4-9, 11, 12, 20, 22, 30, 31

**Brada inhabilis* - 9, 12

Flabelligera affinis - 1, 6, 9

FAM. SCALIBREGMIDAE

Scalibregma inflatum - 27, 29

FAM. STERNASPIDAE

Sternapsis scutata - 18, 29

FAM. PECTINARIIDAE

Cistenides granulata - 1

Cistenides hyperborea - 5, 6, 8

FAM. AMPH.ARETIDAE

Amphicteis sp. - 22

FAM. TEREBELLIDAE

Amphitrite cirrata - 12

PHYLUM MOLLUSCA

CLASS GASTROPODA

ORDER ARCHAEOGASTROPODA

FAM. LEPETIDAE - 28

Lepeta caeca - 20, 25

FAM. TROCHIDAE

Margaritas costalis - 1, 2, 4-12, 14, 16-20, 22-32, 34

Solariella obscura - 4, 6

Solariella varicosa - 2, 16, 17

ORDER MESOGASTEROPODA

FAM. TURRITELLIDAE

Tachyrynchus erosus - 4, 18, 19

Tachyrynchus reticulates - 12, 18, 20, 30, 33

FAM. TRICHOTROPIDIDAE

Trichotropis borealis - 4, 5, 7, 8

Trichotropis kroyeri - 8, 9, 27

FAM. LAMELLARIIDAE"

Onchidiopsis glacialis - 10, 26

Piliscus commondum - 10

Velutina sp. - 1, 10

Velutina undata - 3, 6, 8, 10, 34

Marsenina glabra - 1

FAM. NATICIDAE

Natica clausa - 1, 2, 4-8, 10-13, 34

Polinices pallida - 2, 4, 6-8, 11, 16, 18, 22, 34

ORDER NEOGASTROPODA

FAM. MURICIDAE

Trophonopsis (Boreotrophon) clathratus - 10, 22, 31

Trophonopsis (Boreotrophon) muriciformis - 2, 5, 18

Trophonopsis (Boreotrophon) beringi - 8-10, 13, 16, 17, 19, 20, 22-32

FAM. BUCCINIDAE

Buccinum sp. - 1, 10, 11, 23, 24, 28, 34, B

Buccinum angulosum - 1, 12, 19, 22, 29

Buccinum scalariforme - 1, 2, 8, 9, 12, 16, 18, 19, 28, 29, 31

Buccinum glaciale - 10

Buccinum solenum - 8, 9, 22

Buccinum polare - 1, 2, 5-8, 12, 22, 24, 25

Buccinum ciliatum - 2, 10, 17

Buccinum plectrum - 10, 16

FAM. NEPTUNIDAE

Beringius beringi - 17, 27, A

Colus sp. - 4, 20, 23, 24, 27, 28, 31, 34, B

Colus spitzbergensis - 34

Colus roseus - 4, 5, 9, 12, 20, 22, 28

Colus trombinus - 2

Neptunea sp. - 5, 13

Neptunea sp. cf. *borealis* - 2, 4

Neptunea heros - 10, 12, 18, 20, B

Plicifusus kroyeri - 9, 10, 14, 17, 18, 27, 28, A

Pyrulofusus deformis - 18, 22

Volutopsius fragilus - 12, 24

FAM. CANCELLARIIDAE

Admete sp. - 6

Admete couthouyi (or *middeandorffiana*) - 4, 5, 7, 10, 12, 34

Admete regina - 29

FAM. TURRIDAE

Mangelia sp. - 12

Oenopota sp. -4, 6, 7, 17

Oenopota turricula - 34

Oenopota harpa - 4, 8, 17, 20

Oenopota tenuicostata - 8

ORDER CEPHALASPIDEA

FAM. SCAPHANDRIDAE

Cylichna alba - 2, 5, 6

ORDER NUDIBRANCHIA

Unidentified nudibranch - 6, 8, 10, 25, 26

Dendronotus sp. - 3, 13
Dendronotus dalli - 17
CLASS POLYPLACOPHORA
Ischnochiton albus - 3, 10
Amicula vestita - 3, 10
CLASS BIVALVIA
ORDER NUCULOIDA
FAM. NUCULIDAE
Nucula tenuis - 2, 4, 5, 11, 15, 17, 31
FAM. NUCULANIDAE
Nuculana pernula - 18, 19, 20, 22, 24, 25-31, 33
Nuculana minuta - 4, 15, 17
Yoldia sp. - 7, 28, 29
Yoldia hyperborea - 2, 6, 18, 26
Yoldia myalis - 15, 17, 31
ORDER ARCOIDA
FAM. ARCIDAE
Bathyarca glacialis - 19, 20, 22-29, 31, 33
ORDER MYTILOIDA
FAM. MYTILIDAE
Musculus corrugates - 10
ORDER PTERIOIDA
FAM. PECTINIDAE
Chlamys sp. - 1, 11, 17
Delectopecten greenlandicus - 14, 16-33
ORDER VENEROIDA
FAM. CARDITIDAE
Cyclocardia sp. - 9, 10, B
Cyclocardia cf. *rajabiminae* - 4, 6, 7
Cyclocardia crassidens - 1, 2, 10, 12, 17, 20, 22
FAM. ASTARTIDAE
Astarte sp. - 5, 8, 9, 10, B
Astarte borealis - 1, 2, 12, 22
Astarte montegui - 2, 4, 8, 11, 12, 17, 19, 22, 27, 31, 34
Astarte crenata - 10, 14, 16, 18, 19, 20, 23, 24, 25, 27, 28, 29, 32, 33

FAM. CARDIIDAE

Clinocardium ciliatum - 2, 4, 7, 8, 13

Serripes groenlandicus - 4, 13

FAM. TELLINIDAE

Macoma calcarea - 4, 12

Macoma moesta - 7, 11, 15, 22, 31

Macoma loveni - 2

FAM. VENERIDAE

Liocyma fluctuosa - 17

ORDER MYOIDA

FAM. HIATELLIDAE

Hiatella arctica - 8, 9

ORDER PHOLADOMYOIDA

FAM. LYONSIIDAE

Lyonsia sp. - 5, 6

FAM. CUSPIDARIIDAE

Cuspidaria glacialis - 25

CLASS CEPHALOPODA

FAM. SEPIOLIDAE

Rossia pacifica - 28

FAM. OCTOPODIDAE

Octopus Sp. - 1, 12, 14, 21, 22, 24, 28, B

PHYLUM ARTHROPODA

CLASS PYCNOGONIDA

Nymphon longitarse - 1

Nymphon brevitarse - 3, 20, 21, 24, 30

CLASS CRUSTACEA

SUBCLASS CIRRIPEDIA

Balanus crenatus - 10

SUBCLASS MALACOSTRACA

ORDER CUMACEA

Diastylis bidentata - 10, 27

Diastylis goodsiri - 19, 20, 29

Diastylis spinulosa - 19

ORDER ISOPODA

Saduria sabini - 29

Synidotea bicuspida - 2, 9, 10, 11, 20, 21, 22, 27
Synidotea nodulosa - 11
ORDER AMPHIPODA
FAM. ACANTHONOTOZOMATIDAE
Acanthonotozoma inflatuzn - 2, 7, a, 11, 34
Acanthonotozoma serratum - 10
FAM. AMPELISCIDAE
Ampelisca macrocephala - 30
Ampelisca birulai - 27
Ampelisca eschrichti - 1, 2, 8, 11, 13, 14, 18, 20, 27, 28, 29, A
Byblis gaimardi (eschrichti] - 2
HapZoops sp. - 2, 11, 16, 27
FAM. ATYLIDAE
Atylus smitti - 20, 21, 24, 27, 29, 32, 33
FAM. CALLIOPIIDAE
Halirages nilssoni - 2, 17
FAM. COROPHIIDAE
Ericthonius tolli - 10
FAM. EUSIRIDAE
Eusirus sp. - 14
Eusirus cuspidatus - 2, 10, 20
Rhacotropis aculeata - 1-4, 6-9, 11, 13, 14, 16, 17, 22, 32, A, B
Rozinante fragilis - 2
FAM. GAMMARIDAE
Maera sp. - 10
Melita sp. - 10
FAM. ISAEIDAE
Photis vinogradovi - 2
FAM. ISCHYROCERIDAE
Ischyrocerus latipes - 2, 10
FAM. LYSIANASSIDAE
Unidentified Lysianassid - 10
A.nonyx sp. - 2
Anonyx nugax - 1, 2, 4, 6-11, 14, 18-22, 24, 25-31, 34, A, B
Anonyx laticoxae - 2, 22, 26, 27
Hippomedon sp. - 20

Orchomene sp. - 17
Socarnes bidenticulatus - 1-4, 8, 9, 10, 14, 22, 27, 30, 31, 32
Tryphosella (Tmetonyx) sp. 20, 22, 27, 30
FAM. MELPHIDIPPIDAE
Melphidippa goesi - 2
FAM. OEDICEROTIDAE
Acanthostepheia behringiensis - 2, 4, 6-9, 13, 17-20, 22, 24, 25, 27-31, 33, 34, B
Paroediceros lynceus - 2, 11, 34
FAM. PARAMPHITHOIDAE
Paramphithoe polycantha - 6, 7, 8, 11, 34
Paramphithoe cuspidata -29
FAM. PLEUSTIDAE
Pleustes panoplus - 2, 7, 8, 9
FAM. STEGOCEPHALIDAE
Stegocephalopsis ampulla - 1, 8, 10, 11, 16, 21, 23, 24, 25-28, 30-33
Stegocephala inflatus - 1, 2, 3, 6, 8-11, 16-34, A, B
ORDER DECAPODA
SUBORDER NATANTIA
FAM. HIPPOLYTIDAE
Spirontocaris sp. - 7, 26, 31, 32
Spirontocaris phippsi - 1, 3, 8, 16-18, 21, 22, 27, 30, 31, A
Spirontocaris spina - 1, 7-10, 12, 14, 21, 23-26, 31, 32, A, B
Lebbeus groenlandica - 16, 21, 31
Lebbeus polaris -1, 16, 21, 22, 24, "27, 28, 30-34
Eualus fabricii - 3, 17
Eualus suckleyi - 10, 16, 31, 32
Eualus gaimardii - 1, 2, 3, 5, 6, 7, 9, 10, 11, 16, 17, 18, 20, 21, 22, 25, 26, 28, 30, 31, 34, A, B
Eualus macilenta - 1, 2, 4-13, 16-20, 22, 24-32, 34, A, B
FAM. PANDALIDAE
Pandalus goniurus - 2, 3, 5-8, 10, 11, 12, 14, 32, 33, B
FAM. CRANGONIDAE
Crangon communis - 4, 5, 17
Sclerocrangon boreas - 1, 3, 8, 10
Argis lar - 5, 6, 7, 9, A, B

Argis dentata - 6, 32
Sabinea septemcarinata - 1, 2, 5, 7, 8, 11-34, A, B
SUBORDER REPTANTIA
SECTION ANOMURA
Pagurus sp. - 26, 31
Pagurus trigonocheirus - 2, 10-14, 16, 17, 18, 21, 24, 28, 30, 31, 32, 34, A
Pagurus rathbuni - 1, 4, 6, 8, 9, 11, 12, 13, B
Labidochirus spendescens - 2, 11, 13, 16, 30, 34
SECTION BRACHYURA
Hyas coarctatus alutaceus - 1-4, 8-28, 30, 31, 34, A, B
Chionoecetes opilio - 1, 4-7, 9, 11, 34, B

PHYLUM SIPUNCULA
Golfingia margaritacea - 1, 3, 4, 10

PHYLUM ECTOPROCTA
Alcyonidium vermiculare - 1, 9
Unidentified Flustrellidae - 10
Flustrella gigantea - 9
Beronicea meandrina - 17
Eucratea loricata - 1, 16
Tegella spitzbergensis - 16
Dendrobeania levinseni - , 7, 9
Dendrobeania murrayana - 3, 10
Rhamphostomella gigantea - 1
Cystisella saccata - 16, 18
Cellopora sp. - 10, 17
**Myriozoum orientale* - 1 0
Flustra membranaceotruncata - 1
Flustra serrulata - 4, 9, 11
Carbasea (Flustra) carbasea - 14
Escharopsis sarsi - 1, 10

PHYLUM BRACHIOPODA
Hemithiris psittacea - 27

PHYLUM ECHINODERMATA

CLASS ASTEROIDA

FAM. PORCELLANASTERIDAE

Ctenodiscus crispatus -11, 12, 13, 29, 34, B

FAM. BENTHOPECTINIDAE

Pontaster tenuispinus - 23, 24, 25

FAM. PORANIIDAE

Poraniomorpha tumida - 20, 24, 25, 27, 30, 33

FAM. ECHINASTERIDAE

Henricia sp. - 1, 17

Henricia sanguinolenta? - 14

FAM. PTERASTERIDAE

Pteraster militaris - 30

Pteraster obscurus - 9, 17, 20, 24, 25, 26

FAM. SOLAS'I'ERIDAE '

Crossaster papposus - 1, 3, 8, 9, 10, 14, 17, 20-32, 34, A, B

Lophaster furcifer - 21, 23, 24, 28, 29

Solaster dawsoni - 1, 11, 20, 24, 34, A, B

FAM. ASTERIIDAE

Leptasterias sp. - 4, 5, 7, 9, 10, 13, 16, 22

Leptasterias groenlandica - 5, 12, 16-33, A, B

Leptasterias hylodes cf. *L. arctica* - 18

Urasterias lincki - 15, 18, 19, 24, 28, 29, 31, 33

Icasterias panopla - 21

CLASS OPHIUROIDEA

FAM. GORGONOCEPHALIDAE

Gorgonocephalus caryi - 12, 19, 29, 33, 34

FAM. OPHIURIDAE - 24, 25, 27, 28, 30-33

Ophiocten sericeum - 19, 21, 23, 26, 31

**Ophiura* c.f. *robusta* - 21, 23

Ophiura sarsi -1, 4-9, 11, 12, 13, 16-20, 22, 29, 34, A, B

Stegophiura nodosa - 14, 15, 17

FAM. OPHIACANTHIDAE

Ophiacantha bidentata - 21, 23, 25, 26, 29-32, A, B

FAM. OPHIACTIDAE

**Ophiopholis* sP. c.f. O. *aculeata* - 26

CLASS ECHINODEA

Strongylocentrotis droebachiensis - *1, 3, 10, 17, 21, 23-26, 28, 30-33*

CLASS HOLOTHUROIDEA

Psolus Sp. - 1, *6, 8, 9,* 10, 14, 16, 19, 20, 22, 24, 26, 27, 30, 31, 33, A, B

Cucumaria sp. - 1, *2, 4-11, 16, 17, 20, 21, 22, 27, 34*

Myriotrochus rinkii - 5, 7, 8, 19, 30

CLASS CRINOIDEA

Heliametra glacialis - 11, *19-33,* B

PHYLUM CHORDATA

SUBPHYLUM UROCHORDATA

FAM. POLYCLINIDAE

Synoicum pulmonaria - 9

Aplidiopsis pannosum - 10

FAM. CORELLIDAE

Chelyosoma macleayanum - 10

FAM. ASCIDIIDAE

Ascidia prunum - 1, *23-25, 27, 28,*

FAM. STYELIDAE

Dendrodoa pulchella - 16, 17

Pelonaia corrugata - 4

FAM. PYURIDAE

Boltenia ovifera - 3, 10

Boltenia echinata - 17

FAM. MOLGULIDAE

Molgula griffithsii - 20

SUBPHYLUM VERTEBRATA

CLASS OSTEICHTHYES

FAM. GADIDAE

Arctogadus glacialis - 34

Boreogadus saida - 1-14, 16-22, 24, 26-29, 31, 34, A, B

FAM. ZOARCIDAE

Gymnelis viridis - 1, 4, 7, 9, 16, 25, 27, 28, 30, 31, 32, A

Lycodes mucosus - 16, *24,* A

Lycodes polaris -1, 4, 11, 14, 18, 19, 20, 22, 26, 29, 31, 32, 34 A, B

Lycodes raridens - 1, *24,* B
Lycodes rossi - B
FAM. COTTIDAE
Icelus bicornis - 14, 20, 21, 22, 24, 26-32
Icelus spatula - 1, 20, 31, B
Artediellus scaber - 4-7, 9, 16, 17, 18, 31, 33, A
Gymnocanthus tricuspis - 13, 14, A
Triglops pingeli - 24, 28, A
FAM. CYCLOPTERIDAE (=LIPARIDAE)
Eumicrotremus derjugini - 16, 17, 20, 24-28, 30, 31, 33
Liparis sp. - 1, *2, 6, 12, 17, 18, 19, 21-24, 28-33,* A, B
FAM. AGONIDAE
Aspidophoroides olriki - 1, *11, 12, 34,* A, B
FAM. STICHAEIDAE,
Lumpenus fabricii - A, B
Lumpenus maculatus - 7
Lumpenus medius - 18
Eumesogrammus praecisus - 3, 14, A

* Provisional identifications.

AARON D. SEKERAK

Unpub. species account for NOAA stresses Alaska but summarizes dist. and abund. from Newfoundland to central Bering Sea

NATtJRAL HISTORY AND ECOLOGY OF ARCTIC COD

by

Aaron D. Sekerak

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ARCTIC
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Analysis of Arctic Cod Movements in the Beaufort Sea Nearshore Region, 1978-79

LAWRENCE L. MOULTON[1] and KENNETH E. TARBOX[2]

(Received 26 August 1982; accepted in revisedform 14 October 1986)

ABSTRACT. A study was conducted to investigate distribution and abundance of arctic cod in the nearshore region of the Beaufort Sea. Data collection methods included 3 m otter trawl and hydroacoustic surveys. Temperature and conductivity measurements were taken throughout the study area on a regular basis. The results indicated that arctic cod are associated with a transition layer between a surface water mass, characterized by low salinity and high temperature, and a battom water mass, characterized by high salinity and low temperature. Arctic cod apparently oriented to the shorewardedge of the marine water mass and redistributed themselves depending on the location of the shoreward edge. It is hypothesized that the transition layer concentrates food organisms, and this abundance of food may be one factor that induces shoals of arctic cod to utilize this transition layer.

Key words: arctic cod, Alaskan Beaufort Sea, nearahore movements, temperaturekalinity association, coastal habitat use, *Boreogadus saida*

RÉSUMÉ. Une étude a été menée afin de déterminer la distribution et l'aborrdance de la mome aretique clans la zone côtière de la merde Beaufort. f-es données ont été recueillies A l'aide d'un chalut à plateaux de 3 m et de relevés hydro-acoustiques. Des mesures de température et de conductivité ont été prises de façon régulière, clans toute la zone étudiée. Les résultats ont indiqué que la morue arctique est associée à une couche de transition entre une masse d'eau de surface, caractérisée par une faible salinité et une haute temp&ature, et une masse d'eau profonde, caractérisée par une forte salinité et une basse temp&ature. La mome arctique se dirigeait apparemrrrerst vers la limite côtière de la masse d'eau de mer et sa distribution suivait cette limite côtière. On peut avancer l'hypothèse que la couche de transition est très riche en éléments nutritifs, et que cette abondance de nourriture est un des facteurs qui amènent les banes de momes arctiques à se servir de cette couche de transition.

Mets cL%: morue srctique, mer de Beaufort de l'Alaska, déplacements près des côtes, association température/salinité, utilisation de l'habitat côtier, *Boreogadus saida*

Traduit pour le journal par Nésida Loyer.

INTRODUCTION

Arctic cod *(Boreogadus saida)* is a dominant species in the arctic marine ichthyofauna, yet little information has been published on the distribution and abundance of this species in the North American Arctic (Craig *et af.*, 1982). A number of recent studies have established the numerical abundance of arctic cod in the Alaskan Chukchi and Beaufort Sea region (Quast, 1974; Wolotira et *af.*, 1979). Craig and Haldorson (1981) noted large variations in arctic cod abundance that were not explainable with available data. Griffiths and Gallaway (1982) reported an unusual pattern of fluctuating arctic cod abundance in the nearshore region of Prudhoe Bay but did not address factors that might lead to such a pattern.

The present study was undertaken to assess arctic cod distribution and abundance in the Beaufort Sea nearshore region in the vicinity of Prttdhoe Bay. The objectives of the study were to 1) measure daily and seasonal changes in environmental parameters, 2) identify daily and seasonal patterns of arctic cod distribution and abundance and 3) relate observed changes in fish distribution to changes in environmental conditions.

METHODS

Field Studies

Field investigations were conducted from 16-21 August 1978 and 18 July-1 September 1979. Five subareas, extending from the western end of Stump Island to the east side of Prudhoe Bay, were sampled primarily with otter trawling and hydroacoustic transects (Fig. 1). Trawling was conducted throughout all five subareas, while hydroacoustic surveys were conducted in the offshore subarea.

Sample stations were located utilizing a Motorola Mini-Ranger 111 navigational positioning system. Transpondera were positioned at the end of Dockhead No. 3 and on Stump Island 3000 m from the dock transponder.

A 3 m semi-balloon otter trawl with 13 mm square mesh in the body and 3 mm square mesh cod end was used at each trawl station. The trawl data provided information to ground-ttuth the hydroacoustic sampling. All trawls were made on bottom. With a few exceptions, towing time was 15 min. Trawling effort consisted of 33 samples in August 1978, 43 samples in July 1979 and 32 samples in August 1979.

All fish captured by net sampling were identified and counted. Subsamples of arctic cod (*Boreogadus saida*), kelp snailfish (*Liparis tunicatus*), capelin (*Mallotus villosus*), rainbow smelt (*Osmerus mordax*), Pacific sand lance (*Ammodytes hexapterus*) and fourhorn sculpin (*Myoxocephalus quadricornis*) captured by otter trawl were preserved in 10% formalin for laboratory examination.

Hydroacoustic sampling was conducted by R.E. Theme (University of Washington, Fisheries Research Institute). The primary hydroacoustic equipment used in this study was a Simrad EY-M echo sounder, which transmits a 0.6 $m \cdot sec^{-1}$ pulse of *70* kHz sound, used in conjunction with a wide-angle transducer. The effective angle of detection for this transducer was about 30° under the survey conditions.

Echoes from fish and other targets were printed on a chart recorder as a function of depth and time and were also recorded on magnetic tape for more detailed analysis of echo amplitudes. The pulse repetition rate was 3.2 transmissions. see-'. The hydroacoustic equipment was applied in two modes: fixed location and transecting. In the fixed-location mode, the transducer was suspended just below the surface from a float several

[1]Entrix, Inc., 4794 Business Park Blvd., Suite 6, Anchorage, Alaska 99503, U.S.A.
[2]Alaska Department of Fish and Game, P.O. Box 3150, Soldotna, Alaska 99669, U.S.A.

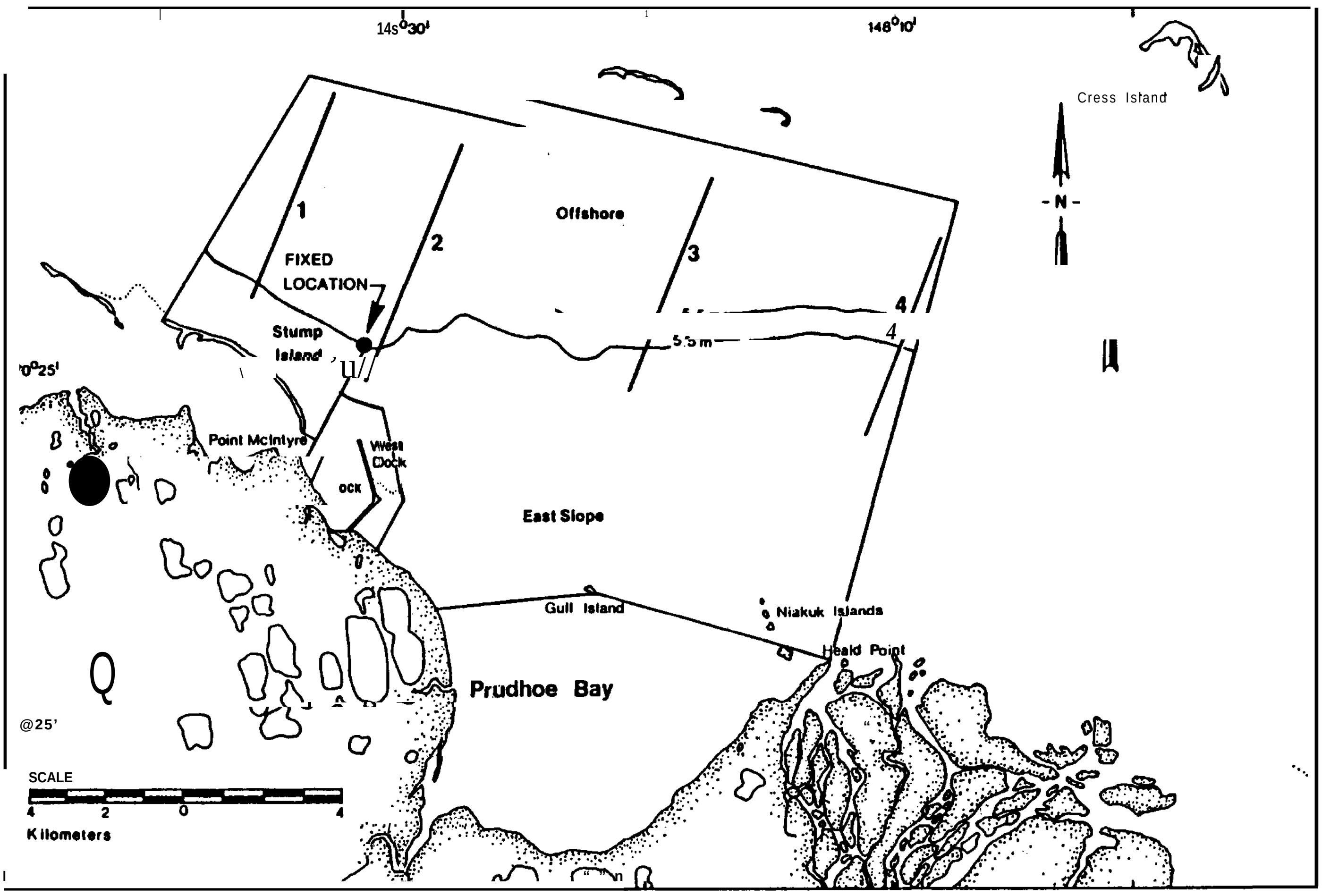

FIG. 1. Location of hydroacoustic transects, fixed location and five trawling subareas (Stump Island, West Dock, East Slope, Pmdhoe Biry and Offshore) surveyed during Beaufort Sea fish studies, 1978 and 1979.

metres from the anchored boat. During transecting, the transducer was towed just below the surface from a wood beam projecting in front of the boat. This arrangement was designed to minimize the effects of fish avoiding the boat in shallow water.

Hydroacoustic data were collected during two periods: 23-27 July and 28 August -1 September. The primary transect design consisted of four north-south lines, which were replicated during each survey (Fig. 1). Transects typically were conducted in water depths >4 m. Some east-west transects were also run along specific depth contours (e.g., 6 m). The fixed location was at a 6 m depth along transect no. 2 (Fig. 1) and was monitored for 9½ and 12 hr in July and August 1979 respectively.

In addition to biological and hydroacoustic samples, a series of water quality measurements was taken to characterize the water sampled. Water conductivity and temperature profiles were measured with a Martek Mark VII water quality analyzer. The sensor head contained a temperature probe (-5° to +50°C range; ±0. 1°C accuracy) and a five-electrode conductivity cell -70 mmho·cm^{-1} range; *0.07 mmho·cm^{-1} accuracy). Both parameters could thus be profiled on a single lowering. Depth of immersion was measured by counting 0.3 m markings on the handling line. Using the computer reduction algorithm described by Chin *etal.* (1979), the conductivity, temperature and depth data were processed to obtain vertical profiles of temperature and salinity.

Laboratory and Data Analyses

In the laboratory, all preserved fish were sorted, identified, measured (total length) and counted. A random sample of arctic cod from the preserved August subsamples was weighed.

The hydroacoustic analysis procedures consisted of echogram analysis supplemented by detailed analysis of magnetic tape records. Echo counts and amplitude characterization of selected transects were made using a storage oscilloscope.

The number of fish counted by the hydroacoustic system was determined by assuming a mean target strength of –50 decibels (dB), which comesponds to a 10 cm fish target. Echoes were counted if they exceeded a threshold of-60 dB. Fish densities were then calculated from the total number of echoes over the threshold divided by the volume sampled. The volume sampled was determined by the depth interval, the number of transmissions and the sampling angle of the transducer.

RESULTS

Depth and Substrate Features

The offshore subarea (water depths 5.5-10 m) was populated by a typically marine flora and fauna including three species of kelp (order Laminariaies), two species of nudibranches, various marine gastropod, soft coral, starfish and sponges. Kelp was collected at 95% (19 of 20) of the 1979 offshore trawl stations. Bottom sediments were apparently composed of fine sand and fine silt (Chin *et al.*, 1979). Scattered patches of sand/gravel and clay deposit were identified during the trawl survey. The East Slope subarea (0.3-5.5 m) was also predominantly soft sediments, with possible sand/gravel deposits. Kelp was collected in 7090 (7 of 10) of the 1979 trawl samples in this area. The Stump Island subarea, with a depth range similar to that of the East Slope, was primarily fine sand with areas of gravel. Kelp was taken in 38% (8 of 21) of the 1979 trawl samples. Maximum depths in the West Dock and Prudhoe Bay subareas were 3.0-3.5 m. Sediments in the West Dock area were composed of sand and silt, with mud found in some areas. In the Prudhoe Bay subarea, sediment types also ranged from fine sand to mud/clay. Kelp was not collected in either subarea.

Ice Features

The presence of ice was a dominant feature in the study area. In July the ice had retreated to approximately the 5 m contour, with a periodic inshore movement of floating ice with west winds. Thus, the ability to navigate at and beyond this boundary was severely limited. In August the ice had essentially retreated to depths > [0 m and surveying could be conducted farther offshore. Grounded ice was observed as far offshore as the 7 m depth contour.

Water Mass Features

Water movements and temperature and salinity characteristics in the general study were dynamic, with wide fluctuations over a short period of time. Basically, there were two water masses: a warm (2-9°C), low-salinity (6-27%o) surface mass with a cold (<–l°C), high-salinity (28-32%o) bottom mass. The depth to the transition layer between the two water masses (i.e., the interface between the two water masses) fluctuated from 1.5 m to > 10 m (Fig. 2). The two- to three-day period between temperature and salinity measurements was often sufficient for the marine water mass (low-temperature, high-salinity) to mix with the surface during strong winds or return to the study area. Following each influx of the marine water mass, there was usually a period of mixing, with a resulting increase in near-surface salinity (Fig. 3) (Chin, 1980). In general, surface temperatures decreased and surface salinities increased during the study period. A decrease in river discharge and ice melt may also have contributed to this pattern.

The transition layer between the two water masses was visible on the hydroacoustic traces, allowing the temporal and spatial fluctuations in the transition layer to be monitored with the hydroacoustic instrumentation (Fig. 4). The layering effect was particularly visible during July, when the density differences between the two masses were greatest. Temporal and spatial fluctuations were particularly evident between 28 August and 1 September. Based on the hydroacoustic transect monitoring, the marine water mass was apparently offshore at depths > 10 m between 28 and 30 August. This observation was verified by the CTD measurements. During the fixed-location monitoring at a depth of 6 m on 31 August and 1 September, the marine water mass moved inshore to a depth of about 4 m. Again, this onshore movement was also observed in the CTD measurements (Fig. 2). The thickness of the marine water mass at the hydroacoustic fixed location increased from essentially zero to 2.2 m in less than 24 hr, demonstrating the area's rapid response to meteorological changes.

Otter Trawl Catch

The otter trawl catch was dominated by arctic cod (98% of the catch), with minor catches of kelp snailfish, fourhom sculpin, Pacific sandlance, capelin, rainbow smelt and least cisco *(Coregonus sardinella).* The length frequency of otter trawl-caught arctic cod in both 1978 and 1979 indicated that primarily one age group, probably age-1 fish, was present; few older fish were captured.

The results of the otter trawling indicate a general offshore movement of arctic cod between the July and August sampling periods. During July 1979, the highest mean catch rate for arctic cod (271 cod/trawl) *was* recorded in the West Dock subarea,

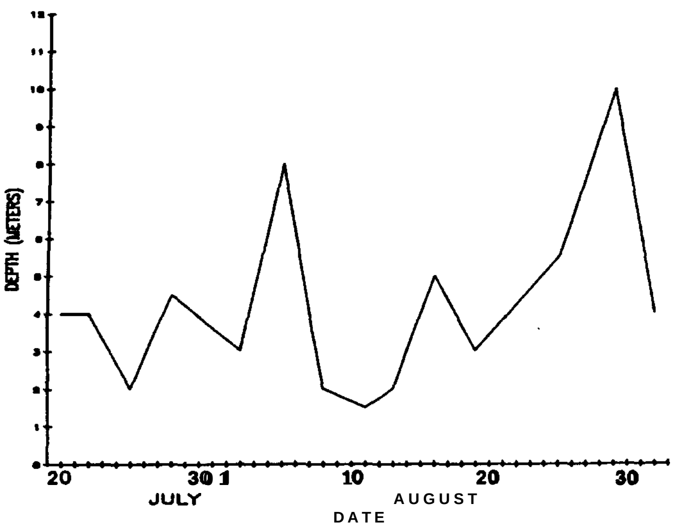

FIG. 2. Location of the transition layer between surface and marine water masses, as determined by CTD surveys 20 July-1 September 1979.

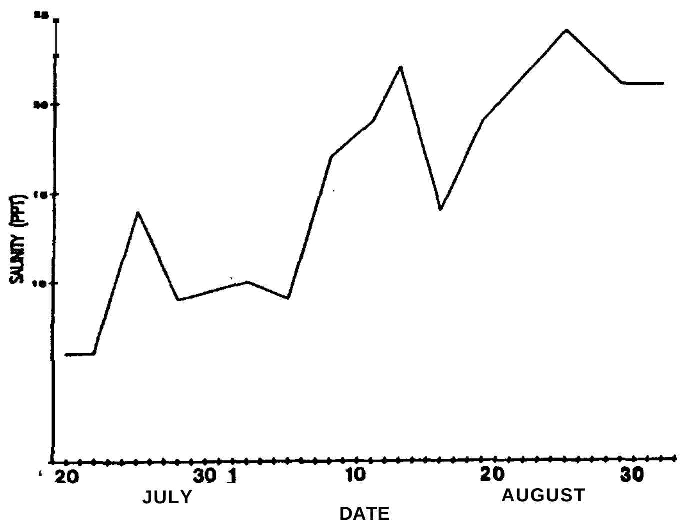

FIG. 3. Summer surface salinity in the study region as determined by CTD surveys 20 July-l September 1979.

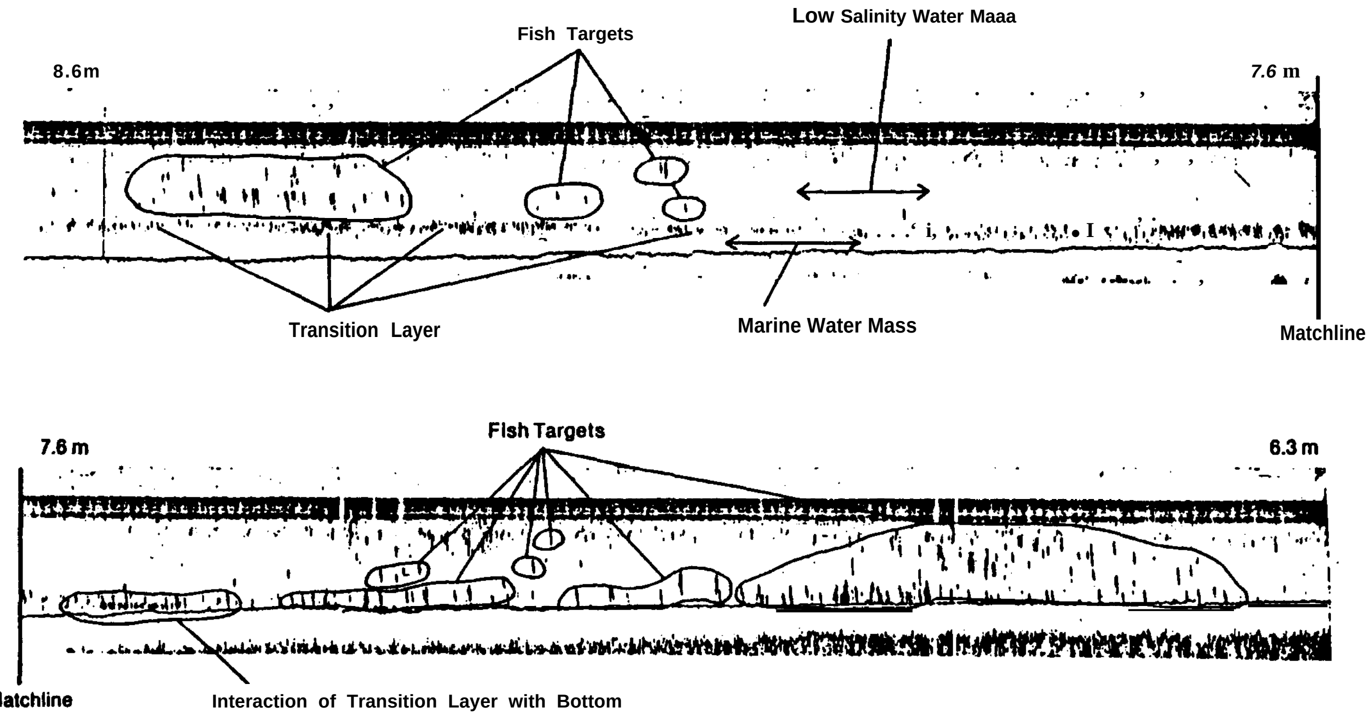

FIG. 4. Intersection of transitinq layer with seabed along tmnaect I on 30 August, illustrating the orientation of pelagic and demersal fish targets to the two Waler masses and transition layer (bottom strip is a continuation of the lop strip).

followed by the Stump Island and East Slope subareas (Table 1). The lowest mean catch rates (0.3 and 0.9 cod/trawl) were recorded in the Pr-udhoe Bay and offshore subareas respectively. In August 1979 the pattern changed, with the highest mean catch (14.8 cod/trawl) recorded in the offshore subarea and lower catches in the inshore subareas. Pmdhoe Bay catches in August 1979 were again the lowest (0.5 cod/trawl) of all five areas. During the August 1978 survey, the highest catches were recorded in the West Dock and Prudhoe Bay subareas respectively, followed by offshore, East Slope and Stump Island (Table 1). During all three trawl surveys (one in 1978 and two in 1979), the mean catches of arctic cod around the West Dock were higher than those in the two subareas on either side of the dock (i.e., Stump Island and East Slope).

The mean bottom depth of capture of arctic cod was 2.7 m (SD= 1.7) in July and 5.8 m (SD=2.0) in August 1979, a statistically significant increase in bottom depth (t-test, $p<.001$). These data again indicate an offshore movement of arctic cod between the July and August sampling periods. In contrast, neither the mean bottom depth of capture of kelp smrilfish (5.5 m in July; 4.8 m in August) nor the mean bottom depth of trawl hauls (4.3 m in July; 4.8 m in August) showed a corresponding significant change between July and August.

Hydroacoustic Measurentents

Transect series were run during four days in July; however, one series was obscured by reverberation from rough water. Additional dista were collected over a 9.5 hr period during two days of fixed-location monitoring in July. During the August *series,* data were collected over five days. A total of 15 hrof data were collected during transects, including complete, replicated four-transect series each of the first three days and a replicated run of transect 2 the last day. In addition, 12 hr of data were collected at the fixed location over two days. The length of transects was increased over July because of the improved weather and ice conditions.

TABLE 1. Relative abundance of arctic cod in each subarea based on catches by 3 m otter trawl during 1978 and 1979 trawl surveys

	August 1978			July 1979			August 1979		
Subarea	Mean catch	SD	N	Mean catch	SD	N	Mean catch	SD	N
Stump Island	3.0	2.6	5	19.7	34.5	13	3.4	3.8	8
West Dock	133.0	58.0	2	270.9	6J5.O	9	6.6	10.9	5
East Slope	3.6	3.2	9	25.8	46.7	5	4.8	10.2	5
Prudhoe Bay	23.9	27.0	9	0.3	0.5	6	0.5	1.0	4
Offshore	8.0	20,6	8	0.9	1.1	10	14.8	17.4	10
			33			43			32

SD = standard deviation.
N = number of samples.

Fish abundance was generally low during July. Results of otter trawlings used to ground-truth the hydroacoustics indicated that most of these fish were arctic cod. Target detection rates for the three series were 6.1, 3.1 and 9.9 targets. hr^{-1} for 23, 24 and 26 July respectively, with corresponding mean fish densities of 2.7,0.7 and 3.5 fish per $10^4 m^3$. The first two series were mid-day, while the third was during the 1820-2140 period. Neither inshore-offshore nor alongshore trends were evident. Targets in the marine water mass were typically located near bottom, with the mean height above bottom about 0.6 m. Targets in the surface water mass (<2.3 m on 23 and 24 July, <3.8 m on 26 July) could not be detected because of the strong surface reverberation in this layer. During the fixed-location monitoring on 25 and 26 July, 13 fish were observed — a mean rate of $1.9 \cdot hr^{-1}$, comesponding to 10.5 fish per 104m3.

Abundance of fish targets and interference from non-fish backscatter were much greater during the August survey. The estimated target densities ranged from O to 329 fish per 104m3, with a mean of 55.6 fish per $10^4 m^3$. There was considerable variability in both abundance and inshore-offshore distribution during the four days (Table 2). These changes appeared to be related to changes in water masses. Discontinuity layers could often be acoustically detected, especially the boundary of the cold (< O"C), high salinity (30‰) marine water mass. This water mass was apparently offshore between 28 and 30 August. Fish concentrations were observed during transect monitoring on 28 August, but not on 29 August (Fig. 5A, B). Concurrent otter trawling indicated most of these fish were arctic cod. Transects were extended offshore during 30 August, and high fish concentrations were discovered just inshore of the depth where the cold marine water intersected the bottom on ail transects (Figs. 4 and 5c). Iligh fish concentrations in the surface water mass, possibly pelagic species, also occurred above the marine layer offshore from this intersection depth on all transects (Figs. 4 and 5C).

Although daily variability appeared to dominate the August-

TABLE 2. Densities and distribution of fish echces along hydroacoustic transect 2, 28 August-1 September

Date	Depth range[1] (m)	Sampled volume ($10^4 m^3$)	Fish echoes	Density (fish ocr $10^4 m^3$)
28 August	4.3-6.1	1.30	105	80.8
	6.t-6.9	2.10	690	328.6
	.6.9-7,6	2.78	63	22.7
29 August	4.3-6.1	1.93	2	1.0
	6.1-6.9	2.80	6	2.1
30 August	4.3-6.1	1.61	0	0
	6.1-6.9	2.49	147	59.0
	6.9-7.6	3.26	592	181.6
	7.6-8.2	6.68	517	77.4
	8.2-7.0	3.34	5t	15.3
I September	6.1-6.9	t .47	o	0
	6.9-7.6	3.85	146	37.9
	7.6-8.2	8.67	127	14.6
	8.2-7.0	4.90	63	12.9
	7.0-5.8	2.35	0	0

[1]From Stump island toward Midway Islands.

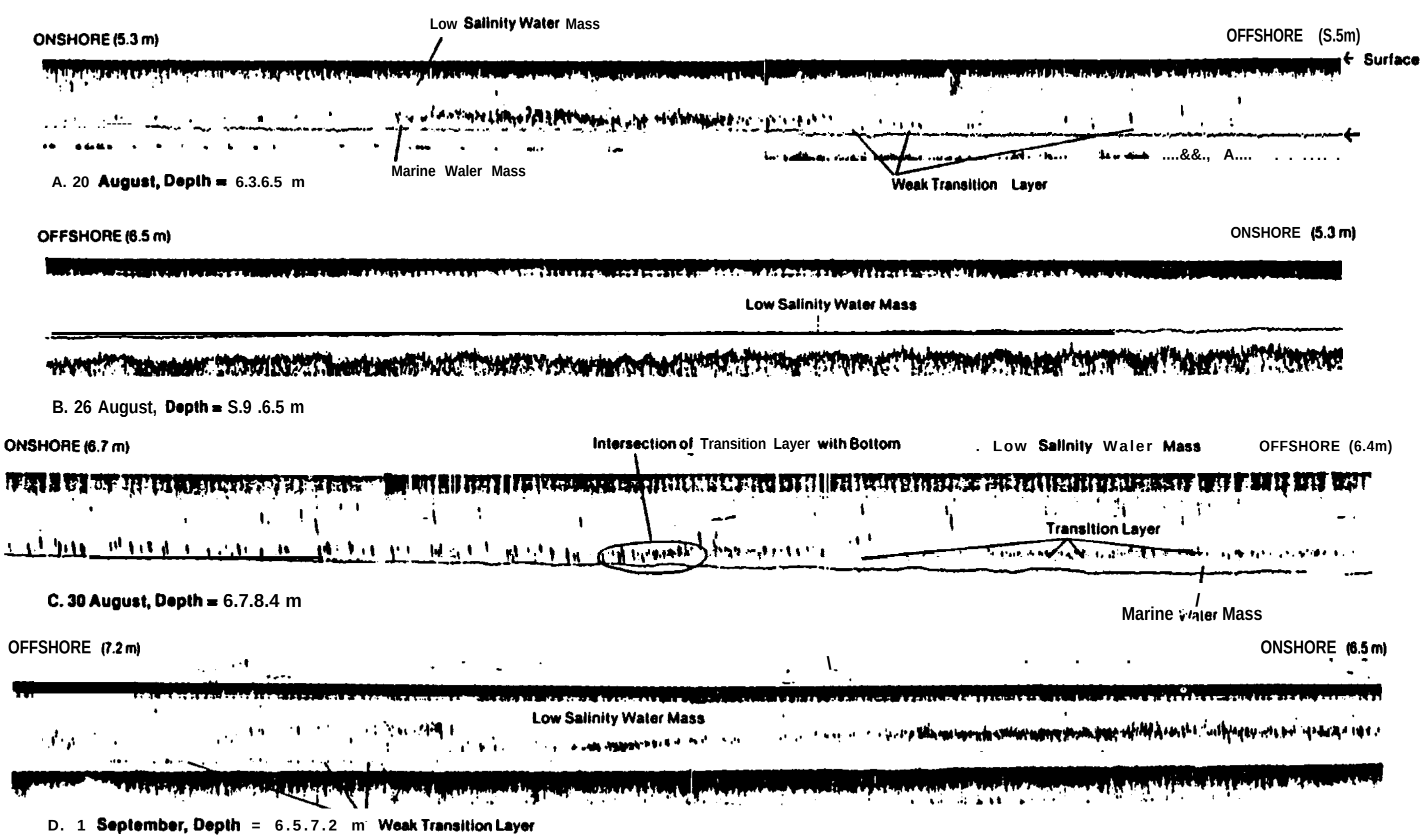

FIG. S. Representative echograms from hydroacoustic transect 2 during 28 August- I September 1979, illustrating the association of fish targets with the two water masses and transition layer. On 28 August the transition layer is weak and diffuse, on 29 August it is absent, on 30 August it is strong and continuous and on I September the transition layer is weak and appears to be mixing srnd dissipating (each strip represents approximately 2 km of transect).

September data, some differences between transects within days were noted. During 28 August, the concentration of targets between 4.0 and 5.8 m was strongest along transect 2 and moderately strong along transect 3. The concentration of targets was limited to the nearshore region along transect 1 and completely absent along transect 4, where the scattering was inshore at depths of 2.4-3.7 m. During 30 August, the fish concentration was again greater along transect 2 between 6.7 and 7.9 m bottom depths. The distribution along transect 1 was similar, though less dense and more inshore (Fig. 5). On transects 3 and 4, high fish concentrations were limited to the outer end of the transects, which terminated just as the water depth began to shallow on the barrier island side.

During the 12 hr of fixed-location monitoring in August, a total of 51 targets were observed – a rate of 5.5. hr^{-1}, corresponding to 15.8 fish per 104m3. Considerable variability was observed between the two days in the depth of the echoes, possibly related to the species present. On 31 August targets were near bottom (6.0-6.4 m), while on 1 September targets were 2.4-3.6 m below the surface. A diel trend was suggested by the lower densities during afternoon.

DISCUSS1ON

The summer 1979 water sampling revealed a dynamic system with two water masses: a warm, low-salinity water mass on top of a cold, high-salinity water mass. The depth to the transition layer (or interface), as measured by CTD, between the two masses varied from 1.5 m to >10 m throughout the study area during the July and August sampling periods. The depth to the transition layer generally increased during the season, probably as a result of mixing by wind action and reduced ice melt and river discharge. Arctic cod also showed a net offshore movement to deeper water between the July and August trawling periods. The move to deeper water did not appear to be an artifact of the trawl sampling, as the solitary kelp snailfish did not show a change in depth between sampling periods.

An association between the leading edge of the marine water mass and arctic cod distribution is indicated by the hydroacoustic measurements. In general, the highest measured fish densities were at the bottom of the warmer, less saline water mass immediately above the intersection of the leading edge of the marine water mass with the bottom. This association was particularly evident during the 28-30 August transect series. On 28 August high fish densities were recorded near bottom along the transition layer at 6-7 m. On 29 August the marine water mass had either mixed with the low-salinity surface water mass or had moved out of the study area because of changes in wind stress, and high fish densities were not observed. However, on 30 August the marine water mass was again observed in the study area (at 7.6 m on transect 2) and high demersal fish densities in front of the leading edge of the marine water mass were again observed. Pelagic fish targets were oriented above the transition layer, offshore of the leading edge of the marine water mass. During July, when few fish targets were encountered, arctic cod were in shallow water (mean bottom depth of capture = 2.7 m) and could not be detected by hydroacoustic ,echniques. The transition layer between the two masses was at 2.5-3.6 m; thus both the intersection of the transition layer with the bottom and high fish densities were inshore of the hydroacoustic transects.

Additional support for the hypothesis that arctic cod position themselves shoreward of the transition layer is provided by data in Craig and Haldorson (1981) and Chin et af. (1979). A massive influx of age 1-3 arctic cod at Milne Point in Simpson Lagoon and along the west side of the West Dock was reported beginning on 14 August 1978 (Craig and Haldorson, 1981). In addition, the second highest otter trawl catch rate recorded in the present study during 16-21 August 1978 sampling ,was in the shallow waters of Prudhoe Bay, an area where catch rates were lowest during 1979. On 13 August 1978, the marine water mass approached to within at least 1.5 m of the surface throughout much of the area, including along the Stump Island, West Dock and Prudhoe Bay subareas (Chin et *al.,* 1979). Arctic cod orienting to the area where the transition layer intersects the bottom thus would have entered depths of approximately 1 m or less and would almost certainly have migrated into Simpson Lagoon as well as into Prudhoe Bay. Catches of arctic cod in Simpson Lagoon remained high until 22 August 1978, then declined as cod moved out of the lagoon (Craig and Haldorson, 1981), presumably in response to the reestablishment of a deeper transition layer offshore.

The pattern of arctic cod catches recorded by Griffiths and Gallaway (1982) appear to be similarly influenced by periodic upwelling events. Arctic cod catches in fyke nets placed along the shoreline were typified by sharp peaks in catch rates, lasting 2-3 days, separated by 9-14 days of low or no catch (Griffiths and Gallaway, 1982:Fig. 16). In each case, the sharp increase in catch rate was accompanied or followed by a sharp increase in salinity. Such a pattern would be expected if the arctic cod are orienting to the leading edge of the marine water mass and are moving inshore in advance of upwelling marine waters.

The indication is that demersal species, such as arctic cod, and some pelagic species, possibly arctic char and cisco, position themselves according to the upper edge of the marine water mass and move inshore and offshore in response to the presence of this transition between water masses. The composition of the scattering Iayerobserved at the transition between the two masses was not determined but may contain biological or detrital components. Plankton samples from the vicinity of the transition layer contained significantly more fish larvae than surface samples (Tarbox and Moulton, 1980) and appeared to contain higher densities of copepods and mysids. The concentration of fish larvae and invertebrates may attract arctic cod, which are known to feed on mysids and copepods. Similarly, the presence of arctic cod could attract their predators, i.e., arctic char. Thus the apparent association of fish with water masses may reflect a predator-prey relationship. The reason the biological activity is concentrated at the transition layer between the water masses is as yet unknown. The probable explanation is that there is increased primary production along the front between the marine water mass and the surface water mass, such as is found in the eastern Bering Sea (Goering and Iverson, 1981). The deeper marine water contains higher levels of dissolved nutrients, which stimt.dates primary productivity when exposed to sunlight at the mixing zone with the warmer surface water. In the Bering Sea, such a transition area is characterized by intense biological activity (Hood and Calder, 1981). It is likely that arctic cod and other fish remain in (he warmer surface water mass to maximize energy conversion during the two- to three-month summer feeding period, since metabolic activity in poikilotherms must be minimal in the cold (<-l ”C) marine water mass.

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Ecological studies of Arctic cod (*Boreogadus saida*) in Beaufort Sea coastal waters, Alaska

P. C. Craig, W. B. Griffiths, L. Haldorson, and [illegible]

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Interest.

ON MASS CONGREGATIONS OF THE CRYOPELAGIC COD FISHES (BOREOGADUS SAIDA AND ARCTOGADUS GLACIALIS) IN CIRCUMPOLAR ARCTIC BASINS.

by

A. P. Andriashev, B. F. Mukhomediyarov,
and E. A. Pavshtiks. 1980., pp 196-211,
In: M. E. Vinogradov and I. A. Melnikov
(Eds), Biology of the Central Arctic Basin.
Shirshov Instit. Oceanology, Academy of Sciencies, U.S.S.R.

Translated by Douglas W. Nelson, College of Fisheries,
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August, 1981

Andriashev, A. P.; B. F. Mukhomediyarov and E. A. Pavshtiks. 1980. On mass congregations of the cryopelagic cod fishes (Boreogadus saida and Arctogadus glacialis) in circumpolar Arctic basins. In: Biology of the Central Arctic Basin. Shirshov Institute of Oceanology AN SSSR. pp. 196 - 211.

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The drifting stations "North Pole", besides dealing with basic research problems, also provided an opportunity of acquiring extraordinarily valuable materials dealing with the biology of the high latitudes of the Arctic basin. As a result of many years of creative research by the department of hydro-biology of the Zoological Institute, AN SSSR and by the collaborations of the Arctic and Antarctic Scientific Research Institute on the drifting stations, — beginning with SP-2, year-round plankton samples were collected using standard methods. Principally due to [these] collections new data were acquired regarding the species composition of the plankton of the Central Arctic, on its vertical distribution and relationship to the water masses, [and] its seasonal and multi-year dynamics' (Virketis, 1957, 1959; Brodskiy, Nikitin, 1956; Pavshtiks, 1971, 1979; Brodskiy, Pavshtiks, 1976; and others). The data collected by the polar explorers on the SP stations regarding high latitude fishes were not of great volume or significance, but presented considerable interest. Thus, ? among the material of S%6, drifting in the high latitudes of the East Siberian Sea, was a very poorly studied species of cod fish, Arctogadus glacialis; established as new to the fauna of the USSR, which previously was known from the shores of Greenland (Andriashev, 1954, 1957). Observations and collections of fish were taken during the studies on the series of drifting SP stations, as a result of which it was established that in the circumpolar Arctic region (80°-88.5° N. Lat.) under the pack ice live two species of cod fish" (Boreogadus saida and Arctogadus glacialis), which at times are present in huge schools, easily accessible for harvest [fishing operations]. This fact has importance [is significant] in understanding the functional structure of the pelagic ecosystem of the Arctic basin, and presents also some practical interest as a possible source of supply of fresh fish for the different participants of the polar expeditions on both transport ships and icebreakers working in the high latitudes of the northern shipping routes. It is appropriate to recall the many endurances of disasters by polar expedition participants who perished from hunger, not suspecting that they had supplies of food under foot.

Ichthyological materials were made available to us by the following workers [colleagues] of the drifting stations: V. I. Shil 'nikov (SP-4), E. M. Gush-" chenkov (SP-6), V. I. Ulitin (SP-10), E. V. Konstantinov and K. I. Grachev (SP-16), N. I. Blinov (SP-17), V. S. Antonov and G. L. Pavlov (SP-19), A. T. Bozhkov (SP-23) and others. To all these polar explorers, [for their] manifestations of attention and initiative in the collection and preservation of the captured fish [fish specimens], the authors express their profound appreciation.

Material and Methods

Besides the written-down observationsjboth verbal reports about conditions and results of under-the-ice fishing, sizeable collections (frozen or in ethanol) were delivered to the Zoological Institute from seven drifting SP stations, belonging to to two species --- saika, or polar, cod (Boreogadus saida) and the ice, or black, cod" (Arctogadus glacialis); see tables–2–and 5.

The greatest collections of fish, both the most systematic and with the most complete notes,(phenological notebook from 9 May 1968 to 30 March 1969) were kept by E. V. Konstaninov and K. I. Grachev at station SP-16, which drifted for the greater part of the year above the pseudo-abyssal depths in the region of the Canadian trough of the Arctic basin (depths greater than 2000 m), located approximately at a midway point between Vrangelia and the north pole. In the journal of this station it appears that distinctive small cod fishes are recorded from the hydrological holes and in the ice fissures during the whole year, and were observed and captured in massive quantities from the end of November to the end of March, in April the fishing ceased. The fishing at different timeswas conducted between the surface and the 25 m depth using different methods: with baited hooks, with a net for cleaning the hole of ice splinters, and with a short gaff. The first mass appearance of fish was observed on 27 November when on hooks baited with meat 450 fish 7-20 cm long were taken in 4 hours. In the following days of November and the beginning of December fish were caught on hooks almost daily at the rate of several scores and hundreds of specimens. On 11 December "fish swarmed in the hole" and by hook and by ice net more than 1600 fish from 8-12 cm long (predominant amount) to to 17-21 cm long were easily caught. In all, in the phonological journal of

SP-16 notes were made about fishes 90 times (days), 15 of these times regarding visual observations (from observations of a single fish to "schools of thousands") and 75 times fish were caught, and for these the quantity of captured fish was noted, depth and capture gear, and minimum and maximum lengths of the captured fish. Data on the number [quantity] of fishermen and captured fish, of course, is dependent on different factors -- on the degree of employment of observation [the time spent in observation] by the polar scientists and [their] work experience [literally; economy of work], on yearly factors, on disturbances caused by rather frequent occurrences of bears, etc. Due to these factors, the figures from the various months are difficult to compare, but, nevertheless, they present in themselves definite interest (Table 1).

From Table 1 it appears that from the end of November to the end of March in the higher latitudes (80°04′ to 81°23.5′ N. Lat.) on the meridian of Vrangel Island under the pack ice schools of these fishes are present constantly, the most successful collections [literally; methods] (schools of thousands) were noted during almost the whole month of December (from 7 to 24) and during the first half of the month of February. Comparison of the notes in the journal with specific composition of the recorded [preserved] samples of fish (see Tables 2 and 5) demonstrated that among the fish rePorted as "ice cod" in reality were not only Arctogadus glacialis, but also Boreo-SK&. saida. The account of the measurements of the fish in the catches does not give guarantees of [correct] specific determination, but all the analyses merit consideration. So, the smallest sizes of fish in the mass captures change rather naturally: in November, according to the notes in the journal, the smallest length (5[1]) was --.7 cm, in December -- 8 cm (very many), in January -- 8-10 cm, in February -- 10-11 cm. Such measurements are able to be correlated with increasing length from November to February of saika of age group 1+, however, this may also be the young of the ice cod, the development of which is not known. Except for these, it is possible to identify "saika" in the notes of the journal, swimming in the hole individually or in schools (but not captured): on 25 May "saika" about 3-4 cm long were observed twice; on 16 June 2 "saika" about 6-7 cm long; in the second half of November -- separate schools of fish from 5 to 7 cm long; on 6 January in the hydrological

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[1] Approximate length of the swimming juveniles in the hole, but not the captured juveniles.

hole "one small fish 2.5 cm long swam".

The greatest measurements of captured (but not preserved) fish in November-January were rather uniform, around 17-19 cm, rarely to 20-22 cm, but in February-March the fish were noticably larger:' in the first half of February the maximum lengths in every catch were up to 23.5-30.5 cm, and in the second half of February to 30-38 cm, and in March -- to 30-43 cm. With respect to this it is important to note that in the preserved sample from SP-16 (7 samples; 167 specimens) the greates length of B. saida most frequently did not exceed 15-17 cm, rarely to 18 cm.

All this provides a basis to propose that from November to January saika on the whole were present in mass sub-ice catches, and in February and March the ice, or black, cod (A. glacial is) predominated. This inference from the journal notes corresponds with the actual composition of the preserved samples; in these [samples] A. glacial is was only in the February and March samples and only one time (SP-10; 75°32' N. Lat.) was taken in the second half of January; during the remainder of the months in all collections from the drifting stations only saika were found (see Table 5). In truth, in the phonological journal of SP-16 are [present] individual notes about relatively large fishes (i.e. supposedly about black cod) in December. Regarding the mass catches on 23-24 December (by means of hooks nearly a thousand fish were thrown on the ice), the length of one fish was 23.5 cm, and on 8 Decenber "in the hole swam a fish nearly 30 cm long, swallowed the bait with the hook, threw the hook [literally; tore away] and left". In this way, A. glacialis, apparently, is found at sub-ice levels in December, but probably more rarely than saika.

Some conclusions, from the notes of the journal, are able to be made regarding the depths of the fish aggregations. In the dark time of the year (November-February) all the fish, possibly attracted to the electric light, were caught close to the surface (not deeper than 2-3.5 m), and, therefore, for the capture net and gaff were employed. In the second half of February they [scientists] more often caught the fish on hooks at depths of 5-15 m, and in March, with the appearance of the sun, the fish stayed deeper and at the end of March were mainly caught at depths of 10-25 m.

This, unfortunately, restricts the conclusions which are able to be considered more-or-less real to the basic analyses of the notes of the phonological journal of SP-16. This applies to the samples of preserved specimens of fish, of which were taken 136 X-ray photographs of saika and 30 of ice cod for the study of variability in the numbers of vertebrae and some other meristic characters; 19 Specimens of A. glacialis had a determinable age[1] (F. B. Mukhomediyarov), and several score fish of both species had the stomach contents examined and identified (E. A. Pavshtiks). The authors also gratefully acknowledge the assistance rendered by O. L. Khristoforov (Leningrad University) for identification of the gonadal conditions of both species.

Arctogadus glacial is 'Peters' (Fig. 2)

Material. 30 specimens total length 136-412 mm (Table 2, Fig. 1).

From 30 specimens: ID 10-13, usually 11-12, IID 16-21, often 21-23, IIID 20-25, usually 12-23, IA 19-24, usually 20-22, 11A 19-25, usually 21-22. In the first interdorsal space (between ID and IID) the are no free (not attached to rays) interneuralia (Andriashev, 1955), but such supporting elements are well developed in the second interdorsal space (4-8, usually 5-6), and similarly in the interanal space (3-8, usually 5-7" free interneuralia). In the caudal fin all the bordering [literally; along the edge] rays were counted, including,the<anteriormost, very short [rays], usually 51-53 rays (23-25 + 4 + 23-24), only 4 rays articulate with the urostyle vertebra "[ural centrum] (to a single, much reduced hypural); the bordering rays extend anteriorly to above the llth (from the final) vertebra. Trunk vertebrae 19-21, usually 20, caudal vertebrae 38-40, total vertebrae 58-61, usually 59-60, mean 59.39 (Table 3). Gill rakers on first arch 28-34, pyloric caecae 29-35.

Teeth on palatines usually well developed, although variable in number (5-12), in a single basal row; in one specimen 29 cm long palatine teeth absent, although in other characters this specimen did not differ from the rest of [the specimens of] A. glacialis; this was observed in American fish (Nielsen, 1967).

The chin barbel was absent in our specimens, either present as a rudiment or a small knob in [this] species or reduced to a slight, triangular [fleshy] appendage; more rarely in our locality a rudimentary barbel less than 2 inn long was developed.

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[1] For future collections done on SP [stations] bear in mind the following: in all the specimens of B. saida kept for a long time in a frozen state, the

The scales [literally; fish scale covering] are typical for cod-fishes -- the scales overlapping in a tile-like fashion, more or-less elongate, cycloid, small; there are no scales or bony plates with spines.

Color dark, dorsal part, sides and ventral part of head blackish-cinnamon, as also is the body, only somewhat lighter on the sides and abdomen; all fins black. Peritoneum blackish-cinnamon. Young specimens colored noticeably lighter.

Age was determined by F. B. Mukhomediyarov using scales and otoliths from 19 large specimens; in the sample 7-year olds predominated (Table 4). The most intensive growth takes place in the first 3-4 years of 1 ife, judging from the wide and clear first rings [annuli] on the otoliths, at [after] this time the rings of subsequent years [become] more narrow.

In the collections from the Canadian Arctic the standard length of most of the specimens was equal 325 mm (Nielsen, 1967), in our material only for two specimens was it [size] greater -- 331 and 377 mm.

In females of standard length 27 cm and greater gonads were found [to be] in the beginning of stage III of maturity (beginning of trophoplasmic growth); apparently these female comparatively recently (not more than 2-3 months before) had spawned. ,The largest of the females (total length 412 mm) had filamentous-like reduced gonads, probably as a result of the physiological "ageing process (Khristoforov, 1978).

The food of adult ice cod is composed of fishes (apparently saika 8-12 cm long), relatively large amphipods Lagunogammarus wilkitzkii ,'Apherusa glacialis, 'Pseudolibrotus "nanseni, Parathemisto libeliula and others [identified by N. L. Tsvetkova), [some] part of which inhabit the lower surface of of the floating ice, that is, perhaps related to cryopelagic forms (Andriashev, 1967, 1976, 1978; Averintsev, Golikov, 1977; Mel'nikov, Kullkov, 1980), small planktonic crustaceans from Calanoida (Calanus hyperboreus , Pareuchaeta glacialis, Metridia longa and others) are found in the stomachs of ice cod noticeably less often [literally; more rarely] than in saika, but the luminescent ~: longa are taken fairly frequently.

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[1] (cont. from preceding page) otoliths were not whole, but in fragments (seen well in X-ray photographs), and only in one sample, preserved in ethanol, were all the otoliths preserved well.

Walters (Walters, 1961) observed mass congregations of A. glacialis also in the wintertime (from the end of November to the beginning of January) approximately in this region, but 200 miles to the south (near 77° N Lat.). Since in Walters' material mature females were absent, he concluded that sub-ice congregations of A. glacialis were tied to wintertime feeding migrations (stomachs were filled "with small crustaceans").

Boreogadus saida (Lepechin)

Material. 176 specimens, 64-248 mm long (.Table, Fig. 3).

By means of X-ray photographs of 136 specimens the variability in the number of vertebrae in saika at SP-16 was examined: (54) 55-57, usually 56, mean 55.79; of these, trunk vertebrae 18-19 (20), mean 18.59, "caudal vertebrae (35) 36-38 (39), mean 37.25 (Table 6). 'From Table 6 may be seen considerable uniformity of the different sample in mean number of vertebrae. In truth, one may notice that the mean in the samples increases somewhat from November to February, that basically these [increases in means] are correlated with the small 'increases in positions of latitude of SP-16 from 80°15' N Lat. to 80°53' N Lat. However, the paucity of material and the small displacements of SP-16 to the north are quite insufficient for conclusions regarding latitudinal variations in numbers of vertebrae.

The scales [literally; the scaly integument] of B-; saida clearly differs from all other representatives of the family Gadidae in two morphological features: (1] very small, oval, cycloid scales, arranged in rows with [respect to] each other, sometimes touching on the edges; but not overlapping each other in a tile-like fashion, as is the case in the remaining cod-fishes (Jensen, 1948; Andriashev, 1954; Nielsen, 1967); (2) besides the usual scales, on the body are many bony plates, each of which is equipped with [bears] spines with blunt tips dorsally and posteriorly directed. These spiny plates are well seen in radiographs and stain much more intensively with alizarin than the scales, arranged along the entire body, except for the head and back [dorsal body surface] in front of ID, and make the surface of the body rough to the touch, as is emery paper. Using the alizarin preparation well differentiated all the different states of development of the spiny plates from formation of little spines on the edges of common flake-like scales, which, gradually expanding, form the individual basal plates with the spine, reminiscent of small plate-like scales. But this feature of acaly integument, unique among cod fishes, merits special examination with detailed photo-documentation.

In our preserved samples from the drifting stations saika of total lengths from 8.5 to 18-19 cm predominate. These in the majority were sexually immature individuals around 16-17 cm, which were not ripening for the next spawning. However, together with these are found fishes 16-19 cm long, which according to the findings of O. L Khristoforov, will [would] participate in the next spawning: these were males in stage IV maturity and females in stage III, having oocytes of incomplete trophoplasmic growth with diameters of 0.6-0.9 mm. Besides these, in the samples are isolated large individuals (to 25 cm) with threadlike, reduced gonads as a result of physiological ageing. Such a for< [the stage IV males and stage III females] in the basic mass of sub-ice schools of saika in near-polar latitudes makes up [constitutes] the first-time ripening individuals, only part of which will participate in the next spawning.

The food of saika from SP-16, identified by E. A. Pavshtiks from 30 stomachs, usually consisted, in the" central Arctic, of species of planktonic animals, basically Calanoida -- Calanus hyperboreus, C. glacialis, Pareuchaeta glacialis, Chiridius obtusifrons, Pseudocalanus major and infrequently Metridia longa (in 230 specimens, in only one stomach). Metridia in the North Pole region makes up (in numbers) about 15% of the zooplankton (Pavshtiks, 1977) and, although its population density did not exceed 10 specimens per m^3, the ability of this copepod to be bioluminescent makes it easily attractive to fish in the polar night. Besides Calanoida in the stomachs were found Hyperiidae "(Parathenlisto libellula juvenile and adults), cryopelagic species of amphipods, mostly young stages (Lagunogammarus wilkitzkii, Apherusa glacial is, Pseudolibrotus "nanseni and others), Harpacticoida, Lirnacine, juvenile stages of Euphausiacea, chaetognaths, Oikopleura and other Arctic planktonic organisms, and also small fish.

Thus, the winter diets of saika and ice cod are rather similar, but in the saika small, planktonic crustaceans predominate, and also young stages of cryopelagic amphipods, at this time in A. glacialis, besides Calanoida, an important role [in diet] is played by fish and by large Amphipoda.

Regarding further studies of the winter diets of these species of cod-fishes attention has been paid to the following topics. In the surface waters of the central Arctic the biomass is shallower during the light months, in the winter the zooplankton moves down to the depths. So, according to material from SP-17, in the winter of 1968-69, the biomass of plankton increased at depths of 100-250 m 4-5 times in comparison with the light period as a result of migrations from the surface layers (Pavshtiks, 1971). But also in the wintertime, along with the minimum plankton biomass, in the sub-ice layers in the high Arctic latitudes mass congregations of A. glacial is and B-. saida were observed on drifting Soviet SP stations, and also on the American station "Charl ie" (Walters, 1961). Whether or not the sub-ice (cryopelagic) and other Amphipoda, the quantity of which during the winter is close to the surface, for example in the Nansen Basin, play a positive role [an important role] here, it [quantity] is noticeably increased (Rozinante fragilis, Lagunogammarus wilkitzkii, Eusirus holmi, Pseudolibrotus nanseni, P. glacial is and others; Pavshtiks, 1971).

On the Cryopelagic Fish Species

New data on the dispersal of saika and ice cod in the sub-ice waters of the high latitudes of the Arctic basin give a basis for briefly considering characteristics of particular categories of ecological forms -- cryopelagic species. It is generally accepted to consider every kind of ice as a negative factor [detriment] for the existence of life in general and for fish in particular. However, for a long time it has been known that in Arctic and Antarctic waters exist species of fish which spend [their] lives to a considerable extent in the midst of landfast and drifting ice. A preliminary [primary] characteristic of these. fishes, called [named] cryopelagic (Andriashev, 1968; Parin, 1968), in an original paper by one of these authors was presented to the Symposium on Antarctic Biolgy in Cambridge (1968) in a lecture: "Cryopelagic fishes of the Arctic and Antarctic and their significance in polar ecosystems" (Andriashev, 1970).. Since this lecture, Which had a direct relationship to the original paper, was not published in the national press, but was printed in an obscurevolume of the transactions of the aforementioned symposium only, we permitted ourselves [took it upon ourselves] i.n thesis form to print some of the findings of the report, supplementary to these recent unpublished findings) regarding this problem (Andriashev, 1976, 1978).

The term "cryopelagic" was suggested for fishes of polar seas, actively swimming in the water column [literally; mass of water] (both in the range of the continental shelf and over great depths), but in its life cycle more-or-less closely constrained by landfast or different kinds of drifting (among these also pack) ice. Juvenile, just as adult, individuals of the cryopelagic species of fish are frequently observed under the lower surface of the ice in the midst of the mass of partially-frozen-crystallized ice plates or in current holes and holes melted in the ice, where they find a refuge for themselves from numerous predators (seabirds, seals, cetaceans, predatory fishes) and, at the same time, feed on small crustaceans and other planktonic organisms and ice and sub-ice diatoms essential in considerable part in the maintenance of primary production. In Antarctica 'the basic cryopelagic "[fish] species represented are two species of "wide-head" [literal translation of Russian common name-- "shirokolobik"] -- Pagothenia borchrevinki (Boul.) and Pagothenia brachysoma (Pappenh.) from the family Nototheniidae. The first accounts of behavior of fishes in ice were done by Capt. James K. Ross, who observed that fishes of the species "Notothenia phocae" (contemporarily named Pagothenia brachysoma; see Andriastiev, 1976) lie concealed from the pursuit of predators 'in cracks and hollows in the pack "ice, and saw that they threw themselves from their refuge when the ship struck the ice or "passed over them (Ross, 1847). Many similar observations have been made in the Arctic with relation to saika -- observing [literally; seeing] that it is churned up from the lower surface of the underside of the ice by the icebreaker, from whence they are caught behind the icebreaker by the following gulls and also skuas. Along the shores of Greenland Jensen [Jensen, 1948) observed that fishes, identified as Phocaegadus megalops [='Arctogadus glacialis], pursued by seals threw themselves onto the ice through the holes and between the cracks in the ice-floes. These simple, but reliable [careful] observations are more precise in our period of underwater biology, both in Antarctica and in the Arctic. Thus, the thought expressed for the first time by Capt. J, K. Ross (Ross, 1847) regarding the bipolarity of existence, constrained by ice, of living forms of fishes ("Merlangus polaris" or saika and its replacement [substitute] at the southern extreme "Notothenia phocae") has received confirmation and elaboration [literally; precision] in contemporary studies. More than this [moreover], it was demonstrated that ice acts [serves] as an essential biotope not only for the detached [free-swimming] cryophilic species, but also for closely associated biocoenoses -- such as cryopelagic amphipod-diatom [associations] (Andriashev, 1967, 1978; Gruzov, 1974; Golikov and Ave-intsev, 1977; and others). It is interesting that trophic, and in large part the taxonomic structure, of these biocoenoses are greatly similar: ice (planktonic and attached) diatoms -- crustaceans, chiefly amphipods (Cheiromedon fongneri, "Pontogoneia Antarctica, Paramoera walkeri and others in Antarctica, Lagunogammarus wilkitzkii, "Apherusa glacialis and others in the Arctic) -- fish (nototheniids in Antarctica, cod-fishes in the Arctic) -- sea birds [penguins, procellariforms in Antarctica, gulls, guillemots, and others in the Arctic) and marine mammals (Antarctic seals and minke whale and others in Antarctica, Greenland seal, bristly seal, beluga whale, narwhal and others in the Arctic). The presence of mass sub-ice congregations of two species of cod-fish in the high latitudes of the Arctic makes more precise some of the features of the problem under investigation, but in the majority [in large part] much effort by polar ecologists is required in order to more fully interpret and quantitatively evaluate the role of cryopelagic fish in the polar ecosystems of the seas of both hemispheres.

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Figure Captions

Fig. 1. (p. **200).** Occurrences of Arctogadus glacial is according to the collections of the drifting stations “North Pole”, 1957-1977.

Fig. 2. (p. 204). Ice, or black, cod (Arctogadus “glacial is) SP-16, 30 March 1969. Total length 412 mm.

Fig. 3. (p. 207). Occurrences of **Boreogadus saida** according to the collections of the drifting stations “North Pole”, 1955-1973.