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Stock Assessment of Arctic Grayling in the Salcha, Chatanika, Goodpaster, and Delta Clearwater Rivers during 1991

by

Douglas F. Fleming,
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Alaska Department of Fish and Game

Division of Sport Fish

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Anchorage, Alaska

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ABSTRACT

Four Arctic grayling *Thymallus arcticus* populations in the Tanana River drainage were assessed using mark-recapture experiments in 1991. Investigations focused on the estimation of abundance and stock composition. Arctic grayling were captured using pulsed-DC electrofishing in all but one investigation, when hook and line gear was used. Population abundance estimated for Arctic grayling greater than 149 millimeter fork length in the Salcha River was 5,429 fish (standard error of 1,044 fish), similar to estimated abundance in 1990. Unlike the other three systems studied, a strong age 5 cohort was found in the Salcha River. Arctic grayling populations in three study sections were assessed on the Chatanika River, each with differing accessibility for sport anglers and potential for exploitation. Assessment in the 10.0 kilometer long upstream section involved estimation of the age and size composition of Arctic grayling during spawning. Abundance of Arctic grayling in the 35.2 kilometer long middle section was 10,981 fish (standard error of 2,190 fish). In the 83.2 kilometer long downstream section abundance was estimated at 20,122 fish (standard error of 3,845 fish) greater than 149 millimeter fork length. These estimates of abundance indicate that density of Arctic grayling in the Chatanika River is greater than most other lotic populations under study in interior Alaska. Relative abundance of quality and preferred size (greater than 269 millimeter fork length) fish in these three sections suggest that levels of exploitation are less in sections where access for sport anglers is difficult. Abundance estimated in a 50.0 kilometer section of the Goodpaster River was 7,836 fish (standard error of 859 fish). The age 2 cohort comprised 53 percent of the population, indicating the potential for good recruitment (numbers of age 3 fish) in 1992 for most of the Tanana River drainage populations currently being studied. Age and size composition of the immigrating stock following spring break-up was estimated in the Delta Clearwater River. Age composition in the Delta Clearwater River and in the Salcha, Chatanika, and Goodpaster rivers all favored age 4 fish. Similarity in age composition estimates may indicate synchrony in recruitment patterns among stocks of the Tanana River drainage. Based on these results, an increase in numbers of quality size (greater than 269 millimeter fork length) Arctic grayling is expected in 1992.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, size composition, Relative Stock Density, electrofishing, movements, Salcha River, Chatanika River, Goodpaster River, Delta Clearwater River, Tanana River drainage.

INTRODUCTION

The Salcha and Chatanika rivers presently support two of the largest Arctic grayling *Thymallus arcticus* fisheries in the Tanana drainage of interior Alaska. Although these fisheries are large, very little is known about the population dynamics of Arctic grayling in these streams. In contrast, the Goodpaster River is a relatively small Arctic grayling fishery. However, Arctic grayling from the Goodpaster River stock are harvested in the Delta and Richardson Clearwater rivers (Ridder 1983). This is a major concern since the Delta Clearwater River supports the fifth largest Arctic grayling fishery in interior Alaska (Mills 1989).

Precise knowledge of fishery characteristics and the dynamics of Arctic grayling populations in these streams is of growing importance to fishery managers. Thus, a multiyear study of Arctic grayling populations in the Salcha, Chatanika, and Goodpaster rivers was initiated in 1989. This report is the third in a series designed to provide this information. In addition, the feasibility of collecting population data from Arctic grayling in the Delta Clearwater River during May was investigated in 1991.

In conjunction with the present study, this report summarizes stock assessment work performed on the Salcha, Chatanika, and Goodpaster rivers from 1952 to 1990. By presenting all data pertinent to these fisheries, decisions regarding future research goals can be made. Summarized data will allow managers to assess the status of Arctic grayling stocks in the Salcha, Chatanika, and Goodpaster rivers.

The research objectives for 1991 were to estimate:

1) the abundance of Arctic grayling greater than 149 mm fork length in a 36.8 km section of the Salcha River;

2) the abundance of Arctic grayling greater than 149 mm fork length in a 35.2 km section of the Chatanika River;

3) the abundance of Arctic grayling greater than 149 mm fork length in the lower 50.0 km of the Goodpaster River;

4) the age composition of Arctic grayling in these sections of the Salcha, Chatanika, and Goodpaster rivers, and a 1.6 km section of the Delta Clearwater River;

5) the Relative Stock Density (RSD) of Arctic grayling in these sections of the Salcha, Chatanika, Goodpaster, and Delta Clearwater rivers;

6) the age composition of Arctic grayling residing in a 10 km section of the Chatanika River that parallels the Steese Highway; and,

7) the RSD of Arctic grayling residing in a 10 km section of the Chatanika River that parallels the Steese Highway.

In addition, abundance and RSD of Arctic grayling in a 83.2 km section of the lower Chatanika River were estimated.

<u>Fishery Descriptions and Study Areas</u>

Arctic grayling fisheries in the Salcha, Chatanika, Goodpaster, and Delta Clearwater rivers have some distinct differences that affect the progress of stock assessment work. Hydrologic characteristics, methods of access, and history of the recreational fishery are factors which describe in part the particular qualities of each fishery. Historic population data for the Salcha, Chatanika, and Goodpaster rivers are presented as a series of tables in Appendices A and B. Historic data for the Delta Clearwater River will be compiled at a later date.

Salcha River:

As with other runoff streams of the Tanana drainage, the Salcha River flows south out of the Tanana hills into the Tanana River (Figure 1). The river is characterized by high gradient, with long shallow runs and exposed gravel bars. Holmes (1984) described four separate areas encompassing the lower 192 km of the Salcha River. The upstream section is characterized by a narrow (~18 m wide), shallow (~0.5 m deep) channel with numerous protruding boulders. Average water velocity in late June is 1 m/sec, with a gradient of 4.2 m/km. The upper midstream section is characterized by a wider (~33 m), deeper (~1.2 m) channel with no protruding boulders. Water velocity and gradient are similar to the upstream section. The lower midstream section is characterized by a 68 m wide and 2.1 m deep channel. Average velocity in this section is 0.8 m/sec, while average gradient is 1.8 m/km. The downstream section is characterized by a single, wide channel with a water velocity of 0.8 m/sec and a gradient of 1.1 m/km. Average stream flow in the downstream section during summer (May-July) has ranged from a low of 50.95 m^3/sec in 1980 to a high of 123.86 m^3/sec in 1984 (USGS 1976-1990). The majority of recreational fishing occurs in the downstream section (river kilometer 0 to river kilometer 80).

Recreational fishing targets Arctic grayling, chinook salmon *Oncorhynchus tshawytscha*, summer chum salmon *O. keta*, northern pike *Esox lucius*, burbot *Lota lota*, and whitefish *Family Coregonidae*. The Salcha River is accessed by car from the Richardson Highway at milepost 348. Access by car is limited to a 1.6 km area adjacent to the Salcha River State Recreation Area. Riverboat and floatplane provide much of the access to upstream areas of the Salcha River. In 1987, regulations were promulgated to protect the Arctic grayling fishery from decline. These regulations were designed to:

1) restrict the harvest of Arctic grayling to fish 305 mm (12 in) or greater in total length;

2) restrict methods of harvest to unbaited artificial lures only; and,

3) eliminate the harvest of Arctic grayling during the spawning period (1 April to the first Saturday in June).

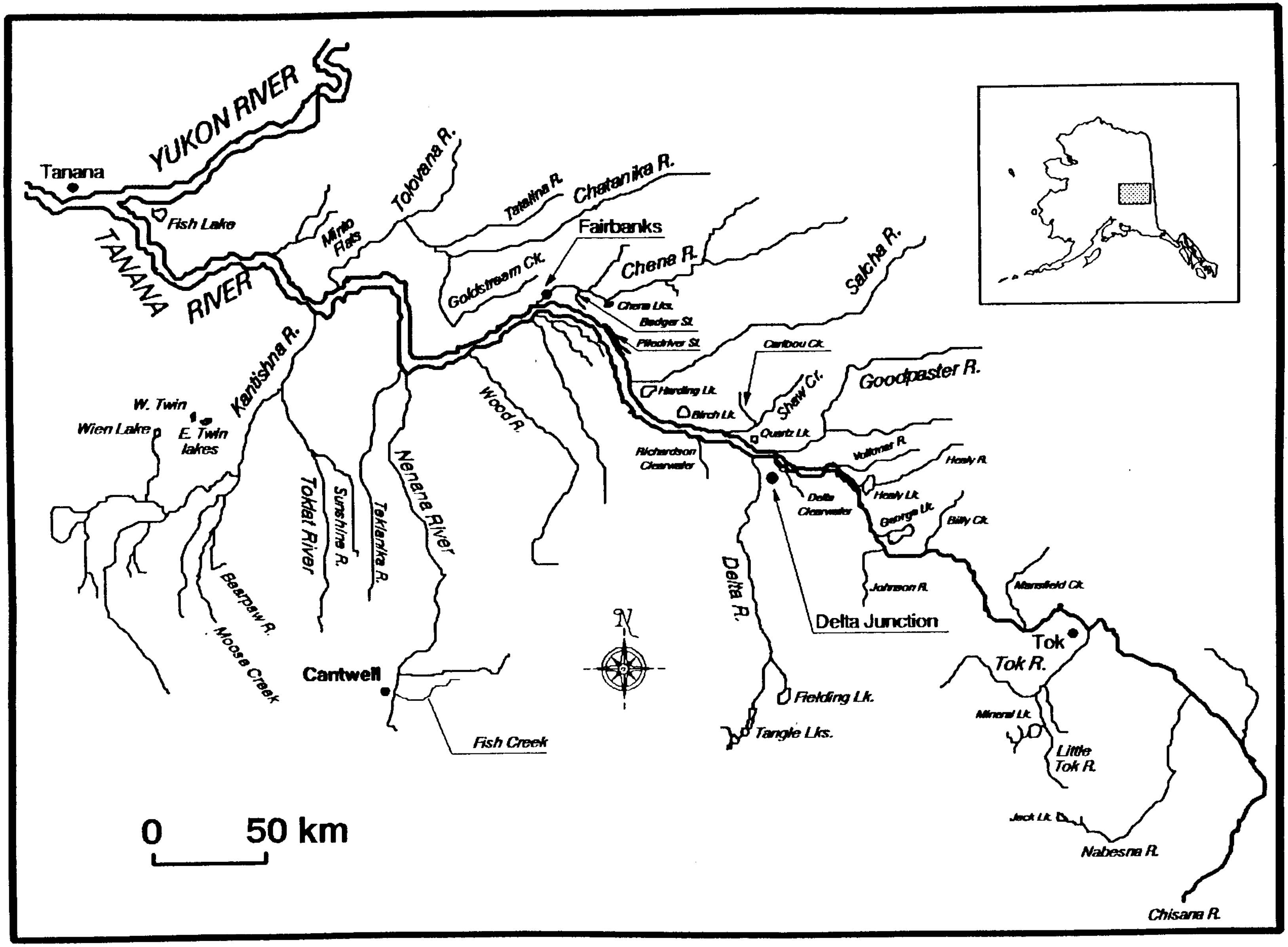

Figure 1. The Tanana River drainage.

Prior to 1977 very little data were collected from the recreational fishery. A creel survey was conducted during the summers of 1953 through 1958. Harvest was not estimated, but angler harvest rates ranged from 0.48 Arctic grayling per hour to 1.09 Arctic grayling per hour (Warner 1959b). Angler harvest rate surveys were also conducted in 1963 and 1964; harvest rates were 0.67 and 0.64 fish per hour, respectively (Roguski and Winslow 1969). The first harvest and effort survey was conducted in 1968. A total of 7,048 Arctic grayling was harvested in 7,035 angler-hours for a harvest rate of 1.00 fish per hour (Roguski and Winslow 1969). A harvest and effort survey was also conducted in 1974, with an estimated 4,728 Arctic grayling harvested in 11,284 angler-hours (Kramer 1975).

Since 1977, Mills (1979-1991) has estimated harvest and angling effort on the Salcha River through a postal survey. Annual harvest of Arctic grayling has averaged 6,341 fish, ranging from 1,992 in 1990 to 13,305 in 1984 (Table 1). Angling effort for all species of sport fish has averaged 10,603 angler-days, ranging from 7,494 angler-days in 1988 to 14,126 angler-days in 1982.

In addition to harvest data provided by Mills (1988), Baker (1988) conducted a creel survey of Salcha River anglers in 1987 (May through August). Catch rate was estimated at 0.66 (SE = 0.40) Arctic grayling harvested per angler-hour.

Chatanika River:

The Chatanika River is a runoff stream that flows southwest out of the White Mountains, draining through Minto Flats into the Tolovana River (Figure 1). Formed by the confluence of Faith and McManus creeks, the Chatanika River parallels the Steese Highway for approximately 70 km. The Chatanika River is also crossed at kilometer 18 of the Elliott Highway. Townsend (1987) described three reaches of the Chatanika River. Much of the upper reach (Long Creek to the headwaters) is accessible from the Steese Highway and supports recreational fishing for Arctic grayling, three species of whitefish, and two species of Pacific salmon. The middle reach is also accessible from the Steese and Elliott highways and supports fishing for these species as well. The lower reach is accessible by riverboat from the Elliott Highway and the Murphy Dome Road Extension. This reach of the Chatanika River supports Arctic grayling, northern pike, sheefish *Stenodus leucichthys*, and burbot fishing.

The Chatanika River is much more accessible than the Salcha or Goodpaster rivers, mainly due to a long history of placer mining in the area. As of 1986, there were placer mining operations on portions of Faith, Sourdough, No Name, and Flat creeks of the upper Chatanika River (Townsend 1987). Townsend (1987) also reported mining activity on Goldstream Creek in the lower Chatanika River. There are four recreation sites on the Chatanika River; 63-km Steese Highway campground, 18-km Elliott Highway (one campground and one picnic area), and 98-km Steese Highway campground.

Although extensive studies of the Chatanika River Arctic grayling fishery were performed before statehood (Warner 1959b), very little creel survey data were obtained prior to 1977. Angler catch rates were estimated during summer 1953-1958, ranging from 0.13 Arctic grayling per hour in 1955 to 0.78 Arctic grayling per hour in 1954 (Warner 1959b). Fishery managers during this period

Table 1. Recreational Arctic grayling harvest and angling effort on the Salcha, Chatanika, Goodpaster, and Delta Clearwater rivers, 1977-1990[a].

Year	Salcha River Harvest[b]	Salcha River Effort[c] (angler-days)	Chatanika River Harvest	Chatanika River Effort (angler-days)	Goodpaster River Harvest	Goodpaster River Effort (angler-days)	Delta Clearwater River Harvest	Delta Clearwater River Effort (angler-days)
1977	6,387	8,167	6,737	9,925	ND[d]	ND	6,118	6,881
1978	9,067	9,715	9,284	10,835	ND	ND	7,657	7,210
1979	5,980	14,788	6,121	4,853	ND	ND	6,492	8,398
1980	5,351	8,858	5,143	5,576	ND	ND	5,680	4,240
1981	3,983	8,090	3,808	4,691	ND	ND	7,362	4,673
1982	6,843	14,126	6,445	9,417	ND	ND	4,779	4,231
1983	9,640	11,802	9,766	10,757	3,021	1,989	6,546	5,867
1984	13,305	8,449	4,180	8,605	1,194	766	4,193	5,139
1985	5,826	13,109	7,404	10,231	2,757	2,844	5,809	8,722
1986	7,540	13,792	2,692	7,783	1,508	933	2,343	10,137
1987[e]	4,762	10,576	5,619	11,065	1,702	3,061	2,005	5,397
1988[e]	2,383	7,494	8,640	11,642	1,273	1,037	2,910	5,184
1989[e]	5,721	9,704	6,934	12,210	1,964	1,930	3,016	5,368
1990[e]	1,992	9,783	4,237	11,801	760	2,083	1,772	4,853
Average	6,341	10,603	6,215	9,242	1,772	1,830	4,763	6,164

[a] Mills (1979-1991).
[b] Harvest is the estimated number of Arctic grayling taken.
[c] Effort is the number of angler-days expended for all species of fish.
[d] ND = data not available.
[e] Special regulations were in effect on the Salcha River in 1988 through 1990, and on the Delta Clearwater from 1987 through 1990. These special regulations are: 1. Catch and release Arctic grayling fishing from 1 April to the first Saturday in June; 2. 12 inch (305 mm) minimum length limit; and, 3. artificial lures or flies only.

thought that excessive harvest of sub-adult Arctic grayling was causing declines in fish abundance and angler catch rates (Wojcik 1954, 1955). A 305 mm (12 inch) minimum length limit for Arctic grayling was enforced between 1955 and 1958, but was removed in 1959 (Warner 1959b).

A creel survey of the Chatanika River Arctic grayling fishery along the Steese Highway was conducted by Kramer (1975) in 1974. An estimated 27,250 angler-hours were expended with a catch rate of 1.02 Arctic grayling per hour. From 1977 through 1990, harvest of Arctic grayling was estimated by Mills (1979-1991). Annual harvest averaged 6,215 fish during this period, with 9,242 angler-days of effort (Table 1). Annual harvests during this period ranged from 2,692 fish in 1986 to 9,766 fish in 1983.

In addition to harvest data provided by Mills (1988), Baker (1988) conducted a creel survey of Chatanika River (Elliott highway area) anglers in 1987 (May through June). Catch rate was estimated at 0.02 Arctic grayling harvested per angler-hour.

Goodpaster River:

The Goodpaster River is a typical rapid runoff stream of interior Alaska. Draining an area of approximately 4,100 km^2, the Goodpaster River originates in the Tanana Uplands and flows southwest for 224 km to its confluence with the Tanana River, 16 km north of Delta Junction (Figure 1). The river has 13 named tributaries, the largest of which are the Eisenmenger Fork (38 km long) at river kilometer 184 and the South Fork (64 km long) at river kilometer 53.

Below the confluence of the South Fork, the river can be characterized as generally shallow (< 1 m deep) but wide (60 m across), slow moving, meandering, slightly humic stained, and susceptible to rapid fluctuations in water level. Van Whye (1964) described this reach as quite low in productivity due to little aquatic vegetation and a bottom type consisting primarily of sand. He described the river above the South Fork confluence as having a predominantly coarse gravel bottom with a high density of aquatic vegetation and food organisms.

The Goodpaster River Arctic grayling population has been included in 26 Federal Aid in Fish Restoration studies since 1955. These studies can be broken into two main categories: inter-stream migration studies from 1955 through 1966 and stock assessment studies from 1969 to the present. The migration studies presented very little data on age and size compositions of the tagged fish and instead presented quantitative data of number tagged and recovered by area. These quantitative data were partially summarized and interpreted by Reed (1961), Nagata (1963), and Roguski (1967). Generally stated, they found that the Goodpaster River served as a spawning and nursery stream for part of the summer Arctic grayling populations found in the Richardson and Delta Clearwater rivers (Figure 1). While presenting no quantitative data, Reed (1961) stated that the majority of Goodpaster River fish were tagged as two and three year olds while the recoveries of these fish in the clearwater streams were at ages five and greater. He suggested an age-size relationship for inter-stream movements. Ridder (1983) summarized the recovery data from the 7,955 fish tagged in the Goodpaster River in these studies. Of the 507 recoveries, 76% were made in the Goodpaster River and 24% in other waters, predominantly the Delta and Richardson Clearwater rivers. Stock separation data from scale pattern analysis of age 3 fish showed that the Goodpaster River could be the source of, at the most, 51% of the Delta Clearwater River Arctic grayling population (Ridder 1983).

Past stock assessment studies presented data on age and size compositions, population abundance (whole river and index sections), and intra-stream movements. Data on the former two parameters are included in Appendix B. Tack (1974, 1980) found and described an upstream, pre- and post-spawning movement in late May and early June followed by a mid-summer period of little movement. During this mid-summer period, juveniles and sub-adults occupied the lower 53 km, a mix of these groups were found in the middle drainage, and adults dominated above river kilometer 98.

The recreational fishery on the Goodpaster River is primarily for Arctic grayling and is conducted from approximately 15 May through 20 September. Most anglers are summer or permanent residents of the Delta Junction area. Some anglers target northern pike and burbot. Some round whitefish *Prosopium cylindraceum* are also harvested. While the river supports a small run of chinook salmon, the fishery is closed by regulation. The river is accessible only by riverboat or airplane. Boat launches are located at Big Delta on the Tanana River and at Clearwater Lake. Riverboat access is feasible only in the lower 98 km of the river and the lower 5 km of the South Fork. Floatplane access occurs only in the lower 36 km. Landing strips are located at Central Creek at river kilometer 118 and at Tibbs Creek, a tributary of the Eisenmenger Fork. There are approximately 50 cabins on the river used by summer residents. All but five cabins are located between river kilometers 11 and 48. No summer cabins lie above Central Creek. The Fairbanks Daily News Miner (4 September 1987) reports, "More than a hundred families own property in the area and transient use has grown rapidly during the past five years."

Data on the recreational fishery in the Goodpaster River are sparse. Tack (1974) conducted an on-site creel survey program in 1973. A check station at river kilometer 1 was used to interview and count angler arrivals and departures with a stratified random sampling schedule. He estimated a harvest of 2,236 Arctic grayling with a monthly harvest rate that ranged from 0.69 to 1.63 Arctic grayling harvested per hour. He reported 241 mm FL as the mean length of the sampled harvest (n = 241), that the harvest came predominantly from the lower 53 km of the river, and that the estimated 899 angler-days of effort were mainly by residents of the area. No other data were available until the statewide harvest survey (Mills 1984-1991) began to obtain estimates of harvest and effort in 1983 (Table 1). Annual harvests since then have averaged 1,772 Arctic grayling. Effort for all species has averaged 1,830 angler-days for the same period.

This report summarizes all data pertinent to stock assessment work conducted on the Goodpaster River from 1955 to 1991. These data can be found in Appendices B1 through B14.

Delta Clearwater River:

The Delta Clearwater River is a spring-fed tributary to the Tanana River, located near Delta Junction (Figure 1). The main river is approximately 32 km long, with a 10 km long north fork. Past stock assessments have emphasized the collection of age and size information from the Arctic grayling population and from angler creels. However, stock assessment has been hampered by low catches of fish with electrofishing gear used in July. In 1988, sampling was performed during spring (15 May through 10 June) along the lower 1.6 km of the river. Marking was done to estimate exploitation rate of Arctic grayling during summer. Approximately 500 fish were sampled in a 10 day period. Based on a favorable experience in 1988, efforts were made in spring of 1991 to sample large numbers of Arctic grayling for age and size information.

During the past 14 years, annual harvests of Arctic grayling in the Delta Clearwater River have averaged 4,763 fish, with angler effort averaging 6,164 angler-days during the same period. Although Arctic grayling harvested in the Delta Clearwater River are produced in other river systems (e.g., the Goodpaster and Volkmar rivers), fish that use the river for summer feeding tend to return to the river every year (Ridder 1991).

METHODS

Estimation of Abundance

Specific methodologies have been developed to estimate abundance of Arctic grayling in rivers of interior Alaska. Sampling schemes have evolved from multiple-sample mark-recapture experiments in short "index" sections (Van Hulle 1968) to single-sample experiments in relatively longer sections of river (Clark and Ridder 1987). These advances were made possible by the use of electrofishing equipment. Paradoxically, the efficiency of electrofishing is offset by its tendency for bias due to size-selectivity (Reynolds 1983). However, mark-recapture methodology can be used to correct for the inherent bias of electrofishing gear without sacrificing the efficacy of sampling programs. Much of what we have learned about Arctic grayling abundance estimation in runoff streams is presented below.

Long study areas (>36 river km) were chosen, in general, to minimize immigration and emigration of fish during the experiments. Collection of mark and recapture data in the Salcha, Chatanika and Goodpaster rivers was segregated by area to facilitate the estimation of fish movement within study sections. To quantify movement of fish during the experiments, each study section was divided into three equal-length study areas.

Population abundance of Arctic grayling greater than 149 mm FL was estimated with mark-recapture methods (Seber 1982), which in these experiments assume:

1) the population is closed (no change in the number of Arctic grayling greater than 149 mm FL in the population during the estimation experiment);

2) all Arctic grayling have the same probability of capture during the first sample <u>or</u> in the second sample <u>or</u> marked and unmarked Arctic grayling mix randomly between the first and second samples;

3) marking of Arctic grayling does not affect their probability of capture in the second sample;

4) Arctic grayling do not lose their mark between sampling events; and,

5) all marked Arctic grayling are reported when recovered in the second sample.

Assumption 1 was not tested directly, but movement of fish out of the river section was inferred from analysis of movements of fish between the three study areas. Other factors possibly contributing to the failure of assumption 1 (mortality and growth recruitment) were assumed to be negligible. The short duration of the experiments should have prevented appreciable mortality or growth.

Assumptions 2 and 3 were tested with two Kolmogorov-Smirnov two-sample statistical tests and a chi-squared contingency table test. The first test compared the length frequency distributions of recaptured Arctic grayling with those captured during the marking sample. The second test compared the length frequency distributions of Arctic grayling captured during the marking sample with those captured in the recapture sample. The results of these two tests determined the methodology used to alleviate bias in abundance estimation (see Appendix C1). The third test compared the rates of recovery (number recaptured per number examined) among the three study areas in a river section. This test was performed after the two Kolmogorov-Smirnov tests, stratified by length if necessary. If recovery rates were similar among areas, then assumption 3 was met. Recovery rates among study areas are generally the same because sampling was conducted with equal effort along the entire river section (Clark 1990). Assumption 4 could be tested because double marking was employed to allow estimation of tag loss. Assumption 5 was valid because only recaptures recovered by sampling crews during the experiment (and not angler returns after the experiment) were used to estimate abundance.

If tests of assumptions 2 and 3 indicated that capture probabilities were not equal among all sizes of Arctic grayling marked, data were stratified into size classes and separate abundance estimates calculated for each data set. Size classes were chosen by maximizing the difference in capture probabilities among sizes of fish marked. Difference in capture probabilities was maximized by observing significance levels in a series of chi-squared tests. These tests compared numbers of fish marked and not seen in the second sample versus numbers of fish marked and seen in the second sample. The number of size classes used for chi-squared tests was restricted to two because further stratification could possibly reduce overall precision while gaining very little additional accuracy.

In two of the capture-recapture experiments conducted in 1991 no small Arctic grayling were recaptured (e.g., no recaptures of fish between 150 and

200 mm FL). In these instances, in conjunction with the application of the Kolmogorov-Smirnov tests described above, we tested the hypothesis that zero recaptures could occur at random given the observed capture ratio of larger size fish. The hypothesis was evaluated using an approximate randomization test, also known as a Monte Carlo test (Noreen 1989, Manly 1991). The test involved randomly simulating the number of recaptures that would be expected to occur given: 1) the observed capture ratio of larger fish; 2) the given number of smaller fish examined during the second event; and, 3) a minimal number of smaller fish were captured, marked, and released during the first event (arbitrarily set to 50 or more fish). A total of 1,000 simulated numbers of expected recaptures were generated. The proportion of simulated values that were equal to or greater than the observed number of recaptures represents the probability that the observed statistic (zero recaptures) could occur at random given the null hypothesis. This proportion is equivalent to a probability value in a classical statistical test. If we failed to reject the null hypothesis, it was assumed that the observed value of zero recaptures could have occurred at random and the population estimated could apply to the full size range (≥ 150 mm FL). If we rejected the null hypothesis, then the population abundance analysis was conducted on a truncated data set, only including fish that were equal to or greater than the approximate length of the smallest recaptured fish. Accordingly, estimated abundance only applied to the truncated size range.

Next, the possibly stratified mark-recapture data were examined for directed movement of fish (assumption 1). In past years, movement of marked fish was observed in the Salcha and Chatanika rivers (Clark et al. 1991), and in the Goodpaster River (Clark and Ridder 1990). However, in 1991 significant movements of fish during these experiments were not observed, so the modified Petersen estimator of Bailey (1951, 1952) could be used to estimate abundance:

$$\hat{N} = \frac{M\,(C + 1)}{(R + 1)} \qquad (1)$$

where: M = the number of Arctic grayling marked and released alive during the first sample;
C = the number of Arctic grayling examined for marks during the second sample;
R = the number of Arctic grayling recaptured during the second sample; and,
$\hat{N}$ = estimated abundance of Arctic grayling during the first sample.

An approximately unbiased estimate of variance was used (Seber 1982):

$$\hat{V}[\hat{N}] = \frac{M^2\,(C + 1)(C - R)}{(R + 1)^2(R + 2)} \qquad (2)$$

where: $\hat{V}[\hat{N}]$ = the estimated variance of $\hat{N}$.

In addition to these estimates of abundance, bootstrapping methods by Efron (1982) allowed examination for statistical bias when point estimates were compared to bootstrap mean estimates. The bootstrapping procedure is as follows: first, capture history of each fish was recorded. Two columns of data were constructed; the first column represented the first, or marking event, and the second column represented the second, or recapture event. A capture in a particular event was denoted with a 1; if the fish was not seen during the event, this was denoted by a zero. The total number of capture histories was the sum of fish marked in the first event plus fish examined in the second event minus the number of fish seen in both events (recaptures). These capture histories were then resampled with replacement 1,000 times by computer. Each replication of the estimation experiment involved sampling of "the total number of capture histories" and then calculating an abundance estimate. After 1,000 replications the mean and sample variance (Snedecor and Cochran 1980) were calculated for all replicates:

$$\hat{N}_B = \frac{\sum_{i=1}^{1,000} \hat{N}_i}{1,000} \tag{3}$$

where:

$\hat{N}_B$ = the bootstrap mean of 1,000 replicates of the mark-recapture experiment;

$\hat{N}_i$ = the ith bootstrap replicate of the mark-recapture experiment obtained from equation 1; and,

$$\hat{V}[\hat{N}_B] = \frac{\sum_{i=1}^{1,000} (\hat{N}_i - \hat{N}_B)^2}{1,000 - 1} \tag{4}$$

where:

$\hat{V}[\hat{N}_B]$ = the bootstrap variance of N_B.

If stratification was necessary, abundance and variance of abundance were then estimated for all sizes of Arctic grayling by adding the independent abundance estimates and variances:

$$\hat{N} = \hat{N}_S + \hat{N}_L \quad \text{and} \tag{5}$$

$$V[\hat{N}] = V[\hat{N}_S] + V[\hat{N}_L] \tag{6}$$

where:

N = the abundance of Arctic grayling greater than 149 mm FL;

N_S = the abundance of small Arctic grayling; and,

N_L = the abundance of large Arctic grayling.

Salcha River:

Population abundance was estimated in a 36.8 km long study section of the Salcha River. The study section was bounded upstream at river km 40.0 and bounded downstream at river km 3.2 (Richardson Highway crossing; Figure 2). To quantify movements of Arctic grayling during abundance estimation, the study section was further subdivided into three study areas. The downstream, midstream and upstream areas were all approximately 12.2 km long. This section of the Salcha River encompasses areas used for stock assessment in 1987 (Clark and Ridder 1988) and 1988 (Clark 1988), and is the same river section used in 1989 (Clark and Ridder 1990) and 1990 (Clark, et al. 1991).

Each electrofishing boat had a crew of two "dippers" and a driver, and each boat was equipped with a pulsed DC variable voltage pulsator (Coffelt Model VVP-15) powered by a 3,500 W single-phase gasoline generator. Anodes were four 15 mm diameter steel cables 1.5 m long arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the aluminum boat was the cathode. Pulsator settings during electrofishing were: duty cycle 50%, pulse width 60 Hz, average voltage 260 VDC; and, average amperage 2.5 A. Conductivity was 120 μS (standardized to 25°C) at river kilometer 40 at the start of the experiment. Water temperature was 15.5°C at the time of the conductivity measurement. Water level was moderate and water clarity was good during the estimation experiment.

The marking event occurred on 18 through 21 June and the recapture event ran from 25 June through 28 June. Lower than average catches and numbers of recaptured fish indicated the need for additional sampling. An additional sampling pass was made through the entire study section on 1 through 2 July. Each sampling event started at the upstream end of the river section. Sampling consisted of electrofishing along each bank to collect as many fish as possible. Each sampling event was divided into 20 minute-long runs. Sampling both banks (along approximately 2 km of river) required two runs. After both banks were sampled, fish greater than 149 mm fork length (FL) were measured to the nearest 1 mm FL, tagged with a uniquely numbered Floy FD-67 internal anchor tag, fin clipped (partial clip of the lower lobe of the caudal fin), and released. The lower lobe of the caudal fin was partially removed to allow determination of mark status if a tag was shed. The use of 20 minute-long runs allowed for even distribution of marked fish in the study section and accurate determination of the area of release.

Chatanika River:

Sampling effort on the Chatanika River was increased substantially over past years (see Clark, et al. 1991). Abundance was estimated in two sections of the Chatanika River (hereafter referred to as the Middle Chatanika and the Lower Chatanika; Figure 3). The Middle area of the Chatanika is more accessible by road and receives more fishing pressure than the Lower Chatanika. Comparisons of heavily fished versus lightly fished sections of the Chatanika River were made from abundance estimates in these two study sections.

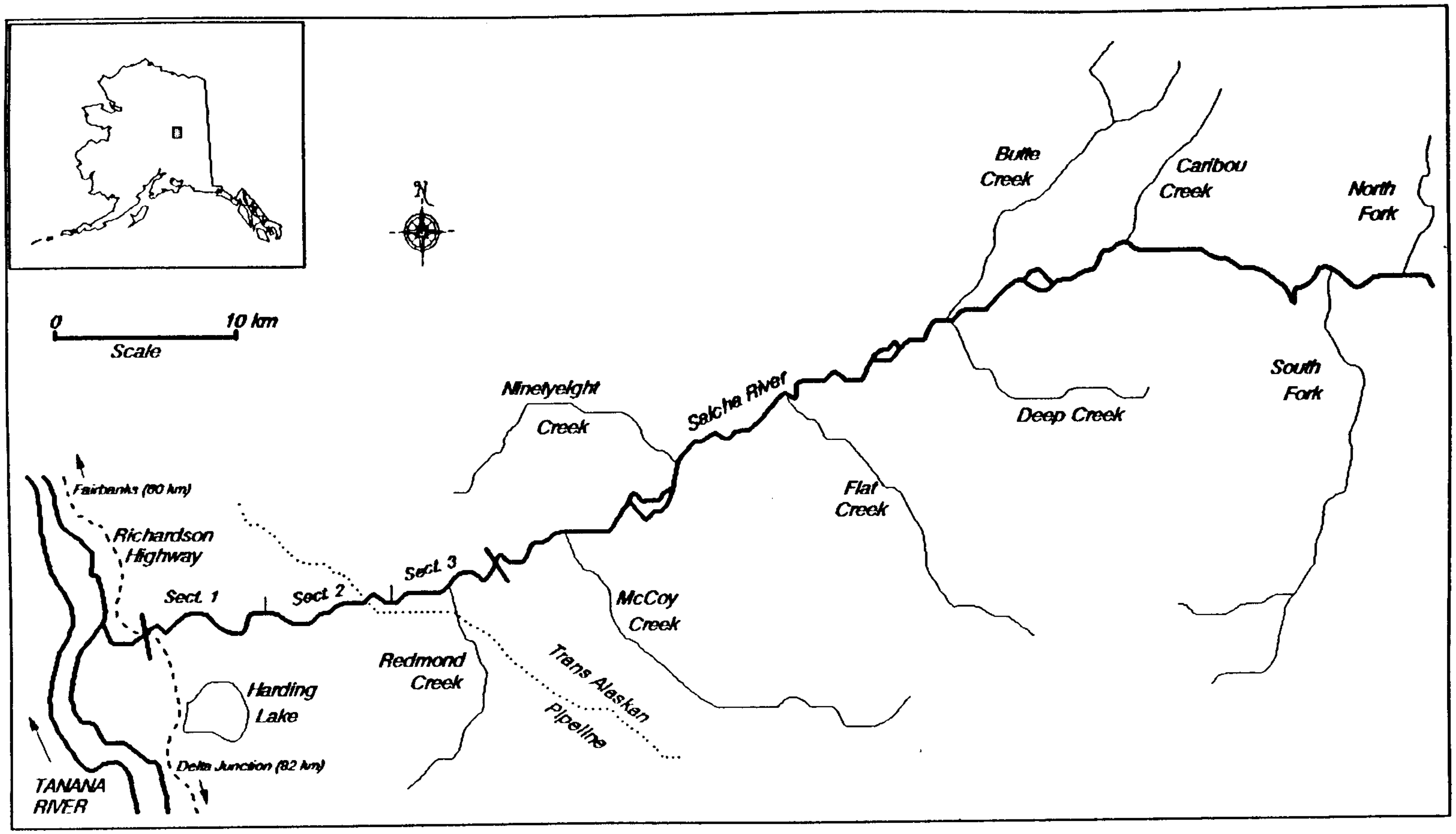

Figure 2. Study sections of the Salcha River in 1991.

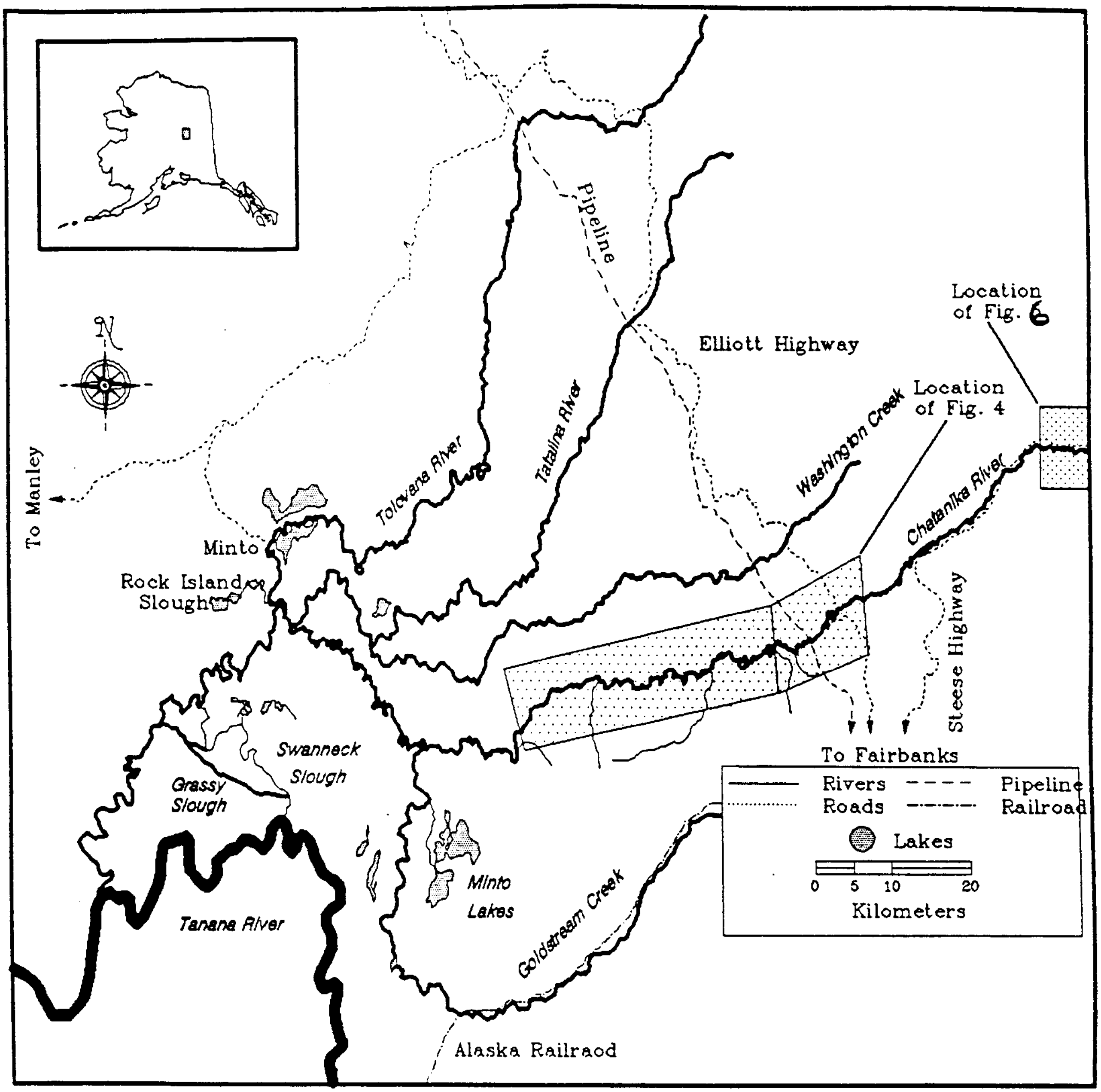

Figure 3. The Chatanika River drainage.

Upper Chatanika. Although a mark and recapture experiment was conducted in a 10 km section of the Upper Chatanika River between 3 and 13 June using hook and line gear, significant movement of smaller fish into the study area during the recapture event indicated nonclosure of the population. For this reason, no population abundance estimate was generated.

Middle Chatanika. Population abundance was estimated in a 35.2 km section of the Chatanika River. The study section extended from 7.5 km upstream of the Elliott Highway crossing to 27.7 km downstream of the highway crossing, at the confluence of Any Creek (Figure 4). To quantify movements of Arctic grayling during abundance estimation, the study section was further subdivided into three study areas. The downstream, midstream, and upstream areas were all approximately 11.7 km long. This section of the Chatanika River encompasses areas used for stock assessment in 1972 (Tack 1973), 1982 (Holmes 1983), 1984 through 1985 (Holmes 1985 and Holmes, et al. 1986), and 1990 (Clark, et al. 1991).

Pulsator settings during electrofishing were: duty cycle 50%, pulse width 60 Hz, average voltage 250 VDC; and, average amperage 3.0 A. Conductivity was approximately 85 μS (standardized to 25°C) at the start of the experiment. Water temperature was 10.5°C at the time of the conductivity measurement. Water level was moderate and water clarity was good during the estimation experiment.

The marking event occurred on 5 through 7 August and the recapture event on 13 through 15 August. Each sampling event started at the upstream end of the river section. Sampling consisted of electrofishing along each bank to collect as many fish as possible. Each sampling event was divided into 20-minute runs. Sampling both banks (along approximately 2 km of river) required only one run because the river is narrow in this section (~10-15 m wide). After both banks were sampled, fish greater than 149 mm fork length (FL) were measured to the nearest 1 mm FL, tagged with a uniquely numbered Floy FD-67 internal anchor tag, fin clipped (partial clip of the lower lobe of the caudal fin), and released. The lower lobe of the caudal fin was partially removed to allow determination of mark status if a tag was shed. The use of 20 minute-long runs allowed for even distribution of marked fish in the study section and accurate determination of the area of release.

Lower Chatanika. Population abundance was estimated concurrently with an abundance estimation experiment for whitefish in a 83.2 km section of the lower Chatanika River. The study section for Arctic grayling extended from 27.7 km downstream of the Elliott Highway crossing (below the confluence of Any Creek) to the river access point of the Murphy Dome Road extension (Figure 4). The study section was divided into five areas of unequal length. There is a different probability for a fish to move through a short study area versus a larger study area, and because these probabilities are unknown for study areas of unequal length, fish movement during the experiment could not be detected.

Pulsator settings during electrofishing were: duty cycle 50%, pulse width 60 Hz, average voltage 280 VDC; and, average amperage 3.5 A. During the first marking event, which ran from 11 through 16 July, water levels were low and

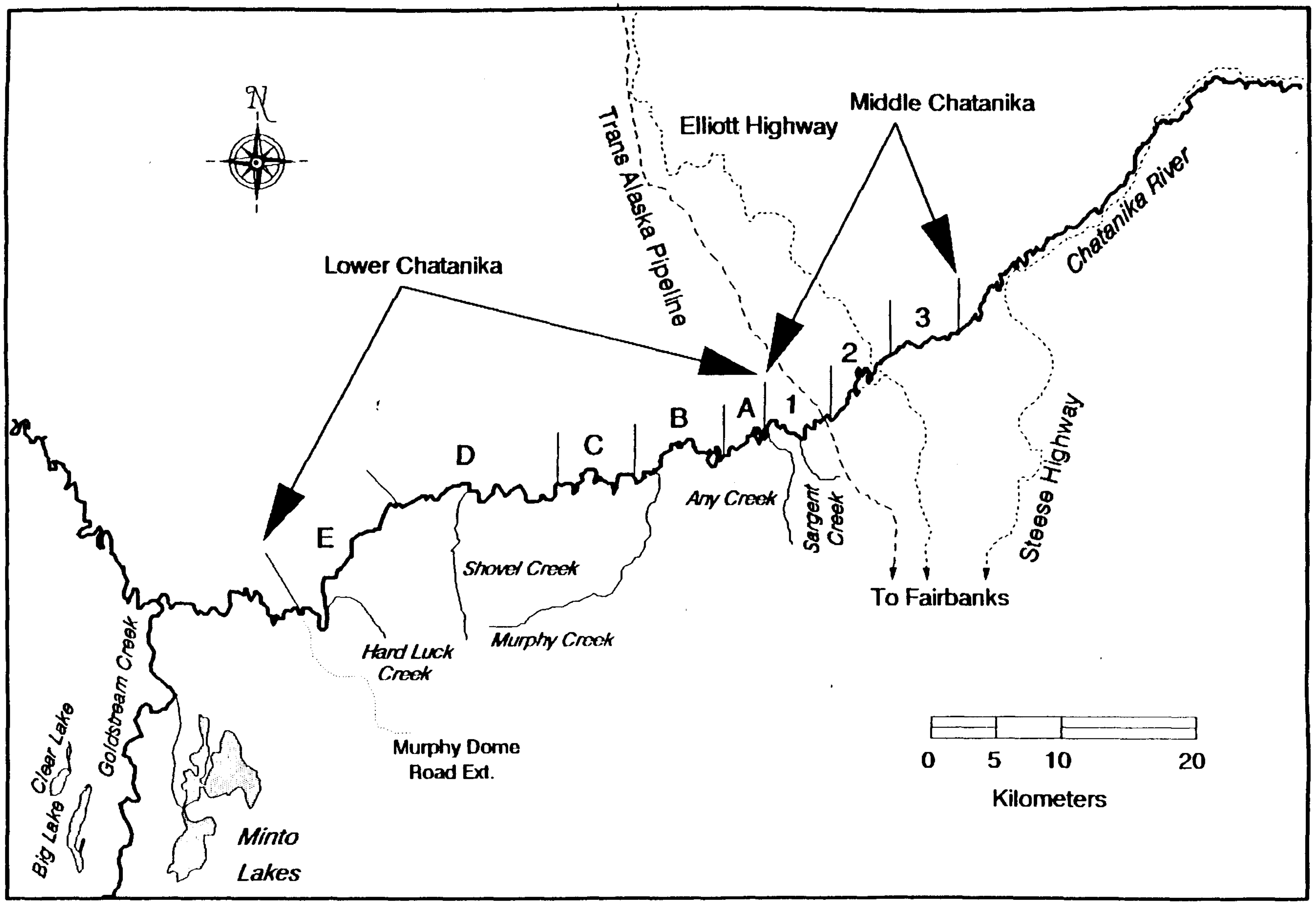

Figure 4. Study sections of the Middle and Lower Chatanika River in 1991.

clear. During the second marking event (23 through 26 August) and the recapture event (9 through 14 September) water levels were high and laden with silt, lowering the visibility. Each sampling event started at the upstream end of the river section. Sampling consisted of electrofishing along each bank to collect as many fish as possible. Sampling both banks required only one run because the river is narrow in this section (~10-15 m wide). The entirety of either bank of the river was not sampled completely. Fish greater than 149 mm fork length (FL) were measured to the nearest 1 mm FL, tagged with a uniquely numbered Floy FD-67 internal anchor tag, fin clipped (partial clip of the lower lobe of the caudal fin), and released. The lower lobe of the caudal fin was partially removed to allow determination of mark status if a tag was shed.

Goodpaster River:

Population abundance was estimated in a 50 km section of the lower Goodpaster River. The upstream boundary of the study section is at river kilometer 52.3 (the confluence of the South Fork of the Goodpaster River) while the lower boundary is at river kilometer 2.7 (Figure 5). While the lower, or main, mouth of the river was to be the lower boundary, high flows in the glacial Tanana River backed up the river 2.7 km producing high turbidity and ineffective electrofishing. The study section was further subdivided into three study areas. Area 1 was 16.5 km long and extended from the downstream boundary to approximately river kilometer 19.2. Area 2 was 14.4 km long and extended to river kilometer 33.6. Area 3, the upstream section, was 18.7 km long. These study areas are similar to those used in 1988 (Ridder 1989), 1989 (Clark and Ridder 1990), and 1990 (Clark, et al. 1991).

Samples were taken during two events, each three days long and each beginning at study area 3 and progressing downstream. The marking event ran from 7 to 9 August and the recapture event ran from 12 to 14 August. One study area in the river section was sampled each day. The time interval between sampling events for each of the three study areas was six days. Sampling started at the upstream end of an area and consisted of two electrofishing boats traveling downstream, one along each bank, collecting as many Arctic grayling as possible in a 20 minute interval. After both banks were sampled, fish greater than 149 mm fork length (FL) were measured to the nearest 1 mm FL, tagged with a uniquely numbered Floy FD-67 internal anchor tag, fin clipped (partial left pectoral fin), and released. The left pectoral fin was partially removed to allow determination of mark status if a tag was shed. The use of 20 minute-long runs allowed for even distribution of marked fish in the study section and accurate determination of the area of release.

Output voltage during electrofishing ranged from 250 to 325 VDC and output current ranged from 1 to 4 amperes. Duty cycle and pulse rate were held constant at 50% and 60 Hz, respectively. Mid-day water temperatures during the experiment ranged from 8.1 to 11.2°C. Conductivity was 100 μS (standardized to 25°C) at the start of the estimation experiment. Water level was moderately high and water clarity was slightly muddy during the marking event, while water level was receding and clarity improved during the recapture event.

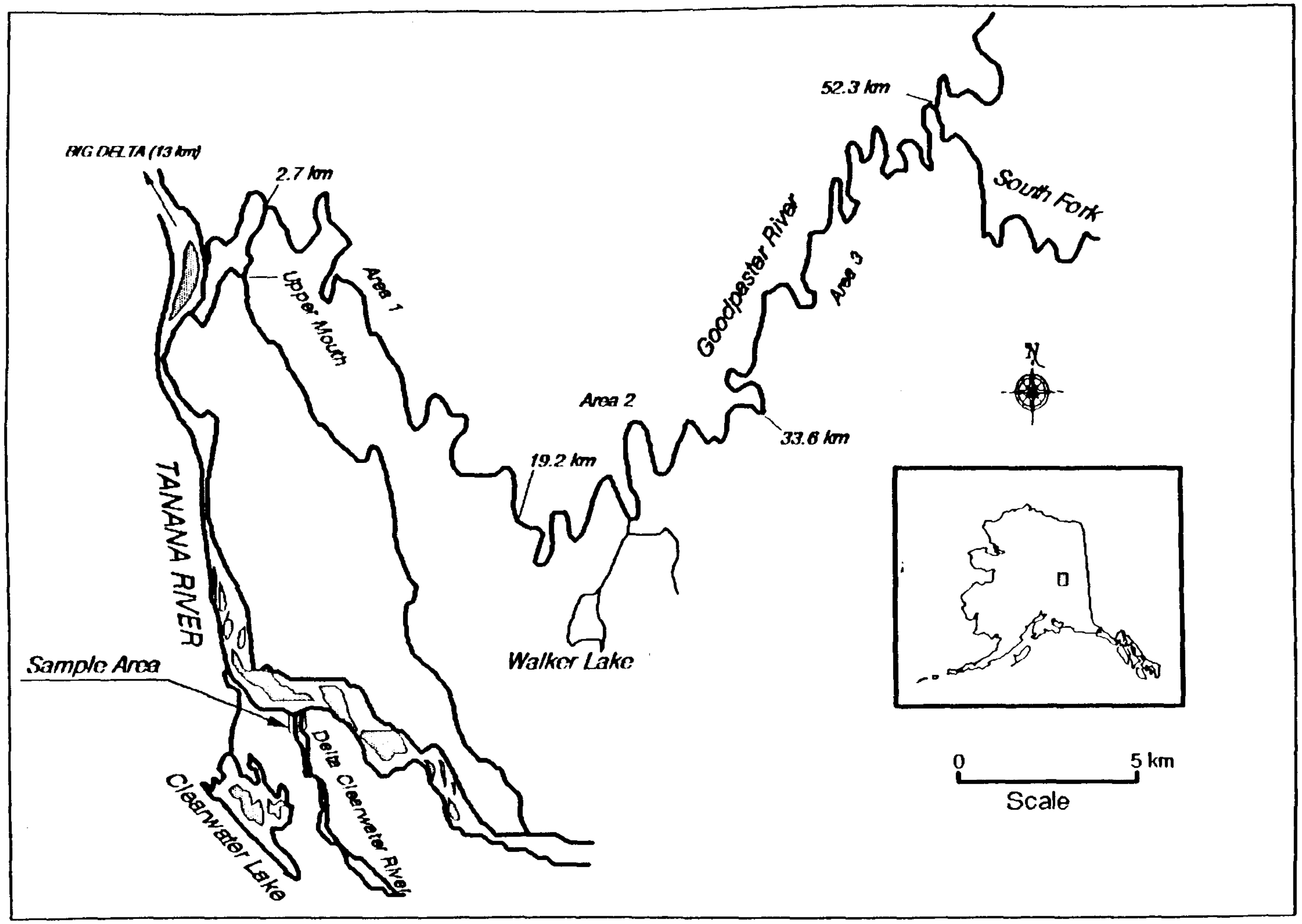

Figure 5. Study sections of the Goodpaster and Delta Clearwater rivers in 1991.

Estimation of Age and Size Composition

The accuracy of age and size composition estimates are dependent on the selectivity of the sampling gear. The pulsed-DC electrofishing boat used to collect age and size data has been shown to exhibit bias in capturing all sizes of Arctic grayling greater than 149 mm FL (Clark and Ridder 1988). The extent of this bias was inferred from the results of the first Kolmogorov-Smirnov two-sample test described in the abundance estimation section (test 1 of Appendix C1). If selectivity was not inferred from the capture-recapture data, the sampled ages and sizes should accurately represent the age and size composition of the stock. In this case, the proportion of fish at age was estimated by:

$$\hat{p}_k = \frac{x_k}{n} \tag{7}$$

where: $\hat{p}_k$ = the proportion of Arctic grayling that are age k;
x_k = the number of Arctic grayling sampled that are age k; and,
n = the number of Arctic grayling sampled that were aged.

Variance of this proportion was estimated with the binomial:

$$\hat{V}[p_k] = \frac{p_k\,(1 - p_k)}{n - 1}. \tag{8}$$

If selectivity was inferred from the capture-recapture data, age and size data were stratified, as was done for the abundance estimate. To compensate for bias introduced by sampling, recapture to mark ratios were used to adjust for differential capture probability by size of fish:

$$\hat{\rho}_l = \frac{RECAP_l}{MARK_l} \tag{9}$$

where: $\hat{\rho}_l$ = the capture probability of Arctic grayling in size class l, regardless of age k;
$RECAP_l$ = the number of recaptures of Arctic grayling in size class l; and,
$MARK_l$ = the number of marked Arctic grayling in size class l.

From the ratio of the largest capture probability to the capture probability in size class l, an adjustment to the number sampled at age k that were also of size class l was estimated (ignoring the hat symbols of ρ):

$$\hat{A}_l = \frac{\rho_L}{\rho_l} \tag{10}$$

where: $\hat{A}_l$ = the adjustment factor for all Arctic grayling of size class *l*, regardless of age class *k*; and,
$\rho_L = \max(\rho_l)$, l = 1, 2, ..., *m* size classes.

The adjustment factor was multiplied by the number of Arctic grayling sampled at age *k* that were also in size class *l*:

$$\hat{x}_{kl} = \hat{A}_l \, n_{kl} \tag{11}$$

where: $\hat{x}_{kl}$ = the adjusted number of Arctic grayling of age *k* that are also in size class *l*; and,
n_{kl} = the actual number of Arctic grayling sampled that are age *k* and also in size class *l*.

The proportion of Arctic grayling that are age *k* then re-evaluated to:

$$\hat{p}_k = \frac{\sum_{l=1}^{m} \hat{x}_{kl}}{\sum_{k=1}^{o} \sum_{l=1}^{m} \hat{x}_{kl}} = \frac{\hat{x}_{k.}}{\hat{x}_{..}} \tag{12}$$

where: k = 1, 2, ..., *o* age classes; and,
l = 1, 2, ..., *m* size classes.

The variances of these adjusted proportions were estimated by bootstrapping recapture to mark ratios 1,000 times in samples of "the number of capture histories". Point estimates and variances of age and size composition were calculated with equations 3 and 4.

Size composition of the stock was described with the incremental Relative Stock Density (RSD) indices adopted from Gabelhouse (1984). The RSD categories for Arctic grayling are: "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 559 mm FL). If selectivity was not inferred from the capture-recapture data, equations 7 and 8 were used to estimate the proportion of fish in each RSD category and the variance of these proportions. If selectivity was inferred from the capture-recapture data, the adjustment factors used to estimate age composition were also used to adjust RSD estimates. Adjustment was accomplished by replacing the number sampled at age *k* that were also in size class *l* (n_{kl}) with the number sampled in RSD category *k* = 1, 2, ..., 5 that were also in size class *l* (equations 9 through 12). Variance was estimated in an identical fashion to variance of proportion at age, bootstrapping the capture histories of all fish 1,000 times (equations 3 and 4).

Salcha River:

Age and size data were collected during all sampling events of the mark-recapture experiment, between 18 June and 2 July. A sample of scales was taken from the preferred zone[1] of each newly captured fish. Two scales from each fish were processed by cleaning in a solution of hydrolytic enzyme and then mounted on gum cards. These gum cards were used to make impressions of the scales on triacetate film (30 seconds at 137,895 kPa, at a temperature of 97°C). Ages were determined by counting annuli on these impressions with the aid of a microfiche reader. Determination of age was performed only once for each readable set of scales.

The Salcha River mark-recapture data did not indicate a significant change in capture probability of marked Arctic grayling during the experiment. Therefore, size samples taken with the electrofishing boat were most likely similar to the true age and size composition of the Salcha River stock at the time these samples were taken. Age composition was then estimated with equations 7 and 8.

Chatanika River:

The Chatanika river was partitioned into three sections for analysis.

Upper Chatanika. Age and size composition were estimated for Arctic grayling within a 10 km section of the Upper Chatanika River (Figure 6). A mark-recapture experiment was conducted so that if necessary, adjustments for size selectivity could be made. Size and age data were collected during both sampling events using hook and line gear; data collection procedures were identical to those of the Salcha River study. Estimates of age and size composition were calculated for each sampling period because of a perceived change towards smaller fish in the later sample. The shift towards smaller fish over time has been observed in other stock assessments of Arctic grayling conducted during periods of spawning activities (Fleming 1989). Estimates of age and size composition were calculated using equations 7 and 8.

Middle Chatanika. Size data were collected during both sampling events and age data collected during the first event of the mark-recapture experiment. Data collection procedures were identical to the Salcha River study. However, the Chatanika River mark-recapture data did show a significant change in capture probability of marked Arctic grayling during the abundance estimation experiment. Therefore, age and size samples taken with the electrofishing boat were most likely different than the true age and size composition of the Chatanika River stock at the time the samples were taken. The same size class strata used for abundance estimation were used to estimate adjustment factors for age and size composition estimates. Equations 9 through 12 were used to adjust for differences in capture probability and estimate age and size composition.

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[1] The preferred zone for Arctic grayling is centered approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin.

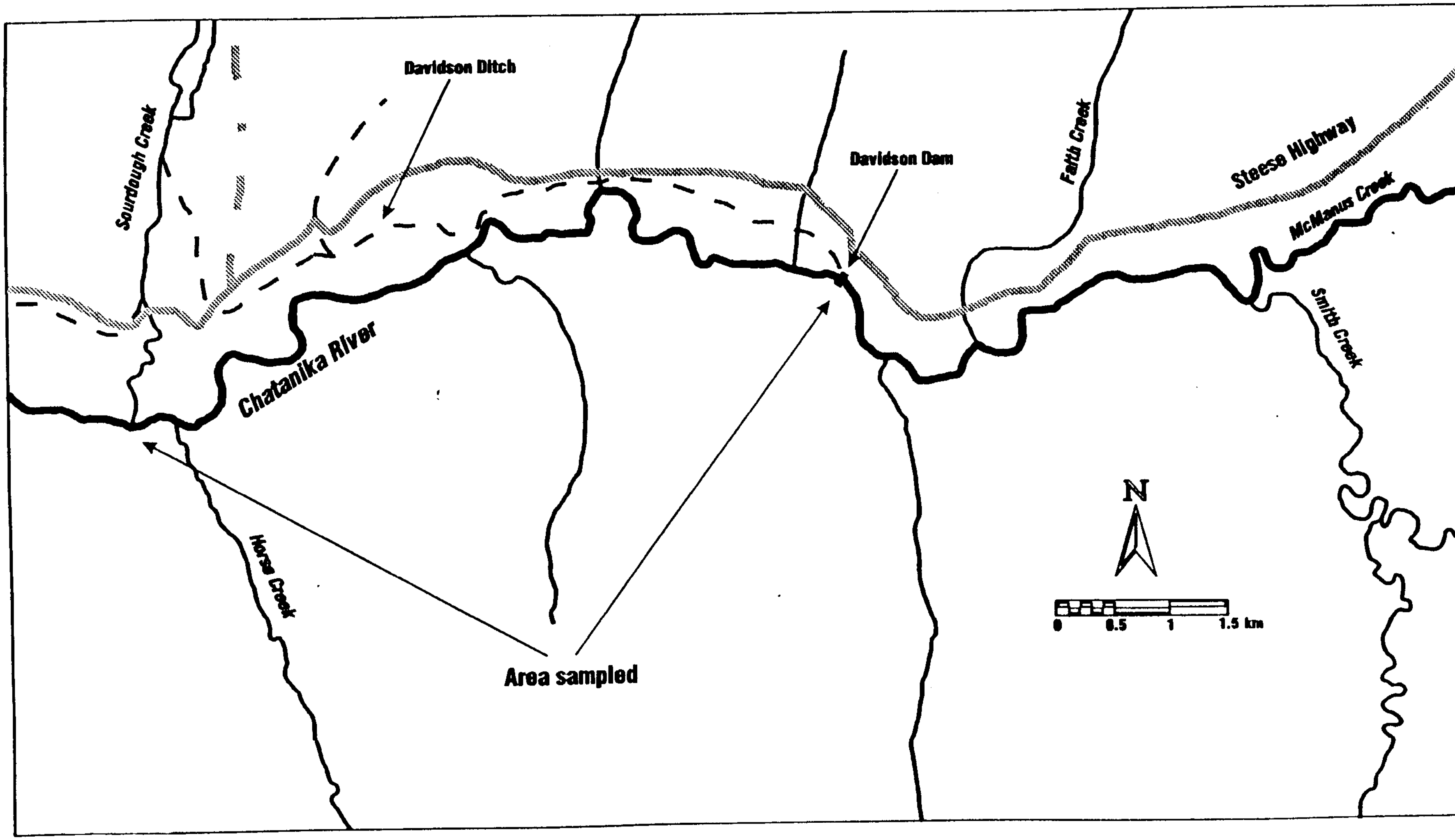


Figure 6. Study sections of the Upper Chatanika River in 1991.

Lower Chatanika. No age data was collected during the study, but size data was collected during each sampling event. The mark-recapture data did not indicate a significant change in capture probability of marked Arctic grayling during the experiment. Therefore, size samples taken with the electrofishing boat were most likely similar to the size composition of the Chatanika River stock at the time these samples were taken. Estimates of size composition were then calculated using the recapture event (equations 7 and 8).

Goodpaster River:

Size data were collected during both sampling events and age data were collected during the first event of the capture-recapture experiment. Data collection procedures were identical to the Salcha River study. Although size selectivity was detected in the capture-recapture data, the bias was considered minimal (case IVb in Appendix C1). Therefore, age and size data were taken from the first event of the experiment to directly estimate age and size composition. Equations 7 and 8 were used to calculate point estimates and variances of the proportions.

Delta Clearwater River:

Age and size data were collected from the lower 1.6 km of the Delta Clearwater River during 20 May through 3 June (Figure 5). Experience from capture-recapture sampling in 1988 indicated that peak migration of Arctic grayling from spawning areas into the Delta Clearwater River occurs between 24 May and 3 June. Fish were collected with a pulsed-DC electrofishing boat (as described above) on seven different occasions. Fishing time was recorded to the nearest 0.1 hour. As in the Upper Chatanika experiment, recaptures of marked fish were to be used to test for size selectivity and adjust age and size composition if size selectivity was detected. However, low catches and low numbers of recaptures prevented the use of the aforementioned Kolmogorov-Smirnov tests. Age and size composition were estimated directly from samples taken during the experiment (equations 7 and 8).

Data from this study were recorded on mark sense forms and electronically stored for analysis and archival (see listing of data files in Appendix D1).

RESULTS

Salcha River

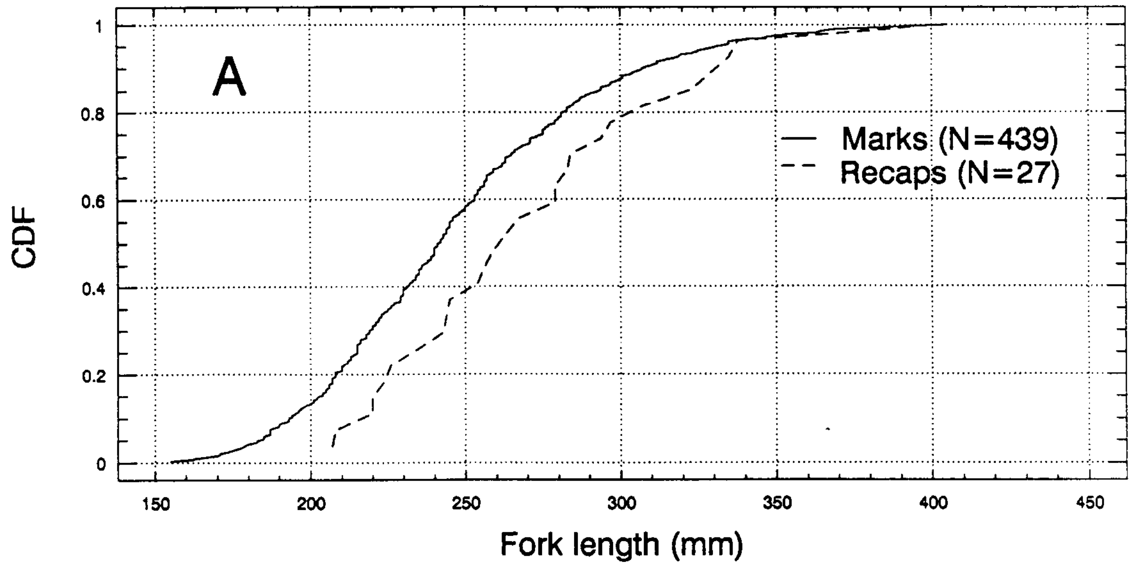
A total of 789 Arctic grayling (≥ 150 mm FL) were captured over an eight-day period in late June-early July, and used in a mark-recapture experiment. During the marking event, a total of 439 Arctic grayling were tagged and released over the 38.6 km section of river. During the recapture event, unseasonably warm and dry weather decreased stream discharge and increased water temperature up to 17°C. During this event 237 fish were examined for marks. Because of the low catches, an additional pass through the study area was made, yielding an additional catch of 97 fish. The resulting catch after two passes through the study area was 334 fish (≥ 150 mm FL), which included 27 fish recaptured from the first event. During the course of the study there were no indications of tag shedding. The overall acute mortality rate from the experiment was 2% based on 16 lethally injured Arctic grayling out of a total of 800 captures (all sizes of fish including those less than 150 mm FL).

The comparison of Cumulative Distribution Functions (CDF's) of lengths from the mark and recapture samples did not indicate a statistically significant difference (Kolomogorov-Smirnov two-sample test: $DN = 0.26$, $P = 0.06$; Figure 7A). The second Kolmogorov-Smirnov test showed a significant difference between the lengths of fish in the marking and recapture sampling events ($DN = 0.13$, $P = 0.002$; Figure 7B). The combined results of these two tests suggested use of an unstratified abundance model (Case II, Appendix C1). Because of the comparatively low power due to small sample sizes (recaptures = 27), a stratified estimate was also generated for comparison. An iterative series of chi-square tests indicated that the maximal difference in capture probability occurred at 279 mm FL.

The smallest recaptured Arctic grayling in the second event was 207 mm FL. A total of 57 fish between 150 and 199 mm FL were captured, marked, and released during the first event. During the second event, a total of 42 unmarked fish between 150 and 199 mm FL were captured. Comparatively, 27 recaptures were observed out of 292 fish examined with lengths greater than 199 mm. The approximate randomization test indicated that out of 1,000 simulated experiments only 11 trials would have had zero small size (150-199 mm) fish recaptured out of 42 examined given the probability of recapture equal to 27/292 or 0.0925. We rejected the null hypothesis of equal recapture ratios for small and large (≥ 200 mm FL) fish (for $\alpha = 0.05$, since $P = 0.011$). Accordingly, it was thought that the least biased abundance estimate would be obtained using a truncated analysis, which included only fish marked and examined that were greater than 199 mm FL (hereafter referred to as the Reduced model). Re-examination for size selectivity using the truncated Reduced model data set resulted in the finding that the CDF's of lengths in the marking sample were similar to those of the recaptured fish ($DN = 0.19$, $P = 0.30$). The second Kolmogorov-Smirnov test showed a significant difference between the lengths of fish in the marking and recapture sampling events ($DN = 0.15$, $P < 0.001$). The results of these tests suggested an unstratified estimate of abundance (Case II; Appendix C1).

Although there were three recaptured fish that moved between sections (Table 2), the estimation of movement was not performed. Examination of area specific capture probabilities found no significant differences (Reduced model: $\chi^2 = 0.23$, df = 2, $P = 0.891$; Full model: $\chi^2 = 0.36$, df = 2, $P = 0.835$). Because the study objective was to estimate abundance and composition estimates for fish ≥ 150 mm FL, stratified and unstratified estimates were calculated using data from fish ≥ 150 mm (the Full model) and ≥ 200 mm FL (the Reduced model). Full model strata included those fish from 150 to 279 mm FL, and those ≥ 280 mm. Reduced model strata included those fish from 200 to 279 mm FL, and those ≥ 280 mm.

Unstratified and stratified abundance estimates from the Full models (Table 3) were similar and the unstratified estimator had the smallest variance (see Case IV, Appendix C1). The unstratified abundance estimate for Arctic grayling ≥ 150 mm FL (Full model) was 5,429 fish (SE = 1,044 fish; CV = 19%).



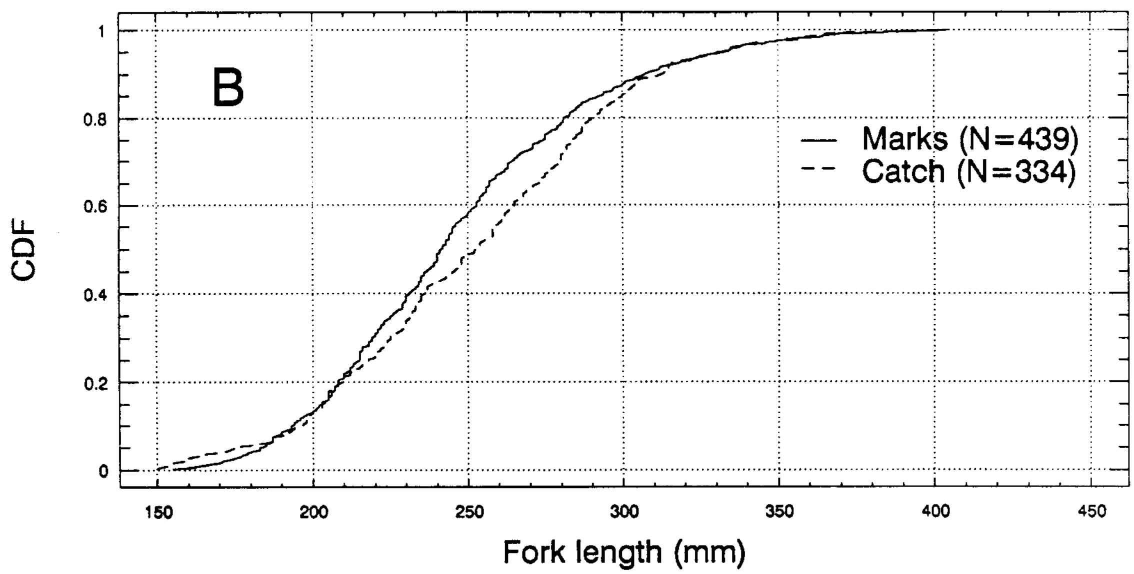


Figure 7. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 36.8 km section of the Salcha River, 18 June through 2 July 1991.

Table 2. Summary of inter-section and inter-run[a] movements of Arctic grayling (≥ 150 mm FL) based on recaptures (R) in the lower 36.8 km of the Salcha River, 18 June through 2 July 1991.

Mark	Recapture: Upstream Section 3					Midstream Section 2					Downstream Section 1								
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	R_{NM}[b]	R_M[c]	Total Recaptured	Total Marked
1	1															1	0	1	27
2	1	0														0	1	1	25
3			1	1												1	1	2	21
4	1			2												2	1	3	50
5			2		2											2(6)	2(5)	4(11)	20(143)[d]
6			1			3										3	1	4	51
7							0									0	0	0	24
8							1	1								1	1	2	29
9								1	2							2	1	3	57
10										0						0(6)	0(3)	0(9)	17(178)
11								1	1		0					0	2	2	33
12												3				3	0	3	15
13													0			0	0	0	23
14														0		0	0	0	26
15															2	2(5)	0(2)	2(7)	21(118)

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 2.4 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 starts at river km 40.0 and run 15 ends at river km 3.2.

[b] R_{NM} = Fish recaptured in same run as marked.

[c] R_M = Fish recaptured either up or downstream of marking location.

[d] Numbers in parentheses are totals.

Table 3. Stratified and unstratified estimates of Arctic grayling (≥ 150 mm FL) capture probability and abundance in a 38.6 km section of the Salcha River, 18 June through 2 July, 1991.

Abundance model	Length category	Mark M	Catch C	Recap R	ρ[a]	SE[ρ][b]	N[c]	SE[N][d]
<u>Petersen-Full model</u>[e]:								
Stratified:								
	150 to 279 mm	343	232	17	0.05	0.01	4,877	1,663
	≥ 280 mm	96	102	10	0.10	0.02	929	181
	Total	439	334	27	---	---	5,806	1,672
Unstratified		439	334	27	0.06	0.01	5,429	1,044
<u>Petersen-Reduced model</u>:								
Stratified:								
	200 to 279 mm	286	190	17	0.06	0.02	3,355	1,097
	≥ 280 mm	96	102	10	0.10	0.02	929	190
	Total	382	292	27	---	---	4,284	1,113
Unstratified		382	292	27	0.07	0.01	4,182	907

[a] ρ is the probability of capture estimated from bootstrap methods.
[b] SE[ρ] is the standard error of ρ estimated from bootstrap methods.
[c] N is the estimated abundance in a stratified length category or unstratified population, estimated through bootstrap methods.
[d] SE[N] is the bootstrap standard error of N.
[e] The Full model refers to the inclusion of all sizes, whether or not all sizes were present in the sample of recaptured fish. The use of this model assumes that the fish smaller than 200 mm Fl would be captured with the same capture probability as the next larger stratum. Because of the uncertainty of the true capture probability, the additional information provided for the proportion of fish between 150 and 199 mm Fl is likely biased.

The unstratified abundance estimate for Arctic grayling ≥ 200 mm FL (Reduced model) was 4,182 fish (SE = 907 fish; CV = 22%). The difference between the Full and Reduced estimates involved the portion of the population between 150 and 199 mm FL, which composed 12.6% of the second event sample.

Based on the results of the tests for size selectivity, age and size compositions were estimated using the unadjusted recapture event sample. Composition estimates were made from both the Full and Reduced samples, but in spite of the bias previously indicated for the Full model, and, for the purpose of between-year comparisons, estimates from the Full unstratified model were used. The estimated age composition within the 38.6 km study area was dominated by ages 4 and 5, with proportional contributions of 25% and 30%, respectively (Table 4). Stock and quality size fish made up 63% and 33% of the sampled Arctic grayling (Table 5). Sizes of Arctic grayling in the Salcha River were varied (Figure 8).

Chatanika River

Abundance of Arctic grayling was estimated for the middle and lower sections of the Chatanika River.

Upper Chatanika:

A total of 599 captures of Arctic grayling (≥ 150 mm FL) were made over an 11 day period in June in a mark-recapture study along a 10 km section of the Upper Chatanika River. During the marking event, which ran from 3 through 7 June, 354 Arctic grayling were tagged and released. During the recapture event, from 10 through 13 June, 245 fish were examined for marks, including 128 recaptures of fish marked in the previous event. No evidence of tag shedding was detected during the experiment, and the overall acute mortality rate due to sampling was 0.5%, based on three lethally injured fish from a total of 624 captures of fish of all sizes.

Comparison of CDF's of length from the mark and recapture samples did not result in a statistically significant difference (Kolomogorov-Smirnov two-sample test: $DN = 0.12$, $P = 0.12$; Figure 9A). The second Kolmogorov-Smirnov test showed a significant difference between the lengths of fish in the marking and recapture sampling events ($DN = 0.12$, $P = 0.02$; Figure 9B). The observed difference in CDF's of size composition over the two-week study indicated an influx of smaller fish into the population between events. Because of this change in size composition, and the unknown status of the first sampling event with respect to bias, adjustments to the sampled age and size compositions were not feasible. The change in size composition was interpreted as a problem with both geographic and demographic closure (most likely immigration). As a result, the two composition estimates reflect changes in composition that may occur during the spawning period of Arctic grayling. In both weeks of sampling the age composition was dominated by ages 6 and 7, but during the recapture event additional young fish had recruited to the sample area and/or to our sampling gear (Table 6). For the purpose of providing the least biased age and size compositions, the recapture event sample more aptly represents the population of the Upper Chatanika River. Relative Stock Densities from the second event indicated that the stock and

Table 4. Estimates of age class composition and standard error for Arctic grayling ($\geq$ 150 mm FL) captured from the Salcha and Chatanika River stocks, 1991.

	Salcha River[a]				Chatanika River[b]			
Age Class	n[c]	p[d]	SE[e]	CV[f]	n	p	SE	CV
2	12	0.04	0.01	27	26	0.05	0.01	20
3	45	0.16	0.02	13	88	0.17	0.02	10
4	69	0.25	0.03	10	226	0.44	0.02	5
5	81	0.30	0.03	9	46	0.09	0.01	15
6	37	0.13	0.02	15	36	0.07	0.01	16
7	19	0.07	0.01	22	47	0.09	0.01	14
8	7	0.03	0.01	38	29	0.06	0.01	18
9	2	0.01	<0.01	50	12	0.02	0.01	30
10	1	<0.01	<0.01	100	4	0.01	<0.01	50
11	1	<0.01	<0.01	100	1	<0.01	<0.01	100
Totals	274	1.00	---	---	515	1.00	---	---

[a] Arctic grayling were sampled from the Salcha River between 25 June and 2 July, 1991. The reported composition estimate corresponds to the unadjusted second (recap) event sample.

[b] Arctic grayling were sampled from a 35.2 km section (referred to in this report as the Middle Chatanika) of the Chatanika River between 5 through 7 August, 1991. The reported composition estimate corresponds to the unadjusted first (mark) event sample.

[c] n = sample size.

[d] p = proportion of Arctic grayling in the population.

[e] SE = standard error of p.

[f] CV = coefficient of variation of p expressed as a percentage.

Table 5. Summary of RSD indices for Arctic grayling (≥ 150 mm FL) in the Salcha, Goodpaster, and Delta Clearwater rivers, 1991[a].

	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
Salcha River (Full Model)[c]:					
Number sampled	212	110	12	0	0
Sample RSD	0.63	0.33	0.04	---	---
Adjusted RSD	0.79	0.19	0.02	---	---
Standard Error	0.05	0.04	0.01	---	---
CV (%)	6	24	49	---	---
Salcha River (Reduced Model):					
Number sampled	170	110	12	0	0
Sample RSD	0.58	0.38	0.04	---	---
Standard Error	0.03	0.03	0.01	---	---
CV (%)	5	7	29	---	---
Goodpaster River					
Number sampled	686	90	11	0	0
RSD	0.87	0.12	0.01	---	---
Standard Error	0.01	0.01	<0.01	---	---
CV (%)	1	8	22	---	---
Delta Clearwater River					
Number sampled	156	97	19	0	0
RSD	0.57	0.36	0.07	---	---
Standard Error	0.03	0.03	0.01	---	---
CV (%)	5	8	21	---	---

[a] Arctic grayling were sampled from the Salcha River between 25 June and 2 July, 1991. Arctic grayling were sampled from the Goodpaster River between 7 and 14 August, 1991. Arctic grayling were sampled from the Delta Clearwater River between 20 May and 3 June, 1991.

[b] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984):
- Stock - 150 mm FL;
- Quality - 270 mm FL;
- Preferred - 340 mm FL;
- Memorable - 450 mm FL; and,
- Trophy - 560 mm FL.

[c] Full model refers to the full range of sizes (≥ 150 mm Fl) of Arctic grayling represented in the composition estimate. When fish were not recaptured over the full range of sizes, randomization tests determined that these smaller fish had dissimilar capture probabilities, which led to the Reduced model, including Arctic grayling ≥ 200 mm Fl.

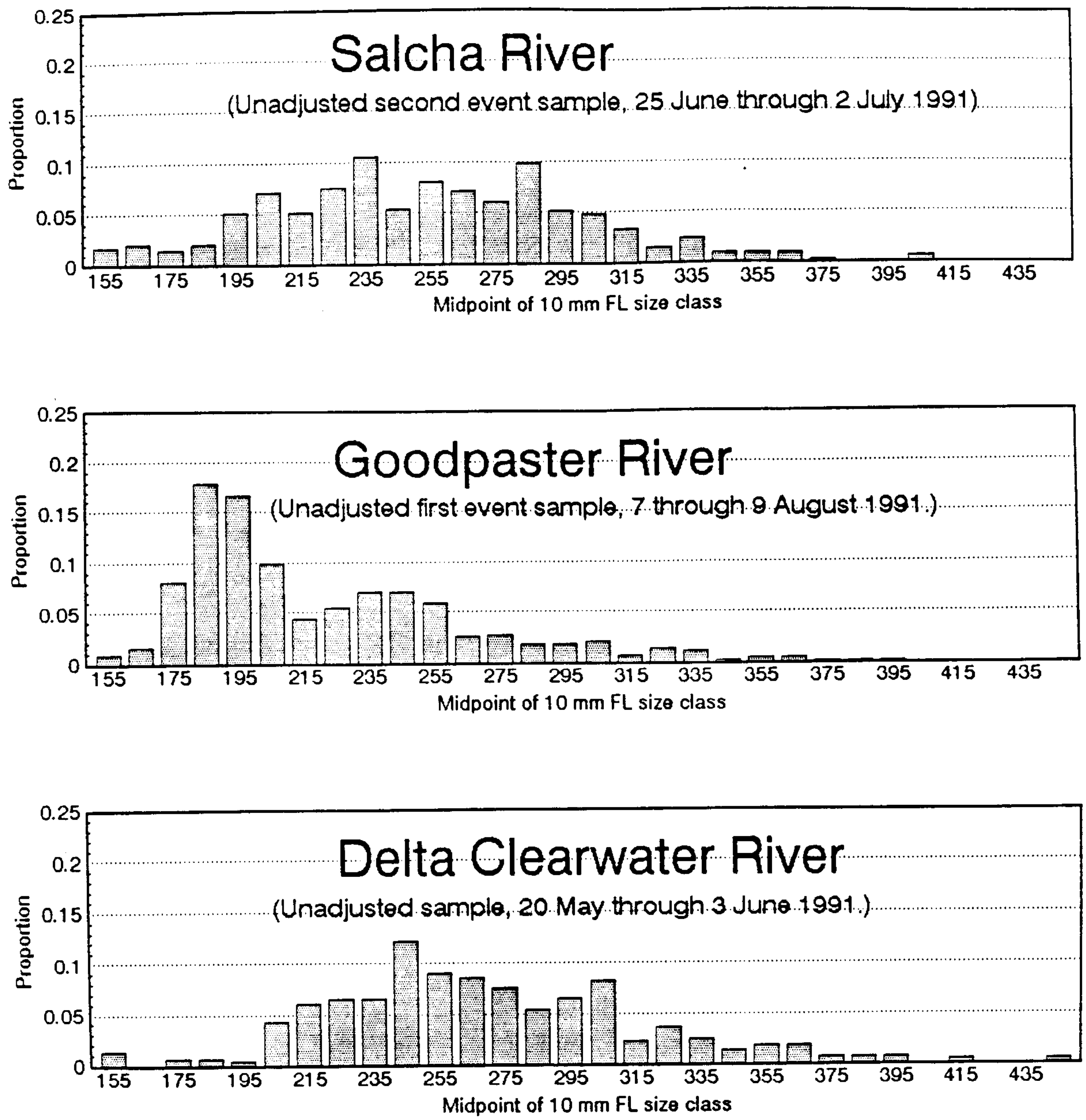
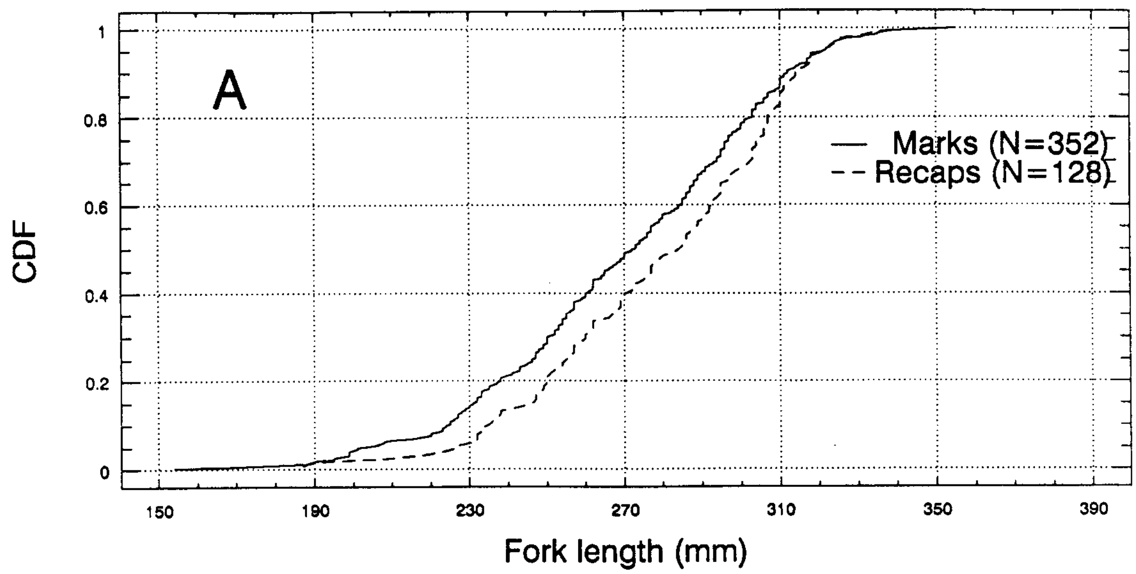


Figure 8. Estimated incremental size compositions for Arctic grayling (≥ 150 mm FL) in the Salcha, Goodpaster, and Delta Clearwater rivers, 1991.



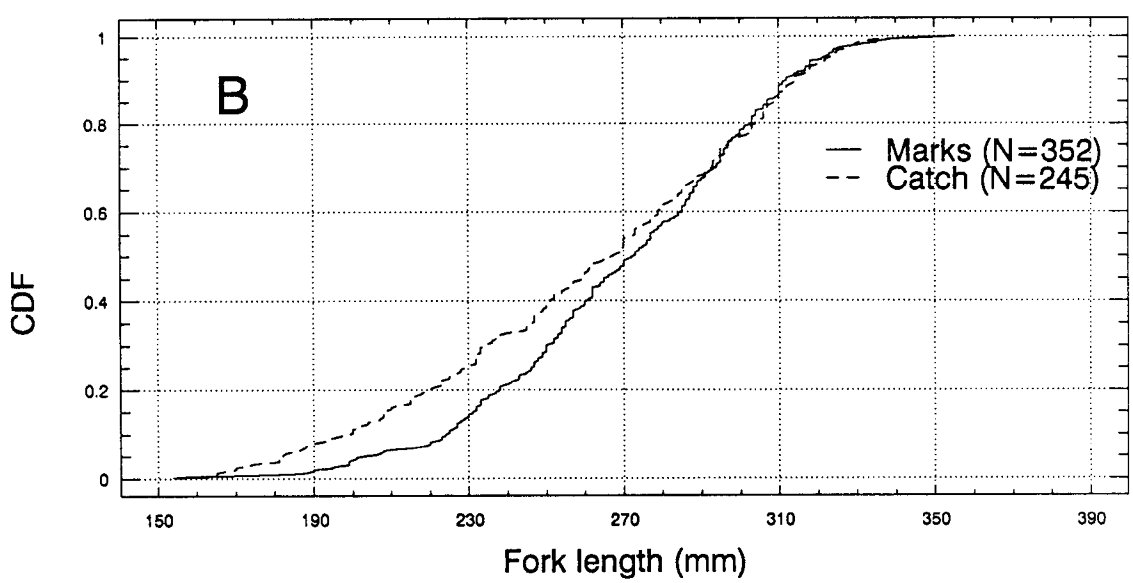


Figure 9. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 10 km section of the Upper Chatanika River, 3 through 13 June 1991.

Table 6. Estimates of the sampled proportional contributions of each age class and standard error for two samples[a] of Arctic grayling captured in the upper Chatanika River during June 1991.

	Sampling event A: 6/03 through 6/7				Sampling event B: 6/10 through 6/13			
Age Class	n[b]	p[c]	SE[d]	CV[e]	n	p[b]	SE	CV
2	1	<0.01	<0.01	100	0	---	----	--
3	2	0.01	<0.01	71	14	0.07	0.02	25
4	33	0.12	0.02	16	34	0.16	0.02	15
5	44	0.15	0.02	14	34	0.16	0.02	15
6	78	0.27	0.03	10	46	0.22	0.03	13
7	84	0.30	0.03	9	54	0.26	0.03	12
8	40	0.14	0.02	15	26	0.12	0.02	18
9	2	<0.01	<0.01	71	2	0.01	<0.01	70
10	0	0	---	--	0	---	---	--
Totals	284	1.00	---	---	210	1.00	---	---

[a] Arctic grayling were sampled with hook and line in the Upper Chatanika River as part of a mark-recapture experiment to assess size and age composition. Corrections to the composition estimates for size selectivity were not possible due to an influx, or recruitment of smaller fish between the two sampling events.

[b] n = sample size.

[c] p = proportion of Arctic grayling in the sample.

[d] SE = standard error of p.

[e] CV = coefficient of variation of p expressed as a percentage.

quality categories were similar (51% and 48%, respectively). Similarly, incremental size composition was skewed towards larger fish (Figure 10), most likely due to the timing of sampling.

Middle Chatanika:

A total of 1,313 Arctic grayling (≥ 150 mm FL) was captured during 5 through 15 August. During the marking event, 5 through 7 August, a total of 608 Arctic grayling was tagged and released over the 35.2 km study section. During the recapture event, 12 through 15 August, there were 763 fish ≥ 150 mm FL examined for marks, of which 58 were recaptures During the course of the experiment, there was one fish recaptured which had shed its tag. The overall acute mortality rate from the experiment was 0.5% based on six lethally injured Arctic grayling out of a total of 1,316 captures.

Comparison of CDF's of length from the mark and recapture samples resulted in a statistically significant difference (Kolomogorov-Smirnov two-sample test: $DN = 0.27$, $P < 0.001$; Figure 11A). The second Kolmogorov-Smirnov test also showed a significant difference between the lengths of fish in the marking and recapture sampling events ($DN = 0.08$, $P = 0.01$; Figure 11B). The demonstrated differences in capture probability with respect to size necessitated that the mark-recapture data be stratified to alleviate bias (Case IV, Appendix C1). To facilitate stratification, an iterative series of chi-square tests indicated that the maximal difference in capture probability occurred at 223 mm FL. Although one recaptured fish moved between areas, movement was considered to be negligible (Table 7). Capture probability by area was examined using a stratified approach; capture probability was found to vary by area for the small fish stratum ($\chi^2 = 6.9$, df = 2, P = 0.032), but not for the larger stratum ($\chi^2 = 1.3$, df = 2, P = 0.522). Area-stratified estimates of abundance were not calculated because there were only eight recaptures in the small fish stratum.

The smallest recaptured Arctic grayling in the second event was 194 mm FL. During the first event, 59 fish between 150 and 189 mm FL were captured, marked, and released. During the second event, a total of 57 unmarked fish between 150 and 189 mm FL were captured. Comparatively, eight recaptures were observed out of 186 fish examined with lengths between 190 and 223 mm FL. The approximate randomization test indicated that out of 1,000 simulated experiments a total of 102 trials would have had zero smallest size (150-189 mm) fish recaptured out of 57 examined, given the probability of recapture equal to 8/186 or 0.043. We failed to reject the null hypothesis of equal recapture ratios for smallest and small (190-223 mm FL) fish (for $\alpha = 0.05$, since $P = 0.102$). Accordingly, a length-stratified abundance estimate could be calculated including all fish marked and examined that were greater than 150 mm FL. The two strata included those fish from 150 to 223 mm FL (small), and those ≥ 224 mm (large).

The estimated abundance of small fish in the 35.2 km study section was 7,199 fish (SE = 2,168 fish, CV = 30%; Table 8). The estimate for large fish was 3,782 fish (SE = 310 fish, CV = 8%). The sum of stratified estimates was 10,981 fish (SE = 2,190 fish, CV = 20%), while the unstratified estimate was 7,928 fish (SE = 687 fish, CV = 8%). Because of the sizeable difference

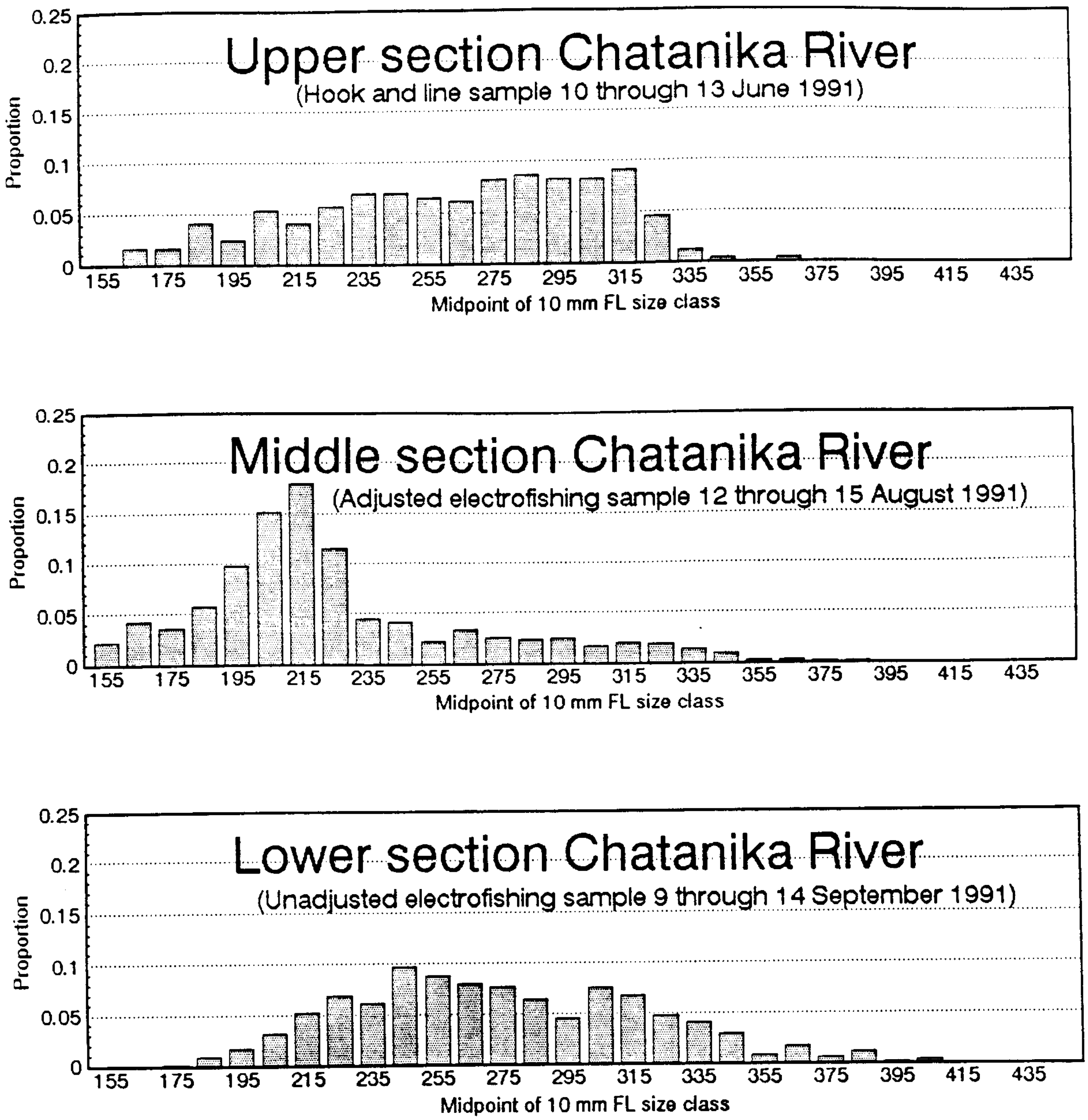


Figure 10. Estimated incremental size compositions for Arctic grayling (≥ 150 mm FL) in three study areas of the Chatanika River, 1991.

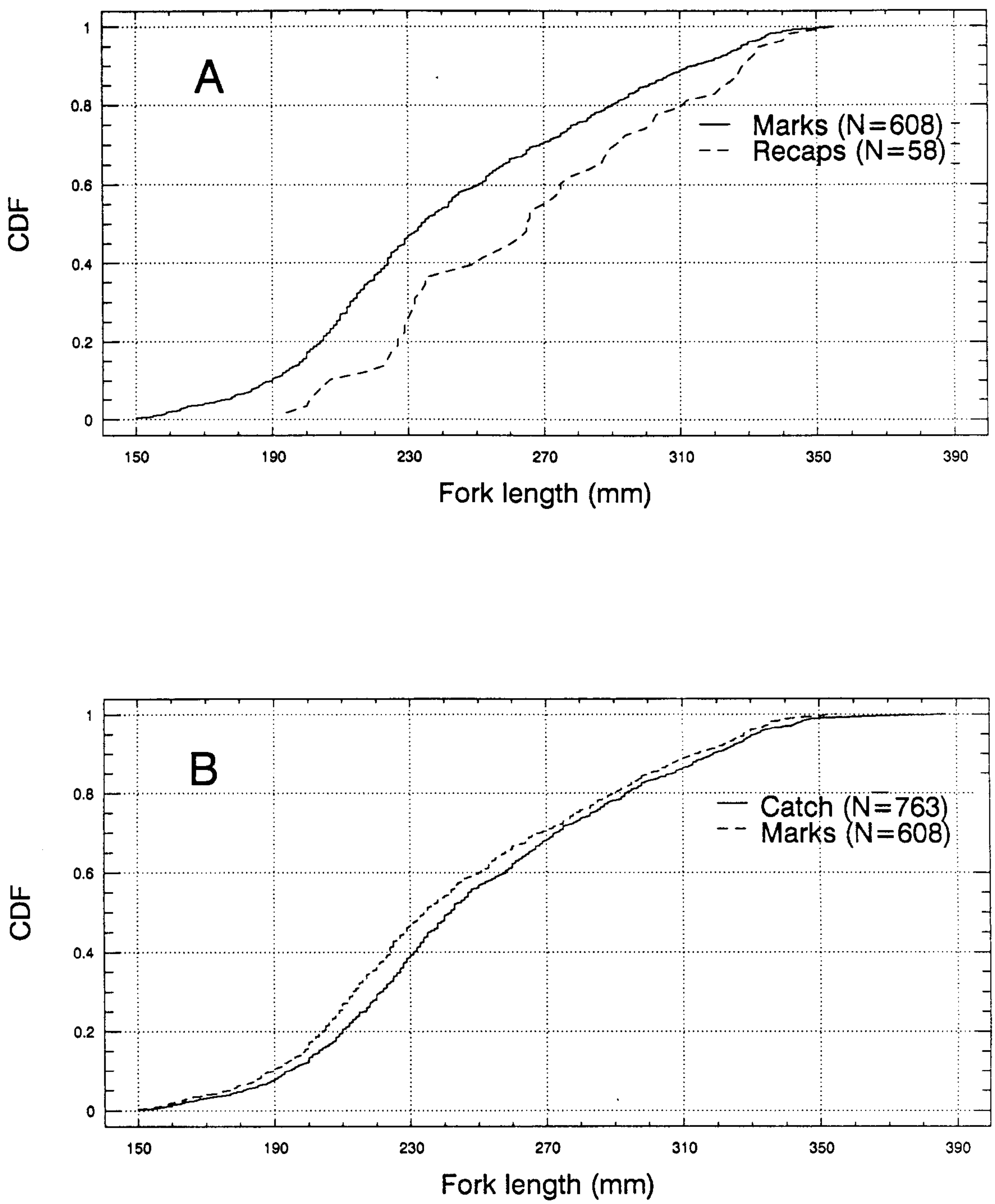


Figure 11. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 38.6 km section of the Middle Chatanika River, 5 through 15 August 1991.

Table 7. Summary of inter-section and inter-run[a] movements of Arctic grayling based on recaptures (R) in a 35.2 km section of the Middle Chatanika River, 5 through 15 August 1991.

Mark	Recapture																							
	Upstream Section 3						Midstream Section 2							Downstream Section 1									Total	Total
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	R_{NM}[b]	R_M[c]	R	M
1	0																				0	0	0	23
2		0																			0	0	0	29
3		1	2																		2	1	3	19
4				2																	2	0	2	33
5				1	0	2															0	3	3	14
6						1															1	0	1	32(150)[d]
7							1				1										1	1	2	17
8								0													0	0	0	15
9									2	1											2	1	3	32
10										1											1	0	1	15
11											2										2	0	2	24
12												1									1	0	1	15
13													3								3	0	3	30(148)
14													1	5	1		1				5	3	8	32
15															3	1					3	1	4	34
16																4	1		1		4	2	6	48
17																	2			1	2	1	3	43
18																		6	1		6	1	7	42
19																			6		6	0	6	46
20																				4	4	0	4	65(310)

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 1.7 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat.
[b] R_{NM} = Fish recaptured in same run as marked.
[c] R_M = Fish recaptured either up or downstream of marking location.
[d] Numbers in parentheses are totals.

Table 8. Stratified and unstratified estimates of Arctic grayling (≥ 150 mm FL) capture probability and abundance in a 35.2 km section of the Middle Chatanika River, 5 through 15 August, 1991.

Length category	Mark M	Catch C	Recap R	ρ[a]	SE[ρ][b]	N[c]	SE[N][d]
150 to 223 mm	238	242	8	0.03	0.01	7,199	2,168
≥ 224 mm	370	521	50	0.14	0.01	3,782	310
Total	608	763	58	---	---	10,981	2,190
Unstratified	608	763	58	0.09	<0.01	7,928	687

[a] ρ is the probability of capture determined from bootstrap methods.
[b] SE[ρ] is the standard error of ρ determined from bootstrap methods.
[c] N is the estimated abundance in a stratified length category or unstratified population, determined through bootstrap methods.
[d] SE[N] is the bootstrap standard error of N.

between stratified and unstratified estimates, the stratified estimate was selected for use (Case IVa, Appendix C1). Age and size compositions from the recapture event were considered unbiased, but no ages were collected during the recapture event. Ages from the first sampling event were used. Age 4 Arctic grayling made up 44% of the sample, the next most prominent cohort was age 3 (Table 4). Because the mean length-at-age for age 3 and age 4 Arctic grayling are largely within the small fish strata (204 and 227 mm FL, respectively), it is likely that these estimated year class strengths are minimum estimates. Adjusted RSDs indicated that 84% of the stock inhabiting the middle section of the Chatanika River is stock size, and 14% is quality size (Table 9).

Lower Chatanika:

A total of 1,796 Arctic grayling (≥ 150 mm FL) were captured over a 66 day period from mid-July through mid-September 1991. The marking events ran from 11 through 16 July, and 23 through 26 August. During these two sampling events 326 and 480 Arctic grayling ≥ 150 mm FL were marked and released while electrofishing for whitefish along a 109 km section of the middle and lower Chatanika River. During the recapture event, from 9 through 14 September, a total of 990 Arctic grayling were examined for marks, 25 of which were recaptures from the earlier marking events. The overall acute mortality was 0.1%, based on two lethally injured fish out of 1,796 handled. One tag loss was observed, but it could not be concluded whether it was from this experiment, or from the experiment being conducted upstream. During the analysis, we reduced the study area after finding zero recaptures from 139 marked and 240 examined in the upper 25.8 km of the study area. Following removal, sample sizes for the experiment were reduced: 667 fish were marked, 749 fish were examined for marks, and 25 fish were recaptured. This reduced study section was immediately downstream of the study section used to estimate abundance of Arctic grayling in the Middle Chatanika.

The comparison of CDF's of lengths from the mark and recapture samples did not indicate any significant differences (Kolomogorov-Smirnov two-sample test: $DN = 0.20$, $P = 0.27$; Figure 12A). The second Kolmogorov-Smirnov test showed a significant difference between the lengths of fish in the marking and recapture sampling events ($DN = 0.08$, $P = 0.02$; Figure 12B). The results of these tests indicated the use of an unstratified data set to estimate abundance, with size compositions based upon the unadjusted second event (Case II, Appendix C1).

Over the extended mixing periods between sampling events, 11 of 25 recaptured Arctic grayling showed signs of movement. Of these movements, eight were in the downstream direction and three moved upstream. Because the delineated areas in the whitefish study section were not of equal size, no adjustments could be made to offset the effects of movement on estimated abundance. There was no significant evidence that capture probability varied among the six study areas ($\chi^2 = 5.5$, df = 5, $P = 0.358$). The abundance of Arctic grayling was 20,122 fish (SE = 3,845 fish, CV = 19%) in the 83.2 km section of river. Fifty-one percent of the sampled Arctic grayling from the lower section of the Chatanika River were stock size, while 42% were quality size (Table 7).

Table 9. Summary of RSD indices for Arctic grayling (≥ 150 mm FL) in three sections of the Chatanika River, 1991[a].

	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Upper Chatanika River</u>					
Number sampled	126	117	2	0	0
Sample RSD	0.51	0.48	0.01	---	---
Standard Error	0.03	0.03	<0.01	---	---
CV (%)	6	7	75	---	---
<u>Middle Chatanika River</u>					
Number sampled	516	222	25	0	0
RSD	0.68	0.29	0.03	---	---
Adjusted RSD[c]	0.84	0.14	0.02	---	---
Standard Error	0.03	0.03	<0.01	---	---
CV (%)	3	18	22	---	---
<u>Lower Chatanika River</u>					
Number sampled	381	312	56	0	0
RSD	0.51	0.42	0.07	---	---
Standard Error	0.02	0.02	0.01	---	---
CV (%)	3	4	13	---	---

[a] Arctic grayling were sampled from the Upper Chatanika River between 10 and 13 June, 1991. Arctic grayling were sampled from the Middle Chatanika River between 12 and 15 August, 1991. Arctic grayling were sampled from the Lower Chatanika River between 9 and 14 September, 1991.

[b] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984):
Stock - 150 mm FL;
Quality - 270 mm FL;
Preferred - 340 mm FL;
Memorable - 450 mm FL; and,
Trophy - 560 mm FL.

[c] Adjusted RSD is determined from methods in Clark and Ridder (1990).

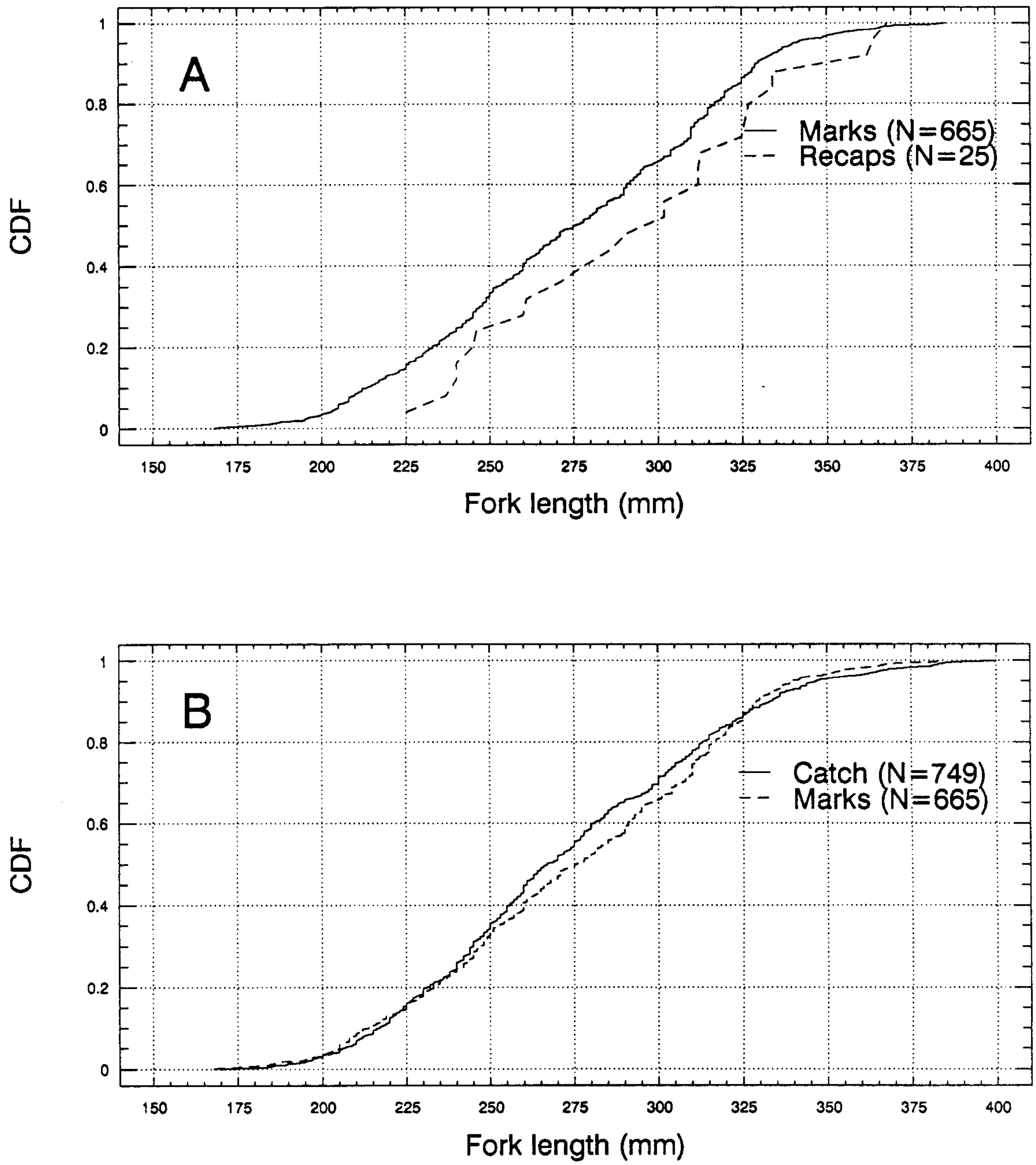


Figure 12. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 83.2 km section of the Lower Chatanika River, 11 July through 14 September 1991.

Goodpaster River

A total of 1,167 Arctic grayling (≥ 150 mm FL) was captured and utilized in the mark-recapture experiment. During the marking event, from 7 to 9 August, 780 Arctic grayling were marked and released in the study section. Following a one week hiatus, 429 fish were examined for marks, 42 of which were recaptures. During the course of this experiment 12 fish were killed and removed from the study, resulting in an overall mortality rate of 1.0%.

The comparison of CDF's of lengths from the mark and recapture samples resulted in a significant difference in capture probability ($DN = 0.29$, $P < 0.01$; Figure 13A). As a result, the mark-recapture data were stratified into small Arctic grayling (150 to 213 mm FL) and large Arctic grayling (greater than 213 mm FL) to investigate the extent of bias. In addition, capture probabilities were not significantly different among the three areas ($\chi^2 = 0.6$, $df = 2$, $P = 0.741$).

Although movement of one marked fish was considerable, the balance of movements between sampling events was small. No overall movement of large numbers of marked fish was detected (Table 10). The abundance of small fish was 4,996 fish (SE = 1,066 fish, CV = 21%), while the abundance of large fish was 3,127 fish (SE = 344 fish, CV = 11%). The sum of the stratified abundance estimates for the lower 50 km of the Goodpaster River was 8,123 fish (SE = 1,120 fish, CV = 14%), while the unstratified abundance estimate was 7,836 fish (SE = 859 fish, CV = 11%; Table 11). The unstratified estimate was considered most appropriate because there was virtually no difference between the stratified and unstratified estimates of abundance and the unstratified estimate had the smaller standard error (difference = 287 fish, SE = 1,412 fish, CV = 492%).

The second Kolmogorov-Smirnov test produced a significant difference in length frequencies of fish marked and fish examined for marks ($DN = 0.22$, $P < 0.01$; Figure 13B). Because the unstratified estimate of abundance was relatively unbiased and more precise when compared to the stratified estimate, age and size compositions were calculated directly from samples taken during the first event of the experiment (case IVb in Appendix C1). Age 2 fish comprised 53% of the estimated abundance, while age 4 fish were next most abundant at 25% (Table 12). Only 10% of the stock was represented by age 3 fish. Ages 5 through 7 occurred in approximately equal percentages in the study section. The oldest fish sampled in the study section was 10 years old. Because of the preponderance of age 2 and age 4 fish, stock size fish dominated (87% of the sample) in this section of the Goodpaster River (Table 5). Quality and preferred size fish represented 12% and 1% of the sample, respectively. No memorable or trophy size fish were captured in the study section.

Delta Clearwater River

Insufficient numbers of recaptures were made to evaluate bias of the electrofishing gear and adjust for potential bias. Of the 233 fish marked and released during the first six days of sampling the Delta Clearwater River, only five fish were subsequently recaptured. Catch rate varied from 10 fish per hour of sampling to 50 fish per hour of sampling (Table 13). Although

Table 10. Summary of inter-section and inter-run[a] movements of Arctic grayling (≥ 150 mm FL) based on recaptures (R) in the lower 50.0 km of the Goodpaster River, 7 through 14 August 1991.

Mark:	Recapture: Section 3									Section 2								Section 1											Total	Total
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	R_{NM}[b]	R_M[c]	R	M
1	1																						1				1	1	2	7
2		0																									0	0	0	8
3			0			1																					0	1	1	9
4				0									1														0	1	1	3
5					1																						1	0	1	8
6						0																					0	0	0	10
7							1																				1	0	1	15
8								0		1																	0	1	1	11
9									1	1																	1(4)	1(5)	2(9)	14(85)
10										1																	1	0	1	14
11											2			1													2	1	3	26
12												1															1	0	1	40
13													2														2	0	2	30
14														2													2	0	2	50
15															2												2	0	2	37
16																4											4	0	4	98
17																	2										2(16)	0(1)	2(17)	86(381)[d]
18																		2									2	0	2	47
19																		1	3								3	1	4	61
20																				0							0	0	0	19
21																					3						3	0	3	37
22																						0					0	0	0	35
23																						1	1				1	1	2	17
24																							1	2			2	1	3	39
25																									1		1	0	1	37
26																										1	1(13)	0(3)	1(16)	23(315)

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 1.8 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 starts at river km 52.3 and run 26 ends at river km 1.7.

[b] R_{NM} = Fish recaptured in same run as marked. Since marked fish were released at the end of a run, recaptures of these fish in the next run downstream were considered to be recaptured in the same location. An exception is fish marked in the last run of a section since they were released 1 km above the lower boundary of the run.

[c] R_M = Fish recaptured either up or downstream of marking location.

[d] Numbers in parentheses are totals.

Table 11. Stratified and unstratified estimates of Arctic grayling (≥ 150 mm FL) capture probability and abundance in a 50.0 km section of the Goodpaster River, 7 through 14 August, 1991.

Length category	Mark M	Catch C	Recap R	ρ[a]	SE[ρ][b]	N[c]	SE[N][d]
150 to 213 mm	445	152	13	0.03	0.01	4,996	1,066
≥ 214 mm	335	277	29	0.09	0.01	3,127	344
Total	780	429	42	---	---	8,123	1,120
Unstratified	780	429	42	0.05	0.01	7,836	859

[a] ρ is the probability of capture determined from bootstrap methods.
[b] SE[ρ] is the standard error of ρ determined from bootstrap methods.
[c] N is the estimated abundance in a stratified length category or unstratified population, determined through bootstrap methods.
[d] SE[N] is the bootstrap standard error of N.

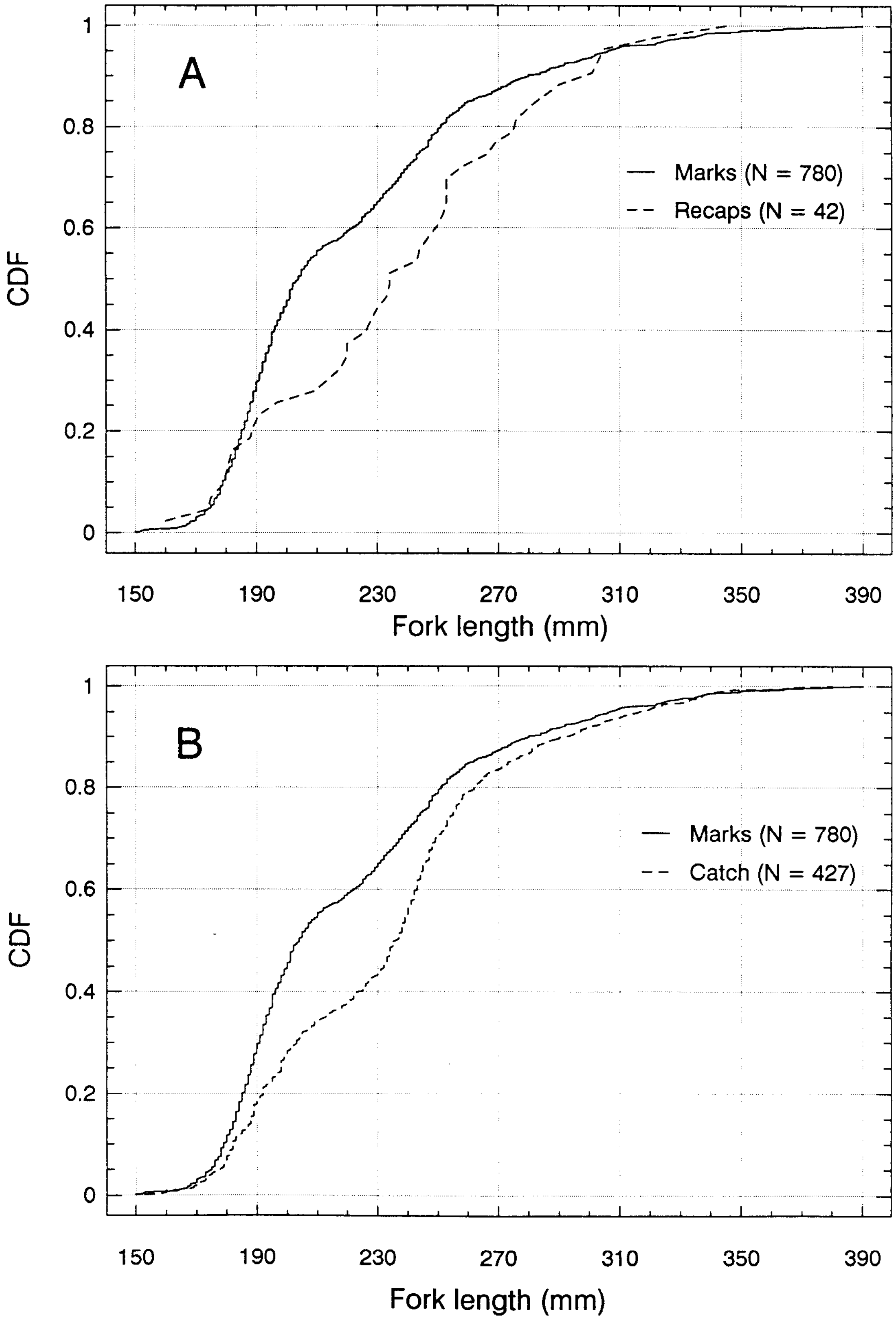


Figure 13. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 50.0 km section of the Goodpaster River, 7 through 14 August 1991.

Table 12. Estimates of the sampled age composition and sampled mean fork length (mm) at age for Arctic grayling (≥ 150 mm FL) captured in the lower 50.0 km of the Goodpaster River, 7 through 9 August, 1991.

	Age composition			Fork length (mm)	
Age	n[a]	p[b]	SE[c]	Mean	SD[d]
1	8	0.01	<0.01	163	12
2	393	0.53	0.02	189	11
3	72	0.10	0.02	217	14
4	186	0.25	0.02	245	15
5	27	0.04	0.01	276	14
6	18	0.02	<0.01	294	21
7	27	0.03	0.01	313	18
8	13	0.02	0.01	328	27
9	5	0.01	<0.01	348	19
10	2	<0.01	<0.01	386	4
Total	751	1.00	---	220	43

[a] n = sample size.
[b] p = proportion of sampled Arctic grayling.
[c] SE = standard error of the proportion.
[d] SD = standard deviation of the mean fork length.

Table 13. Summary of time fished, catch, number of recaptures, and catch rate of a pulsed-DC electrofishing boat for Arctic grayling (≥ 150 mm FL) near river km 1.6 (Mile One) of the Delta Clearwater River, 20 May through 3 June, 1991.

Date	Time fished (hr)	Catch	Recaptures	Catch rate (fish/hr)
5/20	1.3	38	---	29
5/21	1.5	72	0	50
5/22	1.3	29	1	22
5/24	2.0	20	1	10
5/28	2.0	24	1	12
5/31	1.3	50	1	37
6/3	1.3	47	1	37
Totals	10.7	280	5	26

bias due to the electrofishing gear could not be quantified, the sample of ages from the Delta Clearwater indicated that age 4 fish were most abundant (Table 14). Very few age 1 through 3 fish were sampled, while age 5 and age 6 fish made up 24% and 8% of the sample, respectively. Size composition of the sample was 57% stock size fish, 36% quality size fish, and 7% preferred size fish (Table 5).

DISCUSSION

Salcha River

In 1991, stock investigation on the Salcha River dealt with a problem of recapturing fish which span the size range set by our objectives. During the field investigation extremely hot weather led to reduced stream flows and high stream temperatures. Under such conditions, the catchability of Arctic grayling fell off considerably. Although we estimated nearly the same abundance as in 1990, and used considerably more sampling effort, our total catches were lower than in past years. The lack of recaptured fish in the 150 to 199 mm FL size range led us to use a truncated data set to avoid the uncertainty surrounding their capture probability. Bias in the estimate could affect the accuracy of stock composition estimates, and ultimately, parameter estimates of stock dynamics. The sensitivity of abundance estimators to this bias is likely to be greater when many small fish are marked and examined, but not recaptured. Because this problem occurred in several drainages at different times, under different climactic conditions in 1991, no single variable will aptly explain these findings. There are probably several variables other than stream temperature, such as the perceived low recruitment levels of age 3 Arctic grayling seen among our other investigations confounded by gear selectivity.

We found a maturing stock in the Salcha River this year. Relative abundance of smaller sized fish was less in 1991 compared to 1990, or, their catchability was less than in 1990 (Clark et al. 1991). Density of Arctic grayling greater than 150 mm FL, which was 147 fish/km, appeared similar to densities seen in 1989 and 1990 in the same study section (Appendix A2). Relative Stock Density estimates indicate a strong component of quality size fish, the largest since 1988 (Appendix A4).

Chatanika River

This year's sampling program afforded what is probably the first widespread sampling effort on the Chatanika River. We sampled a portion of the Upper Chatanika during June and found a concentration of spawning Arctic grayling. During the experiment we found that smaller fish immigrated (and/or their probability of capture increased) between sampling events. Although we did sample an area of high fish concentration, we generally perceived low densities throughout much of the 10 km section. Suitable habitat and food may be limited to Arctic grayling residing in this portion of the Chatanika River. Much of this section of river was of high gradient and stream velocity, over an embedded or armored streambed. Investigations in areas which have received sediment loads and become embedded have found low invertebrate prey densities

Table 14. Estimates of the sampled age composition and sampled mean fork length (mm) at age for Arctic grayling ($\geq$ 150 mm FL) captured near river km 1.6 (Mile One) of the Delta Clearwater River, 20 May through 3 June, 1991.

	Age composition			Fork length (mm)	
Age	n[a]	p[b]	SE[c]	Mean	SD[d]
1	0	0.00	---	---	---
2	12	0.04	0.01	163	18
3	9	0.03	0.01	218	14
4	132	0.50	0.03	244	22
5	64	0.24	0.03	282	23
6	22	0.08	0.02	311	18
7	11	0.04	0.01	332	24
8	10	0.04	0.01	354	14
9	2	0.01	<0.01	361	29
10	3	0.01	0.01	416	20
11	1	<0.01	<0.01	398	---
Total	266	1.00	---	266	48

[a] n = sample size.
[b] p = proportion of sampled Arctic grayling.
[c] SE = standard error of the proportion.
[d] SD = standard deviation of the mean fork length.

(Weber and Post 1985). Such constraints affect the productivity of the Arctic grayling resource and fishery.

Stock assessment in the Middle Chatanika occurred in largely the same area as in 1990, and was carried out under optimum conditions. The abundance estimated for the current investigation was 10,981 fish ≥ 150 mm FL, which is considerably less than the 19,306 fish estimated in 1990 over a slightly shorter section. It is thought that if the 1990 abundance estimator was unbiased then mortalities would account for this difference. When survival was calculated using fish age 3 and older, we found a 55% survival rate, which represents a minimum estimate. If we conclude that some level of positive bias was inherent in the 1990 investigation, then survival rate could be higher. We found that recruitment in 1991, as gauged by the age 3 cohort, was low in the Chatanika River. This finding is similar to recruitment levels we observed in the Salcha and Goodpaster rivers, and also the Chena River.

While undertaking a mark-recapture experiment for whitefish during July, August, and September, concurrent capturing and sampling of Arctic grayling occurred in an attempt to estimate their abundance in the Lower Chatanika. Marking data from the upper 25.6 km of the study area was removed later after finding no recaptured Arctic grayling from or in this area. Capture probability of Arctic grayling may have been reduced by the high density of whitefish. Under marginal dipnetting conditions (high and silty), whitefish would likely be selected due to their response to the gear in large numbers, and as large obvious targets for the dipnetting team. A portion of the recaptured Arctic grayling from downstream areas were recaptured in areas away from where initially released. The protracted nature of this mark-recapture experiment certainly allowed ample time for the movements we observed. If future investigations occur on the lower Chatanika River, we suggest better control over study area delineation and hiatus between events.

In the Middle and Lower sections, estimated abundances indicate a high density of fish per kilometer (312 and 242 fish per kilometer, respectively; Appendix A6). The two abundance estimates from the two adjacent study areas were assumed to be additive, because sampling in the two sections occurred nearly concurrently, thereby producing abundance estimates for two independent populations. Addition of estimated abundances for the Middle and Lower sections resulted in an estimate of 31,103 fish over 150 mm FL in a 118.4 km long section (263 fish per kilometer). This indicates an abundant population relative to other lotic stocks of Arctic grayling in interior Alaska.

<u>Goodpaster River</u>

Abundance of Arctic grayling in the 50 km section of the Goodpaster River has changed little since the first estimate was calculated for this section in 1988. For comparison, age 2 fish comprised 47% of the stock and abundance was 8,033 fish in 1989. In 1991, age 2 fish again predominated (53% of the stock) and abundance was 7,836 fish. Contrary to the findings of Clark et al. (1991), age 2 fish may be fully recruited to the sampling gear (≥ 150 mm FL) by early to middle August in the Goodpaster River. If this is true, year class strength may be ascertained at age 2 in the Goodpaster River. This is not the case for most stock assessments in interior Alaska. For example, assessments performed throughout the month of July on the Chena River provide no reliable information on year class strength of age 2 fish. Full recruitment to the sampling gear occurs at age 3 on the Chena River (Clark 1990). Year class strength in the Salcha, Chatanika, Goodpaster, and Chena rivers tends to be correlated, with either strong, weak, or average year classes replicated in all of these rivers. If age 2 Arctic grayling were abundant in the Goodpaster River in 1991, it is plausible that numbers of age 3 fish in the Salcha, Chatanika, and Chena rivers will be high in 1992. After high numbers of age 2 fish were found in the Goodpaster River in 1989, above average year class strengths of age 3 fish were found in the Salcha, Chatanika, and Chena rivers in 1990.

Delta Clearwater River

Recruitment of Arctic grayling to the Delta Clearwater from parent streams tends to occur at age 4 or 5 (Ridder 1983, 1991) and the age 4 components were strong in the Salcha, Chatanika, and Goodpaster rivers in 1991.

Although a catch of 280 fish was well below the expected number (~1,000 fish) on the Delta Clearwater River in 1991, sampling of Arctic grayling in spring may prove to be a valuable stock assessment method. If the river were sampled daily during the period from 15 May through the first week of June and catch rate was similar to 1991, approximately 450 fish would have been sampled. Although a sample of 450 fish may not be sufficient for estimation of capture probability by length, creel samples taken during 1987 through 1989 yielded an average of 400 samples of age and length in this fishery. If collection of age and length samples from the Delta Clearwater River is our primary concern, it would be much more efficient to collect the samples during a 15 day period during spring (approximately 1.5 man-months of time) than over a 3 month period during the summer (approximately 2.5 man-months of time).

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LITERATURE CITED

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38: 293-306.

_____. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21: 120-127.

Baker, T. T. 1988. Creel censuses in interior Alaska in 1987. Alaska Department of Fish and Game, Fishery Data Series No. 64, Juneau, Alaska. 138 pp.

Bendock, T. 1974. Fisheries investigations on the Salcha and Tanana drainages - preliminary findings. First Interim Report of the Sport Fish Technical Evaluation Study. Alaska Department of Fish and Game. Special Report No. 6. 19 pp.

Clark, R. A. 1988. Stock assessment of Arctic grayling in the Salcha and Chatanika rivers. Alaska Department of Fish and Game, Fishery Data Series No. 74, Juneau, Alaska. 36 pp.

______. 1990. Stock status of Chena River Arctic grayling. Alaska Department of Fish and Game, Fishery Data Series No. 90-4, Anchorage, Alaska. 52 pp.

Clark, R. A. and W. P. Ridder. 1987. Abundance and length composition of selected grayling stocks in the Tanana drainage during 1986. Alaska Department of Fish and Game, Fishery Data Series No. 26, Juneau, Alaska. 55 pp.

______. 1988. Stock assessment of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Fishery Data Series No. 54, Juneau, Alaska. 79 pp.

______. 1990. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers. Alaska Department of Fish and Game, Fishery Data Series No. 90-7, Anchorage, Alaska. 84 pp.

Clark, R. A., D. F. Fleming, and W. P. Ridder. 1991. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers. Alaska Department of Fish and Game, Fishery Data Series No. 91-15, Anchorage, Alaska. 85 pp.

Efron, B. 1982. The jackknife, the bootstrap, and other resampling plans. Society for Industrial and Applied Mathematics, Monograph 38, CBMS-NSF, Philadelphia, Pennsylvania.

Evenson, M. J. 1988. Movement, abundance and length composition of Tanana River burbot stocks during 1987. Alaska Department of Fish and Game. Fishery Data Series No. 56. 42 pp.

Fleming, D.F. 1989. Effects of spawning run delay on spawning migration of Arctic grayling. Master's thesis. University of Alaska, Fairbanks.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Hallberg, J. E. 1982. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1981-1982, Project F-9-14, 23(R-I). 35 pp.

Holmes, R. A. 1983. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(R-I). 35 pp.

______. 1984. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25(R-I). 38 pp.

______. 1985. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(R-I). 38 pp.

Holmes, R. A., W. P. Ridder, and R. A. Clark. 1986. Population structure and dynamics of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27(G-8-1). 68 pp.

Hop, H. 1985. Stock identification and homing of Arctic grayling *Thymallus arcticus* (Pallas) in interior Alaska. Master's thesis. University of Alaska, Fairbanks. 220 pp.

Kramer, M. J. 1975. Inventory and cataloging of interior Alaska waters - Fairbanks district. Alaska Department of Fish and Game. Federal Aid in Sport Fish Restoration, Annual Report of Progress, 1974-1975, Project F-9-7, 16(G-I-G): 145-181.

Manly, B. F. J. 1991. Randomization and Monte Carlo methods in biology. Chapman and Hall, New York.

Marquardt, D. W. 1963. An algorithm for least-squares estimation of nonlinear parameters. Journal for the Society of Industrial and Applied Mathematics 11: 431-441.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies (1977). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20(SW-I-A). 122 pp.

_____. 1980. Alaska statewide sport fish harvest studies (1978). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21(SW-I-A). 65 pp.

_____. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 77 pp.

_____. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 107 pp.

_____. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23(SW-I-A). 115 pp.

_____. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24(SW-I-A). 118 pp.

_____. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25(SW-I-A). 123 pp.

_____. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26(SW-I-A). 137 pp.

_____. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27(RT-2). 137 pp.

_____. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau, Alaska. 140 pp.

_____. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau, Alaska. 142 pp.

_____. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau, Alaska. 142 pp.

_____. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage, Alaska. 152 pp.

_____. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage, Alaska. 184 pp.

Nagata, T. 1963. Investigations of the Tanana River grayling fisheries: migration study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1962-1963, Project F-5-R-4, 4(14-B): 483-505.

Noreen, E. W. 1989. Computer-intensive methods for testing hypotheses: an introduction. John Wiley and Sons, New York.

Peckham, R. D. 1976. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1975-1976. Project F-9-8, 17(G-III-I): 31-50.

_____. 1977. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1976-1977. Project F-9-9, 18(G-III-I): 88-105.

_____. 1978. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1977-1978. Project F-9-10, 19(G-III-I): 63-82.

_____. 1979. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979. Project F-9-11, 20 (G-III-I): 87-114.

_____. 1980. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(G-III-I): 1-47.

_____. 1981. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981. Project F-9-13, 22(G-III-I): 1-25.

______. 1983. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983. Project F-9-15, 24(G-III-I): 1-38.

Reed, R. J. 1961. Investigations of the Tanana River grayling fisheries: creel census - Chatanika and Delta Clearwater Rivers. Alaska Department of Fish and Game. Federal Aid in Sport Fish Restoration, Annual Report of Progress, 1960-1961, Project F-5-R-2, Job 3-C.

Reynolds, J. B. 1983. p. 147-163. *In* L. A. Nielsen and D. L. [ed.] Fisheries techniques, American Fisheries Society, Bethesda, Maryland USA.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191. 382 pp.

Ridder, W. P. 1983. A study of a typical spring-fed stream of interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(G-III). 54 pp.

______. 1985. Life history and population dynamics of exploited grayling stocks - Delta and Richardson Clearwater Rivers. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985. Project F-9-17, 26(G-III-G):1-58.

______. 1989. Age, length, sex, and abundance of Arctic grayling in the Goodpaster River, 1956 through 1988. Alaska Department of Fish and Game, Fishery Data Series No. 94, Juneau, Alaska. 49 pp.

______. 1991. Summary of recaptures of Arctic grayling tagged in the middle Tanana River drainage, 1977 through 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-34, Anchorage, Alaska. 97 pp.

Roguski, E. A. 1967. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1966-1967, Project F-5-R-8, 8(16-B): 247-255.

Roguski, E. A. and P. C. Winslow. 1969. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1968-1969, Project F-9-1, 10(16-B): 333-351.

Roguski, E. A. and S. L. Tack. 1970. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1969-1970, Project F-9-2, 11(16B): 303-319.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., Ltd. London, U.K. 654 pp.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods, seventh edition. The Iowa State University Press, Ames, Iowa. 507 pp.

Tack, S. L. 1971. Distribution, abundance and natural history of the Arctic grayling in the Tanana River drainage. alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971, Project F-9-3, 12(R-1). 35 pp.

_____. 1973. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14(R-1). 34 pp.

_____. 1974. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1973-1974. Project F-9-6, 15(R-I). 52 pp.

_____. 1975. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage . Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1974-1975. Project F-9-7, 16(R-I). 35 pp.

_____. 1980. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage . Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1971-1980. Project F-9-12, 21(R-I). 32 pp.

Townsend, A. H. 1987. Placer mining in the upper Chatanika River system 1980-1986. Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 87-2, Juneau, Alaska. 29 pp.

USGS. 1976-1990. Water Resources Data - Alaska. U.S. Geological Survey Water-Data Reports.

Van Hulle, F. D. 1968. Investigations of fish populations in the Chena River. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1967-1968, Project F-5-R-9, 9:287-304.

Van Whye, G. 1964. Investigations of the Tanana River grayling fisheries: migration study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Job Completion Report, 1963. Project F-5-R-5, 5(14-B). 16 pp.

Warner, G. 1957. Movements and migrations of grayling in Interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-6, Work Plan C, Job No. 3, 6(4). 5 pp.

_____. 1958. Movements and migrations of grayling in Interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-7, Work Plan C, Job No. 3, 7(3). 15 pp.

_____. 1959a. Tagging and migration of grayling in Interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-8, Work Plan C, Job No. 3, 8(2). 10 pp.

______. 1959b. Catch distribution, age and size composition sport fish in Fairbanks area. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-8, Work Plan A, Job 3c, 8(3). 7 pp.

Weber, P. and R. Post. 1985. Aquatic habitat assessments in mined and unmined portions of the Birch Creek watershed. Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 85-2, Juneau, Alaska. 65 pp.

Wojcik, F. J. 1954. Game fish investigations of Alaska. U.S. Fish and Wildlife Service and Alaska Game Commission. Federal Aid in Fish Restoration, Work Plan No. 5, Job No. 1.

_____. 1955. Life history and management of the grayling in interior Alaska. M.S. Thesis. University of Alaska - Fairbanks. 54 pp.

APPENDIX A

Historic Data Summaries - Salcha and Chatanika Rivers

Appendix A1. Summary of recreational effort and catch rate estimates for Arctic grayling harvested from the Salcha and Chatanika rivers, 1953-1958, 1960, 1963-1964, 1968, 1974, and 1987[a].

	Salcha River			Chatanika River		
Year	Interviews	Angler-hours	GR/hr[b]	Interviews	Angler-hours	GR/hr
1953	102	344	0.48	460	955	0.49
1954	132	646	0.84	243	529	0.78
1955[c]	174	728	1.09	69	294	0.13
1956[c]	391	1,659	0.83	66	223	0.27
1957[c]	86	321	0.78	62	177	0.18
1958[c]	108	423	1.01	68	151	0.76
1960	ND	2,600	1.22	---	---	---
1963	275	---	0.67[d]	---	---	---
1964	409	1,816	0.64	---	---	---
1968	2,013[e]	7,035[e]	1.00	---	---	---
1974	827	11,284[e]	0.42	408	27,250[e]	1.02
1987	152	---	0.66	30	---	0.02

[a] Statistics taken from Warner (1959b) for 1953-1958, Reed (1961) for 1960, Roguski and Winslow (1969) for 1963-1968, Kramer (1975) for 1974, and Baker (1988) for 1987.
[b] GR/hr is the number of Arctic grayling harvested per angler-hour.
[c] From 1955 through 1958 there was a 305 mm (12 inch) minimum length limit for Arctic grayling on the Chatanika River (Warner 1959b).
[d] This catch rate includes salmon (Roguski and Winslow 1969).
[e] Data expanded from sample time/area to the entire fishery.

Appendix A2. Summary of population abundance estimates of Arctic grayling in the Salcha River, 1972, 1974, 1985, 1988-1991[a].

Dates	Area	Marks	Recaps	Estimate[b]	Confidence[c]
8/2-8/4/72	Redmond Creek	ND[d]	5	503/km	Low
7/10-7/22/74	Redmond Creek to TAPS[e]	ND	ND	765/km	490-5,032/km
7/10-7/22/74	TAPS to 8 km upstream	ND	ND	991/km	690-2,595/km
7/10-7/22/74	TAPS to 8 km downstream	ND	ND	551/km	397-1,174/km
8/5-8/9/85	Flat Creek	205	6	497/km	128-1,064/km
5/24-6/8/88	TAPS to 16 km upstream	208	28	138/km	SE = 34/km
6/12-6/16/89	Richardson Hwy. bridge to 36.8 km upstream	616	55	188/km	SE = 21/km
6/26-6/27/90	Richardson Hwy. bridge to 36.8 km upstream	495	40	157/km	SE = 18/km
6/25-7/2/91	Richardson Hwy. bridge to 36.8 km upstream	439[f]	27	147/km	SE = 28/km
		382	27	114/km	SE = 25/km

[a] Data sources are:
1972 - Tack (1973);
1974 - Bendock (1974) and Kramer (1975);
1985 - Holmes, et al. (1986);
1988 - Clark (1988);
1989 - Clark and Ridder (1990);
1990 - Clark, et al. (1991); and,
1991 - this report.

[b] The 1972-1985 estimates were calculated with the modified Schnabel formula (Ricker 1975). The 1988 through 1990 estimates were calculated with a modified Petersen estimate of Evenson (1988). The 1991 estimate was calculated with modified Petersen (Bailey 1952).

[c] Confidence is a crude measure of precision (e.g. Low) or the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975). Estimates for 1988-1991 were from bootstrap methods (Efron 1982); a standard error (SE) is reported for these estimates.

[d] ND = data not furnished in original citation.

[e] TAPS = Trans-Alaska Pipeline System.

[f] Mark-recapture experiment results are for Full model (≥ 150 mm Fl; upper) and Reduced model (≥ 200 mm Fl; lower).

Appendix A3. Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Salcha River, 1985-1991[a].

	1985[b]			1986[c]			1987[d]			1988[e]			1989[f]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	1	0.01	0.01	0	0.00	---	2	<0.01	<0.01	17	0.03	0.01	17	0.03	0.01
3	13	0.06	0.02	19	0.12	0.03	35	0.07	0.01	116	0.20	0.02	155	0.35	0.03
4	3	0.01	0.01	25	0.16	0.03	205	0.40	0.02	83	0.14	0.01	143	0.26	0.02
5	29	0.13	0.02	14	0.09	0.02	120	0.23	0.02	175	0.30	0.02	75	0.13	0.01
6	69	0.32	0.03	37	0.24	0.03	80	0.15	0.02	58	0.10	0.01	74	0.11	0.02
7	58	0.27	0.03	26	0.17	0.03	56	0.11	0.01	54	0.09	0.01	24	0.04	0.01
8	25	0.12	0.02	22	0.14	0.03	15	0.03	0.01	51	0.09	0.01	30	0.05	0.01
9	18	0.08	0.02	8	0.05	0.02	4	0.01	<0.01	22	0.04	0.01	18	0.03	0.01
10	2	0.01	0.01	3	0.02	0.01	2	<0.01	<0.01	4	0.01	<0.01	3	<0.01	<0.01
11	0	0.00	---	1	0.01	0.01	0	0.00	---	1	<0.01	<0.01	0	0.00	---
Totals	218	1.00		154	1.00		519	1.00		581	1.00		539	1.00	

- continued -

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Age Class	1990[g]			1991[h]		
	n	p	SE	n	p	SE
2	45	0.22	0.03	12	0.04	0.01
3	76	0.37	0.03	45	0.16	0.02
4	38	0.19	0.03	69	0.25	0.03
5	18	0.09	0.02	81	0.30	0.03
6	13	0.06	0.02	37	0.13	0.02
7	7	0.03	0.01	19	0.07	0.01
8	5	0.02	0.01	7	0.03	0.01

- continued -

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	1990[g]			1991[h]		
Age Class	n	p	SE	n	p	SE
9	1	<0.01	<0.01	2	0.01	<0.01
10	0	0.00	---	1	<0.00	<0.01
11	0	0.00	---	1	<0.00	<0.01
Totals	203	1.00	---	274	1.00	---

[a] Source documents are: 1985 - Holmes, et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); (Clark et al. 1991); and, 1991- this report.

[b] Sampling was conducted with an AC electrofishing boat and hook-and-line gear from river km 64.0 to river km 57.6 (5-9 August 1985).

[c] Sampling was conducted with a DC electrofishing boat and hook-and-line gear from river km 112.0 to river km 4.8 (11-15 August 1986).

[d] Sampling was conducted with a DC electrofishing boat from river km 38.6 to river km 4.8 (1-9 June 1987).

[e] Sampling was conducted with a DC electrofishing boat from river km 38.6 to river km 16.0 (24 May through 9 June 1988).

[f] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (12 through 16 June 1989). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[g] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (19 through 27 June 1990).

[h] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (25 June through 2 July, 1991).

Appendix A4. Summary of RSD indices of Arctic grayling captured in the Salcha River, 1972, 1974, 1985-1991[a].

		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1972 -	Number sampled	ND[c]	ND	ND	ND	ND
	RSD	0.53	0.46	<0.01	0	0
	SE	ND	ND	ND	---	---
1974 -	Number sampled	153	14	2	0	0
	RSD	0.91	0.08	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1985 -	Number sampled	17	155	57	0	0
	RSD	0.07	0.68	0.25	---	---
	SE	0.02	0.03	0.03	---	---
1986 -	Number sampled	47	71	56	0	0
	RSD	0.27	0.41	0.32	---	---
	SE	0.03	0.04	0.04	---	---
1987 -	Number sampled	275	171	71	1	0
	RSD	0.53	0.33	0.14	<0.01	---
	SE	0.02	0.02	0.02	<0.01	---
1988 -	Number sampled	280	217	110	1	0
	RSD	0.46	0.36	0.18	<0.01	---
	SE	0.02	0.02	0.02	<0.01	---
1989 -	Number sampled	755	342	124	2	0
	Adjusted RSD	0.71	0.22	0.08	<0.01	---
	SE	0.04	0.03	0.01	<0.01	---
1990 -	Number sampled	365	95	40	0	0
	RSD	0.73	0.19	0.08	---	---
	SE	0.02	0.02	0.01	---	---
1991 -	Number sampled	170	110	12	0	0
	RSD	0.58	0.38	0.04	---	---
	SE	0.03	0.03	0.01	---	---

[a] Data sources: 1972 - Tack (1973); 1974 - Bendock (1974) and Kramer (1975); 1985 - Holmes et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); 1990- Clark et al (1991); and, 1991 - this report.

[b] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984): Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL; Memorable 450 mm FL; and, Trophy - 560 mm FL.

[c] ND = data not furnished in original citation.

[d] RSD does not correspond to sample size because of adjustments made for differential capture probability by size of fish.

Appendix A5. Summary of mean length at age data collected from Arctic grayling in the Salcha River, 1952, 1974, 1985-1991[a].

	1952			1974			1981			1985			1986		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND[e]	103	---	6	111	---	20	126	---	---	---	---	---	---	---
2	ND	145	---	88	155	---	25	162	---	1	156	---	---	---	---
3	ND	185	---	61	196	---	11	197	---	13	223	15	19	218	16
4	ND	223	---	26	231	---	9	224	---	3	262	18	25	263	25
5	ND	261	---	16	278	---	7	254	---	29	292	10	14	291	26
6	ND	289	---	3	345	---	5	272	---	69	313	20	37	316	24
7	ND	318	---	---	---	---	8	302	---	58	332	16	26	328	40
8	---	---	---	---	---	---	5	335	---	25	346	15	22	360	30
9	---	---	---	---	---	---	1	353	---	18	378	24	8	372	18
10	---	---	---	---	---	---	---	---	---	2	403	90	3	405	16
11	---	---	---	---	---	---	---	---	---	---	---	---	1	364	---
Totals	32			200			91			219			155		

- continued -

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	1987			1988			1989			1990			1991		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---	1	123	---	---	---	---
2	2	138	8	17	174	16	17	176	39	96	182	19	25	167	17
3	35	203	36	116	200	16	155	214	24	220	213	22	112	206	22
4	205	241	20	83	241	20	143	252	28	157	252	25	194	234	25
5	120	275	33	175	280	24	75	273	30	75	283	32	170	264	29
6	80	311	36	58	302	30	74	302	37	49	317	33	67	290	29
7	56	339	30	54	332	32	24	315	38	38	346	31	33	301	39
8	15	356	36	51	348	24	30	341	44	19	370	33	16	320	49
9	4	371	30	22	373	30	18	368	21	6	396	36	6	356	45
10	2	444	20	4	394	19	3	407	40	0	---	---	2	369	7
11	---	---	---	1	463	---	0	---	---	0	---	---	1	358	---
Totals	519			581			539			661			626		

[a] Data sources: 1952 - Warner (1959b); 1974 - Bendock (1974) and Kramer (1975); 1981 - Hallberg (1982); 1985 - Holmes, et al. (1986); 1986 Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); 1990 - Clark et al. (1991); and, 1991 - this report.

[b] n is the total number of fish aged.

[c] FL is the estimated mean fork length (mm) at age.

[d] SD is the sample standard deviation of FL.

[e] ND = data not furnished in original citation.

Appendix A6. Summary of population abundance estimates of Arctic grayling in the Chatanika River, 1972, 1981, 1984-1985, 1990, 1991[a].

Dates	Area	Marks	Recaps	Estimate[b]	Confidence[c]
8/10-8/17/72	Elliot Highway Bridge	103	4	305/km	Low
8/24-8/26/81	Elliot Highway Bridge	ND[d]	64	169/km	132-197/km
8/15-8/18/84	Elliot Highway Bridge	ND	32	242/km	172-352/km
8/20-8/23/85	Elliot Highway Bridge	132	20	117/km	82-176/km
8/27-9/7/90	28.8 km section from 7.5 km above to Elliot Highway bridge downstream	857	36	670/km	SE = 111/km
8/12-8/15/91	35.2 km section from 9.6 km above to Elliot Highway bridge downstream	608	58	312/km	SE = 62/km
7/11-7/16, 8/23-8/26, 9/9-9/14/1991	83.2 km section from 25.6 km below the Elliot Highway bridge to Murphy Dome Extension Rd.	667	25	242/km	SE = 46/km

[a] Data sources are:
1972 - Tack (1973);
1982 - Holmes (1983);
1984 - Holmes (1985);
1985 - Holmes, et al. (1986);
1990 - Clark et al. (1991); and,
1991 - This report.

[b] All estimates except 1990 and 1991 were calculated with the modified Schnabel formula (Ricker 1975). The 1990 estimate was calculated with the modified Petersen estimate of Evenson (1988) and the modified Petersen estimate of Bailey (1951,1952). The 1991 estimate used the modified Petersen estimate of Bailey (1951,1952).

[c] Confidence is a crude measure of precision (e.g. Low), the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975), or the standard error.

[d] ND = data not furnished in original citation.

Appendix A7. Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Chatanika River, 1984-1991[a].

	1984[b]			1985[c]			1986[d]			1987[e]			1988[f]			1989[g]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	2	0.04	0.03	131	0.55	0.03	0	0.00	---	11	0.02	0.01	22	0.04	0.01	24	0.09	0.03
3	8	0.14	0.05	5	0.02	0.01	119	0.31	0.02	50	0.09	0.01	44	0.09	0.01	47	0.18	0.04
4	22	0.39	0.07	31	0.13	0.02	16	0.04	0.01	295	0.55	0.02	63	0.12	0.01	31	0.12	0.03
5	17	0.30	0.06	59	0.25	0.03	71	0.18	0.02	32	0.06	0.01	216	0.42	0.02	30	0.08	0.02
6	5	0.09	0.04	12	0.05	0.01	119	0.31	0.02	47	0.09	0.01	48	0.09	0.01	88	0.23	0.04
7	1	0.02	0.02	0	0.00	---	47	0.12	0.02	106	0.19	0.02	55	0.11	0.01	54	0.14	0.03
8	1	0.02	0.02	0	0.00	---	12	0.03	0.01	8	0.01	0.01	61	0.12	0.01	47	0.12	0.03
9	0	0.00	---	0	0.00	---	2	0.01	0.00	3	0.01	<0.01	5	0.01	<0.01	15	0.04	0.01
10	0	0.00	---	0	0.00	---	0	0.00	---	1	<0.01	<0.01	1	<0.01	<0.01	2	0.01	<0.01
Totals	56	1.00		238	1.00		386	1.00		553	1.00		515	1.00		338	1.00	

- continued -

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Age Class	1990[h]			1991[i]		
	n	p	SE	n	p	SE
2	126	0.20	0.02	26	0.05	0.01
3	347	0.55	0.02	88	0.17	0.02
4	80	0.11	0.01	226	0.44	0.02
5	45	0.04	0.01	46	0.09	0.01
6	51	0.04	0.01	36	0.07	0.01
7	57	0.04	0.01	47	0.09	0.01
8	17	0.01	<0.01	29	0.06	0.01
9	11	0.01	<0.01	12	0.02	0.01

- continued-

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	1990[h]			1991[i]		
Age Class	n	p	SE	n	p	SE
10	2	<0.01	<0.01	4	0.01	<0.01
11	0	---	---	1	<0.01	<0.01
Totals	736	1.00		515	1.00	

[a] Source documents are: 1984 - Holmes (1985); 1985 - Holmes, et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); 1990 - Clark et al. (1991); and, 1991 - this report.

[b] Sampling was conducted with an AC electrofishing boat near the Elliot Highway bridge (15-18 August 1984).

[c] Sampling was conducted with an AC electrofishing boat near the Elliot Highway bridge (20-23 August 1985).

[d] Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (4-28 August 1986).

[e] Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (10-13 August 1987).

[f] Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (15-26 August and 7-20 September 1988).

[g] Sampling was conducted with a DC electrofishing boat downstream of the Elliot Highway bridge (12 through 28 September 1989). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[h] Sampling was conducted with a DC electrofishing boat in a 28.8 km section, beginning 7.5 km upstream of the Elliot Highway bridge and ending 21.3 km downstream of the bridge (27 August through 7 September 1990). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[i] Sampling was conducted with a DC electrofishing boat in a 35.2 km section, beginning 9.6 km upstream of the Elliot Highway bridge and ending 25.6 km downstream of the bridge (5 through 7 August 1991).

Appendix A8. Summary of RSD indices of Arctic grayling captured in the Chatanika River, 1952-1954, 1972, 1982, 1984-1991[a].

		RSD Category[b]			
	Stock	Quality	Preferred	Memorable	Trophy
1952 - Number sampled	95	1	0	0	0
RSD	0.99	0.01	---	---	---
SE	0.01	0.01	---	---	---
1953 - Number sampled	98	8	0	0	0
RSD	0.92	0.08	---	---	---
SE	0.03	0.03	---	---	---
1954 - Number sampled	42	1	0	0	0
RSD	0.98	0.02	---	---	---
SE	0.02	0.02	---	---	---
1972 - Number sampled	121	0	0	0	0
RSD	1.00	---	---	---	---
SE	---	---	---	---	---
1982 - Number sampled	53	3	0	0	0
RSD	0.95	0.05	---	---	---
SE	0.03	0.03	---	---	---
1984 - Number sampled	206	9	1	0	0
RSD	0.95	0.04	0.01	---	---
SE	0.01	0.01	0.01	---	---
1985 - Number sampled	146	11	0	0	0
RSD	0.93	0.07	---	---	---
SE	0.02	0.02	---	---	---
1986 - Number sampled	279	121	4	0	0
RSD	0.69	0.30	0.01	---	---
SE	0.02	0.02	0.01	---	---
1987 - Number sampled	420	126	7	0	0
RSD	0.76	0.23	0.01	---	---
SE	0.02	0.02	0.01	---	---
1988 - Number sampled	361	221	13	0	0
RSD	0.61	0.37	0.02	---	---
SE	0.02	0.02	0.01	---	---

- continued -

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	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
1989 - Number sampled	150	221	4	0	0
RSD[c]	0.49	0.49	0.02	---	---
SE	0.06	0.06	0.01	---	---
1990 - Number sampled	1,201	309	19	0	0
RSD[c]	0.90	0.09	0.01	---	---
SE	0.02	0.02	<0.01	---	---
1991 - Number sampled	516	222	25	0	0
RSD[c]	0.84	0.14	0.02	---	---
SE	0.03	0.03	<0.01	---	---
1991[d]- Number sampled	381	312	56	0	0
RSD	0.51	0.42	0.07	---	---
SE	0.02	0.02	0.01	---	---

[a] Data sources:

1952-1958 - Warner (1959b);
1972 - Tack (1973);
1982 - Holmes (1983);
1984 - Holmes (1985);
1985 - Holmes, et al. (1986);
1986 - Clark and Ridder (1987);
1987 - Clark and Ridder (1988);
1988 - Clark (1988);
1989 - Clark and Ridder (1990);
1990 - Clark et al. (1991): and,
1991 - this report.

[b] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984):
Stock - 150 mm FL;
Quality - 270 mm FL;
Preferred - 340 mm FL;
Memorable - 450 mm FL; and,
Trophy - 560 mm FL.

[c] RSD does not correspond to sample size because of adjustments made for differential capture probability by size of fish.

[d] In 1991, stock assessment also occurred on the adjacent downstream section of the Chatanika River during assessment of the whitefish population.

Appendix A9. Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1991[a].

	1952			1953			1981			1982			1984			1985		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND[e]	94	---	19	96	---	0	---	---	5	95	---	16	101	---	0	---	---
2	ND	133	---	77	144	---	4	169	---	29	135	---	3	149	---	131	147	15
3	ND	176	---	129	190	---	7	204	---	22	187	---	8	172	---	5	181	25
4	ND	212	---	28	207	---	10	233	---	23	216	---	22	196	---	31	212	22
5	ND	243	---	4	226	---	7	264	---	5	236	---	17	225	---	59	233	24
6	---	---	---	9	254	---	3	286	---	2	280	---	5	251	---	12	268	18
7	---	---	---	---	---	---	1	290	---	1	252	---	1	258	---	---	---	---
8	---	---	---	---	---	---	---	---	---	1	334	---	1	301	---	---	---	---
9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Totals	149			266			32			88			73			238		

- continued -

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	1986			1987			1988			1989			1990			1991		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---	4	125	16	19	125	10	---	---	---
2	---	---	---	11	157	15	22	170	13	30	159	27	143	167	14	26	165	9
3	119	195	21	50	200	24	44	205	16	47	203	38	351	195	17	87	204	22
4	16	231	36	295	228	18	63	238	21	31	234	42	80	242	18	227	227	21
5	71	248	16	32	265	22	216	259	22	30	267	56	45	269	15	46	264	27
6	119	267	20	47	273	21	48	278	24	88	286	36	52	282	19	36	285	17
7	47	292	28	106	288	30	55	298	22	54	305	46	61	297	22	48	300	29
8	12	304	21	8	319	18	61	312	25	47	313	49	17	324	23	29	314	29
9	2	283	35	3	296	55	5	328	8	15	334	86	11	329	12	12	317	40
10	---	---	---	1	325	___	1	352	---	2	337	147	2	337	34	3	334	6
Totals	386			553			515			349			781			514		

[a] Data sources: 1952-1953 - Warner (1959b); 1981 - Hallberg (1982); 1982 - Holmes (1983); 1984 - Holmes (1985); 1985 - Holmes et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); 1990 - Clark et al. (1991); and, 1991 - this report.

[b] n is the total number of fish aged.

[c] FL is the mean fork length (mm) at age.

[d] SD is the standard deviation of FL.

[e] ND = data not furnished in original citation.

Appendix A10. Parameter estimates and standard errors of the von Bertalanffy growth model[a] for Arctic grayling from the Salcha and Chatanika rivers, 1986-1988[b].

	Salcha River		Chatanika River	
Parameter	Estimate	Standard Error	Estimate	Standard Error
L_∞[c]	489	19	375	11
K[d]	0.16	0.02	0.19	0.02
t_0[e]	-0.42	0.16	-1.01	0.20
$Corr(L_\infty, K)$[f]	-0.99	---	-0.98	---
$Corr(L_\infty, t_0)$	-0.88	---	-0.89	---
$Corr(K, t_0)$	0.94	---	0.96	---
Sample size	1,198		1,469	

[a] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_\infty (1 - exp(-K (t - t_0)))$. The parameters of this model were estimated with data collected during 1986 through 1988. This model was fitted to the data by nonlinear regression utilizing the Marquardt compromise (Marquardt 1963). The range of ages used to model growth were age 1 through age 11 for the Salcha River, and age 1 through age 10 for the Chatanika River.

[b] Source citation is Clark (1988).

[c] L_∞ is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[d] K is a constant that determines the rate of increase of growth increments (Ricker 1975).

[e] t_0 represents the hypothetical age at which a fish would have zero length (Ricker 1975).

[f] $Corr(x,y)$ is the correlation of parameter estimates x and y.

APPENDIX B

Historic Data Summaries - Goodpaster River

Appendix B1. Summary of population abundance estimates of Arctic grayling ($\geq$ 150 mm FL) in the Goodpaster River, 1972 - 1991[a].

						Fish/km[b]		
Year	Month	River km	M	C	R	N	95% CI[c]	Rel.Prec[e]
1972	12-14 Jul	4.8 - 9.6	210	---	30	189	---	---
1973	1 Jun-30 Aug	0 - 53	2,328	1,734	122	480	411 - 590	19%
		53 - 98	561	680	16	322	223 - 732	79%
		98 - 184	415	410	19	81	57 - 164	66%
		0 - 184	---	---	---	241	209 - 287	16%
1974[d]	15-29 Jul	0 - 53	1,217	489	55	201	155 - 260	26%
		53 - 98	479	279	9	298	165 - 596	72%
		98 - 184	343	275	27	63	44 - 93	40%
		0 - 184	---	---	---	152	124 - 186	20%
1975	23-27 Jun	4.8 - 9.6	330	145	31	314	223 - 456	37%
		24 - 28.8	317	319	34	604	436 - 863	35%
		combined	647	464	65	475	374 - 603	24%
1976	21-24 Jun	4.8 - 9.6	155	99	9	323	178 - 646	72%
		24 - 28.8	202	165	18	368	238 - 597	49%
		combined	357	264	27	351	245 - 524	40%
1977	21-24 Jun	4.8 - 9.6	234	150	11	613	356-1,150	65%
		24 - 28.8	396	263	60	357	278 - 457	25%
		combined	630	413	71	377	300 - 474	23%
1978	20-23 Jun	4.8 - 9.6	248	167	19	434	284 - 694	47%
		24 - 28.8	373	212	32	502	359 - 726	37%
		combined	621	379	51	473	361 - 618	27%
1980	24-27 Jun	4.8 - 9.6	231	153	13	529	318 - 938	59%
		24 - 28.8	337	213	31	470	334 - 683	37%
		combined	568	366	44	483	362 - 658	31%
1982	29 Jun-2 Jul	4.8 - 9.6	79	107	9	178	98 - 356	72%
		24 - 28.8	214	155	39	174	128 - 242	33%
		combined	293	260	48	163	123 - 219	30%
1984	27-29 Jun	4.8 - 9.6	265	91	12	391	153 - 629	61%
		24 - 28.8	216	169	28	264	161 - 367	39%
		combined	481	260	40	352	249 - 455	29%

- continued -

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Year	Month	River km	M	C	R	Fish/km N	95% CI	Rel. Prec[e]
1985	25-27 Jun	4.8 - 9.6	189	213	7	459	238 - 966	79%
1985	6-13 Aug	4.8 - 9.6	307	455	42	400	296 - 554	32%
		24 - 28.8	303	424	45	328	245 - 450	31%
		combined	610	879	87	364	271 - 502	32%
1986	11-15 Aug	4.8 - 9.6	230	312	15	403	250 - 686	54%
		24 - 28.8	293	389	42	256	193 - 352	31%
		combined	523	701	57	305	234 - 397	27%
1987	4-10 Aug	4.8 - 9.6	138	191	14	188	115 - 324	56%
		24 - 28.8	158	213	24	133	91 - 203	42%
		combined	274	363	35	134	97 - 191	35%
1988	8-18 Aug	4.8 - 53	1,130	1,002	139	158	SE= 12/km	
1989	8-17 Aug	3 - 53	955	984	124	161	SE= 15/km	
							139 - 192	17%
1990	8-16 Aug	3 - 53	1,051	554	82	145	SE= 15/km	
							131 - 168	21%
1991	7-14 Aug	3 - 53	780	429	42	157	SE= 17/km	

[a] Data sources: 1972 - 1974, Tack (1973, 1974, 1975); 1975 - 1978, 1980, Peckham (1976, 1977, 1978, 1979, 1981); 1982, 1984, Ridder (1983, 1985); 1985, Holmes, et al. (1986); 1986 - 1987, Clark and Ridder (1987, 1988), Ridder (1989); 1989, Clark and Ridder (1990); 1990, Clark, et al. (1991); and, 1991 - this report.

[b] Schnabel estimator in 1972, 1973, 1985 through 1987; modified Petersen (Bailey 1951, 1952) estimator in 1974 through 1984; modified Petersen (Evenson 1988) in 1988; bootstrapped modified Petersen (Bailey 1951, 1952) in 1989, 1990, and 1991.

[c] The confidence interval is based on a Poisson distribution of recaptures (Ricker 1975). Estimates for 1988 through 1991 were from bootstrap methods (Efron 1982) and a standard error (SE) is reported.

[d] Estimate was based on total marks in 1973 which were adjusted with a mortality rate of 0.46 (Tack 1975). Number of marks presented shown for 1973 do not include those applied during the final 1973 sampling event.

[e] Rel. Prec. is relative precision.

Appendix B2. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1991[a].

	1955 29 July - 15 Sept.			1956 summer			1957 11 June - 15 Aug.			1958 7 May - 25 July			1969		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	14	0.08	0.02	15	0.05	0.01	3	0.01	<0.01	111	0.10	0.01	0	---	---
2	49	0.27	0.03	109	0.37	0.03	40	0.10	0.02	532	0.48	0.02	9	0.13	0.04
3	40	0.22	0.03	115	0.39	0.03	178	0.44	0.03	106	0.10	0.01	13	0.19	0.05
4	53	0.29	0.03	30	0.10	0.02	122	0.30	0.02	225	0.20	0.01	12	0.17	0.05
5	14	0.08	0.02	19	0.06	0.01	30	0.07	0.01	100	0.09	0.01	11	0.16	0.04
6	6	0.03	0.01	5	0.02	0.01	19	0.05	0.01	16	0.01	<0.01	9	0.13	0.04
7	5	0.03	0.01	4	0.01	0.01	6	0.02	0.01	10	0.01	<0.01	4	0.06	0.03
8	0	---	---	0	---	---	5	0.01	0.01	4	<0.01	<0.01	7	0.10	0.04
9	0	---	---	0	---	---	1	<0.01	<0.01	0	---	---	4	0.06	0.03
10	0	---	---	0	---	---	0	---	---	0	---	---	1	0.01	0.01
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	181	1.00		297	1.00		404	1.00		1104	1.00		70	1.00	

- continued -

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	1973[e] 15 June - 15 Aug.			1975 23 June - 24 June			1976 21 June - 22 June			1977 21 June - 22 June			1978 21 June - 22 June		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	0	---	---	3	0.03	0.02	1	0.01	0.01	8	0.07	0.02	2	0.02	0.01
2	3	0.03	0.02	3	0.03	0.02	13	0.11	0.03	1	0.01	0.01	23	0.22	0.04
3	65	0.65	0.05	52	0.52	0.05	13	0.11	0.03	76	0.66	0.04	13	0.13	0.03
4	27	0.27	0.05	7	0.07	0.03	44	0.37	0.04	6	0.05	0.02	58	0.56	0.05
5	2	0.02	0.01	29	0.29	0.05	25	0.21	0.04	13	0.11	0.03	8	0.08	0.03
6	3	0.03	0.02	5	0.05	0.02	22	0.18	0.03	12	0.10	0.03	0	---	---
7	0	---	---	1	0.01	0.01	1	0.01	0.01	0	---	---	0	---	---
8	0	---	---	0	---	---	1	0.01	0.01	0	---	---	0	---	---
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	100	1.00		100	1.00		120	1.00		116	1.00		104	1.00	

- continued -

Appendix B2. (Page 3 of 5).

	1980 24 June - 25 June			1982 29 June - 2 July			1984 27 June - 28 June			1985[e] 25 June - 26 June			1985[e] 8 - 11 August		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	5	0.05	0.02	0	---	---	7	0.07	0.03	0	---	---	0	---	---
2	26	0.27	0.05	8	0.08	0.03	7	0.07	0.03	3	0.02	0.01	56	0.27	0.03
3	19	0.20	0.04	21	0.22	0.04	17	0.17	0.04	44	0.22	0.03	27	0.13	0.02
4	40	0.42	0.05	43	0.44	0.05	48	0.48	0.05	33	0.16	0.03	22	0.11	0.02
5	6	0.06	0.03	21	0.22	0.04	11	0.11	0.03	79	0.39	0.03	69	0.33	0.03
6	0	---	---	4	0.04	0.02	7	0.07	0.03	25	0.12	0.02	18	0.09	0.02
7	0	---	---	0	---	---	3	0.03	0.02	16	0.08	0.02	15	0.07	0.02
8	0	---	---	0	---	---	0	---	---	4	0.02	0.01	1	0.01	0.01
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	96	1.00		97	1.00		100	1.00		204	1.00		208	1.00	

- continued -

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	1986[e] 11 - 15 August			1987[e] 3 - 10 August			1988[e] 8 - 11 August			1989[e] 8 - 10 August			1990[e] 8 - 10 August		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p[f]	SE[f]	n	p[f]	SE[f]
1	0	---	---	6	0.02	0.01	1	<0.01	<0.01	0	---	---	46	0.05	<0.01
2	80	0.14	0.02	55	0.15	0.02	144	0.18	0.01	364	0.47	0.02	79	0.08	<0.01
3	360	0.63	0.02	51	0.14	0.02	58	0.07	0.01	165	0.21	0.01	562	0.59	0.01
4	26	0.05	0.01	165	0.46	0.03	86	0.11	0.01	37	0.04	0.01	94	0.10	<0.01
5	37	0.07	0.01	9	0.03	0.01	317	0.40	0.02	104	0.09	0.01	36	0.04	<0.01
6	56	0.10	0.01	22	0.06	0.01	34	0.04	0.01	134	0.11	0.02	55	0.05	<0.01
7	8	0.01	0.01	32	0.09	0.02	67	0.09	0.01	44	0.03	<0.01	60	0.06	0.01
8	2	<0.01	<0.01	12	0.03	0.01	45	0.06	0.01	29	0.02	0.01	13	0.01	<0.01
9	2	<0.01	<0.01	5	0.01	0.01	20	0.03	0.01	7	0.01	<0.01	8	0.01	<0.01
10	0	---	---	1	<0.01	<0.01	8	0.01	<0.01	4	<0.01	<0.01	4	<0.01	<0.01
11	0	---	---	0	---	---	3	<0.01	<0.01	1	<0.01	0.00	0	---	---
12	0	---	---	0	---	---	1	<0.01	<0.01	0	---	---	0	---	---
Total	571	1.00		358	1.00		784	1.00		889	1.00		957	1.00	

- continued -

Appendix B2. (Page 5 of 5).

	1991[e] 7 - 9 August		
Age Class	n	p[c]	SE[d]
1	8	0.01	<0.01
2	393	0.53	0.02
3	72	0.10	0.02
4	186	0.25	0.02
5	27	0.04	0.01
6	18	0.02	<0.01
7	27	0.03	0.01
8	13	0.02	0.01
9	5	0.01	<0.01
10	2	<0.01	<0.01
11	0	---	---
12	0	---	---
Total	751	1.00	

[a] Data sources and gear type: 1955 - 1956, hook and line (H&L), Warner (1957); 1957, H&L, Warner (1958); 1958, seine, Warner (1959a); 1969, electrofishing boat (EB), Roguski and Tack (1970); 1973 - 1974, EB, Tack (1973,1974); 1975 - 1980, EB, Peckham (1976, 1977, 1978, 1979, 1980, 1981); 1982 - 1984, EB, Ridder (1983, 1985); 1985, EB, Holmes, et al. (1986); 1986 - 1987, EB, Clark and Ridder (1987, 1988); 1988, EB, Ridder (1989); 1989, EB, Clark and Ridder (1990); 1990, EB, Clark, et al. (1991); and 1991, EB, this report.

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

[e] For Arctic grayling greater than 149 mm FL only.

[f] Proportions and SE were adjusted to compensate for length bias found in the electrofishing sample.

Appendix B3. Summary of age composition estimates and standard errors for Arctic grayling sampled in the middle (53-98 km) and upper (98 - 152 km) sections of the Goodpaster River, summer, 1973 and 1979[a].

	1973[b] 15 June - 15 Aug middle			1973[b] 15 June - 15 Aug upper			1979 23 - 24 June upper		
Age Class	n[c]	p[d]	SE[e]	n	p	SE	n	p	SE
1	0	---	---	0	---	---	0	---	---
2	3	0.03	0.02	0	---	---	0	---	---
3	26	0.26	0.04	0	---	---	0	---	---
4	30	0.30	0.05	11	0.11	0.03	0	---	---
5	31	0.31	0.05	15	0.15	0.04	6	0.10	0.04
6	8	0.08	0.03	17	0.17	0.04	11	0.18	0.05
7	2	0.02	0.01	35	0.36	0.05	23	0.37	0.06
8	0	---	---	6	0.06	0.02	18	0.29	0.06
9	0	---	---	7	0.07	0.03	5	0.08	0.03
10	0	---	---	4	0.04	0.02	0	---	---
11	0	---	---	2	0.02	0.02	0	---	---
12	0	---	---	1	0.01	0.01	0	---	---
Total	100	1.00		98	1.00		63	1.00	

[a] Data sources and gear type: 1973 (middle) electrofishing boat, 1973 (upper) hook and line, Tack (1973, 1974); 1979, hook and line, Peckham (1979).
[b] For Arctic grayling greater than 149 mm FL only.
[c] n = sample size.
[d] p = proportion.
[e] SE = standard error of the proportion.

Appendix B4. Age composition estimates[a] for Arctic grayling weighted by three area population densities, Goodpaster River, 1973 and 1974.

Age Class	1973			1974		
	n[b]	p[c]	SE[d]	n	p	SE
2	ND[e]	0.03	ND	---	---	---
3	ND	0.45	ND	ND	0.07	ND
4	ND	0.28	ND	ND	0.52	ND
5	ND	0.13	ND	ND	0.20	ND
6	ND	0.05	ND	ND	0.06	ND
7	ND	0.04	ND	ND	0.06	ND
8	ND	0.01	ND	ND	0.01	ND
9	ND	0.01	ND	ND	<0.01	ND
10	ND	<0.01	ND	ND	<0.01	ND
11	ND	<0.01	ND	---	---	---
12	ND	<0.01	ND	---	---	---
Total	ND	1.00		277	1.00	

[a] Estimates developed from combining age proportions found in three river sections using the estimated population abundance in each section as a weighting factor. Data source is Tack (1974, 1975).

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

[e] ND = no data in citation.

Appendix B5. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, 1986, and 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE
1	2	0.01	0.01	0	---	---	0	---	---	0	---	---
2	4	0.02	0.01	0	---	---	9	0.03	0.01	4	0.01	0.01
3	26	0.12	0.02	11	0.03	0.01	67	0.20	0.02	2	0.01	0.01
4	30	0.14	0.02	32	0.08	0.01	31	0.09	0.02	49	0.16	0.02
5	29	0.13	0.02	136	0.35	0.02	34	0.10	0.02	11	0.04	0.01
6	45	0.20	0.03	53	0.14	0.02	92	0.28	0.02	28	0.09	0.02
7	29	0.13	0.02	85	0.22	0.02	48	0.14	0.02	72	0.24	0.03
8	33	0.15	0.02	25	0.06	0.01	32	0.10	0.02	53	0.18	0.02
9	16	0.07	0.02	31	0.08	0.01	10	0.03	0.01	45	0.15	0.02
10	7	0.03	0.01	10	0.03	0.01	5	0.02	0.01	16	0.05	0.01
11	1	0.01	<0.01	7	0.02	0.01	2	0.01	<0.01	15	0.05	0.01
12	0	---	---	0	---	---	3	0.01	0.01	3	0.01	0.01
13	0	---	---	0	---	---	2	0.01	<0.01	2	0.01	0.01
14	0	---	---	0	---	---	0	---	---	1	<0.01	<0.01
Total	222	1.00		390	1.00		335	1.00		301	1.00	

[a] All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al., 1986) and are from office files.
[b] n = sample size.
[c] p = proportion.
[d] SE = standard error of the proportion.

Appendix B6. Summary of age composition estimates and standard errors for adult Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, 1986, and 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May			Total		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE	n	p	SE
5	14	0.10	0.03	3	0.02	0.01	1	0.01	0.01	2	0.01	0.01	20	0.03	0.01
6	41	0.29	0.04	25	0.16	0.03	43	0.31	0.04	22	0.10	0.02	131	0.20	0.02
7	29	0.21	0.03	62	0.39	0.04	43	0.31	0.04	68	0.30	0.03	202	0.30	0.02
8	33	0.23	0.04	23	0.14	0.03	32	0.23	0.04	52	0.23	0.03	140	0.21	0.02
9	16	0.11	0.03	31	0.19	0.03	10	0.07	0.02	45	0.20	0.03	102	0.15	0.01
10	7	0.05	0.02	10	0.06	0.02	5	0.04	0.02	16	0.07	0.02	38	0.06	0.01
11	1	0.01	0.01	7	0.04	0.02	2	0.01	0.01	15	0.07	0.02	25	0.04	0.01
12	0	---	---	0	---	---	3	0.02	0.01	3	0.01	0.01	6	0.01	<0.01
13	0	---	---	0	---	---	2	0.01	0.01	2	0.01	0.01	4	0.01	<0.01
14	0	---	---	0	---	---	0	---	---	1	<0.01	<0.01	1	<0.01	<0.01
Total	141	1.00		161	1.00		141	1.00		226	1.00		669	1.00	

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.
[b] n = sample size.
[c] p = proportion.
[d] SE = standard error of the proportion.

Appendix B7. Summary of mean length at age data for Arctic grayling sampled in the Goodpaster River, summer, 1969 - 1991[a].

	1969 summer			1973 15 June-15 August			1975 23-24 June			1976 21-22 June			1977 21-22 June		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	3	82	ND	1	108	ND	8	98	ND
2	9	126	ND[e]	3	146	ND	3	149	ND	13	149	ND	1	151	ND
3	13	171	ND	91	181	ND	52	182	ND	13	187	ND	76	175	ND
4	12	215	ND	68	224	ND	7	207	ND	44	209	ND	6	229	ND
5	11	265	ND	48	276	ND	29	233	ND	25	240	ND	13	245	ND
6	9	297	ND	28	317	ND	5	269	ND	22	264	ND	12	273	ND
7	4	330	ND	37	343	ND	1	346	ND	1	285	ND	0	---	---
8	7	351	ND	6	368	ND	0	---	---	1	364	ND	0	---	---
9	4	362	ND	7	396	ND	0	---	---	0	---	---	0	---	---
10	1	378	ND	4	404	ND	0	---	---	0	---	---	0	---	---
11	0	---	---	3	417	ND	0	---	---	0	---	---	0	---	---
12	0	---	---	1	432	ND	0	---	---	0	---	---	0	---	---
Total	70			295			100			120			116		

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	1978 21-22 June			1979 25-28 June			1980 24-25 June			1982 29-30 June			1984 27-28 June		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	2	101	ND	0	---	---	5	105	ND	0	---	---	7	92	ND
2	23	140	ND	0	---	---	26	156	ND	8	133	ND	7	161	ND
3	13	188	ND	0	---	---	19	202	ND	21	191	ND	17	204	ND
4	58	208	ND	0	---	---	40	220	ND	43	218	ND	48	219	ND
5	8	268	ND	6	281	ND	6	260	ND	21	249	ND	11	259	ND
6	0	---	---	11	320	ND	0	---	---	4	270	ND	7	258	ND
7	0	---	---	23	359	ND	0	---	---	0	---	---	3	289	ND
8	0	---	---	18	379	ND	0	---	---	0	---	---	0	---	---
9	0	---	---	5	395	ND	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	104			63			96			97			100		

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	1985[f] 25-26 June			1985[f] 6-8 August			1986[f] 11-15 August			1987[f] 3-10 August			1988[f] 8-11 August			1989[f] 8-10 August		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	6	166	17	1	155	---	0	---	---
2	3	160	6	56	164	15	80	164	9	55	183	15	144	187	13	364	171	11
3	44	190	12	27	208	10	360	193	19	51	206	14	58	221	14	165	220	14
4	33	224	14	22	236	14	26	235	15	165	233	13	86	243	16	37	253	17
5	79	245	19	69	253	17	37	261	12	9	264	15	317	268	17	104	277	19
6	25	269	20	18	284	13	56	281	22	22	276	14	34	296	17	134	296	18
7	16	284	21	15	292	20	8	305	23	32	288	17	67	307	20	44	315	19
8	4	323	25	1	295	---	2	301	8	12	296	17	45	321	22	29	332	17
9	0	---	---	0	---	---	2	387	27	5	341	34	20	336	33	7	354	19
10	0	---	---	0	---	---	0	---	---	1	311	---	8	352	15	4	384	21
11	0	---	---	0	---	---	0	---	---	0	---	---	3	376	33	1	378	---
12	0	---	---	0	---	---	0	---	---	0	---	---	1	391	---	0	---	---
Total	204	236	37	208	227	47	571	211	72	358	233	38	784	254	46	889	230	59

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	1990[f] 8-10 August			1991[f] 7-9 August		
Age Class	n	FL	SD	n	FL	SD
1	46	156	5	8	163	12
2	79	182	11	393	189	11
3	562	214	15	72	217	14
4	94	252	20	186	245	15
5	36	278	23	27	276	14
6	55	297	26	18	294	21
7	60	311	24	27	313	18
8	13	321	28	13	328	27
9	8	345	18	5	348	19
10	4	365	57	2	386	4
11	0	---	---	0	---	---
12	0	---	---	0	---	---
Total	957	228	45	751	220	43

a Data sources and gear type: 1969, electrofishing boat (EB), Roguski and Tack (1970); 1973 - 1974, EB, Tack (1973,1974); 1975 - 1980, EB, Peckham (1976, 1977, 1978, 1979, 1980, 1981); 1982 - 1984, EB, Ridder (1983, 1985); 1985, EB, Holmes, et al. (1986); 1986 - 1987, EB, Clark and Ridder (1987, 1988); 1988, Ridder (1989); 1989, Clark and Ridder (1990); 1990 - Clark et al. (1991); and, 1991, this report.

b n = sample size.

c FL = mean fork length (mm) at age.

d SD = sample standard deviation of FL.

e ND = no data in citation.

f For Arctic grayling greater than 149 mm FL only.

Appendix B8. Summary of mean length at age data for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1986[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD
1	2	96	11	0	---	---	0	---	---	0	---	---
2	4	137	21	0	---	---	9	133	23	4	183	12
3	26	195	9	11	193	9	67	175	20	2	160	10
4	30	217	10	32	224	15	31	221	15	49	224	21
5	29	262	20	136	250	21	34	252	16	11	280	21
6	45	293	31	53	279	17	92	276	21	28	303	21
7	29	311	36	85	301	28	48	305	18	72	328	22
8	33	337	29	25	323	21	32	317	22	53	338	27
9	16	349	24	31	355	23	10	378	25	45	363	21
10	7	368	24	10	365	28	5	385	25	16	379	23
11	1	383	---	7	381	16	2	405	24	15	393	20
12	0	---	---	0	---	---	3	414	26	3	418	10
13	0	---	---	0	---	---	2	416	14	2	371	4
14	0	---	---	0	---	---	0	---	--	1	472	---
Total	222	278	63	390	280	48	335	259	64	301	320	59

[a] All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al. 1986) and are from office files.
[b] n = sample size.
[c] FL = mean fork length (mm) at age.
[d] SD = sample standard deviation of FL.

Appendix B9. Summary of mean length at age data for adult male Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 16 - 17 May			Total		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	8	276	11	2	304	49	0	---	---	1	339	---	11	286	30
6	21	298	35	7	291	17	21	292	19	15	308	24	64	297	27
7	16	311	42	19	321	30	19	313	17	49	332	22	103	323	28
8	26	337	30	5	329	13	14	318	18	36	344	28	81	336	28
9	11	351	24	11	360	21	4	361	22	37	364	21	63	361	22
10	7	368	24	4	379	35	4	385	23	12	383	25	27	379	27
11	1	383	---	2	394	7	2	405	24	12	390	20	17	391	20
12	0	---	---	0	---	---	3	414	26	3	418	10	6	416	20
13	0	---	---	0	---	---	2	416	14	2	371	4	4	393	25
14	0	---	---	0	---	---	0	---	---	1	472	---	1	472	---
Total	90	322	41	50	333	39	69	325	42	168	350	36	377	337	41

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al. 1986) and are from office files.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

Appendix B10. Summary of mean length at age data for adult female Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May			Total		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	6	280	11	1	248	---	1	253	---	1	296	---	9	275	17
6	20	296	24	18	283	18	22	287	22	7	298	9	67	290	21
7	13	310	25	43	301	26	24	302	16	19	320	19	99	306	24
8	7	334	23	18	322	23	18	317	24	16	326	19	59	323	23
9	5	345	25	20	352	24	6	344	24	8	360	22	39	351	24
10	0	---	---	6	356	17	1	351	---	4	367	13	11	360	16
11	0	---	---	5	376	16	0	---	---	3	405	12	8	387	20
Total	51	307	30	111	316	37	72	304	27	58	333	33	292	313	34

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al. 1986) and are from office files.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

Appendix B11. Summary of RSD estimates for Arctic grayling (≥ 150 mm FL) in the lower Goodpaster River, 1955 - 1991[a].

		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1955	Number sampled	118	45	10	0	0
Jul-	RSD	0.68	0.26	0.06	---	---
Sept	Standard Error	0.04	0.03	0.02	---	---
1956	Number sampled	204	31	4	0	0
Jun-	RSD	0.85	0.13	0.02	---	---
Aug	Standard Error	0.02	0.02	0.01	---	---
1970	Number sampled	802	42	0	0	0
Aug	RSD	0.95	0.05	---	---	---
	Standard Error	0.01	0.01	---	---	---
1972	Number sampled	163	9	0	0	0
Jun	RSD	0.95	0.05	---	---	---
	Standard Error	0.02	0.02	---	---	---
1972	Number sampled	120	2	0	0	0
Aug	RSD	0.98	0.02	---	---	---
	Standard Error	0.01	0.01	---	---	---
1975	Number sampled	636	12	1	0	0
Jun	RSD	0.98	0.02	<0.01	---	---
	Standard Error	<0.01	0.01	<0.01	---	---
1976	Number sampled	337	18	2	0	0
Jun	RSD	0.94	0.05	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1977	Number sampled	633	15	1	0	0
Jun	RSD	0.98	0.02	<0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1978	Number sampled	603	17	0	0	0
Jun	RSD	0.97	0.03	---	---	---
	Standard Error	0.01	0.01	---	---	---
1980	Number sampled	588	12	0	0	0
Jun	RSD	0.98	0.02	---	---	---
	Standard Error	0.01	0.01	---	---	---

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		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1982 May	Number sampled	112	102	37	0	0
	RSD	0.45	0.41	0.15	---	---
	Standard Error	0.03	0.03	0.02	---	---
1982 Jun	Number sampled	314	11	0	0	0
	RSD	0.97	0.03	---	---	---
	Standard Error	0.01	0.01	---	---	---
1984 Jun	Number sampled	443	39	0	0	0
	RSD	0.92	0.08	---	---	---
	Standard Error	0.01	0.01	---	---	---
1985 May	Number sampled	217	210	80	0	0
	RSD	0.43	0.41	0.16	---	---
	Standard Error	0.02	0.02	0.02	---	---
1985 Jun	Number sampled	169	35	1	0	0
	RSD	0.82	0.17	0.01	---	---
	Standard Error	0.03	0.03	0.01	---	---
1985 Aug	Number sampled	322	60	0	0	0
	RSD	0.84	0.16	---	---	---
	Standard Error	0.02	0.02	---	---	---
1986 May	Number sampled	167	151	28	0	0
	RSD	0.48	0.44	0.08	---	---
	Standard Error	0.03	0.03	0.02	---	---
1986 Aug	Number sampled	560	80	6	0	0
	RSD	0.87	0.12	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1987 May	Number sampled	58	128	130	1	0
	RSD	0.18	0.40	0.41	<0.01	---
	Standard Error	0.02	0.03	0.03	<0.01	---
1987 Aug	Number sampled	290	66	2	0	0
	RSD	0.81	0.18	0.01	---	---
	Standard Error	0.02	0.02	<0.01	---	---

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		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1988	Number sampled	1,213	725	73	0	0
Aug	RSD	0.60	0.36	0.04	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1989	Number sampled	1,239	515	62	0	0
Aug	Sampled RSD	0.68	0.28	0.03	---	---
	Adjusted RSD[c]	0.78	0.20	0.02		
	Standard Error[d]	0.02	0.02	<0.01	---	---
1990	Number sampled	1,234	244	46	0	0
Aug	Sampled RSD	0.81	0.16	0.03	---	---
	Adjusted RSD[c]	0.84	0.14	0.02		
	Standard Error[d]	0.02	0.02	<0.01	---	---
1991	Number sampled	686	90	11	0	0
Aug	Sampled RSD	0.87	0.12	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---

[a] Data Sources: 1955-1956, Warner (1957); 1970, 1972, Tack (1971, 1973); 1975- 1982 (June), Peckham (1976, 1977, 1978, 1979, 1983); 1984, Ridder (1985); 1982 (May), 1985, 1986, 1987 (May), Office files; 1987 (Aug), Clark and Ridder (1988); 1988, Ridder (1989); 1989, Clark and Ridder (1990); 1990, Clark, et al. (1991); and, 1991, this report.

[b] Minimum lengths (FL) for RSD categories are (adapted from Gabelhouse 1984):
- Stock - 150 mm
- Quality - 270 mm
- Preferred - 340 mm
- Memorable - 450 mm
- Trophy - 560 mm

[c] RSD adjusted due to bias in length selectivity of the electrofishing boat.

[d] Standard error of the adjusted RSD.

Appendix B12. Summary of RSD estimates for adult Arctic grayling (≥ 150 mm FL) in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Number sampled	17	99	37	0	0
	RSD	0.11	0.65	0.24	---	---
	Standard Error	0.03	0.04	0.04	---	---
1985	Number sampled	20	141	80	0	0
	RSD	0.08	0.59	0.33	---	---
	Standard Error	0.02	0.02	0.03	---	---
1986	Number sampled	8	109	24	0	0
	RSD	0.06	0.77	0.17	---	---
	Standard Error	0.02	0.04	0.03	---	---
1987	Number sampled	1	108	130	1	0
	RSD	<0.01	0.45	0.54	<0.01	---
	Standard Error	<0.01	0.03	0.03	<0.01	---
Total	Number sampled	46	457	271	1	0
	RSD	0.06	0.59	0.35	<0.01	---
	Standard Error	0.01	0.02	0.02	<0.01	---

[a] Minimum lengths (FL) for RSD categories are (adapted from Gabelhouse 1984):
- Stock - 150 mm
- Quality - 270 mm
- Preferred - 340 mm
- Memorable - 450 mm
- Trophy - 560 mm

Appendix B13. Summary of RSD indices for adult Arctic grayling (≥ 150 mm FL) by sex in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Males:					
	Number sampled	10	51	30	0	0
	RSD	0.11	0.56	0.33	---	---
	Standard Error	0.03	0.05	0.05	---	---
1982	Females:					
	Number sampled	7	48	7	0	0
	RSD	0.11	0.77	0.11	---	---
	Standard Error	0.04	0.05	0.04	---	---
1985	Males:					
	Number sampled	4	39	44	0	0
	RSD	0.05	0.45	0.51	---	---
	Standard Error	0.02	0.05	0.05	---	---
1985	Females:					
	Number sampled	16	102	36	0	0
	RSD	0.10	0.66	0.23	---	---
	Standard Error	0.03	0.04	0.03	---	---
1986	Males:					
	Number sampled	2	56	20	0	0
	RSD	0.03	0.72	0.26	---	---
	Standard Error	0.02	0.05	0.05	---	---
1986	Females:					
	Number sampled	7	66	8	0	0
	RSD	0.09	0.82	0.10	---	---
	Standard Error	0.03	0.04	0.03	---	---
1987	Males:					
	Number sampled	1	68	110	1	0
	RSD	0.01	0.38	0.61	0.01	---
	Standard Error	0.01	0.04	0.04	0.01	---
1987	Females:					
	Number sampled	0	40	20	0	0
	RSD	---	0.67	0.33	---	---
	Standard Error	---	0.06	0.06	---	---

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	RSD Category				
	Stock	Quality	Preferred	Memorable	Trophy
Total <u>Males:</u>					
Number sampled	17	214	204	1	0
RSD	0.04	0.49	0.47	<0.01	---
Standard Error	0.01	0.02	0.02	<0.01	---
Total <u>Females:</u>					
Number sampled	30	256	71	0	0
RSD	0.08	0.72	0.20	---	---
Standard Error	0.02	0.02	0.02	---	---

[a] Minimum lengths (FL) for RSD categories are (adapted from Gabelhouse 1984):

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

Appendix B14. Arctic grayling abundance, harvest, and angler exploitation estimates for the Goodpaster River, 1972 through 1990.

Year	Month	Abundance[a]		Harvest	Angler exploitation[b]	
		0-53km	0-152km		0-53 km	0-152 km
1972	JUNE	10,017	20,034	ND[c]	---	---
1973	JUNE	25,440	44,955	2,236	0.09	0.05
1974	JUNE	10,649	27,441	ND	---	---
1975	JUNE	25,166	50,332	ND	---	---
1976	JUNE	18,654	37,307	ND	---	---
1977	JUNE	19,999	39,998	ND	---	---
1978	JUNE	25,054	50,108	ND	---	---
1979	JUNE	ND	ND	ND	---	---
1980	JUNE	25,574	51,149	ND	---	---
1981	JUNE	ND	ND	ND	---	---
1982	JUNE	8,616	17,232	ND	---	---
1983	JUNE	ND	ND	3,021	---	---
1984	JUNE	18,656	37,312	1,194	0.06	0.03
1985	AUGUST	19,292	38,584	2,757	0.13[d]	0.07[d]
1986	AUGUST	16,165	32,330	1,508	0.09[d]	0.05[d]
1987	AUGUST	7,102	14,204	1,702	0.19[d]	0.11[d]
1988	AUGUST	8,374	16,748	1,273	0.13[d]	0.07[d]
1989	AUGUST	8,033	16,066	1,964	0.20[d]	0.11[d]
1990	AUGUST	7,113	14,226	760	0.10[d]	0.05[d]
1991	AUGUST	7,836	15,672	(1,824)[e]	0.19[d]	0.10[d]
Averages:		15,396	30,806	1,824	0.13	0.07

[a] Abundance in the lower 53 km for 1972 and 1975 through 1988 was extrapolated from fish per km estimates (Appendix B1). Abundance for 0 - 152 km for the same years is twice the estimate for the lower 53 km based on the average ratio between the sections estimated in 1973 and 1974 (Appendix B1).

[b] Exploitation rate is harvest divided by abundance.

[c] ND = no data.

[d] Harvests were added to abundance estimates to give an approximation of abundance at start of season prior to calculating exploitation rates.

[e] Average harvest was used in order to obtain exploitation estimates.

APPENDIX C

Methods For Alleviating Bias

Appendix C1. Methodologies for alleviating bias due to gear selectivity by means of statistical inference.

Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]	
Fail to reject H_0	Fail to reject H_0
Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]	
Fail to reject H_0	Reject H_0
Inferred cause: There is no size-selctivity during the second sampling event, but there is during the first sampling event.	
Case III[e]	
Reject H_0	Fail to reject H_0
Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]	
Reject H_0	Reject H_0
Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.
Case IVa: If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.
Case IVb: If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

APPENDIX D

Data File Listing

Appendix D1. Data files[a] used to estimate parameters of Arctic grayling populations in the Salcha, Chatanika, Goodpaster, and Delta Clearwater rivers, 1991.

Data file	Description
U005ALA1.DTA	Population and marking data for Arctic grayling captured during the first event at the Salcha River, 18 through 21 June 1991.
U005BLA1.DTA & U005CLA1.DTA	Population and marking data for Arctic grayling captured during the second event at the Salcha River, 25 through 28 June, and, 1- 2 July 1991.
U004ALA1.DTA	Population and marking data for Arctic grayling captured during the first event at the Upper Chatanika River, 3 through 7 June 1991.
U004BLA1.DTA	Population and marking data for Arctic grayling captured during the second event at the Upper Chatanika River, 10 through 13 June 1991.
U004CLA1.DTA	Population and marking data for Arctic grayling captured during the first event at the Middle Chatanika River, 5 through 7 August 1991.
U004DLA1.DTA	Population and marking data for Arctic grayling captured during the second event at the Middle Chatanika River, 12 through 15 August 1991.
U004ELA1.DTA & U004FLA1.DTA	Population and marking data for Arctic grayling captured during the first event at the Lower Chatanika River, 11 through 16 July, and, 23 through 26 August 1991.
U004DLA1.DTA	Population and marking data for Arctic grayling captured during the second event at the Lower Chatanika River, 9 through 14 September 1991.

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Appendix D1. (Page 2 of 2).

Data file	Description
U0080LA1.DTA	Population and marking data for Arctic grayling captured during the first event at the Goodpaster River, 7 through 9 August 1991.
U0080LB1.DTA	Population and marking data for Arctic grayling captured during the second event at the Goodpaster River, 12 through 14 August 1991.
U0060LA1.DTA	Population and marking data for Arctic grayling captured at the Delta Clearwater River, 20 May through 3 June, 1991.

[a] Data files have been archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.