FRESHWATER FISHERY RESOURCES OF NORTHERN YUKON TERRITORY

THE INFLUENCE OF PIPELINE DEVELOPMENT ON FRESHWATER FISHERY RESOURCES OF NORTHERN YUKON TERRITORY. ASPECTS OF RESEARCH CONDUCTED IN 1971 AND 1972.

by

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1. Summary

The purpose of this study is to evaluate effects of pipeline development on aquatic resources in northern Yukon Territory in order to protect the capacity for fish production. This report describes aspects of the research useful in making preliminary evaluations.

Aquatic organisms were studied in the watersheds of the Porcupine River and the Beaufort Sea, as alternative pipeline routes have been proposed through both watersheds. Some physical and chemical characteristics are described for most rivers and creeks.

The concentration of suspended sediment observed during excavation of a pipeline trench in the La Biche River ranged from 74 to 543 ppm above background levels. Additional studies of pipeline crossings are necessary to determine whether the observed levels are typical. Moreover, appropriate bioassay experiments are needed to establish whether the observed concentrations would be detrimental. These experiments would require representative northern species acclimatized to conditions during the season of proposed construction and exposed to suspended sediment together with other possibly synergistic components of the water. In addition, effects of sediment on fish eggs and invertebrates need to be investigated.

A total of seven fish species were captured in the Beaufort Sea drainage, whereas sixteen were captured in the Porcupine drainage. The most commonly observed fish species in the Beaufort drainage were Arctic char and Arctic grayling. The Porcupine River drainage lacked char, but contained salmon and a greater variety of species resident in freshwater. In both drainages, there were considerable differences in species composition among different rivers and among different regions of the same river.

Some spawning grounds for salmon and char were located by direct observation. For the other species, it was only possible to suggest where spawning grounds may be located by noting the areas where fry were captured. In the Beaufort drainage, char spawning areas, and probably most grayling spawning areas, occurred upstream of the proposed pipeline route. In the Porcupine drainage, spawning areas are thought to occur upstream of the proposed pipeline route for all species except the following, for which there is insufficient information: burbot, broad whitefish, fourhorn sculpin, inconnu, lake whitefish, and least cisco.

In the winter, portions of most rivers were covered by a thick layer of ice, and some rivers were frozen to the bottom. However, sections of some rivers remained unfrozen throughout the winter because of goundwater upwelling. In the Beaufort drainage, char and grayling over-winter in these open water areas. In the Porcupine drainage, some young fish apparently spent the winter in the open water of the Fishing Branch River, but many fish over-wintered in the main-stem of the Porcupine River. During winter, oxygen concentrations were usually much lower than in the summer, and some locations had oxygen concentrations insufficient for survival of fish.

The seasonal movement patterns of salmon and char consisted of downstream migrations in the spring, followed by upstream migrations in the fall. Seasonal migrations of freshwater resident species were complex and varied. In general, the seasonal movements seemed to consist of a spring dispersal from over-wintering areas to feeding or spawning areas followed by reverse migrations in the fall.

Present information indicates that more fish spawning and rearing areas would be affected by a pipeline in the Porcupine River drainage than in the Beaufort Sea drainage. Most char and grayling spawning and over-wintering area lies upstream of the prospective pipeline route in the Beaufort drainage. In the Porcupine drainage, however, spawning and over-wintering habitat for many species is downstream of the prospective route. For five of the sixteen fish species captured in the Porcupine drainage, there are no presently known or suspected spawning grounds which would not be affected by a pipeline along the suggested route.

For the coastal route, the presently recommended times for construction or abandonment of pipeline crossings are between October and May for rivers and creeks which lack downstream over-wintering or spawning areas. For other coastal streams with char populations, July is the preferred month for construction. In the Porcupine system, the best time for construction is possibly mid-June to mid-July. Additional research is required to firmly establish times of construction which would be best from the standpoint of fishery resources.

A number of recommendations are made about safeguards to be followed during construction, operation, and abandonment of pipelines. Fisheries Service should have the responsibility to approve plans and scheduling of pipeline river crossings. Many procedures are suggested to minimize sedimentation of flowing water. No gravel removal should be allowed within the wetted perimeters of stream beds, and a special permit should be required for removal within the flood plain. Fisheries Service approval should be required for use of all toxic chemicals. Extra block valves and thermal insulation would be required at certain river crossings by oil pipelines. Elaborate and continuously improved contingency plans should be required for an oil pipeline.

A number of topics which require further research are described. The most important of these are: location of additional spawning areas; location of overwintering sites; experiments to determine effects of sediment and crude oil on adult fish, fry, and eggs; further development of safeguards for pipeline construction, operation and abandonment.

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2. Introduction

2.1 General nature and scope of study

Several companies are considering the construction of pipelines to carry gas or oil from sources in Alaska across northern Yukon Territory to the Mackenzie River Valley and south to existing pipelines. The purpose of this study is to assess the potential damage to fishery resources in northern Yukon Territory in order to prevent loss of productive capacity. Both this study and a similar one being conducted in the Northwest Territories by the Central Region of Fisheries Service are part of a group of research projects within the Department of the Environment which are designed to assess the environmental effects of proposed northern pipelines. Research by Fisheries Service has focussed on fish rather than other aspects of freshwater aquatic environments because other projects cover: water quantity, water quality, freshwater invertebrate biology and marine biology.

Information about the ecology of fish in the areas affected by prospective pipelines is prerequisite for avoiding adverse effects of pipeline development on fish. It is important to know the distribution of different life history stages of each species in different areas and at different times. Such information is necessary to determine when and where fish would be particularly "sensitive" to pipeline development. Pipeline construction can be schedulued to avoid sensitive times and the route can be altered to avoid certain sensitive areas. Preliminary information about fish distribution is a major topic of this report.

The information included was taken from research conducted in both 1971 and 1972, but does not represent a complete summary of the research in either year. In particular, most results for 1972 have not been analyzed sufficiently to be included. Consequently, some interpretations about information in this report may be subject to modification or expansion. Other information presented is condensed from an earlier report (Bryan, Walker, Kendel, and Elson MS 1972).

2.2 Specific Objectives

The main objective of this study is to preserve the productive capacity of aquatic ecosystems at levels measured in 1971 and 1972. The sub-objectives of the study are:

1. To inventory the indigenous fish stocks qualitatively and quantitatively.

2. To inventory some characteristics of the aquatic environment relevant to the fishery resources.

3. To identify factors associated with pipeline construction or operation which may bring about environmental change detrimental to the fishery resources.

4. To recommend measures that will prevent degradation of the environment during construction and operation of the pipeline.

The research during 1971 consisted of a fishery study in the Porcupine River at Old Crow from the last week of July to the first week of September and a reconnaissance of outlying rivers and creeks. In 1972, the research centered on a detailed study of fish populations in selected areas during spring, summer, and fall. Short-term investigations were made of: chum salmon spawning in the Fishing Branch River, construction of pipeline river crossings, and winter conditions in the study area.

2.3 Some potential effects of pipelines on fishery resources.

Potential effects of northern pipelines on aquatic environments have been described previously (Shotton, 1971; Macpherson, Watson, Hunter, and Hatfield, 1972; Bryan, et al. MS 1972; Hatfield, Stein, Falk, and Jessop, 1972). Macpherson, et al. (1972) point out that most effects can be classified into one of three categories: habitat alteration; pollution hazard; and facilitated harvest. The following paragraphs outline some examples of each type of effect (Bryan, et al. MS 1972).

One effect of any pipeline is increased sedimentation of flowing water. Pipelines will usually be laid under the beds of streams. In the process of trenching for the pipe, sediment from the river bed becomes suspended in the water. Sufficient quantities of such sediment can kill fish immediately downstream of the pipeline excavation (Cordone and Kelley, 1961). Another danger is that newly settled sediment can kill both fish eggs (Cooper, 1956) and the food organisms eaten by fish (Cordone and Kelley, 1961). When sedimentation ceases, spring floods usually transport deposited sediment to downstream areas and restore the suitability of the upstream habitat for fish spawning and invertebrate production.

Since sedimentation during construction will be temporary, the effects will probably not be serious unless adult fish or eggs are killed. However, a permanent and more serious increase in sedimentation may result from increased erosion along the pipeline right of way. Sediment from this source could permanently destroy spawning grounds and fry rearing areas. Rather small increases in sedimentation markedly decrease the number of fish in an area and also decrease their food supply and growth rate (Gammon, 1970).

Removal of gravel from stream and river beds can also be detrimental. Gravel removal could destroy spawning and fry rearing areas. Even when gravel is not removed directly from these areas, decreased or delayed recruitment of gravel to such areas and river channel changes resulting from construction can destroy spawning and rearing habitat. Another type of habitat disruption could result when drinking water is pumped from streams to construction camps during the winter. In the main-stems of some northern rivers, the water stops flowing in winter. Thus the volume available for over-wintering fish is in short supply.

Toxic chemicals and domestic sewage are other hazards of pipeline development. Building, testing, and maintaining pipelines will require the use of many varieties of chemicals which kill aquatic organisms when added to water in sufficient concentration. Most of these chemicals can be shown to have adverse effects even at sublethal concentrations. As in southern areas, toxic chemicals are threats to aquatic environments because of both inadvertent and deliberate disposal into streams and rivers. An obvious example of accidental introduction of toxic chemicals would result from an oil pipeline rupture near a stream or river. In some situations, domestic sewage disposal can be very detrimental, and strict regulations will be required to control all waste disposal.

Another result of pipeline development would be increased sport fishing both by workers building and maintaining the pipeline and by tourists making use of improved access. Improved access would be provided by airstrips, roads, and the pipeline bed itself. As northern fish grow much more slowly and start reproducing when they are older than their southern counterparts, some populations could be over-fished. Regulations must be designed with these considerations in mind, particularly in regions where there would also be competition with subsistence fisheries.

3. Resume of current state of knowledge

Before 1971, there was very little public information about the fish fauna of northern Yukon Territory (McPhail and Lindsey, 1970: 356). Since that time, there have been investigations into the aquatic ecology of the area by several agencies of the Department of the Environment and by two private companies on contract to different consortia of companies seeking to build a natural gas pipeline from Prudhoe Bay, Alaska. Results of research by other agencies (Water Management Service and Fisheries Research Board) within the Department of the Environment will be released with this report.

There has been little duplication of effort among the investigations of fishery biology. What duplication there has been will undoubtedly serve as a useful cross-check. In 1971, the company on contract to Gas Artic Systems (GAS) performed a reconnaissance of some aspects of fishery biology and physical and chemical characteristics of water intersected by prospective pipeline routes (Shotton, 1971). Although the Fisheries Service reconnaissance was made on the same rivers and creeks, samples were spread out over the watersheds rather than being taken at specific pipeline crossing sites. In 1972, the GAS research consisted mainly of detailed study at a few locations which were different from those studied by Fisheries Service. The other company, Northern Engineering Services (NES), did not undertake active research within the Yukon in 1971. In 1972, their research consisted of detailed study of fish populations in coastal rivers. This research will provide information not available from GAS or Fisheries Service. Results of research by both GAS and NES are expected to be released by March, 1973.

The information being compiled by all of the investigations is relevant to pipeline concerns, and most of it will be made available to different investigators. Thus, the same information may be used for several independent evaluations of pipeline impact. Additional information is required to provide an adequate evaluation of the effects of pipelines on fishery resources. Necessary research topics are indicated in subsequent sections, and it is anticipated that the additional information will be available before any pipeline application is approved.

4. The study area

The waters studied are located in roughly the northern two hundred miles of Yukon Territory (Figure 1). The Peel River system was not sampled, hence is not included in descriptions of the study area. In the southern portion of the study area, the rivers and streams flow into the Porcupine River. This river is a major tributary of the Yukon River which flows into the Bering Sea (Pacific Ocean). In the northern part of the study area, most rivers and streams drain directly into the Beaufort Sea (Arctic Ocean), although a few join the Mackenzie River at its delta.

The rivers and creeks which would be affected by presently suggested gas pipeline routes are also shown in Figure 1. As the water current would transport material downstream from the pipeline, aquatic organisms and their habitats which are upstream of the pipeline route would not be directly affected. Along the prospective coastal pipeline route, the upstream portions of the rivers and streams are south of the pipeline crossings. Along the prospective inland route, it is more difficult to describe the portions of the watershed which lie upstream of the proposed pipeline. Some rivers which are not crossed at all are essentially upstream of the prospective pipeline. Although the Porcupine River itself is not crossed by the proposed route, many of its tributaries are crossed; hence all of the Porcupine River downstream of the Bell River is also downstream of the prospective route.

The two watersheds studied have distinctive fish fauna. Grayling and char are the predominant species in flowing waters of the Beaufort drainage, whereas a much greater variety of fish species occurs in many areas of the Porcupine drainage. The Mackenzie River system has an even greater variety of fish species than does the Porcupine River (McPhail and Lindsey, 1970). Except for chinook and coho salmon, all of the species found in the Porcupine system were also found in the Mackenzie. Unlike in the Mackenzie system, however, the chum salmon run in the Porcupine River is large and very important in the subsistence fishery.

Some of the information obtained can be generalized for the watersheds of the Mackenzie and those of the northern Yukon. Aspects of the life history of a particular species may be similar in the different watersheds, although details may vary depending upon local environmental conditions. Pipeline construction in one type of fish habitat would produce similar effects in the different watersheds. Other information cannot be generalized from one watershed to another. Examples of such information are species composition, locations of spawning and rearing habitat, migration pathways, and timing of seasonal movements.

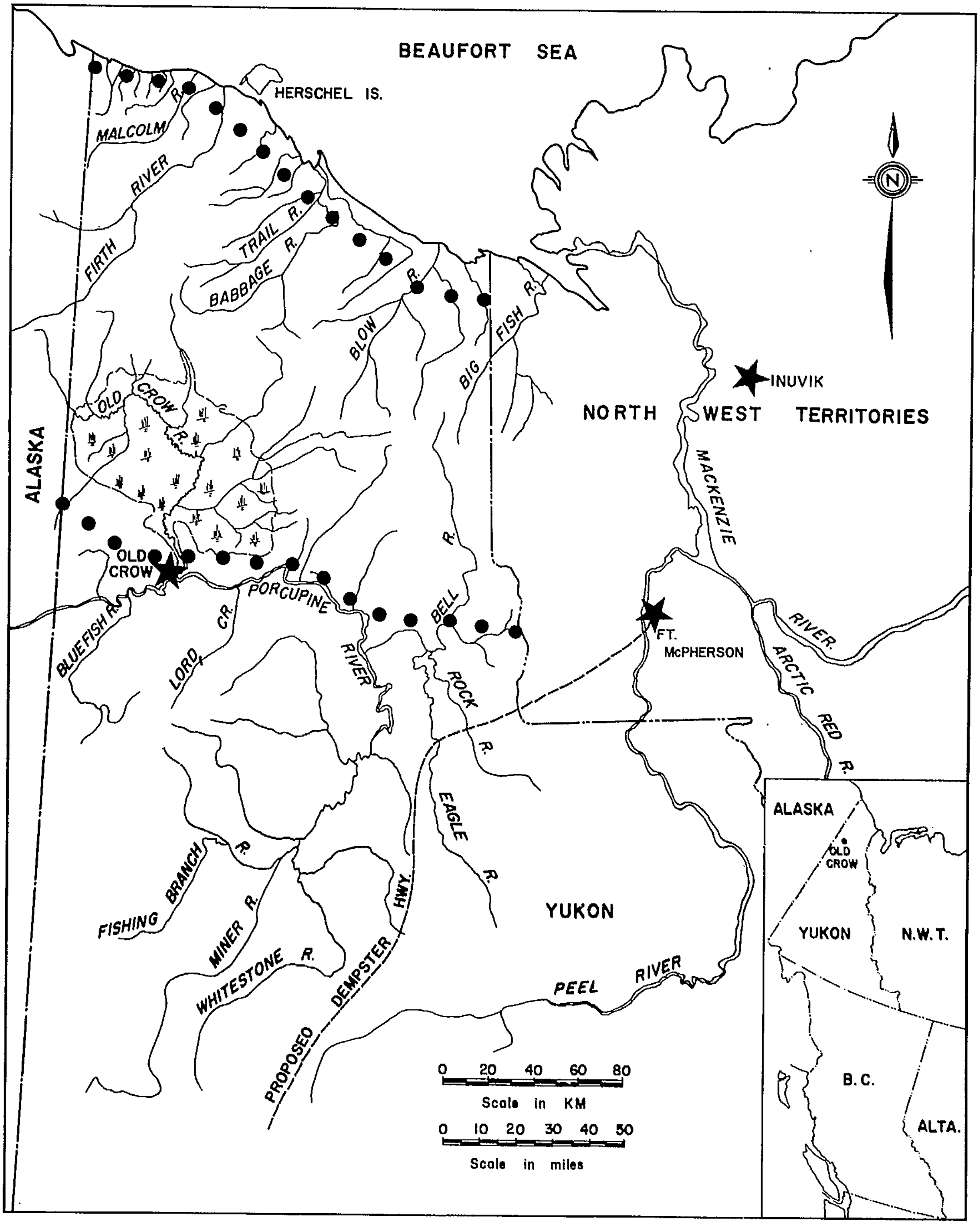

Figure 1. The study area in northern Yukon Territory. Row of dots indicate alternative routes of the prospective gas pipeline from Prudhoe Bay, Alaska.

5. Methods and sources of data

5.1 Physical and chemical characteristics

To estimate the spawning potential of the rivers and streams, the particle size of substratum present at each sampling site was recorded. The area covered by particles classified into 5 size categories ($<$ 2 mm, 2 to 50 mm, 51 to 250 mm, 251 to 10,000 mm, and $>$ 10,000 mm) was estimated visually. The substratum composition was observed over a distance of about 100 meters along the river or stream. When the water was clear, the substratum between sites was inspected from the air. The observed compositions were multiplied by the distances for which the stream beds were similar to those observed. These numbers were divided by the total distance observed to obtain the average substratum composition for a particular river. Thus the measurements of substratum composition are both subjective and approximate.

At some sites, the volume of water discharged was determined by measuring the width and estimating both current speed and mean depth of the stream. Stream width was measured with a tape or Toko Range Finder. Surface current speed was measured by timing a floating object over a known distance. The mean speed was estimated by multiplying this measurement by 0.85 (Clay, 1961: 291). Mean depth estimates were obtained by averaging water depths where the width and current speed had been measured. If wading across the river was not possible, the mean depth was sometimes guessed as indicated in the results. Distances to sampling stations were measured from a map. (scale 1:250,000). Water Management Service provided some information on water flow.

Concentrations of oxygen and total carbonate alkalinity were determined with a Hach Kit (Model Ox-2-0), and pH was measured with a Hach colorimeter. The oxygen measurements are precise within 1 ppm and the alkalinity within 10ppm. Such water samples were analyzed within an hour of collection, usually in duplicate. Other characteristics (TDS, nitrate, and phosphate concentrations) were measured on unpreserved water samples which had been stored for a maximum time of 70 days. TDS (total dissolved solid) was measured by drying and weighing. Total phosphate concentration was measured using the ascorbic acid-reduced molybdophosphoric, blue colour method (Strickland and Parsons, 1968). Nitrate concentration was measured using the modified Brucine method (Anonymous, 1967).

5.2 Suspended sediment analysis

In the Porcupine drainage, samples for suspended sediment analysis were collected in a 1-liter jar filled at the surface of the water. The samples were stored for a maximum of 4 months, then they were centrifuged, dried at 110°C, and weighed (analysis by Fisheries Research Board, Freshwater Institute Yellowknife Laboratory). Sampling suspended sediments during winter pipeline construction was attempted with a US-DH 48 Sampler (Anonymous, 1971a). The sampler froze upon removal from the water, so samples were collected with an improvised method instead (Landeen and Brandt, MS 1972). Plastic bottles (500 ml) were pushed slowly to the bottom with an iron rod then raised slowly to the surface with a string. After a maximum of one month storage, the samples were filtered through a Whatman GF/C, dried at 103°C, and weighed. (Anonymous, 1971b: 291; analysis by Fisheries Service Environmental Quality Laboratory.)

5.3 Fish samples for species composition

Unless specified otherwise, the fish samples were collected with a seine. In 1971, the most commonly used seine measured approximately 2 by 30 meters. This net had 12.6 mm mesh (stretch measure), except near the center, where there was a bunt (approximately 7 meters long) with 4 mm mesh. The length of the net was decreased in 1972, so that most samples were collected with a 2 by 21 meter seine with the same bunt and mesh sizes. Other seines used in fish collection are specified in Appendix Table 1. Generally, seine hauls were made by pulling the net with the current and landing the net so that most fish were caught in the small mesh bunt. At least 2 seine hauls covering a total area of 100 to 2000 m^2 of stream bottom were made at each collection site. Some fish were collected by angling with lures of the spinner or flasher type.

5.4 Fish samples for fry distribution.

The fish samples collected with a seine and used to describe fish distribution were also used to describe areas where fry were captured. Fish were classified as fry (fish less than one year old), by size rather than by age directly. The size to age relationships used were mainly those observed by: Hatfield *et al.*, 1971; Alt, 1969; and Magnuson and Smith, 1963. The expected size of fry was approximately corrected for the time in the growing season when the fish had been captured. Only the smallest specimen of a species was used to decide whether or not fry were present in a sample. The lengths of these fish are given in Appendix Tables 1 and 2.

5.5 Observation of winter open water areas and spawning grounds

Open water areas were located in March from a Beaver airplane. Other conditions of the rivers and creeks were observed in addition to the ice-free areas, and details about methods are presented by Steigenberger (MS 1972).

Spawning grounds were located by aerial reconnaissance during the regular sampling program. Reports of several residents of Old Crow suggested that chum salmon might spawn in the Fishing Branch River where spawning was later observed. The locations of char spawning grounds were made by personnel of Northern Engineering Services (G.J. Glova, personal communication).

5.6 Observations on winter conditions of rivers and creeks

Methods used in water chemistry sampling are the same as those described in Section 5.1 (Steigenberger, MS 1972). Except when specified otherwise, the methods for fish collection were also the same as those described previously (Section 5.3).

5.7 Seasonal movements of fish

In 1972, a program to learn more about seasonal movements of fish was initiated by marking individuals with Floy dart tags and fin clips. Fish were captured for marking with seines, trap nets, and sport fishing gear. Recapture of marked individuals was attempted in subsequent sampling, and some recoveries were made in the subsistence fishery. Information about seasonal movements was also obtained by repeated sampling of the same locations with seines and gill nets.

Between July and September 1971, fish were sampled with 2.5 by 30 meter panel gill nets with six 5-meter sections of different mesh sizes (4, 5, 7.5, 10.5, and 14 cm stretch measure). The three small mesh sizes were monofilament whereas the three larger sizes were polyfilament. These nets were set perpendicular to shore with progressively larger mesh sizes in deeper water. From July 24 to September 7, the nets were set for a 24-hour period, but after that time, they were set for periods of up to 22 days. After September 7, the nets were tended by Mr. Lazarus Charlie, a resident of Old Crow. Between October and December, 10-meter cotton gill nets (10 cm mesh) were used. After the middle of October, the gill nets were set under the ice.

Gill nets were set in the outlet of Fish Lake to determine whether whitefish were moving downstream into the Porcupine River. Three gill nets (2-,5-, and 10-cm mesh) were set in order by mesh size with the smallest mesh closest to the Porcupine River and the largest mesh closest to Fish Lake. None of the nets completely blocked the stream. The nets were set for periods of one to three days, June 10 to 15, 1972.

6. Results

6.1 Physical and chemical characteristics of the rivers and creeks.

Table 1 describes the streams sampled in the Beaufort Sea drainage. For the Babbage River, the substratum composition was only measured to three falls (maximum height 8 m; located 121 km from the mouth) which are thought to be complete barriers to fish migration in most years. The Babbage was the only river studied which had a barrier to fish migration downstream of the headwaters.

There were some differences in the nature of rivers along the coast east and west of the Babbage. Those to the west had more substratum with a greater proportion of large particles and frequently had gravel right to their mouths. The Babbage itself and most eastern rivers had substrata with a greater proportion of small particles. Most of them meandered and had mud substrata near their mouths. Substratum with particle sizes ranging from 2 to 250 mm has the best spawning potential for whitefish, grayling, char, and salmon. Rivers west of the Babbage had more potential spawning area than those to the east. In rivers along the coast, the most extensive potential spawning areas generally occurred upstream of the 50 m (200 ft) elevation. However, in Fish and Craig Creeks, the spawning areas probably occur at lower elevations as the only portions unfrozen in the winter seem to lie below the 60-m elevation.

The observed water discharge in coastal rivers ranged from 0.5 to about 71 m^3/sec (Table 1). Unpublished data of the Water Management Service indicate that the Firth River was frozen to the bottom (137 cm) May 11 and that it had discharges of 87.3 m^3/sec June 27 and 90.0 m3/sec July 25, 1972 (K.F. Davies, personal communication). These observations were made approximately 30 km from the mouth.

Table 2 describes streams sampled in the Porcupine River drainage, except for the Porcupine itself. The substratum composition of the Porcupine River is difficult to observe as the river was so turbid during the summer. Many of the bars consisted of rocks (2 to 250 mm), usually interspersed with sediment.

There were considerable differences in the size and substratum composition of tributaries to the Porcupine River (Table 2). All of the observed tributaries had gravel substratum in their upper reaches. Some of them, (Berry Creek, Bluefish River, Lord Creek, and the Driftwood River) had mainly gravel substrata right to their mouths. Others (Bell River, Rock River, Eagle River, Pine Creek, and most tributaries of the Old Crow River) were turbid and had very silty substrata near their mouths.

Table 1. Geographic location and some physical characteristics of some rivers and streams in the Beaufort Sea drainage. The substratum composition is the approximate percentage of area covered by particles of each size class estimated from the mouth to the headwaters.

River or creek	Location (latitude; longitude in degrees and minutes)	Average substratum composition					Hydrologic characteristics at specified time and place				
		0-2 mm	2-50 mm	50-250 mm	250-10,000 mm	>10,000 mm	Day and month (1971)	Distance from mouth (km)	Stream width (m)	Current speed (cm/sec)	Discharge (m^3/ sec)
Anker Cr.	68:42;137:27	30	10	30	20	10	19/8	--	--	--	--
Babbage R.	69:14;138:27	40	50	9	0	1	26/7	13	46*	--	--
Backhouse R.	69:36;140:32	10	30	60	0	0	27/7	2	8	20	0.5
Big Fish R. (western fork)	68:38;136:00	15	10	35	30	10	3/9	23	20	152	11.8
Blow R.	68:56;137:08	40	20	30	10	0	6/8	37	43	216	71.1**
Caribou Cr.	68:49;138:37	20	20	30	30	0	10/8	2	15*	--	--
Craig Cr.	69:37;140:55	10	30	60	0	0	27/7	2	8	30	0.6
Crow R.	69:09;138:15	10	20	55	14	1	18/8	11	23*	--	--
Deep Cr.	69:11;138:19	65	20	10	5	0	9/8	29	9	--	--
Firth R.	69:32;139:22	5	25	50	20	0	31/7	13	--	--	--
Fish Cr.	69:37;140:07	10	30	50	10	0	27/7	8	17	51	2.2
Fish Cr.	69:37;140:07	10	30	50	10	0	27/7	24	17	64	2.1
Fish Hole Cr.	68:47;138:45	20	17	30	25	8	6/9	19	22	61	5.2
Malcolm R.	69:33;139:37	6	22	55	16	1	29/7	39	18	70	17.9
No. 11200 Cr.	69:23;138:52	40	50	10	0	0	3/8	6	4	61	0.3
Purkis Cr.	68:44;137:26	--	--	--	--	--	6/8	37	21	183	14.6
Rapid Cr.	68:51;137:06	40	30	25	5	0	7/8	64	24	216	40.6**
Running R.	68:56;137:16	20	30	40	10	0	8/8	8	24	113	14.0
Spring R.	69:16;138:40	34	20	40	6	0	18/8	37	12*	--	--
Trail R.	69:07;138:21	10	30	50	10	0	18/8	16	20	34	1.7
Wood Cr.	68:36;138:44	0	30	40	20	10	10/8	3	12*	--	--

\- indicates missing data
* indicates estimate
** mean depth guessed

Table 2. Geographic location and some physical characteristics of some rivers and streams in the Porcupine River drainage. The substratum composition is the approximate percentage of area covered by particles of each size class estimated from the mouth to the headwaters.

		Average substratum composition					Hydrologic characteristisc at specified time and place				
River or creek	Location (latitude; longitude in degrees and minutes)	0-2 mm	2-50 mm	50-250 mm	250-10,000 mm	10,000 mm	Day and month (1971)	Distance from mouth (km)	Stream width (m)	Current speed (cm/sec)	Discharge (m^3/sec)
Bell R.	67:18;137:48	31	7	44	18	0	30/8	138	40	88	17.1
Berry Cr.	67:27;137:56	30	35	35	0	0	27/8	13	12*	--	--
Black Fox Cr.	68:04;139:34	35	50	15	0	0	29/8	39	18*	--	--
Bluefish R.	67:28;140:17	10	39	46	5	0	26/8	6	30*	--	--
Burnthill Cr.	66:42;138:09	30	20	50	0	0	2/9	10	11*	--	--
Caribou Bar Cr.	67:27;140:35	15	30	35	20	0	25/8	6	12*	--	--
Cody Cr.	66:32;138:25	20	10	60	10	0	2/9	35	6	219	4.5
Driftwood R.	67:34;138:27	13	8	57	22	0	27/8	3	13	107	7.3
Eagle R.	67:20;137:07	10	42	44	4	0	4/9	10	46*	--	--
Fishing Br. R.	66:27;138:32	15	30	45	10	0	1/9	24	55	122	42.0*
Fishing Br. R.	66:27;138:32	15	30	45	10	0	9/9	45	30	146	26.0
Johnson Cr.	67:50;139:46	55	13	32	0	0	29/8	56	12*	--	--
Johnson Cr.	66:38;138:09	25	25	50	0	0	25/8	56	18*	--	--
Lord Cr.	67:34;139:07	10	20	60	10	0	25/8	6	12	46	3.9
Lord Cr.	67:34;139:07	10	20	60	10	0	2/9	2	9	152	4.1
Miner R.	66:31;138:33	5	16	62	17	0	5/9	56	43	73	30.8
No. 21000 Cr.	67:38;138:35	15	60	25	0	0	27/8	6	6*	--	--
Old Crow R.	67:35;139:50	60	35	5	0	0	28/8	248	26	76	16.8*
Pine Cr.	66:53;137:56	15	15	70	0	0	25/8	19	15*	--	--
Rat R.	67:26;136:50	20	10	45	35	0	30/8	13	24	61	9.2
Rat Indian Cr.	67:34;138:23	20	10	70	0	0	27/8	6	6*	--	--
Rock R.	67:20;137:05	20	20	60	0	0	30/8	64	21	204	27.4
Surprise Cr.	68:18;140:24	90	10	0	0	0	23/8	45	9*	--	--
Thomas Cr.	68:11;140:39	10	80	10	0	0	28/8	27	12*	--	--
Timber Cr.	68:10;139:55	42	12	23	23	0	28/8	51	15*	--	--
Whitestone R.	66:30;138:24	8	18	46	28	0	5/9	32	137	70	145.6**

- indicates missing data; * indicates estimate; ** mean depth guessed

The discharge of the Porcupine River fluctuates considerably throughout the year. It usually reaches a maximum shortly after ice "break-up" in the spring, then decreases until the onset of fall rains (data of the Water Management Service). The discharge decreases again after "freeze-up" and usually reaches a minimum near the end of winter. During the period from 1961 to 1971, the discharge of the Porcupine River ranged from 23.3 to 6,636 m^3/sec (832 to 237,000 cfs) during the open water season and from 11.9 to 145.5 m^3/sec when covered by ice.

Table 3 presents observations made on some chemical characteristics of the streams in the northern Yukon. The oxygen concentrations observed were usually near saturation levels. Of the coastal streams, those west of the Babbage River were usually higher in pH, total alkalinity, and TDS than those to the east. Nitrate and total phosphate concentrations were also measured but were always less than the detection limits of 0.3 ppm for nitrate and 0.02 ppm for total phosphate.

Table 3. Some chemical characteristics of rivers and creeks in northern Yukon Territory, July to October of 1971. Time is given in Yukon Western Time. Dashes indicate missing observations.

River or creek	Date	Time	Temp (°C)	Oxygen concn	pH	Total alkalinity (ppm)	TDS (ppm)
Babbage R.	July 26	1000	13	10	8.5	120	130
Babbage R.	Aug. 11	1515	7	11	8.0	103	65
Bell R.	Aug. 24	1415	4	11	7.2	34	59
Bell R.	Aug. 30	1115	7	-	7.5	60	106
Blow R.	Aug. 6	1500	11	9	6.8	34	60
Big Fish R.	Sept. 3	1300	4	-	7.0	51	116
Bluefish R.	Aug. 26	1400	9	10	8.0	120	140
Cody Cr.	Sept. 2	1130	6	-	7.5	85	123
Driftwood R.	Aug. 27	1230	-	10	7.0	34	56
Eagle R.	Sept. 4	1500	6	-	6.7	29	140
Firth R.	July 31	1030	10	11	8.5	137	80
Fish Cr.	July 27	1230	14	10	8.5	-	150
Fish Cr.	Aug. 17	1900	8	11	8.0	154	150
Fish Hole Cr.	Sept. 6	1530	3	-	7.8	120	145
Fishing Branch R.	Sept. 1	1600	5	-	8.5	154	161
Fishing Branch R.	Sept. 7	1800	5	-	8.5	154	-
Fishing Branch R.	Oct. 14	1200	3	-	-	165	-
Lord Cr.	Sept. 2	1945	6	-	7.0	51	110
Malcolm R.	July 29	1200	13	11	8.5	120	145
Miner R.	Sept. 5	1200	6	-	8.0	137	184
No. 11200 Cr.	Aug. 3	1100	10	11	8.0	103	-
Porcupine R.	July 23	-	-	-	-	-	125
Porcupine R.	Aug. 22	-	-	-	-	-	100
Porcupine R.	Aug. 29	-	-	-	-	-	133
Porcupine R.	Sept. 9	-	-	-	-	-	127
Rat R.	Aug. 30	1430	6	-	6.8	17	44
Rock R.	Aug. 30	1715	7	-	8.5	120	139
Running R.	Aug. 8	1200	9	11	6.7	34	64
Whitestone R.	Sept. 5	1500	7	-	7.5	51	106

6.2 Suspended sediment levels

Suspended sediment levels were measured before and after "break-up" in the Porcupine system and during excavation of the Pointed Mountain to Beaver River Pipeline. Table 4 describes these levels in some rivers close to Old Crow. In all cases, the levels were very low before "break-up" when most of the river was covered by ice. The levels increased markedly with the increase in water discharge after the ice left the rivers. More extensive sediment measurements in the Porcupine system were made by other agencies within the Department of the Environment (Freshwater Institute of the Fisheries Research Board and Water Quality Division).

Some construction procedures for the Pointed Mountain to Beaver River gas pipeline were observed by Landeen and Brandt (MS 1972). Table 5 shows the increase in suspended sediment level resulting from excavation in the La Biche River for a pipeline crossing. Each value is the average of three measurements in the same location at different times during the digging operation. In most cases, the three measurements were very similar to each other. The data indicate that sediment concentrations increased downstream of the trenching and remained high to 410 m downstream. The maximum single concentration observed during the trenching operation was 543 ppm, and the minimum was 74 ppm. The trenching operation lasted 15 days, and installation with backfilling required 3 more days.

Backfilling the pipeline trench with the dredged substratum was observed during crossing of the Kotaneelee River in construction of the same pipeline. Table 6 shows the resulting increase in the suspended sediment concentrations. The values are the average of two samples collected from the same location at different times during the operation, which required one day; the two samples were similar to each other. During backfilling, there was little difference in suspended sediment concentration at the different distances downstream of the trench. However, the lateral distribution of suspended sediment was skewed toward one bank. The maximum concentration observed was 140 ppm. Although the upstream measurements were made 24 hours after backfilling had ceased, they would presumably have been the same during backfilling. Twenty-four hours after backfilling, the suspended sediment concentrations downstream of the trench were nearly equal to upstream values. Measureable values (13 and 18 ppm maximum) were obtained at only two sites. The total time required for trenching, installation and backfilling was 15 days. The observations in Tables 5 and 6 should not be interpreted to mean that sediment levels were necessarily higher during excavation than during backfilling as the measurements were made on different rivers.

Table 4. Suspended sediment concentration in the surface water of three rivers of the Porcupine system before and after the ice cover left the main-stem (May 27, 1972).

River	Date	Suspended sediment concentration (ppm)
Porcupine (at Old Crow)	May 12, 1972	0.40
Porcupine (at Bluefish R.)	June 13, 1972	224.
Bluefish	May 14, 1972	2.28
Bluefish	June 4, 1972	86.4
Driftwood	May 18, 1972	1.68
Driftwood	June 2, 1972	253.

Table 5. Effect of trenching for a pipeline in the La Biche River on the suspended sediment concentration at different distances downstream. The river discharge was approximately 5.6 m^3/sec (speed 92 cm/sec; width 12 m). The data were condensed from Landeen and Brandt (MS 1972).

Longitudinal direction and distance from trench	Suspended sediment concentration (ppm) in a lateral transect across river				
	Site 1	Site 2	Site 3	Site 4	Site 5
Upstream 25 m	< 1	< 1	< 1	< 1	< 1
Downstream 18 m	81	97	85	102	144
Downstream 153 m	105	124	99	453	172
Downstream 410 m	111	166	146	159	129

Table 6. Effect of backfilling a pipeline trench in the Kotaneelee River on the suspended sediment concentration at different distances downstream. The river discharge was approximately 3.5 m^3/sec (speed 30 cm/sec; width 15 m). The data were condensed from Landeen and Brandt (MS 1972).

Time of observations	Longitudinal distance and direction from trench	Suspended sediment concentration (ppm) in a lateral transect across river			
		Site 1	Site 2	Site 3	Site 4
During backfilling	Downstream 35 m	132	55	13	< 10
	Downstream 186 m	57	66	24	10
	Downstream 512 m	48	26	34	15
24 hours after backfilling ceased	Upstream 78 m	< 10	< 10	< 10	< 10
	Downstream 35 m	15	< 10	< 10	< 10
	Downstream 186 m	< 10	< 10	< 10	< 10
	Downstream 512 m	< 10	< 10	12	< 10

6.3 Fish species composition

Seven species of fish were captured in the Beaufort drainage and sixteen species were captured in the Porcupine (Table 7). The distributions of fish species within the drainages are shown in Figures 2 and 3. Stars indicate the location of sections sampled periodically throughout the summer of 1972. Locations near Old Crow were sampled during the fall and early winter as well. Additional data for the locations indicated with a star will be presented in subsequent reports. Some further information about the fish samples used in Figures 2 and 3 is presented in Appendix Table 1.

Although grayling were captured in nearly all of the coastal streams sampled (Figure 2), the proportion of grayling was usually greater in eastern rivers and creeks. Conversely, Arctic char were captured in greater proportion in western rivers and creeks such as: the Babbage River, Firth River, Malcolm River and Fish Creek. As described previously, sport fishing gear or a seine was used to collect the samples presented in Figure 2. Gill nets were occasionally used to sample fish in some coastal stream systems, although few fish were caught in them. In a lake near the mouth of No. 11200 Creek, broad whitefish were captured in the gill nets; both broad whitefish and northern pike were captured in a small lake connected with Deep Creek.

The species composition of fish in the Porcupine River drainage was more diverse than that of the Beaufort (Figures 2,3). Within the Porcupine drainage, the number of species was greatest in the Porcupine River itself and in large, turbid tributaries such as the Old Crow River, the Eagle River, and the Rock River. Grayling and sculpins occurred in the headwater regions of most streams. Round whitefish were also present in some headwater regions. Headwater regions had gravel substrata and clear water except during periods of heavy runoff. In rivers such as the Bluefish and Driftwood, which had gravel and clear water for their entire length, grayling, sculpins, and sometimes round whitefish were prevalent throughout the river. In tributaries with substrata consisting of gravel near the headwaters and silt near the mouths, the number of species increased toward the mouth.

Table 7. Common names, symbols, and scientific names of fish captured in two drainages of the northern Yukon Territory.

COMMON NAME	SYMBOL	SCIENTIFIC NAME	DRAINAGE WHERE CAPTURED Beaufort	Porcupine
Arctic char	AC	Salvelinus alpinus (Linnaeus)	X	
Arctic grayling	AG	Thymallus arcticus (Pallas)	X	X
Arctic lamprey	AL	Lampetra japonica (Martens)		X
Broad whitefish	BW	Coregonus nasus (Pallas)	X	X
Burbot	B	Lota lota (Linnaeus)		X
Chinook salmon	CK	Oncorhynchus tshawytscha (Walbaum)		X
Chum salmon	CM	Oncorhynchus keta (Walbaum)		X
Coho salmon	CO	Oncorhynchus kistuch (Walbaum)		X
Fourhorn sculpin	FS	Myoxocephalus quadricornis (Linnaeus)	X	
Inconnu	I	Stenodus leucichthys (Guldenstadt)		X
Lake chub	LC	Couesius plumbea (Agassiz)		X
Lake whitefish	LW	Coregonus clupeaformis (Mitchill)		X
Least cisco	CI	Coregonus sardinella Valenciennes		X
Longnose sucker	LS	Catostomus catostomus (Forster)		X
Ninespine stickleback	NS	Pungitius pungitius (Linnaeus)	X	
Northern pike	NP	Esox lucius Linnaeus	X	X
Round whitefish	RW	Prosopium cylindraceum (Pallas)	X	X
Slimy sculpin	SS	Cottus cognatus Richardson		X
Trout-perch	TP	Percopsis omiscomaycus (Walbaum)		X

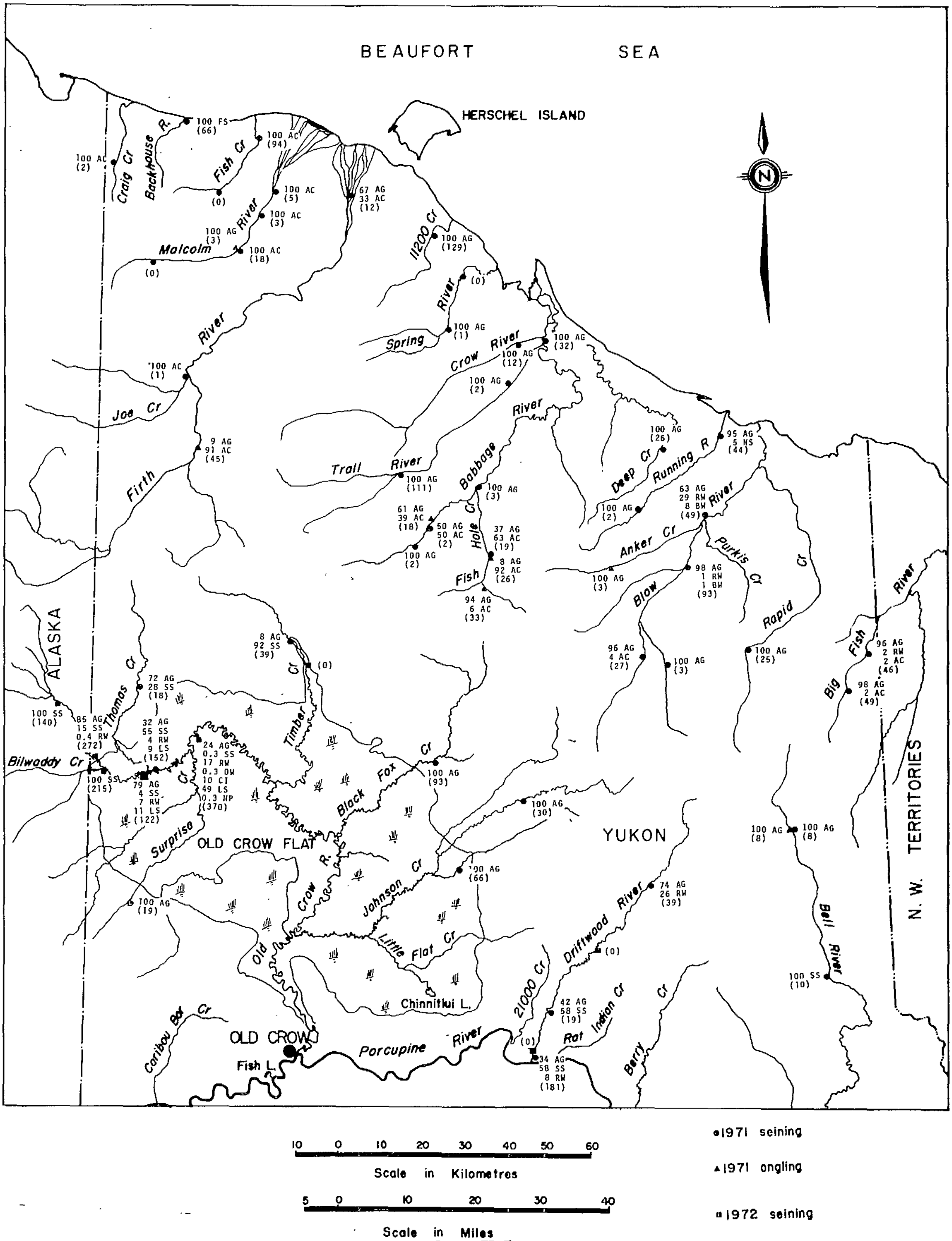

Figure 2. Fish species composition of samples collected in the northern part of the study area. Percentages are written in front of the fish species symbols which are defined in Table 7. The total number of fish in each collection is written in parenthesis.

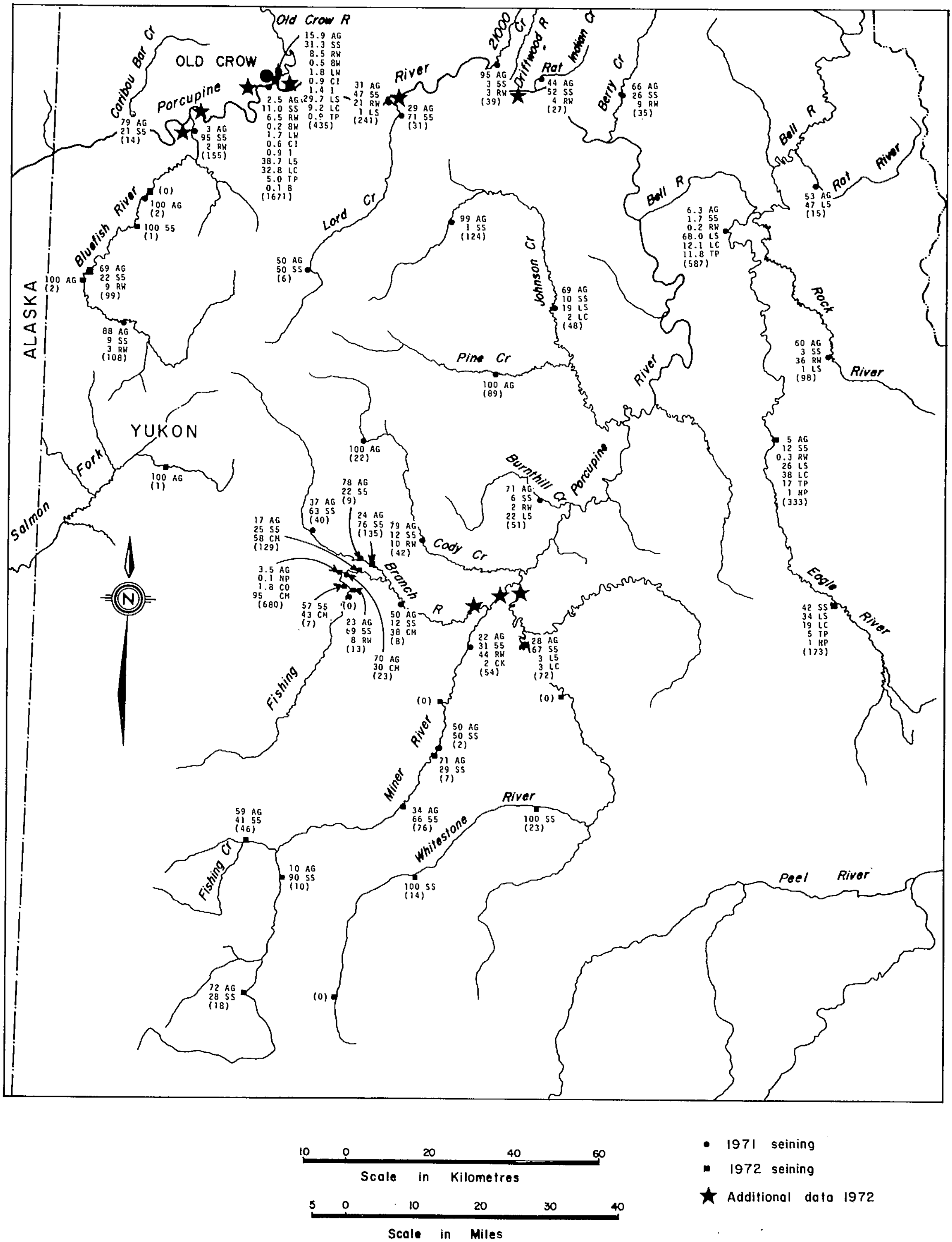

Figure 3. Fish species composition of samples collected in the southern part of the study area. Percentages are written in front of the fish species symbols which are defined in Table 7. The total number of fish in each collection is written in parenthesis.

6.4 Fry distribution in rivers and creeks

The distribution of fish fry (fish less than one year old) was observed so that the location of spawning grounds could be estimated. Figures 4 and 5 present the time and location of fry capture. As described previously, the smallest fish in a collection was used to determine the presence of fry, and the sizes of these fish are presented in Appendix Tables 1 and 2.

Figures 4 and 5 show that grayling fry were captured in most streams of both the Beaufort and Porcupine drainages. Although char fry were only captured in 3 streams of the Beaufort drainage, juveniles (1 to 2 years old) were captured in nearly every stream where char were captured. Char fry readily swam into crevices in the substratum, thus making themselves less easily captured by seines.

In the Porcupine drainage, fry of grayling, sculpins, and round whitefish were the only ones captured in headwater regions. Chum salmon fry were captured in the Fishing Branch River and a chinook salmon fry was captured in the Miner River. Fry of most other species in the Porcupine drainage were captured in areas of turbid water and silty substratum where adults and juveniles were also more abundant. Young Coregonus were captured 33 km upstream from the mouth of the Whitestone River, but the samples were lost. Northern pike fry were captured in Chinnitlui Lake (Figure 4), and they were observed in three other lakes (Cadzow Lake, Tack Lake and an unnamed lake located 67:23; 139:37). Least cisco fry were captured in Whitefish Lake (68:08; 140:15) and whitefish fry were observed in the outlet of Chinnitlui Lake. Fry of Arctic lamprey and burbot were not captured, although young of both species were captured in the Porcupine River near Old Crow. Small burbot, probably fry, were observed in the stomach of adult burbot during the fall.

6.5 Location of some spawning grounds and open water areas

Figures 6 and 7 indicate the geographic location of some areas thought to be particularly important to one or more fish species. These are not necessarily the most important of such areas, but are the only ones for which information is available at present. The open water areas are those observed March 16 to 26, 1972 (Steigenberger, MS 1972). Sections of some river systems were not observed: Blow, Big Fish, Eagle, Rock and upper reaches of the Miner and Whitestone Rivers. In addition to the location of open water, other characteristics of the rivers were observed

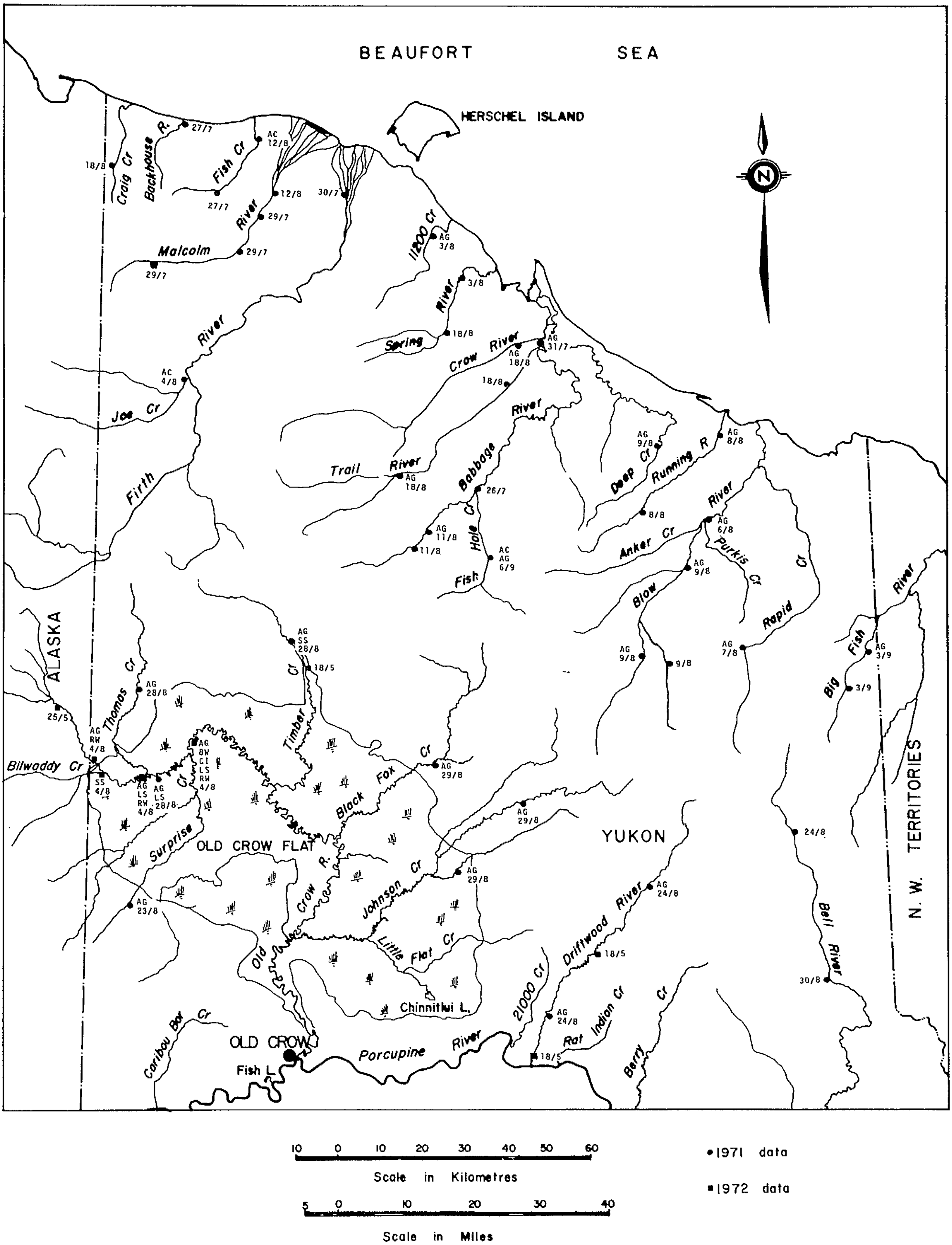

Figure 4. Locations in the northern part of the study area which were seined for fish fry. The numbers indicate the day and month of each sample. Dates alone are shown in locations where no fry were captured.

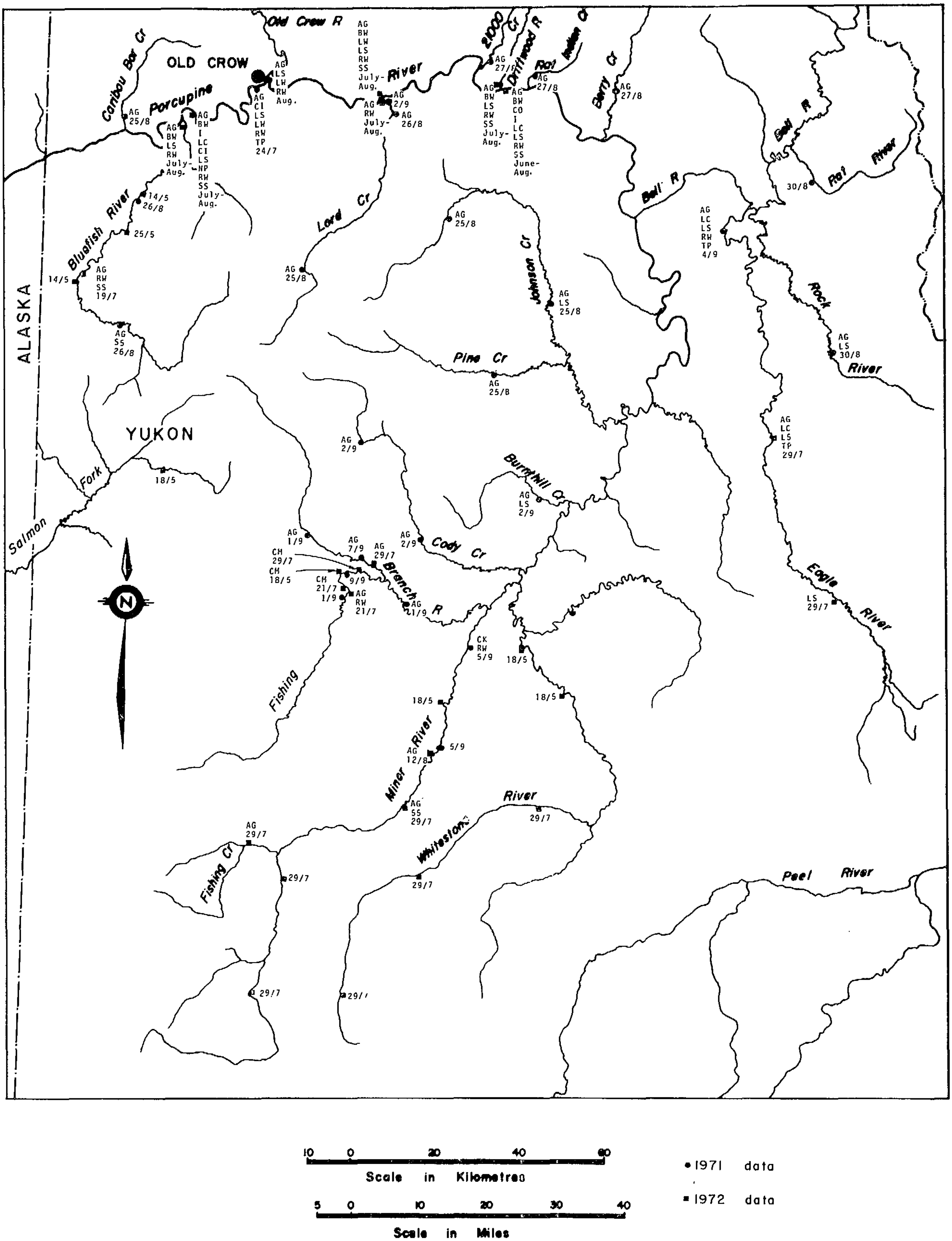

Figure 5. Locations in the southern part of the study area which were seined for fish fry. The numbers indicate the day and month of each sample. Dates alone are shown in locations where no fry were captured.

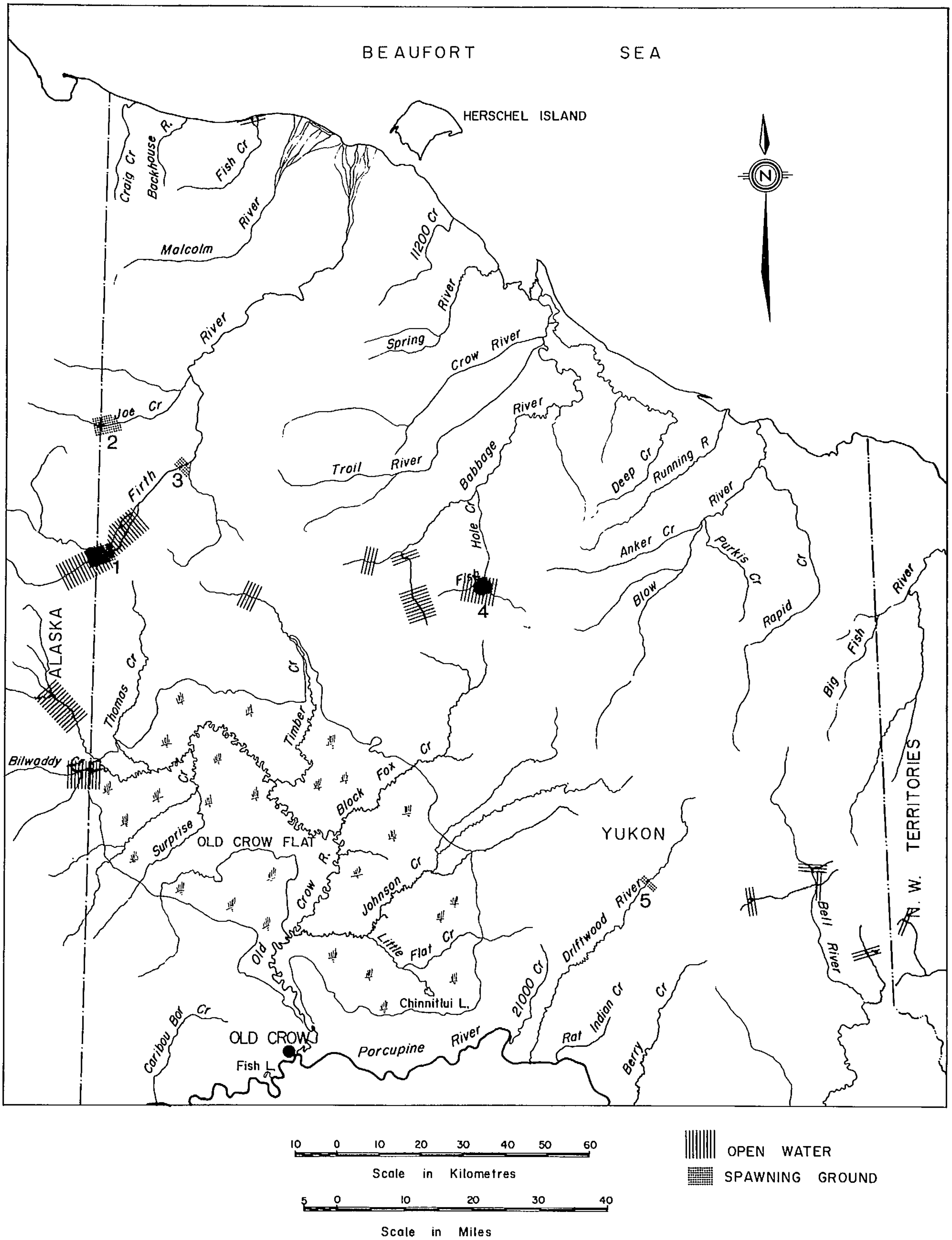

Figure 6. Locations where open in water in March 1972 or fish spawning was observed in the northern part of the study area. The evidence for each spawning ground is described in the text.

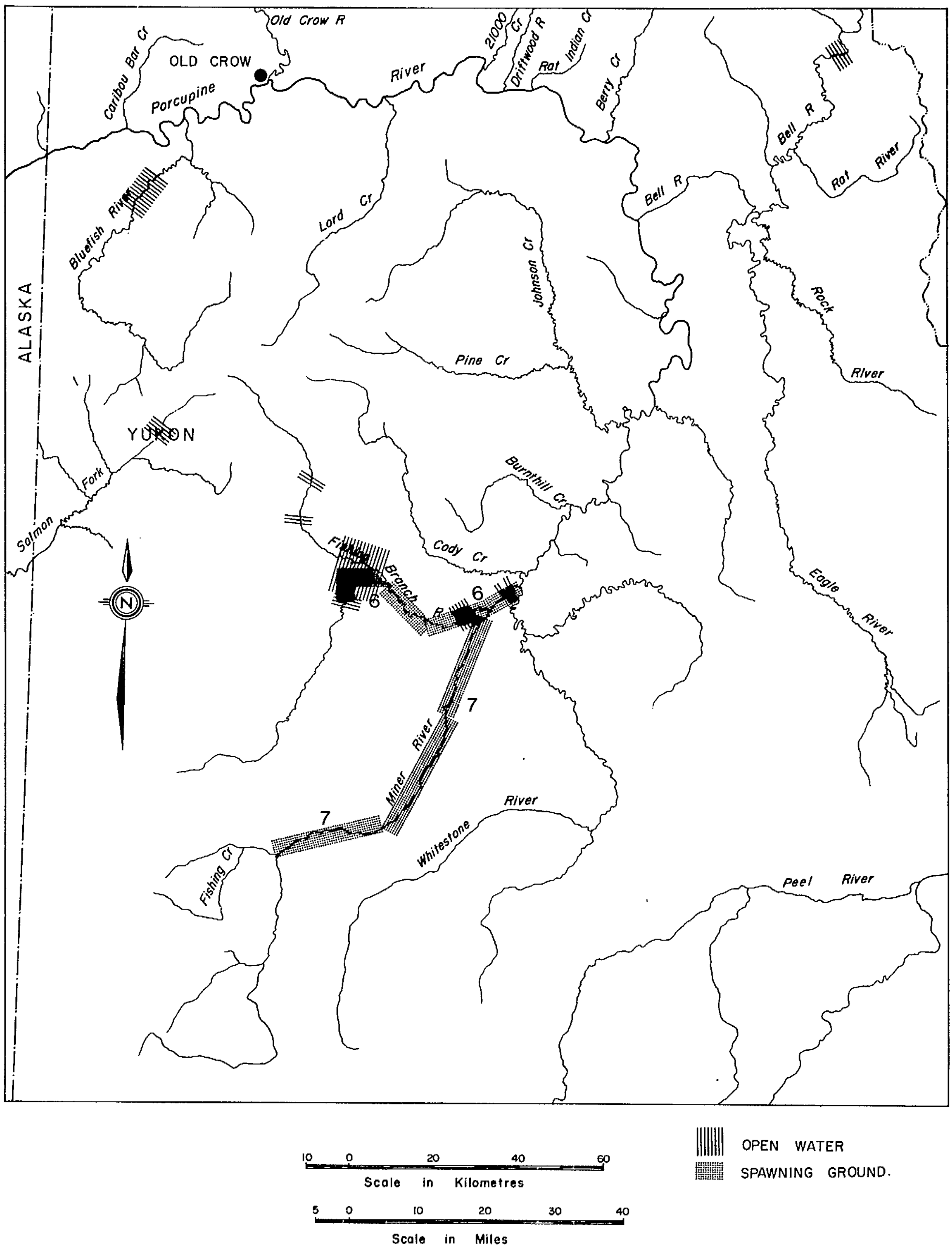

Figure 7. Locations where open water in March 1972 or fish spawning was observed in the southern part of the study area. The evidence for each spawning ground is described in the text.

which give indications about locations of ground water sources and potential overwintering habitat for fish.

Some spawning areas are indicated on Figures 6 and 7 with a symbol and a number. The evidence that each of the areas is a spawning area is described below:

Figure 6:1, 2, 3 show the locations on the Firth River system where personnel of Northern Engineering Services located large concentrations of char during the spawning season and observed spawning behavior (G.J. Glova, personal communication). Our research group captured char fry downstream of the Joe Creek area and captured adults downstream of Area 3 just prior to spawning in 1971 (Figure 2).

Figure 6:4 shows the location on Fish Hole Creek where personnel of Northern Engineering Services saw a large number of char during the spawning season and observed spawning behavior (G.J. Glova, personal communication). On August 10, 1971, our research group captured gravid char downstream of this area and, on September 6, captured spent char and char fry there (Figures 2 and 4).

Figure 6:5 shows the location on the Driftwood River where indirect evidence suggested that round whitefish were spawning August 24, 1971. Gravid, adult round whitefish were captured in this location, and an undetermined proportion of grayling also captured had eaten 100 fish eggs. Tubercles were present on one of the male round whitefish, but no observations were made on whether eggs or milt were flowing freely.

Figure 7:6 shows the location on the Fishing Branch River where chum and coho salmon were observed spawning. Redds and spawning behavior were observed (Bryan, _et al_., MS 1972; A.J. Gibson and O.D. Sweitzer, personal communication) and young of both species were collected in the area. The number of adult chum salmon which spawned in the area was estimated to be 120,000 in 1971 and 35,000 in 1972 (Elson, MS 1973).

Figure 7:7 shows the locations on the Miner River where adult chinook salmon and redds were observed. Dead salmon were also observed, one of which was examined and found to be a spent female.

6.6 Some winter conditions in the rivers and creeks

Preliminary observations in the study area were made in March 1972 (Steigenberger, MS 1972). On many rivers, the ice was very thick--143 cm on the Porcupine, for example. However, some sections of rivers had no ice cover at all (Figures 6 and 7), apparently because of groundwater upwelling. Some areas with little or no water flow had very low oxygen levels (Table 8). Even the Porcupine and Bell Rivers had oxygen concentrations far below levels observed during the open water season (Table 3). The total dissolved solids concentrations, on the other hand, were higher than those usually observed during the open water seasons. Of all the areas where fish collection was attempted in March (Table 8), the only one where fish were captured was the Fishing Branch. One hundred fifty coho salmon and 27 juvenile grayling were captured with an 8-meter seine (covering a shallow riffle area of about 300 m^2). Adult fish may have been present in deeper water nearby.

Open water areas were sampled again before the main ice sheets left the rivers in May 1972; not all such areas had been open in March. Two such areas were sampled in the Bluefish River May 14, and two juvenile grayling were captured in one area (Figure 3). Timber Creek was sampled May 18, but no fish were captured or observed. Open water of the Salmon Fork and Fishing Branch Rivers was also sampled May 18. One juvenile grayling was captured in the Salmon Fork and several species were captured in the Fishing Branch (Figure 3). During a joint sampling program with Northern Engineering Services, large numbers of non-anadromous char were captured by electro-shocking in open water of the Babbage River on May 21. In the same program, both grayling and anadromous char were caught by angling in open water areas of Fish Hole Creek. When open water areas of the Bluefish and Old Crow Rivers were sampled on May 25, only sculpins were captured (Figures 2 and 3).

6.7 Preliminary observations on seasonal movements of fish

Anadromous Arctic char migrate to the sea in the spring and return to freshwater in the fall, where they spawn and over-winter. A resident of Herschel Island reported capturing char entering the sea at the mouth of the Firth River on June 21, 1972. Our research group captured gravid adults in the Firth River as early as July 30, 1971.

The seasonal movements of freshwater fish species within the Porcupine River system are complex and undoubtedly vary with different species and environmental situations. The impression formed from talking with res-

Table 8. Some physical and chemical characteristics of water bodies sampled March 16 to 26, 1972. The data were condensed from Steigenberger (MS 1972).

Water body	Location (latitude and longitude)	Ice depth (cm)	Water depth (cm)	Water discharge (m^3/sec)	Water temperature (^oC)	Oxygen concentration (ppm)	pH	TDS (ppm)	Fishing method(s)
Bell R.	67:17;137:47	20	26	-	-0.6	4	8.5	221	Line
Lake	67:20;137:15	70	207	-	0.0	1	7.5	70	Line
Porcupine R.	67:34;139:49	143	443	-	-0.6	7	-	236	Line
Slough	66:33;138:20	62	192	-	0.0	1	7.0	250	Line
Fishing Br. R.	66:32;139:21	0	30	11.2	1.7	11	8.5	226	Seine
Firth R. (spring)	68:41;140:50	0	20	-	0.0	6	7.5	148	Gillnet and line
Firth R. (open water)	68:41;140:50	0	50	0.9	0.0	11	7.5	111	Gillnet and line
Fish Cr.(spring)	69:36;140:07	20	18	-	0.0	5	8.0	253	-

idents of Old Crow is that many grayling, whitefish, suckers and burbot migrate upstream from the main-stem Porcupine River to tributaries and lakes in the spring and downstream in the fall. In Chinnitlui Lake (Figure 6), several whitefish species and grayling were reportedly captured moving upstream in the spring and downstream in the fall. There are also reports of fish migrating downstream from some lakes in the spring.

Observations made during this study are consistent with these reports. High numbers of the adults of many species were caught with seines in open water sections of the Porcupine River before the ice sheet had left the river. Catches of fish in seines remained high for a few weeks after "break-up" and then decreased markedly. A broad whitefish tagged in Chinnitlui Lake was recaptured in the Porcupine River at Old Crow. This is consistent with reports of fall downstream movement and the possibility of over-wintering in the main-stem Porcupine.

The finding that adult fish were not captured or observed in open water areas of the Porcupine system might suggest that not many spent the winter there. However, it is possible that more fish were over-wintering in or near open water areas but were overlooked because they were hidden under cut banks and overhanging ice sheets. On October 17,1972, large concentrations of adult grayling were observed near the headwaters of the Old Crow River, which remained open all winter. Similar densities had been observed in the area during June and August, and it seems likely that these fish would over-winter in that area.

The timing of adult salmon migrations past Old Crow is indicated in Figure 8. As described in Section 5.7 gill netting procedure changed in September and again in October. The first species to be captured was chinook salmon between July 26 and August 27, 1971. Next came the chum salmon, first recorded on August 11 and last on November 27. The coho salmon was latest to appear at Old Crow. Of four fish caught, the first was on November 2 and the last on December 18. On their downstream migration, salmon juveniles and fry were captured at Old Crow between mid-May and mid-July. As no samples were collected before mid-May, it is possible that some salmon had passed by earlier.

The capture frequency of the non-anadromous species decreased in August as salmon catches increased (Figure 8). When data for non-anadromous species were considered alone for the period July 24 to September 7, no trends were apparent except for round whitefish which increased slightly in number (Bryan et al., MS 1972). As

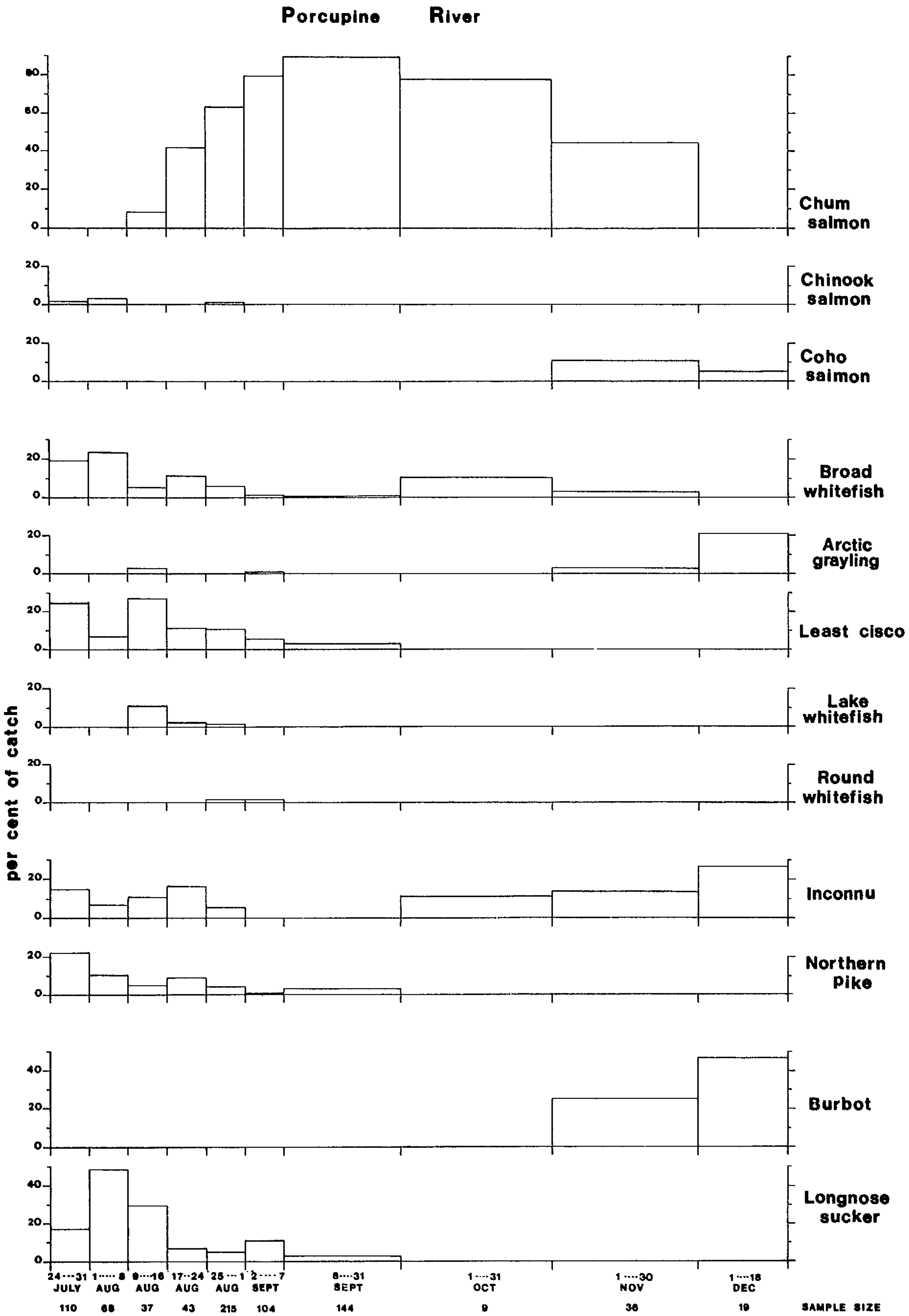

Figure 8. Species composition of fish caught in gill nets set in the Porcupine River near Old Crow at different times in 1971. The total number of all species captured is written below the abscissa.

the capture frequency of salmon decreased, the capture frequency of grayling, inconnu, and burbot increased above summer levels (Figure 8). This suggests that these fish species moved into the Porcupine to over-winter, although the gill nets and their lifting schedule were different from those used during the summer and fall, and sample sizes were small.

Gill nets were set in the outlet of Fish Lake (Figure 4) to document a report that whitefish were migrating from the lake to the Porcupine River in the spring. The sampling was undertaken about two weeks after "break-up" when water levels were very high and the mouth of the outlet was flooded. Of 11 broad whitefish collected, 10 were moving downstream at the time of capture (binomial probability < 0.006, Appendix Table 3). A total of 64 least cisco were also captured and 45 of these were moving downstream (binomial probability $<$ 0.001). A few other species (northern pike, grayling, trout-perch and suckers) were also captured but in numbers too low to determine whether their movements were directed. The broad whitefish captured had considerably more visceral fat than most others captured in the river. A large amount of visceral fat was typical of broad whitefish captured in Fish Lake later in the summer.

7. Discussion

The physical characteristics measured on most rivers and creeks in the study area were very approximate. As described in Section 5.1, the substratum composition was observed on the ground in only a few locations for each river and the measures were subjective. Even so, the measures do provide a rough description of the substrata and also allow comparison among the rivers and creeks since all observations were made by the same observers. Similarly, measurements of water discharge were made using imprecise techniques, so provide only a rough indication of the sizes of different rivers and creeks.

One inevitable result of a pipeline would be an increase in the sediment load in flowing water. A temporary increase in suspended sediment concentration would occur during construction of pipeline river crossings, and a permanent increase would probably result from erosion along the pipeline after construction. During construction of the pipeline crossing on the La Biche River, the maximum recorded suspended sediment concentration was 543 ppm; most recorded concentrations ranged from 90 to 170 ppm. The sediment concentration remained high for a total of about 18 days during the trenching operation.

Because of the sampling technique, it is likely that the suspended sediment concentrations actually present were higher than those observed (Landeen and Brandt, MS 1972). It was impossible to obtain a uniform sample from different depths or to obtain water closer to the bottom than 12 cm where the expected sediment concentration would be the greatest. In addition, some of the sample was unavoidably collected from static water within the hole in the ice. This water probably contained less sediment than the rest of the water column. Because of the possible inaccuracies in sampling method, it is important to repeat the observations on other rivers. Additional sampling would also establish the amount of variation expected among different rivers and creeks.

If it were known that the concentrations were accurate, then there would probably be no mortality of adult or juvenile fish from such excavation during the ice-free season of year. Most of the concentrations observed during the pipeline excavation were similar to those observed in the Porcupine system just after " break-up". Some juvenile salmonids survived for 3 to 4 weeks in silt concentrations of 300 to 750 ppm (Griffin, 1938, cited by Gammon, 1970). However, studies of representative northern fish species seem to be lacking as do studies on possible sublethal effects.

During the winter, it is quite possible that sediment concentrations similar to those observed in the La Biche River crossing might cause serious fish kills. The combined effect of high sediment and low oxygen concentrations might be sufficient to kill adult and juvenile fish. There may be synergism with some sub-lethal component of the water other than the low oxygen. Synergism has been found between suspended sediment and toxic chemicals (Cordone and Kelley, 1961). In addition, the physiology of the fish during the winter might make them much less resistant to high levels of sediment than during the summer. Thus bioassay experiments are necessary before unequivocal statements can be made about the direct effect of high sediment concentrations on fish in the northern Yukon.

Of more lasting consequence than sedimentation during construction is sediment from increased erosion after construction. Relatively slight increases in sediment level can markedly decrease invertebrate and fish populations (Gammon, 1970). An increase of about 80 ppm in suspended sediment concentration decreased invertebrate standing crop to 40% of its original level. The average fish biomass was three times higher in an area with sediment concentrations of 15 to 40 ppm than in an area with concentrations of 40 to 80 ppm. Fish growth rates were slower in areas of high sediment. Thus it is important to prevent erosion along the pipeline right of way and to obtain estimates of the expected increase in sediment concentration and deposition.

More information is also required about the effect of sediment on downstream spawning sites during and after construction of a pipeline. Sediment deposited on spawning areas increases salmon egg mortality, the extent of the increase depending upon the amount and timing of sedimentation (Cooper, 1956; Cordone and Kelley, 1961). Thus sediment could be detrimental to fish species which cover their eggs with gravel (salmon, char, grayling, and possibly some whitefish species). Present information suggests that northern whitefish species do not cover their eggs with gravel (McPhail and Lindsey, 1970:69), although observations of spawning behavior have not been sufficiently detailed to be certain for some species. The levels of sediment harmful to fish eggs which are not buried needs to be investigated.

The fish species composition within the study area was similar to that observed in seine hauls of Shotton (1971). One exception is that our research group observed a greater proportion of grayling and lower proportion of char in some of the coastal streams. Reasons for the difference are that Shotton (1971) sampled in different areas and sampled later in the summer. It is likely that a more intensive sampling effort near the mouths of coastal rivers would have increased the number of fish species captured. At the mouth of the Firth River, J.G. Hunter (personal communication) captured broad whitefish, inconnu, lake whitefish, least cisco, and Arctic cisco (Coregonus autumnalis).

The locations where fry were captured provide an indication of where the adult fish species spawned. Spawning grounds are presumably near or upstream of the locations where fry were captured. Although it is possible for fry to move upstream, it seems likely that the movements would occur slowly and over short distances. Inconnu fry apparently move downstream after hatching (Alt, 1969), and fry of other species probably do so as well.

As indicated in Table 9, some of the known or suspected spawning areas lie upstream of prospective pipeline routes for all species except: burbot, fourhorn sculpin, inconnu, least cisco, broad whitefish, and lake whitefish. For these species, there is insufficient information to determine whether there are upstream spawning grounds. Upstream spawning area is important because of the possibility of some unforeseen consequence of pipeline construction, such as introduction of a toxic pollutant. If such an event occurred, species with upstream spawning area would presumably have the capacity to restore their populations, although perhaps at a lower level. Even if spawning areas for all species were found upstream of prospective pipelines, it would still be important to protect spawning areas and fish which occur downstream of the pipelines. It is unfortunate that no presently known or suspected spawning area for the above species lies upstream of the prospective pipeline route as burbot and the four whitefish species are very important in the subsistence fishery.

Several spawning grounds of Arctic char are upstream of the prospective pipeline routes (Table 9). Presumably, Arctic char spawn in Fish Creek, since young char were captured there. Char eggs are usually deposited in areas of groundwater flow (G.J. Glova, personal communication), so the spawning grounds are probably near the spring or the open water area (Table 8, Figure 6). Both areas are downstream of the prospective pipeline route along the coast. Because of the association between groundwater upwelling and char spawning and over-wintering habitat, it seems likely that other such areas of groundwater flow on coastal rivers serve as char spawning areas. In the Malcolm River, char spawning probably occurs near aufeis which is upstream of the proposed pipeline route.

Table 9. Known or suspected spawning areas of fish species within northern Yukon Territory. The reference column gives the part of this report where evidence of spawning is presented or a publication which describes spawning habitat.

Species	Location	Upstream (U) or downstream (D) of prospective pipeline route	R ference
Arctic char	Firth River	U	Figure 6 (G.J. Glova
	Joe Creek	U	Figure 6 personal
	Fish Hole Creek	U	Figure 6 communication)
	Fish Creek	D	Figure 4
Arctic grayling	many rivers & creeks, particularly headwaters	U	Figures 4 and 5
Arctic lamprey	upper Bell River? gravel substratum (10-50 mm)	U	Shotton (1971) Heard (1966)
Broad whitefish	upper Old Crow R.	D	Figure 4
	Porcupine River upstream or near Driftwood River	D	Figure 5
Burbot	Shallow water under ice-over sand or clay		McPhail and Lindsey (1970:299) Fabricius (1954)
Chinook salmon	Miner River	U	Figure 7
Chum salmon	Fishing Branch R.	U	Figure 7
Coho salmon	Fishing Branch R.	U	Figure 7
Fourhorn sculpin	Soft substratum	D	Westin (1970)
Inconnu	Porcupine R, upstream or near Driftwood R.	D	Figure 5
Lake chub	Eagle River	U	Figure 5
	Porcupine River	D	Figure 5
Lake whitefish	Porcupine R. upstream or near Lord Creek	D	Figure 5

Table 9 continued.

Species	Location	Upstream(U) downstream(D) of prospective pipeline route	Reference
Least cisco	upper Old Crow R.	D	Figure 4
	Porcupine R ? downstream of Old Crow R.	D	Figure 5
	Whitefish Lake?	U	Section 6.4
Longnose sucker	Old Crow R.	U	Figure 4
	Porcupine R.	D	Figure 5
	Rock R.	U	Figure 5
	Eagle River	U	Figure 5
	Johnson Creek	U	Figure 5
	Burnthill Creek	U	Figure 5
Ninespine stickleback	dense vegetation slow current		McPhail & Lindsey (1971:309)
Northern pike	Porcupine R.	D	Figure 5
	Chinnitlui Lake	D	Section 6.4
	Cadzow Lake	U	Section 6.4
	Tack Lake	U	Section 6.4
	Unnamed Lake	U	Section 6.4
Round white-fish	Bluefish R.	U	Figure 5
	Old Crow R.	U	Figure 4
	Driftwood R.?	U	Figure 6
	Fishing Branch R.	U	Figure 5
	Miner R.	U	Figure 5
	Porcupine R.	D	Figure 5
Slimy sculpin	Bluefish R.	U	Figure 5
	Bilwaddy Creek	U	Figure 4
	Miner R.	U	Figure 5
	Timber Creek	U	Figure 5
Trout-perch	Eagle R.	U	Figure 5
	Porcupine R.	D	Figure 5

Although least cisco fry were captured in Whitefish Lake (Table 9), it is uncertain whether they had hatched in the lake or had swum up the outlet. Circumstantial evidence suggested that round whitefish may have been spawning in the Driftwood River in late August (Table 9; Figure 7). The female round whitefish captured were gravid and a male had tubercles. Grayling captured in the same location had eaten fish eggs. On the other hand, there are some reasons for doubting that the round whitefish had spawned nearby. No round whitefish fry were captured and no flow of milt or eggs was observed. The species has been reported to spawn after late October. (McPhail and Lindsey, 1970:113).

More information is required about the location of spawning areas, particularly for: inconnu, least cisco, broad whitefish, and lake whitefish. A greater sampling effort in the Porcupine River would establish the extent of the fry distributions for these species and suggest the upstream limits of their spawning. It is possible that these fish spawn in the Miner, Whitestone, or Fishing Branch Rivers, although their fry were not captured there. However, spawning in the open water area of the Fishing Branch is unlikely. A salmon counting fence was placed on the river just downstream of the salmon spawning grounds, and all fish crossing the fence were observed between September 22 and October 26, 1972. None of the above whitefish species were observed near the fence (M.S. Elson, personal communication).

It seems probable that there are a considerable number of spawning sites upstream of prospective pipeline routes for those fish species which spawn in the spring (Arctic grayling, Arctic lamprey, fourhorn sculpin, lake chub, longnose sucker, ninespine stickleback, northern pike, slimy sculpin, and trout-perch). Possible egg incubation areas for the spring spawners are not restricted by ice conditions and low oxygen concentrations as they are for fall spawners. Grayling and suckers had widespread fry distributions and published descriptions of their spawning habitat also suggest that there are many possible spawning locations for these species (Bishop, 1971; Geen, Northcote, Hartman and Lindsey, 1966). Northern pike fry were rarely captured in larger rivers. This suggests that most pike reproduction occurs in lakes and ponds where plants, the preferred spawning substratum, are prevalent (Fabricius and Gustafson, 1958). For the rest of the spring spawners, the published information on spawning habitat suggests that there are many suitable spawning sites even though our samples indicate that the fry were not widely distributed (Heard, 1966; Westin, 1970; McPhail and Lindsey, 1970: 323; Brown, Hammer, Koshinsky, 1970; McPhail and Lindsey, 1970: 309; Fabricius and Gustafson, 1958; McPhail and Lindsey, 1970:335; Magnuson and Smith, 1963).

Winter is a critical time in the life of fish in the northern Yukon and also a time when little is known about them. Attempts to locate over-wintering areas should be repeated. In the Porcupine drainage, winter open water areas should be re-examined for fish--particularly under cut-banks and ice immediately downstream of open water. One reason for thinking that over-wintering fish populations may have been overlooked is that char were located in March by Northern Engineering Services personnel in an area near that described in Table 8 (G.J. Glova, personal communication). These char were inconspicuous and difficult to capture because they sought cover under overhanging ice. As the Firth River was frozen to the bottom near the mouth (K.F. Davies, personal communication), much of the main-stem may have been unsuitable for over-wintering. Indeed, over-wintering in coastal rivers may only be possible near ground water upwellings. In the Porcupine system, the main-stem of the Porcupine River, and probably other large rivers, seems to be important over-wintering area. This is suggested by the high densities of fish in the spring and by the apparent movement of freshwater species into the main-stem in the fall.

Open water areas are important to fish during the winter even though they may not always provide over-wintering habitat. In winter, most of the water in the river systems presumably comes from areas of groundwater upwelling. The oxygen concentration is frequently low where the water percolates from the ground, but it soon reaches saturation on exposure to air in the open water region (Table 8; van Everdingen MS 1972). Such aeration is very important as the preliminary observations showed that even the Porcupine and Bell Rivers have rather low levels of oxygen in the winter.

The seasonal movement pattern for grayling and other spring spawners, seems to consist of dispersal from over-wintering areas to headwater regions for spawning and summer feeding, followed by a downstream migration in the fall. This pattern was observed by Reed (1964) for grayling in the Yukon River system near Fairbanks, Alaska. As mentioned previously, the grayling in the Old Crow River headwaters may remain near the same location all year. Although there is less direct evidence for other freshwater resident species, the pattern is probably similar to those of grayling. Fall spawners probably disperse to feeding areas in the spring and then migrate to spawning areas and to overwintering areas in the fall.

In the Porcupine system, there is undoubtedly some movement of fish between lakes and rivers. The extent and nature of such movements need to be clarified, however. Many of the lakes are only connected to rivers during periods of high water, thus restricting the times when migration would be possible. Chinnitlui Lake had an outlet which flowed until October, and preliminary observations, together with local reports, provide strong evidence that the lake did serve as a summer feeding area for grayling and whitefish. There was a high standing crop of invertebrates which made the lake very good habitat for summer feeding

Fish Lake probably had a downstream migration of broad whitefish and least cisco in the spring. The Porcupine River was in flood at the time of sampling, and it is possible that both species had merely moved upstream just before sampling and were returning to the river when captured. As the broad whitefish had such large amounts of visceral fat, it seems more likely that they had been lake resident fish and were migrating to the river. The outlet was flowing in September, but it is unknown whether fish migrated back to the lake to over-winter.

The exchange of fish between lakes and river systems needs to be investigated. Although whitefish fry (least cisco) were only captured in one lake, it is possible that some of the lakes have self-sustaining fish populations which contribute recruits to river stocks during periods of high water, when the outlets are full. If so, lakes could be very important in maintaining the river populations of some species, and many of them would provide spawning area which is upstream of proposed pipeline routes. Chinnitlui Lake seems to lack resident fish populations but affords summer feeding habitat. Lakes which have resident fish and are connected to rivers for part of the year presumably provide a refuge for some fish species. Such lakes might help restore river stocks if they were reduced by some natural event or by an unforeseen consequence of pipeline development.

8. Conclusions

Most of the information contained in this report was selected because of some application to fishery problems associated with northern pipelines. Every topic presented in the report needs substantiation through additional observation. Other research results will be presented after they are sufficiently well analyzed. The following are the main conclusions of this report:

1. Some chemical and physical characteristics of the rivers and streams were described during both the summer and winter. Oxygen concentrations under the ice were much lower during the winter than during the summer.

2. The fish species compositions were described for different regions of the study area and found to be similar to those reported by Shotton (1971).

3. Areas where fry of each species had been captured were plotted. This information was used to infer the upstream extent of spawning by most of the fish species.

4. It was possible to locate spawning grounds by direct observation for only salmonid species.

5. In the Porcupine River system, many fish species spend the winter in the main-stem. There was some over-wintering in open waters of the Fishing Branch River, and it is possible that other such areas are over-wintering habitat. In coastal rivers, some grayling and char did spend the winter near open water areas.

6. The observed seasonal movements of some freshwater resident species were a dispersal from the main-stem Porcupine in the spring and a return in the fall. Movement patterns are probably more complex, however.

7. Suspended sediment concentrations during construction of a pipeline river crossing ranged from 74 to 543 ppm. Additional observations are required to establish

whether these levels are typical and whether they are within tolerance limits for northern fish species at all seasons of year.

9. Implications and recommendations for pipeline construction, operation, and abandonment

9.1 Implications for route selection

Spawning grounds and over-wintering areas are probably the fish habitats which would be the most sensitive to effects of a pipeline. Sediment during or after construction could render them unsuitable for spawning. Therefore, a primary consideration in recommending pipeline routes is the desirability of crossing rivers downstream of spawning grounds. Over-wintering areas might also be adversely affected by a pipeline and, because they are so important to adult and juvenile survival, should be avoided.

Along the proposed coastal route, the only strongly suspected "sensitive" area which lies downstream of the route is the char spawning area of Fish Creek. However, there are char rearing areas and there may be char spawning areas on the deltas of the Malcolm and Firth Rivers which lie downstream of the route. (G.J. Glova, personal communication). Other than these, the presently known and suspected char spawning and over-wintering areas lie upstream of the route. The distribution of grayling fry indicates that most grayling spawning areas also lie upstream of the pipeline route.

The inland pipeline route might affect two important areas: the Old Crow River (and its tributaries) and the Porcupine River. Most of the Old Crow River could be affected by effluent deposited in any of its tributaries. Both rivers have fry and juvenile rearing areas and spawning grounds for some fish species. As discussed previously, all of the presently suspected spawning areas for five species important to the Indian subsistence fishery lie downstream of the pipeline route. The main-stem of the Porcupine River is an important over-wintering area for adult and juvenile fish.

At this time, the coastal route seems preferable because important Arctic char habitats are located upstream of the prospective route, and most of the important Arctic grayling habitats probably also are upstream of the route. In addition, it would be simpler to apply appropriate timing and other protective methods of construction because there are fewer fish species in the coastal streams. Although no feasibility evaluations have been undertaken, it is possible that the coastal char populations would be well suited to enhancement with hatcheries and artificial over-wintering areas, and therefore, fish losses associated with pipeline construction or operation might be compensated for by artificial means. Such a project might be required of a pipeline applicant as compensation for damage to fisheries.

Construction along the proposed inland route would be more problematical as more "sensitive" areas and a greater number of fish species occur downstream of potential crossing sites. In addition, a greater expanse of freshwater habitat would be affected by the pipeline in the Porcupine system. However, if the pipeline design and construction methods are acceptable from a fish protection point of view, then either route would probably be acceptable on the basis of potential impact on fishery resources.

9.2 Implications for timing of construction and abandonment.

The timing of construction, or abandonment of stream and river crossings is important because fish populations would be affected differently at different seasons. Where spawning grounds occur downstream of a construction site, it is important not to perform construction while eggs are incubating. Until tolerance limits are established, it is important to avoid construction when major over-wintering fish populations would be affected. Construction and abandonment operations should also be scheduled to avoid interrupting fish migrations, particularly spawning migrations. If construction is allowed to proceed during periods of fish migrations, then it would be necessary to monitor the passage of fish and to halt construction if migration is impeded. After pipeline proposals have been submitted, construction schedules can be developed which are appropriate for each crossing.

In coastal streams, the downstream char migration is probably complete by about the end of June, and the upstream migration probably begins about the last week of July. More precise information about timing will be available from Northern Engineering Services and Fisheries Service studies in subsequent years. If all of the coastal rivers freeze to the bottom at the prospective pipeline crossings, then winter might be the best time to build these crossings. If winter crossing is not feasible or if there are over-wintering fish populations downstream of prospective pipelines, then a safer time might be late June and early July, between the downstream and upstream char migrations. Another desirable time for construction would be after the upstream char migration and just before "freeze-up".

In the Porcupine system, the best time for construction of crossings might be shortly after "break-up" when over-wintering fish have dispersed and fry of fall spawners have emerged. It would be desirable to complete those tributary crossings which are close to the Porcupine River before mid-July when the Chinook salmon migration begins. Before the possibility of winter crossings in the Porcupine system can be considered, more information is required about the extent and effect of increased sediment during construction.

9.3 Safeguards during pipeline construction, operation and abandonment.

The following is a partial list of safeguards necesary to protect fishery resources. Those recommended safeguards which are unreferenced were suggested by personnel of the Pacific Region of Fisheries Service.

9.3.1. Design Phase

1. Fisheries Service should approve the location of specific crossing sites before pipeline construction. This might enable selection of sites where important fish habitat would not be disturbed or where sedimentation and erosion would be reduced.

2. Plans for construction near all water bodies should be submitted to Fisheries Service for approval at least 1 year before construction. The plans should include the pipeline design at proposed crossing sites as well as the proposed construction techniques and schedules.

3. All drawings and instructions for construction should have a fisheries protection clause written on them so that contractors know that departures from the plan which would affect fish must be approved by Fisheries Service.

4. In some cases, pipeline construction on land may be undertaken before construction of river crossings. To prevent siltation, pipeline excavation should be stopped 3 to 40 meters from the wetted perimeter of rivers or streams. The exact distance from the bank should be determined by the individual characteristics of each crossing site.

5. When upstream migrations or spawning grounds are threatened, it may be necessary to provide dry crossings for construction equipment during terrestrial construction.

6. Construction of water crossings should be schedulued to avoid any conflict with the fish of the area; construction may be prohibited at certain times and locations.

7. The pipeline design and construction methods should minimize the amount of material which would erode from the construction area and flow into any water body. Appropriate design and methods would depend upon the local soil condition, terrain, ground cover, side slopes, and weather conditions.

8. All underwater crossings should be excavated sufficiently deep that the pipe will be buried below the maximum anticipated depth of bed scour.

9. It may be necessary to backfill trenches in rivers with rocks or washed gravel when replacement of the excavated material would cause excessive siltation.

10. At some stream or river crossings, temporary wiers or cofferdams may be required to form sediment settling basins. It may be necessary to remove the sediment from some basins during construction and all sediment in the basins must be removed after completion of the crossing.

11. Stream diversion or channelization should not be allowed without a permit.

12. The following restoration should be undertaken after the pipeline installation across a water body has been completed: many of the temporary construction features should be removed; the original configuration of the stream should be restored; all debris and unused construction material should be removed from the crossing site. The methods and timing of restoration should be approved by Fisheries Service.

13. To prevent sloughing and erosion, river banks are to be stabilized in a manner appropriate for each site. Materials and procedure are to be approved by Fisheries Service.

14. Effective erosion control features are to be installed along the pipeline right-of-way (Hatfield, et al., 1972). The nature of these devices would depend upon the characteristics of the soil and terrain.

15. Construction plans for roads and equipment pads, or other construction features near streams should be approved by Fisheries Service. Gravel or rock for such construction should have a low sediment content.

16. During construction at some crossing sites, it may be necessary to provide fish passage facilities to prevent delaying or impeding the migration of fish.

17. Gravel removal should not be allowed near any water body or from any stream bed without a permit. Gravel might be removed from the flood areas of certain streams or rivers, but not from below the existing water level outside the main channel. All areas of gravel removal must be graded so that they would not trap fish when the water level recedes after periods of high water.

18. Subject to Fisheries Service approval and the following conditions, water may be removed from rivers or lakes for testing or cleaning the pipeline:

    a) The water supply at the proposed site must be sufficient that the amount of fish habitat would not be greatly reduced.

    b) The water intakes must be screened with material approved by Fisheries Service.

    c) Water discharge from the pipe must not cause excessive erosion. Discharge into water bodies would not be permitted if the water in a pipe might contain significant quantities of toxic chemicals or novel species of fish.

    d) Siltation is to be minimized during water intake and discharge.

19. Fuel storage areas must be diked with impervious material, located away from the water, and sloped away from water when possible. (Hatfield *et al.*, 1972).

20. Fisheries Service approval should be required for use of all toxic chemicals.

21. Effective contingency plans should be a requirement for the use of any toxic chemical (Hatfield, *et al.*, 1972). The appropriate personnel must be well informed about all contingency plans.

22. For oil pipelines, automatic or remotely controlled block valves should be required at all locations where fish would be particularly sensitive to oil (Hatfield, *et al.*, 1972).

23. For oil pipelines, extra thermal insulation may be required at stream crossings. Standards for thermal pollution from oil pipelines should be developed.

24. It may be necessary to require that pumping stations have storage facilities in order to pump out sections of an oil pipeline in the event of a break.

25. For an oil pipeline, contingency plans for dealing with oil from breaks or leaks should be drawn up before the pipeline is placed in operation.

9.3.2. Construction phase

26. All construction procedures must follow the plans approved by Fisheries Service. The fisheries officer on sight must be notified about any departures from the plan.

27. All companies involved in construction of the pipeline must use methods which will minimize erosion and siltation of all water bodies near the right-of-way.

28. Attempts should be made to develop standards for suspended sediment level during and after construction. The standards would be based on bioassay experiments and might be different for different seasons of operation. The standards for different crossings might vary depending upon the fish species and habitats which would be affected. During construction, changes in procedure may be necessary in order to meet the standards; after completion of the pipeline, additional erosion control features may be required to meet the standards.

29. Construction equipment should not be operated within the wetted perimeter of rivers or streams without permission of the fishery officer on sight.

30. All equipment or machinery used in construction should cross rivers and streams at a single location approved by the fishery officer on sight.

31. No excavated material or construction material should be deposited in water bodies or in a location where it would enter them during periods of high water.

32. Blasting below high water level may not be undertaken without approval of Fisheries Service.

33. Water removal should be allowed only under permit. Such control is necessary particularly during the winter when the amount of suitable fish habitat is very limited in extent. All water intakes must be screened with material approved by Fisheries Service.

34. Use of pesticides should not be allowed without a permit.

35. No waste chemical, garbage, or sewage disposal should be allowed in water (Hatfield, et al., 1972).

9.3.3. Operation Phase

The same precautions as during construction should be required for: use of chemicals, disposal of waste, and storage of fuel.

36. Periodic inspection should be made of all stream crossing sites during operation of the pipeline. Where necessary, additional erosion control features should be implemented.

37. The integrity of the pipe should be inspected to ensure that its strength is not significantly reduced by corrosion or damage.

38. For oil pipelines, contingency plans should be revised and improved continuously to take advantage of new material and procedure for clean-up (Hatfield, et al., 1972).

9.3.4. Abandonment phase

The same precautions as during construction should also be enacted during abandonment. The plan for equipment, procedure, and scheduling should be approved by Fisheries Service.

10. Needs for further study

There are at least three subject areas which require further study: ecology and life history of fish, pollution problems posed by pipelines, and stipulations required during pipeline construction and operation. Aspects which require study are outlined briefly in the following paragraphs. Specific proposals for further study will be developed at a later date.

In order to predict their location during all phases of pipeline development, better description of seasonal movement patterns is required for nearly all fish species. As discussed previously, more observations are required to locate the major over-wintering sites. Mark and recovery may indicate the migration pathways taken from over-wintering areas to spawning or feeding areas. Location of spawning grounds is one of the most important aspects of the research. This can be done in a preliminary way by capturing fry in areas which were not sampled adequately in 1971 and 1972. Fry capture should be followed up with attempts to locate adults on the spawning grounds. Further investigation should be made into reproduction of fish in lakes and migration of fish between rivers and lakes.

Observations should be repeated on construction of pipeline river crossings. More information is required about sediment concentrations and settling rates at different distances downstream of construction. Estimates should also be made of sedimentation from erosion after construction. This could be done by monitoring levels of suspended and settled sediment downstream of southern pipelines and downstream of developments similar to pipelines in permafrost areas. Bioassay experiments should be undertaken to determine effects of suspended and settled sediment on adult fish, fry, and eggs. As winter construction may be considered, the experiments should test for interaction between sediment and low oxygen and other potentially toxic characteristics of the water.

Before construction of an oil pipeline is approved, additional research should be conducted to allow prediction of consequences of oil spills in different areas. Bioassay experiments using crude oil and eggs, fry, and adults of representative northern fish species are necessary. So are studies on the transport and breakdown of oil in water; such studies are being carried out by other agencies within the Environmental-Social Program.

The list and description of stipulations and safeguards for pipelines are incomplete, and a number of subjects should be reviewed to make them complete. Proposed crossing techniques and materials should be studied in order to determine the consequences for aquatic environments and to propose alternatives when necessary. This study may suggest additional safeguards which should be implemented to protect fishery resources. Precautions enacted in similar projects, such as northern road building, should also be reviewed to develop a complete list of protective measures. The growth and catch information from the research should be used to formulate policies for sport, commercial, and subsistence fishery management to be followed during pipeline development.

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APPENDIX 1

Appendix Table 1. Information about fish samples collected in the Beaufort Sea drainage (Figures 2 and 4). For each sample and fish species, the top figure gives the number of individuals captured, and the bottom figure gives the fork length (mm) of the smallest individual captured. Asterisks indicate the lengths of fish considered to be fry (Figure 4). Seine number 1 was about 2 by 8 meters with 12.6 mm stretch-measure mesh, and seine number 2 was approximately 2 by 30 meters of mainly 12.6 mm mesh with a bunt (about 7 meters long) of 4 mm mesh.

River or creek	Date	Sample size	Time of sampling (YWT)	Location lat. & long. degrees and minutes	Seine used	Area seined (m^2)	Angling effort (man hr)	Arctic char	Arctic grayling	Broad whitefish	Fourhorn sculpin	Ninespine stickleback	Round whitefish
Anker Cr.	8/18 1971	3	1430	68:38 137:59	-	-	2		3 323				
Babbage R.	31/7 1971	32	1300	69:08 138:22	2	-	-		32 *31				
Babbage R.	26/7 1971	3	1000	68:48 138:47	1	-	-		3 243				
Babbage R.	11/8 1971	18	1300	68:44 139:02	-	-	4	7 198	11 224				
Babbage R.	11/8 1971	2	1045	68:43 139:04	2	-	-	1 149	1 *39				
Babbage R.	11/8 1971	2	1200	68:41 139:08	2	-	-		2 260				
Backhouse R.	27/7 1971	66	1330	69:35 140:32	1	-	-				66 28		
Big Fish R.	9/3 1971	46	1230	68:26 136:32	2	770	-	1 121	44 *47				1 208
Big Fish R.	9/3 1971	49	1415	68:21 136:41	2	140	-	1 135	48 129				
Blow R.	6/8 1971	23	1300	68:44 137:25	2	-	-		15 *44	4 83			4 146
Blow R.	19/8 1971	26	1200	68:44 137:25	2	-	-		16 59				10 230
Blow R.	9/8 1971	93	1045	68:37 137:33	2	-	-		91 *39	1 246			1 253
Blow R.	9/8 1971	3	1300	68:25 137:41	2	-	-		3 222				
Blow R.	9/8 1971	27	1415	68:26 137:50	2	-	-	1 112	26 *32				
Craig Cr.	18/8 1971	2	2000	69:30 140:56	2	-	-	2 214					

Appendix Table 1 continued

River or creek	Date	Sample size	Time of sampling (YWT)	Location lat. & long. degrees and minutes	Seine used	Area seined (m^2)	Angling effort (man hr)	Arctic char	Arctic grayling	Broad whitefish	Fourhorn sculpin	Ninespine stickleback	Round whitefish
		Description of samples						No. individuals (top) Length of smallest (bottom)					
Crow R.	18/8 1971	12	1545	69:07 138:32	2	-	-		12 103				
Deep Cr.	9/8 1971	26	1530	68:53 137:41	2	-	-		26 *29				
Firth R.	30/7 1971	12	1030	69:26 139:31	2	-	-	4 418	8 92				
Firth R.	30/7 1971	24	1500	68:53 140:25	-	-	5	23 424	1 354				
Firth R.	4/8 1971	21	1300	68:53 140:25	-	-	-	18 441	3 343				
Fish Cr.	27/7 1971	27	1030	69:33 140:05	1	-	-	27 170					
Fish Cr.	12/8 1971	67	1530	69:33	2	-	-	67 *58					
Fish Cr.	27/7 1971	0	1400	69:27 140:20	1	-	-						
Fish Hole Cr.	10/8 1971	26	1515	68:39 138:42	-	-	4	24 415	2 245				
Fish Hole Cr.	6/9 1971	19	1400	68:39 138:42	2	2790	-	12 *62	7 *50				
Fish Hole Cr.(Wood Cr.)	10/8 1971	33	1300	68:35 138:42	-	-	5	2 198	31 201				
Joe Cr.	4/8 1971	1	1200	69:02 140:29	2	-	-	1 *45					
Malcolm R.	12/8 1971	5	1430	69:26 139:58	2	-	-	5 99					
Malcolm R.	29/7 1971	3	1600	69:23 140:03	1	-	-	3 87					
Malcolm R.	29/7 1971	18	1400	69:19 140:11	1	-	-	18 96					
Malcolm R.	29/7	3	1300	69:19 140:11	-	-	-		3 231				
Malcolm R.	29/7 1971	0	1100	69:18 140:43	1	-	-						

Appendix Table 1 continued

		Description of samples						No. individuals (top) Length of smallest (bottom)					
River or creek	Date	Sample size	Time of sampling (YWT)	Location lat. & long. degrees and minutes	Seine used	Area seined (m^2)	Angling effort (man hr)	Arctic char	Arctic grayling	Broad whitefish	Fourhorn sculpin	Ninespine stickleback	Round whitefish
No.1120 Cr.	3/8 1971	129	1300	69:21 138:59	2	-	-		129 *29				
Rapid Cr.	7/8	25	1200	69:02 137:13	2	-	-		25 *33				
Running R.	8/8 1971	44	1100	68:54 137:20	2	-	-		42 *31			2 32	
Running R.	8/8 1971	2	1430	68:45 137:49	2	-	-		2 63				
Spring R.	3/8 1971	0	1615	69:15 138:51	2	-	-						
Spring R.	18/8 1971	1	1415	69:08 138:57	2	-	-		1 68				
Trail R.	18/8 1971	2	0915	69:01 138:34	2	-	-		2 322				
Trail R.	18/8 1971	111	1230	68:50 139:13	2	-	-		111 *45				

Appendix Table 2. Information about fish samples collected in the Porcupine River drainage (Figures 2 to 5). For each sample and fish species, the top figure gives the number of individuals captured and the bottom figure gives the fork length (mm) of the smallest individual captured. Seines 1 and 2 are the same as in Appendix Table 1. Seine 3 was approximately 2 by 21 meters of mainly 12.6 mm mesh with a bunt (about 7 meters long) of 4 mm mesh. Seine 4 was 1 by 10 meters of 4 mm mesh.

Description of samples								Number of individuals (top figure, except **) and fork length (mm) of smallest individual (bottom figure)														
				Location																		
River or creek	Date	Sample size	Time (YWT) of sampling	Latitude Longitude deg. & min.	Seine used	Area seined (m^2)	Angling (man-effort hours)	Arctic grayling	Slimy sculpin	Round whitefish	Broad whitefish	Lake whitefish	Least cisco	Inconnu	Longnose sucker	Lake chub	Trout - perch	Northern pike	Burbot	Chinook salmon	Chum salmon	Coho salmon
Bell R.	30/8 1971	10	1015	67:44 136:50	2	1870			10 57													
Bell R.	24/8 1971	8	1400	68:03 137:00	2	-		8 334														
Bell R.	24/8 1971	8	1300	68:03 137:00	-	-	1	8 338														
Berry Cr.	27/8 1971	35	1530	67:33 137:53	2	280	-	23 *45	9 27	3 178												
Bilwaddy Cr.	4/8 1972	215	1830	68:11 140:55	4	290			215 *11													
Black Fox Cr.	29/8 1971	93	1500	68:13 139:02	2	373		93 *32														
Bluefish R.	26/8 1971	155	1945	67:28 140:14	2	455		4 *47	148 21	3 62												
Bluefish R.	** 1972	**	-	67:28 140:14	4	**		**7 *17	**8 *14	**7 *30	**7 *39											
Bluefish R.	14/5 1972	0	1530	67:20 140:27	2	523																
Bluefish R.	26/8 1971	2	1145	67:19 140:29	2	246		2 291														
Bluefish R.	25/5 1972	1	1130	67:16 140:33	3	397			1 96													
Bluefish R.	19/7 1972	99	0930	67:09 140:47	4	1100		68 *26	22 *12	9 *40												
Bluefish R.	14/5 1972	2	1300	67:09 140:48	2	728		2 71														
Bluefish R.	26/8 1971	108	1315	67:03 140:35	2	1350		95 *43	10 *16	3 70												
Burnthill Cr.	2/9 1971	51	1345	66:41 138:18	2	209		36 *37	3 35	1 251					11 *33							
Caribou Bar Cr.	26/8 1971	14	1000	67:30 140:35	2	280		11 *51	3 25													
Cody Cr.	2/9 1971	42	1100	66:36 138:55	2	372		33 *41	5 29	4 175												
Cody Cr.	2/9 1971	22	0930	66:49 139:15	2	279		22 *27														
Driftwood R.	** 1972	**	-	67:34 138:29	4	**		**7 *22	**7 *15	**7 *42	**7 *39				**8 *18							
Driftwood R.	27/8 1971	181	1000	67:34 138:29	2	1628		61 *42	105 23	15 60												
Driftwood R.	18/5 1972	0	1830	67:35 138:29	3	252																
Driftwood R.	24/8 1971	19	1045	67:40 138:25	2	167		8 *45	11 21													
Driftwood R.	18/5 1972	0	1730	67:48 138:08	3	262																
Driftwood R.	24/8 1971	39	1315	67:57 137:48	2	467		29 *50		10 253												
Eagle R.	4/9 1971	587	1330	67:15 137:18	1	512		37 *38	10 27	1 *47					399 *22	71 *20	69 *19					

Appendix Table 2 continued

River or creek	Date	Sample size	Time (YWT) of sampling	Location: Latitude longitude deg. & min.	Seine used	Area seined (m^2)	Angling (man-effort hours)	Arctic grayling	Slimy sculpin	Round whitefish	Broad whitefish	Lake whitefish	Least cisco	Inconnu	Longnose sucker	Lake chub	Trout - perch	Northern pike	Burbot	Chinook salmon	Chum salmon	Coho salmon
Description of samples								Number of individuals (top figure, except **) and fork length (mm) of smallest individual (bottom figure)														
Eagle R.	29/7 1972	333	2100	66:49 137:04	3	1440		17 *32	39 18	1 230					88 *18	127 *12	58 *17	3 113				
Eagle R.	29/7 1972	173	2030	66:27 136:45	3	748			73 17						58 *18	33 80	8 56	1 254				
Fishing Branch R.	1/9 1971	8	1530	66:28 139:02	2	300		4 *49	1 35												3 625	
Fishing Branch R.	29/7 1972	135	0930	66:32 139:13	3	1410		32 *25	103 24													
Fishing Branch R.	7/9 1971	9	0930	66:33 139:15	2	100		7 -	2 -													
Fishing Branch R.	1/9 1971	40	1415	66:36 139:33	2	519		15 *39	25 18													
Fishing Branch R.	29/7 1972	129	1000	66:31 139:16	3	1300		22 93	32 28												75 *33	
Fishing Branch R.	7/9 1971	23	1730	66:32 139:21	2	468		16 294													7 -	
Fishing Branch R.	18/5 1972	680	1215	66:31 139:22	2	1120		24 64										1 87			643 *29	12 84
Fishing Branch R.	21/7 1972	7	1900	66:30 139:20	3				4 31												3 *34	
Fishing Branch R.	21/7 1972	13	2000	66:29 139:20	3	374		3 *28	9 37	1 *52												
Fishing Branch R.	1/9 1971	0	1800	66:28 139:20	2	562																
Fishing Cr.	29/7 1972	46	1400	66:28 139:20	3	617		27 *25	19 29													
Johnson Cr.	29/8 1971	66	1100	67:59 138:54	2	688		66 *35														
Johnson Cr.	29/8 1971	30	1230	68:08 138:32	2	1250		30 *44														
Johnson Cr.	25/8 1971	48	1315	67:06 138:15	2	372		33 *43	5 33						9 *32	1 99						
Johnson Cr.	25/8 1971	124	1130	67:17 138:50	2	419		123 *37	1 75													
Lord Cr.	** 1972	**	-	67:32 139:09	4	**		**7 *24		**8 *46												
Lord Cr.	2/9 1971	241	1915	67:32 139:09	2	216		74 *42	114 25	51 *54					2 47							
Lord Cr.	25/8 1971	31	0815	67:31 130:07	2	372		9 *49	22 19													
Lord Cr.	25/8 1971	6	1000	67:10 139:36	2	186		3 *42	3 23													
Miner R.	5/9 1971	54	1230	66:22 138:42	1	882		12 56	17 43	24 *52										1 *78		
Miner R.	18/5 1972	0	1515	66:14 138:50	2	1120																
Miner R.	5/9 1971	2	1130	66:09 138:52	1	372		1 56	1 61													
Miner R.	12/8 1972	7	1500	66:08 138:53	1	374		5 *43	2 32													
Miner R.	29/7 1972	76	1245	66:02 139:03	3	1400		26 *30	50 *10													
Miner R.	29/7 1972	10	1500	65:52 139:40	3	653		1 333	9 33													
Miner R.	29/7 1972	18	1530	65:37 139:49	3	374		13 281	5 23													

Appendix Table 2 continued

Description of samples — Location

Number of individuals (top figure, except **) and fork length (mm) of smallest individual (bottom figure)

River or creek	Date	Sample size	Time (YWT) of sampling	Latitude longitude deg. & min.	Seine used	Area seined (m²)	Angling (man-effort hours)	Arctic grayling	Slimy sculpin	Round whitefish	Broad whitefish	Lake whitefish	Least cisco	Inconnu	Longnose sucker	Lake chub	Trout - perch	Northern pike	Burbot	Chinook salmon	Chum salmon	Coho salmon
No.21000 Cr.	27/8 1971	39	0915	67:37 138:34	3	209		37 *44	1 81	1 122												
Old Crow R.	4/8 1972	370	2030	68:16 140:24	4	304		88 *31	1 22	62 *48	1 *35		35 *32		182 *19			1 91				
Old Crow R.	28/8 1971	152	1115	68:11 140:37	2	2920		49 *47	84 26	6 74					13 *28							
Old Crow R.	4/8 1972	122	1550	68:11 140:42	4	675		96 *30	5 17	8 *50					13 *25							
Old Crow R.	4/8 1972	272	1930	68:13 140:59	4	650		230 *35	41 24	1 *48												
Old Crow R.	25/5 1972	140	1900	68:20 141:11	3	560			140 17													
Pine Cr.	25/8 1971	89	1430	66:57 138:33	2	233		89 *35														
Porcupine R.	** 1972	**	–	67:30 140:12	3	**		**7 *40	**7 *11	**7 *25	**7 *48		**8 *44	**8 *77	**8 *16	**8 *15	**7 25	**8 *57				
Porcupine R.	† 1971	1671	–	67:34 139:51	2	–		42 *38	183 22	108 *43	4 78	28 *49	10 *49	15 94	647 *19	548 27	84 *12		2 89			
Porcupine R.	† 1971	435	–	67:35 139:49	2	–		69 *48	136 24	37 *56	2 105	8 *56	4 72	6 78	129 *23	40 26	4 64					
Porcupine R.	** 1972	**	–	67:33 139:09	3	**		**7 *26	**7 *13	**7 *46	**7 *49	**8 *59		**8 98	**7 *18		**8 17					
Porcupine R.	** 1972	**	–	67:33 138:30	3	**		**8 *37	**7 *13	**8 *49	**7 *42			**7 *45	**8 *21	**7 *14						**6 *38
Rat R.	30/8 1971	15	1400	67:21 136:46	2	635		8 351							7 374							
Rat Indian Cr.	27/8 1971	27	1415	67:35 138:20	2	210		12 *54	14 51	1 70												
Rock R.	30/8 1971	98	1700	66:59 136:44	2	521		59 *51	3 31	35 62					1 *28							
Salmon Fork R.	18/5 1972	1	1100	66:45 140:20	2	336		1 60														
Surprise Cr.	23/8 1971	19	1830	67:54 140:45	2	93		19 *36														
Thomas Cr.	28/8 1971	18	1245	68:22 140:45	2	279		13 *56	5 45													
Timber Cr.	18/5 1972	0	1330	68:25 139:45	3	130																
Timber Cr.	28/8 1971	39	1530	68:28 139:52	2	335		3 *36	36 *17													
Whitestone R.	18/5 1972	72	1700	66:22 138:24	2	1870		20 155	48 25						2 38	2 49						
Whitestone R.	18/5 1972	0	1600	66:16 138:10	2	460																
Whitestone R.	29/7 1972	23	1800	66:02 138:18	3	875			23 26													
Whitestone R.	29/7 1972	14	1730	65:52 138:58	3	430			14 26													
Whitestone R.	29/7 1972	0	1630	65:37 139:21	3	196																

* Denotes lengths of fish classified as fry in Figures 4 and 5.
** Indicates samples which were collected periodically during 1972. For each sample and species, the top figure designates the month when thesmallest specimen (bottom figure) was captured.
† Indicates samples collected periodically during 1971.

Appendix Table 3.

Movement direction of whitefish captured in three gill-nets (2-, 5-, and 10-cm mesh) set in the outlet of Fish Lake within 100 meters of the Porcupine River. Six least cisco were so badly tangled that their movement direction could not be determined, and these were excluded from the analysis.

Species	Date	Direction of movement when captured		binomial probability	Range in fork length (mm)	
		Downstream	Upstream	(1-tailed)	Min.	Max.
broad	June 10	2	0	-	470	485
whitefish	11	1	0	-	462	462
	12	2	0	-	381	467
	15	5	1	0.109	81	472
TOTAL		10	1	0.006		
least	June 12	33	12	0.002	212	336
cisco	15	12	7	0.18	227	341
TOTAL		45	19	0.001		

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