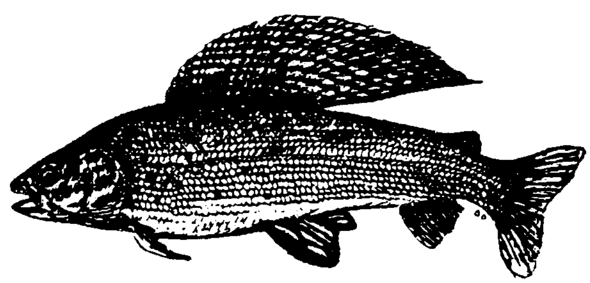
Fish and Habitat Investigations of Flooded North Slope Gravel Mine Sites, 1990

By:
Carl R. Hemming

Technical Report 91-3



Alaska Department of Fish & Game
Division of Habitat

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EXECUTIVE SUMMARY

In 1990 we sampled fish populations in four flooded gravel mine sites in the Prudhoe Bay and Kuparuk River Units of the North Slope oilfields, and water quality information was collected at three recently rehabilitated gravel extraction sites. The 1990 field investigation included four components: evaluation of an experimental Arctic grayling (*Thymallus arcticus*) transplant in Kuparuk Mine Site B (Aanaaliq Lakes), fish sampling in the Put 27 Mine Site, fish sampling in two Sagavanirktok (Sag) River floodplain gravel removal areas, and water quality evaluation of three recently rehabilitated gravel mine sites.

In 1990 we captured 36 grayling in the Aanaaliq Lakes/East Creek system. All but five of the grayling captured retained tags or had tag scars from an experimental transplant conducted in late June 1989. Assuming all the grayling captured in Aanaaliq Lakes and East Creek in 1990 were from the transplanted population, we recaptured 17% of the grayling introduced to the site. Because East Creek does not contain suitable overwintering habitat, overwinter survival of the transplanted fish between 1989 and 1990 can be attributed to available overwintering habitat in Aanaaliq Lakes, a former gravel extraction site. Tagged grayling recaptured in 1990 had rapid growth rates in the first year after introduction to the mine site. The average growth increment for 16 recaptured grayling retaining tags was 58.6 mm. We found no evidence of reproductive success as young-of-the-year grayling were not captured in 1990. A large population of ninespine stickleback (*Pungitius pungitius*) was found in the Aanaaliq Lakes/East Creek system. Stickleback are considered to be competitors with grayling fry and may negatively affect their survival. We also found juvenile least cisco (*Coregonus sardinella*) and broad whitefish (*Coregonus nasus*) using freshwater rearing habitats in Aanaaliq Lakes and East Creek.

In the first open water season after site rehabilitation and flooding, we captured nine species of fish in Put 27, a 14.2 ha (35 ac) deep mined gravel site. The sample catch included individuals with freshwater, anadromous, and marine life history patterns.

In the Sag River floodplain we captured fish in a backwater area formed by shallow scrape gravel removal and in a deep mined gravel extraction site. Grayling, round whitefish (*Prosopium cylindraceum*), and burbot (*Lota lota*) were found in both habitat types, while ninespine stickleback and broad whitefish were found only in the shallow backwater area. Large numbers of juvenile broad whitefish were captured in the shallow backwater site in August.

Water quality information was collected at Aanaaliq Lakes, Kuparuk Mine Site D, and Put 27. Water measurements taken at various depths through the water column indicate mixing during both the open water and ice covered seasons. Specific conductance measurements were higher in the lower Putuligayuk (Put) River which is located nearer the coast than the other mine sites investigated. Lower dissolved oxygen concentrations were found in Aanaaliq Lakes during the ice covered season when compared to dissolved oxygen concentrations found prior to site rehabilitation. It is possible that the rehabilitation project which included construction of an inlet channel has increased use of the site by overwintering fish and this in turn has resulted in increased respiration during the ice covered season and reduced dissolved oxygen concentrations.

INTRODUCTION

In 1986 the Alaska Department of Fish and Game (ADF&G) initiated a multi-year investigation of flooded gravel mine sites within the North Slope oilfields (Figure 1). We identified this study as a priority for the North Slope area, because surface disturbance from oil and gas related gravel extraction is extensive, and gravel mine sites can be rehabilitated as fish and wildlife habitat. Our study provides data to evaluate various habitats resulting from gravel removal, and fish and wildlife use of these areas. We identified site features that increase aquatic productivity and/or use by fish and wildlife. Study results were used to develop site-specific recommendations for rehabilitation of gravel mine sites in the Prudhoe Bay and Kuparuk oilfield areas. The oil industry applied the recommendations in rehabilitation projects at Sag Site C, Kuparuk Mine Site B (referred to as Aanaaliq Lakes by ADF&G staff), Kuparuk Mine Site D, and the Put 27 Mine Site. Gravel extraction and site rehabilitation are occurring concurrently at the Kuparuk Deadarm Mine Site with a plan developed using ADF&G recommendations. For new sites we developed preliminary guidelines for fish and wildlife rehabilitation (Appendix I).

The background information for our continuing studies of flooded gravel mine sites is presented in Technical Reports 88-1, 89-1, 90-2, and 90-4 (Hemming 1988, Hemming et al. 1989, Hemming 1990, Winters 1990). These reports contain the results from the first four years of research and describe the objectives of the study. This annual progress report presents information collected during the 1990 field season. There are four components of the 1990 field investigations: (1) fish sampling in Aanaaliq Lakes and East Creek with emphasis on evaluation of an experimental grayling transplant; (2) fish sampling in the Put 27 Mine Site; (3) fish sampling in two Sag River floodplain sites; and (4) limnological sampling in recently rehabilitated sites.

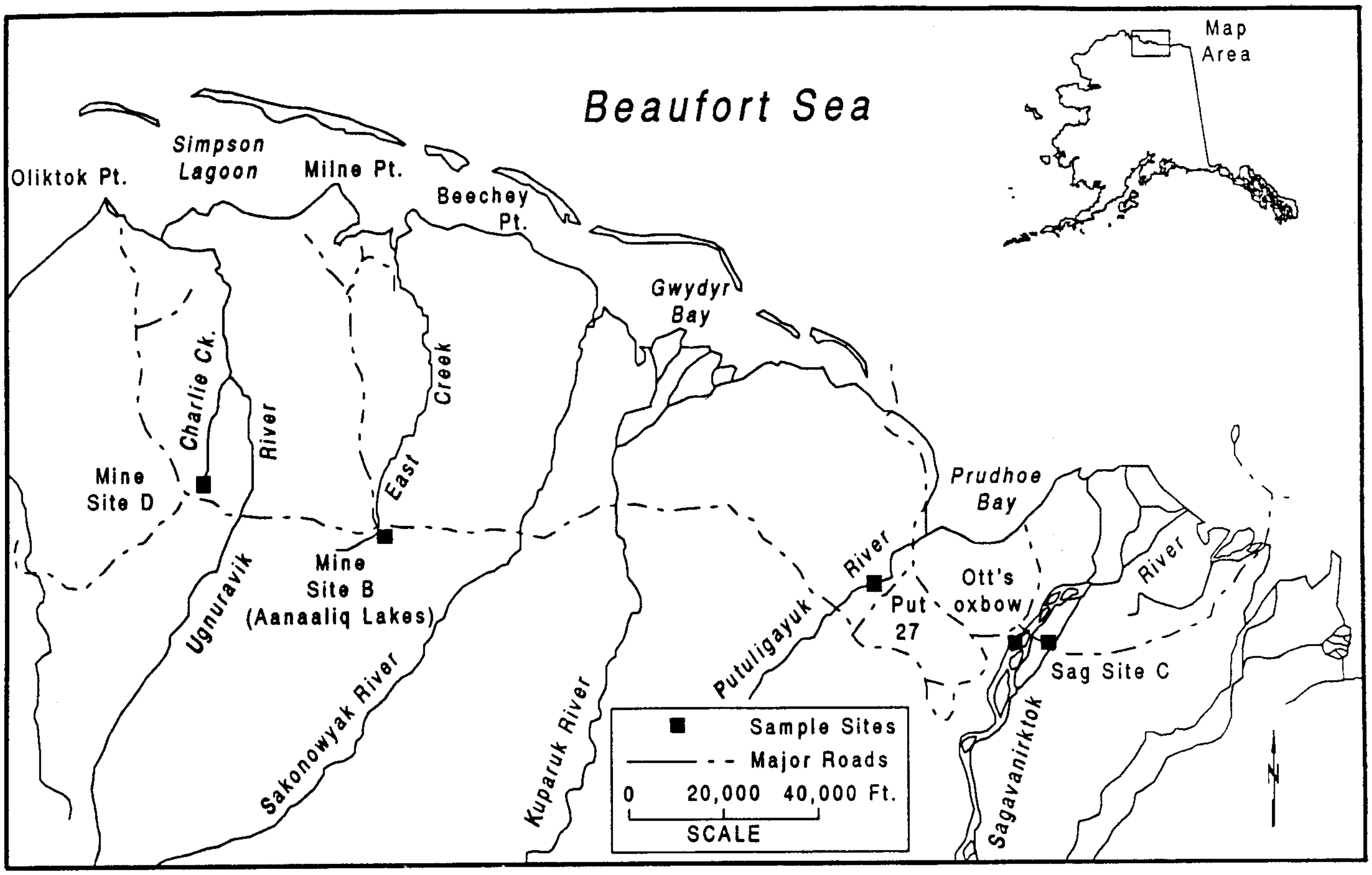


Figure 1. Map of the Prudhoe Bay - Kuparuk oilfield area and the location of flooded gravel mine sites sampled in 1990.

AANAALIQ LAKES/EAST CREEK FISH SAMPLING

Introduction

Fish populations in the mid-Beaufort Region of Alaska's North Slope are limited by the availability of suitable overwintering habitat. Most lakes and tundra stream systems are unsuitable as year round fish habitat, because they contain insufficient quantities of under-ice water, or because the water quality in winter is unsuitable to support fish (Schmidt et al. 1989). Overwintering habitats on the North Slope are confined to a few scattered deep lakes, spring areas, and river pools that do not freeze solid (Craig 1989). In the mid-Beaufort coastal plain area (Colville River to the Sag River), known fish overwintering habitat is limited to several deep isolated pools in the lower Sag and Kuparuk rivers and more extensive areas in the Colville River.

Flooded gravel mine sites excavated to provide construction material for oil and gas development projects provide habitat suitable for overwintering fish. These man-made lakes are deep enough to retain a large volume of under-ice water with dissolved oxygen concentrations that are at or near saturation during the ice covered season (Hemming 1988, Hemming et al. 1989).

Aanaaliq Lakes is a 3.7 ha (9.1 ac) flooded gravel mine site located adjacent to a beaded tundra stream known locally as East Creek. The site consists of two basins with an average depth of approximately 7.0 m (23 ft), and a maximum measured depth of 11.3 m (37 ft). East Creek drains into the Beaufort Sea between the Kuparuk and Colville rivers. To increase access to and use of available overwintering habitat in Aanaaliq Lakes, we recommended that an inlet channel connection be constructed between the lakes and East Creek. The intent of this recommendation was to provide fish with unrestricted access to overwintering habitat in Aanaaliq Lakes and spawning and open water rearing habitat in

East Creek and the lakes. ARCO Alaska, Inc. used the ADF&G recommendations to design and construct the inlet channel between Aanaaliq Lakes and East Creek and channel connections between the two basins of the lake. This project was completed in May 1989 and is described in earlier progress reports (Hemming 1990, Winters 1990).

Fish sampling in Aanaaliq Lakes documented the presence of ninespine stickleback, broad whitefish, and least cisco, but freshwater species were not captured (Hemming 1988, 1990). We concluded that the marine environment of the Beaufort Sea and the absence of overwintering habitat in East Creek prevented the colonization of Aanaaliq Lakes by freshwater fish species.

To determine whether grayling would use the gravel mine site and tundra stream system in a similar manner as do other grayling populations found in tundra stream and deep lake systems, we conducted an experimental fish transplant. In late June 1989, we transplanted 210 large juvenile and adult grayling to Aanaaliq Lakes. The grayling were removed from seven locations within the Sag River drainage near Happy Valley. At the time of initial capture, the grayling ranged from 176 to 399 mm fork length. The grayling were released on June 26 and 27, 1989. Transplant and fish sampling conducted in 1989 are reported in Technical Reports 90-2 and 90-4 (Hemming 1990, Winters 1990).

In 1990 we sampled Aanaaliq Lakes and East Creek to evaluate the survival, growth, and reproductive success of the transplanted grayling. This section of the annual progress report contains information on the transplanted grayling and other fish species captured in the Aanaaliq Lakes/East Creek system.

Methods

We used fyke nets to live capture fish at locations in East Creek and Aanaaliq Lakes. The nets were fished on June 25 to 29, August 18 to 24, and September 24 to 25. Each net was 3.7 m (12 ft) in length with two 1.2 m (4 ft) square entrance frames, five hoops, and a 1.8 m (6 ft) cod end. Net wings measuring 1.2 m (4 ft) by 7.6 m (25 ft) were attached to the first entrance frame. We set the nets perpendicular to shore with a 30.5 m (100 ft) centerlead attached to the entrance frames to divert fish into the fyke net. The water depth and wind conditions governed net placement and the amount of centerlead deployed at each site. We selected net sites upstream of Aanaaliq Lakes, at the inlet to the lakes, in the lakes, and downstream of the lakes (Figure 2). Deep pool areas or beads were used as net sites in East Creek. We set the centerlead across the stream channel such that upstream and downstream fish movements would intercept the gear. The sample periods were selected to provide data on use of lake and stream habitats throughout the open water season.

We checked the nets daily. Fish captured at each net site were emptied from the cod end of the fyke net into a floating holding pen. Each fish was removed from the floating holding pen, identified, examined for tags, and the fork length was measured to the nearest millimeter. Grayling that did not have tags were examined for tag wounds or scars and remarked with Floy internal anchor tags. 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 the holding pen or from a larger dip net. The number of ninespine stickleback in three scoops was counted, yielding 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 this number by 143 to obtain a rough estimate.

We measured the water temperature at each trap site with a hand-held mercury thermometer. The net soak time was recorded to generate catch-per-unit-effort (CPUE) data for each site. Growth information was obtained for grayling by comparing the fork

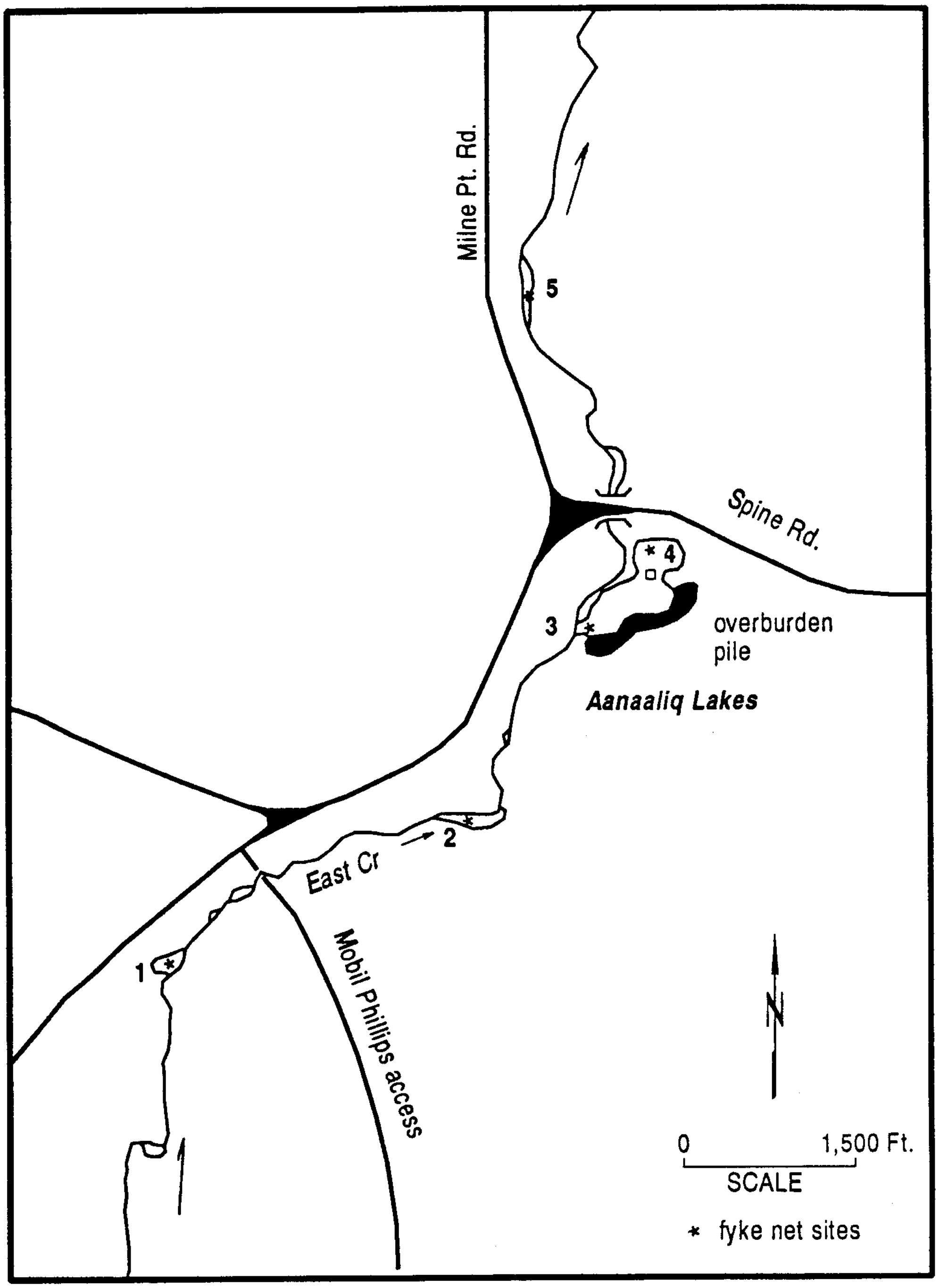


Figure 2. Fyke net sample sites in East Creek and Aanaaliq Lakes, 1990.

length of tagged fish with data recorded when the fish were initially captured and transplanted.

We also used hook and line gear to capture grayling. This technique was used during the June sampling period at locations upstream of Aanaaliq Lakes in East Creek and within the lakes. We found that hook and line sampling with artificial flies was most effective when winds were calm and the grayling were feeding in the upper water column or at the surface.

Results

In June we captured grayling, broad whitefish, ninespine stickleback, least cisco, and round whitefish in fyke nets fished at four locations (Table 1). Broad whitefish were captured at all net sites, while least cisco and round whitefish were captured upstream of Aanaaliq Lakes. The whitefish catch in June consisted of 23 broad whitefish, 3 least cisco, and a single round whitefish. Broad whitefish ranged in length from 72 to 332 mm (mean = 117.3 mm, SD = 62.5), the least cisco ranged from 202 to 208 mm (mean = 204.3 mm, SD = 3.2), and the round whitefish was 202 mm. Ninespine stickleback were most abundant at each net site. Daily catch estimates of stickleback ranged from 286 to 5,148 at the four sites.

We captured grayling at each of the four net sites fished during the June sample period. Grayling were also captured on hook and line in East Creek upstream of the inlet channel and in the lakes. We captured 22 grayling in the four fyke traps and 18 on hook and line (Table 1). The hook and line catch included 3 grayling taken from East Creek upstream of the inlet on June 27 and 15 captured in the lakes on June 27 to 29. Approximately six hours of angler effort was required to capture 18 grayling. Eight grayling were captured more than once. Seven were recaptured at locations downstream of the initial capture

TABLE 1. Number of fish captured and catch-per-unit-effort (CPUE) at four fyke net sites in East Creek and Aanaaliq Lakes, June 1990.

Net * location	Date	Time fished (hr)	Water temp. (C)	Fish ** species		CPUE fish (hr)
1	6/26	25.75	--	3	AG	0.12
				1716	NSB	66.64
1	6/27	23.50	10.5	1	LCi	0.04
				715	NSB	30.43
1	6/28	23.50	12.0	1	AG	0.04
				1	BWF	0.04
				1	LCi	0.04
				5148	NSB	219.06
1	6/29	26.0	14.0	3146	NSB	121.08
2	6/26	22.0	--	3	AG	0.14
				5	BWF	0.23
				2860	NSB	130.0
				1	RWF	0.04
2	6/27	23.5	10.5	2	AG	0.08
				4	BWF	0.17
				1	LCi	0.04
				2574	NSB	109.53
2	6/28	24.5	12.0	3	AG	0.12
				2	BWF	0.08
				3146	NSB	128.40
2	6/29	24.5	13.5	1	AG	0.04
				1	BWF	0.04
				2288	NSB	93.39
3	6/26	21.0	10.0	1	BWF	0.05
				1716	NSB	81.71
3	6/27	23.5	10.0	2	BWF	0.08
				1430	NSB	60.85
3	6/28	25.0	10.0	3	AG	0.12
				2	BWF	0.08
				3718	NSB	148.72
5	6/27	14.5	10.5	4	AG	0.28
				1	BWF	0.07
				286	NSB	19.72
5	6/28	24.0	12.0	1	AG	0.04
				1	BWF	0.04
				1716	NSB	71.5
5	6/29	24.5	14.0	1	AG	0.04
				3	BWF	0.12
				1287	NSB	52.53

* See Figure 2
** Ninespine stickleback numbers estimated

AG = arctic grayling
BWF = broad whitefish
LCi = least cisco
NSB = ninespine stickleback
RWF = round whitefish

Location of fyke nets:
Net 1 = 1.6 km (1.0 mi) upstream inlet
Net 2 = 0.5 km (0.3 mi) upstream inlet
Net 3 = inlet channel
Net 5 = 0.5 km (0.3 mi) downstream inlet

site and one was recaptured at the same net site. We caught and examined 32 individual grayling in June. Fifteen fish had retained tags from the experimental transplant. We observed tag scars on 12 of the 17 grayling that did not retain tags.

In August we fished fyke nets at five locations in East Creek and Aanaaliq Lakes and captured grayling, broad whitefish, least cisco, and ninespine stickleback. Broad whitefish were captured in East Creek upstream of the lakes, at the inlet, and in the lakes while least cisco were found at the inlet channel and in the lakes (Table 2). In August we captured 9 broad whitefish, and 7 least cisco. The broad whitefish ranged from 85 to 355 mm (mean = 169.5, SD = 92.8) and the least cisco ranged from 112 to 308 mm (mean = 238.4 mm, SD = 62.8). Ninespine stickleback was the most abundant species captured. Daily estimated catches ranged from 48 to 15,730 at each net site. Stickleback abundance was greatest in the lakes and inlet channel, while the nets upstream of the lakes caught fewer stickleback, and the net downstream of the lakes in East Creek had the lowest CPUE (Table 2).

We captured four grayling at the inlet channel net (site #3) during the August sample period. Three grayling did not have tags but each had a tag scar. The remaining fish was a tagged individual captured twice at the same net site. Hook and line techniques failed to capture grayling in August.

We set three fyke nets in Aanaaliq Lakes and East Creek on September 24 to 25. We set the nets at the inlet channel (site #3), at the north end of the lakes (site #4), and upstream of the lakes at the Mobil-Phillips access road crossing of East Creek. The East Creek net was oriented to capture downstream migrating fish. Ninespine stickleback was the only species captured in September. The East Creek net was fished for 24 hours and captured an estimated 14,729 ninespine stickleback; the net at the north end of Aanaaliq Lakes (site #4) fished for 25.3 hours and captured 1,859 stickleback; and the inlet channel net

TABLE 2. Number of fish captured and catch per unit effort (CPUE) at five fyke net sites in East Creek and Aanaaliq Lakes, August 1990.

Net * location	Date	Time fished (hr)	Water temp. (C)	Fish **	species	CPUE fish (hr)
1	8/19	23.5	7.0	79	NSB	3.36
1	8/20	25.5	6.2	1	BWF	0.04
				49	NSB	1.92
1	8/21	17.5	4.1	286	NSB	16.34
1	8/22	25.5	4.5	1	BWF	0.04
				572	NSB	22.43
1	8/23	31.0	6.0	286	NSB	9.23
1	8/24	17.25	4.5	143	NSB	8.29
2	8/19	23.5	7.0	210	NSB	8.94
2	8/20	25.5	6.5	1	BWF	0.04
				572	NSB	22.43
3	8/19	22.5	7.5	3	AG	0.13
				2	BWF	0.09
				3861	NSB	171.6
3	8/20	23.0	7.0	1	AG	0.04
				1	LCi	0.04
				3432	NSB	149.22
3	8/21	20.75	6.5	1	BWF	0.05
				1	LCi	0.05
				3575	NSB	172.29
3	8/22	23.50	6.5	2	BWF	0.09
				7150	NSB	304.26
3	8/23	29.75	7.0	1	AG	0.03
				1	LCi	0.03
				5720	NSB	192.27
4	8/19	22.5	8.0	4862	NSB	216.09
4	8/20	23.5	7.0	1	BWF	0.04
				2	LCi	0.09
				15730	NSB	669.36
4	8/21	18.75	7.0	8008	NSB	427.09
4	8/22	24.0	7.0	12298	NSB	512.42
4	8/23	29.75	7.0	2	LCi	0.07
				7722	NSB	259.56
4	8/24	18.5	6.5	9009	NSB	486.97
5	8/19	25.0	7.5	70	NSB	2.8
5	8/20	24.5	6.5	48	NSB	1.96

* See Figure 2
** Ninespine stickleback numbers estimated.

AG = arctic grayling
BWF = broad whitefish
LCi = least cisco
NSB = ninespine stickleback

Location of fyke nets:
Net 1 = 1.6 km (1.0 mi) upstream inlet
Net 2 = 0.5 km (0.3 mi) upstream inlet
Net 3 = inlet channel
Net 4 = north end Aanaaliq Lakes
Net 5 = 0.5 km (0.3 mi) downstream inlet

(site #3) caught 286 in 25.5 hours. We discontinued the fyke net sampling and removed the gear because ice had formed on East Creek freezing the net in place. On September 25 the water temperature was 0°C in East Creek, 0.7°C at the inlet, and 1.2°C at the north end of the lakes.

In the three sample periods fished in 1990, we captured 36 individual grayling and 16 (44%) retained Floy tags. We observed tag scars on 15 (75%) of the 20 grayling that did not retain tags. The 16 tagged fish recaptured in 1990 had annual growth rates ranging from 25 to 92 mm, with an average length increase of 58.6 mm (Table 3).

Discussion

We assume that all grayling captured in East Creek and Aanaaliq Lakes in 1990 were individuals transplanted in 1989. There are three reasons for this assumption: (1) sampling prior to the transplant with various gear types including gill nets, minnow traps, and fyke nets failed to capture grayling; (2) all the grayling captured were in the expected size class from the transplanted population; (3) the majority of untagged fish (75%) had identifiable tag scars. While it is possible that grayling move from neighboring drainages to East Creek, this is considered unlikely. It should be noted, however, that a single round whitefish was captured in East Creek in 1990, which indicates that dispersal of freshwater fish from neighboring Beaufort Sea drainages to East Creek is possible.

If we assume that all the grayling captured in 1990 were from the 1989 transplant, then we recaptured 17.1% of the transplanted population. This represents a minimum survival rate for the first year. Since Aanaaliq Lakes is the only known overwintering habitat in the East Creek system, the documented overwinter survival of grayling can be directly attributed to the availability of overwintering habitat in the former mine site, now called Aanaaliq Lakes.

TABLE 3. Growth rate of individual arctic grayling transplanted to Aanaaliq Lakes, summer 1990.

Tag No.	Date marked	Fork length (mm)	Date recaptured	Fork length (mm)	Total days	Growth (mm)
2151	6/25/89	194	6/26/90	275	367	81
2108	6/24/89	330	6/27/90	369	369	39
2194	6/25/89	335	6/27/90	374	368	39
2173	6/25/89	296	6/27/90	334	368	38
2080	6/23/89	201	6/27/90	270	370	69
2196	6/25/89	292	6/27/90	340	368	48
2056	6/23/89	209	6/27/90	292	370	83
2156	6/25/89	329	6/27/90	365	368	36
2171	6/25/89	303	6/28/90	328	369	25
2118	6/24/89	229	6/28/90	305	370	76
2201	6/25/89	265	6/28/90	335	369	70
2085	6/23/89	283	6/28/90	345	371	62
2104	6/24/89	232	6/29/90	301	371	69
2102	6/24/89	188	6/29/90	280	371	92
2060	6/25/89	198	6/29/90	278	370	80
2089	6/23/89	241	8/19/90	272	423	31

Grayling grew rapidly in the first year after introduction. The average growth increment for the 16 recaptured individuals that retained tags was 58.6 mm, with the largest increments and percentage increase found among the smallest individuals at the time of introduction. Craig and Poulin (1975) reported growth of approximately 40 mm/year through age 7 for grayling in a small tundra stream that drains into the Kavik River near Prudhoe Bay. The growth rate of grayling in the Craig and Poulin study was described as among the fastest for Arctic populations. The mean length of the 36 grayling captured in 1990 was 306.5 mm (SD = 35.3). If the current growth rate continues, all remaining transplanted fish should be of reproductive size (>300 mm) by the next spawning period (June 1991). We found no evidence of grayling reproductive success in 1990 as our fyke net sampling in East Creek and Aanaaliq Lakes failed to capture young-of-the-year grayling. The apparent lack of reproductive success could result from the large population of ninespine stickleback found in Aanaaliq Lake and East Creek. Ninespine stickleback could influence grayling reproductive success through competition with fry for food, or predation on grayling eggs or fry by adult stickleback. Skaugstad (1989) noted little or no survival of sac fry grayling in Interior Alaska ponds containing threespine stickleback (*Gasterosteus aculeatus*).

In the August and September sampling periods, the catch rate for grayling in East Creek and Aanaaliq Lakes was reduced from that found in June. The reduced catch rate in late summer and fall may be due to reduced activity levels during periods with lower water temperatures. In June the water temperature exceeded 10°C at all net sites while the water temperature in August was below 7°C at most net sites, and by September the water temperature did not exceed 1.2°C at the three net sites fished. It is also possible that as water temperatures decrease, grayling use deeper areas in the lakes and are not effectively sampled with fyke net gear that is not effective in water depths greater than 1.2 m (4.0 ft).

Juvenile broad whitefish were found at all fyke net sites fished in June. In August, broad whitefish were captured in East Creek upstream of the lakes, at the inlet, and in the lakes. These data indicate that the lakes and stream habitats near the lakes are used as summer rearing areas for juvenile broad whitefish. Juvenile least cisco were found upstream of Aanaaliq Lakes in June, and in the lakes and inlet channel in August. These data also indicate that East Creek and Aanaaliq Lakes provide summer rearing habitat for least cisco.

Ninespine stickleback were found at all net sites during the three sample periods. The highest catch rates were found at the inlet channel and in the lakes during August, indicating movement from East Creek to the lakes in late summer. In September we found the highest catch rate in East Creek upstream of the lakes with a net oriented to capture downstream migrants. These data indicate that downstream movement of ninespine stickleback was occurring in late September as ice was forming on East Creek.

PUT 27 FISH SAMPLING

Introduction

The Put 27 Mine Site is located within Section 27, T11N, R14E, Umiat Meridian at a point approximately 115 m (125.8 yds) south of the right bank of the Putuligayuk (Put) River, hence the origin of the site name. Put 27 is 6.4 km (4.0 mi) from the mouth of the Put River which empties into the central portion of Prudhoe Bay. The North Slope Borough landfill and the Put 23 Mine Site are 0.8 km (0.5 mi) downstream of Put 27 adjacent to the Put River.

Put 27 was created in 1973 by mining within a large oxbow of the Put River. Later the area between the banks of the oxbow was mined leaving a large circular excavation with a bottom depth 20 m (65.6 ft) or more below the tundra elevation (BP Exploration 1989). The mine site is separated from the Put River by a large dike consisting of overburden. The dike was constructed in 1980 to prevent the river from flooding the pit. In March 1989 we recommended construction of a channel connection between the Put River and the Put 27 Mine Site. The intent of the rehabilitation recommendation was to allow flooding of the Put 27 site and to provide a permanent connection between the deep water site and the river system such that additional fish overwintering habitat would be available (Figure 3).

In January 1990, BP Exploration developed a rehabilitation plan for Put 27 which included a breach channel between the Put River and the mine site. The breach was designed with a bottom width of 9.1 m (30 ft) and a top width of 36.6 m (120 ft) for a length of roughly 76.2 m (250 ft) between the river and the mine site. The breach design included a 3:1 side slope and a design depth of 1.8 m (6 ft) below the water surface elevation of the Put River. The designated disposal area for material excavated from the

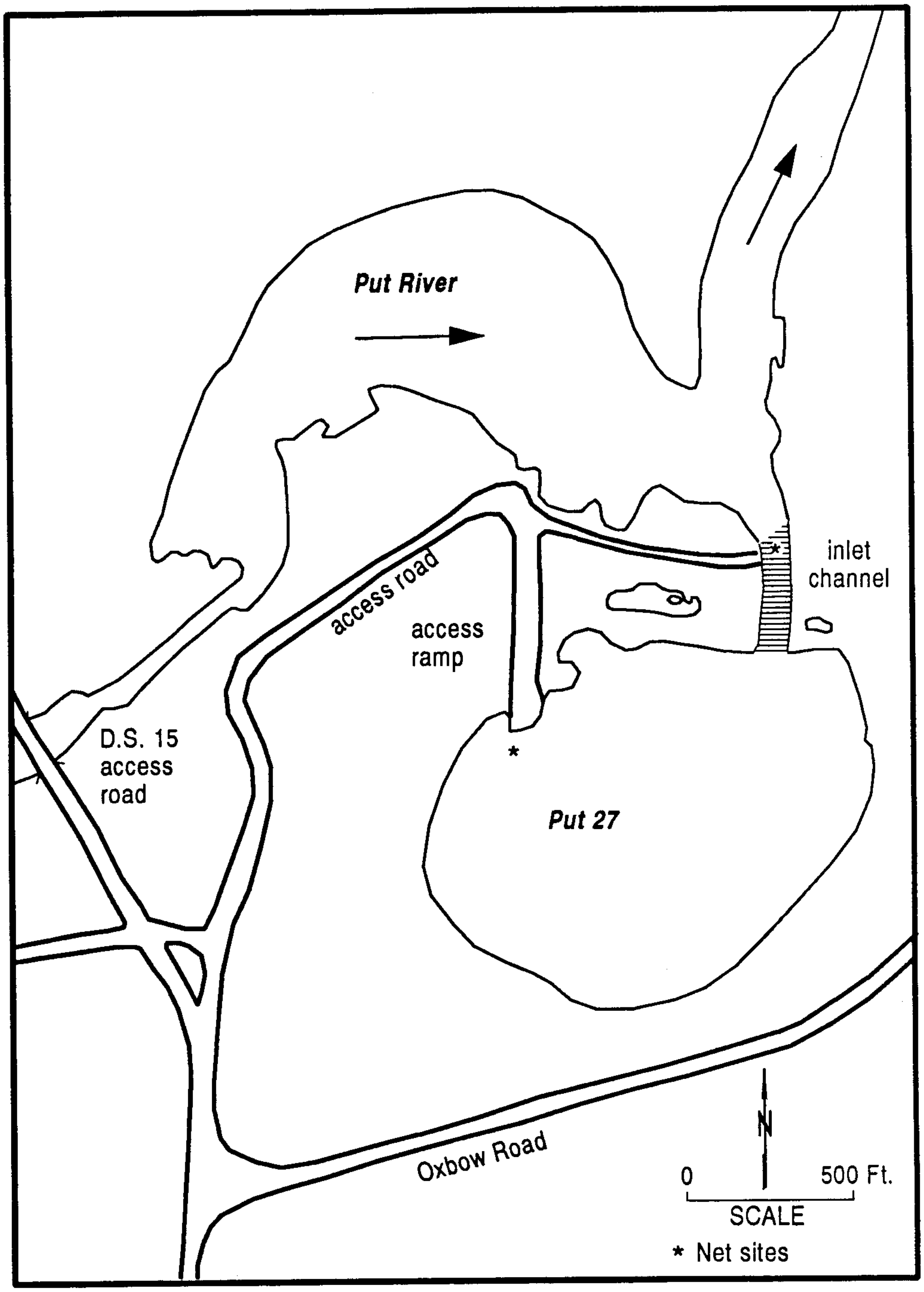


Figure 3. Put 27 rehabilitation plan location map.

breach was the Put 27 Mine Site.

The breach channel project was completed in April 1990 under the direction of BP Exploration and the mine site excavation was filled with spring break-up waters from the Put River in late-May 1990. The filling process created a 14.2 ha (35 ac) lake containing an estimated 1.5 billion L (396 M gal) of water (Appendix II).

We sampled fish in Put 27 to evaluate colonization and use of the site in the first year after rehabilitation and flooding.

Methods

We used a fyke net to live capture fish at the access ramp to the Put 27 Mine Site. The equipment and procedures were the same as described for East Creek/Aanaaliq Lakes except fish were not marked at Put 27. We fished the fyke net on June 25 to 28, August 18 to 22, and September 24 to 25. In addition we fished a 38.1 m (125 ft) x 1.8 m (6.0 ft) monofilament, variable mesh, sinking gill net in the inlet channel on June 28 to 29 and August 18 to 19. The gill net had five 7.6 m (25 ft) panels with bar mesh sizes of 1.3 cm (0.5 in), 2.5 (1.0), 3.8 (1.5), 5.1 (2.0), and 6.4 (2.5). Fish captured in the gill net were measured and released if alive. Additional data consisting of sexual condition and stomach content was gathered from dead or severely injured fish removed from the gill net.

Results

In June we captured Dolly Varden (*Salvelinus malma*), ninespine stickleback, and round whitefish in the fyke net fished at the access ramp to Put 27 (Table 4). A gill net fished in the inlet channel captured a single grayling. Ninespine stickleback were most abundant in the June fyke net catch. The daily estimated stickleback catch ranged from

TABLE 4. Number of fish captured and catch-per-unit-effort (CPUE) at fyke net and gill net sites in Put 27, 1990.

Net Type	Date	Time Fished (hr)	Water Temp (C)	Fish *	Species	CPUE Fish (hr)	Comment
fyke	6/26	20.0	5.0	1	DV	0.05	released
				2002	NSB	100.1	released
				12	RWF	0.6	released
fyke	6/27	26.5	5.2	1859	NSB	70.15	released
				9	RWF	0.34	released
fyke	6/28	25.0	6.5	715	NSB	28.6	released
				4	RWF	0.16	released
gill	6/29	28.0	--	1	AG	0.04	removed
gill	8/19	24.0	7.0	1	BWF	0.04	removed
				2	RWF	0.08	released
fyke	8/19	12.50	7.0	none	--	--	net not fishing due to wind
fyke	8/20	24.75	7.0	1	ACI	0.04	released
				2	BWF	0.08	released
				1	NSB	0.04	released
fyke	8/21	27.75	7.0	4	BWF	0.14	released
				1	LCi	0.04	released
				286	NSB	10.31	released
				2	RBS	0.07	released
				1	RWF	0.04	released
fyke	8/22	18.0	7.0	5	BWF	0.28	released
				429	NSB	23.83	released
				2	RWF	0.11	released
fyke	9/25	24.0	0.7	1	ACi	0.04	released
				1	BWF	0.04	released
				858	NSB	35.75	released
				1	FHS	0.04	released

* Ninespine stickleback numbers estimated.

ACi = arctic cisco
AG = arctic grayling
BWF = broad whitefish
DV = Dolly Varden char
FHS = fourhorn sculpin

LCi = least cisco
NSB = ninespine stickleback
RBS = rainbow smelt
RWF = round whitefish

Location of nets
fyke net = at access ramp
gill net = inlet channel

715 to 2,002 between June 25 and 28. We also caught 15 juvenile round whitefish ranging from 75 to 125 mm (mean = 85.0, SD = 16.2), and a single 125 mm Dolly Varden. The gill net was fished for one net night and captured a 242 mm grayling. The grayling was an immature female with a full stomach. Identifiable food items included amphipods, terrestrial flies, chironomid larvae, and adult beetles. Amphipods were the dominant food item on a volume basis while chironomid larvae were most numerous.

In August we captured arctic cisco (*Coregonus autumnalis*), broad whitefish, least cisco, ninespine stickleback, rainbow smelt (*Osmerus mordax*), and round whitefish. We also fished a gill net in the inlet channel and captured two round whitefish (174 and 178 mm) and a broad whitefish (440 mm). The broad whitefish was a developing female with a full stomach. The stomach content consisted of chironomid larvae. Gill netting was discontinued after one net night (August 18 to 19) when two red throated loons (*Gavia stellata*) became entangled in the net and drowned.

Ninespine stickleback were most abundant in the August fyke net catch. Daily catches ranged from one fish to an estimated 429. We also caught 11 broad whitefish, 3 round whitefish, 2 rainbow smelt, 1 least cisco, and 1 arctic cisco. One adult broad whitefish (420 mm) was captured while the remaining broad whitefish were juveniles ranging from 59 to 74 mm. The round whitefish ranged from 96 to 110 mm, the rainbow smelt were 68 and 69 mm, and the least cisco and arctic cisco were 186 and 68 mm respectively. We fished a fyke net at the access ramp to Put 27 on September 24 to 25 and caught an estimated 858 stickleback, one 65 mm arctic cisco, one 75 mm broad whitefish, and one 75 mm fourhorn sculpin (*Myoxocephalus quadricornis*).

Discussion

In the first open water season after rehabilitation and flooding of Put 27 we captured nine species of fish. The sample catch included species with marine, anadromous, and freshwater life history patterns (Table 5).

It is likely the juvenile round whitefish and ninespine stickleback that appeared in the June sample catch are part of a resident overwintering population in the lower Put River system. These fish were present in the Put River system and may have been carried into the excavated area during the flooding process. Our previous investigations documented a limited amount of suitable overwintering habitat in the lower Put River adjacent to Put 27 and we captured an overwintering round whitefish at this site in May 1989 (Hemming 1990). Ninespine stickleback have been observed in the lower Put River under ice cover near water extraction sites. Ninespine stickleback are also found in other tundra streams that are similar in nature to the Put River. Ninespine stickleback presence in Put 27 fits a pattern of rapid colonization of available habitat in tundra stream systems located near flooded gravel extraction sites (Hemming 1990). In June we also captured a grayling and a juvenile Dolly Varden. The grayling could have overwintered in the deeper sections of the lower Put River or moved into the Put River from the Sag River during the spring flood when a plume of low salinity water spreads from the Sag River mouth. Springs or ground water sources are selected as spawning and overwintering areas for Dolly Varden. No known spring or ground water sources are present in the Put River; therefore, it is likely that the Dolly Varden captured in Put 27 moved from the Sag River system during the spring flood, since it is the closest stream supporting overwintering Dolly Varden.

In August we captured four species of anadromous fish: arctic cisco, least cisco, broad whitefish, and rainbow smelt. It is likely that anadromous fish move into the lower Put River from nearshore areas in response to changes in temperature and salinity in late summer. Put 27 is 6.4 km (4.0 mi) upstream of Prudhoe Bay in an estuarine area that may be attractive to anadromous fish when more marine conditions are found in nearshore areas. In late September, arctic cisco and broad whitefish were still present in

TABLE 5. Life history patterns of fish captured in Put 27, 1990.

Fish Species	Marine Resident	Anadromous	Freshwater Resident
Arctic grayling (*Thymallus arcticus*)			X
Arctic cisco (*Coregonus autumnalis*)		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

Put 27 indicating that some of the anadromous fish found during the open water season may overwinter in the deep water site. We also captured a fourhorn sculpin in September. Fourhorn sculpin are generally found in colder, more marine waters. It is likely that colder, high salinity waters were present in Prudhoe Bay prior to freeze-up, creating conditions favorable for fourhorn sculpins to move into nearshore areas and the lower reaches of tundra stream systems. Juvenile fourhorn sculpins have been found in the lower reaches of other Beaufort Sea drainages (Morrow 1980).

SAGAVANIRKTOK RIVER FLOODPLAIN FISH SAMPLING

Introduction

Gravel extraction techniques used in floodplain areas of the Sag River have changed over time. Gravel was removed by shallow scraping of riverine deposits during the early development of the Prudhoe Bay Oilfield. Due to environmental concerns regarding surface disturbance associated with this practice, more recent gravel extraction sites have used deep mining techniques. Deep mining minimizes surface disturbance while consolidating gravel use to fewer large sites that are mined up to 20 m below the surface elevation. In 1990 we monitored fish use of two Sag River floodplain gravel removal sites, each having different physical characteristics resulting from the gravel extraction technique used. Sag Site C is a 15.5 ha (38.2 ac), deep mined, gravel site that was flooded in 1986 when the perimeter berm was breached allowing Sag River water to fill the excavated area (Figure 4). Ott's Oxbow is a site name used in this study to identify a 6.9 ha (17.1 ac), shallow, backwater area formed by parallel scraping of riverine gravel deposits in the mid-1970's (Figure 5). Previous progress reports present more detailed descriptions of these sites and the sampling results obtained prior to 1990 (Hemming 1988, Hemming et al. 1989, Hemming 1990).

Our earlier investigations of Sag River sites indicate that the physical characteristics of floodplain gravel removal areas are influenced by seasonal discharge patterns of the river and the distribution of active channels within the floodplain. Discharge also affects the species diversity, abundance, and size distribution of fish in each site (Hemming 1990). In 1990, spring flood waters redistributed gravels in the inlet channel to Sag Site C. The deposition of gravels has nearly filled a 2.0 ha (4.9 ac) shallow water area excavated in the autumn of 1987 as a habitat enhancement project. In late August, flow in the inlet channel was discontinuous, but the outlet channel was still connected to main channels of

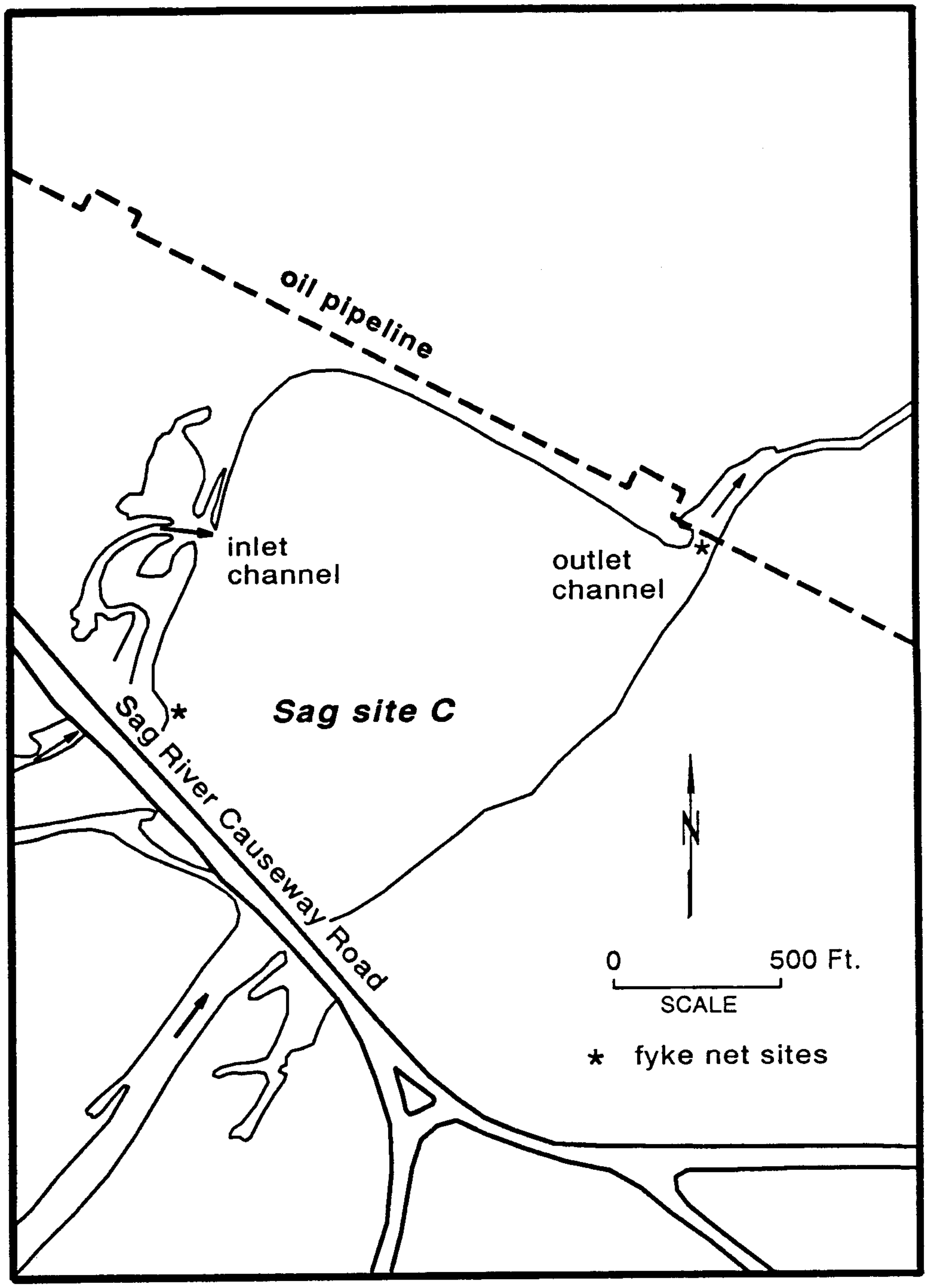


Figure 4. Fyke net sample sites in Sag Site C, 1990.

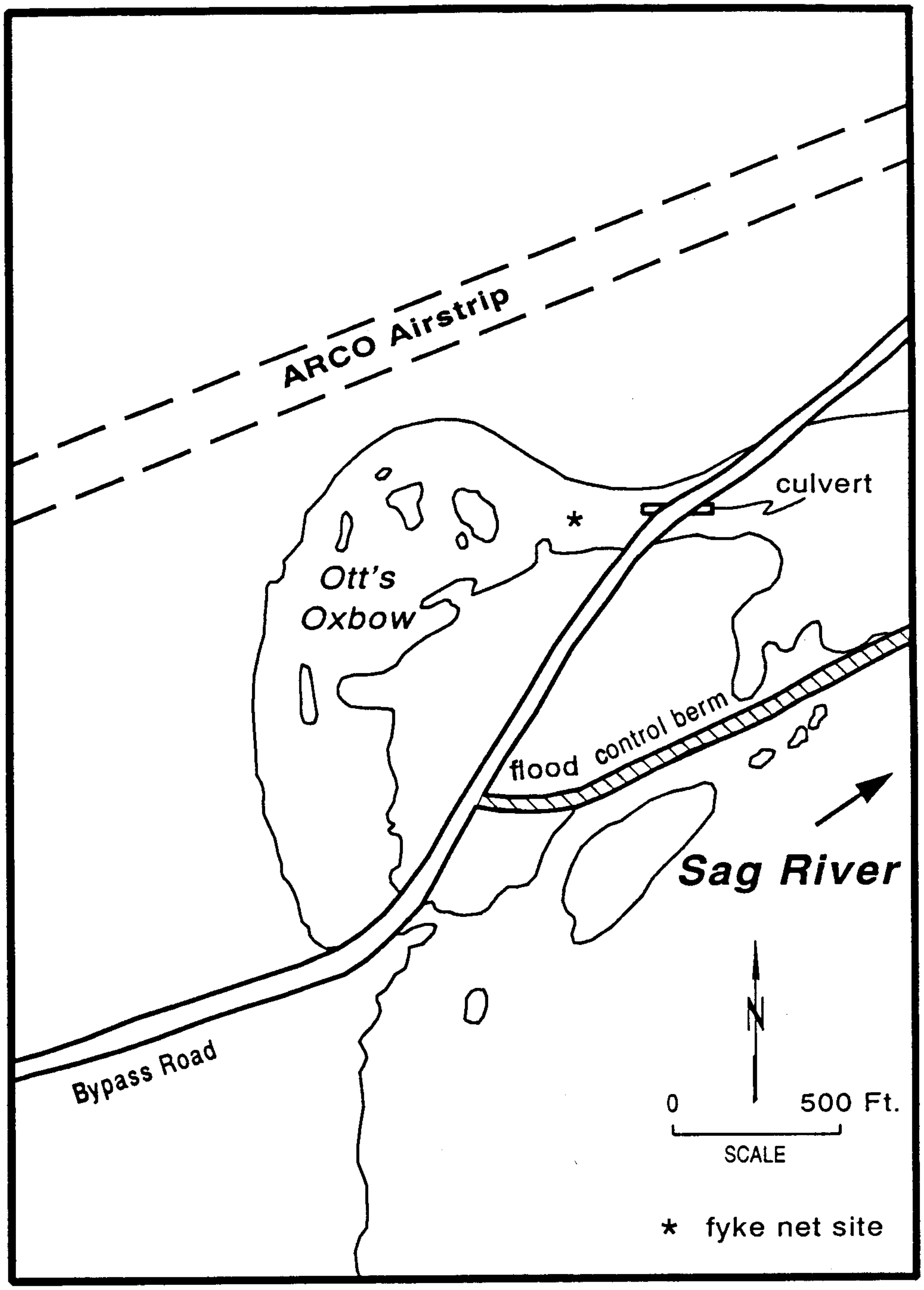


Figure 5. Fyke net sample site in Ott's Oxbow, 1990.

the Sag River, although discharge in the outlet was minimal. Ott's Oxbow was connected to the west channel of the Sag River in June, but by late August the site was nearly isolated as water levels in the Sag River floodplain receded such that the culvert was nearly blocked by a small gravel bar. By October 20 water levels in the Sag River had risen maintaining the connection between the site and the river under a continuous ice cover.

In this section, information on the species composition and length frequency distribution of fish captured in Sag Site C and Ott's Oxbow in 1990 is presented.

Methods

We used fyke nets to live capture fish at each site. One net was fished at the north end of Ott's Oxbow on June 25 to 27 and on August 20 to 21. Two nets were fished in Sag Site C on August 22 to 23. We set the nets at the access ramp to the site and in the outlet channel. The equipment and procedures used were the same as described for East Creek/Aanaaliq Lakes except that fish were not marked at either site.

Results

In June we captured grayling, broad whitefish, burbot, and ninespine stickleback in Ott's Oxbow (Table 6). Grayling were most abundant in the June sample catch. We captured 22 grayling ranging from 68 to 288 mm with two net nights of fishing effort (Figure 6). On June 26 we captured a single adult broad whitefish (490 mm) and a 82 mm burbot. On June 27 we captured another adult broad whitefish (460 mm) and 20 ninespine stickleback.

In August we captured the same species found in June plus round whitefish. Broad whitefish were most abundant in August as 237 were captured in a single net night. Nearly all the broad whitefish were small juveniles with 234 in the same size class. We

TABLE 6. Number of fish captured and catch-per-unit-effort (CPUE) in Sagavanriktok River sites, 1990.

Net Location	Date	Time Fished (hr)	Water Temp. (C)	Fish	Species	CPUE Fish (hr)
Ott's Oxbow	6/26	20.0	11.0	5	AG	0.25
				1	BWF	0.05
				1	BB	0.05
Ott's Oxbow	6/27	28.0	12.5	17	AG	0.60
				1	BWF	0.04
				20	NSB	0.71
Ott's Oxbow	8/20	19.25	6.5	20	AG	1.04
				237	BWF	12.31
				5	BB	0.26
				38	NSB	1.97
				11	RWF	0.57
Sag Site C at access ramp	8/23	29.25	7.0	22	AG	0.75
Sag Site C at outlet	8/23	27.50	5.5	6	AG	0.22
				1	BB	0.04
				1	RWF	0.04

AG = arctic grayling
BWF = broad whitefish
BB = burbot
NSB = ninespine stickleback
RWF = round whitefish

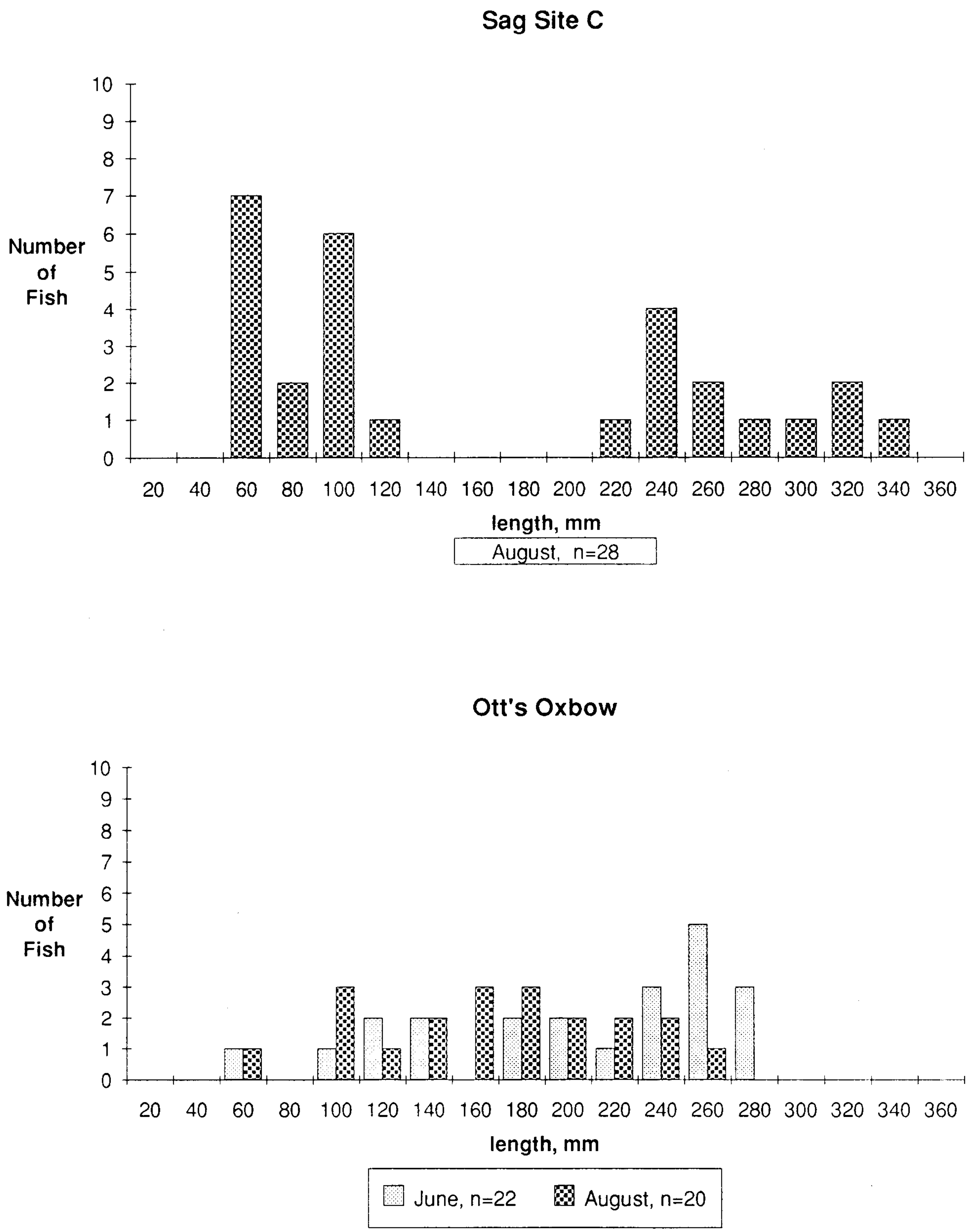


Figure 6. Length frequency distribution of grayling captured in the Sagavanirktok River floodplain gravel removal sites, 1990.

measured a subsample of 52, having a mean length of 74.8 mm (SD = 2.6). The remaining broad whitefish consisted of 2 larger juveniles (145 and 155 mm) and a single adult (470 mm). We captured 20 grayling ranging from 60 to 260 mm (mean = 176.5, SD = 53.2), 11 round whitefish ranging from 65 to 123 mm (mean 115.0, SD = 23.8), and 5 burbot ranging from 130 to 160 mm (Figure 6).

We fished two nets in Sag Site C on August 22 to 23 and captured 28 grayling, 1 burbot, and 1 round whitefish. The grayling ranged from 67 to 358 mm (Figure 6). The round whitefish was 290 mm and the burbot 130 mm.

Discussion

We found grayling, round whitefish, and burbot in both of the Sag River sites sampled in 1990. Ninespine stickleback and broad whitefish were only found in Ott's Oxbow, but these species had been captured previously in Sag Site C (Hemming 1990). In 1990 we sampled Ott's Oxbow in June and August while Sag Site C was only sampled in August.

The most notable difference between the two Sag River sites was the large number of juvenile broad whitefish captured in Ott's Oxbow in August. In 1989 we had similar results when 114 young-of-the-year broad whitefish were captured in an overnight net set in the same location (Hemming 1990). The high catch rate for small broad whitefish in two successive open water seasons is a strong indication that shallow backwater habitats are a preferred summer rearing area. Ott's Oxbow is partially isolated from active channels of the Sag River by a roadway embankment, and the only direct hydraulic connection to the river system is a single 48 inch smooth wall culvert which passes through the road fill at the downstream end of the site. Water depth in the site does not exceed 1.5 m; therefore, seasonal use of the area depends upon movement from major channels of the river, through the culvert into the backwater area. We also assume out-migration occurs as fish move to suitable overwintering sites.

Sag Site C differs from Ott's Oxbow because it is only connected to the Sag River during high water periods and the site is used for overwintering as well as for summer rearing (Hemming 1990). Sag Site C has a limited amount of littoral habitat and aquatic productivity levels are low when compared to sites with extensive littoral habitat (Hemming et al. 1989). While the grayling catch rate in Sag Site C is comparable to Ott's Oxbow, the later is a more productive summer rearing habitat. A deep mine site such as Sag Site C, which is connected to a river system, will increase available overwintering habitat, but this additional habitat may do little to benefit local fish populations without access to productive summer rearing areas and spawning sites. The connection between riverine rearing and spawning areas and overwintering habitat in Sag Site C is discontinuous and dependent upon discharge in the Sag River. A permanent channel connection between the site and the river would provide continuous open water access to riverine habitats and possibly increase use of overwintering habitat in Sag Site C.

WATER QUALITY SAMPLING

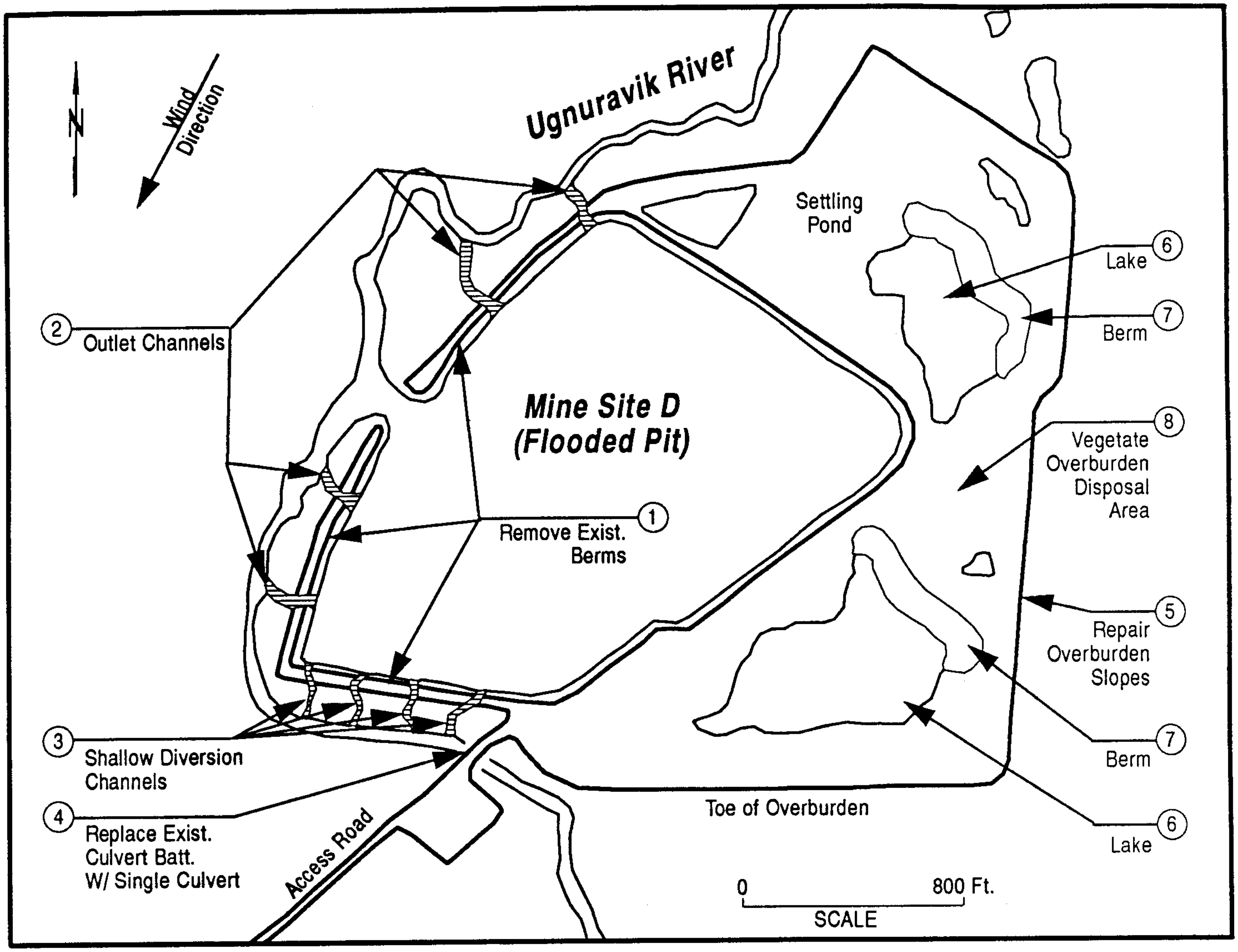
Introduction

The suitability of flooded gravel mine sites as habitat for fish and wildlife is determined in part by water quality characteristics of the impoundments. Rehabilitation projects such as those which direct stream water into an excavation or those which alter basin morphology may affect water quality. In 1990 we monitored basic chemical parameters at three recently rehabilitated sites. The sites monitored were Aanaaliq Lakes, Put 27, and Kuparuk Mine Site D. Descriptions of the rehabilitation projects at Aanaaliq Lakes and Put 27 are found in preceding sections of this report.

The Kuparuk Mine Site D rehabilitation project was completed in early May 1990. The project included: excavation of inlet and outlet channels between the mine site and a tributary to the Ugnuravik River (Charlie Creek); removal of the overburden berms on the south and west sides of the site 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 (Figure 7). The intent of the restoration project was to provide connections between the deep water mine site and Charlie Creek and to increase the amount of shallow backwater rearing habitat. The material placed on top of the ice settled throughout the 1990 thaw season adding organic and fine grained material to the basin. Water levels in Mine Site D were lower than those observed in previous years and the new inlet and outlet channels did not convey water for most of the 1990 open water season.

Methods

Water samples were collected beneath the ice at each of the three rehabilitated mine sites



Adapted from ARCO Alaska Inc. Restoration Project Plan 12-15-89.

1. Remove overburden berms on south and west sides. The spoil material to be pushed into the flooded pit. Winter construction will inable the spoil material to be pushed onto the ice surface of pit.
2. Excavate and construct several outlet channels on north west side of the site. Overburden material to be placed on the ice surface of the pit.
3. Excavate and construct multiple shallow diversion channels with irregular shorelines between the diversion channel and pit (south side of site). Excavated material to be placed on the ice surface of the pit.
4. Remove the existing culvert battery located on the access road and replace it with a large single culvert.
5. Excavate within the overburden disposal area to form 2 lakes with irregular shorelines on the north and south sides of the disposal area. Each lake will encompass approximately 5 to 10 acres.
6. The spoil material will be pushed and placed on the north east sides of the excavated areas to form a berm for snow/water collection.
7. The entire disposal area wil be fertilized and seeded.

Figure 7. Kuparuk Mine Site D rehabilitation plan location map.

on May 2 to 4. Open water sampling was conducted on August 23 at Aanaaliq Lakes and Put 27. Put 27 was not flooded in early May; therefore, water sample sites were selected in the Put River near the inlet channel and in the deepest area of the mine site off the access ramp. The water collected from Put 27 in early May had accumulated in the excavated area from snow melt and tundra runoff prior to site flooding. At Aanaaliq Lakes we selected water sample sites in the center of each lobe of the pit in May. In August we only sampled the southern lobe of the site. At Kuparuk Mine Site D we selected a sample site between the access ramp and the inlet channel breach. Kuparuk Mine Site D was not sampled in August because the access road was closed for culvert repair.

In May we drilled 25.4 cm (10 in) holes through the ice with a gasoline powered ice auger. The ice and water depth were measured with a sounding tape and calibrated rod. In August we used a boat as a work platform. Water samples were collected at 1 or 2 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 bottles and prepackaged reagents in plastic pillows. Dissolved oxygen concentrations were measured by the azide modification of the Winkler procedure using a Hach digital titrator. Water collected in the Van Dorn sampler in excess of that needed for dissolved oxygen measurements was transferred to 1 L plastic containers and stored in a cooler. This water was used to measure pH, conductivity, alkalinity, and hardness. The pH was determined with an Orion model 407 meter calibrated against buffer solutions of known pH concentration. Conductivity was determined with a Hach, Drel 5 meter after calibration against standards of known conductivity. The alkalinity and hardness concentration were determined with colormetric methods. We used 50 mL samples for the hardness tests and titrated the prepared sample with 0.8 M EDTA. For alkalinity tests

100 mL samples were used and the prepared sample was titrated with 1.6 N sulfuric acid.

Water transparency was measured with a standard 20-cm Secchi disk during August. The depth at which the disk disappeared on descent and reappeared on retrieval was averaged to obtain the mean depth of water transparency.

Results

Water quality characteristics in Aanaaliq Lakes varied little with depth during sample periods in early May and August 1990 (Appendix III). In May, water temperatures ranged from 0.5 to 0.8° C at each depth sampled in the northern lobe of the site, while temperatures ranged from 1.4 to 1.6° C in the southern lobe. On August 23, water temperature was a uniform 6.5° C at all depths sampled in the southern lobe of the site. Specific conductance declined during the open water season from that measured under ice cover. Conductivity exceeded 505 µS/cm at all sample depths in May while August samples did not exceed 210 µS/cm. Alkalinity and hardness concentrations also declined during the open water season. During August, dissolved oxygen concentrations ranged from 10.3 to 11.8 mg/L with an average concentration of 11.0, while concentrations under ice cover in May, ranged from 7.2 to 5.2 mg/L with a mean value of 5.9 mg/L. The secchi disk water transparency was 2.0 m on August 23.

Water quality characteristics in the lower Put River and Put 27 varied little with depth during the open water and ice covered sample periods (Appendix IV). Temperature in the lower Put River ranged from 1.8 to 2.1° C in early May, while the temperature in Put 27 was 2.8 and 4.0° C at the two depths sampled. In August the lower Put River and Put 27 were isothermal at 6.0 and 7.0° C respectively. The highest conductivity levels were found under ice in the lower Put River. Specific conductance declined in both the Put River and Put 27 during the August sample period. Alkalinity and hardness concentrations were also highest in the lower Put River under ice cover. Dissolved oxygen concentrations remained high during both the ice covered and open water seasons in the lower Put River and Put 27. In the lower Put River, dissolved oxygen concentration ranged from 7.1 mg/L to 10.4 mg/L at various depths under ice cover, while the open water values ranged from 9.6 mg/L to 11.9 mg/L. The under ice dissolved oxygen concentration at Put 27, prior to flooding, was 13.1 mg/L and 13.7 mg/L at the two depths sampled. After flooding during the open water season, dissolved oxygen concentrations ranged from 8.6 mg/L to 11.6 mg/L at five sample depths. The secchi disk water transparency was 1.9 m in the lower Put River and 2.7 m in Put 27 on August 23.

Early May water temperatures under ice cover ranged from 1.6 to 1.9°C at Kuparuk Mine Site D (Appendix V). We found uniform water quality characteristics at each sample depth through the water column. Dissolved oxygen concentration ranged from 10.6 to 12.8 mg/L.

Discussion

We found uniform water quality characteristics at each depth sampled within the three mine sites and in the lower Put River. These data indicate that the flooded mine sites are well mixed during the open water season and beneath ice cover. Factors which promote mixing include high ambient wind speeds, lack of topographic relief or vegetative protection, and rapid fall cooling.

Conductivity, hardness, and alkalinity values increased during the ice covered season. This pattern could result from salt exclusion during ice formation which results in an increase in ionic concentration of water beneath the ice. Stream discharge during the ice free season may also change the chemical characteristics of mine sites with channel connections. During the ice covered season the mine site basins are closed systems with limited or no exchange of water.

Specific conductance was greater in the lower Put River and Put 27 than in the Kuparuk area mine sites. Elevated conductivity may result from periodic salt water intrusion into the lower Put River. In May 1989 we found estuarine conditions at the lower Put River sample site with salinity concentrations of 6.7 ppt (Hemming 1990). Put 27 filled during the 1990 spring flood as fresh water from the Put River flowed into the site. Conductivity levels remained in the fresh water range (< 1 ppt salinity) during August 1990, but values were higher than those measured in Kuparuk area sites located upstream of estuarine influence. As discharge in the Put River decreases in the fall, more marine waters may move into the lower Put River and increase the specific conductance in Put 27.

August pH values increased at all sites from that measured under ice cover. It is likely that summer algal production increases pH values. Dissolved oxygen concentrations remained near saturation at all sites during the ice covered season with the exception of Aanaaliq Lakes. It is possible that overwintering fish, including a large population of ninespine stickleback, reduce dissolved oxygen concentration through respiration during the ice covered season. We found dissolved oxygen concentrations ranging from 9.0 mg/L to 12.0 mg/L at four depths through the water column on April 30, 1987 (Hemming 1988). These measurements were taken prior to construction of the inlet channel and introduction of grayling to the site. On May 2, 1990, dissolved oxygen concentrations ranged from 5.2 mg/L to 7.2 mg/L at various depths through the water column. It is likely that the inlet channel connection to East Creek has increased use of Aanaaliq Lakes by overwintering fish resulting in increased respiration and reduced dissolved oxygen concentration during the ice covered season. While dissolved oxygen concentrations have decreased they are still within the range considered acceptable for overwintering fish populations.

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APPENDIX I.

PRELIMINARY GUIDELINES FOR FISH AND WILDLIFE HABITAT REHABILITATION IN THE DEVELOPMENT OF NORTH SLOPE GRAVEL SITES

1. Site selection should consider both upland and floodplain sources with the overall objective to minimize loss of existing high value fish and wildlife habitat. At this stage, consideration should be given to such factors as fish and wildlife habitat including the importance and quality of existing habitat, the amount of habitat to be lost in relation to its total availability, enhancement opportunities, quality and quantity of materials available, future uses of the site, and the economics of site development, operation, and rehabilitation.

2. A site-specific rehabilitation plan, with a schedule and engineering drawings, should be prepared and approved prior to the issuance of any permits for the development of a material source. Mining plans should incorporate rehabilitation concurrent with all phases (e.g., overburden extraction, gravel stockpiling, gravel washing, etc.) of the mining operation such that major features of the rehabilitated site are in place at the conclusion of gravel removal.

3. The rehabilitation plan for a gravel site that will be flooded following gravel removal should incorporate the following basic concepts:

   a. The site should be developed in small aliquots with rehabilitation of each aliquot completed prior to opening of additional aliquots;

   b. During active mining for more than one season, the site should be isolated from adjacent waters with berms of overburden or other materials. Upon completion of mining, all perimeter berms should be removed and material graded back into the mined area such that a shallow-water zone (i.e., less than 0.5 meters deep) is created within the site perimeter. If the site is mined and rehabilitated during a single winter season, berms are not necessary. Substrate materials in the shallow-water zone should be appropriate to support emergent vegetation and should include plant propagules where practicable;

   c. Approximately 20 to 25 percent of the total surface area of the gravel site should be left as littoral habitat (i.e., water depth less than two meters);

   d. Shoreline length and diversity should be maximized by leaving an irregular outline with bays, spits, and islands. Generally, the greater the ratio of shoreline to surface area, the more productive the rehabilitated site will be for fish and wildlife;

   e. Criteria for island design for waterfowl are as follows:

      (1) Slopes (transition zones from deep water to islands and non-island shoreline) should be no greater than 10:1 and optimal would be 20:1;

      (2) Large islands (optimum size 0.1 acres or larger) with dense vegetative cover are preferred by ducks for nesting;

(3) Islands as small as ten feet by ten feet with low vegetation are preferred by geese for nesting;

(4) The minimum distance from shore to islands should be 30 feet to minimize mammalian predation;

(5) The maximum elevation of islands above mid-summer water levels should be one meter;

(6) Islands should be roughly rectangular, with an irregular shoreline, and oriented with the long axis parallel to prevailing winds;

(7) Islands should optimally be sited in proximity to open water and areas with emergent vegetation for waterfowl use; and

(8) Loafing areas, which could also be gravel islands, should have minimal vegetative cover to allow waterfowl to exit the water but have visibility in all directions.

f. The minimum depth for a flooded gravel pit that will provide fish overwintering habitat and allow some water use during the winter months should be 30 feet encompassing 25 to 50 percent of the total surface area;

g. Continuous open-water access between the flooded pit and stream system should be maintained through a permanent connection. Inlet and outlet connections should be selected based on site-specific characteristics of the gravel site and waterbody affected. Existing drainage channels should be incorporated in the site design as inlet or outlet channels to the maximum extent possible. Inlet/outlet connections should be designed to minimize long-term sedimentation and maintenance;

h. Overburden including the surface organic layer should be stockpiled and disposed of within the limits of the mine area so that the area of impact outside the active mine is minimized. The quantity of overburden to be replaced within the pit will vary with the individual site. Material should be distributed such that it provides a substrate for the establishment of aquatic plants and associated benthic communities;

i. Removal of overburden from terrestrial storage should be accomplished so that the original site contours and elevations are reestablished (i.e., material is removed to re-expose the buried vegetation/organic layer);

j. Excess overburden should be stabilized, possibly graded to retain moisture (e.g., perched wetland), and revegetated (e.g., seed bed preparation and fertilization) to accomplish natural revegetation to the extent practicable. Fertilization of adjacent natural wetlands should be conducted, where deemed necessary, to increase natural seed production;

k. Aliquots developed within the same general area should be connected upon completion of mining of each aliquot in such a manner that islands are created with an elevation above water surface of less than one meter at mid-summer water levels;

l. Basic biological monitoring should be conducted to evaluate the effectiveness of rehabilitation for various fish and wildlife species and to monitor changes in habitat characteristics with time. Monitoring should be conducted at each site and should be designed in such a manner that a long term (ten plus years) historical data base is obtained.

INFORMATION SOURCES USED IN THE DEVELOPMENT OF THESE PRELIMINARY GUIDELINES

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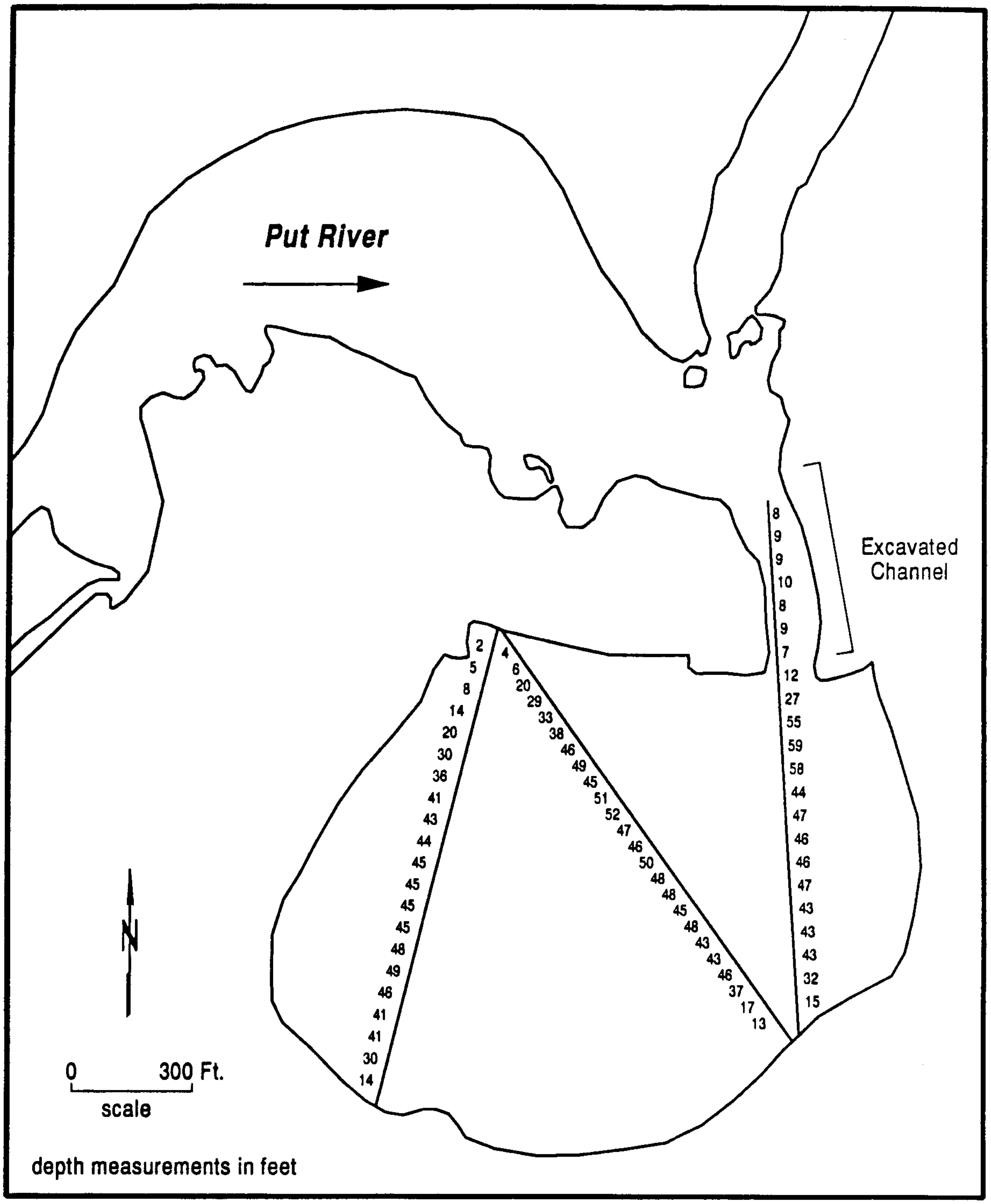
APPENDIX II.

Bathymetric map of Put 27.



APPENDIX III.

Results of water quality sampling in Aanaaliq Lakes, 1990.

Sample Site	Date	Ice Thickness (m)	Depth* (m)	Sample Depth (m)	Temp (°C)	Conductivity** uS/cm	Alkalinity*** mg/L	Hardness*** mg/L	pH	Dissolved Oxygen mg/L
Northern lobe	5/3/90	2.15	10.45	2	0.8	505	204	254	7.28	5.4
				4	0.7	505	210	242	7.22	5.7
				6	0.8	505	210	258	7.20	7.2
				8	0.6	510	209	254	7.22	6.0
				10	0.5	510	214	232	7.20	6.4
Southern lobe	5/3/90	2.14	9.0	2	1.50	540	219	254	7.08	5.2
				4	1.45	560	225	258	7.15	6.3
				6	1.60	580	217	248	7.00	5.7
				8	1.40	560	221	262	7.13	5.5
Southern lobe	8/23/90	-	8.15	1	6.50	195	68	81	8.14	11.4
				2	6.50	210	71	81	7.63	10.3
				4	6.50	195	69	82	7.87	10.9
				6	6.50	195	67	85	7.78	11.8
				8	6.50	195	70	80	7.78	10.5

* Depth measured from ice surface in May and from water surface in August.
** Conductivity temperature corrected at 25°C.
*** Alkalinity and hardness expressed as $CaCo_3$

APPENDIX IV.

Results of water sampling in Put 27 and the lower Put River, 1990.

Sample Site	Date	Ice Thickness (m)	Depth* (m)	Sample Depth (m)	Temp (°C)	Conductivity** uS/cm	Alkalinity*** mg/L	Hardness*** mg/L	pH	Dissolved Oxygen mg/L
Lower Put R	5/2/90	2.1	4.6	2	1.8	1213	485	462	7.60	10.1
				3	2.1	1229	483	477	7.55	10.4
				4	1.9	1356	467	478	7.61	7.1
Lower Put R	8/23/90	-	4.1	1	6.0	990	124	200	8.32	11.9
				2	6.0	990	127	203	8.35	9.6
				3	6.0	990	125	204	8.35	11.2
Put 27	5/2/90	2.1	3.8	2	2.8	882	259	194	7.70	13.1
				3	4.0	906	261	194	7.78	13.7
Put 27	8/23/90	-	9.1	1	7.0	760	116	178	8.24	10.6
				2	7.0	780	118	177	8.33	11.5
				4	7.0	780	119	178	8.29	11.6
				6	7.0	780	118	181	8.34	8.6
				8	7.0	780	116	175	8.31	10.4

* Depth measured from ice surface in May and from water surface in August.
** Conductivity temperature corrected at 25°C.
*** Alkalinity and hardness expressed as $CaCO_3$

APPENDIX V.

Results of water quality sampling in Kuparuk Mine Site D, 1990.

Sample Site	Date	Ice Thickness (m)	Depth* (m)	Sample Depth (m)	Temp (°C)	Conductivity** uS/cm	Alkalinity*** mg/L	Hardness*** mg/L	pH	Dissolved Oxygen mg/L
Kuparuk Mine Site D	5/4/90	2.05	12.90	2	1.9	430	120	175	7.7	12.8
				4	1.6	460	114	177	7.2	10.6
				6	1.9	440	108	171	7.63	12.6
				8	1.7	420	122	172	7.70	11.0
				10	1.8	430	120	177	7.65	12.5
				12	1.7	430	112	192	7.40	11.8

* Depth measured from ice surface.
** Conductivity temperature corrected at 25°C.
*** Alkalinity and hardness expressed as $CaCO_3$.