

January 31, 2009

EI - 16412
Rec'd 2/20/09

Mr. David Navecky
STB Finance Docket #34658
Surface Transportation Board
395 E. St. S.W.
Washington DC 20423-0001

RE: Draft Environmental Impact Statement Finance Docket #34658 Alaska Railroad Corporation Construction and Operation of a Rail Line between North Pole and Delta Junction Alaska.

Dear Sir:

My comments today concern the South Common segment of the northern rail extension between North Pole and Delta Junction. In the south common segment the plan calls for "three bridges over headwaters of the Richardson Clearwater River and several smaller drainages and would include culverts to cross drainage ways and wetland flow ways". "The three proposed bridges crossings and headwaters of the Richardson Clearwater River include single span bridges ranging from 45 to 65 feet in length".

THE RICHARDSON CLEARWATER

The Richardson Clearwater Creek is a spring fed perennial stream that flows Northwestward for fourteen miles to the Tanana River approximately 80 miles Southeast of Fairbanks, Alaska and is depicted on the westerly end of the south common segment. It receives the majority of its flow from ground water rather than surface water runoff. Consequently stream flow fluxuates within a very narrow range. The stream's headwaters are formed by numerous springs that emanate from a low bank at the 1000 foot elevation contour line in section 4 of township 9 south range 9 east, Fairbanks meridian. The largest of these feeder springs contributes approximately 12 cubic feet per second of flow. The stream also receives flow from small springs along its length and two spring fed tributaries.

The Richardson is a very unusual interior Alaska stream because of its short length, laminar flow, stable channel, and exceptional clarity. The streambed is composed of gravel and cobble size rock which is underlain by fine grained sand. Aquatic moss grows submerged in long sinuous clumps or mats attached to the streambed. Stream banks are vegetated and show no signs of erosion. The riparian habitat is a mature spruce and birch forest. Beavers are active near the headwaters and have impounded the tributaries in the recent past.

The Richardson Clearwater supports populations of Coho Salmon, Chum Salmon, Arctic Grayling, Round Whitefish and Longnosed Suckers. Of the above species only Coho Salmon

spawn over winter in the creek. The other species use the stream as a summer feeding area. The only access to this creek is by boat or floatplane.¹

The Richardson Clearwater is characterized by its clear and cold water, stable discharge and the fact that its access is limited to river boats via the Tanana River and small float planes on the Richardson Clearwater. The nearest boat launch is at Shaw Creek. In a recent study by the Department of Fish and Game². The Ridder Study characterizes the river as follows:

“The Richardson Clearwater River rises from springs located on the southern flood plane of the Tanana River, three km west of Big Delta. The river is 19 km in length and enters the Tanana River 13 km downstream of Shaw Creek. As with other spring fed systems in the drainage, most notably the Delta Clearwater River, the Richardson Clearwater River can be characterized by its clear and cold water, and stable discharge. Access is limited to river boats via the Tanana River and small float planes on the Richardson Clearwater. The nearest boat launch is at Shaw Creek. The river supports a recreational fishery for Grayling and little angling effort is directed at other available species (white fish, coho salmon, and chum salmon). The Grayling fishery can be characterized as ‘Blue Ribbon’ due to its availability of large fish, high density of fish, aesthetic qualities of the river and lack of direct road access.”³

It is clear from the Department of Fisheries Study that the Richardson Clearwater River is a summer feeding grounds for the Arctic Grayling that migrate into the river in Mid May from spawning areas located in the Caribou and Rapids Creek in the Shaw Creek drainage area and the Good Pasture River. Tagging studies have shown that the migration is deliberate and characterized by a strong homing behavior.

With a water quality as documented in Footnote 1, The Water Quality Study, and with an abundance of the four varietal sects of fish as documented in Ridder Studies Footnotes #2 and #3. All of which are attached to this comment, there is no question that the Northern Railway extension at least as far as the south common segment is concerned will impact the existing ecosystem and may very likely have disastrous effects on it.

IMPACT OF THE PROPOSED RAILROAD ROUTE ON WATER QUALITY

The water quality will be impacted by the construction and installation of bridges and culverts in the aquifer and wetlands of the Richardson Clearwater. Sluffing and erosion of the stream banks

¹ See water quality study of the Richardson Clearwater Creek near Big Delta, Alaska by Mary A. Maurer Alaska Division of Mining and Water Management Alaska Hydrological Survey March, 1999 released by State of Alaska Department of Natural Resources Division of Geological and Geophysical Surveys 794 University Ave., Suite 200, Fairbanks, AK 99709-3645 appended hereto.

² Contributions of Arctic Grayling from Caribou Creek to the Richardson Clearwater River and Shaw Creek, 1980 – 1988 by William P. Ridder November 1994 Alaska Department of Fish and Game Division of Sportfish Fisheries Data Series 94-49 appended hereto.

³ See Fishery Data Series #120 Age, Length, Sex and Abundance of Arctic Grayling in the Richardson Clearwater River and Shaw Creek 1988 by William P. Ridder Alaska Department of Fish and Game Division of Sportfish, Juneau, AK 99802.

is a given. There will undoubtedly be increased channel scour, bank erosion and down stream sedimentation. It is unclear what effect thermal erosion of cuts made into the perma frost soils will have but one only has to look at the effect of the Carla Lake fires to see what effect the lack of vegetation in the wetland areas in the headwaters of the Richardson Clearwater has already had.

The fear of all of the residents of the Richardson Clearwater Creek is that three bridges, and numerous culverts that are planned, will destroy the aquifers and interrupt the flow of a totally spring fed river that houses numerous species of fish. We have already had one disaster at the headwaters of this river which was the Carla Lake Fire in the summer of 1998. That fire burned approximately 54,000 acres and its effects on the Richardson Clearwater Creek have been annual floods in which the stream flow, organic matter content, turbidity, and color have been affected. The loss of vegetation due to the forest fire has produced an inability of the vegetation (in the headwaters) to contain the waters at times of heavy rains. Complicating this problem with three to four bridges and numerous culverts will very likely produce a complete disaster with regards to water stability, flow and turbidity.

Obviously geotechnical bore holes will provide direct communication between surface water and ground water but no one knows the effect it will have on the aquifers if they are drilled into. The proposed clearing of 251 acres in the south common segment at a time when the vegetation is trying to rebuild itself can only increase the turbidity and sediment loads associated with that action and with the installation of culverts and bridges.

IMPACT OF THE PROPOSED RAILROAD ROUTE ON FISH HABITAT

The Clearwater River supports Coho spawning and rearing. The noise and vibration caused by pile driving and culvert installation will most certainly impact egg mortality and hatching time in areas near the stream crossings. Vibrations are known to negatively impact development on salmonoid eggs and at certain times disrupt egg membranes leading to egg death. The most devastating thing that could occur in the Coho run is avoidance behavior which will cause them to abandon their winter spawning grounds.

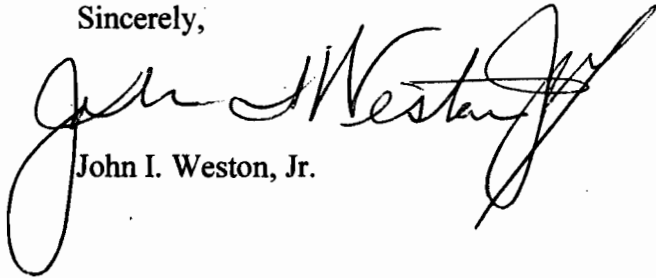
Vibrations and pile driving activities as well as sediment will most certainly have an impact on the Grayling population who also may change their natural patterns and abandon the upper portions of the Richardson Clearwater.

CONCLUSION

The aquifers and headwaters of the Richardson Clearwater produce the constant flow for the river. Any interruption of this flow by blockage of bore holes, bank erosion and downstream sedimentation will certainly affect the water quality of the Richardson Clearwater as well as the fish habitat for the four species of fish that inhabit that area. There is no question under these conditions which are especially fragile after the Carla Lake fire that the south common segment of the Northern Rail Extension should be placed further south and out of the headwaters of the Richardson Clearwater River. Placing it closer to Rainbow Lake or to the south of Rainbow

Lake would give the railroad almost a straight shot into the Donnelly training area and Fort Greeley using the Delta one alternative segment. There is no reason for the Northern Rail Extension to take the chance of drastically injuring the headwaters of the Richardson Clearwater. I would respectfully submit that if the rail extension is acted upon it should be placed much further south and out of the headwaters of the Richardson Clearwater.

Sincerely,

A handwritten signature in cursive script, appearing to read "John I. Weston, Jr.", written in black ink. The signature is fluid and somewhat stylized, with a large loop at the end of the last name.

John I. Weston, Jr.

FISHERY DATA SERIES NO. 120

AGE, LENGTH, SEX, AND ABUNDANCE OF
ARCTIC GRAYLING IN THE RICHARDSON
CLEARWATER RIVER AND SHAW CREEK, 1988¹

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Juneau, Alaska 99802

September 1989

¹ This investigation was partially funded by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-4, Job No. G-8-5.

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ABSTRACT

Arctic grayling were captured by electrofishing within a 12.8 kilometer section of the Richardson Clearwater River in July 1988, and within a 1 kilometer section of the Tanana River at the mouth of Shaw Creek in April 1988. Population abundance in the Richardson Clearwater River was estimated at 4,599 Arctic grayling greater than 250 millimeters fork length, and at Shaw Creek, 6,080 Arctic grayling greater than 270 millimeters fork length. The majority of the two populations were adult fish with age 5 Arctic grayling being the predominant age class. Relative indices of abundance based on electrofishing catch rates showed a significant correlation to absolute population abundance in the Richardson Clearwater River.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Richardson Clearwater River, Shaw Creek, population abundance, age composition, size composition, harvest, fishing effort, Relative Stock Density, electrofishing, Tanana River drainage.

INTRODUCTION

The 19.2-km long Richardson Clearwater River is a spring-fed tributary to the Tanana River, approximately 43 km northwest of Delta Junction (Figure 1). The river is semi-remote and access is limited to riverboats. The nearest boat launch is 9 km up the Tanana River at Shaw Creek. Limited floatplane access is available at river kilometer 5. There are 17 summer cabins on the river. The river supports a recreational fishery on Arctic grayling *Thymallus arcticus*. Round whitefish, *Prosopium cylindraceum*, coho salmon, *Oncorhynchus kisutch*, and chum salmon, *Oncorhynchus keta*, are also present but are not presently utilized. The fishery is primarily conducted by summer residents and their guests. The fishery can be characterized as "blue ribbon" due to the availability of large fish, ease of fishing, the river's esthetics, and its semi-remoteness. Harvests have ranged from 2,822 to 798 Arctic grayling with a six year mean of 1,519 (Table 1). Angling effort has ranged from 1,365 to 596 man-days with a mean of 1,061 (Table 1). The majority of angling occurs in the river's lower 9.6 km.

As with other spring-fed systems in the area, most notably the Delta Clearwater River, the Richardson Clearwater River can be characterized by its clear waters, constant water temperatures and discharge (3 - 5°C; 8.5 - 11.3 m³/s), and by the seasonal availability and mixed stock composition of its Arctic grayling population. Arctic grayling utilize the river strictly as a summer feeding area. The population is predominantly comprised of adult and sub-adult Arctic grayling that migrate into the river beginning in mid-May from spawning areas located in other waters. Three of these areas have been documented from tagging studies; Caribou and Rapids Creek in the Shaw Creek drainage and the Goodpaster River (Ridder 1984). Tack (1980) has summarized studies that show this migration is deliberate and characterized by strong homing behavior. Out-migration can begin as early as mid-August and is essentially complete by mid-November.

Shaw Creek is bog-fed, 112 km in length and is located 32 km northwest of Delta Junction (Figure 1). Since 1980, 8,000 Arctic grayling have been tagged in the Shaw Creek drainage, the majority of which were tagged as they migrated out of a major tributary, Caribou Creek, after spawning. Angler returns of 780 tags have identified six other recreational fisheries within 72 km of the mouth of Shaw Creek, ranging from the Little Salcha River to the Delta Clearwater River (Ridder 1985, and unpublished data). Ridder (1985) estimated that fish from Caribou Creek accounted for 30 to 50% of Arctic grayling abundance in the Richardson Clearwater River. Until 1987, when a season closure became effective, Shaw Creek's major fishery occurred in the spring on pre-spawning adult grayling congregating off the mouth awaiting ice break-up. This fishery was closed twice by Emergency Order in 1981 and 1985. Spring harvests have ranged from 4,343 fish in 1981 to 270 fish in 1986 (Table 2). Annual harvests from 1983 to 1986 have ranged from 2,584 fish in 1985 to 505 fish in 1986 (Table 3). From 1983 to 1986, the spring harvest has accounted for an average 58% of the annual harvest.

Studies in the mid 1980's (Holmes et al. 1986; Clark and Ridder 1987a, b) found that significant declines in Arctic grayling abundance and harvest rates had occurred in these and other waters of the Tanana River drainage. Results

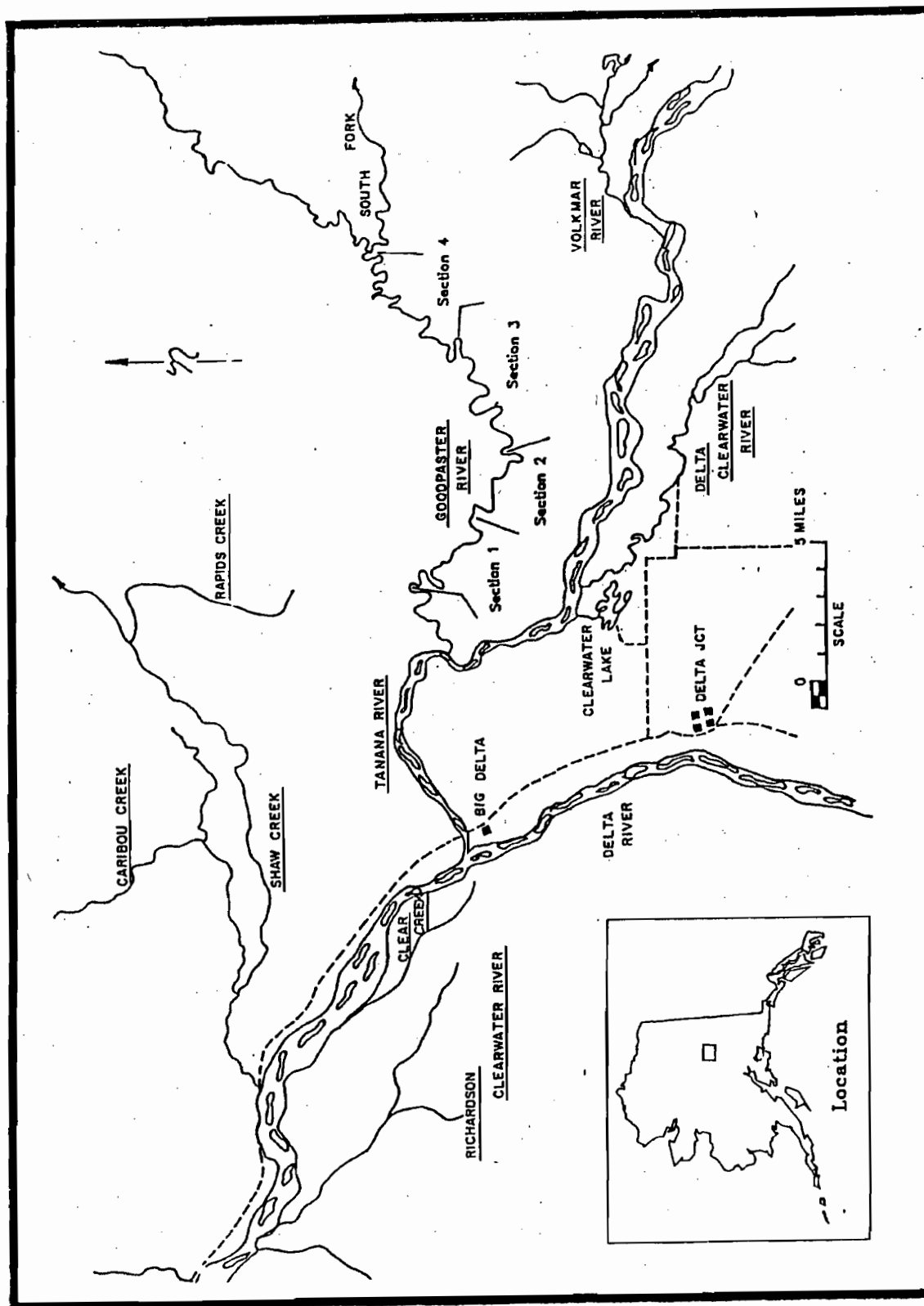


Figure 1. Map of the middle Tanana River drainage and study area.

Table 1. Estimated recreational Arctic grayling harvest and angling effort on the Richardson Clearwater River, 1981 - 1986¹.

Year	Effort		Harvest	CPUE ³
	Anglers	Man-days ²		
1981	NA ⁴	916	1,562	1.65
1982	NA	1,365	1,729	1.27
1983	NA	1,349	2,822	2.09
1984	NA	1,080	1,376	1.27
1985	NA	NA	798	---
1986	289	596	827	1.39
Averages	289	1,061	1,519	1.43

¹ Data sources: 1986, Mills (1987); other years, Mills (unpubl.).

² Estimates of man-days includes effort expended for all species.

³ CPUE - the number of Arctic grayling harvested per man-day.

⁴ NA - data not available.

Table 2. Estimated spring recreational Arctic grayling harvest and angling effort¹ at the mouth of Shaw Creek from on site creel census surveys, 1974 - 1986².

Year	Effort		Harvest	CPUE ³
	Man-days	Angler-hours		
1974	85	NA ⁴	500	2.40
1975	200	NA	1,150	1.60
1981 ⁵	966	2,029	4,343	2.14
1982	555	1,172	979	0.87
1983	874	2,005	1,864	0.89
1984	1,095	2,292	913	0.41
1985 ⁶	372	970	1,533	1.58
1986	479	1,003	270	0.27
Averages	578	1,579	1,444	1.27

¹ Since 1987, spring fishery has been closed by Emergency Order and then by regulation till the first Saturday in June.

² Data sources: 1974 - 1975, Peckham (1976); 1981 - 1984, Ridder (1982, 1983, 1984, 1985); 1985, Holmes et al. (1986); 1986, Clark and Ridder (1987a).

³ CPUE - the number of Arctic grayling harvested per angler hour.

⁴ NA - data not available.

⁵ Spring fishery closed by Emergency Order from 23 April to 15 May.

⁶ Spring fishery closed by Emergency Order from 1 May to 15 May.

Table 3. Estimated recreational Arctic grayling harvest and angling effort on Shaw Creek from Statewide Harvest Surveys, 1983 - 1987¹.

Year	Effort		Harvest	CPUE ³
	Anglers	Man-days ²		
1983	NA ⁴	2,495	2,297	0.92
1984	888	2,195	2,570	1.17
1985 ⁵	939	1,248	2,584	2.07
1986	1,313	2,003	505	0.25
1987 ⁶	607	797	567	0.71
Averages	937	1,748	1,705	0.98

¹ Data sources: Mills (1984-1988).

² Estimates of man-days includes effort expended for all species.

³ CPUE - the number of Arctic grayling harvested per man-day.

⁴ NA - data not available.

⁵ Spring fishery closed by Emergency Order from 1 May to 15 May.

⁶ Spring fishery closed by Emergency Order from 3 April to 5 June.

of a dynamic pool model indicated severe overfishing was occurring in some fisheries and that environmental conditions during the first year of life can significantly affect subsequent recruitment to the fisheries (Holmes et al. 1986). In response, regulation changes restricting harvest of Arctic grayling were made in 1987 for the Richardson Clearwater River, Shaw Creek, and other waters of the Tanana River drainage. These regulations limited the harvest to fish 305 mm total length or greater, restricted methods to unbaited artificial lures only, and imposed catch and release fishing during the spring spawning period. This study continued the monitoring and assessment of Arctic grayling stocks affected by regulation changes. The goal was to further the understanding of Arctic grayling life history and population dynamics.

The research objectives for 1988 were to estimate:

- 1) the abundance of Arctic grayling (≥ 150 mm fork length) in the Richardson Clearwater River and Shaw Creek; and
- 2) the age composition of the population of Arctic grayling (≥ 150 mm fork length) in the Richardson Clearwater River.

In addition, age composition of the population of Arctic grayling (≥ 150 mm FL) in Shaw Creek was estimated.

METHODS

Estimation of Absolute Abundance

In the Richardson Clearwater River, abundance of Arctic grayling was estimated with the modified Peterson formula of Bailey (1951, 1952). The binomial model of Bailey is most appropriate for the systematic sampling design used in this study; the population is assumed to be closed. In Shaw Creek, abundance of Arctic grayling was estimated using the generalized Jolly-Seber model (Seber 1982). This population in Shaw Creek is assumed to be open and the sampling design is a single capture event.

Richardson Clearwater River:

In the Richardson Clearwater River, the abundance of Arctic grayling was estimated in the lower 12.8 km of the river. The upper 6.4 km was not included because its small size prevented safe boat-mounted electrofishing, and few fish have been found there in previous surveys (Ridder field notes). The sampled river was divided into three sections based on distinct geographical differences (Figure 2). These sections were electrofished once a day with intervals of at least one day between sampling events. Section 2 is separated from the other two sections by large pools (270 and 810 m long) formed by old beaver dams. Section 1 extends 4.8 km upstream from the mouth to the longest "pool"; Section 2 extends the same distance upstream from the head of this "pool" to the second "pool"; Section 3 is 3.2 km long and extends upstream to the river's second tributary. Ridder (1983) described these sections in more detail.

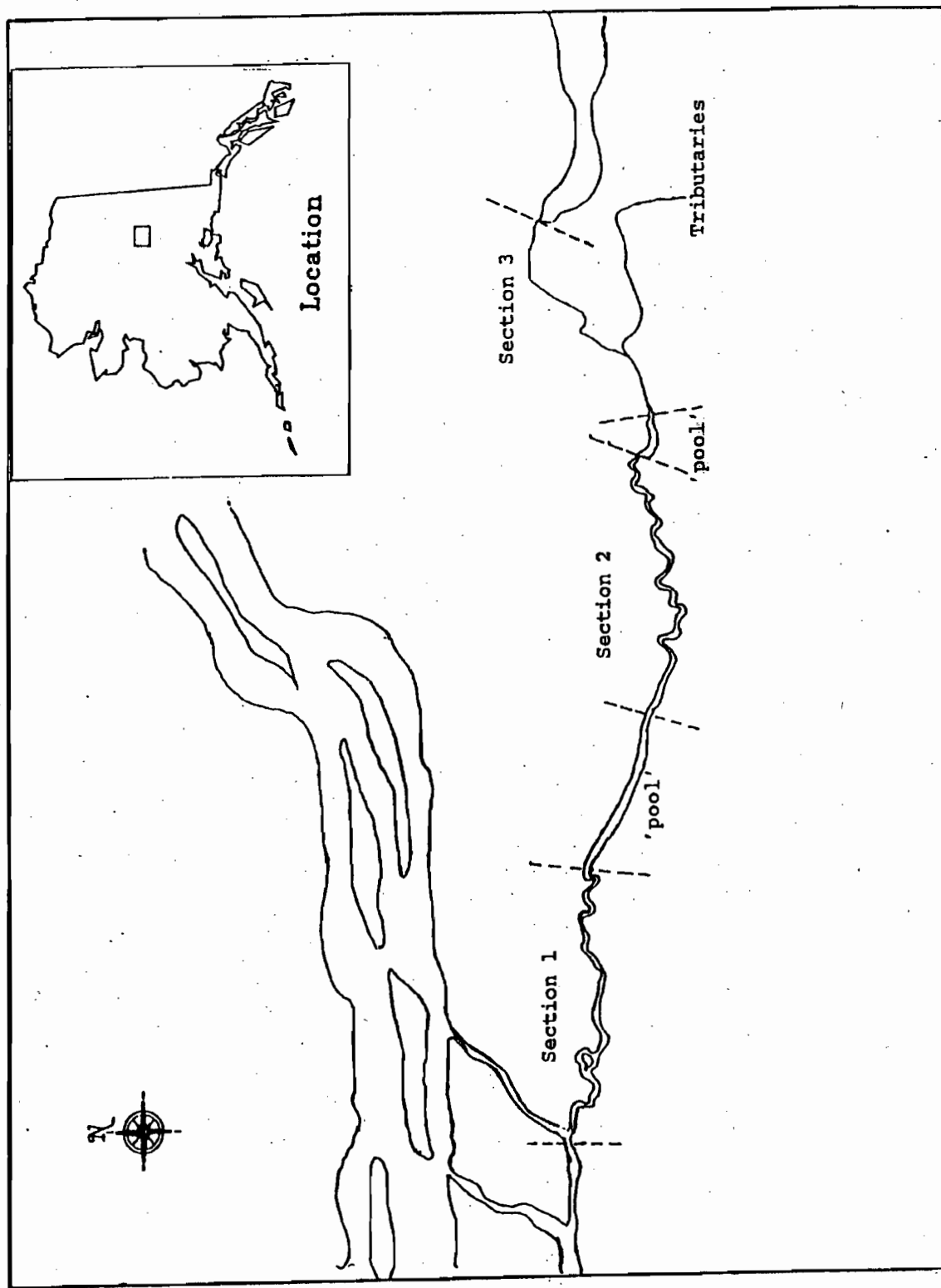


Figure 2. Map of the Richardson Clearwater River and study sections.

Sampling started at the upstream end of a section and consisted of an electrofishing boat traveling downstream collecting as many Arctic grayling as possible. The boat had a crew of three and used a pulsed DC variable voltage pulsator with four 1.5 m long steel cables, 13 mm in diameter (flexible conduit) as anodes and the unpainted bottom of the boat as the cathode. At the end of an approximately 20 minute run or the capture of 40 fish, all captured fish were measured to the nearest 1 mm of fork length (FL). Those greater than 149 mm FL were tagged with Floy FD-67 anchor tags. A partial upper caudal fin clip was used as a secondary mark to determine tag loss. The fish were then released individually throughout the section they were captured in. Resumption of sampling started at the end of the previous run. Data collection was segregated by section to facilitate analysis of migration between sections.

While the stated objective for the Richardson Clearwater River was to estimate the abundance of Arctic grayling greater than 149 mm FL, insufficient numbers of small fish were captured (Appendix Table 1). Instead, the abundance was estimated for fish greater than 249 mm FL. This change allowed direct comparisons to 1987 estimates of abundance which also addressed fish greater than 249 mm (Clark and Ridder 1988). Three sampling events were conducted from 5 through 8 July and constituted the marking stage. The recapture stage was made up of three sampling events conducted from 13 through 19 July. The necessary assumptions for an unbiased estimate are (from Seber 1982):

- 1) the population in the study area must be closed;
- 2) no tags can be lost between samples;
- 3) all fish have the same probability of capture during the first sample or during the last sample or marked fish must completely mix with unmarked fish between samples;
- 4) marking must not influence fish behavior between samples; and,
- 5) mortality is the same for both marked and unmarked fish between samples.

The Kolmogorov-Smirnov test showed that there was no significant recruitment by growth or immigration during the experiment indicating fulfillment of assumption 1. Fin-clipping, in addition to tagging, satisfied the second assumption. The four day hiatus between the marking and recapture events facilitated mixing of marked and unmarked fish. However, size selective gear bias during sampling events was suggested in two of three tests. A Kolmogorov-Smirnov two-tailed test (Conover 1980) applied to all fish recaptured and not recaptured showed a marginal difference in capture probabilities and size selectivity during the marking event ($D = 0.217$, $P = 0.053$). A contingency test applied to the same groups divided into two length strata (250-349 and ≥ 350 mm FL) showed significant differences ($\chi^2 = 6.96$, $df = 1$, $P < 0.05$; Appendix Table 1). A Kolmogorov-Smirnov two-tailed test on the lengths of all fish captured during the marking event and those during the recapture event showed no significant differences ($D = 0.074$, $P = 0.205$). The estimate was accordingly stratified by length. Length strata

were chosen on the basis of recaptured to marked ratios (Appendix Table 1) and were the same strata chosen in 1987 (Clark and Ridder 1988).

The abundance estimate was further stratified by river section. Sections 1 and 2 were combined due to low numbers of recaptures within length strata in Section 1. Although there were equal probabilities of capture during the recapture event among all three river sections ($\chi^2 = 2.38$, $df = 2$, $P > 0.05$), population stratification by size among river sections was apparent and separate river section estimates were appropriate. Relative Stock Density indices were significantly different between all three sections and between Section 3 and the lower two sections ($\chi^2 = 301.84$, $df = 4$, $P < 0.05$; $\chi^2 = 172.47$, $df = 2$, $P < 0.05$, respectively; Appendix Table 2). Age compositions were likewise significantly different between the same section groupings ($\chi^2 = 101.75$, $df = 8$, $P < 0.05$; $\chi^2 = 78.72$, $df = 4$, $P < 0.05$, respectively; Appendix Table 3).

Since the section abundance estimates were independent within each stratum, the whole river abundance estimate and its variance were calculated as the sum of the strata estimates. It was assumed that the underlying probability distribution of the estimate was normal and thus a confidence interval was calculated as:

$$(1) \quad \hat{N} \pm 1.96 * SE[\hat{N}]$$

where: $\hat{N}$ - the abundance estimate; and,
SE - the standard error of the estimate.

Shaw Creek:

In Shaw Creek, the absolute abundance of Arctic grayling during 1987 was estimated with the generalized Jolly-Seber model (Seber 1982). This model has been used since 1981 to estimate the abundance of age 4 (≥ 200 mm FL) and older Arctic grayling (Clark and Ridder 1987b; Clark and Ridder 1988). Arctic grayling were tagged during previous years (June 1980 through 1987) at Caribou Creek, the major spawning tributary of Shaw Creek (Figure 1). Since there is at least one other known spawning area in the drainage at Rapids Creek (Ridder 1983), abundance estimation of the Shaw Creek stock using the tagging at Caribou Creek would only be possible when the whole stock is accessible to sampling.

In April after the ice had gone out of the Tanana River but before the ice break-up of Shaw Creek, Arctic grayling are concentrated at the mouth of Shaw Creek awaiting ice break-up and access to upstream spawning areas. At this time, Arctic grayling were captured with a pulsed DC electrofishing boat (described above). During one sampling event, four electrofishing runs (two runs along each bank) were made along a reach 0.8 km above and below the mouth of Shaw Creek. Prior to 1987, recaptures of tagged fish were obtained from creel censusing the spring fishery in the same location (Ridder 1985). Since the fishery was closed in 1987, recovery of tags has been conducted by electrofishing during the time the fishery would have been occurring.

Unlike previous applications of the Jolly estimator that estimated the population greater than 199 mm FL (Clark and Ridder 1988), the abundance estimate presented in this report pertains to the population greater than 270 mm FL. Due to the size selectivity of capture methods for the marking event (weir) and the recapture event (hook and line and electrofishing), the sum of all samples since 1986 were significantly different in size compositions ($\chi^2 = 317.23$, $df = 3$, $P < 0.05$; Appendix Table 4). Including fish less than 270 mm FL in the mark sample (nearly absent in the recapture sample and including no tag recaptures) would produce a large bias in the parameter estimates. Data prior to 1986 are likely to be similarly affected. Holmes et al. (1986) reports that the spring fishery harvests predominantly adult Arctic grayling which comprised 85% of the 1985 harvest. Estimates derived from these early data are not included pending computer entry and restructuring of the data base.

In limiting the available data base (1985 - 1988) to fish greater than 269 mm FL, only one recapture of a 1985 mark was found in 1986 at Shaw Creek. Clark and Ridder (1988) also reported on the paucity of recaptures from all years in this sample ($n = 4$; including fish 200 - 269 mm FL) and stated that the condition seriously biased parameter estimates for 1985 and 1986. With the model requiring large sample sizes, this recapture sample was also not included in the model. With the available data limited to three years, sampling in 1988 provided one abundance estimate pertinent to the time of tagging in 1987.

Estimation of Relative Abundance

In the Richardson Clearwater River, sampling was conducted in conjunction with the absolute abundance estimation described earlier and used the same river sections. On a given day, one run was made through each section collecting as many electrofished Arctic grayling as possible. The timing of each run was recorded by a stop watch to the nearest 1 minute. Runs were separated by at least one day. The total number of Arctic grayling captured in a run was the catch rate (CPUE) and was used as an index to estimate relative abundance. CPUE data were collected for each of the three river sections. Although six runs were made during the abundance estimation, only those data from five runs were used to estimate CPUE. The third run in Sections 1 and 2 was excluded because it occurred the day after the second run. The catch rate in the third run indicated an apparent downstream displacement of fish from Section 2 to Section 1 (Appendix Table 4). This apparent displacement of fish by repetitive electrofishing has been demonstrated in other studies (Ridder 1983; Clark 1989; Ridder in press). Crew members and fishing gear were the same during all runs.

Bootstrapping was performed to estimate mean CPUE and the variance of mean CPUE. This estimation technique was used because of a small sample size and a concern that the assumption of a normally distributed variance would be violated. Past studies (Clark and Ridder 1988) have shown mean CPUE to be more closely related to the Poisson distribution (variance nearly equal to the mean and asymmetric confidence intervals). Bootstrap mean CPUE was

approximated by Monte Carlo methods, randomly sampling the mean of five data points (with replacement) 1,000 times as follows:

$$(2) \quad \text{CPUE}_B = \frac{\sum_{j=1}^B \left\{ \text{CPUE}_j - \left[\sum C_{B1} \right] + 5 \right\}}{B}$$

where: B = the number of bootstrap samples;
 $i = 1, 2, 3, 4, 5$ random draws from the five original data points (with replacement);
 C_{Bi} = the i th random draw from the original data;
 CPUE_B = the bootstrap mean catch rate; and,
 CPUE_j = the catch rate of the j th bootstrap iteration.

The bootstrap variance was approximated by the standard variance formula:

$$(3) \quad V(\text{CPUE}_B) = \left[\sum_{j=1}^B (\text{CPUE}_j - \text{CPUE}_B)^2 \right] + (B - 1)$$

where: $V(\text{CPUE}_B)$ = the bootstrap variance of CPUE_B .

A non-parametric 95% confidence interval was estimated for CPUE_B by the percentile method of Efron (1981). Bootstrap mean CPUE was calculated for each of the three river sections and with the combined data sets for the whole river estimate.

A correlation coefficient, r , was calculated between relative and absolute abundance estimates with the formula:

$$(4) \quad r = \frac{\sum x_k y_k}{(\sum x_k^2 \sum y_k^2)^{1/2}}$$

where: x_k = total catch from the first electrofishing run in year k ;
 y_k = estimated population abundance in year k .

Although equation 4 requires that the two samples to be taken from normally distributed populations, the underlying distributions of CPUE and abundance estimates were not known, but assumed to be non-normal. No statistical significance can be attributed to these correlation statistics until more samples are collected and the empirical distributions known.

Estimation of Age and Size Composition

A minimum of two scales from all initial captures of Arctic grayling greater than 149 mm FL were removed from an area four to six scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were processed by cleaning in a hot solution of common dish detergent, inspected for regeneration, and then mounting the two best scales from each fish on

gummed cards. The cards were used to make impressions of the scales on 20 mil acetate film using a Carver press at 137,895 kPa heated to a temperature of 97°C. Ages were determined by replicate readings using a microfiche reader.

The proportion of Arctic grayling in each age class was estimated as:

$$(5) \quad \hat{p}_g = \frac{y_g}{n}$$

where:

y_g = the number of Arctic grayling of age g in the sample; and,
 n = the number of Arctic grayling in the sample.

The unbiased variance of this proportion is:

$$(6) \quad V[\hat{p}_g] = \frac{\hat{p}_g (1 - \hat{p}_g)}{n - 1}$$

Age class composition of Arctic grayling in the Richardson Clearwater River was adjusted for bias due to length selectivity of the electrofishing boat and population stratification within the river. Within each length stratum and river section, the proportion of each age class and its variance were first estimated with equations 5 and 6. The age composition in Section 3 and Section 1 and 2 combined was then estimated separately with the following equations. The age composition of the population (all Sections combined) was estimated with the same equations (7 through 10) substituting "Section" for "stratum". The estimated abundance of age g in the population (Section) is:

$$(7) \quad \hat{N}_g = \sum_{h=1}^K \hat{p}_{gh} \hat{N}_h$$

where:

$\hat{N}_g$ = the estimated abundance of age g ;
 $\hat{p}_{gh}$ = the proportion of fish of age g in stratum h ;
 $\hat{N}_h$ = the estimated abundance in stratum h ; and,
 K = 1, 2 length strata.

The variance of $\hat{N}_g$ is a sum of the exact variance of a product from Goodman (1960):

$$(8) \quad V[\hat{N}_g] = \sum_h (V[\hat{p}_{gh}] \hat{N}_h^2 + V[\hat{N}_h] \hat{p}_{gh}^2 - V[\hat{p}_{gh}] V[\hat{N}_h])$$

The estimated proportion of the population that belongs to age g ($\hat{p}_g$) is:

$$(9) \quad \hat{p}_g = \hat{N}_g / \hat{N}, \text{ where: } N = \sum N_h.$$

The variance of the estimated proportion can be approximated with the delta method (see Seber 1982):

$$(10) \quad V[\hat{p}_g] = \sum V[\hat{p}_{gh}] \left\{ \frac{\hat{N}_h}{N} \right\}^2 + \frac{\sum V[N_h] (p_{gh} - p_g)^2}{N^2}$$

Length-at-age information was used to characterize growth of adult Arctic grayling. Mean lengths were calculated as the arithmetic mean fork length at each age of all Arctic grayling captured.

Size composition of initial captures is described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories for Arctic Grayling were: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and "trophy" (greater than 560 mm FL). RSD indices were estimated with equations 1 through 8, substituting the RSD categories for age classes.

Sex and Maturity

Since sampling at Shaw Creek was conducted during the pre-spawning concentration of Arctic grayling, sex and maturity were readily determined by either sexual dimorphism or the presence of milt or eggs. Dimorphism is evident in differences in length of the dorsal fin (the male dorsal fin usually extends to the adipose fin whereas the female dorsal fin is noticeably shorter) and the swelling of the anal vent and abdomen fullness (gravid) or flaccidity (spawned out) in females. Some error was associated with the use of these morphological characteristics as the sole determinator of sex. For example, at the time of sampling, small males may have been classed as juveniles since their dorsal fin may not have reached the adipose and they may not be able to give milt. Sex ratios were presented as the ratio of the number of males to females.

RESULTS AND DISCUSSION

Richardson Clearwater River

Absolute abundance of Arctic grayling in the Richardson Clearwater River continued to increase in 1988 from the historical low estimated in 1986 (Appendix Table 5). The estimated abundance of fish greater than 249 mm FL in 1988 was 4,599 (SE = 751) with a 95% confidence interval of 3,127 to 6,071 ($\pm 32\%$) (Table 4). The 9.6 km of the lower river representing Sections 1 and 2 had an estimated 2,406 Arctic grayling or 251 per km (Table 4). The 3.2 km upper river section, Section 3, had an estimated 2,193 Arctic grayling or 685 per km (Table 4).

Table 4. Estimated abundance of Arctic grayling (≥ 250 mm FL) in the Richardson Clearwater River, 5 July through 19 July 1988.

Length Category	Marks	Catch	Recaps	N ¹	SE ²	CV(%) ³
<u>Section 1 and 2</u>						
250-349	99	199	6	1,697	564	33.3
≥ 350	93	121	15	709	147	20.7
Total	192	240	21	2,406	583	24.2
<u>Section 3</u>						
250-349	147	185	13	1,953	463	23.7
≥ 350	40	47	7	240	66	27.6
Total	187	232	20	2,193	468	21.3
River Total	379	472	41	4,599	748	16.3

¹ Modified Peterson estimate (Bailey 1951, 1952).

² Standard error of the estimate.

³ Coefficient of variation.

As with the absolute abundance estimates, the relative abundance estimate in 1988 showed an increase over those found in 1986 and 1987 (Appendix Table 5). The relative abundance, or CPUE (number of Arctic grayling caught in one electrofishing run through a section), for fish greater than 249 mm FL had a mean value of 162.9 in 1988 (Table 5). The CPUE for all Arctic grayling caught was 171.9 (Appendix Table 6). By river section, the mean CPUE for fish greater than 249 mm FL was 18.0 in Section 1, 51.9 in Section 2, and 92.9 in Section 3 (Table 5). The variation for these estimates was greatest in Section 3 (98.3) and the lowest in Section 1 (1.9) (Table 5). This variability within sections, i.e. increasing from the lower to upper sections, has been consistent in two of the three years that mean CPUE has been calculated.

The six electrofishing passes on the river represented a total of 13.4 hours spent capturing 932 grayling for a catch rate of 70 grayling per electrofishing hour (Appendix Table 7). The five runs represented in the relative abundance estimation took 11.6 hours to catch 860 grayling or 74 grayling per hour. These figures compare to the 38, 19, and 73 Arctic grayling caught per hour in 1987, 1986, and 1985, respectively.

Since 1977, the number of Arctic grayling captured in one downstream pass with an electrofishing boat has been used as an index of relative abundance in monitoring population trends (Ridder 1985). Correlation coefficients (r) were calculated between relative and absolute abundance estimates from the whole river ($n = 4$) and from Section 3 ($n = 7$) (Appendix Table 5; Figure 3). Correlation between the two abundance estimates in Section 3 was high ($r = 0.97$) as it was for the whole river ($r = 0.98$). Considering these correlations, relative indices can be considered a reliable and cost-effective method for monitoring the abundance of Arctic grayling in the Richardson Clearwater River given that gear and sampling time are held constant.

A total of 662 Arctic grayling were sampled for age and size composition in the Richardson Clearwater River. Age 5 was the most numerous age class comprising 32% of the sample (Table 6). Ages 6 through 9 comprised 10% to 16% of the sample. Juvenile fish of ages 1 through 4 comprised 7% of the sample. When age composition was adjusted to compensate for length bias in the electrofishing sample, ages 8 and older decreased in proportion, while ages 7 and younger tended to increase in proportion. (With the adjustment, ages 1 and 2 were not represented; Table 6). Age 5 was predominant in the adjusted sample, comprising 36% (Table 6). Ages 7 and 8 were similar at 11 and 13%. RSD indices reflected the high abundance of older grayling in the river with 30% of the population in the preferred category and only 15% in the stock category (Table 7). Stock sized fish were more abundant in the lower two sections (29% of the sample) than the upper section (2%) while the inverse was true of the larger fish (15 and 44%, respectively).

Shaw Creek

Five days were spent electrofishing the Tanana River approximately 0.8 km above and below the mouth of Shaw Creek from 18 to 22 April. As in 1987 (Clark and Ridder 1988), quickly rising water levels and increasing turbidity made further sampling unproductive. A total of 357 Arctic grayling was captured during 7.9 hrs of electrofishing. The majority of captures occurred

Table 5. Electrofishing catch rate (CPUE)¹ statistics for Arctic grayling greater than 249 mm FL from each of five electrofishing runs through three sections of the Richardson Clearwater River, 5 through 19 July 1988².

Date	Run	Catch Rate			
		Section 1	Section 2	Section 3	Total
5 July	1	17	43	122	182
7 July	2	23	46	72	141
8 July	3	NA ³	---	---	---
13 July	4	17	69	108	194
15 July	5	15	50	70	135
19 July	6	18	66	84	168
mean		18.0	51.9	92.9	162.9
variance		1.9	20.5	98.3	125.2
95% C.I.		15.8-20.6	45.0-60.0	78.0-108.8	145.6-181.0

¹ CPUE is the number of grayling caught in one electrofishing run through a section.

² Summary statistics developed from bootstrap methods (Efron 1981 and 1982).

³ NA = not applicable to CPUE estimate; see Methods and Appendix Table 7.

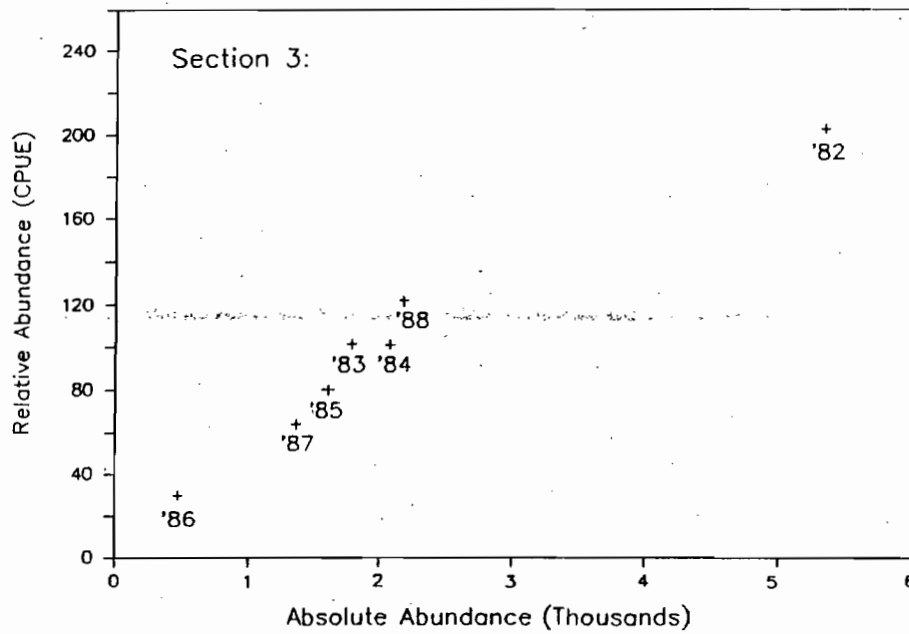
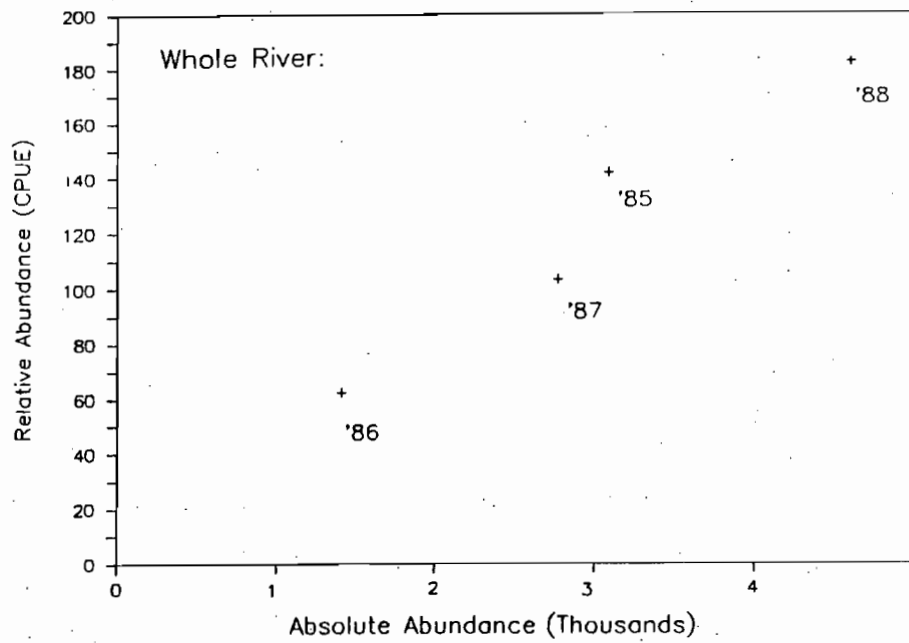


Figure 3. Scatter plots of relative abundance versus absolute abundance for two areas of the Richardson Clearwater River, 1982 through 1988.

Table 6. Estimates of the sampled and adjusted¹ proportional contribution of each age class and sampled mean fork length (mm) at age for Arctic grayling captured in the Richardson Clearwater River, 5 July to 15 July 1988.

Age	Sampled:		Adjusted:		Fork Length	
	n ²	p ³	p ⁴	SE ⁵	Mean	SD ⁶
1	1	0.002	0.000	---	100	---
2	1	0.002	0.000	---	190	---
3	4	0.006	0.002	0.002	245	15
4	38	0.057	0.051	0.010	258	20
5	212	0.320	0.358	0.033	281	24
6	104	0.157	0.205	0.022	313	22
7	73	0.110	0.114	0.014	345	24
8	95	0.144	0.127	0.017	356	21
9	68	0.103	0.077	0.015	377	24
10	36	0.054	0.036	0.010	398	20
11	17	0.026	0.016	0.006	406	17
12	12	0.018	0.013	0.005	408	32
13	1	0.002	0.001	0.001	446	---
Total	662	1.000	1.000		324	51

¹ Age composition is adjusted to compensate for length bias in the electrofishing sample.

² n = sample size.

³ p = proportion of sampled grayling.

⁴ p = adjusted proportion of grayling (≥ 250 mm) in stock.

⁵ SE = standard error of the adjusted proportion.

⁶ SD = standard deviation of the mean fork length.

Table 7. Summary of sampled and adjusted Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled in the Richardson Clearwater River, 5 through 18 July 1988.

	RSD Category ¹				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Section 1 and 2</u>					
Number sampled	118	230	97	0	0
Sampled RSD ²	0.265	0.517	0.218	---	---
Adjusted RSD ³	0.288	0.561	0.151	---	---
Standard Error ⁴	0.025	0.032	0.035	---	---
<u>Section 3</u>					
Number sampled	7	163	244	0	0
Sampled RSD	0.017	0.394	0.589	---	---
Adjusted RSD	0.023	0.537	0.440	---	---
Standard Error	0.009	0.066	0.068	---	---
<u>Total</u>					
Number sampled	125	393	341	0	0
Sampled RSD	0.146	0.458	0.397	---	---
Adjusted RSD	0.149	0.549	0.302	---	---
Standard Error	0.005	0.007	0.007	---	---

¹ Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):

Stock - 150 mm

Quality - 270 mm

Preferred - 340 mm

Memorable - 450 mm

Trophy - 560 mm

² RSD calculated directly from the number sampled.

³ RSD adjusted for Arctic grayling ≥ 250 mm FL due to bias in length selectivity of the electrofishing boat.

⁴ Standard error of the adjusted RSD.

upstream of the creek mouth. Of the 336 individual fish captured, 33 were recaptures of fish tagged in previous years. Twenty-three fish were initially tagged at Caribou Creek and 10 fish were tagged in April 1987 in the Tanana River by Shaw Creek.

The Jolly-Seber abundance estimate in Shaw Creek in April 1987 was 6,080 Arctic grayling greater than 270 mm FL (SE = 3,596, CV = 59.1%). The survival estimate from 1986 to 1987 was 0.76 (SE = 0.39, CV = 51.3%). This estimate compares with the 1987 Peterson estimate for Shaw Creek of 10,520 Arctic grayling greater than 289 mm FL (SE = 3,881, CV = 36.9%; Clark and Ridder 1988).

Age 5 was the most numerous age class comprising 31% of the 318 Arctic grayling sampled for age in 1988 (Table 8). The compositions of ages 6 through 8 were similar and ranged from 13 to 15%. Age 4 and younger fish made up 11% of the sample. This sample was represented by fewer older aged fish than in 1987. Forty-one percent of the sample were age 7 and older compared to 81% of the 1987 sample.

Adults (n = 176) made up 52% of the 336 Arctic grayling sampled. Two percent of the adults and 36% of the total sample were less than 270 mm, or stock-sized fish (Table 9). Of the adults, males were generally larger than females. Fifty-two percent of males and 30% of females were in the preferred category, or greater than 340 mm.

Mean lengths at age ranged from 138 mm FL for age 2 Arctic grayling to 413 mm for an age 12 fish (Table 10). Mean lengths at age were generally larger for the adult component of a cohort than for the subadults.

ACKNOWLEDGEMENTS

I wish to thank Mark Ross, James Harrild, and Al Mathews for their assistance in the field, their accurate transcriptions of historical data and capable lab work. Thanks goes to Robert Clark for his much appreciated technical and editorial assistance. And thanks to John H. Clark and Rolland Holmes for their administrative support without which this study would not have been undertaken. This project and report were made possible by partial funding provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act under Project F-10-4, Job Number G-8-5.

Table 8. Estimated proportional contribution of each age class for Arctic grayling in the total and adult sample collected off the mouth of Shaw Creek, 18 through 22 April 1988.

Age Class	Total Catch			Adult Catch		
	n ¹	p ²	SE ³	n	p	SE
2	2	0.006	0.004	0	---	---
3	11	0.035	0.010	0	---	---
4	23	0.072	0.015	0	---	---
5	100	0.314	0.026	11	0.068	0.020
6	49	0.154	0.020	24	0.148	0.028
7	41	0.129	0.019	39	0.241	0.034
8	43	0.135	0.019	41	0.253	0.034
9	22	0.069	0.014	21	0.130	0.026
10	18	0.057	0.013	18	0.111	0.025
11	8	0.025	0.009	7	0.043	0.016
12	1	0.003	0.003	1	0.006	0.006
Total	318	1.000		162	1.000	

¹ n = sample size.

² p = proportion.

³ SE = standard error of the proportion.

Table 9. Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled off the mouth of Shaw Creek, 18 through 22 April 1988.

	RSD Category ¹				
	Stock	Quality	Preferred	Memorable	Trophy
<u>All</u>					
Number sampled	122	133	81	0	0
RSD	0.363	0.396	0.241	---	--
Standard Error	0.026	0.027	0.023	---	--
<u>Adults</u>					
Number sampled	4	96	76	0	0
RSD	0.023	0.545	0.432	---	--
Standard Error	0.011	0.038	0.037	---	--
<u>Males</u>					
Number sampled	1	48	54	0	0
RSD	0.010	0.466	0.524	---	--
Standard Error	0.010	0.049	0.049	---	--
<u>Females</u>					
Number sampled	3	48	22	0	0
RSD	0.041	0.658	0.301	---	--
Standard Error	0.023	0.056	0.054	---	--

¹ Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):

Stock - 150 mm
 Quality - 270 mm
 Preferred - 340 mm
 Memorable - 450 mm
 Trophy - 560 mm

Table 10. Mean fork length (mm) at age for Arctic grayling by sex, collected off the mouth of Shaw Creek, 18 through 22 April 1988.

Age Class	Total			Male			Female		
	n ¹	Mean	SD ²	n	Mean	SD	n	Mean	SD
2	2	138	7	0	---	---	---	---	---
3	11	184	13	0	---	---	---	---	---
4	23	224	20	0	---	---	---	---	---
5	100	254	27	5	310	32	6	276	14
6	49	289	19	16	302	16	8	291	17
7	41	317	28	19	335	21	20	303	25
8	43	342	22	25	345	23	16	336	20
9	22	357	16	13	358	18	8	354	15
10	18	372	27	13	375	29	5	364	21
11	8	398	23	4	408	8	3	373	12
12	1	413	---	1	413	---	0	---	---
Total	318	293	57	96	343	34	66	320	34

¹ n = sample size.

² SD = sample standard deviation.

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APPENDIX

Appendix Table 1. The number of Arctic grayling by 25 mm FL groups that were marked, caught, recaptured, and their recapture rate (R/M) in a Peterson experiment in the Richardson Clearwater River, 5 through 19 July 1988.

Length Group	Marked	Caught	Recaptured	R/M
150 - 174	0	0	---	---
175 - 199	0	2	---	---
200 - 224	1	1	0	0
225 - 249	25	16	1	0.040
250 - 274	57	50	2	0.035
275 - 299	68	86	7	0.103
300 - 324	64	98	6	0.094
325 - 349	55	73	6	0.109
350 - 374	62	65	9	0.145
375 - 399	39	63	7	0.179
400 - 424	27	29	6	0.222
425 - 449	7	7	0	0
Total	405	490	42	0.103

Appendix Table 2. Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) sampled in three sections of the Richardson Clearwater River, 5 through 19 July 1988.

	RSD Category ¹				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Section 1</u>					
Number sampled	83	59	18	0	0
RSD	0.519	0.369	0.113	---	---
Standard Error	0.040	0.038	0.025	---	---
<u>Section 2</u>					
Number sampled	35	171	79	0	0
RSD	0.123	0.600	0.277	---	---
Standard Error	0.019	0.029	0.027	---	---
<u>Section 3</u>					
Number sampled	7	163	244	0	0
RSD	0.017	0.394	0.589	---	---
Standard Error	0.006	0.024	0.024	---	---
<u>Total</u>					
Number sampled	125	393	341	0	0
RSD	0.146	0.458	0.397	---	---
Standard Error	0.012	0.017	0.017	---	---

¹ Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):

Stock - 150 mm
 Quality - 270 mm
 Preferred - 340 mm
 Memorable - 450 mm
 Trophy - 560 mm

Appendix Table 3. Estimates of the proportional contribution of each age class of Arctic grayling greater than 249 mm FL captured in each of three sections of the Richardson Clearwater River, 5 through 19 July 1988.

Age Class	Section 1			Section 2			Section 3			Total		
	n ²	p ³	SE ⁴	n	p	SE	n	p	SE	n	p	SE
3	0	---	---	1	0.005	0.005	0	---	---	1	0.002	0.002
4	10	0.097	0.029	10	0.050	0.015	7	0.022	0.008	27	0.043	0.008
5	61	0.592	0.048	72	0.360	0.034	55	0.173	0.021	188	0.303	0.018
6	12	0.117	0.032	43	0.215	0.029	49	0.154	0.020	104	0.167	0.015
7	6	0.058	0.023	23	0.115	0.023	44	0.138	0.019	73	0.118	0.013
8	8	0.078	0.026	25	0.125	0.023	61	0.192	0.022	94	0.151	0.014
9	2	0.019	0.014	16	0.080	0.019	50	0.157	0.020	68	0.110	0.013
10	2	0.019	0.014	7	0.035	0.013	27	0.085	0.016	36	0.058	0.009
11	1	0.010	0.010	2	0.010	0.007	14	0.044	0.012	17	0.027	0.007
12	0	---	---	1	0.005	0.005	11	0.035	0.010	12	0.019	0.006
13	1	0.010	0.010	0	---	---	0	---	---	1	0.002	0.002
Total	103	1.000		200	1.000		318	1.000		621	1.000	

¹ All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1984); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

² n = sample size.

³ p = proportion.

⁴ SE = standard error of the proportion.

Appendix Table 4. Number of Arctic grayling captured (N) and recaptured¹ (R) in four length groups (mm FL) at Shaw and Caribou Creeks, 1985 through 1988.

Group	Shaw Creek						Caribou Creek		
	1986		1987		1988		1985	1986	1987
	N	R	N	R	N	R	N	N	N
200 - 249	3	0	12	0	67	0	71	270	277
250 - 259	25	0	4	0	45	0	64	74	130
270 - 349	135	2	101	13	154	8	182	300	283
>349	21	2	147	24	60	15	9	68	60
Total	184	4	264	37	326	23	326	712	750

¹ Recaptures include fish tagged at Caribou Creek from 1980 through 1988.

Appendix Table 5. Relative (CPUE¹) and absolute abundance estimates for Arctic grayling in the Richardson Clearwater River, July, 1980 through 1988².

Year	Whole River			Section 3		
	CPUE	Absolute Abundance		CPUE	Absolute Abundance	
		N	95% CI		N	95% CI
1980	170	ND ³		NA ⁴	ND	
1981	167	ND		NA	ND	
1982	324	ND		203	5,340	3,028 - 10,680
1983	220	ND		103	1,792	1,016 - 3,460
1984	138	ND		101	2,076	1,148 - 4,520
1985	142	3,114	1,939 - 4,289	83	1,610	974 - 2,876
1986	62	1,418	786 - 2,837	30	468	191 - 1,170
1987 ⁵	103	2,775	1,653 - 3,896	64	1,368	476 - 2,260
1988 ⁵	182	4,599	3,127 - 6,071	122	2,193	1,274 - 3,112

¹ CPUE = the total catch of Arctic grayling made in the first electrofishing run through a section (river).

² Data is from Ridder 1985; Holmes et al 1986; and Clark and Ridder 1987, 1988.

³ ND = not done.

⁴ NA = not available.

⁵ Data is for fish greater than 249 mm FL only.

Appendix Table 6. Electrofishing catch rate (CPUE)¹ statistics for all Arctic grayling captured in each of five electrofishing runs through three sections of the Richardson Clearwater River, 5 through 19 July 1988².

Date	Run	Catch Rate			
		Section 1	Section 2	Section 3	Total
5 July	1	22	48	122	192
7 July	2	29	46	72	147
8 July	3	NA ³	---	---	---
13 July	4	26	69	108	203
15 July	5	20	56	70	146
19 July	6	21	67	84	172
mean		24.2	54.7	92.9	171.9
variance		2.5	16.5	98.3	128.9
95% C.I.		21.6-26.6	48.4-61.8	78.0-108.8	155.4-189.6

¹ CPUE is the number of grayling caught in one electrofishing run through a section.

² Summary statistics developed from bootstrap methods (Efron 1981 and 1982).

³ NA = not applicable to CPUE estimate; see Methods, Appendix Table 7.

Appendix Table 7. Catch, mortality, and time (minutes) statistics from six electrofishing runs through three sections of the Richardson Clearwater River, 5 through 19 July 1988.

Section	Date	Run	Time	Catch			Mortality	CPUE ¹
				Total	≥200mm	≥250mm		
1	5 July	1	42	22	22	17	0	31
	7 July	2	47	29	29	23	0	37
	8 July	3	53	52	51	42	0	59
	13 July	4	43	26	25	17	0	36
	15 July	5	49	20	20	15	0	35
	19 July	6	43	21	21	18	1	39
Total			277	170	168	132	1	37
2	5 July	1	51	48	48	43	1	57
	7 July	2	54	46	46	46	2	51
	8 July	3	51	20	20	19	0	24
	13 July	4	53	69	69	69	0	78
	15 July	5	58	56	56	50	0	58
	19 July	6	60	67	67	66	1	67
Total			327	306	306	293	3	56
3	5 July	1	39	122	122	122	1	188
	7 July	2	38	72	72	72	1	114
	8 July	3	ND ²	---	---	---	---	---
	13 July	4	41	108	108	108	2	158
	15 July	5	41	70	70	70	3	104
	19 July	6	40	84	84	84	2	126
Total			199	456	456	456	9	138
All	5 July	1	132	192	192	182	2	87
	7 July	2	139	147	147	141	3	64
	8 July	3	104	72	71	61	0	42
	13 July	4	137	203	202	194	2	89
	15 July	5	148	146	146	135	3	59
	19 July	6	143	172	172	168	3	72
Total			803	932	930	881	13	70

¹ CPUE = number of Arctic grayling caught per hour.

² ND = not done.

March 21, 1999 Price: \$2.80

Division of Geological & Geophysical Surveys

PUBLIC-DATA FILE 99-21

**WATER QUALITY STUDY OF RICHARDSON
CLEARWATER CREEK NEAR BIG DELTA, ALASKA**

by

Mary A. Maurer
Alaska Division of Mining & Water Management
Alaska Hydrological Survey

March 1999

THIS REPORT HAS NOT BEEN REVIEWED FOR
TECHNICAL CONTENT (EXCEPT AS NOTED IN TEXT) OR FOR
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INTRODUCTION

Richardson Clearwater Creek is a pristine, spring-fed, perennial stream that flows northwestward for 14 miles to the Tanana River, approximately 80 miles southeast of Fairbanks, Alaska. The creek is identified as Clear Creek on the U.S. Geological Survey Big Delta (A-5) Quadrangle (fig. 1), but is known locally as Richardson Clearwater Creek to differentiate it from Delta Clearwater Creek, a spring-fed stream east of Delta Junction, Alaska.

The Richardson Clearwater Creek receives the majority of its flow from ground water rather than surface water runoff. Consequently, streamflow fluctuates within a very narrow range. The stream's headwaters are formed by numerous springs that emanate from a low bank at the 1000 foot elevation contour line in section 4 of Township 9 South, Range 9 East, Fairbanks Meridian (near site 10 in fig. 2). The largest of these springs contributes approximately 12 cubic feet per second of flow. The stream also receives flow from small springs along its length and two spring-fed tributaries.

Richardson Clearwater Creek is an unusual Interior Alaska stream because of its short length, laminar flow, stable channel, and exceptional clarity. The streambed is composed of gravel and cobble-sized rock which is underlain by fine-grained sand. The aquatic moss *Cratoneuron filicinum* grows in long, sinuous submerged clumps or mats attached to the streambed. Stream banks are vegetated and show no sign of erosion. The riparian habitat is a mature spruce and birch forest. Ice scar marks on mature spruce trees along the creek's lower reaches indicate ice jams occur during spring breakup. Beavers are active near the headwaters and have impounded the tributaries in the recent past.

Richardson Clearwater Creek supports populations of coho salmon, chum salmon, Arctic grayling, round whitefish, and longnose suckers. Of these species, only coho salmon spawn and overwinter in the creek. The other species utilize the stream as a summer feeding area (Ridder, 1980). The Arctic grayling fishery is popular with local summer residents who have recreational cabins along the lower reaches of the creek. Summer access is by boat or floatplane.

State lands in the Richardson Clearwater Creek area are managed for recreational use and fish and wildlife habitat protection, according to the Delta-Salcha Area Plan (Alaska Department of Natural Resources, 1982). In the early 1980's agricultural development was proposed for lands that lay to the south and upgradient of Richardson Clearwater Creek. However, no lands have been cleared for agriculture in the area during the last 20 years.

In May 1998 the Carla Lake forest fire started as the result of a lightning strike on the Fort Greeley military reservation, about 15 miles southwest of Delta Junction. The fire spread north and crossed Richardson Clearwater Creek (fig. 1). Firefighters successfully defended the threatened cabins along the creek, and suppressed the fire in the late summer of 1998. The fire burned a total of 53,720 acres. Presently, the State is proposing timber salvage operations in the burn area.

Carla Lake forest fire effects on Richardson Clearwater Creek are unknown. Forest fires can produce changes in a stream's flow regime, organic matter content, turbidity, color, chemical oxygen demand, and potassium concentration (Lotspeich and others, 1970). Fire control efforts such as trail and ditch construction in permafrost areas also have the potential to produce erosion and increase sediment loading.

In 1983 the Alaska Department of Natural Resources, Alaska Hydrologic Survey (AHS) collected streamflow and water-quality data on Richardson Clearwater Creek to document baseline conditions within the proposed agricultural area. In hindsight these data also document pre-fire water quality conditions. This report presents the data collected in the 1983 AHS investigation. The purpose of the report is to make previously unpublished data available to land managers and the public.

ACKNOWLEDGEMENTS

The State of Alaska and the Agricultural Action Council funded this study. Steve Mack (formerly of AHS) was project manager. Roy Ireland (AHS), Steve Mack, George McCoy, Roger Allely, and Larry Dearborn (all formerly of AHS) assisted with field data collection. Barbara Murray (University of Alaska Museum Herbarium, Fairbanks, AK) identified the aquatic moss. Dave Hendren (Alaska Department of Natural Resources, Division of Forestry) provided a map of the Carla Lake fire. Jim Vohden (AHS) reviewed the report.

METHODS

Streamflow was measured with a Marsh McBirney current meter according to U.S. Geological Survey methods (Carter and Davidian, 1968). Water temperature, dissolved oxygen, and specific conductance were measured in the field with a Model 4041 Hydrolab that was pre- and post-calibrated according to the user manual. On-site pH was measured with an Orion Research model 201 digital pH meter. Bicarbonate alkalinity was measured on-site by titrating an untreated, unfiltered 100-ml water sample with 0.01639N sulfuric acid to an endpoint of pH 4.5 (U.S. Environmental Protection Agency, 1983).

Although no water-quality assurance plan was written, sampling and treatment was in general accordance with U.S. Geological Survey (1977) procedures. Grab samples were obtained at mid-channel and mid-depth of the stream. All samples were processed in the field. Water for dissolved inorganic constituent analysis and dissolved nutrient analysis was filtered through a 0.45- μ m membrane filter and poured into pre-cleaned plastic bottles. Water for total nutrient analysis was collected in pre-cleaned plastic bottles. Nutrient samples were frozen within eight hours of returning from the field. Water for organic compound analysis was collected in 1-liter amber glass bottles. Water for total metal analysis was poured into pre-cleaned plastic bottles, and acidified with double-

distilled 70-percent nitric acid. All samples were placed in a cooler with ice while in transit from the field to the laboratory.

Anatec Laboratories in Santa Rosa, California analyzed dissolved inorganic constituent and trace metal samples according to the methods of the American Public Health Association (1980) or the U.S. Environmental Protection Agency (1983). The Alaska Department of Fish and Game Limnology Laboratory in Soldotna, Alaska analyzed nutrient samples according to methods described in Koenings and others (1987). Northern Testing Laboratories, Inc. in Fairbanks, Alaska analyzed tannin and lignin samples according to the methods of the American Public Health Association and others (1980). Water Analysis and Consultants in Eugene, Oregon analyzed pesticide and herbicide samples under contract to Northern Testing Laboratories, Inc. according to the methods of the U.S. Environmental Protection Agency (1981).

Benthic invertebrate samples were collected from mineral substrate and the aquatic moss *Cratoneuron filicinum* with a 0.1-meter² cylindrical substrate sampler, similar to a modified-Hess sampler. The sampler is 2 feet in height and is constructed of heavy gauge aluminum. Netting fits over the frame and is held in place by aluminum rim bands. The netting that faces the water current has 600-micron NITEX nylon mesh, whereas the backside and attached bag has 300-micron mesh. Mineral substrate samples were obtained by working the sampler into the streambed and rubbing the rocks to dislodge invertebrates. Moss samples were obtained by placing the sampler over the moss, detaching the moss from the streambed, and placing the moss in the net bag. Organisms were preserved in a 70 percent alcohol solution. Rose bengal bacteriological stain was added to facilitate sorting. All organisms were hand-picked from mineral substrate samples. A one-eighth or one-sixteenth subsample was taken from moss samples. Benthic invertebrates were identified to the lowest practicable level using the taxonomic keys of Pennak (1978), Usinger (1956), Flint (1960), Jensen (1966), Smith (1968), Edmunds and others (1976), Baumann and others (1977), Wiggins (1977), and Merritt and Cummins (1978).

RESULTS AND DISCUSSION

Chemical Water Quality

Streamflow and on-site water-quality measurements are shown on table 1. Streamflow fluctuates within a very narrow range at each site. Water temperature ranges from -0.1°C in October to 12.4°C in July. Mainstem water temperatures are generally similar among sites, except on July 26 when water temperatures near the stream's headwaters (site 6) dropped significantly (fig. 3). By mid-summer, water held in seasonally frozen soils probably recharges the shallow groundwater. Discharge of this colder ground water at headwater springs may account for the lower water temperature at site 6. The pH ranges from near neutral (pH 6.9 at site 9) to basic (pH 8.2 at site 7). Specific conductance ranges from 193 to 285 $\mu\text{S}/\text{cm}$ @ 25°C. Dissolved oxygen concentrations are generally

high, except in spring water at site 9. Alkalinity ranges from 97 to 152 mg/L as CaCO_3 , indicating the water has good acid-neutralizing capacity.

Inorganic constituent concentrations are similar among sites (table 2). The calculated hardness value ranges from 111 to 146 mg/L as CaCO_3 , indicating moderately hard to hard water (Hem, 1985). Total filterable residue concentration ranges from 140 to 200 mg/L, which indicates a moderate amount of dissolved mineral content in the water. The ion balance error ranges from 0.02 to 9.3% for 38 samples, which indicates that there are no major errors in the reported concentrations of major inorganic constituents.

The trilinear diagram is a graphical representation of water type, based on the average percentages of total cations (positively charged ions) and anions (negatively charged ions), in milliequivalents per liter (meq/L). The percentages are based on the average ion concentrations at each site. Richardson Clearwater Creek sites have very similar ionic composition (fig. 4). Calcium is the predominant cation and bicarbonate is the predominant anion. Therefore, the water type is calcium bicarbonate for all sites.

Slight differences in ionic composition among surface waters can also be illustrated on a trilinear diagram (fig. 5). The water type for Richardson Clearwater Creek in October is compared to the water type of the Tanana River and Delta Rivers in October, based on data collected by the U.S. Geological Survey (USGS, 1979). The USGS water-quality data are listed in the appendix. The sampling sites are shown in fig. 1. The datasets are comparable because most of the streamflow in October is from ground water sources rather than surface water runoff. All three surface waters have calcium bicarbonate water (fig. 5). However, the Richardson Clearwater Creek water type overlaps the Tanana River water type, but not the Delta River water type, in the diamond-shaped area of the trilinear diagram (fig. 5). The Delta River has a higher percentage of sulfate. Based on these data, it appears Richardson Clearwater Creek is not being directly recharged by seepage losses from the Delta River.

Total and dissolved nutrient concentrations are generally low at all sites (table 3). Nitrate and nitrite nitrogen concentrations rose slightly in October. Filterable reactive phosphorus (soluble orthophosphate) concentrations are generally less than 10 $\mu\text{g/L}$ as P. No seasonal trend is observed in the phosphorus fractions. Reactive silicon, a primary nutrient required by diatoms, is present in concentrations that range from 4.2 to 6.2 mg/L as Si.

Total trace element concentrations are either below detection limits or are present in low concentrations (table 4). Total concentrations of barium and strontium range up to several hundred micrograms per liter ($\mu\text{g/L}$), which is more typical of ground water (Hem, 1985). This is further evidence of the large ground-water contribution to streamflow. Iron concentrations are generally low. The highest iron concentration (430 $\mu\text{g/L}$) was measured in a small spring (site 9) along the stream, which is highly visible because a reddish-colored iron hydroxide precipitate coats the ground at the spring's orifice.

The pesticides endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP are not detected at any site (table 5). These compounds are typically applied to agricultural lands. Tannin and lignin are naturally occurring plant substances that contribute to the organic carbon content of water. Runoff from agricultural lands often increases tannin and lignin levels in water. Tannin and lignin concentrations in Richardson Clearwater Creek range from <0.10 to 0.19 mg/L (table 5). The highest tannin and lignin concentration (0.27 mg/L) was measured in a tributary of Delta Creek (site 8) immediately downstream of a beaver dam. By comparison, tannin and lignin concentrations range from 0.04 to 4.2 mg/L in surface waters of Canada's pacific region (Environment Canada, 1987).

Biological Water Quality

Stream benthic invertebrates are excellent indicators of water quality because community structure reflects ambient stream water-quality conditions over time. Benthic invertebrate abundance and taxonomic diversity respond to a wide range of impacts such as sedimentation, organic loading, and changes in chemical water quality. In Richardson Clearwater Creek benthic invertebrates were sampled in mineral substrate (composed of gravel and pebble-sized rocks) and a filamentous aquatic moss, *Cratoneuron filicinum*. One or two samples were collected at five sites in July and seven sites in October. Number of organisms per meter² and taxonomic groups collected in July and October are listed on tables 6 and 7, respectively. Taxonomic groups present in moss and mineral substrate are similar. Chironomid midges are the most abundant taxonomic group in moss. Other common moss taxa are baetid mayflies, seed shrimp (Ostracoda), and water mites (Hydracarina). The most common taxa in mineral substrate are chironomid midges, seed shrimp, water mites, and flatworms (Turbellaria). Invertebrate abundance and taxonomic composition are similar between headwater and downstream sites.

Benthic invertebrate numbers are one and a half times higher in October than in July, which is due to the appearance of mayfly and stonefly nymphs in moss and mineral substrates, and non-insect invertebrate groups in moss (table 8). Benthic invertebrate numbers are five times higher in moss than in mineral substrate (fig 6). The mean number of benthic invertebrates is 246,140 organisms per meter² in moss and 44,730 organisms per meter² in mineral substrate (table 8). Invertebrate numbers in sparse moss are usually higher than in mineral substrate (fig. 6).

Benthic invertebrate numbers are typically higher in Richardson Clearwater Creek than in other Interior Alaska streams. For example, the mean number of benthic invertebrates in streams of the Forty-Mile River drainage ranges from 200 to 1,000 organisms per meter² (Lotspeich and others, 1970; Maurer, 1987). The Richardson Clearwater Creek has higher and more consistent groundwater input than most Interior Alaska streams. Consequently, streamflow is more consistent and the streambed is more stable. Such habitat conditions are optimal for benthic invertebrate colonization. In addition, high water clarity, high dissolved gas content, and sufficient nutrient concentrations support abundant plant and animal life. For example, aquatic mosses are present because they

require free carbon dioxide for photosynthesis, which is abundant in spring-fed streams (Ruttner, 1963).

High benthic invertebrate numbers in moss are the result of form and function. Long, thickly vegetated moss mats provides the invertebrates with more surface area for attachment and protection from predators. Few benthic invertebrates feed directly on moss. Instead, moss acts as a food trap. Benthic invertebrates, especially chironomid midges, feed on the epiphytic algae, diatoms, and fine particulate organic matter that adhere to the moss.

CONCLUSIONS

Chemical water quality in Richardson Clearwater Creek is good, characterized by highly oxygenated water, basic pH, moderate hardness, good acid-neutralizing capacity, and low concentrations of trace metals and nutrients.

Biological water quality, based on benthic invertebrate abundance, is very good in Richardson Clearwater Creek. The number of organisms per meter² is substantially higher in the creek than in other Interior Alaska streams. Chironomid midges are the most abundant taxa. The presence of aquatic moss enhances benthic invertebrate abundance.

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Appendix: U.S. Geological Survey water-quality data for the Delta and Tanana Rivers

(Ref. Source: Water resource data for Alaska, water year 1979:
U.S. Geological Survey Water-Data Report AK-79-1, Anchorage, AK, p. 318)

ANALYSES OF SAMPLES COLLECTED AT MISCELLANEOUS SITES

YUKON ALASKA--Continued

WATER QUALITY DATA, WATER YEAR OCTOBER 1978 TO SEPTEMBER 1979

640735145500000 - DELTA R NR BIG DELTA AK (LAT 64 07 35 LONG 145 50 00)

DATE	TIME	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	TEMPERATURE (DEG C)	HARDNESS AS CaCO3 (MG/L)	HARDNESS NONCARBONATE AS CaCO3 (MG/L)	CALCIUM DIS-SOLVED (MG/L AS Ca)	MAGNESIUM DIS-SOLVED (MG/L AS Mg)	SODIUM DIS-SOLVED (MG/L AS Na)	POTASSIUM DIS-SOLVED (MG/L AS K)	BICARBONATE AS HCO3 (MG/L)
OCT 16...	1530	295	8.2	4.0	120	24	35	7.6	3.0	3.7	110
JUN 20...	1805	186	7.0	13.0	81	19	22	6.4	2.4	2.4	76

DATE	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLORIDE DIS-SOLVED (MG/L AS CL)	FLUORIDE DIS-SOLVED (MG/L AS F)	SILICA DIS-SOLVED (MG/L AS SiO2)	SOLIDS RESIDUE AT 180 DEG C DIS-SOLVED (MG/L)	SOLIDS SUM OF CONSTITUENTS DIS-SOLVED (MG/L)	NITROGEN NO2+NO3 DIS-SOLVED (MG/L AS N)	PHOSPHORUS DIS-SOLVED (MG/L AS P)	IRON DIS-SOLVED (UG/L AS FE)	MANGANESE DIS-SOLVED (UG/L AS MN)
OCT 16...	45	1.0	.1	5.6	148	156	.28	.00	<10	2
JUN 20...	27	1.2	.1	4.3	103	103	.11	.00	40	4

154780000 - TANANA R AT BIG DELTA AK (LAT 64 09 20 LONG 145 51 00)

DATE	TIME	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	TEMPERATURE (DEG C)	HARDNESS AS CaCO3 (MG/L)	HARDNESS NONCARBONATE AS CaCO3 (MG/L)	CALCIUM DIS-SOLVED (MG/L AS Ca)	MAGNESIUM DIS-SOLVED (MG/L AS Mg)	SODIUM DIS-SOLVED (MG/L AS Na)	POTASSIUM DIS-SOLVED (MG/L AS K)	BICARBONATE AS HCO3 (MG/L)
OCT 16...	1630	277	7.9	.0	130	27	37	8.1	4.1	2.3	125
JUN 20...	1745	214	7.4	13.0	97	16	28	6.5	5.1	1.7	98

DATE	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLORIDE DIS-SOLVED (MG/L AS CL)	FLUORIDE DIS-SOLVED (MG/L AS F)	SILICA DIS-SOLVED (MG/L AS SiO2)	SOLIDS RESIDUE AT 180 DEG C DIS-SOLVED (MG/L)	SOLIDS SUM OF CONSTITUENTS DIS-SOLVED (MG/L)	NITROGEN NO2+NO3 DIS-SOLVED (MG/L AS N)	PHOSPHORUS DIS-SOLVED (MG/L AS P)	IRON DIS-SOLVED (UG/L AS FE)	MANGANESE DIS-SOLVED (UG/L AS MN)
OCT 16...	32	1.4	.1	10	154	158	.21	.00	<10	9
JUN 20...	29	2.7	.1	8.8	124	131	.15	.00	170	6

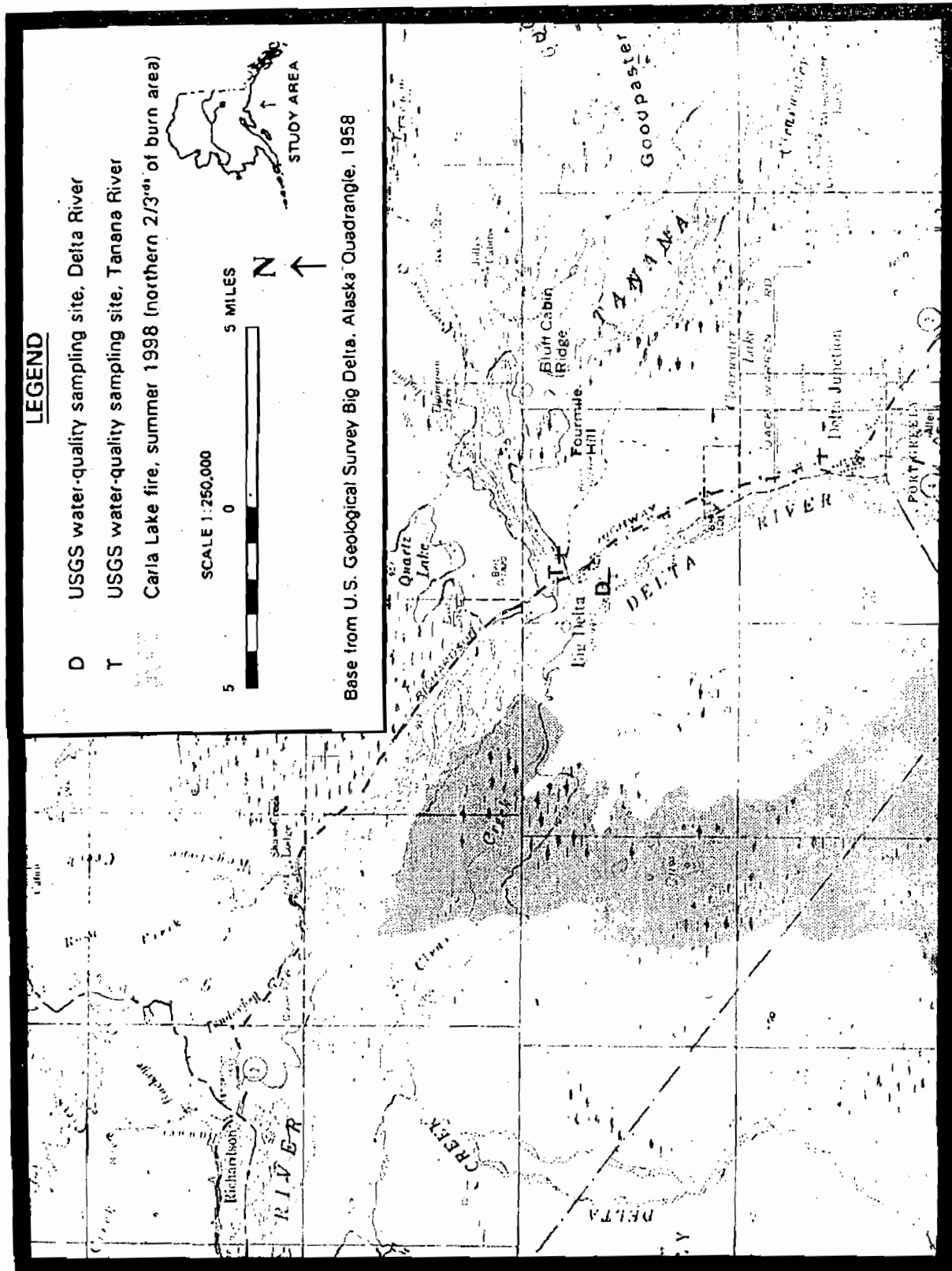


Figure 1. Location of the Richardson Clearwater Creek study area near Big Delta, Alaska.

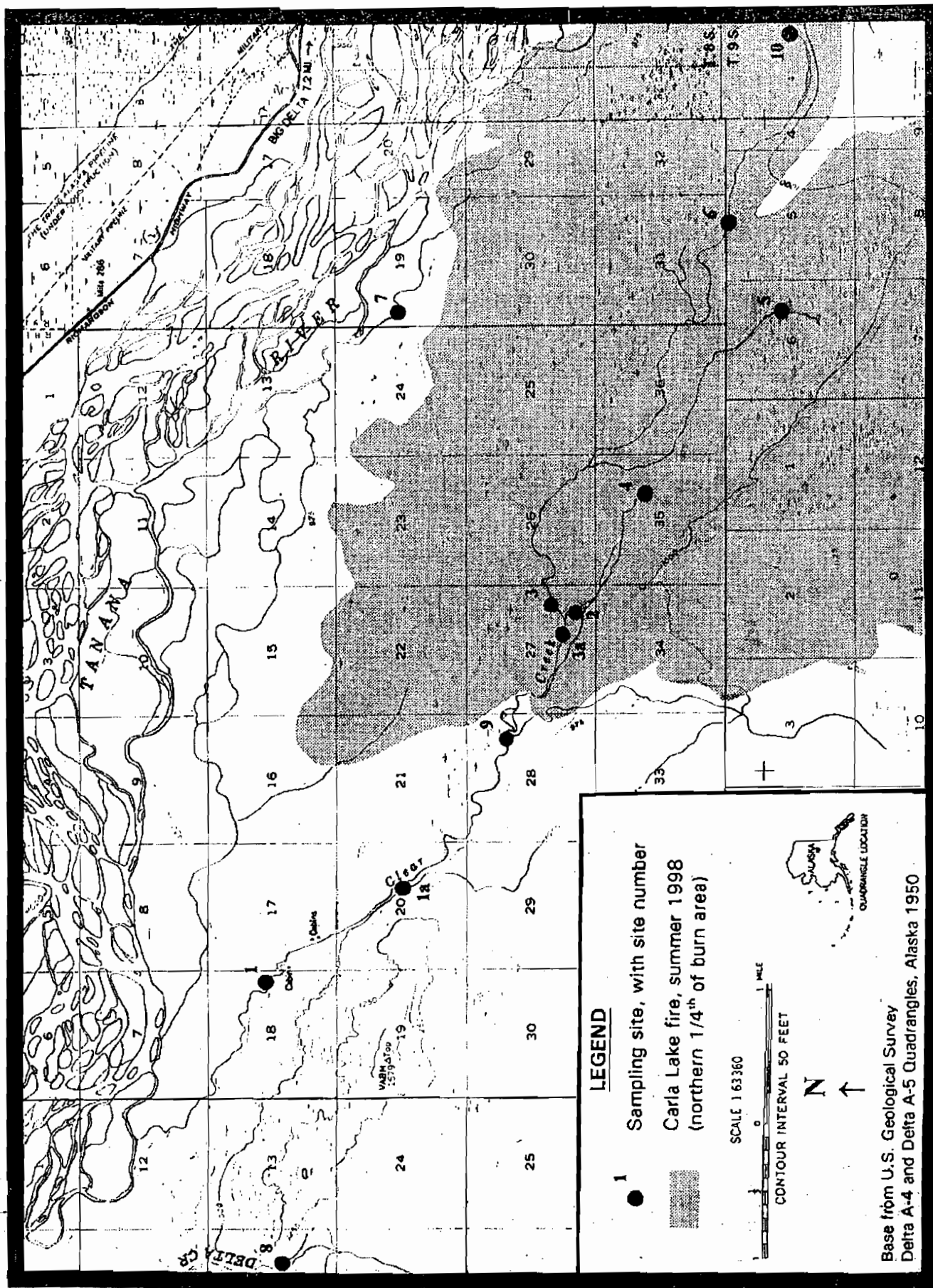


Figure 2. Location of sampling sites, Richardson Clearwater Creek area, near Big Delta, Alaska, 1983.

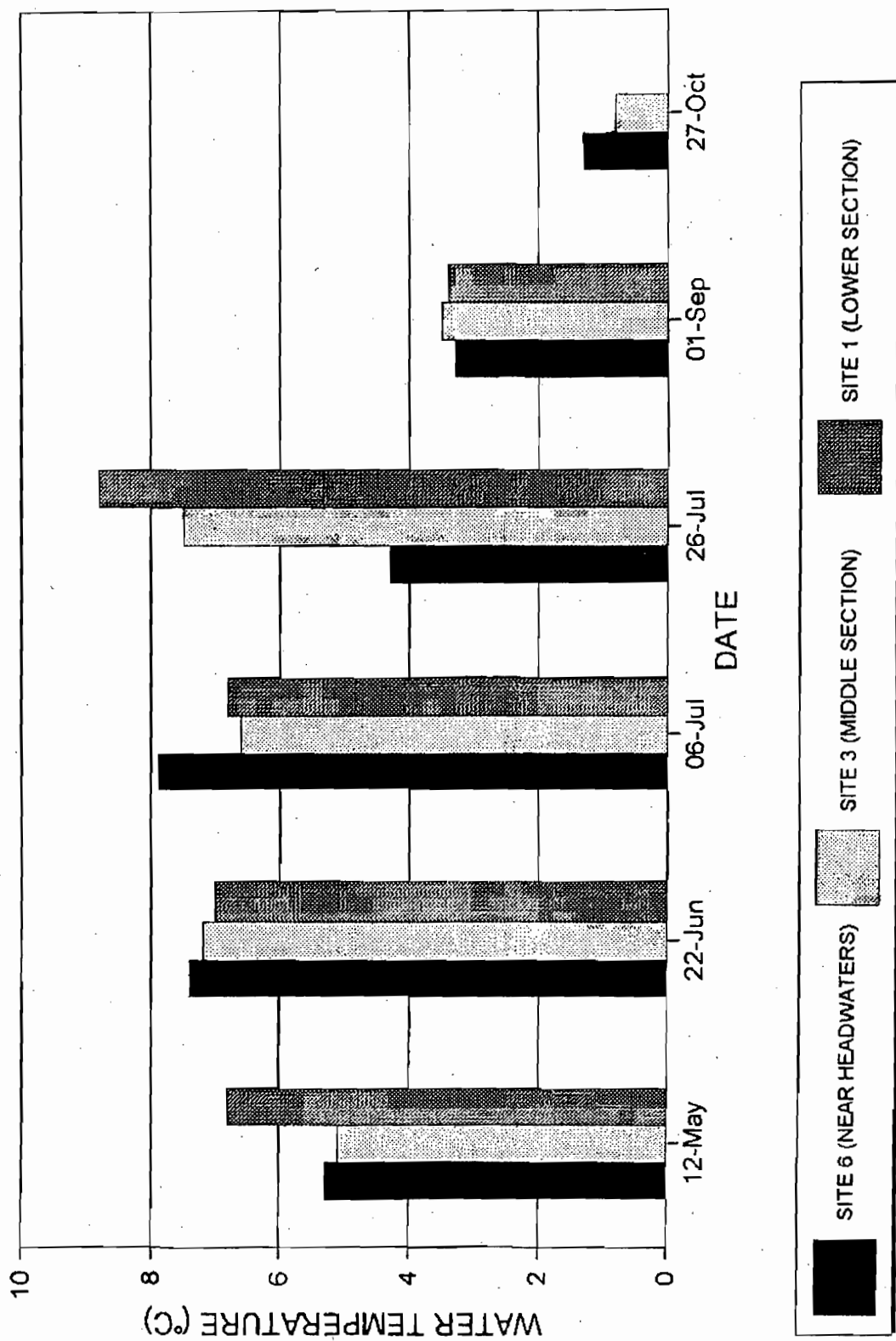
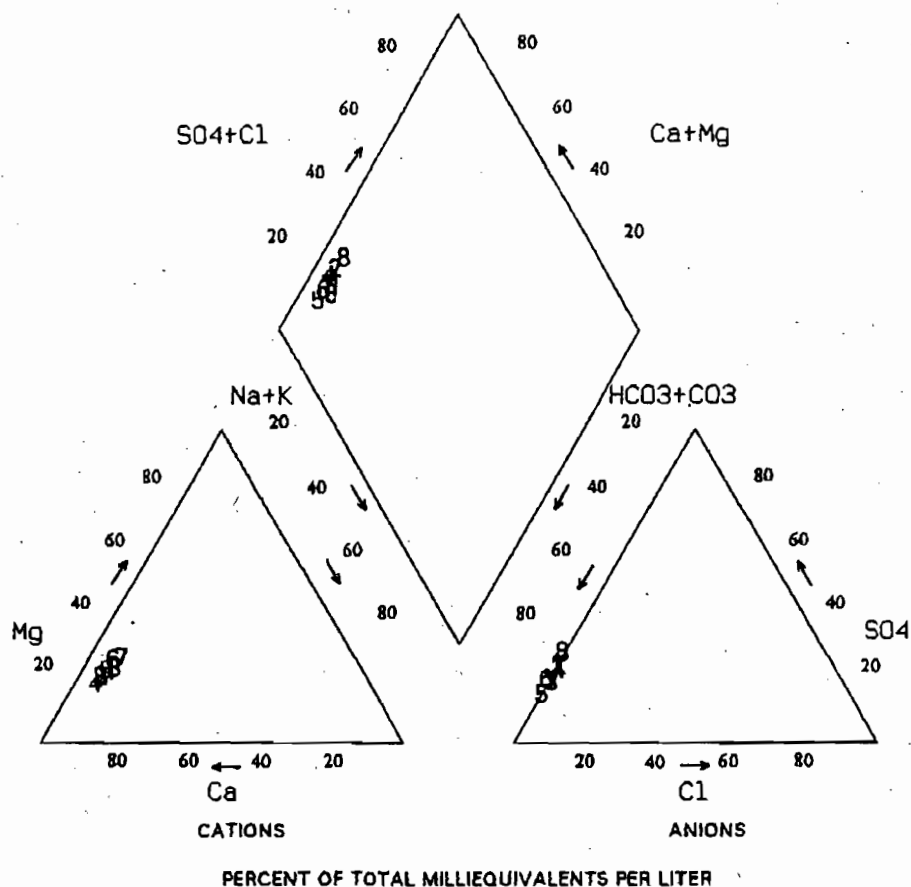


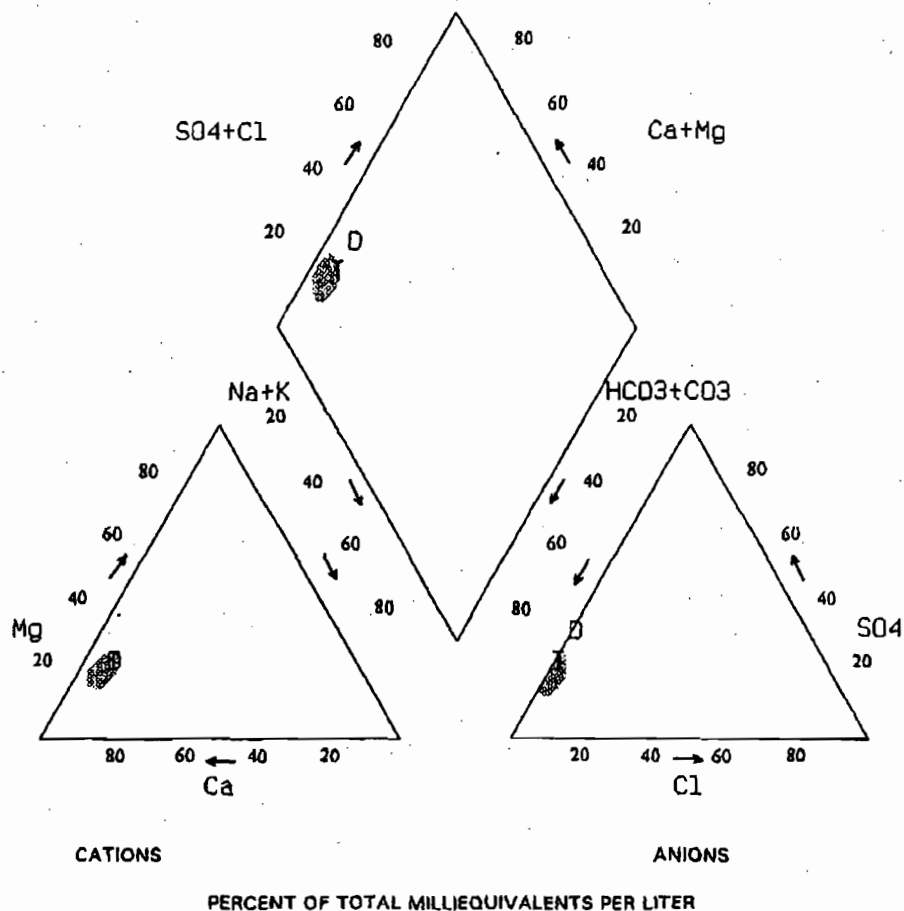
Figure 3. Water temperatures at three Richardson Clearwater Creek sites during 1983



EXPLANATION

Site No.	Location	Water Type
1	Richardson Clearwater Creek near Vanderbilt's Cabin	Calcium bicarbonate
2	Tributary #2 at mouth	Calcium bicarbonate
3	Richardson Clearwater Creek above tributary #2	Calcium bicarbonate
4	Tributary #2 near headwaters	Calcium bicarbonate
5	Tributary #1 near headwaters	Calcium bicarbonate
6	Richardson Clearwater Creek above Tributary #1	Calcium bicarbonate
7	Tanana River Tributary	Calcium bicarbonate
8	Delta Creek Tributary	Calcium bicarbonate

Figure 4. Trilinear diagram of water analyses from eight sites in the Richardson Clearwater Creek area, near Big Delta, Alaska, 1983.



EXPLANATION

<u>Symbol</u>	<u>Location</u>	<u>Water Type</u>
D	Delta River near Big Delta, Alaska	Calcium bicarbonate
T	Tanana River at Big Delta, Alaska	Calcium bicarbonate
	Richardson Clearwater Creek	Calcium bicarbonate

Figure 5. Trilinear diagram of surface-water analyses in the Big Delta area, Alaska. The Delta River and Tanana River were sampled by the U.S. Geological Survey on October 16, 1978. USGS sites are shown on Figure 1. The shaded area shows the range of five samples collected in Richardson Clearwater Creek by the Alaska Hydrologic Survey on October 27 and 28, 1983.

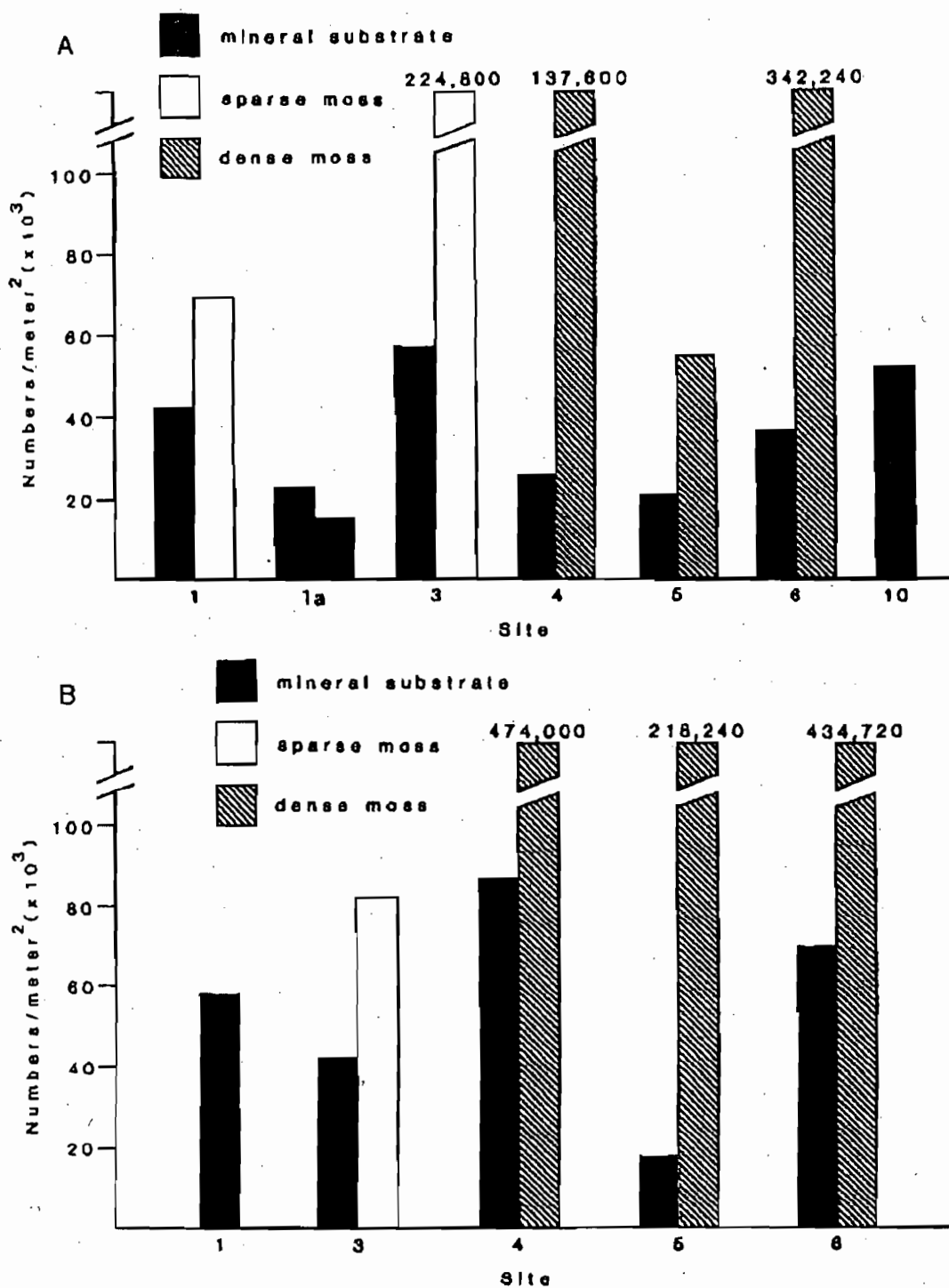


Figure 6. Numbers per meter² of benthic invertebrates at sites in Richardson Clearwater Creek and its tributaries on (A) July 26-27, 1983 and (B) October 27-28, 1983. Only one sample was taken at site 1 in October because of frazil ice.

Table 1. Streamflow and on-site water-quality measurements taken in the Richardson Clearwater Creek area, 1983

Site No.	Site	Date	Time	Streamflow (cfs)	Water Temperature (°C)	pH (units)	Specific Conductance (µS/cm @25°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (percent saturation)	Alkalinity (mg/L as CaCO ₃)
1	Richardson Clearwater Cr near Vanderbilt's Cabin	12 MAY 1983	--	--	6.8	IM	238	12.6	100	--
		19 MAY 1983	--	415	--	--	--	--	--	--
		22 JUN 1983	1030	434	7.0	7.9	228	11.3	96	102
		06 JUL 1983	1025	429	6.8	7.9	213	12.3	100	107
		27 JUL 1983	1355	431	8.8	7.9	201	IM	--	97
		01 SEP 1983	1000	442	3.4	7.6	282	13.4	100	110
2	Tributary #2, above confluence with Richardson Clearwater Cr	27 OCT 1983	1105	--	-0.1	7.6	IM	13.9	99	110
		12 MAY 1983	--	78	--	--	--	--	--	--
		22 JUN 1983	1130	77	5.7	7.4	230	8.8	70	101
		06 JUL 1983	1205	72	6.7	7.5	225	10.0	84	109
		26 JUL 1983	1715	75	7.7	7.9	231	EM	--	105
		01 SEP 1983	1110	77	3.0	7.4	263	12.0	92	108
3a	Richardson Clearwater Cr below Tributary #2	27 OCT 1983	1200	76	0.9	7.3	273	13.0	95	98
		12 MAY 1983	1300	--	5.1	IM	249	10.2	82	--
3	Richardson Clearwater Cr above Tributary #2	12 MAY 1983	1315	218	--	--	--	--	--	--
		22 JUN 1983	1215	256	7.2	8.1	242	10.0	88	107
		06 JUL 1983	1130	259	6.6	7.9	227	10.8	91	121
		26 JUL 1983	1350	244	7.5	8.0	193	IM	--	102
		01 SEP 1983	1137	237	3.5	7.7	268	12.8	100	121
		27 OCT 1983	1205	238	0.8	7.6	276	13.2	96	111
4	Tributary #2, near headwaters	22 JUN 1983	1310	42	8.7	7.7	253	9.2	81	104
		06 JUL 1983	1255	43	8.9	8.0	241	10.7	95	116
		25 JUL 1983	1155	42	7.0	8.0	210	IM	--	113
		01 SEP 1983	1230	43	3.6	7.7	289	12.8	100	112
		27 OCT 1983	1355	43	1.0	7.6	274	13.0	96	102

-- = no measurement made
IM = instrument malfunction

Table 1 (con). Streamflow and on-site water quality measurements taken in the Richardson Clearwater Creek area, 1983

Site No.	Site	Date	Time	Streamflow (cfs)	Water Temperature (°C)	pH (units)	Specific Conductance (µS/cm @25°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (percent saturation)	Alkalinity (mg/L as CaCO ₃)
5	Tributary #1, near headwaters	12 MAY 1983	1130	12	5.1	7.8	268	7.4	59	—
		22 JUN 1983	—	17	8.7	7.7	264	5.2	55	123
		08 JUL 1983	1405	21	9.8	7.7	249	7.8	71	136
		25 JUL 1983	1335	23	8.3	7.9	209	IM	—	125
		01 SEP 1983	1318	19	4.0	7.7	276	9.8	78	134
		27 OCT 1983	1520	22	1.4	7.5	285	9.1	67	—
6	Richardson Clearwater Cr. above Tributary #1	12 MAY 1983	1216	—	5.3	IM	267	8.3	67	—
		22 JUN 1983	1440	79	7.4	7.4	260	8.5	73	112
		06 JUL 1983	1505	81	7.9	7.9	231	9.5	83	124
		26 JUL 1983	1020	82	4.3	7.8	239	IM	—	117
		01 SEP 1983	1417	84	3.3	7.9	279	12.1	95	125
		28 OCT 1983	1010	82	1.3	7.7	266	12.1	91	152
7	Tanana River Tributary	22 JUN 1983	1520	61	11.3	8.2	264	9.7	91	105
		06 JUL 1983	1645	66	12.4	8.0	257	10.9	100	121
		25 JUL 1983	1507	84	8.9	8.0	241	IM	—	116
		01 SEP 1983	1500	72	4.2	7.9	268	13.8	100	119
		28 OCT 1983	1120	59*	0.1	7.9	274	15.2	100	117
8	Delta Creek Tributary	22 JUN 1983	1600	3.7	7.2	7.7	280	9.4	81	102
		06 JUL 1983	1645	4.8	12.4	7.7	257	10.0	97	109
		25 JUL 1983	1100	7.8	8.2	7.8	248	10.7	94	107
		01 SEP 1983	1540	8.3	4.9	7.6	278	13.4	100	110
		28 OCT 1983	1220	4.3*	-0.1	7.3	269	14.3	100	108
9	Red-stain spring along Richardson Clearwater Cr	27 JUL 1983	0830	—	2.3	6.9	227	2.8	21	—
10	Big spring, at headwaters	25 JUL 1983	1845	12	1.9	7.5	212	IM	—	—

— = no measurement made
IM = instrument malfunction
* = streamflow measurement affected by shore ice

Table 2. Laboratory analyses of major inorganic constituents for surface waters in the Richardson Clearwater Creek area, 1983

Site No.	Date	Calcium, Dissolved (mg/L)	Magnesium, Dissolved (mg/L)	Sodium, Dissolved (mg/L)	Potassium, Dissolved (mg/L)	Chloride, Dissolved (mg/L)	Sulfate, Dissolved (mg/L)	Fluoride, Dissolved (mg/L)	Total Filterable Residue, at 180 °C (mg/L)	Hardness, Calculated (mg/L as CaCO ₃)
1	22 JUN 1983	33	6.9	3.4	3.3	<1.0	30	0.16	180	111
	06 JUL 1983	33	6.9	3.2	3.3	<1.0	28	0.13	180	111
	27 JUL 1983	38	7.3	3.2	2.5	<1.0	31	0.16	180	125
	01 SEP 1983	40	7.2	3.7	2.9	<1.0	30	0.13	140	129
	27 OCT 1983	41	7.5	3.1	3.7	<1.0	38	0.13	200	133
2	22 JUN 1983	35	6.5	2.1	3.6	<1.0	32	0.13	180	114
	06 JUL 1983	36	6.5	2.1	3.6	<1.0	33	0.12	180	117
	26 JUL 1983	43	6.9	2.2	2.5	<1.0	33	0.14	170	136
	01 SEP 1983	43	6.9	2.2	2.9	<1.0	30	0.12	160	136
	27 OCT 1983	41	6.9	2.2	3.7	<1.0	33	0.13	200	131
3	22 JUN 1983	34	7.2	4.1	2.6	<1.0	23	0.13	180	114
	06 JUL 1983	35	7.4	3.9	2.7	<1.0	24	0.13	180	118
	26 JUL 1983	41	8.0	3.9	2.0	<1.0	27	0.14	180	135
	01 SEP 1983	40	8.2	4.2	2.0	<1.0	25	0.12	150	134
	27 OCT 1983	41	7.9	4.1	2.5	<1.0	31	0.13	170	136
4	22 JUN 1983	38	6.2	2.9	3.3	<1.0	29	0.13	180	120
	06 JUL 1983	37	6.2	2.1	3.4	<1.0	29	0.13	170	118
	25 JUL 1983	45	6.7	2.0	2.4	<1.0	33	0.14	180	140
	01 SEP 1983	45	6.7	2.0	2.5	<1.0	30	0.11	150	140
	27 OCT 1983	43	6.7	2.1	2.8	<1.0	32	0.13	180	135
5	22 JUN 1983	39	7.4	3.7	2.3	<1.0	20	0.13	190	128
	06 JUL 1983	37	7.3	2.9	2.5	<1.0	20	0.13	180	122
	25 JUL 1983	42	7.7	3.0	2.0	<1.0	21	0.13	170	136
	01 SEP 1983	43	7.4	3.0	1.9	<1.0	20	0.11	140	138
	27 OCT 1983	44	8.1	3.0	2.0	<1.0	22	0.12	180	143

Sampling locations:

- Site 1: Richardson Clearwater Creek near Vanderbilt's Cabin
- Site 2: Tributary #2 above confluence with Richardson Clearwater Creek
- Site 3: Richardson Clearwater Creek above Tributary #2
- Site 4: Tributary #2 near headwaters
- Site 5: Tributary #1 near headwaters

Table 2 (con). Laboratory analyses of major inorganic constituents for surface waters in the Richardson Clearwater Creek area, 1983

Site No.	Date	Calcium, Dissolved (mg/L)	Magnesium, Dissolved (mg/L)	Sodium Dissolved (mg/L)	Potassium, Dissolved (mg/L)	Chloride, Dissolved (mg/L)	Sulfate, Dissolved (mg/L)	Fluoride, Dissolved (mg/L)	Total Filterable Residue, at 180 °C (mg/L)	Hardness, Calculated (mg/L as CaCO ₃)
6	22 JUN 1983	--	--	--	--	--	--	--	--	--
	06 JUL 1983	35	8.4	3.5	2.8	<1.0	26	0.12	180	122
	26 JUL 1983	42	8.7	3.6	1.9	<1.0	29	0.12	160	140
	01 SEP 1983	40	9.2	3.6	2.0	<1.0	27	0.11	140	138
	28 OCT 1983	41	9.1	4.1	2.1	<1.0	29	0.12	180	140
7	22 JUN 1983	34	8.5	4.0	2.8	<1.0	26	0.12	180	120
	06 JUL 1983	33	8.5	3.3	2.9	<1.0	25	0.12	170	117
	25 JUL 1983	39	8.7	3.4	2.4	<1.0	28	0.12	180	133
	01 SEP 1983	37	9.3	2.8	2.4	<1.0	26	0.11	150	131
	28 OCT 1983	39	8.8	3.5	2.1	<1.0	31	0.12	170	133
8	22 JUN 1983	38	6.3	1.6	4.7	<1.0	39	0.12	190	121
	06 JUL 1983	38	6.4	1.5	4.8	<1.0	34	0.12	180	121
	25 JUL 1983	44	8.7	1.0	3.8	<1.0	43	0.12	160	146
	01 SEP 1983	45	6.9	1.4	4.0	<1.0	42	0.10	160	141
	27 OCT 1983	46	7.0	1.7	4.3	<1.0	42	0.12	180	144
9	27 JUL 1983	31	7.4	2.0	3.3	<1.0	42	0.12	150	108

-- = no measurement made

Sampling locations:

Site 6: Richardson Clearwater Creek above Tributary #1

Site 7: Tanana River Tributary

Site 8: Delta Creek Tributary

Site 9: Red-atain spring along Richardson Clearwater Creek

Table 3. Laboratory analyses of nutrients for surface waters in the Richardson Clearwater Creek area, 1983

Site No.	Date	Nitrogen, nitrate plus nitrite, Dissolved ($\mu\text{g/L as N}$)	Nitrogen, ammonia, Total ($\mu\text{g/L as N}$)	Nitrogen, ammonia plus organic, Total ($\mu\text{g/L as N}$)	Phosphorus, Total ($\mu\text{g/L as P}$)	Phosphorus, Filterable Total ($\mu\text{g/L as P}$)	Phosphorus, Filterable Reactive* ($\mu\text{g/L as P}$)	Silicon, Reactive** (mg/L as Si)
1	22 JUN 1983	62	3	18	6	5	5	4.9
	08 JUL 1983	72	3	25	3	7	7	5.8
	27 JUL 1983	55	2	50	8	5	4	5.8
	01 SEP 1983	89	1	34	10	4	4	5.8
	27 OCT 1983	136	1	32	12	8	11	6.1
2	22 JUN 1983	95	1	25	7	4	4	4.9
	06 JUL 1983	91	1	36	8	6	6	5.6
	26 JUL 1983	66	2	43	7	5	4	5.5
	01 SEP 1983	89	<1	23	9	4	4	5.9
	27 OCT 1983	141	1	22	9	9	9	6.0
3	22 JUN 1983	65	2	33	12	9	10	4.9
	06 JUL 1983	68	3	31	13	10	8	5.7
	26 JUL 1983	65	2	30	13	9	6	5.9
	01 SEP 1983	79	2	27	12	7	8	5.7
	27 OCT 1983	109	1	46	9	12	14	5.9
4	22 JUN 1983	85	3	78	5	5	4	4.7
	06 JUL 1983	75	2	31	8	5	6	5.5
	25 JUL 1983	78	2	34	5	4	4	5.5
	01 SEP 1983	95	1	30	8	4	4	5.8
	27 OCT 1983	144	1	25	8	7	5	5.8
5	22 JUN 1983	66	1	60	10	6	7	5.1
	06 JUL 1983	63	1	43	10	7	7	6.0
	25 JUL 1983	57	<1	35	10	6	5	6.1
	01 SEP 1983	82	<1	25	9	7	7	6.2
	27 OCT 1983	99	1	34	9	10	7	6.1
6	22 JUN 1983	--	--	--	--	--	--	--
	06 JUL 1983	101	3	28	8	8	8	5.2
	26 JUL 1983	98	1	21	8	5	5	5.5
	01 SEP 1983	108	<1	28	7	5	5	5.2
	26 OCT 1983	158	<1	21	8	9	10	6.2
7	22 JUN 1983	116	2	43	9	3	3	4.4
	06 JUL 1983	121	3	45	10	4	4	5.0
	25 JUL 1983	154	2	35	11	4	4	5.4
	01 SEP 1983	140	<1	29	8	4	3	5.1
	26 OCT 1983	195	1	22	8	6	4	5.9
8	22 JUN 1983	85	1	55	10	2	2	4.2
	06 JUL 1983	52	2	55	5	2	2	4.4
	25 JUL 1983	64	1	55	6	3	3	4.7
	01 SEP 1983	54	1	51	4	2	2	4.4
	27 OCT 1983	129	3	36	5	5	3	5.1

* = filterable reactive phosphorus is soluble orthophosphate

** = reactive silicon is the inorganic form available for algal uptake

-- = no measurement made

Sampling locations:

Site 1: Richardson Clearwater Creek near Vanderbilt's Cabin

Site 2: Tributary #2 above confluence with Richardson Clearwater Creek

Site 3: Richardson Clearwater Creek above Tributary #2

Site 4: Tributary #2 near headwaters

Site 5: Tributary #1 near headwaters

Site 6: Richardson Clearwater Cr above Tributary #1

Site 7: Tanana River Tributary

Site 8: Delta Creek Tributary

Table 4. Laboratory analyses of total trace elements for surface waters in the Richardson Clearwater Creek area, July 6, 1983

Site No.	Aluminum, Total (µg/L)	Antimony, Total (µg/L)	Arsenic, Total (µg/L)	Barium, Total (µg/L)	Beryllium, Total (µg/L)	Boron, Total (µg/L)	Cadmium, Total (µg/L)	Chromium, Total (µg/L)	Copper, Total (µg/L)	Iron, Total (µg/L)
1	<75	<10	<2	150	<2	<50	<0.5	<5	<5	12
2	<75	<10	<2	160	<2	50	<0.5	<5	<5	9.8
3	<75	<10	<2	170	<2	<50	<0.5	<5	<5	9.3
4	<75	<10	<2	170	<2	<50	<0.5	<5	<5	15
5	<75	<10	<2	160	<2	<50	<0.5	<5	<5	13
6	<75	<10	<2	110	<2	65	<0.5	<5	<5	7.3
7	<75	<10	<2	81	<2	<50	<0.5	<5	<5	91
8	<75	<10	<2	94	<2	<50	<0.5	<5	<5	49
9	--	--	--	--	--	--	--	--	--	430*

-- = no measurement made
 * = sampled on July 27, 1983

Sampling locations:

Site 1: Richardson Clearwater Creek near Vanderbilt's Cabin
 Site 2: Tributary #2 above confluence with Richardson Clearwater Cr
 Site 3: Richardson Clearwater Creek above Tributary #2

Site 4: Tributary #2 near headwaters
 Site 5: Tributary #1 near headwaters
 Site 6: Richardson Clearwater Cr above Tributary #1

Site 7: Tanana River Tributary
 Site 8: Delta Creek Tributary
 Site 9: Spring along Richardson Clearwater Cr

Table 4 (con). Laboratory analyses of total trace elements for surface waters in the Richardson Clearwater Creek area, July 6, 1983

Site No.	Lead, Total (µg/L)	Manganese, Total (µg/L)	Mercury, Total (µg/L)	Nickel, Total (µg/L)	Selenium, Total (µg/L)	Silver, Total (µg/L)	Strontium, Total (µg/L)	Titanium, Total (µg/L)	Vanadium, Total (µg/L)	Zinc, Total (µg/L)
1	<2	<20	<0.05	<5	<2	<2	460	<100	<10	<2
2	<2	<20	<0.05	<5	<2	<2	430	<100	<10	<2
3	<2	<20	<0.05	<5	<2	<2	510	<100	<10	6
4	<2	<20	<0.05	<5	<2	<2	440	<100	<10	<2
5	<2	<20	<0.05	<5	<2	<2	570	<100	<10	<2
6	<2	<20	<0.05	<5	<2	<2	500	<100	<10	<2
7	<2	<20	<0.05	<5	<2	<2	470	<100	<10	<2
8	<2	<20	<0.05	<5	<2	<2	390	<100	<10	<2
9	--	<20*	--	--	--	--	--	--	--	--

-- = no measurement made
 * = sampled on July 27, 1983

Sampling locations:

Site 1: Richardson Clearwater Creek near Vanderbilt's Cabin
 Site 2: Tributary #2 above confluence with Richardson Clearwater Cr
 Site 3: Richardson Clearwater Creek above Tributary #2

Site 4: Tributary #2 near headwaters
 Site 5: Tributary #1 near headwaters
 Site 6: Richardson Clearwater Cr above Tributary #1

Site 7: Tanana River Tributary
 Site 8: Delta Creek Tributary
 Site 9: Spring along Richardson Clearwater Cr

Table 5. Laboratory analyses of organic compounds for surface waters in the Richardson Clearwater Creek area, 1983

Site No.	Date	Endrin ($\mu\text{g/L}$)	Lindane ($\mu\text{g/L}$)	Methoxychlor ($\mu\text{g/L}$)	Toxaphene ($\mu\text{g/L}$)	2,4-D ($\mu\text{g/L}$)	2,4,6-TP ($\mu\text{g/L}$)	Tannin and Lignin. (mg/L)
1	06 JUL 1983 01 SEP 1983	<0.005 B	<0.003 B	<0.02 B	<0.05 B	<0.05 B	<0.005 B	0.11 <0.10
2	06 JUL 1983 01 SEP 1983	<0.005 <0.005	<0.003 <0.003	<0.02 <0.05	<0.05 <0.05	<0.05 <0.04	<0.005 <0.005	0.16 <0.10
3	06 JUL 1983 01 SEP 1983	<0.005 <0.005	<0.003 <0.003	<0.02 <0.05	<0.05 <0.05	<0.05 <0.04	<0.005 <0.005	0.13 <0.10
4	06 JUL 1983 01 SEP 1983	B B	B B	B B	B B	B B	B B	0.18 0.11
5	06 JUL 1983 01 SEP 1983	B <0.005	B <0.003	B <0.05	B <0.05	B <0.04	B <0.005	0.19 <0.10
6	06 JUL 1983 01 SEP 1983	<0.005 <0.005	<0.003 <0.003	<0.02 <0.05	<0.05 <0.05	<0.05 <0.04	<0.005 <0.005	0.16 0.12
7	06 JUL 1983 25 JUL 1983 01 SEP 1983	<0.005 <0.005 <0.005	<0.003 <0.003 <0.003	<0.02 <0.02 <0.05	<0.05 <0.05 <0.05	<0.05 <0.05 <0.04	<0.005 <0.005 <0.005	0.10 -- <0.10
8	06 JUL 1983 01 SEP 1983	<0.005 <0.005	<0.003 <0.003	<0.02 <0.05	<0.05 <0.05	<0.05 <0.04	<0.005 <0.005	0.25 0.27

B = sample bottle broken in transit
-- = no measurement made

Sampling locations:

Site 1: Richardson Clearwater Creek near Vanderbilt's Cabin
Site 2: Tributary #2 above confluence with Richardson Clearwater Creek
Site 3: Richardson Clearwater Creek above Tributary #2
Site 4: Tributary #2 near headwaters
Site 5: Tributary #1 near headwaters
Site 6: Richardson Clearwater Creek above Tributary #1
Site 7: Tanana River Tributary
Site 8: Delta Creek Tributary

Table 6. Taxa and number of organisms per meter² of benthic invertebrates collected in Richardson Clearwater Creek, July 25-27, 1983
Sampling sites are shown in Figure 2. Mineral = Mineral Substrate; S Moss = Sparse Moss; D Moss = Dense Moss.

Taxon	Site											
	1		1a		3		4		5		6	
	Mineral	S Moss	Mineral	S Moss	Mineral	S Moss	Mineral	D Moss	Mineral	D Moss	Mineral	D Moss
Non-insect invertebrates												
Turbellaria (flatworms)	2490	1600	2070	1380	790	3840	570	480	1980	160	1190	19200
Nematoda (roundworms)	10	90	50	20	80	160	990	3360	790	160	80	2720
Oligochaeta (earthworms)	260	220	290	100	40	160	370	640	2780	160	250	3520
Hirudinea (leeches)	10	10										
Pelecypoda (clams)												
Hydracarina (water mites)	5350	10330	1510	1100	1940	10720	2200	4640	130	2560	3200	20000
Ostracoda (seed shrimp)	3650	690	1540	110	38120	8480	160	2400	3190	800	1270	22080
Copepoda						160		480		640		4160
Amphipoda (scuds)						160				960	260	
Ephemeroptera (mayflies)												
Baetis bicaudatus					2940	4960	220	800			2630	7040
Cinygmula sp.	940	1720	4180	4130	1370	1280	10				1070	800
Ephemerella daddsi	1930	1580	1020	1720	220	1280	200	160			700	
Plecoptera (stoneflies)	10	70	20				10					640
Chloroperiidae	10	180	240		60						10	
Perlidae	90	90	100		50	480		480	10	1120	150	960
Isoperla ebria												
Capniidae			10	10								
Zapada cinctipes	170	380	180	50	120	6880		1600			1920	9920
Zapata oregonensis	11960	13970	4780	2530	1570	6400	890	13280	30	480	4030	5600
Trichoptera (caddisflies)	10	10										
Limnephiliidae							10	160				
Apatania sp.	80	470	10	10			30					
Ecdiomyia sp.	210	360	60	30	90		230		290		10	480
Glossosoma sp.	770	410	960	1700	380	1120	560				30	
Rhyacophila vepulsa	10	30	30	60	10	160	950	1280	90		290	320
Diptera (true flies)												
Empididae							60					
Chelifera sp.	410	1580	580	580	150	480	2000	320	60		140	640
Chironomidae	14400	35900	6090	1980	9410	176160	16180	104000	10970	46720	17790	243840
Dicranota sp.	30	10		10	30	160	30		360	480		
Atherix sp.							10					
Palpomyia sp.			10						10			
Pericoma sp.		40		10								
Limnophora sp.		10									30	
Simulium sp.	40	170				1440	80	480			1790	160
Prosimulium sp.						320	20	2880				
Total organisms/meter ²	42840	69740	23660	15780	57370	224800	25810	137600	20690	54720	36840	342240
												51850

Table 7. Taxa and number of organisms per meter² of benthic invertebrates collected in Richardson Clearwater Creek, October 27-28, 1983
Sampling sites are shown in Figure 2. Mineral = Mineral Substrate; S Moss = Sparse Moss; D Moss = Dense Moss.

Taxon	Site									
	1		3		4		5		6	
	Mineral	S Moss	Mineral	D Moss	Mineral	D Moss	Mineral	D Moss	Mineral	D Moss
Non-insect invertebrates										
Turbellaria (flatworms)	4320	1540	2980	1900	9920	5180	12960	3420	11840	
Nematoda (roundworms)	210	610	70	330	5200	720	4640	110	3840	
Oligochaeta (earthworms)	600	570	1600	650	4720	1380	3040	1010	640	
Hydracarina (water mites)	800	990	3450	1600	17360	1140	2400	1300	13600	
Ostracoda (seed shrimp)	11980	5310	5540	30	4320	570	4960	900	32480	
Copepoda				30	560	190	10720	250	4960	
Amphipoda (scuds)										
Ephemeroptera (mayflies)										
<i>Baetis bicaudatus</i>	170	1530	7760	27710	219280	370	1440	47340	133600	
<i>Cinygmula</i> sp.	710	50	1380	3290	320	20		1750		
<i>Ephemerella dodeisi</i>	260	440	860	570	80	10		90		
Plecoptera (stoneflies)	280	70	570	17590	53200	370		1820	4800	
Chloroperiidae	20			20				30		
Perlidae	30	30	120		880	20	800	30		
Capniidae	750	30	40		1520	120		130		
<i>Zapada cinctipes</i>		10	140	150	2800			280	480	
<i>Zapata oregonensis</i>	1570	1840	3800	4710	14560	40	480	440	1440	
Trichoptera (stoneflies)				10						
Limnephilidae							160			
<i>Apatania</i> sp.	30									
<i>Ecdisionomyia</i> sp.	20	110	180	20	320	540		80	640	
<i>Glossosoma</i> sp.	110	20	350	2170		10		60		
<i>Rhyacophila vepulsa</i>			40	670	1200	10	160	60	960	
Diptera (true flies)										
<i>Chelifera</i> sp.	170	10	60	670	960	100			480	
<i>Clinocera</i> sp.	10									
Chironomidae	36120	29300	53820	16250	122160	6970	175840	9790	224000	
<i>Dicranota</i> sp.	10	20	20	30	1280	200	160			
<i>Hesperoconopa</i> sp.				100						
<i>Palpomyia</i> sp.			10	30	960		320			
<i>Pericoma</i> sp.					160		160	10		
<i>Limnophora</i> sp.				80						
<i>Simulium</i> sp.	10			6880	7680	20		580		
<i>Prosimulium</i> sp.				1500	4480			260	960	
Collembola (springtails)										
Isotomidae						10				
Total organisms/meter ²	58180	42480	82790	86910	474000	17990	218240	69740	434720	

Table 8. Taxonomic composition and mean number of organisms per meter² of benthic invertebrates collected in Richardson Clearwater Creek in mineral substrate and moss, July and October 1983. Mean number of organisms per meter² is based on benthic invertebrates collected at sites 3, 4, 5, and 6.

Taxonomic Group	July 1983		October 1983	
	Mineral substrate	Moss	Mineral substrate	Moss
Non-insect Invertebrates	15,100	28,320	7,430	40,450
Mayflies (Ephemeroptera)	2,340	4,080	20,790	91,180
Stoneflies (Plecoptera)	2,210	11,960	6,930	21,410
Caddisflies (Trichoptera)	740	880	940	1,000
True Flies (Diptera)	14,790	144,600	18,180	148,400
Mean number of organisms per meter ²	35,180	189,840	54,270	302,440

Fishery Data Series No. 94-49

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¹ This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-9, Job No. R-3-2(a).

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ABSTRACT

The proportion of Arctic grayling ≥ 270 millimeters fork length that emigrate from Caribou Creek after spawning to the Richardson Clearwater River, and are subsequently harvested the following year in the spring fishery in the Tanana River at Shaw Creek, was estimated for 1980 - 1988. On average, 67% of the population in the Richardson Clearwater River was comprised of Arctic grayling from Caribou Creek during the same year. On average, 48% of the pre-spawning aggregation of Arctic grayling in the Tanana River at Shaw Creek were from Caribou Creek one year previous. On average, 73% of post-spawning emigrants from Caribou Creek were from Caribou Creek one year previous. Although these results are not conclusive, they do indicate that a majority of Arctic grayling in the Richardson Clearwater River are from Caribou Creek. Similarly, a majority of Arctic grayling potentially harvested in the spring fishery at Shaw Creek could be from Caribou Creek, necessitating careful management of this fishery to prevent declines in abundance at the Richardson Clearwater River. Contributions of Arctic grayling from Caribou Creek back to the same creek one year later indicate that homing to this spawning area occurred. Future research should focus on quantification of contributions to the Richardson Clearwater River from streams other than Caribou Creek, and development of a management plan for Arctic grayling in this area of the Tanana River drainage that allows for sustainable harvest of Caribou Creek fish in the Shaw Creek and Richardson Clearwater River fisheries.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, contribution rate, abundance, spawning, migrations, mixed stock fisheries, Alaska, Shaw Creek, Richardson Clearwater River, Caribou Creek, Tanana River drainage.

INTRODUCTION

Riverine stocks of Arctic grayling *Thymallus arcticus*, hereafter referred to in the text as grayling, in the Tanana River drainage of interior Alaska commonly exhibit seasonal inter- and intrastream movements as a behavioral strategy for survival (Tack 1980). Through these movements, grayling utilize a variety of habitats for different life stages (Armstrong 1982). Some large rivers offer all habitat types for a particular grayling population and movements are predominantly intrastream (e.g., stocks in the Chena and Chatanika rivers). Populations inhabiting other large river systems, which seemingly afford all the necessary habitat, have a component of the population that exhibits interstream movements (e.g., the stocks in the Salcha and Goodpaster rivers (Ridder 1991)). Movements of grayling out of these rivers are typically to summer feeding (spring-fed systems) and overwintering areas (the Tanana River). Interstream movements are particularly important for grayling populations that utilize small drainages, in which habitat is seasonally unsuitable for all of the fish's life cycle. These populations typically use two or more river systems for spawning, rearing, and overwintering (e.g., stocks of Shaw Creek (Ridder 1991) and Piledriver Slough (Douglas Fleming, Alaska Department of Fish and Game, personal communication)). While the habitat of these various river systems are dramatically different from one another, each is optimum, or at least available, for utilization by grayling during a particular season or life stage. Interstream movements can confound stock assessment data, subsequently biasing estimates of dynamic rates, and reducing the efficacy of management actions. While movements of grayling in the middle Tanana River drainage have been identified (most recently by Ridder 1991), the magnitude of movements expressed in terms of contributions to receptor river systems have not been investigated prior to this study. This report provides estimates of the proportion of fish that are subsequently found in the Richardson Clearwater River during summer after emigrating from Caribou Creek after spawning that same year. In addition, estimates of contribution to the spring fishery at the mouth of Shaw Creek one year later are presented. Hopefully, these estimates will inspire further inquiries into interstream movements of grayling in the Tanana River drainage.

The specific objective of this report was to estimate the relative contribution of grayling greater than 269 mm fork length (FL) that were marked and released at Caribou Creek in year *i* and recovered in year *i* in the Richardson Clearwater River and in year *i*+1 in Shaw Creek during 1980 through 1988. Since the number of fish marked and released in Caribou Creek varied by year, estimated contribution rates could be severely biased if the proportion of marks in the emigrating population were not constant among years. Thus to estimate the yearly proportion of marked fish, annual abundance estimates were developed for the Caribou Creek population.

Studies of the Delta and Richardson Clearwater rivers (Figure 1) have shown that few, if any, grayling spawn or overwinter in these streams (Reed 1961, Roguski and Shallock 1967, Tack 1980, Peckham and Ridder 1979). Yet both rivers offer popular fisheries for large grayling during summer months. Immature (< 270 mm FL) grayling immigrate to the Delta and Richardson Clearwater rivers as early as April, followed by spent adults ($\geq$ 270 mm FL) in May and June (Ridder 1981 - 1985). Grayling are nearly absent in these

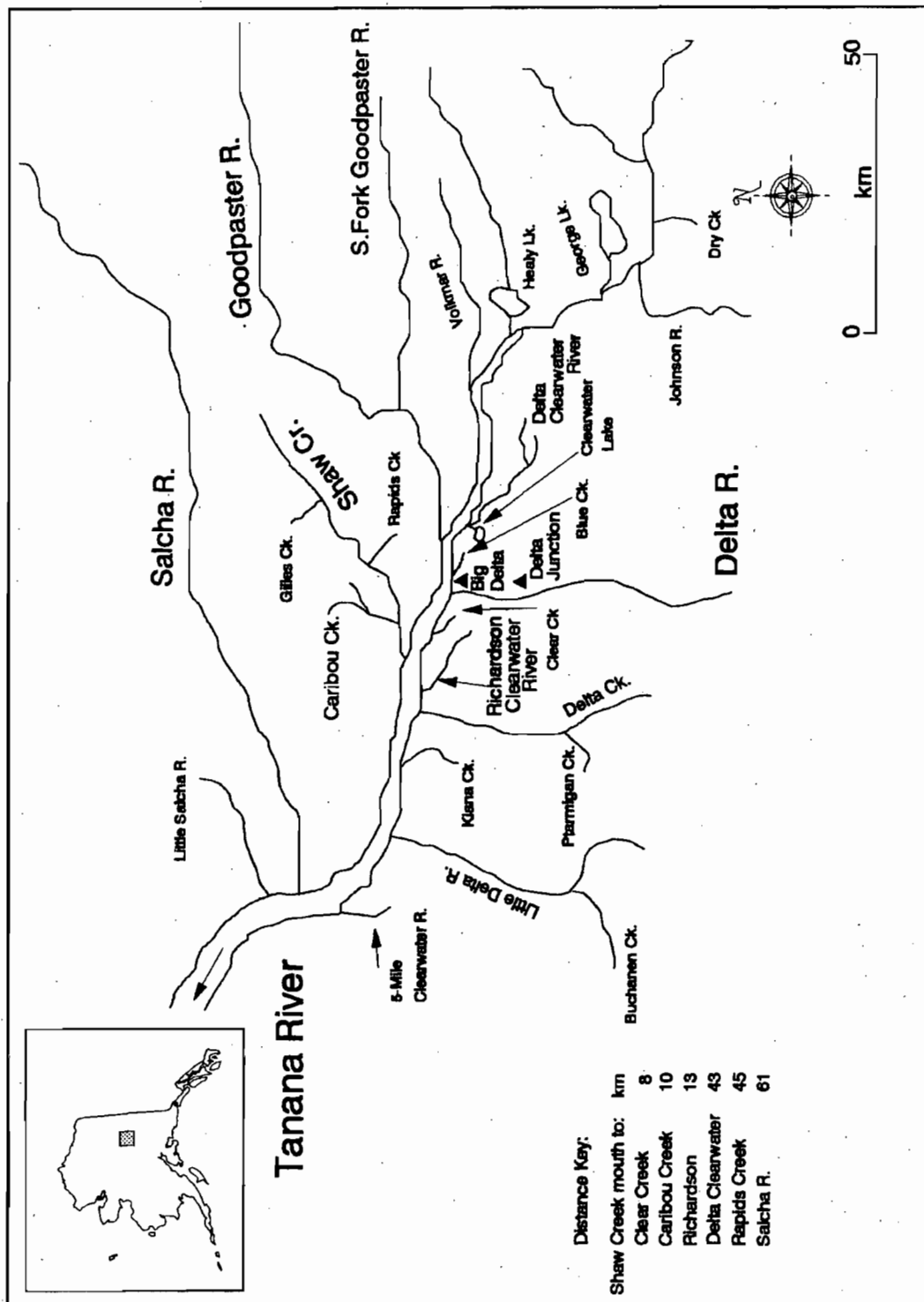


Figure 1. Map of the Middle Tanana drainage and sampling locations.

streams from October through March. Ridder (1991) documented the annual return (i.e. homing) of grayling to these summer feeding areas. Reed (1961) and Tack (1980) suggested that the use of these streams as summer feeding areas is a result of a mix of movements of immature and adult grayling from overwintering and spawning areas. Grayling tagged in the Goodpaster, Salcha, and Volkmar rivers and Shaw Creek (Figure 1), which they referred to as donor streams, have been commonly recovered in the spring-fed systems (Ridder 1991). The individual importance of these donor streams to the level of abundance in these spring-fed systems was not known. Investigations of likely donor (spawning) streams were initiated in the middle Tanana River drainage surrounding Delta Junction (Figure 1) in 1979 and continued through 1987 (Peckham and Ridder 1980; Ridder 1981, 1982, 1983, 1984, 1985, 1989, and 1991; Holmes et al. 1986; Clark and Ridder 1987, 1988). These investigations focused predominantly on Caribou Creek, a tributary of Shaw Creek. Additionally the studies included yearly monitoring of population composition and abundance in the Richardson Clearwater River and of grayling harvest, fishing effort, and composition of the harvest in the spring fishery at Shaw Creek.

Shaw and Caribou Creeks

Shaw Creek is a tannic stained, bog-fed stream, 112 km in length and located 32 km northwest of Delta Junction (Figure 1). By midwinter, the creek freezes solid in shallow areas, and upriver pools become anoxic. Two of six tributaries to Shaw Creek are known to provide spawning habitat for grayling. Between 1979 and 1988, 8,000 grayling were tagged and released in the Shaw Creek drainage. The majority were tagged in June as they emigrated from Caribou Creek, a major tributary of Shaw Creek, after spawning. Angler returns of 780 of these tags came from six recreational fisheries within 72 km of the mouth of Shaw Creek, ranging from the Little Salcha River downstream to the Delta Clearwater River upstream (Figure 1, Ridder 1991). Based on limited tag recapture-to-catch ratios, Ridder (1985) estimated that fish from Caribou Creek accounted for 30 to 50% of grayling abundance in the Richardson Clearwater River.

The recreational fishery at Shaw Creek occurred in April over a span of 4 to 11 days¹. This brief and concentrated fishery targeted grayling congregating in the Tanana River, adjacent to the mouth of Shaw Creek, awaiting ice break-up. Creel surveys conducted from 1981 through 1986 found that harvests consisted of greater than 80% mature, pre-spawning grayling and ranged from 4,343 fish in 1981 to 270 fish in 1986 (Table 1, Figure 2, Appendices A1, A2.1, and A2.2). Annual harvests of grayling for the entire fishing season ranged from 2,584 fish in 1985 to 111 fish in 1992 (Mills 1984-1994; Table 1). From 1983 through 1986, the harvest during April accounted for an average of 58% of the total annual harvest. Annual fishing effort for all species (small fisheries also exist for burbot, *Lota lota*, and northern pike, *Esox lucius*) has ranged from 2,495 angler-days in 1983 to 488 angler-days in 1989 and has averaged 1,203 angler-days (Table 1). The majority of angling effort occurs in the lower 1.6 km of Shaw Creek.

¹ The spring fishery was closed by regulation (1 April through the first Saturday in June) beginning in 1987. Emergency Order closures were in effect in 1981 (23 April - 15 May) and 1985 (1 - 15 May).

Table 1. Estimated Arctic grayling abundance, harvest, and angling effort in Shaw Creek, 1981 - 1993.

Year	Abundance ^a	SE ^b	Harvest		Effort	
			Season ^c	Spring ^d	Season ^{c,e}	Spring ^d
1980	NA ^f	---	NA	NA	NA	NA
1981	27,509	7,708	NA	4,343 ^g	NA	966
1982	20,297	4,863	NA	979	NA	555
1983	12,267	3,010	2,297	1,864	2,495	874
1984	13,994	5,767	2,570	913	2,195	1,095
1985	14,812	7,370	2,584	1,533 ^g	1,248	372
1986	78,596	50,021	505	270	2,003	479
1987 ^h	6,080	3,596	567	closed	797	closed
1988	NA	---	873	"	564	"
1989	NA	---	411	"	488	"
1990	NA	---	203	"	1,452	"
1991	NA	---	453	"	773	"
1992	NA	---	111	"	491	"
1993	NA	---	383	"	732	"
Averages	NA	---	996	1,650	1,203	724

^a Abundances estimated from the Jolly-Seber model for grayling ≥ 200 mm FL in 1981 - 1986 (Clark and Ridder 1988) and for grayling ≥ 270 mm FL in 1987 (Ridder 1989).

^b SE = standard error of the abundance estimate.

^c Data sources: for 1983-1987 and 1989-1993, Mills (1984-1994); for other years, Mills (unpubl.).

^d Data sources for spring fisheries: 1981-1984, Ridder (1982-1985); 1985, Holmes et al. (1986); 1986, Clark and Ridder (1987). Effort pertains to grayling fishery.

^e Effort is the number of angler-days expended for all fish species.

^f NA = data is either not available, not collected, or not applicable.

^g Spring fishery closed by Emergency Order: 23 April - 15 May 1981; 1 - 15 May 1985.

^h Fishing regulations changed from no size limit to a 12" minimum size limit and from no closed season to a spring closure (1 April through the first Saturday in June).

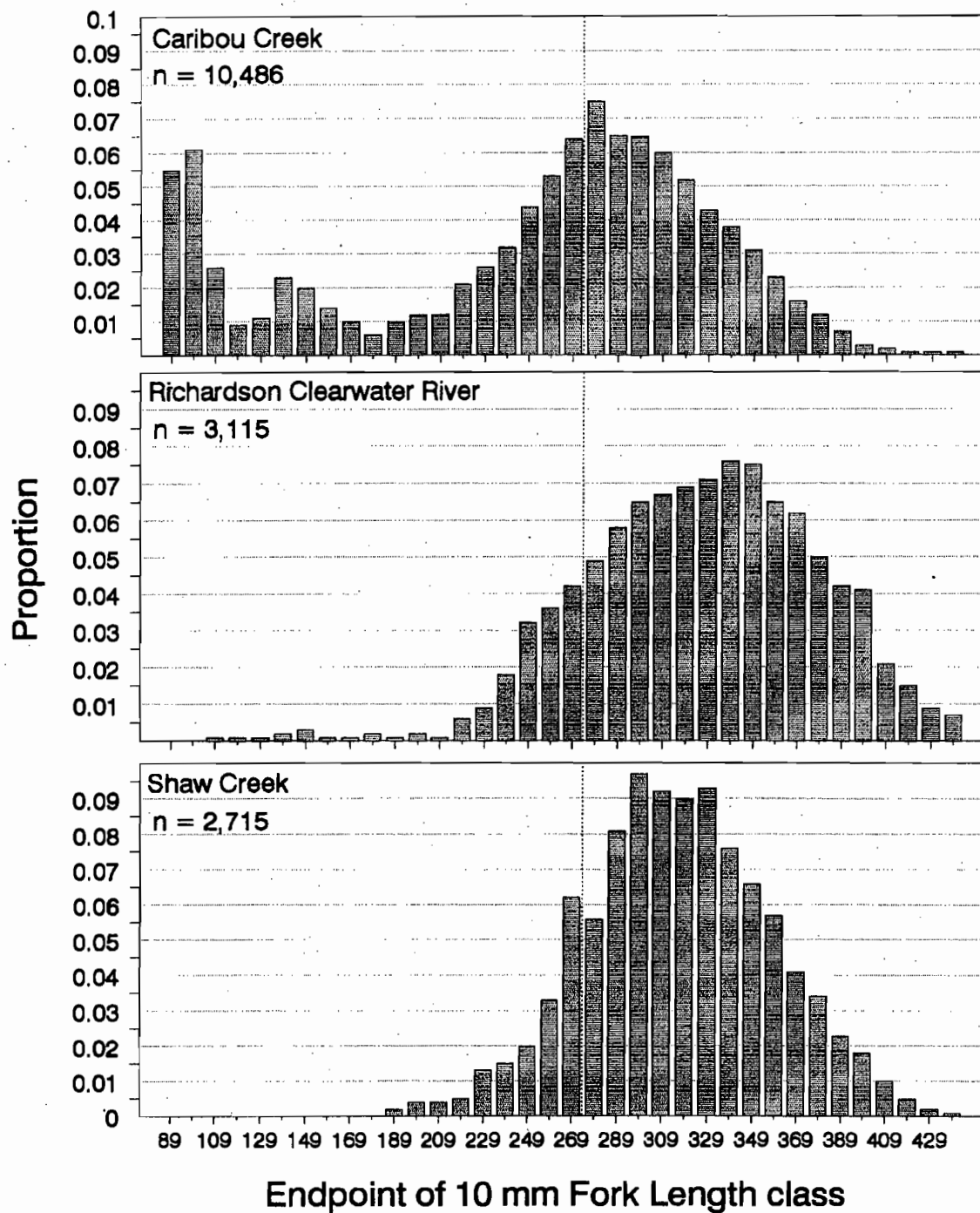


Figure 2. Length frequencies for all Arctic grayling sampled during the June outmigration from Caribou Creek 1980 - 1987, in April at the mouth of Shaw Creek 1981 - 1988, and in July in the Richardson Clearwater River 1980 - 1988.

Estimates of grayling abundance adjacent to the mouth of Shaw Creek have ranged from 6,080 fish (SE = 3,596) ≥ 270 mm FL in 1987 to 78,596 fish (SE = 50,021) ≥ 200 mm FL in 1986 (Table 1). These abundance estimates were considered biased high due to mixing of stocks in the Tanana River and to lack of recoveries of small grayling (Clark and Ridder 1988).

Caribou Creek, approximately 26 km long, is located 10 km upstream of the mouth of Shaw Creek. Caribou Creek is small, averaging 6 m wide with an average depth and discharge of 46 cm and 0.52 m³/s, respectively, at the confluence with Shaw Creek. Harvest and angling effort in Caribou Creek is negligible. From 1980 through 1987, grayling were sampled each June as they emigrated from Caribou Creek. The size composition of the emigration included all sizes (and ages) of grayling except fish between 120 and 230 mm FL (Figure 2, Appendices B1.1 and B1.2). Mature and spent grayling comprised from 25 to 70% of the emigration. The majority of grayling ≥ 200 mm FL were tagged with anchor tags. While recoveries of these tags were subsequently made in six other river systems, same year recoveries of an immature fish and one spent adult were also made in June in Gilles Creek, a Shaw Creek tributary 70 km above Caribou Creek, and indicated that not all Caribou Creek adult emigrants leave the drainage (Ridder 1991).

Richardson Clearwater River

The Richardson Clearwater River arises from springs located on the southern floodplain of the Tanana River, 3 km west of Big Delta (Figure 1). The river is 19 km in length and enters the Tanana River 13 km downstream of Shaw Creek. As with other spring-fed systems in the drainage, most notably the Delta Clearwater River, the Richardson Clearwater River can be characterized by its clear and cold water, stable discharge (3 - 7°C and 8.5 - 11.3 m³/s, respectively). Access is limited to riverboats via the Tanana River and to small float planes on the Richardson Clearwater. The nearest boat launch is at Shaw Creek. There are 21 cabins on the river. The river supports a recreational fishery for grayling and little angling effort is directed at other available species (round whitefish, *Prosopium cylindraceum*, coho salmon, *Oncorhynchus kisutch*, and chum salmon, *Oncorhynchus keta*). The grayling fishery can be characterized as "blue ribbon" due to the availability of large fish, high density of fish, esthetic qualities of the river, and lack of direct road access. From 1981 through 1993, harvests have ranged from 2,822 to 251 grayling and averaged 1,048 (Table 2). Angling effort has ranged from 1,365 to 255 angler-days with an average of 934 (Table 2). The majority of angling occurs in the lower 9.6 km of river.

Catch per unit effort (CPUE) statistics and age, length, and weight samples were taken annually in the Richardson Clearwater River from 1976 through 1988. From 1980 through 1988, sample methods, timing, and area were held constant and occurred in July in three contiguous study sections. CPUE statistics were considered a relative index of the population's abundance and ranged from 324 grayling-per-electrofishing-pass in 1982 to 65 grayling-per-electrofishing-pass in 1986 (Table 2). These indices showed a high correlation to abundance estimates from mark-recapture experiments performed in the upper study section (Section 3), from 1982 through 1988 and in the combined study area (whole river) from 1985 through 1988 ($r = 0.98$ and 0.91 , respectively, Ridder 1989).

Table 2. Estimated Arctic grayling abundance (relative and absolute^a), harvest, and angling effort in the Richardson Clearwater River, July, 1980 - 1993.

Year	Whole River					Section 3 ^b			
	Abundance			Fishery ^c		Abundance			
	Relative	Absolute	95% CI	Harvest	Effort ^d	Relative	Absolute	95% CI	
1980	170	NA ^e	---	NA	NA	NA	NA	---	
1981	167	NA	---	1,562	916	NA	NA	---	
1982	324	NA	---	1,729	1,365	203	5,340	3,028 - 10,680	
1983	220	NA	---	2,822	1,349	103	1,792	1,016 - 3,460	
1984	138	NA	---	1,376	1,080	101	2,076	1,148 - 4,520	
1985	142	3,114	1,939 - 4,289	798	902	83	1,610	974 - 2,876	
1986	65	1,418	786 - 2,837	827	596	30	468	191 - 1,170	
1987 ^f	113	2,775 ^g	1,653 - 3,896	251	724	69	1,368 ^h	476 - 2,260	
1988	187	4,599 ^g	3,127 - 6,071	509	255	127	2,193 ^h	1,274 - 3,112	
1989	NA	NA	---	972	1,364	NA	NA	---	
1990	NA	NA	---	523	518	NA	NA	---	
1991	NA	NA	---	1,419	1,199	NA	NA	---	
1992	NA	NA	---	436	1,355	NA	NA	---	
1993	NA	NA	---	405	514	NA	NA	---	
Averages	170	NA	---	1,048	934	102	NA	---	

^a Data is from Ridder 1989. Relative abundance is the total catch of Arctic grayling made in the first electrofishing run through a section (river). Absolute abundance is a mark-recapture (Petersen) estimate.

^b Section 3 is the upper 3.2 km of the navigable portion of the Richardson Clearwater River.

^c Data sources: for 1986 and 1989-1993, Mills (1984-1994); for other years, Mills (unpubl.).

^d Effort is the number of angler-days expended for all fish species.

^e NA = data is either not available, not collected, or not applicable.

^f Fishing regulations changed from no size limit to a 12" minimum size limit and from no closed season to a spring closure (1 April though the first Saturday in June).

^g Estimate is for fish greater than 249 mm FL.

Whole river abundance estimates ranged from 4,599 grayling in 1988 to 1,418 grayling in 1986 (Table 2).

The sampled population is predominantly comprised of adult and immature grayling that migrate into the river beginning in mid-May from spawning areas in other rivers (Appendices C1.1 and C1.2). Three of these spawning areas have been documented from tagging studies: Caribou and Rapids Creek in the Shaw Creek drainage and the Goodpaster River (Ridder 1991). The average size of grayling in the Richardson Clearwater River is skewed towards larger fish in relation to fish sampled at Shaw Creek (Figure 2).

METHODS

Data Collection

The data in this report represents a portion of that collected in the aforementioned studies of the Richardson Clearwater River and Shaw and Caribou creeks over a nine year period, 1980 through 1988. These studies employed relatively consistent methodologies and objectives. The original data, which have been archived in standardized ASCII databases (Ridder 1991; Appendix D1), were truncated for this report to include only fish greater than 269 mm FL. Truncation was done for the following reasons:

- 1) movements of fish of different maturity (fry, juvenile, and adult) may differ (Tack 1980, Ridder 1991);
- 2) previous attempts at abundance estimation at Shaw and Caribou creeks for fish greater than 200 mm FL were severely biased due to lack of recaptures of smaller sized fish (Clark and Ridder 1988, Ridder 1989);
- 3) the length at maturity for 50% of the population was 279 mm FL (Clark 1992);
- 4) fisheries in the Richardson Clearwater River and Shaw Creek predominantly catch fish greater than 269 mm FL (Holmes et al. 1986; Ridder 1989);
- 5) regulations enacted in 1987 limited harvests to fish greater than 269 mm FL in Shaw Creek and the Richardson Clearwater River; and,
- 6) Caribou Creek sampling occurred during a post-spawning migration that included adult fish.

After truncation, tagging histories, stratified by year of release, were constructed for each marked fish released at Caribou Creek. For each year, recaptures of these fish were tabulated for each sample specific to year of release and recapture location (Appendices A, B, and C). This study treats both newly tagged and previously tagged fish released in any year as members of one cohort that is the population emigrating from Caribou Creek in year *i*.

Caribou Creek:

Grayling were captured with a fyke trap in 1980 and a weir in 1981 through 1987. Each gear type blocked the creek to the majority of migrants except during periods of high water. During low water conditions, seining was sometimes employed to drive grayling into the downstream trap. All gear types used 9.5 mm meshes. Both immigrating and emigrating fish were captured in 1980 through 1982 while only emigrants were captured from 1983 to 1987. For the former three years, the small number of immigrants greater than 269 mm FL ($n = 40, 10, \text{ and } 71$, respectively) are included in this study under the assumption that they would emigrate out of the creek after spawning. Recaptures of fish tagged during immigration were commonly made during the emigration in 1980 through 1982 (Ridder 1983). In all years, with the following exceptions, sampling for emigrants was continuous and scheduled for the first three weeks of June (Table 1). In 1983, the weir was closed for a two day period (6 through 8 June) and in 1984 and 1985 sampling was curtailed early due to high water flooding the weir. Based on observations from 1980 through 1982, in which large numbers of grayling remained above the weir at the end of sampling (Ridder 1982) and the high water events, it is assumed that in no year were all emigrating fish sampled.

Richardson Clearwater River:

Grayling were collected in July with an electrofishing boat using an AC pulsator from 1980 to 1986 and a DC pulsator in 1987 and 1988 (Ridder 1989). Sampling consisted of one downstream pass through the lower 13 km of the river (1 unit of effort). The total catch of grayling per downstream pass (CPUE) was used as an annual index of relative abundance. Additional electrofishing and hook and line sampling were used in mark/recapture (M/R) experiments in the upper 3.2 km in 1982 through 1984 and in the entire 13 km reach in 1985 through 1988. The additional M/R samples in 1982 and 1983, which included recaptures of tagged Caribou Creek grayling, were not used in this report since lengths of these fish were not recorded.

Shaw Creek and Tanana River:

In the Tanana River adjacent to the mouth of Shaw Creek, grayling were sampled from angler creels during the April fishery in 1981 through 1986 (Clark and Ridder 1987). Sampling was done in conjunction with a creel survey for a single exit fishery. In all years except 1981, the grayling kept by interviewed anglers was measured for length and tag recaptures noted. In 1981, 181 of the sampled harvest of 471 fish were not measured unless they had tags. The tagged fish were assumed to have the same length frequency as the sampled fish. With the fishery closed by regulation beginning in 1987, a pulsed-DC electrofishing boat was used during the same time period in 1987 and 1988 to gather samples for continuation of the Jolly-Seber estimator for Shaw Creek (see Clark and Ridder 1988; Ridder 1989).

Regardless of location and capture method, with the exceptions noted above, all captured grayling were measured to the nearest 1 mm FL. In Caribou Creek (1980 through 1982 and 1984 through 1987) and Shaw Creek (1987 and 1988), grayling greater than 200 mm FL were tagged with an individually-numbered Floy internal anchor tag. A double finclip was used as the primary mark in 1983 at Caribou Creek. Secondary marks (finclips) were also used in 1982 at Caribou

Creek. Date, location, fork length, finclip, tag number, and gear type were recorded for individual fish at all locations.

Estimation of Abundance in Caribou Creek

Abundance of grayling (≥ 270 mm FL) in Caribou Creek was estimated for the years 1980 through 1986 using the modified Petersen formula of Robson and Flick (1965) that culls recruitment between two sample events. Sample events occurred at one year intervals. A low number of recaptures during sampling in 1985 prevented calculation of an abundance estimate for 1984.

Since the Petersen estimator allows for recruitment or mortality between sample events but not both, the nonparametric method of testing and culling growth recruitment was used (Robson and Flick 1965). The Robson-Flick technique uses the range of unique lengths (cells) of recaptured fish from the mark event as boundaries for a length frequency distribution of unmarked fish in the recapture event. By both plotting the running averages of these length frequencies (Appendices E1 through E6) and performing a series of hypothesis tests in program FLICK (Bernard and Hansen 1992), the cell (length range) where recruitment is no longer significant was determined. The running average of unmarked fish in this cell was used in place of the catch component of the Petersen estimator resulting in an abundance estimate applicable to the year of the first (mark) event.

The necessary assumptions for a reliable abundance estimate are (from Seber 1982):

- 1) all grayling in the target population have the same probability of being caught in the i th sample;
- 2) all grayling in the target population have the same probability of surviving from the i th to the $(i+1)$ th sample;
- 3) all grayling caught in the i th sample have the same probability of being marked and released alive into the population;
- 4) all marked grayling do not lose their marks and all marks are reported on recovery; and,
- 5) all samples are instantaneous and each release is made immediately after the sample.

Assumptions 1 and 2 are central to reliable parameter estimation. Differences in capture probability can be related to size selective sampling due to either the availability of different sized fish (behavioral differences) or gear selectivity. Yet, if marked fish mix completely with unmarked fish between the i th and $i+1$ sample, assumption 1 can be violated without biasing the estimate. The year interval between events and the fact that sampling occurred on a population in transit would appear to ensure mixing. However, changes in the probability of capture cannot be separated from changes in survival rate. So, these assumptions were subjected to testing as described below.

The Robson-Flick model provides unbiased estimates of abundance when the first event sample is not size selective (Bernard and Hansen 1992). To test this assumption, two Kolmogorov-Smirnov (KS) two-sample tests were performed to compare length distributions of marked fish from the first event versus unmarked fish captured in the second event and of marked fish versus the recaptured fish in the second event to evaluate size selectivity. To alleviate the problem of growth between events, lengths at tagging for recaptured fish were used in the first KS test. Plots of the KS tests are found in Appendices E1 through E6. The first KS test provided an inference whether bias may exist in the two events. The second KS test provided an inference whether the bias occurred during the second event. If the first test was significant and the second was not, then the recapture event was unbiased while the first event was biased. With the Robson-Flick estimator requiring an unbiased first event, an insignificant test between marked and unmarked fish was mandatory.

Assumption 3 was assumed to be valid for all of the seven years it was used, excepting the 1983 and 1984 samples. In 1983 at Caribou Creek, all fish greater than 199 mm FL were released with a double finclip but were not tagged. In the recapture event one year later, growth of these fish complicated the decision of which finclipped recaptures were in the 1983 target population (≥ 270 mm FL) and which recaptured fish were not. A mean annual growth increment was determined through comparisons and hypotheses testing between the finclipped recaptures and the tagged recaptures from 1981 through 1983 (Appendix B2). A growth increment of 15 mm was chosen based on similarities between the finclipped recaptures and the recaptures of 132 fish tagged in 1982. This growth increment was added to the minimum size of the target population, 270 mm, and all finclipped recaptures that were ≥ 285 mm FL in 1984 were considered recaptures. These finclipped recaptures were used in the 1983 Robson-Flick model. In regards to the 1984 sample, 49% of the catch were tagged and released (308 marks released from a catch of 632, Appendix B3). The Robson-Flick model could not be used with the 1984 data due to insufficient recaptures ($n = 3$) in 1985.

Assumption 4 was violated since double marking was not employed in all but the 1982 sample. Mark loss (tag shedding) has been estimated for grayling at an annual rate of 8% in Caribou Creek (Ridder 1984). The failure to acknowledge marked fish would bias abundance estimates high. To estimate this bias, the Robson-Flick model was applied to the 1982 data with and without accounting for tag loss. With tag losses ($n = 13$) included in the recaptures provided that they were at least 285 mm FL, the 1982 abundance was 6,134 with a standard error (SE) of 653 and a coefficient of variation (CV) of 10.6%. Without the accounting for tag loss, the abundance was 6,495 with a SE of 666 and CV of 10.3%. Thus a failure to detect marks in 1982 resulted in an overall 6% bias in estimates of abundance, proportion marked, and contributions to Shaw Creek and the Richardson Clearwater River. This bias was considered insignificant and an adjustment to number of recaptures was not attempted for any estimate.

While sample events ranged from 8 to 25 days and averaged 15 days (Appendix B3), assumption 5 was considered met. The violation of the assumption would introduce bias from differential mortality among those fish

tagged at the onset of sampling and those tagged at the end of sampling. This bias is considered insignificant.

During data analysis it was necessary to partition abundance estimates from the three waters to fish greater than 269. The abundance of this population component was estimated with:

$$\hat{N}_a = \hat{p}_a \hat{N} \quad (1)$$

where:

$\hat{N}_a$ = the estimated abundance of grayling of component a; and,

$\hat{p}_a$ = the proportion of component a from equation 9.

The variance of the product $\hat{N}_a$ was estimated using Goodman's (1960) exact variance of a product:

$$V[\hat{N}_a] = \hat{N}^2 V(\hat{p}_a) + \hat{p}_a^2 V(\hat{N}) - V(\hat{p}_a) V(\hat{N}) \quad (2)$$

Estimation of Contribution Rate

Proportional estimates of marked grayling (≥ 270 mm FL) in each year (i) for the emigrating adult population at Caribou Creek were used in conjunction with the proportions of these marked fish in samples (≥ 270 mm FL) from the Richardson Clearwater River in year i+h and from Caribou and Shaw creeks in year i+h to estimate the contribution of Caribou Creek fish outmigrating in year i over a series of years.

From abundance estimates, the proportion of fish marked in Caribou Creek in year i was estimated by:

$$\hat{p}_t = \frac{\hat{m}_t}{\hat{N}_t} \quad (3)$$

where:

$\hat{p}_t$ = the estimated proportion of grayling marked in Caribou Creek;

$\hat{m}_t$ = the number of unique grayling marked in Caribou Creek; and,

$\hat{N}_t$ = the abundance of grayling in Caribou Creek.

The variance of p_t was approximated by:

$$\hat{V}[\hat{p}_t] \approx \frac{\hat{m}_t^2 \hat{V}[\hat{N}_t]}{\hat{N}_t^4} \quad (4)$$

where: $\hat{V}[\hat{N}_t]$ = the variance of abundance of grayling in Caribou Creek.

Upon recovery, the proportion of marked fish in the Shaw Creek spring fishery, the Caribou Creek out-migration, and the Richardson Clearwater River was the ratio of marks to those examined for marks:

$$\hat{p}_m = \frac{c_m}{n_m} \quad (5)$$

where: $\hat{p}_m$ = the estimated proportion of grayling marked in Caribou Creek and recovered in area m ;
 c_m = the number of marked grayling from Caribou Creek that are recovered in area m ; and,
 n_m = the number of grayling examined for marks in area m in year $i+h$.

The variance of p_m was the variance of a binomial, or:

$$\hat{V}[\hat{p}_m] = \frac{\hat{p}_m (1 - \hat{p}_m)}{n - 1} \quad (6)$$

The contribution rate of fish from Caribou Creek that was relative to the adult population in Caribou and Shaw creeks and the Richardson Clearwater River was estimated with:

$$\hat{p}_c = \frac{\hat{p}_m}{\hat{p}_t} \quad (7)$$

Variance of the contribution rate was approximated with the Delta method (Seber 1982; ignoring the hat symbols, all quantities were estimated)

$$\hat{V}[\hat{p}_c] \approx \left[\frac{\hat{p}_m}{\hat{p}_t} \right]^2 \left[\frac{\hat{V}[\hat{p}_m]}{\hat{p}_m^2} + \frac{\hat{V}[\hat{p}_t]}{\hat{p}_t^2} \right] \quad (8)$$

Contribution estimates were produced not only for the same year but also for successive years to investigate delayed contribution or potential bias in contributions over time.

RESULTS AND DISCUSSION

Abundance in Caribou Creek

Of 4,916 grayling captured, 3,967 fish were marked and released with tags between 1980 and 1987 in Caribou Creek (from Appendix B3). An additional 490 fish in 1983 were marked and released with finclips. From those fish marked and released, 368 were recaptured from 1981 through 1987 and used in the Robson-Flick model (Table 3). The model produced six abundance estimates from the eight years of Caribou Creek data. No estimate was generated for the 1984 population because the three recaptures prevented the culling of recruitment. Abundance estimates ranged from 9,820 grayling (SE = 2,058) in 1980 to 4,877 grayling (SE = 943) in 1986 with coefficients of variation ranging from 9.4% in 1983 to 21.6% in 1985 (Table 3). While differences in capture probability due to size selectivity were found to have occurred during the first event in four of the six estimates (Table 4, Appendices E1-E6) and implied a bias in the abundance estimates, the bias most likely resulted from variable recruitment between events and not gear selectivity. The second KS test between the two events, comparing the lengths of fish marked to those recaptured in the second event, found no differences in four of the six estimates and inferred that no bias was present in the second event. Since this second event was also the first event for the next abundance experiment, the case for a non-gear-selectivity related cause is strongly supported. Since the Robson-Flick model was developed to accommodate recruitment, the abundance estimates for 1980 through 1982 and for 1986 are considered unbiased.

The 1983 and 1985 estimates of abundance appear to be biased. The statistical differences in the KS test between marks and recaptures for the 1983 estimate and functional differences seen for the 1985 estimate (Table 4, Appendices E4 and E5) inferred that some bias was present in the estimates. For both data sets, there were less recaptures of smaller sized fish than expected. There was significant difference in the probability of capture between fish of lengths 270 through 329 mm and those ≥ 330 mm: for 1983, $p = 0.10$ and $p = 0.19$, respectively; $\chi^2 = 10.00$, $df = 1$, $p = 0.0016$; for 1985, $p = 0.04$ and $p = 0.21$, respectively; $\chi^2 = 9.02$, $df = 1$, $p = 0.0027$). The similarity and equal distance between the distribution curves for the 1984 (Appendix E4) data suggests that the growth adjustment applied to recaptured fish (see Methods) could be the cause of the bias. Holmes et al. (1986) reported that the 1985 sample was distinctly different in regards to total catch and tag recapture rates when compared to previous years (Appendix B4) and noted that grayling were observed in a normally marshy area of the drainage (in 1985 it was a navigable lake) 3.2 km below Caribou Creek. They suggested that persistent high water during sampling displaced grayling from Caribou Creek in 1985.

Table 3. Summary of statistics and parameter estimates from the Robson-Flick model for abundance estimation of Arctic grayling (~ 270 mm FL) in Caribou Creek, 1980 -1986.

Year(i)	M(i)	C(i+1) ^c	R(i+1)	R/M ^d	R/C ^d	Robson-Flick statistics ^a					N(i)	95% confidence interval ^b	
						R' length	r	r+1	u(r+1)	Sum		cv%	z
1980	900	641	19	0.02	0.03	18	312	7	8	9.9	688.9	2,058	21.0%
1981	635	1,406	105	0.17	0.08	55	322	31	32	14.4	2,782.2	1,370	14.0%
1982	1,387	779	132	0.10	0.17	83	321	34	35	3.7	564.9	666	10.3%
1983	679	632	78	0.12	0.12	53	305	8	9	8.1	1,517.2	582	9.4%
1984	308	192	3	0.01	0.02	ND ^e	---	---	---	---	---	---	---
1985	190	367	11	0.06	0.03	10	303	1	2	25.3	2,904.1	1,085	21.6%
1986	363	343	20	0.06	0.06	16	327	6	7	12.4	738.5	943	19.3%
Total			368										

^a Statistics were generated for the Robson-Flick estimator from a spreadsheet program associated with Bernard and Hansen (1992) and are: R' = the number of recaptures of marked fish (cells) with unique lengths in the second event; length = the estimated length at which recruitment is negligible (corresponding to cell r+1); r = the last cell (length group) significantly influenced by recruitment; u(r+1) = the running average of unmarked fish in cell r+1; and, Sum = the sum of counts of unmarked fish in cell i minus the running average of unmarked fish in cell i+1.

^b Confidence intervals calculated as $N \pm t * SE$ ($\alpha = 0.05$, $df = 5$) and rounded to nearest hundred fish.

^c C and R are from year i+1. M is from year i.

^d R/M is the rate of the number of recaptures of marked fish to the total number of marked fish released in the first (mark) event. R/C is the rate of the number of recaptures of marked fish to the total catch of fish in the second (recapture) event.

^e ND = not done. Lack of recaptures prevented detection of recruitment and application of estimator.

Table 4. Kolmogorov-Smirnov test statistics from capture-recapture data^a of Arctic grayling (≥ 270 mm FL) in Caribou Creek used in the Robson-Flick model, 1980 - 1987.

Years of sampling	Marks vs Unmarked		Marks vs Recaptures	
	D	p	D	p
1980-1981	0.35	0.00	0.20	0.47
1981-1982	0.21	0.00	0.07	0.82
1982-1983	0.06	0.08	0.14	0.02
1983-1984	0.28	0.00	0.22	<0.01
1984-1985	ND ^b	---	ND	---
1985-1986	0.35	0.00	0.33	0.22
1986-1987	0.07	0.42	0.14	0.84

^a Tests compared the lengths of fish marked in year i to lengths (at time of marking) of marked fish recaptured in year $i+1$ and to lengths of unmarked fish captured in year $i+1$. Tests are plotted as cumulative function distributions in Appendix E.

^b ND = not done.

Contribution Rate

The proportion of marked grayling released in Caribou Creek ranged from 0.03 (SE = <0.01) in 1983 to 0.21 (SE = 0.02) in 1982 (Table 5).

Caribou Creek to Richardson Clearwater River:

The proportion of marked grayling from Caribou Creek sampled at the Richardson Clearwater River in the same year (p_m) ranged from 0.01 for the 1985 release to 0.12 for the 1982 release (Appendix C2). Using abundances estimated with the Robson-Flick model, contribution of grayling released in Caribou Creek that migrated to the Richardson Clearwater River in the same year ranged from 1.03 (SE = 0.35; or 103%) in 1980 to 0.32 (SE = 0.18; or 32%) in 1985, with an average of 0.67 (SE = 0.11; or 67%, Table 6). Average contribution decreased in following years (Table 6).

These results imply that, on average, two-thirds of the population in the Richardson Clearwater River is comprised of fish that emigrated from Caribou Creek the same year. The remaining one-third of the population could be comprised of fish from other tributaries of the Shaw Creek drainage, or from other donor streams, or a combination of donors.

Caribou Creek to Tanana River at Shaw Creek:

The proportion of marked grayling from Caribou Creek sampled at the Tanana River near Shaw Creek one year later (p_m), ranged from 0.01 for the 1984 and 1985 releases to 0.09 for the 1983 release (Appendix A3). Using abundances estimated with the Robson-Flick model, contribution of grayling released in Caribou Creek that migrated to the mouth of Shaw Creek one year later ranged from 0.75 (SE = 0.24) in 1986 to 0.17 (SE = 0.17) in 1985, with an average of 0.48 (SE = 0.07; Table 7). Average contribution decreased in following years (Table 7).

These results imply that, on average, one-half of the population at the mouth of Shaw Creek during the pre-spawning migration is comprised of fish that originated from Caribou Creek the prior year. The remaining one-half could be comprised of new recruits to Caribou Creek, fish from other tributaries to Shaw Creek, fish from other systems, or a combination of all of these potential donors.

Caribou Creek to Caribou Creek:

The proportion of marked grayling from Caribou Creek sampled at Caribou Creek one year later (p_m) ranged from 0.02 for the 1985 release to 0.17 for the 1983 release (Appendix B4). Using abundances estimated with the Robson-Flick model, contribution of grayling released in Caribou Creek that came back to Caribou Creek one year later ranged from 1.15 (SE = 0.19) in 1981 to 0.32 (SE = 0.10) in 1980, with an average of 0.73 (SE = 0.08; Table 8). Average contribution decreased in following years (Table 8).

These results imply that, on average, three-quarters of the population in Caribou Creek during the post-spawning migration is comprised of fish that originated from Caribou Creek the prior year. The remaining one-quarter

Table 5. Estimates of the proportion of Arctic grayling (≥ 270 mm FL) marked in Caribou Creek, 1980 - 1986 based on Robson-Flick estimates of abundance.

Year	m_t^a	N_t^b	SE^c	p_t^d	SE^e
1980	899	9,820	2,058	0.09	0.02
1981	635	9,793	1,370	0.07	0.01
1982	1,387	6,495	666	0.21	0.02
1983	186	6,187	582	0.03	<0.01
1984	ND	---	---	---	---
1985	190	5,022	1,085	0.04	0.01
1986	363	4,877	943	0.07	0.01

^a m_t = the number of Arctic grayling released with marks in year t .

^b N_t = the estimated abundance of Arctic grayling in year t .

^c SE = the standard error of the estimated abundance in year t .

^d p_t = the proportion of Arctic grayling with marks in year t .

^e SE = the standard error of p_t .

Table 6. Estimates of the contribution (p_c) and standard error of Arctic grayling (≥ 270 mm FL) marked and released in year i in Caribou Creek and recovered in the Richardson Clearwater River, 1980 - 1988. Contributions are based on the Robson-Flick model of abundance estimation in Caribou Creek.

Year (i) of release	Year of recapture in the Richardson Clearwater River							
	i	$i+1$	$i+2$	$i+3$	$i+4$	$i+5$	$i+6$	$i+7$
1980	1.03	0.53	0.86	0.37	0.16	0.27	0	0.03
SE	0.35	0.22	0.26	0.17	0.10	0.11	---	0.03
1981	0.64	0.52	0.61	0.07	0.05	0	0	0.04
SE	0.27	0.19	0.24	0.07	0.05	---	---	0.03
1982	0.55	0.34	0.23	0.16	0.07	0.04	0.03	
SE	0.11	0.10	0.07	0.05	0.04	0.02	0.01	
1983	0.94	0.48	0.31	0.32	0	0.14		
SE	0.42	0.28	0.18	0.23	---	0.08		
1984	NE ^a	---	---	---	---			
SE	---	---	---	---	---			
1985	0.32	0.13	0.06	0.18				
SE	0.18	0.13	0.06	0.09				
1986	0.52	0.29	0.20					
SE	0.21	0.11	0.07					
Average	0.67	0.38	0.38	0.22	0.07	0.11	0.01	0.03
SE	0.11	0.07	0.07	0.06	0.03	0.03	<0.01	0.02

^a NE = no estimate.

Table 7. Estimates of the contribution (p_c) and standard error of Arctic grayling (≥ 270 mm FL) marked and released in year i in Caribou Creek and recovered in the Tanana River at the mouth of Shaw Creek, 1980 - 1988. Contributions are based on the Robson-Flick model of abundance estimation in Caribou Creek.

Year (i) of release	Year of recapture at the mouth of Shaw Creek						
	i+1	i+2	i+3	i+4	i+5	i+6	i+7
1980	0.55	0.52	0.27	0.09	0.09	0.07	0.17
SE	0.17	0.17	0.12	0.06	0.06	0.07	0.09
1981	0.69	0.33	0.13	0.04	0	0.18	0
SE	0.20	0.14	0.08	0.04	---	0.11	---
1982	0.42	0.15	0.10	0.03	0.11	0	
SE	0.09	0.04	0.05	0.03	0.05	---	
1983	0.28	0.28	0	0.13	0		
SE	0.17	0.16	---	0.13	---		
1984	NE ^a	---	---	---			
SE	---	---	---	---			
1985	0.17	0.53	0.37				
SE	0.17	0.26	0.22				
1986	0.75	0.50					
SE	0.24	0.20					
Average	0.48	0.38	0.17	0.07	0.05	0.08	0.09
SE	0.07	0.07	0.05	0.04	0.02	0.04	0.05

^a NE = no estimate.

Table 8. Estimates of the contribution (p_e) and standard error of Arctic grayling (≥ 270 mm FL) marked and released in year i in Caribou Creek and recovered in Caribou Creek, 1980 - 1987. Contributions are based on the Robson-Flick model of abundance estimation in Caribou Creek.

Year (i) of release	Year of recapture in Caribou Creek						
	i+1	i+2	i+3	i+4	i+5	i+6	i+7
1980	0.32	0.50	0.31	0.48	0.11	0.12	0.06
SE	0.10	0.12	0.09	0.14	0.08	0.06	0.05
1981	1.15	0.87	0.46	0	0.08	0.04	
SE	0.19	0.18	0.12	---	0.06	0.05	
1982	0.79	0.56	0.02	0.13	0.15		
SE	0.10	0.08	0.02	0.04	0.05		
1983	1.00	0.17	0.54	0.68			
SE	0.24	0.17	0.23	0.26			
1984	NE ^a	---	---				
SE	---	---	---				
1985	0.79	0.85					
SE	0.29	0.31					
1986	0.35						
SE	0.13						
Average	0.73	0.59	0.33	0.32	0.11	0.08	0.06
SE	0.08	0.08	0.07	0.10	0.04	0.04	0.05

^a NE - no estimate.

should be comprised of new recruits to Caribou Creek if homing to natal streams for spawning was occurring.

CONCLUSIONS

1. A majority of grayling (≥ 270 mm FL) in the Richardson Clearwater River are from the Caribou Creek population. Management of these two systems must be linked.
2. A majority of grayling (≥ 270 mm FL) potentially harvestable in the spring fishery at Shaw Creek are from Caribou Creek. Management of this fishery must take into account exploitation in the Richardson Clearwater River.
3. Homing to the spawning area at Caribou Creek is indicated. Declines in abundance at Caribou Creek can be minimally attributed to exploitation in the Richardson Clearwater River and any future spring fishery at Shaw Creek.

RECOMMENDATIONS

1. Identify donor stocks and streams to the Richardson Clearwater River for the unexplained 33% of contributions. Potential candidates for research are the Goodpaster River, Salcha River, and Volkmar River.
2. Develop a management plan for the Caribou Creek stock that addresses utilization of these fish in the Richardson Clearwater River fishery and any future fishery at Shaw Creek.

ACKNOWLEDGMENTS

Foremost, I wish to thank Dick Peckham and George Van Wyhe who tolerated and abetted a young biologist's enthusiasm and Billie Harrild who for her love of fishing and exploration led me to Caribou Creek. Also, my thanks to those many Department personnel and "civilians" who assisted me in data collection. I am especially grateful to Bob Clark for his interest and insights in analyzing the data and to John Clark, Peggy Merritt, and Fred Andersen for their patience and support of a slow writer. Lastly, thanks are extended to Sara Case for her help in the editing and final publication of this report. This project and report were made possible by partial funding provided by the U. S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act under Project F-10-9, Job Number 3-2(a).

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APPENDIX A

Appendix A1. Summary of Arctic grayling sampled^a during early spring at the mouth of Shaw Creek, 1981 - 1988.

Year	Dates	Total	>269mm FL			>329mm FL		
			n	p ^b	SE ^c	n	p ^d	SE
1981	5 - 22 April	471	357	0.76	0.02	82	0.23	0.02
1982	24 April - 2 May	384	314	0.82	0.02	92	0.29	0.03
1983	17 - 24 April	305	279	0.92	0.02	144	0.52	0.03
1984	8 - 25 April	364	351	0.96	0.01	141	0.40	0.03
1985	27 - 30 April	402	360	0.90	0.02	101	0.28	0.02
1986	24 April - 4 May	184	156	0.85	0.03	49	0.31	0.04
1987	15 - 23 April	267	251	0.94	0.02	192	0.77	0.03
1988	18 - 22 April	338	214	0.63	0.03	101	0.47	0.03
Total		2,715	2,282	0.84	0.01	902	0.40	0.01

^a Samples came from angler creels in 1981 through 1986 and from electrofishing in 1987 and 1988.

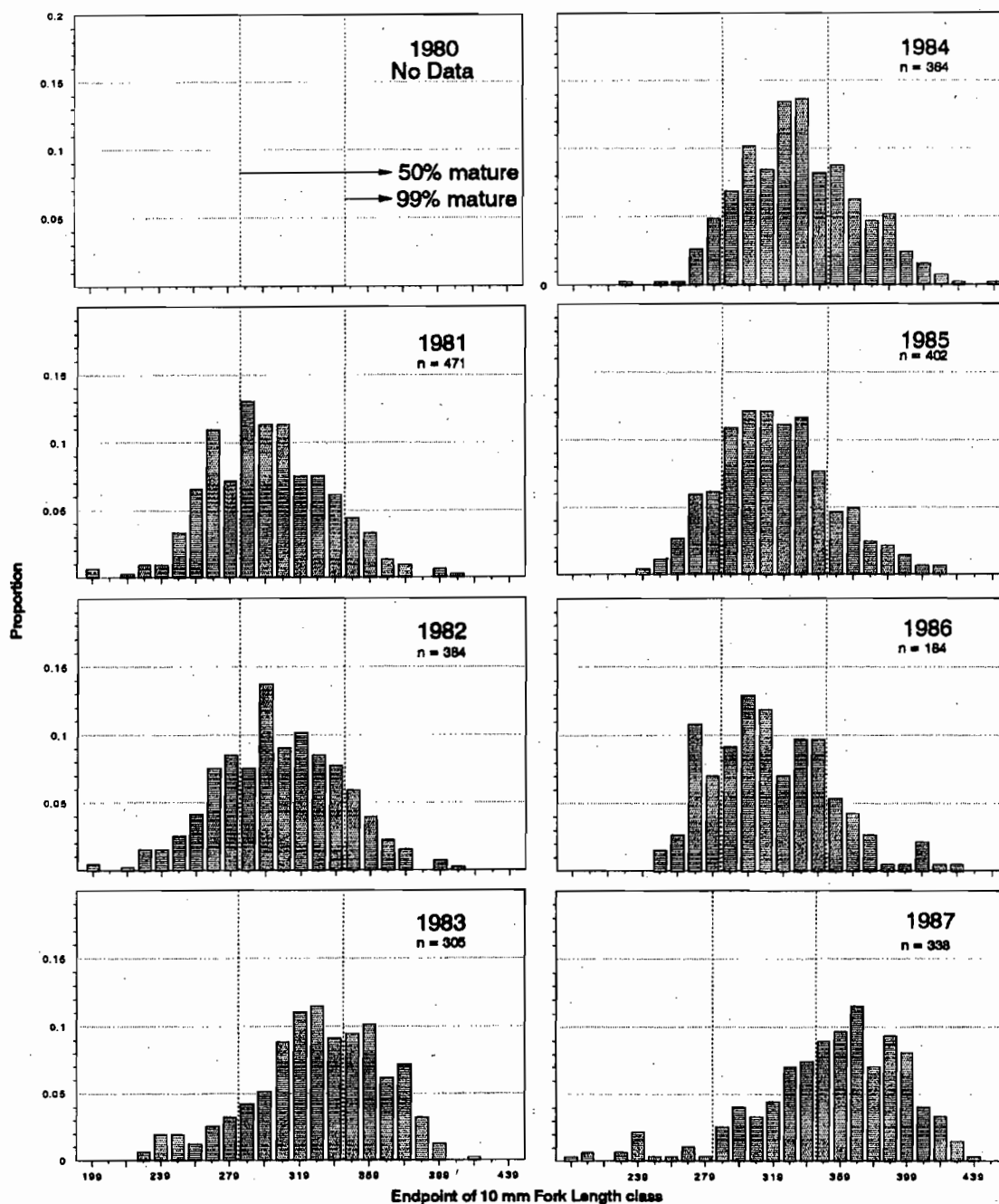
^b p = proportion of total catch.

^c SE = standard error of the proportion.

^d p = proportion of catch greater than 269 mm FL that were greater than 329 mm FL.

Appendix A2.1. The number of Arctic grayling in 10 mm FL groups in samples from the Tanana River at the mouth of Shaw Creek from angler creels, April, 1981 - 1986, and from electrofishing, April, 1987 and 1988.

Length	1981	1982	1983	1984	1985	1986	1987	1988
<270	70	70	26	13	42	28	16	124
270 - 279	21	33	10	18	25	13	1	18
280 - 289	38	29	13	25	44	17	7	22
290 - 299	33	53	16	37	49	24	11	18
300 - 309	33	35	27	31	49	22	9	22
310 - 319	22	39	34	49	45	13	12	18
320 - 329	22	33	35	50	47	18	19	15
330 - 339	18	30	28	30	31	18	20	20
340 - 349	13	23	29	32	19	10	24	21
350 - 359	10	17	31	23	20	8	26	14
360 - 369	4	9	19	17	10	5	31	14
370 - 379	3	6	22	19	9	1	19	11
380 - 389	0	3	10	9	6	1	25	8
390 - 399	2	3	4	6	3	4	22	3
400 - 409	1	1	0	3	3	1	11	7
410 - 419	0	0	1	1	0	1	9	1
420 - 429	0	0	0	0	0	0	4	1
430 - 439	0	0	0	0	0	0	1	1
440 - 449	0	0	0	1	0	0	0	0
Totals	290	384	305	364	402	184	267	338



Appendix A2.2. Yearly length frequencies of Arctic grayling sampled in April at the mouth of Shaw Creek 1981 through 1988.

Appendix A3. Number (R) and recapture rates (p_m^a) of Arctic grayling (~ 270 mm FL) that were tagged and released in Caribou Creek and recaptured from the Tanana River at the mouth of Shaw Creek, 1981 through 1988.

Tagging Year:		1980			1981			1982			1983			1984		
Year ^b	n ^c	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE	R	p_m	SE
1981	357	18	0.05	0.01	---	---	---	---	---	---	---	---	---	---	---	---
1982	314	15	0.05	0.01	14	0.04	0.01	---	---	---	---	---	---	---	---	---
1983	279	7	0.03	0.01	6	0.02	0.01	25	0.09	0.02	---	---	---	---	---	---
1984	351	3	0.01	<0.01	3	0.01	<0.01	11	0.03	0.01	3	0.01	<0.01	---	---	---
1985	360	3	0.01	<0.01	1	<0.01	<0.01	8	0.02	0.01	3	0.01	<0.01	9	0.03	0.01
1986	156	1	0.01	0.01	0	0	---	1	0.01	0.01	0	0	---	2	0.01	0.01
1987	251	4	0.02	0.01	3	0.01	0.01	6	0.02	0.01	1	<0.01	<0.01	4	0.02	0.01
1988	217	0	0	---	0	0	---	0	0	---	0	0	---	2	0.01	0.01

Tagging Year:		1985			1986			1987		
Year	n	R	p_m	SE	R	p_m	SE	R	p_m	SE
1981	357	---	---	---	---	---	---	---	---	---
1982	314	---	---	---	---	---	---	---	---	---
1983	279	---	---	---	---	---	---	---	---	---
1984	351	---	---	---	---	---	---	---	---	---
1985	360	---	---	---	---	---	---	---	---	---
1986	156	1	0.01	0.01	---	---	---	---	---	---
1987	251	5	0.02	0.01	14	0.06	0.01	---	---	---
1988	217	3	0.01	0.01	8	0.04	0.01	7	0.03	0.01

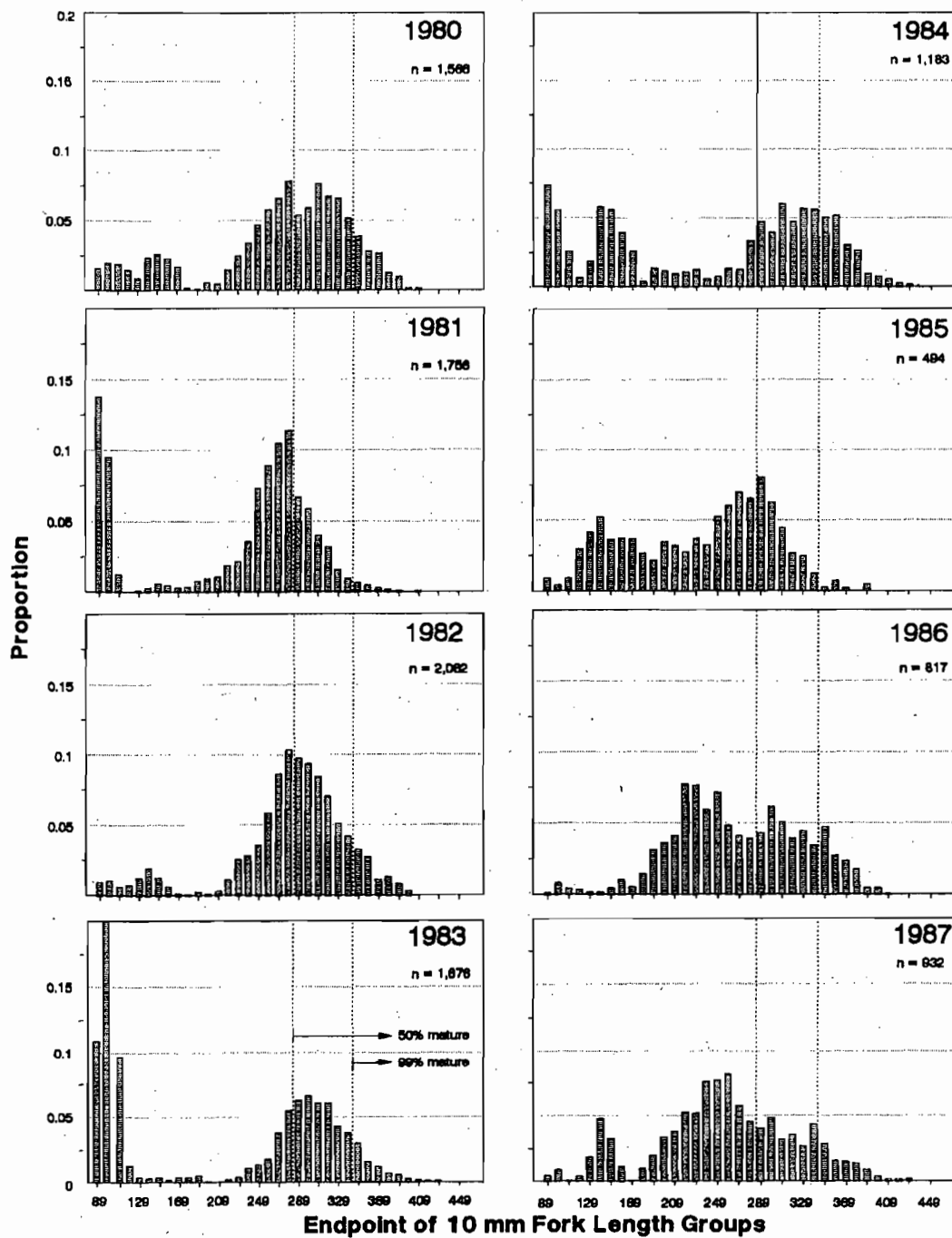
^a p_m = recapture rate; recaptures/sample size.

^b Year = sample year.

^c n = sample size.

Appendix B1.1 The number of Arctic grayling in 10 mm FL groups in samples from Caribou Creek, June, 1980 - 1987.

Length	1980	1981	1982	1983	1984	1985	1986	1987
<270	667	1,483	2,470	897	551	302	450	589
270 - 279	123	206	237	93	40	37	32	43
280 - 289	84	123	217	106	57	45	36	38
290 - 299	94	101	205	112	47	36	51	45
300 - 309	119	71	189	103	71	24	43	29
310 - 319	106	59	149	102	57	16	34	34
320 - 329	103	28	112	72	68	15	37	26
330 - 339	82	18	89	64	66	8	29	41
340 - 349	61	13	68	51	60	2	38	27
350 - 359	44	9	59	26	61	5	23	15
360 - 369	42	6	25	20	37	1	19	14
370 - 379	21	3	28	11	32	0	15	13
380 - 389	15	2	18	10	12	3	4	8
390 - 399	3	0	9	4	10	0	4	4
400 - 409	3	1	1	3	7	0	1	2
410 - 419	0	0	0	1	3	0	0	2
420 - 429	0	0	0	1	2	0	0	2
430 - 439	0	0	0	0	2	0	0	0
440 - 449	0	0	0	0	0	0	1	0
Totals	1,567	2,123	3,876	1,676	1,183	494	817	932



Appendix B1.2. Yearly length frequencies of Arctic grayling sampled during the June outmigration from Caribou Creek, 1980 - 1987.

Appendix B2. Summary statistics and test results for comparisons between recaptures of Arctic grayling (≥ 270 mm FL) tagged in Caribou Creek in 1981 - 1983 and finclipped in 1983.

Year	Event	Sample Size	Mean Length	STD	Min	Max	Mean Growth	Testing ^a			
								D ^b	p ^b	t ^c	p ^c
1981	Mark	105	295	23	270	369					
1982	Recapture	105	313	23	280	385	18	0.35	<0.01	-4.101	<0.01
1982	Mark	132	312	29	270	392					
1983	Recapture	132	327	29	273	403	15	0.11	0.73	-0.477	0.63
1983	Mark	19	334	32	287	396					
1984	Recapture	19	347	31	288	396	13	0.31	0.14	2.466	0.02
1983 ^d	Recapture in 1984	59	329	26	285	399					

^a Testing was between 1983 finclipped recaptures and the tag recaptures.

^b Kolmogorov-Smirnov two sample test statistic and probability.

^c A t-test for the null hypothesis concerning the difference between the mean length of finclipped recaptures versus the mean length of tagged recaptures.

^d Finclipped recaptures.

Appendix B3. Summary of captures and marks released^a of Arctic grayling during spring sampling, Caribou Creek, 1980 - 1987.

Year	Dates	Effort (Days)	Migrant ^b Total	Catch				Marks (>269) Released					
				Catch >269mm FL		Catch >329mm FL		Marks >329mm FL		Marks >329mm FL			
				n	p ^c	SE ^d	n	p ^e	SE	Total	n	p ^e	SE
1980	18 May - 12 June	25	US+DS 1,567	900	0.57	0.01	271	0.30	0.02	899	271	0.30	0.02
1981	6 June - 19 June	13	US+DS 2,123	640	0.30	0.01	52	0.08	0.01	635	52	0.08	0.01
1982	1 June - 20 June	19	US+DS 3,876	1,406	0.36	0.01	297	0.21	0.01	1,387	293	0.21	0.01
1983	2 June - 20 June	16 ^f	DS 1,676	779	0.47	0.01	191	0.25	0.02	186	142	0.76	0.03
1984	4 June - 15 June	11	DS 1,183	632	0.53	0.02	292	0.46	0.02	308	165	0.54	0.03
1985	4 June - 15 June	11	DS 494	192	0.39	0.02	19	0.10	0.02	190	19	0.10	0.02
1986	2 June - 18 June	16	DS 817	367	0.45	0.02	136	0.37	0.03	363	134	0.37	0.03
1987	3 June - 11 June	8	DS 932	343	0.37	0.02	128	0.37	0.03	341	128	0.38	0.03
Total			12,668	5,259	0.42	0.00	1,386	0.26	0.01	4,308	1,204	0.28	0.01

- ^a Marks were anchor tags.
^b Catch represents fish migrating US (upstream) and/or DS (downstream).
^c p = proportion of total catch that were >269 mm FL.
^d SE = standard error of the proportion.
^e p = proportion of catch greater than 269 mm FL that were >329 mm FL.
^f Weir was closed for two days, 6 - 8 June.