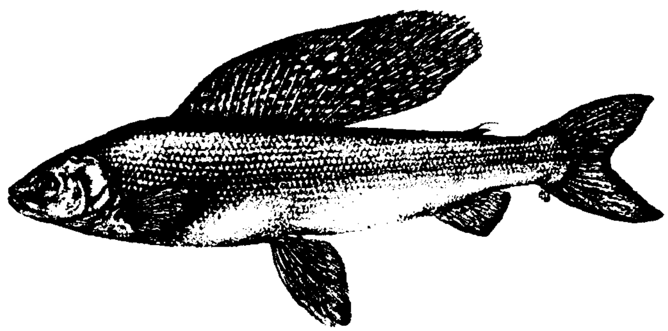
TUNDRA STREAM FISH HABITAT INVESTIGATIONS IN THE NORTH SLOPE OILFIELDS

By

Carl R. Hemming

Technical Report 93-1



Alaska Department of Fish & Game
Habitat and Restortion Division

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Frank Rue
Director
Habitat and Restoration Division
P.O. Box 25526
Juneau, Alaska 99802-55265

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INTRODUCTION

The Alaska North Slope was opened to petroleum development after the 1968 oil discovery. With this development came a substantial demand for gravel to construct the access roads, drill pads, camps, and other facilities necessary for oil and gas production. Direct impacts to aquatic habitat resulted from gravel fills in Arctic tundra wetlands and the excavation of gravel extraction sites in floodplain areas. Nineteen large multi-user gravel sites were developed to provide material for construction of oilfield infrastructure. These excavations cover 324 ha (800 ac) and are located in or adjacennt to North Slope river and stream systems. In an effort to mitigate impacts to aquatic habitat we identified gravel extraction areas as a priority for North Slope research. Research has been directed toward increasing our understanding of the physical, chemical, and biological characteristics of deep mined gravel extraction reservoirs. The objective is to promote the development and implementation of effective methods for reclaiming abandoned gravel extraction sites as fish and wildlife habitat, while providing a source of water for oil and gas exploration and development.

In 1986 the Alaska Department of Fish and Game (ADF&G) initiated field investigations of selected flooded gravel mine sites in the North Slope oilfields. These initial studies provided information on the physical, chemical, and biological characteristics of deep water impoundments resulting from gravel extraction. More recent field investigations have focused on evaluation of completed physical enhancement projects and the experimental introduction of Arctic grayling (*Thymallus arcticus*) at Kuparuk Mine Site B. The results of these field investigations are presented in a series of Habitat Division Technical Reports (Hemming 1988, Hemming et al. 1989, Hemming 1990, Winters 1990, Hemming 1992a).

This progress report summarizes results of tundra stream fish sampling in the Prudhoe and Kuparuk Units of the North Slope oilfields and water quality investigations at the Put 27 Mine Site and Kuparuk Mine Site B and D. Information on experimental introductions of grayling to Kuparuk Mine Site B and D is presented in separate reports (Hemming 1992b). The objectives of the tundra stream fish sampling and water quality investigations conducted in 1991 and 1992 are as follows:

(1) To determine the species composition and length frequency distribution of fish using tundra stream systems at various times during the open water season.

(2) To compare the species composition and relative abundance of fish in tundra streams with connected flooded gravel sites versus comparable stream systems without deep water mine sites.

(3) To evaluate the water quality characteristics of Put 27 and Kuparuk Mine Site D.

In 1991 the field program shifted focus from flooded gravel mine sites to tundra stream systems. We collected data on fish use of tundra streams with deep water areas resulting from gravel removal projects and similar tundra stream systems without deep water habitat. Future habitat enhancement projects will provide additional deep water habitat in some of the tundra streams investigated. Data presented in this report can be used to predict changes in fish community structure that may occur following construction of the proposed projects.

STUDY AREA

Prudhoe Bay Unit

In the Prudhoe Bay Unit we sampled three tundra stream systems: the Putuligayuk (Put) River, the Little Put River, and Washout Creek (Figure 1). A description of each of these stream systems is presented below.

Putuligayuk River

The Put River is a tundra stream system that originates in lakes located south of the Prudhoe Bay Oilfield. The 64 km stream system drains a 455 km^2 area and flows in a northeast direction emptying into Prudhoe Bay (Figure 1). Previous gravel mining in the lower 8 km of the Put River has altered the morphology of this stream reach. For example a 9.5 ha pool with an average depth of 3.8 m is located downstream of the Drill Site 15 Access Road. This pool resulted from instream gravel excavation during the early development of the Prudhoe Bay Oilfield. Our previous investigations

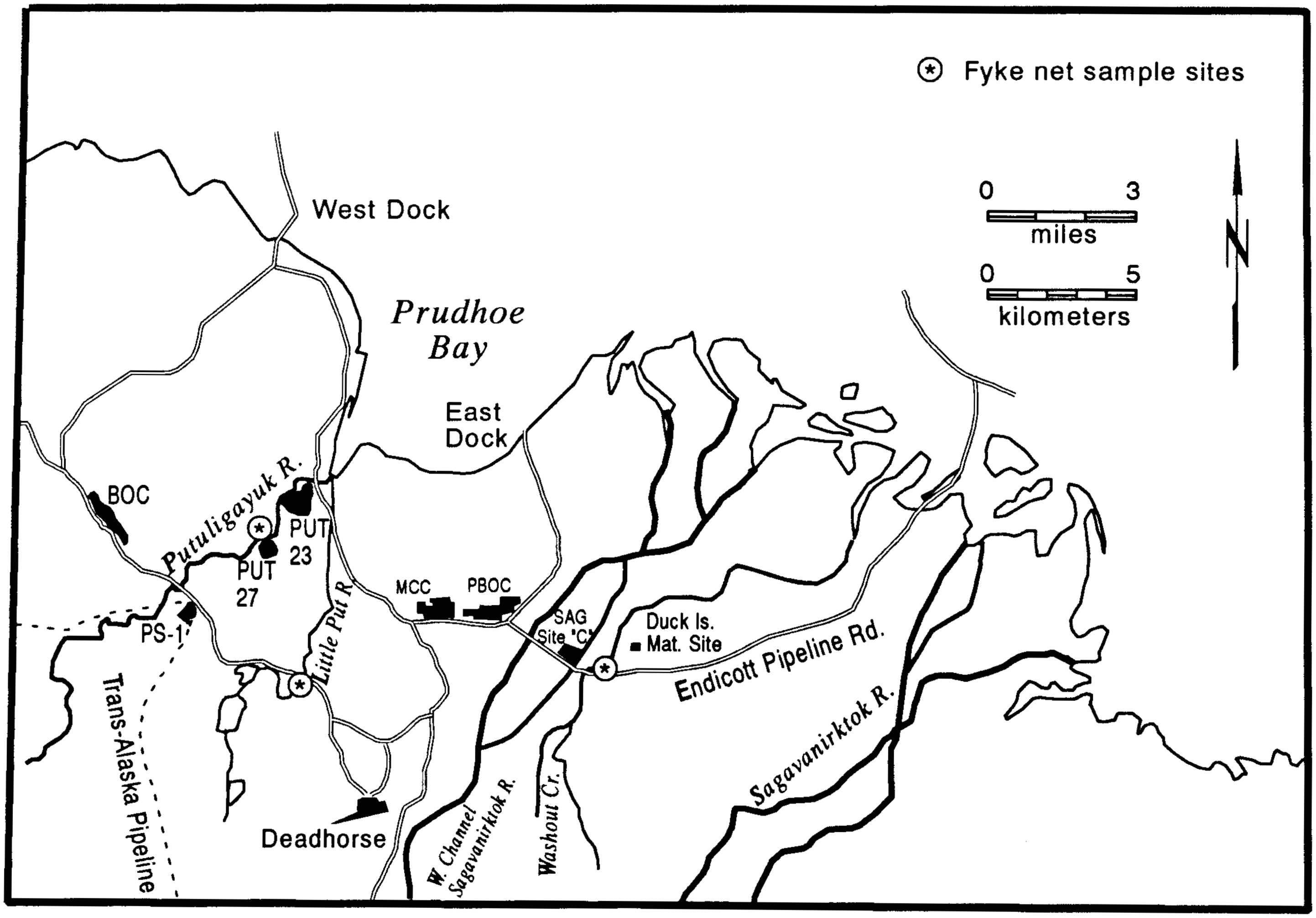

Figure 1. Map of Prudhoe Bay Unit tundra streams and fish sampling sites, 1991 and 1992.

documented winter use of this deep pool by round whitefish (*Prosopium cylindraceum*), and ninespine stickleback (*Pungitius pungitius*) (Hemming 1990).

In 1990 a channel was constructed between the Put River and a 14.2 ha deep mined gravel site known locally as Put 27. This project allowed water from the Put River to fill the deep basin and substantially increased the amount of deep water habitat in the lower Put River. We sampled the Put 27 Mine Site during the 1990 open water season and captured nine species of fish including those with marine, anadromous, and freshwater life history patterns. Fish species captured in Put 27 were: grayling, Arctic cisco (*Coregonus autumnalis*), broad whitefish (*Coregonus nasus*), Dolly Varden (*Salvelinus malma*), fourhorn sculpin (*Myoxocephalus quadricornis*), least cisco (*Coregonus sardinella*), ninespine stickleback, rainbow smelt (*Osmerus mordax*), and round whitefish (*Prosopium cylindraceum*) (Hemming 1992).

Recommendations on quantities of water available from Put 27 for winter use were developed. Using the assumption that 20% of the water could be removed without jeopordizing wintering fish, we estimated that 300 k m^3 (80 M gal) would be available for various industrial uses.

Put 23, a 42 ha active gravel extraction area is located 0.8 km downstream from Put 27. An area adjacent to Put 23 is an active landfill site operated by the North Slope Borough. The draft rehabilitation plan for Put 23 includes a channel connection between the deep gravel extraction basin and the Put River.

Little Putuligayuk River

The Little Put River is a small tundra stream that originates in the coastal plain south of the oilfield. This stream flows through a series of shallow tundra lakes in the vicinity of Drill Site 14 (Figure 1). The Little Put River empties into the Put River estuary one km upstream from Prudhoe Bay. No previous fish sampling has been conducted in the Little Put River system.

Washout Creek

Washout Creek is a small side channel located in the Sagavanirktok (Sag) River Delta east of the west channel (Figure 1). Washout Creek drains a tundra area and crosses the Drill Site 16 and Endicott Access Roads and flows adjacent to Drill Site 9.

Discharge in Washout Creek is extremely variable with peak flow occurring shortly after breakup in early June and lasting one to two weeks. In July and August discharge may decrease to a point where surface flow becomes discontinuous. Stream flow in Washout Creek is controlled by the Sag River West Channel and fish distribution in Washout Creek is dependant upon seasonal movements from the Sag River. Although no previous fish sampling has been conducted in Washout Creek, grayling and ninespine stickleback have been observed (Ott 1989).

Washout Creek is located 300 m west of the Endicott Duck Island gravel mine site. The proposed rehabilitation plan for the 42.9 ha (106 ac) mine site includes a connection channel between Washout Creek and the excavated basin. This project will substantially increase the amount of deep water habitat in the Washout Creek system.

Kuparuk Unit

In 1991 and 1992 we sampled six tundra streams in the Kuparuk Unit. The steams sampled were: Kalubik Creek, Ugnuravik River, East Creek, Sakonowyak River, Smith Creek, and Pebble Creek (Figure 2). A description of each of these systems is presented below.

Kalubik Creek

Kalubik Creek is a beaded tundra stream that flows into the Beaufort Sea at a location 5.5 km east of the western most distributary channels of the Colville Delta (Figure 2). Kalubik Creek drains a 72 km^2 tundra area which produces an average peak discharge of approximately 14 m^3/s in early June. By July discharge generally decreases to 0.3 m^3/s or less and discontinuous flow often occurs by late summer (Drage et al 1983). Ice cover forms by mid-September in most years and flow ceases during the winter.

Previous fish sampling documented the presence of grayling, Arctic cisco, least cisco, broad whitefish, and ninespine stickleback in the lower 3 km of Kalubik Creek. This stream reach is influenced by estuarine conditions and two deep pools have been identified. Grayling, round whitefish, fourhorn sculpin, broad whitefish, ninespine stickleback, and rainbow smelt have been documented in the first tributary to Kalubik Creek, but only grayling and ninespine stickleback have been found upstream in the vicinity of the Kuparuk oilfield road system (Moulton 1984).

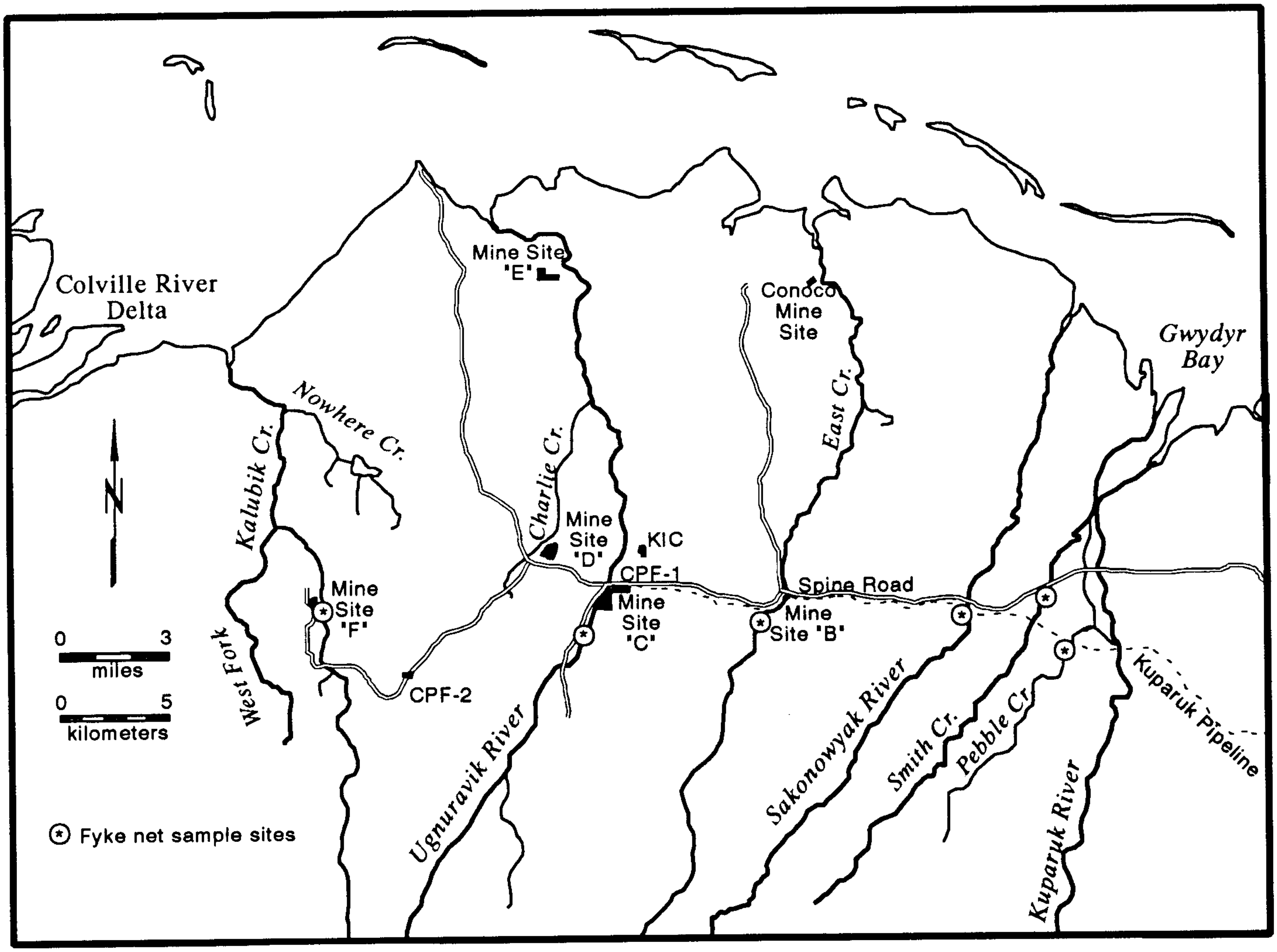

Figure 2. Map of Kuparuk Unit tundra streams and fish sampling sites, 1991 and 1992.

Kuparuk Mine Site F, a 12 ha deep mined gravel extraction site is located 150 m east of Kalubik Creek 20 km upstream from the mouth. The proposed rehabilitation plan for Mine Site F includes a channel connection between the deep gravel extraction basin and Kalubik Creek. This proposed project will increase the amount of deep water habitat available to fish in the Kalubik Creek system.

Ugnuravik River

The Ugnuravik River is a beaded tundra stream that drains a 85 km^2 area. Average peak discharge in the Ugnuravik River is approximately 28 m^3/s (Drage et al 1983). The Ugnuravik drains into Simpson Lagoon 2.3 km east of Oliktok Point (Figure 2). The seasonal discharge pattern in the Ugnuravik is similar to that described for Kalubik Creek.

There are three deep mined gravel extraction sites in the Ugnuravik River drainage. The largest of the sites is Kuparuk Mine Site C which is located adjacent to the Kuparuk Operations Center (KOC). This site includes a 47.5 ha active mine site and a 4.5 ha flooded area that is currently used as a water reservoir for KOC. The water reservoir is periodically connected to the river when high water floods a narrow sedge wetland that separates the two waterbodies. A second water reservoir similar to the one at KOC is located adjacent to the Ugnuravik River at the Kuparuk Industrial Center (KIC). This waterbody also has a high water connection to the Ugnuravik River. Kuparuk Mine Site D, a 15.6 ha deep mined gravel site is located on a tributary to the Ugnuravik River known locally as Charlie Creek.

A habitat enhancement project was completed at Kuparuk Mine Site D in 1990. Major elements of the project included: excavation of inlet and outlet channels connecting the site to Charlie Creek, removal of the overburden berms on the south and west sides of the excavation and placement of the spoil material on top of the ice, replacement of the culvert battery in the inlet channel, and excavation of two perched wetland ponds on top of the overburden pile. The intent of the restoration project was to provide hydraulic connections between the deep water mine site and Charlie Creek and to increase the amount of shallow water rearing habitat available to fish. The proposed restoration plan for Kuparuk Mine Site C includes a connection channel between the Ugnuravik River and the mine site basin. We anticipate that this project will increase deep water habitat available in the Ugnuravik River system.

Ninespine stickleback was the only fish species captured in previous fish surveys of the Ugnuravik River system (Dew 1982). In our sampling of Kuparuk Mine Site D we captured ninespine stickleback and least cisco (Hemming 1990).

East Creek

East Creek is a 26 km beaded tundra stream that drains 132 km^2 area upstream of the Spine Road (Figure 2). East Creek empties into Simpson Lagoon between the Colville and Kuparuk rivers. Peak discharge in the East Creek system often exceeds 28 m^3/s and generally occurs during the first week in June. By mid-June discharge decreases to less than 0.3 m^3/s, and by late summer channel sections between pools may become intermittent.

Kuparuk Mine Site B is located adjacent to East Creek 16 km upstream from Simpson Lagoon. The site was flooded in 1978 when water from East Creek filled the excavated area. The 3.7 ha waterbody consists of adjoining 1.3 and 2.4 ha basins having a maximum depth of 11.3 m and a mean depth of 7.1 m (Hemming 1988). Prior to site rehabilitation, hydraulic communication between Kuparuk Mine Site B and East Creek occurred only during periods of high water. In 1989 three connection channels were excavated at Kuparuk Mine Site B. An 18 by 24 m inlet channel was excavated to a depth of 1.8 m between East Creek and Kuparuk Mine Site B and two similar size channels were excavated between the two adjacent lake basins forming an island. The excavated channels provide continuous open water hydraulic communication between East Creek and Mine Site B.

In 1986 and 1987 we sampled Kuparuk Mine Site B with gill nets and minnow traps and captured broad whitefish and ninespine stickleback. In June 1989 we transplanted 210 large juvenile and adult grayling from the Sagavanirktok River to Kuparuk Mine Site B. Fish sampling conducted with fyke net gear in East Creek and Mine Site B in 1990 and 1991 documented the presence of least cisco, Dolly Varden and round whitefish in addition to the species captured prior to site rehabilitation.

Sakonowyak River

The Sakonowyak River is a 56 km, beaded, tundra stream system which drains a 250 km^2 area and empties into Gwyder Bay four km west of the Kuparuk River mouth (figure 2). Previous fisheries investigations documented grayling and ninespine stickleback in the Sakonowyak River system (McMillan and Barnard 1983). The Kuparuk Spine Road crosses the river at a point approximately 18 km upstream of Gwyder Bay. There are no current or proposed gravel extraction sites in the Sakonowyak River system.

Smith Creek

Smith Creek is a name we assigned a 57 km tributary to the Kuparuk River that drains a 310 km^2 tundra area west of the mainstem Kuparuk (Figure 2). This drainage has also been called Kuparuk Tributary I or West Tributary in other reports. Smith Creek joins the Kuparuk River at a deep water pool located near S Pad. Smith Creek has the largest drainage area and greatest discharge of the tundra stream systems investigated in the Kuparuk River Oilfield. Peak discharge has been measured at 102 m^3/s and by late summer surface flow often becomes intermittent (Drage et al 1983). This stream system differs from other tundra streams in the area because it has a gravel bottom and submerged aquatic vegetation is present but not abundant.

In 1982 grayling, slimy sculpin (*Cottus cognatus*), and ninespine stickleback were captured in Smith Creek in July and September (McMillan and Barnard 1983). McMillan and Barnard concluded that Smith Creek was used for spawning and rearing by these species.

Pebble Creek

Pebble Creek is a name we assigned a 18 km tributary to the Kuparuk River that drains a 80 km^2 tundra area located west of the mainstem Kuparuk (Figure 2). This drainage has also been called Kuparuk Tributary II or East Tributary in other reports. Pebble Creek drains into a side channel of the Kuparuk River located on the western side of the floodplain.

Pebble Creek is a beaded tundra system and emergent and submerged aquatic vegetation is abundant. Sections of the stream channel substrate is composed of pebble size material. Previous fisheries investigations documented use of Pebble Creek by grayling, slimy sculpin and ninespine stickleback (McMillan and Barnard 1983).

METHODS

Tundra Stream Fish Sampling

Fyke nets were used to capture fish in nine tundra streams within the Prudhoe Bay and Kuparuk River Oilfield Units during 1991 and 1992. In 1991 we sampled the Put River, Little Put River, and Washout Creek in the Prudhoe Bay Unit. Each of the three Prudhoe Bay Unit streams were sampled in June and July while the Put River and Little Put River were sampled again in August. In 1992 the Put River and Little Put River were sampled in early September.

In 1991 we sampled Kalubik Creek, the Ugnuravik River, East Creek, and the Sakonowyak River in the Kuparuk River Unit. All four streams were sampled in June and July while Kalubik Creek and the Sakonowyak River were sampled again in August. Our 1992 fish sampling program in the Kuparuk Unit included Kalubik Creek, East Creek, the Sakonowyak River, Smith Creek, and Pebble Creek. Kalubik Creek, Smith Creek and Pebble Creek were sampled in June, July, and early September, the Sakonowyak River was sampled in June and July, and East Creek was sampled only in June.

The nets used were 3.7 m (12 ft) in length with two 1.2 m (4 ft) square entrance frames, five hoops, a 1.8 m (6 ft) cod end, and 1.2 m (4 ft) by 7.6 m (25 ft) net wings attached to the entrance frame. The nets were set perpendicular to shore with a 30.5 m (100 ft) center lead attached to the entrance frame. Water depth, current and wind conditions determined net placement and the amount of center lead deployed at each net site. We selected road-accessible pool locations for net sites. With few exceptions we checked the nets daily. Fish captured were identified and fork length (FL) was measured to the nearest millimeter for all species except ninespine stickleback and slimy sculpin. Grayling and whitefish were marked with fin clips or tags to identify recaptured individuals. All fish captured were released near the net site with the exception of those retained for transplanting or disease screening.

Ninespine stickleback were too numerous to enumerate at most net sites; therefore, we estimated abundance. To estimate stickleback abundance we used a 15.3 cm (6 in) diameter screen scoop to remove fish from a larger dip net or holding pen. The number of stickleback in a standard scoop was determined by counting three scoops which yielded an average of 143 fish per scoop (SD = 31). We determined ninespine stickleback abundance at each net site by counting the number of scoops and multiplying by a standard scoop to obtain a rough estimate of abundance. We measured water temperature at each net site with a hand-held mercury thermometer. The net soak time was recorded to generate catch-per-unit-effort (CPUE) for each net location.

In 1992 grayling captured from Pebble Creek and Smith Creek were transported from the capture sites and released at Kuparuk Mine Site B and D as part of an experimental introduction. Thirty grayling captured from Pebble and Smith Creek in 1992 were sacrificed and sent to the ADF&G Fish Pathology Lab for disease screening.

Gravel Mine Site Water Quality Sampling

In early May 1991 water samples were collected from beneath the ice in Kuparuk Mine Site B and D, the Put River and Put 27. Open water sampling was conducted in August at Put 27 and Kuparuk Mine Site D. In 1992 we sampled water quality in Put 27 and Kuparuk Mine Site B and D in early May.

In our May sampling we used the ice surface as a work platform and drilled 25.4 cm (10 in) holes through the thick ice cover with a auger. The ice and water depth were measured with a sounding tape and calibrated rod. In August we collected water samples from a boat. Water samples taken in both May and August were collected at one or two m intervals through the water column with a Van Dorn sampler. The water temperature was determined with a mercury thermometer as each sample was brought to the surface. Dissolved oxygen samples were fixed in the field using 300 mL glass stoppered bottles and prepackaged reagents in plastic pillows. Dissolved oxygen concentrations were determined by the azide modification of the Winkler procedure using a digital titrator. Water collected in excess of that needed for dissolved oxygen measurements was transferred to 1 L plastic containers and stored in a cooler. These samples were used to measure pH, conductivity, alkalinity, and hardness. Hydrogen ion concentration was determined with an Orion model 407 meter calibrated against buffer solutions of known concentration and conductivity was determined with a Hach, Drel 5 meter. The alkalinity and hardness concentration were determined by colormetric methods. We used 50 mL samples for the hardness test and titrated the prepared sample with 0.8 M EDTA. For alkalinity tests we used 100 mL samples and titrated with 1.6 N sulfuric acid. In August 1991 chemical tests were performed as described except for salinity, conductivity and pH which were run at a commercial lab in Kuparuk. Because of the increased hardness values found at Put 27 during our May 1992 water sampling, the test was run three times and the values presented in this report are a numerical average of the three tests.

In May 1991 we also fished two monofilament, sinking, gill nets beneath the ice in Put 27 to evaluate winter fish use. We used 9.1 x 1.8 m nets having three panels with mesh sizes of 1.3, 1.9, and 2.5 cm. The nets were fished near the access ramp to Put 27 and off the inlet channel.

RESULTS

Prudhoe Bay Unit Tundra Steam Fish Sampling

Putuligayuk River

In 1991 we sampled the Put River at a location adjacent to the Put 27 Mine Site during sample periods in June, July, and August. Broad whitefish, least cisco, ninespine stickleback, and round whitefish were captured (Table 1). In 1992 we sampled the same location in early September and captured Arctic cisco, broad whitefish, fourhorn sculpin and ninespine stickleback.

In early June ninespine stickleback was the only species captured. In July round whitefish and least cisco were captured while ninespine stickleback increased in abundance from that found in June. The round whitefish and least cisco catch in July consisted of juvenile size fish (Appendix 1). We captured ten round whitefish that ranged from 110 to 138 mm with a mean length of 125 mm and six least cisco that ranged from 64 to 83 mm with a mean length of 73 mm.

In August ninespine stickleback continued to be most abundant while least cisco, broad whitefish, and round whitefish also appeared in the sample catch. We captured a

TABLE 1. Number of fish captured and catch per unit effort (CPUE) in Prudhoe Bay Unit streams.

Location	Date	Time Fished h	Water Temp ° C	Fish * Species Captured	Number **	CPUE Fish/h
Put River	6/5/91	19.0	0.9	NSB	127	6.68
	6/6/91	24.0	1.3	NSB	24	1.00
	6/7/91	14.3	0.5	NSB	54	3.78
	7/18/91	13.5	11.0	NSB	286	21.19
	7/19/91	26.0	12.0	LCi	5	0.19
				NSB	858	33.00
				RWF	8	0.31
	7/20/91	23.0	11.5	NSB	286	12.43
		23.0		RWF	2	0.09
	8/20/91	23.5	6.5	BWF	2	0.09
				LCi	2	0.09
				NSB	286	12.17
				RWF	1	0.04
	8/21/91	21.8	7.5	NSB	286	13.15
	8/22/91	22.5	7.0	NSB	143	6.36
	9/2/92	23.5	5.5	ACi	1	0.04
				FHS	2	0.09
				NSB	18	0.77
	9/3/92	22.5	5.0	BWF	2	0.09
				FHS	3	0.13
				NSB	10	0.44
Little Put River	6/7/91	69.0	1.2	NSB	1	0.01
	7/18/91	14.8	11.0	NSB	143	9.69
	7/19/91	26.3	12.0	NSB	34	1.30
	7/20/91	25.0	12.0	BWF	2	0.08
				NSB	6	0.24
	8/20/91	24.3	7.0	NSB	14	0.58
	8/21/91	21.5	8.0	NSB	6	0.28
	8/22/91	22.8	7.0	NSB	17	0.75
	9/2/92	22.0	6.0	DV	1	0.05
				NSB	146	6.64
	9/3/92	22.5	5.0	NSB	143	6.36

TABLE 1. Number of fish captured and catch per unit effort (CPUE) in Prudhoe Bay Unit streams.

Location	Date	Time Fished h	Water Temp ° C	Fish * Species Captured	Number **	CPUE Fish/h
Washout Creek	6/5/91	27.3	0.6	NSB	0	0.00
	6/6/91	23.8	0.4	NSB	6	0.25
	6/7/91	12.3	1.5	NSB	0	0.00
	7/18/91	14.8	11.5	NSB	8	0.54
	7/19/91	26.8	13.0	NSB	0	0.00
	7/20/91	24.5	13.0	NSB	5	0.20

** Ninespine stickleback numbers estimated

*. ACi = Arctic cisco
BWF = Broad whitefish
DV = Dolly Varden
FHS = Fourhorn sculpin
LCi = Least cisco
NSB = Ninespine stickleback
RWF = Round whitefish

single 127 mm round whitefish, two juvenile broad whitefish (114 and 54 mm), and two least cisco (332 and 87 mm) in August.

In early September 1992 only anadromous and marine fish species were captured. We captured young of the year size class broad whitefish, juvenile fourhorn sculpin, a single 90 mm Arctic cisco and ninespine stickleback.

Little Putuligayuk River

In 1991 we fished a single fyke trap in the Little Put River near the Spine Road crossing in June, July, and August and captured broad whitefish and ninespine stickleback. In 1992 we fished the same location in early September and captured ninespine stickleback and Dolly Varden.

In June we fished the net upstream of the Spine Road crossing during the peak discharge period. High water and strong currents limited net site selection to a slack water zone located in a tundra area outside the normal stream channel and we captured a single ninespine stickleback.

In July after water levels receded we moved the net to the scour pool downstream of the Spine Road culvert battery and captured two adult broad whitefish (420 and 425 mm FL) and ninespine stickleback. The ninespine stickleback catch in July was the highest of the three sample periods (Table 1). In August ninespine stickleback was the only species captured. In September 1992 we fished the Little Put River net site for two days and captured ninespine stickleback and a single 165 mm Dolly Varden (Appendix I).

Washout Creek

We fished a single fyke trap in Washout Creek at the Endicott Pipeline crossing in early June and July 1991 and captured ninespine stickleback. Few stickleback were captured in each of the two sample periods (Table 1).

Kuparuk Unit Tundra Stream Fish Sampling

Kalubik Creek

We fished a single fyke net in a large pool area in Kalubik Creek near Kuparuk Site F in 1991 and 1992. In 1991 we sampled in June, July, and August and captured broad whitefish, grayling, least cisco and round whitefish (Table 2). In 1992 we sampled the same location in June, July, and early September and captured grayling, broad whitefish and ninespine stickleback.

In June (1991) we captured broad whitefish, grayling, ninespine stickleback, and round whitefish during a period of decreasing discharge and rising water temperature following the spring flood. Ninespine stickleback were most abundant and were captured on each of the six days the net was fished. Grayling first appeared in the sample catch on June 20 and followed ninespine stickleback in abundance. We captured 50 grayling ranging from 103 to 304 mm having a mean length of 171 mm (Figure 3). On June 23 we captured an adult broad whitefish (450 mm) and a 263 mm round whitefish.

We fished the Kalubik Creek net for a five-day period in July and captured grayling, least cisco, ninespine stickleback and round whitefish. Ninespine stickleback were most abundant in the sample catch. Twenty six juvenile grayling were captured. The grayling ranged from 122 to 192 mm with a mean length of 154 mm (SD = 24). Three juvenile round whitefish and two juvenile least cisco were captured in July (Appendix II).

In August (1991), we fished the Kalubik Creek net for three days and captured grayling, ninespine stickleback and round whitefish. Ninespine stickleback were most abundant in our sample catch (Table 2). We captured 22 juvenile grayling ranging from 148 to 234 mm with a mean length of 175 mm (SD = 28 mm). A single 174 mm round whitefish was captured on August 20.

In 1992 we had similar results in June as broad whitefish, grayling and ninespine stickleback were captured. The 1992 broad whitefish catch consisted of a single adult (425 mm) caught on June 21. The grayling catch included 17 fish ranging from 87 to 301 mm with a mean length of 227 mm. In 1992 only 6 ninespine stickleback were captured in June. We captured grayling and ninespine stickleback in July.

TABLE 2. Number of fish captured and catch per unit effort (CPUE) in Kalubik Creek.

Date	Time Fished h	Water Temp °C	Fish ** Species Captured	Number *	CPUE Fish/h
6/18/91	27.0		NSB	6	0.22
6/19/91	20.0		NSB	26	1.30
6/20/91	22.5	18.0	AG	8	0.36
			NSB	143	6.36
6/21/91	23.0	19.0	AG	10	0.43
			NSB	40	1.74
6/22/91	19.0	14.0	AG	17	0.89
			NSB	20	1.05
6/23/91	29.0	15.0	AG	15	0.52
			BWF	1	0.03
			NSB	20	0.69
			RWF	1	0.03
7/17/91	23.5	13.0	AG	11	0.47
			LCi	1	0.04
			NSB	143	6.09
			RWF	2	0.09
7/18/91	29.0	13.0	AG	3	0.10
			NSB	31	1.07
7/19/91	31.5	14.0	AG	6	0.19
			LCi	1	0.03
			NSB	29	0.92
7/21/91	35.0	10.5	AG	6	0.17
			NSB	38	1.09
			RWF	1	0.03
8/20/91	27.0	8.5	AG	12	0.44
			NSB	56	2.07
			RWF	1	0.04
8/21/91	24.0	9.5	AG	4	0.17
			NSB	34	1.42
8/22/91	18.5	7.5	AG	6	0.32
			NSB	48	2.59
6/21/92	32.3	14.0	AG	3	0.09
			BWF	1	0.03
			NSB	2	0.06
6/22/92	32.8	12.0	None		
6/23/92	20.0	9.5	AG	2	0.10
			NSB	2	0.10
6/24/92	23.5	8.5	AG	7	0.30
6/25/92	26.0	9.0	AG	4	0.17
			NSB	2	0.08

TABLE 2. Number of fish captured and catch per unit effort (CPUE) in Kalubik Creek.

Date	Time Fished h	Water Temp °C	Fish ** Species Captured	Number *	CPUE Fish/h
7/19/92	30.8	18.0	AG	3	0.10
			NSB	9	0.29
7/20/92	23.8	17.0	AG	1	0.04
			NSB	6	0.25
7/21/92	24.0	17.5	AG	3	0.13
7/22/92	20.5	16.0	NSB	12	0.59
7/23/92	26.5	18.0	AG	2	0.08
			NSB	1	0.04
9/2/92	30.5	8.0	AG	9	0.30
			NSB	1716	30.50
9/3/92	23.0	7.5	NSB	858	37.30

* Ninespine stickleback numbers estimated

** AG = Arctic grayling
BWF =Broad whitefish
LCi = Least cisco
NSB = Ninespine stickleback
RWF = Round whitefish

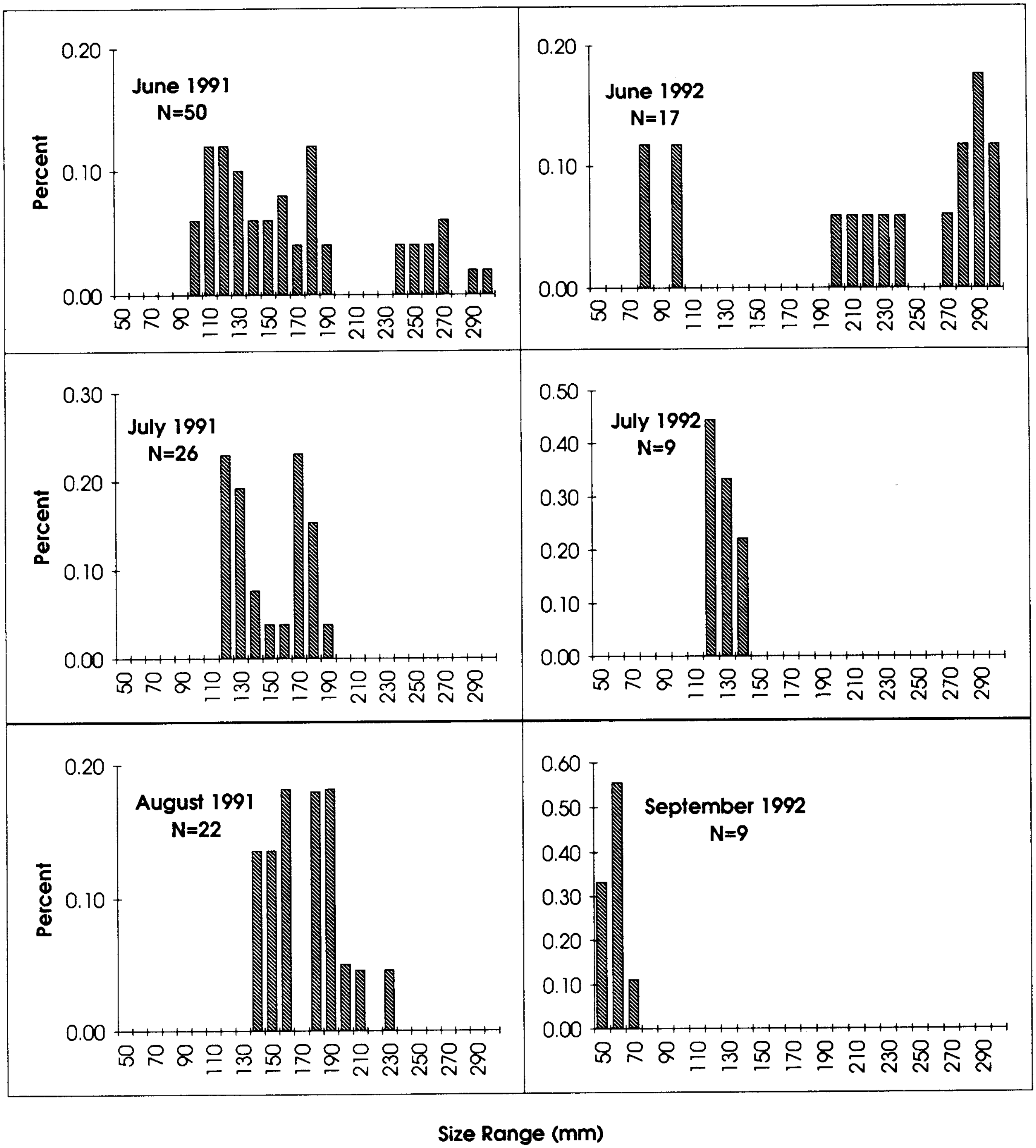

Figure 3. Length frequency distribution of Arctic grayling captured in Kalubik Creek, 1991 and 1992.

The July grayling catch included 9 juveniles ranging from 126 to 141 mm with a mean length of 134 mm (SD = 6). Only 28 ninespine stickleback were captured in July. In early September we fished the Kalubik Creek net for three days and captured 9 grayling and an estimated 2,574 ninespine stickleback. The grayling captured were young-of-the-year size class fish ranging from 52 to 70 mm. The young-of-the-year grayling captured in September were the only grayling fry captured from Kalubik Creek in six sample periods during the 1991 and 1992 open water seasons.

Ugnuravik River

We fished a single fyke net in a pool area of the Ugnuravik River upstream of the Spine Road off the Drill Site 1F Access Road. This site was fished in 1991 during sample periods in June and July. Ninespine Stickleback was the only species captured in the Ugnuravik River system (Table 3). In June estimated stickleback catches ranged from a high of 1144 on June 18 to four on June 21. High water conditions and current prevented optimal net deployment during part of the June sample period. In July the estimated catches ranged from a high of 5005 on July 19 to 2145 on July 18.

East Creek

In 1991 and 1992 we fished a net in East Creek at a location 1.6 km upstream from the inlet to Kuparuk Mine Site B. We captured broad whitefish, grayling, and ninespine stickleback at this site in 1991 while grayling and ninespine stickleback were captured at the same location in 1992.

In 1991 ninespine stickleback were most abundant in June while grayling and broad whitefish were also present (Table 3). The June sample catch included nine adult grayling ranging from 294 to 365 mm and three broad whitefish consisting of two juveniles (97 and 151 mm) and a single adult (525 mm) (Appendix 2). The grayling were introduced fish that were transplanted from the Sag River in June 1989. In July ninespine stickleback was the only species captured. Ninespine stickleback abundance declined in July from June.

We captured ninespine stickleback and grayling in 1992 at the same net site used in 1991. During the June sample period ninespine stickleback were most abundant. The grayling catch included four adult grayling from the 1989 introduction and one juvenile (172 mm) that could be the progeny of the introduced grayling.

TABLE 3. Number of fish captured and catch per unit effort (CPUE) in East Creek and the Ugnuravik R.

Location	Date	Time Fished h	Water Temp °C	Fish ** Species Captured	Number *	CPUE Fish/h
Ugnuravik River	6/18/91	24.5	12.5	NSB	1144	46.69
	6/19/91	19.0	14.5	NSB	26	1.37
	6/20/91	25.0	18.0	NSB	286	11.44
	6/21/91	21.5	18.5	NSB	4	0.19
	6/22/91	20.0	13.5	NSB	92	4.60
	7/17/91	23.5	13.5	NSB	4004	170.38
	7/18/91	28.5	13.5	NSB	2145	75.26
	7/19/91	30.5	13.0	NSB	5005	164.10
	7/20/91	12.5	12	NSB	2574	205.92
East Creek	6/20/91	24.5	16.0	AG	4	0.16
				NSB	3289	134.24
	6/21/91	27.5	18.5	AG	2	0.07
				NSB	2288	83.20
	6/22/91	21.0	13.0	AG	1	0.05
				BWF	1	0.05
				NSB	858	40.86
	6/23/91	21.0	9.5	AG	2	0.10
				BWF	2	0.10
				NSB	143	6.81
	7/16/91	29.5	14.0	NSB	858	29.08
	7/17/91	14.5	13.5	NSB	286	19.72
	7/18/91	26.8	13.0	NSB	143	5.35
	6/21/92	30.8	14.5	NSB	115	3.74
	6/22/92	23.8	10.0	AG	1	0.03
				NSB	77	3.24
	6/23/92	23.5	9.0	AG	1	0.04
				NSB	38	1.62
	6/24/92	22.0	7.0	AG	2	0.09
				NSB	18	0.82
	6/25/92	25.0	8.0	AG	1	0.04
				NSB	25	1.00
	6/26/92	15.5	6.0	NSB	14	0.90

* Nine spine stickleback numbers estimated

** AG = Arctic grayling
BWF = Broad whitefish
NSB = Ninespine stickleback

Sakonowyak River

In 1991 we fished a single fyke trap in a pool upstream of the Spine Road during sample periods in June, July, and August. Grayling, broad whitefish, and ninespine stickleback were captured. In 1992 we fished a net in the same general location during sample periods in June and July and captured ninespine stickleback.

We captured ninespine stickleback in 1991 during June while grayling and stickleback were captured in July (Table 4). In July we captured 15 juvenile grayling which ranged from 86 to 172 mm with a mean length of 127 mm (Figure 4). Ninespine stickleback abundance decreased in July from that found during the June sample period.

In August we captured a juvenile broad whitefish (200 mm) in addition to grayling and stickleback (Appendix 2). The August grayling catch included 36 juveniles which ranged from 96 to 188 mm with a mean length of 132 mm. Ninespine stickleback abundance was greater in August than in the preceding sample periods.

In 1992 ninespine stickleback was the only species captured during June and July sample periods. Relatively few ninespine stickleback were captured in 1992.

Smith Creek

We sampled Smith Creek three times during the 1992 open water season. A pool area downstream of the Spine Road was fished in June, July, and early September. Grayling, ninespine stickleback and slimy sculpin were captured during each of the three sample periods (Table 5).

We sampled Smith Creek for a six-day period in June and captured 55 grayling, 9 ninespine stickleback, and five slimy sculpin. The grayling ranged from 49 to 399 mm and averaged 226 mm in length (SD = 105 mm). Of the grayling captured in June, 17 (31%) exceeded 300 mm (Figure 5).

In July we sampled Smith Creek at the same location for a six-day period and captured 13 grayling, 24 ninespine stickleback, and a single slimy sculpin. The grayling captured in July ranged from 112 to 310 mm with an average length of 244 mm (SD = 50). Only one grayling captured in July exceeded 300 mm.

TABLE 4. Number of fish captured and catch per unit effort (CPUE) in the Sakonowayak River.

Date	Time Fished h	Water Temp °C	Fish ** Species Captured	Number *	CPUE Fish/h
6/19/91	23.5	11.5	NSB	286	12.17
6/20/91	24.0	15.0	NSB	143	5.96
6/21/91	32.0	19.0	NSB	572	17.88
6/22/91	19.0	14.5	NSB	143	7.53
7/17/91	22.0	14.0	AG	9	0.41
			NSB	70	3.18
7/18/91	24.5	12.0	AG	2	0.08
			NSB	22	0.90
7/19/91	31.5	14.5	AG	3	0.10
			NSB	18	0.57
7/21/91	41.5	11.0	AG	1	0.02
			NSB	16	0.39
8/20/91	30.0	8.0	AG	16	0.53
			BWF	1	0.03
			NSB	572	19.07
8/21/91	22.0	9.0	AG	14	0.64
			BWF	1	0.05
			NSB	858	39.00
8/23/91	39.5	4.0	AG	6	0.15
			NSB	715	18.10
6/21/92	22.8	12.0	NSB	3	0.13
6/22/92	24.0	10.0	NSB	9	0.38
6/23/92	23.0	8.5	NSB	12	0.52
7/18/92	20.0	14.5	NSB	10	0.50
7/19/92	25.5	16.5	NSB	13	0.51
7/20/92	28.8	16.0	NSB	24	0.83
7/21/92	21	17	NSB	10	0.48
7/22/92	17.2	15.0	NSB	6	0.35
7/23/92	26.8	16.0	NSB	34	1.27

* Ninespine stickleback numbers estimated

** AG = Arctic grayling
BWF = Broad whitefish
NSB = Ninespine stickleback

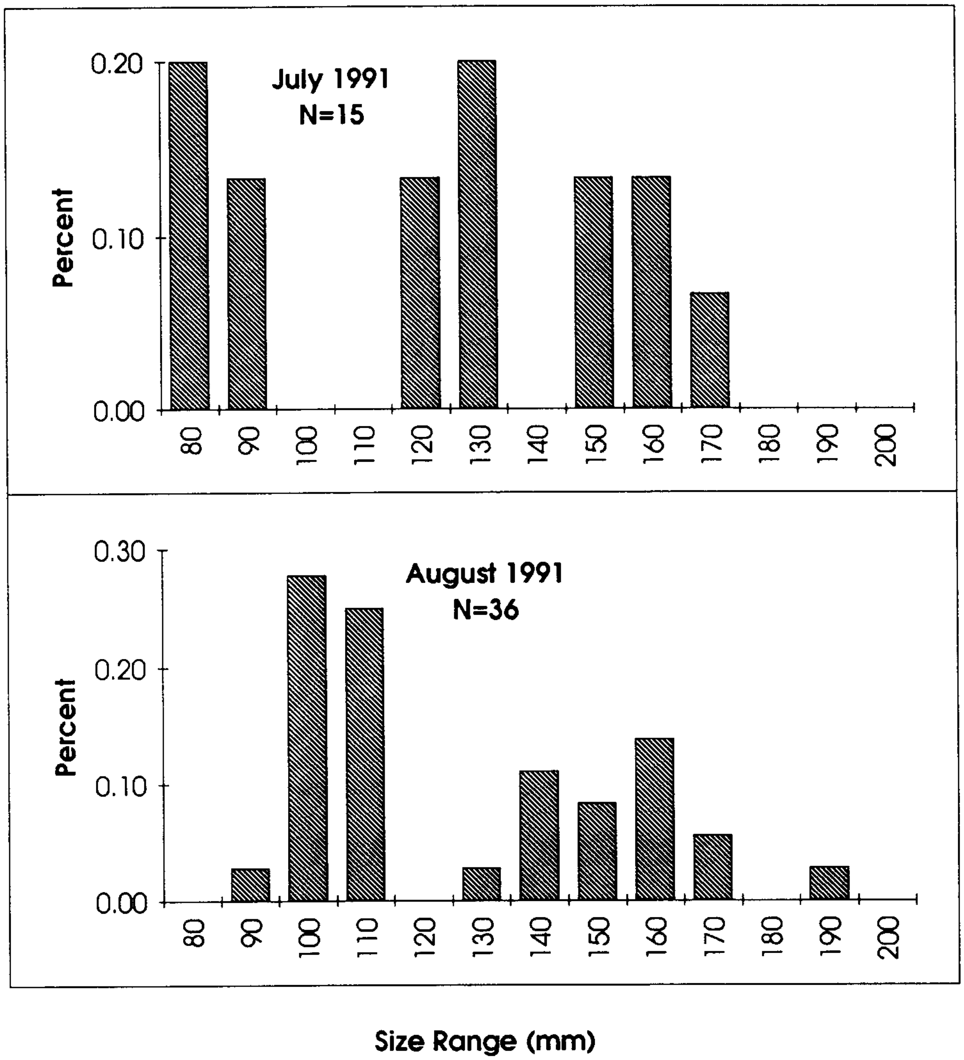

Figure 4. Length frequency distribution of Arctic grayling captured in the Sakonowayak River, 1991.

Table 5. Number of fish captured and catch per unit effort (CPUE) in Smith Creek.

Date	Time Fished h	Water Temp °C	Fish ** Species Captured	Number *	CPUE Fish /h
6/21/92	21.5	10.5	None		
6/22/92	22.5	9.0	AG	4	0.18
			NSB	7	0.31
			SSc	1	0.04
6/23/92	23.3	7.5	AG	6	0.26
6/24/92	28.0	6.5	AG	15	0.54
			SSc	1	0.04
6/25/92	22.5	6.0	AG	10	0.44
			NSB	1	0.04
6/26/92	22.3	5.5	AG	20	0.90
			NSB	1	0.04
			SSc	3	0.13
7/18/92	28.0	14.0	AG	4	0.14
			NSB	1	0.04
7/19/92	21.0	14.0	AG	3	0.14
7/20/92	23.0	15.0	AG	1	0.04
			NSB	1	0.04
7/21/92	24.5	14.0	NSB	6	0.24
7/22/92	20.0	14.0	AG	1	0.05
			NSB	6	0.30
7/23/92	25.0	15.0	AG	2	0.08
			NSB	2	0.08
			SSc	1	0.04
7/24/92	22.5	14.0	AG	2	0.09
			NSB	8	0.36
9/1/92	25.0	7.0	AG	24	0.96
			NSB	20	0.80
9/2/92	21.8	6.0	AG	45	2.07
			NSB	110	5.06
			SSc	1	0.05
9/3/92	19.0	5.0	AG	80	4.21
			NSB	286	15.05
			SSc	6	0.32
9/4/92	22.5	4.5	AG	97	4.31
			NSB	214	9.51
			SSc	7	0.31

* Ninespine stickleback numbers estimated

** AG = Arctic grayling
NSB = Ninespine Stickleback
SSc = Slimy sculpin

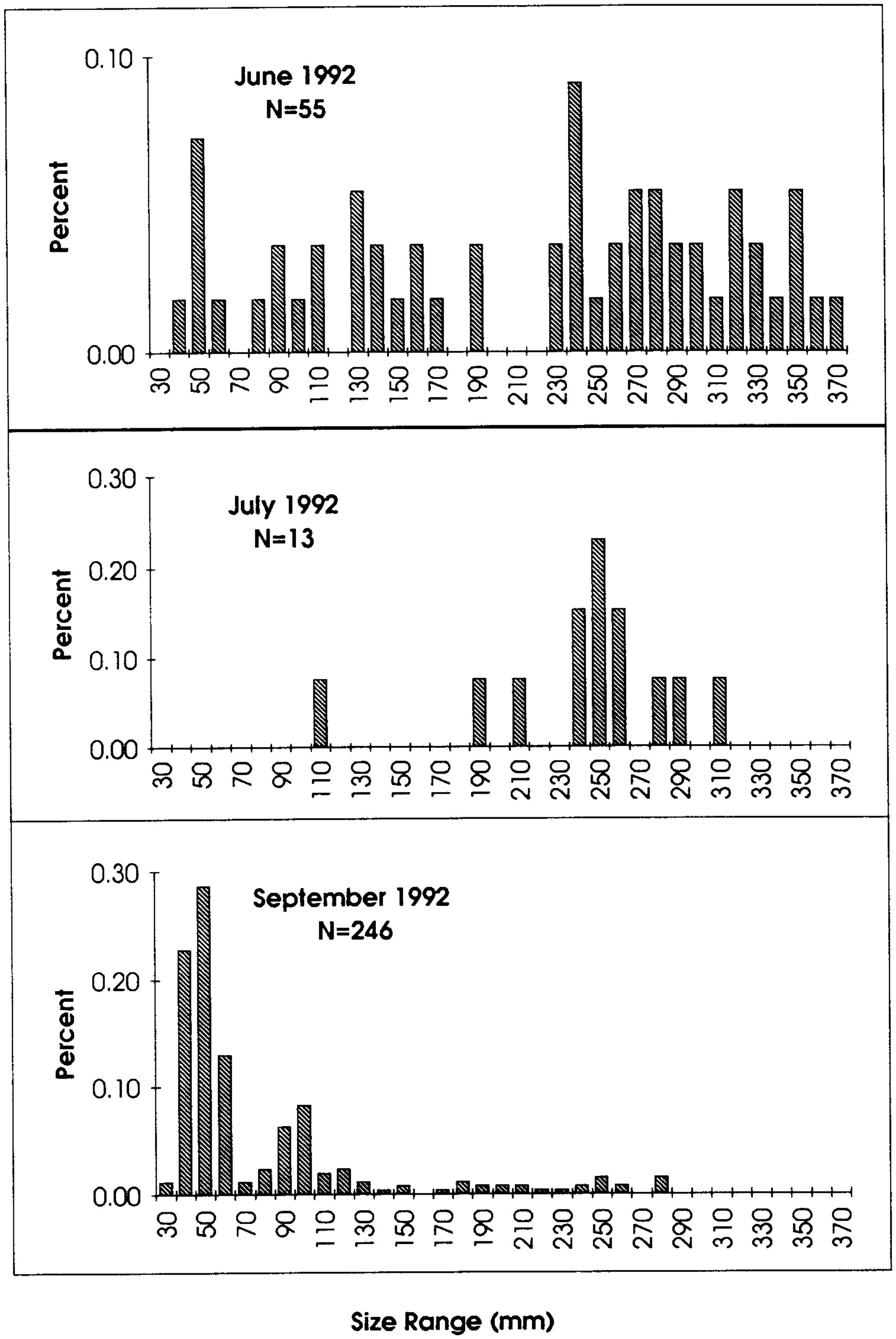

Figure 5. Length frequency distribution of Arctic grayling captured in Smith Creek, 1992.

In early September the Smith Creek net was fished for four days and 246 grayling, an estimated 630 ninespine stickleback, and 14 slimy sculpin were captured. Grayling captured in September ranged from 39 to 329 mm and averaged 84 mm (SD = 59 mm). During the September sample period 157 young-of-the-year grayling were captured. Only one grayling captured in September exceeded 300 mm (Appendix II).

Pebble Creek

We sampled Pebble Creek three times during the 1992 open water season. A pool located upstream of the Kuparuk Pipeline was used as a sample site in June, July, and early September. Burbot (*Lota lota*), grayling, ninespine stickleback, and slimy sculpin were captured (Table 6).

We sampled Pebble Creek for a six-day period in June and captured 38 grayling, 8 ninespine stickleback and 9 slimy sculpin. The grayling ranged from 47 to 379 mm and averaged 161 mm (SD = 108 mm). Six (16%) of the grayling captured in June exceeded 300 mm (Figure 6).

In July we sampled Pebble Creek during a seven-day period and captured 39 grayling and 20 ninespine stickleback. The grayling ranged from 73 to 292 mm and averaged 170 mm (SD = 72 mm).

Pebble Creek was sampled for a three-day period in early September and 56 grayling, an estimated 597 ninespine stickleback, 7 slimy sculpin, and two burbot were captured. The grayling ranged from 52 to 247 mm and averaged 147 mm (SD = 63). Two juvenile burbot (70 and 75 mm) were captured on September 2 (Appendix II).

Gravel Mine Site Water Quality Sampling

We found little variation in water quality with depth in Kuparuk Mine Site D during two sample periods in early May (1991 and 1992) and an open water sample period in August (Appendix 3). In May water temperatures did not exceed 1.0° C at the various depths sampled while August temperatures ranged from 6.5 to 7.0° C. In May under ice cover dissolved oxygen concentration exceeded 10.5 mg/l at each sample depth while August concentrations exceeded 11.2 mg/l. Hydrogen ion concentration (pH)

TABLE 6. Number of fish captured and catch per unit effort (CPUE) in Pebble Creek.

Date	Time Fished h	Water Temp °C	Fish ** Species Captured	Number *	CPUE Fish/h
6/21/92	22.3	10.5	AG	10	0.45
			NSB	2	0.09
			SSc	2	0.09
6/22/92	24.5	9.5	AG	4	0.16
			NSB	2	0.08
			SSc	1	0.04
6/23/92	22.5	7.5	AG	11	0.49
			NSB	1	0.04
			SSc	2	0.09
6/24/92	28.0	7.0	AG	4	0.14
			NSB	1	0.04
			SSc	1	0.04
6/25/92	22.0	6.5	AG	2	0.09
			NSB	2	0.09
			SSc	1	0.05
6/26/92	22.5	6.0	AG	7	0.31
			SSc	2	0.09
7/18/92	19.0	17.0	AG	15	0.79
7/19/92	21.0	16.5	AG	5	0.24
7/20/92	23.3	15.0	AG	9	0.39
			NSB	6	0.26
7/21/92	25.0	17.0	AG	4	0.16
7/22/92	22.0	14.0	AG	2	0.09
7/23/92	25.5	15.0	AG	2	0.08
			NSB	2	0.08
7/24/92	22.3	13.5	AG	2	0.09
			NSB	12	0.54
9/1/92	24.3	8.0	AG	39	1.61
			NSB	99	4.08
9/2/92	24.5	6.5	AG	6	0.24
			BB	2	0.08
			NSB	429	17.51
			SSc	2	0.08
9/3/92	19.5	5.0	AG	11	0.56
			NSB	69	3.54
			SSc	5	0.26

* Ninespine Stickleback numbers estimated

** AG = Arctic grayling
BB = Burbot
NSB = Ninespine stickleback
SSC = Slimy sculpin

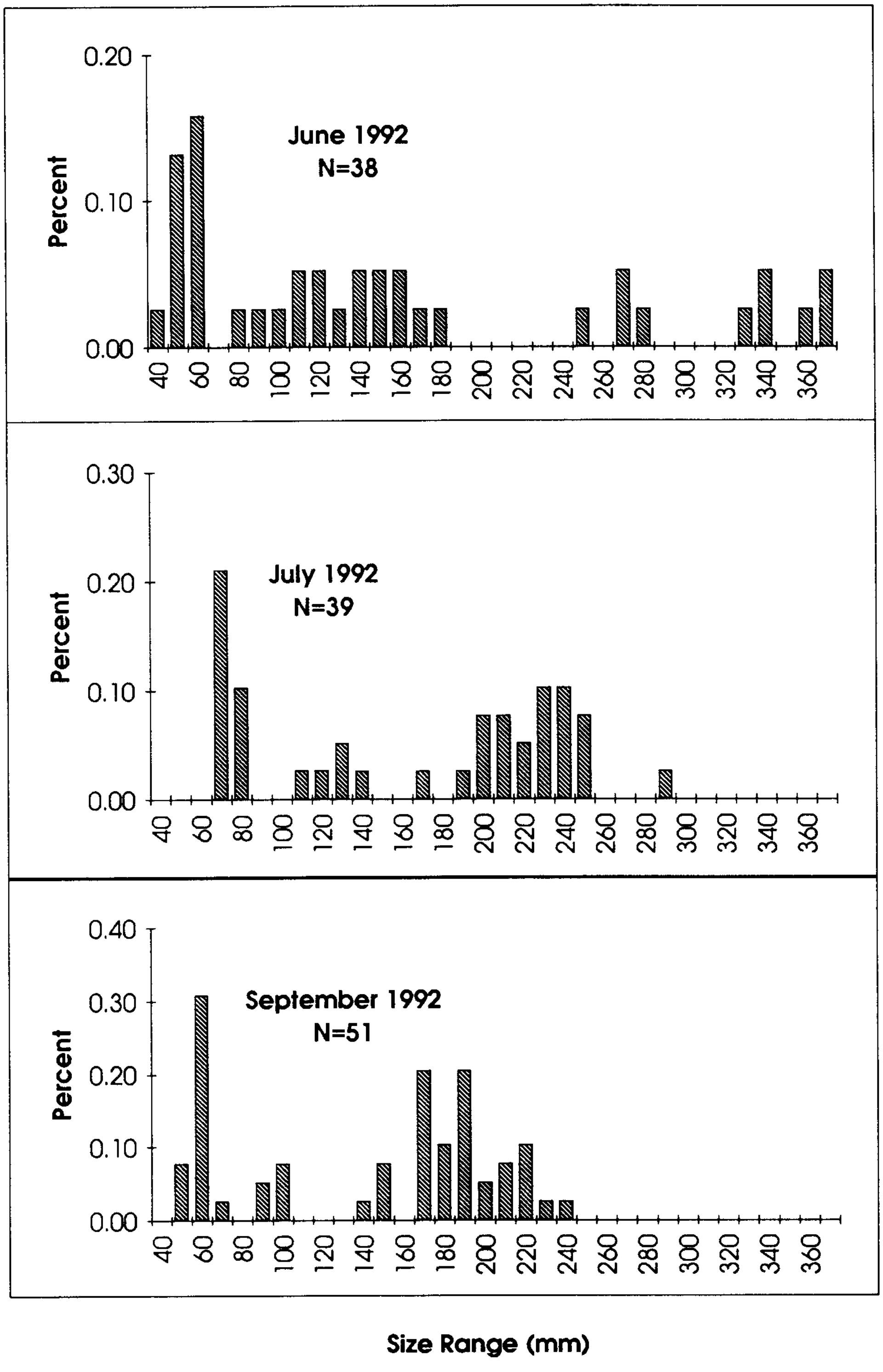

Figure 6. Length frequency distribution of Arctic grayling captured in Pebble Creek, 1992.

was slightly basic during each of the three sample periods. Specific conductance was greater during the ice covered season than during open water. Alkalinity and hardness concentration also were greatest in May under ice cover when compared to August.

In 1991 and 1992 we monitored water quality in Kuparuk Mine Site B in early May under the ice and found little variation in chemical characteristics through the water column. Water temperatures were isothermal and < 0.5° C while dissolved oxygen concentrations exceeded 7.6 mg/l at each depth sampled with the exception of the 8 m sample taken in May 1992 that was 1.3 mg/l. (Appendix IV). The remaining parameters measured were nearly uniform between depths.

We sampled Put 27 in early May (1991 and 1992) and in August (1991). In May (1991) we also sampled the lower Put River adjacent to Put 27. We found nearly uniform water quality characteristics with depth in Put 27 during the ice-covered season in 1991 and 1992. Water temperatures ranged between 0.3 and 0.6° C while dissolved oxygen concentration ranged between 9.1 and 12.3 mg/l at the various depths sampled (Appendix 5). The remaining parameters measured were fairly uniform between depths. Specific conductance was 6,598 uS/cm at each depth sampled in 1991 and increased in 1992 to levels ranging from 9950 to 10500 uS/cm at the various depths sampled.

In the Lower Put River all water quality characteristics except pH varied with depth when sampled in early May 1991 (Appendix V). Specific conductance increased with depth from 7,076 to 15,024 uS/cm, hardness also increased from 910 to 1,778 mg/l, while alkalinity decreased from 200 to 154 mg/l and dissolved oxygen decreased from 13.7 to 4.0 mg/l. Denser more saline water was found at depth in the Put River while lighter, fresher water was found near the surface.

In August 1991 we found two water masses in Put 27. Water at or above four meters shared one set of physical and chemical characteristics while water at or below six meters shared differing characteristics (Appendix V). Water at and below six meters was similar chemically to that found in May under ice cover. Water at or above six meters was warmer, contained a greater concentration of dissolved oxygen, and lower alkalinity, hardness and salinity concentrations while pH was slightly more basic.

We fished two sinking gill nets in Put 27 for a 44 h period between May 1 and May 3, 1991. The nets were set on the bottom under two meters of ice. We selected net locations off the inlet channel and near the access ramp. Under ice water depths were four meters at the inlet channel net site and 6.5 meters at the access ramp site. We captured two juvenile round whitefish (132 and 216 mm) in the inlet channel net. No food items were found in the stomachs of either fish.

DISCUSSION

Prudhoe Bay Unit Tundra Stream Fish Sampling

Putuligayuk River

The Lower Put River and Put 27 provide both wintering and summer rearing habitat for round whitefish and ninespine stickleback. We captured round whitefish under the ice in the Lower Put River in May 1989 and in Put 27 in May 1991 (Hemming 1990). Ninespine stickleback have been observed under thick ice cover in the Lower Put River at water extraction sites. During the 1991 open water season round whitefish and ninespine stickleback were the most frequently captured species in the Put River.

Ninespine stickleback were most abundant during each of four sample periods and the only species captured in June. It is likely that a resident population winters in the deeper areas of the Lower Put River and will rapidly occupy additional wintering habitat in Put 27. Ninespine stickleback abundance may increase in the Put River system in response to additional wintering habitat but only to the extent that suitable open water spawning and rearing areas are available to these fish. In the lower sections of the Put River near the Put 27 Mine Site there are few areas with shallow water and emergent vegetative communities suitable for spawning and rearing ninespine stickleback. Suitable spawning and rearing areas occur in the Put River but these habitats are located upstream of the Spine Road and are not in close proximity to wintering areas.

Our 1991 fish sampling results indicate that the Put River supports a resident round whitefish population. We found juvenile round whitefish in the lower Put River in July and August and in Put 27 in May. Round whitefish have a freshwater life history pattern and are less likely to move from freshwater or low salinity areas than other whitefish species. Although no adult round whitefish were captured in the Put River the presence of juvenile fish indicate that adult fish are present in the system or the juvenile fish moved through nearshore low salinity waters from neighboring freshwater systems such as the Sag River. In either case round whitefish were using the system for both wintering and summer rearing in 1991.

Least cisco and broad whitefish were captured in the Put River in July and August 1991. It is likely that these anadromous fish are associated with large river systems in the area such as the Colville or Sag Rivers. Anadromous broad whitefish and least cisco use coastal areas including tundra stream systems as summer rearing habitat. Anadromous whitefish and ciscos may remain in the Put River system using deep water areas to winter or return to large river systems in the fall.

In 1992 we captured marine and anadromous fish during a sample period in early September. The increasing salinity concentrations found in Put 27 may be a factor causing a shift in species composition away from freshwater fish such as round whitefish toward marine and anadromous fish such as fourhorn sculpin, Arctic cisco, broad whitefish and ninespine stickleback.

The draft rehabilitation plan for Put 23 includes connection channels between the deep gravel mine excavation and the Put River. This project will add an additional 113 ha of deep water habitat to the lower Put River. Estuarine intrusion into the Lower Put River will influence water quality in Put 23 in a similar manner to that found in Put 27. Since Put 23 is located downstream of Put 27, salinity concentrations will equal or exceed those found at the upstream site. It is likely that after rehabilitation the new deep water area will provide conditions favorable for wintering by anadromous fish such as Arctic cisco.

Salinity concentrations in Put 27 in early May 1992 were in the 5 to 6 ppt range and the trend in water quality measurements has been toward increasing salinity over time. These conditions are not suitable for the introduction of a freshwater obligatory fish species such as grayling.

Little Putuligayuk River

Ninespine stickleback were captured during each of three sample periods in 1991 and in September 1992. Ninespine stickleback abundance at the Little Put River sample site was lower than that found in other tundra streams with deep water habitat near the sample site. The greatest ninespine stickleback catch rates occurred in September 1992. High catch rates in late summer indicate downstream movements to wintering areas.

Shallow, vegetated areas and tundra lakes are found in the Little Put River system and these habitats provide conditions favorable for ninespine stickleback spawning and rearing but wintering habitat is limited. The estuarine zone near the mouth of the Put River may provide the only habitat suitable for wintering ninespine stickleback.

In July 1991 we captured two adult broad whitefish. These anadromous whitefish were using the Little Put River for summer rearing. A large, shallow, lake complex located upstream of the net site may provide rearing habitat during the open water season. It is possible that the broad whitefish captured in July were moving to or from the lake complex.

In 1992, a single 165 mm Dolly Varden was captured in September. It is likely that the juvenile Dolly Varden was moving downstream from summer rearing areas in the Little Put River and initiating migration to a wintering area.

There are no current or proposed gravel extraction sites in the Little Put River system. Fish abundance and use of productive summer rearing habitat might be increased by gravel extraction designed to provide additional wintering habitat.

Washout Creek

In 1991 ninespine stickleback was the only species captured in Washout Creek during sample periods in July and August and ninespine stickleback abundance was lower in Washout Creek than in any of the tundra stream systems sampled. Although Washout Creek has shallow vegetated areas which provide suitable spawning and rearing habitat relatively few ninspine stickleback were captured.

The proposed rehabilitation plan for the Duck Island Mine Site includes a channel connection between Washout Creek and the excavated basin. This project will add deep water wintering habitat to the Washout Creek system. It is likely that ninespine stickleback abundance will increase in response to wintering habitat in the Duck Island Site. Other species such as grayling, whitefish, and burbot may also increase in abundance if high water events provide a mechanism for dispersal from the Sag River. After rehabilitation the Duck Island Mine Site should be evaluated as a potential fish transplant location.

Kuparuk Unit Tundra Stream Fish Sampling

Kalubik Creek

Arctic grayling and ninespine stickleback were captured during each of six sample periods in 1991 and 1992. While Kalubik Creek contains productive rearing habitats wintering areas are limited to two deep pool areas in the lower portion of the drainage. It is likely that fish captured upstream disperse from these deep water areas or from other drainages during or shortly after break-up. The absence of wintering habitat near the sample site may be a factor in lower ninespine stickleback catch rates when compared to systems with wintering habitat in close proximity to the sample site. Grayling catch rates were lower than that found in Kuparuk River tributaries where extensive deep water wintering habitat is found downstream of the sample sites in the mainstem Kuparuk River.

In both 1991 and 1992 only small juvenile grayling were captured in each sample period except June when larger juvenile and adult fish were also present. In 1992 we captured nine young-of-the-year grayling on September 2. The 1992 data indicate that Kalubik Creek is a grayling spawning system.

The grayling catch rate was much lower in Kalubik Creek than that found in Kuparuk River tributaries although most habitat characteristics are similar between these systems. One important difference is that the Kuparuk River tributaries are located in the same watershed as deep water wintering areas.

The Colville River is the largest river system draining Alaska's North Slope and is likely to be the natal system for juvenile grayling that use Kalubik Creek during the open water season. Kalubik Creek is located on the eastern edge of the Colville River Delta and discharge from the Colville River distributes low salinity water outward along the coast to the mouth of Kalubik Creek, providing a mechanism for dispersal of freshwater fish. Grayling migration between coastal drainages has been documented in the Arctic National Wildlife Refuge (ANWR) using radio telemetry techniques. In the ANWR study adult grayling moved from summer rearing areas in a coastal stream, through nearshore areas of the Beaufort Sea to wintering areas in another drainage (West et al 1992).

The Colville River Delta contains extensive areas of deep water suitable for wintering fish. Grayling found in Kalubik Creek may disperse from deep water areas in the Colville River Delta when low salinity conditions in nearshore areas favor movement between drainages. The ecological advantage of movement from a large river to a tundra stream system may be related to conditions such as warmer water temperatures, a more abundant food source, or to reduce competition from other fish.

Fall movements of Kalubik Creek grayling are likely to occur in late August or early September. Grayling were present upstream in Kalubik Creek September 2, 1992, and tundra streams generally freeze over by mid-September. Winter survival is unlikely among grayling that do not move to suitable wintering areas prior to the onset of freezing conditions. West et al (1992) found that peak migration rates among adult grayling in ANWR occurred about September 1.

Juvenile round whitefish were also captured in low numbers during each of three sample periods in 1991. The migration patterns for round whitefish in Kalubik Creek are thought to be similar to that of grayling. In both 1991 and 1992 broad whitefish were captured in June while least cisco were only captured during the July 1991 sample period. Favorable rearing conditions in tundra stream systems may attract anadromous whitefish and ciscos that use nearshore areas of the Beaufort Sea during the open water season.

The proposed rehabilitation of Kuparuk Mine Site F will add a substantial amount of deep water habitat to the Kalubik Creek system. We expect that ninespine stickleback will rapidly invade and use available deep water areas. Spawning and rearing areas located in close proximity to Mine Site F provide habitat that may support growth in the ninespine stickleback population.

Grayling may remain and winter in the Kalubik Creek system if additional deep water habitat is available. If a larger wintering population remained in Kalubik Creek, migrational patterns may change such that all grayling life history stages would be present throughout the year. Additional wintering habitat may allow grayling abundance to increase. After rehabilitation Kuparuk Mine Site F may also be used by wintering round whitefish, broad whitefish, and least cisco.

Our catch results indicate that grayling and ninespine stickleback would colonize new deep water habitat simultaneously. If this occurs neither species should have a competitive advantage and the relative abundance of each should be more stable than that found where ninespine stickleback colonize a site and grayling are introduced after a period of years (e.g., Kuparuk Mine Site B and D).

Ugnuravik River

Ninespine stickleback was the only species captured in the Ugnuravik River during sample periods in June and July 1991. In July the catch rate exceeded that of all tundra streams sampled. The Ugnuravik River system contains many pool and backwater areas with submerged and emergent vegetation providing conditions suitable for spawning and rearing ninespine stickleback. The KIC and KOC reservoirs are deep water basins suitable for wintering fish. The catch rate indicates that ninespine stickleback are abundant in the Ugnuravik River near the two deep water reservoirs.

The rehabilitation plan for Kuparuk Mine Site C includes connection channels between the Ugnuravik River and the mine site basin. We anticipate that ninespine stickleback will rapidly colonize the new deep water area and abundance will increase. After completion of the proposed rehabilitation project Kuparuk Mine Site C should be considered as a candidate for a fish transplant using Kuparuk River grayling as the donor stock.

In 1992 we transplanted 708 grayling from the Kuparuk River to Kuparuk Mine Site D. While Kuparuk Mine Site D provides suitable winter habitat for grayling the competitive interaction between grayling and ninespine stickleback and the suitability of Charlie Creek as spawning and rearing habitat for grayling will determine the long term success of the introduction.

East Creek

We captured ninespine stickleback in East Creek during each of three sample periods. In June 1991 the ninespine stickleback catch rate exceeded that of all tundra streams sampled while the July catch rate was only exceeded by the Put and Ugnuravik River systems. Ninespine stickleback catch rates at fyke net sites in Kuparuk Mine Site B increased in July and August from June indicating movement from rearing areas in East Creek to deep water in Kuparuk Mine Site B (Hemming 1992).

East Creek contains pools and backwater areas with submerged and emergent vegetative communities suitable for rearing and spawning ninespine stickleback, while Kuparuk Mine Site B provides wintering habitat. The combination of spawning, rearing and wintering habitat provide conditions suitable for ninespine stickleback and catch rates in East Creek indicate a large population. In 1978 wintering habitat for ninespine stickleback was increased when Kuparuk Mine Site B was flooded. It is likely that this expansion of wintering habitat has increased ninespine stickleback abundance over a fourteen-year period. The lack of significant competition by other fish species is another factor that favored ninespine stickleback.

Adult and juvenile broad whitefish were captured in East Creek in June 1991. Previous sampling in Kuparuk Mine Site B documented use of the deep water site by juvenile and adult broad whitefish at various times during the open water season (Hemming 1988, Hemming 1990, Hemming 1992). The absence of broad whitefish in our sampling in East Creek and Kuparuk Mine Site B in 1992 indicates that use of East Creek by broad whitefish may be seasonal and variable between years.

In 1989 we transplanted 210 large juvenile and adult grayling from the Sag River system to Kuparuk Mine Site B. In June 1991 and 1992 we recaptured introduced grayling in East Creek upstream of Mine Site B. Tagged grayling that were recaptured multiple times moved upstream from Kuparuk Mine Site B after break-up followed by downstream movement back to the deep water site (Hemming 1992). Spring upstream movements by adult grayling are likely related to spawning. Kuparuk Mine Site B is used as summer rearing habitat and for wintering by adult grayling.

Rapid growth rates have been documented among the introduced grayling (Hemming 1992b). We examined the stomach content of an adult grayling net mortality captured in 1992 and found four ninespine stickleback. This observation indicates that ninespine stickleback are an important food item for adult grayling in East Creek. The large ninespine stickleback population provides a readily available prey source for adult grayling and may be a factor in the rapid growth rates found among the introduced grayling.

Few young-of-the-year grayling have been captured in East Creek indicating poor reproductive success among the introduced grayling. Grayling reproductive success may be limited by predation of fry and or eggs by ninespine stickleback. Over time, competition between ninespine stickleback and grayling may lead to exclusion of one of the two species or greater population stability will occur with a decrease in ninespine stickleback and an increase in grayling.

The habitat enhancement project at Kuparuk Mine Site B improved access to wintering habitat. The East Creek system provides year round habitat for ninespine stickleback and introduced grayling as well as summer rearing habitat for broad whitefish. It is likely that accessible deep water habitat in Kuparuk Mine Site B has allowed an increase in the abundance of ninespine stickleback in the East Creek system. The presence of introduced grayling in East Creek demonstrate that winter survival is possible in a tundra stream system not previously used by grayling when suitable deep water habitat is available. In June 1992 we captured a 172 mm grayling that was not introduced in 1989. This juvenile grayling is either the progeny of the introduced fish or it migrated through nearshore areas from another freshwater drainage.

In 1992 we transplanted an additional 293 grayling to Kuparuk Mine Site B using the Kuparuk River as the donor stock. It is likely that additional grayling will increase predation on ninespine stickleback and grayling reproductive success may also increase over time with more potential spawners in the system.

Sakonowyak River

The species composition of sample catches from the Sakonowyak River varied between 1991 and 1992. In 1991 Arctic grayling, ninespine stickleback and broad whitefish were captured while only ninespine stickleback were captured in 1992.

Ninespine stickleback were most abundant in each sample period. These data indicate that a resident population of ninespine stickleback use the Sakonowyak River system.

Ninespine stickleback catch rates were lower than that found in similar tundra stream systems with deep water excavated areas such as the Ugnuravik River and East Creek. Although the Sakonowyak River provides suitable spawning and rearing habitat for ninespine stickleback, winter habitat may limit abundance.

In 1991 we captured juvenile grayling in July and August but adult and young-of-the-year fish were not present in our sample catch. These data suggest that juvenile grayling rear in the Sakonowyak River while other life history stages occur in different freshwater systems. The Kuparuk River is located 4 km east of the mouth of the Sakonowyak River and is likely to be the natal system for juvenile grayling that rear in the Sakonowyak River during the open water season.

The absence of grayling in our 1992 sample catch indicates that use of the Sakonowyak River is variable between years. Movement of juvenile grayling between the Kuparuk and Sakonowyak Rivers is facilitated by low salinity water in nearshore areas of Gwyder Bay. Climatic conditions such as wind direction and velocity are important factors influencing nearshore conditions. It is likely that unfavorable water quality characteristics in Gwyder Bay prevented the dispersal of rearing grayling in 1992.

We captured juvenile grayling in the Sakonowyak River on August 23, 1991. Fall movements to wintering habitat occur in the last week of August or early September prior to freeze-up. The Sakonowyak River lacks suitable grayling wintering habitat therefore fall movement to deep water habitat is necessary to avoid suboptimal winter conditions and high mortality. Fall migration between coastal drainages in ANWR have been documented by adult grayling using radiotelemetry techniques (West et al 1992).

A single juvenile broad whitefish was captured in August. The presence of anadromous broad whitefish indicate that tundra streams such as the Sakonowyak River provide conditions suitable for summer rearing.

There are no current or proposed gravel extraction sites in the Sakonowyak River system. With the addition of deep water wintering habitat ninespine stickleback and grayling abundance would likely increase.

Smith Creek

The 1992 fish sampling data indicate that Smith Creek is an important grayling spawning and rearing system. Grayling catch rates were greater in Smith Creek than that found in other tundra streams sampled and in June 31% of the grayling catch consisted of adult fish exceeding 300 mm. Spring upstream movements by adult grayling are related to spawning. In early September young-of-the-year grayling were abundant providing further evidence that Smith Creek is a spawning and nursery area. During September 157 (64%) of the 246 grayling captured were < 70 mm, a size generally considered to be young-of-the-year. Large catches in September indicate downstream migration to wintering areas.

Greater grayling catch rates and use by all age and size classes indicate that Smith Creek supports a reproductive population. The most important difference between Smith Creek and other tundra streams in our study is the proximity of the stream system to riverine winter habitat. Suitable habitat for all life history stages is found in Smith Creek and associated deep water areas in the Kuparuk River.

Ninespine stickleback were captured in each sample period but catch rates were lower than that found in other tundra stream systems. Although suitable winter habitat is available in the Kuparuk River, competition with grayling may limit ninespine stickleback abundance to levels below that of other tundra streams. While emergent vegetative communities are found in Smith Creek these communities are not abundant. Ninespine stickleback use vegetated areas for spawning and rearing therefore Smith Creek may be less productive for ninespine stickleback than other tundra stream systems in the area. Ninespine stickleback were most abundant in our sample catches in September. These results indicate downstream migration to suitable wintering areas.

Slimy sculpin were captured in both Kuparuk River tributaries but were absent in catches from other tundra stream systems. Slimy sculpin are found in most large freshwater stream systems on the North Slope and are often associated with rock and gravel substrates. The Kuparuk River provides habitat suitable for slimy sculpins. Summer rearing and possibly spawning habitat extends into small tributaries such as Smith Creek.

There are no current or proposed gravel extraction areas in the Smith Creek drainage. The sampling results indicate that Smith Creek provides spawning and summer rearing habitat for a segment of the grayling population found in the lower Kuparuk River. The risk of disturbance and alteration of productive fish habitat in Smith Creek is greater than the potential benefits from habitat enhancement of future gravel extraction sites.

Pebble Creek

Pebble Creek is used by spawning and rearing grayling. In June 16% of the grayling captured were adult fish exceeding 300 mm. Fifteen (27%) of the 56 grayling captured in September were young-of-the-year size fish <70 mm. These results are similar to that found in Smith Creek. Both Smith and Pebble Creek are tributaries of the Kuparuk River.

Ninespine stickleback were captured during each of three sample periods but catch rates were much lower than that found in tundra streams with deep water excavated areas. While ninespine stickleback have access to deep water habitat in the Kuparuk River it is likely that the competitive interaction with grayling keep abundance lower than that found in other tundra streams. The highest ninespine stickleback catch rates occurred in September indicating downstream movement to wintering areas.

Small numbers of slimy sculpin were captured during each sample period. Slimy sculpins were absent in sample catches from all tundra streams but Pebble and Smith Creeks. These data suggest that the Kuparuk River system supports a population of slimy sculpins and tributaries such as Pebble and Smith Creek, provide summer rearing and possibly spawning habitat.

Pebble Creek was the only tundra stream system where burbot were captured. These data indicate that burbot from the Kuparuk River system use tundra streams for summer rearing.

There are no current or proposed gravel extraction sites on Pebble Creek. A stream channel restoration project has been completed at a site immediately upstream of the Pebble Creek sample site. This project involved removal of a section of abandoned gravel road and culverts that had washed out and disturbed the stream channel and adjacent wetlands. This project has removed potential barriers to fish passage and opened upstream areas of Pebble Creek for use by fish. Upstream of the restored area a second abandoned road crossing has impacted wetland areas associated with Pebble Creek. A plan should be developed to restore the wetlands impacted by gravel deposition.

Gravel Mine Site Water Quality Sampling

We sampled Kuparuk Mine Site D in early May under thick ice cover and during the open water season in August and found uniform water quality characteristics at each depth sampled. These measurements indicate that Kuparuk Mine Site D is well mixed throughout the year and thermal stratification does not occur.

Dissolved oxygen concentrations in Kuparuk Mine Site D were at or near saturation during both the ice-covered and open water seasons. Dissolved oxygen concentration is an important factor for winter survival of fish. In a paper describing aquatic habitat potential of gravel pits Herricks (1982) presents chemical parameters typically measured and ranges of values which support fisheries. The results of our sampling indicate that the water quality characteristics found in Kuparuk Mine Site D are within these ranges and suitable for fish production.

In May under ice cover we found much higher specific conductance levels in Put 27 than that found during the first open water season after the site was flooded (Hemming 1992). In August (1990) conductivity ranged between 760 and 780 uS/cm at the various depths sampled while levels found in May (1991) were uniform at 6598 uS/cm at each depth sampled through the water column. The conductivity levels measured in May are of interest because they substantially exceed that of freshwater lakes in the area. This pattern continued in 1992 as conductivity levels increased again and exceeded 9950 uS/cm at each depth sampled.

In August (1991) we found two water masses in Put 27. Water at or below six meters had similar chemical characteristics to that found during the ice covered season while the shallow water consisted of lighter freshwater from river runoff. Spring flood waters which originate from snowmelt in tundra areas fill the Put River system and flow into Put 27 above dense high salinity water. The depth at which rapid changes in water quality characteristics were found is similar to the depth of the inlet channel to

Put 27. In May (1992) Put 27 returned to uniform and more marine conditions. These seasonal changes are caused by estuarine intrusion into the Put River.

In May (1991) we captured round whitefish under the ice in Put 27. This finding is important because it demonstrates use of Put 27 by wintering fish. As water quality conditions change toward more marine conditions, freshwater species such as round whitefish may be excluded and use by anadromous and marine species may increase.

CONCLUSIONS

- Small Tundra stream systems are productive aquatic habitats characterized by extensive shallow water areas supporting emergent and submerged aquatic vegetative communities. The results of water quality monitoring indicate that tundra stream systems in the North Slope oilfield area are suitable for fish production.

- Fish sampling conducted with fyke net gear in 1991 and 1992 indicates that relatively few fish species use tundra streams in the North Slope oilfield area and fish abundance is low in relation to the amount of rearing habitat available.

- Ninespine stickleback are the numerically dominant fish species in tundra stream systems. Ninespine stickleback were captured in each of the nine tundra stream systems sampled and catch rates exceeded that of other fish species in each system. The greatest ninespine stickleback catch rates occurred in systems with emergent and submerged aquatic vegetative communities suitable for spawning and rearing and with deep water wintering areas located in close proximity to rearing habitat. If wintering habitat is expanded by gravel extraction ninespine stickleback will rapidly colonize these deep water areas and abundance will increase if suitable rearing areas are present.

- Grayling were found in small tundra streams that are tributary to a large river system (Kuparuk River) with wintering habitat and in similar streams that drain directly to the Beaufort Sea but are located in close proximity to a large river. Because wintering habitat is limited in small tundra streams, movements may occur between coastal drainages when conditions in nearshore areas favor dispersal. These movements appear to be most common among juvenile grayling and may vary between years depending on conditions in the nearshore Beaufort Sea. Our working hypothesis is that Kalubik Creek grayling are associated with the Colville River, and Sakonowyak River grayling are associated with the Kuparuk River population. The ecological advantage of movements between coastal drainages may be related to favorable summer rearing habitat in small tundra stream systems or to minimize competition in the larger river systems.

- Anadromous fish that are known to occur in nearshore areas of the Beaufort Sea during the open water season also use small tundra stream systems. Least cisco, broad whitefish, Arctic cisco, and Dolly Varden were captured in small tundra stream systems sampled in this study. While the abundance of anadromous fish captured in our study was relatively low the numerous small freshwater systems draining into the Beaufort Sea may in aggregate represent an important habitat for rearing anadromous fish.

- The Kuparuk Mine Site B experimental grayling transplant demonstrates that if wintering habitat is available in a small tundra stream system it is possible to introduce freshwater fish common to the area but not found in the drainage. The ability of introduced grayling to establish a self sustaining population will be influenced by the competitive interaction with ninespine stickleback. If grayling are introduced soon after wintering habitat is available the competitive advantage obtained by ninespine stickleback through early colonization may be reduced.

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APPENDIX I. Length of fish captured in Prudhoe Bay Unit tundra streams, 1991 and 1992.

Location	Date	Fish * Species	Fork Length (mm)	Comments
Put River	7/19/91	RWF	110	adipose fin clip
		RWF	120	adipose fin clip
		RWF	124	adipose fin clip
		RWF	125	adipose fin clip
		RWF	125	adipose fin clip
		RWF	126	adipose fin clip
		RWF	129	adipose fin clip
		LCI	64	adipose fin clip
		LCI	82	adipose fin clip
		LCI	83	adipose fin clip
		LCI	70	adipose fin clip
		LCI	68	adipose fin clip
	7/20/91	RWF	123	recapture
		RWF	138	adipose fin clip
	8/20/91	LCi	87	adipose fin clip
		LCi	332	adipose fin clip
		BWF	54	adipose fin clip
		BWF	114	adipose fin clip
		RWF	127	adipose fin clip
	9/2/92	ACi	90	no marks
		FHS	50	no marks
		FHS	59	no marks
	9/3/92	BWF	55	no marks
		BWF	60	no marks
		FHS	55	no marks
		FHS	60	no marks
		FHS	62	no marks
Little Put River	8/20/91	BWF	420	tag # 2246
		BWF	425	tag # 2247
	9/2/92	DV	165	top caudal fin clip

* ACi = Arctic cisco
BWF = Broad whitefish
DV = Dolly Varden
FHS = Fourhorn sculpin
LCi = Least cisco
RWF = Round whitefish

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Kalubik Creek	6/20/91	AG	147	adipose fin clip
		AG	151	adipose fin clip
		AG	192	adipose fin clip
		AG	240	adipose fin clip
		AG	279	adipose fin clip
		AG	282	adipose fin clip
		AG	293	adipose fin clip
		AG	304	adipose fin clip
	6/21/91	AG	120	adipose fin clip
		AG	125	adipose fin clip
		AG	130	adipose fin clip
		AG	147	adipose fin clip
		AG	162	adipose fin clip
		AG	172	adipose fin clip
		AG	182	adipose fin clip
		AG	185	adipose fin clip
		AG	253	adipose fin clip
		AG	268	adipose fin clip
	6/22/91	AG	103	adipose fin clip
		AG	107	adipose fin clip
		AG	113	adipose fin clip
		AG	114	adipose fin clip
		AG	115	adipose fin clip
		AG	121	adipose fin clip
		AG	125	adipose fin clip
		AG	128	adipose fin clip
		AG	130	recapture
		AG	132	adipose fin clip
		AG	134	adipose fin clip
		AG	135	adipose fin clip
		AG	152	adipose fin clip
		AG	155	adipose fin clip
		AG	160	adipose fin clip
		AG	182	recapture
		AG	187	adipose fin clip
	6/23/91	AG	104	recapture
		AG	111	recapture
		AG	118	recapture
		AG	119	recapture
		AG	124	recapture
		AG	142	recapture
		AG	162	adipose fin clip
		AG	165	recapture

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Kalubik Creek	6/23/91	AG	170	recapture
		AG	180	recapture
		AG	192	adipose fin clip
		AG	240	recapture
		AG	260	recapture
		AG	273	recapture
		AG	275	adipose fin clip
		BWF	450	Tag # 2232
		RWF	263	adipose fin clip
	7/17/91	AG	123	adipose fin clip
		AG	128	adipose fin clip
		AG	130	adipose fin clip
		AG	135	adipose fin clip
		AG	143	adipose fin clip
		AG	160	adipose fin clip
		AG	170	adipose fin clip
		AG	173	adipose fin clip
		AG	175	adipose fin clip
		AG	185	adipose fin clip
		AG	192	recapture
		LCi	195	adipose fin clip
		RWF	190	adipose fin clip
		RWF	235	adipose fin clip
	7/18/91	AG	135	adipose fin clip
		AG	175	recapture
		AG	187	adipose fin clip
	7/19/91	AG	122	recapture
		AG	128	recapture
		AG	128	adipose fin clip
		AG	132	recapture
		AG	172	adipose fin clip
		AG	178	adipose fin clip
		LCi	192	recapture
	7/21/91	AG	127	adipose fin clip
		AG	138	recapture
		AG	145	adipose fin clip
		AG	155	adipose fin clip
		AG	182	recapture
		AG	185	adipose fin clip
		RWF	233	recapture
	8/20/91	AG	107	adipose fin clip

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Kalubik Creek	8/20/91	AG	155	adipose fin clip
		AG	155	adipose fin clip
		AG	164	adipose fin clip
		AG	165	adipose fin clip
		AG	168	adipose fin clip
		AG	184	adipose fin clip
		AG	186	recapture
		AG	192	recapture
		AG	195	adipose fin clip
		AG	211	adipose fin clip
		AG	234	adipose fin clip
		RWF	174	adipose fin clip
	8/21/91	AG	143	adipose fin clip
		AG	148	adipose fin clip
		AG	184	recapture
		AG	190	adipose fin clip
	8/22/91	AG	148	recapture
		AG	154	adipose fin clip
		AG	167	adipose fin clip
		AG	188	recapture
		AG	197	adipose fin clip
		AG	208	adipose fin clip
	6/21/92	AG	205	caudal fin clip
		AG	217	caudal fin clip
		AG	243	caudal fin clip
		AG	282	caudal fin clip
		BWF	425	caudal fin clip
	6/23/92	AG	282	caudal fin clip
		AG	300	caudal fin clip
	6/24/92	AG	87	caudal fin clip
		AG	88	caudal fin clip
		AG	107	recapture
		AG	108	caudal fin clip
		AG	277	recapture
		AG	299	recapture
		AG	301	caudal fin clip
	6/25/92	AG	229	caudal fin clip
		AG	236	caudal fin clip
		AG	296	recapture
		AG	298	recapture
	7/19/92	AG	126	caudal fin clip

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Kalubik Creek	7/19/92	AG	131	caudal fin clip
		AG	137	caudal fin clip
	7/20/92	AG	134	caudal fin clip
	7/21/92	AG	126	recapture
		AG	140	recapture
		AG	141	recapture
	7/23/92	AG	132	recapture
		AG	138	recapture
	9/2/92	AG	52	unmarked
		AG	55	unmarked
		AG	58	unmarked
		AG	60	unmarked
		AG	60	unmarked
		AG	65	unmarked
		AG	65	unmarked
		AG	69	unmarked
		AG	70	unmarked
East Creek	6/20/91	AG	302	TAG # 2228
		AG	317	TAG # 2149
		AG	322	TAG # 2227
		AG	365	TAG # 2197
	6/21/91	AG	318	TAG # 2272
		AG	394	TAG # 2255
	6/22/91	AG	318	TAG # 2274
		BWF	151	adipose fin clip
	6/23/91	AG	312	TAG # 2017,adipose fin clip
		AG	318	TAG # 2272, recapture
		BWF	97	not marked
		BWF	525	adipose fin clip
	6/22/92	AG	375	TAG # 2220, caudal fin clip
	6/23/92	AG	172	not from 1989 introduction
	6/24/92	AG	327	caudal fin clip
		AG	330	TAG # 2099, caudal fin clip
	6/25/92	AG	329	recapture
Sakonowayak River	7/17/91	AG	86	adipose fin clip
		AG	90	adipose fin clip
		AG	93	adipose fin clip
		AG	123	adipose fin clip
		AG	128	adipose fin clip

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Sakonowayak River	7/17/91	AG	154	adipose fin clip
		AG	155	adipose fin clip
		AG	166	adipose fin clip
		AG	172	adipose fin clip
	7/18/91	AG	86	adipose fin clip
		AG	165	recapture
	7/19/91	AG	87	adipose fin clip
		AG	133	adipose fin clip
		AG	136	adipose fin clip
	7/21/91	AG	138	recapture
	8/20/91	AG	105	adipose fin clip
		AG	106	adipose fin clip
		AG	107	adipose fin clip
		AG	107	adipose fin clip
		AG	107	recapture
		AG	108	adipose fin clip
		AG	108	adipose fin clip
		AG	109	adipose fin clip
		AG	117	adipose fin clip
		AG	136	adipose fin clip
		AG	144	adipose fin clip
		AG	149	adipose fin clip
		AG	151	adipose fin clip
		AG	160	adipose fin clip
		AG	168	adipose fin clip
		AG	188	adipose fin clip
		BWF	200	adipose fin clip
	8/21/91	AG	96	adipose fin clip
		AG	104	recapture
		AG	110	adipose fin clip
		AG	110	adipose fin clip
		AG	113	recapture
		AG	115	recapture
		AG	115	recapture
		AG	116	recapture
		AG	118	adipose fin clip
		AG	148	recapture
		AG	155	recapture
		AG	165	recapture
		AG	167	adipose fin clip
		AG	178	recapture
		BWF	200	recapture

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Sakonowayak River	8/23/91	AG	108	recapture
		AG	117	adipose fin clip
		AG	144	recapture
		AG	157	recapture
		AG	167	recapture
		AG	171	adipose fin clip
Smith Creek	6/22/92	AG	130	Transplant Kuparuk Mine Site D
		AG	137	Transplant Kuparuk Mine Site D
		AG	158	Transplant Kuparuk Mine Site D
		AG	173	Transplant Kuparuk Mine Site D
	6/23/92	AG	52	mortality
		AG	96	Transplant Kuparuk Mine Site D
		AG	98	Transplant Kuparuk Mine Site D
		AG	119	Transplant Kuparuk Mine Site D
		AG	168	Transplant Kuparuk Mine Site D
		AG	247	Transplant Kuparuk Mine Site D
	6/24/92	AG	88	Transplant Kuparuk Mine Site D
		AG	107	Transplant Kuparuk Mine Site D
		AG	113	Transplant Kuparuk Mine Site D
		AG	162	Transplant Kuparuk Mine Site D
		AG	193	Transplant Kuparuk Mine Site D
		AG	199	Transplant Kuparuk Mine Site D
		AG	234	Transplant Kuparuk Mine Site D
		AG	237	Transplant Kuparuk Mine Site D
		AG	240	Transplant Kuparuk Mine Site D
		AG	243	Transplant Kuparuk Mine Site D
		AG	286	Transplant Kuparuk Mine Site D
		AG	306	Transplant Kuparuk Mine Site D
		AG	339	Transplant Kuparuk Mine Site D
		AG	351	Transplant Kuparuk Mine Site D
		AG	353	Transplant Kuparuk Mine Site D
	6/25/92	AG	66	Transplant Kuparuk Mine Site D
		AG	265	Transplant Kuparuk Mine Site D
		AG	273	Transplant Kuparuk Mine Site D
		AG	282	Transplant Kuparuk Mine Site D
		AG	295	Transplant Kuparuk Mine Site D
		AG	328	Transplant Kuparuk Mine Site D
		AG	336	Transplant Kuparuk Mine Site D
		AG	352	Transplant Kuparuk Mine Site D
		AG	382	Transplant Kuparuk Mine Site D
		AG	399	Transplant Kuparuk Mine Site D
	6/26/92	AG	49	Transplant Kuparuk Mine Site D

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Smith Creek	6/26/92	AG	51	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	54	mortality
		AG	136	Transplant Kuparuk Mine Site D
		AG	143	Transplant Kuparuk Mine Site D
		AG	149	Transplant Kuparuk Mine Site D
		AG	246	Transplant Kuparuk Mine Site D
		AG	246	Transplant Kuparuk Mine Site D
		AG	262	released
		AG	270	released
		AG	273	released
		AG	305	released
		AG	311	released
		AG	324	released
		AG	328	released
		AG	341	released
		AG	350	released
		AG	369	released
		AG	370	released
	7/18/92	AG	192	Transplant Kuparuk Mine Site D
		AG	216	disease sample
		AG	240	disease sample
		AG	252	disease sample
	7/19/92	AG	284	disease sample
		AG	296	disease sample
		AG	310	disease sample
	7/20/92	AG	260	disease sample
	7/22/92	AG	112	Transplant Kuparuk Mine Site B
	7/23/92	AG	249	Transplant Kuparuk Mine Site B
		AG	250	Transplant Kuparuk Mine Site B
	7/24/92	AG	257	Transplant Kuparuk Mine Site B
		AG	264	Transplant Kuparuk Mine Site B
	9/1/92	AG	39	Transplant Kuparuk Mine Site B
		AG	45	Transplant Kuparuk Mine Site B
		AG	50	Transplant Kuparuk Mine Site B
		AG	63	Transplant Kuparuk Mine Site B
		AG	135	Transplant Kuparuk Mine Site B
		AG	135	Transplant Kuparuk Mine Site B
		AG	150	Transplant Kuparuk Mine Site B
		AG	155	Transplant Kuparuk Mine Site B
		AG	174	Transplant Kuparuk Mine Site B

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Smith Creek	9/1/92	AG	181	Transplant Kuparuk Mine Site B
		AG	185	Transplant Kuparuk Mine Site B
		AG	190	Transplant Kuparuk Mine Site B
		AG	200	Transplant Kuparuk Mine Site B
		AG	200	Transplant Kuparuk Mine Site B
		AG	215	Transplant Kuparuk Mine Site B
		AG	227	Transplant Kuparuk Mine Site B
		AG	245	Transplant Kuparuk Mine Site B
		AG	247	Transplant Kuparuk Mine Site B
		AG	253	Transplant Kuparuk Mine Site B
		AG	255	Transplant Kuparuk Mine Site B
		AG	283	Transplant Kuparuk Mine Site B
		AG	283	Transplant Kuparuk Mine Site B
		AG	288	Transplant Kuparuk Mine Site B
		AG	329	Transplant Kuparuk Mine Site B
	9/2/92	AG	42	Transplant Kuparuk Mine Site D
		AG	43	Transplant Kuparuk Mine Site D
		AG	43	Transplant Kuparuk Mine Site D
		AG	43	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	46	Transplant Kuparuk Mine Site D
		AG	47	Transplant Kuparuk Mine Site D
		AG	47	Transplant Kuparuk Mine Site D
		AG	47	Transplant Kuparuk Mine Site D
		AG	48	Transplant Kuparuk Mine Site D
		AG	48	Transplant Kuparuk Mine Site D
		AG	48	Transplant Kuparuk Mine Site D
		AG	48	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	53	Transplant Kuparuk Mine Site D
		AG	53	Transplant Kuparuk Mine Site D
		AG	53	Transplant Kuparuk Mine Site D
		AG	53	Transplant Kuparuk Mine Site D
		AG	54	Transplant Kuparuk Mine Site D

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Smith Creek	9/2/92	AG	54	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	56	Transplant Kuparuk Mine Site D
		AG	57	Transplant Kuparuk Mine Site D
		AG	57	Transplant Kuparuk Mine Site D
		AG	58	Transplant Kuparuk Mine Site D
		AG	58	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	90	Transplant Kuparuk Mine Site D
		AG	101	Transplant Kuparuk Mine Site D
		AG	183	Transplant Kuparuk Mine Site D
		AG	191	Transplant Kuparuk Mine Site D
		AG	233	Transplant Kuparuk Mine Site D
		AG	251	Transplant Kuparuk Mine Site D
		AG	260	Transplant Kuparuk Mine Site D
	9/3/92	AG	40	Transplant Kuparuk Mine Site D
		AG	40	Transplant Kuparuk Mine Site D
		AG	42	Transplant Kuparuk Mine Site D
		AG	43	mortality
		AG	43	Transplant Kuparuk Mine Site D
		AG	43	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	45	Transplant Kuparuk Mine Site D
		AG	46	Transplant Kuparuk Mine Site D
		AG	47	Transplant Kuparuk Mine Site D
		AG	48	Transplant Kuparuk Mine Site D
		AG	48	Transplant Kuparuk Mine Site D
		AG	48	Transplant Kuparuk Mine Site D
		AG	49	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	50	Transplant Kuparuk Mine Site D
		AG	51	Transplant Kuparuk Mine Site D

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Smith Creek	9/3/92	AG	51	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	52	Transplant Kuparuk Mine Site D
		AG	53	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	55	Transplant Kuparuk Mine Site D
		AG	56	Transplant Kuparuk Mine Site D
		AG	56	Transplant Kuparuk Mine Site D
		AG	56	Transplant Kuparuk Mine Site D
		AG	57	Transplant Kuparuk Mine Site D
		AG	58	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	60	Transplant Kuparuk Mine Site D
		AG	61	Transplant Kuparuk Mine Site D
		AG	63	Transplant Kuparuk Mine Site D
		AG	65	Transplant Kuparuk Mine Site D
		AG	65	Transplant Kuparuk Mine Site D
		AG	65	Transplant Kuparuk Mine Site D
		AG	70	Transplant Kuparuk Mine Site D
		AG	70	Transplant Kuparuk Mine Site D
		AG	85	Transplant Kuparuk Mine Site D
		AG	85	Transplant Kuparuk Mine Site D
		AG	87	Transplant Kuparuk Mine Site D
		AG	95	Transplant Kuparuk Mine Site D
		AG	96	Transplant Kuparuk Mine Site D
		AG	97	Transplant Kuparuk Mine Site D
		AG	100	Transplant Kuparuk Mine Site D
		AG	100	Transplant Kuparuk Mine Site D
		AG	100	Transplant Kuparuk Mine Site D
		AG	102	Transplant Kuparuk Mine Site D
		AG	103	Transplant Kuparuk Mine Site D

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Smith Creek	9/3/92	AG	103	Transplant Kuparuk Mine Site D
		AG	103	Transplant Kuparuk Mine Site D
		AG	105	Transplant Kuparuk Mine Site D
		AG	105	Transplant Kuparuk Mine Site D
		AG	106	Transplant Kuparuk Mine Site D
		AG	120	Transplant Kuparuk Mine Site D
		AG	145	Transplant Kuparuk Mine Site D
		AG	215	Transplant Kuparuk Mine Site D
		AG	255	Transplant Kuparuk Mine Site D
		AG	263	Transplant Kuparuk Mine Site D
		AG	280	Transplant Kuparuk Mine Site D
	9/4/92	AG	35	released
		AG	39	released
		AG	40	released
		AG	40	released
		AG	40	released
		AG	40	released
		AG	40	released
		AG	41	released
		AG	43	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	45	released
		AG	46	released
		AG	47	released
		AG	47	released
		AG	47	released
		AG	47	released
		AG	48	released
		AG	49	released
		AG	50	released
		AG	50	released
		AG	50	released
		AG	50	released
		AG	50	released
		AG	50	released
		AG	50	released

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Smith Creek	9/4/92	AG	50	released
		AG	50	released
		AG	50	released
		AG	50	released
		AG	50	released
		AG	52	released
		AG	53	released
		AG	53	released
		AG	53	released
		AG	53	released
		AG	55	released
		AG	55	released
		AG	55	released
		AG	55	released
		AG	55	released
		AG	55	released
		AG	55	released
		AG	56	released
		AG	60	released
		AG	60	released
		AG	63	released
		AG	63	released
		AG	63	released
		AG	65	released
		AG	69	released
		AG	70	released
		AG	83	released
		AG	85	released
		AG	89	released
		AG	90	released
		AG	90	released
		AG	91	released
		AG	92	released
		AG	93	released
		AG	93	released
		AG	94	released
		AG	95	released
		AG	95	released
		AG	95	released
		AG	95	released
		AG	99	released
		AG	100	released
		AG	100	released
		AG	100	released
		AG	100	released
		AG	103	released

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Smith Creek	9/4/92	AG	103	released
		AG	107	released
		AG	107	released
		AG	107	released
		AG	109	released
		AG	110	released
		AG	110	released
		AG	111	released
		AG	112	released
		AG	112	released
		AG	120	released
		AG	122	released
		AG	122	released
		AG	125	released
		AG	125	released
		AG	130	released
		AG	183	released
Pebble Creek	6/21/92	AG	54	Transplant Kuparuk Mine Site D
		AG	57	Transplant Kuparuk Mine Site D
		AG	57	Transplant Kuparuk Mine Site D
		AG	59	Transplant Kuparuk Mine Site D
		AG	81	mortality
		AG	90	Transplant Kuparuk Mine Site D
		AG	118	Transplant Kuparuk Mine Site D
		AG	169	Transplant Kuparuk Mine Site D
		AG	178	Transplant Kuparuk Mine Site D
		AG	334	Transplant Kuparuk Mine Site D
	6/22/92	AG	133	Transplant Kuparuk Mine Site D
		AG	142	Transplant Kuparuk Mine Site D
		AG	164	Transplant Kuparuk Mine Site D
		AG	183	Transplant Kuparuk Mine Site D
	6/23/92	AG	47	Transplant Kuparuk Mine Site D
		AG	55	mortality
		AG	60	mortality
		AG	61	Transplant Kuparuk Mine Site D
		AG	64	Transplant Kuparuk Mine Site D
		AG	114	Transplant Kuparuk Mine Site D
		AG	126	Transplant Kuparuk Mine Site D
		AG	257	Transplant Kuparuk Mine Site D
		AG	348	Transplant Kuparuk Mine Site D
		AG	348	Transplant Kuparuk Mine Site D
		AG	377	Transplant Kuparuk Mine Site D
	6/24/92	AG	65	Transplant Kuparuk Mine Site D
		AG	273	Transplant Kuparuk Mine Site D
		AG	284	Transplant Kuparuk Mine Site D

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Pebble Creek	6/24/92	AG	365	Transplant Kuparuk Mine Site D
	6/25/92	AG	152	Transplant Kuparuk Mine Site D
		AG	277	Transplant Kuparuk Mine Site D
	6/26/92	AG	61	Transplant Kuparuk Mine Site D
		AG	65	Transplant Kuparuk Mine Site D
		AG	108	Transplant Kuparuk Mine Site D
		AG	123	Transplant Kuparuk Mine Site D
		AG	149	Transplant Kuparuk Mine Site D
		AG	159	Transplant Kuparuk Mine Site D
		AG	379	Transplant Kuparuk Mine Site D
	7/18/92	AG	73	Transplant Kuparuk Mine Site D
		AG	78	Transplant Kuparuk Mine Site D
		AG	86	Transplant Kuparuk Mine Site D
		AG	140	Transplant Kuparuk Mine Site D
		AG	202	disease sample
		AG	217	disease sample
		AG	229	disease sample
		AG	231	disease sample
		AG	241	disease sample
		AG	242	disease sample
		AG	243	disease sample
		AG	248	disease sample
		AG	251	disease sample
		AG	253	disease sample
		AG	256	disease sample
	7/19/92	AG	73	Transplant Kuparuk Mine Site D
		AG	134	Transplant Kuparuk Mine Site D
		AG	136	Transplant Kuparuk Mine Site D
		AG	231	disease sample
		AG	231	disease sample
	7/20/92	AG	75	Transplant Kuparuk Mine Site D
		AG	78	Transplant Kuparuk Mine Site D
		AG	78	Transplant Kuparuk Mine Site D
		AG	80	Transplant Kuparuk Mine Site D
		AG	113	Transplant Kuparuk Mine Site D
		AG	126	Transplant Kuparuk Mine Site D
		AG	171	Transplant Kuparuk Mine Site D
		AG	200	disease sample
		AG	291	disease sample
	7/21/92	AG	196	Transplant Kuparuk Mine Site B
		AG	211	Transplant Kuparuk Mine Site B
		AG	216	Transplant Kuparuk Mine Site B
		AG	233	Transplant Kuparuk Mine Site B

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Pebble Creek	7/22/92	AG	83	Transplant Kuparuk Mine Site B
		AG	223	Transplant Kuparuk Mine Site B
	7/23/92	AG	83	Transplant Kuparuk Mine Site B
		AG	207	Transplant Kuparuk Mine Site B
	7/24/92	AG	77	Transplant Kuparuk Mine Site B
		AG	79	Transplant Kuparuk Mine Site B
	9/1/92	AG	58	Transplant Kuparuk Mine Site B
		AG	60	Transplant Kuparuk Mine Site B
		AG	61	Transplant Kuparuk Mine Site B
		AG	62	Transplant Kuparuk Mine Site B
		AG	63	Transplant Kuparuk Mine Site B
		AG	64	Transplant Kuparuk Mine Site B
		AG	65	Transplant Kuparuk Mine Site B
		AG	65	Transplant Kuparuk Mine Site B
		AG	95	Transplant Kuparuk Mine Site B
		AG	171	Transplant Kuparuk Mine Site B
		AG	173	Transplant Kuparuk Mine Site B
		AG	176	Transplant Kuparuk Mine Site B
		AG	177	Transplant Kuparuk Mine Site B
		AG	178	Transplant Kuparuk Mine Site B
		AG	178	Transplant Kuparuk Mine Site B
		AG	179	Transplant Kuparuk Mine Site B
		AG	179	Transplant Kuparuk Mine Site B
		AG	180	Transplant Kuparuk Mine Site B
		AG	182	Transplant Kuparuk Mine Site B
		AG	183	Transplant Kuparuk Mine Site B
		AG	184	Transplant Kuparuk Mine Site B
		AG	190	Transplant Kuparuk Mine Site B
		AG	190	Transplant Kuparuk Mine Site B
		AG	192	Transplant Kuparuk Mine Site B
		AG	193	Transplant Kuparuk Mine Site B
		AG	196	Transplant Kuparuk Mine Site B
		AG	197	Transplant Kuparuk Mine Site B
		AG	197	Transplant Kuparuk Mine Site B
		AG	202	disease sample
		AG	204	Transplant Kuparuk Mine Site B
		AG	213	Transplant Kuparuk Mine Site B
		AG	217	disease sample
		AG	217	disease sample
		AG	220	disease sample
		AG	222	disease sample
		AG	222	Transplant Kuparuk Mine Site B
		AG	225	disease sample

APPENDIX II. Length of fish captured in Kuparuk River Unit tundra streams.

Location	Date	Fish* Species	Fork Length (mm)	Comments
Pebble Creek	9/1/92	AG	237	disease sample
		AG	247	disease sample
	9/2/92	AG	52	Transplant Kuparuk Mine Site D
		AG	58	Transplant Kuparuk Mine Site D
		AG	62	Transplant Kuparuk Mine Site D
		AG	62	Transplant Kuparuk Mine Site D
		AG	102	Transplant Kuparuk Mine Site D
		AG	192	Transplant Kuparuk Mine Site D
		BB	70	released
		BB	75	released
	9/3/92	AG	60	Transplant Kuparuk Mine Site D
		AG	69	Transplant Kuparuk Mine Site D
		AG	69	Transplant Kuparuk Mine Site D
		AG	70	Transplant Kuparuk Mine Site D
		AG	96	Transplant Kuparuk Mine Site D
		AG	103	Transplant Kuparuk Mine Site D
		AG	105	Transplant Kuparuk Mine Site D
		AG	147	Transplant Kuparuk Mine Site D
		AG	150	Transplant Kuparuk Mine Site D
		AG	150	Transplant Kuparuk Mine Site D
		AG	159	Transplant Kuparuk Mine Site D

* AG = Arctic grayling
BB = Burbot
BWF = Broad whitefish
LCi = Least cisco

APPENDIX III. Results of water quality sampling in Kuparuk Mine Site B and D.

	Depth (m)	Temp (C)	Dissolved Oxygen mg/L	Hardness mg/L	Alkalinity mg/L	Conductivity uS/cm	pH
Kuparuk Mine Site D 5/2/91	2	0.8	11.0	167	108	450	7.8
	4	1.0	13.0	164	102	384	7.6
	6	1.0	11.0	162	102	393	7.6
	8	1.0	10.5	166	101	393	7.7
	10	0.3	11.3	170	105	403	7.7
	12	1.0	12.6	163	105	393	7.4
	14	0.8	11.4	163	102	393	7.7
		Ice Depth 2.2 m					
8/21/91	1	7.0	11.5	124	68	308	7.9
	2		11.8	123	76	312	7.9
	4		11.3	123	77	312	7.8
	6		11.3	126	72	307	7.8
	8	6.8	11.3	127	71	304	7.8
	10		11.5	127	88	311	7.7
	12		11.3	127	74	310	7.6
	14		11.2	126	73	313	7.2
	16	6.5	11.2	126	75	313	6.7
5/6/92	2	0.5	13.7	143	94	390	7.8
	4	0.5	12.7	145	100	350	7.7
	6	0.5	11.7	143	99	380	7.7
	8	0.5	n/a	143	101	380	7.9
	10	0.5	13.4	142	98	380	7.8
	12	0.5	12.8	142	97	350	7.7
		Ice Depth 2.0					
Kuparuk Mine Site B 5/3/91	2	0.5	8.7	201	148	390	7.3
	4	0.5	8.8	194	147	390	7.3
	6	0.5	7.6	188	146	390	7.5
		Ice Depth 2.2					
5/5/92	2	0.0	11.5	109	101	280	7.7
	4	0.0	12.0	106	101	250	7.3
	6	0.0	10.1	122	103	280	7.6
	8	0.0	1.3	154	103	380	7.3
		Ice Depth 2.1					

APPENDIX IV. Results of water quality sampling in the Lower Put River and Put 27.

	Depth (m)	Temp (C)	Dissolved Oxygen mg/L	Hardness mg/L	Alkalinity mg/L	Conductivity uS/cm	pH
Put 27 5/1/91	2	0.4	10.9	794	168	6598	7.7
	3	0.3	9.8	799	168	6598	7.7
	4	0.4	10.8	826	158	6598	7.7
	6	0.5	10.4	818	165	6598	7.7
	8	0.6	9.5	824	162	6598	7.7
	10	0.5	9.1	814	176	6598	7.7
	12	0.5	11.2	812	168	6598	7.7
	14	0.5	10.6	818	167	6598	7.7
		Ice Depth 2.0					
8/20/91	1	6.5	11.6	350	116	2279	8.2
	2	6.0	11.6	347	118	2129	8.2
	4	6.0	11.3	342	120	2305	8.1
	6	4.5	9.5	826	157	6150	7.8
	8	2.5	9.1	778	159	6393	7.7
	10	2.5	9.2	779	161	6405	7.7
	12	2.5	9.0	768	161	6441	7.7
5/6/92	2	0.5	9.6	1147	140	9950	7.8
	4	0.5	9.6	1171	187	9950	7.8
	6	0.5	11.6	1179	175	10200	7.7
	8	0.5	9.6	1184	153	10500	7.6
	10	0.5	12.3	1170	170	10200	7.7
	12	0.5	7.0	1195	147	10500	7.6
		Ice Depth 1.7 m					
Lower Put River 5/1/91	2	0.2	13.7	910	200	7400	7.8
	4	0.5	7.5	1446	180	12200	7.7
	6	0.8	4.0	1778	154	15700	7.6
		Ice depth 2.0					