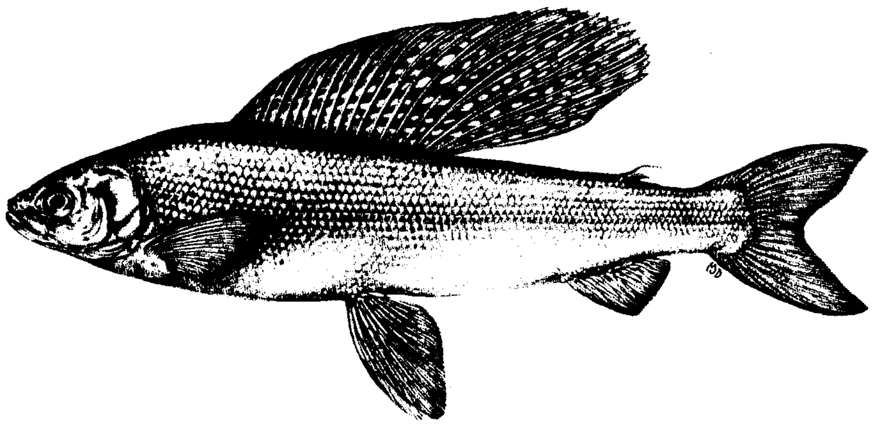
FISHERIES ENHANCEMENT INVESTIGATIONS IN THE PRUDHOE BAY AND KUPARUK RIVER OILFIELDS, 1993

By

Carl R. Hemming

Technical Report 95-3



Alaska Department of Fish & Game
Habitat and Restoration Division
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EXECUTIVE SUMMARY

In the North Slope oilfield region deep water gravel extraction sites provide unique opportunities for fisheries enhancement. Freshwater rearing habitats are present but few fish use these areas because wintering habitat is absent. Deep gravel extraction sites are suitable for fish wintering and when connected to rearing areas in tundra streams all habitat elements needed to support freshwater fish are present. Based on the assumption that such systems would support freshwater fish populations we introduced Arctic grayling (*Thymallus arcticus*) to two deep-mined gravel extraction sites in the Kuparuk River oilfield. In this report we present results of fish sampling including data that evaluate the grayling introductions.

We found excellent winter survival among introduced grayling at each of the two deep water gravel extraction sites. In late summer young-of-the-year grayling were abundant in the sample catch. The presence of young-of-the-year grayling indicates spawning success.

Shallow thaw ponds are an important landscape feature in the North Slope coastal plain region. These waterbodies are biologically productive and support seasonally abundant zooplankton communities. Although tundra ponds are food rich they are not used by fish because they are isolated from wintering areas. To assess fish enhancement potential we conducted an experimental rearing project. Grayling were captured from the Kuparuk River and introduced to a isolated tundra pond in mid-June and recaptured from the pond in late summer. We recaptured 95% of the grayling introduced to the pond. Growth increments among the pond reared grayling approached 1 mm per day during the 70-day experiment.

In the Prudhoe Bay Unit we investigated fish use of mine sites located in estuarine and freshwater reaches of river systems. We also evaluated fish use of a shallow lake located within a tundra stream system. The greatest species richness was found at the estuarine site (Put 27), where we captured 11 species including; three marine, six anadromous, and two freshwater life history types. At a freshwater site located in the Sagavanirktok (Sag) River floodplain we captured seven species including; four freshwater and three anadromous life history types. In a shallow thaw lake (Lake Judith) we captured three anadromous fish species.

ACKNOWLEDGEMENTS

We appreciate financial and logistical support received from the Prudhoe Bay and Kuparuk River oil production units. Martin Bozeman of ARCO Alaska Inc. coordinated and assisted in our effort to obtain grant funding for this project. Larry Krizan, Al Schuyler and the field environmental staff of the Kuparuk River oilfield were very helpful in arranging field logistical support.

The Alaska Department of Fish and Game (ADF&G), Region III, Sport Fish Division assigned personnel to the project through an interdivision loan. In 1993, Dave Stoller assisted with the field work. Sheree Warner of ADF&G Habitat and Restoration Division edited this report and helped with field data collection. Overall project direction and constructive review comments were provided by Dr. Alvin G. Ott.

INTRODUCTION

In 1986, the Alaska Department of Fish and Game (ADF&G) Habitat Division (now Habitat and Restoration Division), initiated a multi-year investigation of flooded gravel sites within the North Slope oilfields. This project developed from a common interest of the oil industry and ADF&G in the potential of abandoned gravel extraction sites as wintering habitat for fish. Phase one provided data on the physical, chemical, and biological characteristics of flooded gravel mine sites with emphasis on fish colonization and use of these man-made deep water sites (Hemming 1988, Hemming et al 1989, Hemming 1990).

In phase one we identified site characteristics that enhance aquatic productivity and use by fish. We used this information to develop site-specific recommendations for rehabilitation of gravel mine sites in the Prudhoe Bay and Kuparuk oilfields. The Prudhoe Bay and Kuparuk Unit operators responded to these recommendations and implemented rehabilitation projects at abandoned gravel mine sites and developed detailed rehabilitation plans for operational gravel extraction sites.

The second phase involved monitoring the chemical characteristics and fish use of rehabilitated sites (Hemming 1992, Roach 1993). Concurrent with biological monitoring we introduced Sag River grayling to Kuparuk Mine Site B. Subsequently we gathered data to evaluate survival, growth, and reproduction among the transplanted grayling (Winters 1990, Hemming 1992).

In 1991, we initiated a five-year study program to continue and expand upon our earlier investigations of North Slope gravel mine sites. Major elements of the study plan include: investigation of fish use of tundra streams in the oilfield area, additional grayling transplants, and experimental tundra pond rearing of grayling. The tundra stream investigations were completed in 1992 (Hemming 1993) and Kuparuk River grayling were transplanted to Mine Site B and D in 1992 (Hemming 1994).

This progress report summarizes the results of field investigations conducted in 1993 which include:

(1) Evaluation of grayling introductions at Kuparuk Mine Site B and D.

(2) Description and evaluation of experimental tundra pond rearing of juvenile grayling from the Kuparuk River system.

(3) Investigation of fish use of Sag Site C, Put 27, and a shallow lake in the Little Put River system (Lake Judith).

(4) Monitoring of salinity concentrations at Put 27.

PART I: INVESTIGATIONS IN THE KUPARUK RIVER OILFIELD

Introduction

The creation of deep water habitat in tundra stream systems provide unique opportunities for fisheries enhancement. We found that isolated tundra stream systems contain relatively few fish species and our working hypothesis is that fish use of tundra streams is limited by wintering habitat (Hemming 1993). With the addition of deep water wintering habitat all elements of productive freshwater fish habitat appear to be present. Based on the assumption that a deep water site connected to a tundra stream system would provide suitable habitat for freshwater fish we transplanted grayling to Kuparuk Mine Site B. The first introduction occurred in 1989 when we captured 210 large juvenile and adult grayling from the Sag River and transplanted these fish to Mine Site B (Winters 1990). Sampling indicates that roughly 50 of the grayling survived until 1992. Growth rates were rapid among the introduced fish but we found little evidence of reproductive success (Hemming 1994).

In 1992, we captured an additional 1,001 grayling from the Kuparuk River system and introduced these fish to Kuparuk Mine Sites B and D (Hemming 1994). The second introduction included all ages and size classes from young-of-the-year (40-60 mm) to adult (>300 mm). We released 293 in Mine Site B and 708 in Mine Site D. In the first section of PART I we present fish sampling results from Kuparuk Mine Sites B and D which includes data that evaluate survival, growth, and reproductive success among the introduced grayling.

Tundra ponds are a dominant feature in the Arctic coastal plain environment. These shallow, food rich, ponds provide ideal conditions for freshwater fish but water depths are insufficient for winter survival and most are not accessible to fish. In 1993, we introduced Kuparuk River grayling to an isolated tundra pond to determine if increased survival and accelerated growth could be attained by pond reared fish. The second section of PART I describes the grayling rearing experiment and evaluates the potential of tundra ponds in fish enhancement.

Study Sites and Sampling History

In 1993, we sampled Kuparuk Mine Site B, East Creek, and Kuparuk Mine Site D (Figure 1). The tundra pond rearing experiment included fish captured from the Kuparuk

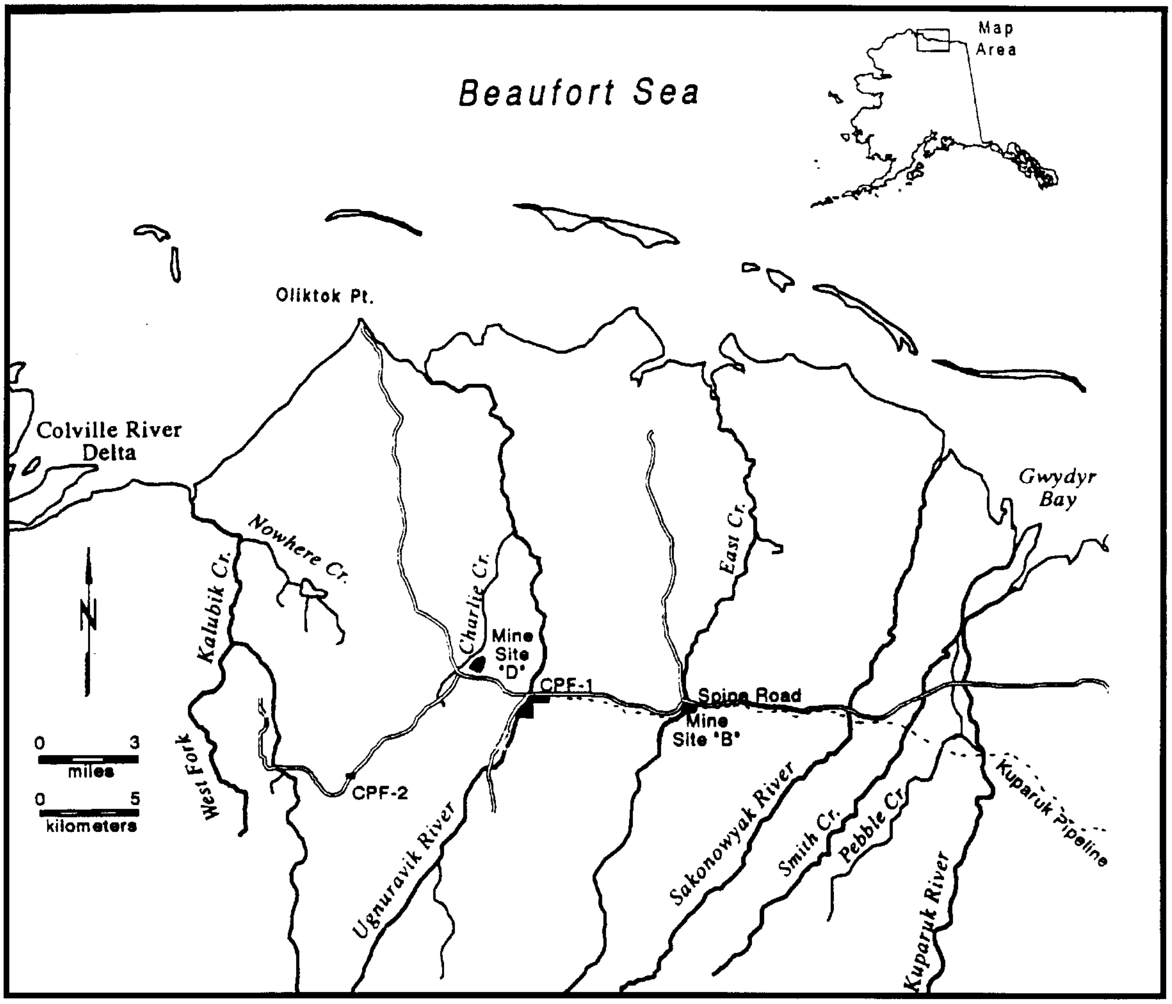

Figure 1. Map of Kuparuk area waterbodies investigated.

river system and summer rearing in a small, isolated pond located north of the Spine Road near the eastern border of the Kuparuk Unit. We refer to this site as Unit Sign Pond because it is located next to the Kuparuk Unit sign. Descriptions of each of these systems is presented below.

East Creek and Mine Site B

East Creek is a 26 km beaded tundra stream that drains a 132 km^2 area upstream of the Spine Road. East Creek empties into Simpson Lagoon between the Colville and Kuparuk rivers. Peak discharge in East Creek 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. Maximum water depth is 11.3 m and the mean depth is 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 May 1989, ARCO Alaska, Inc. established an inlet channel and permanently connected the two lake basins. The inlet channel was 18 m x 24 m excavated to a depth of 1.8 m while the lake basins were connected by two similar channels forming an island. The channels connect East Creek and Mine Site B and allow fish movement between deep water areas in Mine Site B and summer rearing habitats in East Creek.

Before the channels were excavated we sampled East Creek and Kuparuk Mine Site B with minnow traps and gill nets and captured broad whitefish (*Coregonus nasus*) and ninespine stickleback (*Pungitius pungitius*). In 1989, we captured 210 large juvenile and adult grayling from the Sag River and transplanted these fish to Kuparuk Mine Site B. The Sag River grayling ranged from 176 to 399 mm (fork length) and averaged 283 mm (SD = 52 mm). In 1992, we transplanted an additional 293 grayling from the Kuparuk River system. The Kuparuk River fish included all size classes ranging from 40 to 403 mm, with an average length of 122 mm (SD = 77). Fish sampling conducted in East Creek and Mine Site B after site rehabilitation documented the presence of least cisco

(*Coregonus sardinella)*, Dolly Varden (*Salvelinus malma*), and round whitefish (*Prosopium cylindraceum*) in addition to the introduced grayling and the species captured prior to site rehabilitation.

Ugnuravik River and Mine Site D

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 River drains into Simpson Lagoon 2.3 km east of Oliktok Point (Figure 1). The seasonal discharge pattern in the Ugnuravik River is similar to that described for East Creek.

There are three deep mined gravel extraction sites in the Ugnuravik River drainage. Kuparuk Mine Site C is the largest of the sites and includes a 47.5 ha active mine site and a 4.5 ha flooded area that is used as a water reservoir for the Kuparuk Operations Center (KOC). The water reservoir is periodically connected to the river when high water floods a sedge wetland that separates the two waterbodies. A second water reservoir similar to the one at KOC is located downstream adjacent to the Kuparuk Industrial Center (KIC). Ninespine stickleback were captured in the Ugnuravik River at a location upstream of the KOC reservoir (Hemming 1993).

Kuparuk Mine Site D is located on a western tributary of the Ugnuravik River known locally as Charlie Creek. In early June 1984, excavation of a channel between Kuparuk Mine Site D and Charlie Creek resulted in diversion of stream flow into the excavation and formation of a 15.6 ha lake. The project caused significant erosion in the diversion channel and in Charlie Creek. In 1984 and 1985, the entire flow of Charlie Creek diverted into the mine site basin. In 1986, water levels in Mine Site D reached the stream water surface level, reestablishing flow downstream of the mine site. Maximum water depth in Mine Site D is 18.3 m and the average depth is 14.0 m. Ninespine stickleback and least cisco were captured in Mine Site D prior to site rehabilitation (Hemming 1990).

Rehabilitation efforts were completed in early May 1990 and included: construction of several inlet and outlet channels, removal of overburden berms from the south and west side of the mine site, improvements to the access road culvert, and excavation of two perched ponds on top of the overburden stockpile located east of the site. Material removed from the overburden berms was placed on top of the ice to provide organic and fine grained material to the basin after the ice thawed. The outlet channel excavations lowered the water surface elevation and the inlet channels located upstream of Mine Site D are now perched above the water surface elevation. Three attempts have been made to plug the outlet channels and reflood the areas upstream of the site. Each of the three channel plug attempts has failed.

In 1992, we transplanted 708 Kuparuk River grayling to Mine Site D (Hemming 1994). The transplanted grayling ranged from 40 to 408 mm and averaged 115 mm (SD = 85 mm).

Kuparuk River

The Kuparuk River drains a 9,200 km^2 tundra watershed extending south of the oilfield. The multiple interlaced channels of the Kuparuk River resemble the pattern of a braided river. However, unlike a true braided river, the intermediate islands that separate the major river subchannels are relatively stable due to their frozen condition. For this reason, a split channel classification is appropriate (Drage et al 1983).

The majority of total annual discharge in the Kuparuk River occurs during spring breakup. It has been estimated that 78% of the annual discharge occurs in June, with flows decreasing dramatically for the remainder of the summer. The width of active channels also vary markedly during the open water season. The Kuparuk River differs from other tundra streams in the oilfield area because some stream reaches maintain water beneath the ice throughout the winter. The deep water areas occur at the confluence of subchannels and in areas where flow impinges on a resistant bank. These deep water areas provide winter refugia used by fish.

Fish captured and used in the tundra pond rearing experiment were collected from three shallow backwater areas of the Kuparuk River and from two small tundra streams that are tributary to the Kuparuk River (Figure 2).

Unit Sign Pond

Unit Sign Pond is a 0.8 ha, isolated thaw lake. Maximum water depth is less than 1.2 m. The substrate consists of soft organic material that thaws to a depth of roughly 0.6 m by late summer. Pendant grass (*Arctophilia fulva*) occurs in patches around the perimeter of the pond. In our reconnaissance of the site we observed clouds of zooplankton in the water column. A grab sample of these organisms included cladocerans *(Daphnia* sp.)

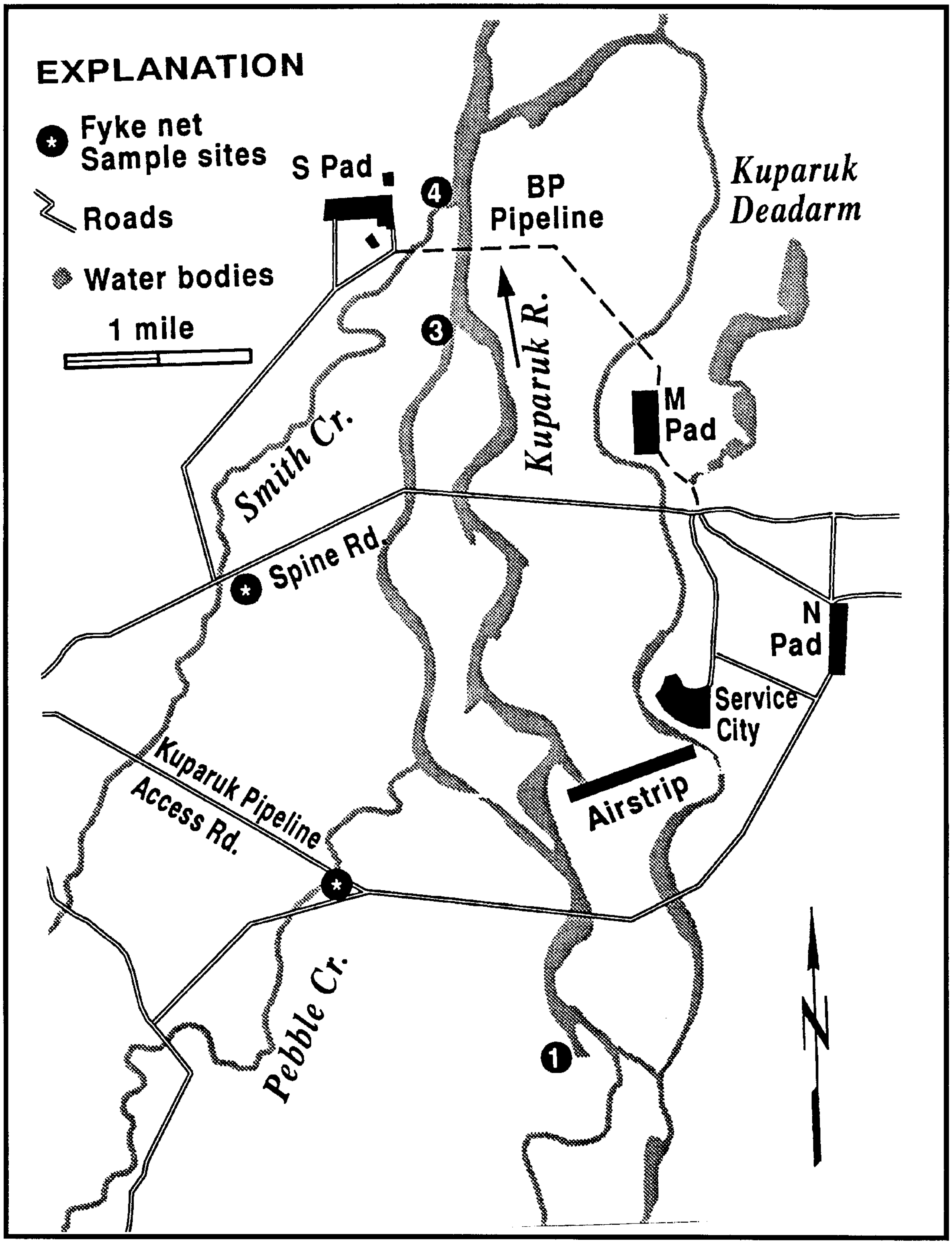

Figure 2. Map of Kuparuk River fish capture locations, 1993.

and eubrachiopods consisting of fairy and tadpole shrimp. A maximum water temperature of 14° C was measured in July.

Methods

Fish Sampling in Kuparuk Mine Sites B and D

We used fyke nets to capture fish at Kuparuk Mines Site B and D. Each net was 3.7 m in length with two 1.2 m square entrance frames, five hoops and a 1.8 m cod end. At Mine Site B we set nets at three road accessible locations; 1.6 km upstream from the mine site in East Creek, at the inlet channel, and at the north end of Mine Site B. At Mine Site D we fished nets at two locations; the southeast corner at the access ramp and the southwest corner at the Charlie Creek inlet. We checked the nets daily. Water temperature was measured at each net site with a hand held mercury thermometer. Netting duration was recorded to determine catch-per-unit-effort (CPUE) for each species at each net site.

Each fish captured was identified and released at the net site. We measured fork length to the nearest millimeter for all fish captured except ninespine stickleback. Grayling were examined for marks and tags. Ninespine stickleback were too numerous to enumerate at most net sites; therefore, we estimated their abundance. We used a 15 cm scoop to release ninespine stickleback and multiplied the number of individuals in a standard scoop by the number of scoops required to empty the net to obtain a rough estimate of abundance.

We used a single census mark-recapture experiment to estimate grayling abundance in Kuparuk Mine Sites B and D. In Mine Site B all grayling were marked with upper caudal fin clips during June and July sample periods while fish greater than 200 mm were tagged with numbered internal anchor tags. We followed similar marking procedures at Mine Site D using adipose rather than upper caudal fin clips. We recaptured marked fish in late summer and used the adjusted Peterson method to estimate the number of grayling at each site (Ricker 1975). Young-of-the-year grayling were not included in the population estimate but data on frequency of occurrence was gathered. Lengths of tagged and recaptured grayling were evaluated to determine growth rates among the introduced fish.

Tundra Pond Rearing Experiment

We collected small (<100 mm) grayling from the Kuparuk River system and introduced these fish to Unit Sign Pond for summer rearing. Grayling were captured in fyke traps fished in backwater areas of the Kuparuk River and in two small tundra stream systems (Figure 2). Grayling within the target size class were measured, placed in coolers equipped with battery powered aerators, transported to Unit Sign Pond, and released. Larger grayling and other fish species were measured and released at the net site.

To recapture the pond reared grayling we fished two fyke traps in Unit Sign Pond for five days (August 28-September 2). Recaptured fish were measured, transported to Mine Site B, and released.

Results

Fish Sampling in Kuparuk Mine Site B

We expended 45.4 net days of fishing effort in the Mine Site B system during 1993. We captured 1,477 grayling, an estimated 6,782 ninespine stickleback, and a single round whitefish (Table 1).

The catch rate for grayling increased during each of the three sample periods with a sharp increase during the August-September sample period. We captured 1,306 young-of-the-year size class (40-60 mm) grayling during the late summer sample period. The largest catch occurred on September 1, when we captured 399 young-of-the-year grayling in a net set in Mine Site B.

Ninespine stickleback numbers also increased during each of the three sample periods. Ninespine stickleback were most abundant in Mine Site B during the July and August-September sample periods. A 339 mm round whitefish was captured at the inlet to Mine Site B on June 24.

Population Estimate

In June and July we fin clipped and released 89 grayling (Appendix I). In August-September we captured 85 grayling and examined these fish for marks (Table 2). We identified 21 fin clipped fish during the recapture event. Using the adjusted Peterson method (Ricker 1975) the estimated grayling population is 352 (95% CI, 553-225). We

Table 1. Results of fyke net sampling in Kuparuk Mine Site B, 1993.

Net Location	Dates	Time Fished Days	Mean * Water Temp (°C)	Fish ** Species	Number	CPUE Fish/day
East Creek	June 19-24	4.9	6.9	AG	12.0	2.4
				NSB	22.0	4.5
Inlet	June 19-25	5.7	7.6	AG	14.0	2.5
				NSB	35.0	5.1
				RWF	1.0	0.2
Mine Site B	June 19-25	5.9	6.9	AG	17.0	2.9
				NSB	83.0	14.1
East Creek	July 18-22	3.9	12.9	AG	7.0	1.8
				NSB	54.0	13.8
Inlet	July 18-22	5.0	13.6	AG	25.0	5.0
				NSB	716.0	143.2
Mine Site B	July 18-22	5.0	13.8	AG	39.0	7.8
				NSB	2,297.0	458.4
East Creek	Aug 28-Sept 2	5.0	4.4	AG	417.0	83.4
				NSB	715.0	143.0
Inlet	Aug 28-Sept 2	5.0	5.3	AG	137.0	27.4
				NSB	858.0	171.6
Mine Site B	Aug 28-Sept 2	5.0	5.3	AG	809.0	161.8
				NSB	2,002.0	400.4

*** Mean temperatures from daily measurements at net sites**

**** AG = Arctic grayling**
NSB = Ninespine stickleback
RWF = Round whitefish

Table 2. Arctic grayling population estimates in Kuparuk Mine Site B and D, 1993.

	Total Number of Grayling		Number of Marked Grayling		Recapture/Capture Ratio	
	Mine Site B	Mine Site D	Mine Site B	Mine Site D	Mine Site B	Mine Site D
In the sample						
Actual number	85 (C)	154 (C)	21 (R)	22 (R)	0.25	0.14
95% CI			13-32	13.8 - 33.2	0.15 - 0.38	0.09 - 0.22
In the Mine Site						
Actual number	352 (N)	553 (N)	89 (M)	81 (M)		
95% CI	553-225	859-372				
Ratio C / N			0.24	0.28		
95% CI			0.15 - 0.36	0.18 - 0.41		
Survival						
% of grayling remaining from introductions	70%	78%				
95% CI	47 - 110%	67 - 121%				

C = Number of grayling captured in August and September (93)

R = Number of recaptures in sample

N = Size of population at time of marking

M = Number of grayling marked in June and July introduced 503 grayling to Kuparuk Mine Site B, therefore, 70% (95% CI, 47 to 110%) of the introduced fish survived until 1993.

Growth

We recaptured 11 tagged grayling from the 1989 Sag River transplant and these fish ranged from 325 to 393 mm and averaged 370 mm. The average length of tagged grayling recaptured in Mine Site B has increased steadily since the 1989 introduction (Figure 3). Seven grayling that were transplanted from the Kuparuk River in 1992 were tagged and recaptured in 1993. The length of time between tagging and recapture ranged from 26 to 67 days and averaged 39 days while growth increments for the Kuparuk River fish ranged from 12 to 31 mm and averaged 20 mm.

Reproduction

We captured young-of-the-year (40-60 mm) grayling at each net site fished between August 29 and September 2. Daily catches ranged from 170 to 475 grayling fry per day (Table 3). Eighty eight percent of the grayling captured from Mine Site B in 1993 were young-of-the-year.

<u>Fish Sampling in Kuparuk Mine Site D</u>

In 1993, we expended 27.4 net days of fishing effort in Mine Site D and captured 531 grayling, an estimated 4,043 ninespine stickleback and a single broad whitefish (Table 4).

The grayling catch rate increased during each of the three sample periods with a sharp increase in August-September. We captured 285 young-of-the-year size class (40-60 mm) grayling during the late summer sample period. The largest catch of young-of-the-year grayling occurred on August 29 when we captured 55 at the inlet to Mine Site D.

Ninespine stickleback numbers also increased during each of the three sample periods. Ninespine stickleback abundance in August-September increased two orders of magnitude from that found in June. A 263 mm broad whitefish was captured at the inlet to Mine Site D on July 23.

Arctic Grayling Growth
Kuparuk Mine Site B

Year	Number	Length Range (mm)	Mean Length (mm)	Standard Deviation
1989 (Transplanted fish)	210	176 - 399	283	52
1990	36	255 - 374	306	35
1991	45	293 - 390	336	23
1992	39	300 - 388	354	21
1993	11	325-393	370	19

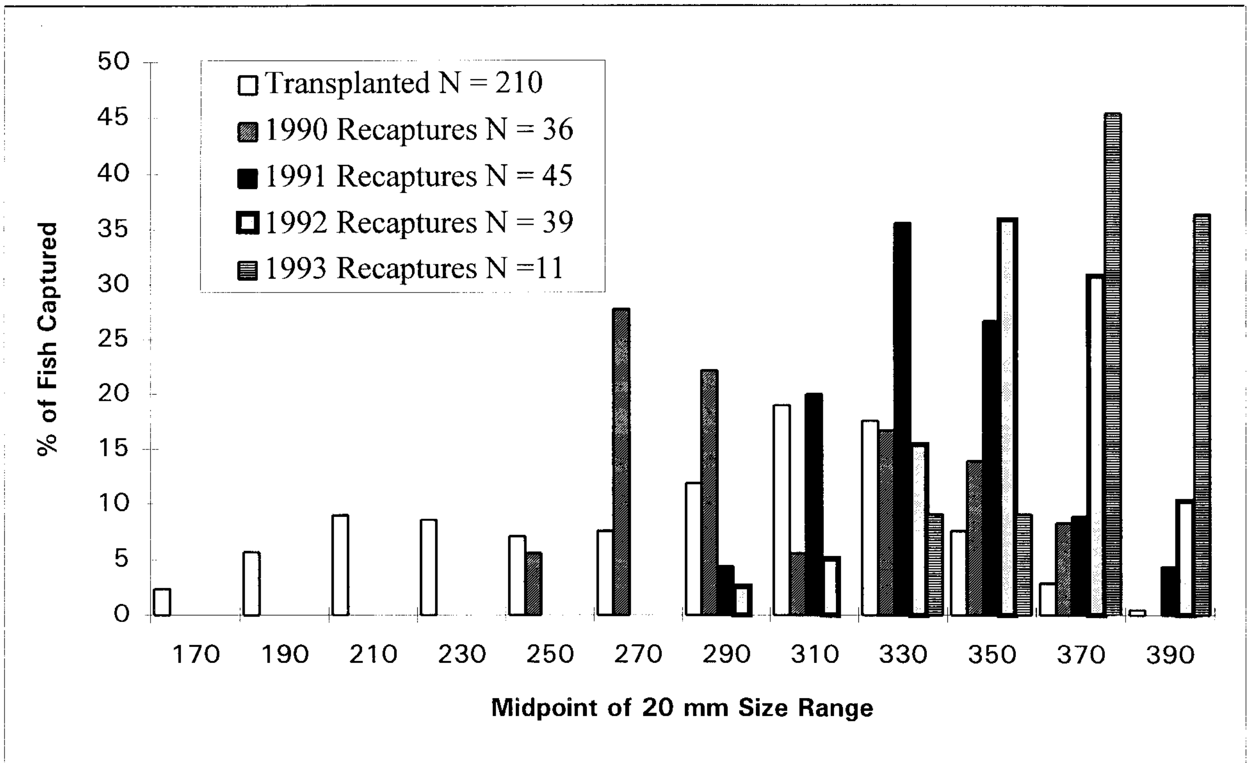

Figure 3. Length frequency distibution of grayling transplanted to Kuparuk Mine Site B and recaptured in 1990, 1991, 1992, and 1993.

Table 3. Number of young-of-the-year grayling captured in Kuparuk Mine Sites B and D, 1993.

Site	Date	Net Locations			Daily Total
		East Creek	Inlet Channel	Mine Site B	
Kuparuk Mine Site B	8/29/93	93	16	98	207
	8/30/93	98	14	58	170
	8/31/93	139	7	138	284
	9/1/93	39	37	399	475
	9/2/93	25	49	96	170
		Net Locations			
		Access Ramp	Southwest Corner		
Kuparuk Mine Site D	8/29/93	14	55		69
	8/30/93	37	6		43
	8/31/93	14	19		33
	9/1/93	53	6		59
	9/2/93	60	21		81

Table 4. Results of fyke net sampling in Kuparuk Mine Site D, 1993.

Net Location	Dates	Time Fished Days	Mean * Water Temp (°C)	Fish ** Species	Number	CPUE Fish/day
Access Ramp	June 19-25	6.1	3.2	AG	29.0	4.7
				NSB	50.0	8.2
Access Ramp	July 17-23	5.6	11.2	AG	33.0	5.9
				NSB	325.0	58.0
Inlet	July 17-23	5.7	11.5	AG	30.0	5.3
				BWF	1.0	0.2
				NSB	202.0	35.4
Access Ramp	Aug 28 - Sept 2	5.0	6.7	AG	248.0	49.6
				NSB	1,633.0	326.6
Inlet	Aug 28 - Sept 2	5.0	6.8	AG	191.0	38.2
				NSB	1,833.0	366.6

* **Mean temperatures from daily measurements at net sites**

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

Population Estimate

In June and July we fin clipped and released 81 grayling (Appendix II). In August-September we captured 154 grayling and examined these fish for marks (Table 2). We identified 22 fin clipped fish in the recapture event. The Mine Site D population estimate is 553 (95% CI, 895-372). We introduced 708 Kuparuk River grayling to Mine Site D in 1992, therefore, 78% (95% CI, 67-121%) of the introduced fish survived until 1993.

Growth

Four Kuparuk Mine Site D grayling were tagged and later recaptured. The slowest growing of the four was 310 mm when tagged and 311 mm when recaptured 42 days later. The other recaptured grayling which were smaller (201, 205, and 221 mm) when tagged grew much faster. Growth increments among the smaller grayling were; 50 mm in 69 days, 19 mm in 27 days, and 14 mm in 23 days.

Reproduction

We captured young-of-the-year (40-60 mm) grayling at both Mine Site D nets between August 29 and September 2. Daily catches ranged from 33 to 81 grayling fry (Table 3). Fifty four percent of the grayling captured in 1993 were young-of-the-year.

Tundra Pond Rearing Experiment

We expended 23 net days of fishing effort to capture grayling for the tundra pond rearing experiment. Nets were fished at five locations in the Kuparuk River and we captured 359 fish (Appendix III). The sample catch included 341 (95%) grayling, 10 (3%) burbot (*Lota lota*), one broad whitefish (<1%), four ninespine stickleback (1%), and three (1%) slimy sculpin (*Cottus cognatus*).

We selected 256 small (<100 mm) grayling and introduced these fish to a 0.8 ha thaw pond (Unit Sign Pond) for summer rearing. The small grayling ranged from 46 to 100 mm in length and averaged 65 mm when captured from the Kuparuk River and released in Unit Sign Pond. The length frequency distribution of fish selected for the experiment was bimodal with 50-70 mm (age-1) and 80-100 mm (age-2) size classes occurring most frequently.

We fished two nets in Unit Sign Pond from August 28 to September 2 and recaptured 242 (95%) of the introduced fish. The recaptured grayling ranged from 100 to 179 mm in length and averaged 126 mm (Figure 4). The average growth increment among grayling during the pond rearing experiment was 61 mm or 0.87 mm/day.

Discussion

Grayling Introductions at Kuparuk Mines Site B and D

High survival rates were found among Kuparuk River grayling in the first year after introduction to Kuparuk Mine Sites B and D. Results obtained from Sag River grayling introduced to Mine Site B indicate lower survival rates among fish introduced in 1989 (Hemming 1994). In 1989, we selected only large juvenile and adult grayling from the Sag River for introduction to Mine Site B. In 1992, we transplanted all size classes of grayling from the Kuparuk River. By selecting all size classes we were able to introduce a larger number of fish with a size distribution closely resembling that of a natural population. Young-of-the-year grayling were most abundant among the fish introduced in 1992 while few adult fish were transplanted. Our 1993 fish sampling results suggest that higher survival rates may occur when smaller fish are introduced.

In 1993, young-of-the-year grayling were abundant in the sample catches from both Mine Sites B and D during late summer. The young-of-the-year grayling provide evidence of spawning success among adult grayling at both sites. We found few young-of-the-year grayling in Mine Site B after the 1989 introduction of Sag River grayling although comparable levels of fish sampling occurred in 1990, 1991, and 1992. Poor reproductive success among Sag River grayling introduced to Mine Site B was attributed to predation of fry or eggs by ninespine stickleback (Hemming 1994).

The most abundant fish in both Mine Sites B and D is ninespine stickleback. We compared five years (1989 to 1993) of ninespine stickleback catch data from Mine Site B using information collected at the same net locations and similar dates and found that catch abundance decreased sharply in 1993 (Table 5). A smaller ninespine stickleback population may have allowed greater grayling fry survival through decreased predatory pressure.

We found strong evidence of reproductive success among grayling in Mine Site D the first year after introduction. Observations and fish sampling at Mine Site D indicate that

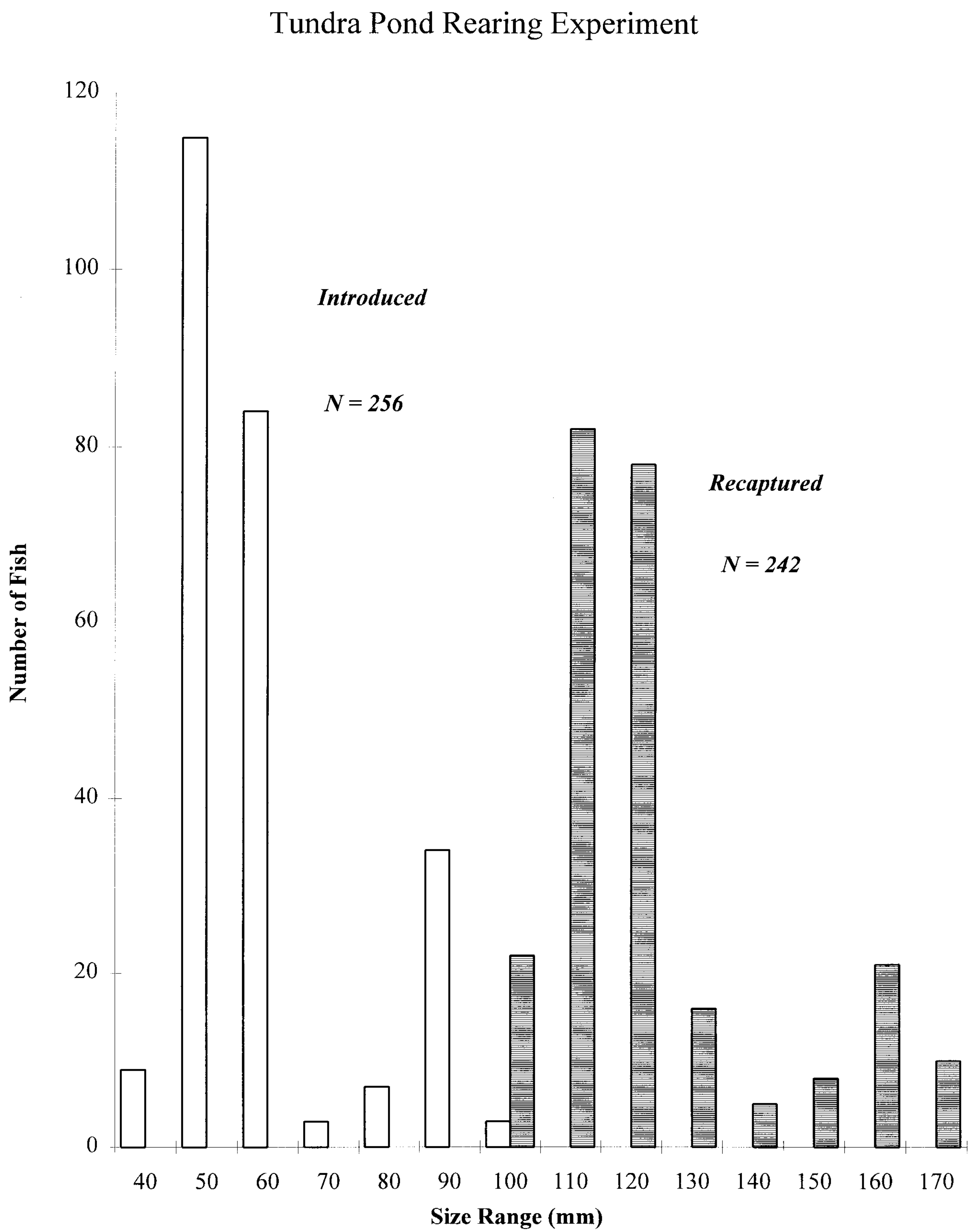

Figure 4. Length of grayling when introduced and when recaptured from a tundra pond, 1993.

Table 5. Ninespine stickleback catch rates in Mine Site B, 1989 to 1993.

Net Location	Dates	Time Fished Days	CPUE Fish/day
Inlet Mine Site B	August 22-24,1989	2.1	8,571
	August 18-23,1990	5.0	4,748
	August 19-23, 1991	3.7	3,053
	September 1-3, 1992	2.3	2,300
	August 28-September 2, 1993	5.0	172
Mine Site B	August 22-24, 1989	2.1	13,333
	August 18-24, 1990	5.7	10,110
	August 28-September 2, 1993	5.0	400

ninespine stickleback abundance is comparable to that found in Mine Site B in 1993. A smaller population of ninespine stickleback and the resultant lower level of predatory pressure on grayling fry and eggs may be an important factor in the survival of young-of-the-year grayling at Mine Site D.

Only 49 of the 708 grayling introduced to Mine Site D and 8 of 293 introduced to Mine Site B were adults (>300 mm) when transplanted from the Kuparuk River in 1992. If strong survival and growth continues among the introduced grayling the number of spawners will increase over time. An increase in the number of spawners will increase fry production and if fry survival continues grayling numbers will increase at both Mine Sites B and D.

Hook injuries indicate that anglers have caught and released grayling introduced to Mine Sites B and D. If grayling abundance increases, angler success may also increase and in turn attract additional fishing effort. Catch and release recommendations have been followed by anglers observed and angling mortality is thought to be minimal.

Tundra Pond Rearing Experiment

Grayling introduced to a isolated thaw pond at a density of 320/ha had a high (95%) survival rate during the summer rearing period. Growth among the pond reared fish was rapid as the small grayling nearly doubled in length in ten weeks. This experiment demonstrates that shallow ponds are favorable rearing habitat for juvenile grayling.

The numerous shallow ponds in the North Slope coastal plain region have potential as fish rearing sites that may be used in enhancement projects. This experiment evaluated pond rearing of small grayling, but this technique may also work with other fish species.

Mine site rehabilitation designed for fisheries enhancement should include areas designed to be similar to thaw ponds, or channel connections should be excavated to existing thaw ponds. Shallow water areas with emergent vegetation provide productive habitat for rearing fish such as the small grayling used in this experiment.

PART II : INVESTIGATIONS IN THE PRUDHOE BAY OILFIELD

Introduction

The 1993 study plan included an experimental transplant introduction of Sag River grayling to Put 27 in the Prudhoe Bay Unit. A fish transport permit was obtained for the grayling introduction but salinity concentrations in Put 27 were found to exceed those acceptable for grayling and the experimental transplant was dropped from the field program. As an alternative to the grayling introduction we investigated fish use of Put 27 to characterize the changes in fish species composition that occur with increasing salinity concentrations. We also investigated fish use of Sag Site C and a large thaw lake in the Little Put River System (Lake Judith).

Study Sites and Sampling History

In 1993, Prudhoe Bay Unit study sites were Put 27 and Lake Judith in the Put River system and Sag Site C in the Sag River system (Figure 5). The following narrative describes each of the sample sites and summarizes the fish sampling history.

<u>Put 27</u>

Put 27 is a circular lake created by gravel removal within a large oxbow of Put River. The site is within section 27 which explains the name. The mouth of the Put River is located 6.4 km downstream from Put 27.

In April 1990, BP Exploration (Alaska) Inc. excavated a 75 m channel between the Put River and the mine site, which allowed the site to flood creating the 14.2 ha lake. This project was designed using ADF&G recommendations with the intent of expanding the volume of wintering habitat available to fish. The channel was excavated with side slopes of 3:1 to a depth of 1.8 m and the excavated material was deposited within the mine site to provide organic debris and fine grained sediment. Hydraulic erosion deepened the inlet channel during the flooding process. Average water depths in Put 27 exceed 10 m.

We monitored fish colonization and use of Put 27 during the first open water season after flooding (1990). Nine fish species were captured including marine, anadromous and freshwater life history types. We captured grayling, round whitefish, Arctic cisco

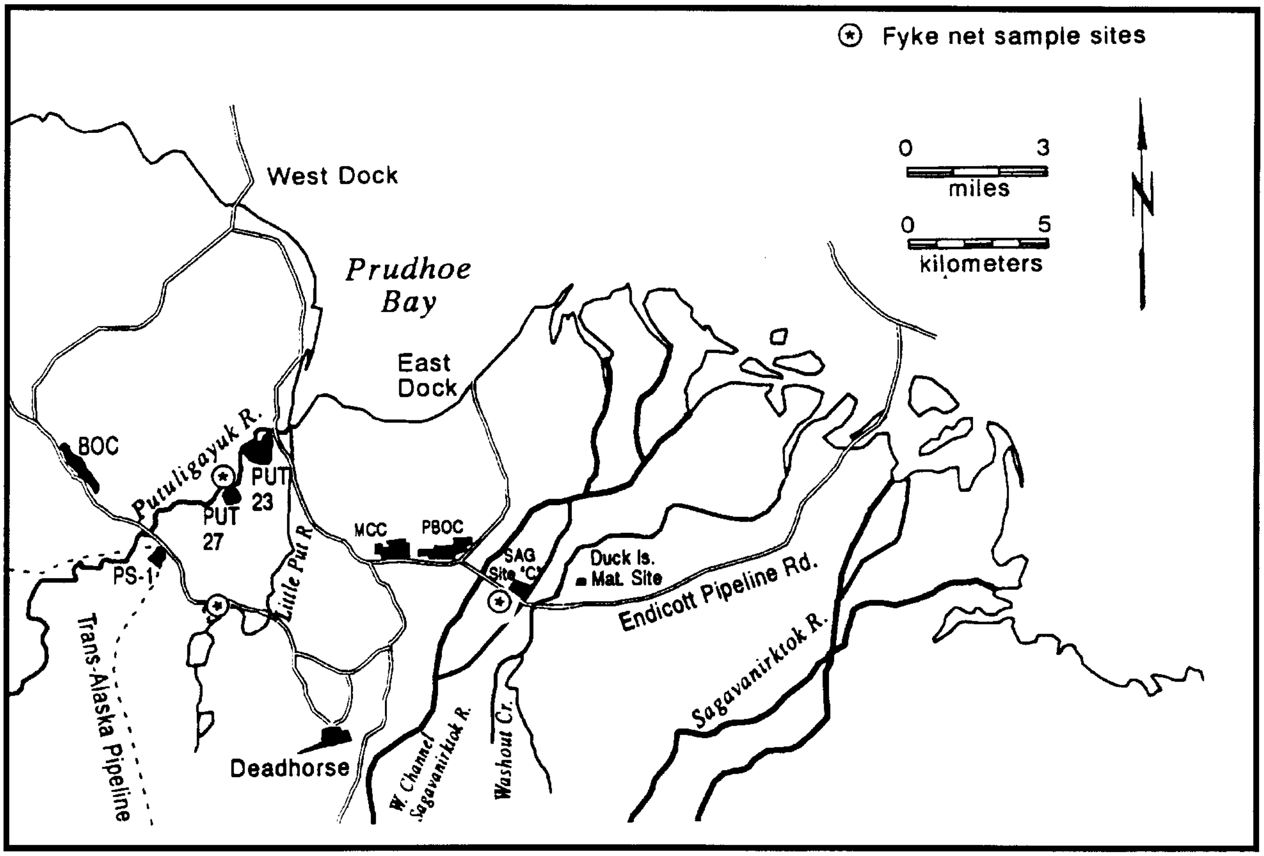

Figure 5. Map of Prudhoe Bay study area and sample sites, 1993.

(*Coregonus autumnalis*), broad whitefish, Dolly Varden, least cisco, ninespine stickleback, rainbow smelt (*Osmerus mordax*) and fourhorn sculpin (*Myoxocephalus quadricornis*). Ninespine stickleback were most abundant in the sample catch while round whitefish were the second most frequently captured species. In early May 1991, we fished gill nets under the ice and captured juvenile round whitefish. This result is important because it demonstrates winter use of Put 27 (Hemming 1993).

Lake Judith

The Little Put River is a beaded tundra stream that originates in the coastal plain south of the oilfield and flows through a series of thaw lakes before emptying into the Put River Estuary and Prudhoe Bay. Lake Judith is the northern most thaw lake connected to the Little Put River (Figure 5). The lake covers 37 ha and maximum water depth is less than two meters. In our previous investigation of the Little Put River we captured ninespine stickleback, broad whitefish and Dolly Varden downstream from Lake Judith.

Sag Site C

Sag Site C is a 15.5 ha, deep mined, gravel extraction site located in a high water floodplain area of the West Channel of the Sag River (Figure 5). The mine site was flooded on June 8, 1986, when the perimeter berm on the west side of the site was breached, allowing Sag River flood water to fill the basin.

In fall 1987, ARCO Alaska, Inc. excavated a 2 ha shallow water zone by removing 183 m of the gravel perimeter berm and excavating floodplain gravel 0.6 to 1.2 m below the water surface elevation in Sag River. By 1993, erosion and sediment deposition from spring flooding had completely filled the shallow water zone that was excavated to provide habitat for rearing fish. In fall 1992, ARCO Alaska Inc. installed culverts on a high water inlet channel bordering the east side of the site. Water now enters the site through the culvert inlet and exits through an outlet channel that has developed at the northeast corner of the lake.

Fish sampling was conducted in Sag Site C from 1986 through 1990. We captured eight fish species including four freshwater and four anadromous life history types. Fish captured in Sag Site C include: grayling, broad whitefish, burbot, Dolly Varden, least cisco, ninespine stickleback, round whitefish and slimy sculpin.

Methods

Fish Sampling

In the Prudhoe Bay unit we used fyke nets to capture fish at Sag Site C, Put 27, and Lake Judith. The equipment and procedures were the same as those described for Kuparuk area fish sampling.

At Sag Site C we fished nets at the access ramp and inlet channel from July 17 to 22. We identified, enumerated, and released all fish at the capture sites. Fork length or total length measurements were taken from all fish captured except ninespine stickleback. Ninespine stickleback were enumerated and released without measurement. Grayling, round whitefish, and Dolly Varden were given adipose fin clips.

At Lake Judith we fished a single fyke net from the northern shore of the lake adjacent to the Spine Road from July 17 to 22 and from August 28 to September 1. Similar procedures were used at Lake Judith as those described for Sag Site C.

At Put 27 we fished a single fyke trap at the access ramp to the site from July 17 to 22 and from August 28 to September 1. We encountered large catches of fourhorn sculpin in August-September. Length measurements were taken from all fourhorn sculpin captured the first two days the net was fished but later catches were enumerated and released. Sinking gill nets were fished from August 29 to 30 at the access ramp and inlet channel. The nets were 38.1 m in length with five 7.6 m panels having mesh sizes of 1.3, 2.5, 3.8, 5.1, and 7.6 cm. Fish that did not appear seriously injured were measured and released. Fish that were dead or appeared unlikely to survive were sacrificed and examined to determine sex and maturity, stomachs were also removed and preserved for analysis of content.

Water Quality Investigations

On March 31 and September 2 we collected water samples from Put 27. The samples were taken at two meter intervals through the water column using a Van Dorn sampler. Water depth at the sample site determined the number of samples collected. Samples collected at each depth were analyzed for conductivity and salinity. In March we drilled a 25.4 cm hole in the ice using a power auger and collected the samples from the ice surface. In September we used a small boat to collect the samples.

Results

Put 27

Fyke Net Sampling

In July and late August, we fished a fyke trap at the access ramp to Put 27. Eleven fish species were captured including those with freshwater, anadromous, and marine life history patterns (Table 6). Arctic cisco, broad whitefish, fourhorn sculpin, least cisco and ninespine stickleback were captured during both sampling periods, Arctic cod, Arctic flounder, Dolly Varden, and round whitefish were captured in July and grayling and rainbow smelt were captured in late August.

Ninespine stickleback, fourhorn sculpin, and broad whitefish were captured most frequently (Table 7). In July the sample catch contained 42% ninespine stickleback, 41% broad whitefish, and 10% fourhorn sculpin. In August 50% of the fish captured were fourhorn sculpin, while 46% were ninespine stickleback and only 2.5% were broad whitefish. The remaining fish species were captured infrequently.

We captured 113 young-of-the-year broad whitefish in July (Appendix IV). These small broad whitefish ranged from 37 to 48 mm and averaged 42 mm (SD = 3.7). In Late August we captured 21 young-of-the-year broad whitefish that ranged from 55 to 77 mm and averaged 66 mm (SD = 4.3).

Gill Net Sampling

We fished experimental gill nets at the access ramp and in the inlet channel to Put 27 from August 29 to 30. At the access ramp we captured five large broad whitefish ranging from 429 to 485 mm in length. At the inlet channel we captured three large broad whitefish (454 to 483 mm), seven least cisco (297 to 358 mm), and a single 144 mm Dolly Varden (Table 8).

We examined stomach content from three broad whitefish and four least cisco. The broad whitefish contained amphipods while the least cisco stomachs contained mysids.

Table 6. Fish species captured in Put 27, 1993.

Fish Species		Marine	Anadromous	Freshwater
Common Name	**Scientific name**			
Arctic cod	*Boreogadus saida*	X		
Arctic cisco	*Coregonus autumnalis*		X	
Arctic flounder	*Liopsetta glacialis*	X		
Arctic grayling	*Thymallus arcticus*			X
Broad whitefish	*Coregonus nasus*		X	
Dolly Varden	*Salvelinus malma*		X	
Fourhorn sculpin	*Myoxocephalus quadricornis*	X		
Least cisco	*Coregonus sardinella*		X	
Ninespine stickleback	*Pungitius pungitius*		X	
Rainbow smelt	*Osmerus mordax*		X	
Round whitefish	*Prosopium cylindraceum*			X

Table 7. Results of fyke net fish sampling in Put 27, 1993.

Net Location	Dates	Time Fished Days	Mean * Water Temp (C°)	Fish ** Species	Number	CPUE Fish/day
Put 27 Access Ramp	July 17-22	5.0	13.2	ACi	2	0.4
				ACD	1	0.2
				AFL	7	1.4
				BWF	113	22.6
				DV	2	0.4
				FHS	27	5.4
				LCi	1	0.2
				NSB	116	23.2
				RWF	4	0.8
Put 27 Access Ramp	Aug 18 - Sept 1	4.0	6.1	ACi	1	0.3
				AG	1	0.3
				BWF	21	5.3
				FHS	421	105.3
				LCi	3	0.8
				NSB	389	97.3
				RBS	1	0.3

* **Mean temperatures from daily measurements at net sites**

** **ACi = Arctic cisco**
ACD = Arctic cod
AFL = Arctic flounder
AG = Arctic grayling
BWF = Broad whitefish
DV = Dolly Varden
FHS = Fourhorn sculpin
LCi = Least cisco
NSB = Ninespine stickleback
RBS = Rainbow smelt
RWF = Round whitefish

Table 8. Gill net fish sampling results from Put 27, August 1993.

Net Location	Species	Length (mm)	Sex	Condition	Stomach Content	Comment
Access Ramp	BWF	429	M	Immature	amphipod fragments	tag scar
		444	-	-	-	released
		456	-	-	-	released
		461	-	-	-	White # 92 LGL 00523 released
		485	M	redeveloping	135 large amphipods	-
Inlet Channel	BWF	454	-	-	-	released
		483	-	-	-	released
		465	M	developing	60 amphipods	-
	DV	144	-	-	-	released
	LCi	297	F	developing	45 mysids	tag # 92 LGL 15436
		309	-	-	-	released
		320	-	-	-	released
		340	F	ripe	85 mysids	-
		346	F	ripe	mysids	-
		357	F	ripe	empty stomach	Yellow tag # 93 LGL 10971
		358	F	developing	1 mysid	-

BWF = Broad whitefish
DV = Dolly Varden
LCi = Least cisco

Water Quality Sampling

At Put 27 we monitored salinity concentrations at two meter intervals through the water column. Samples were collected on March 31 from beneath the ice and during the open water season on September 2. In March, we found salinity concentrations of 9.7 ppt at 2 m and 9.3 ppt at 4 and 6 m, while September concentrations were 3.0 ppt at 2 m, 4.1 ppt at 4 m, and 7.9 ppt at 6 through 12 m.

Lake Judith

We fished a single fyke net in Lake Judith during July and late August and captured broad whitefish, Dolly Varden, and ninespine stickleback. In July we captured ninespine stickleback and broad whitefish while all three species were found in late August (Table 9). Catch rates for ninespine stickleback and broad whitefish increased in late August from those found in July.

In July we captured six broad whitefish including a large adult (470 mm) and five juveniles ranging from 35 to 93 mm in length (Appendix V). In late August we captured 55 juvenile broad whitefish ranging from 61 to 88 mm. Two juvenile Dolly Varden (88 and 161 mm) were captured in August.

Sag Site C

We fished two fyke nets in Sag Site C from July 17 to 22 and captured seven species of fish (Table 9). Included in the catch were four freshwater (grayling, burbot, round whitefish, and slimy sculpin) and three anadromous life history types (broad whitefish, Dolly Varden, and ninespine stickleback).

Grayling were most frequently captured. Thirty grayling from Sag Site C ranged from 109 to 393 mm and averaged 213 mm (SD = 64). Round whitefish followed grayling in frequency of occurrence. We captured round whitefish ranging in size from young-of-the-year to large adults (Appendix VI). Six Dolly Varden were uniform in size ranging from 230 to 260 mm.

Table 9. Results of fyke net fish sampling in Sag Site C and Lake Judith, 1993.

Net Location	Dates	Time Fished Days	Mean * Water Temp C	Fish ** Species	Number	CPUE Fish/day
Sag Site C Access Ramp	July 17-22	5.0	11.8	AG	21	4.2
				BWF	2	0.4
				DV	4	0.8
				RWF	8	1.6
Sag Site C Outlet	July 17-22	5.0	11.9	AG	9	1.8
				BB	1	0.2
				DV	2	0.4
				NSB	8	1.6
				RWF	3	0.6
				SSc	1	0.2
Lake Judith	July 17-22	5.0	13.0	BWF	6	1.2
				NSB	243	48.6
Lake Judith	Aug 21-Sept 1	3.9	5.5	BWF	55	14.1
				DV	2	0.5
				NSB	425	109.0

* **Mean temperatures from daily measurements at net sites**

** **AG = Arctic grayling**
BWF = Broad whitefish
BB = Burbot
DV = Dolly Varden
NSB = Ninespine stickleback
RWF = Round whitefish
SSc = Slimy sculpin

Discussion

Put 27

Salinity concentrations have increased steadily since Put 27 was flooded in 1990 (Table 10). We also found changes in fish species richness and catch rates among various species between 1990 and 1993. The trend has been toward greater species richness and increased abundance among marine and anadromous fish while the number of freshwater fish has decreased. In 1990, ninespine stickleback and round whitefish were most abundant. In 1993, ninespine stickleback were still abundant but fourhorn sculpin and juvenile broad whitefish also were abundant while few round whitefish were captured. In 1993, Arctic cod and Arctic flounder were captured. These marine species were not captured in 1990.

In 1993 large broad whitefish and least cisco were captured in gill nets. The presence of adult and young-of-the-year broad whitefish indicate that the Put River system supports a broad whitefish population. The adult fish found in Put 27 in late summer may use the deep water lake as a wintering site.

Mysids were the principal food item of least cisco captured in Put 27 while amphipods were found in the stomach content of broad whitefish. Both of these fish food organisms are predominantly marine with few freshwater species. Increasing salinity concentrations in Put 27 provide conditions favorable for marine organisms selected as food by broad whitefish and least cisco.

The length of small broad whitefish captured from Put 27 increased between the July and late August sample periods. Growth among juvenile broad whitefish indicates favorable summer rearing conditions in the Lower Put River and Put 27.

Lake Judith

We captured three fish species in Lake Judith and all were anadromous life history types. Marine species are unlikely to occur in Lake Judith because the lake basin is located 6.4 km upstream from the Put River estuary and beyond the zone influenced by marine intrusion. Although productive freshwater fish habitat is present freshwater fish were not found in Lake Judith. The absence of suitable wintering habitat limits the distribution of

Table 10. Put 27 salinity/conductivity profiles, 1990 through 1993.

	Date											
	Aug-90		May-91		Aug-91		May-92		Mar-93		Sep-93	
Depth m	sal ppt	cond uS/cm	sal ppt	cond uS/cm	sal ppt	cond uS/cm	sal ppt	cond uS/cm	sal ppt	cond uS/cm	sal ppt	cond uS/cm
2	0.4	780	3.4	6598	1.0	2129	5.4	9950	9.7	16700	3.0	5830
4	0.4	780	3.4	6598	1.1	2305	5.4	9950	9.3	16200	4.1	7800
6	0.4	780	3.4	6598	3.1	6150	5.5	10200	9.3	16200	7.9	14000
8	0.4	780	3.4	6598	3.3	6393	5.7	10500			7.9	14000
10			3.4	6598	3.3	6405	5.5	10200			7.9	14000
12			3.4	6598	3.3	6441	5.7	10500			7.9	14000
14			3.4	6598								

freshwater fish in small tundra streams and associated thaw lakes that might otherwise support fish populations. Anadromous fish that disperse along the Beaufort Sea coastline move into tundra streams and thaw lake systems to take advantage of seasonally abundant food supplies or to reduce competition with other fish.

Sag Site C

Sag Site C is located 13 km upstream from the mouth of the Sag River and above the influence of marine waters. This deep freshwater lake has been colonized by freshwater and anadromous fish. We captured grayling most frequently in each of six years we sampled Sag Site C (Table 11). Round whitefish followed grayling in frequency of occurrence in four of the six years the site was sampled including 1993.

Increased colonization and use of Sag Site C should result from the culvert inlet that connects a Sag River high water channel to the northeast corner of the lake. The culvert inlet provides access to rearing areas and riverine spawning habitat important for freshwater fish such as grayling. Sag Site C provides critical winter habitat but access to shallow water areas also is important. Shallow water habitats are important to rearing fish because they produce more fish food organisms. Grayling growth is limited to the open water season therefore, any fisheries enhancement projects that increase the quantity of rearing habitat or provide access to rearing habitats should benefit local populations.

Table 11. Sag Site C fish sampling results, 1986 through 1993.

Year	Months Sampled	Gear Number/Type	Effort Days	Fish Captured	*Species	Catch Composition (%)
1986	August	2 gill nets	2	26	AG	92%
		5 minnow traps	2		DV	8%
1987	July	3 gill nets	1	34	AG	82%
		6 minnow traps	1		BWF	9%
					DV	3%
					RWF	6%
1988	July	1 to 3 fyke nets	8	1,636	AG	60%
	August	3 to 4 fyke nets	2		BWF	8%
					BB	>1%
					DV	>1%
					NSB	>1%
					RWF	30%
					SSc	>1%
1989	July	3 fyke nets	2	**1659	AG	69%
	August	3 fyke nets	1		BWF	2%
					BB	2%
					DV	>1%
					LCi	>1%
					NSB	**
					RWF	27%
					SSc	>1%
1990	August	2 fyke nets	1	30	AG	93%
					BB	3%
					RWF	4%
1993	July	2 fyke nets	5	60	AG	50%
					BWF	3%
					BB	2%
					DV	10%
					NSB	13%
					RWF	19%
					SSc	3%

***AG = Arctic grayling**
BWF = Broad whitefish
BB = Burbot
DV = Dolly Varden
LCi = Least cisco
NSB = Ninespine stickleback
RWF = Round whitefish

**** An estimated 15,900 ninespine stickleback were captured in August and these fish were not included in the catch composition total for 1989**

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Appendix I. Length and marking history of grayling captured in Mine Site B and East Creek, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin Clip	Comment
Marking Event							
6/20/93	East Creek	7.9	47	-	-	Upper caudal	
			56	-	-	Upper caudal	
			204	Orange	1982	Upper caudal	
	Mine Site B	6.5	44	-	-	Upper caudal	
			52	-	-	Upper caudal	
			98	-	-	Upper caudal	
6/21/93	East Creek	6.7	49	-	-	Upper caudal	
			51	-	-	-	Mortality
			52	-	-	Upper caudal	
			52	-	-	Upper caudal	
			53	-	-	Upper caudal	
			57	-	-	Upper caudal	
			350	Orange	1984	Upper caudal	
	Inlet	7.0	184	-	-	Upper caudal	
	Mine Site B	6.6	56	-	-	Upper caudal	
			417	Orange	1985	Upper caudal	
6/22/93	East Creek	6.0	53	-	-	Upper caudal	
	Inlet	6.5	53	-	-	Upper caudal	
			202	Orange	1986	Upper caudal	
	Mine Site B	7.0	46	-	-	Upper caudal	
			54	-	-	Upper caudal	
			160	-	-	Upper caudal	
			209	Orange	1982	Recapture	
6/23/93	Inlet	7.4	220	Orange	1994	Upper caudal	
			256	Orange	1992	Upper caudal	
			325	Yellow	2226	Upper caudal	
			351	Orange	1991	Upper caudal	
			384	Orange	1993	Upper caudal	
	Mine Site B	7.2	89	-	-	Upper caudal	
			194	-	-	Upper caudal	
			395	Orange	1995	Upper caudal	male postspawner
6/24/93	East Creek	6.7	50	-	-	Upper caudal	
	Inlet	7.5	345	Yellow	2221	Upper caudal	
			363	Yellow	2065	Upper caudal	male postspawner
	Mine Site B	7.5	190	-	-	Recapture	
			196	-	-	Upper caudal	
6/25/93	Inlet	7.6	209	Orange	1970	Upper caudal	
			383	Yellow	2220	Upper caudal	
			393	Yellow	2185	Upper caudal	
			413	Orange	1985	Recapture	

Appendix I. Length and marking history of grayling captured in Mine Site B and East Creek, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin Clip	Comment
6/25/93	Mine Site B	7.7	46	-	-	Upper caudal	
			159	-	-	Upper caudal	
			197	-	-	Recapture	
			381	Orange	1942	Upper caudal	
7/15/93	Mine Site B	-	365	Yellow	2230	Upper caudal	hook and line
7/19/93	East Creek	13.8	181	-	-	Upper caudal	
	Inlet	14.5	186	-	-	Upper caudal	
			195	-	-	Upper caudal	
			210	Orange	1931	Upper caudal	
			224	Orange	1986	Recapture	
			224	Orange	1933	Upper caudal	
			252	Orange	1930	Upper caudal	
			292	Orange	1929	Upper caudal	
			315	Orange	1934	Upper caudal	
			356	Orange	1932	Upper caudal	
			382	Yellow	2273	Upper caudal	
	Mine Site B	14.8	170	-	-	Upper caudal	
			185	-	-	Upper caudal	
			350	Orange	1935	Upper caudal	
			353	Orange	1937	Upper caudal	
			372	Orange	1936	Upper caudal	
7/20/93	East Creek	13.2	143	-	-	Upper caudal	
			252	Orange	1938	Upper caudal	
			265	Orange	1939	Upper caudal	
	Inlet	14.0	127	-	-	Upper caudal	
			215	-	-	Recapture	
			232	Orange	1940	Upper caudal	
			263	Orange	1941	Upper caudal	
			355	Yellow	2221	Upper caudal	
			370	Yellow	2089	Upper caudal	
			386	Orange	1993	Recapture	
	Mine Site B	14.0	135	-	-	Recapture	
			204	Orange	1947	Upper caudal	
			226	Orange	1948	Upper caudal	
			258	Orange	1946	Upper caudal	
			281	Orange	1949	Upper caudal	
			315	Orange	1945	Upper caudal	
			350	Orange	1991	Recapture	
			358	Orange	1984	Recapture	
			360	Orange	1950	Upper caudal	
			384	Orange	1944	Upper caudal	
			385	Orange	1942	Upper caudal	

Appendix I. Length and marking history of grayling captured in Mine Site B and East Creek, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin Clip	Comment
7/20/93	Mine Site B	14.0	386	Orange	1943	Upper caudal	
7/21/93	East Creek	13.1	232	Orange	1982	Recapture	
	Inlet	13.8	227	Orange	1970	Recapture	
			350	Orange	1925	Upper caudal	
			400	Orange	1923	Upper caudal	
	Mine Site B	13.7	252	Orange	1920	Upper caudal	
			258	Orange	1919	Upper caudal	
			360	Orange	1922	Recapture	
			388	Orange	1921	Upper caudal	
7/22/93	East Creek	11.6	196	-	-	Upper caudal	
			248	Orange	1938	Recapture	
	Inlet	13.2	87	-	-	Upper caudal	
			314	Orange	1934	Recapture	
	Mine Site B	13.2	135	-	-	Recapture	
			207	Orange	1947	Recapture	
			280	Orange	1949	Recapture	
			281	Orange	1918	Upper caudal	
			286	Orange	1915	Upper caudal	
			314	Orange	1917	Upper caudal	
			350	Orange	1935	Recapture	
			358	Orange	1984	Recapture	
			364	Orange	1914	Upper caudal	hook injury
			365	Yellow	2230	Recapture	
			367	Yellow	2104	Upper caudal	
			374	Orange	1913	Upper caudal	
			407	Orange	1916	Upper caudal	
7/23/93	Inlet	12.1	89	-	-	Upper caudal	
			244	Orange	1904	Upper caudal	
			268	Orange	1941	Recapture	
	Mine Site B	13.0	130	-	-	Recapture	
			270	Orange	1902	upper caudal	
			312	Orange	1903	upper caudal	
			355	Orange	1950	Recapture	
			370	Orange	1936	Recapture	
Recapture Event							
8/29/93	Inlet	7.0	180	-	-	-	
			203	-	-	-	
			244	Orange	1990	Recapture	
			245	-	-	-	
			253	-	-	-	

Appendix I. Length and marking history of grayling captured in Mine Site B and East Creek, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin Clip	Comment
8/29/93	Inlet	7.0	256	-	-	-	
			258	-	-	-	
			287	Orange	1992	Recapture	
			295	Orange	1918	Recapture	
			311	-	-	-	
			335	-	-	-	
			362	Orange	1914	Recapture	
			364	Orange	1922	Recapture	
			377	Yellow	2109	-	shed tag
			406	-	-	-	
	Mine Site B	7.3	359	-	-	-	
			385	Orange	1913	Recapture	
			390	Orange	1943	Recapture	
8/30/93	East Creek	5.5	107	-	-	-	
			107	-	-	-	
			110	-	-	-	
			111	-	-	-	
			113	-	-	-	
			119	-	-	-	
			149	-	-	-	
			164	-	-	Recapture	
			170	-	-	-	
			200	-	-	Recapture	
	Inlet	6.0	114	-	-	-	
			116	-	-	-	
			117	-	-	-	
			120	-	-	-	
			121	-	-	-	
			127	-	-	-	
			156	-	-	-	
			158	-	-	-	
			164	-	-	-	
			235	-	-	-	
			372	-	-	-	
			384	Yellow	2085	-	
	Mine Site B	6.9	121	-	-	-	
			181	-	-	-	
			293	-	-	-	
			366	Yellow	2230	Recapture	
			388	Orange	1921	Recapture	
8/31/93	East Creek	4.7	103	-	-	-	
			106	-	-	-	

Appendix I. Length and marking history of grayling captured in Mine Site B and East Creek, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin Clip	Comment
8/31/93	East Creek	4.7	110	-	-	-	
			114	-	-	-	
			114	-	-	-	
			118	-	-	-	
			119	-	-	-	
			123	-	-	-	
			235	-	-	-	
	Inlet	4.9	107	-	-	-	
			262	-	-	-	
			291	-	-	-	
			384	Yellow	2273	Recapture	
	Mine Site B	1.1	159	-	-	-	
			323	Orange	1917	Recapture	
			414	Orange	1985	Recapture	
9/1/93	East Creek	3.0	114	-	-	-	
			120	-	-	-	
			165	-	-	-	
	Inlet	5.6	195	-	-	-	
			279	Orange	1941	Recapture	
			350	-	-	-	
			360	Orange	1991	Recapture	
			364	Orange	1914	Recapture	hook injury
			422	-	-	-	
	Mine Site B	6.3	111	-	-	-	
			113	-	-	-	
			116	-	-	-	
9/2/93	East Creek	2.7	115	-	-	-	
	Inlet	3.1	115	-	-	-	
			200	-	-	-	
			230	-	-	Recapture	
			251	-	-	-	
			353	-	-	-	
	Mine Site B	6.1	108	-	-	-	
			117	-	-	-	
			123	-	-	-	
			353	Orange	1984	Recapture	
			380	Orange	1913	Recapture	
			416	-	-	Recapture	shed tag

*** Young-of-the-year Arctic grayling are not included**

Appendix II. Length and marking history of grayling captured in Mine Site D, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin clip	Comment
Marking Event							
6/20/93	Access ramp	3.6	66	-	-	Adipose	
			201	Orange	1981	Adipose	
			217	Orange	1980	Adipose	
			243	Orange	1978	Adipose	
			260	Orange	1979	Adipose	
6/21/93	Access ramp	4.3	57	-		Adipose	
			219	Orange	1983	Adipose	
6/22/93	Access ramp	3.1	103	-	-	Adipose	
			107	-	-	Adipose	
			108	-	-	Adipose	
			110	-	-	Adipose	
			122	-	-	Adipose	
			124	-	-	Adipose	
			148	-	-	Adipose	
			151	-	-	Adipose	
			153	-	-	Adipose	
			155	-	-	Adipose	
			166	-	-	Adipose	
6/23/93	Access ramp	2.0	167	-	-	Adipose	
			195	-	-	Adipose	
			205	Orange	1990	Adipose	
			221	Orange	1987	Adipose	
			222	Orange	1989	Adipose	
6/24/93	Access ramp	1.7	62	-	-		Mortality
			249	Orange	1997	Adipose	
			256	Orange	1996	Adipose	
6/25/93	Access ramp	4.4	201	Orange	1999	Adipose	
			265	Orange	2000	Adipose	
			340	Orange	1998	Adipose	
7/18/93	Access ramp	10.8	80	-	-	Adipose	
			183	-	-	Adipose	
			185	-	-	Adipose	
			205	Orange	1965	Adipose	
	Inlet	10.2	70	-	-	Adipose	
			142	-	-	Adipose	
			157	-	-	Adipose	
			174	-	-	Adipose	
			176	-	-	Adipose	
			215	Orange	1999	Recapture	
			226	Orange	1962	Adipose	

Appendix II. Length and marking history of grayling captured in Mine Site D, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin clip	Comment
7/19/93	Access ramp	11.6	77	-	-	Adipose	
			145	-	-	Adipose	
			145	-	-	Adipose	
			152	-	-	Adipose	
			174	-	-	Adipose	
			185	-	-	Adipose	
			191	-	-	Adipose	
			210	Orange	1927	Adipose	
	Inlet	12.0	310	Orange	1928	Adipose	
7/20/93	Access ramp	11.5	85	-	-	Adipose	
			123	-	-	Adipose	
			224	Orange	1990	Recapture	
	Inlet	11.4	66	-	-	Adipose	
			92	-	-	Adipose	
			123	-	-	Adipose	
			131	-	-	Adipose	
			144	-	-	Adipose	
			161	-	-	Adipose	
7/21/93	Access ramp	11.7	94	-	-	Adipose	
			122	-	-	Adipose	
			130	-	-	Adipose	
			153	-	-	Recapture	
			195	-	-	Adipose	
			199	-	-	Adipose	
	Inlet	12.1	75	-	-	Recapture	
7/22/93	Inlet	13.0	75	-	-	Adipose	
			76	-	-	Adipose	
			77	-	-	Adipose	
			85	-	-	Adipose	
			87	-	-	Adipose	
			97	-	-	Adipose	
			100	-	-	Adipose	
			102	-	-	Adipose	
			227	Orange	1926	Recapture	
			243	Orange	1910	Adipose	
			285	Orange	1911	Adipose	
7/23/93	Access ramp	10.2	68	-	-	Recapture	
			69	-	-	Adipose	
			84	-	-	Adipose	
			90	-	-	Recapture	
			91	-	-	Adipose	
			94	-	-	Recapture	

Appendix II. Length and marking history of grayling captured in Mine Site D, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin clip	Comment
7/23/93	Access ramp	10.2	131	-	-	Adipose	
			131	-	-	Adipose	
			136	-	-	Adipose	
			137	-	-	Adipose	
			154	-	-	Recapture	
			160	-	-	Adipose	
	Inlet	10.3	79	-	-	Recapture	
			104	-	-	Adipose	
			232	Orange	1907	Adipose	
			243	Orange	1906	Adipose	
			255	Orange	1905	Adipose	
Recapture Event							
8/29/93	Access ramp	6.9	114	-	-	-	
			121	-	-	-	
			209	-	-	-	
	Inlet	7.2	100	-	-	-	
			105	-	-	-	
			106	-	-	-	
			111	-	-	-	
			112	-	-	-	
			121	-	-	-	
			138	-	-	-	
			212	-	-	-	
			216	-	-	-	
			233	-	-	-	
			262	-	-	-	
8/30/93	Access ramp	7.0	109	-	-	-	
			114	-	-	Recapture	
			116	-	-	-	
			117	-	-	-	
			120	-	-	Recapture	
			120	-	-	-	
			122	-	-	-	
			123	-	-	-	
			130	-	-	-	
			137	-	-	-	
			154	-	-	-	
			155	-	-	-	
			166	-	-	Recapture	
			173	-	-	-	

Appendix II. Length and marking history of grayling captured in Mine Site D, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin clip	Comment
8/30/93	Access ramp	7.0	200	-	-	-	
	Inlet	6.7	128	-	-	-	
			149	-	-	Recapture	
			160	-	-	-	
			165	-	-	-	
			174	-	-	-	
			183	-	-	-	
			185	-	-	-	
			197	-	-	-	
			202	-	-	Recapture	
			212	-	-	-	
			220	-	-	-	
			220	-	-	-	
			223	-	-	-	
			230	-	-	-	
			266	-	-	-	
			311	Orange	1928	Recapture	
			321	-	-	-	
			346	-	-	-	
			351	-	-	-	hook injury
8/31/93	Access ramp	6.8	104	-	-	-	
			104	-	-	-	
			105	-	-	Recapture	
			109	-	-	-	
			115	-	-	-	
			116	-	-	-	
			118	-	-	-	
			124	-	-	Recapture	
			124	-	-	-	
			127	-	-	-	
			131	-	-	-	
			134	-	-	-	
			147	-	-	-	
			156	-	-	Recapture	
			162	-	-	Recapture	
			165	-	-	-	
			174	-	-	Recapture	
			181	-	-	-	
			185	-	-	-	
			189	-	-	-	
			194	-	-	-	
			196	-	-	-	

Appendix II. Length and marking history of grayling captured in Mine Site D, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin clip	Comment
8/31/93	Access ramp	6.8	202	-	-	-	
			206	-	-	-	
			212	-	-	-	
			222	-	-	-	
			238	-	-	-	
			262	-	-	-	
			264	-	-	-	
			276	-	-	-	
			316	-	-	-	
	Inlet	7.0	110	-	-	-	
			122	-	-	-	
			129	-	-	-	
			145	-	-	-	
			149	-	-	-	
			153	-	-	-	
			165	-	-	-	
			166	-	-	-	
			172	-	-	-	
			173	-	-	Recapture	
			181	-	-	-	
			186	-	-	Recapture	
			192	-	-	-	
			197	-	-	-	
			202	-	-	-	
			203	-	-	-	
			207	-	-	-	
			208	-	-	Recapture	
			208	-	-	-	
			210	-	-	-	
			211	-	-	-	
			212	-	-	-	
			215	-	-	-	
			215	-	-	-	
			219	-	-	Recapture	
			221	-	-	-	
			224	-	-	-	
			225	-	-	-	
			227	-	-	-	
			230	-	-	Recapture	
			230	-	-	-	
			237	-	-	Recapture	shed tag
			242	-	-	-	

Appendix II. Length and marking history of grayling captured in Mine Site D, 1993.

Date	Location	Temp (°C)	Length * (mm)	Tag Color	Tag Number	Fin clip	Comment
8/31/93	Inlet	7.0	271	Orange	1987	Recapture	
			273	-	-	-	
			279	-	-	-	
			425	-	-	-	
9/1/93	Access ramp	6.4	96	-	-	-	
			101	-	-	-	
			104	-	-	-	
			110	-	-	-	
			111	-	-	-	
			114	-	-	-	
			115	-	-	-	
			118	-	-	-	
			120	-	-	Recapture	
			123	-	-	-	
			124	-	-	-	
			125	-	-	-	
			143	-	-	-	
			158	-	-	-	
			219	-	-	-	
			388	-	-	-	
	Inlet	9.7	90	-	-	-	
			98	-	-	-	
			115	-	-	-	
			115	-	-	-	
			155	-	-	-	
			181	-	-	-	
			186	-	-	Recapture	
			212	-	-	-	
			294	-	-	-	
9/2/93	Access ramp	6.3	110	-	-	-	
			118	-	-	-	
			128	-	-	-	
			214	-	-	Recapture	
			429	-	-	-	
	Inlet	6.3	91	-	-	Recapture	
			98	-	-	-	
			111	-	-	-	
			115	-	-	-	
			117	-	-	-	
			210	-	-	-	
			262	-	-	-	
			277	-	-	-	

*** Young-of-the-year grayling are not included**

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/20/93	Kuparuk River 1		AG	3	46	transplanted to tundra pond
					53	transplanted to tundra pond
					58	transplanted to tundra pond
			SSc	2	69	released
					78	released
	Kuparuk River 4	8.0	AG	88	46	transplanted to tundra pond
					47	transplanted to tundra pond
					49	transplanted to tundra pond
					51	transplanted to tundra pond
					51	transplanted to tundra pond
					51	transplanted to tundra pond
					52	transplanted to tundra pond
					53	transplanted to tundra pond
					54	Mortality
					54	transplanted to tundra pond
					54	transplanted to tundra pond
					54	transplanted to tundra pond
					54	transplanted to tundra pond
					55	transplanted to tundra pond
					55	transplanted to tundra pond
					55	transplanted to tundra pond
					55	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					59	Mortality
					59	transplanted to tundra pond
					59	transplanted to tundra pond
					59	transplanted to tundra pond
					59	transplanted to tundra pond

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/20/93	Kuparuk River 4	8.0	AG		59	transplanted to tundra pond
					59	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					61	transplanted to tundra pond
					61	transplanted to tundra pond
					61	transplanted to tundra pond
					61	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					64	transplanted to tundra pond
					68	transplanted to tundra pond
					70	transplanted to tundra pond
					70	transplanted to tundra pond
					84	transplanted to tundra pond
					88	transplanted to tundra pond
					90	transplanted to tundra pond
					92	transplanted to tundra pond
					93	transplanted to tundra pond
					95	transplanted to tundra pond
					96	transplanted to tundra pond
					96	transplanted to tundra pond
					96	transplanted to tundra pond
					96	transplanted to tundra pond
					97	transplanted to tundra pond
					97	transplanted to tundra pond
					98	transplanted to tundra pond
					98	transplanted to tundra pond
					98	transplanted to tundra pond
					99	transplanted to tundra pond
					100	transplanted to tundra pond
					101	adipose fin clip and released
					102	adipose fin clip and released
					102	adipose fin clip and released
					103	adipose fin clip and released
					103	adipose fin clip and released
					104	adipose fin clip and released
					105	adipose fin clip and released
					106	adipose fin clip and released
					106	adipose fin clip and released

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/20/93	Kuparuk River 4	8.0	AG		108	adipose fin clip and released
					110	adipose fin clip and released
					111	adipose fin clip and released
					112	adipose fin clip and released
					114	adipose fin clip and released
					118	adipose fin clip and released
					118	adipose fin clip and released
					118	adipose fin clip and released
					123	adipose fin clip and released
					200	adipose fin clip and released
					331	adipose fin clip and released
			NSB	2		
	Smith Creek	7.9	AG	2	100	transplanted to tundra pond
					314	adipose fin clip and released
6/21/93	Kuparuk River 1	7.4	AG	1	55	transplanted to tundra pond
			BB	3	59	released
					69	released
					80	released
	Kuparuk River 3	5.9	AG	50	48	transplanted to tundra pond
					52	transplanted to tundra pond
					52	transplanted to tundra pond
					53	transplanted to tundra pond
					55	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					59	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					62	transplanted to tundra pond
					63	transplanted to tundra pond

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/21/93	Kuparuk River 3	5.9	AG		63	transplanted to tundra pond
					63	transplanted to tundra pond
					63	transplanted to tundra pond
					63	transplanted to tundra pond
					64	transplanted to tundra pond
					66	transplanted to tundra pond
					67	transplanted to tundra pond
					67	transplanted to tundra pond
					67	transplanted to tundra pond
					67	transplanted to tundra pond
					70	transplanted to tundra pond
					80	transplanted to tundra pond
					89	transplanted to tundra pond
					90	transplanted to tundra pond
					92	transplanted to tundra pond
					93	transplanted to tundra pond
					94	transplanted to tundra pond
					98	transplanted to tundra pond
					99	transplanted to tundra pond
					100	transplanted to tundra pond
					102	adipose fin clip and released
					102	adipose fin clip and released
					105	adipose fin clip and released
					105	adipose fin clip and released
					127	adipose fin clip and released
					148	adipose fin clip and released
					163	adipose fin clip and released
			BB	1	91	
			NSB	2		
	KuparukRiver 4	6.4	AG	41	46	transplanted to tundra pond
					46	transplanted to tundra pond
					50	transplanted to tundra pond
					51	transplanted to tundra pond
					51	transplanted to tundra pond
					52	transplanted to tundra pond
					52	transplanted to tundra pond
					53	transplanted to tundra pond
					53	transplanted to tundra pond
					53	transplanted to tundra pond
					55	transplanted to tundra pond
					55	transplanted to tundra pond

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/21/93	KuparukRiver 4	6.4	AG		55	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					57	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					59	transplanted to tundra pond
					59	transplanted to tundra pond
					59	transplanted to tundra pond
					59	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					61	transplanted to tundra pond
					61	transplanted to tundra pond
					61	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					63	transplanted to tundra pond
					64	transplanted to tundra pond
					65	transplanted to tundra pond
					65	transplanted to tundra pond
					66	transplanted to tundra pond
					67	transplanted to tundra pond
					382	adipose fin clip and released
	Pebble Creek	6.5	None			no fish captured
	Smith Creek	6.5	AG	7	57	transplanted to tundra pond
					64	transplanted to tundra pond
					92	transplanted to tundra pond
					95	transplanted to tundra pond
					107	adipose fin clip and released
					112	adipose fin clip and released
					159	recapture
	Kuparuk River 1	9.4	AG	2	58	transplanted to tundra pond
					60	transplanted to tundra pond
	Kuparuk River 3	8.3	AG	1	56	transplanted to tundra pond
6/22/93	Kuparuk River 4	8.3	AG	40	55	mortality

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/22/93	Kuparuk River 4	8.3	AG		57	mortality
					59	mortality
					61	mortality
					65	transplanted to tundra pond
					66	transplanted to tundra pond
					80	transplanted to tundra pond
					92	transplanted to tundra pond
					94	transplanted to tundra pond
					95	transplanted to tundra pond
					96	transplanted to tundra pond
					97	transplanted to tundra pond
					97	transplanted to tundra pond
					99	transplanted to tundra pond
					102	recapture, released
					103	adipose fin clip and released
					105	recapture, released
					105	adipose fin clip and released
					105	adipose fin clip and released
					105	adipose fin clip and released
					108	adipose fin clip and released
					111	adipose fin clip and released
					113	adipose fin clip and released
					113	adipose fin clip and released
					113	adipose fin clip and released
					113	adipose fin clip and released
					117	adipose fin clip and released
					128	adipose fin clip and released
					135	adipose fin clip and released
					136	adipose fin clip and released
					136	adipose fin clip and released
					154	adipose fin clip and released
					167	adipose fin clip and released
					181	adipose fin clip and released
					208	adipose fin clip and released
					314	adipose fin clip and released
					334	adipose fin clip and released
					336	adipose fin clip and released
					359	adipose fin clip and released
					370	adipose fin clip and released
	Pebble Creek	6.7	AG	4	61	transplanted to tundra pond
					99	transplanted to tundra pond

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/22/93	Pebble Creek	6.7	AG		344	adipose fin clip and released
					388	adipose fin clip and released
	Smith Creek	6.6	AG	5	93	transplanted to tundra pond
					109	adipose fin clip and released
					113	adipose fin clip and released
					114	adipose fin clip and released
					163	adipose fin clip and released
6/23/93	Kuparuk River 1	7.9	AG	2	48	transplanted to tundra pond
					300	adipose fin clip and released
	Kuparuk River 3	6.9	AG	3	53	transplanted to tundra pond
					56	transplanted to tundra pond
					63	transplanted to tundra pond
		6.9	BB	2	61	released
					62	released
	Kuparuk River 4	6.8	AG	4	52	transplanted to tundra pond
					54	transplanted to tundra pond
					55	transplanted to tundra pond
					65	transplanted to tundra pond
			BB	1	84	released
	Pebble Creek	7.0	AG	1	102	adipose fin clip and released
	Smith Creek	6.8	AG	4	87	transplanted to tundra pond
					105	adipose fin clip and released
					138	adipose fin clip and released
					205	adipose fin clip and released
6/24/93	Kuparuk River 1	9.3	AG	2	53	mortality
					65	transplanted to tundra pond
			BB	2	66	released
					74	released
	Kuparuk River 3	7.6	AG	5	56	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					62	transplanted to tundra pond
					63	transplanted to tundra pond
			BB	1	70	released
			SSc	1	65	released
	Kuparuk River 4	7.4	AG	70	46	transplanted to tundra pond
					51	transplanted to tundra pond
					52	transplanted to tundra pond
					52	transplanted to tundra pond
					53	transplanted to tundra pond
					54	transplanted to tundra pond

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/24/93	Kuparuk River 4	7.4	AG		54	transplanted to tundra pond
					55	transplanted to tundra pond
					55	transplanted to tundra pond
					55	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					56	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					57	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
					58	transplanted to tundra pond
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					59	transplanted to tundra pond
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					60	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					60	transplanted to tundra pond
					61	transplanted to tundra pond
					61	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					62	transplanted to tundra pond
					63	transplanted to tundra pond

Appendix III. Results of Kuparuk River fyke net fish sampling, 1993.

Date	Location *	Temp ** (°C)	Fish *** Species Captured	Number	Length (mm)	Comment
6/24/93	Kuparuk River 4	7.4	AG		63	transplanted to tundra pond
					64	transplanted to tundra pond
					64	transplanted to tundra pond
					64	transplanted to tundra pond
					65	transplanted to tundra pond
					66	transplanted to tundra pond
					66	transplanted to tundra pond
					66	transplanted to tundra pond
					66	transplanted to tundra pond
					66	transplanted to tundra pond
					67	transplanted to tundra pond
					68	mortality
					68	transplanted to tundra pond
					68	transplanted to tundra pond
					87	transplanted to tundra pond
					94	transplanted to tundra pond
					98	transplanted to tundra pond
					98	transplanted to tundra pond
					111	adipose fin clip and released
					205	adipose fin clip and released
					313	adipose fin clip and released
					336	adipose fin clip and released
					363	adipose fin clip and released
			BWF	1	64	released
	Pebble Creek	6.7	None			no fish captured
	Smith Creek	6.6	AG	6	63	transplanted to tundra pond
					65	transplanted to tundra pond
					67	transplanted to tundra pond
					105	adipose fin clip and released
					214	adipose fin clip and released
					282	adipose fin clip and released

* **Figure 2**

** **Water temperature measured at net site**

*** **AG = Arctic grayling**
BB = Burbot
BWF = Broad whitefish
NSB = Ninespine stickleback
SSc = Slimy sculpin

Appendix IV. Results of fyke net fish sampling at Put 27, 1993.

Date	Species	Number	Length (mm)	Comments
7/18/93	Arctic cisco	2	40	
			92	
	Arctic cod	1	109	mortality
	Arctic flounder	4	55	
			57	
			58	
			58	
	Broad whitefish	3	38	
			40	
			42	
	Fourhorn sculpin	3	74	
			85	
			143	
	Ninespine stickleback	52		
	Round whitefish	1	56	
7/19/93	Broad whitefish	10	39	
			41	
			42	mortality
			42	
			42	
			43	
			43	
			43	
			43	
			47	
	Fourhorn sculpin	3	65	
			69	
			76	
	Ninespine stickleback	22		
7/20/93	Arctic flounder	2	35	
			50	
	Broad whitefish	64	(37-48)	1 mortality several stressed
	Fourhorn sculpin	7	36	
			40	
			57	
			67	
			75	
			75	
			85	

Appendix IV. Results of fyke net fish sampling at Put 27, 1993.

Date	Species	Number	Length (mm)	Comments
7/21/93	Arctic flounder	1	60	
	Broad whitefish	36	(38-47)	mortality (4)
	Fourhorn sculpin	10	60	
			67	
			76	
			76	
			80	
			82	
			82	
			94	
			96	
			107	
	Least cisco	1	81	
	Ninespine stickleback	21		
	Round whitefish	1	90	
7/22/93	Dolly Varden	2	155	
			184	
	Fourhorn sculpin	4	71	
			76	
			80	
			145	
	Round whitefish	2	85	
			84	
	Ninespine stickleback	21		
8/29/93	Broad whitefish	10	(60-77)	
	Fourhorn sculpin	70	(51-113)	
	Least cisco	1	326	
	Ninespine stickleback	42		
	Rainbow smelt	1	66	
8/30/93	Broad whitefish	5	(55-69)	
	Fourhorn sculpin	106	(41-92)	
	Least cisco	2	207	
			280	
	Ninespine stickleback	143		
8/31/93	Arctic cisco	1	155	
	Broad whitefish	2	64	
			72	
	Fourhorn sculpin	112		

Appendix IV. Results of fyke net fish sampling at Put 27, 1993.

Date	Species	Number	Length (mm)	Comments
8/31/93	Ninespine stikleback	61		
9/1/94	Arctic grayling	1	191	
	Broad whitefish	4	(65-67)	
	Fourhorn sculpin	133		
	ninspine stickleback	143		

Appendix V. Fish captured in Lake Judith, 1993.

Date	Species	Number	Length (mm)	Comments
7/18/93	Broad whitefish	2	63	
			470	Tag LGLAk 9200503
7/19/93	Ninespine stickleback	79	-	
7/20/93	Ninespine stickleback	48	-	
7/21/93	Broad whitefish	1	93	mortality
	Ninespine stickleback	79	-	
7/22/93	Broad whitefish	3	35	
			42	
			43	
	Ninespine stickleback	37	-	
8/29/93	Broad whitefish	7	(65-88)	
	Ninespine stickleback	89	-	
8/30/93	Broad whitefish	28	(63-85)	1 mortality
	Dolly Varden	1	166	
	Ninespine stickleback	143	-	estimate
8/31/93	Broad whitefish	9	(64-69)	4 mortalities
	Dolly Varden	1	80	
	Ninespine stickleback	143	-	estimate
9/1/93	Broad whitefish	11	(61-79)	
	Ninespine stickleback	50	-	

Appendix VI. Fish captured in Sag Site C, July 1993.

Date	Location	Species	Number	Length (mm)	Adipose fin clip	Recapture	Comments
7/18/93	Access Ramp	Arctic grayling	12	116	X		
				176	X		
				180	X		
				193	X		
				195	X		
				202	X		
				222	X		
				250	X		
				265	X		
				285	X		
				390	X		
				393	X		
		Broad whitefish	2	38			mortality
				41			mortality
		Round whitefish	5	73	X		
				315	X		
				325	X		
				394	X		
				430	X		
	Outlet	Arctic grayling	4	109	X		
				185	X		
				188	X		
				229	X		
		Burbot	1	85			
		Ninespine stickleback	2				
		Round whitefish		78	X		
				109	X		
7/19/93	Access Ramp	Arctic grayling	6	179	X		
				187		X	
				195		X	
				198	X		
				201	X		
				230	X		
		Dolly Varden	3	230	X		
				240	X		
				260	X		
		Round whitefish	1	68			
	Outlet	Arctic grayling	2	135	X		
				194	X		
		Ninespine stickleback	4				
7/20/93	Access ramp	Dolly Varden	1	230	X		
	Outlet	Arctic grayling	1	197	X		
		Ninespine stickleback	1				
7/21/93	Access ramp	Round whitefish	2	97	X		
				241	X		

Appendix VI. Fish captured in Sag Site C, July 1993.

Date	Location	Species	Number	Length (mm)	Adipose fin clip	Recapture	Comments
7/21/93	Access ramp	Slimy sculpin	1	59			
7/22/93	Access ramp	Arctic grayling	3	223		X	
				228		X	
				297		X	
	Outlet	Arctic grayling	2	176	X		
				183	X		
		Dolly Varden	2	239		X	
				243	X		
		Round whitefish	1	228	X		
		Slimy sculpin	1	59			
		Ninespine Stickleback	1				