Arctic Gas

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FISHERIES INVESTIGATIONS ALONG THE NORTH SLOPE FROM PRUDHOE BAY, ALASKA TO THE MACKENZIE DELTA, N.W.T.

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CANADIAN ARCTIC GAS STUDY LIMITED

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CHAPTER I

WATER AVAILABILITY
NG THE PROPOSED ARCTIC GAS PIPELINE ROUTE
FROM PRUDHOE BAY, ALASKA,
THE MACKENZIE DELTA, NORTHWEST TERRITORIES

M.L. JONES

ABSTRACT

A water availability study was conducted along the Prime Route of the Arctic Gas Pipeline from Prudhoe Bay, Alaska, to the Mackenzie Delta, Northwest Territories.

The purposes of this study were to:

1) identify potential water sources along the pipeline route,
2) determine the volumes of water available from these sources,
3) compare the volumes of water available with the estimated volumes of water required,
4) assess the environmental impact of water withdrawn from the potential sources, and
5) present recommendations regarding maximum withdrawal rates, construction procedures, etc., to minimize potential damage to aquatic habitats.

The major conclusions and recommendations of this study are:

1) There are more than adequate quantities of water available to meet the estimated water requirements of the pipeline. Overall, the total estimated water requirement of 8,222,000 bbl would amount to slightly more than 1% of the approximately 550,967,000

bbl available in the lakes surveyed. In addition, the springs surveyed discharge approximately 5,807,000 bbl/day, slightly less than the total estimated water requirement.

2) Water can be safely withdrawn from most of the lakes surveyed, provided that no more than 10% of the total volume of any one lake is withdrawn.

3) Water can be safely withdrawn from most of the springs surveyed, provided that:

   a) water is withdrawn from a single point downstream of fish concentrations and spawning areas, and that collection areas are screened to prevent the entry of fish,

   b) natural spring channels are not excessively rechanneled or closely paralleled by access roads,

   c) angling is strictly prohibited.

It is further recommended that:

1) additional site-specific biological, hydrological, and engineering studies be conducted as final selections of water sources are made;
2) during the development of water sources and during water withdrawal, locations with known spawning or overwintering populations of fish be individually monitored by a fisheries biologist familiar with the lakes and springs of the North Slope.

ACKNOWLEDGEMENTS

I wish to acknowledge the help that many people have given during the course of this study. Field assistance was provided by W. Melhorn; editorial assistance by P. McCart and J. McCart; laboratory assistance by G. Williams; and manuscript assistance by C. Gossen, J. McCart, S. Whiston, and J. Harris.

The Arctic Gas Biological Report Series, of which this report is a part, is a series of consultant project reports presenting data based on field and laboratory studies. The format and presentation vary in accordance with the authors' discretion.

The data for this work were obtained as a result of investigations carried out by Aquatic Environments Limited for Canadian Arctic Gas Study Limited and Alaskan Arctic Gas Study Company. The text of this report may be quoted provided the usual credits are given.

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INTRODUCTION

Winter construction of the proposed Alaskan and Canadian Arctic Gas Pipeline will require large volumes of fresh water for the construction of ice and snow roads and for domestic use in the construction camps themselves. Other major uses of water include hydrostatic testing and ditch flooding. Overall, water requirements will be greatest in the first months of winter when the ice and snow roads are under construction, and will diminish later in the winter. In some cases, construction camps will require dependable supplies of high quality water throughout the winter.

The purpose of this study was to identify water sources along the proposed pipeline route from Prudhoe Bay to the west side of the Mackenzie Delta, and to assess their withdrawal potential in relation to the estimates of water requirements prepared for each pipeline segment and camp along the route.

The study was based on a review of the pertinent literature and field surveys along a 300 mi by 10 mi corridor from Prudhoe Bay, Alaska, to the Mackenzie Delta, Northwest Territories (Figure 1). The objectives of these field surveys were to obtain the following:

a) depth information for lakes considered potential water sources,

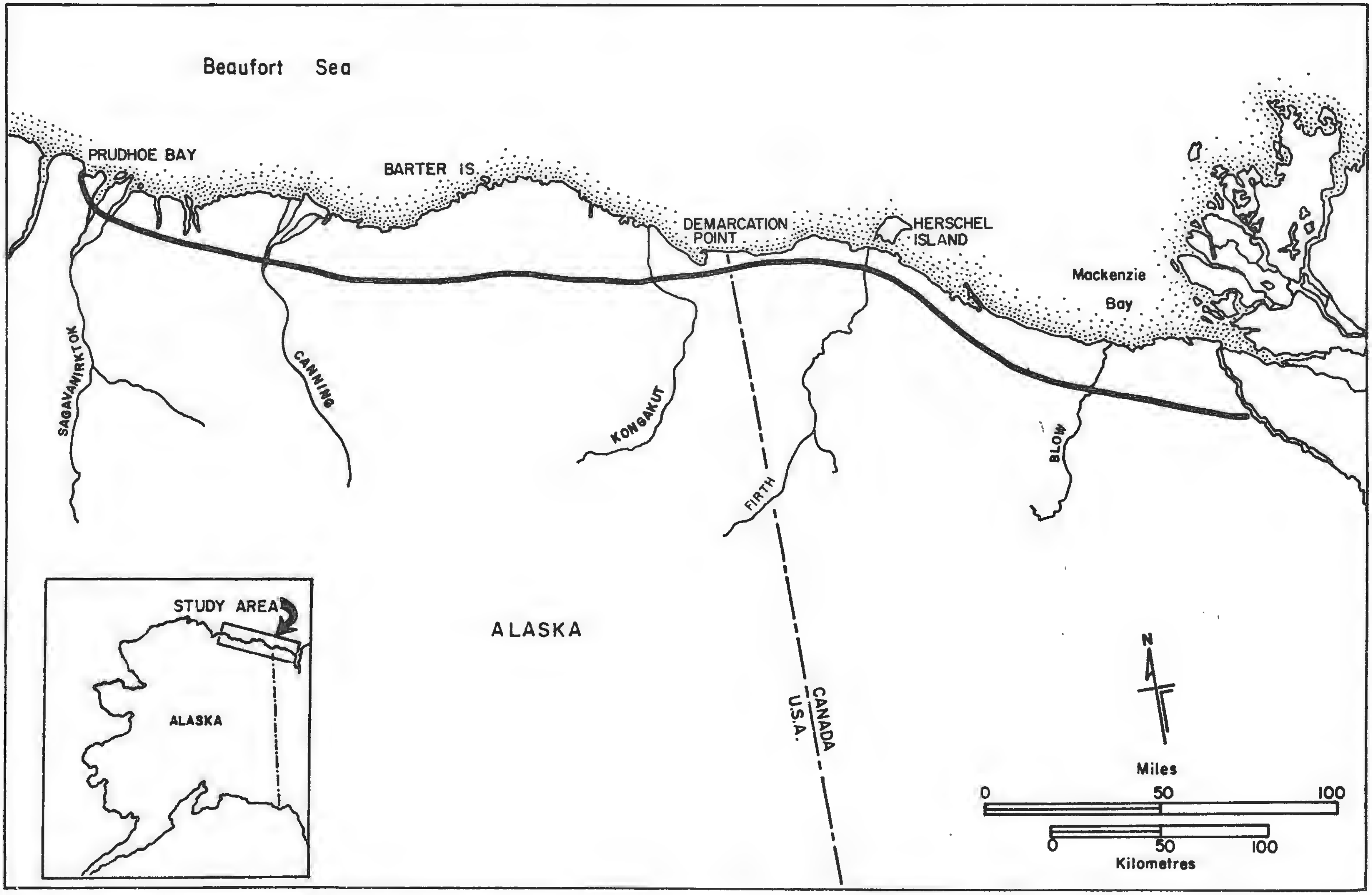

FIGURE 1. Study Area. The pipeline route from Prudhoe Bay, Alaska, to the Mackenzie Delta, Northwest Territories.

b) discharge information for springs considered potential water sources,

c) water samples from lakes and springs to determine basic water chemistry, and

d) information on fish utilization of lakes and springs considered potential water sources.

Additional information including discharges, ice thickness, and water chemistry was obtained during a joint Alaskan Arctic Gas Study Company (AAGSC) and United States Geological Survey (USGS) winter trip to Alaska during November, 1975. Aquatic Environments Limited (AEL) personnel were present during part of this trip and the information obtained has been incorporated into this report.

In addition to fisheries information obtained during the course of this study, data are available from previous fisheries surveys along the pipeline route in Alaska and the Yukon and Northwest Territories. These data are referred to in subsequent sections of this report.

For this study, fisheries effort consisted of the following:

a) gillnetting lakes which were potential water sources, and for which no previous fisheries information had been gathered, and

b) surveying springs during the fall of 1975 to determine the distribution of fish.

Some springs along the pipeline route are already known to be spawning and overwintering areas critical to the survival of populations of Arctic char and grayling (Craig, 1973). In addition, some of the deeper lakes along the pipeline route support overwintering populations of one or more species including Arctic char, lake trout, grayling, whitefishes, ciscoes, pike, pond smelts, and sticklebacks (McCart *et al.*, 1974; de Graaf, 1973). Water withdrawn from these critical spawning and overwintering sites should be carefully regulated to avoid possible damage to fish populations.

METHODS

During the fall of 1975, AEL conducted field surveys at 51 lakes and 18 springs along the Arctic Gas Pipeline Route from Prudhoe Bay, Alaska, to the Mackenzie Delta. Generally, in areas where there was an abundance of potential water sources, only a few of the larger lakes within a 5 mi strip on either side of the prime pipeline route were examined. In areas where potential sources were few, the corridor was expanded to encompass the nearest lakes or springs that could be considered potential sources of water.

A helicopter equipped with floats was used for transportation and as a platform for sounding water depths and obtaining samples from lakes. Depending on their size, lakes were sounded at three to six stations along the longest axis. Average depths were calculated from these soundings, and, along with areas (obtained from 1:50,000 scale maps using a planimeter), used to calculate approximate volumes.

Water samples were taken with a 3 litre Kemmerer bottle at a depth of 1 m near the centre of the lake. Dissolved oxygen values and temperatures were determined in the field using a Hach OX-10 Dissolved Oxygen Kit and a pocket thermometer. Water samples taken for suspended sediments, turbidity, conductivity, pH, and dissolved organic carbon were preserved and returned to Calgary for analysis.

Each lake was fished for approximately 24 hr using a standard gillnet gang of six 25 ft panels of 1, 1.5, 2, 2.5, 3.5, and 4.5 in stretch mesh monofilament. A 20 ft nylon marquisette minnow seine was used to sample the shallows of the lakes wherever substrate conditions and water depth allowed. Captured fish were identified, measured, and released alive whenever possible. Selected specimens were kept for detailed life history analysis as described by McCart and Craig (1973).

Each spring was sampled for fish using a Smith-Root type VA Backpack Electrofisher and a 20 ft nylon marquisette minnow seine. Since most of these springs have been repeatedly examined during previous fisheries surveys, only in unusual cases were fish kept for detailed life history analysis. Most fish were identified, measured, and released alive. In the course of this study, the main emphasis was on verifying the presence or absence and longitudinal distribution of fish in each spring. The distribution of fish within a spring is important because it may limit where, when, and how much water can be withdrawn without affecting fish populations.

Water samples for suspended sediments, turbidity, conductivity, pH, and dissolved organic carbon were taken from each spring at an orifice and preserved for analysis in the laboratory. Dissolved oxygen concentrations and temperature were measured and recorded in the field. At the end of each day, dissolved organic carbon samples (100 ml) from lakes and springs were preserved by freezing and sent to Chemex Laboratories Limited in Calgary, Alberta, for analysis. All other water samples (500 ml) were preserved with 1 mg of 0.4% copper sulfate solution and shipped to the AEL laboratory. Tests performed in the laboratory included specific conductivity (Beckman RB4-250 Solu-Bridge), pH (Radiometer pH Meter, type 29, with GK 2311C electrode), turbidity (Hach Model 2100A turbidimeter), and suspended sediments (gravimetric method, dried at 180°C).

RESULTS AND DISCUSSION

Water Quality

Water quality data are summarized in Table 1. In general, the water in the lakes sampled was of high quality and slightly alkaline (pH 7.4 to 8.5) in character. Two were slightly acidic (pH 6.2 to 6.7). Except for some suspended material stirred up by wave action, turbidity and suspended sediment values were uniformly low. Specific conductivities ranged from a low of 15 to a high of 504 µmhos/cm. Some of the lakes were slightly stained, yellow or brown, probably as a result of decay of organic materials.

Of the springs sampled, all those that were potential water sources had high quality water. Conductivities ranged from 29 to 399 µmhos/cm and turbidity values and suspended sediment concentrations were low. All springs sampled were slightly alkaline. One small hot spring, located approximately 30 mi south of Milepost 120, was sampled. This spring flows into the Okpilak River near the base of Mt. Michelson. The temperature of the water was 48°C (118°F) at the spring orifice. Because of its distance from the pipeline route and its small discharge (0.008 m^3/sec; 0.3 cfs) this spring has little potential as a water source for pipeline development.

TABLE 1. Water Chemistry Summary, Water Availability Study, 1975.

Location/Milepost		code	Sample No.	Date	Water Temp. (°C)	O_2	Cond.	pH	Turbidity Shaken (FTU)	Turbidity Settled (FTU)	Susp. Solids mg/1	Dissolved Org. Carbon µg/1c
Lake 3 mi. E	2.0	L-1	S-95 Y-48	23 Aug.	6	12	483	-	12.0	7.9	-	9.0
Lake 1 mi. E	3.0	L-2	S-359 Y-37	23 Aug.	6	12	257	8.0	11.0	8.9	8.4	3.0
Lake 3.5 mi. S	5.0	L-3	S-169 Y-32	23 Aug.	6	12	301	8.0	8.5	6.7	8.0	2.5
Lake 1 mi. S	12.0	L-4	S-211 Y-43	22 Aug.	8	12	284	8.1	11.0	10.0	8.4	4.0
Lake 1 mi. N	13.0	L-5	S-357 Y-56	22 Aug.	9	12	320	8.0	7.1	6.2	6.4	3.5
Lake 2 mi. S	16.5	L-6	S-332 Y-31	22 Aug.	8	12	336	8.2	21.0	13.0	17.6	4.5
Lake 1 mi. S	22.0	L-7	S-171 Y-21	22 Aug.	7	12	112	7.4	3.2	2.7	4.0	5.5
Lake 3 mi. S	24.0	L-8	S-339 Y-34	22 Aug.	6	13	215	-	6.2	4.6	5.2	2.5
Lake 1 mi. S	26.0	L-9	S-342 Y-25	22 Aug.	6	12	137	-	2.9	2.2	1.0	4.5
Lake 3 mi. S	26.0	L-10	S-362 Y-39	22 Aug.	7	13	223	8.1	5.6	3.1	1.0	4.5

(Continued)

TABLE 1. Continued.

Location/Milepost	Sample No.	Date	Water Temp. (°C)	O_2	Cond.	pH	Turbidity Shaken (FTU)	Turbidity Settled (FTU)	Susp. Solids mg/1	Dissolved Org. Carbon µg/1c
Lake 2 mi. N 32.0 L-11	S-361 Y-41	22 Aug.	6	12	441	8.0	5.0	3.6	1.8	2.5
Lake 2 mi. N 34.0 L-14	S-52 Y-24	22 Aug.	6.5	13	504	8.2	14.0	8.7	6.4	3.5
Lake 1 mi. S 39.0 L-16	S-358 Y-23	22 Aug.	6	22	132	7.9	3.4	3.1	2.0	7.0
Lake 2 mi. N 47.0 L-17	S-331 Y-28	21 Aug.	6	13	188	-	4.8	2.7	2.2	4.0
Lake 0.5 mi. N 51.0 L-18	S-338 Y-22	21 Aug.	7	13	197	8.1	3.4	2.3	<1.0	3.5
Lake 1.5 mi. S 53.0 L-19	S-334 Y-38	21 Aug.	6	11	296	-	9.8	4.8	6.2	3.0
Lake 1.5 mi. S 62.0 L-20	S-178 Y-29	21 Aug.	6	12	103	-	2.4	1.4	<1.0	2.5
Lake 1.5 mi. S 63.0 L-21	S-175 Y-57	21 Aug.	6	12	200	-	8.3	2.9	9.8	3.5
Katakturuk Sps.W.Fork 5 mi. S 86.5 S-1	S-173 Y-55	20 Aug.	2	12	260	-	0.62	0.25	1.3	1.0
Katakturuk Sps.E.Fork 5 mi. S 87.0 S-2	S-336 Y-16	20 Aug.	5	11	293	-	1.2	0.24	<1.0	0.5

(Continued)

TABLE 1. Continued.

Location/Milepost	Sample No.	Date	Water Temp. (°C)	O_2	Cond.	pH	Turbidity Shaken (FTU)	Turbidity Settled (FTU)	Susp. Solids mg/1	Dissolved Org. Carbon µg/1c
Sadlerochit Sps. 6 mi. S 111.0 S-3	S-273 Y-58	20 Aug.	14	10	399	-	0.49	0.26	<1.0	2.0
Hulahula Sps. 1 mi. N 116.5 S-4	S-340 Y-53	20 Aug.	2	10	231	-	1.4	1.0	5.8	1.0
Okpilik R. (Hot Sps.) 30 mi. S 120.0 S-5		26 Sept.	48	1.5	680	8.4	2.3	1.8	6.5	-
Lake 4 mi. N 131.0 L-22	S-91 Y-20	17 Aug.	9	10	120	-	8.7	5.4	4.5	5.5
Okerokovik Sps. @ 138.0 S-6	S-88 Y-52	17 Aug.	1	6.5	278	8.3	0.4	0.25	<1.0	1.5
Ekaluakat Sps. 5 mi. S 162.0 S-7	S-51 Y-51	17 Aug.	2	8	336	-	0.62	0.26	<1.0	2.0
Kongakut Sps. 6 mi. N 173.0 S-8	S-202 Y-54	16 Aug.	4	11	231	8.2	4.6	1.3	2.2	1.5
Kongakut Sps. 6 mi. S 174.0 S-9	S-363 Y-9	16 Aug.	2	6	257	8.5	0.82	0.6	<1.0	0.5
Clarence R. Sps. 5 mi. S 190.0	S-354 Y-9	16 Aug.	10	10	257	8.4	1.3	0.89	<1.0	2.5
Clarence Sps. 9 mi. S 192.0 S-10	S-262	25 Sept.	2	11	-	-	-	-	-	-

(Continued)

TABLE 1. Continued.

Location/Milepost	Sample No.	Date	Water Temp. (°C)	O_2	Cond.	pH	Turbidity Shaken (FTU)	Turbidity Settled (FTU)	Susp. Solids mg/1	Dissolved Org. Carbon µg/1c
Lake 2 mi. N 192.0 L-23	S-166 Y-19	15 Aug.	10	10	124	8.0	3.6	2.3	5.8	2.5
Lake 2 mi. N 193.0 L-24	S-96 Y-11	15 Aug.	11	10	211	-	2.5	1.2	<1.0	7.5
Lake 4 mi. N 193.0 L-25	S-337 Y-14	15 Aug.	11	10	236	-	5.4	2.6	5.8	1.5
Craig Ck. 3 mi. S 197.0 S-11	S-1003	9 Oct.	2	11	250	8.0	8.0	0.3	22.7	-
Spring 2 mi. S 198.0 S-12	S-387	10 Sept.	5	10	265	-	0.7	0.3	1.3	1.5
Lake 2 mi. N 215.0 L-26	S-227 Y-74	10 Sept.	4	10	78	-	2.1	1.2	<1.0	4.5
Fish Ck. Sps. 2 mi. N 217.5 S-13	S-186 Y-35	10 Sept.	5	9	271	-	0.8	0.3	1.2	2.5
Malcolm R. Sps. 2 mi. N 225.0 S-14	S-391 Y-42	9 Sept.	5	10	237	-	0.4	0.6	<1.0	0.5
Firth Sps. 2 2 mi. N 227.0 S-15	S-394 Y-27	9 Sept.	1	11	325	-	2.7	1.1	2.8	2.0
Lake 2 mi. S 231.0 L-28	S-389 Y-49	10 Sept.	3	10	86	-	1.8	1.3	<1.0	2.5

(Continued)

TABLE 1. Continued.

Location/Milepost			Sample No.	Date	Water Temp. (°C)	O_2	Cond.	pH	Turbidity Shaken (FTU)	Turbidity Settled (FTU)	Susp. Solids mg/1	Dissolved Org. Carbon μg/1c
Firth R. Sps. 2 mi. N	233.0	S-16	S-333 Y-71	10 Sept.	5	9	29	-	0.9	0.5	1.5	1.5
Lake 1 mi. N	233.0	L-29	N/T	10 Sept.	2	10	-	-	-	-	-	-
Lake 1 mi. N	240.0	L-30	S-388 Y-44	9 Sept.	2	11	110	-	7.1	4.5	5.2	2.5
Lake 1 mi. N	242.5	L-32	S-364 Y-73	9 Sept.	3	10	90	-	1.6	1.2	<1.0	4.0
Lake 1 mi. E	250.0	L-33	S-379 Y-30	9 Sept.	3	11	185	-	3.8	3.1	1.1	7.5
Lake 2 mi. N	252.0	L-34	S-385 Y-69	9 Sept.	3	11	70	-	5.0	2.7	4.1	3.5
Spring R. Sps. 2 mi. N	256.0	S-17	S-390 Y-68	9 Sept.	2	11	35	-	0.8	0.8	<1.0	1.5
Lake 1 mi. N	259.0	L-36	S-386 Y-67	9 Sept.	2	11	153	6.7	1.9	1.4	<1.0	6.0
Bloomfield Lake 3.5 mi. N	264.0	L-37	S-215 Y-26	10 Sept.	3	10	190	-	8.7	5.1	6.8	2.5
Crow R. Sps. 2 mi. N	268.0	S-18	S-203 Y-66	9 Sept.	2	12	271	-	0.7	0.6	<1.0	1.5

(Continued)

TABLE 1. Continued.

Location/Milepost			Sample No.	Date	Water Temp. (°C)	O_2	Cond.	pH	Turbidity Shaken (FTU)	Turbidity Settled (FTU)	Susp. Solids mg/1	Dissolved Org. Carbon µg/1c
Lake 2 mi. S	272.0	L-38	S-89 Y-72	4 Sept.	7	11	41	-	8.1	5.5	3.1	5.5
Lake 2 mi. S	274.0	L-39	S-97 Y-70	4 Sept.	6	11	122	-	9.1	5.6	3.8	4.0
Lake 2 mi. N	281.0	L-40	S-83 Y-64	4 Sept.	7	11	30	-	7.1	4.6	3.2	4.0
Lake 1 mi. N	289.0	L-41	S-330 Y-63	4 Sept.	7.5	12	28	-	8.6	5.7	1.6	5.0
Lake 1.5 mi. E	290.0	L-42	S-355 Y-50	3 Sept.	9	10	25	7.0	3.8	3.1	1.8	5.0
Lake 8 mi. N	298.0	L-43	S-380 Y-61	3 Sept.	8	11	36	-	7.0	3.7	5.7	5.5
Lake 3 mi. N	305	L-45	S-270 Y-1	5 Aug.	10	11	15	6.2	5.4	3.9	8.2	5.0
Lake 6.5 mi N	309	L-46	S-201 Y-46	3 Sept.	8.5	11	83	-	9.1	4.8	7.0	3.5
Lake 1 mi. N	309.0	L-47	S-274 Y-7	7 Aug.	9	10	82	8.6	22.0	12.0	86.4	13.0

(Continued)

TABLE 1. Continued.

Location/Milepost	Sample No.	Date	Water Temp. (°C)	O_2	Cond.	pH	Turbidity Shaken (FTU)	Turbidity Settled (FTU)	Susp. Solids mg/1	Dissolved Org. Carbon µg/1c
Lake 4 mi. N 315.0 L-48	S-269 Y-8	7 Aug.	9	10	61	7.2	78.0	34.0	27.6	21.0
Lake 3 mi. N 317.5 L-49	S-335 Y-40	4 Sept.	7	11	38	7.1	12.0	7.4	4.8	11.0
Lake 0.5 mi. S 318.0 L-50	S-54 Y-65	3 Sept.	9	10	61	-	8.6	6.7	2.9	8.0
Lake 0.5 mi. N 321.0 L-51	S-341 Y-45	3 Sept.	8	12	35	-	8.4	4.7	6.5	7.5

In general, only minimal water treatment (e.g., filtration and chlorination) should be necessary to provide potable water for domestic use in the construction camps. However, water quality in lakes deteriorates in winter as minerals and solids become concentrated in the free water below the ice cover, so that some additional water treatment may be necessary in areas where no groundwater sources are available for domestic use.

Water Availability

In this section of the report, each segment of the prime coastal pipeline corridor is examined relative to:

a) the volumes of water available in the lakes and streams surveyed,

b) the proportion of the available water required for pipeline development,

c) any additional or alternate water sources that might be considered,

d) special environmental considerations (e.g., critical spawning and overwintering areas for fish),

e) specific recommendations regarding maximum withdrawal rates, construction procedures, etc., which minimize the potential damage to aquatic habitats.

Detailed appendix tables have been prepared which show water requirements, water volumes available in lakes, discharge rates of springs, and fish utilization of potential water sources along the pipeline route.

Appendix Table 1 shows the uses and estimated monthly water requirements for each section of pipeline during various phases of construction.

Appendix Table 2 summarizes the morphometric characteristics of the lakes surveyed, including: the average depths, surface areas, estimated volumes, and the calculated maximum volumes of free water remaining after ice accumulations of 0.73 and 1.5 m.

Appendix Table 3 shows the depths, velocities, and discharges of the springs surveyed during the course of this study. Summaries of the information in the appendix tables are presented for each segment of the pipeline route in the following section-by-section discussion.

Appendix Table 4 summarizes water availability information from a joint USGS/AAGSC hydrological survey in November, 1975.

Appendix Table 5 summarizes fisheries information for each potential water source along the pipeline route.

Milepost 0 to 56

This segment of the proposed Arctic Gas Pipeline extends south and east from Prudhoe Bay to the vicinity of the Canning River. The area is characterized by low-lying coastal plain dotted with numerous shallow lakes. Figures 2a and 2b show the location of the lakes surveyed in this section of the pipeline corridor.

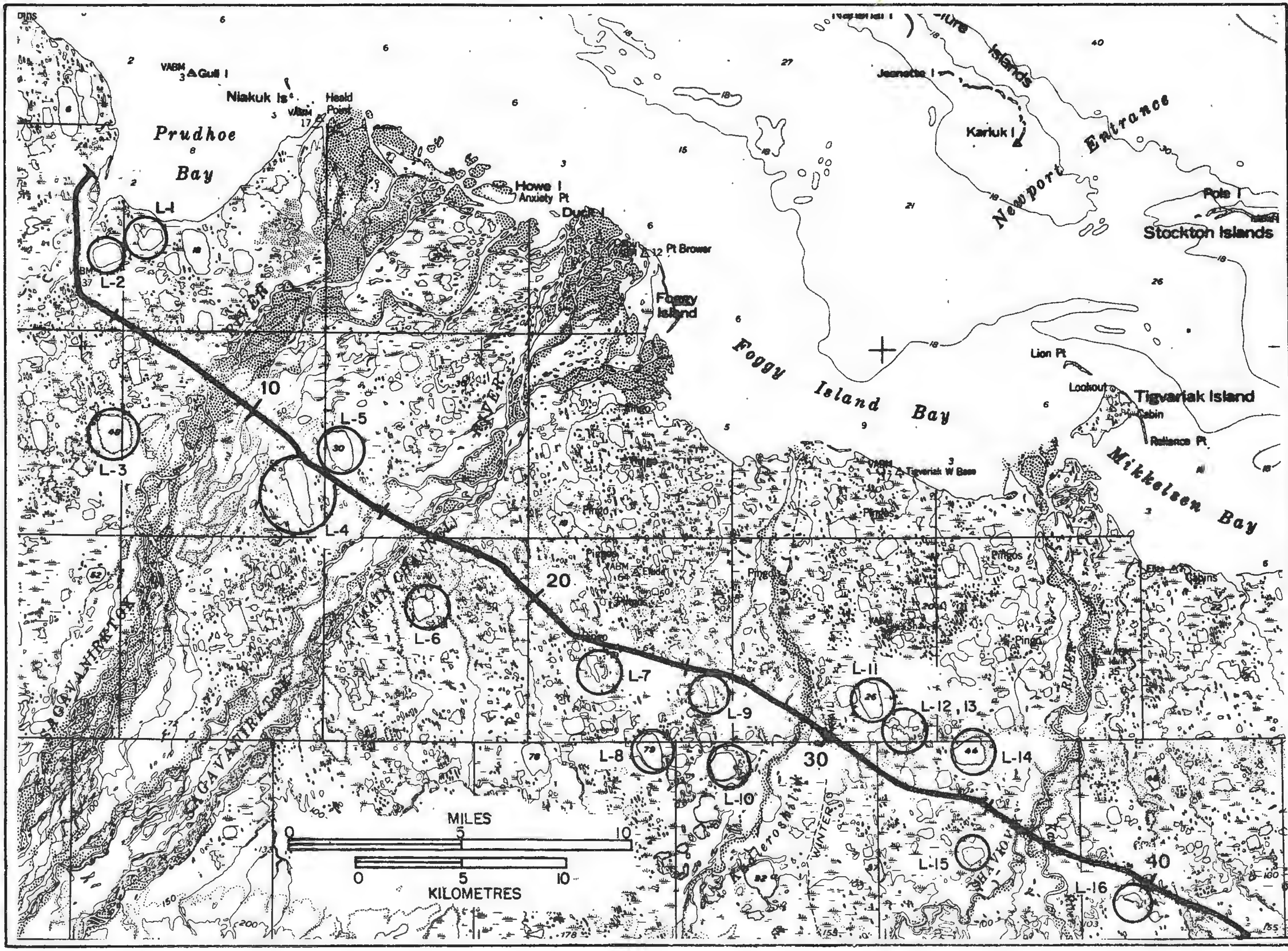

FIGURE 2a. Locations of waterbodies surveyed between Mileposts 0-45.

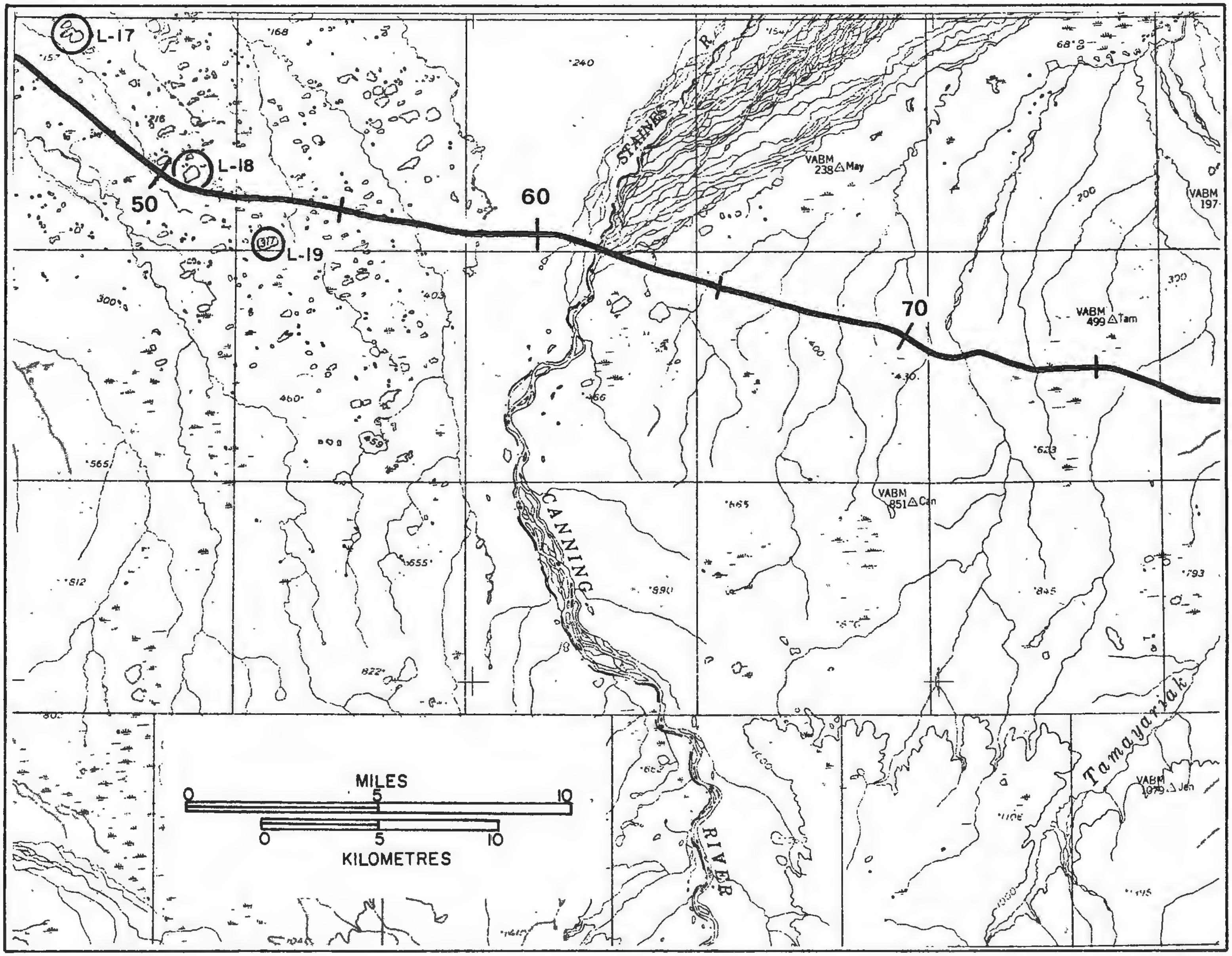

FIGURE 2b. Locations of waterbodies surveyed between Mileposts 45-56.

In these lakes, available water is more than adequate to meet the requirements for pipeline development (Table 2). As indicated in the table, only small percentages of the total available water are required and the mean drawdown would be minimal. In mid and late winter, however, conditions change and water supplies are more limited. Appendix Table 2 shows that up to 88% of the average volume of the lakes in this segment is frozen after ice accumulates to a depth of 1.5 m, and seven of the 19 lakes freeze solid. It is likely, therefore, that in many years, most, if not all, of these lakes could be frozen solid by the end of the winter. The construction activities requiring large volumes of water should be scheduled for early winter when water supplies are abundant.

Hobbie (1962) conducted limnological studies spanning parts of three winters on Lake Peters, a deep Arctic lake in the Brooks Range, Alaska. Hobbie found that 90% of the ice thickness was produced in the first four months of winter, and reached a maximum thickness of up to 2 m by May (Figure 3). He also found a relationship between the amount of snow accumulation on the ice and the rate of ice production. In 1961, for instance, when there was a heavy snowfall, the ice was thinner than in 1959, a year of light snowfall. Thus, the greater the snow accumulation and the earlier in the season the accumulation begins, the thinner the ice will be. Particularly in years of light snowfall then, the camps planned for Mileposts 9 and 44 may have to develop alternative water supplies in the late winter months. One method of retarding ice development and maximizing the availability of free water would be to encourage snow accumulation by constructing snow fences on the ice of lakes selected as water sources.

TABLE 2. Water Availability. Milepost 0 to 56. All volumes are barrels x 1000.

MILEPOST	Volume Required	Number of Lakes	Code	Surface Area (m^2 x 1000)	Mean Depth (m)	Lake Volumes	Mean Volume	Percent Required	Mean Drawdown (m)
0-17	909	6	L-1	1,164	1.25	8,890			
Camp 0	270		L-2	1,265	1.8	13,912	15,503	7.6	0.1
			L-3	2,409	2.0	29,438			
			L-4	2,489	1.5	22,812			
			L-5	1,867	1.85	11,104			
			L-6	803	1.4	6,869			
17-34	198	8	L-7	642	1.9	7,459	8,950	2.2	0.03
			L-8	1,485	1.7	15,425			
			L-9	522	2.1	6,698			
			L-10	1,224	1.6	11,966			
			L-11	1,465	1.8	16,112			
			L-12	201	0.6	737			
			L-13	442	0.8	2,160			
			L-14	1,445	1.25	11,036			
Camp 44	98	5	L-15	682	0.5	2,084	3,561	3.8	0.05
34-56	37		L-16	301	2.0	3,678			
			L-17	361	1.9	4,191			
			L-18	321	2.4	4,707			
			L-19	321	1.6	3,138			

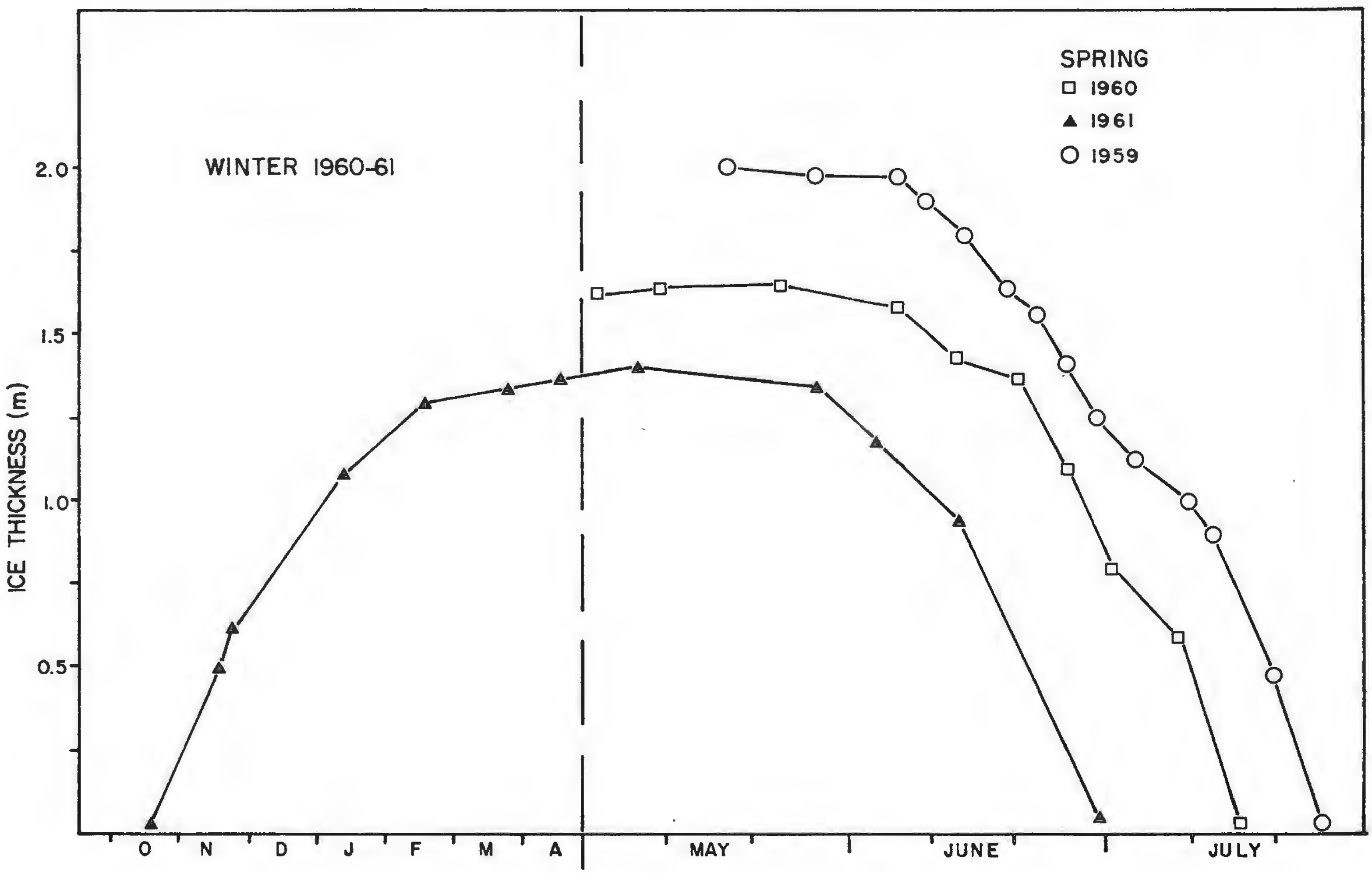

FIGURE 3. Ice buildup and melt at Lake Peters, Alaska, 1959 to 1961 (Hobbie, 1962).

There is a possibility that some flowing water persists in the Sagavanirktok and Canning channels, or that sub-gravel water may be available in these rivers throughout the winter. Conditions, however, appear to vary. In November and April of 1973, for example, no flow was found at pipeline crossings in any of the drainages crossed by the pipeline from Prudhoe Bay up to and including the Canning River (Ward and Craig, 1974). In late November of 1975, however, a flow of 228 cfs was measured in the Canning River at the pipeline crossing. In addition, two smaller drainages, the Shaviovik River and Kavik River, at Mileposts 36 and 37, had discharges of 12.2 and 0.5 cfs. In the West Channel of the Sagavanirktok River, at the pipeline crossing, there was approximately 0.9 m of free water under 0.7 m of ice. The velocity of the water was lower than the threshold velocity needed to operate the measuring instruments so discharge, if any, could not be calculated (Appendix Table 4).

The precise extent of the free water in these drainages and the potential of sub-gravel water as a water source is not known, although it could be determined by geophysical programs (e.g., drilling and pumping tests conducted in winter).

In the lakes surveyed between Mileposts 0 and 56, the only fish captured were ninespine stickleback. These small fish are apparently tolerant of the low oxygen levels and other marginal habitat conditions that characterize these lakes in winter. Their presence does, however, indicate that in the lakes where they occur, at least some free water persists throughout the winter. The withdrawal of large amounts of water from these lakes could render conditions unsuitable for even the ninespine stickleback. Since there are numerous lakes in addition to those surveyed within the pipeline corridor, AEL recommends that no more than 10% of the total volume of water be withdrawn from any given lake. The 10% limit is an arbitrary one. The drawdown of any given lake at 10% of its volume is small and it is unlikely that any serious ecological damage would result from water withdrawal within this arbitrary limit.

Milepost 56 to 112

At Milepost 62, the pipeline route crosses the Canning River and leaves the low, lake-studded coastal plain to enter rolling uplands characterized by numerous ephemeral drainages. Only two lakes (L-20 and 21), three springs (S-1, 2, 3), and possibly the Canning River itself can be considered potential sources of water for this segment of the pipeline route (Figures 4a and 4b).

Adequate water for the section of pipeline between Mileposts 56 and 73 can be obtained from the two lakes (L-20 and L-21) in the vicinity of Milepost 63 (Table 3). Between Mileposts 73 and 83 (including the camp at Milepost 83), water requirements are large. The closest sources of water are two springs (S-1 and S-2) on the Katakturuk River about 5 mi south of Milepost 87, one on the east fork and one on the west fork of the river. Each spring flows from multiple orifices into small channels leading to an *aufeis* area about ¼ mi downstream. These springs had a daily discharge of about 350,000 barrels (bbl) when measured in August, 1975. Assuming little variation in flow, there is more than adequate water here to meet the total requirement of 338,000 bbl.

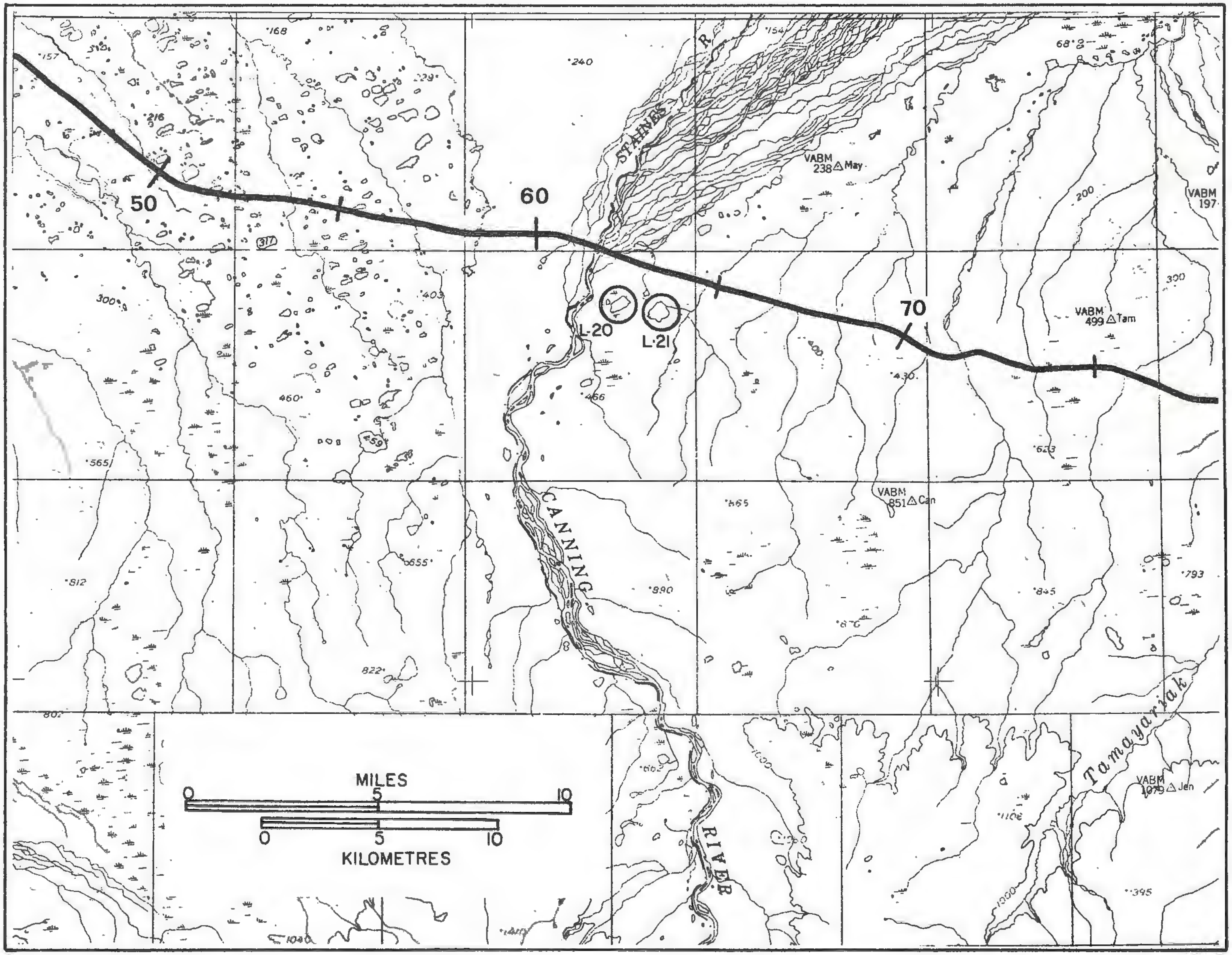

FIGURE 4a. Locations of waterbodies surveyed between Mileposts 56-75.

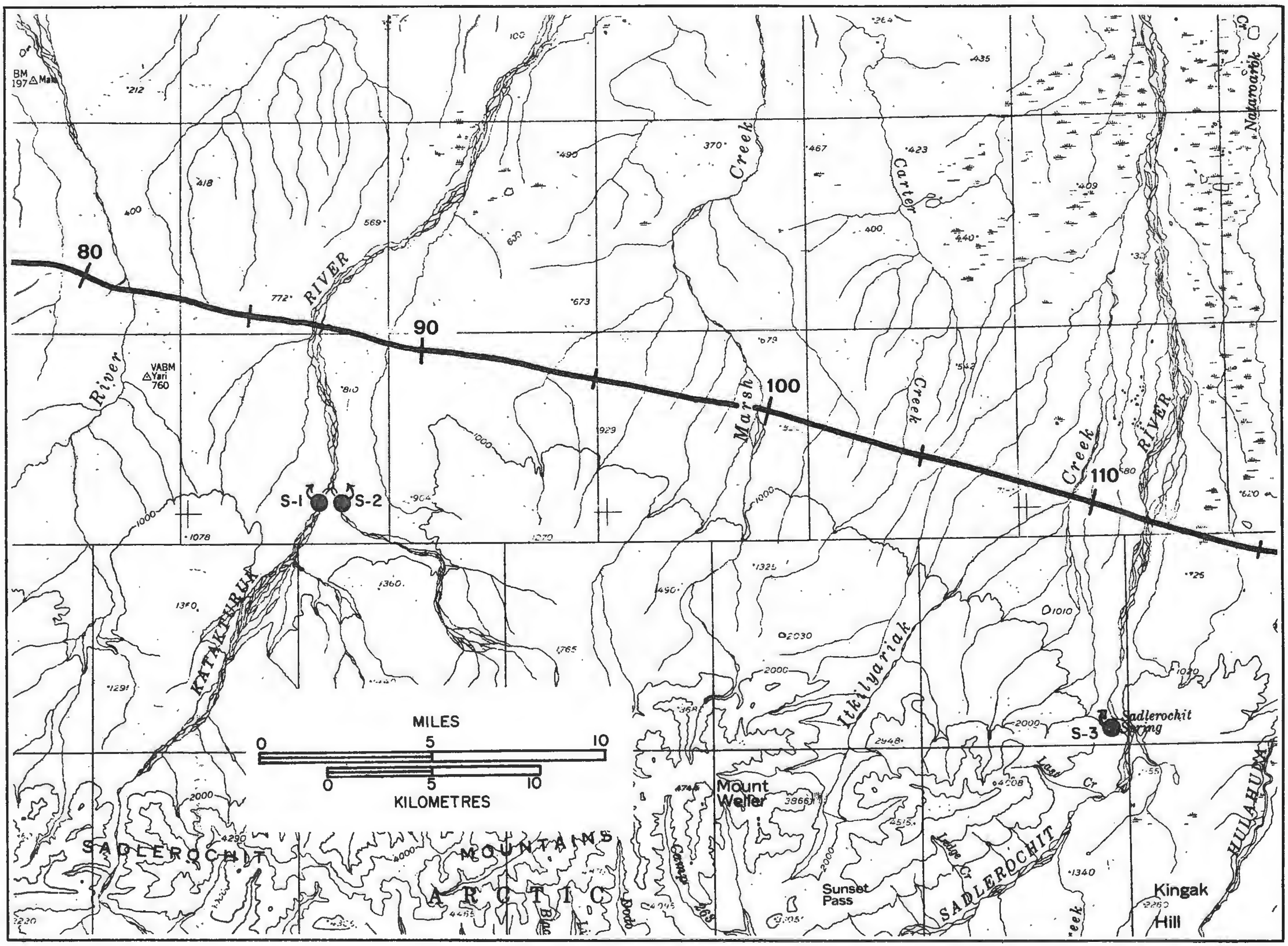

FIGURE 4b. Locations of waterbodies surveyed between Mileposts 75-112.

TABLE 3. Water Availability. Milepost 56 to 112. All volumes and discharges are barrels x 1000.

MILEPOST	Volume Required	Number of Lakes	Code	Surface Area (m^2 x 1000)	Mean Depth (m)	Lake Volumes	Mean Volume	Percent Required	Mean Drawdown (m)	Spring Sources (Code)	Daily Discharge
56-73	50	2	L-20	381	2.8	6,518	6,942	0.7	0.02		
			L-21	482	2.5	7,363					
73-83	10	0									
Camp 83	328									Katakturuk (S-1) (S-2)	354
83-112	1357	0								Sadlerochit (S-3)	645

Despite repeated surveys, no fish have been captured or observed in these springs, but they do support an abundant growth of riparian vegetation (similar to that shown in Plate 1), as well as populations of benthic invertebrates.

Since, even in springs with no known fish populations, every effort should be made to preserve as much as possible of the natural environment of the spring, it is recommended that water withdrawal be confined to a single area as far downstream as possible from the orifices, preferably at a point just above the *aufeis* field. It may be possible to extract water from a sump or dugout adjacent to the spring channels, using intragravel flow and not disturbing the channels. Site-specific hydrological surveys including gravel drilling and pump tests, should be conducted to determine the feasibility of these methods of water withdrawal.

The section of the pipeline route from Milepost 83 to 112 has no known water sources except for Katakturuk Springs, already described, which lie just to the west, and Sadlerochit Spring (S-3) which rises approximately 7 mi south of Milepost 111. Sadlerochit Spring is a large, warmwater spring (10 to 14°C) flowing primarily from a single orifice (Plate 2). The spring channel parallels the Sadlerochit River channel north for approximately 6 mi, and enters the river channel after passing through a large *aufeis* field lying just above the pipeline crossing. In August 1975, the discharge from the spring was approximately 645,000 bbl/day. This rate of flow is more than adequate to meet the total water requirement (1,357,000 bbl) for this section of pipeline. The discharge of warm water keeps the spring channel open for at least 5 mi

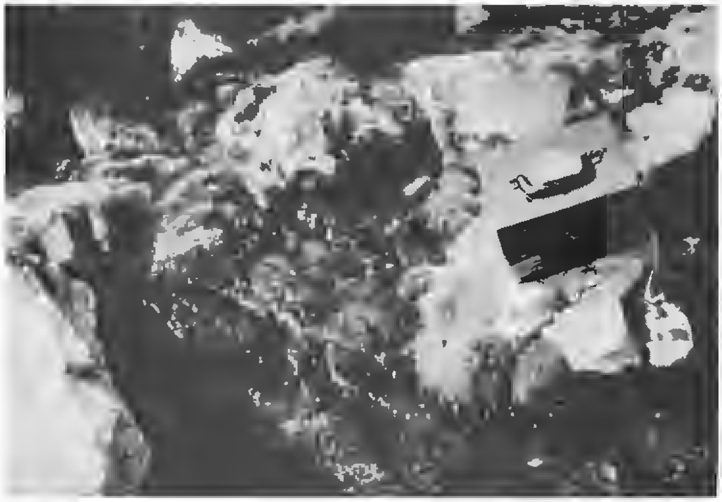

PLATE 1

An orifice of Okerokovik Spring (S-6). This spring is uninhabited by fish, but aquatic vegetation and invertebrates are abundant.

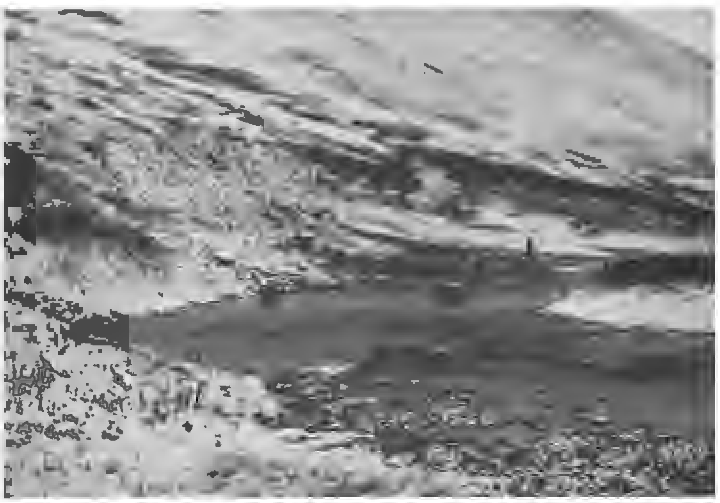

PLATE 2

The main orifice of Sadlerochit Spring (S-3). This large spring is densely populated by stream-resident Arctic char and is also used by overwintering populations of juvenile grayling.

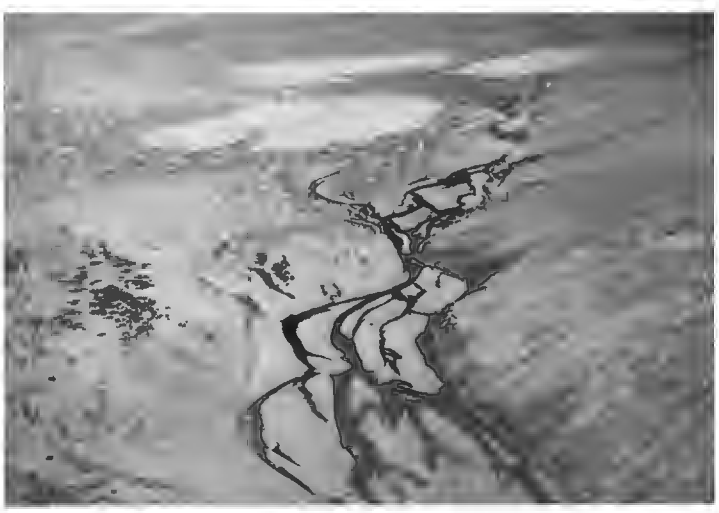

PLATE 3

The Ekaluakat Springs and *aufeis* (S-7). This spring is utilized by spawning and overwintering anadromous Arctic char. If developed as a water source, withdrawal should be from a point near the *aufeis*.

during the winter, providing an excellent source of water close to the pipeline route.

There are, however, some important environmental considerations. The spring is inhabited by a large population of stream-resident Arctic char similar to those described by McCart and Craig (1973) as well as a sizeable overwintering population of grayling, mostly juveniles. During fisheries surveys in the fall of 1975, these fish were concentrated in the upper one-third of the spring. Fry and juvenile char occurred in small numbers, however, as far downstream as the *aufeis* field.

After a safe withdrawal site has been selected, collection ponds and the inlet to the pump should be screened to avoid pumping fish out of the spring channel. The screen or barrier should be far enough from the pump to ensure that the velocity of the water passing through the screen won't result in small fish and fry becoming exhausted and pinned against the screen. Mesh size of the screen should be 1/8 in or smaller to prevent the passage of young-of-the-year char.

A sump excavated in the gravel adjacent to the main channel could possibly supply all the necessary water from intragravel flow with minimal effect on stream habitats. The gravel remaining between the sump and spring channel would provide a barrier to fish movement into the collection pond. A sump of this kind would have to be a sufficient distance downstream to prevent drawing the flow down far enough to dewater char redds in the main channel.

The Sadlerochit Spring area is one of a number of Alaskan North Slope areas under consideration by the National Park Service as Natural Landmarks. Sadlerochit Spring, along with the Sagavanirktok River, Kadleroshilik River and Plain, Jago River and Clarence Plain are considered to have distinctive ecological and geological characteristics.

Milepost 112 to 168

This segment of the pipeline route has fewer and smaller water sources than any other segment of the route. Within the pipeline corridor, there are only three small spring sources and one lake (Figures 5a and 5b). These water sources are adequate to meet the requirements (Table 4) although transport distances will be considerable. If necessary, the two large springs just beyond the ends of this pipeline segment, Sadlerochit Spring (S-3) and the large groundwater sources in the Kongakut Delta (S-8), can be used to augment the water supply. The only other possible sources of water are a small number of widely scattered lakes 10 to 20 mi north of the pipeline route.

For the segment of the pipeline route between Mileposts 112 and 129, water could be transported from either Sadlerochit Spring (S-3) at Milepost 111 or the Hulahula Springs (S-4) located approximately 2 mi north of Milepost 117. The proposed camp in the vicinity of Milepost 129 will have a water requirement of 108,000 bbl, the major part of the 212,000 bbl requirement for this section of pipeline development. Hulahula Springs has a discharge of approximately 150,000 bbl/day, more than adequate to handle the expected maximum daily water requirement of about 15,000 bbl/day.

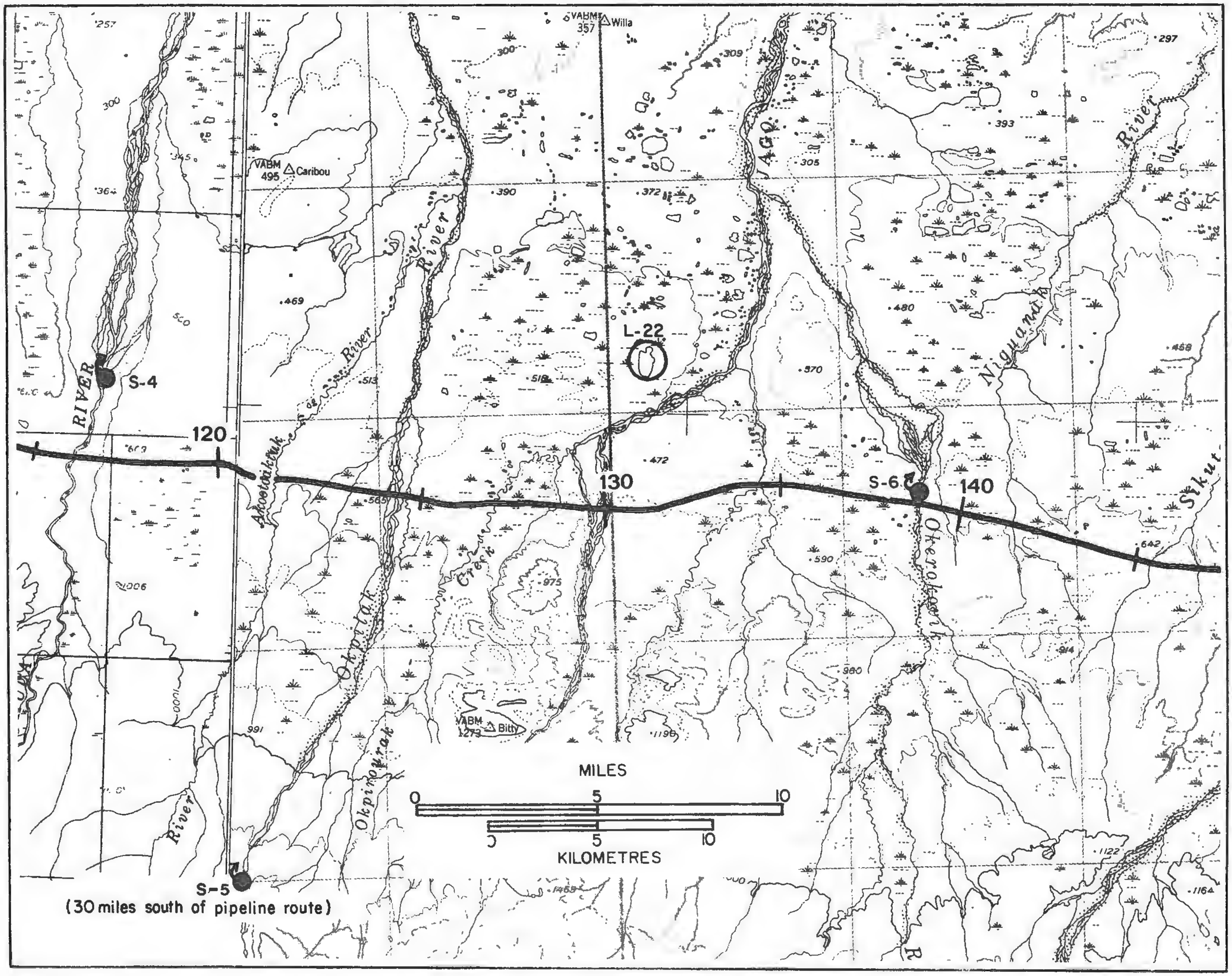

FIGURE 5a. Locations of waterbodies surveyed between Mileposts 112-145.

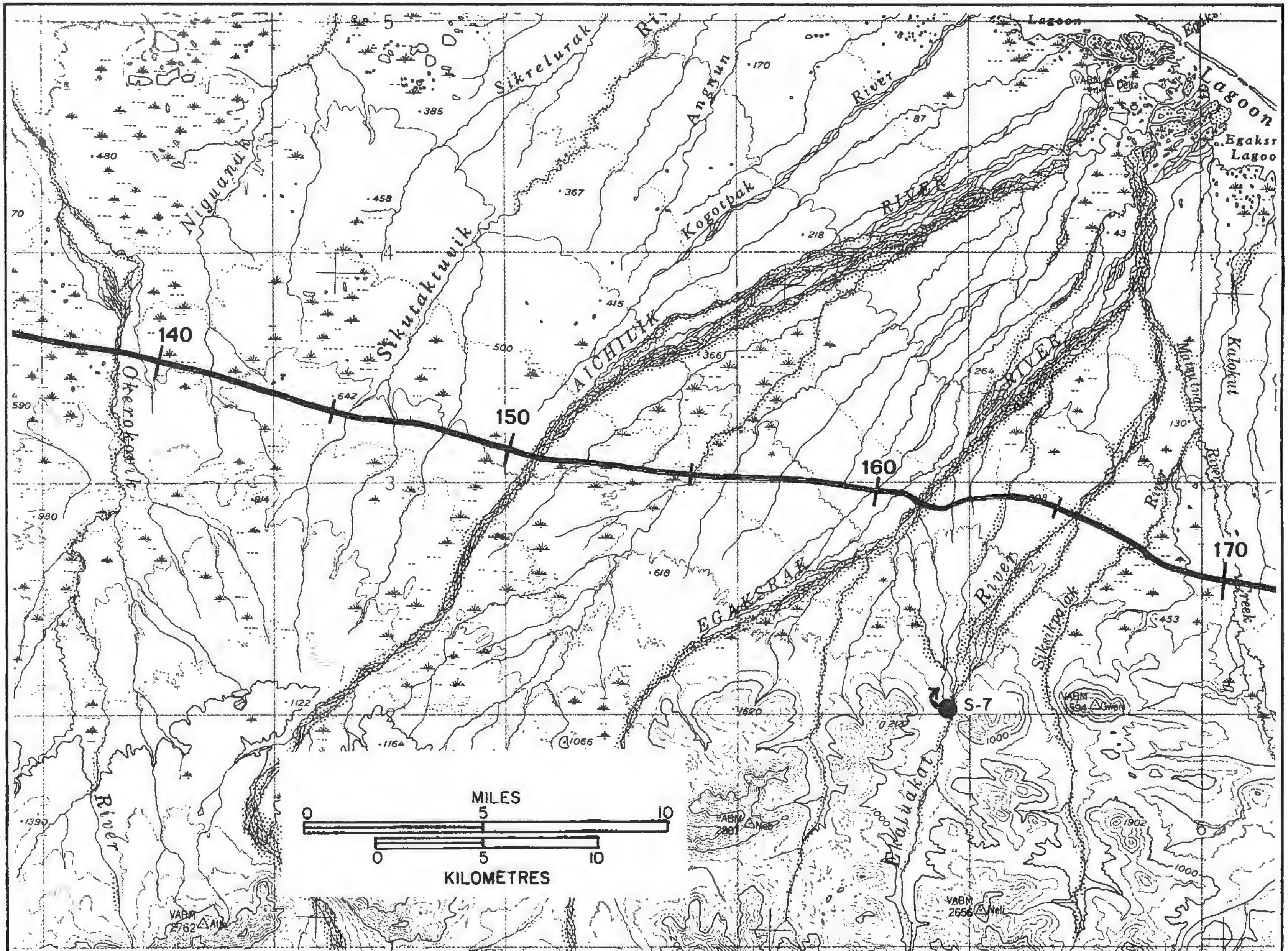

FIGURE 5b. Locations of waterbodies surveyed between Mileposts 145-168.

TABLE 4. Water Availability. Milepost 112 to 168. All discharges and volumes are barrels x 1000.

MILEPOST	Volume Required	Number of Lakes	Code	Surface Area (m^2 x 1000)	Mean Depth (m)	Lake Volumes	Percent Required	Mean Drawdown (m)	Spring Sources	Code	Daily Discharge
112-129	33										
Camp 129	108	0							Hulahula	S-4	153
129-146	33	1	L-22	763	1.6	7,459	0.4	0.01	Okerokovik	S-6	50
146-168	38	0							Ekaluakat	S-7	432

Even though no fish were observed in the Hulahula Springs during the survey in November, 1975, they are a potential overwintering area for Arctic char. Conversations with native fishermen in the village of Kaktovik on Barter Island indicate that in past years this spring was used by small numbers of overwintering anadromous Arctic char. At present, most of the Hulahula River char population overwinters in a second larger spring about 25 mi further upstream (south) of the pipeline crossing.

AEL recommends that water be taken from a point just above the *aufeis* where the spring channels converge, or from a sump dug in the gravel alongside the active channel. If water is withdrawn directly from the spring channel, we recommend that the pump intake be screened to prevent the intake of fish. To preserve the spring area in as natural a condition as possible, rechannelization or collection pond construction should be avoided.

From Milepost 129 to 146, the total water requirement is 33,000 bbl. A lake (L-22) located approximately 5 mi north of Milepost 131 could supply this volume of water by utilizing only 0.4% of its total volume. During the 1975 surveys, no fish were captured in this lake.

In addition to the lake, there is a small spring (Plate 1) on the Okerokovik River lying close to the pipeline route at Milepost 138 (S-6). This spring discharges approximately 50,000 bbl/day and is apparently uninhabited by fish. The spring has a number of channels which rise from small orifices and wind their way independently toward the *aufeis* field.

Once again, AEL recommends that the area of the spring near the orifices be avoided. Any rechannelization in the permanent spring channels would destroy plant and animal communities associated with them. In order to preserve as many of the natural channels of the spring as possible, water should be withdrawn either further downstream where the spring channels enter the river floodplain, or from a sump in the gravel.

The water requirements between Mileposts 146 and 168 are small (38,000 bbl). The nearest source of water is the Ekaluakat River Springs (S-7) located about 5 mi south of Milepost 162. These large springs were flowing at a rate of approximately 335,000 bbl/day when surveyed. The Ekaluakat Springs are, however, some of the most environmentally sensitive springs on the Alaskan portion of the pipeline route. They serve as an important spawning and overwintering site for anadromous and non-anadromous Arctic char. Plate 3 shows the numerous groundwater sources of Ekaluakat Springs and the *aufeis* about 1 mi downstream. At the time of the October, 1975, survey, both maturing fish and overwintering juveniles were concentrated in the mid-reaches of the spring (centre of photo), but precise spawning locations are not known.

If this spring is selected as a water source, then detailed surveys should be carried out during the final design phase to determine the timing and location of spawning. Provisionally, AEL recommends that water be withdrawn from this spring only below those areas utilized by Arctic char. In this way, dewatering of char redds and sedimentation of spawning and overwintering areas could be avoided. As mentioned before, fish should be prevented from entering collection ponds and the vicinity of the pump intake with screens or barriers. An alternative might be to take advantage of intragravel flow by placing a sump in the gravel downstream near the *aufeis*.

Milepost 168 to 190

This segment of the pipeline route crosses the south of the Kongakut Delta and then drops down out of the rolling uplands to the flat, marshy, coastal plain. There are a number of potential sources of water in this region (Figure 6).

A large source of groundwater is located in the Kongakut Delta approximately 7 mi north of Milepost 174 (S-8). This source has a discharge in excess of 1,500,000 bbl/day. This large groundwater source can easily provide all the water required within hauling distance of the spring. There are additional springs upstream on the Kongakut (S-9) and on the Clarence River (S-10). These springs are heavily populated with Arctic char, but they should not be needed as sources of water.

If there is a camp at Milepost 177, the total estimated water requirement for this segment of the pipeline is 1,199,000 bbl. The springs in the Kongakut Delta could easily supply all of this water. If the haul distance to the east end of this segment is prohibitive, a number of lakes 3-4 mi north of Milepost 193 could be used. The volume of water available and the requirements for this segment of the pipeline appear in Table 5.

Ward and Craig (1974) describe the Kongakut Delta Springs as

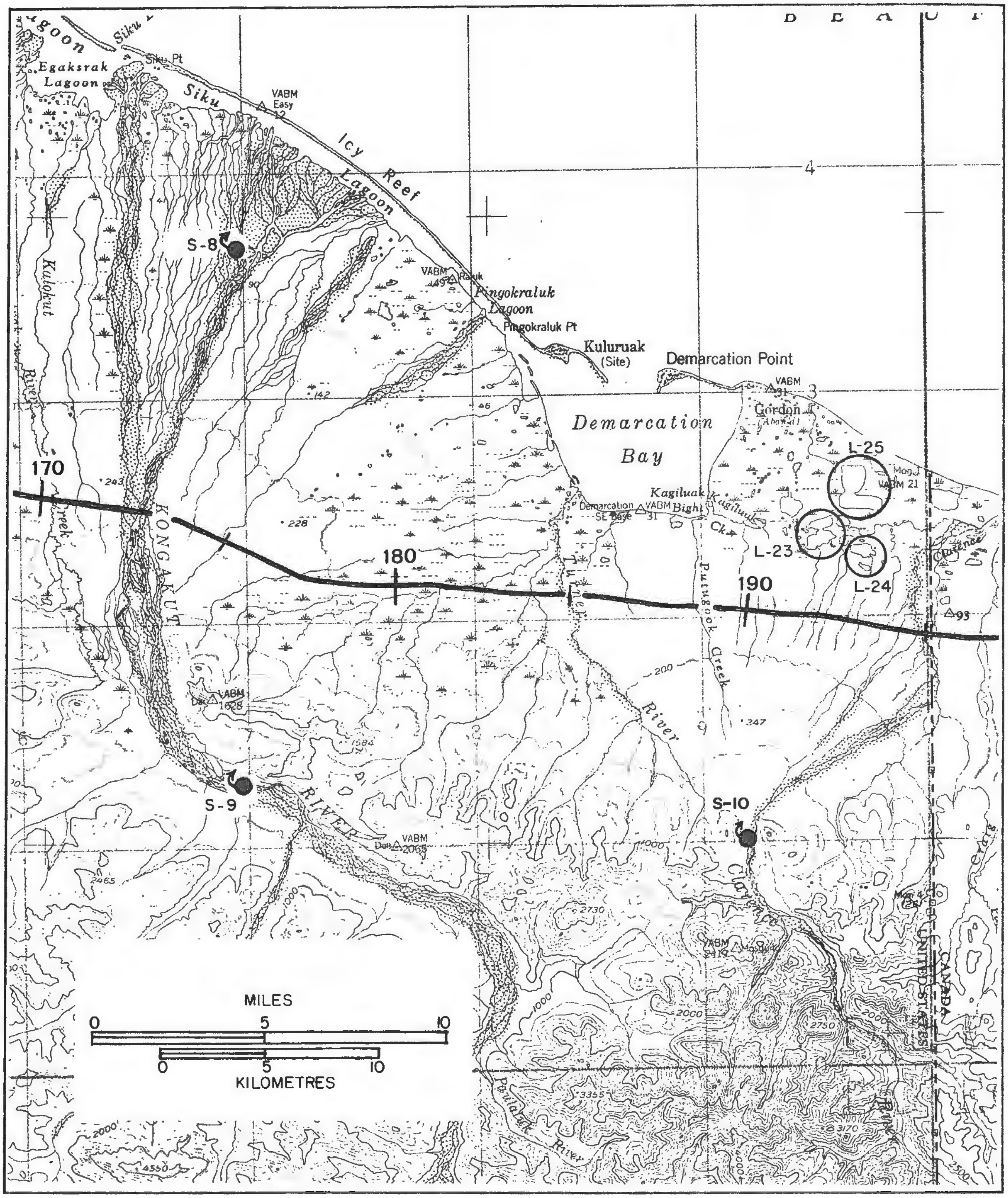

FIGURE 6. Locations of waterbodies surveyed between Mileposts 168-190.

TABLE 5. Water Availability. Milepost 168 to 190. All volumes and discharges are barrels x 1000.

MILEPOST	Volume Required	Number of Lakes	Spring Sources	Code	Daily Discharge
168-177	122	0	Kongakut	S-8	1,558
Camp 177	260			S-9	281
177-190	817	0	Clarence	S-10	37

important rearing and overwintering areas for large numbers of juvenile Arctic char. If pumping facilities are used in this area, water collection areas and pump inlets should be screened to avoid drawing fish into the pumps. Care should be taken to avoid diversion works or excessive pumping from one channel that might result in dewatering those channels inhabited by overwintering fish.

Milepost 190 to 224

This segment of the pipeline corridor continues along the coastal plain close to the Beaufort Sea. In the vicinity of Milepost 210, the coastal plain narrows to a width of 5 mi.

Four lakes and three springs were surveyed along this portion of the route (Figure 7, Table 6). The total water requirement for this segment is approximately 1,613,000 bbl and would require about 2% of the total volume of the lakes surveyed. Alternatively, the three springs surveyed could supply the total water requirement with only 3.5 days' discharge.

Between Mileposts 190 and 207, large volumes of water are available from the lakes located 2-4 mi north of Milepost 193 (L-23, 24, 25). There are also two small springs in the area, one on Craig Creek (S-11) and one on a tributary of Craig Creek (S-12), about 3 mi south of Milepost 197. These springs emerge from multiple orifices, generally into divergent channels, to wind independently across the floodplain to an *aufeis* area. Although the springs appear to be uninhabited by fish, aquatic and riparian vegetation and benthic invertebrates are abundant. To avoid

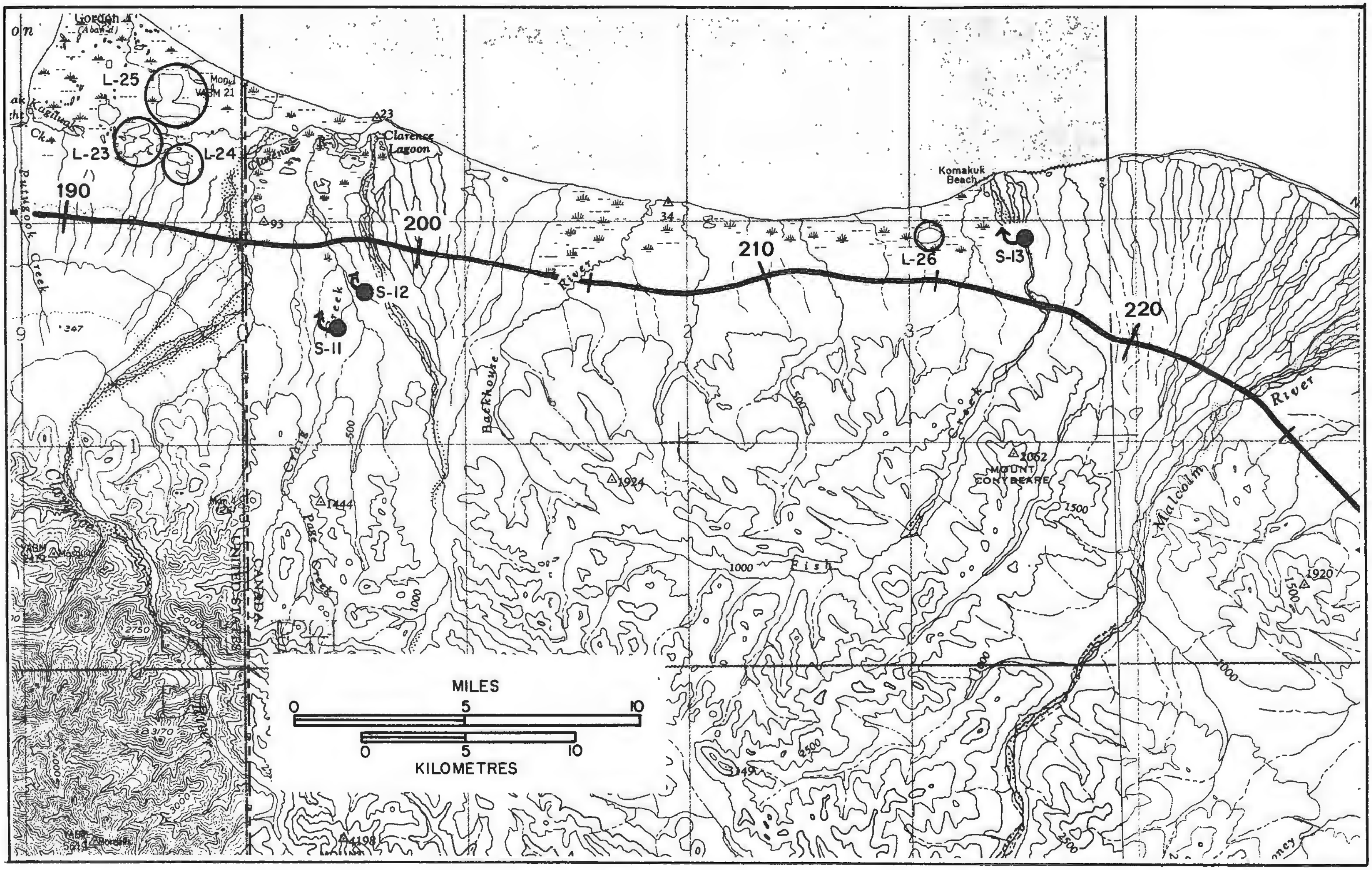

FIGURE 7. Locations of waterbodies surveyed between Mileposts 190-224.

TABLE 6. Water Availability. Milepost 190 to 224. All volumes and discharges are barrels x 1000.

MILEPOST	Volume Required	Number of Lakes	Code	Surface Area (m^2 x 1000)	Mean Depth (m)	Lake Volumes	Mean Volume	Percent Required	Mean Drawdown (m)	Spring Sources	Code	Daily Discharge
190-207	325	3	L-23	1,204	2.7	19,862				Craig Cr.	S-11	50
			L-24	521	2.8	8,913	20,695	1.6	0.04	Craig Cr. Trib.	S-12	175
			L-25	2,369	2.3	33,292						
207-216	548	1		550	2.8	9,409	9,409	9.3	0.25			
Camp 216	328											
216-224	412	0								Fish Cr.	S-13	236

disturbing the vegetation and invertebrates in the channels, AEL recommends that water be withdrawn from a sump located on the floodplain.

From Milepost 207 to 216 (including the camp proposed at Milepost 216) water can either be drawn from lake L-26, located about 2 mi north of Milepost 215, or from the springs on Fish Creek, 2 mi north of Milepost 217.5. The DEW Line site at Komakuk uses this lake (L-26) for its water supply, however, so there may be some conflict over water use, especially in mid-winter when most of the water is frozen.

Fish Creek Springs (S-13) had a discharge of 236,000 bbl/day when surveyed. This spring supports a small number of juvenile Arctic char; however, water could be withdrawn from sumps or screened collection ponds below the spring without seriously disturbing either the aquatic habitat or the fish in the spring. A second larger spring on Fish Creek is located approximately 6 mi upstream of the pipeline crossing. This spring is a critical spawning and overwintering area for Arctic char and should not be utilized as a water source (Craig and McCart, 1974).

Milepost 224 to 280

After crossing the Malcolm and Firth river deltas, the pipeline route veers away from the coast and re-enters the rolling uplands. The terrain differs from similar terrain on the Alaskan side of the border in that upland lakes are more abundant. Many of these lakes are deep and harbour overwintering populations of fish. There are also springs within this portion of the pipeline corridor that are potential sources of water for pipeline development (Figures 8a and 8b).

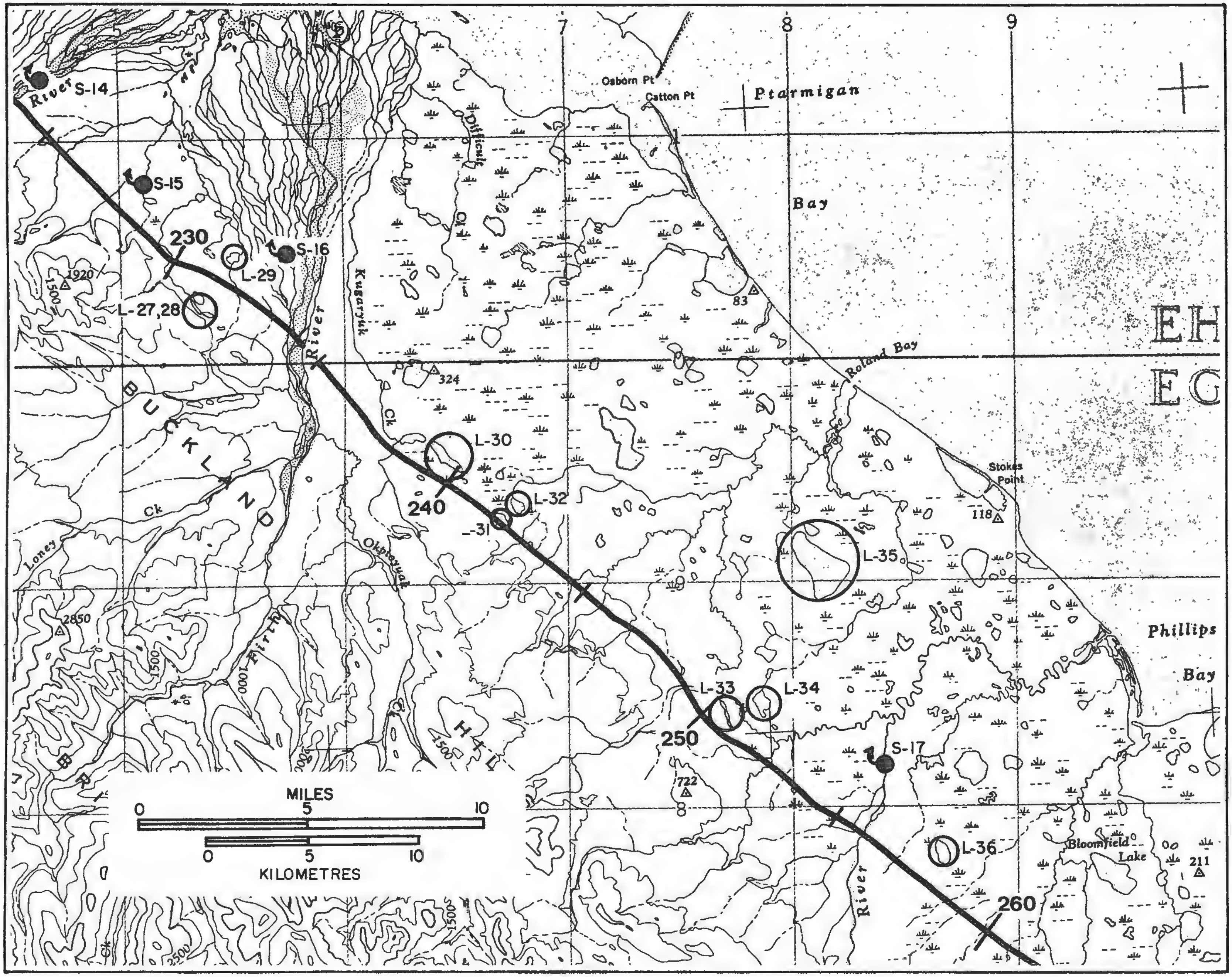

FIGURE 8a. Locations of waterbodies surveyed between Mileposts 224-260.

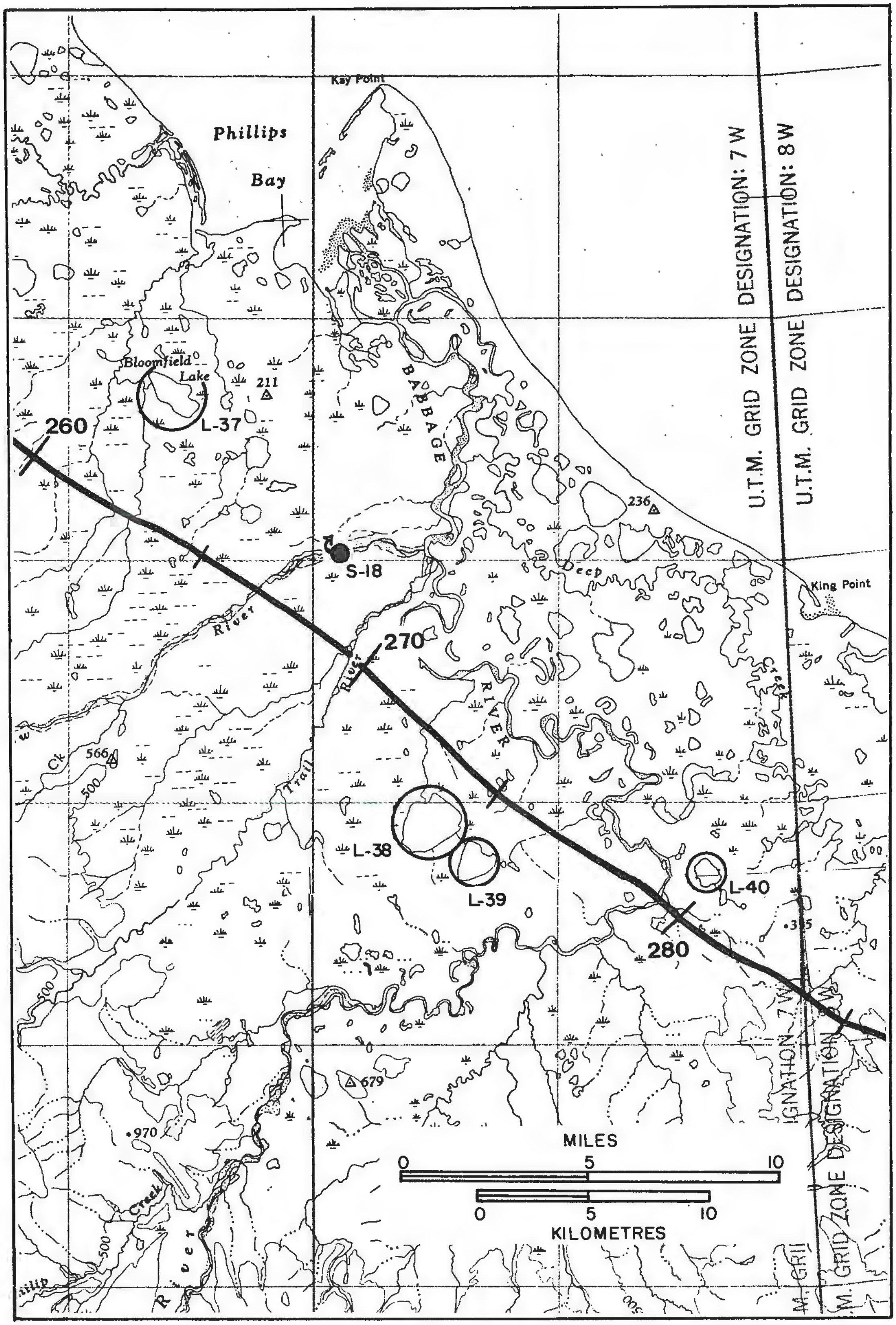

FIGURE 8b. Locations of waterbodies surveyed between Mileposts 260-280.

Between Mileposts 224 and 226, water requirements are small, totalling 182,000 bbl. While it is apparent that any one of the sources surveyed (Table 7) could fulfill all the water requirements for this section, several of the springs and lakes serve as critical spawning and overwintering habitat for fish.

The springs on the east side of the Malcolm Delta (S-14), for example, are densely populated with juvenile Arctic char and grayling. In October, 1975, fish were concentrated in the upper one-third of the spring above the *aufeis*. Once again, water could be safely withdrawn from this spring downstream of the fish concentrations, provided that collection ponds, sumps and pump intakes are screened to prevent the entry of fish.

The next spring (S-15) lies mid-way between the Malcolm and Firth rivers, 1 mi north of Milepost 228. This spring is a critical spawning and overwintering area for anadromous Arctic char. On October 9, 1975, char were found actively spawning throughout the open water of the spring, and redd sites in the channel (Plate 4) extended downstream to and beyond the point where the channels were frozen over. During earlier surveys carried out in the fall and winter of 1972 and 1973 (McCart *et al.*, 1974; Craig and McCart, 1974), no adult fish were found in the open water of the spring. Juveniles and fry were present, however, and since there are deep pools above, in, and below the *aufeis* field, it is likely that the adult anadromous char overwinter in these pools under the ice cover. This spring may also support a stream-resident population of Arctic char, as several small male char were captured during surveys in 1975.

TABLE 7. Water Availability. Milepost 224 to 280. All volumes and discharges are barrels x 1000.

MILEPOST	Volume Required	Number of Lakes	Code	Surface Area (m^2 x 1000)	Mean Depth (m)	Lake Volumes	Mean Volume	Percent Required	Mean Drawdown (m)	Spring Sources	Code	Daily Discharge
224-246	182	6	L-27	125	4.3	3,284				Malcolm	S-14	342
			L-28	50	13.6	4,155						
			L-29	175	1.8	1,925	4,848	3.8	0.1	Firth 2	S-15	400
			L-30	687	2.9	12,173						
			L-31	250	2.3	3,513				Firth Delta	S-16	868
			L-32	300	2.2	4,033						
246-263	62	4	L-33	150	2.7	2,475	14,786	0.9	0.02	Spring River	S-17	91
Camp 270	68		L-34	500	2.2	6,721						
			L-35	2,595	2.7	42,810						
			L-36	487	2.4	7,141						
263-280	21	3	L-37	2,050	2.4	30,061	30,790	0.1	0.001	Crow River	S-18	135
			L-38	4,012	3.1	75,991						
			L-39	1,675	1.3	13,305						

PLATE 4

Springs between Malcolm and Firth rivers (S-15). The entire open water channel is heavily utilized for spawning by anadromous Arctic char. This spring is not recommended as a water source for pipeline construction.

PLATE 5

Firth River Delta Springs and *aufeis* (S-16). This large groundwater source is not heavily utilized by fish.

PLATE 6

Lake in rolling uplands near MP 289 (L-41). This lake is 4 m deep and is inhabited by grayling in the summer. It may also be used for overwintering.

In some respects, this spring is unique. It is closer to the coast than other areas where Arctic char are known to spawn, and it is not directly associated with a major river system. The fish utilizing this spring may be a separate population from that inhabiting the Firth or Malcolm river systems. Both because this spring is unusual and because it would be difficult to withdraw water from it without pumping directly out of the spring channel, AEL recommends that it should not be disturbed and that other sources of water should be used for pipeline development. Even a sump downstream near the *aufeis* field might jeopardize fish overwintering in pools under the ice cover.

The springs in the Firth Delta (S-16, 2 mi north of Milepost 233) have a discharge of approximately 868,000 bbl/day. These springs (Plate 5) are not heavily utilized by overwintering fish, and water can be safely withdrawn from screened collection ponds or from sumps in the gravel. The entire Firth River drainage, however, is under consideration as an Ecological Reserve under the International Biological Program, so disturbance of aquatic habitats in the region of the spring should be confined to as small an area as possible.

Two lakes, Lake L-27 and Lake L-28, located 2 mi south of Milepost 231, support slow-growing populations of lake-resident Arctic char (McCart *et al.*, 1974). These lakes are both deep, Lake L-27 averaging 4.3 m and Lake L-28 averaging 13.6 m. If withdrawal is carefully regulated to less than 10% of the volume of either lake, water could be safely withdrawn from them. AEL would recommend, however, that angling be strictly prohibited in these lakes.

Four other lakes were surveyed in this area, one a mile north of Milepost 233, one a mile north of Milepost 240, and two small ones in the vicinity of Milepost 242. Apparently these lakes are inhabited only by ninespine stickleback and are good potential sources of water.

From Mileposts 246 to 280, seven lakes and two small springs were surveyed (Table 7). As indicated, there is abundant water to meet the water requirements for pipeline development.

Three of the lakes in this section support large populations of fish during the summer. These lakes have never been fished in the winter, but it is likely that at least some of the fish are year-round residents. In the case of Lake L-35 (5 mi north of Milepost 255) and Lake L-38 (2 mi south of Milepost 272), lake volumes are so large that the total water requirement for this section of pipeline would amount to less than 1% of their total volume, a drawdown of only a few centimetres.

The third lake, Lake L-34 (2 mi north of Milepost 252) is both smaller and shallower than lakes L-35 and L-38. Unregulated water withdrawal from a lake of this size could draw water levels down to the point where conditions could be unfavourable to the survival of fish. If, however, water withdrawal is restricted to 10% of the total volume of the lake, there should be no serious effects.

The construction camp planned for the vicinity of Milepost 270 could use Bloomfield Lake as a water source. The estimated water requirements for this camp total 68,000 bbl. This amount is less than 1% of the volume of Bloomfield Lake. No fish were caught in Bloomfield Lake during surveys in 1972 (AEL, unpublished data).

The small springs on the Spring River (S-17, about 2 mi north of Milepost 256) and those on the Crow River (S-18, 2 mi north of Milepost 268) could also be developed as water sources for the camp at Milepost 256. These springs had discharges of approximately 90,000 and 135,000 bbl/day when they were surveyed in August of 1975. Seasonal variation, however, could be great. During the October survey, for example, the Spring River spring had little open water and a small *aufeis* field, so that diminished discharge during the winter months is indicated. Although neither of these springs supports an overwintering fish population, measures should be taken to avoid unnecessary disruption of the spring channels and the aquatic vegetation and invertebrate populations associated with them.

Milepost 280 to 336

Twelve lakes were surveyed along this segment of the pipeline route (Figures 9a and 9b; Table 8). The water available in these lakes will easily fill the estimated requirements for pipeline development, and there are numerous other lakes within 5 to 10 mi of the pipeline corridor that could be used to augment water supplies.

Three of the lakes surveyed are known to have populations of fish during at least part of the year. Two of the lakes are deep enough to suggest that they are suitable for overwintering. Lake L-41 (Plate 6), 1 mi north of Milepost 289, has an average depth of 4 m and was inhabited

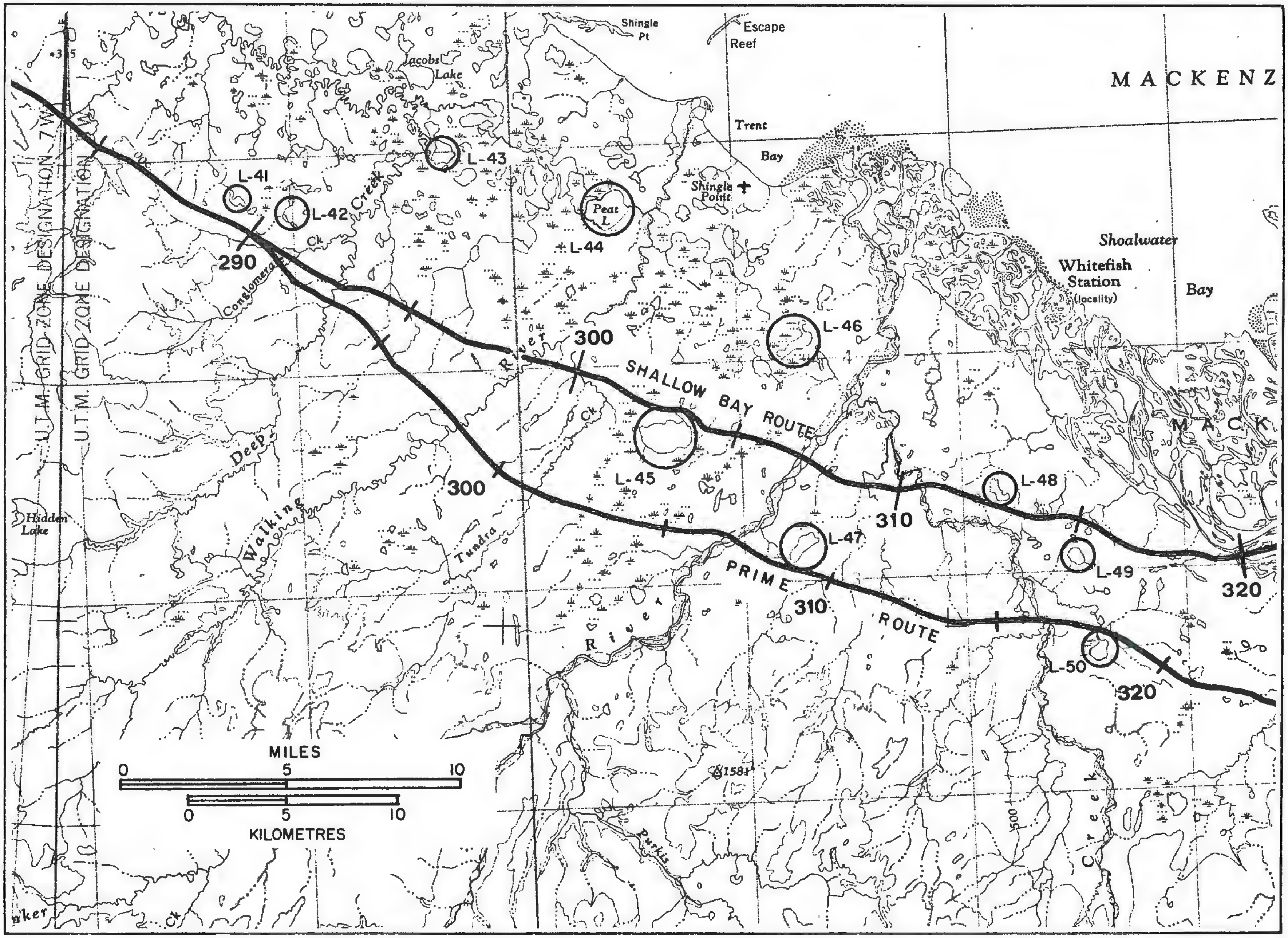

FIGURE 9a. Locations of waterbodies surveyed between Mileposts 280-320.

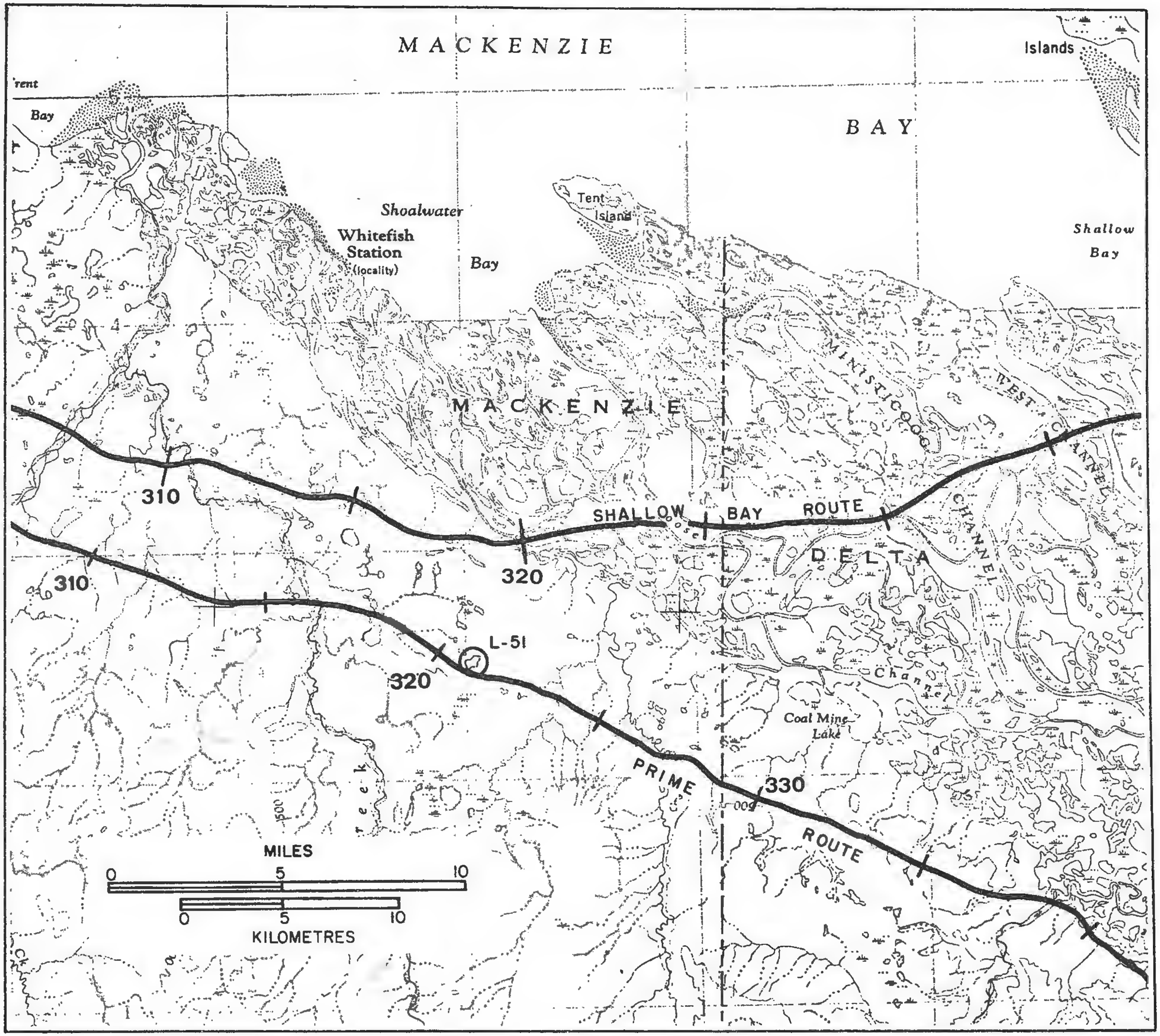

FIGURE 9b. Locations of waterbodies surveyed between Mileposts 320-336.

TABLE 8. Water Availability. Milepost 280 to 336. All volumes are barrels x 1000.

MILEPOST	Volume Required	Number of Lakes	Code	Surface Area (m^2 x 1000)	Mean Depth (m)	Lake Volumes	Mean Volume	Percent Required	Mean Drawdown (m)
280-300	24	4	L-40	1,200	2.1	15,397	8,187	4.3	0.09
Camp 300	328		L-41	275	4.0	6,721			
			L-42	113	2.8	1,933			
			L-43	750	1.9	8,707			
300-319	1187	8	L-44	2,275	1.1	15,290	11,967	9.9	0.19
			L-45	2,575	2.5	39,334			
			L-46	775	2.6	12,312			
			L-47	750	1.6	7,332			
			L-48	400	2.3	5,621			
			L-49	437	2.1	5,607			
			L-50	550	2.0	6,721			
			L-51	250	2.3	3,513			
319-336	69	0							

by grayling during surveys in 1975. This lake, which is typical of many lakes in this region, is sufficiently deep to support overwintering fish, but small enough to require regulation of water withdrawal. A maximum withdrawal of 10% of the total volume of the lake would ensure adequate overwintering conditions for fish.

The second lake (L-46, 6.5 mi north of Milepost 309) has a population of lake whitefish. However, this lake is deep enough and large enough to permit withdrawal of up to 10% of the volume with little or no effect on fish populations.

Only ninespine stickleback have been reported from a third lake (L-45) located approximately 3 mi southeast of Milepost 300. Water from this lake could be used to supply the construction camp planned in the vicinity of Milepost 300. All of the water required by the camp (328,000 bbl) and all the water required for the section of pipeline between Mileposts 300 and 319 (1,187,000 bbl) could come from this lake without utilizing more than 4% of its total volume.

The nine other lakes surveyed in this region have no known fish populations except ninespine stickleback. Since it is likely, however, that some of these lakes are invaded periodically by grayling and other species of fish, it is recommended that not more than 10% of the volume of any one source be withdrawn.

Beyond Milepost 320, the pipeline route lies close to the western edge of the Mackenzie River Delta. In addition to the adequate quantities of water available in the lakes surveyed, large amounts of water are available from both the western channel of the Mackenzie River and from the numerous lakes in the delta.

CONCLUSIONS AND RECOMMENDATIONS

The general conclusions and recommendations of this study are:

1) There are more than adequate quantities of water available to meet the estimated water requirements for construction of the proposed Arctic Gas Pipeline from Prudhoe Bay to the Mackenzie River Delta. Overall, the total estimated water requirement of 8,222,000 bbl would amount to slightly more than 1% of the 550,967,000 bbl of water available in the lakes surveyed. In addition, the springs surveyed discharge 5,807,000 bbl/day (or slightly less than the total estimated water requirements).

In addition to the lake and spring sources surveyed, other sources of water might be utilized (e.g., sub-gravel flow in rivers where surface flow is frozen).

2) Water can be withdrawn from most of the lakes and springs surveyed (or from others) without serious environmental damage, provided proper safeguards and precautions are observed. Provided that withdrawal is spread out among the sources surveyed, and that no more than 10% of the total volume is taken from any one source, the effects upon aquatic habitats should be minimal.

3) A preliminary selection of water sources can be made on the basis of the information provided in this report. However, additional site-specific biological, hydrological, and engineering studies are needed before final selection of water sources is made. These studies should include the following:

a) fisheries surveys in the fall and winter to determine spawning and overwintering areas in springs and lakes;
b) hydrological assessments of recharge rates, seasonal and annual variability in spring discharge rates, and precise volumetric measurements of lakes known to be overwintering areas for fish;
c) engineering studies including geophysical and drilling programs, as well as pump tests to determine the availability of sub-gravel flows in river channels, and studies to determine the feasibility of using sumps in the vicinity of springs;
d) since a number of springs (including Hulahula, Malcolm, Firth, and Crow River springs) are located a short distance downstream (north) of the pipeline crossings on these rivers, it should be determined whether or not the deep burial of the pipeline in river channels above these springs might interfere with the aquifers that feed these springs.

4) During the construction phase, it is recommended that:

a) the volume of water withdrawn from any one source should not exceed 10% of the total volume of water available;

b) during development of sources and during water withdrawal, each location with known populations of spawning or overwintering fish should be individually monitored by a fisheries biologist familiar with the lakes and springs of the North Slope;

c) springs known to support fish populations should not be developed as sources of water if suitable alternative sources are available;

d) when springs are developed as water sources, damage to the aquatic environment can be minimized by:

- avoiding rechannelization of natural spring channels
- using sumps in the gravel downstream toward the *aufeis* and away from the spring orifice
- providing suitable barriers or screens to prevent fish from entering sumps or collection ponds
- avoiding long parallels between spring channels and access roads.

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APPENDIX TABLE 1. Estimated monthly water requirements, Prudhoe Bay to west side Mackenzie River Delta (near Milepost 336). These requirements assume worst case estimate of need to manufacture all snow required for access roads, and 20 miles of right-of-way road and work pad for each of five construction spreads.

APPENDIX TABLE 1.

Milepost/Water Use	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total Water Requirement
				Monthly Water Requirements (Thousands of Barrels)						
0-Prudhoe Bay										
Camp	8	11	23	55	56	52	25			
Testing						40				270
0-17										
Ditch Flood						21				
Snow Coat						5				
Snow Roads			451	297	135					909
17-34										
Ditch Flood							34			
Snow Coat							5			
Snow Roads			80	56	23					198
34-44										
Ditch Flood								12		
Snow Coat								3		15
44										
Camp							30	48	20	98
44-56										
Ditch Flood								11	8	
Snow Coat								2	1	22
65										
Testing						40				40
56-73										
Ditch Flood						3				
Snow Coat						7				10

(Continued)

APPENDIX TABLE 1. Continued.

Milepost/Water Use	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total Water Requirement
	Monthly Water Requirement (Thousands of Barrels)									
73-83										
Ditch Flood							6			
Snow Coat							4			10
83										
Camp	8	10	24	55	56	52	55	48	20	328
83-90										
Ditch Flood							1			
Snow Coat							3			
Snow Roads			186	112	55					357
90-112										
Ditch Flood								2	6	
Snow Coat								7	2	
Snow Roads			492	344	147					1000
112-129										
Ditch Flood						24				
Snow Coat						9				33
129										
Camp								48	20	
Testing						40				108
129-146										
Ditch Flood							24			
Snow Coat							9			33

(Continued)

APPENDIX TABLE 1. Continued.

Milepost/Water Use	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total Water Requirement
	Monthly Water Requirements (Thousands of Barrels)									
146-168										
Ditch Flood								20	6	
Snow Coat								9	3	38
168-177										
Ditch Flood								5	6	
Snow Coat								2	3	
Snow Road			53	37	16					122
177										
Camp	8	10	24	55	56	52	55			260
177-190										
Ditch Flood								13		
Snow Coat								7		
Snow Roads			408	267	122					817
190-207										
Ditch Flood							11			
Snow Coat							9			
Snow Roads			133	93	39					
Testing						40				325
207-216										
Ditch Flood						3				
Snow Coat						5				
Snow Roads			270	189	81					548
216-Komakuk Beach										
Camp	8	10	24	55	56	52	55	48	20	328

(Continued)

APPENDIX TABLE 1. Continued.

Milepost/Water Use	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total Water Requirement
	Monthly Water Requirements (Thousands of Barrels)									
216-224										
Ditch Flood						2				
Snow Coat						4				
Snow Roads			212	130	64					412
224-246										
Ditch Flood								14	2	
Snow Coat								5	2	
Snow Roads			80	56	23					182
246-263										
Ditch Flood							17			
Snow Coat							5			
Testing						40				62
270										
Camp								48	20	68
263-280										
Ditch Flood						16				
Snow Coat						5				21
280-300										
Ditch Flood								16	5	
Snow Coat								2	1	24
300-Shingle Point										
Camp	8	10	24	55	56	52	55	48	20	328

(Continued)

APPENDIX TABLE 1. Continued.

Milepost/Water Use	Monthly Water Requirements (Thousands of Barrels) Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total Water Requirement
300-319										
Ditch Flood							25	3		
Snow Coat							2			
Snow Roads			588	393	176					1187
319-336										
Ditch Flood						14				
Snow Coat						2				
Snow Roads			27	19	7					69

APPENDIX TABLE 2. Summary of the morphometric characteristics of the lakes surveyed. Water Availability Study, 1975. Volumes are barrels x 1000.

APPENDIX TABLE 2.

Location/Milepost	Code	Average Depth (m)	Surface Area (m^2 x 1000)	Total Estimated Volume	Estimated Freewater Volume with 0.73 m of ice	Estimated Freewater Volume with 1.5 m of ice
3 mi E MP 2	L-1	1.25	1,164	8,890	3,699	0
1 mi E MP 3	L-2	1.8	1,265	13,912	8,268	2,318
3.5 mi S MP 5	L-3	2.0	2,409	29,438	18,691	7,359
1 mi S MP 12	L-4	1.5	2,489	22,812	11,710	0
1 mi N MP 13	L-5	1.85	1,867	21,104	12,775	3,992
2 mi S MP 16.5	L-6	1.4	803	6,869	3,287	0
1 mi S MP 22	L-7	1.9	642	7,453	4,592	1,570
3 mi S MP 24	L-8	1.7	1,485	15,425	8,803	1,815
1 mi S MP 26	L-9	2.1	522	6,698	4,369	1,913
3 mi S MP 26	L-10	1.6	1,224	11,966	6,509	748
2 mi N MP 32	L-11	1.8	1,465	16,112	9,580	2,686
2 mi N MP 33	L-12	0.6	201	737	0	0
2 mi N MP 33	L-13	0.8	442	2,160	188	0
2 mi N MP 34	L-14	1.25	1,445	11,036	4,592	0
2 mi S MP 34	L-15	0.5	582	2,084	0	0
1 mi S MP 39	L-16	2.0	301	3,678	2,336	920

(Continued)

APPENDIX TABLE 2. Continued.

Location/Milepost	Code	Average Depth (m)	Surface Area (m^2 x 1000)	Total Estimated Volume	Estimated Freewater Volume with 0.73 m of ice	Estimated Freewater Volume with 1.5 m of ice
2 mi N MP 47	L-17	1.9	361	4,191	2,583	883
0.5 mi N MP 51	L-18	2.4	321	4,707	3,277	1,766
1.5 mi S MP 53	L-19	1.6	321	3,138	1,707	196
1.5 mi S MP 62	L-20	2.8	381	6,518	4,823	3,029
1.5 mi S MP 63	L-21	2.5	482	7,363	5,210	2,943
4 mi N MP 131	L-22	1.6	763	7,459	4,055	466
2 mi N MP 192	L-23	2.7	1,204	19,862	14,497	8,831
2 mi N MP 193	L-24	2.8	521	8,913	6,601	4,145
4 mi N MP 193	L-25	2.3	2,369	33,292	22,722	11,578
2 mi N MP 215	L-26	2.8	550	9,409	6,957	4,369
2 mi S MP 231	L-27	4.3	125	3,284	2,727	2,139
2 mi S MP 231	L-28	13.6	50	4,155	3,929	3,696
1 mi N MP 233	L-29	1.8	175	1,925	1,144	321
1 mi N MP 240	L-30	2.9	687	12,173	9,116	5,881
0.5 mi N MP 242	L-31	2.3	250	3,513	2,398	1,222
1 mi N MP 242.5	L-32	2.2	300	4,033	2,695	1,283

(Continued)

APPENDIX TABLE 2. Continued.

Location/Milepost	Code	Average Depth (m)	Surface Area (m^2 x 1000)	Total Estimated Volume	Estimated Freewater Volume with 0.73 m of ice	Estimated Freewater Volume with 1.5 m of ice
1 mi E MP 250	L-33	2.7	150	2,475	1,805	1,100
2 mi N MP 252	L-34	2.2	500	6,721	4,491	2,139
5 mi N MP 255	L-35	2.7	2,595	42,810	37,668	19,925
1 mi N MP 259	L-36	2.4	487	7,141	4,975	2,680
3.5 mi N MP 264	L-37	2.4	2,050	30,061	20,918	11,273
2 mi S MP 272	L-38	3.1	4,012	75,991	58,106	39,228
2 mi S MP 274	L-39	1.3	1,675	13,305	5,834	0
2 mi N MP 281	L-40	2.1	1,200	15,397	10,045	4,399
1 mi N MP 289	L-41	4.0	275	6,721	5,495	4,201
1.5 mi E MP 290	L-42	2.8	113	1,933	1,423	894
8 mi N MP 298	L-43	1.9	750	8,707	5,362	1,833
9 mi N MP 304	L-44	1.1	2,275	15,290	5,143	0
3 mi N MP 305	L-45	2.5	2,575	39,334	27,849	15,733
6.5 mi N MP 309	L-46	2.6	775	12,312	8,855	5,209
1 mi N MP 309	L-47	1.6	750	7,332	3,986	458

(Continued)

APPENDIX TABLE 2. Continued.

Location/Milepost	Code	Average Depth (m)	Surface Area (m^2 x 1000)	Total Estimated Volume	Estimated Freewater Volume with 0.73 m of ice	Estimated Freewater Volume with 1.5 m of ice
4 mi N MP 315	L-48	2.3	400	5,621	3,837	1,955
3 mi N MP 317.5	L-49	2.1	437	5,607	3,662	1,609
0.5 mi S MP 318	L-50	2.0	550	6,721	4,268	1,680
0.5 mi N MP 321	L-51	2.3	250	3,513	2,398	1,222

APPENDIX TABLE 3. Depths, velocities, and discharges of the springs surveyed. Water Availability Study, 1975.

APPENDIX TABLE 3.

Name/Milepost	Code	Mean Depth (m)	Mean Velocity (m/sec)	Discharge m^3/sec.	Discharge cfs	Daily Discharge Bbl.x1000
Katakturuk W. Fork	S-1	0.12	0.44	0.24	8.50	-
5 mi. S. M.P.86.5		0.06	0.05	0.01	0.45	-
(4 channels)		0.05	0.08	0.01	0.39	181
		0.10	0.15	0.08	2.75	-
Katakturuk E. Fork	S-2	0.13	0.23	0.22	7.67	-
5 mi. S. M.P. 87		0.09	0.21	0.11	3.91	173
(2 channels)						
Sadlerochit R.	S-3	0.25	0.46	1.22	43.20	645
7 mi. S. M.P. 111						
Hulahula R.	S-4	0.13	0.14	0.14	4.83	153
1 mi. N. M.P. 116.5		0.17	0.20	0.15	5.43	-
(2 channels)						
Okpilik (Hot Sps.)	S-5	0.03	0.10	0.008	0.27	4
Okerokovik R.	S-6	0.03	0.09	0.008	0.31	-
@ M.P. 138		0.06	0.11	0.035	1.25	-
(4 channels)		0.04	0.13	0.21	0.75	-
		0.05	0.13	0.03	1.04	50
Ekaluakat R.	S-7	0.13	0.34	0.64	22.40	335
5 mi. S. M.P. 162						
Kongakut Delta	S-8	0.31	0.36	2.08	73.59	-
6 mi. N. M.P. 173		0.06	0.40	0.22	7.87	-
(4 channels)		0.04	0.17	0.07	2.56	1558
		0.12	0.27	0.57	20.22	-

(Continued)

APPENDIX TABLE 3. Continued.

Name/Milepost	Code	Mean Depth (m)	Mean Velocity (m/sec)	Discharge m^3/sec.	Discharge cfs	Daily Discharge Bbl.x1000
Kongakut R. 6 mi. S. M.P. 174	S-9	0.12	0.30	0.53	18.8	281
Clarence R.	S-10	0.10	0.21	0.07	2.48	37
Craig Cr. 3 mi. S. M.P. 197	S-11	0.11	0.28	0.10	3.37	50
Craig Cr. Trib. 2 mi. S. M.P. 198 (10 channels)	S-12	0.10	0.27	0.20	6.95	-
		0.04	0.10	0.01	0.44	-
		0.04	0.10	0.01	0.44	-
		0.04	0.10	0.01	0.44	-
		0.04	0.10	0.01	0.44	-
		0.04	0.10	0.01	0.44	-
		0.04	0.10	0.01	0.44	-
		0.04	0.10	0.01	0.44	-
		0.05	0.15	0.02	0.81	-
		0.045	0.12	0.02	0.84	175
Fish Cr. 2 mi. N. M.P. 217.5	S-13	0.12	0.21	0.10	3.42	-
		0.15	0.61	0.35	12.35	236
Malcolm R. 2 mi. N. M.P. 225	S-14	0.19	0.44	0.65	22.91	342
Firth 2 Spring 2.2 mi. N. M.P. 227	S-15	0.15	0.40	0.78	26.78	400

(Continued)

APPENDIX TABLE 3. Continued.

Name/Milepost	Code	Mean Depth (m)	Mean Velocity (m/sec)	Discharge m^3/sec.	Discharge cfs	Daily Discharge Bbl.x1000
Firth Delta 2 mi. N. M.P. 233	S-16	0.15	0.40	1.64	58.04	868
Spring R. 2 mi. N. M.P. 256	S-17	0.17	0.22	0.17	6.07	91
Crow R. 2 mi. N. M.P. 268	S-18	0.26	0.17	0.26	9.03	135

APPENDIX TABLE 4 . Summary of water availability information from joint USGS/Alaskan Arctic Gas hydrological survey, November, 1975.

APPENDIX TABLE 4.

Location/Milepost	Ice Thickness (m)	Water Depth (m)	Specific Conductivity (µmhos)	Turbidity (NTU)	Discharge (cfs)	Date November
Sagavanirktok River, W Channel 3 mi S PLC	0.73	0.88	400	0	0-5	11
Sagavanirktok River, E Channel	0.67	0.06	460	0	0	11
Lake 1 mi S MP 12	0.67	0.49	620	1	-	10
Lake 1 mi N MP 13	0.46	1.20	600	1	-	8
Lake 3 mi S MP 26	0.63	0.67	510	0	-	10
Kadleroshilik River, @ PLC	0.46	0	-	-	-	10
Lake 2 mi N MP 22	0.76	0.76	990	0	-	10
Shaviovik River, @ PLC	0.76	0.58	340	0	12.2	7
Kavik River, 2 mi S MP 37	0.82	0.18	390	0	0-1	9
Canning River, L mi S MP 61	0.70	0.61	320	0	228	8
Canning River Delta	1.50	0	-	-	0	30
Lake 13 mi N MP 82	1.10	1.06	220	1	-	30
Sadlerochit Springs	0	0.15	360	0	38.7	16
Hulahula Springs	0	0.21	225	1	4.6	26
Hulahula River, near mouth	0.76	0	-	-	0	22
Lake 24 mi N MP 126	0.98	0.92	520	0	-	25
Lake 20 mi N MP 124	1.09	0.79	115	0	-	22

(Continued)

APPENDIX TABLE 4. Continued.

Location/Milepost	Ice Thickness (m)	Water Depth (m)	Specific Conductivity (µmhos)	Turbidity (NTU)	Discharge (cfs)	Date November
Okerokovik River, @ PLC	0	0.06	300	0	2.6	24
Lake 1 mi E Jago, 4 mi from coast	0.82	1.5	80	1	-	17
Lake 3 mi E Jago, 1 mi from coast	0.85	2.2	280	0	-	17
Aichilik River, 1 mi S PLC	1.2	0.1	370	1	0-0.25	25
Aichilik River, near mouth	1.09	0	-	-	0	23
Egaksrak River, 1 mi S PLC	0.92	0	-	-	0	24
Egaksrak River, near mouth	1.07	2.06	560	0	0-25	23
Ekaluakat River, 2 mi N PLC	0.92	0	-	-	0	24
Lake, Aichilik Delta	1.04	2.2	600	0	-	24
Kongakut Delta Springs	0	0.27	210	0	88.4	18
Lake near Demarcation Point	0.85	1.3	410	0	-	18
Clarence River Springs	0	0.09	250	0	4.7	18

APPENDIX TABLE 5. Summary of fisheries information for the potential water sources surveyed along the pipeline route.

APPENDIX TABLE 5.

Location/Milepost	Code	Information* Sources	Fish Species Present**							
			None	NNST	CHAR	GRAY	LKWT	BDWT	LSCO	POND
3 mi E MP 2	L-1	1	+							
1 mi E MP 3	L-2	1	+							
3.5 mi S MP 5	L-3	No data								
1 mi S MP 12	L-4	1	+							
1 mi N MP 13	L-5	1	+							
2 mi S MP 16.5	L-6	1	+							
1 mi S MP 22	L-7	1	+							
3 mi S MP 24	L-8	1	+							
1 mi S MP 26	L-9	1	+							
3 mi S MP 26	L-10	1		+						
2 mi N MP 32	L-11	1	+							
2 mi N MP 33	L-12	No data								
2 mi N MP 33	L-13	No data								
2 mi N MP 34	L-14	1	+							
2 mi S MP 34	L-15	No data								
1 mi S MP 39	L-16	1	+							

(Continued)

APPENDIX TABLE 5. Continued.

Location/Milepost	Code	Information* Sources	Fish Species Present** None	NNST	CHAR	GRAY	LKWT	BDWT	LSCO	POND
2 mi N MP 47	L-17	1	+							
0.5 mi N MP 51	L-18	1		+						
1.5 mi S MP 53	L-19	1	+							
1.5 mi S MP 62	L-20	1		+						
1.5 mi S MP 63	L-21	1		+						
Katakturuk Sp. 5 mi S MP 87	S-1 S-2	1,2	+							
Sadlerochit Sp. 7 mi S MP 111	S-3	1,2			+	+				
Hulahula Sp. 1 mi N MP 116.5	S-4	1,2			+					
Okpilik Hot Sp. 30 mi S MP 120	S-5	1			+					
4 mi N MP 131	L-22									
Okerokovik Sp. MP 138	S-6	1,2	+							
Ekaluakat Sp. 5 mi S MP 162	S-7	1,2			+					
Kongakut Delta Sp. 7 mi N MP 174	S-8	1,2			+					

(Continued)

APPENDIX TABLE 5. Continued.

Location/Milepost	Code	Information* Sources	None	NNST	CHAR	GRAY	LKWT	BDWT	LSCO	POND
			Fish Species Present**							
Kongakut R. Sp. 6 mi S MP 174	S-9	1,2			+					
Clarence R. Sp. 5 mi S MP 190	S-10	1,2			+					
2 mi N MP 192	L-23	1		+						
2 mi N MP 193	L-24	1		+						
4 mi N MP 193	L-25	1		+						
Craig Creek Sp. 3 mi S MP 197	S-11	1,3	+							
Craig Cr. Trib. Sp., 2 mi S MP 198	S-12	1,3	+							
2 mi N MP 215	L-26	1		+						
Fish Cr. Sp. 2 mi N MP 217.5	S-13	1,3			+					
Malcolm R. Sp. 2 mi N MP 225	S-14	1,3			+	+				
Firth Sp. 2 1 mi N MP 228	S-15	1,3			+					
Lake 103 2 mi S MP 231	L-27	3		+	+					

(Continued)

APPENDIX TABLE 5. Continued.

Location/Milepost	Code	Information* Sources	Fish Species Present**							
			None	NNST	CHAR	GRAY	LKWT	BDWT	LSCO	POND
Lake 104 2 mi S MP 231	L-28	3		+	+					
1 mi N MP 233	L-29	No data								
Firth R. Delta Sp. 2 mi N MP 233	S-16	1,3			+					
1 mi N MP 240	L-30	3	+							
MP 242	L-31	No data								
1 mi N MP 242.5	L-32	No data								
1 mi E MP 250	L-33	No data								
2 mi N MP 252	L-34	3		+		+	+	+		+
5 mi N MP 255	L-35	3,4		+		+	+	+		+
Spring R. Sp. 2 mi N MP 256	S-17	1,3	+							
1 mi N MP 259	L-36	No data								
Bloomfield Lake 3.5 mi N MP 264	L-37	3	+							
Crow R. Sp. 2 mi N MP 268	S-18	1,3	+							
2 mi S MP 272	L-38	1,3				+		+	+	

(Continued)

APPENDIX TABLE 5. Continued.

Location/Milepost	Code	Information* Sources	Fish Species Present** None	NNST	CHAR	GRAY	LKWT	BDWT	LSCO	POND
2 mi S MP 274	L-39	1	+							
2 mi N MP 281	L-40	1	+							
1 mi N MP 289	L-41					+				
1.5 mi E MP 290	L-42	1		+		+				
8 mi N MP 298	L-43	1	+							
Peat Lake 9 mi N MP 304	L-44	1		+						
3 mi N MP 305	L-45	1		+						
6.5 mi N MP 309	L-46	1		+			+			
1 mi N MP 309	L-47	1	+							
4 mi N MP 315	L-48	1	+							
3 mi N MP 317.5	L-49	1	+							
0.5 mi S MP 318	L-50	5				+				
0.5 mi N MP 321	L-51	1		+						

(Continued)

APPENDIX TABLE 5. Continued.

* Information Sources CODE

1 - Water Availability Study, 1975

2 - Ward and Craig, 1974

3 - McCart *et al.*, 1974

4 - de Graaf, 1974

5 - Steigenberger *et al.*, 1975

** Fish Species CODE

None - No fish present

NNST - ninespine stickleback

CHAR - Arctic char

GRAY - Arctic grayling

LKWT - lake whitefish

BDWT - broad whitefish

LSCO - least cisco

POND - pond smelt

CHAPTER II

FISHERIES INVESTIGATIONS IN A COASTAL REGION OF THE BEAUFORT SEA (KAKTOVIK LAGOON, ALASKA)

W. B. GRIFFITHS
J. K. DEN BESTE
P. C. CRAIG

ABSTRACT

The Kaktovik Lagoon (Barter Island, Alaska) study was designed to provide seasonal baseline data on the ecology of benthic invertebrates and fish at a proposed staging site on the Beaufort Sea coast in Alaska. In 1975, surveys were carried out during late winter (May), during the open water period from June to September, and during early winter (November). Samples were collected from a variety of sites in Kaktovik Lagoon and adjacent areas and, where possible, results compared to a similar study conducted at Nunaluk Lagoon (Yukon Territory) the previous year.

A variety of physical and chemical parameters were recorded throughout the open water season: temperature, salinity, pH, conductivity, dissolved oxygen, macronutrients, and major ions. Benthic invertebrates were sampled using coring devices, Ekman grabs, and dredge hauls.

Twelve fish species were collected in Kaktovik Lagoon. Life history information was obtained for the five most abundant species: Arctic char, Arctic cisco, fourhorn sculpin, least cisco, and Arctic cod. Seasonal abundance, diel variation, and food habits of the major species were studied.

The Kaktovik domestic fishery was monitored in 1975. An estimated 3,000 kg of Arctic char, Arctic cisco, lake trout, and Arctic cod were taken by Kaktovik residents.

Results from both Kaktovik and Nunaluk lagoons were similar but there were some differences resulting from the following:

1) Lagoon Depth. Kaktovik Lagoon was deeper than Nunaluk Lagoon and did not freeze to the bottom during winter, thereby providing an ice-free refuge.

2) Freshwater Input. Kaktovik Lagoon was a more marine habitat that Nunaluk Lagoon. The latter received direct discharge from two large rivers.

3) Geographic Location. It is suggested that for some species (Arctic and least cisco), the fish caught at Nunaluk Lagoon originated from the Mackenzie River whereas those caught at Kaktovik Lagoon originated from the Colville River.

ACKNOWLEDGEMENTS

We thank Frank Graves for his field assistance; Anne Pilger, Pauline Marek, Barbara Draskoczi, and Geoff Williams for their assistance in the laboratory; and Cecilia Gossen, Joyce Harris, Joyce McCart, and Sheila Whiston for their help in preparing the manuscript.

We would especially like to thank the residents of Kaktovik for their aid during the present study and in particular for their assistance in the domestic fishing portion of the study.

The Arctic Gas Biological Report Series, of which this report is a part, is a series of consultant project reports presenting data based on field and laboratory studies. The style and presentation vary in accordance with the authors' discretion.

The data for this work were obtained as a result of investigations carried out by Aquatic Environments Limited for Canadian Arctic Gas Study Limited and Alaskan Arctic Gas Study Company. The text of this report may be quoted provided the usual credits are given.

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INTRODUCTION

There have been few intensive studies of nearshore habitats along the portion of Alaskan Beaufort Sea coast paralleled by the proposed Alaskan Arctic Gas pipeline. The present study, conducted at a proposed staging site at Barter Island, represents the second year of a two-year program. A similar study of nearshore habitats was conducted at Nunaluk Spit on the Firth River Delta, Yukon Territory, during the summer of 1974.

Pipeline-related activities may affect nearshore habitats in several ways. These include the construction of staging areas at several locations along the coast, barge traffic along the coast for several summers, and construction activities along the pipeline right-of-way. There is a possibility that materials (e.g., sediments or chemicals) originating at the right-of-way may affect nearshore habitats downstream.

Kaktovik* Lagoon at Barter Island was selected as a study area because the lagoon is a proposed staging site and it appears to be representative of nearshore habitats found along the Alaskan Beaufort Sea coast. The Kaktovik study was designed to provide baseline data on the ecology of benthic invertebrates and fish in a nearshore marine environment. The program included a late winter survey from May 6 to 10, 1975, an intensive open water study from June 28 to September 26, 1975, and an early winter survey from November 1 to 6, 1975.

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*The literature contains five spellings of "Kaktovik". The spelling "Kaktovik" appears to be the most common and is the spelling used by the natives of the village of Kaktovik.

This report emphasizes a comparison of fisheries information, specifically distribution, life histories and food habits of the three most abundant species, Arctic char, Arctic cisco, and fourhorn sculpin found in Nunaluk Lagoon in 1974 (Griffiths *et al.*, 1975) and Kaktovik Lagoon in 1975.

Two surveys were carried out at other proposed staging areas (Bullen Point and Demarcation Bay) and information was gathered on the Kaktovik domestic fishery. Results are included in Appendices.

STUDY AREA

Kaktovik Lagoon is located along the Beaufort Sea coast at Barter Island (Figure 1). Two major sampling stations were established in the study area (Figure 2). One was located on the west side of Kaktovik Lagoon approximately 110 m south of Pipsuk Point (Station A), and the other on the seaward side of Barter Island (Station B).

Barter Island is a large, irregularly-shaped island 0.5 km off the Alaskan coast. The two major landmarks on the island are the Distant Early Warning Line Station just west of Station B and the Village of Kaktovik (population 130) on the south shore of Pipsuk Bight. The north and east shores of the island are lined with cliffs (maximum height 9 m) composed of sand, gravel, and peat (Lewis, 1959). These cliffs are protected from direct wave erosion by a narrow gravel beach. Two large sandpits (about 2 km long) on the north shore of Barter Island are characterized by medium-sized pebble gravel. A runway has been constructed on the eastern spit.

In the south and the east, the island is predominantly a lowland marsh dotted with tundra ponds. The ponds vary in surface area but are typically shallow with a mud-silt substrate, and contain submerged macrophytes. The large freshwater lake near the centre of Barter Island is also shallow (about 2 m).

Ocean depths drop to 4.8 m within 50 m of the shoreline, on the seaward side of Barter Island. The substrate in nearshore areas is sand

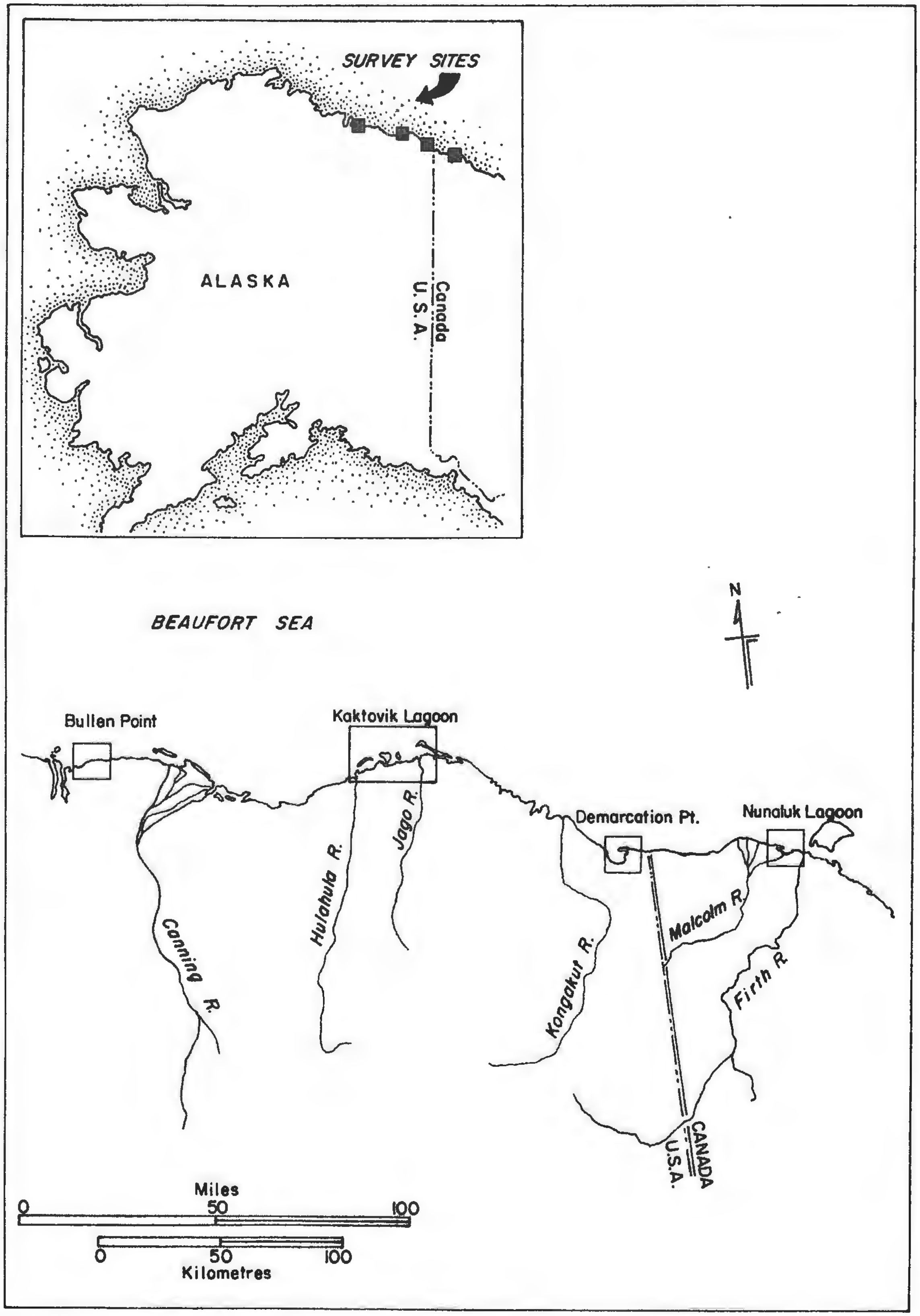

FIGURE 1. Location of Kaktovik Lagoon on the Alaskan North Slope. Locations of Nunaluk Lagoon and two survey sites, Bullen Point and Demarcation Bay, are also indicated.

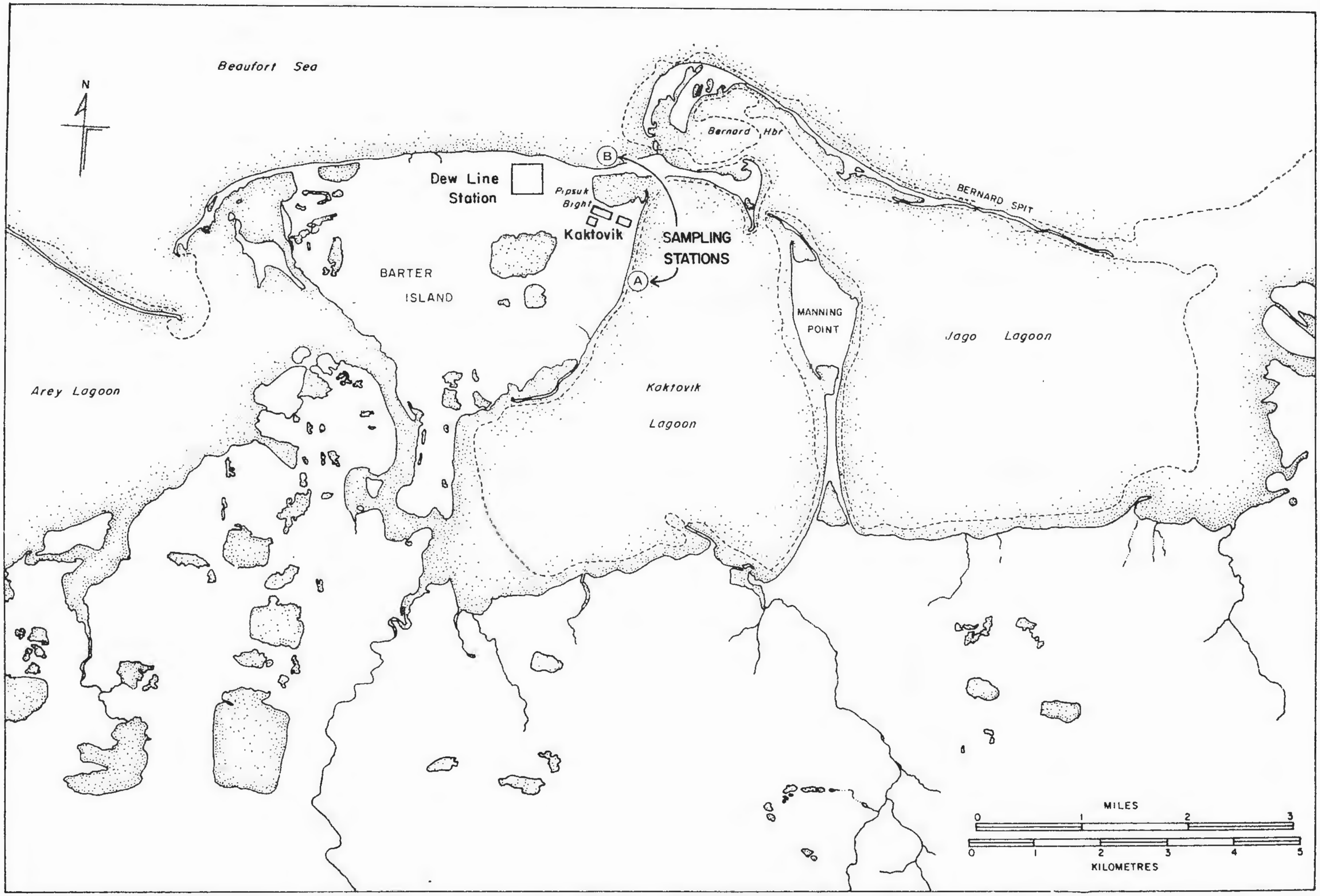

FIGURE 2. Map of Barter Island study area showing location of two major sampling stations A and B. Dotted line indicates the one metre water depth contour.

and gravel grading to sand and mud 20-30 m from shore. These conditions were typical of the permanent ocean sampling site, Station B.

Kaktovik Lagoon is a large, enclosed body of water with two entrances. The northern entrance is protected from direct ocean exposure by Bernard Spit. Water depths in the lagoon vary to a maximum of 4.0 m. Station A was located in water 1-1.5 m deep on the east side of Barter Island. Substrates in the lagoon vary according to water depth and location. Fine to medium pebble gravel characterizes the shallow waters around the lagoon, except in the southwest corner where mud predominates. The deep central portion is made up of sand, mud, and soft clay.

The mainland along the south shore of Kaktovik Lagoon is lined with cliffs 1-4 m in height, fronted by narrow gravel beaches. Fresh water enters the lagoon from five tundra streams fed by a few small ponds and runoff from surrounding tundra. Other tundra ponds are found on the marshy mainland southwest of Barter Island, but few of these ponds have any connection with the lagoon. No large streams flow directly into the lagoon.

Pipsuk Bight is a large inlet at the northwest corner of Kaktovik Lagoon. The average depth is a uniform 1.5 m, and the substrate is predominantly sand and mud. The bight is bounded on the north by the runway spit, on the west by a sandy beach, and on the south by the village of Kaktovik. On the south shore is a slumping cliff approximately 2.0-2.5 m in height.

WATER QUALITY STUDIES

Methods

Selected physical and chemical parameters were measured in a late winter survey (May 6-10, 1975) and throughout the open water season. Weather permitting, the following measurements were made in the field every two days: pH, salinity, conductivity, dissolved oxygen, and temperature. Methods used for field measurements are summarized in Table 1. Location of sites drilled during the winter survey are shown in Figure 3A.

A 500 ml surface water sample was collected weekly for turbidity and suspended sediment determinations. The unfiltered sample was treated with 2 ml of 0.4% $CuSO_4$. At two week intervals, two surface water samples (500 ml) were collected for nutrient and major ion analyses. Both samples were filtered using Whatman GF/C filter discs. One bottle of filtrate was preserved with 5 ml 4N HCl for total dissolved nitrogen, phosphorous, and metal ion determinations, and the second bottle of filtrate was preserved with 2.5 ml $CHCl_3$ (chloroform) for reactive silica and major ion analyses. All samples were shipped to Calgary for laboratory analysis (Table 1).

Temperature, conductivity, and salinity profiles were carried out in Kaktovik Lagoon on August 4 and August 25, 1975. Nine sites were sampled on each date (Figure 3B). Three readings were taken at each site from the surface, middle, and bottom of the lagoon. Where large

TABLE 1. Description of instruments, units, and accuracy of techniques used to measure various physical and chemical parameters.

Parameter	Instruments or Techniques Used	Units	Lower Limits of Accuracy
*Salinity	YSI-33 Salinity/Conductivity Meter	Parts per thousand (‰)	±0.9 ‰ above 4°C ±1.0 ‰ below 4°C
*Conductivity	YSI-33 Salinity/Conductivity Meter	μhos/cm	± 3% at mid scale
*Temperature	1) YSI-33 Salinity/Conductivity Meter	°C	±0.1° at -2° ±0.6° at 45°C
	2) Fisher Max/Min Thermometer	°C	-
	3) Mercury Pocket Thermometer (after Aug.1,1975)	°C	±0.5°C
Dissolved Oxygen	Hach Portable Oxygen Determination Kit	mg/1	±0.5 mg/1
pH	Merck non-bleeding indicator sticks**	pH units	±0.5 pH units
Suspended Sediments	Standard Methods***	mg/1	±0.5 mg/1
Turbidity	Hach Model 2100A Turbidimeter	Formazin Turbidity units (F.T.U.)	± 2% of full scale
Chloride Ion	Standard Methods:Argentometric titration	mg/1	±0.5 mg/1
Sulphate Ion	Standard Methods:Turbidimetric method	mg/1	1.0 mg±10% @ lower limit of detection

(Continued)

TABLE 1. Continued.

Parameter		Instruments or Techniques Used	Units	Lower Limits of Accuracy
Total Dissolved Phosphorous		Standard Methods:		
	****1)	Sulphuric acid-perchlorate digestion method	μg/1	+ 5 μg/1
	2)	Phosphate detection by ascorbic acid reduction method		
Total Dissolved Nitrogen (TDN)	1)	U.V. irradiation (Strickland and Parsons, 1965)	μg/1	+ 5 μg/1
	2)	Cadmium reduction to nitrites Standard Methods	μg/1	+ 5 μg/1
	3)	Nitrite analysis (Strickland and Parsons, 1965)	μg/1	+ 5 μg/1
Reactive Silicates		Standard Methods:Heteropoly blue	μg/1	± 100 μg/1
Na^+, K^+, Mg^+, and Ca^{++}, Fe^{++}		Atomic absorption:Instrumentation Laboratories Model 151 aa/ae spectrophotometer	mg/1	± 1.0 mg/1 for all ions
Total Alkalinity		Standard Methods:Acid Titration	mg/1	± 1.0 mg/1

* Measure using 50 ft leads.

** Readings spot-checked in lab using Radiometer pH Meter Type 296, combined Electrode type Radiometer GK 2311 C. Accuracy ±0.1 pH units.

*** Standard Methods refers to procedures outlined in Standard Methods for the Examination of Water and Wastewater - 13th Ed.(1971).

**** Numbers refer to the steps involved in test.

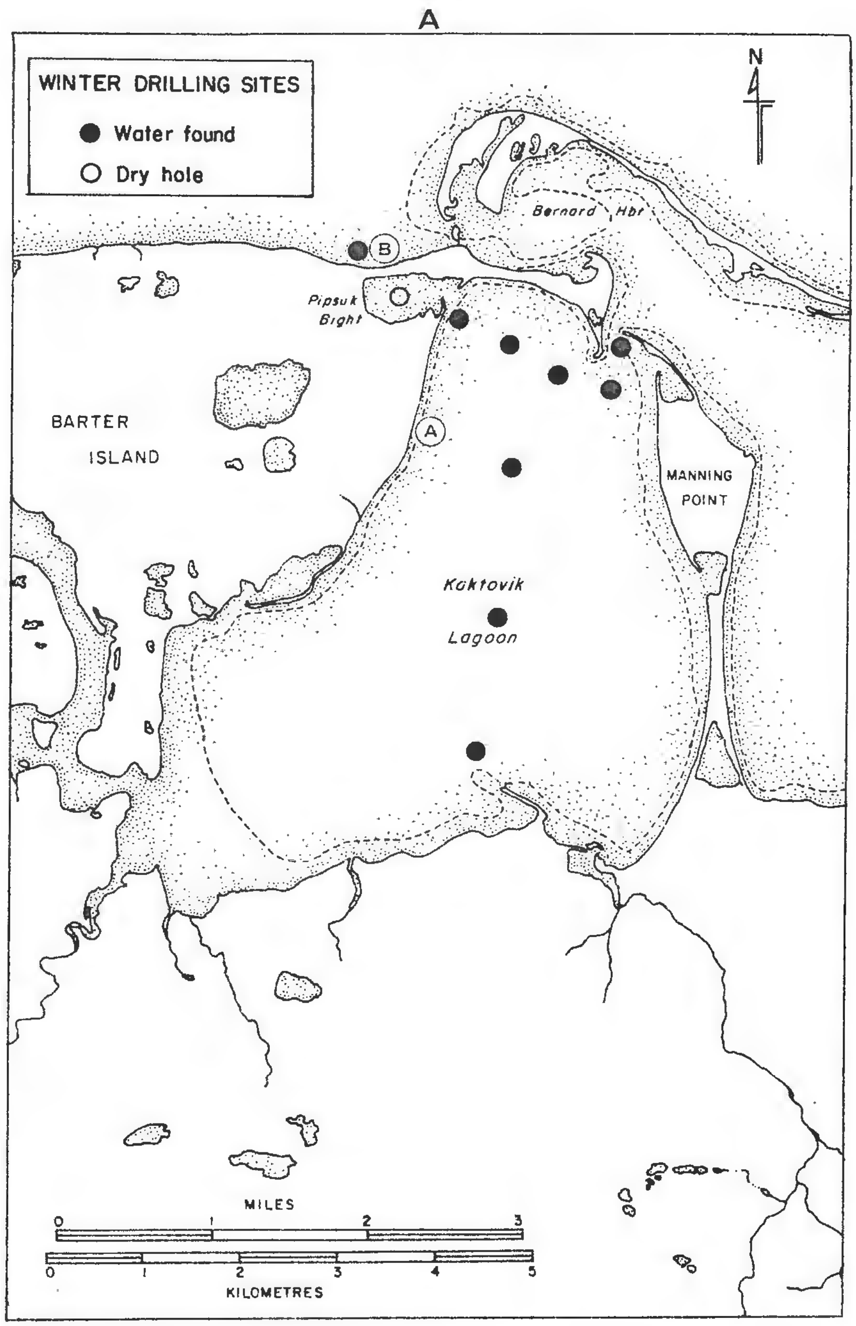

FIGURE 3A. Location of winter drilling sites, May 6-10, 1975.

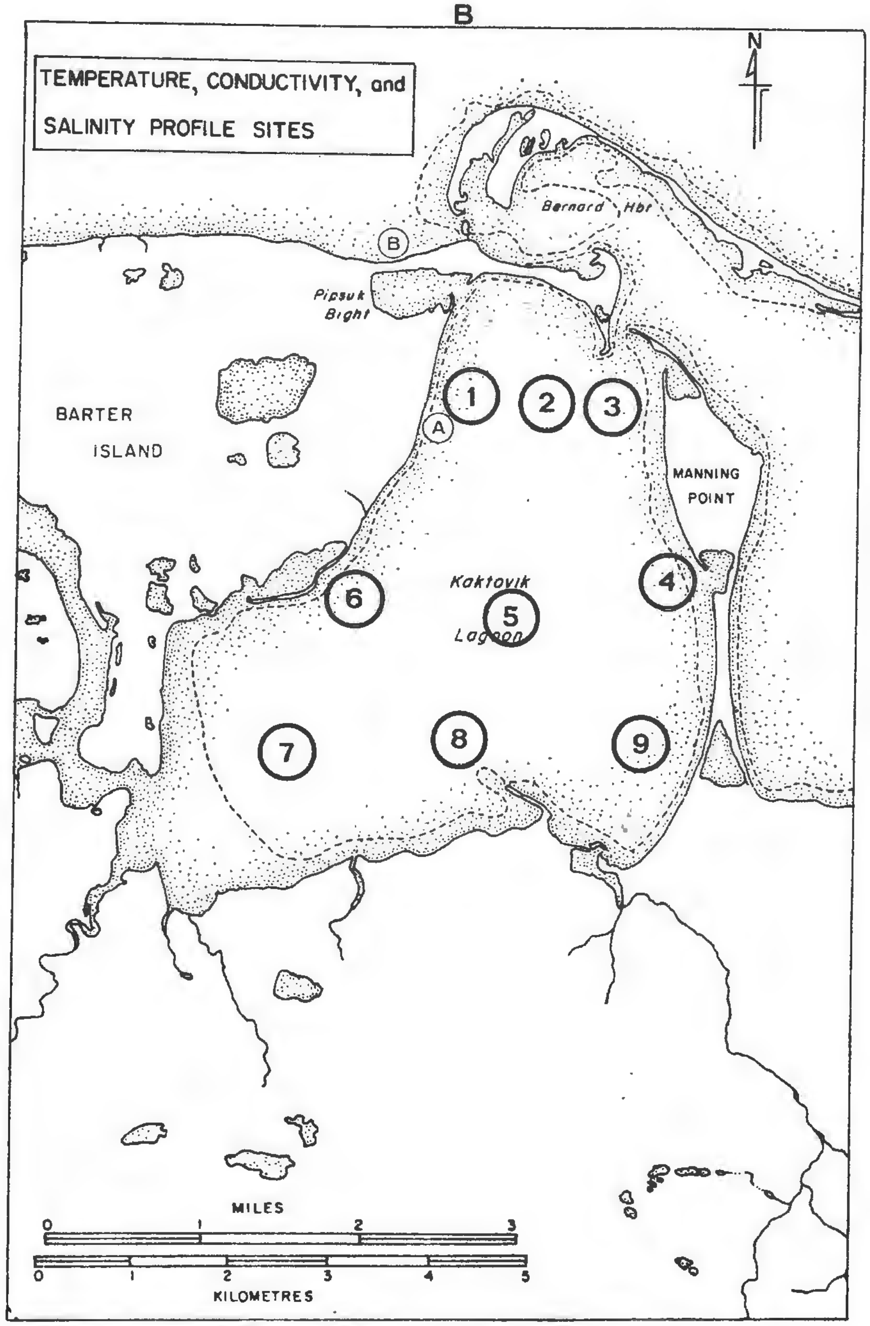

FIGURE 3B. Location of temperature, conductivity, and salinity profile sites (August 4 and 25, 1975) in Barter Island study area.

fluctuations were recorded, additional readings were taken to determine the depth of the interface between low salinity and marine layers. Two 500 ml water samples (surface and bottom) were taken at site 8, then filtered, preserved, and returned to the laboratory for major ion and nutrient analyses.

Results

Physical Environment

During the late winter survey in May, Kaktovik Lagoon was frozen over, but free water was present under the ice at each of eight holes drilled (Figure 3A). Water depths varied from 0.2-2.0 m, under ice which ranged from 1.6-2.0 m in thickness. Pipsuk Bight was frozen to the bottom with no free water between ice and substrate. At an ocean site 50 m offshore from Station B, there was 0.9 m of free water underneath 1.9 m of ice.

In 1975, breakup started in the first two weeks of June. When the sampling program began on June 27, most of the lagoon was still ice-covered, although there was open water in the western one-third of Pipsuk Bight, a ring of water around the bight, and a narrow band of water along the ocean side of Barter Island. Under the influence of winds and warm temperatures, the ice receded rapidly. Pipsuk Bight was ice-free by July 6, and Kaktovik Lagoon by July 11. Both of these areas remained ice-free for the remainder of the summer, except for an occasional ice floe in Kaktovik Lagoon. By July 11, Bernard Harbour was also relatively ice-free but became clogged with ice periodically due to the influence of westerly winds. The ocean ice broke up rapidly during the early part of July, and by July 20 only large solitary pieces of ice remained. These large pieces stayed within 1-2 km of shore, often remaining beached against the coastline. The 1975 open water season was very unusual in this respect--in most years all ocean ice recedes a distance of 5-20 km from the coastline.

Freeze-up for both the ocean and lagoon occurred September 23 when a layer of ice 5 to 10 cm thick formed overnight. By November 1, the waters around Barter Island were frozen to a depth of approximately 45 cm.

The tides along the Beaufort Sea coast are small, irregular, and unpredictable (Johnson and Hartman, 1969; Lewellen, 1970). Wind-generated changes in water levels are of more importance than those caused by tidal fluctuations. Typical daily fluctuations in water levels in the Kaktovik Lagoon area average 10-15 cm (Figure 4), although the difference between the highest level (August 27) and the lowest level (August 24) was 75 cm (Figure 5). The highest water levels corresponded to periods of strong westerly winds, and the lowest levels to periods of easterly winds.

There is a weak coastal current moving from the east to the west along the Beaufort Sea coast (Johnson and Hartman, 1969). Surface currents along the shore depend on local winds and vary between 0 and 60 cm/sec (Hufford, 1974). This is usually the case at Barter Island where currents are influenced by prevailing easterly winds (Hufford, 1974), but in 1975 winds and associated currents were predominantly out

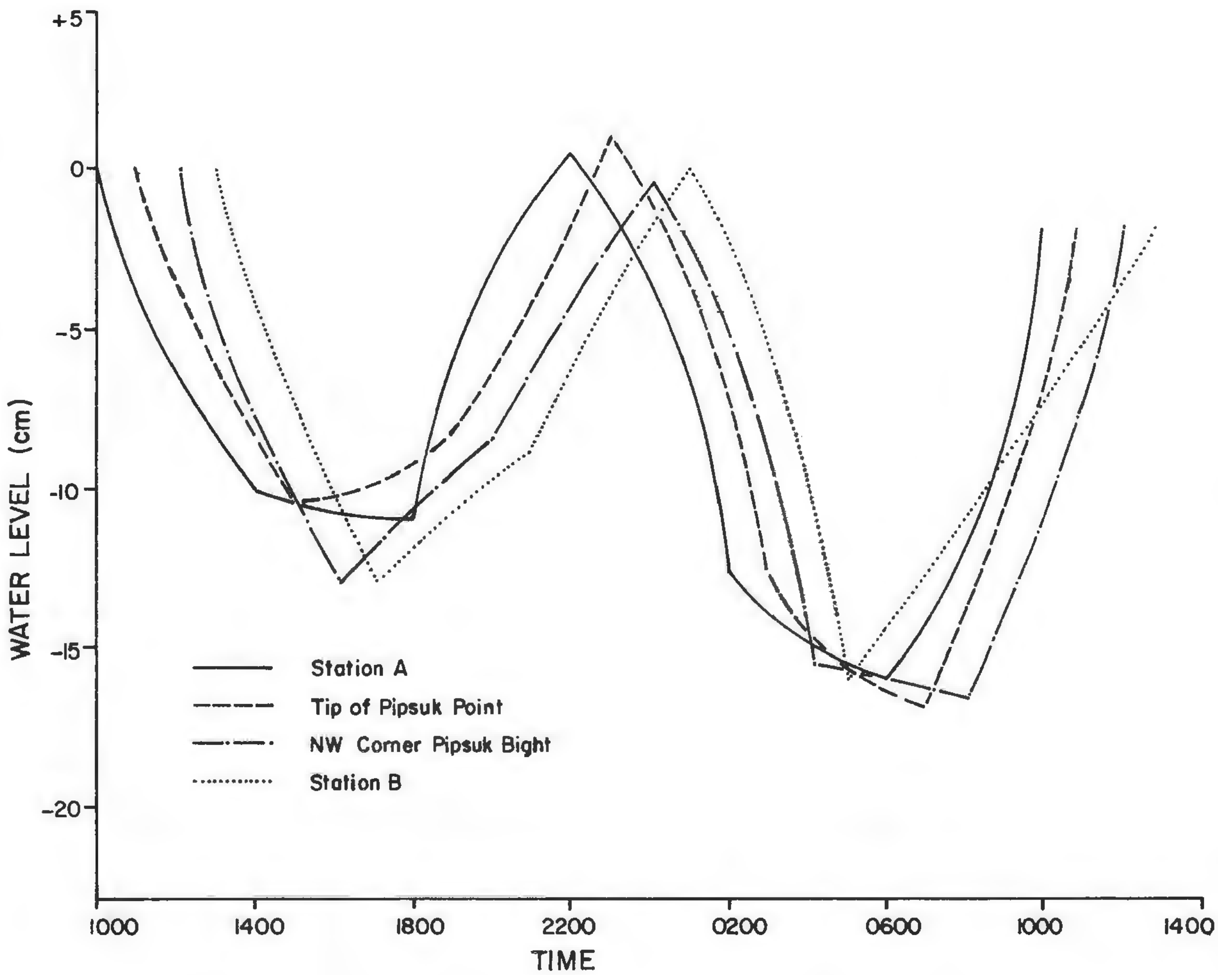

FIGURE 4. Typical 24-hour tide fluctuations recorded at four locations in the Kaktovik Lagoon study area, July 26, 1975. Changes in water levels are measured against an arbitrary reference point.

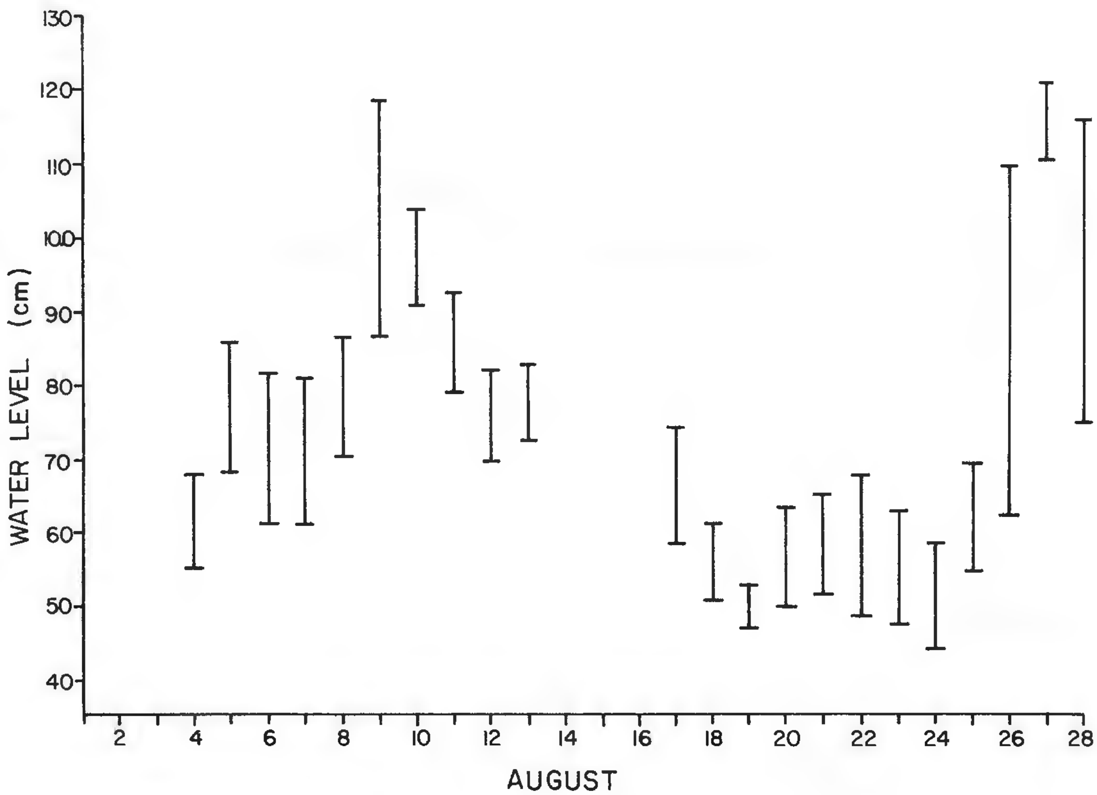

FIGURE 5. Water level fluctuations in Pipsuk Bight in August, 1975. Bars indicate approximate daily range of water levels. Changes in water levels are measured against an arbitrary reference point.

of the west.

Physical and Chemical Parameters

Stations A and B

Seasonal trends in selected physical and chemical measurements at Station A (located inside Kaktovik Lagoon) and Station B (located in the ocean) are shown in Figure 6. Values for Station A parameters show a wide seasonal range: pH, 7.0 to 8.5; dissolved oxygen, 9.0 to 13.0 mg/l; temperature, -3.0 to 11.5°C; conductivity, 5,360 to 31,960 μmhos/cm at 25°C; salinity, 2.5 to 23.0 ‰; suspended sediments, 2.8 to 47.2 mg/l; and turbidity (shaken), 1.3 to 22.0 FTU. A similar range of values was recorded at Station B.

Oxygen concentrations at both Station A and Station B remained high throughout the open water season as they did in a similar study at Nunaluk Lagoon (Griffiths *et al.*, 1975). Salinity and conductivity at Station A dropped sharply between May 8 (23‰ and 31,500 μmhos/cm) and June 28 (3.5‰ and 6,660 μmhos/cm) probably as a result of the large amount of fresh water released in the form of ice-melt. Salinity and conductivity steadily increased after June 28, reaching a maximum (20.8‰ and 32,300 μmhos/cm) on September 17. Station B followed a similar pattern although salinity was higher than Station A during most of the season.

In contrast to the high salinity and conductivity readings in Kaktovik Lagoon, the values in Nunaluk Lagoon were usually much lower (4‰ and 3,500 μmhos/cm) due to the direct freshwater discharge of the Firth and Malcolm rivers (Griffiths *et al.*, 1975). The maximum reading

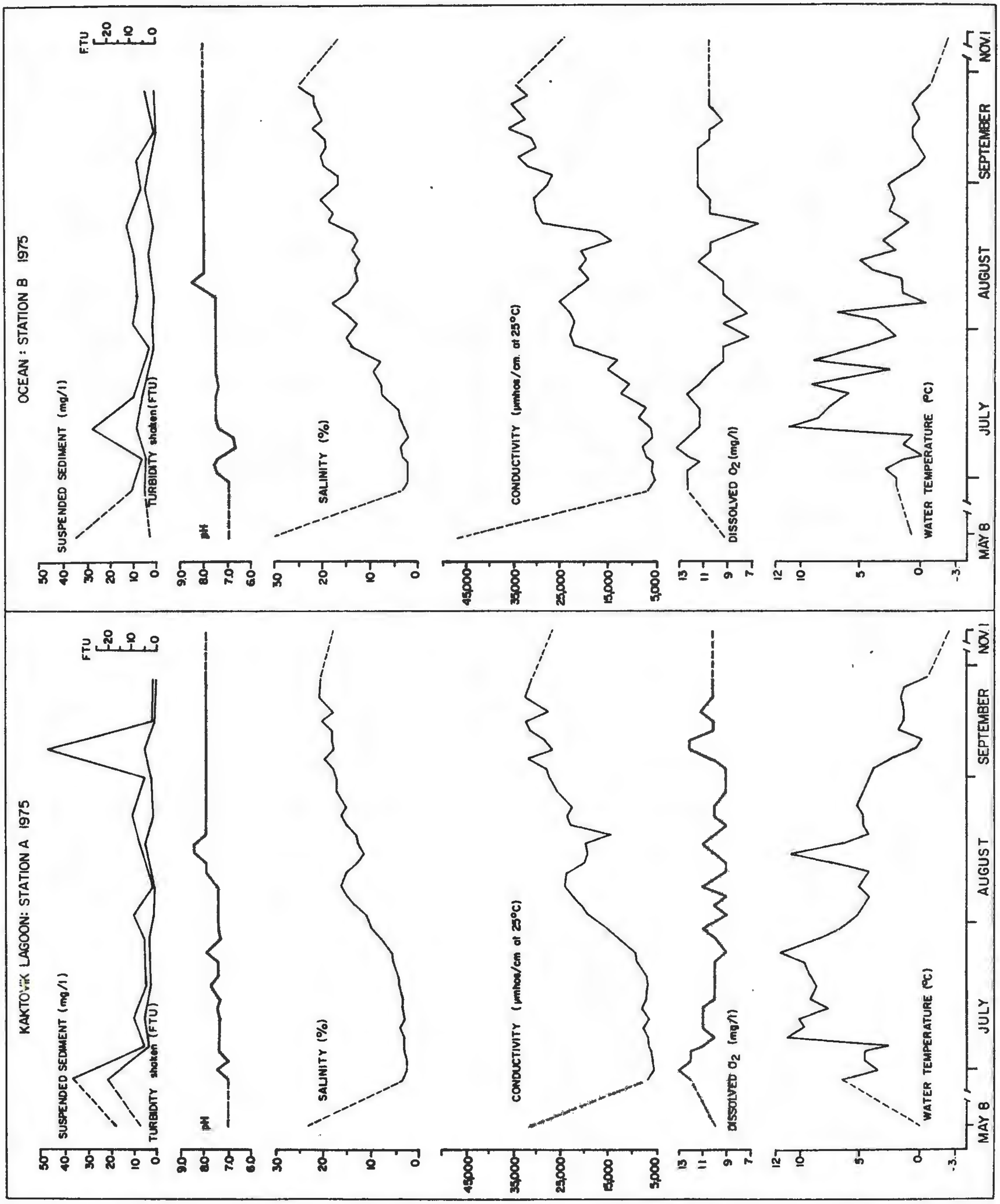

FIGURE 6. Seasonal variation in pH, dissolved oxygen, temperature, conductivity, salinity, suspended sediments, and turbidity at Station A in Kaktovik Lagoon and Station B in the adjacent ocean, 1975.

at Nunaluk Lagoon (29.8‰), however, exceeded the maximum at Kaktovik (20.8‰). This was due to an influx of marine water into Nunaluk Lagoon just prior to freeze-up. Similarly, the maximum salinity during the open water season at Station B (25.0‰) was less than the maximum recorded in the ocean at Nunaluk Lagoon (30.0‰).

Water temperatures in the shallow waters (0.5 m deep) adjacent to the shoreline were generally higher and less variable at Station A than at Station B due to the close proximity of ice throughout the season at Station B. Station A remained ice-free for the entire period from June 28 to September 23. High water temperatures at Station A in July (11.5°C) were the result of unusually high air temperatures (26.7°C) heating the shallow nearshore waters.

Suspended sediments and turbidities were typically low throughout the open water season. The two exceptions were in late June, during breakup, and in early September, when wave action churned up the bottom sediments at Station A. In general, wave action was responsible for the minor weekly fluctuations in suspended sediments and turbidities at Station A. Wind-generated turbulence was generally not a factor at Station B as the floe ice acted to prevent heavy wave action from reaching the shallow nearshore areas.

Seasonal variation in concentrations of major ions and nutrients at Station A and Station B are presented in Table 2 and Table 3. Variation in levels of all major ions paralleled increases in salinity at both stations. Field measurement of salinity is based on conductance and

TABLE 2. Physical and chemical parameters of water from Station A in Kaktovik Lagoon, 1975.

Date	June 30	July 13	July 28	August 11	August 25	September 8	September 21
PHYSICAL PARAMETERS							
Temperature (°C)	3.5	7.5	8.0	4.0	5.0	-0.5	-1.0
Conductivity (μmhos/cm@25°C)	5,360	7,920	12,638	23,384	22,330	28,000	30,800
Salinity (‰)	2.5	3.5	8.0	15.0	15.0	18.0	20.5
pH	7.5	7.5	7.4	8.0	8.0	8.0	8.0
CHEMICAL PARAMETERS							
Dissolved Oxygen mg/l	13.0	11.0	10.0	9.0	10.0	12.0	10.0
Total Dissolved Nitrogen μg/l	NF	NF	106	134	153	276	156
Total Dissolved Phosphorous μg/l	<30	<30	<30	<30	<30	<30	35
Elemental Silica μg/l	190	140	235	526	414	280	295
Calcium meq/l	1.9	2.4	4.7	8.3	8.2	10.8	11.3
Magnesium meq/l	NT	NT	26.9	46.2	44.4	56.3	58.9
Sodium meq/l	40.6	62.6	130.1	201.2	197.9	276.2	288.2
Potassium meq/l	NT	NT	2.8	4.3	4.1	5.6	5.7
Sulphate meq/l	NT	NT	15.0	18.5	22.3	32.4	34.8
Chloride meq/l	44.8	68.0	134.7	235.5	239.7	310.2	334.2
Total Alkalinity meq/l as $CaCO_3$	NT	NT	1.1	1.6	1.8	1.7	1.8
Iron meq/l	TR	TR	TR	TR	TR	TR	TR
Sum of Cations meq/l	-	-	164.8	260.0	254.6	348.9	364.1
Sum of Anions meq/l	-	-	150.6	255.6	263.7	344.4	370.8
% Error	-	-	4.5	0.9	1.8	0.7	0.9

TR=Trace

NF=None Found

NT=Not Tested

TABLE 3. Physical and chemical parameters of water from Station B in the ocean near Kaktovik Lagoon, 1975.

Date	June 30	July 13	July 28	August 11	August 25	September 8	September 21
PHYSICAL PARAMETERS							
Temperature (°C)	1.5	8.0	3.8	3.5	2.0	-0.5	-1.5
Conductivity (μmhos/cm@25°C)	5,292	8,520	22,080	18,700	29,800	29,750	33,820
Salinity (‰)	2.5	4.0	14.0	13.0	18.0	19.8	25.0
pH	7.0	7.5	7.5	8.5	8.0	8.0	8.0
CHEMICAL PARAMETERS							
Dissolved Oxygen mg/1	12.0	11.0	9.0	9.0	10.0	11.0	10.0
Total Dissolved Nitrogen μg/1	NF	NF	86	137	193	160	214
Total Dissolved Phosphorous μg/1	<30	<30	<30	<30	31	31	42
Elemental Silica μg/1	250	204	280	464	520	322	375
Calcium meq/1	1.9	2.7	5.3	7.3	10.7	11.1	13.9
Magnesium meq/1	NT	NT	49.4	40.7	58.3	57.6	71.4
Sodium meq/1	43.7	65.7	241.9	184.9	265.4	278.4	315.4
Potassium meq/1	NT	NT	4.8	3.6	6.2	5.7	6.7
Sulphate meq/1	NT	NT	25.0	15.0	32.2	27.1	35.3
Chloride meq/1	48.8	73.0	251.3	214.3	325.7	313.0	382.8
Total Alkalinity meq/1 as $CaCO_3$	NT	NT	1.44	1.39	1.6	1.7	1.9
Iron meq/1	TR	TR	TR	TR	TR	TR	TR
Sum of Cations meq/1	-	-	301.9	236.5	340.5	352.8	407.4
Sum of Anions meq/1	-	-	277.5	230.7	359.6	341.9	420.0
% Error	-	-	4.2	1.2	2.7	1.6	1.5

TR=Trace

NF=None Found

NT=Not Tested

therefore reflects the increase in total ionic concentration rather than increases in sodium chloride specifically.

At Station A, concentrations of all major ions increased between July 28 and September 21. Levels of sodium increased from 130.1 meq/1 on July 28, to 288.2 meq/1 on September 21, while levels of chloride increased from 134.7 meq/1 to 334.2 meq/1 during the same period. Concentrations of major ions at Station B also increased during the season, but remained higher than at Station A. Increases in the concentrations of all ions were relatively uniform at both stations. Seasonal increases in concentrations of major ions were also reported at Nunaluk Lagoon (Griffiths *et al.*, 1975). The increase in major ion concentrations was directly related to the increasing influence of marine waters mixing with nearshore brackish water.

Marine influence caused a slight increase in phosphorous levels at both stations late in the season, but generally phosphorous levels remained extremely low (<30 μg/1). Nitrogen levels remained low and slightly variable at both Station A and Station B.

Temperature, Salinity, and Conductivity Profiles

Temperature, salinity, and conductivity in Kaktovik Lagoon were fairly uniform to a depth of approximately 2.7-3.0 m (Table 4). Below this depth (chemocline) pools of highly saline water remained throughout the season. These pools are probably formed in the winter by the process of ionic exclusion as fresh water freezes. During the late winter field trip in May, salinities as high as 45‰ were recorded in mid-lagoon.

TABLE 4. Temperature, conductivity and salinity profile of Kaktovik Lagoon on August 4 and August 25, 1975. Sampling sites are indicated in Figure 3B.

	AUGUST 4, 1975				AUGUST 25, 1975			
Site	Depth m	Temperature °C	Conductivity μmhos/cm@25°C	Salinity ‰	Depth m	Temperature °C	Conductivity μmhos/cm@25°C	Salinity ‰
1	Surf	4.5	20,280	13.3	Surf	5.0	22,330	15.0
	1.5	4.5	20,280	13.3	2.0	5.0	22,330	15.0
	3.0	4.3	20,400	13.3	3.5	5.0	26,180	17.5
					3.6	4.5	44,460	30.0
					3.9	4.5	49,920	33.5
2	Surf	5.0	20,790	13.5	Surf	5.0	16,632	15.5
	1.5	5.0	20,790	13.5	1.3	5.0	16,632	15.5
	2.5	5.0	21,560	14.0	2.5	4.0	17,064	15.5
	2.8	5.0	30,800	14.0				
	3.0	4.5	42,120	28.8				
3	Surf	5.0	22,176	14.8	Surf	5.0	17,248	15.2
	1.3	5.0	22,330	14.8	1.3	5.0	17,248	15.5
	2.6	4.5	22,620	14.8	2.5	3.5	18,880	16.5
4	Surf	6.5	19,980	13.1	Surf	5.0	16,170	15.5
	1.5	6.5	19,980	13.1	1.7	5.0	16,170	15.5
	2.5	5.4	25,688	16.5	3.4	5.0	26,950	17.0
	2.7	5.8	36,750	24.8				
	3.0	5.9	43,950	29.6				
5	Surf	6.5	20,128	13.2	Surf	4.5	16,848	15.5
	1.8	6.3	20,572	13.4	1.8	4.5	16,848	15.5
	2.5	4.4	22,776	14.3	3.5	4.5	33,540	25.0
	2.6	4.4	31,200	22.0				
	3.5	5.8	51,000	35.0				
6	Surf	6.0	21,000	13.6	Surf	5.0	16,940	16.2
	2.0	6.1	21,150	13.5	1.9	5.0	18,172	17.0
	2.7	-	-	14.5	3.5	4.0	25,280	17.5
	2.9	-	-	33.0	3.6	4.0	41,080	27.0
	4.0	5.0	55,286	37.0	3.7	4.0	50,560	35.5
7	Surf	6.5	18,500	11.9	Surf	5.0	16,632	14.8
	0.9	6.5	18,500	11.9	0.9	5.0	16,632	14.8
	1.7	6.5	18,500	11.9	1.7	5.0	16,632	14.8
8	Surf	6.5	19,240	12.5	Surf	5.0	16,940	15.2
	1.8	6.5	19,092	12.4	1.4	5.0	16,940	15.2
	2.9	6.2	22,500	14.5	2.7	5.0	17,710	15.2
	3.1	6.2	47,250	32.0				
	3.5	6.2	51,730	34.6				
9	Surf	6.5	20,128	13.1	Surf	4.5	15,912	14.5
	1.6	6.8	19,992	13.1	1.5	4.5	15,912	14.5
	2.6	-	-	13.4	2.9	4.5	15,912	14.5
	2.7	-	-	25.0				
	3.3	6.7	47,922	32.5				

Similar results were reported from Simpson Lagoon where pools with salinities as high as 68‰ were found (Crane and Cooney, 1974).

The irregular nature of the lagoon bottom is evident from the differences in depth recorded on the two sampling dates. Slight movements in sampling locations resulted in depth differences of nearly 1 m in some instances. Irregular bottom features probably tend to restrict the saline pools.

A comparison of surface and highly saline bottom water shows that the levels of major ions in the bottom sample are twice those of the surface sample (Table 5). However, temperatures remained relatively uniform from surface to bottom, as did levels of total dissolved nitrogen, phosphorous, and elemental silica.

TABLE 5. Physical and chemical parameters of water from surface and bottom of Kaktovik Lagoon, August 4, 1975. Water depth = 3.5m. Samples were taken at site 8 on Figure 3B.

Parameter	Surface	Bottom
PHYSICAL PARAMETERS		
Temperature (°C)	6.5	6.2
Conductivity (µmhos/cm@25°C)	13,000	34,500
Salinity ‰	12.5	34.6
CHEMICAL PARAMETERS		
Dissolved Oxygen mg/l	11.0	13.0
Total Dissolved Nitrogen µg/l	109	166
Total Dissolved Phosphorous µg/l	<30	<30
Elemental Silica µg/l	400	404
Calcium mg/l (meq/l)	141 (7.0)	400 (20.0)
Magnesium mg/l (meq/l)	484 (39.8)	1,228(101.1)
Sodium mg/l (meq/l)	3,925(170.7)	11,300(491.6)
Potassium mg/l (meq/l)	145 (3.7)	395 (10.1)
Sulphate mg/l (meq/l)	690 (14.4)	1,440 (30.0)
Chloride mg/l (meq/l)	7,200(203.0)	19,700(555.5)
Total Alkalinity mg/l (meq/l) as $CaCO_3$	64.0 (1.3)	147.5 (3.0)
Iron mg/l (meq/l)	TR (-)	0.9 (0.05)
Sum of Cations (meq/l)	(221.3)	(622.7)
Sum of Anions (meq/l)	(218.7)	(588.4)
% Error	0.6	2.8

TR=Trace

INVERTEBRATE STUDIES

Methods

Substrates in shallow (<1 m) and deep (2-4 m) water were sampled adjacent to Station A in July (19-21) and August (20-21) and along the south shore of the lagoon on September 13. Shallow water samples were taken with a core sampler (surface 31.6 cm^2, depth 10 cm). Five cores were taken at each location and combined to form a single sample. Deep waters were sampled using an Ekman grab (surface 232.3 cm^2, depth 7 to 10 cm). Three grabs taken at each location were combined to form a single sample. Ten such samples were taken in both shallow and deep waters, at 50 m intervals, along a transect parallel to shore.

The techniques used in sampling the deep and shallow water substrates differed because while the Ekman grab is effective in sampling sand and mud substrates in deeper water, it is ineffective in the coarse gravel found nearshore. In contrast, core sampling is effective in shallow water but fails to hold samples when used in deeper water.

In addition to Ekman and core samples, dredge samples were taken with a custom-built dredge. The dredge (Figure 7) consisted of a tubular metal frame (1.0 x 0.5 m) kept open by a series of floats mounted on the top of the frame and weighted on the bottom with an iron plate (1 m x 7.5 cm x 2.5 cm). Two metal skids attached to the plate prevented the dredge from digging excessively into the substrate. A net (5 m long) made up of equal lengths of 1.3 cm and 0.6 cm stretch-mesh nylon

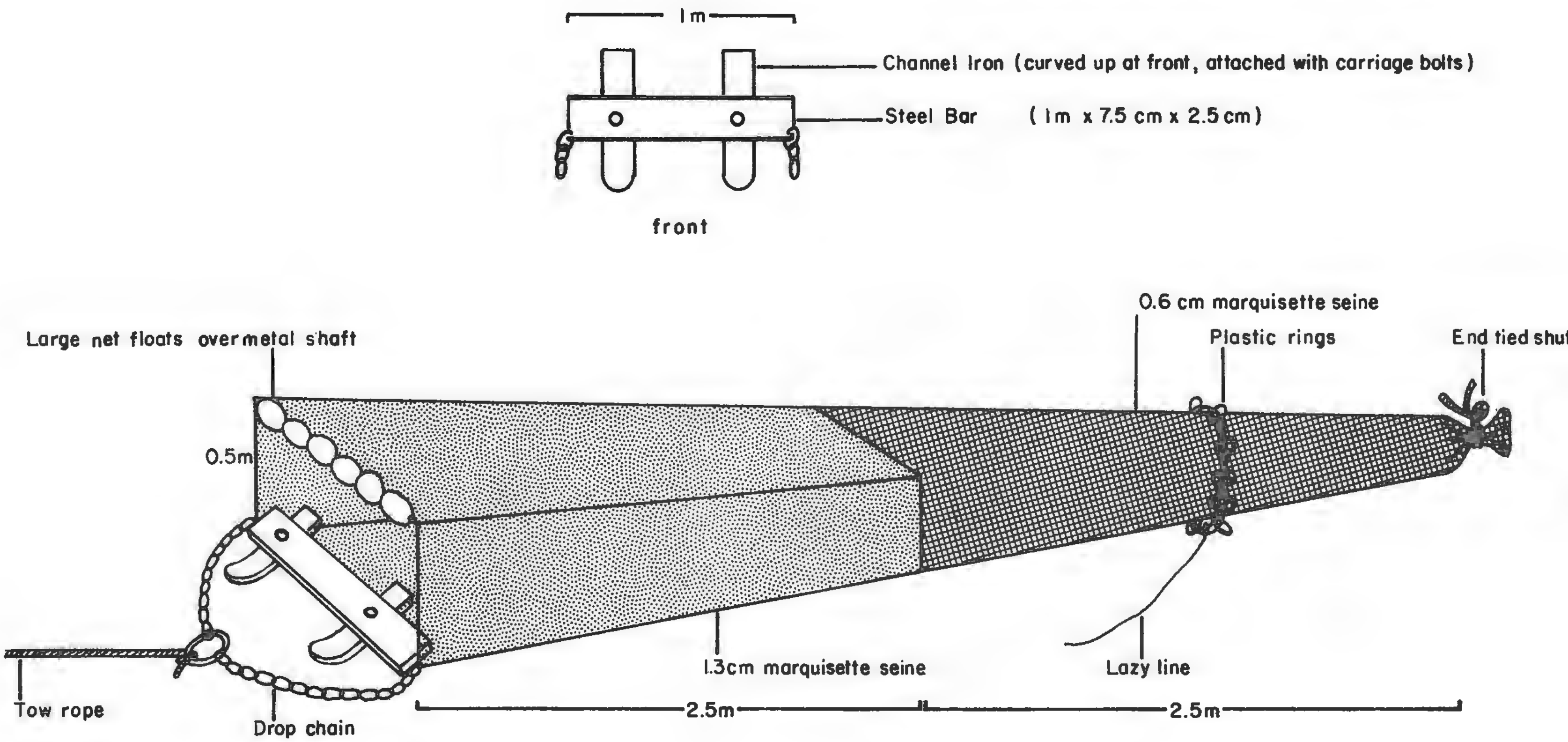

FIGURE 7. Bottom dredge used to sample epibenthic and some infaunal invertebrates in Kaktovik Lagoon, 1975.

marquisette, was attached to the frame and tapered to a small opening (0.1 x 0.1 m).

On August 20, both shallow water (<1 m) and deep water (2-4 m) substrates were sampled using the dredge. Three tows were made in shallow water and five in deep water parallel to the shore at Station A. The dredge was towed at approximately 5 km/hr for a premeasured distance of 100 m. After each tow, the contents of the dredge net were washed into a plastic container.

All of the substrate samples taken were washed and rough sorted in the field. After the coarser materials had been removed, samples were washed through a set of Canadian Standard Sieves (smallest mesh 450 μ). Retained materials were preserved in 10% formalin and shipped to the laboratory where organisms were picked and sorted into major taxa with the aid of a binocular microscope.

Results

Invertebrates collected in Kaktovik Lagoon fell into two general categories:

1) epibenthic organisms: organisms living near or on the surface of the substrate, and

2) infauna: organisms living within the substrate.

As discussed below, the kinds of invertebrates collected depended on both sampling method and sample location.

Core Samples

In shallow water, organisms from only three major groups (amphipods, isopods, and gastropods) were found. Core samples taken July 19 at Station A (Table 6) contained an average of 44 organisms/m^2 (range 0 to 127 organisms/m^2). Four of the 10 samples contained no invertebrates at all and four others contained only amphipods. Amphipods made up 72.7% of the total organisms sampled on this date.

On August 20, only amphipods and isopods were taken at Station A (Table 6). The number of taxa decreased by one (no gastropods were taken) while the total number of organisms increased from 44 organisms/m^2 to 202 organisms/m^2. This increase in numbers is significant ($t=3.0$, $df=18$, $p<0.05$) and was attributed to the increase in amphipods from 32 organisms/m^2 on July 19 to 189 organisms/m^2 on August 20. Only one sample contained no invertebrates, and 7 of the 10 samples contained only amphipods. The large increase in the number of amphipods may have been due to a dispersal of amphipods from the deeper waters.

Cores taken September 13 along the south shore of Kaktovik Lagoon contained more taxa than those taken at Station A (Table 6), possibly due to the more varied substrates (sand, gravel, and organic matter) found along the south shore. An average of 189 organisms/m^2 (range 0-569) were taken here. Amphipods were again the most abundant species collected, appearing in 7 of the 10 samples and averaging 120 organisms/m^2. Polychaetes occurred in 5 of the 10 samples and averaged 44 organisms/m^2.

TABLE 6. Number of benthic and epibenthic invertebrates per m^2 taken in core samples in Kaktovik Lagoon, 1975. Samples taken on July 19 and August 20 are from Station A. Samples taken September 13 are from the south shore of the lagoon. All sampling was done in less than one metre of water. Each sample consists of five cores.

Organism	Sample Number										Mean
	1	2	3	4	5	6	7	8	9	10	
JULY 19, (STATION A)											
CRUSTACEA											
Mysidacea	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	-	-	127	63	-	63	-	-	63	-	32
Isopoda	-	-	-	-	63	-	-	-	-	-	6
TOTAL CRUSTACEA	-	-	127	63	63	63	-	-	63	-	38
GASTROPODA	-	63	-	-	-	-	-	-	-	-	6
GRAND TOTALS	0	63	127	63	63	63	0	0	63	0	44
AUGUST 20, (STATION A)											
CRUSTACEA											
Mysidacea	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	189	189	504	441	126	189	126	63	-	63	189
Isopoda	-	-	-	-	-	63	63	-	-	-	13
TOTAL CRUSTACEA	189	189	504	441	126	252	189	63	-	63	202
GASTROPODA	-	-	-	-	-	-	-	-	-	-	-
GRAND TOTALS	189	189	504	441	126	252	189	63	0	63	202
SEPTEMBER 13, (SOUTH SHORE OF LAGOON)											
CRUSTACEA											
Mysidacea	-	-	-	-	63	-	-	-	-	-	6
Amphipoda	-	-	126	63	253	63	-	443	126	126	120
Isopoda	-	-	-	-	-	-	-	-	-	-	-
TOTAL CRUSTACEA	-	-	126	63	316	63	-	443	126	126	126
ANNELIDA											
Polychaeta	63	-	63	-	126	-	-	126	-	63	44
Oligochaeta	-	-	-	-	-	126	-	-	-	-	13
TOTAL ANNELIDA	63	-	63	-	126	126	-	126	-	63	57
PELECYPODA	63	-	-	-	-	-	-	-	-	-	6
GRAND TOTALS	126	0	189	63	442	189	0	569	126	189	189

Ekman Grab Samples

Ekman grabs taken July 21 at Station A averaged 5,352 organisms/m^2, the highest number collected at Kaktovik Lagoon (Table 7). Crustaceans comprised only 15.6% of the total, while annelids (polychaetes and oligochaetes) made up 65.8% of the samples. Similar results were reported for studies in the southwestern Beaufort Sea (Carey *et al.*, 1974).

The density of organisms decreased significantly (Table 8), from 5,352 on July 21 to 654 on August 21 ($t=3.6$, $df=18$, $p<0.05$). Annelids were most abundant, representing 50.1% of the sample, and the percentage of crustaceans in the sample increased from 15.6 to 39.5. Thirteen taxonomic groups were collected on August 21 and, with the exception of tunicates, all were represented in the July 21 samples. Reasons for the decrease in the number of organisms/m^2 between July 21 and August 21 samples are obscure, but may be related to a non-random distribution of the benthic infaunal organisms and resultant sampling error.

Ekman samples collected from the south shore of Kaktovik Lagoon on September 13 averaged 744 organisms/m^2 (Table 9). Annelids were the most abundant (383 organisms/m^2) with crustaceans (177 organisms/m^2) and molluscs (174 organisms/m^2) the next most abundant groups. There was a wide variation in the density of organisms within the samples (range 71 to 2,231). A total of 10 taxonomic groups were collected in this area.

Dredge Samples

Only three invertebrate taxa were collected in dredges made in shallow

TABLE 7. Number of marine invertebrates per m^2 taken by Ekman grab at Station A in Kaktovik Lagoon on July 21, 1975. Each sample consists of three grabs at one site. All samples were taken in 2-4 m of water.

Organism	Sample 1	2	3	4	5	6	7	8	9	10	Mean
CRUSTACEA											
Mysidacea	14	29	-	-	-	14	-	-	14	-	7
Amphipoda	14	29	763	1397	115	130	446	158	706	216	397
Isopoda	-	-	14	58	-	14	-	14	14	-	11
Copepoda	101	187	-	14	-	-	-	-	-	14	32
Cumacea	14	14	29	-	-	14	-	14	-	43	13
Ostracoda	-	1958	173	-	-	1123	302	-	-	173	373
TOTAL	143	2217	979	1469	115	1295	748	186	734	446	833
MOLLUSCA											
Tetrabranchiata	-	-	-	-	-	14	-	-	-	-	1
Gastropoda	130	345	29	29	-	547	101	29	29	734	197
Pelecypoda	-	72	29	-	-	202	72	86	29	187	68
TOTAL	130	417	58	29	-	763	173	115	58	921	266
ANNELIDA											
Polychaeta	936	2909	1785	2333	-	1498	3326	403	1181	6494	2087
Oligochaeta	1138	3413	374	331	2693	590	1598	158	187	3874	1436
TOTAL	2074	6322	2159	2664	2693	2088	4924	561	1368	10368	3523
MISCELLANEOUS											
Acarina	-	-	-	-	-	-	-	202	-	-	20
Tunicata	-	-	-	-	-	-	-	-	-	-	-
Nematoda	158	2822	274	-	-	187	1051	360	-	835	569
Diptera larvae	-	-	-	-	-	-	43	-	-	-	4
Priapulida	72	360	216	57	-	115	187	72	58	230	137
TOTAL	230	3182	490	57	-	302	1281	634	58	1065	730
GRAND TOTALS	2577	12138	3686	4219	2808	4449	7126	1496	2218	12801	5352

TABLE 8. Number of marine invertebrates per m^2 taken by Ekman grab at Station A in Kaktovik Lagoon on August 21, 1975. Each sample consists of three grabs at one site. All samples were taken in 2-4 m of water.

Organism	Sample 1	2	3	4	5	6	7	8	9	10	Mean
CRUSTACEA											
Mysidacea	29	14	115	29	29	29	43	43	43	43	42
Amphipoda	-	58	86	14	86	72	158	331	259	158	122
Isopoda	-	14	14	14	29	-	29	86	58	-	24
Copepoda	58	29	29	-	-	-	-	101	58	14	29
Cumacea	-	-	-	-	-	-	-	-	14	-	1
Ostracoda	-	-	-	-	-	-	-	72	144	187	40
TOTAL	87	115	244	57	144	101	230	633	576	402	258
MOLLUSCA											
Tetrabranchiata	14	-	-	-	-	29	-	29	29	43	14
Gastropoda	-	29	-	-	-	14	-	58	86	43	23
Pelecypoda	-	-	-	-	-	14	14	-	58	29	12
TOTAL	14	29	-	-	-	57	14	87	173	115	49
ANNELIDA											
Polychaeta	230	86	115	58	43	43	58	158	130	58	98
Oligochaeta	245	216	29	202	43	72	302	130	187	893	232
TOTALS	475	302	144	260	86	115	360	288	317	951	330
MISCELLANEOUS											
Acarina	-	-	-	-	-	-	-	-	-	-	-
Tunicata	-	-	14	-	-	43	-	43	-	-	10
Nematoda	-	-	-	-	-	-	-	72	-	-	7
Diptera Larvae	-	-	-	-	-	-	-	-	-	-	-
Priapulida	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	-	14	-	-	43	-	115	-	-	17
GRAND TOTALS	576	446	402	317	230	316	604	1123	1066	1468	654

TABLE 9. Number of marine invertebrates per m^2 taken by Ekman grab along south shore of Kaktovik Lagoon on September 13, 1975. Each sample consists of three grabs at one site. All samples were taken in 2-4 m of water.

Organism	Sample 1	2	3	4	5	6	7	8	9	10	Mean
CRUSTACEA											
Mysidacea	14	14	-	-	29	14	-	14	-	14	10
Amphipoda	274	216	101	14	216	173	216	-	43	58	131
Isopoda	-	14	14	43	43	14	72	43	43	72	36
Copepoda	-	-	-	-	-	-	-	-	-	-	-
Cumacea	-	-	-	-	-	-	-	-	-	-	-
Ostracoda	-	-	-	-	-	-	-	-	-	-	-
TOTAL	288	244	115	57	288	201	288	57	86	144	177
MOLLUSCA											
Tetrabranchiata	-	-	-	-	-	-	-	-	-	-	-
Gastropoda	-	-	-	-	-	-	-	-	14	-	1
Pelecypoda	-	-	-	-	14	14	418	720	302	259	173
TOTAL	-	-	-	-	14	14	418	720	316	259	174
ANNELIDA											
Polychaeta	-	533	-	14	173	-	230	1339	662	562	351
Oligochaeta	-	-	-	-	58	-	130	72	-	58	32
TOTAL	-	533	-	14	231	-	360	1411	662	620	383
MISCELLANEOUS											
Acarina	-	-	-	-	-	-	-	-	-	-	-
Tunicata	-	-	-	-	-	-	-	-	-	-	-
Nematoda	-	-	-	-	-	-	14	-	-	-	1
Diptera Larvae	-	-	-	-	-	-	-	-	-	-	-
Priapulida	-	-	-	-	-	-	14	43	-	29	9
TOTAL	-	-	-	-	-	-	28	43	-	29	10
GRAND TOTALS	288	777	115	71	533	215	1094	2231	1064	1052	744

water (<1 m): mysids, amphipods, and isopods (Table 10). Mysids were most numerous (mean number of organisms/100 m pull= 155) followed by amphipods ($\bar{x}$=75) and isopods ($\bar{x}$=16).

Thirteen taxonomic groups of invertebrates were captured in deep water (>2 m) dredge samples (Table 10). Crustaceans were by far the most abundant species ($\bar{x}$ number of organisms/100 m pull= 2,064). Epibenthic organisms predominated in deepwater dredge samples: infaunal organisms were likely underestimated by this sampling period.

Comparison of Shallow and Deepwater Fauna

The data obtained by cores, grabs, and dredging cannot be statistically compared because of the different capture capabilities of the samplers (Flannagan, 1970). However, the data indicate definite trends in the distribution of invertebrates in Kaktovik Lagoon.

In comparison to shallow water (<1 m) habitats, deepwater (2-4 m) habitats are characterized by larger numbers of invertebrates and a greater diversity in the kinds of invertebrates present. Both core and dredge samples in shallow waters contained low numbers of organisms with a corresponding low diversity. Dredge and Ekman samples indicate that much higher numbers of organisms and greater diversities exist in deepwater substrates. Dredge samples taken in these two habitats on the same date show almost a nine-fold difference in invertebrate abundance (Figure 8A) and a four-fold difference in the number of taxa (Figure 8B). Core and Ekman grab data demonstrate similar differences in the number and kinds of invertebrates caught in shallow and deepwater habitats (Tables 6-9).

TABLE 10. Number of marine invertebrates taken in dredge sampler in Kaktovik Lagoon, 1975. Data indicate number of organisms caught per 100 metre pull of the dredge. FHSC=fourhorn sculpin; FSSC=false seascorpion; ARCD=Arctic cod; STBY=stout eel blenny.

	SHALLOW WATER (<1 m)				DEEPER WATER (>2 m)					
Organsism	1	2	3	Mean	1	2	3	4	5	Mean
CRUSTACEA										
Mysidacea	171	187	107	155	553	684	1176	6120	436	1794
Amphipoda	93	82	50	75	52	172	112	240	416	198
Isopoda	18	23	7	16	20	12	40	192	76	68
Copepoda	-	-	-	-	-	-	-	-	-	-
Cumacea	-	-	-	-	-	-	-	-	12	2
Ostracoda	-	-	-	-	-	-	-	-	8	2
TOTAL	282	292	164	246	625	868	1328	6552	948	2064
MOLLUSCA										
Tetrabranchiata	-	-	-	-	-	-	-	160	20	36
Gastropoda	-	-	-	-	-	-	-	16	16	6
Pelecypoda	-	-	-	-	-	-	-	-	36	7
TOTAL	-	-	-	-	-	-	-	176	72	49
ANNELIDA										
Polychaeta	-	-	-	-	-	-	-	-	240	48
Oligochaeta	-	-	-	-	-	-	-	8	4	2
TOTAL	-	-	-	-	-	-	-	8	244	50
FISH										
FHSC	5	3	6	4.7	2	-	3	1	-	1.2
FSSC	2	1	1	1.3	2	-	1	-	-	0.6
ARCD	-	4	-	1.3	-	-	-	1	-	0.2
STBY	-	-	-	-	-	-	1	-	-	0.2
TOTAL	7	8	7	7.3	4	-	5	2	-	2.2
MISCELLANEOUS										
Tunicata	-	-	-	-	-	-	-	35	48	17
Nematoda	-	-	-	-	-	-	-	-	12	2
Priapulida	-	-	-	-	-	-	-	-	64	13
TOTAL	-	-	-	-	-	-	-	35	124	32
GRAND TOTALS	289	300	171	253.3	629	868	1333	6773	1388	2197.2

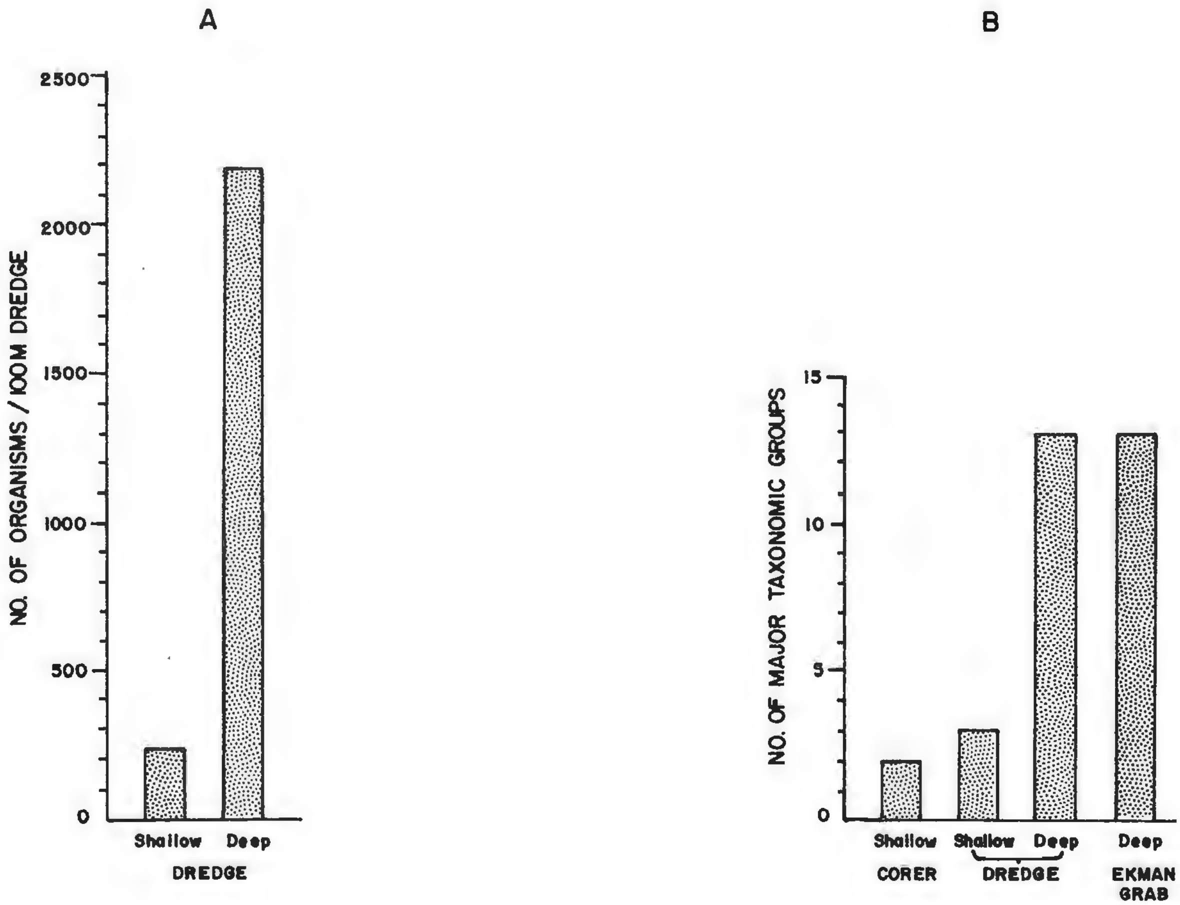

FIGURE 8. Comparison of numbers and taxa of invertebrates collected by three sampling methods from shallow water (<1 m) and deep water (2-4 m) substrates in Kaktovik Lagoon.

A third difference between shallow and deepwater collections is that virtually all invertebrates taken in shallow waters were epibenthic organisms whereas deepwater samples contained both epibenthic and infauna groups. This difference in invertebrate composition reflects two important differences in habitat:

1) Substrate. Shallow water substrates were composed largely of gravel; deepwater substrates contained more sand, mud, and organic matter;

2) Ice-free refuge. There is no free water between ice and substrate during the winter in the shallow water habitat. Substrates freeze solid and are scoured by grounded ice during breakup. In contrast, substrates in deeper water remain unfrozen year-round and are subject to less disturbance and scour during breakup.

Other studies have shown that shallow water substrates provide poor habitat for invertebrate survival (Knox, 1970; Crane and Cooney, 1974; Griffiths *et al.*, 1975). A near-barren condition existing in the shallow water habitat at breakup gives way to the invasion of mobile epibenthic invertebrates from deeper water habitats (Griffiths *et al.*, 1975). The abundance of epibenthic organisms in shallow water continues to increase during the open water season, and it is likely that their occurrence is directly affected by currents and wind-generated changes in water masses. It is not known whether the shallow water habitat is an important rearing or breeding area for epibenthic species.

FISHERIES STUDIES

Methods

Fish were collected during the open water season and under the ice in early November at a number of sites throughout the study area (Figures 9 and 10). Sampling gear included gillnets, seines, and, to a limited extent, angling equipment and a Faber net.

Gillnet sets varied in duration from 1 to 24 hours. Standard gangs of variable mesh monofilament gillnets, 2.4 m (8 ft) in depth and 45.0 m (150 ft) in length were used. Six panels, each 7.5 m (25 ft) long constituted a gang. Each gang was standardized by assembly in the following sequence: 2.5, 5.1, 11.4, 6.3, 3.8, and 8.9 cm (1, 2, 4.5, 2.5, 1.5, 3.5 in) stretch mesh.

To document seasonal changes in abundance of various fish species, a standardized 24 hr gillnet set was repeated every 10-14 days at Station A in Kaktovik Lagoon. Regular sampling began on June 30 and continued through the open water season until freeze-up (September 25). In addition, one 24 hr set was made under the ice at Station A on November 1. During the first two gillnet sets (June 30 and July 6), only 9 m (30 ft) of 5.1 cm (2 in) stretch mesh was used due to ice conditions.

The seine used was a fine-mesh nylon minnow seine measuring 4 m (13 ft) x 1.2 m (4 ft). Seine hauls covered a standard distance of 10 m (33 ft) along the shoreline.

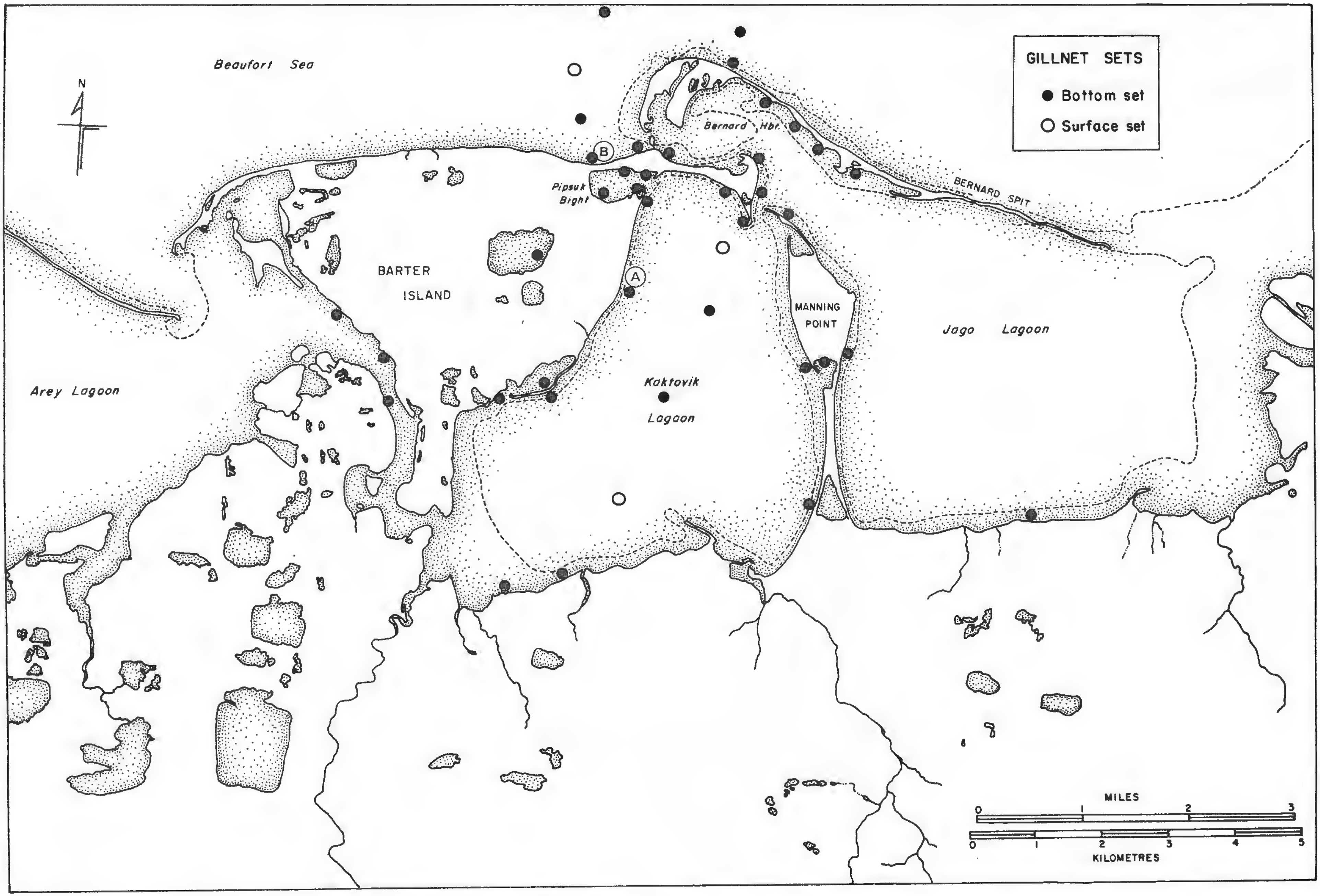

FIGURE 9. Detailed map of the Barter Island study area showing location of gillnet sets.

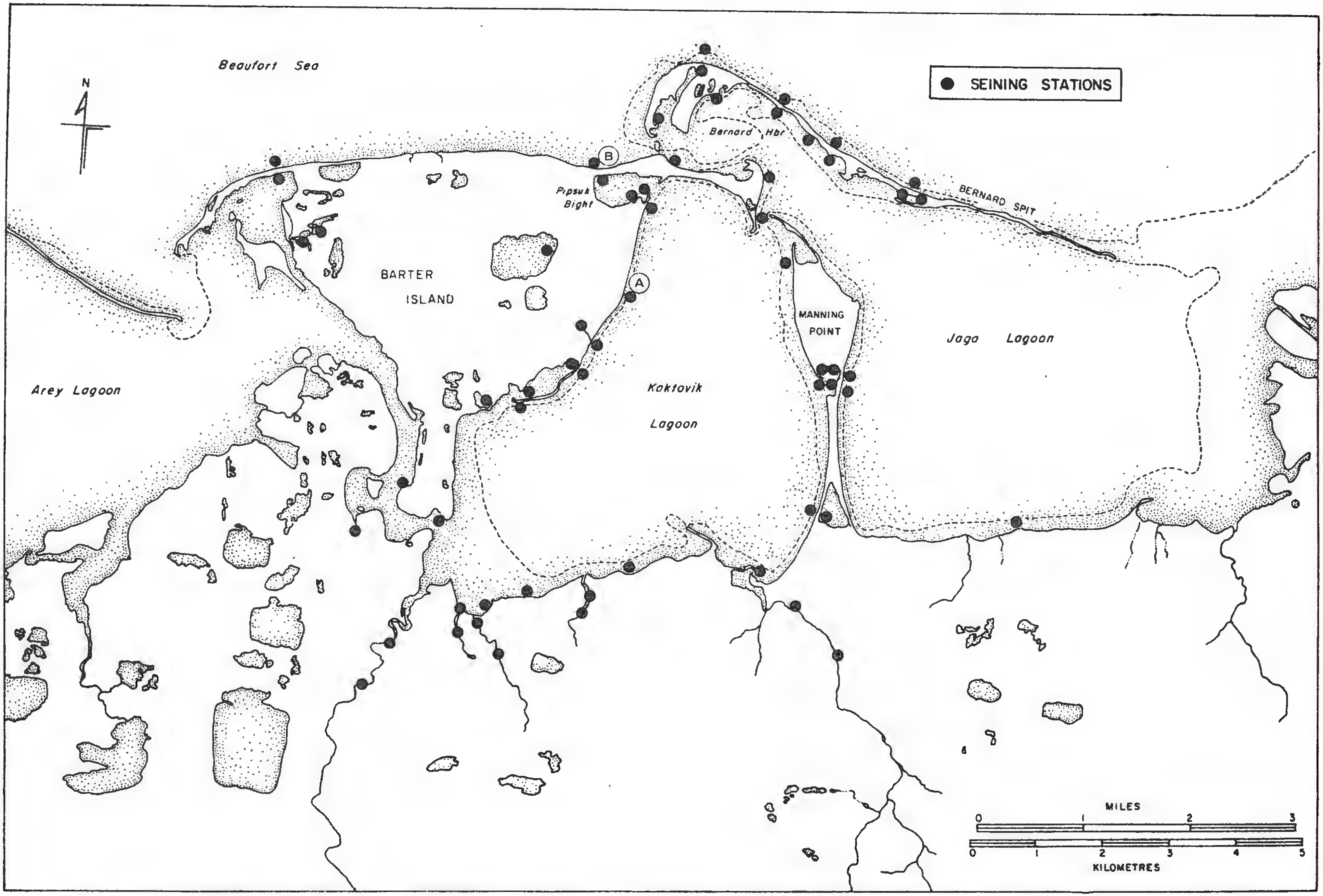

FIGURE 10. Detailed map of the Barter Island study area showing location of seining sites.

During the November survey, Arctic cod were captured by angling through holes drilled in the ice. A weighted monofilament line (10 lb test) with several hooks containing bits of red yarn was hand held. Hooks were spaced at 25 cm intervals between the bottom and the lower surface of the ice.

In mid-September, a modified Faber net (Faber, 1968) was used to sample small fish in surface waters in the study area. The net is described in an earlier report (Griffiths *et al.*, 1975).

In the field laboratory, fork or total length was measured to the nearest mm and weighed to the nearest 0.1 g. Egg diameters were determined to the nearest 0.1 mm by calculating the mean diameter of 10 unpreserved eggs of the largest size class lined up in a row. Otoliths were removed, placed in glycerin, and stored for later age determination.

State of maturity and condition of fish were estimated in the field using the criteria of McCart *et al.* (1972) and Craig and Mann (1974). Fish were classified as either "immature" (negligible gonadal development and no evidence of a previous spawning), "mature green" (sufficient gonadal development to indicate that the fish would spawn during the year of capture), or "mature non-spawner" (some gonadal development but would not spawn in the year of capture). This method is partially subjective and must include considerations of fish size, age, gonad shape, egg diameter, and general gonadal appearance. Dissection procedures also included a search for retained eggs. Early in the season, when gonadal development was similar, there was some difficulty in distinguishing a) large immatures from small mature non-spawners, and b) mature green fish from mature non-spawners. Despite these difficulties, the data are thought to be a reasonably accurate reflection of state of maturity for each species.

The stomach contents were analysed in the field, using a modification of Hynes's Point Method (Hynes, 1950) as outlined by Griffiths *et al.* (1975). In this manner, the percent fullness of the whole stomach and the percent composition for each food item were recorded. Individual food items were identified to the level of class or order. For each fish species, all contents from stomachs containing food were grouped to provide a representative or "average stomach". These results are presented in two ways. The first indicates the observed "average stomach" and the percent content for each food item. The second takes the fullness of the "average stomach" and converts this figure to 100% in order to emphasize the relative importance of each food item.

Results

Species Composition and Relative Abundance

Of the 12 species collected in the study area (Table 11), 8 were primarily marine species, 3 were anadromous, and 1 was freshwater. A total of 2,507 fish were captured in gillnets and seines and of these 75.2% were marine species. In contrast to these results, only 8 species (4 anadromous, 2 freshwater, and 2 marine) were taken in the Nunaluk Lagoon study and of these only 20.5% were marine (Griffiths *et al.*, 1975). These differences may be due to the predominant freshwater influence of the Firth and Malcolm rivers in Nunaluk Lagoon.

TABLE 11. Fish caught in the Barter Island study area, 1975. Fish appear in order of relative abundance.

COMMON NAME	SCIENTIFIC NAME	HABITAT	ABUNDANCE	% TOTAL CATCH
Fourhorn sculpin	*Myoxocephalus quadricornis*	M	+++	69.5
Arctic cisco	*Coregonus autumnalis*	A	+++	17.0
Arctic char	*Salvelinus alpinus*	A	+++	6.1
Arctic cod	*Boreogadus saida*	M	++	3.0
Ninespine stickleback	*Pungitius pungitius*	FW	++	1.2
False sea scorpion	*Myoxocephalus scorpioides*	M	++	1.1
Least cisco	*Coregonus sardinella*	A	++	1.0
Stout eel blenny	*Lumpenus medius*	M	+	0.3
Capelin	*Mallotus villosus*	M	+	0.3
Northern snailfish	*Liparis liparis*	M	+	0.2
Arctic flounder	*Liopsetta glacialis*	M	+	0.2
Slender eel blenny	*Lumpenus fabricii*	M	+	0.1

M marine

A anadromous

FW freshwater

In the Kaktovik study, fourhorn sculpin were the most abundant fish (69%), followed by Arctic cisco (17%) and Arctic char (6%). Arctic cod, false sea scorpion, least cisco, and ninespine stickleback occurred occasionally and the remaining species only incidentally (Table 11). The abundant species at Nunaluk Lagoon were Arctic cisco (47%), fourhorn sculpin (37%), and Arctic char (18%). These three species and the least cisco also formed the major portion of catches in other coastal areas (Roguski and Komarek, 1972; Kendel *et al.*, 1974; Furniss, 1975).

It appears that Arctic cisco, Arctic char, and fourhorn sculpin are the three most common species in nearshore coastal waters which are outside the direct influence of the Mackenzie and Colville rivers. Least cisco become abundant toward these two large rivers. Several other freshwater, anadromous, and marine species are also present, though not in abundance. However, in the case of the marine species, most of the fish caught were young-of-the-year, indicating that nearshore areas may be used more extensively for rearing and possibly spawning than indicated by the commonly used sampling methods.

Seasonal Abundance

Seasonal abundance of several fish species captured during the study is shown in Figure 11.

Fourhorn sculpin were abundant throughout the season, particularly during the early weeks (July 13-31). A single 4 hr gillnet set in Pipsuk Bight on July 16 caught 620 fourhorn sculpins. Little is known of the movements of this species, and reasons for the subsequent decline in

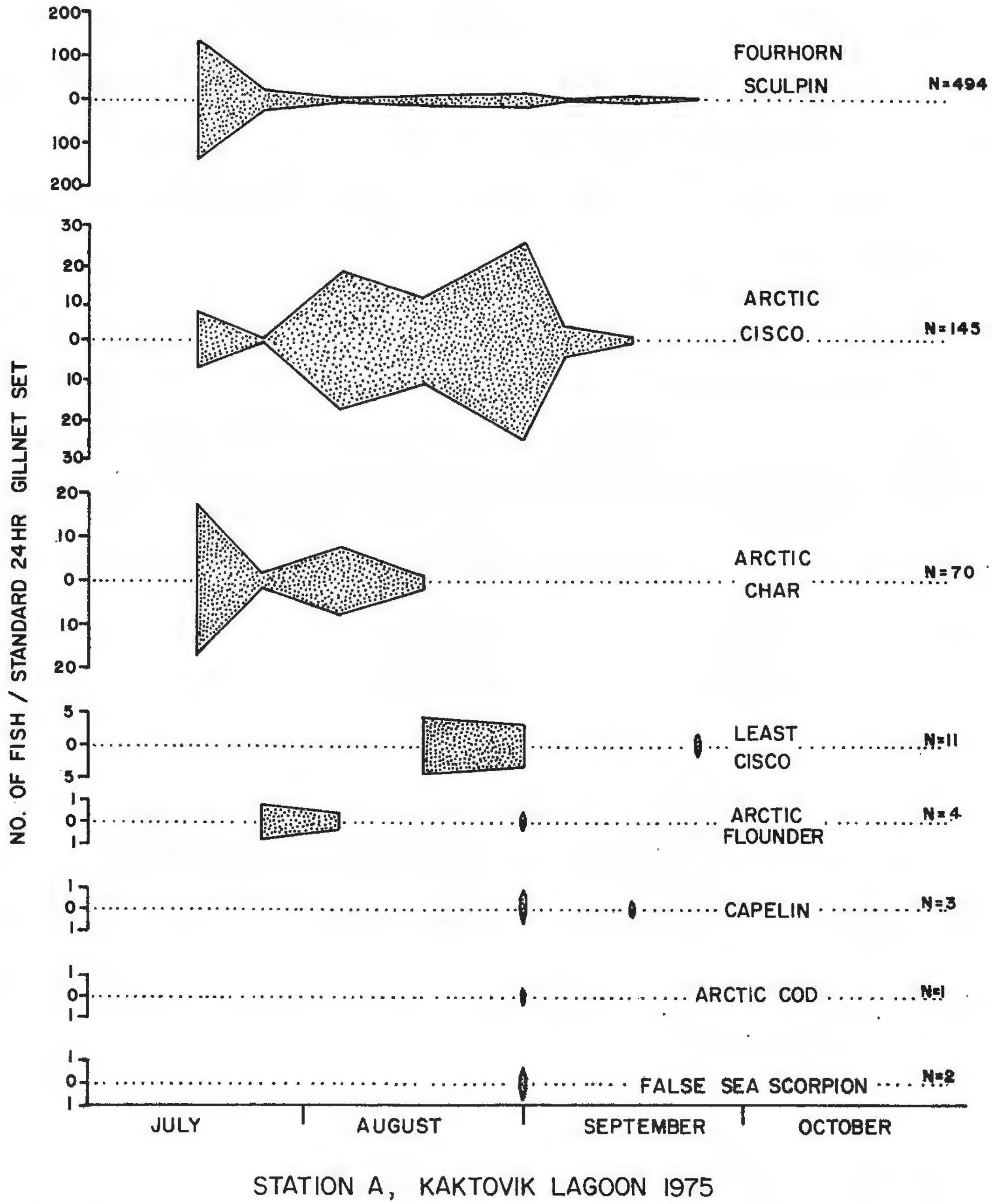

FIGURE 11. Seasonal abundance of all fish captured in standard 24-hour gillnet sets at Station A in Kaktovik Lagoon, 1975. Sets were made at approximately two week intervals. No fish were caught during a 24-hour gillnet set at Station A on November 1, 1975. Note that ordinate scales differ.

abundance are not understood. Ice conditions prevented use of full net gangs before July 13, but single panels caught one fourhorn sculpin on June 30 and 29 on July 6. No fourhorn sculpin was captured under the ice on November 1. At Nunaluk Lagoon, 1974, fourhorn sculpins were not abundant in the study area until mid-September (Figure 12), when fully one-third of the sculpin catch was taken in the last gillnet set on September 25.

Arctic cisco were not collected in the study area until July 13. Thereafter this species was abundant until mid-September but was not taken after September 17, probably because they had migrated to their overwintering areas. At Nunaluk Lagoon, Arctic cisco were sparse early in the season (July 1 to July 17), but after mid-July they were the most abundant fish with the largest catch taken just prior to freeze-up (September 25, 1974). Arctic cisco may leave the vicinity of Kaktovik Lagoon sooner than the Nunaluk Lagoon areas, as they must travel a greater distance to their overwintering areas which are located in the Colville or Mackenzie rivers (Craig and McCart, 1975).

The first Arctic char was collected in Kaktovik Lagoon on July 6. Arctic char were abundant in the first half of the season but none was caught in the 24 hr gillnet sets after August 21. Evidently, most char utilize the nearshore areas for only a short period and return to fresh water by mid-August. Similar results were reported from Nunaluk Lagoon, 1974, although a few stragglers returning to the Firth River were taken in late August and September.

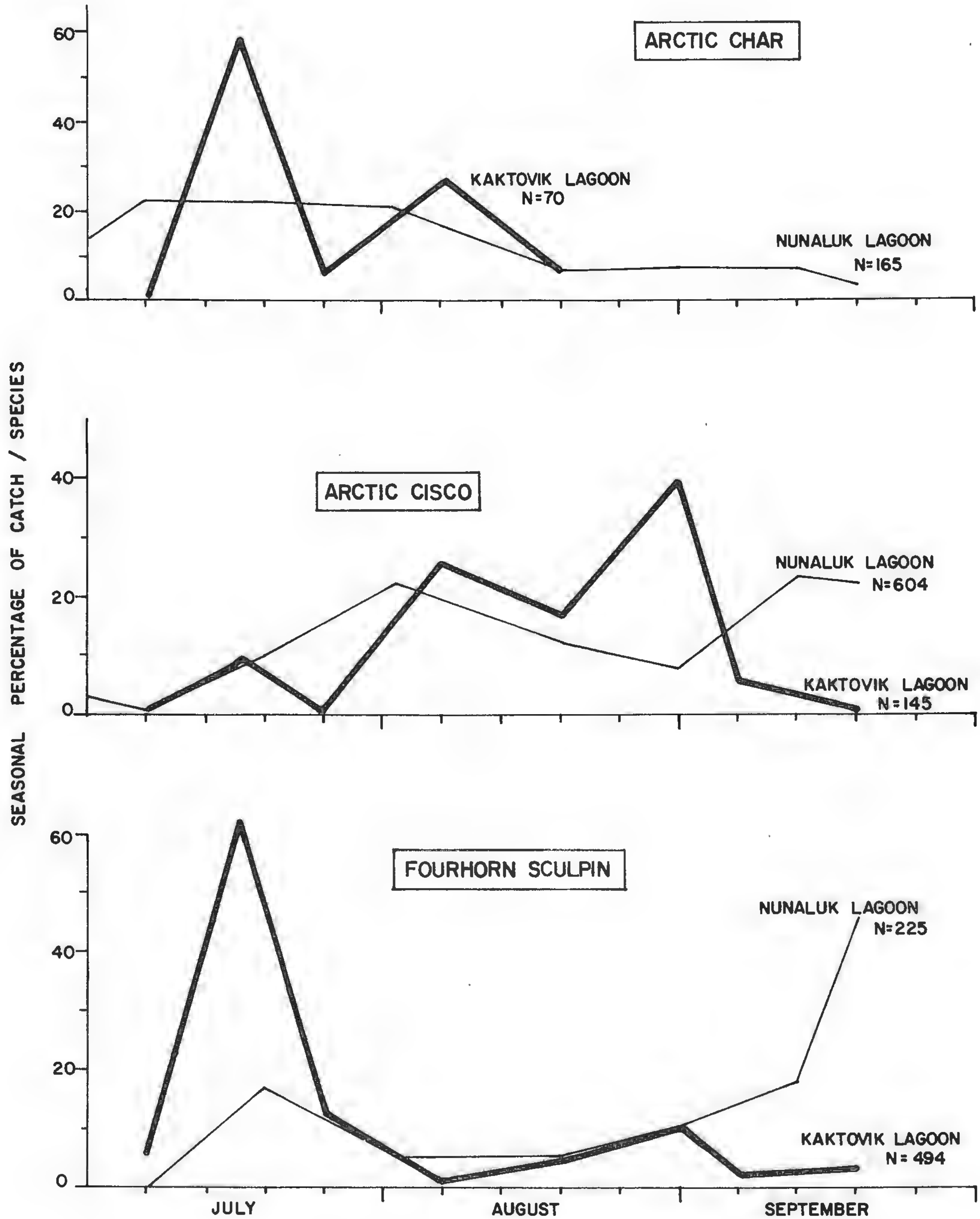

FIGURE 12. Seasonal abundance of the three major species at Kaktovik Lagoon, 1975, and Nunaluk Lagoon, 1974 (Griffiths *et al.*, 1975).

Other fishes were caught occasionally in 24 hr gillnet sets in Kaktovik Lagoon (Figure 11).

Nearshore v. Offshore Abundance

Catch statistics for fish caught in nearshore gillnet sets (located adjacent to the shoreline) and offshore gillnet sets (located at least 100 m offshore were compared. The results indicate that fish utilized the nearshore areas almost exclusively (Table 12). Similar results were reported for Nunaluk Lagoon (Griffiths *et al.*, 1975) and Prudhoe Bay (Terry Bendock, pers. comm., Alaska Department of Fish and Game, 1975).

Diel Variation For Major Species

Data were analysed to determine whether the three major species (fourhorn sculpin, Arctic cisco, and Arctic char) were caught more frequently during the day or night. The standard 24 hr gillnet sets at Station A were cleared at 12 hr intervals (0800 and 2000 hrs), so each set could be roughly divided into "day" (0800-2000) and "night" (2000-0800) catches. In the Arctic, however, the situation is complicated by the extended periods of summer daylight (Figure 13). The first two gillnet samples (July 7 and 13) were taken at a time when the sun did not set below the horizon, though there was a marked reduction in light intensity during the "night" period. By the date of the last gillnet set, the light regime was approaching 12 hours of daylight and 12 hours of darkness (Figure 13).

The diel abundance of the three major species in the Kaktovik Lagoon

TABLE 12. Comparison of the number of fish caught in nearshore gillnet sets (located adjacent to the shoreline) with offshore gillnet sets in Kaktovik Lagoon and nearby areas, 1975.

Date	Location	Gillnet Set (hours)	Number of Fish per Gillnet Hour
NEARSHORE SITES			
August 8	Lagoon	4.0	5.8
August 22	Lagoon	4.0	8.8
September 5	Lagoon	24.0	0.7
August 28	Station B	4.0	4.8
August 29	Ocean side Bernard Spit	1.5	7.5
OFFSHORE SITES			
August 7	Mid-lagoon (surface set)	8.0	0.5
August 25	Mid-lagoon (bottom)	8.0	0.0
September 4	Mid-lagoon (bottom)	4.0	0.0
August 28	Station B (300 m offshore)	2.0	0.0
August 28	Station B (1500 m offshore)	2.0	0.0
August 29	Ocean side Bernard Spit (100 m offshore)	1.5	1.0

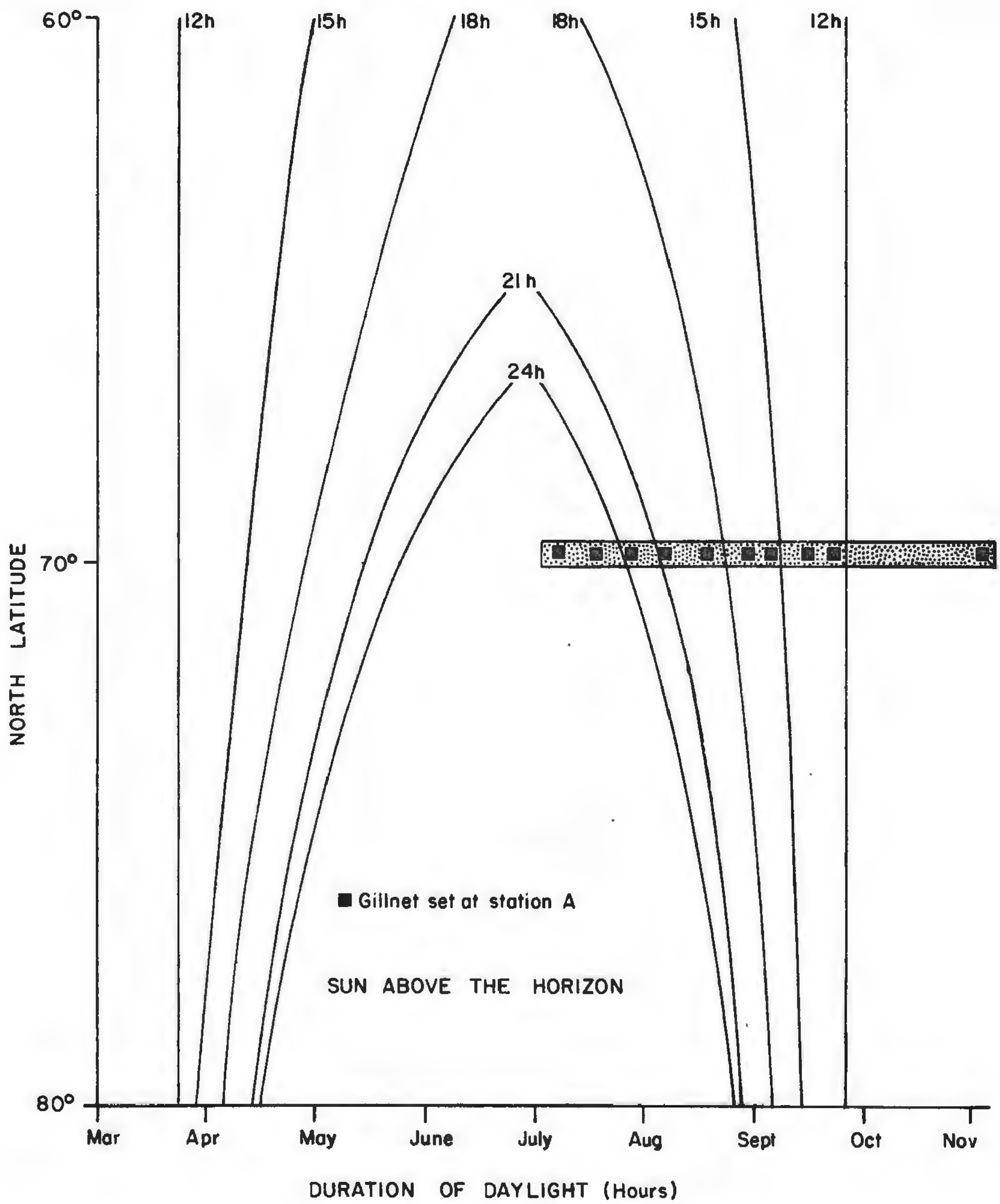

FIGURE 13. Seasonal variation in the number of daylight hours at the Kaktovik Lagoon study area (stippled bar). Also indicated are the dates when 24-hour gillnet sets were made at Station A (dark squares). The last gillnet set was made under ice cover.

study is shown in Figure 14. Fourhorn sculpin at Kaktovik were slightly more abundant during the day than at night, while Arctic cisco and Arctic char demonstrated no clear trend. These results differ slightly from those obtained at Nunaluk Lagoon (Griffiths *et al.*, 1975) where catches of Arctic char and fourhorn sculpin appeared to be independent of light intensity but Arctic cisco catches were greater during the "night". There are insufficient data available to determine the reasons for differences between the Kaktovik and Nunaluk Lagoon studies.

On August 24 and 25, a seining effort was conducted over a 24 hr period to ascertain whether there are any patterns in the diel movements of small fish in the shallow waters of the study area. Only the young-of-the-year of the fourhorn sculpin were taken in the seines and the results show a decrease in their abundance throughout the daylight hours (Figure 15). Numbers increased during the dark hours to a maximum at 0500 hrs on August 25. Young-of-the-year fourhorn sculpin apparently move offshore during the daylight hours and onshore during the dark hours. There appears to be a slight negative correlation between these movements and temperature, but no correlation with tidal fluctuations (Figure 15).

Life History of the Arctic Char

Of all the fish species found within the region that encompasses the Alaskan portion of the Arctic Gas pipeline, the Arctic char *(Salvelinus alpinus)* ranks as one of the most abundant in both fresh and marine waters. The char is a prized sport fish and it is also important in domestic fisheries.

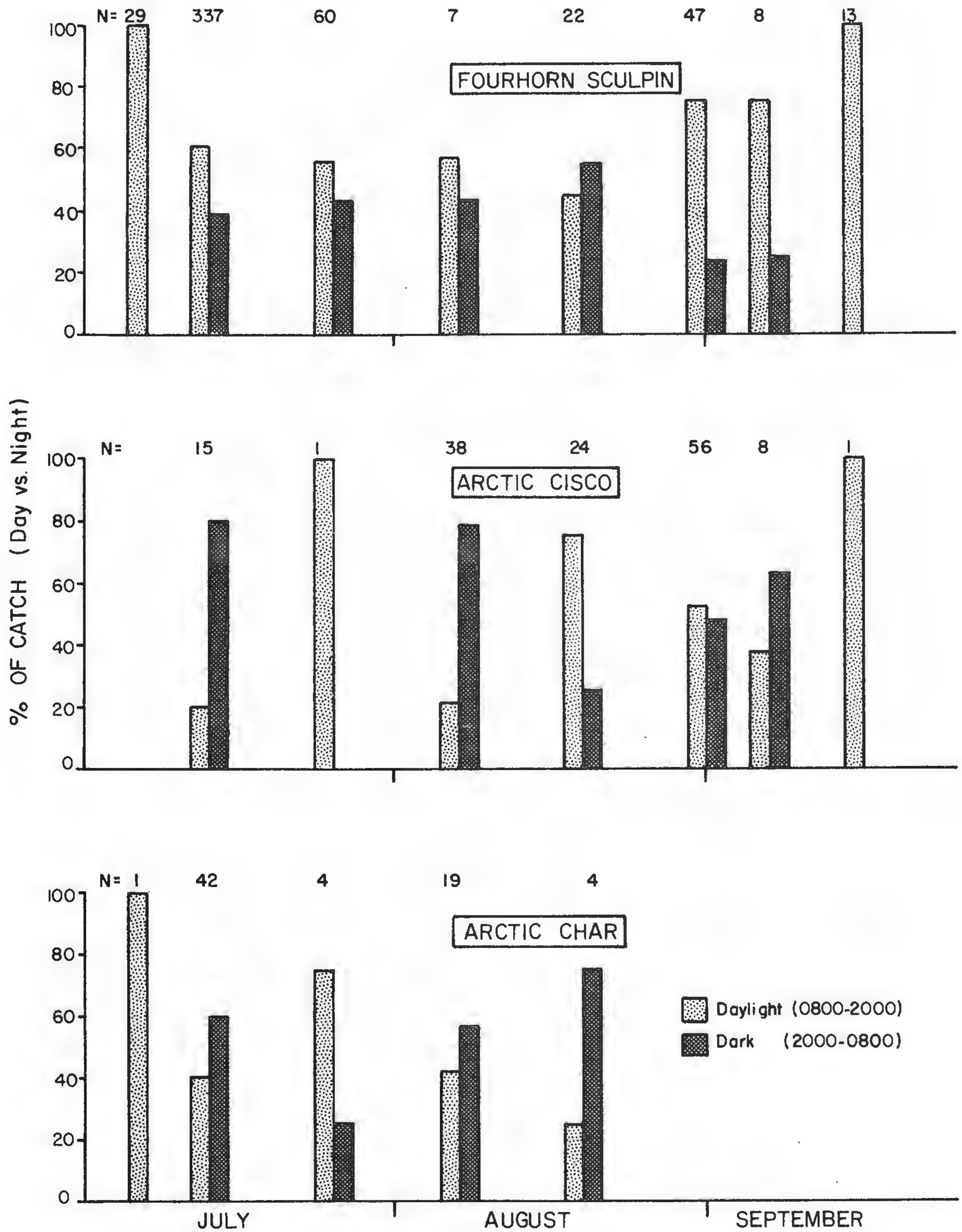

FIGURE 14. Diel variation in fish catches of Arctic char, Arctic cisco, and fourhorn sculpin from Station A in Kaktovik Lagoon, 1975. All gillnet samples were 24-hour sets cleared at 12-hour intervals.

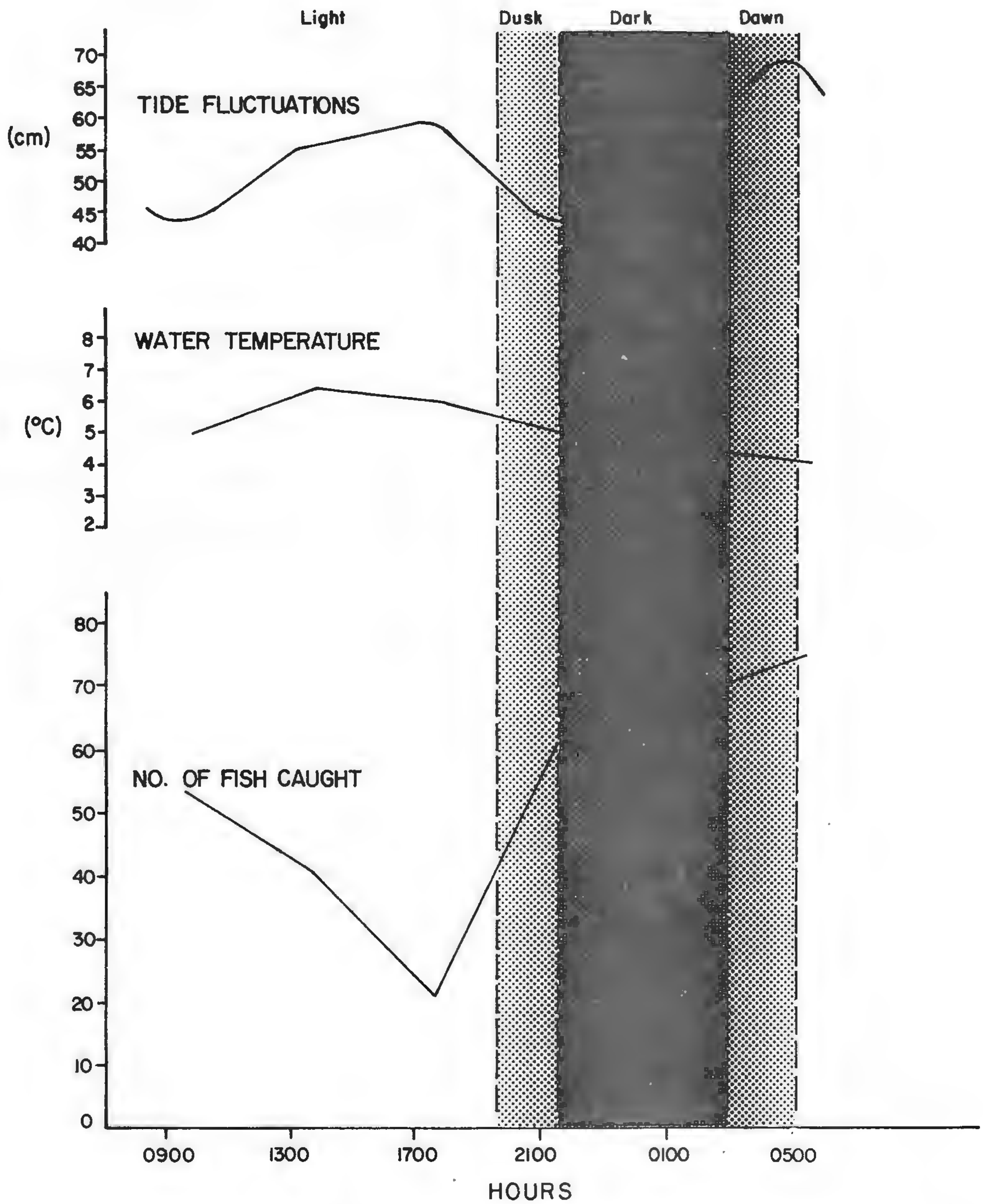

FIGURE 15. Diel variation in catches of fourhorn sculpin young-of-the-year at Kaktovik Lagoon, August 24-25, 1975. Also shown are water temperatures and tidal fluctuations on these dates.

In this section, the age, growth, reproduction, movements, and distribution of Arctic char caught in coastal waters around Kaktovik Lagoon are described. These data are compared in some detail to those gathered the previous year at Nunaluk Lagoon, Yukon Territory (Griffiths *et al.*, 1975) and also to results from other studies conducted along the Beaufort Sea coastline between the Colville and Mackenzie rivers.

Source of Kaktovik Char and Coastal Movements of Fish

Unlike Nunaluk Lagoon (Griffiths *et al.*, 1975), Kaktovik Lagoon has no char stream feeding directly into it. Consequently, all char caught in the present study originated in North Slope streams at some distance from Kaktovik Lagoon. Most of the streams in this region have been surveyed for fish populations (Ward and Craig, 1974). The nearest of the larger streams are the Sadlerochit, Hulahula, Okpilak, and Jago rivers, all located 8-24 km (5-15 mi) from Barter Island. There are three traditional fishing areas on the Hulahula River used by Kaktovik Eskimos and this stream probably supports the largest char population in the area. It is likely that a large proportion of the char taken at Kaktovik originated there.

The status of the char population in the Jago River is not well known, but the lack of traditional fishing areas on this stream suggests that the population is small. The Sadlerochit River supports an isolated resident population in Sadlerochit Springs, but the drainage apparently lacks sea-run char. The same appears to hold true for the Okpilak River. These streams probably contribute little, if at all, to the numbers of char taken at Kaktovik Lagoon.

Several tagged char from other studies were recovered in the Barter Island area. The data indicate widespread coastal movements by char during the short Arctic summer. Recaptures at or near Barter Island included fish from both Alaskan and Canadian rivers. Three char from the Firth River, Yukon Territory, were taken in subsistence catches (Glova and McCart, 1974), two from the Canning River (Craig, 1976), and one from the Sagavanirktok River (Furniss, 1974). These recaptures represent longshore movements of at least 190 km (120 mi) for some fish.

It is apparent that the char caught in the study area originated in North Slope streams both to the east and west of Barter Island, from the Firth to Sagavanirktok rivers. Unfortunately, it is not yet possible to distinguish these individual populations, and so all char in the Kaktovik sample have been combined for analyses.

Seasonal Changes in Composition

The kinds of char present in the study area during the open water season mirror the results obtained the previous year at Nunaluk Lagoon (Griffiths *et al.*, 1975). While there was a wide range in sizes of fish caught at various times during the brief summer, there was again a tendency for large mature fish to be present during the first part of the season and smaller immature fish in the latter part (Figure 16).

Distribution in the Study Area

Mature and immature char were present throughout Kaktovik Lagoon and adjacent areas (Figure 17). As in the case of the Nunaluk Lagoon study (Griffiths *et al.*, 1975), there was again a slight tendency for the

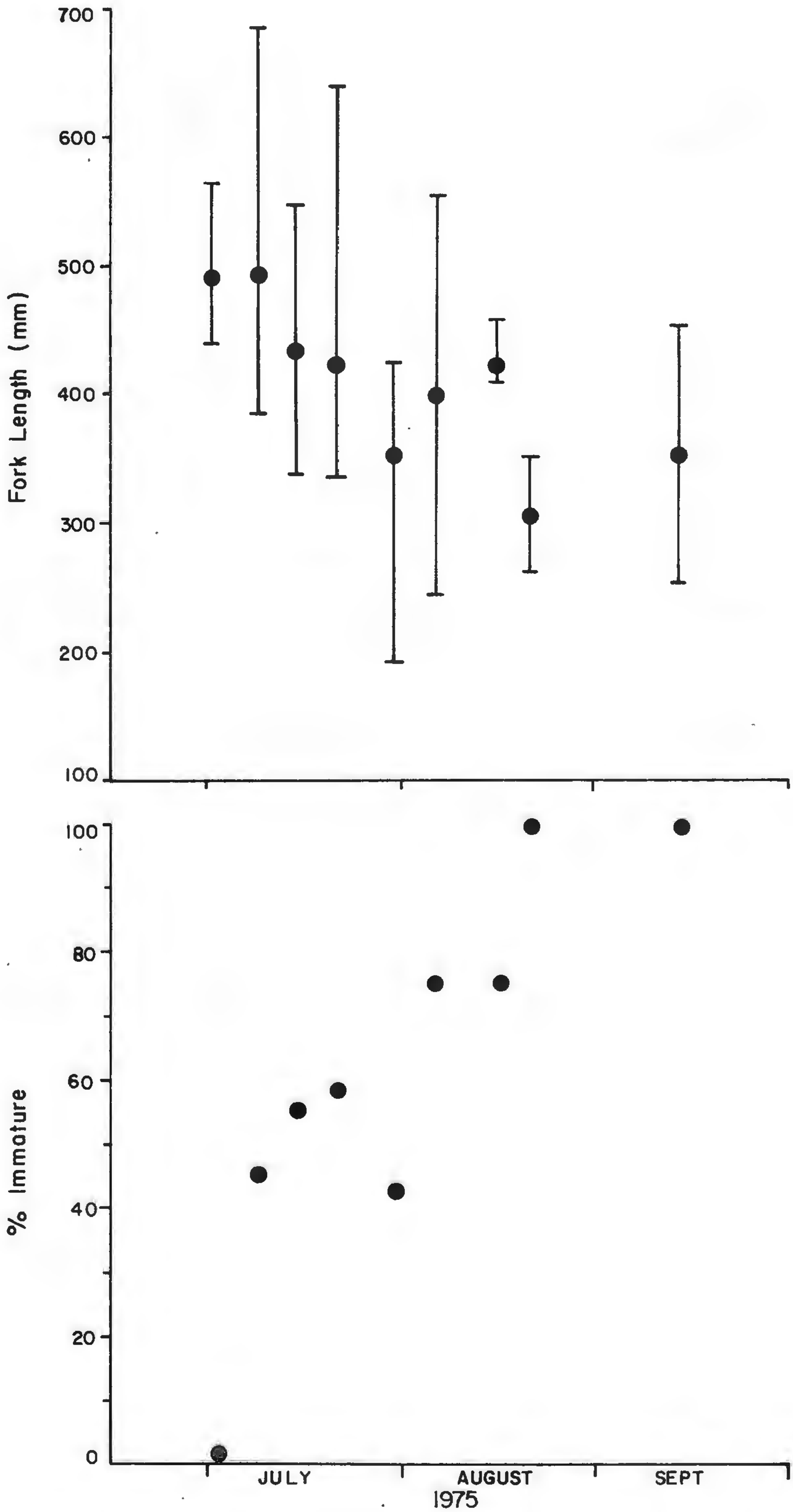

FIGURE 16. Seasonal changes in the size and maturity of char at Kaktovik Lagoon and adjacent areas. The mean and range of fork lengths and the percent of immatures in combined

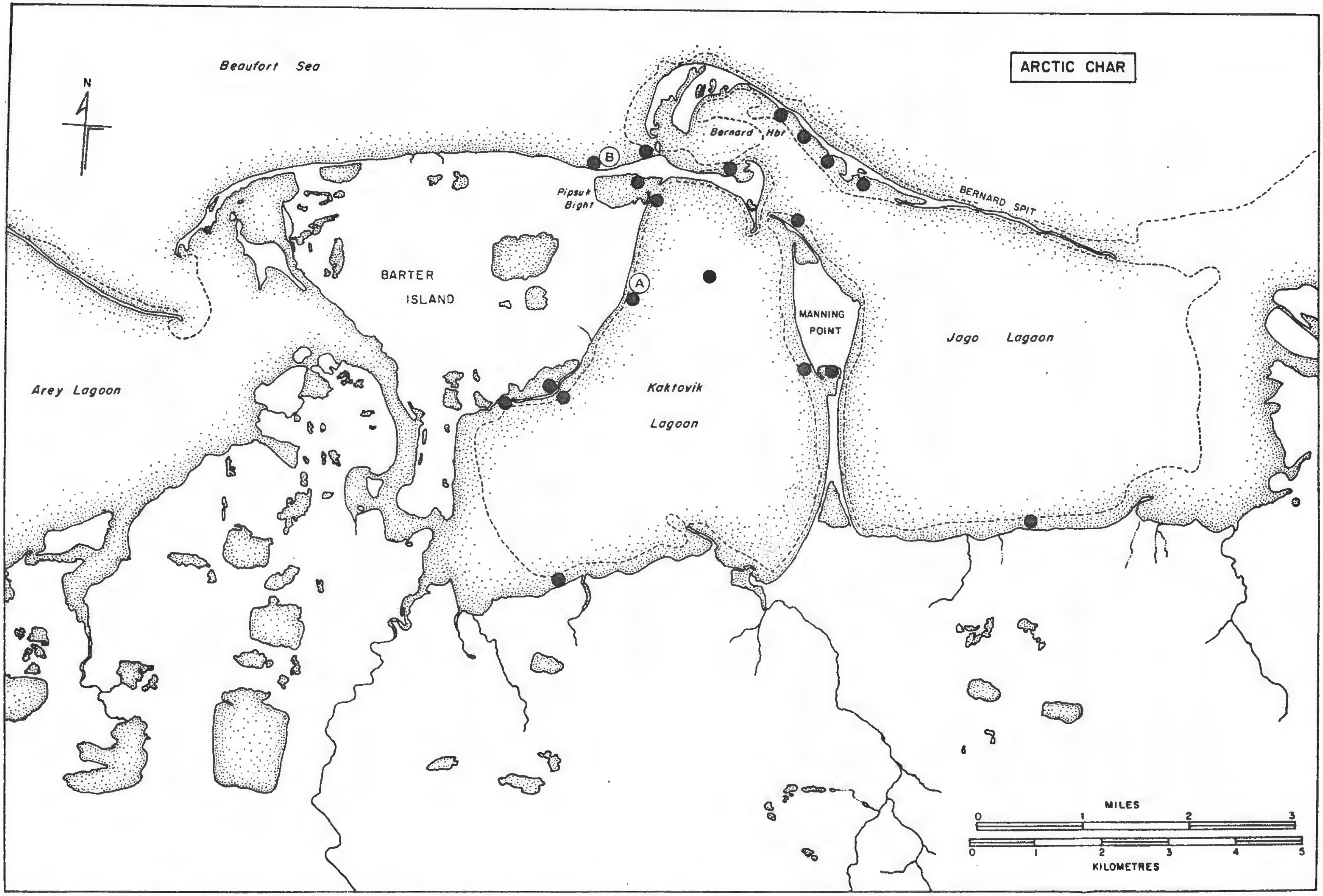

FIGURE 17. Distribution of capture sites for Arctic char in Kaktovik Lagoon and adjacent areas, 1975.

youngest fish to remain near the mainland and not disperse far in the seaward direction. Five of the six youngest fish in the sample (i.e., fish aged 3 and 4) were collected at lagoon sites as opposed to sites located in Bernard Harbour or along Bernard Spit.

Size Distribution

The length-frequency of the Kaktovik sample follows the pattern that has been observed for sea-run char along the Beaufort Sea coastline (Craig and McCart, 1975). Few fish under 320 mm were caught in the brackish coastal waters, and most of the sample consisted of moderate-sized fish in the 380-460 mm categories (Figure 18). The largest fish taken was a 685 mm male.

Some differences are apparent between the length-frequency data obtained in the present study and those gathered by Roguski and Komarek (1972) during a coastal survey across the entire Arctic National Wildlife Range. These authors report a modal frequency around 370-379 mm which is some 30 mm lower than the mode shown in Figure 18. While there may be several factors involved in this discrepancy, sample location is probably one of the more important. The two studies actually collected fish from very different locations. Approximately 66% of Roguski and Komarek's catch was taken from the eastern portion of the Arctic National Wildlife Range, 30% from the western portion, and only 4% from the central area within 30 coastal kilometres on either side of Barter Island. Only three char in their study were taken at Barter Island itself.

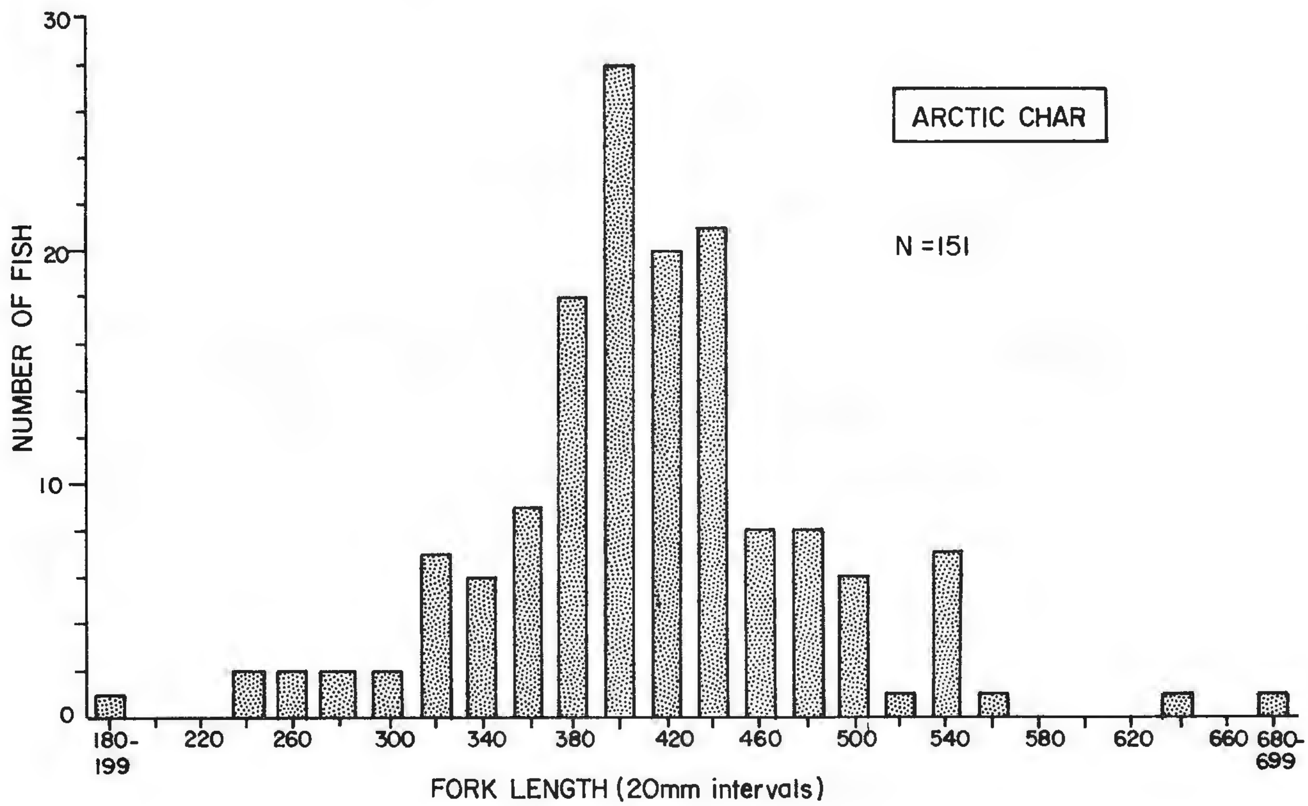

FIGURE 18. Length-frequency of sea-run char in Kaktovik Lagoon and adjacent areas, 1975.

Age-Frequency

Although the char at Kaktovik Lagoon ranged in age from 3 to 12 years, most were of intermediate age, with ages 5-8 representing 80% of the sample (Figure 19). These results are similar to those obtained from coastal locations to the east and west of Barter Island, and there is an overall uniformity in the ages of char which enter coastal waters at various locations along the Beaufort Sea coastline. As a generalization, few char younger than age 3 or older than age 12 are taken in these waters:

Location	Age range	Age mode	Reference
1. Central Yukon coast	3-11	6	Kendel *et al.*, 1974
2. Nunaluk Lagoon, Y.T.	2-12	6	Griffiths *et al.*, 1975
3. Arctic National Wildlife Range	3-12	-	Roguski and Komarek, 1972
4. Kaktovik Lagoon	3-12	7	This study
5. Coast--Canning R. to Sagavanirktok R.	2-14	8	Craig, 1976
6. Prudhoe Bay	3-12	10	Furniss, 1975

Fish outside these age limits are most often encountered when the sample size and effort are large or when the sample location is near the delta of a river which supports a char population. Age 1 and 2 fish are occasionally taken in the latter areas; however, it appears that these char do not venture far from their stream of origin.

There were, however, some differences in age structure. Age 6 was the modal age of char from Nunaluk Lagoon and from the Central Yukon coast further to the east. Age 7 was the modal age for the Kaktovik sample,

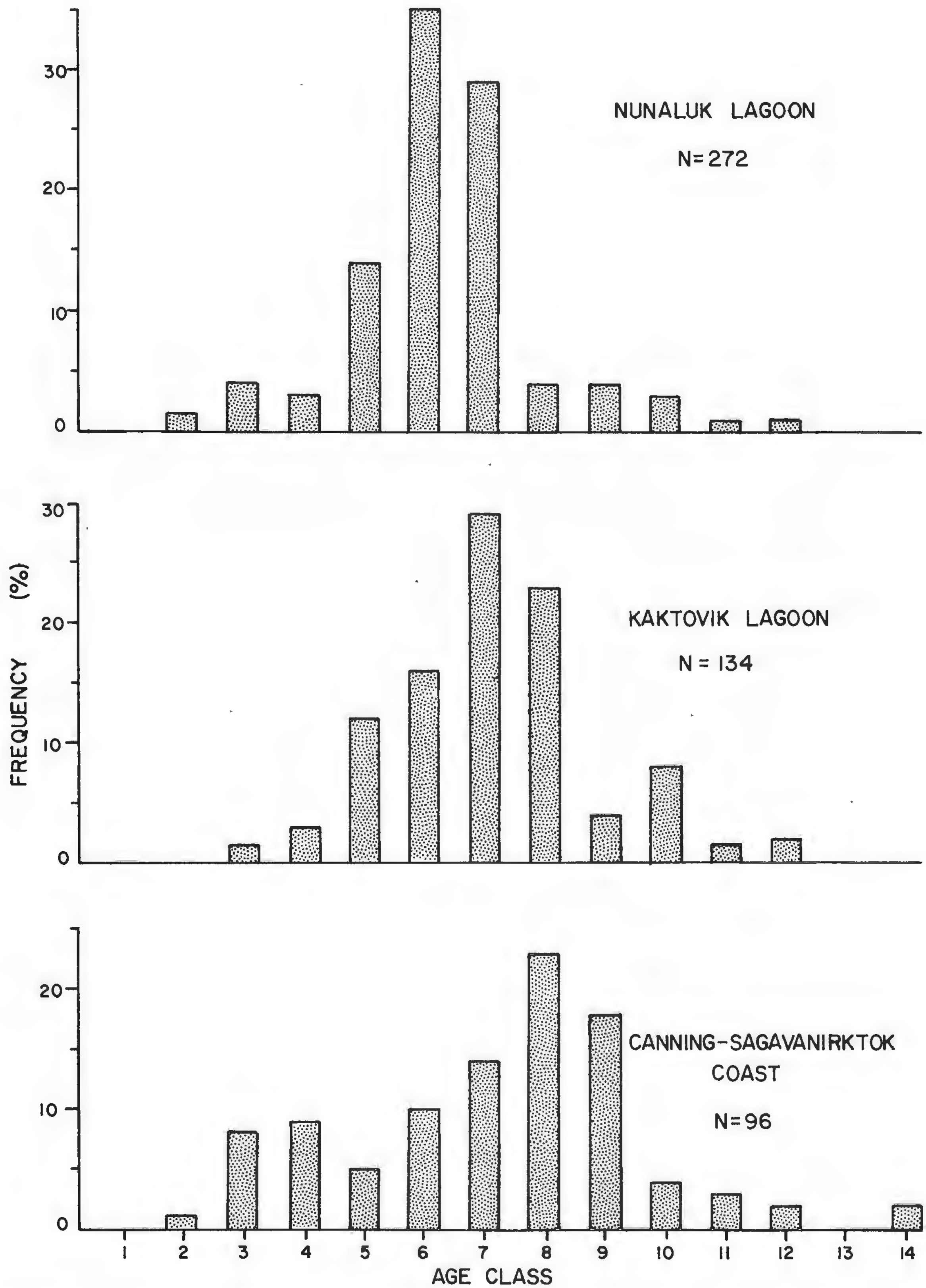

FIGURE 19. Age composition of Arctic char from three coastal locations, Beaufort Sea.

age 8 for the Canning-Sagavanirktok sample, and age 10 for the Prudhoe Bay sample. It is not known if this east-west trend toward older fish is significant or coincidental.

Age and Growth

Johnson (1972), Kendel *et al.* (1974) and others, have noted that the lengths of Arctic fish cover a wide range within each age interval and that there is a large degree of size overlap between age groups within populations. This situation also occurred in the Kaktovik sample and the size range of each age class overlaps at least two and up to seven other age classes (Figure 20). Many factors contribute to this variability, including, 1) the number of summers spent feeding in coastal waters, 2) the number of times each fish has spawned, 3) the mixture of char from several different populations in the sample, and 4) the opportunistic growth of individual fish in the density-dependent fashion as hypothesized by Johnson (1972).

The growth curve of the Kaktovik char fits within the range recorded for other coastal char populations (Figure 21). There is roughly a 60-70 mm difference per age class between the fastest and slowest growing coastal populations, with the Kaktovik sample falling on the lower end of the scale. It should be remembered, however, that each of these coastal collections probably consists of varying proportions of fish which originated from more than one Beaufort Sea drainage.

Maturity

Three points emerge with respect to the sexual condition of the

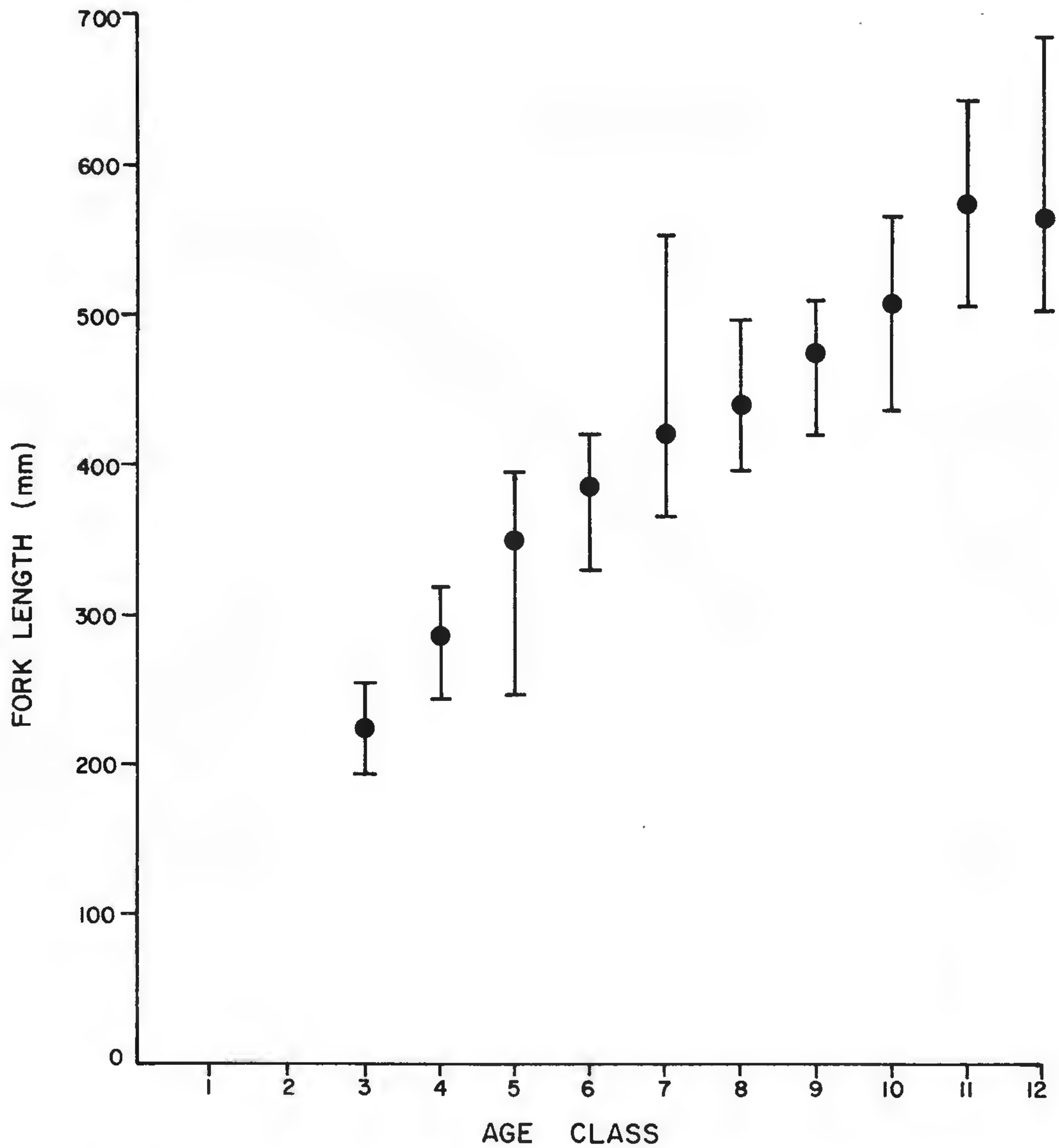

FIGURE 20. Age-length relationship for Kaktovik char. Means (dots) and ranges (bars) are indicated.

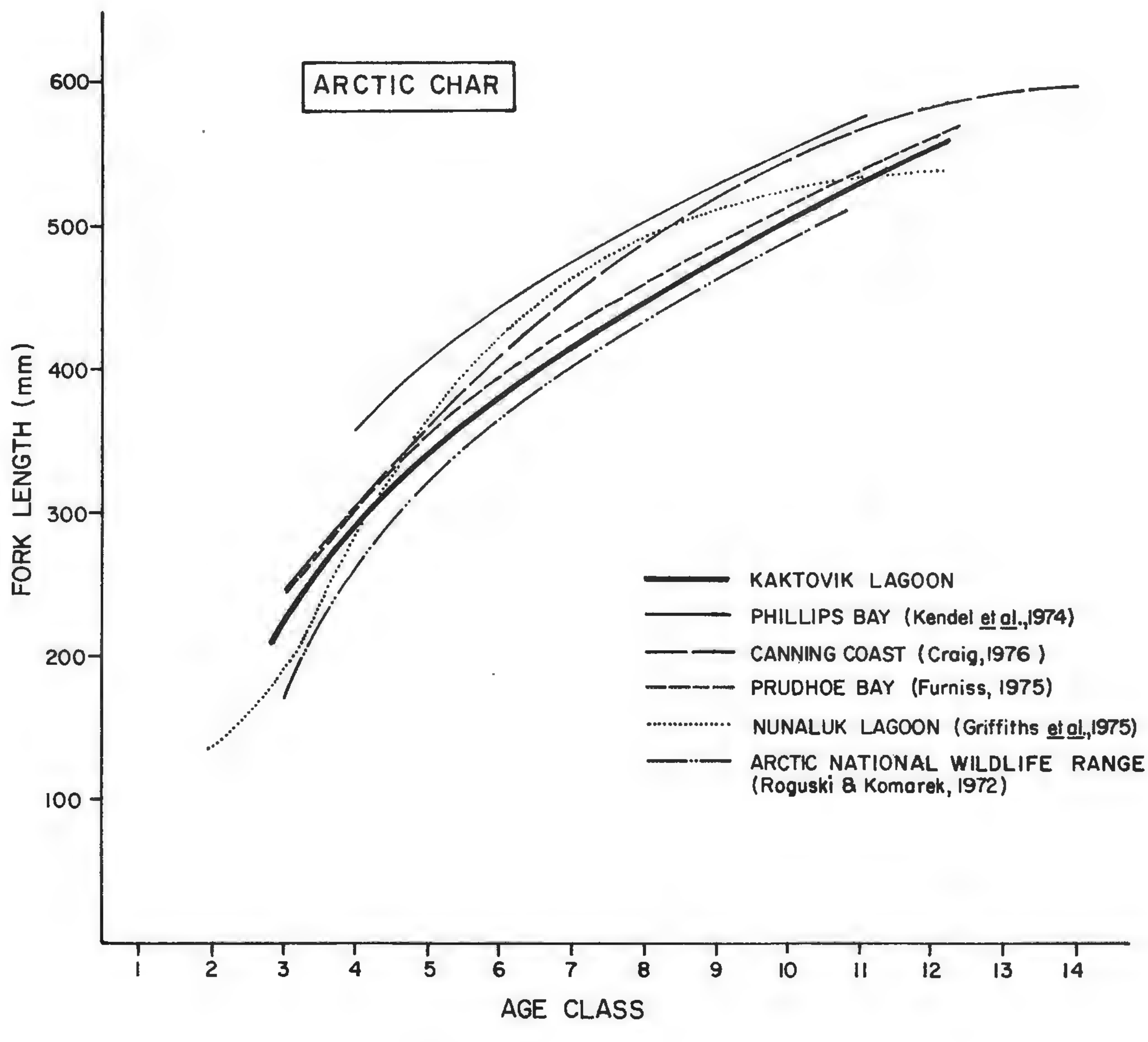

FIGURE 21. Comparison of growth curves for sea-run char caught at six coastal locations in Alaska and the Yukon Territory.

Kaktovik char. First, almost two out of every three char were immature (Table 13). Second, among mature fish (n=46), equal numbers of spawners and non-spawners were present (i.e., fish which would spawn in the year of capture or mature fish between spawnings). More information on this point is presented in a following section (Egg Size and Testes Weight). Third, approximately half of the fish were mature by age 8 and all by age 9.

These results concur with the findings of other workers although some variation exists at different coastal locations. For example, at Nunaluk Lagoon (Griffiths *et al.*, 1975) 65% of the char were immature, but only 45% along the coast near the Canning River (Craig, 1976) were immature.

Sex Ratio

Female char have a greater tendency than males to undertake a seaward migration, and consequently, females are more abundant in coastal waters (Craig and McCart, 1975). Further documentation of this difference in sex ratio was obtained in the present study (Table 13). Females were significantly more abundant (62.4%) than males in the coastal waters around Barter Island (X^2=8.2, $p<0.005$).

Egg Size and Testes Weight

Data describing seasonal changes in egg sizes of female char are presented in Figure 22. The pattern is generally similar to that found for char in Nunaluk Lagoon by Griffiths *et al.* (1975) and the speculative comments made by these authors would seem to apply to the present sample. It appears that females whose egg diameters measure 1.5 mm or less are primarily immature fish, although some mature females between spawnings are

TABLE 13. Age-specific maturity, condition, and sex ratios of char in the Kaktovik sample.

		Sex Ratio	MATURITY				
			Males	Females	Sexes Combined		
Age	n	% Male	% Mature	% Mature	Immature	Mature Spawner	Mature Non-Spawner
3	2	50	-	-	100	-	-
4	4	25	-	-	100	-	-
5	16	44	-	-	100	-	-
6	21	29	-	-	100	-	-
7	38	42	-	17	84	16	-
8	31	23	43	62	42	26	32
9	5	60	100	100	-	20	80
10	11	45	100	100	-	17	73
11	2	50	100	100	-	100	-
12	3	100	100	-	-	67	33
TOTALS	133	37.6%	32%	36%	66%	17%	17%

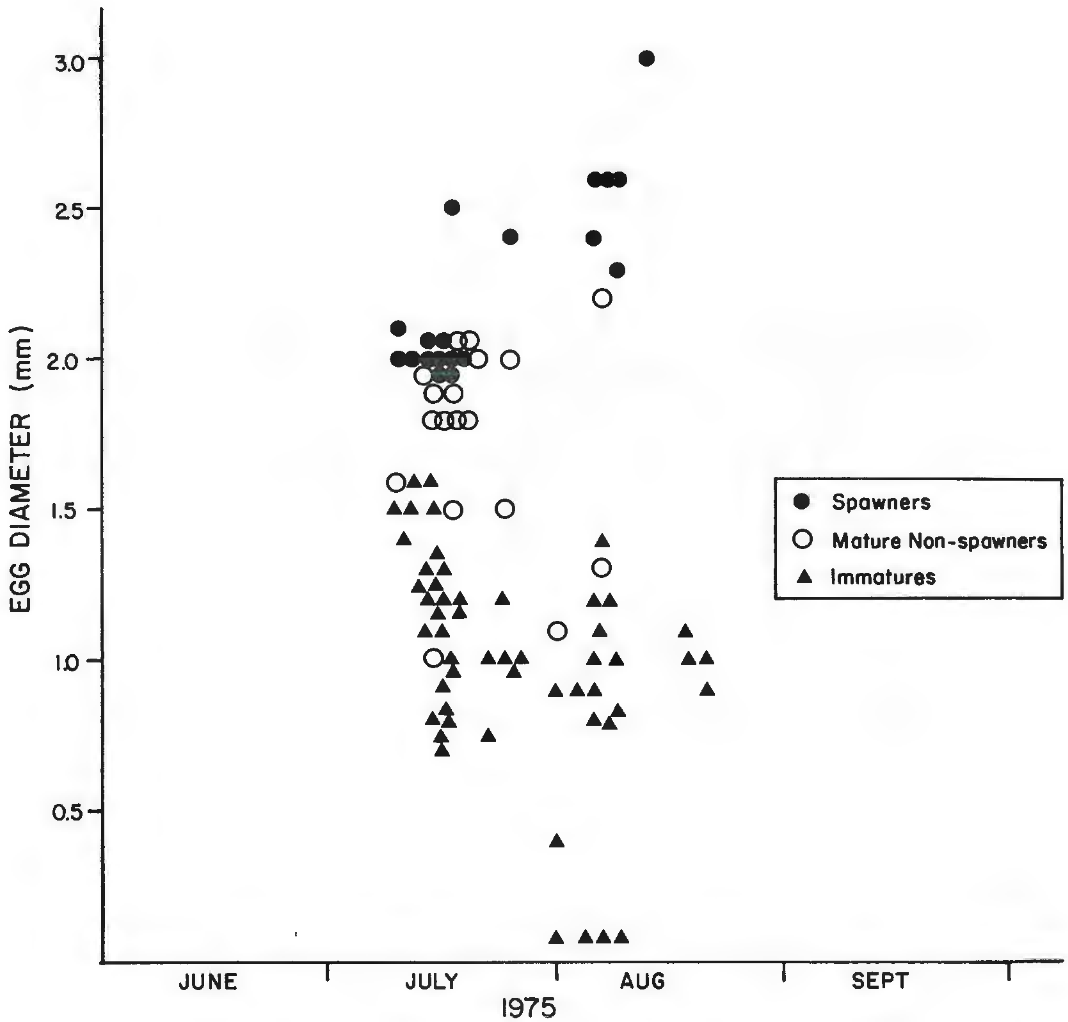

FIGURE 22. Seasonal pattern of egg size in female Arctic char from Kaktovik Lagoon and adjacent areas, 1975.

also present.

Some of the females with eggs larger than 1.7 mm would almost certainly have had eggs of spawning size by fall, suggesting that at least some females venture into coastal waters in the summer months prior to spawning. Recent data presented by Craig (1976) for char caught in the Canning River and adjacent coastal waters suggest that most females with larger (>1.7 mm) egg sizes are spawners.

Some fish do not fit neatly into any maturity pattern. These are probably fish whose eggs failed to reach a certain minimum size by the spawning period in a particular year, and consequently would not spawn until the following year.

Testes weights (total gonad weight) were extremely variable among male char, ranging from 0.1-93.9 g. As in the case of the females, sexual condition was tentatively determined by field examination (Figure 23). The data confirm the general findings of Griffiths *et al.* (1975) and Craig (1976). The testes weights of some fish fell within the range of values obtained for known spawners taken off spawning grounds; thus some males appear to enter coastal waters during the summer months prior to spawning. However, most of the males taken in coastal waters are either immatures or mature non-spawners.

Food Habits

Arctic char appear to be opportunistic feeders, utilizing most of the available food items. Crustaceans (84.8%) were the major food group

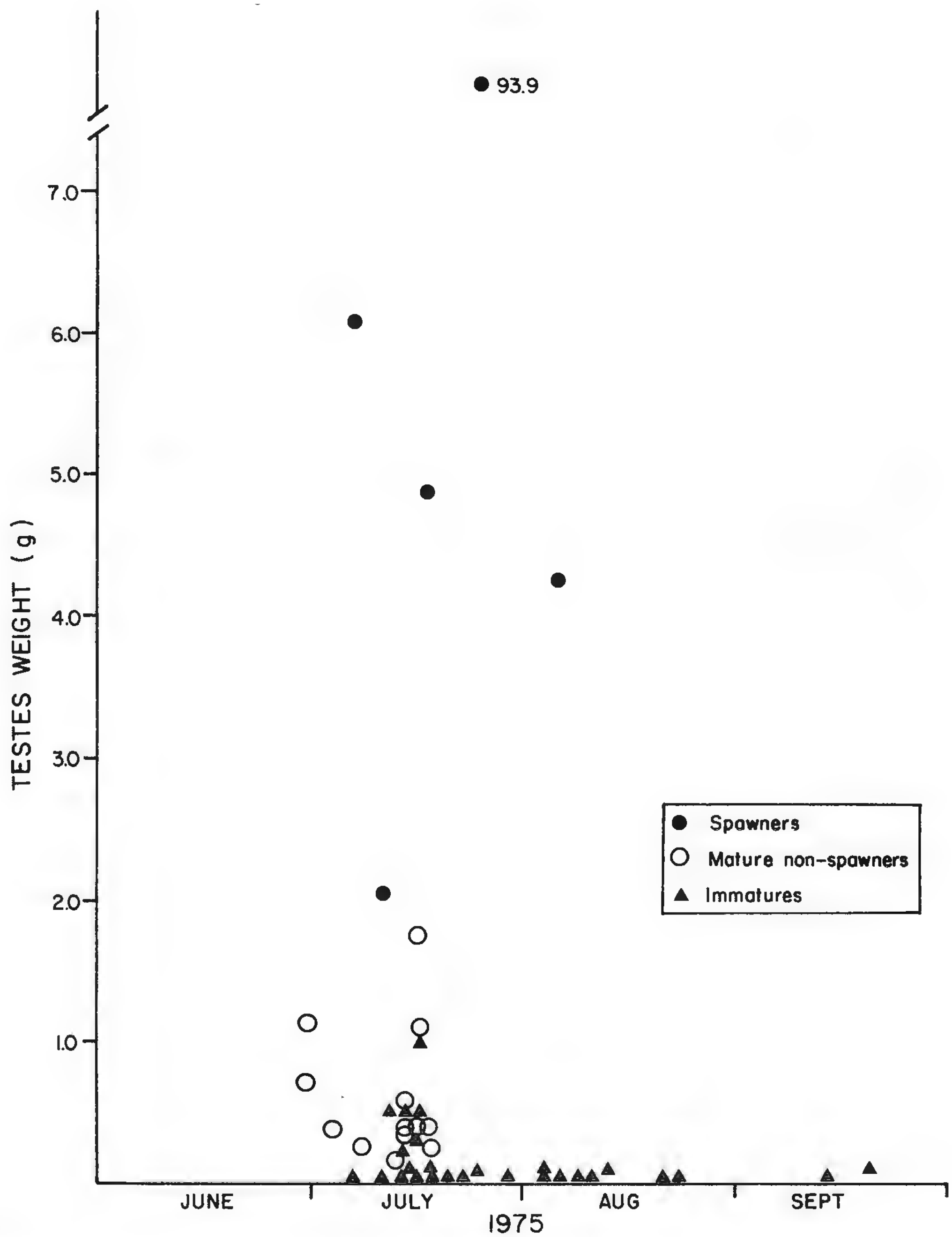

FIGURE 23. Seasonal pattern of testes weight for male Arctic char from Kaktovik Lagoon and adjacent areas, 1975.

utilized by Arctic char, with amphipods (55.8%) and mysids (28.5%) being the predominant taxa within the group (Table 14). Fish (12.4%) were the second most important group, fourhorn sculpin (6.9%) being the most common species. The Arctic char from the Nunaluk Lagoon study (Griffiths *et al.*, 1975) consumed approximately equal amounts of fish (31.9%), crustaceans (29.8%), and insects (23.4%). The most noticeable difference between the two study areas is the almost total absence of insects in the diet of the Kaktovik Arctic char. The reason for the lack of insects is not known but may be related in part to the differences in freshwater inflow between the two areas. At Nunaluk Lagoon, the large Firth and Malcolm rivers wash freshwater insect larvae and pupae into the brackish water of the lagoon, while the only drainage into Kaktovik Lagoon is from five small tundra streams.

The average stomach of char from Kaktovik Lagoon contained more food than the average stomach from Nunaluk (42.8-24.8%). Only 4.1% of Kaktovik Lagoon char had empty stomachs compared to 32.5% of char from Nunaluk Lagoon. Other authors report the percentage of empty stomachs in char in nearshore areas as from 20-31% (Kogl, 1972; Yoshihara, 1973; Craig and Mann, 1974).

Life History of Arctic Cisco

The Arctic cisco is one of the most abundant species inhabiting the estuarine waters of the Beaufort Sea coast from the Colville River, Alaska, to the Mackenzie River, Northwest Territories (Craig and Mann, 1974; Craig and McCart, 1975; Griffiths *et al.*, 1975). It also forms an important segment of the native domestic fisheries in this region

TABLE 14. Food items eaten by Arctic char in Kaktovik Lagoon and adjacent areas, 1975. Percent composition in "average stomach" was determined by the Points Method. "Average stomach" as 100% indicates results when only those fish with food in their stomachs are considered. NNST=ninespine stickleback; FHSC=fourhorn sculpin; STBY=stout eel blenny.

Food Item	% in average stomach n=137	average stomach as 100%
INSECTA	0.1	0.3
MOLLUSCA	0.004	0.001
CRUSTACEA		
Copepoda	0.04	0.1
Amphipoda	23.8	55.8
Isopoda	0.2	0.4
Mysidacea	12.2	28.5
Conchostraca	-	-
TOTAL	36.2	84.8
FISH		
Fish Remains	0.9	2.0
FHSC	3.0	6.9
NNST	-	-
STBY	1.4	3.2
Coregonus spp.	0.1	0.3
TOTAL	5.4	12.4
MISCELLANEOUS		
Unidentified	1.1	2.5
Plant Material	-	-
Sand and Stone	-	-
TOTAL	1.1	2.5
GRAND TOTALS	42.8%	100.0%

(Hatfield *et al.*, 1972; Kogl and Schell, 1974; Furniss, 1975; Delury *et al.*, 1975).

Source of Kaktovik Arctic Cisco

Despite their widespread distribution along the Beaufort Sea coast from the Mackenzie River delta west to the Colville River, it appears that Arctic cisco in this area utilize only the Colville and Mackenzie rivers for spawning and overwintering (Craig and McCart, 1975). Since the Kaktovik Lagoon study lies midway between these two rivers, a preliminary attempt was made during the present study to separate fish originating in each drainage on the basis of meristic characteristics.

Collections of Arctic cisco were taken at two Beaufort Sea locations in addition to the Kaktovik sample. Fish taken at Aklavik, N.W.T., represent the Mackenzie stock of Arctic cisco. The Bullen Point, Alaska, sample is presumably from the Colville stock since the site lies much closer to the Colville than the Mackenzie (130 km to the east of the Colville and 440 km to the west of the Mackenzie River). Three meristic characters were examined (Table 15). There was wide variation in the parameters studied (gillrakers, lateral line scales, and pyloric caeca) and no two populations could be separated on this basis. McPhail (1966) gives the range of meristic characteristics for Arctic cisco as: gillrakers, 15-17 + 26-31; pyloric caeca, 113-183; and lateral line scales, 82-110. Meristic data for the three samples lie within this range, with the exception of two Arctic cisco from Kaktovik Lagoon with pyloric caeca counts of 94 and 96. No significant differences between mean values for various characters were found when Student's t-test was

TABLE 15. Number of gillrakers, pyloric caeca, and lateral line scales for Arctic cisco from Bullen Point and Kaktovik Lagoon, Alaska, and Aklavik, N.W.T.

Location		No. of Gillrakers Upper Arch	No. of Gillrakers Lower Arch	No. of Pyloric Caeca	No. of Lateral Line Scales
Bullen Point	(n=20) $\bar{x}$	16	27	130	89
	S.D.	1.1	1.1	12.1	5.0
	(range)	(14-19)	(26-30)	(113-149)	(82-106)
Kaktovik Lagoon	(n=25) $\bar{x}$	16	27	131	89
	S.D.	0.9	1.0	15.6	5.0
	(range)	(14-18)	(26-30)	(94-149)	(83-106)
Aklavik	(n=10) $\bar{x}$	16	28	133	88
	S.D.	0.7	1.3	15.8	5.5
	(range)	(15-17)	(26-30)	(113-165)	(80-98)

applied.

Distribution in the Study Area

Mature and immature Arctic cisco were equally abundant throughout the shallow waters of Kaktovik Lagoon and the coastal beach areas, but were absent in the offshore marine areas and the deep (3 m) central portion of the Lagoon (Figure 24). Similar results were reported at Nunaluk Lagoon, Yukon Territory (Griffiths *et al.*, 1975), and in the Prudhoe Bay area (Terry Bendock, pers. comm.).

The mean length of captured fish was greatest early in the season (Figure 25). The number of immature fish was low early in the season, but increased rapidly until mid-August when their numbers dropped off sharply. Differences in the migration patterns between mature and immature fish are likely involved.

Size Distribution

The length-frequency of Arctic cisco in the Kaktovik Lagoon sample (Figure 26) was similar to those observed along the Beaufort Sea coast (Craig and McCart, 1975). Few fish under 280-300 mm were caught, and the majority (74%) consisted of fish in the 320-360 mm range. The largest fish taken was a 440 mm female. Similar results are reported for other areas along the Alaskan and Yukon coast: the Arctic National Wildlife Range (Roguski and Komarek, 1972), the Colville River Delta (Kogl and Schell, 1974), and the Yukon Coast (Craig and Mann, 1974; Griffiths *et al.*, 1975).

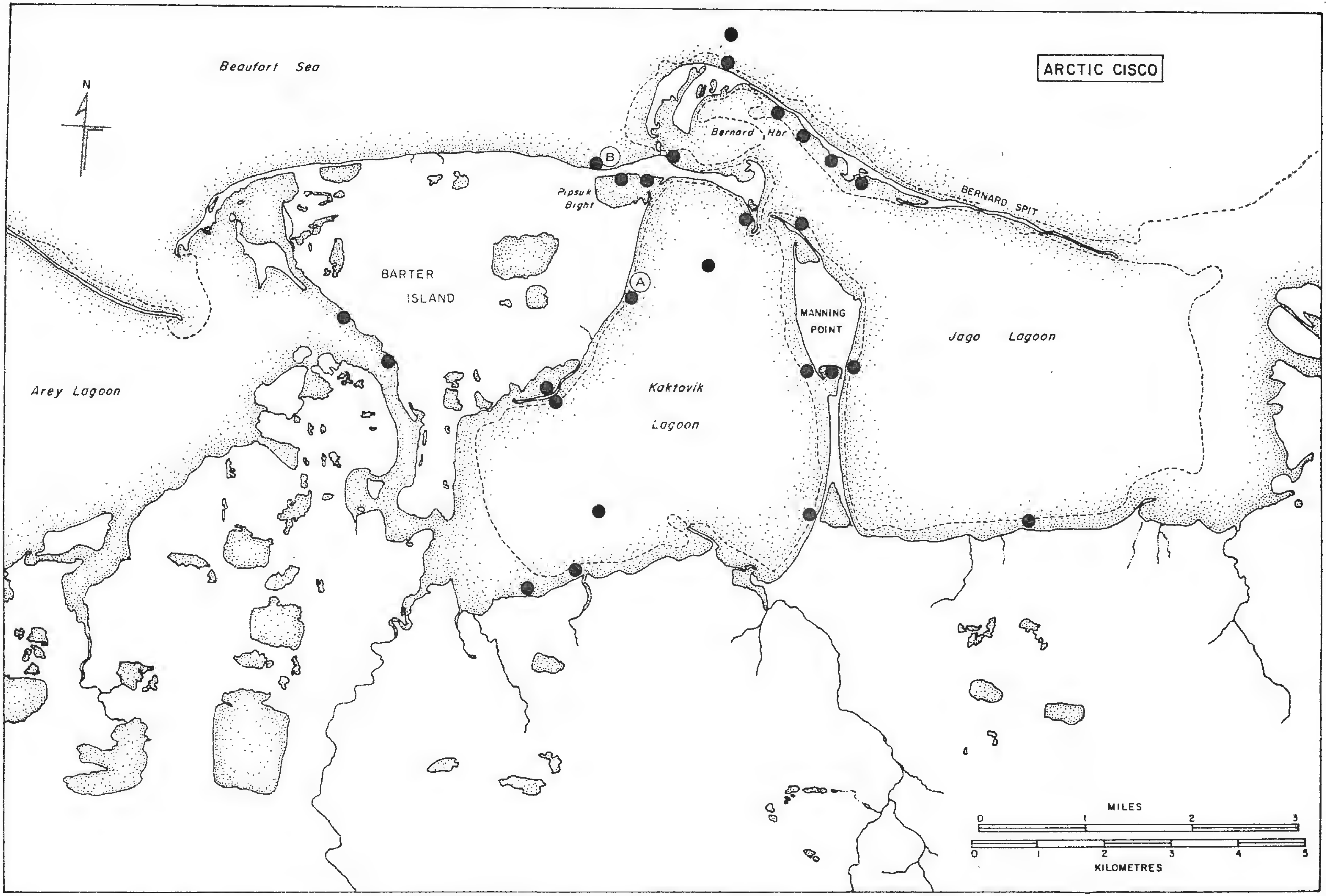

FIGURE 24. Distribution of Arctic cisco in Kaktovik Lagoon and adjacent areas, 1975.

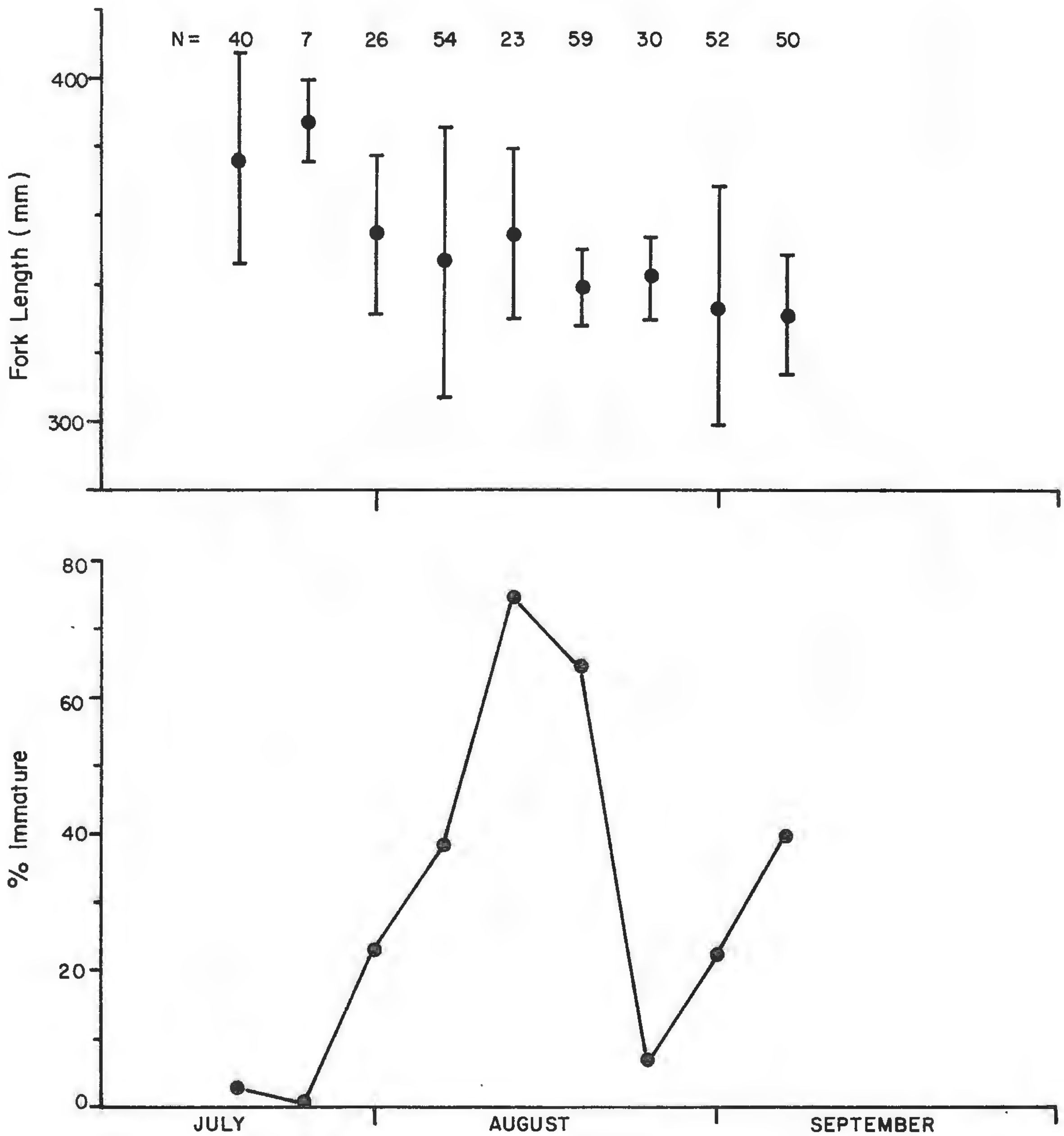

FIGURE 25. Seasonal changes in size and maturity of Arctic cisco in Kaktovik Lagoon and adjacent areas, 1975. Mean fork lengths (dots) and standard deviations (bars) and percent immatures are indicated for combined weekly samples.

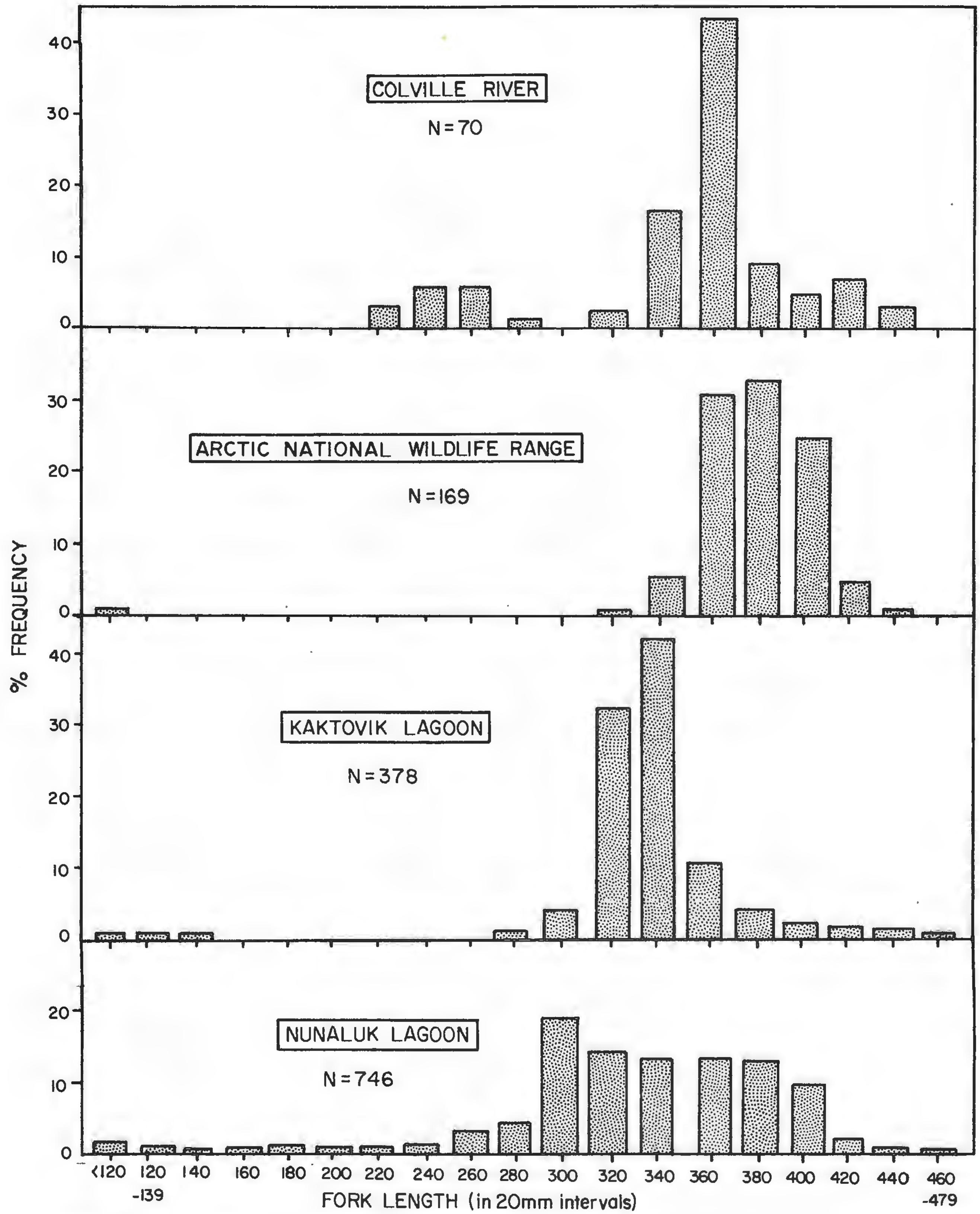

FIGURE 26. Length-frequency relationship of Arctic cisco caught at four locations along the Beaufort Sea coast in Alaska and the Yukon Territory.

Age and Growth

The age-length relationship for Kaktovik Arctic cisco is similar to those reported for this species in other areas along the Alaskan coast (Roguski and Komarek, 1972; Craig and Mann, 1974; Furniss, 1975) (Figure 27). Although the fish ranged in age from 3 to 11, 87% were either 7 or 8 (Table 16).

Differences in growth between male and female Arctic cisco were observed, with females tending to be larger than males. These differences were significant for the 6, 7, and 8 year age classes (Table 15).

Maturity

Most Arctic cisco in the Kaktovik sample appear to mature between the ages of 6 and 9 (Table 17). Similar results have been reported from other localities along the Beaufort Sea coast and the Mackenzie River (Hatfield *et al.*, 1972; Craig and Mann, 1974; Griffiths *et al.*, 1975).

Thirty-four percent of the Kaktovik Arctic cisco were immature fish (Table 17). The 1974 study at Nunaluk Lagoon reported 48.4% immature Arctic cisco (Griffiths *et al.*, 1975). At other locations, there is a wide range in the proportion of immature fish in samples (Table 17). Reasons for these differences are not known but possibly they reflect the difficulty in distinguishing between immature fish and mature fish in the field, as discussed by Craig and McCart (1975).

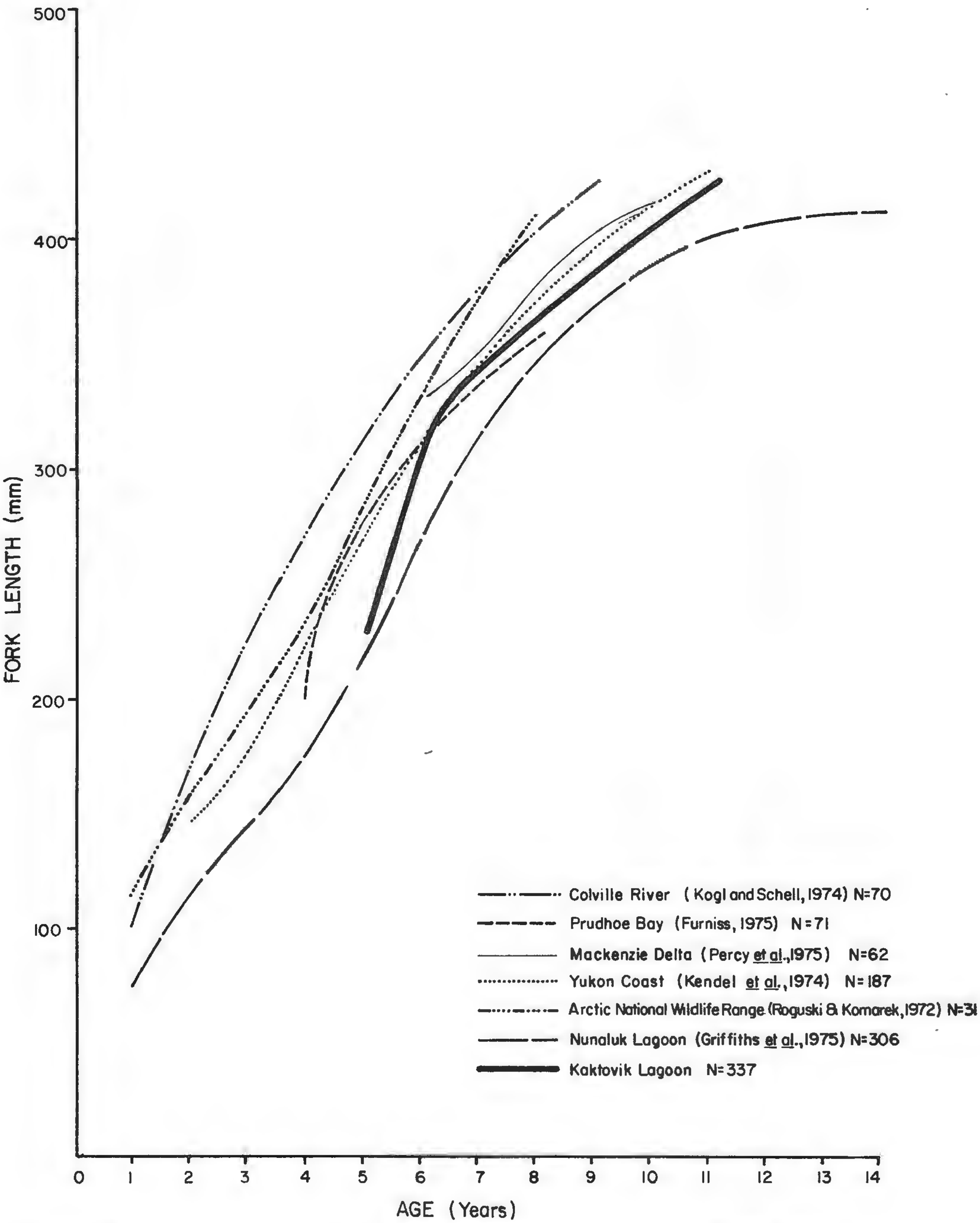

FIGURE 27. Comparison of growth curves for Arctic cisco from seven locations along the Beaufort Sea coast in Alaska and Canada.

TABLE 16. Age-length relationship (derived from otoliths) for Arctic cisco, sexes separate and combined. Differences in mean length at each age for males and females were tested for significance using Student's t-test. An asterisk indicates cases where p<0.05.

	TOTAL SAMPLE				MALES				FEMALES				
Age	n	mean	(range)	S.D.	n	mean	(range)	S.D.	n	mean	(range)	S.D.	t-test
1	0	-	-	-	0	-	-	-	0	-	-	-	-
2	0	-	-	-	0	-	-	-	0	-	-	-	-
3	2	121.5	(119-124)	3.5	0	-	-	-	1	119.0	-	-	-
4	1	158.0	-	-	1	158.0	-	-	0	-	-	-	-
5	0	-	-	-	-	-	-	-	0	-	-	-	-
6	13	317.8	(281-345)	22.1	9	322.1	(282-345)	18.2	4	308.3	(281-338)	29.9	1.05
7	195	340.1	(295-378)	15.5	128	336.7	(295-375)	14.5	66	346.5	(308-378)	15.4	*4.36
8	98	350.1	(301-390)	17.7	53	346.6	(312-388)	15.8	45	353.9	(301-390)	19.3	*2.05
9	15	399.7	(349-445)	22.8	3	372.7	(349-396)	23.5	12	406.5	(380-445)	17.6	*2.82
10	9	410.6	(395-460)	21.0	3	396.3	(395-399)	2.3	6	417.7	(397-460)	22.8	1.57
11	4	428.3	(420-440)	8.5	0	-	-	-	4	428.3	(420-440)	8.5	-
TOTALS	337				197				138				

TABLE 17. Age-specific sex ratios, maturity, and reproductive condition of Arctic cisco. Mature fish which would (green) or would not (non-spawner) spawn in the year of capture are indicated. N=number of fish in the sample.

			MATURITY (%)				
		Sex Ratio		Males		Females	
Age	n	% Male	Immature	green	non-spawner	green	non-spawner
1	0	-	-	-	-	-	-
2	0	-	-	-	-	-	-
3	2	0.0	100.0	-	-	-	-
4	1	100.0	100.0	-	-	-	-
5	0	-	-	-	-	-	-
6	13	69.2	46.2	15.4	38.5	0.0	0.0
7	194	66.0	36.6	0.5	46.9	0.0	16.0
8	98	54.1	33.7	0.0	38.8	5.1	22.4
9	15	20.0	6.7	0.0	13.3	0.0	80.0
10	9	33.3	0.0	0.0	33.3	11.1	55.6
11	4	0.0	0.0	0.0	0.0	25.0	75.0
TOTALS							
	336	58.6%	33.9%	0.9%	41.4%	2.1%	21.7%

Sex Ratio

Male Arctic cisco (58.6%) were significantly more abundant than females (N=336, X^2=5.0, $p<0.05$). Similar results have been reported for most other locations on the Beaufort Sea coast (Table 18) though more females than males were present in samples taken along the Arctic National Wildlife Range (Roguski and Komarek, 1972) and near the Canning River (Craig and Mann, 1974). Kogl (1972) reported no significant difference in the sex ratio of Arctic cisco taken in the Colville Delta.

Egg Size

The seasonal pattern of egg size development for Kaktovik Lagoon Arctic cisco (Figure 28) indicates that almost all are non-spawning individuals (e.g., immature or mature non-spawners). Only eight females, caught early in the season, appeared to be fish which might spawn in the year of capture (egg diameter 0.8-1.0 mm). The data indicate that Arctic cisco which will spawn in the current year do not disperse far from either the Mackenzie or Colville rivers. These results are similar to those summarized by Craig and McCart (1975).

Food Habits

Arctic cisco in both Kaktovik and Nunaluk lagoons are opportunistic in their feeding habits. Crustaceans (80.5%) were the major group utilized as food in Kaktovik Lagoon, with amphipods (56.6%) and mysids (16.5%) being the predominant taxa (Table 19). Fish (14.3%) were the second most important group, with fourhorn sculpin young-of-the-year most common. Arctic cisco from the Nunaluk study (Griffiths *et al.*, 1975) had a similar diet except that they consumed fewer fish (2.0%) and a

TABLE 18. Sex ratio, age at maturity, and percent immature of Arctic cisco caught in various studies.

Study Area	N	% Male	Age at Maturity	% Immature
MACKENZIE DRAINAGE				
Arctic Red River (Hatfield *et al.*, 1972)	759	53.0	-	0.0
Norman Wells (Stein *et al.*, 1973)	406	56.0	-	0.0
Mackenzie Delta (Percy *et al.*, 1975)	138	-	7	80.0
YUKON COAST				
Yukon Coast and Phillips Bay (Kendel *et al.*, 1974)	1,170	56.5	-	-
Yukon Coast (Craig and Mann, 1974)	149	66.0	7	34.0
Nunaluk Lagoon (Griffiths *et al.*, 1975)				
aged	304	50.4	7	48.4
aged and unaged combined	701	59.0	-	-
ALASKAN COAST				
Arctic National Wildlife Range (Roguski and Komarek, 1972)	169	39.0	6-8	7.0
Near Canning River (Craig and Mann, 1974)	33	39.0	-	91.0
Kaktovik Lagoon	336	58.6	6	34.0
Prudhoe Bay (Furniss, 1975)	70	85.0	5	91.0
Colville Delta (Kogl and Schell, 1974)	58	51.0	-	100.0

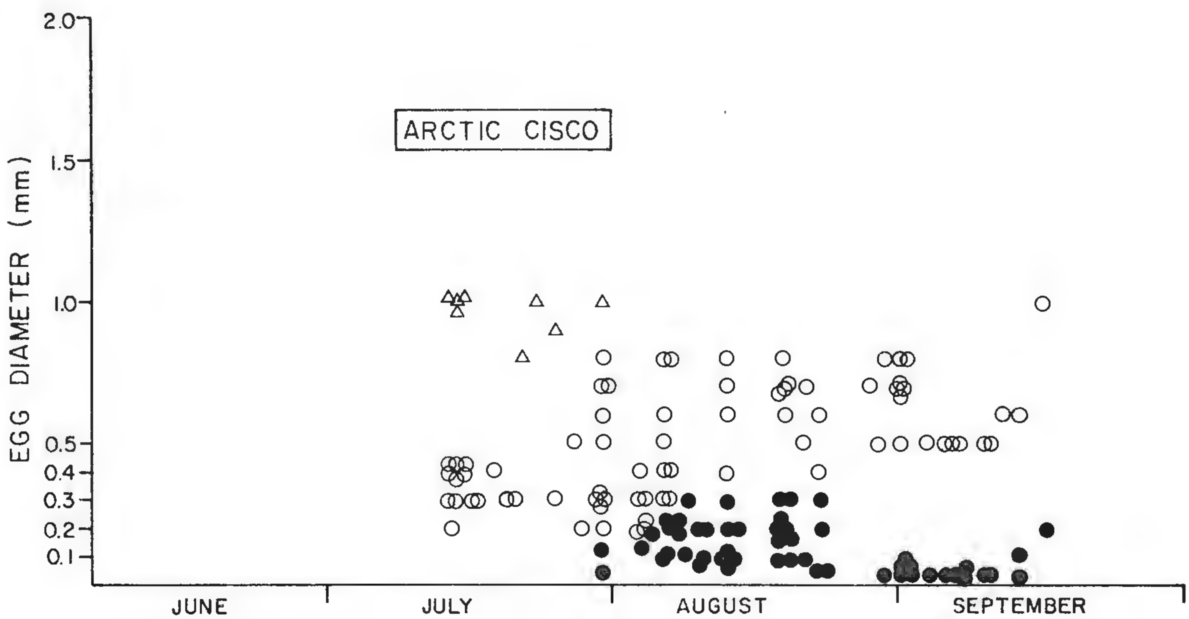

FIGURE 28. Seasonal patterns of egg size in female Arctic cisco at Kaktovik Lagoon and adjacent areas, 1975. Immature fish (closed circles), mature non-spawners (open circles), and mature spawners (triangles) are indicated separately.

TABLE 19. Food items eaten by Arctic cisco in Kaktovik Lagoon and adjacent areas, 1975. Percent composition in "average stomach" was determined by the Points Method. "Average stomach" as 100% indicates results when only those fish with food in their stomachs are considered. NNST=ninespine stickleback; FHSC=fourhorn sculpin; STBY=stout eel blenny.

Food Item	% in average stomach n=301	average stomach as 100%
INSECTA	-	-
MOLLUSCA	-	-
CRUSTACEA		
Copepoda	3.7	7.4
Amphipoda	28.2	56.6
Isopoda	0.01	0.02
Mysidacea	8.2	16.5
Conchostraca	-	-
TOTAL	40.1	80.5
FISH		
Fish Remains	0.3	0.6
FHSC	6.1	12.3
NNST	0.01	0.02
STBY	0.7	1.4
Coregonus spp.	-	-
TOTAL	7.1	14.3
MISCELLANEOUS		
Unidentified	2.2	4.5
Plant Material	0.3	0.7
Sand and Stone	-	-
TOTAL	2.5	5.2
GRAND TOTALS	49.7%	100.0%

substantial number of insects (21.3%). The average stomach of Arctic cisco from Kaktovik Lagoon contained more food than the average stomach from Nunaluk (49.7-39.9%). The percentage of empty stomachs (4.6%) found in Arctic cisco from Kaktovik Lagoon is also lower than that reported for Nunaluk Lagoon (25.0%) and other areas along the Beaufort Sea coastline (14-47%)(Kogl, 1972; Yoshihara, 1973; Craig and Mann, 1974; Furniss, 1975).

Life History of Fourhorn Sculpin

The fourhorn sculpin *(Myoxocephalus quadricornis)* was the most abundant species in the study area (69.5% of the total catch). This fish is of interest since it is the only abundant marine species in the study area which utilizes nearshore habitats for spawning, rearing, and over-wintering. The life history of the fourhorn sculpin has been reviewed by Griffiths *et al.* (1975).

Distribution in the Study Area

Fourhorn sculpin were very abundant throughout the shallow regions (0-2 m) of Kaktovik Lagoon, but relatively scarce in the shallow waters of the coastal beaches and spits (Figure 29). This species was absent in the deeper waters (3.0 m) of the lagoon. Fourhorn sculpin juveniles were also present in the five small streams flowing into Kaktovik Lagoon. Young-of-the-year were most abundant in the cove mid-way along the west shore of Manning Point and along the southeast shore of Barter Island.

Size Distribution

The length-frequency of fourhorn sculpin in the Kaktovik sample is

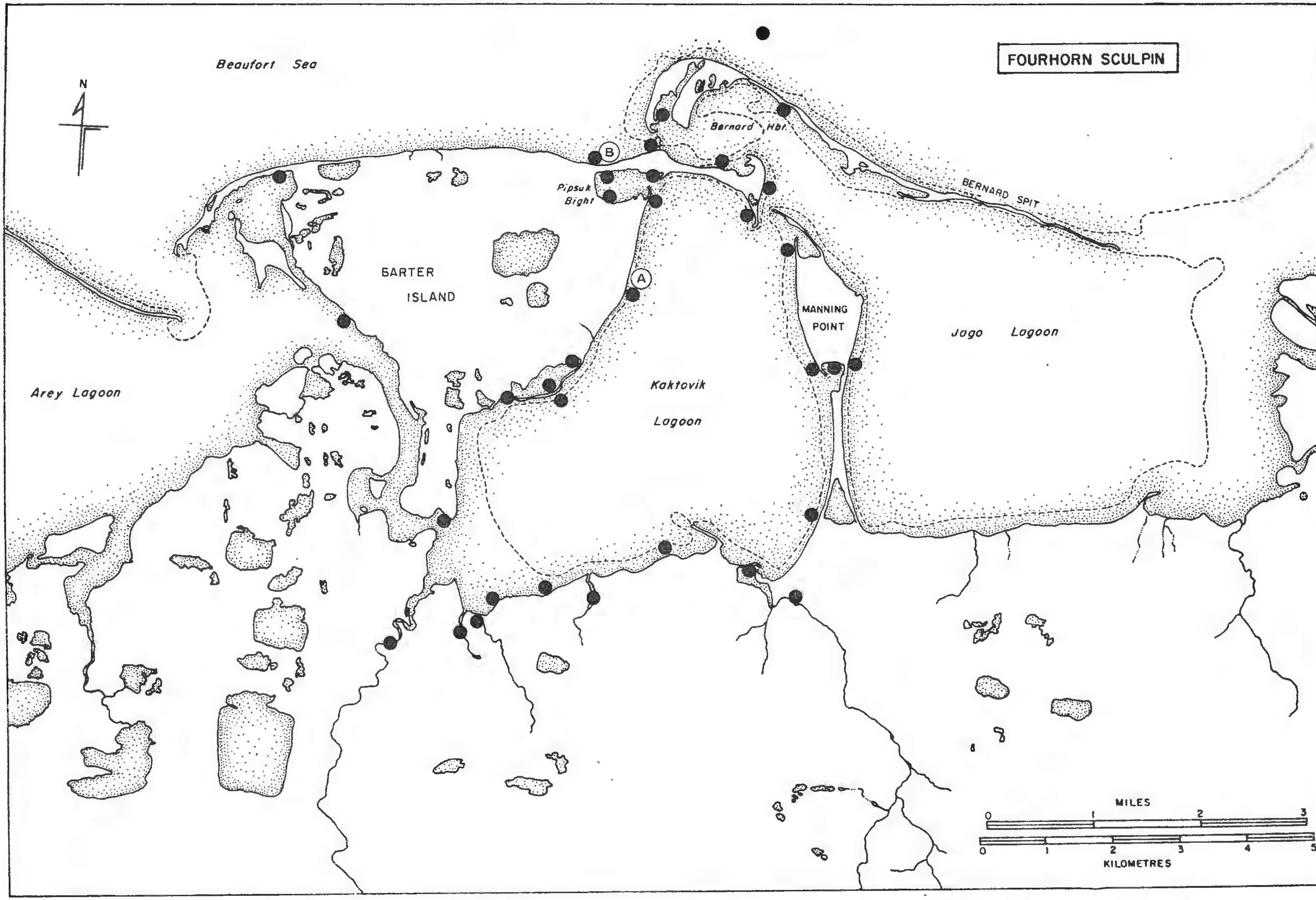

FIGURE 29. Distribution of fourhorn sculpin in Kaktovik Lagoon and adjacent areas, 1975.

similar to that of fish taken in Nunaluk Lagoon in 1974 (Figure 30). Few fish in the 40-139 mm range were captured in either seines or gillnets. In seines, the 20-39 mm range was the most common and in gillnets, the 200-239 mm range. The largest fourhorn sculpin taken was a 288 mm female.

Age and Growth

The growth rate of fourhorn sculpin young-of-the-year in Kaktovik Lagoon (Figure 31) appeared to be greater than the rate reported for Nunaluk Lagoon in 1974. At Kaktovik Lagoon, the young-of-the-year grew from a mean total length of 15 mm in early July to 31 mm in September, while at Nunaluk, fourhorn sculpin grew from 16 mm to 22 mm in the same period during 1974. This difference in growth rate may indicate a more favourable habitat at Kaktovik (e.g., more food and a more protected rearing area).

For older fourhorn sculpin, the age-length relationship for the Kaktovik sample is shown in Table 20 and Figure 32. The Kaktovik sculpins were approximately 20 mm larger at each age interval than the Nunaluk sculpins. A somewhat faster growth rate is reported for fourhorn sculpin in the Mackenzie Delta (Percy, 1975).

In both Nunaluk Lagoon and the Mackenzie Delta, the fourhorn sculpin ranged in age from 0 to 14, with the fish being relatively evenly distributed among all age classes (Percy, 1975; Griffiths *et al.*, 1975). Ages in the Kaktovik sample ranged only from 0 to 9 with 62% of the specimens in the 6 to 8 year age classes.

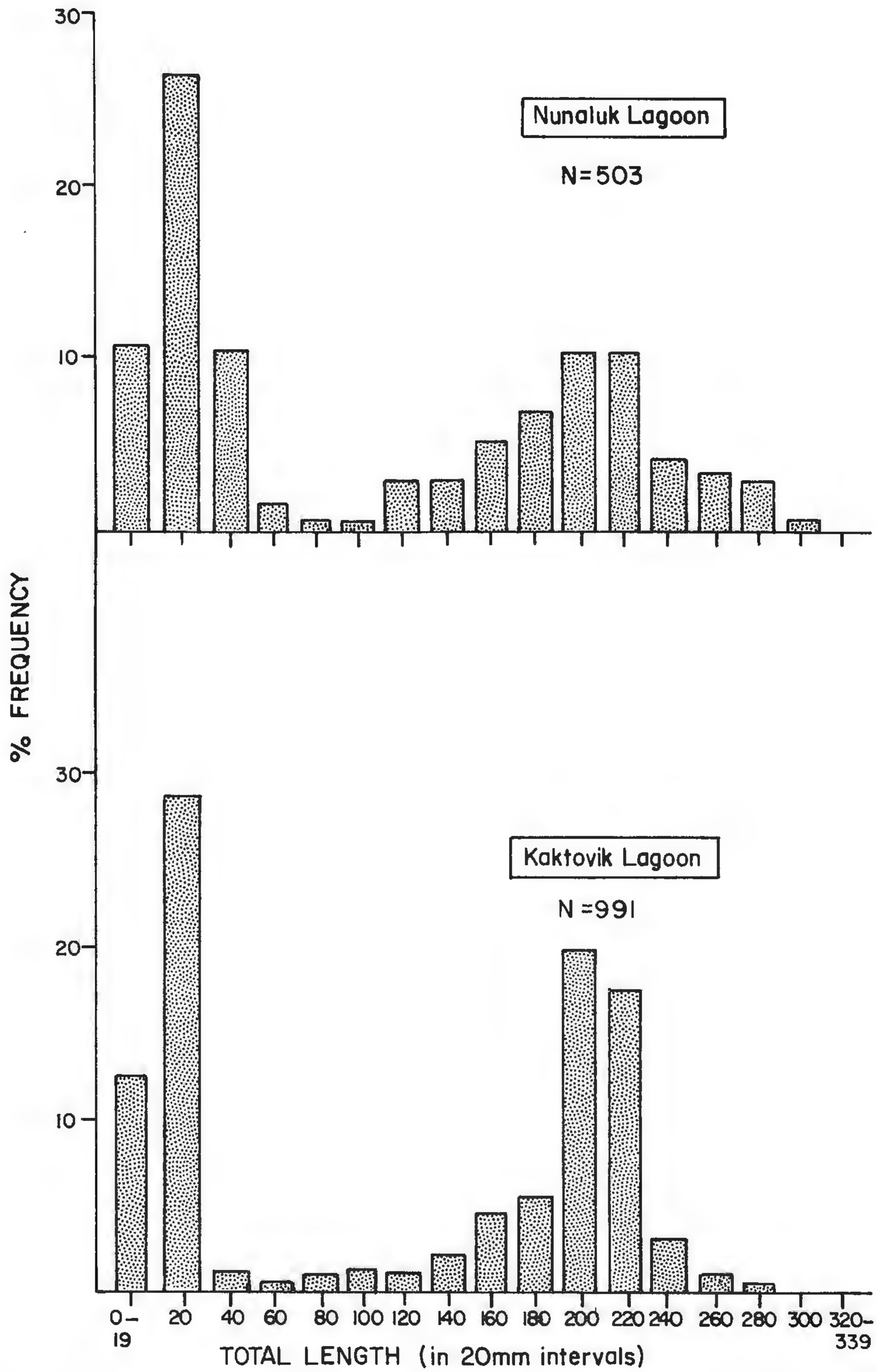

FIGURE 30. Length-frequencies of fourhorn sculpin caught in Nunaluk Lagoon, 1974, and Kaktovik Lagoon, 1975.

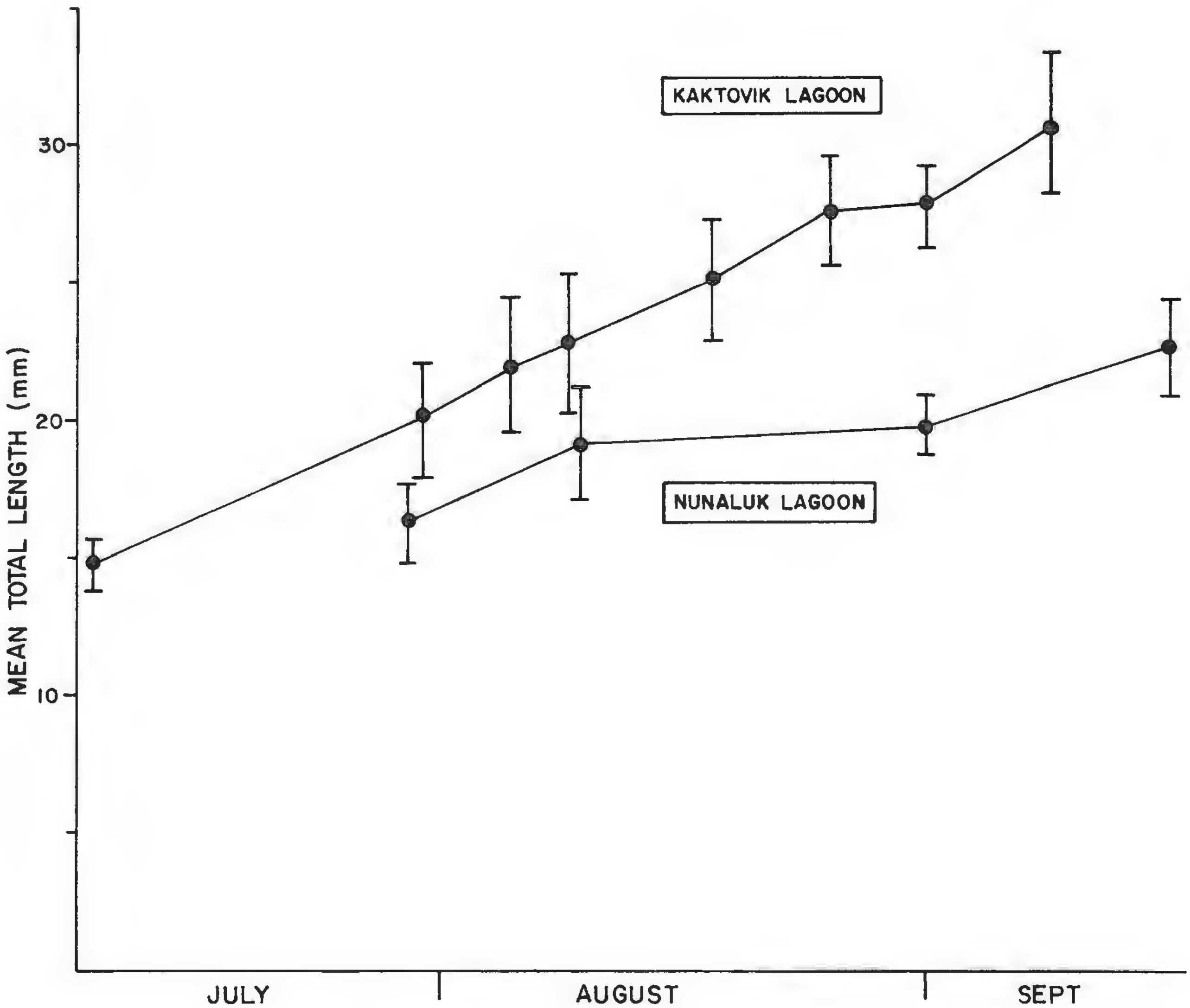

FIGURE 31. Comparison of growth rates for young-of-the-year fourhorn sculpin in Nunaluk Lagoon, 1974, and Kaktovik Lagoon, 1975.

TABLE 20. Age-length relationships for fourhorn sculpin from Kaktovik Lagoon and adjacent areas, 1975, sexes combined and separated. Student's t-test values are given for male and female length comparisons. Unsexed fish (8.4%) are not included in calculation of t value.

	TOTAL LENGTH (mm)												
	Sexes Combined				Males				Females				
Age	N	Mean	Range	S.D.	N	Mean	Range	S.D.	N	Mean	Range	S.D.	t-test
0	13	29.0	(23-37)	3.8	-	-	-	-	-	-	-	-	-
1	25	41.5	(30-70)	10.2	4	52.8	(41-70)	12.3	5	43.8	(37-54)	7.2	1.377
2	5	73.6	(58-87)	10.5	3	77.7	(72-87)	8.1	1	58.0	-	-	-
3	20	104.4	(84-136)	14.1	16	105.4	(90-136)	13.4	3	105.3	(84-117)	18.5	0.012
4	19	132.5	(108-149)	13.5	13	130.5	(108-149)	13.4	6	136.8	(109-147)	14.0	0.953
5	42	173.5	(140-225)	16.5	21	170.3	(140-195)	14.4	21	176.0	(149-225)	18.3	1.117
6	64	200.5	(170-236)	16.0	37	195.4	(170-223)	32.6	27	199.9	(172-236)	17.8	0.643
7	108	216.3	(165-260)	13.6	94	214.3	(165-241)	11.8	14	229.8	(205-260)	17.6	4.285*
8	58	231.0	(204-263)	13.2	44	226.7	(204-250)	9.8	14	244.5	(220-263)	13.5	5.363*
9	16	257.4	(224-288)	21.0	5	232.6	(224-252)	11.1	11	268.7	(242-288)	12.8	5.413*
TOTALS													
	370				237				102				

*Significant at p<0.05

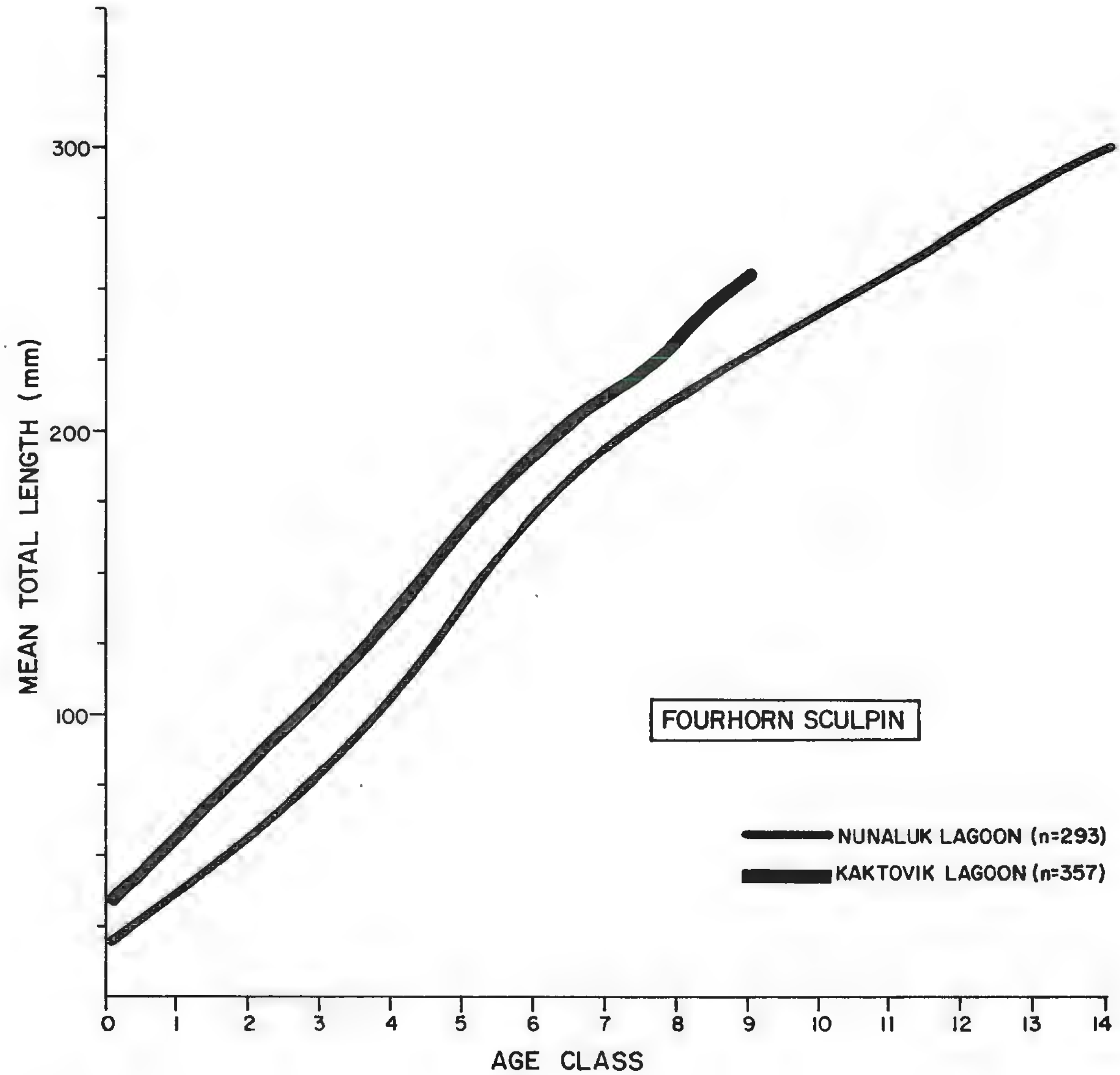

FIGURE 32. Length-age relationship of fourhorn sculpin in Nunaluk Lagoon, 1974, and Kaktovik Lagoon, 1975.

In almost all age classes, females tended to be larger than males, significantly so for ages 7 through 9 (Table 20). This corresponds with results from the Mackenzie Delta (Percy, 1975), Nunaluk Lagoon (Griffiths *et al.*, 1975), the Arctic National Wildlife Range (Roguski and Komarek, 1972), and Siberia (Andriyashev, 1954).

Maturity

Sexual maturity of fourhorn sculpins was determined by field examination of ovaries and testes. The youngest mature males were age 3 and the youngest mature females age 4 (Table 21). Similar ages at maturity were reported in the Mackenzie Delta (Percy, 1975). In the Nunaluk sample, maturity was not reached by either sex until age 5 (Griffiths *et al.*, 1975).

Sex Ratio

In the study area, male fourhorn sculpin were significantly more abundant (Table 21) than females (X^2=28.3, $p<0.05$, df=1). All other studies report significantly more females than males (Andriyashev, 1954; Roguski and Komarek, 1972; Griffiths *et al.*, 1975; Percy *et al.*, 1975). Reasons for this difference are not known.

Egg Size and Testes Weight

Fourhorn sculpin spawn annually. The egg size of maturing females increased from approximately 0.5-0.8 mm in early July, to 1.2-2.0 mm in mid-September (Figure 33). Griffiths *et al.* (1975) report similar increases in egg diameter in Nunaluk Lagoon. Andriyashev (1954) reports that near-ripe eggs are 2.0 mm in diameter. Westin (1968) found that

TABLE 21. Age - specific sex ratios and maturity of fourhorn sculpin from Kaktovik Lagoon and adjacent areas, 1975. Unsexed fish (8.4%) are not included.

Age	Sex Ratio		Maturity			
			Males		Females	
	n	% ♂	n	% Mature	n	% Mature
0	0	0.0	-	-	-	-
1	9	44.4	4	0.0	5	0.0
2	4	75.0	3	0.0	1	0.0
3	19	84.2	16	37.5	3	0.0
4	19	68.4	13	53.9	6	33.3
5	42	50.0	21	95.2	21	81.0
6	64	57.8	37	100.0	27	92.6
7	108	87.0	94	100.0	14	92.9
8	58	75.9	44	100.0	14	100.0
9	16	31.3	5	100.0	11	100.0
TOTALS	339	69.9%	237	89.9%	102	80.4%

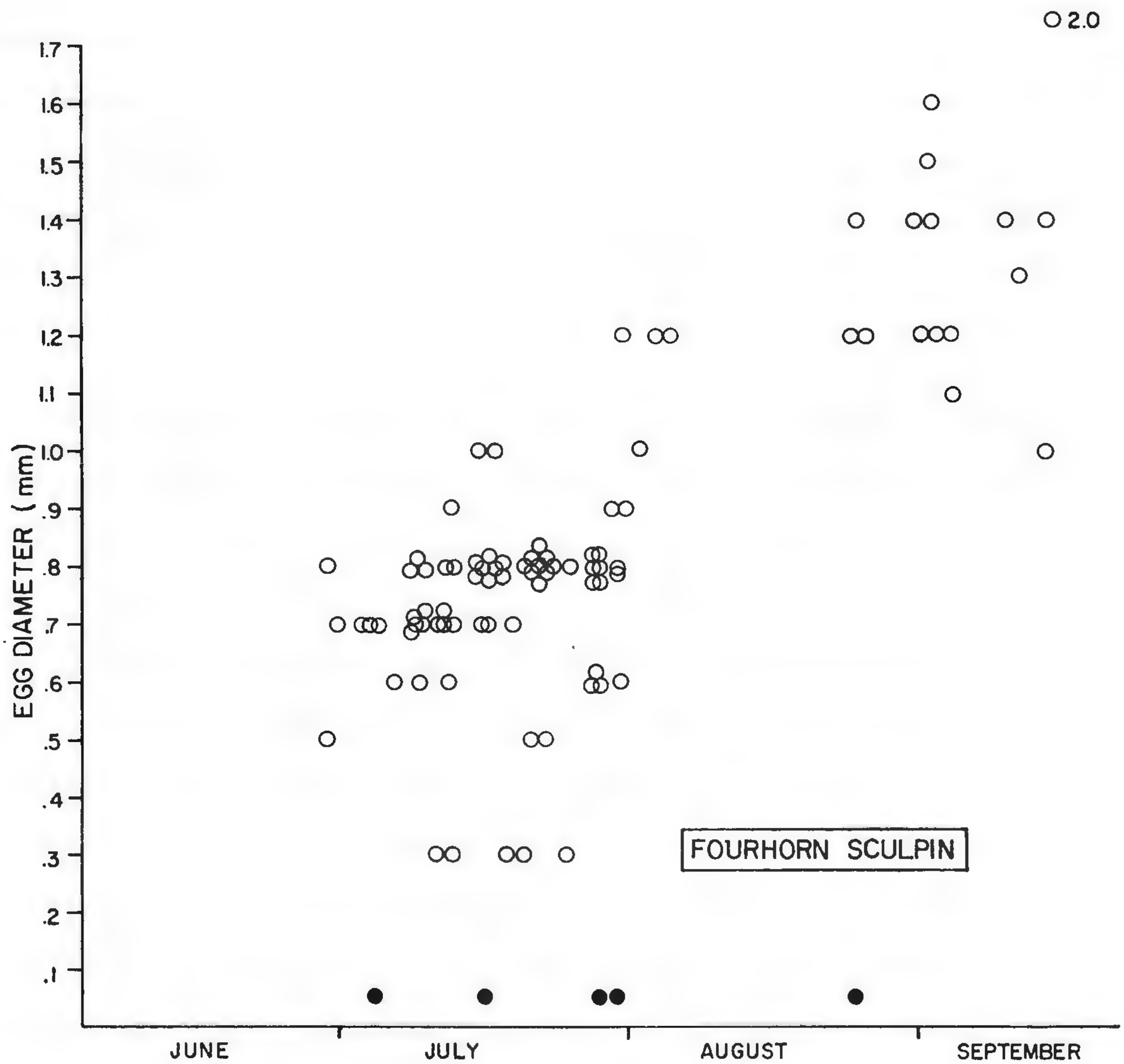

FIGURE 33. Seasonal pattern of egg size in female fourhorn sculpin at Kaktovik Lagoon in 1975. Immature fish (closed circles) and mature spawners (open circles) are indicated.

the diameters of mature eggs range from 2.4-2.9 mm when fish spawn in late December to late January.

Testes weight, as a percent of total body weight, increased steadily throughout the season (Figure 34). Actual testes weights ranged from 1.8 to 9.6 gm by September. Similar increases were observed in male fourhorn sculpin from Nunaluk Lagoon (Griffiths *et al.*, 1975).

Food Habits

Fourhorn sculpin at both Nunaluk and Kaktovik lagoons appear to be selective feeders. In each instance, crustaceans accounted for 73-79% of their diets (Table 22). At Kaktovik Lagoon, isopods (41.0%) and amphipods (37.0%) were the most abundant crustaceans. Similar results were recorded at Nunaluk Lagoon, where isopods contributed 40.4% of the total and amphipods 27.2% (Griffiths *et al.*, 1975). At both locations, fourhorn sculpins fed predominantly on benthic and epibenthic organisms.

The average stomach of fourhorn sculpin from Kaktovik Lagoon was less full than the average stomach from Nunaluk Lagoon (40% v. 60%). The percentage of empty stomachs for the Kaktovik sculpins (20%) was within the range (5-20%) reported for other fourhorn sculpin samples along the Beaufort Sea coast (Craig and Mann, 1974; Furniss, 1975; Griffiths *et al.*, 1975).

The food habits of young-of-the-year fourhorn sculpin were also examined because these abundant fish are sometimes the only small fish encountered in nearshore waters (Craig and McCart, 1975). Results showed

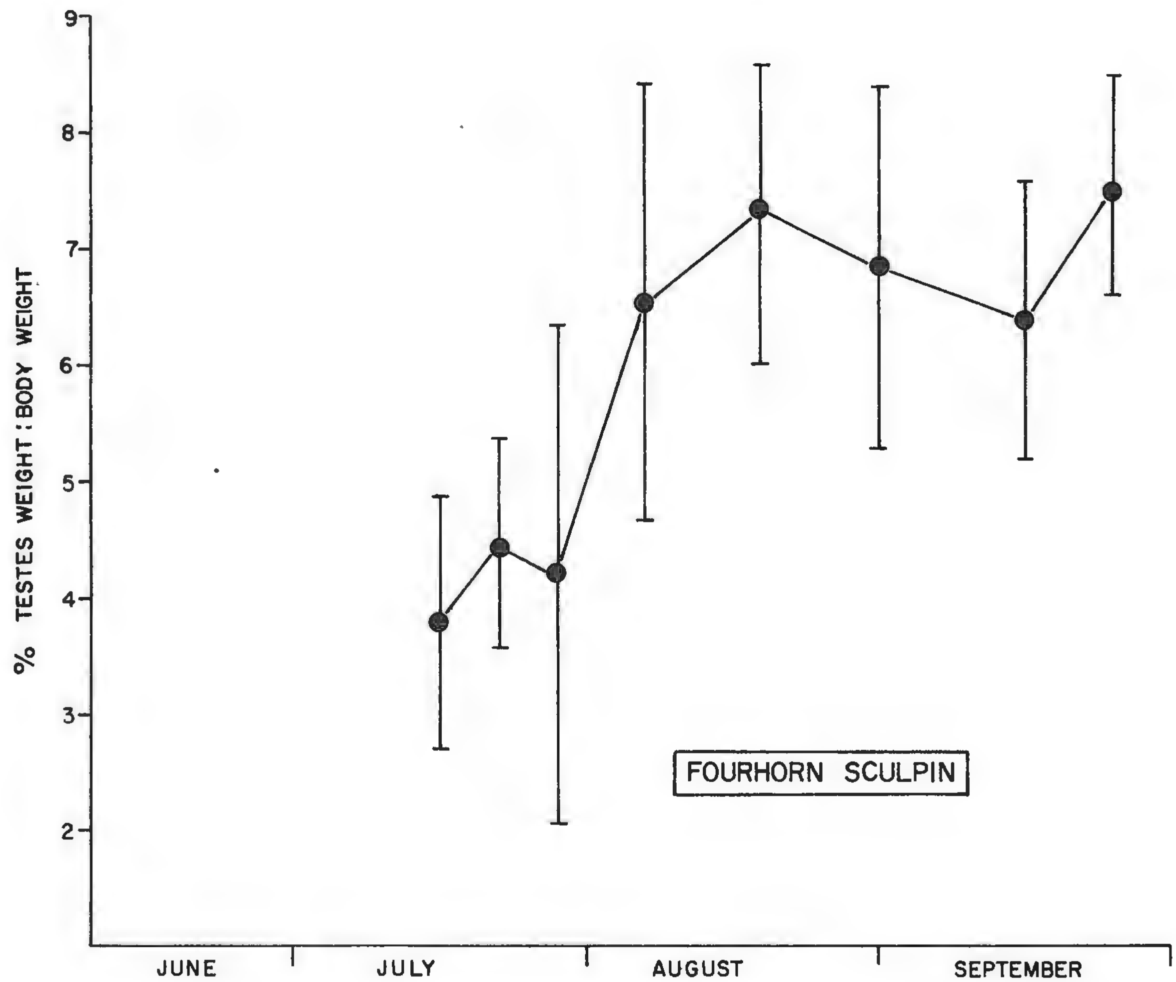

FIGURE 34. Seasonal pattern of male gonad weights (expressed as percent of total body weight) for fourhorn sculpin collected in Kaktovik Lagoon and adjacent areas, 1975.

TABLE 22. Food items eaten by fourhorn sculpin in Kaktovik Lagoon and adjacent areas, 1975. Percent composition in "average stomach" was determined by the Points Methods. "Average stomach" as 100% indicates results when only those fish with food in their stomachs are considered. NNST=ninespine stickleback; FHSC=fourhorn sculpin; STBY=stout eel blenny.

Food Item	% in average stomach n=275	average stomach as 100%
INSECTA	0.4	1.0
MOLLUSCA	-	-
CRUSTACEA		
Copepoda	0.004	0.01
Amphipoda	16.3	37.0
Isopoda	18.0	41.0
Mysidacea	0.6	1.0
Conchostraca	0.03	0.1
TOTAL	34.9	79.1
FISH		
Fish Remains	0.01	0.03
FHSC	0.5	1.1
NNST	-	-
STBY	0.6	1.4
Coregonus spp.	-	-
TOTAL	1.1	2.5
MISCELLANEOUS		
Unidentified	7.2	16.4
Plant Material	0.4	1.0
Sand and Stone	0.004	0.01
TOTAL	7.6	17.4
GRAND TOTALS	44.0%	100.0%

that these rely heavily on small crustaceans (Table 23). Similar results were reported in Siberia (Andriyashev, 1954). In the July 12 sample, notostracans (84.8%) were the most abundant. In the July 30 sample, mysids (70.2%) were most common. Amphipods were the most prevalent food item in the remainder of the collections (Table 23).

Surprisingly, fish were also occasionally easten by young-of-the-year sculpins. On August 3, sculpins had eaten Arctic cod young-of-the-year, while in the September 8 sample, both Arctic cod (9.8%) and stout eel blenny (19.5%) were eaten. The Arctic cod found in the sculpin stomachs measured approximately 12-15 mm and the stout eel blenny, 12-20 mm.

The average fullness of the stomachs of these young-of-the-year varied from 55.5-90.2%, and the number of empty stomachs varied from 0-35%.

Least Cisco

Least cisco *(Coregonus sardinella)* were not abundant in Kaktovik Lagoon (N=23), but were caught throughout the study area (Figure 35). Most of these fish were between 270-310 mm fork length (Figure 36). A greater size range has been found in other areas along the Beaufort Sea coast (Kendel *et al.*, 1974; Kogl and Schell, 1974; Griffiths *et al.*, 1975; Furniss, 1975).

Least cisco in the Kaktovik sample ranged in age from 5 to 8 years (Table 24) but most were age 7 (73%). The growth of these fish is similar to that described for least cisco from other localities along the

TABLE 23. Food items eaten by fourhorn sculpin young-of-the-year in Kaktovik Lagoon and adjacent areas, 1975. Percent composition in "average stomach" was determined by the Points Method. "Average stomach" as 100% indicates results when only those fish with food in their stomachs are considered. ARCD=Arctic cod, STBY=Stout eel blenny.

Food Item	JULY 12 ($\bar{x}$=15 mm) % in average stomach n=13	JULY 12 average stomach as 100%	JULY 30 ($\bar{x}$=20 mm) % in average stomach n=18	JULY 30 average stomach as 100%	AUGUST 3 ($\bar{x}$=23 mm) % in average stomach n=20	AUGUST 3 average stomach as 100%	AUGUST 17 ($\bar{x}$=26 mm) % in average stomach n=18	AUGUST 17 average stomach as 100%	AUGUST 31 ($\bar{x}$=28 mm) % in average stomach n=11	AUGUST 31 average stomach as 100%	SEPTEMBER 8 ($\bar{x}$=31 mm) % in average stomach n=14	SEPTEMBER 8 average stomach as 100%
CRUSTACEA												
Amphipoda	0.4	0.6	1.4	1.8	33.5	37.1	23.6	42.9	65.9	83.0	41.1	56.2
Mysidacea	3.9	5.8	54.2	70.2	12.2	13.6	13.9	25.3	-	-	-	-
Isopoda	-	-	1.6	2.1	-	-	6.6	12.1	-	-	10.3	14.1
Copepoda	-	-	-	-	-	-	7.2	13.1	13.7	17.0	0.3	0.4
Notostraca	57.3	84.8	11.9	15.5	-	-	-	-	-	-	-	-
TOTAL	61.6	91.0	69.1	89.6	45.7	50.7	51.3	93.4	79.6	100.0	51.7	70.7
ANNELIDA												
Polychaeta	1.9	2.8	-	-	1.2	1.4	-	-	-	-	-	-
Oligochaeta	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	1.9	2.8	-	-	1.2	1.4	-	-	-	-	-	-
MOLLUSCA	0.7	1.0	-	-	-	-	-	-	-	-	-	-
FISH												
ARCD	-	-	-	-	41.3	45.7	-	-	-	-	7.2	9.8
STBY	-	-	-	-	-	-	-	-	-	-	14.3	19.5
TOTAL	-	-	-	-	41.3	45.7	-	-	-	-	21.5	29.3
MISCELLANEOUS												
Unidentified	-	-	7.5	9.7	-	-	3.4	6.1	-	-	-	-
Plant Material	2.7	4.0	-	-	2.0	2.2	-	-	-	-	-	-
Stones & Gravel	0.7	1.0	0.6	0.7	-	-	0.3	0.5	-	-	-	-
TOTAL	3.4	5.0	8.1	10.4	2.0	2.2	3.7	6.6	-	-	-	-
GRAND TOTALS	67.6%	100.0%	77.2%	100.0%	90.2%	100.0%	55.0%	100.0%	79.6%	100.0%	73.2%	100.0%

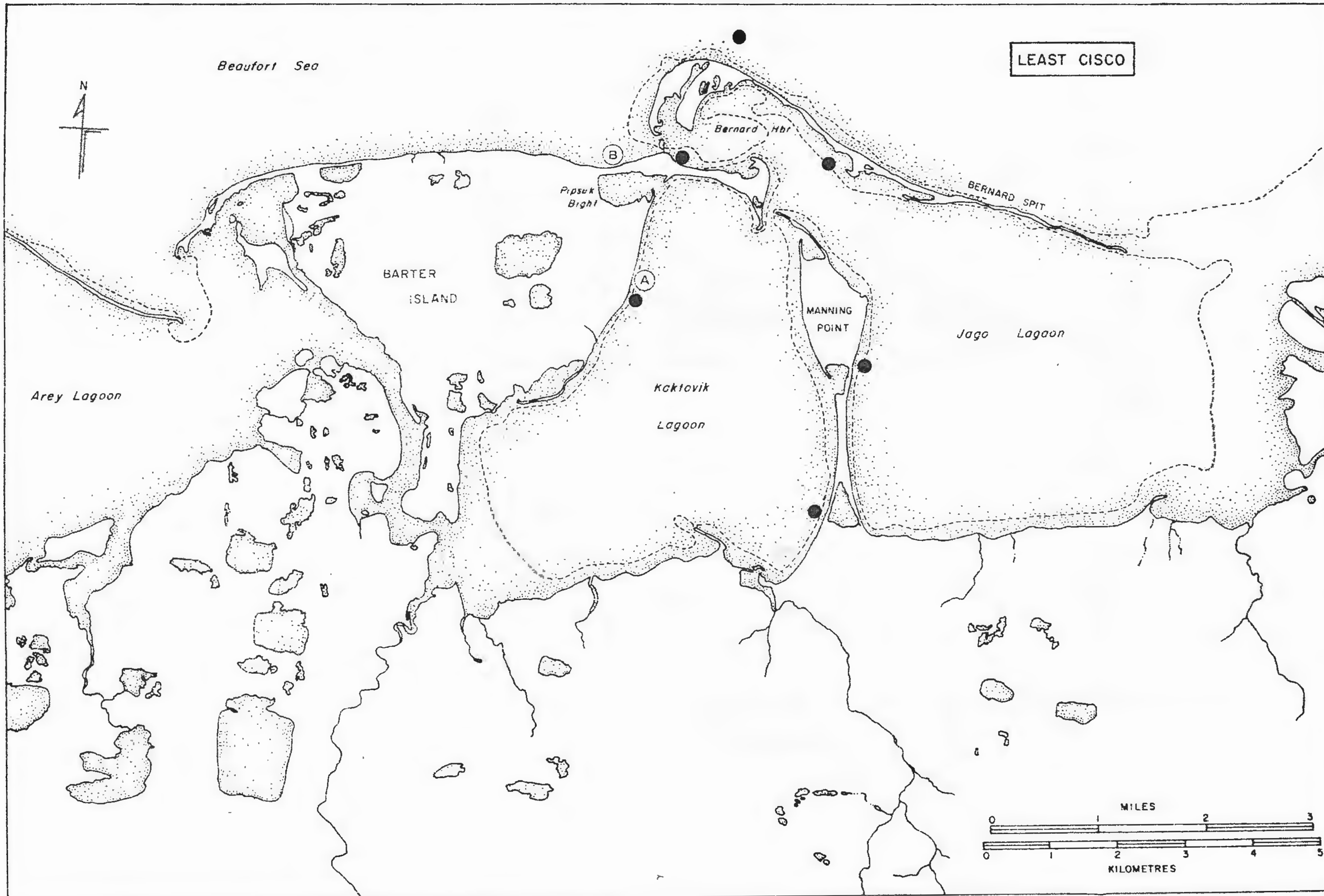

FIGURE 35. Distribution of least cisco in Kaktovik Lagoon and adjacent areas, 1975.

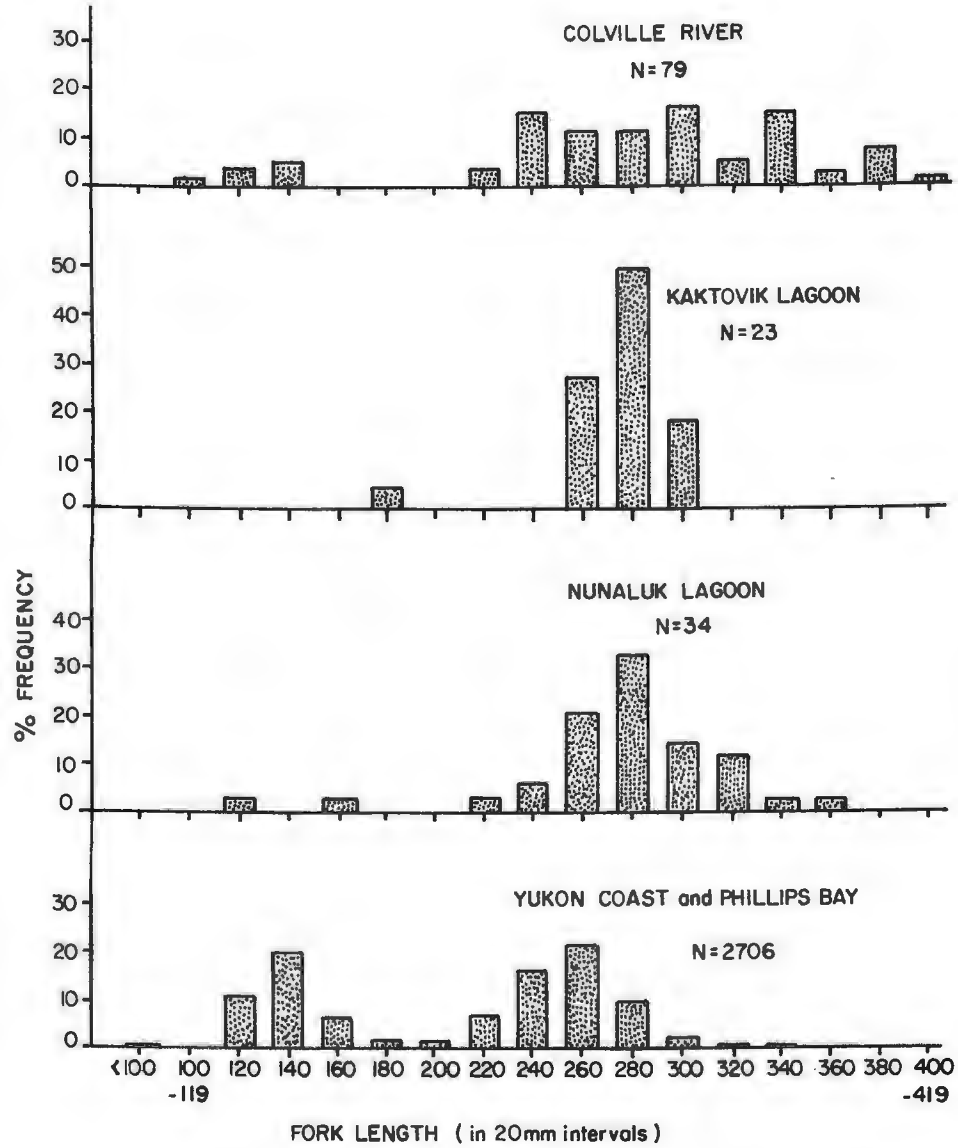

FIGURE 36. Length-frequency relationship of least cisco taken at four coastal Beaufort Sea locations.

TABLE 24. Observed age-length relationship, sex ratios, maturity, and condition of least cisco from Kaktovik Lagoon and adjacent areas, 1975.

Age	n	Fork Length (mm) mean	Fork Length (mm) (range)	Fork Length (mm) S.D.	% Male	Maturity (sexes combined) % Immature	Maturity (sexes combined) % Mature Green	Maturity (sexes combined) % Mature Non-spawner
5	1	184	-	-	100	0	100	0
6	1	276	-	-	100	0	100	0
7	16	286	(271-308)	9.6	69	0	75	25
8	4	295	(287-304)	9.5	50	0	100	0
TOTALS	22				68%	0%	82%	18%

Beaufort Sea coast (Figure 37).

All least cisco caught in the study area were mature fish (Table 24). The large egg sizes of the females and testes weights of the males (Figure 38) indicated that 82% of these would have spawned in the year of capture. Only six mature non-spawners were caught. Somewhat similar results were reported from Prudhoe Bay, where 39% of the least cisco were spawners, 60% were mature non-spawners, and only 1% were immature (Furniss, 1975).

The Nunaluk Lagoon sample, in contrast to the results at Kaktovik Lagoon, contained 0% spawners, 50% mature non-spawners, and 50% immature least ciscos. The largest egg sizes of females taken at this location measured only 0.4 mm. Reasons for these differences are not known, but may involve the source of the least cisco stocks as discussed by Craig and McCart (1975).

Only 21 least cisco stomachs were analysed during the season. Crustaceans (53.6%) were the most abundant food item while amphipods (49.8%) were the most important food item (Table 25). Fish (21.0%) were also an important food item, with fourhorn sculpin the only species utilized. This may be due to the large number of fourhorn sculpin young-of-the-year in Kaktovik Lagoon. Mann (1974), Furniss (1975), and Griffiths *et al.* (1975) found that crustaceans were the only important food item for this species.

Least cisco stomachs contained less food at Kaktovik Lagoon than at

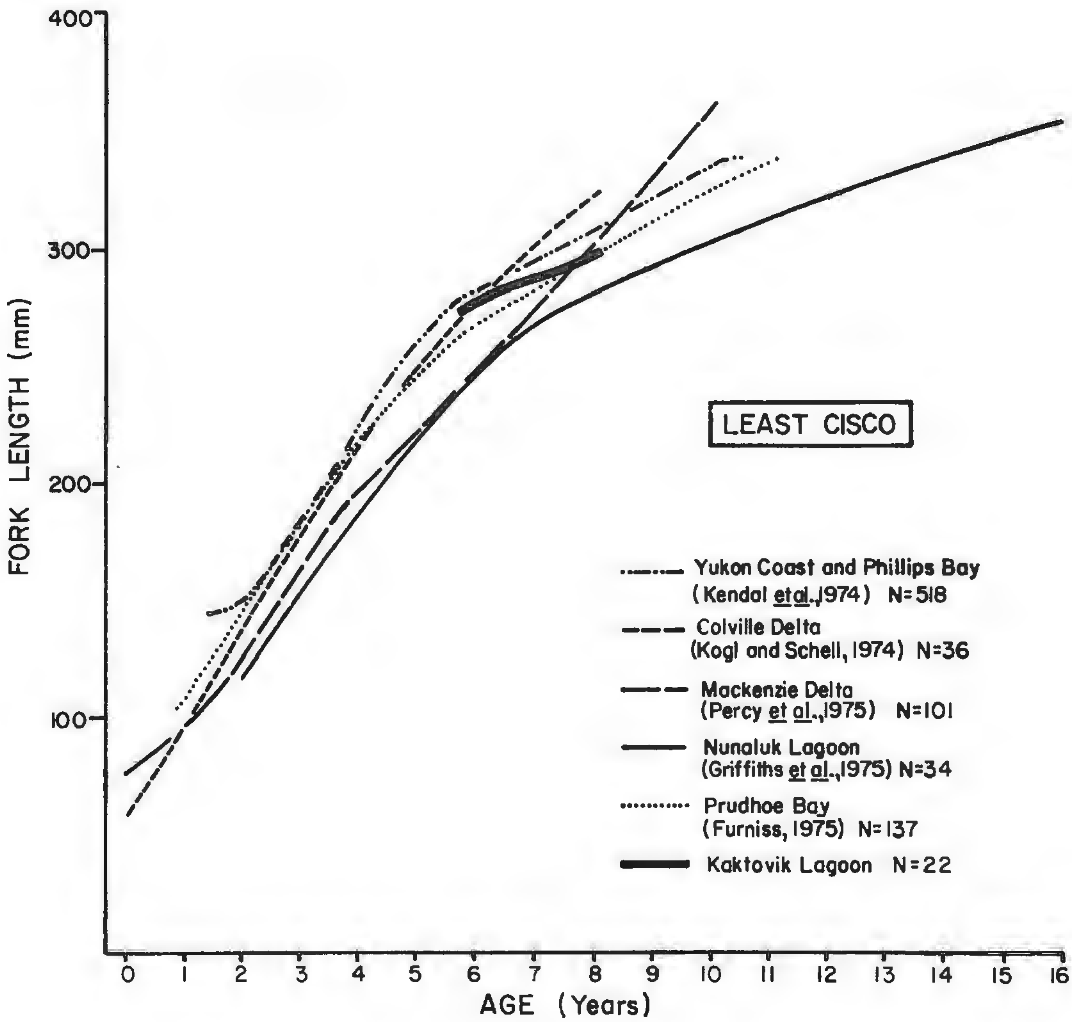

FIGURE 37. Observed age-length relationship of least cisco taken in six locations along the Beaufort Sea coast.

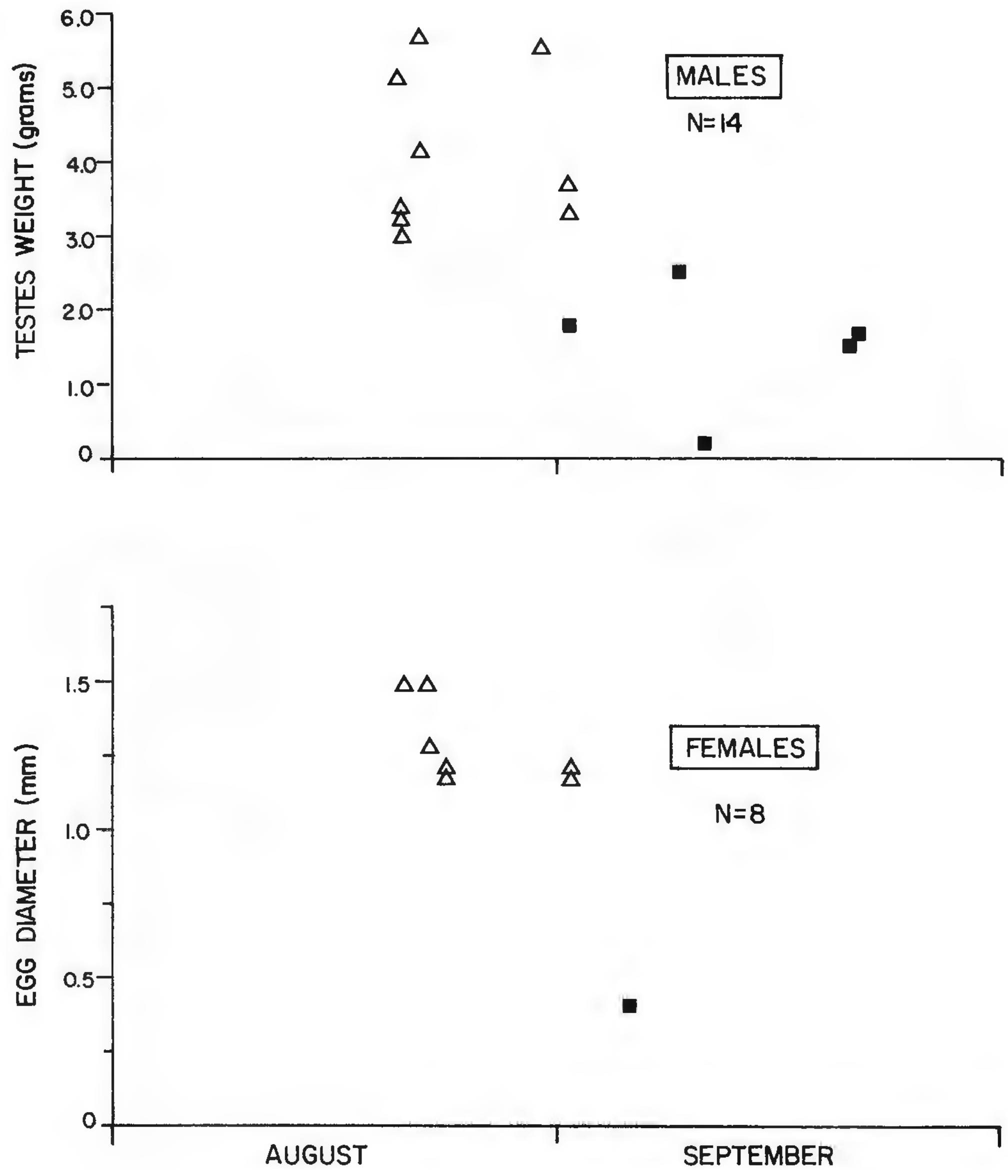

FIGURE 38. Egg diameters and testes weight of least cisco taken in Kaktovik Lagoon and adjacent areas, 1975. Mature spawners (triangles) and non-spawners (squares) are indicated.

TABLE 25. Food items eaten by least cisco in Kaktovik Lagoon and adjacent areas, 1975. Percent composition in "average stomach" was determined by the Points Method. "Average stomach" as 100% indicates results when only those fish with food in their stomachs are considered. NNST=ninespine stickleback; FHSC=fourhorn sculpin; STBY=stout eel blenny.

Food Item	% in average stomach n=21	average stomach as 100%
INSECTA	-	-
MOLLUSCA	-	-
CRUSTACEA		
Copepoda	0.9	3.0
Amphipoda	14.8	49.7
Isopoda	-	-
Mysidacea	0.2	0.7
Conchostraca	-	-
TOTAL	15.9	53.4
FISH		
Fish Remains	-	-
FHSC	6.3	21.1
NSST	-	-
STBY	-	-
Coregonus spp.	-	-
TOTAL	6.3	21.1
MISCELLANEOUS		
Unidentified	7.6	25.4
Plant Material	-	-
Sand and Stone	-	-
TOTAL	7.6	25.4
GRAND TOTALS	29.8%	100.0%

Nunaluk Lagoon (30% v. 54%). The percentages of empty stomachs were similar at both Kaktovik and Nunaluk lagoons (4.5% and 6.0%), but were lower than other areas along the Beaufort Sea coast (13-25%) (Craig and Mann, 1974; Furniss, 1975).

Arctic Cod

Information on the life history of the Arctic cod *(Boreogadus saida)* is limited. According to Andriyashev (1954), its distribution is circumpolar, reaching nearly to the North Pole. In the North American Arctic, it is found from Point Barrow to Hudson Bay. It is a demersal fish associated with low temperatures (Quast, 1974). This fish matures when about four years old and spawns near coasts in January and February (Andriyashev, 1954). The Arctic cod is eaten by a variety of predators: Arctic char, Arctic flounder, sculpins, seals, walrus, beluga whales, and sea gulls (Andriyashev, 1954; Craig, 1976).

No mature Arctic cod were caught during this study, but immatures were taken at Station A (N=1) and Station B (N=20). All of the Arctic cod taken at Station B were caught through the ice on November 1. It is possible that Arctic cod were more abundant in the study area than these results indicate, since Bendock (pers. comm.) caught larger numbers of these fish at Prudhoe Bay by using a sampling method (fyke net) not used in this study.

Unlike the older Arctic cod, young-of-the-year were taken throughout the sample area (Figure 39). These fish were captured by Faber net in surface waters and were abundant in Kaktovik Lagoon (Table 26). The

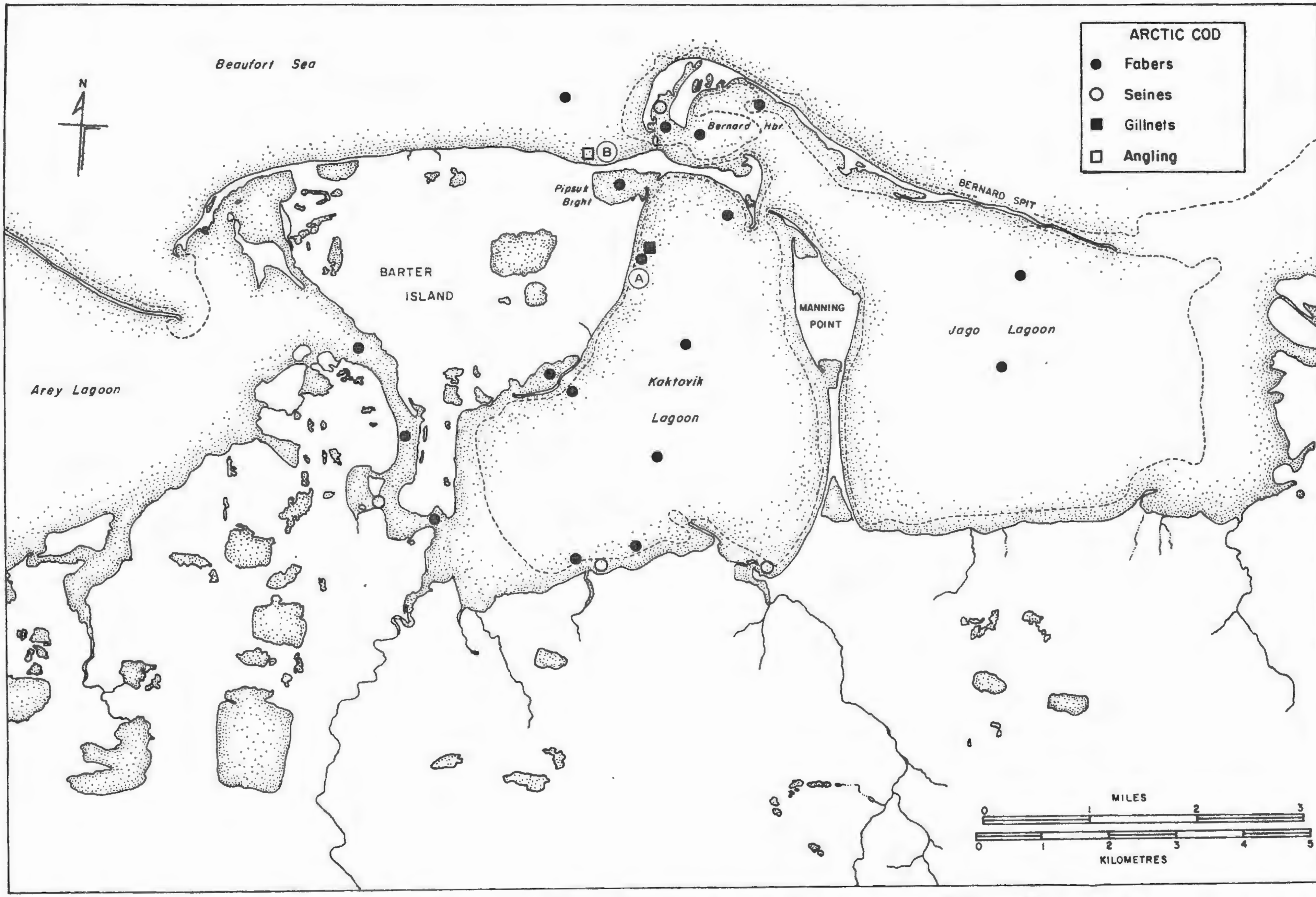

FIGURE 39. Distribution of Arctic cod caught in Kaktovik Lagoon and adjacent areas, 1975. Adults and juveniles were caught by gillnet and angling; young-of-the-year were caught by gillnet and Faber net.

TABLE 26. Number of Arctic cod young-of-the-year caught by Faber net in Kaktovik Lagoon and adjacent areas, September 8-12, 1975.

Location	Estimated Volume Sampled (1000 m^3)	No. of Fish Caught	No. of fish/ 1000 m^3
Kaktovik Lagoon	1.7	101	60.0
Strait between Barter Island and Mainland	0.2	9	45.0
Jago Lagoon	0.2	6	30.0
Offshore Ocean	0.1	2	25.0
Bernard Harbour	0.6	5	10.0

density values obtained in this study are approximate, but they are similar to those reported by Quast (1974) for Arctic cod in the Chukchi Sea (28 fish/1000 m^3). No Arctic cod young-of-the-year were taken in Faber tows the previous year in the Nunaluk Lagoon study area (Griffiths *et al.*, 1975).

Length-frequency data for Arctic cod indicate two distinct groups, one between 0-39 mm in length and the other between 120-180 mm (Figure 40). The absence of fish between 40-119 mm in length may be an artifact of sampling technique.

The 20 Arctic cod caught by angling were all immature fish of the age 2 year class. The mean length of these fish was 152.9 mm (range 120-180 mm, SD=14.23). The one fish taken in the gillnet was an immature three year old (169 mm).

There was no significant difference in the sex ratio of the 21 immature Arctic cod (X^2=0.024, df=1, p>0.05).

Amphipods (100%) were the only organism found in the stomachs of the Arctic cod. Stomachs of young-of-the-year Arctic cod were not examined.

Other Species

Seven additional species were caught in small numbers in the study area. Each is briefly described in this section. Their distributions are shown in Figures 41 and 42.

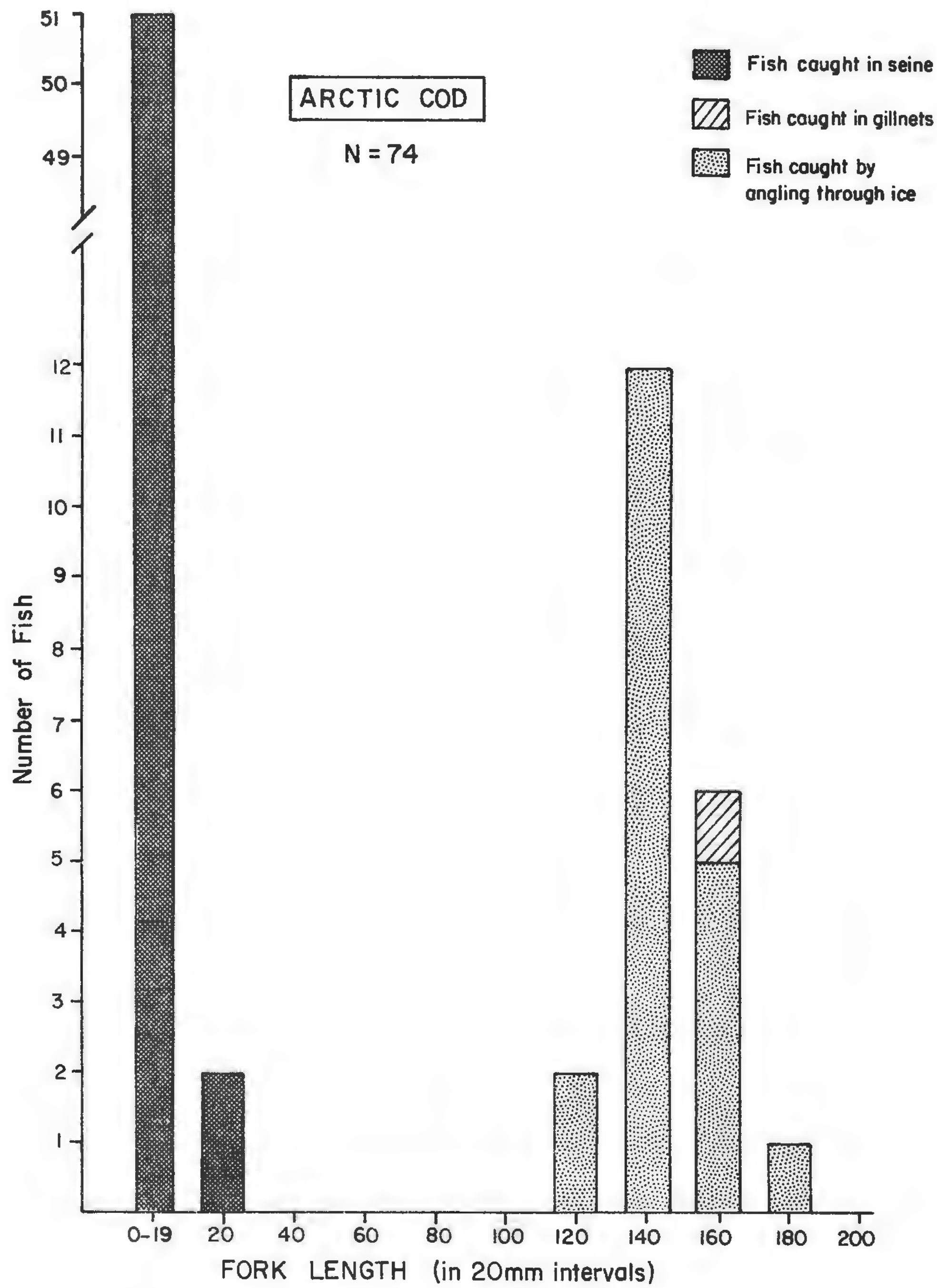

FIGURE 40. Length-frequency relationship for Arctic cod caught in Kaktovik Lagoon and adjacent areas, 1975.

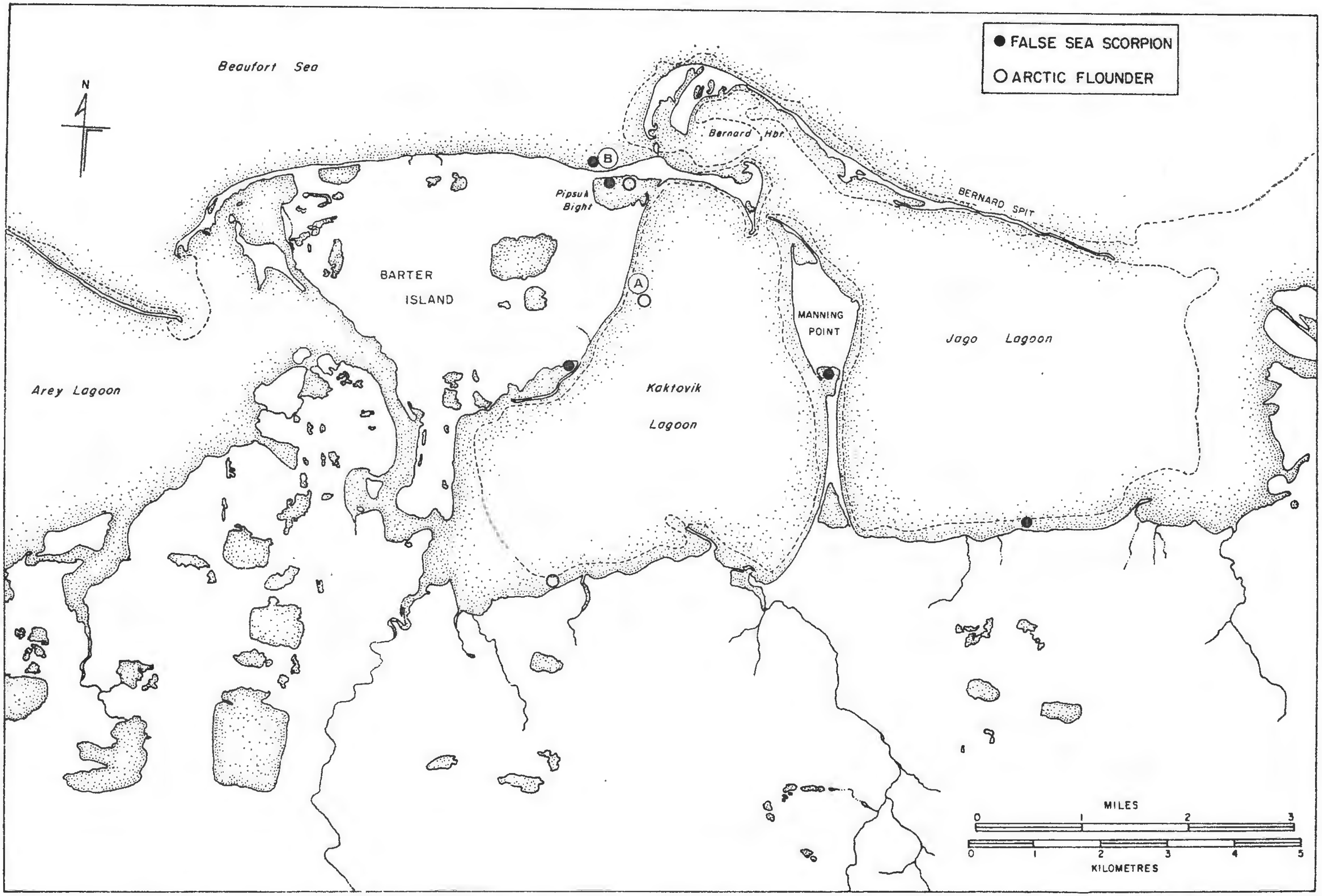

FIGURE 41. Distribution of false sea scorpion and Arctic flounder in Kaktovik Lagoon and adjacent areas, 1975.

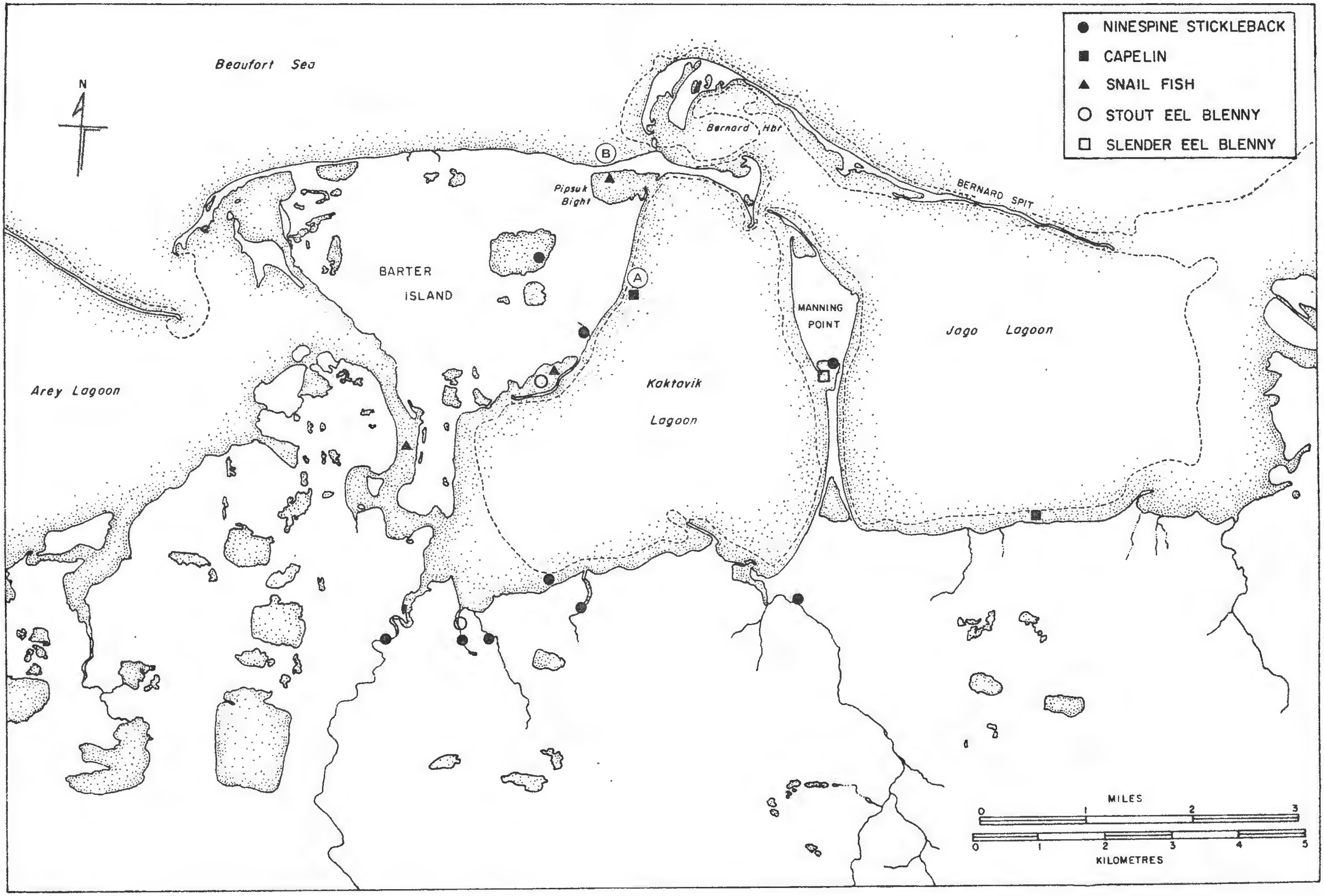

FIGURE 42. Distribution of ninespine stickleback, capelin, snailfish, stout eel blenny, and slender eel blenny in Kaktovik Lagoon and adjacent areas, 1975.

False Sea Scorpion *(Myoxocephalus axillaris)*

The taxonomy of the false sea scorpion appears to be in question. The specimens taken in the present study fit Andriyashev's (1954) description of *M. axillaris*. Willimovsky (1958) calls this species *M. scorpioides*, while Walters (1955) states that *M. verrucosus* and *M. axillaris* are sibling species in the western Arctic and *M. scorpioides* and *M. scorpius groenlandicus* are sibling species in the eastern Arctic. Walters also states that *M. axillaris* (Gill) is probably identical to *M. scorpioides* (Fabricius). The common name "false sea scorpion" will be used in this report as it appears most often in the literature.

Twenty-seven young-of-the-year false sea scorpions were captured during the season. On July 30, the mean length of seven fish was 13.7 mm (range 9-19 mm) and by August 31 the mean length of 16 fish was 23.4 mm (range 20-26 mm). Two juvenile false sea scorpions (30 and 35 mm in length) were collected in nearshore dredges. In addition, two mature male false sea scorpions (85 and 190 mm) were taken in gillnet sets. A review of the limited information on the life history of this species is presented by Andriyashev (1954).

Difficulty arises in separating false sea scorpion young-of-the-year from the large numbers of fourhorn sculpin young-of-the-year present in nearshore areas. The following differences were observed between young-of-the-year of the two species:

Characteristic	fourhorn sculpin	false sea scorpion
Width at caudal peduncle	narrow <4% body length <17% head length	wider >4% body length >17% head length
Head shape	extremely flattened	rounder appearance
Number of clearly visible preopercular spines	4	3
Postoccipital protuberances	present	absent
Size	larger (early emergence or faster growth)	smaller (later emergence or slower growth)

Capelin *(Mallotus villosus)*

Eleven capelin were collected in mid-September. Six were dissected and found to be mature green males aged 4 and 5 years (mean length 133.7 mm, range 125-146 mm). It appeared that the male capelin had moved nearshore in preparation for spawning. A similar behavioural pattern has been reported for capelin in the eastern Canadian Arctic (Jangarrd, 1974).

Arctic Flounder *(Liopsetta glacialis)*

Seven Arctic flounder (mean length 213 mm, range 142-239 mm) were caught at various times throughout the field season. A similar length-frequency was reported by Andriyashev (1954) and Griffiths *et al.* (1975). These fish ranged in age from 6 to 11. Their age-length relationship was similar to that of the small sample of Arctic flounder caught in Nunaluk Lagoon.

Ninespine Stickleback *(Pungitius pungitius)*

Thirty ninespine sticklebacks were taken, mostly in freshwater habitats. Specimens ranged in size from 20 to 55 mm. Ninespine stickleback were the only species found in the large freshwater lake on Barter Island which serves as the local drinking water supply. A few sticklebacks (N=10) were taken inside Kaktovik Lagoon in waters with salinities as high as 18‰.

Northern Snailfish *(Liparis liparis)*

Only eight young-of-the-year northern snailfish (12-30 mm) were caught in the Barter Island study area. These fish were all captured in seines. The general body shape of snailfish may prevent the capture of adults in gillnets.

Stout Eel Blenny *(Lumpenus medius)* and Slender Eel Blenny *(Lumpenus fabricius)*

Tentative identifications of stout and slender eel blennys were made from specimens collected in Kaktovik Lagoon and adjacent areas (Figure 42). Twelve stout eel blenny, all young-of-the-year and juveniles (17-65 mm), were captured in seines. Only three slender eel blenny (35-75 mm) were collected. Since numerous eel blenny were found in stomach contents of other fishes and no eel blenny was taken in Faber tows in the Barter Island study area, it appears that these species may utilize deeper water areas more extensively than shallow waters.

SUMMARY

An intensive study of the ecology of benthic invertebrates and fish in nearshore environments along the Beaufort Sea coastline was initiated in response to the proposal by Canadian Arctic Gas Study Limited and Alaskan Arctic Gas Study Company to construct a gas pipeline and associated facilities across the North Slope from Prudhoe Bay to the Mackenzie Delta. Two locations were chosen for comparative studies of fish and invertebrate utilization of nearshore habits. In 1974, a detailed study was conducted at Nunaluk Lagoon located off the Firth River in the Yukon Territory. Results from this study have been presented in an earlier report (Griffiths *et al.*, 1975). The present study was conducted in 1975 at Kaktovik Lagoon, located at Barter Island, Alaska.

In addition to the Nunaluk Lagoon report mentioned above, some fisheries data obtained in these nearshore investigations have been summarized in another report by Craig and McCart (1975). These authors describe the general use of nearshore habitats by major fish species. The report emphasized the life histories and distributions of anadromous species, principally Arctic char and Arctic cisco, in Beaufort Sea coastal waters.

This present report analyses the fisheries, invertebrates, and water quality data gathered at Kaktovik Lagoon and also at two additional survey sites, Bullen Point and Demarcation Bay. The following is a summary of the Kaktovik Lagoon and Nunaluk Lagoon findings.

Nearshore Habitats

Physical and chemical features of the two Arctic lagoons studied, Nunaluk Lagoon and Kaktovik Lagoon, were similar in several respects. These lagoons, which are separated by approximately 170 km (105 mi) of shoreline, appear typical of the many brackish water habitats found along the Beaufort Sea coastline in Alaska and the Yukon Territory. The lagoons are protected from direct exposure to the ocean by offshore islands or spits of gravel and sand.

The open water season in protected nearshore habits lasts for approximately three months. Breakup begins in mid-June, but the lagoons are not free of surface ice until early July. Lagoons generally remain ice-free for the summer in contrast to exposed coastal areas which may have, in some years, grounded ice floes along the shoreline. Freeze-up occurs in late September and by mid-October there is usually a thick (30 cm) ice cover. All shallow nearshore areas less than about 2 m deep freeze to the bottom.

The study lagoons are characterized by cool, well-oxygenated waters. Oxygen levels remain greater than 6 ppm year-round, even in areas frozen nearly to the bottom. Summer water temperatures generally range from 2 to 12°C. Diel air temperatures commonly range from 2 to 15°C. Water temperatures in lagoons tend to be a few degrees warmer than nearby coastal waters which are more directly subject to the influence of periodic ice floes brought in by a change in wind direction.

Though waters in these lagoons are typically brackish, salinities may fluctuate from nearly freshwater to marine conditions. Salinities are lowest during spring breakup as the ice melts and the North Slope rivers discharge large quantities of fresh water into coastal areas. In the fall, when freshwater sources dwindle and then freeze altogether, lagoon waters become saline. Peak salinities (18-45‰) are reached in the winter during the period of maximum ice thickness.

Wind-generated tidal fluctuations (10-70 cm) are more important than lunar tides (10 cm) in determining changes in water height along the Arctic coastline. A change in the direction of prevailing winds may also cause a rapid influx of marine water in coastal habitats with associated changes in temperature, salinity, major ions, and nutrients.

Despite a basic habitat similarity, Nunaluk and Kaktovik lagoons differ in several significant respects. There are three important differences which account for many of the variations observed in fish and invertebrate populations in the two study areas:

1. Size and Depth of Lagoon

Kaktovik Lagoon is larger and deeper than Nunaluk Lagoon. The surface area of Kaktovik Lagoon is approximately three times larger, but more important, Kaktovik Lagoon is deep enough (3-4 m) that it does not freeze completely to the bottom during the winter. The central portion of the lagoon provides an ice-free refuge for overwintering fish and invertebrates. Nunaluk Lagoon, however, is shallower (1-2 m) and freezes solid in the winter. Fish and most invertebrates which utilize

Nunaluk Lagoon during the open water season must overwinter elsewhere.

2. Fresh Water Input

Although both lagoons are brackish, salinities at Nunaluk Lagoon are consistently lower (2-5‰) than those at Kaktovik Lagoon (14-18‰). Reasons for this large difference are clear. Nunaluk Lagoon is a partially enclosed pocket of water which is fed by two large North Slope rivers, the Firth and the Malcolm. Except when these rivers cease to flow in the winter, there is a large freshwater discharge directly into Nunaluk Lagoon and a net flow of low-salinity water from the lagoon into the Beaufort Sea.

Kaktovik Lagoon, on the other hand, receives little fresh water. A few, small tundra streams flow into the lagoon, but the nearest large rivers are 9 km to the east and 13 km to the west. Kaktovik Lagoon also has two entrances, one on either side, which facilitate a continual mixing of marine and fresh waters.

3. Geographic Location

This point concerns the location of the study areas in relation to the Colville and Mackenzie rivers. The importance of these two rivers with respect to fish populations along the Beaufort Sea coastline has been discussed by Craig and McCart (1975). The Colville and Mackenzie rivers serve as major spawning areas for anadromous Arctic cisco, one of the most abundant fishes caught in both Nunaluk and Kaktovik lagoons.

Due to the proximity of Nunaluk Lagoon to the Mackenzie River

(135 km), it is likely that the Arctic cisco taken at Nunaluk originated in the Mackenzie. The Colville is much farther away (425 km). Furthermore, satellite imagery shows clearly that Mackenzie waters directly influence much of the Yukon coastline.

Kaktovik Lagoon lies slightly closer to the Colville River (260 km) than to the Mackenzie River (320 km). It is not known whether the Arctic cisco caught here originated from the Colville, Mackenzie, or both. In any case, it seems a reasonable assumption that fish species and numbers, and probably other physical, chemical, and biological factors at Nunaluk Lagoon, are influenced to a greater degree by the Mackenzie River than are those at Kaktovik Lagoon.

Invertebrates

A wide range in the numbers of benthic and epibenthic invertebrates was found in the nearshore habitats sampled. Values ranged from 0 to 12,425 organisms/m^2 at Nunaluk Lagoon, and 0 to 12,801 organisms/m^2 at Kaktovik Lagoon.

Water depth and type of substrate appear to be the most important factors influencing the distribution and abundance of benthic and epibenthic invertebrates in nearshore habitats. First, the various kinds of substrate (mud, sand, or gravel) accounted for some of the variability noted above, especially for infaunal groups. Second, numbers and diversity of invertebrates were lower in shallow water (<1 m) habitats than deeper water (2-4 m) habitats. Much of this difference may be attributed to the fact that shallow water habitats freeze solid during the Arctic winter, whereas there are unfrozen water and substrates in deeper waters. Most nearshore invertebrates are not permanent residents in shallow water habitats. Those that are collected here during the open water season are generally mobile, epibenthic organisms which disperse into shallow waters from deeper areas.

Amphipods, copepods, oligochaetes, polychaetes, and mysids are often the most abundant invertebrates sampled in nearshore waters. Densities are seasonally variable and are also influenced by periodic, wind-generated changes in water masses as previously discussed. Pelagic invertebrates occurring in the Nunaluk study area are discussed by Griffiths *et al.* (1975).

Fish

Although 14 species of fish were collected in the Nunaluk and Kaktovik study areas, only three species account for most of the fish taken by gillnet. Two of these, Arctic char and Arctic cisco, are anadromous species and the third, fourhorn sculpin, is a marine species.

Craig and McCart (1975) recently reviewed the use of nearshore areas by the anadromous species. For these species, "...nearshore waters may be loosely characterized as areas containing few fry or young (small) juveniles but large numbers of older (larger) juveniles and mature fish".

In Nunaluk and Kaktovik lagoons, the majority of anadromous fish caught were non-spawners (i.e., immatures and mature fish between spawnings) which were foraging along the coastline during the brief open water season.

Marine fishes were more common at Kaktovik Lagoon than at Nunaluk Lagoon. Of all the fish caught by gillnet or seine at Kaktovik Lagoon, 75% were marine species compared with only 21% in Nunaluk Lagoon. Much of this difference is due to the relative abundance of a single species, the fourhorn sculpin. Of the common nearshore species, the fourhorn sculpin is the only permanent resident, utilizing nearshore habitats for spawning, rearing, and overwintering. In addition to the large numbers of fourhorn sculpins, fry of several other marine species were also collected at Kaktovik Lagoon. Reasons for the overall difference in species composition and relative abundance of marine fishes in Nunaluk and Kaktovik lagoons is not known but may involve annual variation, habitat differences, or geographical differences in the locations of the two study areas.

Food habits of the major species in Nunaluk and Kaktovik lagoons were similar. Most fish appear to be opportunistic feeders. Crustaceans (amphipods, copepods, mysids, and isopods) were the major food items.

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APPENDIX I

DOMESTIC AND SPORT FISHERIES IN THE VICINITY OF BARTER ISLAND

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INTRODUCTION

Information on domestic and sport fisheries along the North Slope of Alaska is limited. With the increased activity in oil and gas exploration along the coast and the possible construction of a gas pipeline in the same general area, the need for documentation of these topics has increased in importance. Therefore, the fisheries study at Kaktovik Lagoon (a possible staging area for the construction of the Alaskan Arctic Gas pipeline) included a documentation of the 1975 domestic and sport fisheries in the area of Barter Island, Alaska.

The term "domestic fishing", as used in this report, includes all subsistance and sport fishing by the residents of Kaktovik. "Resident" includes all people presently residing in Kaktovik both native and white. "Sport fishing" refers only to recreational fishing by both natives and whites not residing in Kaktovik proper (i.e. DEW Line site personnel, hunters, hikers, etc.).

METHODS

Domestic fisheries information was gathered from Kaktovik residents by questionnaire between July 18 and September 6, 1975. The questionnaire requested the following information: fish species captured, the number of each species captured, the length of each species, the type of fishing gear, the time fished, the date fished, and the name of the fisherman. The questionnaires were distributed to people and families engaged in domestic fishing and completed forms were collected at 10-14 day intervals. Additional information was collected through interviews with various residents of Kaktovik. The estimated weight of fish caught in the domestic fishery was determined using the average weight of fish caught in the Kaktovik Lagoon study.

Information on sports fishing in the Barter Island area was gathered through interviews with DEW Line personnel, Walt Audi's Air Taxi, hikers, and hunters.

RESULTS

Fish for domestic purposes were taken from both coastal and freshwater locations. Some fishermen used Kaktovik as their base and fished at particular sites in the Barter Island area; others set up and maintained fishing camps at distant coastal locations or at freshwater sites in the Hulahula drainage. Since Barter Island is a possible staging area for pipeline activities, the 1975 domestic and sport fishery in the Barter Island area is described separately from fisheries at other sites.

Domestic Fishing in the Barter Island Area

Although only three families responded to the questionnaire, they represent approximately 46 to 50 of the 130 individuals living in Kaktovik. Thus, information was obtained for approximately 40% of the village. All those responding to the questionnaire were natives. No white residents responded to the questionnaire.

The general locations of domestic fishing sites in the immediate vicinity of Barter Island are shown in Figure I-1. The placement of gillnet sites was dictated by patterns of ice movement (i.e., nets were rarely placed on the ocean side of Bernard Spit due to the large amount of floe ice present). The standard gillnet used by resident fishermen was a green polyfilament (5.0 cm stretch mesh) floating net measuring 30 m (100 ft) in length and 2.4 m (8 ft) in depth. The nets were set

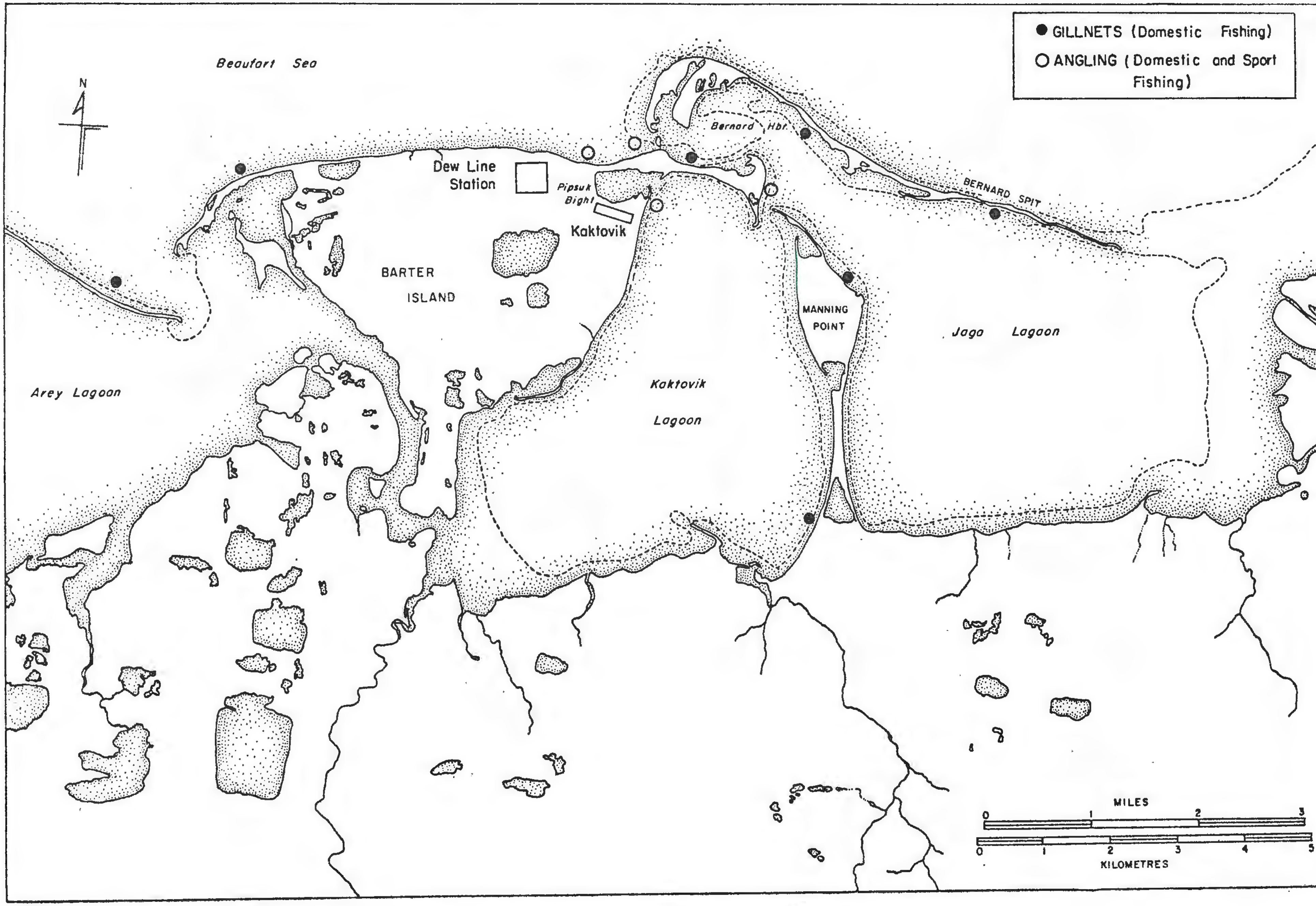

FIGURE I-1. Domestic and sport fishing sites in the vicinity of Barter Island.

1-2 m out from the edge of shore and were generally checked daily, weather permitting. Villagers often supplemented their fish catch by angling at nearby sites (Figure I-1).

Anadromous species form the most important portion of the domestic fishery at Kaktovik, while marine species are little more than incidental. A total of 1,484 fish were reported caught from July 18 to September 5 (Table I-1). These included 89 Arctic char, 1,113 Arctic cisco, and 282 undifferentiated Arctic char and Arctic cisco. Although some fish recorded as Arctic cisco were probably least cisco, the number of least cisco caught would be minimal since only 23 of this species were taken during the Kaktovik Lagoon study as described in the main body of this report.

A comparison of fish caught in the domestic fishery with those caught in the Kaktovik Lagoon study shows marked similarities, and therefore the more detailed study data are assumed to be representative of domestic fishery catches. Size ranges of both Arctic char and Arctic cisco taken by the Kaktovik fishermen and in the Kaktovik Lagoon study were similar (Arctic char, 200-630 mm and 180-680 mm, respectively; Arctic cisco, 180-430 mm and 120-460 mm, respectively). Both species showed a general decrease in average size through the season. In both instances, Arctic char disappeared from the catches at approximately the same time (August 16-21), and the numbers of Arctic cisco decreased early in September.

TABLE I-1. Summary of reported catch of Arctic char and Arctic cisco taken by Kaktovik residents in the vicinity of Kaktovik Lagoon, 1975.

Date	Arctic char	Size Range mm	Arctic cisco	Size Range mm	Undiffer-entated (char and cisco)	Size Range mm	Method of Capture
JULY 18	5	300-430	25	300-350	-	-	Gillnet
19	9	300-460	50	330-380	-	-	Gillnet
20	5	? -630	23	330+	-	-	Gillnet
21	4	380-430	2	380-430	-	-	Gillnet
21	5	300-460	-	-	-	-	Angling
22	-	-	-	-	9	350-360	Angling
22	4	350	1	300	-	-	Gillnet
23	5	250-500	12	280-400	-	-	Gillnet
23	3	250-350	-	-	-	-	Angling
29	-	-	2	300-380	-	-	Gillnet
AUG. 1	-	-	-	-	30	200-380	Gillnet
2	-	-	-	-	32	300-380	Gillnet
3	-	-	5	200-380	-	-	Gillnet
5	-	-	-	-	18	300-380	Gillnet
6	-	-	-	-	20	200-380	Gillnet
7	-	-	-	-	42	200-380	Gillnet
9	-	-	172	200-380	-	-	Gillnet
10	6	200-320	6	200-280	-	-	Gillnet
10	-	-	-	-	7	300-380	Gillnet
10	-	-	-	-	61	300-380	Gillnet
11	7	200-320	6	200-280	-	-	Gillnet
11	-	-	17	300-430	-	-	Gillnet
12	6	200-320	69	200-280	-	-	Gillnet
12	-	-	-	-	31	200-460	Gillnet
13	16	200-280	151	200-320	-	-	Gillnet
13	-	-	-	-	32	300-380	Gillnet
14	2	200-320	92	200-280	-	-	Gillnet
14	10	200-250	20	180-200	-	-	Gillnet
15	1	250	73	200-280	-	-	Gillnet
16	1	250	84	200-280	-	-	Gillnet
31	-	-	178	200-380	-	-	Gillnet
SEPT. 1	-	-	30	200-380	-	-	Gillnet
2	-	-	6	200-380	-	-	Gillnet
3	-	-	73	200-380	-	-	Gillnet
4	-	-	8	200-380	-	-	Gillnet
5	-	-	4	200-380	-	-	Gillnet
6	-	-	4	200-380	-	-	Gillnet
TOTALS	89		1113		282		
GRAND TOTAL			1484				

Several marine species were also taken by the resident fishermen. Arctic cod and capeline were captured by angling, while fourhorn sculpin and Arctic flounder were caught in gillnets. In 1975, Arctic cod were taken in large numbers (1,250) in early winter under the ice at Station B. However, according to the residents, this species does not appear every year. Capelin and Arctic flounder are only occasionally taken. Fourhorn sculpin are fairly common, but are discarded by the resident fishermen though old-timers remember eating this species.

Domestic Fishing Outside the Barter Island Area

While most domestic fishing sites are in the Barter Island area, other coastal locations are also important. Griffin Point (35-40 km east of Barter Island) is the site of a fishing camp set up each year by two or three families from Kaktovik. Only a few members of each family occupy the camp at any one time during the open water season. No precise fish catch records are available for the Griffin Point camp. However, based on estimates from previous years, approximately 2,000 fish, mostly Arctic cisco and Arctic char, are taken (Marx Simms, pers. comm., Mayor of Kaktovik).

Only one North Slope river (the Hulahula River) and one lake (Lake Schrader) are presently fished by Kaktovik residents. There is some thought, however, that this operation may expand to the Kongakut and Canning rivers in the future (W. Schmidt, pers. comm., Assistant Manager, Arctic National Wildlife Range).

Domestic fishing on the Hulahula River is an annual event. Three traditional fishing areas are located on the mainstem (Figure I-2). These sites are important spawning or overwintering areas for Arctic char and grayling (Craig and McCart, 1974; Ward and Craig, 1974). In the fall and winter months, residents of Kaktovik first fish the lower area (located approximately 30 km upstream), taking most of the fish present. Fishermen then turn to the spawning and overwintering area located further upstream in the foothills of the Brooks Mountains. The annual take is approximately 300-400 Arctic char (size range 120-600 mm). The percentage of spawners taken is unknown.

Lake Schrader (Sadlerochit drainage) is also fished by residents of Kaktovik during the winter. Approximately 100-200 lake trout *(Salvelinus namaycush)* are taken each winter (Marx Simms, pers. comm.). These are often large fish (up to 1 m in length, weighting about 9 kg). However, in a sample of 29 lake trout angled from Lake Schrader, the average weight per fish was 2 kg with a range of 0.3-9 kg (Aquatic Environments Limited, unpublished data).

Estimate of 1975 Domestic Catch

The 40% of the village which responded to questionnaires is estimated to represent over two-thirds of the actual domestic fishing at Kaktovik. Using 70% as the proportion of the fishery actually reported, an estimated 5,680 fish (weighing 3,000 kg) were taken by the residents of Kaktovik in 1975 (Table I-2). This value is slightly higher than the annual average

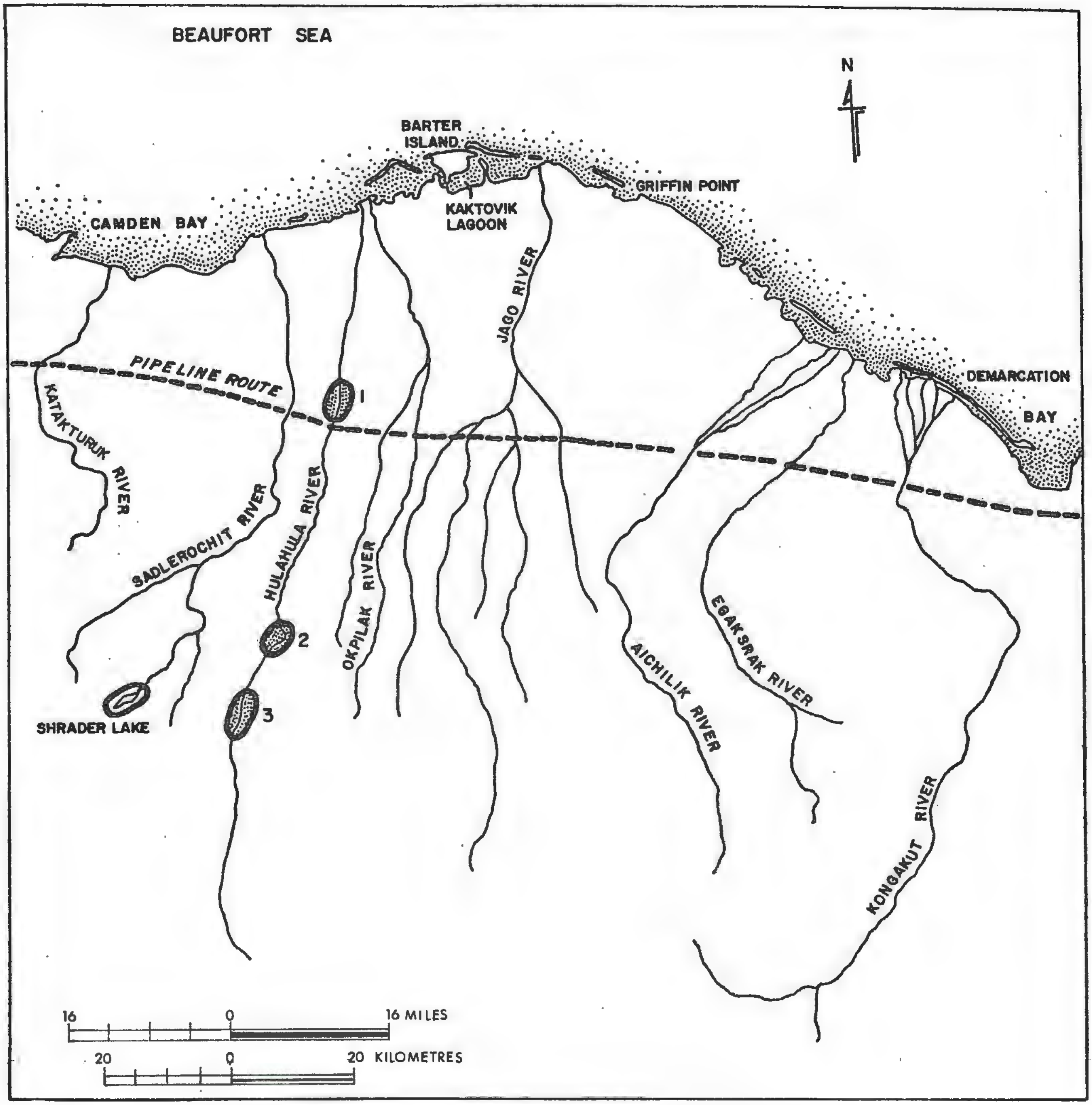

FIGURE I-2. Location of three traditional native fishing sites on the Hulahula River (dark areas).

TABLE I-2. Estimated total catch and weight of fish taken in the domestic fisheries of Kaktovik, 1975. Estimated values were determined by using the reported catch (Table I-1) as 70% of the total catch. Undifferentiated Arctic char and Arctic cisco catches were separated in a 1:3 ratio (char:cisco).

Location	Species	Estimate of 1975 catch	Average weight/fish (kg)	Estimate of total weight (kg)
Kaktovik	Arctic char	208	0.70	146
	Arctic cisco	1,722	0.60	1,033
	Arctic cod	1,250	0.03	38
Griffin Point	Arctic char and Arctic cisco	2,000	0.65	1,300
Hulahula	Arctic char	350	0.52	182
Lake Schrader	Lake trout	150	2.00	300
TOTAL		5,680		2,999

of 2,700 kg reported in the U.S. Department of the Interior, environmental impact statement (1975). However, according to Dupere *et al.* (1973) the average annual catch was 7,100 kg. Because the ice conditions in 1975 were severe enough to limit placement of nets, the estimate of 3,000 kg may represent a below-average catch.

Uses of Fish

Most fish taken by Kaktovik residents are used for human consumption although a small amount is fed to the village dogs. The reliance on domestic fishing has declined in recent years due to the availability of processed foods. However, domestic fishing still represents an important food source for most families in Kaktovik.

Sport Fishing

Sport fishing is not a major attraction in the Barter Island area and is limited to a few DEW Line station personnel and possibly a few hunters and hikers passing through the area. Almost all sport fishing is done along the northern shore of the island. An estimated 40-60 Arctic char and Arctic cisco were taken in 1975.

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APPENDIX II

BULLEN POINT SURVEY

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INTRODUCTION

Surveys of water quality, benthic invertebrates, and fish were conducted at Bullen Point, a proposed staging area for the Alaskan Arctic Gas pipeline. The surveys consisted of two short periods of intensive sampling, from July 31 to August 2, and on August 23, 1975. The data presented here are limited, but some comparisons have been made with the results of studies at Kaktovik Lagoon and other coastal areas.

STUDY AREA

Bullen Point, located approximately 24 km west of Flaxman Island, forms the eastern boundary of Mikkelsen Bay (Figures II-1 and II-2). The area consists of a gravel bar extending approximately 1 km into the ocean. The body of water protected by this gravel bar will be referred to as Bullen Harbour.

The gravel bar at Bullen Point is comprised of large pebble gravel (up to 8 cm in diameter) and coarse quartz sand. Ice and wave action have eroded away approximately 250 m of the central portion of the gravel bar (Figure II-2). Consequently, during high tides and storms, the western end of Bullen Point is isolated by water up to 1 m deep which covers the middle portion of the gravel bar. This occurred during the early August survey. During low tide, the entire bar is exposed.

The maximum water depth in Bullen Harbour is 3 m. The substrate in the shallow water areas of Bullen Harbour is composed of coarse quartz sand and gravel (>5 cm in diameter) with little or no organic material. The substrate in the deeper portion of the harbour is mud, sand, and fine gravel, with a moderate organic content.

The east shoreline of Bullen Harbour consists of a gravel bank 3 m in height, gradually sloping into the harbour. This bank is composed of gravel under 5 cm in diameter. In the southeast corner of Bullen Harbour, the gravel bank tapers down to form a gravel bar (1 m in height) which fronts a slumping tundra-covered bluff approximately 3 m in height.

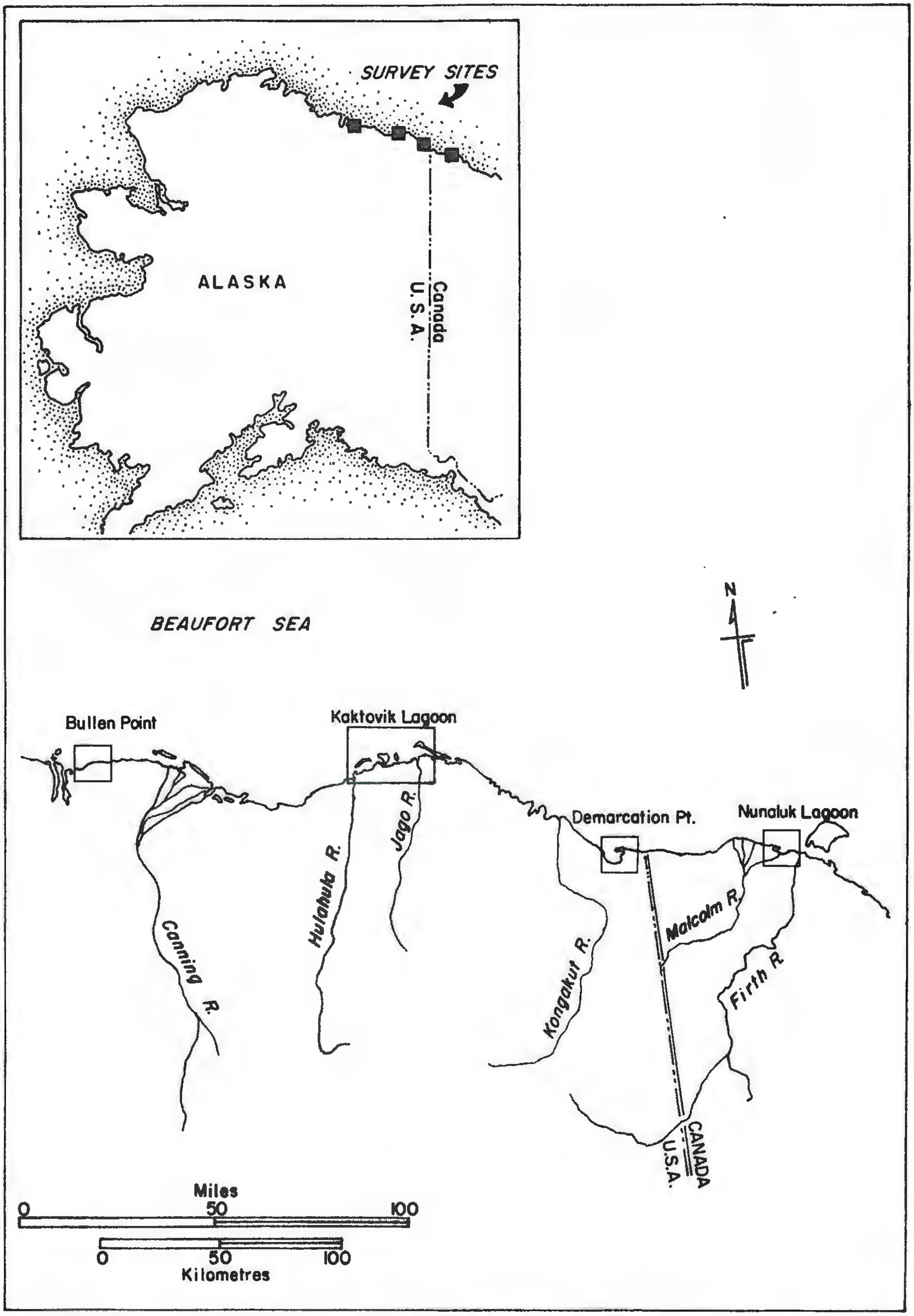

FIGURE II-1. Location of Bullen Point and other survey sites on the northern coast of Alaska.

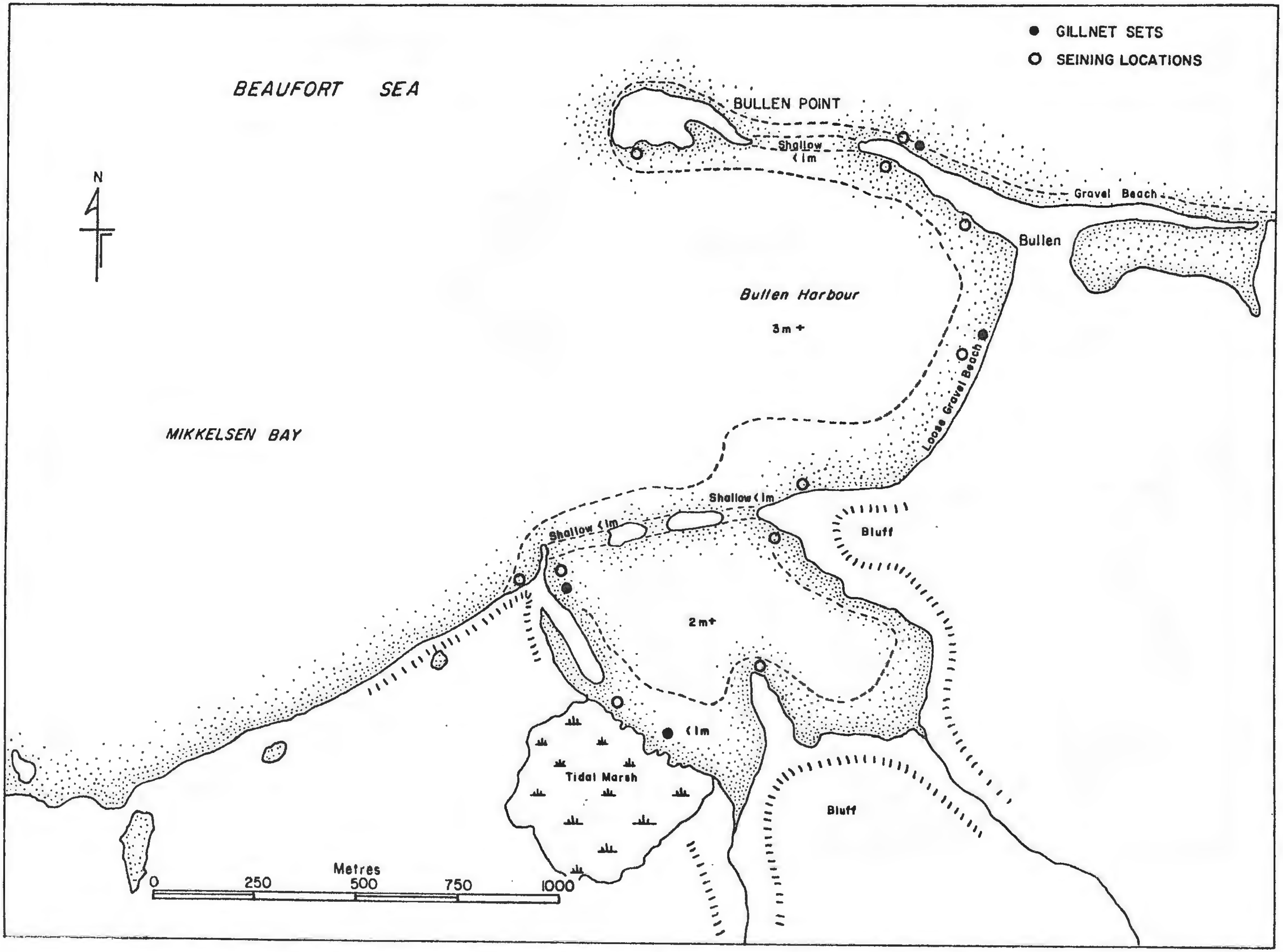

FIGURE II-2. Map of the Bullen Point study area showing location of gillnet sets and seining sites. Dashed line indicates shallow water areas.

A shallow protected lagoon along the south shore is separated from Bullen Harbour by a gravel bar running east and west. Portions of the bar were covered by 0.5 m of water during the early August survey. Maximum water depth in the lagoon is less than 3 m with a 50 m wide band adjacent to the south shoreline less than 1 m deep.

Two small tundra streams enter the lagoon along the south shore (Figure II-2). Each had a flow rate less than 0.5 m^3/min on August 1, 1975.

WATER STUDIES

Ice Conditions

During the early August survey, some floe ice was present in Bullen Harbour. Easterly winds predominated at this time and prevented a large buildup of ice in the harbour. However, during periods of strong westerly winds, large accumulations of ice may collect inside the harbour, completely blocking off the entrance and piling up against the east shoreline (Walt Audi, pers. comm., Audi's Air Taxi, Kaktovik). Heavy floe ice remained within 300 m of shore during the early August sampling period.

Physical and Chemical Parameters

Water samples were taken from Bullen Harbour and the adjacent ocean on August 1, 1975 (Table II-1). Water temperature, conductivity, and salinity were slightly higher in Bullen Harbour than in the adjacent ocean. Major ion concentrations were also slightly higher inside Bullen Harbour than in the ocean. Suspended sediments and turbidity (shaken) were similar in both areas.

TABLE II-1. Physical and chemical parameters in Bullen Harbour and adjacent ocean on August 1, 1975.

	BULLEN HARBOUR		ADJACENT OCEAN	
Temperature °C	5.0		4.0	
Conductivity μmhos/cm@25°C	23,870		21,330	
Salinity ‰	14.5		13.2	
pH	7.5		7.5	
Dissolved O_2 mg/1	11.0		11.0	
Turbidity - shaken F.T.U.	1.8		2.1	
Turbidity - settled F.T.U.	1.5		1.6	
Suspended Solids mg/1	12.2		15.4	
Reactive Silicate μg Si/1	446		340	
Total Dissolved Phosphorous μg P/L	<30		<30	
Total Dissolved Nitrogen μg N/L	121		134	
Calcium mg/1 (meq/1)	160	(8.0)	170	(8.5)
Magnesium mg/1 (meq/1)	617	(50.8)	570	(46.9)
Sodium mg/1 (meq/1)	4,875	(212.1)	4,550	(197.9)
Potassium mg/1 (meq/1)	188	(4.8)	153	(3.9)
Iron mg/1 (meq/1)	TR	(TR)	0.6	(0.03)
Sulphate mg$SO_4^{=}$/L (meq/1)	1,000	(20.8)	650	(13.5)
Chloride mgCL^{-}/L (meq/1)	9,250	(260.9)	8,400	(236.9)
Alkalinity mg$CaCO_3$/L (meq/1)	76.0	(1.5)	73.0	(1.5)
Total Cations meq/1	275.6		257.2	
Total Anions meq/1	283.2		251.9	
% Error	1.4		1.1	

TR=Trace

INVERTEBRATE STUDIES

Shallow water (<1 m) substrates were sampled during the early August survey of Bullen Point. Three Ekman grab samples were collected at each of 10 sites, spaced at intervals of approximately 50 m, along a transect parallel to the east shoreline of Bullen Harbour.

The numbers of benthic invertebrates collected are presented in Table II-2. Epibenthic invertebrates (81.8% amphipods and 15.8% isopods) comprised the majority of organisms sampled, while infaunal invertebrates composed only 1.1%. A total of six taxonomic groups were identified, including polyzoan colonies which were not quantified. Wide variation occurred in the density of organisms in samples (range 28-1,310/m^2) largely due to the irregular distribution of amphipods. The low diversity and relatively low numbers of organisms in shallow water are similar to the results from Kaktovik Lagoon. The same factors which limited the establishment of infaunal organisms in shallow water in Kaktovik Lagoon apply in Bullen Harbour.

TABLE II-2. Densities of marine invertebrates (N/m^2) taken in Ekman grabs at Bullen Point on August 1, 1975. Each sample consists of three grabs. All samples were taken in less than one metre of water.

Organisms	Sample 1	2	3	4	5	6	7	8	9	10	Mean
<u>CRUSTACEA</u>											
Mysidacea	-	-	-	-	-	-	-	-	-	14	1
Amphipoda	115	274	14	302	360	274	158	216	202	1138	306
Isopoda	29	43	14	58	86	72	29	72	72	115	59
<u>MOLLUSCA</u>											
Pelecypoda	-	-	-	-	14	-	-	-	-	-	1
<u>ANNELIDA</u>											
Polychaeta	-	-	-	-	-	-	-	-	29	-	3
TOTALS	*144	317	28	360	*460	346	*187	288	*303	1267	370

*Indicates sample containing Polyzoan colonies which were not quantified.

FISHERIES STUDIES

This section presents limited information on the relative abundance, distribution, and food habits of the fish species caught at Bullen Point and adjacent areas in 1975. Samples were collected by gillnet and seine from various locations during the July 31 to August 2 survey (Figure II-2). Fish taken in seine hauls were measured and released.

Four species were taken: Arctic char, Arctic cisco, fourhorn sculpin, and broad whitefish. Of these, only Arctic cisco and fourhorn sculpin were caught in sufficient numbers to allow comparisons with the Kaktovik sample. Arctic char are compared to an earlier collection of char from the same area (AEL, unpublished data).

Distribution

Of the four fish species collected, three were anadromous (Arctic char, Arctic cisco, and broad whitefish) and one was marine (fourhorn sculpin). Arctic char and Arctic cisco were found in Bullen Harbour and in the adjacent ocean, while only Arctic char and one broad whitefish were captured in the lagoon (Figure II-3). No fourhorn sculpins were caught in gillnet sets and only fourhorn sculpin young-of-the-year were taken in seine hauls.

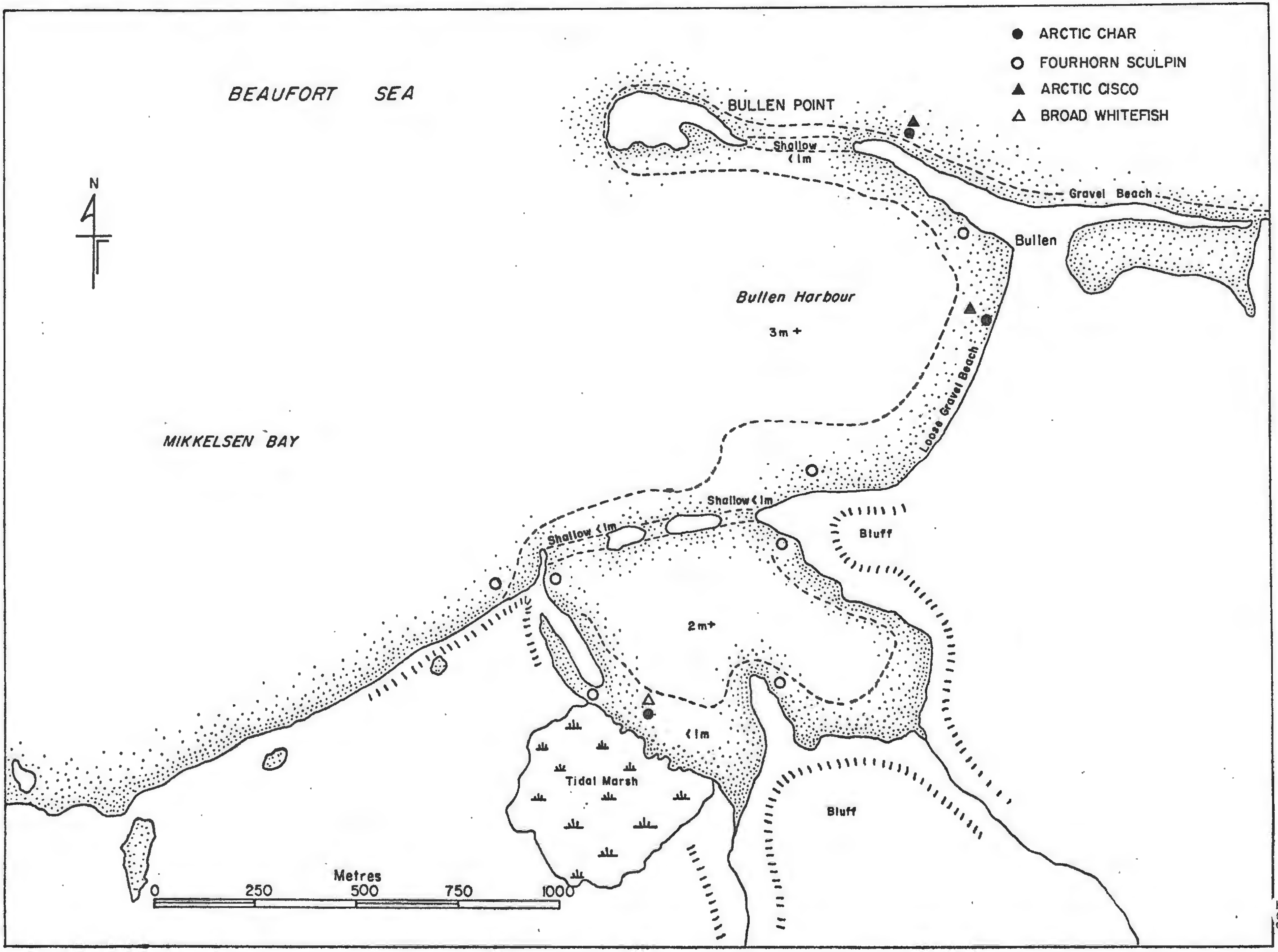

FIGURE II-3. Distribution of fish species caught in the Bullen Point study area, 1975.

Relative Abundance

Table II-3 indicates the relative abundance of the species during the survey period. Arctic cisco (N=73) were the most abundant species in both the ocean and Bullen Harbour. Twenty-six fourhorn sculpin young-of-the year, 19 Arctic char, and a single broad whitefish (length 540 mm, age 12) were the only other fish caught in the study area. No fish were taken in two gillnet sets made during the August 23 survey.

Description of Major Species

Arctic Char

A comparison between the Arctic char caught in 1975 and those taken in 1973 (AEL, unpublished data) illustrates the variation found from year to year at the same location. In 1975, all aged Arctic char were in the 5-8 year classes, while in 1973 the char ranged in age from 4 to 14 (Table II-4). The mean fork length was 420 mm (N=19) in 1975 and 477 mm (N=17) in 1973 (Figure II-4). The number of immature Arctic char varied widely (81.8% in 1975 and 35.3% in 1973) as did the sex ratio (45.5% males in 1975 and 29.5% males in 1973). These differences probably reflect the small sample size and short sampling period (two days).

Crustaceans accounted for 81.4% of the stomach contents for Arctic char caught at Bullen Point in 1975. Amphipods (34.9%) and mysids (40.6%) were the most important organisms utilized (Table II-5). These results are almost identical to those found at Kaktovik Lagoon. However, the Arctic char taken at Bullen Point in mid-July, 1973, differed

TABLE II-3. Catch per unit effort of fish taken in gillnets near Bullen Point in August, 1975.

Area	Date	Total Gang Hours	Species Caught	Number per Gang Hour	Total Number
Bullen Harbour	July 31	1	Arctic char	10	10
			Arctic cisco	39	39
Adjacent Ocean	August 1	4	Arctic char	0.5	2
			Arctic cisco	8.5	34
South Shore of Lagoon	August 1	1	Arctic char	7	7
			Broad whitefish	1	1
South Bullen Harbour	August 23	4	None	0	0

TOTALS Arctic char N=19

Arctic cisco N=73

TABLE II-4. Age, length, maturity, and sex ratio of char caught at Bullen Point in 1973 and 1975 surveys.

Age	Total n	Fork Length (mm) mean	range	S.D.	% Immature	% Male
BULLEN POINT 1973						
4	1	241	-	-	100	100
5	-	-	-	-	-	-
6	1	358	-	-	100	0
7	5	473	(454-483)	11.2	80	20
8	3	483	(468-500)	16.0	0	0
9	4	503	(485-514)	13.4	0	0
10	2	613	(587-638)	36.1	0	100
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	1	593	-	-	100	100
TOTALS	17				35.3%	29.5%
BULLEN POINT 1975						
5	1	419	-	-	100	100
6	7	416	(393-447)	21.4	100	43
7	2	429	(392-446)	52.3	50	0
8	1	538	-	-	0	100
TOTALS	11				81.8%	45.5%

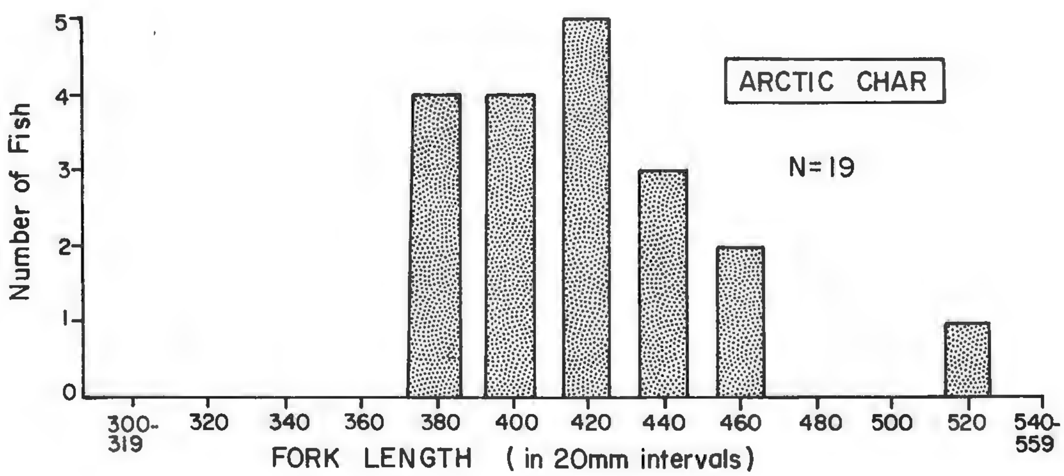

FIGURE II-4. Length-frequency relationship for Arctic char from Bullen Point and adjacent areas, 1975.

TABLE II-5. Food items eaten by Arctic char and Arctic cisco caught in the vicinity of Bullen Point on July 31 and August 1, 1975. Data for Arctic char caught at Bullen Point in July and August, 1973 are also included. Per cent composition in "average stomach" was determined by the Points Method. "Average stomach" as 100% indicates results when only those fish with food in their stomachs are considered.

	Arctic char (1973)		Arctic char (1975)		Arctic cisco (1975)	
Food Item	% in average stomach n=12	average stomach as 100%	% in average stomach n=18	average stomach as 100%	% in average stomach n=33	average stomach as 100%
CRUSTACEA						
Amphipoda	5.4	6.9	14.3	34.9	5.1	13.0
Mysidacea	16.3	20.9	16.1	40.6	24.9	63.0
Isopoda	-	-	1.8	4.7	6.6	16.7
Decapoda	-	-	0.5	1.2	-	-
TOTAL	21.7	27.8	32.7	81.4	36.6	92.7
FISH						
FHSC	-	-	1.4	3.5	-	-
ARCD	15.9	20.2	-	-	-	-
Fish Remains	31.3	40.2	-	-	-	-
TOTAL	47.2	60.4	1.4	3.5	-	-
MISCELLANEOUS						
Unidentified	9.2	11.8	5.9	15.1	2.7	6.9
Plant Material	-	-	-	-	0.2	0.4
TOTAL	9.2	11.8	5.9	15.1	2.9	7.3
GRAND TOTALS	78.1%	100.0%	40.0%	100.0%	39.5%	100.0%

significantly in that 60.4% of the stomach contents were fish, while in 1975 only 3.5% were fish. In 1973, crustaceans (27.8%) were not as important a food item, but in 1975, crustaceans accounted for 81.4% of stomach contents. Arctic char at Bullen Point appear to be non-selective feeders.

Arctic Cisco

The sample of Arctic cisco included fish aged 6, 7, and 8 (Table II-6). Their lengths were similar to those of fish from Kaktovik Lagoon. The large proportion of immature Arctic cisco at Bullen Point (91.2%) compared to Kaktovik Lagoon (33.9%) may be an artifact of the short sampling period.

The length-frequency relationship shows only a narrow range of lengths, which is common for samples of this species taken along the Alaskan Beaufort Sea coast (Craig and McCart, 1975). Most fish (74%) were between 320-359 mm (Figure II-5).

Crustaceans (92.7%), particularly mysids (63.0%) and isopods (16.7%), were the most important food item for the Arctic cisco in the sample (Table II-5). In Kaktovik Lagoon, amphipods (56.6%) and mysids (16.5%) were the two dominant groups among the Crustacea. The Arctic cisco appeared to feed on the available organisms, indicating they are non-selective feeders.

Fourhorn Sculpin

The 26 fourhorn sculpin young-of-the-year had a mean total length

TABLE II-6. Age-length relationship, maturity, and sex ratio of Arctic cisco from Bullen Point and adjacent areas, August 1, 1975.

Age	Total n	Fork Length (mm) mean	range	S.D.	% Immature	% Male
6	4	334	(327-338)	5.5	100	75
7	27	341	(325-355)	8.5	89	33
8	3	362	(344-377)	16.8	100	67
TOTALS	34				91.2%	41.2%

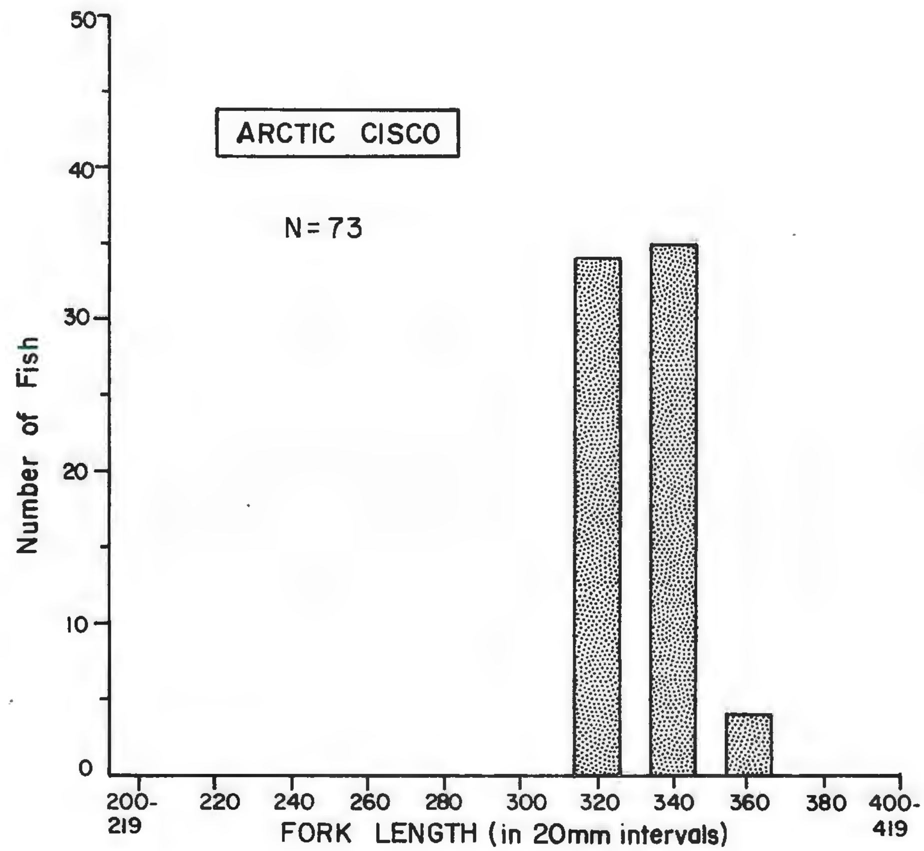

FIGURE II-5. Length-frequency relationship of Arctic cisco from Bullen Point and adjacent areas, 1975.

of 18.0 mm on August 1, 1975. However, a sample from Kaktovik Lagoon during the same time period was significantly larger ($\bar{x}$=22 mm, t=6.1, df=51, p<0.05), while a sample from Nunaluk Lagoon taken July 29 of the previous year was significantly smaller ($\bar{x}$=16, t=2.979, df=42, p<0.05). Apparently, growth rates of young-of-the-year of this species vary considerably along the Arctic coast.

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APPENDIX III

DEMARCATION BAY SURVEY

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INTRODUCTION

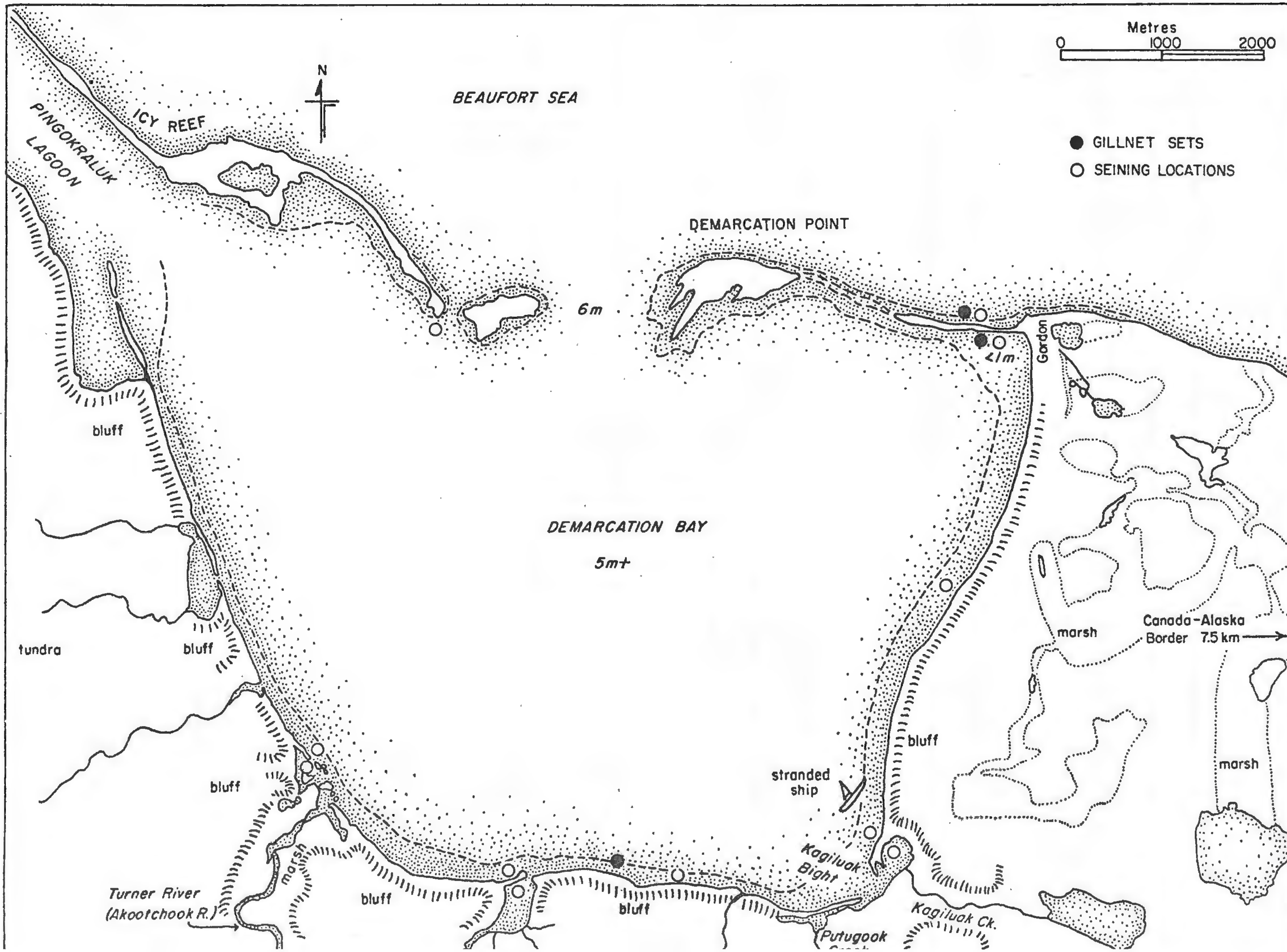
A mid-season survey of water quality, benthic invertebrates, and fish was conducted at Demarcation Bay (August 14 to 16, 1975), a proposed staging area for the Alaskan Arctic Gas pipeline. The data presented here are limited, but some comparisons have been made with the results of studies from Kaktovik Lagoon and other coastal areas.

STUDY AREA

Demarcation Bay is located approximately 7.5 km west of the Yukon Territory-Alaska border on the Beaufort Sea coast (Figure III-1). The bay is large, with a maximum length of 9 km and maximum width of 5 km. The northwest corner of the bay opens to Pingokraluk Lagoon. Maximum water depths (5-6 m) occur in the central portion of Demarcation Bay. A 50-200 m wide band of shallow water (<1 m) parallels most of the shoreline.

The shoreline of Demarcation Bay is dominated by slumping bluffs with occasional breaks where tundra streams enter the bay. The majority of the bluffs on the southern and western shorelines are of moderate relief (2-5 m), while bluffs along the east shoreline range from moderate to high relief (4-6 m) (Hartwell, 1973). Nearly all the bluffs within Demarcation Bay are fronted by narrow sand and gravel beaches that protect the exposed bluffs from erosion.

The substrate along the south and west shores of Demarcation Bay consists of fine gravel and coarse quartz sand with some small areas of mud. Considerable organic material, composed largely of eroding tundra, is present throughout this area. Substrate in the shallow water along the east shore of Demarcation Bay is composed of mud with a high organic content strewn with large granite and diabase boulders similar to Flaxman boulders (Leffingwell, 1919; Lewis, 1959).


Metres
0
1000
2000
N
BEAUFORT SEA
ICY REEF
PINGOKRALUK
LAGOON
GILLNET SETS
SEINING LOCATIONS
DEMARCATION POINT
6m
<1m
Gordon
bluff
DEMARCATION BAY
5m+
tundra
bluff
marsh
Canada-Alaska
Border 7.5 km
bluff
marsh
stranded
ship
bluff
marsh
Kagiluak
Bight
Turner River
(Akootchook R.)
bluff
bluff
Kagiluak Ck.
Putugook

Demarcation Point is a narrow gravel bar composed of coarse gravel and quartz sand. The spit rises approximately 1.5 m above sea level. The central portion was submerged to a depth of 1 m during the August survey.

The bay is fed by several small streams. Flow rate for the largest of these streams, the Turner (Akootchook) River, was estimated at 2 m^3/sec on August 14.

The substrate in shallow water surrounding the offshore spits and Demarcation Point consists of fine gravel and coarse quartz sand with little or no organic material present.

The western third of Demarcation Bay is protected from the ocean by the east end of Icy Reef spit which extends for 26 km along the coastline. Composition of this spit is similar to that of Demarcation Point.

WATER STUDIES

Strong winds (30-40 knots) from the west a few days before the sampling at Demarcation Bay deposited a considerable amount of floe ice against the outer spits and barriers. Due to the relatively narrow entrances to the bay, however, only a limited amount of this ice was able to enter the bay.

The physical and chemical characteristics of water from Demarcation Bay and the adjacent ocean were determined from samples taken August 15, 1975 (Table III-1). The water temperature in Demarcation Bay (10°C) was considerably higher than in the adjacent ocean (4.5°C) due to the presence of ice against the ocean shoreline. Salinity and major ion concentrations were higher in the ocean than in Demarcation Bay. Conductivity, pH, and dissolved oxygen values were similar at the two locations. Suspended solids and turbidity (shaken) were low at both locations.

TABLE III-1. Physical and chemical parameters in Demarcation Bay and adjacent ocean on August 15, 1975.

	DEMARCATION BAY		ADJACENT OCEAN	
Temperature °C	10.0		4.5	
Conductivity µmhos/cm@25°C	19,312		19,500	
Salinity ‰	11.5		12.5	
pH	8.5		8.0	
Dissolved O_2 mg/l	10.0		11.0	
Turbidity - shaken F.T.U.	3.6		1.8	
Turbidity - settled F.T.U.	1.7		1.0	
Suspended Solids mg/l	2.6		4.2	
Reactive Silicate µg Si/l	630		580	
Total Dissolved Phosphorous µg P/L	<30		<30	
Total Dissolved Nitrogen µg N/L	115		160	
Calcium mg/l (meq/l)	141	(7.0)	148	(7.4)
Magnesium mg/l (meq/l)	472	(38.8)	494	(40.7)
Sodium mg/l (meq/l)	3,625	(157.7)	4,050	(76.2)
Potassium mg/l (meq/l)	133	(3.4)	150	(3.8)
Iron mg/l (meq/l)	TR	(TR)	TR	(TR)
Sulphate mgSO_4/L (meq/l)	720	(15.0)	820	(17.1)
Chloride mgCL^-/L (meq/l)	6,700	(188.9)	7,500	(211.5)
Alkalinity mg$CaCO_3$/L (meq/l)	83.0	(1.66)	74.0	(1.48)
Total Cations meq/l	207.0		228.1	
Total Anions meq/l	205.6		230.0	
% Error	0.3		0.4	

TR=Trace

INVERTEBRATE STUDIES

Shallow water (<1 m) substrates were sampled by Ekman grab during the August 15 survey. A transect was established parallel to the south shore of the bay in typical shallow water habitat and three Ekman grab samples were collected at each of 10 sites spaced at intervals of approximately 50 m. The results are summarized in Table III-2.

Only four major taxonic groups were represented in samples. Crustaceans (amphipods, isopods, and mysids) comprised over 99% of the sample, with simuliids the only other group sampled. The density of organisms was extremely low. Infaunal groups were absent from shallow water samples in Demarcation Bay. The results from Demarcation Bay are similar to those from Kaktovik Lagoon.

TABLE III-2. Number of marine invertebrates per m^2 taken in Ekman grabs in Demarcation Bay on August 15, 1975. Each sample consists of three grabs. All samples were taken in less than one metre of water.

Organism	Sample										Mean
	1	2	3	4	5	6	7	8	9	10	
CRUSTACEA											
Mysidacea	43	-	-	-	-	-	14	-	14	-	7
Amphipoda	29	29	14	14	-	-	-	43	58	43	23
Isopoda	-	-	14	-	-	-	-	-	14	14	4
MISCELLANEOUS											
Simuliidae larvae	-	-	-	-	-	14	-	-	-	-	1
TOTALS	72	29	28	14	-	14	14	43	86	57	35

FISHERIES STUDIES

Fish samples were collected by gillnet and seine at several locations during the mid-August survey (Figure III-1). Only Arctic cisco and fourhorn sculpin were collected in sufficient numbers to allow comparisons with the Kaktovik data.

Results

Distribution

Of the eight species captured in the survey area, four were marine (fourhorn sculpin, Arctic flounder, capeline, and stout eel blenny), three were anadromous (Arctic char, Arctic cisco, and least cisco), and one was freshwater (grayling). All species, except least cisco, were caught inside Demarcation Bay, but only Arctic char, Arctic cisco, and least cisco were taken in the ocean (Figure III-2). One juvenile Arctic cisco (55 mm in length, age 1) was caught along the south shore of the bay. Young-of-the-year and juvenile fourhorn sculpin were uniformly distributed in Demarcation Bay, while a single mature fourhorn sculpin was gillnetted along the south shore. Capeline, Arctic flounder, grayling, and stout eel blenny were caught only in the south portions of the bay.

Relative Abundance

Table III-3 indicates the relative abundance of the species within the study area. Arctic cisco (N=55) were the most abundant species taken in gillnets in both the ocean and Demarcation Bay. Fourhorn sculpin (N=80) were most abundant in seine collections inside Demarcation Bay.

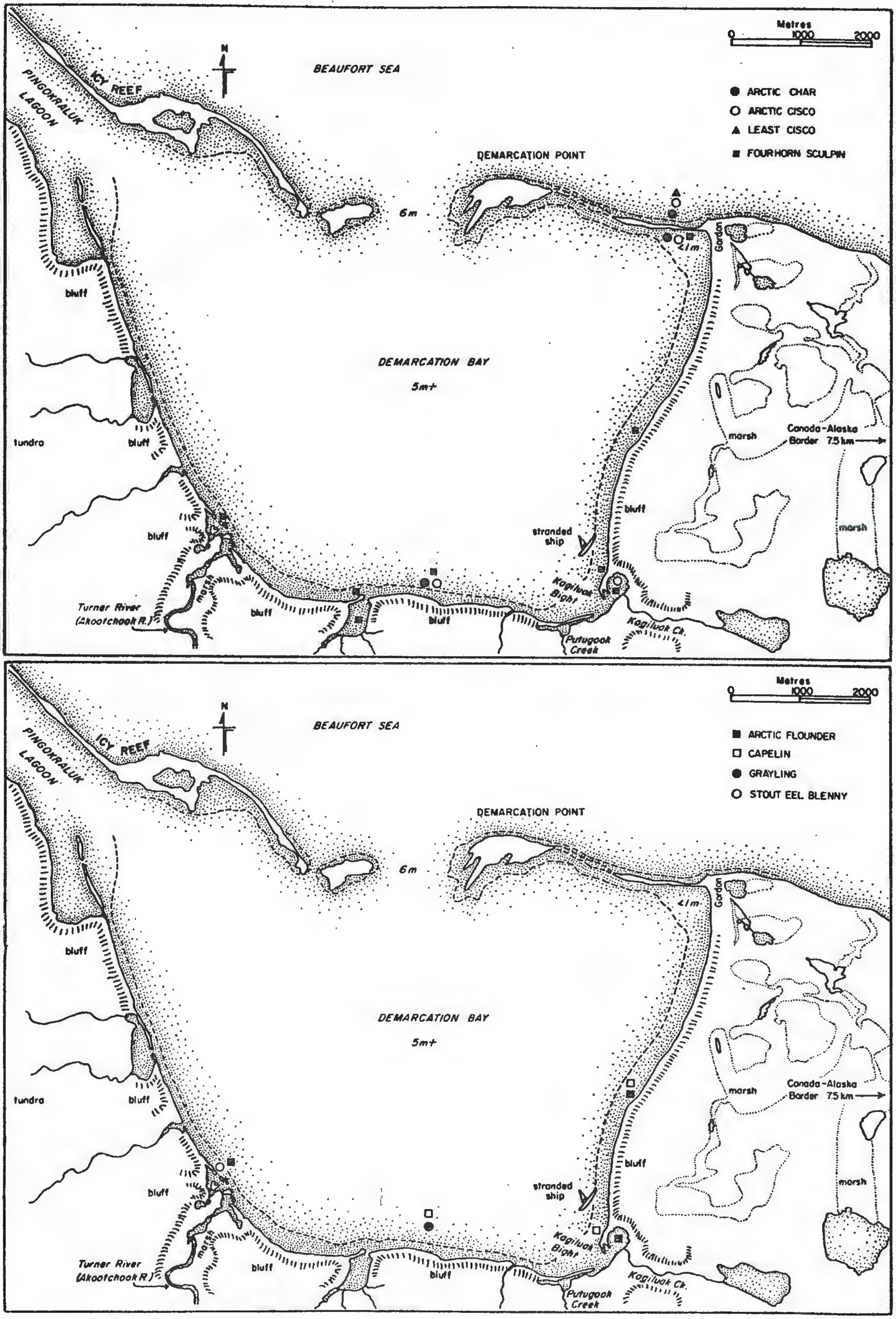


FIGURE III-2. Distribution of Arctic char, Arctic cisco, least cisco, fourhorn sculpin, Arctic flounder, capeline, grayling, and stout eel blenny in Demarcation Bay and adjacent areas, 1975.

TABLE III-3. Catch per unit effort of fish taken in gillnets in Demarcation Bay and adjacent areas in August, 1975.

Area	Date	Total Gang Hours	Species Caught	Number per Gang Hour	Total Number
Ocean off Demarcation Point	August 14	1	Arctic char	7	7
			Arctic cisco	19	19
			Least cisco	1	1
Inside Demarcation Point	August 15	0.1	Arctic char	20	2
			Arctic cisco	270	27
South Shore Demarcation Bay	August 15	3	Arctic char	1.3	4
			Arctic cisco	2.7	8
			Grayling	0.3	1
			Fourhorn sculpin	0.3	1
TOTALS Arctic char N=11					
Arctic cisco N=54					

Arctic char were present in both areas but not in large numbers, since most had returned to the rivers by this time.

Young-of-the-year capelin (N=22, $\bar{x}$=25 mm, range 21-32 mm) were common in shallow (<1 m) areas along the east and south shorelines of the bay on August 14, 1975. Two juvenile capelin (45 and 50 mm) were also taken in seine hauls in the same area.

Least cisco (N=1, 277 mm, age 8), Arctic flounder (N=3), grayling (N=1, 289 mm, age 8), and stout eel blenny (N=2, 23 and 26 mm) were uncommon in the survey area.

Description of Major Species

Arctic Cisco

The length-frequency and age-length relationships of Arctic cisco taken in the vicinity of Demarcation Bay are presented in Figure III-3 and Table III-4, respectively. Arctic cisco had a size range of 327-442 mm and an age range of 6-10. Similar findings have been reported elsewhere along the Alaskan Beaufort Sea coast (Roguski and Komarek, 1972; Kogl and Schell, 1974; Craig and Mann, 1974; Furniss, 1975). In contrast, Arctic cisco from the Yukon Beaufort Sea coast (thought to be from the Mackenzie River) had much higher maximum ages ranging from 17 to 21 years (Craig and Mann, 1974; Griffiths *et al.*, 1975).

Seventy-three per cent of the Arctic cisco were immature. There was no significant difference in the sex ratio (X^2=0.063, df=1, $p>0.05$).

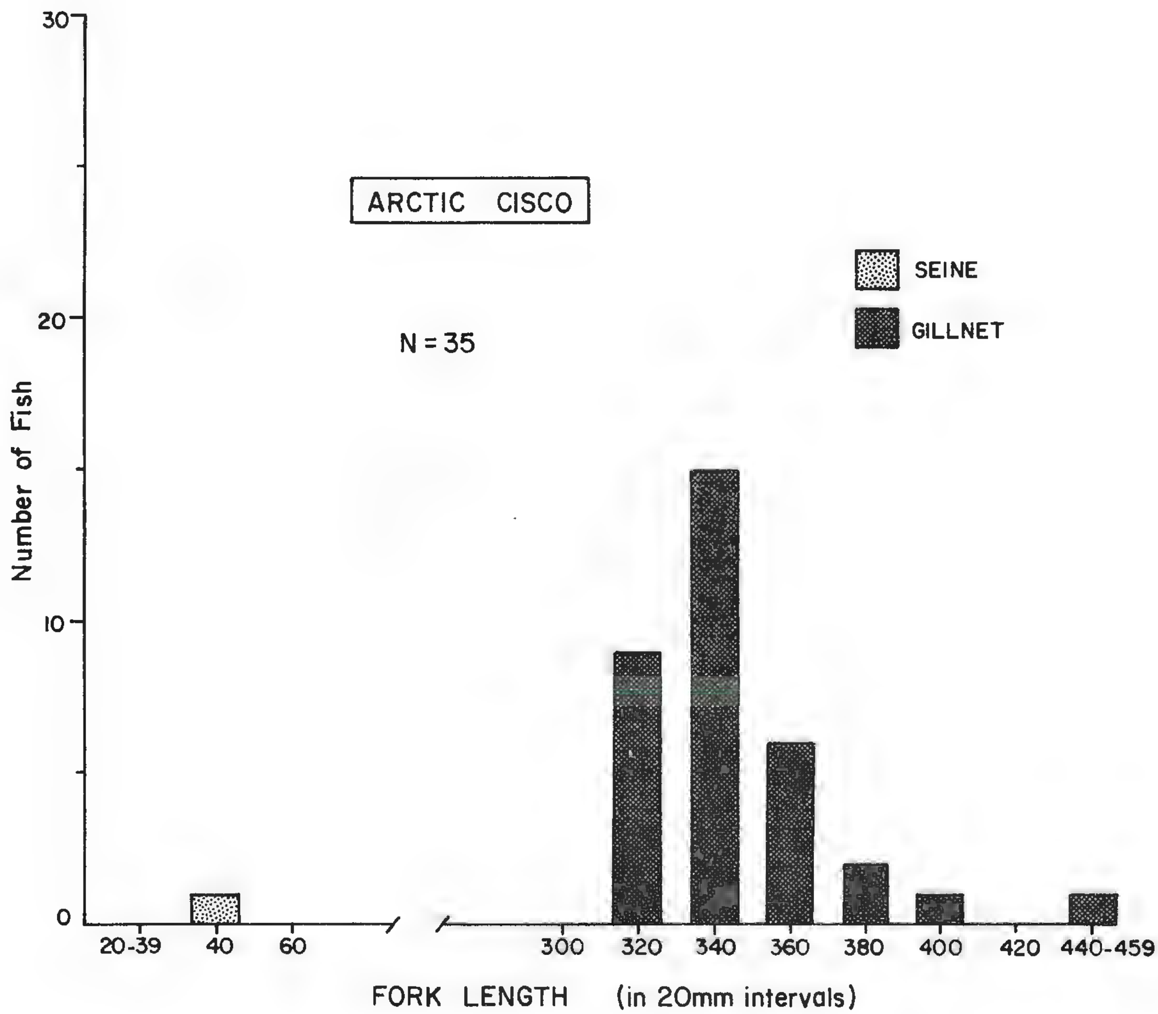


FIGURE III-3. Length-frequency relationship for Arctic cisco from Demarcation Bay and adjacent areas, 1975.

TABLE III-4. Age, length, maturity, and sex ratio of Arctic cisco from Demarcation Bay, August 14-15, 1975.

Age	Total n	Fork Length (mm) mean	range	S.D.	% Immature	% Male
6	1	343	-	-	100	0
7	16	346	(328-378)	13.6	81	56
8	14	358	(327-393)	19.1	71	43
9	1	442	-	-	-	-
10	1	409	-	-	-	-
TOTALS	33				73%	45%

Crustaceans (91.5%) were the most abundant food item utilized by these fish. Mysids (71.3%) and amphipods (20.3%) were the only two major taxa present (Table III-5). These results are similar to those found at Kaktovik Lagoon where crustaceans represented 80.5% of the stomach contents. A high percentage of the Arctic cisco stomachs (32.4%) were empty and the average stomach was 10.2% full, well below the average fullness (49.7%) of Kaktovik fish.

Fourhorn Sculpin

With the exception of one mature male (204 mm, age 8), all fourhorn sculpin caught in Demarcation Bay were under 100 mm in total length (Figure III-4).

At Demarcation Bay, the mean total length of fourhorn sculpin young-of-the-year was 22.9 mm (range 18-26, SD=1.9, N=38). At Kaktovik Lagoon during the same time period, mean total length of young-of-the-year was significantly greater ($\bar{x}$=25.1, t=4.68, df=92, p<0.05), while at Nunaluk Lagoon, on August 8 of the previous year, it was significantly lower ($\bar{x}$=19.0, t=5.53, df=73, p<0.05). The wide range of growth rates for young-of-the-year fourhorn sculpin may be due to differences in habitat in areas along the Beaufort Sea coast.

TABLE III-5. Food items eaten by Arctic cisco in Demarcation Bay and adjacent areas, August, 1975. Percent composition in "average stomach" was determined by the Points Method. "Average stomach as 100%" indicates results when only those fish with food in their stomachs are considered. Fish with empty stomachs (32.4%) are not included.

Food Item	% in Average Stomach n=23	Average Stomach as 100%
CRUSTACEA		
Amphipoda	2.1	20.2
Mysidacea	7.2	71.3
Unidentified	0.9	8.6
TOTALS	10.2%	100.0%

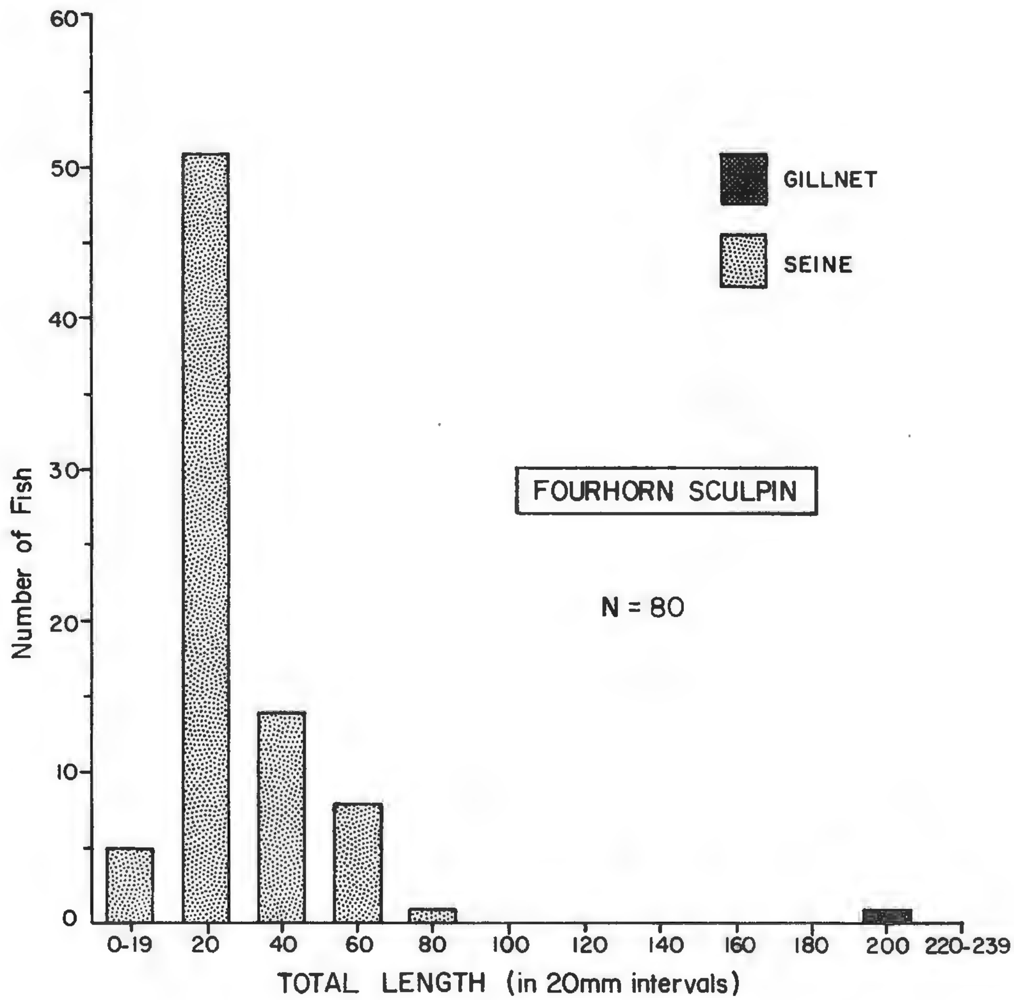


FIGURE III-4. Length-frequency relationship for fourhorn sculpin from Demarcation Bay and adjacent areas, 1975.

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