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STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE SALCHA, CHATANIKA, AND GOODPASTER RIVERS[1]

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ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by pulsed direct current electrofishing in the Salcha, Chatanika, and Goodpaster rivers in 1989. Stock assessment was accomplished through estimation of population abundance, age composition, and size composition. Population abundance in a 36.8 kilometer section of the Salcha River was 6,935 Arctic grayling greater than 149 millimeter fork length. Population abundance in the lower 50.0 kilometers of the Goodpaster River was 8,033 Arctic grayling greater than 149 millimeter fork length. Age 3 and age 4 Arctic grayling accounted for over 60 percent of the estimated abundance in the Salcha River. Age 6 Arctic grayling were most abundant in the Chatanika River, although efforts to determine the probability of capture by size class were unsuccessful. Age 2 Arctic grayling were the predominant age class in the Goodpaster River. Poor recruitment of the 1984 and 1985 cohorts to the Goodpaster River and Chatanika River populations was again indicated by a paucity of age 4 and 5 fish in 1989. All historical data on age, size, and sex compositions, harvest and effort, and population abundance from 1952 to 1989 are presented.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population size, harvest, fishing effort, age composition, size composition, sex composition, relative stock density, electrofishing, movements, Salcha River, Chatanika River, Goodpaster 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 has been initiated. This report is the first in a series designed to provide this information.

In conjunction with the present study, this report summarizes stock assessment work performed on the Salcha, Chatanika, and Goodpaster rivers from 1952 to 1989. 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 1989 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 the lower 50 km of the Goodpaster River;

3) the relative probability of capture by length category of Arctic grayling greater than 149 mm fork length in a 16 km section of the Chatanika River;

4) the age composition of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers; and,

5) the Relative Stock Density (RSD) of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers.

Additionally, data from the Goodpaster River concerning recaptures of marked fish from other tagging programs and electrofishing capture effort are presented for the historical database and future analysis.

Fishery Descriptions and Study Areas

The Salcha, Chatanika, and Goodpaster Arctic grayling fisheries have some distinct differences that affect the progress of stock assessment work. Each fishery is described by hydrologic characteristics, methods of access, and past performance of the recreational fishery. Historic population data are presented as a series of tables in Appendices A and B.

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 was 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 was 0.8 m/sec, while average gradient was 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 1976-1988). 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 *Oncorhynchus 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:

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).

Prior to 1977 very little recreational fishery data were collected. 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).

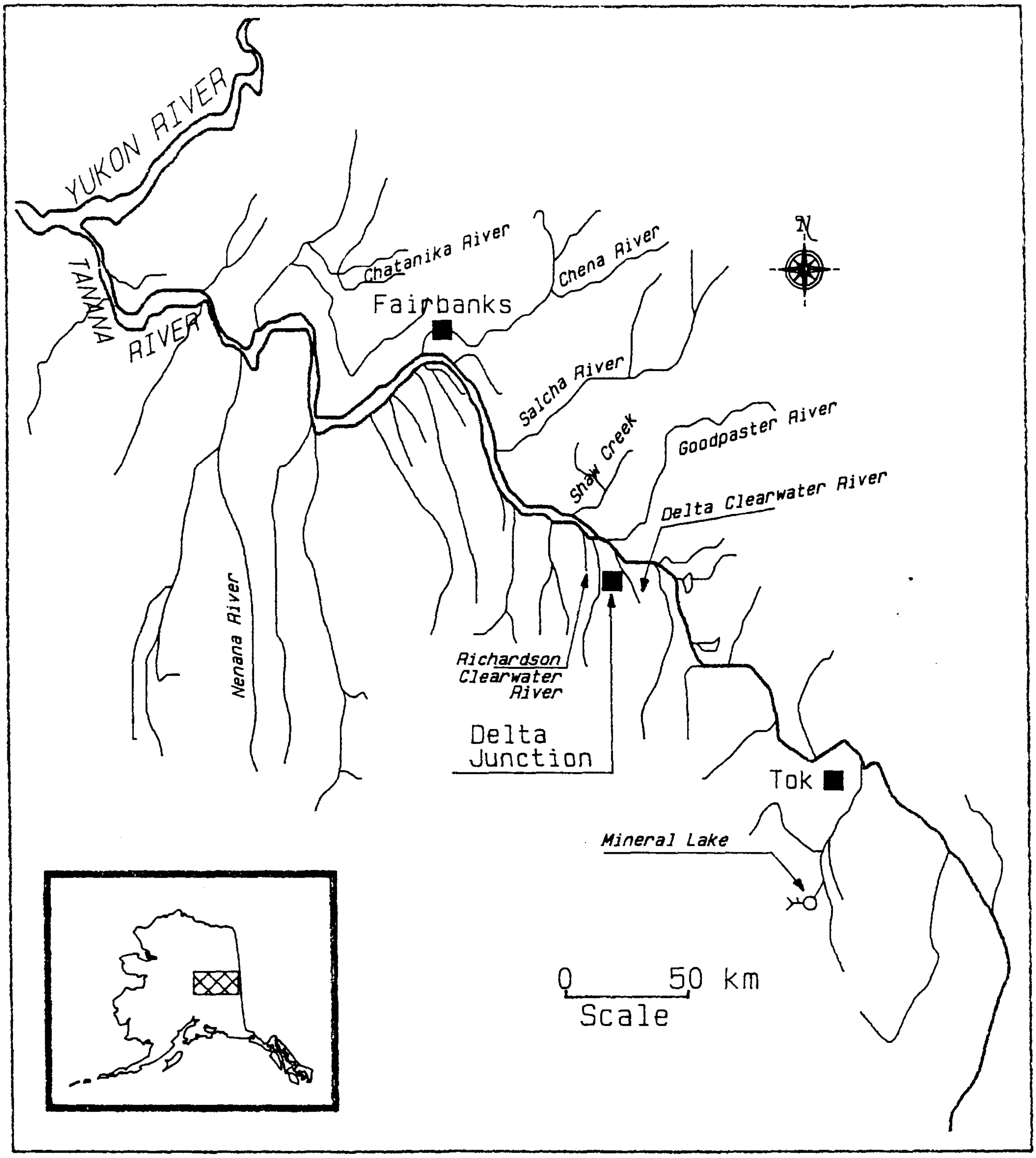

Figure 1. The Tanana River drainage.

Since 1977, Mills (1979-1989) has estimated harvest and angling effort on the Salcha River through a postal survey. Annual harvest of Arctic grayling has averaged 6,756 fish, ranging from 2,383 in 1988 to 13,305 in 1984 (Table 1). Angling effort for all species of sport fish has averaged 10,747 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 Elliot 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 Elliot highways and supports fishing for these species as well. The lower reach is accessible by riverboat from the Elliot highway and the Murphy Dome Road Extension. This reach of the Chatanika River supports northern pike, sheefish *Stenodus leucichthys*, and burbot fishing.

The Chatanika River is much more accessible than the Salcha River, 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. There are four recreation sites on the Chatanika River; 63-km Steese Highway campground, 18-km Elliot 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 thought that excessive harvest of sub-adult 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 man-hours were expended with a catch rate of 1.02 Arctic grayling per hour. From 1977 through 1988, harvest of Arctic grayling was estimated by Mills (1979-1989). Annual harvest averaged 6,320 fish during this period, with 8,782 man-days of effort (Table 1). Annual harvests during this period ranged from 2,692 fish in 1986 to 9,766 fish in 1983.

Table 1. Recreational Arctic grayling harvest and angling effort on the Salcha, Chatanika, and Goodpaster rivers, 1977-1988[a].

Year	Salcha River		Chatanika River		Goodpaster River	
	Harvest[b]	Effort[c] (man-days)	Harvest	Effort (man-days)	Harvest	Effort (man-days)
1977	6,387	8,167	6,737	9,925	ND[d]	ND
1978	9,067	9,715	9,284	10,835	ND	ND
1979	5,980	14,788	6,121	4,853	ND	ND
1980	5,351	8,858	5,143	5,576	ND	ND
1981	3,983	8,090	3,808	4,691	ND	ND
1982	6,843	14,126	6,445	9,417	ND	ND
1983	9,640	11,802	9,766	10,757	3,021	1,989
1984	13,305	8,449	4,180	8,605	1,194	766
1985	5,826	13,109	7,404	10,231	2,757	2,844
1986	7,540	13,792	2,692	7,783	1,508	933
1987	4,762	10,576	5,619	11,065	1,702	3,061
1988[e]	2,383	7,494	8,640	11,642	1,273	1,037
Averages	6,756	10,747	6,320	8,782	1,909	1,772

[a] Mills (1979-1989).
[b] Harvest is the estimated number of Arctic grayling taken.
[c] Effort is the number of man days expended for all fish species.
[d] ND = data not available.
[e] Special regulations were in effect on the Salcha River in 1988. These 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.

In addition to harvest data provided by Mills (1988), Baker (1988) conducted a creel survey of Chatanika River (Elliot 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 25 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 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 fifty 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 CPUE 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 man-days of effort were mainly by residents of the area. No other data were available until the statewide harvest survey (Mills 1984-1989) began to obtain estimates of harvest and effort in 1983 (Table 1). Annual harvests since then have averaged 1,909 Arctic grayling. Effort for all species has averaged 1,772 man-days for the same period.

This report summarizes all data pertinent to stock assessment work conducted on the Goodpaster River from 1955 to 1989. These data can be found in Appendices B1 through B14.

METHODS

Estimation of Abundance

Specific methodologies have been developed to estimate abundance of Arctic grayling in runoff 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. 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 abundance estimation in runoff streams is presented below.

Long study areas were chosen, in general, to minimize emigration of fish during the experiments. Collection of mark and recapture data in the Salcha 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 is divided into three study areas. The downstream and upstream areas are usually shorter than the midstream area.

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 then 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. A chi-squared goodness of fit test was performed to determine the significance of movement in the study section between areas. The test compares the proportion of fish movement observed from mark-recapture with the proportion of fish movement expected if no movement had occurred. 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 and growth from occurring. In practice, we perform this test after testing (and adjusting if necessary) assumptions 2 and 3, as shown below.

Assumptions 2 and 3 were tested with two Kolmogorov-Smirnov two-sample statistical tests. 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 C). 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 difference in capture probabilities among sizes of fish marked. Difference in capture probabilities was maximized by observing significance levels in a series of chisquared 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 chisquared tests was restricted to two because further stratification could possibly reduce overall precision while gaining very little additional accuracy.

Next, the possibly stratified mark-recapture data were examined for directed movement of fish (assumption 1). If fish did not appear to migrate during the experiment, the modified Petersen estimator of Bailey (1951, 1952) was used to estimate abundance:

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

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.

Alternatively, if significant interarea movement of fish in the study section was observed between the marking (first event) and recapture (second event) samples a modified Petersen estimator (Bernard pers. comm.[1], Evenson 1988) was used to compensate for the movement of marked Arctic grayling out of the study section. The additional assumptions necessary for accurate use of this estimator are (Evenson 1988):

6) no Arctic grayling tagged in the midstream area migrate out of the study section; and,

7) a single process causes upstream movement, and a single process causes downstream movement.

The modified Petersen estimator that accounts for movements of tagged fish is:

$$\hat{N} = \frac{\{\, M_1(1-\hat{\Theta}_d) + M_2 + M_3(1-\hat{\Theta}_u) \,\}\ \{C + 1\}}{R_{..} + 1} \qquad (2)$$

---

[1] Bernard, David. Personal Communication. ADFG, Sport Fish Division, 333 Raspberry Road, Anchorage, AK 99518.

where:

M_x = the number of Arctic grayling marked in the first event in section x (x = 1, 2, and 3 for the downstream, midstream, and upstream areas, respectively);

$R_{..}$ = the number of Arctic grayling recaptured during the second event;

θ_z = the probability that an Arctic grayling will move out of an area in the *z* direction (upstream or downstream);

C = the catch made during the second event; and,

N = the abundance of Arctic grayling in all areas at the start of the second event.

The probabilities of movements are estimated by:

$$\hat{\theta}_d = \frac{M_2(R_{32} + R_{21})}{R_{2.}(M_3 + M_2)}, \text{ and} \qquad (3)$$

$$\hat{\theta}_u = \frac{M_2(R_{12} + R_{23})}{R_{2.}(M_1 + M_2)} \qquad (4)$$

where:

R_{xy} = the number of Arctic grayling that were marked in area *x* during the first event and were recaptured in area *y* during the second event; and,

$R_{2.}$ = the number of Arctic grayling that were marked in the midstream area during the first event and were recaptured during the second event.

Variance of these abundance estimates was calculated by bootstrapping (Efron 1982). First, capture history of each fish was recorded by study area. A capture was denoted with the study area (1 for downstream, 2 for midstream, and 3 for upstream area). If the fish was not seen, this was denoted by a zero. The total number of capture histories was the sum of fish marked in the fish 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 500 times by computer. Each replication of the estimation experiment involved sampling of "the total number of capture histories" and then calculating an abundance estimate (and probabilities of movement for the modified estimator). After 500 replications the mean and standard variance (Snedecor and Cochran 1980) for a mean were calculated for all replicates. For the Goodpaster River experiment, a non-parametric 95% confidence interval for the bootstrapped abundance and movement estimates were estimated by the percentile method of Efron (1981).

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 9.6, 17.6, and 9.6 km long, respectively. This section of the Salcha River encompasses areas used for stock assessment in 1987 (Clark and Ridder 1988) and 1988 (Clark 1988).

Marking data were collected with a pulsed-DC electrofishing boat using a variable voltage pulsator and 10 mm diameter steel cable anodes. The unpainted bottom of the boat served as the cathode. Pulsator settings during electrofishing were: duty cycle 50%, pulse width 60 Hz, average voltage 250 VDC; and, average amperage 3.5 A. Conductivity measurements were not taken, but conductivities are known to range from 50 to 150 μS in streams similar to the Salcha River in interior Alaska. Recapture data were collected with two electrofishing boats of similar design and operating characteristics.

The marking event occurred on 12 through 16 June and the recapture event on 19 and 20 June. Events started at the upstream end of the study 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 (left ventral fin), and released. The left ventral fin was 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.

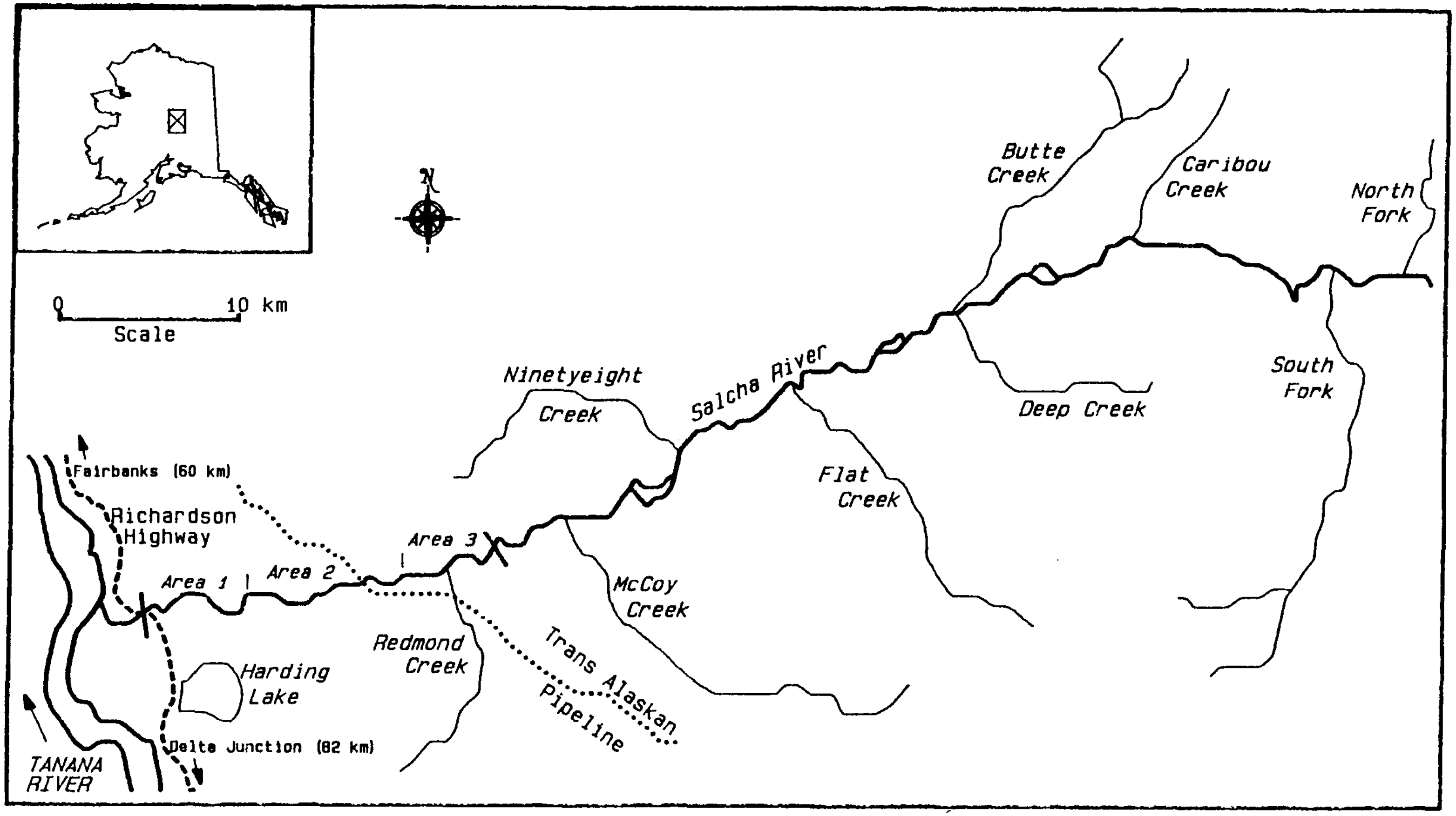

Figure 2. Study section on the Salcha River.

Goodpaster River:

Population abundance was estimated in a 50 km reach of the lower Goodpaster River. The upstream boundary of the reach 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 3). 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 area was further subdivided into three sections. Section 1 was 16.5 km long and extended from the downstream boundary to approximately river kilometer 19.2. Section 2 was 14.4 km long and extended to river kilometer 33.6. Section 3, the upstream section, was 18.7 km long. These sections are similar to those used in 1988 (Ridder 1989).

Samples were taken during two events, each three days long and each beginning at section 3 and progressing downstream. The marking event ran from 8 to 10 August and the recapture event ran from 15 to 17 August. One river section was sampled each day. The time interval between sampling events for each of the three study sections was seven days. Sampling started at the upstream end of a section and consisted of two electrofishing boats traveling downstream, one along each bank, collecting as many Arctic grayling as possible in a 20 minute interval.

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 10 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. Voltages ranged from 280 to 350 volts and current ranged from 2 to 5 amperes. Duty cycle and pulse rate were held constant at 40% and 80 Hz, respectively. Mid-day water temperatures during the experiment ranged from 9.5 to 14.0°C. Although no measurement of conductivity was taken in 1989, a reading of 71 μS (standardized to 25°C) was taken at river kilometer 52.3 on 8 August 1988 (Ridder 1989).

Estimation of Age and Size Composition

Estimates of age and size composition are used to characterize the structure of Arctic grayling stocks in the Tanana drainage. Changes in age and size composition often indicate serious fishery or environmental effects on recruitment and survival. When population abundance estimates are not possible or not cost effective, these indices of stock structure can help managers to compare the health of fishery stocks.

Salcha River:

Age and size data were collected during both sampling events between 12 and 20 June. A sample of scales was taken from the preferred zone[2] of each newly

[2] 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.

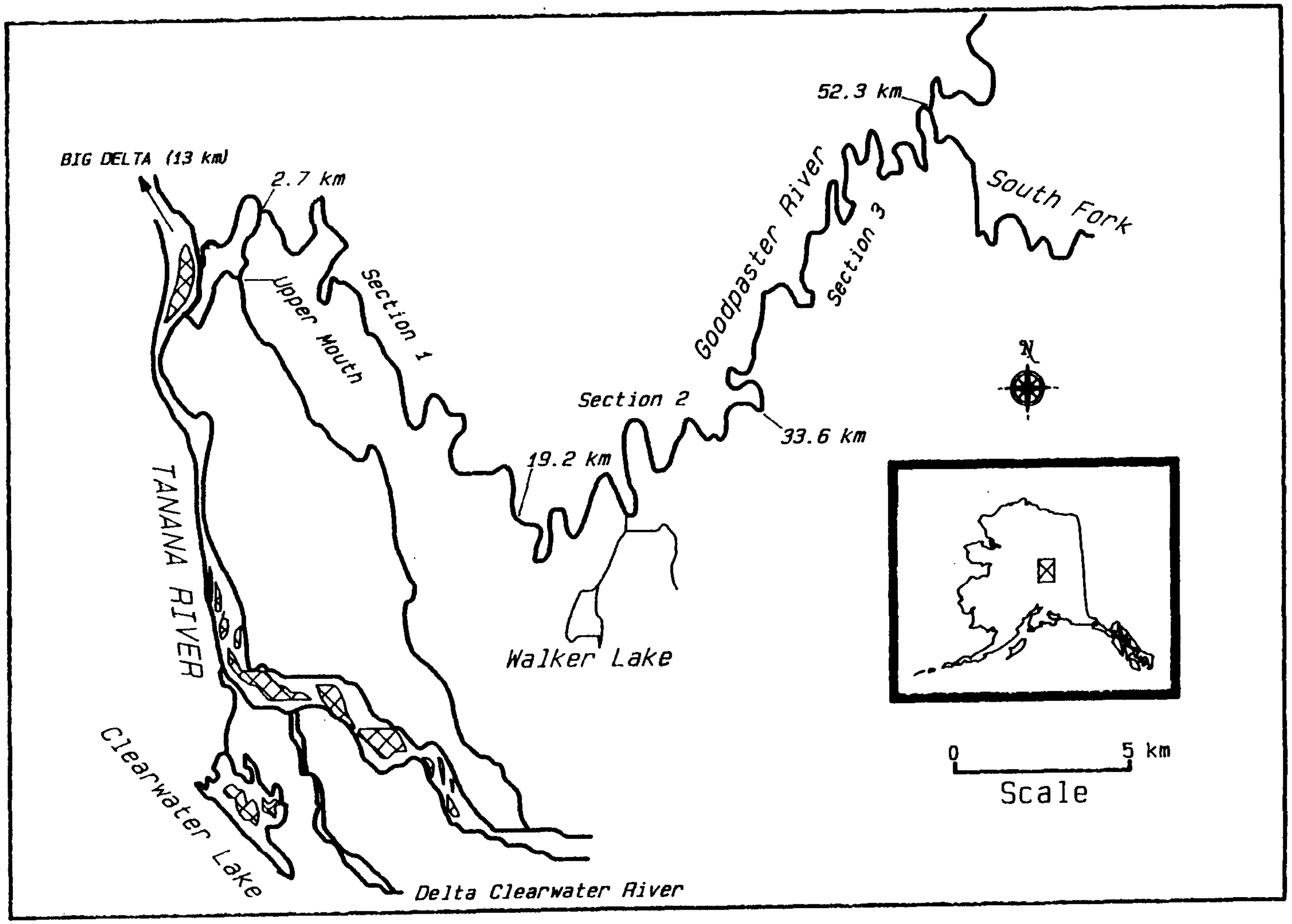

Figure 3. The three study sections of the Goodpaster River.

captured fish. Fork length was measured to the nearest 1 millimeter. 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.

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 these data and has been shown to exhibit bias in capturing all sizes of Arctic grayling greater than 149 mm FL (Clark and Ridder 1988). In addition, the Salcha River mark-recapture data did show a significant change in capture probability of marked Arctic grayling during the experiment. Therefore, age and size samples taken with the electrofishing boat were most likely different than the true age and size composition of the Salcha River stock at the time these samples were taken. The same size class strata used for abundance estimation were used to estimate adjustment factors for age and size composition estimates.

To compensate for bias introduced by electrofishing, recapture to mark ratios were used to adjust for differential capture probability by size of fish:

$$\hat{\rho}_l = \frac{RECAP_l}{MARK_l} \tag{7}$$

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):

$$\hat{A}_l = \frac{\rho_L}{\rho_l} \tag{8}$$

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

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

$$\hat{x}_{kl} = \hat{A}_l \, n_{kl} \tag{9}$$

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:

$$\hat{p}_k = \frac{\sum_{l=1}^{m} \hat{x}_{kl}}{\sum_{k=1}^{o} \sum_{l=1}^{m} \hat{x}_{kl}} = \frac{\hat{x}_{k.}}{\hat{x}_{..}} \qquad (10)$$

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 500 times in samples of "the number of capture histories".

Size composition of the Salcha River stock was described with the incremental Relative Stock Density (RSD) indices of 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). The adjustment factors used to estimate age composition were also used to adjust biased RSD estimates, 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*.

Chatanika River:

Age and size composition data were collected during 12 through 28 September in a 16 km reach of the Chatanika River (Figure 4). The river section was bounded upstream by the Elliot Highway bridge and bounded downstream by a point 6 km below the Trans-Alaska Pipeline crossing. This area encompasses the areas sampled by Tack (1973), Holmes (1983, 1985), and Holmes et al. (1986). Samples were collected with a pulsed-DC electrofishing boat of similar design and operating characteristics as the gear used at the Salcha and Goodpaster rivers. Data collection procedures were identical to the Salcha River study.

In contrast to studies described above, a mark-recapture experiment was performed on the Chatanika River solely to estimate the relative probabilities of capture by length of fish. Although movements of Arctic grayling to overwintering areas of the Chatanika River occur during September (Tack 1980), these movements were assumed to not be size specific. Therefore, the relative rates of recapture could be used to detect and correct for size selectivity of the electrofishing boat. The period from 12 through 22 September was used to

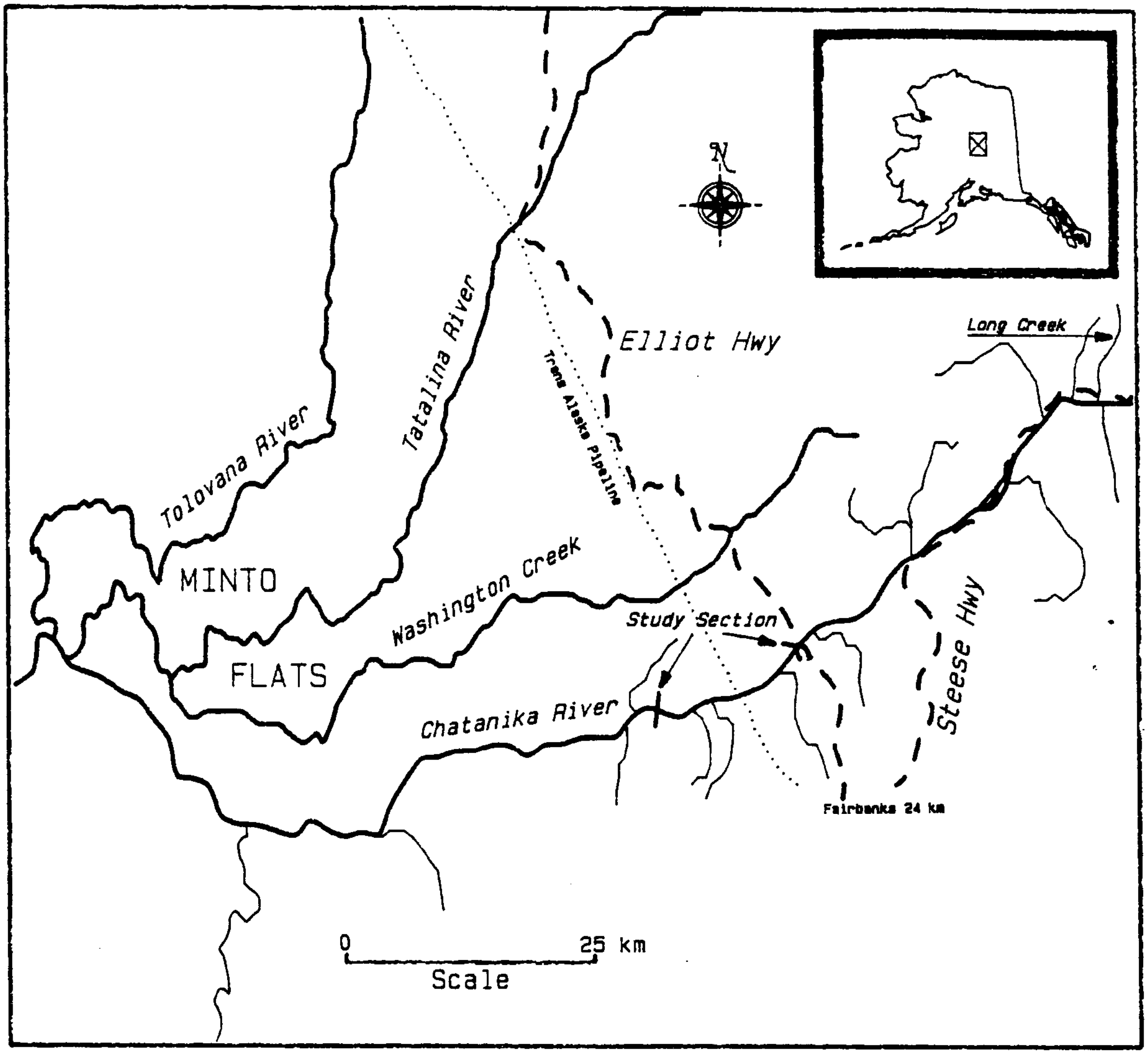

Figure 4. Study section on the Chatanika River.

mark Arctic grayling in a 16 km area below the Elliot Highway bridge (Figure 4). Methods of capture, marking, releasing of fish were identical to those of the Salcha River study. The period from 25 through 28 September was used to recapture Arctic grayling marked during the first event.

Insufficient recaptures (three) were obtained to perform the analyses necessary for detection and correction of size selectivity. However, Clark and Ridder (1988) found that capture probabilities estimated from electrofishing gear used on the upper Chena River could be used to adjust age and size composition in the Chatanika River in 1987. In 1989, the same electrofishing gear used on the Chatanika River was used on the Salcha River, so that capture probabilities from the Salcha River experiment could be used to adjust age and size composition on the Chatanika River. As a result, the adjusted estimates of Arctic grayling age and size composition for the Chatanika may be biased, since the true capture probabilities are not known and may differ from those of the Salcha River experiment.

As with the Salcha River data, equation 9 was used to adjust the sampled number of age *k* Arctic grayling in size class *l*. However, the calculation of variances could not be performed with the same bootstrap methods as described for the Salcha River data. Instead the adjustment factors and variances from bootstrap analysis of the Salcha River data were used in combination with the sampled age and size composition data from the Chatanika River to estimate the variance of adjustment factors using a formula derived from the delta method (Seber 1982):

$$\hat{V}[A_l] = \frac{\rho_L^2}{\rho_l^2}\left[\frac{V[\rho_L]}{\rho_L^2} + \frac{V[\rho_l]}{\rho_l^2}\right] \qquad (11)$$

where: $\hat{V}[A_l]$ = variance of the adjustment factor for size class *l*;
ρ_l = capture probability of Arctic grayling in size class *l*, regardless of age *k* (from bootstrap of Salcha River data);
ρ_L = $\max(\rho_l)$, l = 1, 2 size classes;
$V[\rho_l]$ = variance of ρ_l (from bootstrap of Salcha River data); and,
$V[\rho_L]$ = variance of ρ_L.

Next, equation 9 is used to calculate the adjusted number of Arctic grayling at age *k* that are also in size class *l*. The variance of this product (Goodman 1960) was :

$$\hat{V}[x_{kl}] = (n_{kl}^2\, \hat{V}[A_l]) + (\hat{A}_l^2\, \hat{V}[n_{kl}]) - (\hat{V}[n_{kl}]\, \hat{V}[A_l]) \qquad (12)$$

where: $\hat{V}[x_{kl}]$ = variance of the adjusted number of Arctic grayling at age *k* that are also in size class *l*;
n_{kl} = the sampled number of Arctic grayling at age *k* that are also in size class *l* (from Chatanika River data); and,
$\hat{V}[n_{kl}]$ = variance of the sampled number of Arctic grayling at age *k* that are also in size class *l* (bootstrap estimate from Chatanika River data);

Then equation 10 is used to estimate the adjusted proportion of Arctic grayling at age k. An estimate of the variance of equation 10 is approximated by Bernard (1983, page 7) for two dependent variables (ignoring hat symbols):

$$V[p_k] = \frac{V[x_{k.}]}{V[x_{..}]} = \left[\frac{x_{k.}}{x_{..}}\right]^2 \left[\frac{V[x_{k.}]}{x_{k.}^2} + \frac{V[x_{..}]}{x_{..}^2} - \frac{2V[x_{k.}]}{x_{k.}\ x_{..}}\right] \quad (13)$$

where: $V[p_k]$ = variance of the adjusted proportion of Arctic grayling at age k;

$$V[x_{k.}] = \sum_{l=1}^{m} V[x_{kl}]; \text{ and,}$$

$$V[x_{..}] = \sum_{k=1}^{o} V[x_{k.}].$$

Equations 9 through 13 were also used to adjust size composition estimates. The adjustment factors used to estimate age composition were also used to adjust biased RSD estimates 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.

Goodpaster River:

Age class compositions and RSD indices of Arctic grayling in the lower 50 km of the Goodpaster River were adjusted for bias due to size selectivity of the electrofishing gear. The adjustment procedure and formulae are identical to procedures used for the Salcha River data (equations 7 through 10).

RESULTS

Salcha River

A total of 1,223 Arctic grayling (≥ 150 mm FL) was captured during the mark-recapture experiment. Fourteen mortalities or serious injuries were recorded for an overall immediate mortality rate of 1.1%.

During 12 through 16 June, 616 Arctic grayling (≥ 150 mm FL) were marked along the 36.8 km section of the Salcha River. During 19 and 20 June, 593 Arctic grayling were examined for marks along the same 36.8 km section of river. A total of 55 Arctic grayling was recaptured during the second sample. The cumulative distribution function (CDF) of lengths of marked Arctic grayling was marginally different than the CDF of lengths of recaptured Arctic grayling (DN[3] = 0.18, P = 0.08; Figure 5A). Therefore, the second sample was biased with respect to equal probability of capture of marked Arctic grayling by size. The mark-recapture data were stratified by size into two categories:

[3] DN = test statistic for the Kolmogorov-Smirnov test.

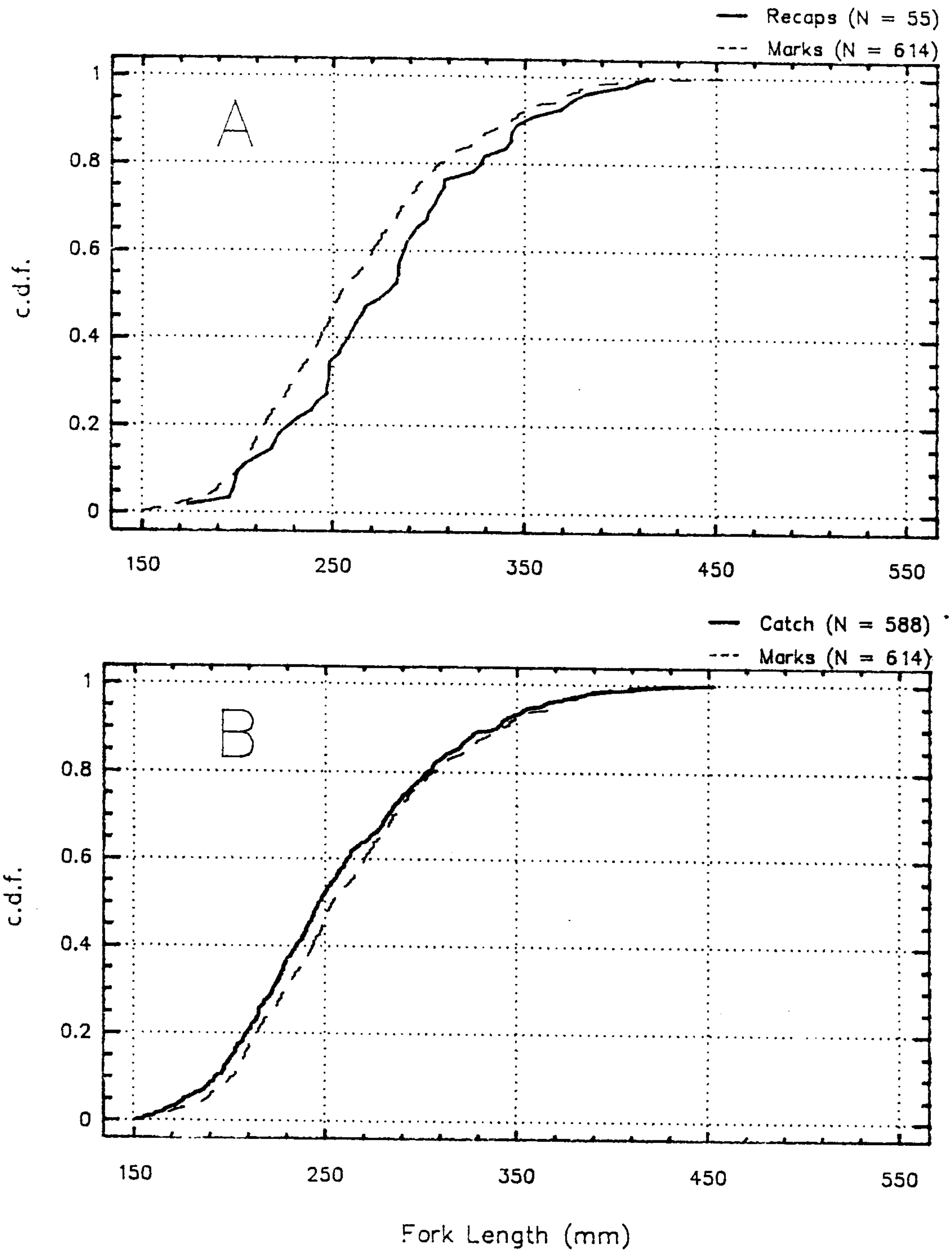

Figure 5. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 36.8 km section of the Salcha River, 12 through 20 June, 1989.

small Arctic grayling (150 to 249 mm FL), and large Arctic grayling (greater than 249 mm FL).

When tested for interarea movement of Arctic grayling between sampling events, small fish exhibited no significant movement ($\chi^2 = 1.1$, $df = 1$, $P > 0.25$; Table 2), while large fish exhibited significant movement ($\chi^2 = 5.8$, $df = 1$, $0.01 < P < 0.02$; Table 3). Abundance of small fish, using the modified Petersen estimator of Bailey (1951, 1952), was 4,468 fish (SE = 702 fish, CV = 16%). Abundance of large fish, using the bootstrap estimate of the modified Petersen estimator of Bernard (Evenson 1988) was 2,467 fish (SE = 307 fish, CV = 12%; Table 4). Probabilities of movement for large fish were 3% for downstream and 12% for upstream (Table 4). Total abundance for the 36.8 km section of the Salcha River was 6,935 fish (SE = 766 fish, CV = 11%).

The CDF of lengths of marked Arctic grayling was also marginally different than the CDF of lengths of Arctic grayling examined for marks ($DN = 0.08$, $P = 0.07$), although no meaningful difference was evident (Figure 5B). The significant difference seen can be accounted for by the large sample sizes, leading to detection of a small difference in length distribution. Therefore, age and size samples taken during the first and second events were pooled to calculate age and size composition. After adjustment for size-selectivity, age 3 Arctic grayling were dominant in this section of the Salcha River. Age 3 Arctic grayling accounted for 35% of the estimated abundance, while age 4 Arctic grayling accounted for 26% of the stock (Table 5). Age 5 and age 6 Arctic grayling were next most abundant, accounting for 13% and 11% of the estimated abundance, respectively.

Size composition of Arctic grayling in the study section was weighted heavily towards stock size fish, accounting for 71% of the estimated abundance (Table 6). Of the fish greater than 269 mm FL, 22% were quality size, 8% were preferred size, and < 1% were memorable size. No trophy size Arctic grayling were sampled in the study section.

<u>Chatanika River</u>

A total of 375 Arctic grayling (≥ 150 mm FL) was captured during the mark-recapture experiment. Four mortalities or serious injuries were recorded for an overall immediate mortality rate of 1.1%.

Bootstrap capture probabilities from the Salcha River experiment were 0.07 (SE = 0.01) for small fish and 0.10 (SE = 0.01) for large fish. The adjusted age composition of Arctic grayling in the Chatanika River was weighted most heavily towards age 6 and age 3 fish, representing 23% and 18%, respectively (Table 5). These two year classes were followed by age 7 and age 8 Arctic grayling, accounting for 14% and 12% of the sample, respectively.

Quality size Arctic grayling accounted for 49% of the adjusted size composition in the Chatanika River (Table 6). Of fish greater than 269 mm FL, only 2% were also greater than 339 mm FL. The remaining 49% of fish from the Chatanika River were stock size.

Table 2. Summary of inter-section and inter-run[a] movements of small (150 to 249 mm FL) Arctic grayling based on recaptures (R) in the lower 36.8 km of the Salcha River, 12 through 20 June, 1989.

Mark	Recapture																			
	Sect. 3				Sect. 2							Sect. 1						Total	Total	R/M
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	R_{NM}[b]	R_M[c]	R	M	Ratio
1	1															1	0	1	26	0.038
2		0														0	0	0	15	0.000
3			0													0	0	0	14	0.000
4				0												0	0	0 (1)	10 (65)	0.000 (0.015)
5					2											2	0	2	12	0.167
6						0										0	0	0	18	0.000
7							2									2	0	2	9	0.222
8								1								1	0	1	19	0.053
9							1		3							3	1	4	22	0.182
10									1	1	1					1	2	3	15	0.200
11										1	1					1	1	2 (14)	18 (113)	0.111 (0.124)
12												0				0	0	0	18	0.000
13													0			0	0	0	18	0.000
14											1		2	0		0	3	4	24	0.167
15															1	1	0	1 (5)	39 (99)	0.026 (0.050)
	Upstream				Midstream							Downstream								

[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.

Table 3. Summary of inter-section and inter-run[a] movements of large (≥ 250 mm FL) Arctic grayling based on recaptures (R) in the lower 36.8 km of the Salcha River, 12 through 20 June, 1989.

Mark	Recapture: Sect. 3				Sect. 2							Sect. 1								
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	R_{NM}[b]	R_M[c]	Total R	Total M	R/M Ratio
1	2															2	0	2	32	0.062
2		3	1													3	1	4	27	0.148
3			1													1	0	1	19	0.053
4				0	1											0	1	1 (8)	18 (96)	0.055 (0.083)
5					0											0	0	0	17	0.000
6						2	1									2	1	3	16	0.187
7	1						3									3	1	4	23	0.174
8							2	1								2	1	3	30	0.100
9								1	2							2	1	3	24	0.125
10						1	1			5						5	2	7	22	0.318
11								1			0					0	1	1 (21)	24 (156)	0.042 (0.135)
12											1	1				1	1	2	20	0.100
13									1			1	0			0	2	2	28	0.071
14						1							1	1		1	2	3	20	0.150
15															0	0	0	0 (7)	12 (80)	0.000 (0.087)
	Upstream				Midstream							Downstream								

[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.

Table 4. Population abundance estimate of large Arctic grayling (≥ 250 mm FL) in the lower 36.8 km (23 mile) of the Salcha River, 12 through 20 June, 1989.

Parameter	Calculated or Known Quantity	Bootstrap Estimate
M_1	80	80
M_2	156	156
M_3	96	96
C	281	281
$R_{..}$	36	36
R_{11}	3	3
R_{12}	3	3
R_{13}	0	0
R_{21}	0	0
R_{22}	21	21
R_{23}	1	1
R_{31}	0	0
R_{32}	1	1
R_{33}	7	7
θ_d	0.03	0.03
SE	Unknown	0.03
θ_u	0.12	0.12
SE	Unknown	0.06
$\hat{N}$ (Evenson 1988)	2,425	2,467
SE	Unknown	307
$\hat{N}$ (Bailey 1951, 1952)	2,530	2,646
SE	383	293

Table 5. Estimates of age class composition and standard error for Arctic grayling (≥ 150 mm FL) captured from the Salcha and Chatanika River stocks, 1989[a].

	Salcha River				Chatanika River			
Age Class	n[b]	p[c]	SE[d]	CV[e]	n	p	SE	CV
2	17	0.03	0.01	21	24	0.09	0.03	27
3	155	0.35	0.03	7	47	0.18	0.04	23
4	143	0.26	0.02	8	31	0.12	0.03	24
5	75	0.13	0.01	8	30	0.08	0.02	22
6	74	0.11	0.02	16	88	0.23	0.04	16
7	24	0.04	0.01	19	54	0.14	0.03	20
8	30	0.05	0.01	17	47	0.12	0.03	21
9	18	0.03	0.01	26	15	0.04	0.01	28
10	3	<0.01	<0.01	53	2	0.01	<0.01	71
Totals	539	1.00	---	---	338	1.00	---	---

[a] Arctic grayling were sampled from the Salcha River between 12 and 20 June, 1989. Arctic grayling were sampled from the Chatanika River between 12 and 28 September, 1989.

[b] n = sample size.

[c] p = adjusted proportion of Arctic grayling in the population. Adjustment was performed with bootstrap methods (Efron 1982; Clark and Ridder 1988).

[d] SE = standard error of p.

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

Table 6. Summary of Relative Stock Density (RSD) indices for Arctic grayling ($\geq$ 150 mm FL) in the Salcha and Chatanika rivers, 1989[a].

	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
Salcha River					
Number sampled	755	342	124	2	0
Sample RSD	0.62	0.28	0.10	<0.01	---
Adjusted RSD[c]	0.71	0.22	0.08	<0.01	---
Standard Error	0.04	0.03	0.01	<0.01	---
CV (%)	5	12	15	76	---
Chatanika River					
Number sampled	150	221	4	0	0
RSD	0.40	0.59	0.01	---	---
Adjusted RSD[c]	0.49	0.49	0.02	---	---
Standard Error	0.06	0.06	0.01	---	---
CV (%)	13	13	36	---	---

[a] Arctic grayling were sampled from the Salcha River between 12 and 20 June, 1989. Arctic grayling were sampled from the Chatanika River between 12 and 28 September, 1989.

[b] Minimum lengths for RSD categories are (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 bootstrap methods (Efron 1982; Clark and Ridder 1988).

Goodpaster River

A total of 1,946 Arctic grayling (≥ 150 mm FL) was captured during the mark-recapture experiment on the lower 50 km of the Goodpaster River. Total electrofishing effort was 37.9 hours for a catch rate of 51 Arctic grayling per hour per boat. Eighteen mortalities or serious injuries were recorded for an overall immediate mortality rate of 0.9%. Of the total catch, 203 Arctic grayling were recaptures of fish tagged and/or finclipped in previous years in the Goodpaster and Delta Clearwater rivers (n = 190 and n = 13, respectively). During the marking run, 955 Arctic grayling were marked and released alive from 8 through 10 August. During the recapture run from 15 through 17 August, 984 Arctic grayling were examined and 124 were found to be recaptures from the first event (Table 7).

A Kolmogorov-Smirnov test between the CDF of lengths of marked and recaptured fish indicated the second sample is biased with respect to equal probability of capture by size ($DN = 0.15$, $P = 0.01$; Figure 6A). Two size strata, 150 to 259 mm FL (small fish) and greater than 259 mm FL (large fish), were chosen to reduce bias.

A significant difference was also found in the size composition between section 3, and sections 1 and 2 combined ($\chi^2 = 180.8$, $df = 2$, $P < 0.05$; Figure 7) suggesting additional stratification by river section. However, no statistical difference in capture probabilities among rivers sections taken individually ($\chi^2 = 3.5$, $df = 2$, $P > 0.05$) or with river sections 1 and 2 combined ($\chi^2 = 1.6$, $df = 1$, $P > 0.05$; see Table 7) was observed. As a result of these tests, size selectivity was deemed responsible for biased recapture-to-mark ratios. Therefore, the mark-recapture data were combined among sections for estimation of abundance, and age and size compositions.

While movement of marked fish was observed between sampling events, no significant movement between sections was detected ($\chi^2 = 0.4$, $df = 2$, $P > 0.05$). Twenty-one (17%) of the 124 recaptures were caught in different areas (38% upstream and 62% downstream) but only four recaptures, three small and one large fish, were caught outside the section in which they were marked (Table 8). All four fish had moved downstream from section 3 into section 2 (one fish moved less than 1 km). The probability of this downstream movement was calculated at 0.12 for small fish (SE = 0.11; 95% CI of 0.00 to 0.37) and 0.02 (SE = 0.02; 95% CI of 0.00 to 0.05) for large fish. Yet, there were significant differences in <u>the amount</u> of movement between sections ($\chi^2 = 10.5$, df = 2, $p < 0.05$). The amount of mov ement decreased to almost zero as one headed downstream. This decrease may be compromised by the fact that as one moves downstream, capture probability tends to decrease (Table 8). This decrease may bias the ability to detect movement. Yet, assuming the highly turbid waters at the downstream boundary of the study area was an emigration barrier, no significant loss of marks, at least in the downstream direction, was indicated. Marked fish may have moved upstream out of the study area since 50% of the fish that showed upstream movement were in the upper section, but the probability of movement could not be estimated. Considering the rather high capture probabilities in this section and the number marked and recaptured (lowest of the three sections), loss of marks upstream is

Table 7. Summary of mark-recapture data of Arctic grayling (≥ 150 mm FL) from three sections of the lower 50.0 km of the Goodpaster River, 8 through 17 August, 1989.

Section	Length Category	Marks	Catch	Recaps	R/M[a]
1	150-259	309	317	33	0.11
	≥260	113	96	11	0.10
	Total	422	413	44	0.10
2	150-259	211	236	19	0.09
	≥260	108	101	27	0.25
	Total	319	337	46	0.14
3	150-259	90	82	10	0.11
	≥260	124	152	24	0.19
	Total	214	234	34	0.16
Combined	150-259	610	635	62	0.10
	≥260	345	349	62	0.18
	Total	955	984	124	0.13

[a] R/M = recapture rate or catchability.

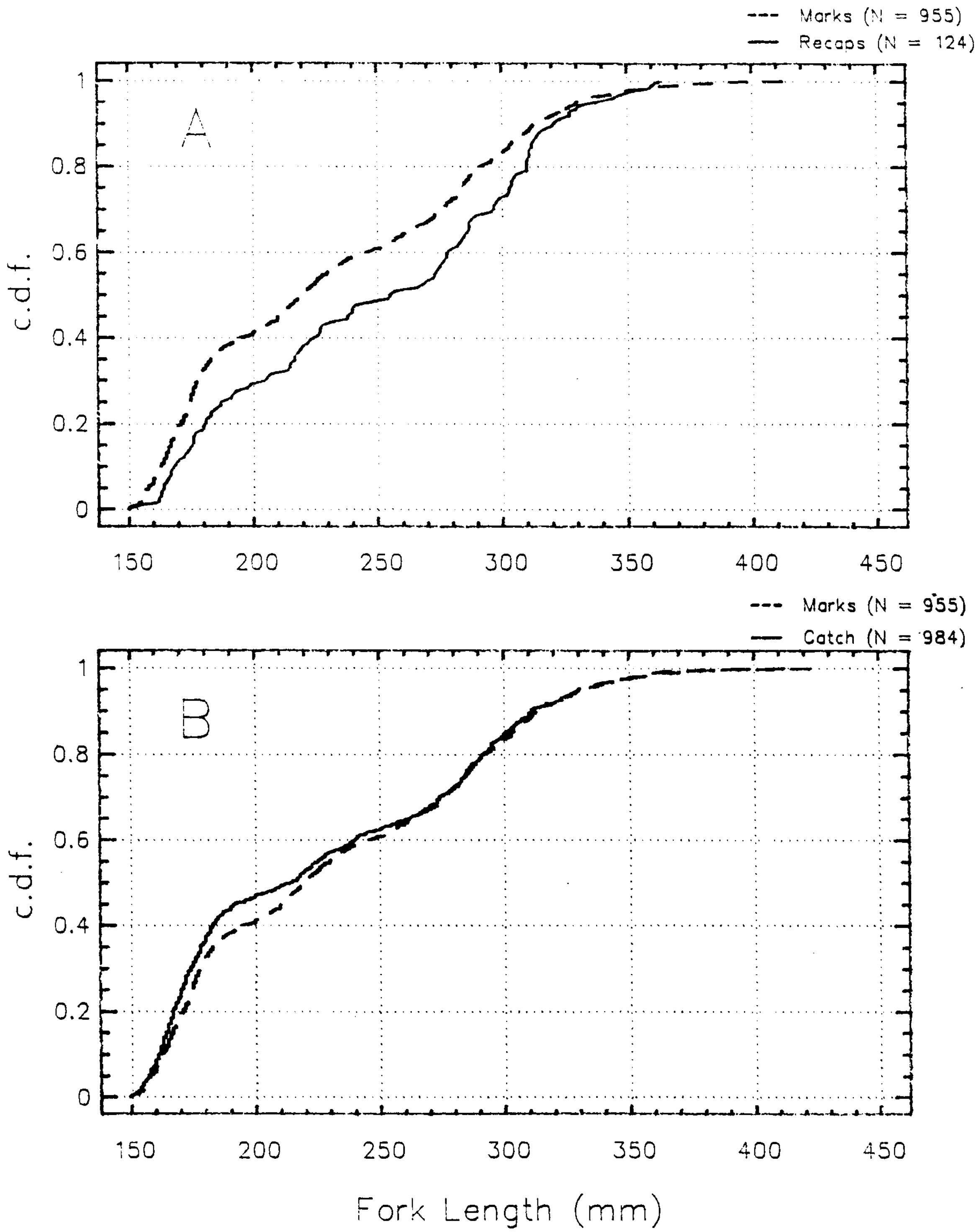

Figure 6. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 50.0 km section of the Goodpaster River, 8 through 17 August, 1989.

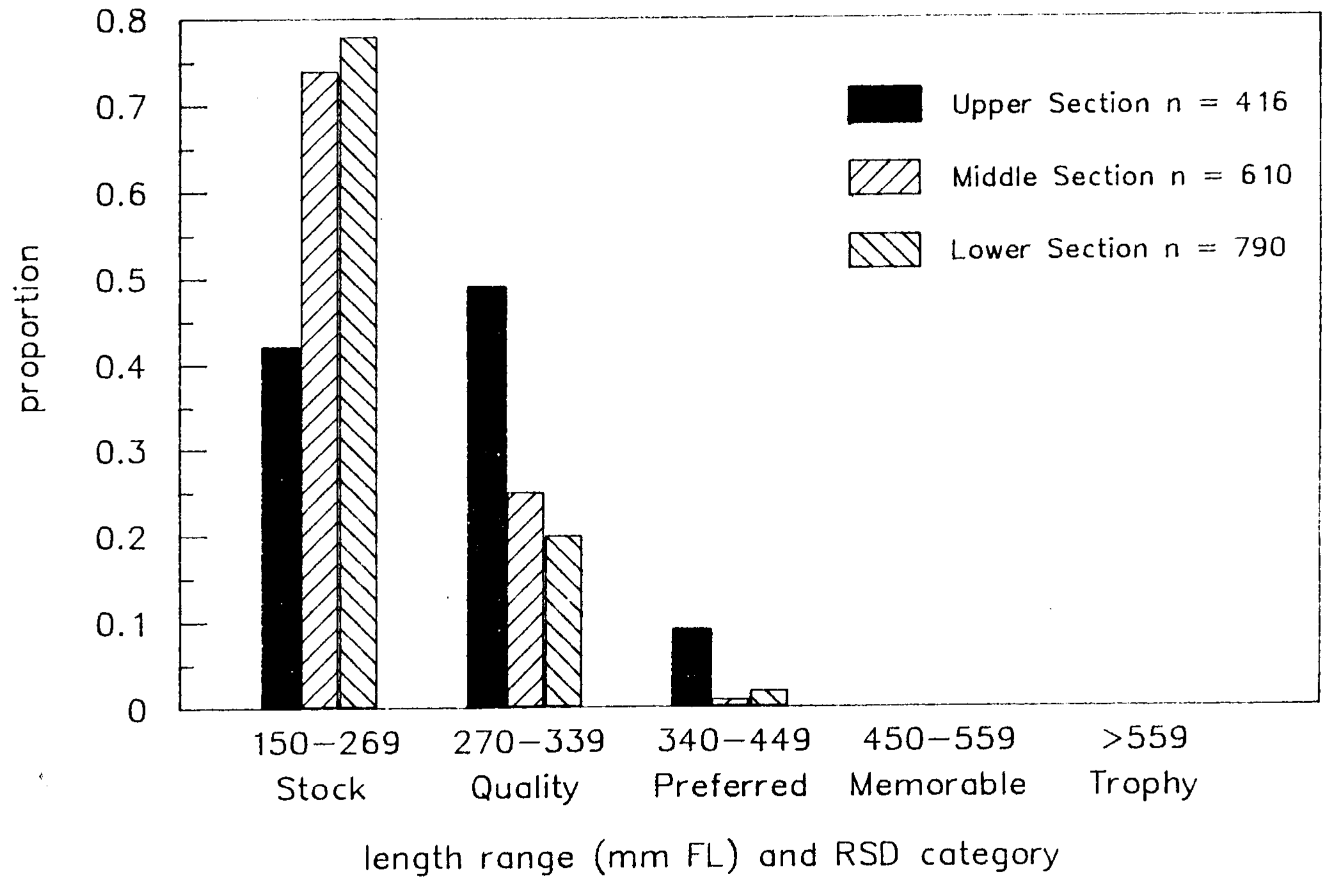

Figure 7. Relative Stock Density estimates for three sections of the Goodpaster River, 8 through 17 August, 1989.

Table 8. 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, 8 through 17 August, 1989.

Mark	Recapture Section 3										Section 2								Section 1									R_{NM}[b]	R_M[c]	Total R	Total M	R/M Ratio
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	27					
1	3									1			1															3	2	5	24	0.21
2		3	1	1		1																						4	2	6	51	0.12
3	1		2																									2	1	3	29	0.10
4				0																								0	0	0	10	0.00
5		1			1	1			1																			2	2	4	18	0.22
6						1																						1	0	1	10	0.10
7						1	3																					3	1	4	12	0.33
8		1						3	1		1	1																4	3	7	21	0.33
9									3																			3	0	3	19	0.16
10										4	1																	4 (26)	1 (12)	5 (38)	20 (214)	0.25 (0.18)
11											5		1	1														5	2	7	31	0.23
12												5	1	1				1										6	2	8	30	0.27
13											1		4	1														5	1	6	36	0.17
14														3	1													4	0	4	33	0.12
15															4													4	0	4	49	0.08
16															1	3												3	1	4	46	0.09
17																	5											5	0	5	62	0.08
18																	1	3										3 (35)	1 (7)	4 (42)	33 (319)	0.12 (0.13)
19																			4	2								6	0	6	61	0.10
20																				5								5	0	5	46	0.11
21																				1	4	1						5	1	6	51	0.12
22																						3	1					4	0	4	63	0.06
23																							6	1		1		7	1	8	71	0.11
24																								4	3			7	0	7	45	0.16
25																									1	2		3	0	3	48	0.06
26																										4		4	0	4	23	0.17
27																											1	1 (42)	0 (2)	1 (44)	13 (422)	0.08 (0.10)

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 1.9 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 27 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.

considered insignificant to the final abundance estimate. As such, the modified Peterson estimator of Bailey (1951, 1952) was used.

The estimated abundance of Arctic grayling in the lower 50 km of the Goodpaster River in 1989 was 8,033 Arctic grayling (SE = 739 fish, CV = 9.0%) with a 95% confidence interval of 6,948 to 9,594 (±17%). This estimate results in an average density of 161 Arctic grayling per river kilometer which is similar to the 158 fish per kilometer found in 1988 (Appendix B1).

Although the Kolmogorov-Smirnov test showed significant differences between fish captured during the two sampling events ($DN = 0.07$, $P = 0.03$; Figure 6B), no meaningful difference was evident (Figure 6B). Therefore, age-length samples taken during the first sampling event could be used to estimate the age and size compositions of Arctic grayling in the lower Goodpaster River, provided, that adjustments for the different capture probabilities of large and small fish were made (see also Appendix C). The adjustments did not alter general trends of the sampled proportions (Table 9). Age 2 Arctic grayling was the predominant age class in the lower Goodpaster River comprising 47% of the population. Age 3 fish were the next most abundant at 21% of the population followed by age 6 at 11.1%. The composition of age 4 and age 5 fish, 4% and 9% respectively, indicated poor recruitment of the 1984 and 1985 year classes.

Size composition of Arctic grayling in the lower Goodpaster River favored stock size fish which comprised 79% of the estimated population (Table 10; Figure 7). Quality size fish made up 28% and no memorable or trophy size fish were detected. Section 3 had larger fish than the lower two sections, with stock and quality sized fish nearly equally represented in the sample (both events combined) at 42 and 49%, respectively.

DISCUSSION

Salcha River

Population abundance of Arctic grayling has been estimated twice in the lower Salcha River. In 1988, a 16 km section of river had a density of 136 Arctic grayling per kilometer. In 1989, a 36.8 km section of river encompassing the area used in 1988 had an average density of 188 Arctic grayling per kilometer. Density of Arctic grayling in the lower Salcha River may have increased between 1988 and 1989. However, Arctic grayling density probably varies considerably from river section to river section. When estimates are performed on identical river sections, useful comparisons can be made. Estimates of recruitment (age 3 fish entering the population) can be compared among years to gauge year class strength or weakness. Density can be compared among years when abundance estimates are performed in identical sections during the same time period. Relative rates of survival could be calculated, but these estimates would be conservative in years when older fish predominate in the stock and liberal in years when younger fish predominate in the stock. The possibility of using age composition estimates in conjunction with abundance to index recruitment and survival for a particular life stage should be considered in this light. The importance of monitoring changes in stock

Table 9. Estimates of the sampled and adjusted[a] proportional contributions of each age class 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, 8 through 10 August, 1989.

	Sampled:		Adjusted:		Fork Length	
Age	n[b]	p[c]	p[d]	SE[e]	Mean	SD[f]
2	364	0.41	0.47	0.02	171	11
3	165	0.19	0.21	0.01	220	14
4	37	0.04	0.04	0.01	253	17
5	104	0.12	0.09	0.01	277	19
6	134	0.15	0.11	0.02	296	18
7	44	0.05	0.03	<0.01	315	19
8	29	0.03	0.02	0.01	332	17
9	7	0.01	0.01	<0.01	354	19
10	4	<0.01	<0.01	<0.01	384	21
11	1	<0.01	<0.01	<0.01	378	---
Total	889	1.00	1.00		230	59

[a] Age composition is adjusted to compensate for length bias in the electrofishing sample.
[b] n = sample size.
[c] p = proportion of sampled grayling.
[d] p = adjusted proportion of grayling (≥ 150 mm) in stock.
[e] SE = standard error of the adjusted proportion.
[f] SD = standard deviation of the mean fork length.

Table 10. Summary of sampled and adjusted Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) in three sections of the lower 50.0 km of the Goodpaster River, 8 through 17 August, 1989.

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
<u>Section 1</u>					
Number sampled	614	158	18	0	0
Sampled RSD[b]	0.78	0.20	0.02	---	---
Standard Error	0.02	0.01	0.01	---	---
<u>Section 2</u>					
Number sampled	450	152	8	0	0
Sampled RSD	0.74	0.25	0.01	---	---
Standard Error	0.02	0.02	0.01	---	---
<u>Section 3</u>					
Number sampled	175	205	36	0	0
Sampled RSD	0.42	0.49	0.09	---	---
Standard Error	0.02	0.03	0.01	---	---
<u>Total</u>					
Number sampled	1,239	515	62	0	0
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	---	---

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

[b] RSD calculated directly from the number sampled.

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

[d] Standard error of the adjusted RSD.

status of Salcha River Arctic grayling, when weighed against budgetary constraints, necessitates the use of river sections for assessment of the stock. The lower sections of rivers such as the Salcha River may be useful for monitoring change if the parameters of interest are chosen carefully and insights into life history of Arctic grayling are incorporated into sampling designs.

Although 1989 represents the first year in a long-term stock assessment program, some comparisons with other runoff rivers of interior Alaska can be made in light of management objectives. Recruitment during the last four years appears to have been relatively strong when compared to the Chatanika and Goodpaster rivers (Table 5 and Table 9). While the Chatanika and Goodpaster rivers exhibit weak 1984 and 1985 year classes, the Salcha appears to have had fairly stable recruitment during these two years. A steadily descending proportion of fish at age as one progresses from recruitment age (three years) to approximate spawning age (five and six years) indicates possible stable recruitment from 1986 through 1989. Thus, the process affecting recruitment of Arctic grayling in the Salcha River may differ from that in the Chatanika and Goodpaster rivers. If recruitment is stable in the Salcha River, then abundance may be stable and sustained yields may be high. However, the historic data base shows much higher densities of Arctic grayling in this section of the Salcha River. Density may have been as high as 991 Arctic grayling per kilometer in this section of the Salcha River as recently as 1974 (Appendix A2). If density was higher in past years, then either mortality has increased or recruitment has been lower. If mortality has increased, then sustained yields were exceeded and the hypothesis of high potential sustained yields is invalid. If recruitment has faltered, then the hypothesis of stable recruitment is also invalid.

The preceding scenario illustrates the danger of projecting short term assessments of stock status into long-term generalities. As stock assessment proceeds on the Salcha River, the dynamics that control abundance and potential yields of Arctic grayling may be described in terms adequate for long-term management of this resource.

Chatanika River

Synthesis of available stock status data from the Chatanika River Arctic grayling into logical management recommendations cannot proceed until reliable (accurate and precise) stock composition data are available. The inability to correct for size selectivity of the electrofishing boat prevented reliable estimation of age and size composition in 1989. This problem was a consequence of small sample size and seasonal movement of Arctic grayling out of the study section. To alleviate the problem, a larger section of river will be chosen for stock assessment in 1990. In addition, stock assessment will begin in mid-August to decrease the probability of movement out of the study section. The Salcha River estimation experiment shows that Arctic grayling may move according to size (larger fish moving upstream and smaller fish not moving in June), so that a sampling design to estimate relative probabilities of capture by size may be biased. The river section will most likely be up to 35 km long and take up to two weeks to sample. If geographic closure is achieved, then abundance estimates and accurate age and size compositions can be estimated on a yearly basis.

Goodpaster River

This is the second year that accurate and unbiased abundance and age composition estimates for the Arctic grayling population in the lower Goodpaster River have been made (Ridder 1989). Methodology in 1988 and 1989 differs from most past years in timing (August vs. June), length of river sampled (50 km vs. 9.6 km), marking (tags vs. fin clips), gear (two boats vs. one), and data analysis (testing and adjustments for movement and gear biases vs. no testing). For example, in comparison to density estimates made from 1975 to 1987 (range = 163 - 475 fish/km, mean = 382; Appendix B1), which were likely biased high (Ridder 1989), the 1989 density estimate of 161 fish/km is biased low by including an area not sampled in the early years. In 1989, section 3 had a density approximately 65% lower than sections 1 and 2[3] (77 and 223 fish/km, CV = 14% and 11%, respectively). The earlier studies were located in sections 1 and 2.

Judged from historical age composition estimates (Appendix B2), recruitment tends to be highly variable among years in the Goodpaster River. The temporal pattern, or frequency, of this variation could explain an apparently fluctuating population with or without other causal factors included (e.g., fishing mortality). In comparison to a similar study in 1973[4], the 1989 population is depressed. From 1975 to 1978, strong and weak recruitment (age 3 fish) alternated in an apparent cyclical pattern (weak in one year, strong in the next year). Since 1985, weak recruitment has appeared in two successive years, each separated by strong recruitment (weak for two years, strong in the third year). While the two years of weak recruitment in the 1985 and 1986 populations did not drastically reduce abundance from 1973 levels, the four weak years of recruitment present in the population since 1987 have reduced abundance. The strong recruitment shown for age 2 and age 3 fish in 1989 breaks this recent recruitment pattern and indicates some increase in stock abundance for 1990.

The Goodpaster River Arctic grayling are harvested in at least four different fisheries in the mid Tanana River drainage (the Delta and Richardson Clearwater rivers, Tanana River at Big Delta, and the Goodpaster River). The harvest of Goodpaster River fish is considered significant in only two of these fisheries, the Goodpaster River and the Delta Clearwater River. Recommendations to alter the present management of the stock can not be made without additional knowledge of the level of harvest in each fishery and the mechanisms of recruitment to these fisheries. While data indicate that the

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[3] Using a stratified Bailey estimator for the three river sections in Table 3 and adjusting for movement of four recaptures into Section 2, fish per kilometer estimates would be, proceeding upstream, 230, 174, and 77.

[4] The abundance in 1989, 161 Arctic grayling per km, was 66% lower than the 1973 Schnabel estimate of 480 per km (Appendix Table B1). The latter estimate covered the same 50 km stretch of river and used the same marking regime as this study and included three sampling events over a two month period (Tack 1974).

Goodpaster River stock is depressed in 1989 relative to 1973 (Tack 1974), the causes, whether environmentally driven, the result of recreational harvest, or both is speculative. However, recruitment data in 1989 looks good.

Ideally, the present sampling methodology should be expanded to cover the entire Goodpaster River. Stock assessment of the entire river, coupled with stock separation studies in the Delta Clearwater River, would allow estimation of fishery mortality rates for the entire stock. However, given the realities of cost and other priorities, continuing the present sampling design should allow data collection for analysis of temporal trends and estimation of mortality rates. Coupled with harvest these statistics should give managers good information to manage the stock.

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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, 1974, 1987[a].

	Salcha River			Chatanika River		
Year	Interviews	Man-hours	GR/hr[b]	Interviews	Man-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 man-hour.
[c] From 1955 through 1958 there was a 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, 1988-1989[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

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

[b] All estimates are calculated with the modified Schnabel formula (Ricker 1975) except the 1988 and 1989 estimates. The 1988 and 1989 estimates are calculated with a modified Petersen estimate of Evenson (1988).

[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 and 1989 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.

Appendix A3. Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Salcha River, 1985-1989[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	

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

Appendix A4. Summary of Relative Stock Density indices of Arctic grayling captured in the Salcha River, 1972, 1974, 1985-1989[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
RSD[d]	0.71	0.22	0.08	<0.01	---
SE	0.04	0.03	0.01	<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); and,
1989 - this report.

[b] Minimum lengths for RSD categories are (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, 1985-1989[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		

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	1987			1988			1989		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---
2	2	138	8	17	174	16	17	176	39
3	35	203	36	116	200	16	155	214	24
4	205	241	20	83	241	20	143	252	28
5	120	275	33	175	280	24	75	273	30
6	80	311	36	58	302	30	74	302	37
7	56	339	30	54	332	32	24	315	38
8	15	356	36	51	348	24	30	341	44
9	4	371	30	22	373	30	18	368	21
10	2	444	20	4	394	19	3	407	40
11	---	---	---	1	463	---	0	---	---
Totals	519			581			539		

[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); and, 1989 - this report.

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

[c] FL is the population mean fork length at age.

[d] SD is the population 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[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

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

[b] All estimates are calculated with the modified Schnabel formula (Ricker 1975).

[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).

[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, 1984-1989[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	

[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); and, 1989 - 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.

Appendix A8. Summary of Relative Stock Density indices of Arctic grayling captured in the Chatanika River, 1952-1954, 1972, 1982, 1984-1989[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	---	---

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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	---	---

[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); and,
1989 - this report.

[b] Minimum lengths for RSD categories are (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.

Appendix A9. Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1989[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		

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Age Class	1986 n	1986 FL	1986 SD	1987 n	1987 FL	1987 SD	1988 n	1988 FL	1988 SD	1989 n	1989 FL	1989 SD
1	---	---	---	---	---	---	---	---	---	4	125	16
2	---	---	---	11	157	15	22	170	13	30	159	27
3	119	195	21	50	200	24	44	205	16	47	203	38
4	16	231	36	295	228	18	63	238	21	31	234	42
5	71	248	16	32	265	22	216	259	22	30	267	56
6	119	267	20	47	273	21	48	278	24	88	286	36
7	47	292	28	106	288	30	55	298	22	54	305	46
8	12	304	21	8	319	18	61	312	25	47	313	49
9	2	283	35	3	296	55	5	328	8	15	334	86
10	---	---	---	1	325	___	1	352	---	2	337	147
Totals	386			553			515			349		

[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); and, 1989 - this report.

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

[c] FL is the mean fork length 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 Summary - Goodpaster River

Appendix B1. Summary of population abundance estimates of Arctic grayling (≥ 150 mm FL) in the Goodpaster River, 1972 - 1989[a].

						Fish/km[b]		
Year	Month	River km	M	C	R	N	95% CI[c]	Rel.Prec
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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						Fish/km		
Year	Month	River km	M	C	R	N	.95 CI	Rel.Prec
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%

[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).

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

[c] The confidence interval is based on a Poisson distribution of recaptures (Ricker 1975). Estimates for 1988 and 1989 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.

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 - 1989[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	

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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	

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	1980			1982			1984			1985[e]			1985[e]		
	24 June - 25 June			29 June - 2 July			27 June - 28 June			25 June - 26 June			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	

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

[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.

	1973			1974		
Age Class	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 - 1989[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

[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).

[b] n = sample size.

[c] FL = mean fork length 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].

Age Class	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May		
	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 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 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 at age.

[d] SD = sample standard deviation of FL.

Appendix B11. Summary of Relative Stock Density (RSD) estimates for Arctic grayling (≥ 150 mm FL) in the lower Goodpaster River, 1955 - 1989[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	---	---	---

- Continued -

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

- Continued -

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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	---	---

[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).

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

Appendix B13. Summary of Relative Stock Density (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 Males:					
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 Females:					
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 (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 1989.

		Abundance[a]			Angler exploitation[b]	
Year	Month	0-53km	0-152km	Harvest	0-53	0-152
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	(1,956)[e]	0.20[d]	0.11[d]
Averages:		16,481	32,904	1,956	0.11	0.06

[a] Abundance in the lower 53 km for 1972 and 1975 through 1988 was extrapolated from fish per km estimates (Appendix Table 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 Table 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.
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.
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.