Fisheries Investigations of Flooded North Slope Gravel Mine Sites, 1989

by:
Carl R. Hemming

Technical Report No. 90-2

Alaska Department of Fish & Game
Division of Habitat

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Frank Rue
Director
Habitat Division
Alaska Department of Fish and Game
P.O. Box 3-2000
Juneau, Alaska 99802

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Introduction

As part of an ongoing program to monitor the use of flooded gravel mine sites by fish, we continued and expanded fyke net and gill net sampling in 1989. This annual progress report on the gravel mine site project presents information on the species composition and length-frequency distribution of fish captured at six flooded gravel mine sites in the Prudhoe Bay and Kuparuk oilfield development areas. Sites sampled in 1989 were Sag Site C, Kuparuk Mine Site D, Kuparuk Mine Site B (Aanaaliq Lakes), Kuparuk Deadarm Reservoirs 5 and 6, the Sagavanirktok (Sag) River Bypass Road Oxbow (Ott's Oxbow), and the lower Putuligayuk (Put) River (Figure 1). We added the lower Put River and Ott's Oxbow to the fish sampling program in 1988 and 1989 respectively. This progress report contains water quality and bathymetric data for the lower Put River and descriptive information on the Oxbow site. Earlier progress reports (Hemming 1988, Hemming et al. 1989), present background information on the other four sites.

The objective of the fish sampling program is to provide information on the seasonal use of several different habitat types resulting from North Slope gravel extraction activities. This information will guide habitat enhancement of gravel mine sites with the goal of increasing biological productivity and use by fish and wildlife.

Description of New Sites

The lower Put River is a 9.5 ha pool resulting from gravel extraction operations during the early development of the Prudhoe Bay oilfield. This stream reach has a maximum depth of 4.3 m and a mean depth of 3.8 m (see Appendix I for data from fathometer transects). The site is 3.2 km upstream of Prudhoe Bay within estuarine influence. Put 27, a 15.9 ha deep mined gravel site, is next to the lower Put River. A 115 m buffer strip with a gravel flood control berm separates the lower Put River from the Put 27 Mine Site.

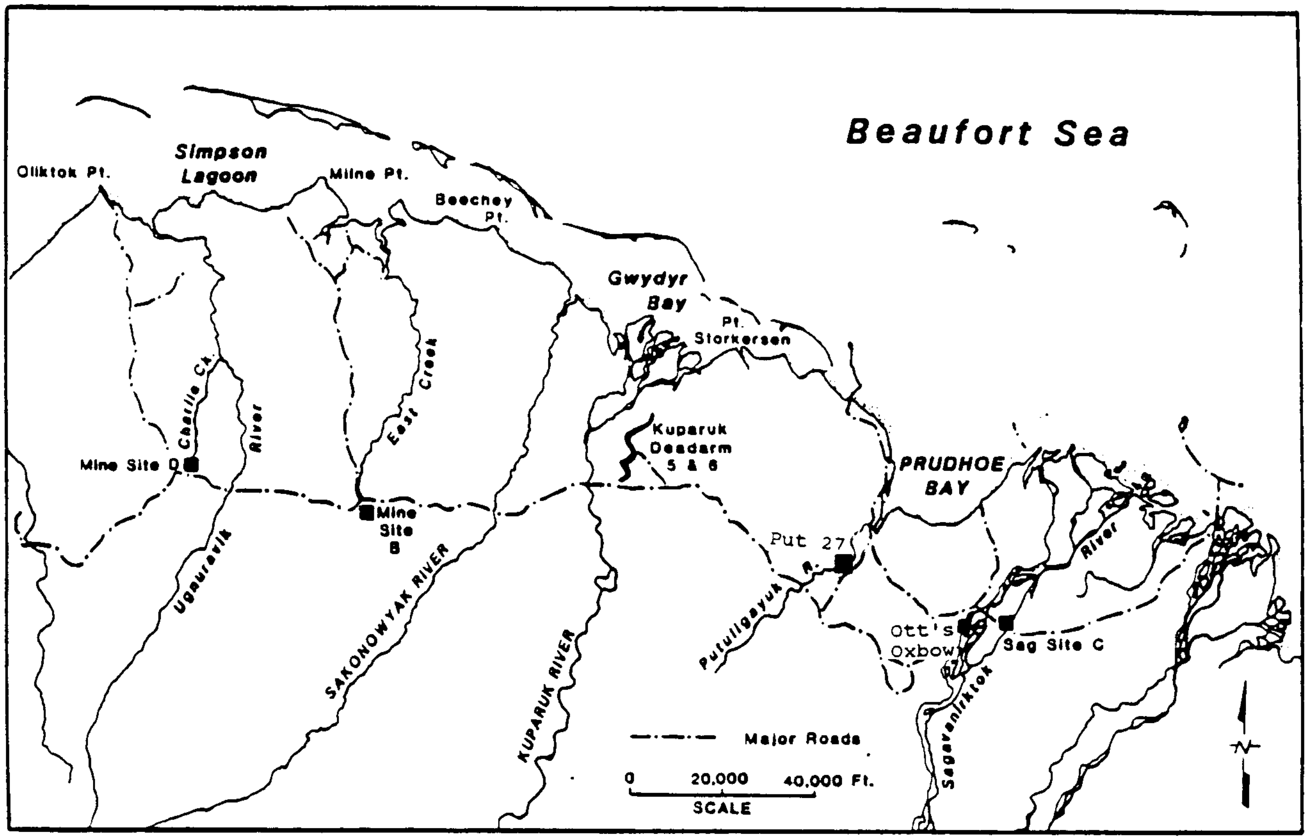

Figure 1. Map of the Prudhoe Bay-Kuparuk oilfields and the locations of flooded gravel mine sites sampled in 1989.

Habitat rehabilitation recommended for this site is a channel connection between the Put River and the Put 27 Mine Site.

Ott's Oxbow is a 6.9 ha, shallow, back-water area of the Sag River. Parallel, shallow scraping of riverine gravel deposits formed the site. This gravel extraction technique created a quiet water zone with a depth of less than 1.5 m. Several small islands and spits result from irregularities in the depth of material removal. A gravel roadway partially isolates this back-water habitat from active channels of the Sag River. A single 48" thick walled pipe downstream of the site provides the only connection to active channels of the river. The bottom material is soft, fine sand or silt. Ott's Oxbow is upstream of the ARCO Sag River bridge, on the west side of the river near the Prudhoe Bay Operations Center. Gravel removal occurred in the mid-1970's at this site.

Previous Fish Sampling

In August 1986, we initiated fish sampling at Sag Site C, Aanaaliq Lakes, and Kuparuk Mine Site D and we continued the sampling at selected sites in 1987 and 1988. Fish were sampled with graduated mesh gill nets and baited minnow traps in 1986. In April 1987, we set gill nets beneath the ice at Sag Site C and Kuparuk Mine Site D. In July 1987 we sampled Sag Site C, Aanaaliq Lakes, and Kuparuk Mine Site D with gill nets and minnow traps. In August 1987 we sampled Kuparuk Deadarm Reservoirs 5 and 6 with gill nets. In mid-May 1988 we set a gill net under the ice at Sag Site C. With the exception of the under ice sampling periods, we captured fish in each of the flooded gravel mine sites sampled, but there were differences in the species composition and the catch per unit effort at the various sites. Hemming (1988) and Hemming et al. (1989) reported that species richness and relative abundance of fish was greatest in the flooded mine sites located in the floodplains of large river systems, such as the Sag and Kuparuk rivers. Large river systems provide fish overwintering habitat. Sites connected to small tundra streams draining directly to the Beaufort Sea were colonized by ninespine stickleback (*Pungitius pungitus*), broad whitefish (*Coregonus nasus*), and least cisco (*Coregonus sardinella*). We failed to capture freshwater fish in the sites connected to small tundra streams (Hemming 1988).

In 1988, we used fyke nets in a mark-recapture estimate of arctic grayling abundance in Sag Site C. The estimated abundance of arctic grayling (*Thymallus arcticus*) >80 mm FL was 229±16 (standard error = 8; 95% confidence interval). The estimated density of arctic grayling >80 mm FL was 14.8 grayling per ha in the 15.5 ha site. During the two sampling periods in July and August 1988, we captured seven species of fish in fyke nets fished at up to four locations in Sag Site C. Arctic grayling was the most frequently captured species. Of the 1,636 fish captured, including recaptures, 60% were arctic grayling. Round whitefish (*Prosopium cylindraceum*) and broad whitefish made up 30% and 8% of the catch respectively, while the remaining 2% consisted of Dolly Varden char (*Salvelinus malma*), burbot (*Lota lota*), slimy sculpin (*Cottus cognatus*), and ninespine stickleback (Hemming et al. 1989).

Mine Site Rehabilitation

Recent oil industry habitat enhancement and gravel extraction projects altered the configuration of three sites investigated during the 1989 open water season. ARCO Alaska, Inc. completed a habitat enhancement project at Sag Site C in the fall of 1987. Project personnel removed 183 m of the gravel perimeter berm to allow flooding of the area on the west side of the site. ARCO Alaska, Inc. also excavated floodplain gravels outside of the berm to a depth of 0.6 to 1.2 m below the water surface elevation of Sag Site C. These excavations provided 2.0 ha of shallow water habitat.

In May 1989, ARCO Alaska, Inc. completed their second mine site habitat enhancement project. This project involved excavating an 18 m x 24 m inlet channel to a depth of 1.8

m connecting Aanaaliq Lakes to an adjacent tundra stream (East Creek). An island was formed by cutting two 14 m x 24 m channels through the overburden dike that separated two lake basins. Rehabilitation of Aanaaliq Lakes provided a permanent connection between the stream and the lakes and allowed fish access to both the deep water lakes and the tundra stream. After rehabilitation, we transplanted 210 arctic grayling to the site from the Sag River. We hope to establish a reproducing population of grayling in the lake and tundra stream complex.

BP Exploration excavated an expansion to Kuparuk Deadarm Reservoir 5 in the winter of 1988/1989 to provide gravel for a new drill site pad and access road. Spring high water flooded the excavation creating a 6.2 ha bay estimated to be less than 2.5 m in depth. A large overburden dike breached by a deeply notched channel separates the expansion area from the older portion of Deadarm Reservoir 5. The two areas are also connected during high water at an excavation south of the overburden pile.

In addition to the man-made changes in the gravel mine sites, natural events such as spring flooding, thawing of adjacent ice rich soils and wind driven wave erosion altered the sites over time. For example, in early June 1989, spring flood waters in the Sag River built up behind the Sag River causeway road resulting in a roadway failure. Gravel from the road failure deposited on top of the ice in Sag Site C, covering an estimated area of 5 ha. High water in the Sag River floodplain restricted through a culvert crossing in the causeway redistributed gravel in the shallows excavated for habitat enhancement. Gravel filled the shallows and reduced the littoral habitat to 0.3 ha. The outlet channel expanded during the spring flood as 0.2 ha of shallow water developed. Spring flood waters also carried willow branches and other small woody debris and deposited this material along the shore and in the shallows near the outlet. Tundra subsidence occurred along the east side of the site. The direction of surface flow changed in a wetland area near the northeast corner of the site and a small drainage developed that flowed into Sag Site C in August 1989.

Methods

Fyke nets 3.7 m in length with two 1.2 m square entrance frames, five hoops and a 1.8 m cod end captured fish at five flooded gravel mine sites in the Prudhoe Bay and Kuparuk oilfield areas. Net wings measuring 1.2 m by 7.6 m were attached to the first entrance frame. We set the nets perpendicular to shore with a 30 m center lead attached to the entrance frames to divert fish into the net. The water depth at each net site governed the amount of center lead deployed. We emptied fish captured at each fyke net into a floating holding pen. Each fish was identified, examined for tags, and the fork length was measured to the nearest millimeter. At some net sites when more than 20 fish of the same species and size class were captured, we sub-sampled the catch to verify the size class. The remainder of fish in that size class were counted and released. At Sag Site C and the Kuparuk Deadarm where the nets were fished on consecutive days, we used caudal fin clips to identify recaptured fish.

At Kuparuk Mine Site D, we fished 38.1 x 1.8 m graduated mesh gill nets with five 7.6 m panels having bar mesh sizes of 1.3, 2.5, 3.8, 5.1, and 6.4 cm. One net fished at Kuparuk Mine Site D was a floater while the remaining nets were sinkers. In the lower Put River we fished both multifilament and monofilament graduated mesh gill nets under the ice. These nets measured 9.1 x 1.8 m and had three 3.0 m panels with mesh sizes of 1.3, 1.9, and 2.5 cm.

In late spring we collected water quality information in the lower Put River. Holes were drilled through the ice with a gasoline powered ice auger and water samples were collected just below the ice and at one meter intervals through the water column with a Van Dorn water sampler. We measured the water temperature, dissolved oxygen concentration, and salinity concentration of the water samples collected at each depth. Water temperatures were measured in the Van Dorn bottle with a mercury thermometer and a digital thermometer to check calibration. A Yellow Springs Instrument (YSI) Model 33, temperature, conductivity, and salinity meter was used to measure the salinity concentration of samples collected with the Van Dorn bottle. We calibrated the meter readings with salinity standards of 1, 5, and 15 ppt. Dissolved oxygen concentrations were determined with the azide modification of the Winkler procedure on 300 ml prepared samples using a digital titrator.

We gathered depth profile data at the lower Put River with an electronic fathometer. Depth soundings were taken at 10 second intervals as the boat was operated at a constant slow speed along an identified transect line. We recorded the depth soundings in feet and later converted these measurements to metric equivalents.

In July 1988, we used floy tags to mark 37 arctic grayling in Sag Site C. These tagged fish provided an opportunity to obtain recapture information in 1989. We also measured water temperatures at each fyke net station with a hand held mercury thermometer (Appendix II). The area estimates presented in this report were determined from aerial photographs (scale 1" = 500 ft) using computer assisted, digitizing equipment.

Results

Sag Site C

The relative abundance and species composition of fish captured in Sag Site C varied considerably between sample periods in mid-July and late August. Arctic grayling, burbot, and ninespine stickleback numbers increased during the August sampling period while round whitefish numbers showed little change between sample periods. We captured few broad whitefish, Dolly Varden char, and slimy sculpin. Broad whitefish were found in both sample periods and slimy sculpin and Dolly Varden char were captured only in July. A single 176 mm least cisco was captured in August (Table 1).

We set fyke nets in the shallows near the inlet, off the access ramp, and in the outlet channel on July 17-19 and August 23-24 (Figure 2). During the two day sample period in July, we captured 378 fish. The most frequently captured species was round whitefish, accounting for 61% (n = 233) of the catch. Twenty eight percent (n = 108) of the July catch were arctic grayling. The remaining species, ranked in decreasing order of abundance, was broad whitefish, ninespine stickleback, Dolly Varden char, burbot, and slimy sculpin (Table 1). The most productive net location during the July sample period was the outlet channel with 50% (n = 191) of the catch. The access ramp location accounted for 36% (n = 137) of the catch, and the inlet shallows produced only 14% (n = 51).

We captured juvenile arctic grayling ranging from 40-160 mm and juvenile round whitefish ranging from 40-120 mm more frequently than other species and size classes of fish during the July sample period. A dominant size mode in the length frequency distribution of round whitefish appeared in the 60-79 mm size class (Figure 3). We captured only three round whitefish that exceeded 200 mm in July.

We set three fyke nets for 16 hours on August 23-24. The most abundant species captured during the second sample period was ninespine stickleback. We captured an estimated 15,900 stickleback with the majority of the sticklebacks occurring at the outlet channel net site (Table 1). In July and August 1988 and July 1989, fyke nets captured fewer than 10 ninespine stickleback from Sag Site C. Arctic grayling numbers also increased in August 1989: 1,030 grayling were captured, compared to the 108 captured in July 1989 (Table 1); we found 94% (n = 967) of the grayling were 40-59 mm (Figure 4). Previous investigations of arctic grayling on the North Slope identified individuals in

Table 1. Number of fish captured, by species, at three fyke net locations in Sag Site C, 1989.

	Arctic Grayling	Broad Whitefish	Burbot	Dolly Varden	Least Cisco	Ninespine Stickleback	Round Whitefish	Slimy Sculpin	Combined Species** Total
July 18									
Net 1	3	4	0	0	0	0	19	1	27
Net 2	27	8	1	2	0	0	78	0	116
Net 3	30	4	0	3	0	1	106	0	143
TOTAL	60	16	1	5	0	1	203	1	286
July 19									
Net 1	17	0	0	0	0	6	0	0	17
Net 2	9	3	1	0	0	0	8	0	21
Net 3	22	0	0	1	0	2	22	0	45
TOTAL	48	3	1	1	0	8	30	0	83
August 24									
Net 1	91	1	2	0	0	350*	69	0	163
Net 2	557	8	32	0	0	550*	122	0	719
Net 3	382	0	5	0	1	15,000*	20	0	408
TOTAL	1,030	9	39	0	1	15,900*	211	0	1,290

Location of fyke nets:
1 = shallow water littoral zone
2 = access ramp
3 = outlet channel

* ninespine stickleback numbers were estimated
** ninespine stickleback excluded from total

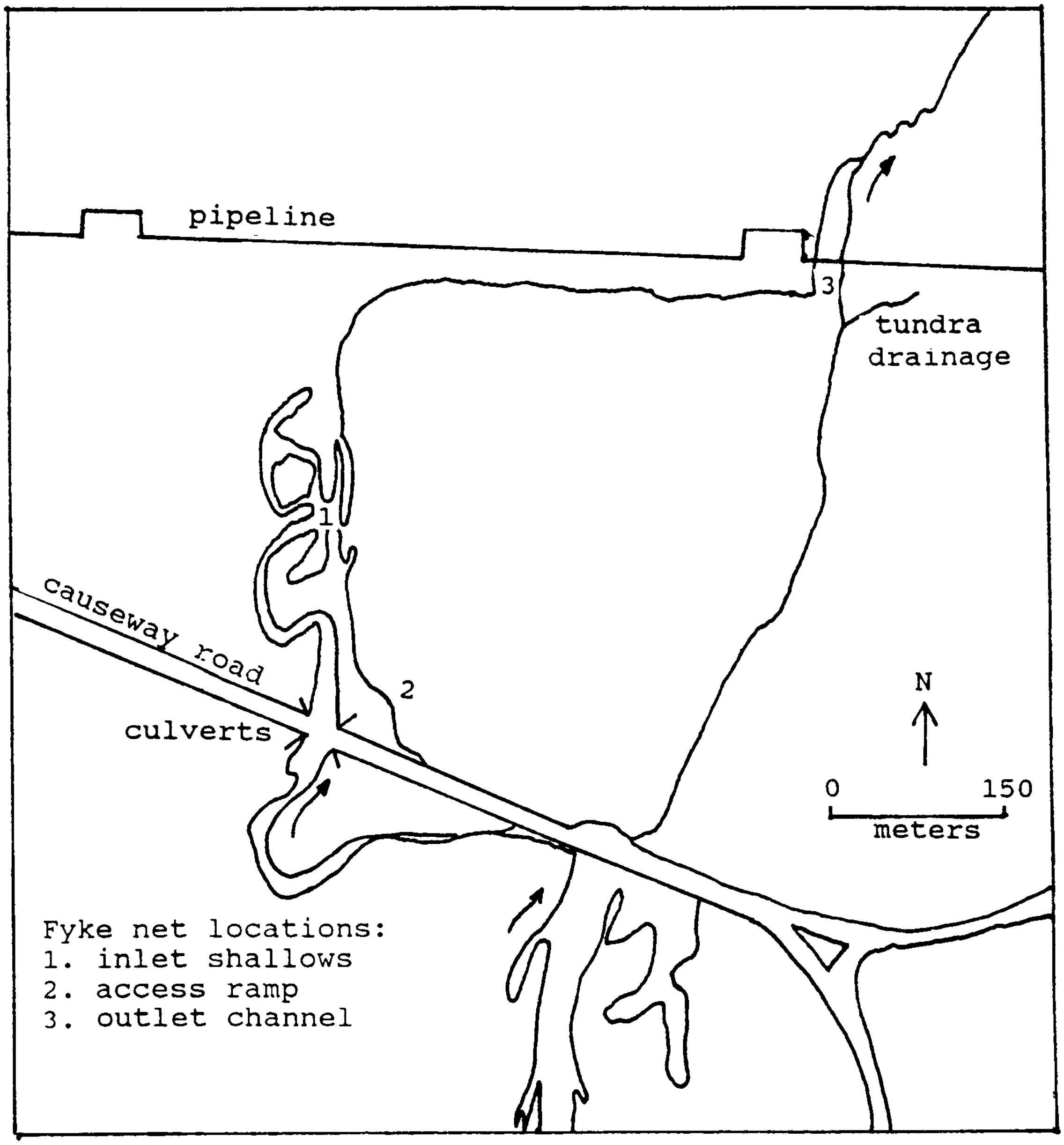

Figure 2. Locations of fyke nets for fish sampling in Sag Site C, July and August 1989.

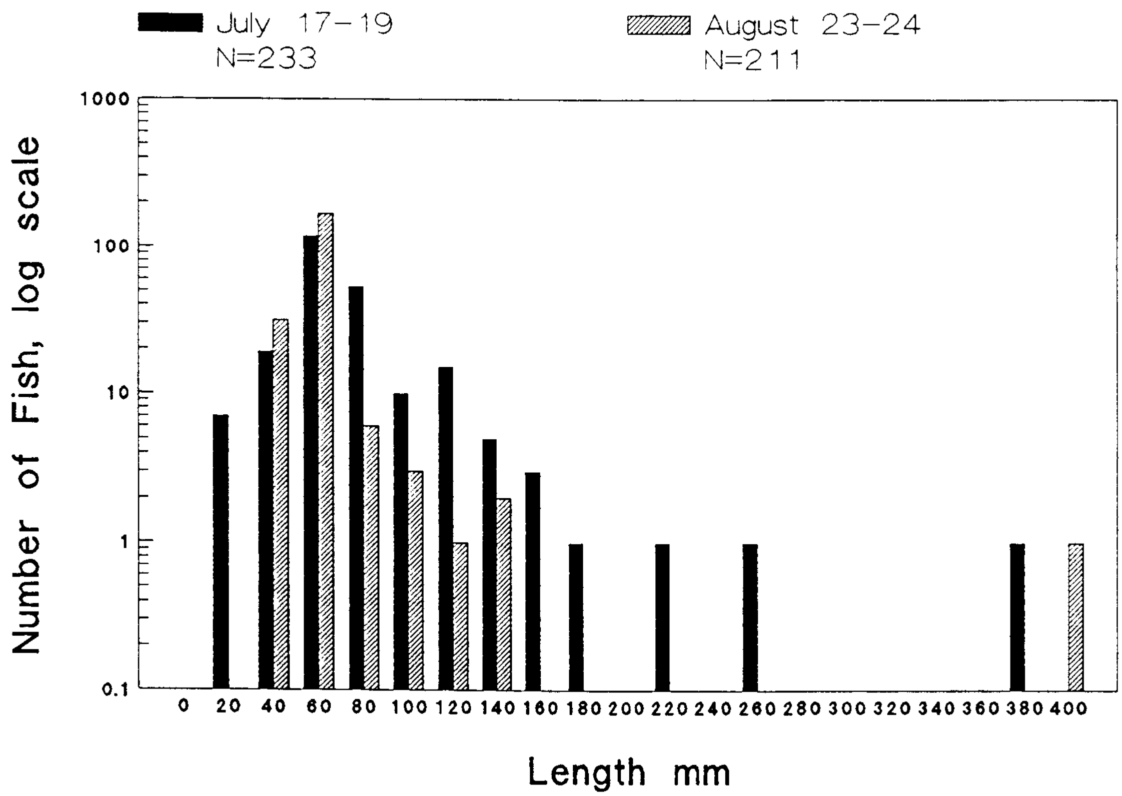

Figure 3. Length frequency distribution of round whitefish captured in Sag Site C, July and August 1989.

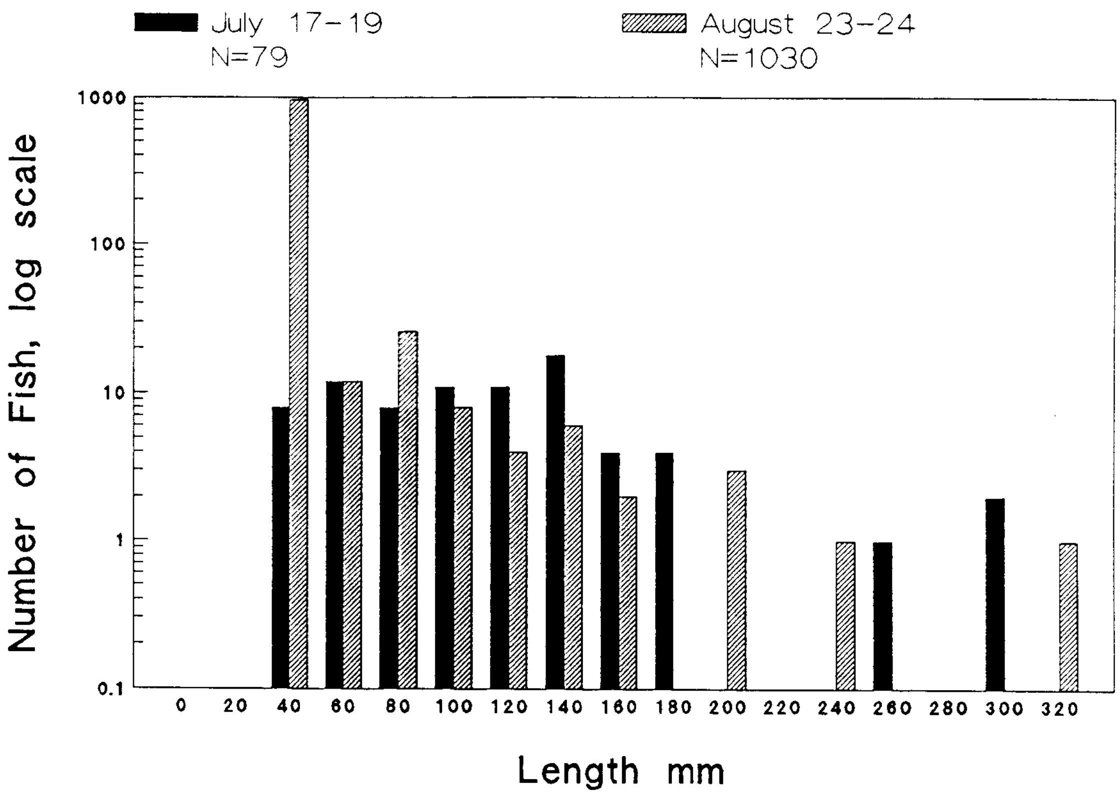

Figure 4. Length frequency distribution of Arctic grayling captured in Sag Site C, July and August 1989.

this size class as young-of-the-year fish (deBruyn and McCart 1974, Bendock 1979). The distribution of lengths of grayling captured in the July and August samples were compared using the Kolomogrov Smirnov (KS) test to determine if the two samples were from the same statistical population. The cumulative probability distribution of fork lengths of grayling captured in July was significantly different from the August sample ($p < 0.01$, $d = 0.8772$); therefore, we concluded the samples were from different populations. A plot of the length-frequency distribution of the two samples (Figure 3) indicates that the differences are due to the young-of-the-year grayling found in the August sample.

The distribution of the August catch among the three net site locations varied from the pattern observed during the July sample period. In August 54% (n = 557) of the arctic grayling were captured at the access ramp net while the outlet channel net contained 37% (n = 382) and the inlet shallows accounted for 9% (n = 91).

The number of burbot increased from two captured in July to 39 in August. The burbot captured in August ranged from 52-145 mm and averaged 68 mm (SD 14.3 mm). A typical length for burbot in interior Alaska at age 1+ is 136 mm (Chen 1969); therefore, it is likely that most of the burbot were young-of-the-year fish.

In the July and August sample periods we recaptured 2 of the 37 arctic grayling that were marked with floy tags in July 1988. Low water levels in the Sag River kept the site isolated from active channels of the Sag River until June 1989. The recaptured fish had slow growth rates between the time of tagging and the time of recapture (Table 2) when compared to the arctic grayling in Aanaaliq Lakes. The Aanaaliq Lakes arctic grayling were marked in late June 1989 and recaptured in August and early October 1989.

Table 2. Growth rate of recaptured arctic grayling, Sag Site C, July-August 1989.

Tag No.	Date Marked	Fork Length (mm)	Date Recaptured	Fork Length (mm)	Total Days	Growth (mm)	Est. Growth (mm/day)
509	7/13/88	304	7/18/89	317	371	13	0.035
509	7/13/88	304	8/24/89	323	408	19	0.046
552	7/14/88	305	7/18/89	302	370	-3	-0.008

Ott's Oxbow

We fished a single fyke net in Ott's Oxbow on July 17-18, at the north end of the site with 30 m of center lead (Figure 5). We captured 129 fish, including 114 small broad whitefish, 13 arctic grayling, 1 ninespine stickleback, and 1 round whitefish (Table 3). The broad whitefish ranged from 43-55 mm (mean = 48.5 mm, SD = 2.6) and the 13 arctic grayling ranged from 138-350 mm (mean = 229.6 mm, SD = 62.5).

We fished the net at the same location on August 22-23 for a 27 hour period. We captured 559 fish including 327 arctic grayling, 150 ninespine stickleback, 50 round whitefish, 28 burbot and 4 broad whitefish. Juvenile arctic grayling were captured most frequently as 83% (n = 273) of the arctic grayling catch was in the 40-59 mm size class (Figure 6). A subsample of 15 round whitefish ranged from 60-77 mm (mean = 66.9, SD = 5.0), and we judged the 50 round whitefish to be in the 60-79 mm size class. A subsample of 10 burbot ranged from 60-69 mm (mean = 65.3 mm, SD = 3.3)and we judged the 28 burbot to be in the 60-70 mm size class. The 4 broad whitefish captured ranged from 87-93 mm.

Kuparuk Deadarm

We set three fyke nets in Kuparuk Deadarm Reservoirs 5 and 6 on July 18-21. The nets fished at the south end of the expansion area of Reservoir 5, at the south end of Reservoir 5, and on the west side of Reservoir 6 (Figure 7). The three nets captured 127 fish, including 72 grayling, 52 ninespine stickleback, 2 slimy sculpin, and a single burbot (Table 4). Juvenile arctic grayling in the 100-160 mm size range occurred most frequently in the sample catch (Figure 8). The Reservoir 6 net captured 65 fish, while the expansion area of Reservoir 5 produced 51, and the remaining 12 were captured in Reservoir 5. We used only 10 m of center lead in Reservoir 5, while 25 m of center lead

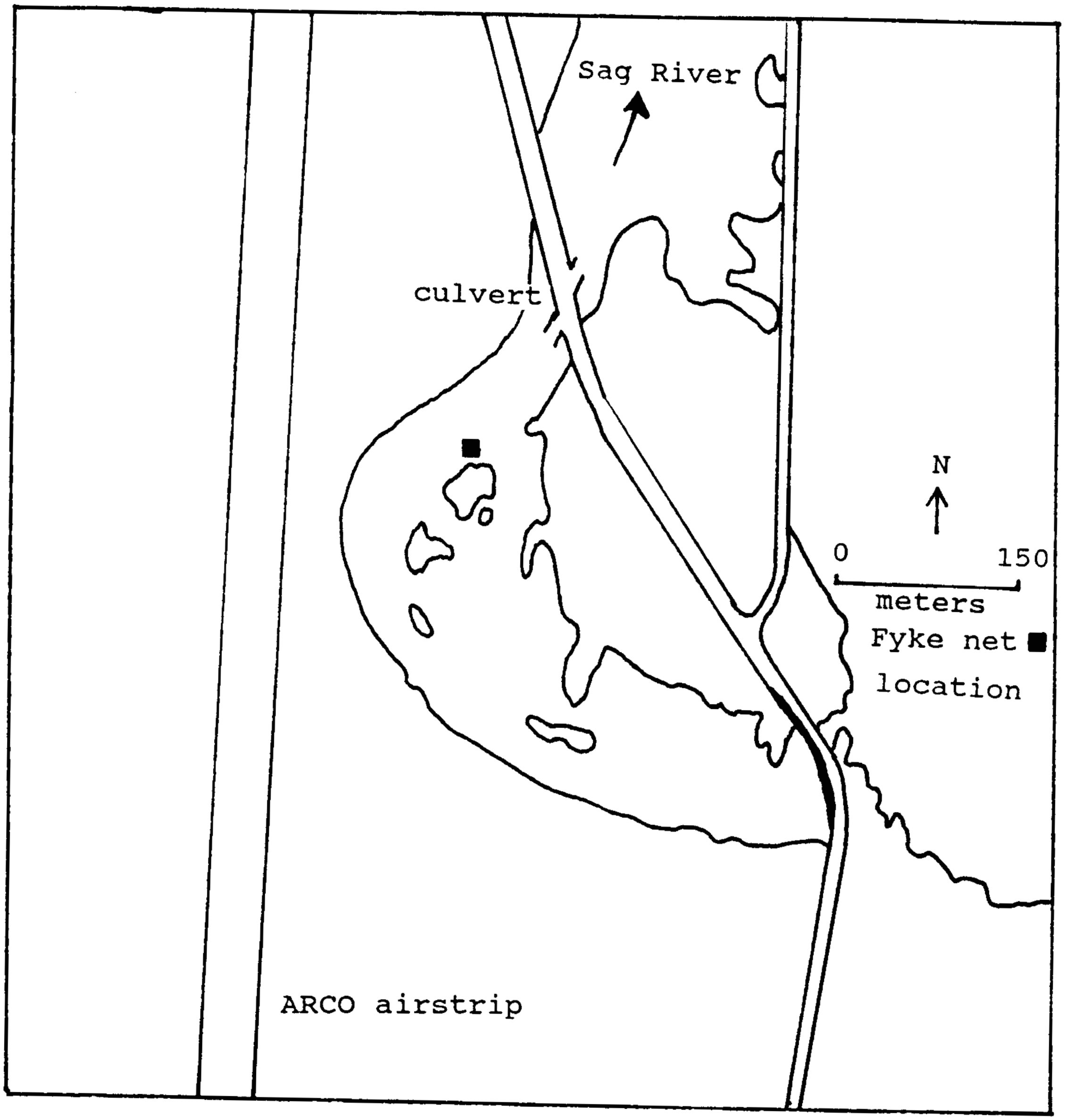

Figure 5. Location of fyke net for fish sampling in Ott's Oxbow, July and August 1989.

Table 3. Number of fish captued, by species, in fyke nets at Ott's Oxbow, lower Put River, and Aanaaliq Lakes, 1989.

	Arctic Grayling	Broad Whitefish	Burbot	Fourhorn Sculpin	Least Cisco	Ninespine* Stickleback	Round Whitefish	Combined Species** Total
July 18								
Ott's Oxbow	13	114	0	0	0	1	1	129
August 23								
Ott's Oxbow	327	4	28	0	0	150*	52	411
July 21								
Put River	0	0	0	3	0	14	0	3
August 24								
Put R. (2 nets)	0	1	0	3	0	400*	0	4
August 23								
Aanaaliq Lakes:								
Area A	0	0	0	0	0	10,000*	0	0
Area B	1***	0	0	0	1	10,000*	0	2
August 24								
Aanaaliq Lakes:								
Area A	0	0	0	0	0	18,000*	0	0
Area B	1***	1	0	0	2	8,000*	0	4

* Ninespine stickleback numbers estimated
** Ninespine stickleback excluded from total
*** Arctic grayling transplanted to site

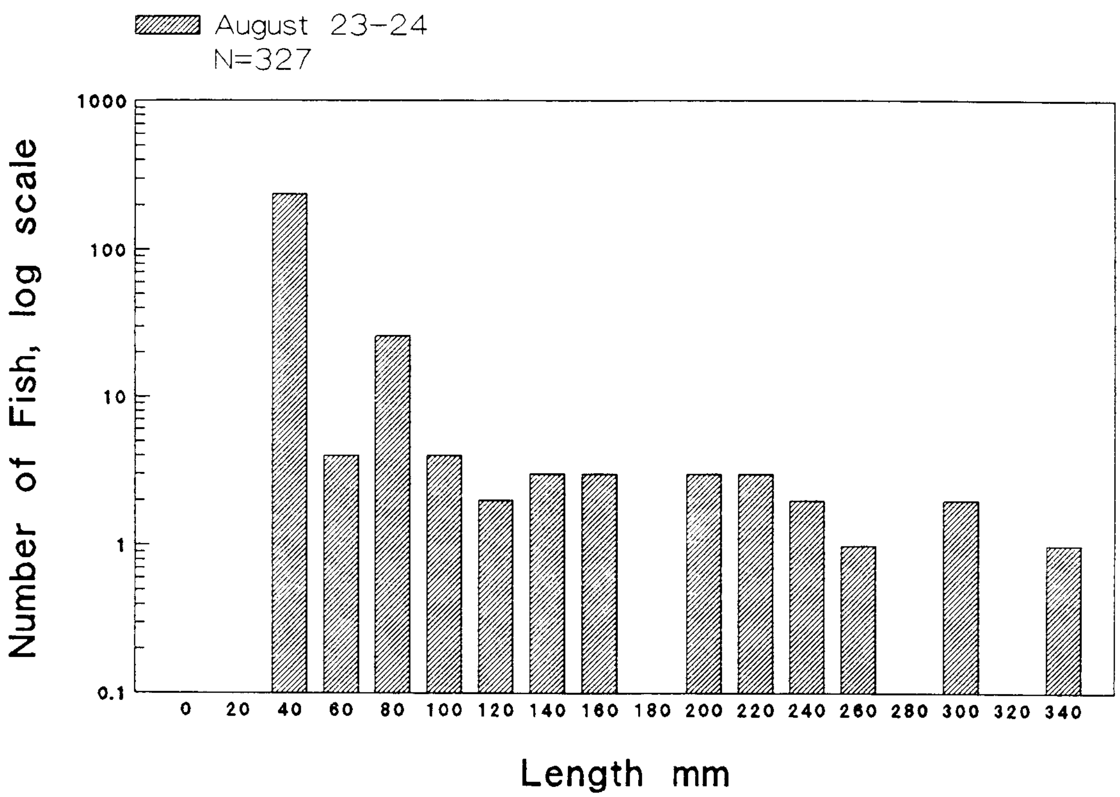

Figure 6. Length frequency distribution of arctic grayling captured in Ott's Oxbow, August 1989.

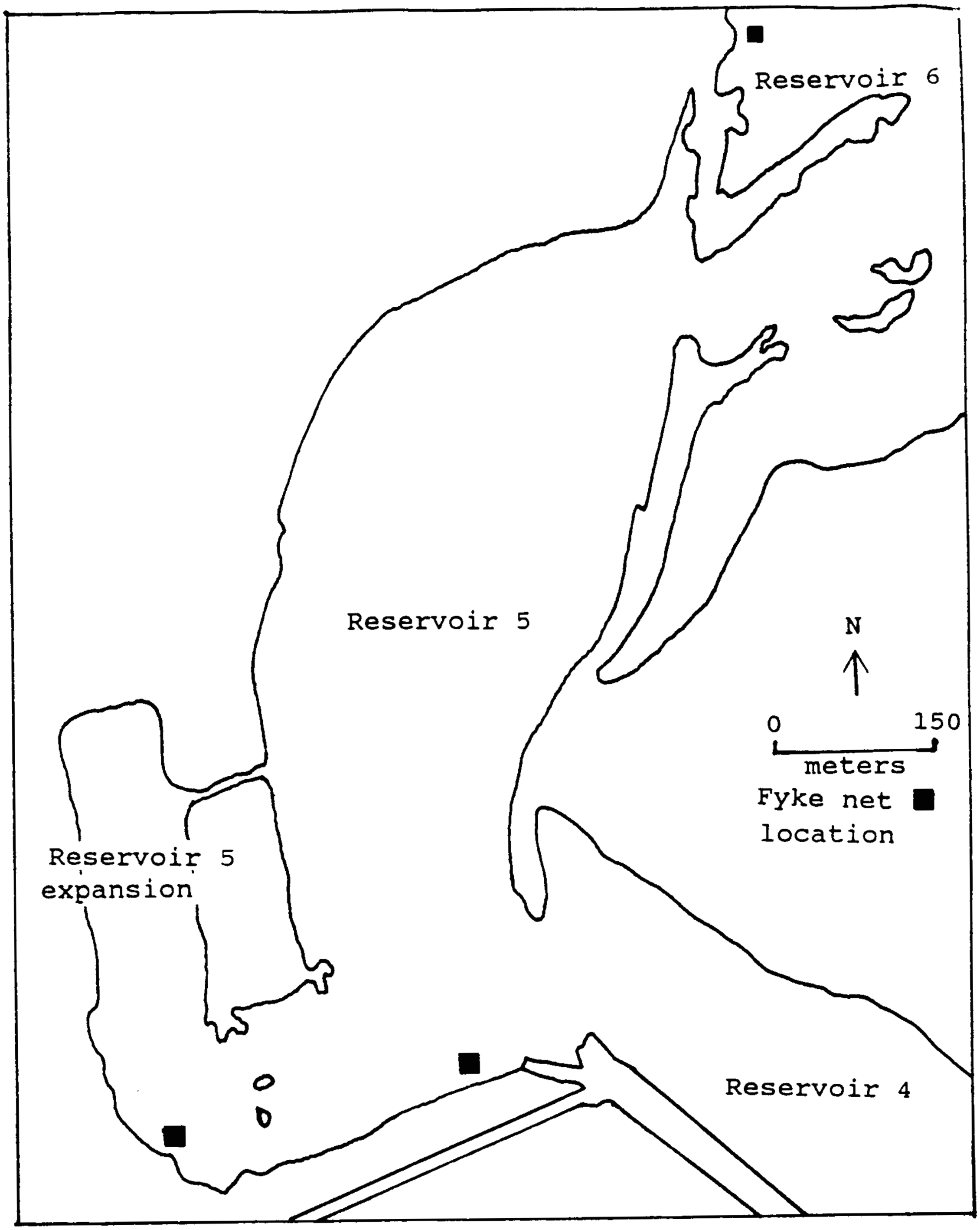

Figure 7. Locations of fyke nets for fish sampling in Kuparuk Deadarm, July 1989.

Table 4. Number of fish captured, by species, at three fyke net locations in the Kuparuk Deadarm Reservoirs, 1989.

	Arctic Grayling	Burbot	Ninespine Stickleback	Slimy Sculpin	Combined Species Total
July 19					
KDR 5	6	0	0	0	6
KDR 5 exp.	24	0	0	0	24
KDR 6	8	0	31	0	39
TOTAL	38	0	31	0	69
July 20					
KDR 5	2	1	2	0	5
KDR 5 exp.	8	0	0	0	8
KDR 6	7	0	8	0	15
TOTAL	17	1	10	0	28
July 21					
KDR 5	1	0	0	0	1
KDR 5 exp.	14	0	40	0	18
KDR 6	3	0	6	2	11
TOTAL	18	0	10	2	30

KDR = Kuparuk Deadarm Reservoir

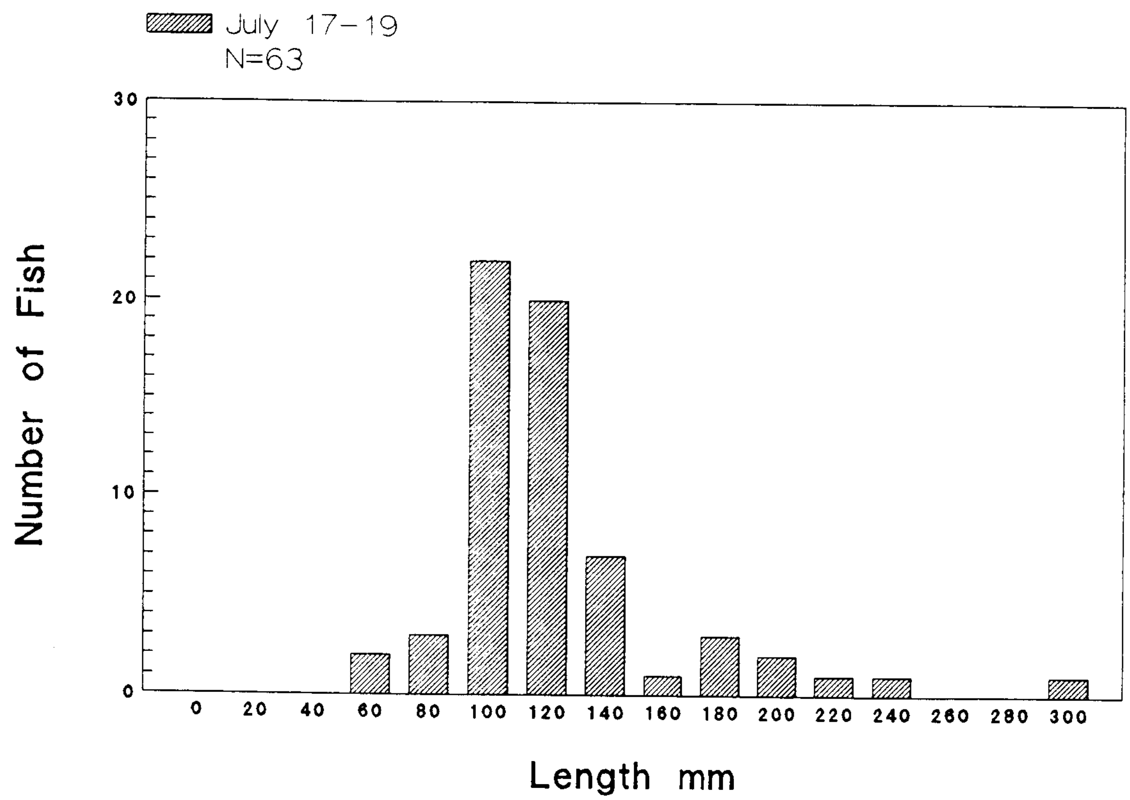

Figure 8. Length frequency distribution of Arctic grayling captured in the Kuparuk Deadarm, July 1989.

was used in the expansion area and 30 m of lead was used in Reservoir 6. The Reservoir 5 expansion area produced 63% (n = 46) of the grayling captured.

Kuparuk Mine Site D

We set four variable mesh gill nets in Kuparuk Mine Site D for 17 hours on August 22-23, 1989. Sinking nets fished at the access ramp, in the inlet channel, and at the northwest corner of the site, while a floating gill net fished at the northeast corner (Figure 9). We captured a single 191 mm least cisco at the access ramp.

Aanaaliq Lakes

We set two fyke nets in Aanaaliq Lakes on August 22-24, 1989. The nets fished at the northwest corner of the site and at the inlet channel. We used 15 m of center lead at each location. Each net produced a large catch of ninespine stickleback. We estimated the number of stickleback in each net based on visual examination of the net content. The estimates ranged from 8,000 to 18,000 at each site (Table 3). The trap at the inlet channel captured 3 least cisco, 2 arctic grayling, and 1 broad whitefish in addition to the stickleback. The net at the northwest corner of the site failed to capture species other than stickleback. The three least cisco ranged from 184-196 mm and the broad whitefish was 240 mm.

Lower Put River

We fished two variable mesh gill nets beneath the ice of the lower Put River on May 17-18, 1989. On May 17 we collected water quality information at the gill net sample sites. Open water fish sampling was conducted with fyke traps on July 20-21 and August 23-24, 1989.

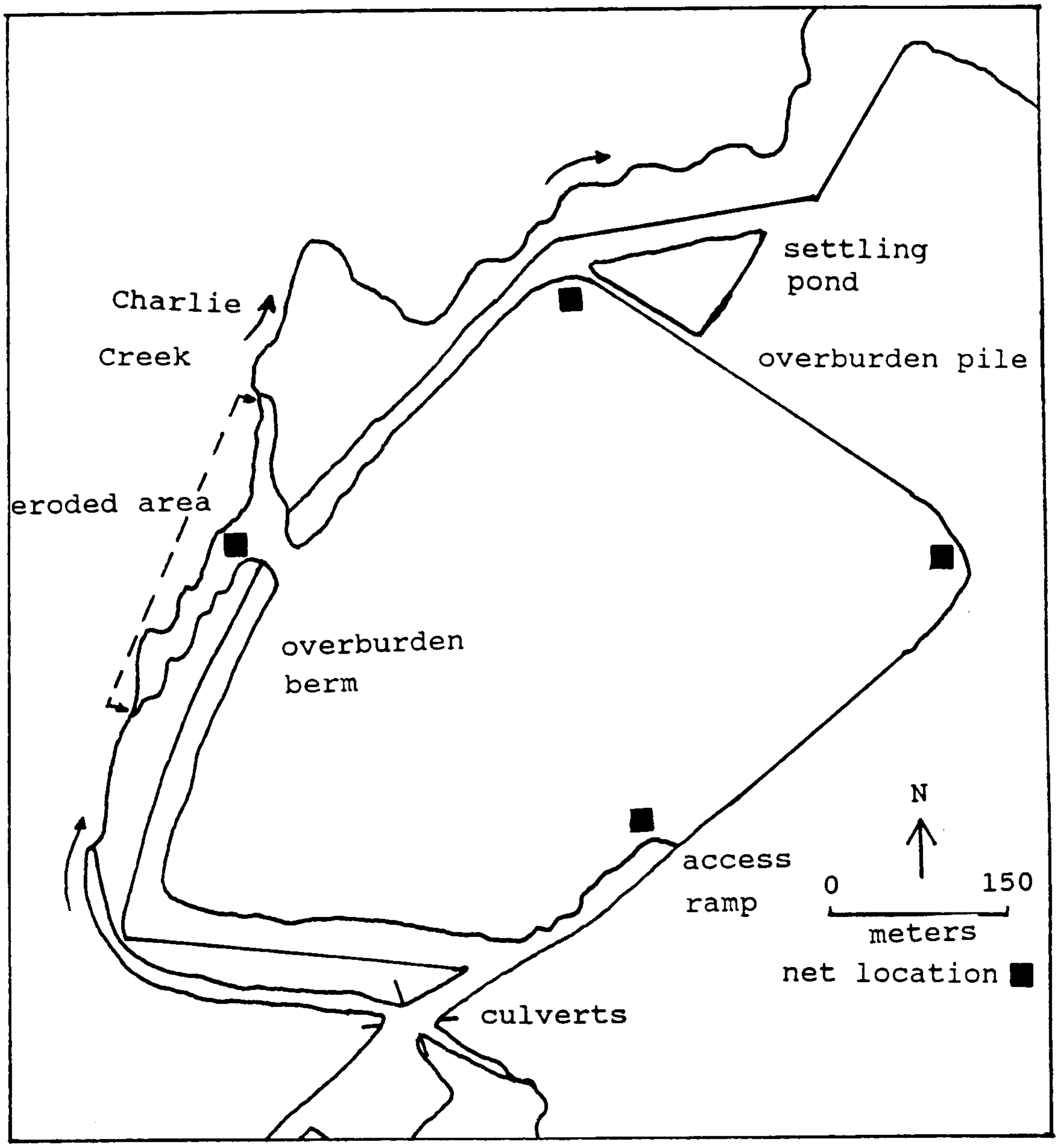

Figure 9. Locations of gill nets for fish sampling in Kuparuk Mine Site D, August 1989.

We set gill nets in the Put River at locations 400 m and 600 m downstream of Drill Site 15 access road crossing (Figure 10). The downstream net produced a single 260 mm round whitefish. An analysis of the stomach content of the round whitefish indicated recent feeding as the stomach was full. Identifiable food items included midge and caddisfly larvae. The midge larvae were numerous while only two caddisfly larvae were identified.

We found similar water temperatures, dissolved oxygen concentration, and salinity at each depth sampled in the lower Put River (Table 5). Both sample sites had the same pattern of uniform water quality characteristics at each depth sampled. The water temperature measurements indicated a slight super-cooling effect (-0.5°C) at all depths. The dissolved oxygen concentrations ranged from 6.4 mg/L to 6.9 mg/L. The salinity concentrations were 6.7 ppt. The water depth was 4.5 m at both sample locations. The ice depth was 2.1 m at the downstream sample site which was windblown and 1.7 m at the upstream site where more snow cover was present.

In July, we set a single fyke net 250 m downstream of Drill Site 15 access road crossing of the Put River. The net captured 14 ninespine stickleback and 3 fourhorn sculpin (*Myoxocephalus quadricornis*) (Table 3). In August we set two nets, they fished at locations 250 m and 800 m downstream of Drill Site 15 access road. High winds rolled the upstream trap onto its side and it captured only two ninespine stickleback. We set the downstream net partially blocking the stream channel at a location where the pool narrows. This net captured one adult broad whitefish (475 mm), three fourhorn sculpin, and an estimated 400 ninespine stickleback (Table 3).

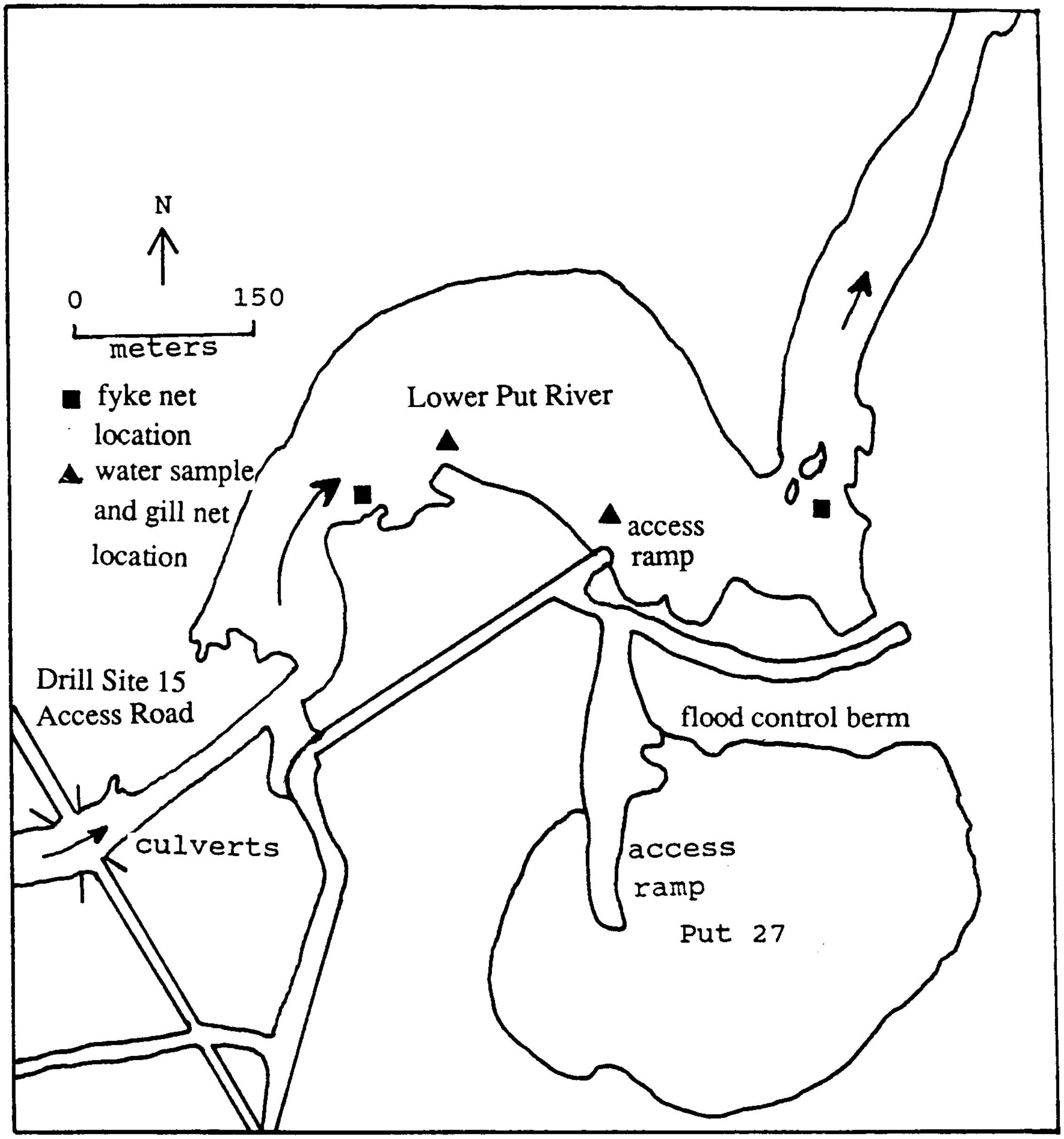

Figure 10. Lower Put River water quality and fish sampling locations, 1989.

Table 5. Limnological sampling in the lower Putuligayuk River near Put River Mine Site 27, 17 May 1989.

Location	Total Depth m	Ice Thickness m	Sampling Depth m	Temperature °C	Dissolved Oxygen mg/L	Salinity ppt
Site A*	4.5	2.1				
			2	-0.5	6.5	6.7
			3	-0.5	6.9	6.7
			4	-0.5	6.5	6.7
Site B**	4.5	1.7				
			2	-0.5	6.4	6.7
			3	-0.5	6.9	6.7
			4	-0.5	6.6	6.7

* 600 m downstream of Drill Site 15 road crossing
** 400 m downstream of Drill Site 15 road crossing

Discussion

Sag Site C

High water levels in the Sag River kept inlet and outlet channel connections open through most of the 1989 open water season. These highwater channel connections provide a mechanism for the movement of fish between Sag Site C and the Sag River system. The outlet channel flowed during both the July and the August sampling periods while the inlet channel became discontinuous just prior to the August sampling period.

During the 1988 open water season, Sag Site C did not have active inlet or outlet connections to the Sag River system, except for a brief period during the spring flood in early June. In mid-July, we captured and marked 37 large grayling (>200 mm) with floy tags. Between the time of marking in July and the spring flood in June 1989, Sag Site C was isolated from the Sag River system. In July 1989, we recaptured two tagged grayling demonstrating overwinter use and winter survival in Sag Site C.

The arctic grayling recaptured in Sag Site C had slower growth rates than those recaptured in Aanaaliq Lakes. Our earlier progress report (Hemming et al. 1989) provides data that compares Aanaaliq Lakes to Sag Site C in phytoplankton production and zooplankton density. We found Aanaaliq Lakes ranked higher than Sag Site C in both areas. The arctic grayling growth rate data also supports the conclusion that Aanaaliq Lakes provides more productive aquatic habitat than Sag Site C.

We captured only seven grayling >200 mm in 1989. The absence of large grayling in the sample catch indicates that tagged grayling may have moved into the Sag River during the spring flood as high water provided a mechanism for dispersal. Out-migration to the Sag River could occur as fish seek suitable spawning areas or more productive summer rearing habitats.

Rainfall events caused severe flooding in headwater areas of the Sag River between the July and August sample periods. The USGS water stage recorder located near Pump Station 3 measured a peak, late summer, mean daily discharge of 9,040 cfs on August 3, 1989 (USGS 1989). It is likely that this high water event moved juvenile fish from rearing areas and transported them downstream. The abundance of young-of-the-year grayling, burbot fry, and ninespine stickleback showed a marked increase in the fyke net catches during the late August sample period. It is possible that the flood event that peaked on August 3 transported the small stickleback, grayling, and burbot downstream into the lower Sag River resulting in the increased rate of catch. Sag Site C remained connected to the Sag River by an outlet channel during the August sample period. Fish found in the site in late summer remained in the deep water mine site when access to riverine habitats was available. It is possible that these fish selected Sag Site C as an overwintering area.

Ott's Oxbow

Ott's Oxbow is a shallow, warm, backwater area that is best characterized as a summer rearing habitat. It is unlikely that this site provides suitable fish overwintering habitat; therefore, use by fish depends upon seasonal movements between the site and the Sag River system. These movements might include those from overwintering areas in the river after spring break-up and out-migration to deep overwintering areas in the river late in the open water season.

Ott's Oxbow remained connected to the Sag River system during both the July and August sampling periods. The species composition and relative abundance of fish captured varied considerably between sample periods. It is likely that an exchange of fish occurred between the site and the Sag River system. Seasonal movements of fish into and out of Ott's Oxbow are notable because the site is connected to the river system by a single 48" culvert placed through a gravel road fill that partially isolates the site from the river system (Figure 5).

During July, juvenile broad whitefish were the most abundant species in the sample catch. It is possible that small broad whitefish transported from the Sag River overwintering areas during the spring flood moved into the shallow backwater area of Ott's Oxbow seeking conditions favorable for summer rearing.

In August, broad whitefish numbers decreased in the fyke net catch indicating that the juvenile broad whitefish moved out of the site and into the Sag River system. The timing of this movement out of Ott's Oxbow corresponds with the appearance of young-of-the-year broad whitefish at offshore fyke net locations. These data suggest that young-of-the-year broad whitefish occupy backwater rearing habitats in the Sag River until late summer when a downstream movement occurs. High-water events in late summer may be a factor in the downstream movement (Dillinger and Gallaway 1989). The numbers of young-of-the-year grayling, burbot fry, and ninespine stickleback increased in the August sample catch. This pattern is similar to that found in the 1989 fyke net catch at Sag Site C. In addition round whitefish numbers increased in the August catch. It is possible that the August high-water event in the Sag River transported ninespine stickleback, burbot, grayling, and round whitefish downstream into the lower Sag River resulting in an increase in the abundance of these species in downstream rearing areas such as Ott's Oxbow. It is likely that these fish out-migrate from shallow rearing areas to deeper sections of the river suitable for overwintering with the onset of cooler weather.

Kuparuk Deadarm

During the July sample period low water levels in the Kuparuk River isolated the Deadarm Reservoir complex from the river system. We observed a high water connection between the Kuparuk Deadarm Reservoirs and the Kuparuk River during the spring flood and in August following late summer rainfall events.

The species diversity and relative abundance of fish captured in Kuparuk Deadarm Reservoirs 5 and 6 were lower than that found in the Sag River sites sampled in 1989. Fyke nets fished in the lower Kuparuk River to obtain grayling for disease screening also caught fewer fish than those fished in the Sag River sites in 1989. The results of the fyke net sampling suggests that fewer fish are available in the lower Kuparuk River for dispersal into the Kuparuk Deadarm Reservoirs than that found in the lower Sag River.

In August 1987, we captured 10 large (368-425 mm) arctic cisco (*Coregonus autumnalis*) in gill nets fished in the Kuparuk Deadarm Reservoirs (Hemming 1988). Arctic cisco were not captured in the July 1989 fyke net catch. It is possible that the large arctic cisco out-migrated from the Kuparuk Deadarm to the Kuparuk River during high water. Data obtained from the Colville River commercial fishery and from several oil development related fish monitoring studies indicate that arctic cisco in the size class captured in the Kuparuk Deadarm are likely to be mature. Mature arctic cisco are captured infrequently in the Colville River and Sag River area. The theory has been advanced that mature arctic cisco return to the Mckenzie River in Canada to spawn (Gallaway et al. 1983). Therefore, it is possible that the large arctic cisco found in the Kuparuk Deadarm in 1987 moved out of the site upon reaching sexual maturity and migrated to the Mckenzie River system to spawn. It is also possible that arctic cisco are present in the deeper areas of the Kuparuk Deadarm Reservoir that are not effectively sampled with fyke nets fished in the shallows.

Kuparuk Mine Site D

We captured least cisco in Kuparuk Mine Site D during gill net sampling periods in August 1986 and August 1989. On August 21, 1986 we captured a single 280 mm least cisco in a gill net set at the access ramp to the site. In 1989 a gill net set at the same location captured a single 191 mm least cisco. Graduated mesh gill nets fished at the access ramp and other locations in Kuparuk Mine Site D in August 1986, April 1987, July 1987, and August 1989 failed to capture fish other than the two least cisco.

Kuparuk Mine Site D is connected to the Ugnuravik River system which drains into the Beaufort Sea. It is unlikely that the Ugnuravik River system provides suitable overwintering habitat; therefore, the least cisco found in Mine Site D originated in other drainages (e.g., Colville River) and moved into the Ugnuravik River from the Beaufort Sea. The water levels in the Ugnuravik and other tundra streams in the Kuparuk area appeared higher in 1989 than observed previously. High water in the Ugnuravik River may have been a factor in the movement of least cisco into Mine Site D. It is interesting to note that fyke nets fished in Aanaaliq Lakes and Sag Site C also captured least cisco in August 1989.

In previous field investigations we observed large concentrations of ninespine stickleback in the shallow water areas of the inlet channel to Kuparuk Mine Site D and in Charlie Creek, a tundra stream that is connected to the mine site. We also observed concentrations of stickleback in the Ugnuravik River near Kuparuk Mine Site C and in East Creek near Aanaaliq Lakes. These observations indicate that the abundance of ninespine stickleback is greater in Kuparuk area streams connected to flooded mine sites than in area streams without mine sites (Ott 1989). It is likely that the stickleback population in these tundra streams has increased in response to the substantial expansion in available overwintering habitat provided by the deep water areas of the mine sites.

Aanaaliq Lakes

Fyke nets captured broad whitefish and least cisco in Aanaaliq Lakes in August 1989. Broad whitefish were captured in gill nets fished in July 1987 while least cisco had not been captured previously. It is likely that the broad whitefish and least cisco found in Aanaaliq Lakes moved into the site from neighboring drainages (e.g., Colville River) because East Creek does not provide suitable overwintering habitat. It is not known if the broad whitefish and least cisco found in Aanaaliq Lakes overwinter there or out-migrate to the Beaufort Sea and move to other overwintering areas.

We captured thousands of ninespine stickleback in fyke traps fished in August 1989. It is likely that the number of ninespine stickleback in East Creek and Aanaaliq Lakes increased in response to the expansion of available overwintering habitat provided by the mine site.

The grayling captured were part of an experimental fish transplant conducted in June 1989.

Lower Put River

In July 1988, fyke net sampling documented use of the lower Put River by juvenile arctic char, broad whitefish, ninespine stickleback, and fourhorn sculpin (Appendix III). Fyke nets fished in the lower Put River in July and August 1989 captured fourhorn sculpin, ninespine stickleback, and a single adult broad whitefish. The open water fyke net catch indicates that the lower Put River is a summer rearing habitat for marine and anadromous fish.

We found estuarine conditions in the lower Put River in May 1989. Stream sections with similar water quality characteristics in the lower Sag River and lower Colville River are used by overwintering arctic cisco and least cisco (Schmidt 1987, Adams 1987). We captured a single round whitefish in the lower Put River in May 1989.

Habitat enhancement proposed for the Put 27 Mine Site consists of a channel connection to the lower Put River. This project will result in a substantial increase in the volume of available fish overwintering habitat in the lower Put River. The water quality characteristics of the Put 27 reservoir will depend on the nature of the spring flood event in the Put River that fills the reservoir. We anticipate that the reservoir will fill with fresh water initially, with the possibility that an increase in salinity may occur over time, resulting from storm surge events.

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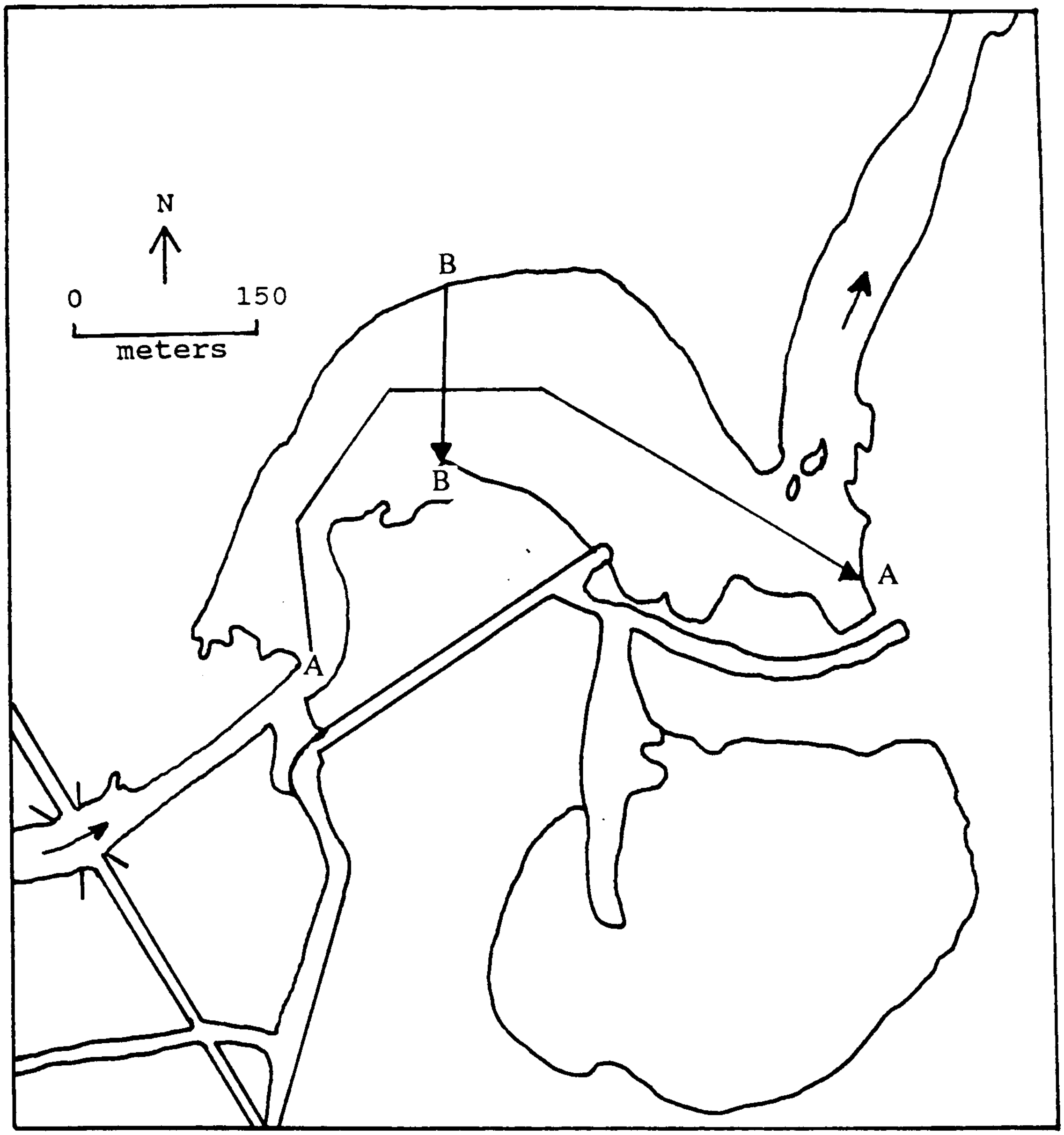
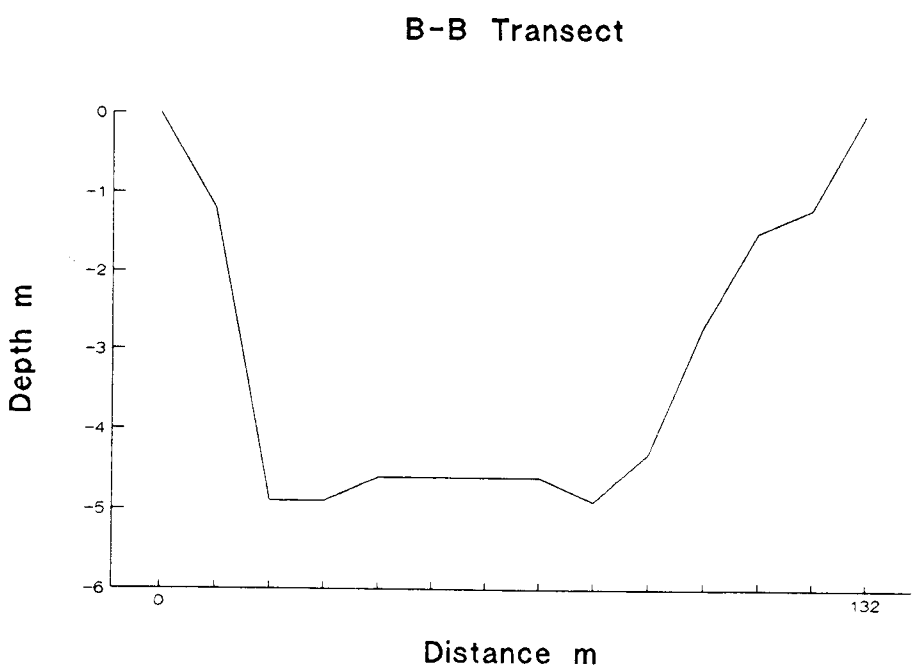
Appendix I. Depth profile transects in the lower Put River, August 1989.

Location of Transects



Depth Profile Transects



Appendix II. Water temperatures at fyke net sites, 1989.

Date	Location of Fyke Trap	*Temperature
7/18	Ott's Oxbow	14.0
7/19	Sag Site C Net Site 1	13.5
"	Sag Site C Net Site 2	10.5
"	Sag Site C Net Site 3	12.0
"	Kuparuk Deadarm Reservoir 5	11.5
"	Kuparuk Deadarm Reservoir 5 expansion	13.5
"	Kuparuk Deadarm Reservoir 6	14.0
7/20	Kuparuk Deadarm Reservoir 5	11.0
"	Kuparuk Deadarm Reservoir 5 expansion	13.0
"	Kuparuk Deadarm Reservoir 6	12.5
7/21	Lower Put River	11.0
"	Kuparuk Deadarm Reservoir 5	10.0
"	Kuparuk Deadarm Reservoir 5 expansion	11.5
"	Kuparuk Deadarm Reservoir 6	11.0
8/23	Aanaaliq Lakes, north	11.5
"	Aanaaliq Lakes, south	11.0
"	Ott's Oxbow	13.0
8/24	Aanaaliq Lakes, north	12.0
"	Aanaaliq Lakes, south	12.0
"	Sag Site C Net Site 1	10.0
"	Sag Site C Net Site 2	10.5
"	Sag Site C Net Site 3	10.0

* measurements to the nearest 0.5°C

Appendix III. Fish caught in the lower Putuligayuk River near Put River Mine Site 27, July 27-30, 1988.

LOCATION	NUMBER & LENGTH OF FISH CAUGHT			
	Ninespine Stickleback	Arctic Char	Broad Whitefish	Fourhorn Sculpin
600 m downstream of Drill Site 15 road crossing				
July 27	2	-	-	-
July 28	37	1(203)+	1(82)+	-
200 m downstream of Drill Site 15 road crossing	60*	2(233;102)+	3(422;93;88)+	9(87)+
	30*	3(191;203;200)+	1(96)+	

+ length of each fish in millimeters
* estimated number