Fishery Data Series No. 95-9

Stock Assessment of Arctic Grayling in the Salcha, Chatanika, and Goodpaster Rivers During 1994

by

Stafford M. Roach

July 1995

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE SALCHA, CHATANIKA, AND GOODPASTER RIVERS DURING 1994

by

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ABSTRACT

Abundances and stock compositions of Arctic grayling *Thymallus arcticus* were estimated for portions of the Salcha, Chatanika, and Goodpaster rivers in 1994 using single-sample mark-recapture experiments. The Salcha River study area extended from river kilometer 40 downstream to the Richardson Highway Bridge (river kilometer 3.2); the Chatanika River study area extended from 3.2 kilometers above the Elliott Highway Bridge downstream to Any Creek; and, the Goodpaster River study area extended from river kilometer 52.3 downstream to river kilometer 2.7. Estimated abundance of Arctic grayling greater than or equal to 150 millimeters fork length for the Salcha River study area was 14,562 fish (standard error was 1,762), for the Chatanika River study area 6,044 fish (standard error 839), and for the Goodpaster River study area 7,574 fish (standard error 1,617). Estimated densities of Arctic grayling greater than or equal to 150 millimeters fork length within the Salcha River study area was 396 fish per kilometer (standard error was 48), within the Chatanika River study area 204 fish per kilometer (standard error 28), and within the Goodpaster River study area 151 fish per kilometer (standard error 32). The densities of age-3 fish were 101 fish per kilometer (standard error was 11) within the Salcha River study area; 38 fish per kilometer (standard error 5) within the Chatanika River study area, and; 17 fish per kilometer (standard error 4) within the Goodpaster River study area. The proportions of age-3 fish were 0.23 (standard error was 0.02) in the Salcha River study area; 0.19 (standard error 0.02) in the Chatanika River study area, and; 0.33 (standard error 0.02) in the Goodpaster River study area. The densities of Arctic grayling greater than or equal to 270 millimeters fork length were 60 fish per kilometer (standard error was 7) within the Salcha River study area, 83 fish per kilometer (standard error 11) within the Chatanika River study area, and 31 fish per kilometer (standard error 7) within the Goodpaster study area. The proportions of Arctic grayling greater than or equal to 270 millimeters fork length were 0.15 (standard error was 0.02) within the Salcha River study area, 0.41 (standard error 0.02) within the Chatanika River study area, and 0.20 (standard error 0.01) within the Goodpaster study area. For comparison of abundance between years: abundance of Arctic grayling greater than or equal to 150 millimeters fork length within the Salcha River study area was 15,950 fish (standard error was 2,442) in 1993; within the Chatanika River study area 7,311 fish (standard error 1,200) in 1993; and, within the Goodpaster River study area 10,841 fish (standard error 1340) in 1993.

Key Words: Arctic grayling, *Thymallus arcticus*, abundance, population abundance, age composition, size composition, length composition, electrofishing, movements, Salcha River, Chatanika River, Goodpaster River, Tanana River drainage.

INTRODUCTION

Mills (1994) estimated that sport anglers harvested 17,658 Arctic grayling *Thymallus arcticus* within the Tanana River drainage (Figure 1) of interior Alaska in 1993. In addition to the harvest, it was estimated that 193,088 Arctic grayling were caught and released. Two of the largest Arctic grayling fisheries within the Tanana River drainage take place in the Salcha River (10% of the harvest) and Chatanika River (11% of the harvest). The Goodpaster River supports a smaller, but nonetheless important, Arctic grayling fishery (3% of the drainage harvest). The Goodpaster River Arctic grayling stock is important because Arctic grayling from the Goodpaster River are harvested in at least five fisheries including the Delta Clearwater and Richardson Clearwater rivers fisheries (Ridder 1991). The Goodpaster, Delta Clearwater, and Richardson Clearwater rivers account for 8% of Arctic grayling harvested within the Tanana River drainage. Although these fisheries are large, very little is known about the population dynamics of Arctic grayling in these rivers.

As noted by Ridder et al. (1993), Arctic grayling fisheries in the Salcha, Chatanika, and Goodpaster rivers have some distinct differences that affect the characteristics of each stock. Some of these differences include hydrologic characteristics, methods of access, and history of the recreational fishery. All three rivers are rapid run-off streams. However, there is variation in

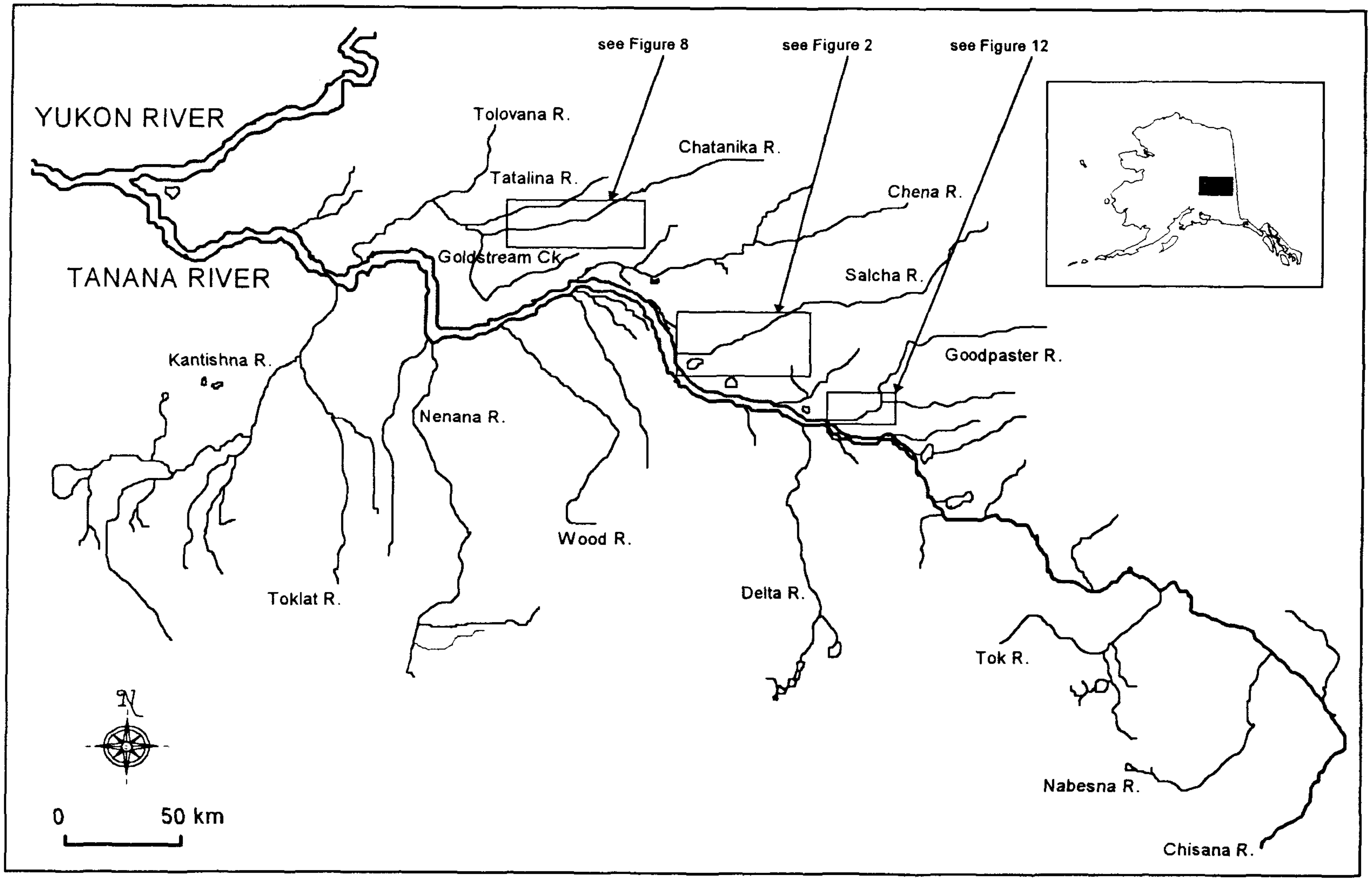

Figure 1.-Tanana River drainage.

gradient, water depth, channelization, and bottom structure among these rivers. Access to these rivers for recreational fishing is also variable; the Goodpaster River is less accessible than either the Salcha or Chatanika rivers, both of which have roadside access. The primary recreational fish targeted in the Salcha and Goodpaster rivers are Arctic grayling. In the Chatanika River, however, whitefish (least cisco *Coregonus sardinella* and humpback whitefish *Coregonus pidschian*) are also important. These factors, as well as others, influence the quality of each fishery.

A goal of this study is to provide stock assessment data on Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers to assist area fishery managers in stock management decisions. Precise knowledge of fishery characteristics and population dynamics of Arctic grayling in these streams is important to fishery managers. The present report is the sixth in a series of reports initiated in 1989 that summarize, at minimum, age-3 and older (≥ 150 mm FL) Arctic grayling abundance and composition characteristics of the Salcha, Chatanika, and Goodpaster rivers.

The research objectives for 1994 were to:

1) estimate abundance of Arctic grayling (≥ 150 mm FL) in a 36.8 km section of the Salcha River, such that this estimate is within 25% of the true abundance 95% of the time;

2) estimate abundance of Arctic grayling (≥ 150 mm FL) in a 30 km section of the Chatanika River, beginning 3.2 km above the Elliott Highway Bridge downstream to Any Creek, such that the estimate is within 25% of the true abundance 95% of the time;

3) estimate abundance of Arctic grayling (≥ 150 mm FL) in a 50.0 km of the Goodpaster River, such that the estimate is within 25% of the true abundance 95% of the time;

4) estimate age composition of Arctic grayling (≥ 150 mm FL) within the study areas of the Salcha, Chatanika, and Goodpaster rivers, such that all proportions are within five percentage points of the true proportions 95% of the time; and,

5) estimate length composition of Arctic grayling (≥ 150 mm FL) within the study areas of the Salcha, Chatanika, and Goodpaster rivers, such that all proportions are within five percentage points of the true proportions 95% of the time.

In addition, historical stock-assessment data summaries are presented for the Salcha (Appendix A), Chatanika (Appendix B), and Goodpaster (Appendix C) rivers. Although not always directly comparable, these summaries provide an historical context that managers may use to evaluate the results of the present investigation.

GENERAL METHODS

Specific methodologies have been developed to estimate abundance of Arctic grayling in rivers of interior Alaska. Sampling schemes have evolved from multiple-sample mark-recapture experiments in short index areas (Van Hulle 1968) to single-sample experiments in relatively longer study areas (Clark and Ridder 1987). This change to longer study areas was made possible, in part, because jet propelled riverboats enabled investigators to sample longer contiguous sections of rivers that were previously not sampled because of shallow runs. In addition, the use of boat-mounted electrofishing equipment have provided a means to capture a greater number of fish and cover longer stretches of river in less time and with less effort. However, as with other sampling methods, electrofishing may be size selective (Reynolds 1983). To correct for length bias from sampling gear and sampling technique, the methodology outlined in Appendix D was followed.

For these experiments, the study area of each river was ≥ 30 km in length. The longer study areas, in general, minimize the proportion of fish that immigrate or emigrate during the experiment. The study area of each river was divided into three approximately equal sections to evaluate movement. To standardize effort, each section was divided into several electrofishing runs (the distance covered during 20 minutes of active electrofishing; usually < 2.5 km).

Each aluminum electrofishing boat had a crew of three; two captured fish with dip nets and one piloted the boat. Each boat was equipped with a pulsed DC variable voltage pulsator (VVP; Coffelt Model VVP-15) powered by a 3,500 W single-phase gasoline generator. Anodes consisted of four 15 mm diameter steel cables (1.5 m long) arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the aluminum boat was used as the cathode. Settings on the VVP were standardized at 60 Hz and 50% duty cycle (duty cycle is the duration the electrical pulse is on during one cycle, expressed as a percent of the cycle). At a given voltage, amperage varied according to the conductivity, substrate, and water depth of the river. The boat operator, however, made every effort to keep the output constant to minimize fish injury and mortality. Voltage was adjusted at the VVP to keep the output at < 5 amperes as conditions changed.

Sampling was spread evenly down each river with equal effort throughout the study areas. Each sampling event started at the upstream boundary of the study area and continued downstream. During the marking and recapture events, two electrofishing boats simultaneously fished (one on each bank) in a downstream direction for a standard 20 minute run. During a run, as many Arctic grayling as possible were captured with dip nets and placed in a holding tub that was aerated with running water. At the end of each run fishing ceased; fish were sampled and released before continuing. Before release, the fork length of each captured fish was measured to the nearest mm, scales were taken for age determination (during the recapture event only), a Floy FD-68 internal anchor tag was attached (during the marking event only), and a fin was clipped as a double mark. Run boundaries were either marked with flagging or a unique landmark was noted in field notes or on a topographic map.

Two scales were taken from each captured fish during the recapture events. All scales came from an area on the fish centered approximately six scale rows above the lateral line and just posterior to the insertion of the dorsal fin. Scales were placed on gum cards in the field and retained for future processing and reading. Impressions of the scales were made on triacetate film using a scale press (30 seconds at 137,895 kPa, at a temperature of 97°C). Ages were determined by counting annuli with the aid of a microfiche reader. Determination of age was performed only once for each readable set of scales and all scales were read by one reader.

All data pertaining to age, length, sampling induced mortality, tag identification numbers and colors, capture location (by run and river section), finclips, recapture status, and tag loss were recorded on mark-sense forms and electronically stored for analysis and archival (see listing of data files in Appendix E1).

ESTIMATION OF ABUNDANCE

Abundances of Arctic grayling ≥ 150 mm FL were estimated for the Salcha, Chatanika, and Goodpaster river study areas with single-sample mark-recapture methods (Seber 1982), which in these experiments assume:

1) the population is closed (no change in the number or composition of Arctic grayling in the population during the experiment);

2) all Arctic grayling have the same probability of capture during the marking event or the same probability of capture during the recapture event or marked and unmarked Arctic grayling mix completely between the marking and recapture events;

3) marking of Arctic grayling does not affect their probability of capture in the recapture event;

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

5) all marked Arctic grayling are reported when recovered in the recapture event.

Assumption 1 was not tested directly, but examination of fish movement from one section to another was used to infer significant movement of fish out of, or into the study area. Mortality and growth, which may also contribute to the violation of assumption 1, were assumed to be negligible because of the short duration of the experiment within each river (approximately ten days from beginning to end).

Assumptions 2 and 3 were evaluated by a series of tests that were designed to detect unequal catchability and gear selectivity, which violate these two assumptions. These tests included a chi-square contingency table test that compared catchability by river section, inspection of movement, and two Kolmogorov-Smirnov two-sample tests that compared catchability by length. The results of these tests, in combination, determined the methods used to compensate for bias in the abundance estimation. Probabilities of a Type I error (α) of 0.05 or lower were considered significant.

Specifically, the chi-square tests compared catchability among sections during the recapture event (the frequency of fish with marks to the frequency of fish without marks). Inspection of movement was an empirical comparison of fish with marks that moved from one section of the river to another section between events to fish with marks that stayed in the same section. Movement was determined to be significant if more than 10% of fish marked in one section were recaptured in another section. Using the results of these tests, Appendix D1 outlines the methodology used to determine stratification by area and choice of abundance estimators, which are summarized in Appendix D3. In cases when stratification by area was necessary, the dividing point of the strata was chosen as the point that resulted in the maximum difference in catchability between the strata. The maximum difference was determined as the greatest chi-square value from a series of chi-squared tests that compared the frequency of fish marked in each stratum to the frequency of fish recaptured in each stratum.

After evaluating equal catchability by river section, equal catchability by length was addressed for each stratum separately or for the complete study area when stratification by area was not necessary. Kolmogorov-Smirnov two-sample tests were used to compare: 1) the length frequency distributions of recaptured Arctic grayling with all Arctic grayling captured during the recapture event; and 2) the length frequency distributions of Arctic grayling captured during the marking event with those captured in the recapture event. Using the results of these tests, Appendix D2 outlines the methodology used to determine stratification by length and choice of abundance estimators, which are summarized in Appendix D3. In cases when stratification by length was necessary the fish were divided into two strata by length. The dividing point of the two strata was chosen as the point that resulted in the maximum difference in catchability between the two strata. The maximum difference was determined as the greatest chi-square value from a series of chi-squared tests that compared the frequency of marked fish not recaptured in each length stratum to the frequency of fish recaptured in each length stratum. The number of size classes used for chi-squared tests was restricted to two because further stratification reduced overall precision while only minimally reducing bias.

Double marking allowed investigators to test assumption 4. Tag loss was noted when a fish was recovered with a specific fin clip but without a floy tag. In addition, floy tag placement was standardized, which enabled the fish handler to verify tag loss by locating recent tag wounds.

Violations of assumption 5 were minimized by a thorough examination of the fins of each fish for clips and the recording of fin clips and floy tag numbers whether the fish was believed to be a recaptured fish or not.

ESTIMATION OF LENGTH AND AGE COMPOSITIONS

Length and age compositions of Arctic grayling ≥ 150 mm were estimated for the study area of each river and adjusted for differential capture probability when necessary. The integrity of these composition estimates relies on the same assumptions as abundance estimates. Unequal movement by length or age and gear selectivity by length or age violate these assumptions. Methodology to compensate for bias from violation of these assumptions is outlined in Appendices D1, D2, and D4 for estimates of length composition. Age compositions were estimated from samples from the recapture events. There may be bias associated with the estimates of these age compositions for three reasons: 1) equal catchability by age was not directly tested (it may not be necessary to test because age and length are correlated); 2) all fish in a sample were not aged (fish that were aged were not randomly selected; scales from larger fish were likely less readable); and, 3) fish < 150 mm FL were not included regardless of age (for example, the estimated proportion of age-2 fish does not include all age-2 fish but only age-2 fish that are ≥ 150 mm FL).

Length and age proportions were estimated for each river directly when no adjustments were necessary; for each section when there was differential catchability by river section; and for each length stratum when there was differential catchability by length. When differential catchability was detected and the methodology of Appendices D2 and D1 called for stratification by river section or length the proportions were weighted by the ratio of the stratum to total abundance and summed for composition estimates for the study area using the equations of Appendix D4.

SALCHA RIVER

Abundance and stock compositions of Arctic grayling were estimated within a 36.8 km portion of the Salcha River in 1994. The Salcha River study area extended from river kilometer 40 downstream to river kilometer 3.2 at the Richardson Highway Bridge (Figure 2). Prior investigators estimated Arctic grayling abundance and stock composition within this same study area each year since 1989 (Clark and Ridder 1990, Clark et al. 1991, Fleming et al. 1992, Ridder et al. 1993, Roach 1994). In addition, abundance of Arctic grayling was estimated near Redmond Creek in 1972 (Tack 1973); within 8 km upstream and downstream of the Trans-Alaska pipeline crossing in 1974 (Bendock 1974, Kramer 1975); near Flat Creek in 1985 (Holmes et al. 1986); and from the Trans-Alaska pipeline crossing to 16 km upstream in 1988 (Clark 1988; Appendix A2).

SALCHA RIVER STUDY AREA AND FISHERY DESCRIPTION

The Salcha River is a rapid run-off stream that flows south out of the Tanana Hills into the Tanana River (Figure 1). The river intersects the Parks highway at milepost 348, approximately 70 km south of Fairbanks. The river is characterized by high gradient, long shallow runs, and exposed gravel bars. Holmes (1984) characterized the current study area as a single wide channel, average velocity of 0.8 m/s, and average gradient of 1.1 m/km. Average stream flow varies according to weather and spring runoff. For example, average stream flow in the study area from May through July ranged from a low of 50.95 m^3/sec in 1980 to a high of 123.86 m^3/sec in 1984 (USGS 1976-1990).

The Salcha River fisheries are road accessible at the Richardson Highway Bridge at river kilometer 3.2. Access by car is limited to a 1.6-km section of river adjacent to the Salcha River State Recreation Area. A boat ramp, parking lot, picnic, and camping area are available at this state recreation area. Access to the river above the state recreation area is limited to river boat or airplane. Landing strips are located at Caribou Creek at river kilometer 96 and Pasco Creek at river kilometer 104.

The majority of recreational fishing in the Salcha River takes place in the lower 80 km of the river. Almost 80% of all fish caught (released or kept) in the Salcha River in 1993 were Arctic grayling. In addition to Arctic grayling, fish caught in the Salcha River in 1993 included (from greatest to least number caught): chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, northern pike *Esox lucius*, burbot *Lota lota*, and whitefish *Family Coregonidae* (Mills 1994).

Prior to 1977, information collected from Salcha River Arctic grayling fishermen was sparse. Creel survey data for harvest rates were obtained during the summers of 1953 through 1958, 1963, and 1964. Harvest rates ranged from 0.48 Arctic grayling per hour to 1.09 Arctic grayling per hour from 1953 through 1958 (Warner 1959b); 0.67 Arctic grayling per hour in 1963; and 0.64 fish per hour in 1964 (Roguski and Winslow 1969). Harvest and effort surveys were conducted in 1968 and 1974. In 1968, Roguski and Winslow (1969) estimated 7,035 hours of effort and 7,048 Arctic grayling harvested for an estimated harvest rate of one fish per hour. In 1974, Kramer (1975) estimated 11,284 hours of effort and 4,728 Arctic grayling harvested.

Each year since 1977, as part of a statewide harvest survey Mills (1979-1994) estimated annual harvest and effort on the Salcha River through a postal survey (Table 1). Average annual harvest

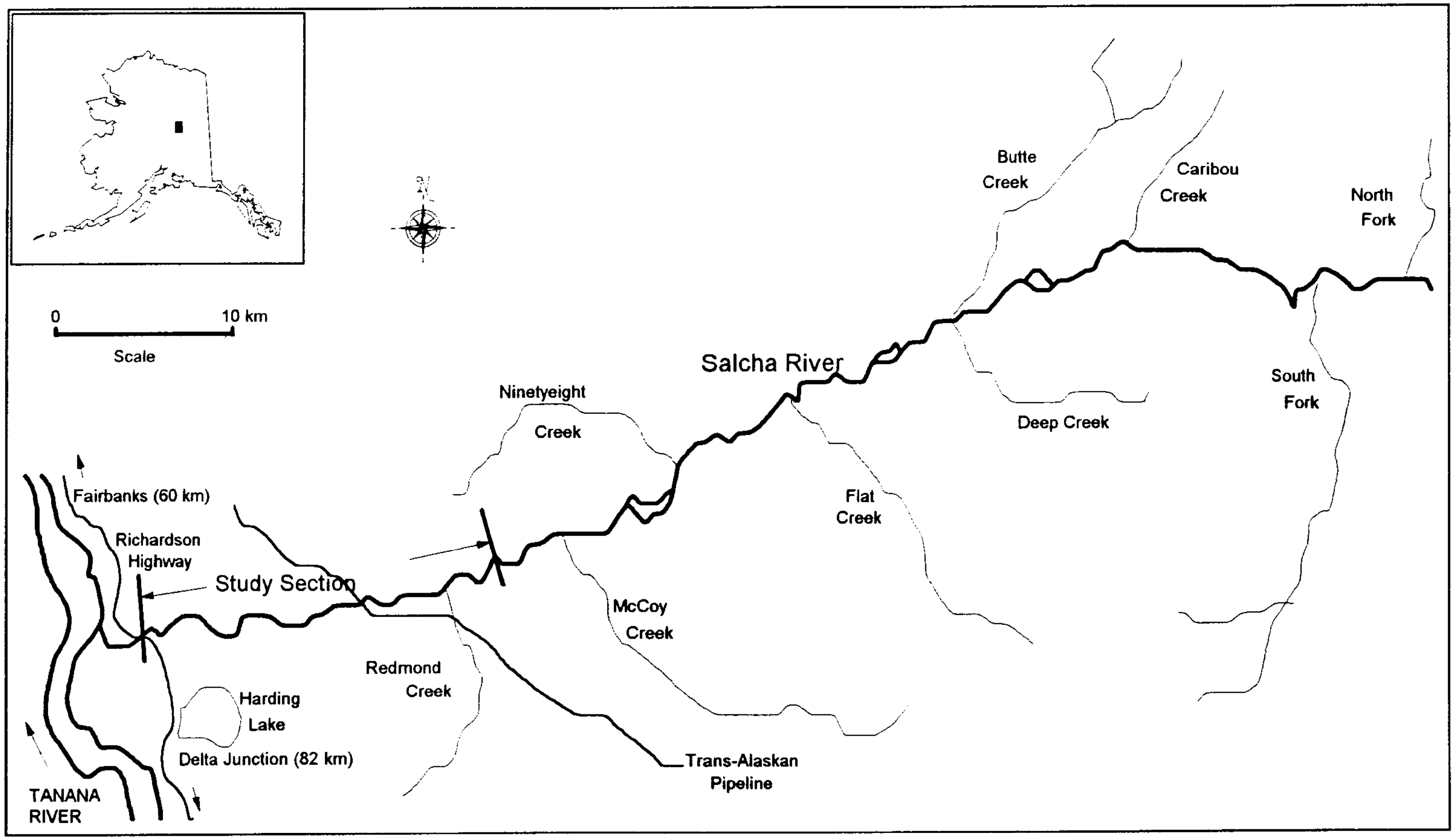

Figure 2.-Salcha River drainage.

Table 1.-Arctic grayling harvest and effort on the Salcha, Chatanika, and Goodpaster rivers, 1977-1993 (Mills 1979-1994).

	Salcha River		Chatanika River		Goodpaster River	
Year	Harvest[a]	Effort[b]	Harvest	Effort	Harvest	Effort
1977	6,387	6,737	8,167	9,925	ND[c]	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[d]	2,383	7,494	8,640	11,642	1,273	1,037
1989[d]	5,721	9,704	6,934	12,210	1,964	1,930
1990[d]	1,992	9,783	4,237	11,801	760	2,083
1991[d]	1,688	11,242	2,642	8,085	636	786
1992[d]	1,592	4,833	1,751	6,775	766	1,430
1993[d]	1,768	11,254	2,001	7,671	588	1,162
Average	5,519	10,256	5,578	8,937	1,470	1,638

[a] Harvest is the estimated number of Arctic grayling caught and kept.

[b] Effort is the number of angler-days expended for all species of fish.

[c] ND = data not available.

[d] Special regulations were in effect on the Salcha River. These special regulations were; catch and release Arctic grayling fishing from 1 April to the first Saturday in June; 12 inch (305 mm) minimum length limit; and, artificial lures or flies only.

of Arctic grayling on the Salcha River was 5,519 fish, ranging from a high in 1984 of 13,305 and a low in 1992 of 1,592. Average effort on the Salcha River for all species of sport fish was 10,256 angler-days, ranging from a high in 1982 of 14,126 angler-days to a low in 1992 of 4,833 angler-days. In addition, each year since 1990, Mills (1991-1994) estimated annual fish caught (fish harvested plus fish caught and released) on the Salcha River (Table 2). The average annual catch of Arctic grayling on the Salcha River from 1990 through 1993 was 9,432 fish. In addition to the 1987 harvest data provided by Mills (1988), Baker (1988) estimated a catch rate of 0.66 (SE = 0.40) Arctic grayling harvested per angler-hour from May through August 1987.

Sport fishing has been restricted since the 1988 fishing season to protect the Salcha River Arctic grayling fishery from decline. These restrictions:

1) eliminated fishing for Arctic grayling from 1 April to the first Saturday in June;
2) restricted methods of catching Arctic grayling to unbaited artificial lures;
3) restricted the harvest of Arctic grayling to fish > 305 mm (12 in) total length (TL)[1]; and,
4) limited the harvest of Arctic grayling to five fish per day and five in possession.

SALCHA RIVER METHODS

The Salcha River marking event occurred from 13 June through 16 June 1994 and the recapture event from 29 June through 30 June 1994. An upper-caudal fin punch was used as a second mark during the marking event. In addition to the general methods used for the three rivers, the marking event for the Salcha River consisted of two complete passes through the study area instead of one. This change was initiated in 1992 and ensured that the sample size of the marking event would be sufficient to meet accuracy and precision objectives. There was difficulty in meeting these objectives in 1991 with only one marking pass (Fleming et al. 1992).

Abundance Estimation

Abundance of Arctic grayling ≥ 150 mm was estimated within the Salcha River study area using modified Petersen estimators; the Bailey estimator described by Seber (1982; Appendix D3), and the movement estimator described by Evenson (1988). To reduce bias from unequal movement by length, it was necessary to divide the fish into two length strata to estimate abundance; 150 to 235 mm FL (small fish) and greater than 235 mm FL (large fish). The abundance of small fish was estimated using the movement estimator and the abundance of large fish was estimated using the Bailey estimator.

Length and Age Compositions

Length and age compositions for Arctic grayling were estimated using lengths and ages from the recapture event for each length stratum within the Salcha River study area. The estimated proportion of fish by length and age was adjusted to reduce bias from unequal movement by length (Appendix D4).

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[1] 305 mm TL is approximately equal to 270 mm FL.

Table 2.-Arctic grayling catch and catch per angler-day on the Salcha, Chatanika, and Goodpaster rivers, 1990-1993 (Mills 1991-1994).

	Salcha River[a]		Chatanika River[b]		Goodpaster River[c]	
Year	Catch[d]	Catch/ Angler-Day[e]	Catch	Catch/ Angler-Day	Catch	Catch/ Angler-Day
1990	8,609	0.88	17,960	1.52	3,342	1.60
1991	9,600	0.85	12,830	1.59	905	1.15
1992	8,265	1.71	11,570	1.71	3,599	2.52
1993	11,254	1.54	14,283	1.86	1,923	1.65
Average	9,432	1.25	14,161	1.67	2,442	1.73

[a] On average, 86% of all fish caught from the Salcha River are Arctic grayling.

[b] On average, 70% of all fish caught from the Chatanika River are Arctic grayling.

[c] On average, 95% of all fish caught from the Goodpaster River are Arctic grayling.

[d] Catch is the estimated number of Arctic grayling caught (kept or released).

[e] Angler-day is not specific to Arctic grayling fishing. This should be viewed as an index to compare effort between years within the same river but should not be viewed as a comparison among rivers because the proportion of effort toward Arctic grayling varies by river.

SALCHA RIVER RESULTS

Investigators handled 1,959 unique Arctic grayling (≥ 150 mm FL) during the Salcha River mark-recapture experiment. During the marking event, 1,103 Arctic grayling[2] were tagged and released alive (779 during the first pass and 324 during the second pass of the marking event). During the recapture event, 913 Arctic grayling[3] were examined for marks. Of these, 856 were unique and 57 were recaptured from the marking event. Of the 57 recaptured fish, one (1.7% of tagged fish recaptured) lost its tag between events but was identified by the presence of a recent upper-caudal fin punch. During the marking event 30 Arctic grayling were killed or severely injured (2.6% of fish handled during the marking event). These fish were not included in the experiment. During the recapture event 17 Arctic grayling were killed or severely injured (1.9% of fish handled during the recapture event). These fish were included in the experiment. Investigators identified 102 Arctic grayling from prior mark-recapture experiments (5.2% of unique fish handled).

Abundance

Estimated abundance of Arctic grayling within the Salcha River study area was germane to fish ≥ 150 mm FL during the last week in June 1994. Recapture rates of Arctic grayling were not significantly different among three approximately equal-length sections of the study area ($\chi^2 = 1.42$, 2 df, $P = 0.49$). The recapture rate (fish recaptured divided by fish examined for marks in the recapture event; R/C) throughout the study area averaged 0.06 (Figure 3).

Comparison of sections where Arctic grayling were marked with sections where the fish were recaptured indicated movement between sections (Table 3). Of recaptured Arctic grayling with known capture histories by location, 19 of 56 (34%) moved from one section to another between events; four moved upstream and 15 moved downstream. This was viewed as significant movement between sections because more than 10% moved and the movement was directional. Furthermore, there was unequal movement by length; Arctic grayling from 150 mm to 235 mm FL were more likely to have moved than Arctic grayling greater than 235 mm FL ($\chi^2 = 9.64$, 1 df, $P < 0.01$; Figure 4). Even though, there was no significant difference between the lengths of fish marked and fish recaptured ($D = 0.15$, $P = 0.17$; Figure 5-A), bias from movement of small fish compared to large fish was minimized by dividing the fish into two length strata (150 to 235 mm FL and greater than 235 mm FL).

Even though there was unequal movement throughout the study area, at least one of the "or" conditions of assumption two was satisfied because there was no difference in catchability between sections and there was equal effort throughout the study area. Therefore, Petersen estimators were chosen to estimate abundance of Arctic grayling within the study area. The movement estimator (Evenson 1988) and the Bailey estimator (Bailey 1951; 1952) were compared and the methodology outlined in Appendix D1, Case II was followed. The movement estimator and the Bailey estimator resulted in dissimilar estimates of abundance (greater than 10% difference) for fish from 150 mm to 235 mm FL; but similar estimates of abundance (less than 10% difference) for fish greater than 235 mm FL. Additionally, the coefficient of variation (CV) of the combined stratified abundance estimates was lower than the CV for either estimator used singly for all fish ≥ 150 mm FL. Therefore, the movement estimator was used to estimate

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2 Lengths were recorded for 1,099 of these Arctic grayling.

3 Lengths were recorded for 911 and ages were estimated for 814 of these Arctic grayling.

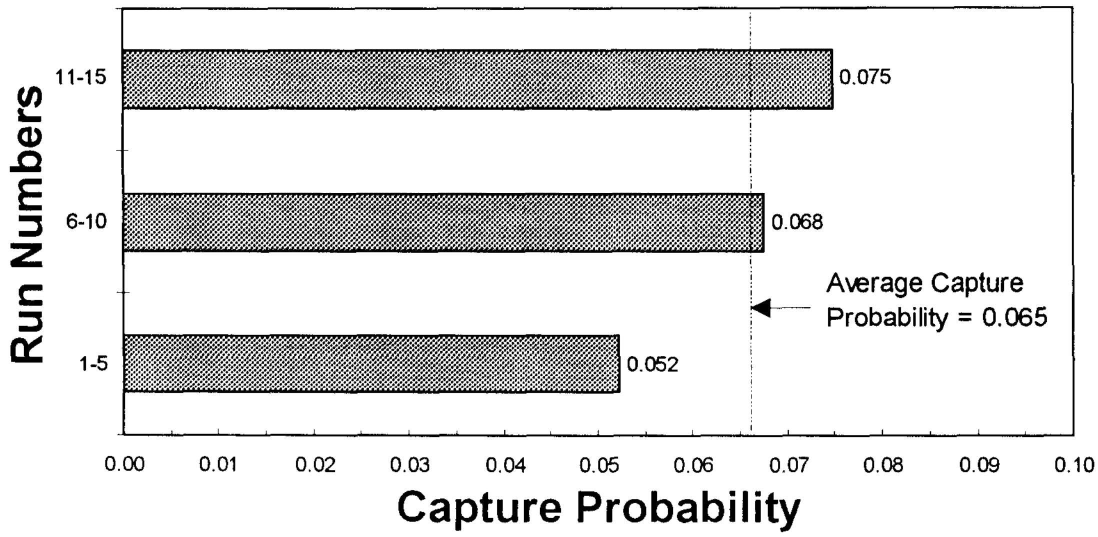

Figure 3.-Estimated capture probabilities (number of fish marked in the marking event and recaptured in the recapture event divided by the total number of fish captured in the recapture event) by section and the average capture probability for Arctic grayling captured within the Salcha River study area.

Table 3.-Number of Arctic grayling recaptured in a section and run (n = 57) of the Salcha River summarized by the section and run in which the fish was marked.

Mark	Number Recaptured[b]															Number Moved
	Section III					Section II					Section I					Between
Run[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Sections
1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	1
2	1	6	0	3	0	0	0	1	1	1	0	0	0	0	0	3
3	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	1
4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	2
6	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	2
7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
8	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	2
10	0	0	1	0	0	0	0	1	0	2	3	0	0	1	0	5
11	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1
12	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
13	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
Total	1	7	4	8	1	1	3	5	4	7	5	1	2	6	2	19

[a] A run was approximately 2.4 km; the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 started at river kilometer 40 and run 15 ended at river kilometer 3.2.

[b] Marking run was unknown for one fish that was recaptured (this fish was not included in table).

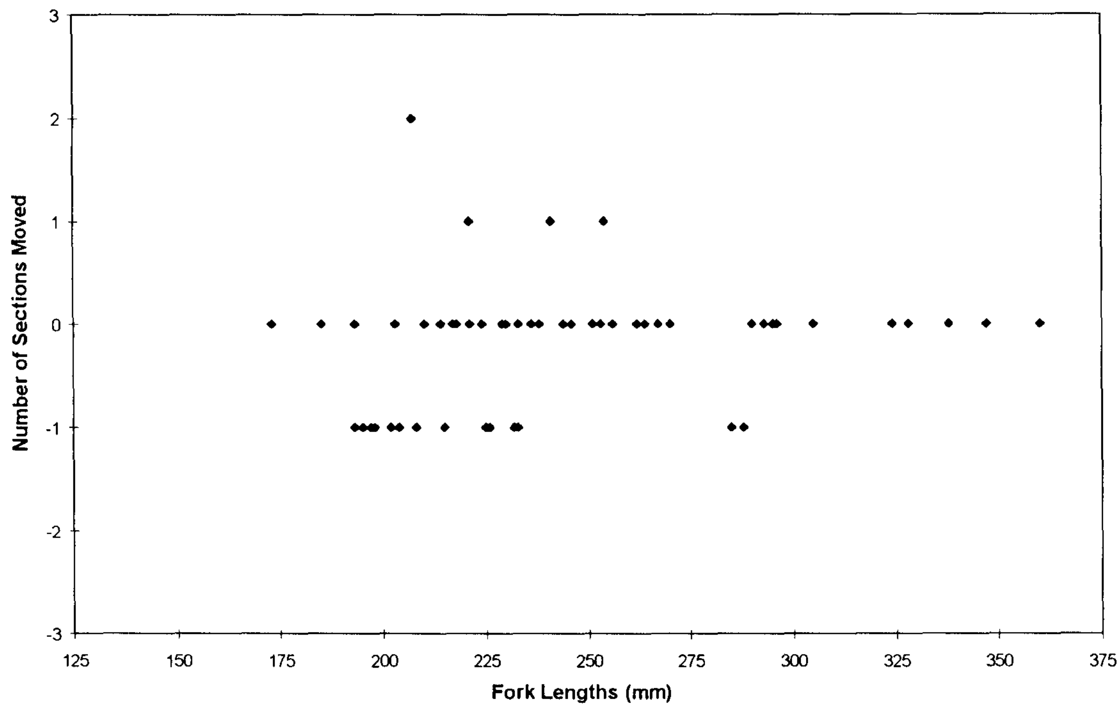

Figure 4.-Number of sections that recaptured Arctic grayling moved (upstream movement is shown as positive and downstream movement is shown as negative) within the Salcha River study area between the marking and recapture events by length.

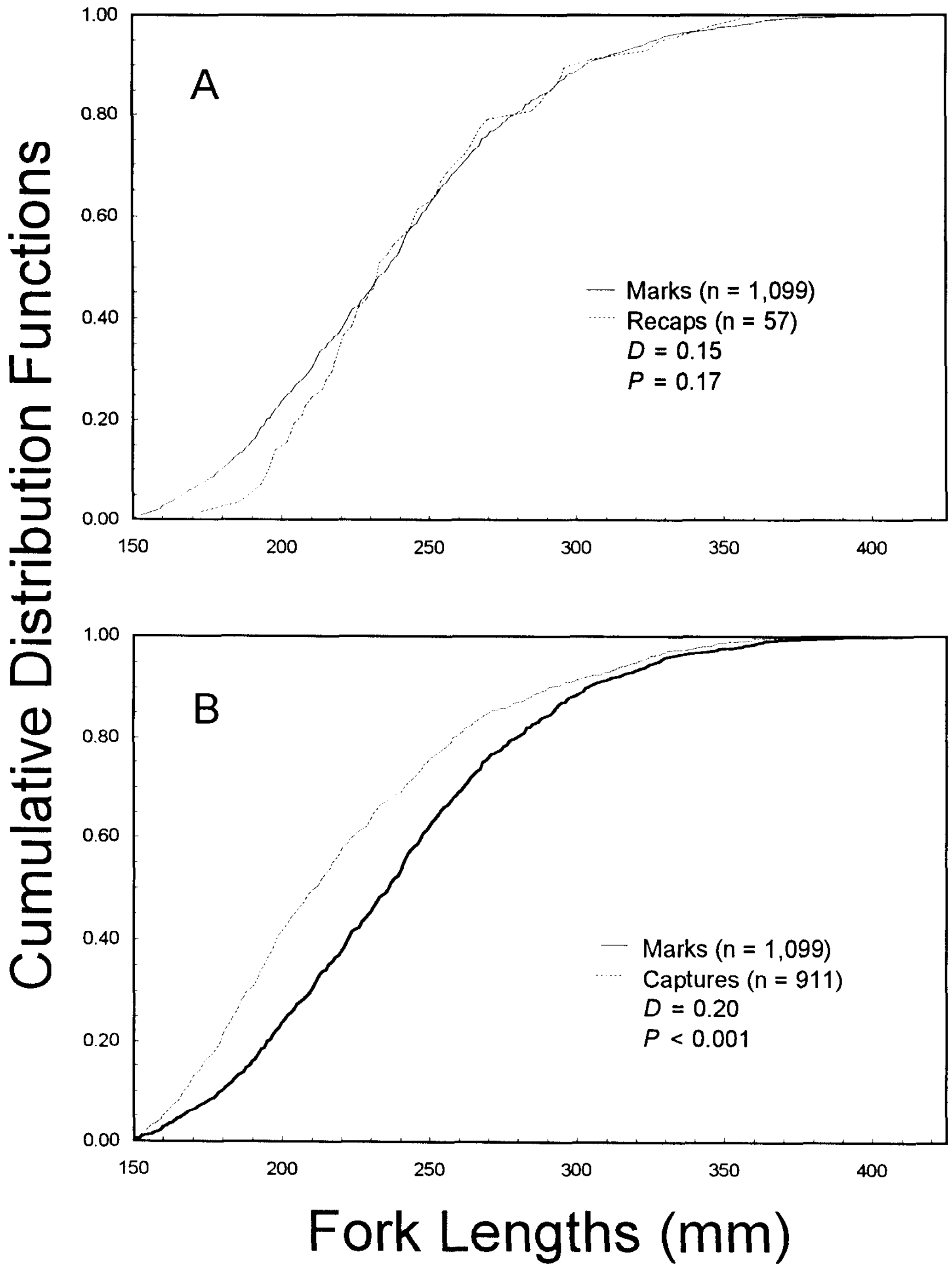

Figure 5.-Cumulative distribution functions of fork lengths of Arctic grayling captured in the Salcha River . (A) Arctic grayling marked versus Arctic grayling recaptured; and (B) Arctic grayling marked versus Arctic grayling examined for marks in the recapture event.

abundance for Arctic grayling from 150 mm to 235 mm FL, and the Bailey estimator for Arctic grayling > 235 mm FL. The combined estimated abundance of Arctic grayling ≥ 150 mm FL within the Salcha River study area was 14,562 fish (SE = 1,762, CV = 12%; Table 4). Estimated densities of Arctic grayling ≥ 150 mm FL within the Salcha River study area was 396 (SE = 49) fish per kilometer.

Length and Age Compositions

For the Salcha River study area, there was not a significant difference between the length distributions of fish marked and fish recaptured ($D = 0.15$, $P = 0.17$; Figure 5-A), but there was a significant difference between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event ($D = 0.20$, $P < 0.01$; Figure 5-B). This indicated that there was no difference in catchability by length during the recapture event but there was a difference during the marking event. Therefore, lengths from the recapture event were used to estimate length composition of Arctic grayling ≥ 150 mm FL within the Salcha River study area. Length composition was adjusted, however, to account for the unequal movement by length (Appendix D4). Fork lengths measured from 911 of 913 Arctic grayling ≥ 150 mm FL from the Salcha River recapture event ranged from 150 to 408 mm FL (mean = 221 mm, SE = 2 mm). The estimated proportion of Arctic grayling from 150 to 269 mm FL within the Salcha River study area was 0.85 (SE = 0.03), and of Arctic grayling ≥ 270 mm FL was 0.15 (SE = 0.03; Figure 6). The largest Arctic grayling sampled from the Salcha River in 1994 was 411 mm FL, which was captured during the marking event.

Ages from Arctic grayling captured during the recapture event were used to estimate age composition of Arctic grayling ≥ 150 mm FL within the Salcha River study area. Ages were estimated for 814 of 913 Arctic grayling. Age classes, estimated from the scales of Arctic grayling ≥ 150 mm FL from the Salcha River recapture event, ranged from age-1 to age-11 (mean = 3.43, SE = 0.05). The age class with the largest proportion of Arctic grayling ≥ 150 mm FL within the Salcha River study area was age-2 (0.29, SE = 0.03; Table 5).

SALCHA RIVER DISCUSSION

Even though the estimated harvest of Arctic grayling from the Salcha River has decreased since 1989, the estimated harvest has not fluctuated much since 1990 (mean = 1,760 fish, between year S.D. = 171 fish) (Table 1). The decline in estimated harvest of Salcha River Arctic grayling may be a result of regulations, enacted in 1988, designed to protect the Salcha River Arctic grayling stock from decline. Restricted fishing regulations may have diverted some effort to catch-and-release fishing. There are no data, however, to support this hypothesis because there are no comparisons for catch-and-release information before the restricted regulations were put into effect (Table 2). It is believed, however, that catch-and-release fishing has generally increased over the last few years. Total fishing effort on the Salcha River during the same period has been variable and related more to the strength of the chinook salmon run than to Arctic grayling fishing.

Density of Arctic grayling ≥ 150 mm FL was greater within the Salcha River study area than either the Chatanika or Goodpaster river study areas (Table 6). In addition, recruitment of Arctic grayling ≥ 150 mm FL was strongest within the Salcha River study area compared to the other study areas (Figure 7).

Table 4.-Number of fish marked (M), number of fish examined for marks (C), number of fish recaptured with marks (R), capture probabilities (R/C and R/M), estimated abundance (N), and standard error of estimated abundance SE[N] of Arctic grayling (≥ FL 150 mm) within the Salcha River study area summarized by two length strata with unequal probabilities of movement (χ^2 = 9.64, 1 df, P 0.01).

Length (FL)[a]	M[b]	C[b]	R	R/C	R/M	N	SE[N]
150 to 235 mm	539	613	29	0.05	0.05	8,788[c]	1,449
> 235 mm	560	298	28	0.09	0.05	5,774[d]	1,002
Total	1,099	911	57	0.06	0.05	14,562[e]	1,762

[a] Length strata were divided at the length that maximized the difference in movement probabilities.

[b] Since the estimate was stratified by length, the number of fish used for the mark and catch included only fish with known lengths; lengths were not known for four fish captured during the marking event and two fish captured during the capture event.

[c] The movement estimator described by Evenson (1988) was used to estimate abundance of fish 150 to 235 mm FL.

[d] The Bailey (1981;1982) estimator was used to estimate abundance of fish > 235 mm FL.

[e] Abundance of both length strata were summed to estimate the total abundance of Arctic grayling within the study area.

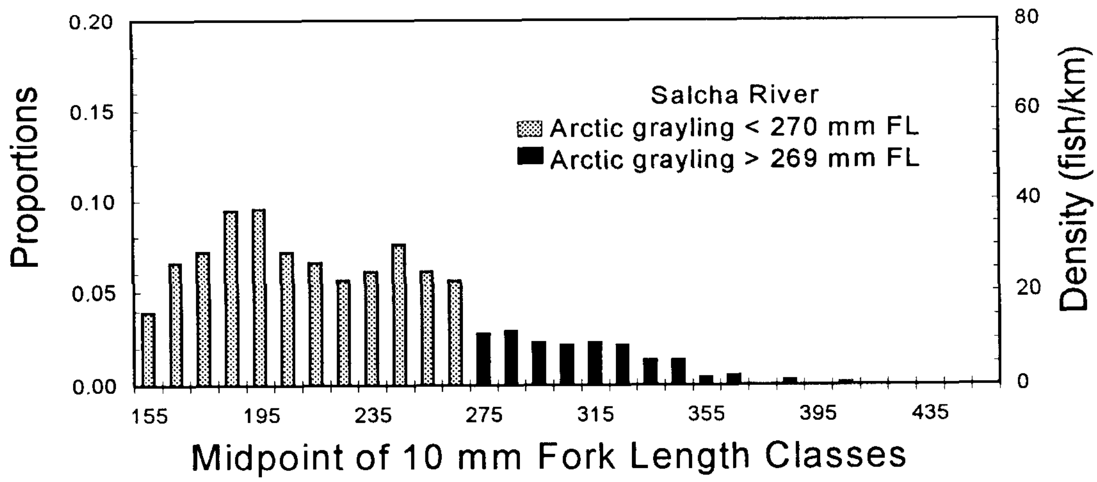

Figure 6.-Estimated proportions and densities of Arctic grayling ≥ 150 mm FL by 10 mm length classes within the Salcha River study area during June 1994 adjusted for movement of small fish (≤ 235 mm FL) compared to large fish (> 235 mm FL).

Table 5.-Estimated abundance (N), standard error of abundance (SE[N]), proportion (p), and standard error of proportion (SE[p]) of Arctic grayling ≥ 150 mm FL by age within the Salcha River study area adjusted for unequal movement by length.

Age Classes	N	SE[N]	p	SE[p]
1	79	10	0.01	<0.01
2	4,203	508	0.29	0.03
3	3,383	409	0.23	0.02
4	3,646	441	0.25	0.02
5	1,432	173	0.10	0.02
6	1,031	125	0.07	0.01
7	451	55	0.03	0.01
8	203	25	0.01	<0.01
9	90	11	0.01	<0.01
10	23	3	0.01	<0.01
11	23	3	0.01	<0.01
Totals	14,562	1,762	1.00	0.12

Table 6.-Estimated density (number of fish/km) and standard error of density (SE) for Arctic grayling ≥ 150 mm FL within the Salcha, Chatanika, and Goodpaster rivers study areas from 1990 to 1994.

	Density and (SE)				
Study Area	1990	1991	1992	1993	1994
Salcha River	157(18)	147[a](28)	209[a](69)	433(66)	396 (48)
Chatanika River	670(111)	312[b](62)	271[b](47)	252(41)	204 (28)
Goodpaster River	145(15)	157 (17)	138(16)	217(27)	151 (32)

[a] 1991 and 1992 Salcha River estimates did not include Arctic grayling less than 200 mm FL.

[b] 1991 and 1992 lower section of the Chatanika extended approximately 24 km farther downstream than the 1993 study section.

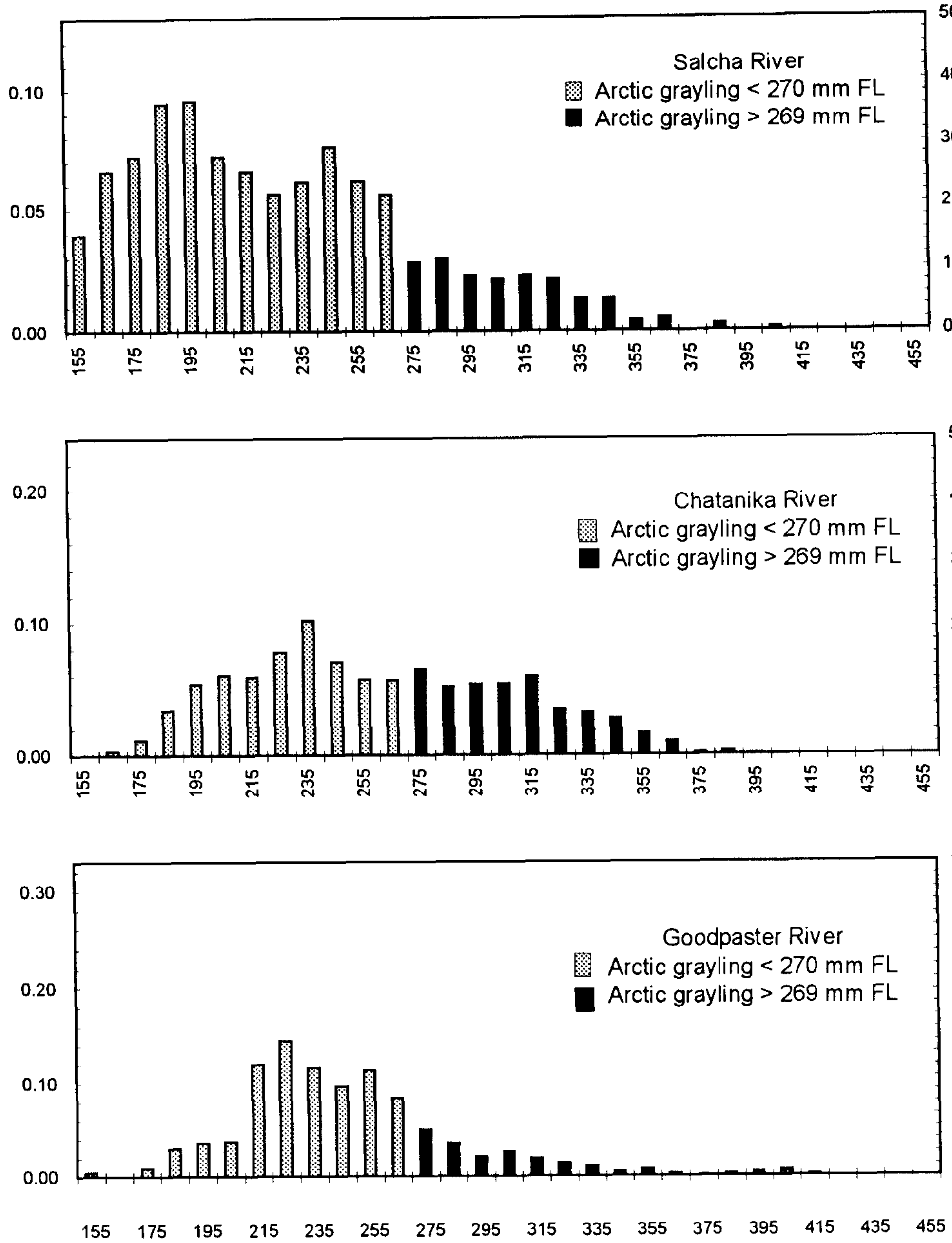

Figure 7.-Estimated proportions and densities of Arctic grayling ≥ 150 mm FL by 10 mm length classes within the Salcha, Chatanika, and Goodpaster river study areas.

Even though estimated abundance of Arctic grayling ≥ 150 mm FL dropped 9% in 1994 compared to 1993, estimated abundance of Arctic grayling within the Salcha River study area has increased 169% since 1991. This increase was probably due to strong recruitment of age-3 Arctic grayling in each of the last four years. In addition to good recruitment, survival of Arctic grayling between 150 mm FL and 270 mm FL has been good since 1988, the year that the 12-inch legal-length limit for Arctic grayling on the Salcha River was enacted. The Salcha River stock assessment data supports the hypothesis of Clark et al. (1991) that lower fishing mortality of prespawners will increase spawner abundance[4], which ultimately increases abundance through recruitment. It is hypothesized that abundance of legal-length Arctic grayling will increase in each of the next three years due to strong recruitment in 1992, 1993, and 1994.

CHATANIKA RIVER

Abundance and stock composition of Arctic grayling were estimated within a 30 km portion of the Chatanika River in 1994. The Chatanika River study area extended from 3.2 km above the Elliott Highway Bridge downstream to Any Creek (Figure 8). For comparison purposes, prior investigators estimated Arctic grayling abundance and stock composition within this section of the Chatanika River each year since 1990 (Clark et al. 1991, Fleming et al. 1992, Ridder et al. 1993, Roach 1994). In addition, abundance of Arctic grayling was estimated within an index area near the Elliott Highway Bridge in 1972 (Tack 1973), 1982 (Holmes 1983), 1984 (Holmes 1985), and 1985 (Holmes et al. 1986; Appendix B2).

In addition to the specified objectives, the sampling area extended approximately 27 km below the study area[5] (Figure 8). Abundance of Arctic grayling within this extended area was also estimated.

CHATANIKA RIVER SAMPLING AREA AND FISHERY DESCRIPTION

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). The Chatanika River is formed by the confluence of Faith and McManus creeks. This river parallels the Steese Highway for approximately 70 km, continues in a westerly direction past the Elliott Highway, and continues on to the Tolovana River. The Chatanika River sampling area is characterized by moderate gradient, meandering stretches, narrow to wide channels, and exposed gravel bars. There is a history of placer mining within the Chatanika River drainage. 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)

The Chatanika River fisheries are road accessible along the Steese Highway, from the Elliott Highway Bridge, and at the end of Murphy Dome Road extension. A boat ramp, parking lot, picnic and camping area are available at the Elliott Highway Bridge, a camping and picnic area at 101-km Steese Highway, and a campground at 98-km Steese Highway. However, access to the study area is limited to float plane or river boat launched from the Elliott Highway Bridge boat ramp or a gravel bar at the end of Murphy Dome extension.

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[4] The amount of reduction in fishing mortality during this period is not known. Mills (1993) reported that 92% of Arctic grayling < 12 in TL caught from the Salcha River were not kept but were released. How much of this percent was due to the 12 in legal-length regulation is not known.

[5] Within the text, "sampling area" refers to all areas sampled and "study area" refers to the section of the Chatanika River described in the objectives (3.2 km above the Elliott Highway Bridge downstream to Any creek).

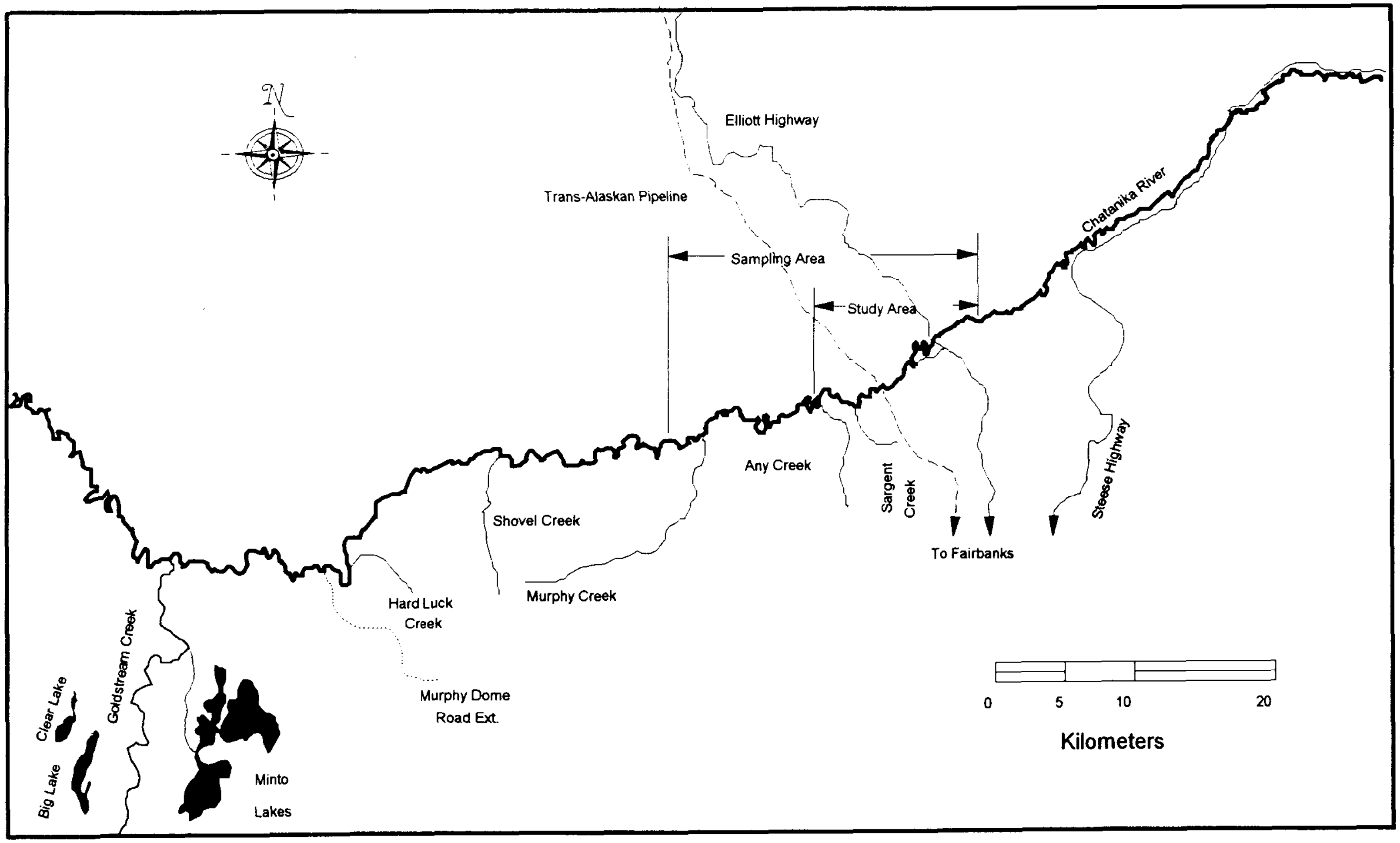

Figure 8.-Chatanika River drainage.

More than 50% of all fish caught by sport fishermen (released or kept) in the Chatanika River in 1993 were Arctic grayling. In addition to Arctic grayling, fish caught in the Chatanika River in 1993 included (from greatest to least number caught): northern pike, chinook salmon, whitefish, coho salmon *Oncorhynchus kisutch*, and sheefish *Stenodus leucichthys* (Mills 1994).

Prior to 1977, information collected from Chatanika River Arctic grayling fishermen was sparse. Creel survey data for harvest rates were obtained during the summers of 1953 through 1958 and 1974. Harvest rates ranged from 0.13 Arctic grayling per hour to 0.78 Arctic grayling per hour from 1953 through 1958 (Warner 1959b); and 1.02 Arctic grayling per hour in 1974 (Kramer 1975).

Each year since 1977, Mills (1979-1994) estimated annual harvest and effort on the Chatanika River through a postal survey (Table 1). Average annual harvest of Arctic grayling on the Chatanika River was 5,578 fish, ranging from a high in 1983 of 9,766 and a low in 1992 of 1,751. Average effort on the Chatanika River for all species of sport fish was 8,937 angler-days, ranging from a high in 1989 of 12,210 angler-days to a low in 1981 of 4,691 angler-days. In addition, each year since 1990, Mills (1991-1994) estimated annual fish caught (fish harvested plus fish caught and released) on the Chatanika River (Table 2). The average annual catch of Arctic grayling on the Chatanika River from 1990 through 1993 was 14,161 fish. In addition to the 1987 harvest data provided by Mills (1988), Baker (1988) estimated that the catch rate near the Elliott Highway Bridge was 0.21 (SE = 0.14) Arctic grayling per angler-hour fished from May through June 1987.

The low estimated harvest rates in the early 1950's prompted fishery managers to restrict the harvest of Arctic grayling from the Chatanika River to fish 305 mm (12 in) or greater in total length (Wojcik 1954, 1955) between 1955 and 1958. Similarly, sport fishing regulations were restricted since the 1992 fishing season to protect the Chatanika River Arctic grayling fishery from decline. These regulations were designed to:

1) eliminate the harvest of Arctic grayling from 1 April to the first Saturday in June;
2) restrict methods of catching Arctic grayling during the spawning period to unbaited, single-hook artificial lures; and,
3) restrict the harvest of Arctic grayling to fish > 305 mm (12 in) total length (TL)[6] in the portion of the Chatanika River upstream from a point 1.6 km above the Elliott Highway Bridge (no size restriction within the study area).

Chatanika River Methods

The Chatanika River marking event was completed from 15 through 17 August 1994 and the recapture event from 22 to 24 August 1994. A partial upper caudal finclip was used as a second mark during the marking pass and a partial lower caudal finclip was used to prevent sampling redundancy during the recapture event. As outlined in the general methods for the three rivers, two boats were used during the recapture event to simultaneously sample both banks of the river with the exception of the upper eleven runs, where one boat was used. Whitefish were also sampled during the Chatanika River experiment but not reported here.

[6] 305 mm TL is approximately equal to 270 mm FL.

Abundance Estimation

Abundance of Arctic grayling ≥ 150 mm FL was estimated within the Chatanika River study area using a modified Petersen estimator (Bailey 1951; 1952), as described by Seber (1982; Appendix D3). To reduce bias from unequal catchability by area, it was necessary to divide the study area into two area strata to estimate abundance; an upper stratum (3.2 km above the Elliott Highway Bridge downstream to approximately 3.5 km above Any Creek) and a lower stratum (from approximately 3.5 km above Any Creek downstream to just below Any Creek). In addition, sampling extended beyond the study area and the estimated abundance of Arctic grayling ≥ 150 FL within this additional area was treated as a third stratum using the modified Petersen estimator (Bailey 1951; 1952).

Length and Age Compositions

Length and age compositions for Arctic grayling ≥ 150 mm were estimated for each area stratum. Proportions of fish by length and age were estimated directly for the three strata without length stratification (Appendix D4).

CHATANIKA RIVER RESULTS

Investigators handled 1,603 unique Arctic grayling ≥ 150 mm FL during the Chatanika River mark-recapture experiment. During the marking event, 1,014 Arctic grayling were tagged and released alive. During the recapture event, 691 Arctic grayling were examined for marks. Of these 691 fish, 589 were unique and 102 were recaptured from the marking event. Of the 102 recaptured fish, two (1.9% of tagged fish recaptured) lost their tags between events but were identified by the presence of a recent upper caudal finclip. During the marking event six Arctic grayling were killed or severely injured (< 1% of fish handled during the marking event). These fish were not included in the experiment. During the recapture event there were two Arctic grayling killed (< 1% of fish handled during the capture event). These fish were included in the experiment. Investigators identified 181 Arctic grayling (11.3% of unique fish handled) from prior mark-recapture experiments.

Abundance

Estimated abundance of Arctic grayling within the Chatanika River sampling area was germane to fish ≥ 150 mm FL during the last half of August 1994. Recapture rates of Arctic grayling within the study area were significantly different among three approximately equal-length sections (χ^2 = 7.18, 2 df, P = 0.03). Furthermore, maximal difference in catchability was obtained by dividing the study area into two strata at approximately 3.5 km upstream of Any Creek (upper stratum included runs 1 - 15; lower stratum included runs 16 - 17; χ^2 = 15.24, 1 df, P < 0.01). The recapture rate (fish recaptured divided by fish examined for marks in the recapture event; R/C) for the upper stratum was 0.09 and for the lower stratum 0.27 (Figure 9). Recapture rates of Arctic grayling, below the study area, within the third stratum were not significantly different between two approximately equal-length sections (χ^2 = 0.42, 1 df, P = 0.52). The recapture rate throughout this extended area averaged 0.22 (Figure 9).

Comparison of sections where Arctic grayling were marked with sections where the fish were recaptured did not indicate movement between sections (Table 7). Of recaptured Arctic grayling with known capture histories by location, five of 98 (5.1%) moved from one section to another between events (marking location of four fish were not known). This was not considered

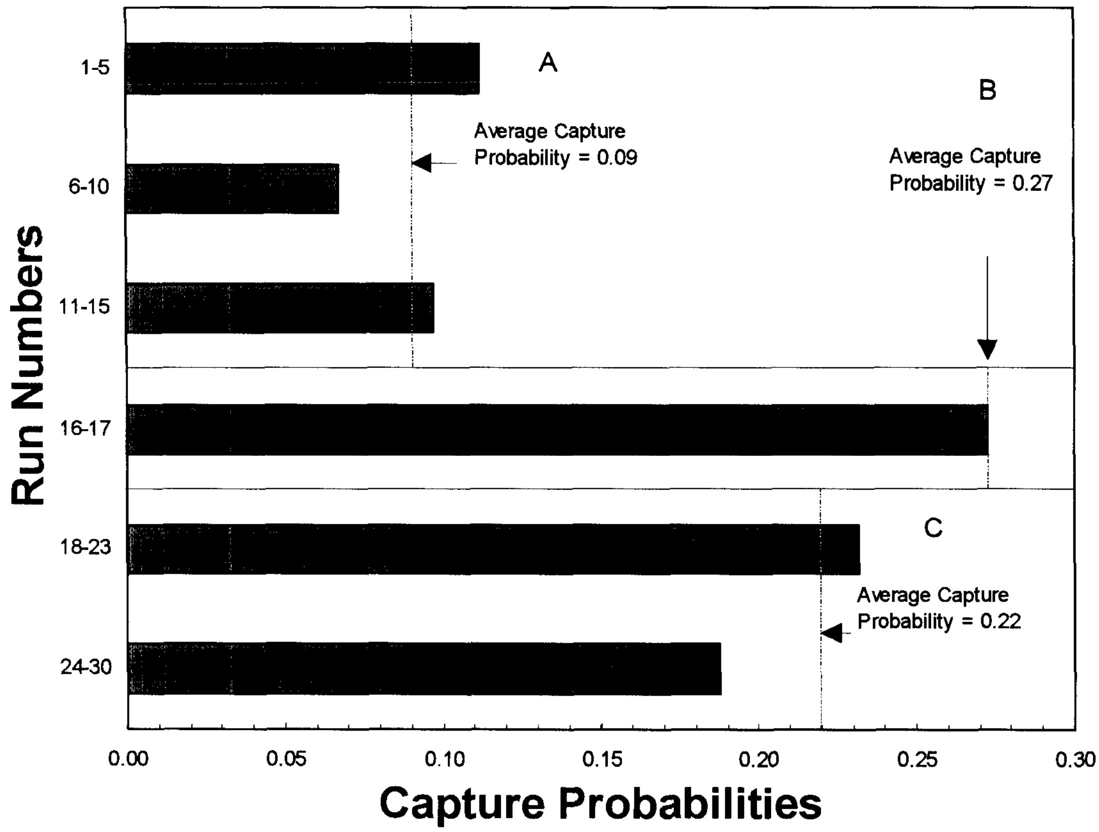

Figure 9.-Estimated capture probabilities (number of fish marked in the marking event and recaptured in the recapture event divided by the total number of fish captured in the recapture event) by section and the average capture probability for Arctic grayling captured in the upper (A), lower (B), and third (C) section of the Goodpaster River sampling area.

Table 7.-Number of Arctic grayling recaptured in a section and run (n = 98) of the Chatanika River study area summarized by the section and run in which the fish was marked.

Mark Run[a]	Number Recaptured[b] Section III 1	2	3	5	6	7	8	9	10	Section II 11	12	13	14	15	16	17	18	19	20	Section I 21	22	24	25	26	27	28	29	30	Number Moved Between Sections
1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	2	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	0	0	0	0	1	1	0	0	0	0	0	2
17	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	2	1	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	8	1	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	2	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	1
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	0	0	0	0	1
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOT	6	2	4	4	0	1	1	0	6	2	4	2	2	3	8	7	13	10	7	5	2	4	3	1	1	0	0	0	5

[a] A run was approximately 2 km; the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 started 3.2 km above the Elliott Highway Bridge and run 30 ended 53 km below the bridge.

[b] Marking run was unknown for four fish that were recaptured (these fish were not included in table).

significant movement between sections because movement was less than 10%. No movement between sections and a difference in catchability between sections of the study area indicated that none of the "or" conditions of assumption 2 were satisfied. Bias from different catchabilities between sections was compensated for by following the methodology outlined in Appendix D1 (Case III). The Bailey estimator was chosen to estimate abundance of each area stratum.

There was no significant difference between the length distributions of fish marked and fish recaptured within the upper stratum ($D = 0.14$, $P = 0.41$; Figure 10-A1), the lower stratum ($D = 0.26$, $P = 0.35$; Figure 10-A2), or the third stratum ($D = 0.14$, $P = 0.34$; Figure 10-A3). A visual inspection of Figure 10-A2 along with the large-test statistic, however, suggested that there may have been some bias from size-selective sampling within the lower stratum. Length stratified estimates of abundance were similar to estimates of abundance without length stratification indicating that this bias was negligible. In view of these results, one of the "or" conditions of assumption 2 was satisfied in each area strata. Specifically, there was not length selectivity during the recapture event. Therefore, an unstratified abundance estimate was used to estimate Arctic grayling abundance within each strata (Appendix D2).

Estimated abundance of Arctic grayling ≥ 150 mm FL within the Chatanika River study area (3.2 km above the Elliott Highway Bridge downstream to Any Creek) was 6,044 fish (SE = 839; CV = 14%; Table 8). Estimated abundance of Arctic grayling ≥ 150 mm FL within the Chatanika River sampling area (3.2 km above the Elliott Highway Bridge downstream to Any Creek plus an additional 27 km downstream) was 7,668 fish (SE = 864; CV = 11%; Table 8). Estimated densities of Arctic grayling ≥ 150 mm FL varied between the two strata of the Chatanika study area; 237 (SE = 35) fish per kilometer in the upper stratum and 57 (SE = 12) fish per kilometer in the lower stratum ($Z = 6.43$, $P < 0.01$).

Length and Age Compositions

There was no significant difference between the length distributions of fish marked and fish recaptured within the upper stratum ($D = 0.14$, $P = 0.41$; Figure 10-A1), the lower stratum ($D = 0.26$, $P = 0.35$; Figure 10-A2), or the third stratum ($D = 0.14$, $P = 0.34$; Figure 10-A3); or between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event within the upper stratum ($D = 0.07$, $P = 0.17$; Figure 10-B1), the lower stratum ($D = 0.19$, $P = 0.17$; Figure 10-B2), or the third stratum ($D = 0.11$, $P = 0.08$; Figure 10-B3). A visual inspection of Figure 10-A2 along with the large test statistic, however, suggested that the lengths and ages of the capture event for the lower stratum may have been biased. Length and age compositions of the capture event were similar to the marking event indicating that this bias was negligible. These results indicated that there was no difference in catchability by length during either the marking or recapture events within each area stratum.

Fork lengths of Arctic grayling captured during both the marking and capture event were pooled to estimate length composition of Arctic grayling ≥ 150 mm FL within each strata of the Chatanika River. Fork lengths measured from 1,699 Arctic grayling (970 from the upper stratum, 153 from the lower stratum, and 576 from the third stratum) ≥ 150 mm FL from the Chatanika River sampling area ranged from 150 to 390 mm FL (mean = 272 mm, SE = 3 mm). There was greater density of Arctic grayling ≥ 270 mm FL within the upper stratum than within

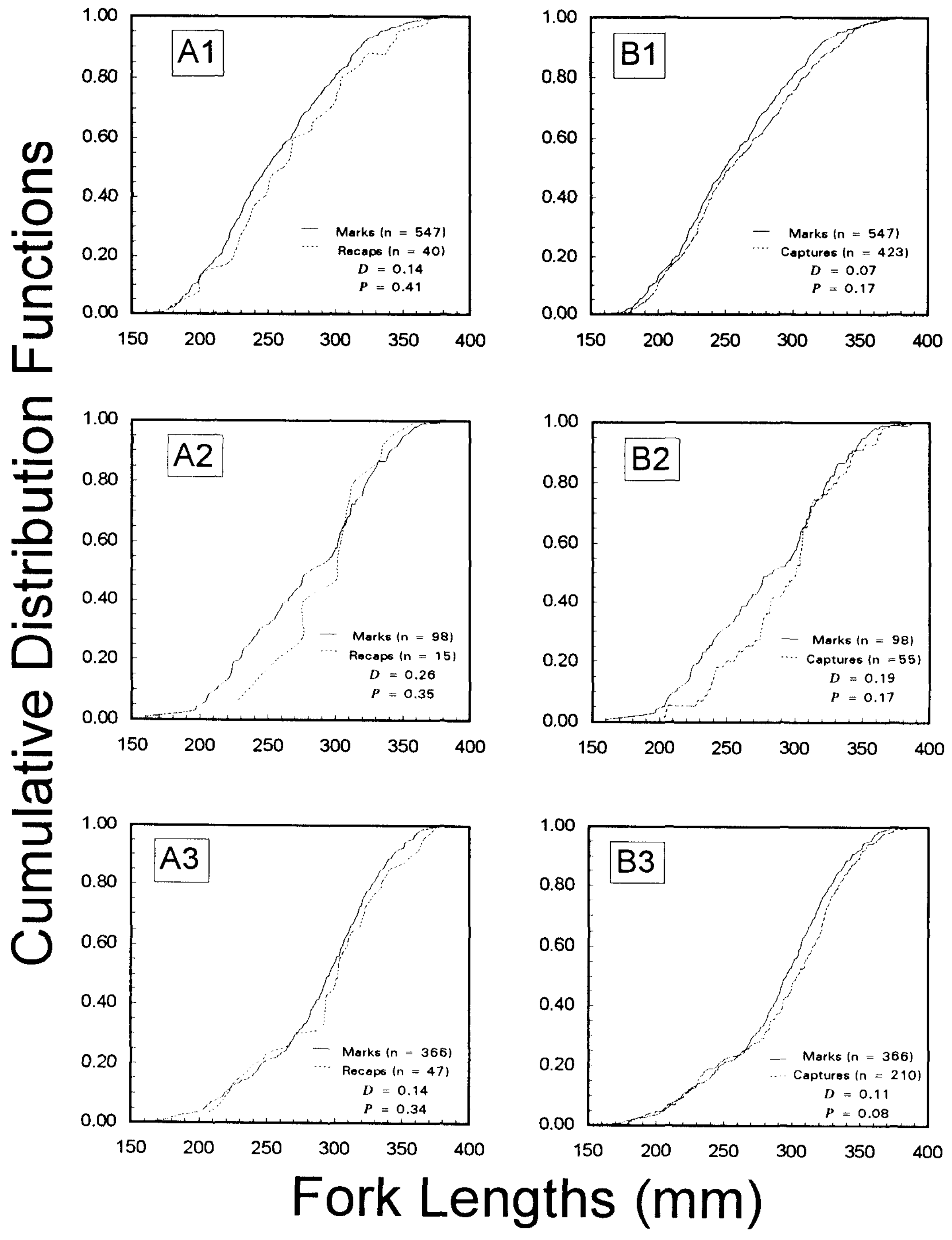

Figure 10.-Cumulative distribution functions of fork lengths of Arctic grayling captured in three sections of the Chatanika River; (1) upper section, (2) lower section, and (3) third section. (A) Arctic grayling marked versus Arctic grayling recaptured; and (B) Arctic grayling marked versus Arctic grayling examined for marks in the recapture event.

Table 8.-Number of fish marked (M), number of fish examined for marks (C), number of fish recaptured with marks (R), capture probabilities (R/C and R/M), estimated abundance (N), and standard error of estimated abundance SE[N] of Arctic grayling (≥ FL 150 mm) within the Chatanika River study area summarized by strata with unequal probabilities of capture (χ^2 = 25.65, 2 df, P   0.01), study area, and sampling area.

Section	M	C	R	R/C	R/M	N[a]	SE[N]
Upper Stratum[b]	550	424	40	0.09	0.07	5,701	836
Lower Stratum[c]	98	55	15	0.27	0.15	343	70
Study Area[d]	648	479	55	0.11	0.08	6,044	839
Third Stratum[e]	366	212	47	0.22	0.13	1,624	204
Sampling Area[f]	1,014	691	102	0.15	0.10	7,668	864

[a] The Bailey (1951; 1952) estimator was used to estimate abundance of each strata.

[b] The upper stratum extended from 3.2 km above the Elliott Highway bridge downstream to 20 km below the Elliott Highway bridge.

[c] The lower stratum extended from 20 km below the Elliott Highway bridge downstream to just below Any Creek.

[d] Abundance estimates of the upper and lower strata were summed to estimate the total abundance within the study area.

[e] The third stratum extended from Any Creek downstream 27 km.

[f] Abundance estimates of the upper, lower, and third strata were summed to estimate the total abundance within the sampling area.

the lower stratum ($Z = 5.54$; $P < 0.01$). The estimated proportion of Arctic grayling ≥ 270 mm FL within the Chatanika River study area was 0.41 (SE = 0.02; Figure 11).

Ages from Arctic grayling captured during the recapture event were used to estimate age composition of Arctic grayling ≥ 150 mm FL within the Chatanika River sampling area. Ages were estimated from 496 of 691 Arctic grayling captured during the recapture event. Age classes, estimated from the scales of Arctic grayling ≥ 150 mm FL from the Chatanika River captured during the recapture event, ranged from age-2 to age-14. The age classes with the largest proportion of Arctic grayling ≥ 150 mm FL within the Chatanika River study area were age-4 (0.29, SE = 0.02) and age-3 (0.19, SE = 0.02; Table 9). A larger proportion of age-3 Arctic grayling was estimated within the upper stratum of the study area compared to the downstream strata ($Z = 13.64$, $P < 0.01$).

CHATANIKA RIVER DISCUSSION

Harvest of Arctic grayling from the Chatanika River decreased 80% from 1988 to 1992 and fishing effort decreased 44% from 1989 to 1992. However, both harvest and effort increased slightly in 1993 but remains low compared to harvest and effort in the late 1980's (Table 1). The decline in harvest and fishing effort, however, is probably a result of regulations, increased catch-and-release fishing, and decreased density of Arctic grayling within the study area during this same period. The proportion of the river-wide harvest and effort that takes place within the study area, however, is not known.

For comparison purposes, the study area was standardized this year to a section of the Chatanika River that was similar to all Chatanika River Arctic grayling investigations since 1991 (3.2 km above the Elliott Highway Bridge downstream to approximately Any Creek[7]). Within this standardized study area density of Arctic grayling ≥ 150 mm FL has decreased significantly since 1990 (Table 6).

The strong recruitment of the 1987 Arctic grayling year class discussed by Ridder et al. (1993) and Roach (1994) was not as conspicuous within the 1994 age composition as in the age compositions of the past few years. At age-3, the strength of these year classes have averaged 15% of the 1987 year class. The consistently weaker year classes since 1987 may explain the decrease in abundance reported each year since 1990. Estimated abundance of Arctic grayling in 1994 was one-third of what it was in 1990.

Within the Chatanika River study area from 1990 through 1994, estimated abundance of Arctic grayling ≥ 270 mm FL was greatest in 1993 and then decreased in 1994. Furthermore, it is hypothesized that abundance of Arctic grayling ≥ 270 within the Chatanika River study area will continue to decline at least for the next two years and probably for the next three years.

GOODPASTER RIVER

Abundance and stock composition of Arctic grayling were estimated within a 50-km portion of the Goodpaster River in 1994. The Goodpaster River study area extended from river kilometer 52.3 downstream to river kilometer 2.7 (Figure 12). For comparison purposes, prior investigators

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[7] This section of the study area has been referred to as the upper section (Ridder et al. 1993; Roach 1994), the Middle Chatanika River (Fleming et al. 1992), the Chatanika River (Clark et al. 1991), and the study area (present report).

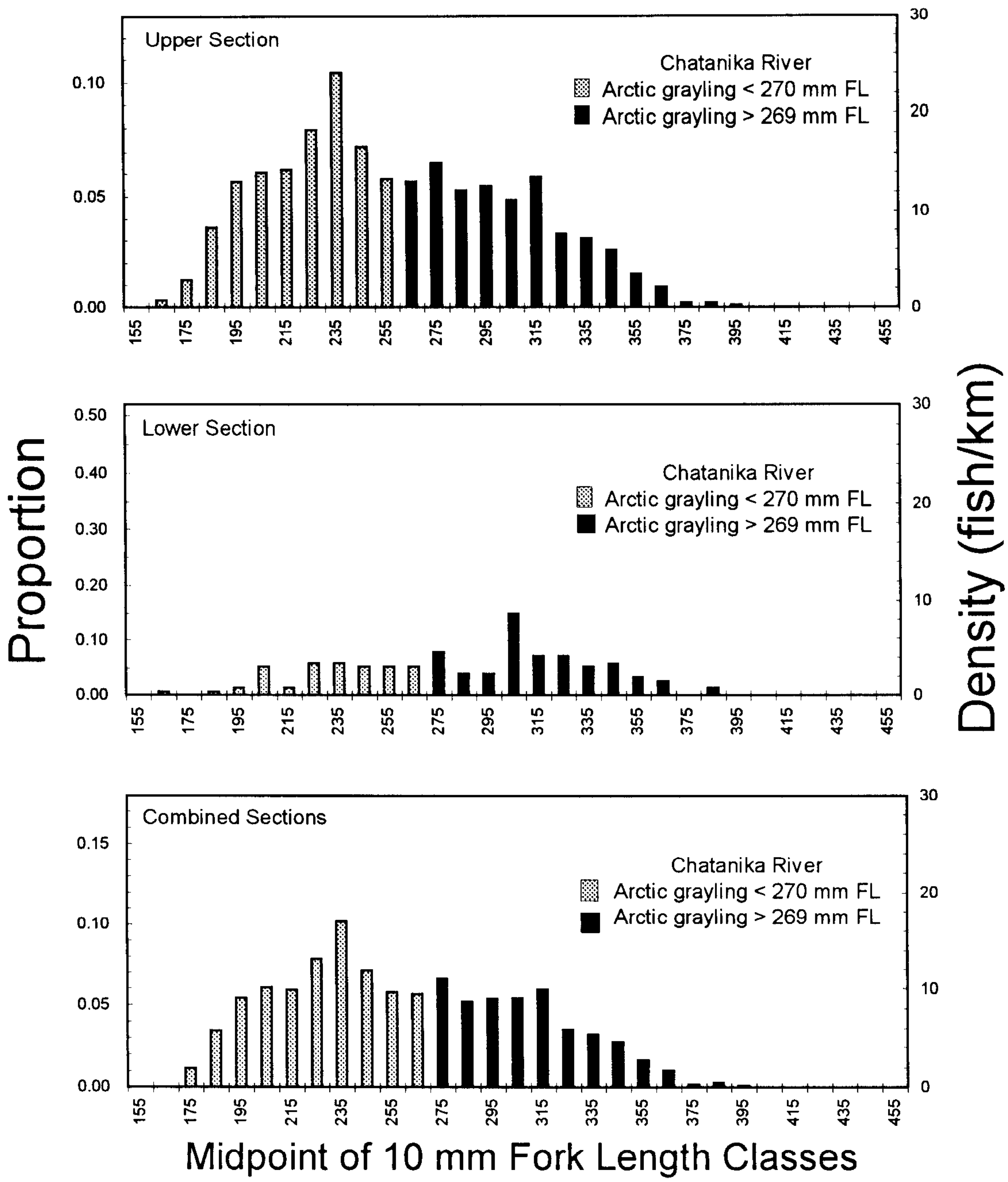

Figure 11.-Estimated proportions and densities of Arctic grayling ≥ 150 mm FL by 10 mm length classes within the upper, lower, and combined sections of the Chatanika River study area during late August 1994 adjusted for different capture probabilities by river section.

Table 9.-Estimated abundance (N), standard error of abundance (SE[N]), proportion (p), and standard error of proportion (SE[p]) of Arctic grayling ≥ 150 mm FL by age within the Chatanika River study area adjusted for different capture probabilities by river section.

Age Classes	N	SE[N]	p	SE[p]
2	109	15	0.02	0.01
3	1,147	159	0.20	0.02
4	1,757	244	0.30	0.03
5	555	77	0.10	0.02
6	765	106	0.13	0.02
7	864	120	0.14	0.01
8	409	57	0.07	0.01
9	164	23	0.03	0.01
10	118	16	0.02	0.01
11	55	8	0.01	0.01
12	82	11	<0.01	0.01
13	-	-	-	-
14	18	3	<0.01	<0.01
Totals	6,044	839	1.000	-

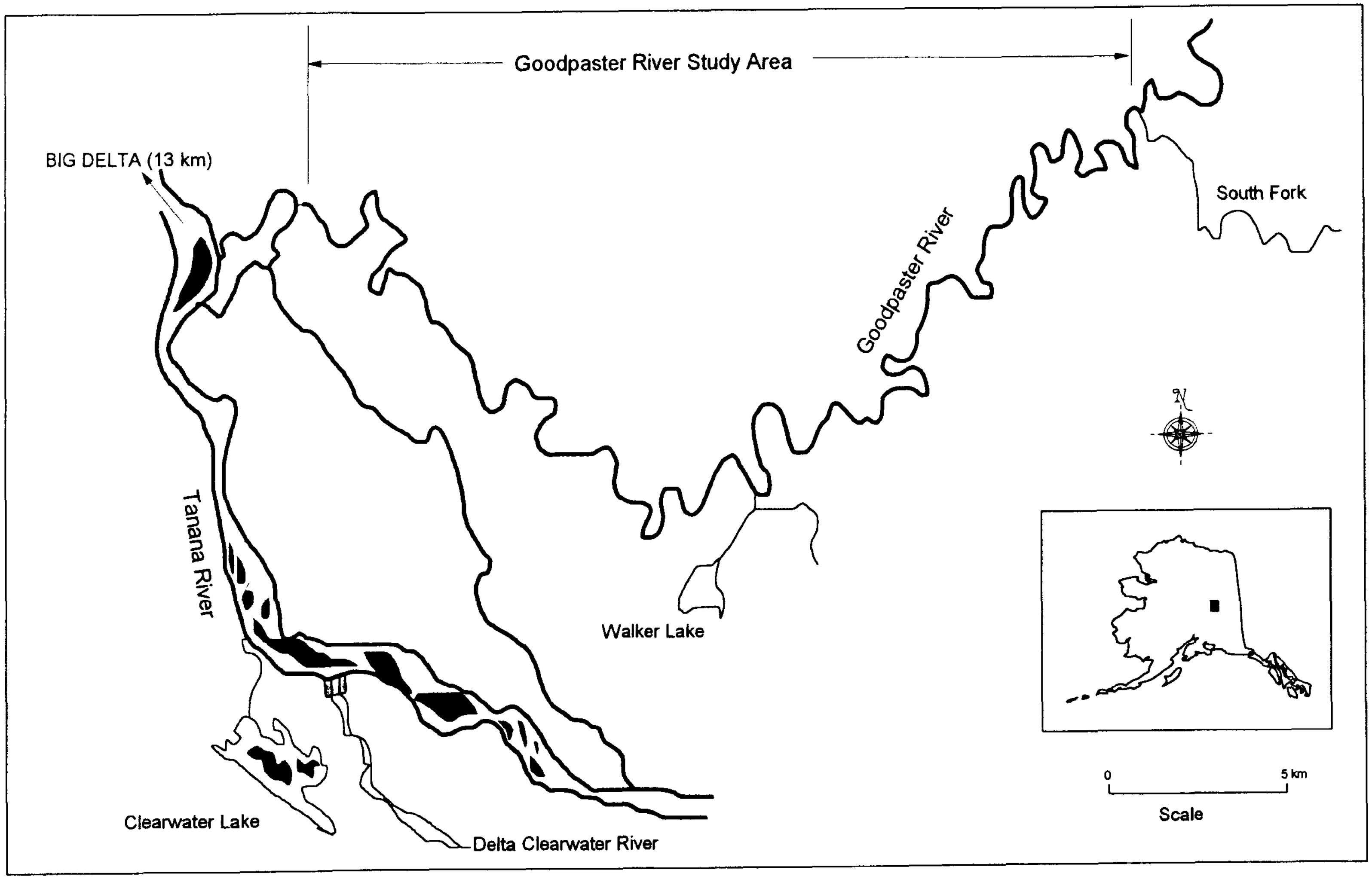

Figure 12.-Goodpaster River drainage.

estimated Arctic grayling abundance and stock compositions within this same study area in 1973 (Tack 1974) and 1974 (Tack 1975); and in each year since 1988 (Ridder 1989; Clark and Ridder 1990; Clark et al. 1991; Fleming et al. 1992; Ridder et al. 1993; Roach 1994). In addition, abundance of Arctic grayling was estimated within two 5-km index sections 11 different years from 1975 through 1987 (Appendix C1).

GOODPASTER RIVER STUDY AREA AND FISHERY DESCRIPTION

The Goodpaster River is a rapid runoff stream that originates in the Tanana Hills and flows southwest for 224 km to its confluence with the Tanana River, which is 16 km north of Delta Junction (Figure 1). The Goodpaster River drainage includes an area of approximately 4,100 km^2 (Figure 12). The river has 13 named tributaries, the largest of which are the Eisenmenger Fork (38 km in length) at river kilometer 184 and the South Fork (64 km in length) at river kilometer 52.3. Ridder et al. (1993) characterized the current study area as generally shallow (< 1 m deep), wide (~60 m across), slow moving, meandering, slightly tannic stained, and susceptible to rapid fluctuations in water level. In addition, Van Wyhe (1964) described the current study area of the Goodpaster River as low in productivity due to sparse aquatic vegetation and predominant sandy bottom. In contrast, he described the river above the study area as high in productivity due to a coarse gravel bottom, high density of aquatic vegetation, and high density of Arctic grayling prey organisms.

Previous investigators hypothesized that the Goodpaster River serves as a spawning and nursery stream for a portion of the summer Arctic grayling populations of the Richardson and Delta Clearwater rivers (Reed 1961; Nagata 1963; Roguski 1967). Reed (1961) observed that the majority of Arctic grayling tagged within the Goodpaster River were age-2 and age-3 and recoveries of Goodpaster fish within clearwater streams were age-5 and older. He suggested an age-size relationship for interstream movements. In addition, scale pattern analysis of age-3 Arctic grayling indicated that the Goodpaster River may be the source of up to 51% of the Delta Clearwater River Arctic grayling population (Ridder 1983).

Ridder (1991) supported these movement hypotheses with additional data reported in a summary of Arctic grayling recaptures within the middle Tanana River drainage. He reported that Goodpaster River Arctic grayling tags were recovered from six streams other than the Goodpaster River. Furthermore, recovery rates of Goodpaster River tags in these other streams were related to the time of year that the fish were tagged. Of 64 Arctic grayling tagged in the Goodpaster River during June and later recovered, 58% were recovered in other streams and predominantly from the Delta Clearwater River. However, of 98 Goodpaster River tags that were put out in August and later recovered, only 16% were recovered in other streams. This suggests that some Arctic grayling enter the Goodpaster River in the spring to spawn and then leave, while others remain in the river for the summer. Of fish that remain within the Goodpaster River, Tack (1974, 1980) described an upstream movement, both before and after spawning but little movement during the summer. In addition, he reported smaller and younger fish within the present study area compared to further upstream.

The Goodpaster River fisheries are only accessible by riverboat or airplane. However, riverboat travel on the Goodpaster River is limited to the lower 98 km of the main-stem river and the lower 5 km of the South Fork. Float plane access is limited to the lower 36 km of the river. Boat launches are located at Big Delta on the Tanana River (22.4 km downstream) and at Clearwater

Lake (11.2 km upstream). Landing strips are located at Central Creek at river kilometer 118 and at Tibbs Creek, a tributary of the Eisenmenger Fork. There are approximately 50 cabins on the river and all but five are located between river kilometers 11 and 48.

More than 90% of all fish caught (released or kept) in the Goodpaster River in 1993 were Arctic grayling. In addition to Arctic grayling, fish caught in the Goodpaster River in 1993 included (from the greatest to least number caught): burbot, northern pike, and chum salmon (Mills 1994). There is a small run of chinook and chum salmon in the Goodpaster River but salmon harvest is prohibited by regulation.

Prior to 1983, information collected from Goodpaster River fishermen was sparse. Tack (1974) conducted an onsite creel survey in 1973. Harvest rates in 1973 ranged from 0.69 to 1.63 Arctic grayling per hour. Estimated harvest of Arctic grayling during that year was 2,236 fish and estimated mean length of the harvest was 241 mm FL (n = 241). The harvest was predominantly from the lower 53 km of the river and effort was mainly from residents of the Delta Junction area.

Each year since 1983, Mills (1984-1994) estimated annual harvest and effort on the Goodpaster River through a postal survey (Table 1). Average annual harvest of Arctic grayling on the Goodpaster River was 1,470 fish, ranging from a high in 1983 of 3,021 and a low in 1993 of 588. Average effort on the Goodpaster River for all species of sport fish was 1,638 angler-days, ranging from a high in 1987 of 3,061 angler-days to a low in 1984 of 766 angler-days. In addition, each year since 1990, Mills (1991-1994) estimated annual fish caught (fish harvested plus fish caught and released) on the Goodpaster River (Table 2). The average annual catch of Arctic grayling on the Goodpaster River from 1990 through 1993 was 2,442 fish.

GOODPASTER RIVER METHODS

The Goodpaster River marking event was completed from 2 through 4 August 1994 and the recapture event from 9 through 11 August 1994. A partial upper caudal finclip was used as a second mark during the marking pass and a partial lower caudal finclip was used to prevent sampling redundancy during the recapture event. An exception to the general methods used for the three rivers was that both banks of the Goodpaster River were not sampled completely during the recapture event. The electrofishing boat alternated river banks, favoring the more productive outside bends over the inside bends, which are typically shallow with sandy bottoms and no overhead cover. Both banks, however, were sampled in areas where both sides of the river offered favorable habitat. Water temperatures were taken daily throughout the experiment, once in the morning and once in the afternoon.

Abundance Estimation

Abundance of Arctic grayling ≥ 150 mm FL was estimated within the Goodpaster River study area using a modified Petersen estimator (Bailey 1951; 1952), as described by Seber (1982; Appendix D3). To reduce bias from unequal catchability by area, it was necessary to divide the study area into two area strata to estimate abundance; an upper stratum (from river kilometer 52.3 downstream to river kilometer 21 and a lower stratum (from river kilometer 21 downstream to river kilometer 2.7).

Length and Age Compositions

Length and age compositions for Arctic grayling ≥ 150 mm FL were estimated for each area stratum. Proportions of fish by length and age were estimated directly for each stratum without length stratification (Appendix D4).

GOODPASTER RIVER RESULTS

Investigators handled 933 unique Arctic grayling ≥ 150 mm FL during the Goodpaster River mark-recapture experiment. During the marking event, 668 Arctic grayling were tagged and released alive. During the recapture event, 294 Arctic grayling were examined for marks. Of these 294 fish, 265 were unique and 29 were recaptured from the marking event. Of the 29 recaptured fish, none lost tags between events. During the marking event 14 Arctic grayling were killed or severely injured (2% of fish handled during the marking event). These fish were not included in the experiment. During the recapture event there were ten Arctic grayling killed (3.5% of fish handled during the capture event). These fish were included in the experiment. Investigators identified 74 Arctic grayling (7.9% of unique fish handled) from prior mark-recapture experiments. During the experiment, water temperature ranged from 13.6° C to 18.5° C, air temperature exceeded 32 °C on occasion, and water level of the river dropped throughout the experiment.

Abundance

Estimated abundance of Arctic grayling within the Goodpaster River study area was germane to fish ≥ 150 mm FL during the first two weeks of August 1994. Recapture rates of Arctic grayling within the study area were significantly different among three approximately equal-length sections ($\chi^2 = 9.18$, 2 df, $P = 0.01$). Furthermore, maximal difference in catchability was obtained by dividing the study area into two strata at river mile 13 (upper stratum included runs 1 - 16; lower stratum included runs 17 - 26; $\chi^2 = 10.84$, 1 df, $P < 0.01$). The recapture rate (fish recaptured divided by fish examined for marks in the recapture event; R/C) for the upper stratum was 0.06 and for the lower stratum 0.18 (Figure 13).

Comparison of sections where Arctic grayling were marked with sections where the fish were recaptured indicated movement between sections (Table 10). Of recaptured Arctic grayling, four of 29 (14%) moved from one section to another between events; one moved upstream and three moved downstream. Even though the number of fish that moved from one section to another was small, this was treated as significant movement between sections because more than 10% moved and the movement was directional. Movement between sections and a difference in catchability among sections of the study area indicated that none of the "or" conditions of assumption 2 were satisfied. Bias from different catchabilities between sections and movement, however, was compensated for by following the methodology outlined in Appendix D1 (Case IV). The Darroch (1961) estimator was compared with the Bailey estimator because movement out of the study area was not probable. These two estimates resulted in similar estimates of abundance (less than 10% difference), however, the Bailey estimator yielded a smaller variance. Therefore, the Bailey estimator was chosen to estimate abundance of Arctic grayling within the Goodpaster River study area.

There was no significant difference between the length distributions of fish marked and fish recaptured within the upper stratum ($D = 0.19$, $P = 0.77$; Figure 14-A1) or the lower stratum ($D = 0.21$, $P = 0.46$; Figure 14-A2). A visual inspection of Figures 14-A1 and 14-A2 along with

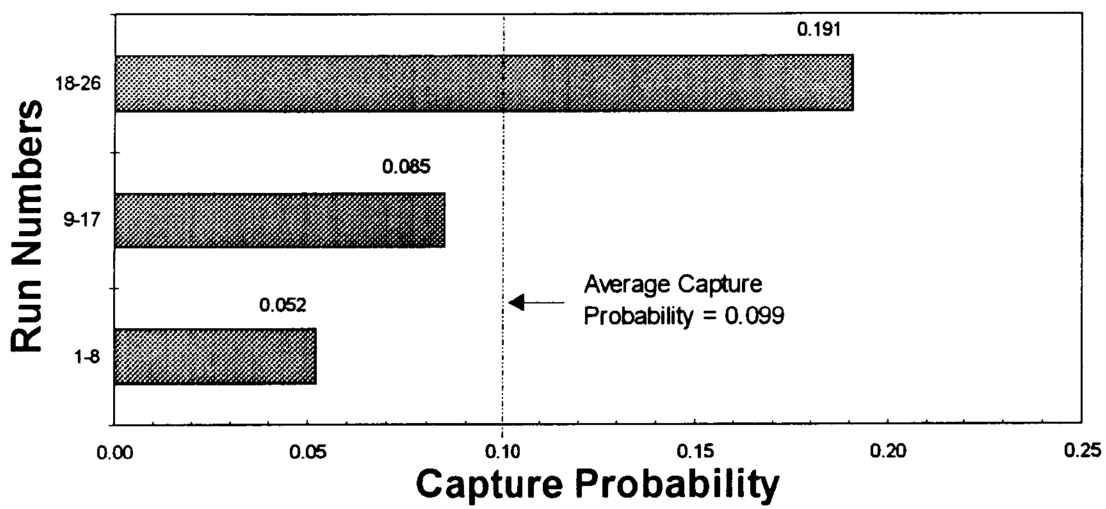

Figure 13.-Estimated capture probabilities (number of fish marked in the marking event and recaptured in the recapture event divided by the total number of fish captured in the recapture event) by section and the average capture probability for Arctic grayling captured in the Goodpaster River study area.

Table 10.-Number of Arctic grayling recaptured in a section and run[a] (n = 29) of the Goodpaster River summarized by the section and run in which the fish was marked.

Mark Run	Number Recaptured: Section III								Section II									Section I									Number Moved Between Sections
	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	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	1	0	0	0	1
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOT	1	0	0	1	2	0	1	0	0	0	1	1	0	2	1	2	4	3	0	1	4	4	1	0	0	0	4

[a] A run was approximately 2 km; the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 started at river kilometer 52.3 and run 26 ended at river kilometer 2.7.

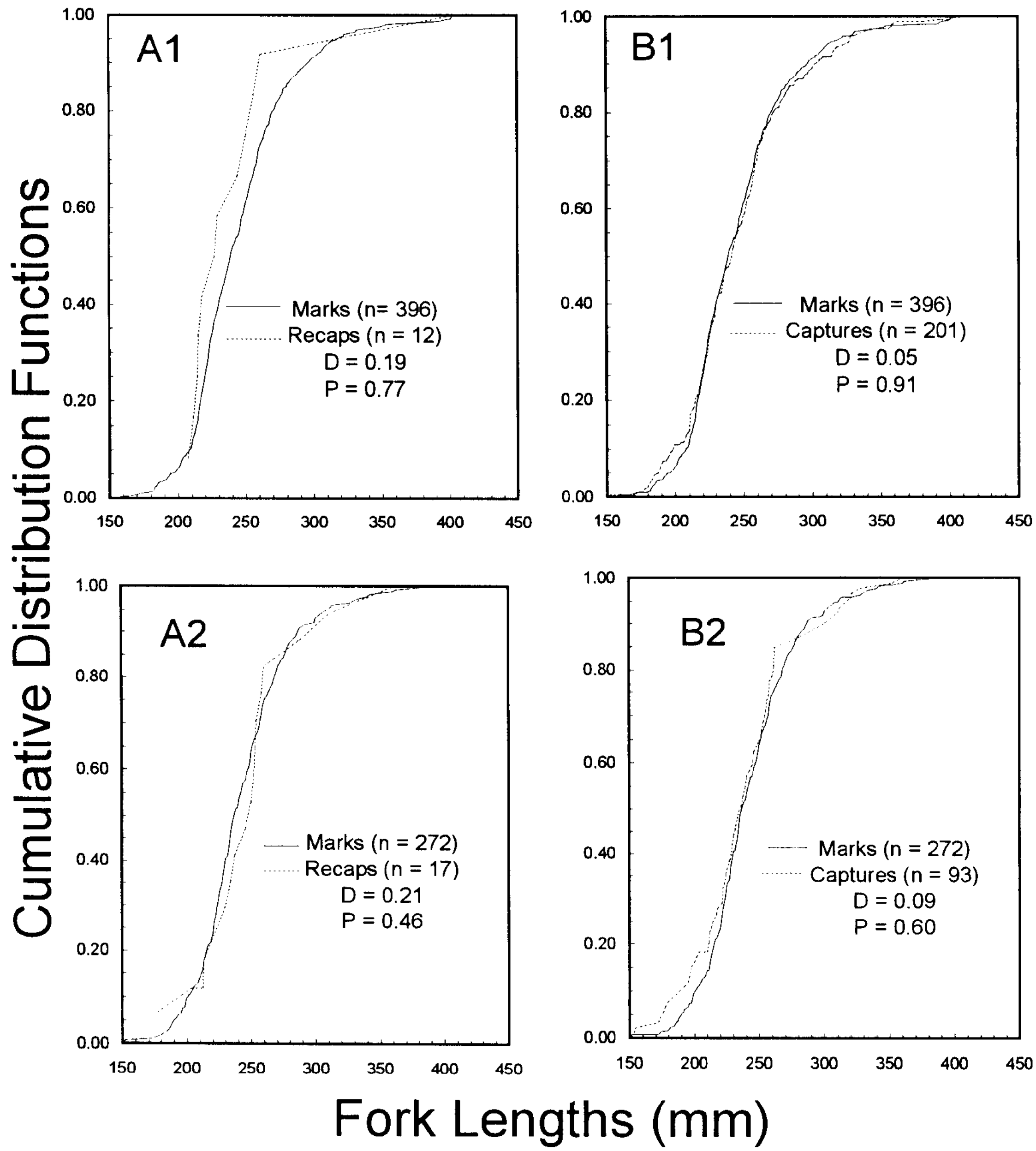

Figure 14.-Cumulative distribution functions of fork lengths of Arctic grayling captured in two sections of the Goodpaster River. (A) Arctic grayling marked versus Arctic grayling recaptured; and (B) Arctic grayling marked versus Arctic grayling examined for marks in the recapture event.

the large-test statistics, however, suggested that there may have been some bias from size-selective sampling. Length stratified estimates of abundance were similar to estimates of abundance without length stratification indicating that this bias was negligible. In view of these results, one of the "or" conditions of assumption 2 was satisfied in each area strata. Specifically, there was no length selectivity during the recapture event. Therefore, an unstratified abundance estimate was used to estimate Arctic grayling abundance within each area stratum of the Goodpaster River study area (Appendix D2).

Estimated abundance of Arctic grayling ≥ 150 mm FL within the Goodpaster River study area was 7,574 fish (SE = 1,617; CV = 21%; Table 11). Estimated densities of Arctic grayling ≥ 150 mm FL varied between the two strata of the Goodpaster River study area; 192 (SE = 50) fish per kilometer in the upper section and 79 (SE = 16) fish per kilometer in the lower section ($Z = 0.91$, $P = 0.18$). Estimated densities of Arctic grayling ≥ 150 mm FL within the study area was 151 (SE = 32) fish per kilometer (Table 6).

Length and Age Compositions

There was no significant difference between the length distributions of fish marked and fish recaptured within the upper stratum ($D = 0.19$, $P = 0.77$; Figure 14-A1) or the lower stratum ($D = 0.21$, $P = 0.46$; Figure 14-A2); or between the length distributions of fish marked in the marking event and fish examined for marks in the recapture event within the upper stratum ($D = 0.05$, $P = 0.91$; Figure 14-B1) or the lower stratum ($D = 0.09$, $P = 0.60$; Figure 14-B2). These results indicated that there was no difference in catchability by length during either the marking or recapture events within each area stratum.

Fork lengths of Arctic grayling captured during both the marking and capture event were pooled to estimate length composition of Arctic grayling ≥ 150 mm FL within each area stratum of the Goodpaster River. Fork lengths measured from 962 Arctic grayling (597 from the upper stratum and 365 from the lower stratum) ≥ 150 mm FL from the Goodpaster River study area ranged from 151 to 411 mm FL (mean = 245 mm, SE = 1 mm). The estimated proportion of Arctic grayling from 150 to 269 mm FL within the Goodpaster River study area was 0.80 (SE = 0.01), and ≥ 270 mm FL was 0.20 (SE = 0.01; Figure 15). The largest Arctic grayling sampled from the Goodpaster River in 1994 was 411 mm FL, which was captured during the marking event.

Ages from Arctic grayling captured during the marking event were used to estimate age composition of Arctic grayling ≥ 150 mm FL within the Goodpaster River study area. Ages were estimated from the scales for 274 of 294 Arctic grayling. Age classes, estimated from the scales of Arctic grayling ≥ 150 mm FL from the Goodpaster River marking event, ranged from age-1 to age-10 (mean = 3.78, SE = 0.05). The age class with the largest proportion of Arctic grayling ≥ 150 mm FL within the Goodpaster River study area was age-4 (0.39, SE = 0.03; Table 12).

GOODPASTER RIVER DISCUSSION

Harvest of Arctic grayling from the Goodpaster River has decreased 70% since 1989, however, fishing effort on the Goodpaster River during the same period has fluctuated from a high in 1990 to a low in 1991 (Table 1). Some fishing effort during this period may have been diverted to catch-and-release but there are no data to evaluate this hypothesis because there are no comparisons for catch-and-release information before 1990 (Table 2). It is believed, however, that catch-and-release fishing has generally increased over the last few years.

Table 11.-Number of fish marked (M), number of fish examined for marks (C), number of fish recaptured with marks (R), capture probabilities (R/C and R/M), estimated abundance (N), and standard error of estimated abundance SE[N] of Arctic grayling (≥ FL 150 mm) within the Goodpaster River study area summarized by strata with unequal probabilities of capture (χ^2 = 10.84, 1 df, P 0.01) and study area.

Section	M	C	R	R/C	R/M	N[a]	SE[N]
Upper Stratum[b]	396	201	12	0.06	0.03	6,153	1,591
Lower Stratum[c]	272	93	17	0.18	0.06	1,420	293
Study Area[d]	668	294	29	0.10	0.04	7,574	1,617

[a] The Bailey (1951; 1952) estimator was used to estimate abundance of each strata.

[b] The upper stratum extended from river kilometer 52.3 downstream to approximately river kilometer 21.

[c] The lower stratum extended from approximately river kilometer 21 downstream to river kilometer 2.7.

[d] Abundance estimates of the upper and lower strata were summed to estimate abundance within the study area.

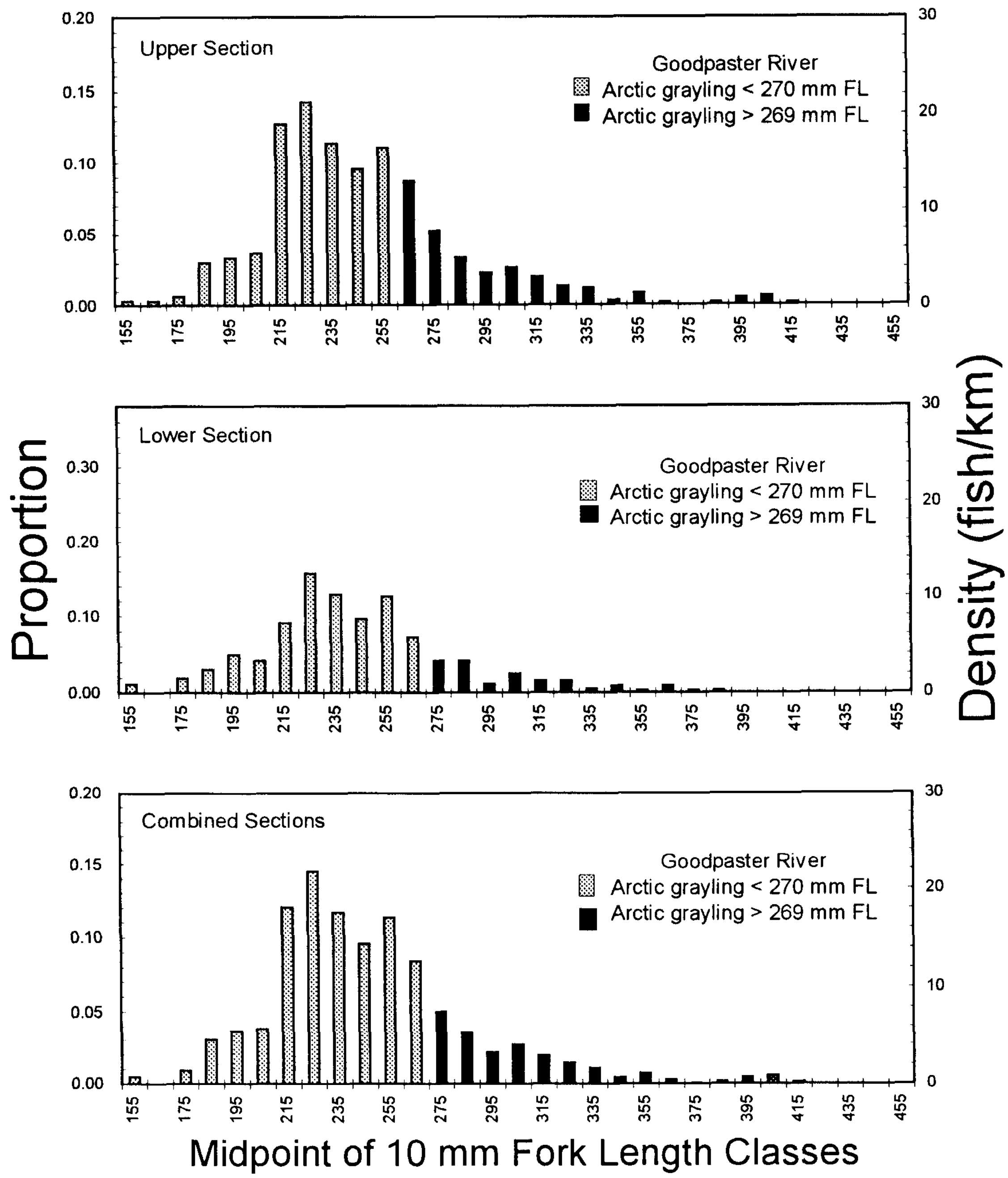

Figure 15.-Estimated proportions and densities of Arctic grayling ≥ 150 mm FL by 10 mm length classes within the upper and lower sections of the Goodpaster River study area during early August 1994 adjusted for different capture probabilities by river section.

Table 12.-Estimated abundance (N), standard error of abundance (SE[N]), proportion (p), and standard error of proportion (SE[p]) of Arctic grayling ≥ 150 mm FL by age within the Goodpaster River study area adjusted for different capture probabilities by river section.

Age Classes	N	SE[N]	p	SE[p]
1	65	14	0.009	0.005
2	854	182	0.113	0.020
3	2,537	542	0.335	0.030
4	2,964	633	0.391	0.031
5	412	88	0.054	0.015
6	280	60	0.037	0.012
7	247	53	0.033	0.011
8	0	0	0.000	0.000
9	132	28	0.017	0.008
10	82	18	0.011	0.007
Totals	7,573	1,617	1.000	---

It was suggested by Ridder et al. (1993) that Arctic grayling abundance within the Goodpaster River may have been depressed but stable during the years from 1988 through 1992 when compared to historic data, in particular when compared to the estimated abundance of 1973 (Tack 1974; Appendix C1). This assessment was probably correct even though the authors characterized the estimates prior to 1988 as low in precision and high in variability. Even though, estimated abundance of Arctic grayling ≥ 150 mm FL within the Goodpaster River study area decreased from 10,841 fish in 1993 to 7,574 fish in 1994, the estimate was similar to the average of the last seven years (8,064 fish; SE = 504). The greater abundance in 1993 was probably due to good recruitment of fish ≥ 150 mm FL in 1992 and 1993 (1989 and 1990 year classes). The lack of recruitment in 1994 explains the disparity between the 1993 and 1994 estimates of abundance. Nonetheless, Arctic grayling ≥ 150 mm FL within the Goodpaster River study area remained below historic estimates of abundance in both 1993 and 1994 (Appendix C1).

The influence of recruitment on the abundance of Arctic grayling in the Goodpaster River study area is amplified due to the departure of adult Arctic grayling from the study area from one year to the next. A portion of adult (age-4 and up) Arctic grayling either move out of the river itself (Reed 1961, Ridder 1991) or move upstream out of the study area (Tack 1974, 1980). Reed (1961) and Ridder (1991) analyzed data that strongly indicated that the Goodpaster River serves as a spawning and nursery stream for Arctic grayling that oversummer in other places, namely, but not limited to, the Richardson and Delta Clearwater rivers.

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APPENDIX A

Historic Data Summaries - Salcha River

Appendix A1.-Number of interviews, angler-hours, and harvest rates (fish/hr) for Arctic grayling harvested from the Salcha River summarized by year[a].

Year	Interviews	Angler-hours	Fish/Hr[b]
1953	102	344	0.48
1954	132	646	0.84
1955[c]	174	728	1.09
1956[c]	391	1,659	0.83
1957[c]	86	321	0.78
1958[c]	108	423	1.01
1960	ND	2,600	1.22
1963	275	---	0.67[c]
1964	409	1,816	0.64
1968	2,013[e]	7,035[d]	1.00
1974	827	11,284[d]	0.42
1987	152	---	0.66

[a] Data 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] AG/hr is the number of Arctic grayling harvested per angler-hour.

[c] This catch rate includes salmon (Roguski and Winslow 1969).

[d] Data from sample time per area expanded to the entire fishery.

Appendix A2.-Study area, number of marks, number of recaps, and estimated densities (fish/km) of Arctic grayling studies in the Salcha River by dates for 1972, 1974, 1985, and 1988-1994.

Dates	Area	Marks	Recaps	Density[b]	Confidence[c]
8/2/72 - 8/4/72	Redmond Creek	ND	5	503/km	Low
7/10/74 - 7/22/74	Redmond Creek to TAPS[d]	ND	ND	765/km	490-5,032/km
7/10/74 - 7/22/74	TAPS to 8 km upstream	ND	ND	991/km	690-2,595/km
7/10/74 - 7/22/74	TAPS to 8 km downstream	ND	ND	551/km	397-1,174/km
8/5/85 - 8/9/85	Flat Creek	205	6	497/km	128-1,064/km
5/24/88 - 6/8/88	TAPS to 16 km upstream	208	28	138/km	SE = 34/km
6/12/89 - 6/16/89	Richardson Hwy. bridge to 36.8 km upstream	616	55	188/km	SE = 21/km
6/26/90 - 6/27/90	Richardson Hwy. bridge to 36.8 km upstream	495	40	157/km	SE = 18/km
6/25/91 - 7/2/91	Richardson Hwy. bridge to 36.8 km upstream	439[e] 382	27 27	147/km 114/km	SE = 28/km SE = 25/km
6/15/92 - 6/25/92	Richardson Hwy. bridge to 36.8 km upstream	709[f]	52	209/km	SE = 69/km
6/7/93 - 6/17/93	Richardson Hwy. bridge to 36.8 km upstream	1,294	66	433/km	SE = 66/km
6/13/94 - 6/30/94	Richardson Hwy. bridge to 36.8 km upstream	1,099	57	396/km	SE = 48/km

[a] Data sources: 1972 (Tack 1973); 1974 (Bendock 1974; Kramer 1975); 1985 (Holmes et al. 1986); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); and, 1994 (present report).

[b] The 1972-1985 estimates were calculated with the modified Schnabel formula (Ricker 1975). The 1988 through 1990 and 1994 estimates were calculated with the modified Petersen estimator modified by Evenson (1988). The 1991, 1992, and 1993 estimates was calculated with modified Petersen (Bailey 1952).

[c] Confidence is a crude measure of precision (e.g. Low), the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975), or the standard error. Estimates for 1988-1990 and 1994 were from bootstrap methods (Efron 1982); a standard error (SE) is reported for these estimates.

[d] TAPS = Trans-Alaska Pipeline System.

[e] Mark-recapture experiment results are for Full model ($\geq$ 150 mm Fl; upper) and Reduced model ($\geq$ 200 mm Fl; lower).

[f] Mark-recapture results are for the Reduced model ($\geq$ 200 mm Fl), due to the lack of recaptures of Arctic grayling < 207 mm.

Appendix A3.-Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Salcha River, 1985-1994[a].

	1985[b]			1986[c]			1987[d]			1988[e]			1989[f]		
Age	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	1	0.01	0.01	0	0	---	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	---

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Age	1990[g]			1991[h]			1992[i]			1993[k]			1994[l]		
	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	45	0.22	0.03	12	0.04	0.01	1(25)[j]	<0.01	<0.01	42	0.08	0.02	265	0.29	0.03
3	76	0.37	0.03	45	0.16	0.02	62(96)	0.15	0.03	193	0.47	0.03	207	0.23	0.02
4	38	0.19	0.03	69	0.25	0.03	251(254)	0.48	0.04	116	0.21	0.02	186	0.25	0.02
5	18	0.09	0.02	81	0.30	0.03	183	0.25	0.03	114	0.17	0.02	68	0.10	0.01
6	13	0.06	0.02	37	0.13	0.02	66	0.07	0.02	53	0.05	0.01	46	0.07	0.01
7	7	0.03	0.01	19	0.07	0.01	28	0.03	0.01	11	0.01	0.01	20	0.03	0.01
8	5	0.02	0.01	7	0.03	0.01	18	0.02	0.01	4	<0.01	<0.01	9	0.01	0.01
9	1	<0.01	<0.01	2	0.01	<0.01	5	0.01	<0.01	0	0.00	0.00	4	0.01	<0.01
10	0	0.00	---	1	<0.01	<0.01	1	<0.01	<0.01	1	<0.01	<0.01	1	<0.01	<0.01
11	0	0.00	---	1	<0.01	<0.01	0	0.00	---	0	0.00	0.00	1	<0.01	<0.01
Totals	203	1.00	---	274	1.00	---	552	1.00	---	552	1.00	---	807	1.00	---

a Source documents are: 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); and, 1993 (Roach 1994).

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

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

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

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

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

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

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

i Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (22 June through 25 June, 1992). Age composition and standard error are adjusted for differential probability of capture by size of fish.

j Numbers in parentheses represent the number of fish sampled at age that were ≥ 150 mm FL.

k Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (7 June through 8 June, 1993). Age composition and standard error are adjusted for differential probability of capture by size of fish in the lower section of the study area.

l Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (13 June through 16 June, 1994). Age composition and standard error are adjusted for differential probability of movement by size of fish.

Appendix A4.-Summary of estimated RSD categories for Arctic grayling within the Salcha River study areas by year[a].

		RSD Category[b]				
Year	Statistic	Stock	Quality	Preferred	Memorable	Trophy
1972	Number	ND[c]	ND	ND	ND	ND
	RSD	0.53	0.46	<0.01	0	0
	SE	ND	ND	ND	---	---
1974	Number	153	14	2	0	0
	RSD	0.91	0.08	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1985	Number	17	155	57	0	0
	RSD	0.07	0.68	0.25	---	---
	SE	0.02	0.03	0.03	---	---
1986	Number	47	71	56	0	0
	RSD	0.27	0.41	0.32	---	---
	SE	0.03	0.04	0.04	---	---
1987	Number	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	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	755	342	124	2	0
	RSD[d]	0.71	0.22	0.08	<0.01	
	SE	0.04	0.03	0.01	<0.01	

1990	Number	365	95	40	0	0
	RSD	0.73	0.19	0.08	---	---
	SE	0.02	0.02	0.01	---	---
1991	Number[e]	170	110	12	0	0
	RSD	0.58	0.38	0.04	---	---
	SE	0.03	0.03	0.01	---	---
1992	Number[e]	377	290	42	0	0
	RSD[d]	0.71	0.25	0.04	---	---
	SE	0.08	0.07	0.01	---	---
1993	Number	458	186	24	0	0
	RSD	0.82	0.16	0.03	---	---
	SE	0.03	0.03	0.01	---	---
1994	Number[d]	772	119	20	0	0
	RSD	0.82	0.16	0.03	---	---
	SE	0.03	0.03	0.01	---	---

[a] Data sources: 1972 (Tack 1973); 1974 (Bendock 1974; Kramer 1975); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); and, 1994 (present report).

[b] Minimum lengths for RSD categories were adapted from Gabelhouse (1984): stock (150 - 269 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

[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 or area.

[e] Includes only Arctic grayling ≥ 200 mm Fl.

Appendix A5.-Summary of mean length at age data collected from Arctic grayling in the Salcha River, 1952, 1974, 1981, and 1985-1994[a].

	1952			1974			1981			1985			1986		
Age	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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Age	1987			1988			1989			1990			1991			1992			1993		
	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---	1	123	---	---	---	---	---	---	---	1	180	---
2	2	138	8	17	174	16	17	176	39	96	182	19	25	167	17	25	166	14	42	181	13
3	35	203	36	116	200	16	155	214	24	220	213	22	112	206	22	96	206	21	193	202	23
4	205	241	20	83	241	20	143	252	28	157	252	25	194	234	25	254	252	23	116	260	28
5	120	275	33	175	280	24	75	273	30	75	283	32	170	264	29	183	280	26	114	290	29
6	80	311	36	58	302	30	74	302	37	49	317	33	67	290	29	65	306	30	53	306	29
7	56	339	30	54	332	32	24	315	38	38	346	31	33	301	39	28	323	34	11	327	19
8	15	356	36	51	348	24	30	341	44	19	370	33	16	320	49	18	344	38	4	360	26
9	4	371	30	22	373	30	18	368	21	6	396	36	6	356	45	5	362	44	---	---	---
10	2	444	20	4	394	19	3	407	40	0	---	---	2	369	7	1	385	---	1	373	---
11	---	---	---	1	463	---	0	---	---	0	---	---	1	358	---	---	---	---	---	---	---
Totals	519			581			539			661			626			674			535		

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	1994		
Age	n	FL	SD
1	5	154	5
2	265	180	16
3	207	204	29
4	186	240	27
5	68	259	33
6	46	303	27
7	20	306	36
8	9	328	36
9	4	357	24
10	1	365	---
11	1	348	---
Totals	812		

[a] Data sources: 1952 (Warner 1959b); 1974 (Bendock 1974; Kramer 1975); 1981 (Hallberg 1982); 1985 Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); and, 1994 (present report).

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

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

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

[e] ND = data not furnished in original citation

APPENDIX B

Historic Data Summaries - Chatanika River

Appendix B1.-Number of intervews, angler-hours, and harvest rates (fish/hr) for Arctic grayling harvested from the Chatanika River summarized by year[a].

Year	Interviews	Angler-hours	Fish/Hr[b]
1953	460	955	0.49
1954	243	529	0.78
1955[c]	69	294	0.13
1956[c]	66	223	0.27
1957[c]	62	177	0.18
1958[c]	68	151	0.76
1974	408	27,250[d]	1.02
1987	30	---	0.02

[a] Data taken from Warner (1959b) for 1953-1958, Kramer (1975) for 1974, and Baker (1988) for 1987.

[b] AG/hr is the number of Arctic grayling harvested per angler-hour.

[c] From 1955 through 1958 there was a 305 mm (12 inch) minimum length limit for Arctic grayling on the Chatanika River (Warner 1959b).

[d] Data from sample time per area expanded to the entire fishery.

Appendix B2.-Study area, number of marks, number of recaps, and estimated densities (fish/km) of Arctic grayling studies the Chatanika River by dates for 1972, 1981, 1984-1985, 1990-1994[a].

Dates	Area	Marks	Recaps	Density[b]	Confidence[c]
8/1072 - 8/17/72	Elliott Highway Bridge	103	4	305/km	Low
8/24/81 - 8/26/81	Elliott Highway Bridge	ND[d]	64	169/km	132-197/km
8/15/84 - 8/18/84	Elliott Highway Bridge	ND	32	242/km	172-352/km
8/20/85 - 8/23/85	Elliott Highway Bridge	132	20	117/km	82-176/km
8/27/90 - 9/7/90	28.8 km section from 7.5 km above the Elliott Highway bridge downstream to Any Creek	857	36	670/km	SE = 111/km
8/12/91-8/15/91	35.2 km section from 9.6 km above the Elliott Highway bridge downstream to Any Creek	608	58	312/km	SE = 62/km
7/11/91 - 7/16/91; 8/23/91 - 8/26; 9/9/91 - 9/14/91	73.8 km section from Any Creek to Murphy Dome Road extension	667	25	271/km	SE = 52/km
8/17/92 - 8/28/92	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	679	41	271/km	SE = 47/km
	73.8 km section from Any Creek to Murphy Dome Road extension	1,767	224	158/km	SE = 17/km
8/16/93 - 8/26/93	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	617	32	252/km	SE = 41/km
	50 km section from Any Creek to 16 km above Murphy Dome Road extension	758	89	89/km	SE = 9/km
8/15/94 - 8/24/94	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	648	55	201/km	SE = 28/km

[a] Data sources: 1972 (Tack 1973); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994) and, 1994 (present report).

[b] All estimates except 1990 through 1994 were calculated with the modified Schnabel formula (Ricker 1975). The 1990 estimate was calculated with the modified Petersen estimator of Evenson (1988) and the modified Petersen estimate of Bailey (1951, 1952). The 1991 through 1994 estimates used the modified Petersen estimate of Bailey (1951, 1952).

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

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

Appendix B3.-Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Chatanika River, 1984-1994[a].

	1984[b]			1985[c]			1986[d]			1987[e]			1988[f]			1989[g]		
Age	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	

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Age	1990[h] n	p	SE	1991[i] n	p	SE	1992[j] n	p	SE	1993[k] n	p	SE	1994[l] n	p	SE
2	126	0.20	0.02	26	0.05	0.01	56	0.14	0.03	88	0.15	0.02	6	0.02	0.01
3	347	0.55	0.02	88	0.17	0.02	32	0.08	0.01	123	0.21	0.02	64	0.19	0.02
4	80	0.11	0.01	226	0.44	0.02	83	0.22	0.03	26	0.04	0.01	100	0.29	0.02
5	45	0.04	0.01	46	0.09	0.01	198	0.36	0.03	100	0.16	0.02	32	0.09	0.02
6	51	0.04	0.01	36	0.07	0.01	81	0.11	0.01	162	0.25	0.02	45	0.13	0.02
7	57	0.04	0.01	47	0.09	0.01	30	0.03	0.01	57	0.08	0.02	52	0.14	0.02
8	17	0.01	<0.01	29	0.06	0.01	39	0.04	0.01	27	0.04	0.01	25	0.07	0.01
9	11	0.01	<0.01	12	0.02	0.01	28	0.03	0.01	20	0.03	0.01	10	0.03	0.01
10	2	<0.01	<0.01	4	0.01	<0.01	10	0.01	<0.01	17	0.02	0.01	8	0.02	0.01
11	0	---	---	1	<0.01	<0.01	1	<0.01	<0.01	10	0.01	0.01	3	0.01	0.01
12	---	---	---	---	---	---	---	---	---	7	0.01	0.01	5	0.01	0.01
13	---	---	---	---	---	---	---	---	---	1	<0.01	<0.01	1	<0.01	<0.01
Totals	736	1.00		515	1.00		558	1.00		668	1.00		351	1.00	

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[a] Source documents are: 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); and, 1994 (present report).

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

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

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

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

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

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

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

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

[j] Sampling was conducted with a DC electrofishing boat in a 101 km section, beginning 3.2 km upstream of the Elliott Highway bridge and ending downstream at the Murphy Dome Road terminus (24 through 28 August 1992). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[k] Sampling was conducted with a DC electrofishing boat in a 78.2 km section, beginning 3.2 km above the Elliott Highway bridge and ending downstream 24 km above Murphy Dome Road extension (23 through 26 August 1993).

[l] Sampling was conducted with a DC electrofishing boat in a 29.6 km section, beginning 3.2 km above the Elliott Highway bridge and ending downstream to Any Creek (22 through 24 August 1994).

Appendix B4.-Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1994.

	1952			1953			1981			1982			1984			1985		
Age	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND	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			87			73			238		

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

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	1992			1993			1994		
Age	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	1	195	---	---	---	---
2	56	175	22	88	172	17	6	182	7
3	32	213	24	123	204	22	64	212	27
4	83	248	26	26	243	23	100	243	25
5	198	262	24	100	270	23	32	267	22
6	81	289	21	162	284	21	45	288	27
7	30	310	22	57	300	19	52	301	29
8	39	320	16	27	317	17	25	312	40
9	28	337	24	20	322	23	10	331	18
10	10	329	21	17	334	12	8	341	15
11	1	350	---	10	345	20	3	369	15
12	---	---	---	7	344	10	5	344	13
13	---	---	---	1	362	---	1	376	---

[a] Data sources: 1952-1953 (Warner 1959b); 1981 (Hallberg 1982); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); and, 1994 (present report).

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

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

[d] SD is the standard deviation of FL.

Appendix B5.-Summary of estimated RSD categories for Arctic grayling within the Chatanika River by year[a].

		RSD Category[b]				
Year		Stock	Quality	Preferred	Memorable	Trophy
1952	Number	95	1	0	0	0
	RSD	0.99	0.01	---	---	---
	SE	0.01	0.01	---	---	---
1953	Number	98	8	0	0	0
	RSD	0.92	0.08	---	---	---
	SE	0.03	0.03	---	---	---
1954	Number	42	1	0	0	0
	RSD	0.98	0.02	---	---	---
	SE	0.02	0.02	---	---	---
1972	Number	121	0	0	0	0
	RSD	1	---	---	---	---
	SE	---	---	---	---	---
1982	Number	53	3	0	0	0
	RSD	0.95	0.05	---	---	---
	SE	0.03	0.03	---	---	---
1984	Number	206	9	1	0	0
	RSD	0.95	0.04	0.01	---	---
	SE	0.01	0.01	0.01	---	---
1985	Number	146	11	0	0	0
	RSD	0.93	0.07	---	---	---
	SE	0.02	0.02	---	---	---
1986	Number	279	121	4	0	0
	RSD	0.69	0.3	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1987	Number	420	126	7	0	0
	RSD	0.76	0.23	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1988	Number	361	221	13	0	0
	RSD	0.61	0.37	0.02	---	---
	SE	0.02	0.02	0.01	---	---
1989	Number	150	221	4	0	0
	RSDc	0.49	0.49	0.02	---	---
	SE	0.06	0.06	0.01	---	---
1990	Number	1,201	309	19	0	0
	RSDc	0.9	0.09	0.01	---	---
	SE	0	0.02	<0.01	---	---
1991[d]	Number	516	222	25	0	0
	RSDc	0.84	0.14	0.02	---	---
	SE	0.03	0.03	<0.01	---	---

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Year		RSD Category				
		Stock	Quality	Preferred	Memorable	Trophy
1991[e]	Number	381	312	56	0	0
	RSD	0.51	0.42	0.07	---	---
	SE	0.02	0.02	0.01	---	---
1992[f]	Number	294	134	9	0	0
	RSD[c]	0.84	0.15	0.01	---	---
	SE	0.03	0.03	<0.01	---	---
1992[g]	Number	1,250	1,507	175	0	0
	RSD[c]	0.44	0.5	0.06	---	---
	SE	0	0	<0.01	---	---
1993[d]	Number	226	155	9	0	0
	RSD[c]	0.58	0.4	0.02	---	---
	SE	0.03	0.03	<0.01	---	---
1993[h]	Number	215	279	34	0	0
	RSD[c]	0.41	0.53	0.06	---	---
	SE	0.02	0.02	0.01	---	---
1994[d]	Number	639	410	74	0	0
	RSD[c]	0.57	0.36	0.07	---	---
	SE	0.02	0.02	0.01	---	---

[a] Data sources: 1952-1958 (Warner 1959b); 1972 (Tack 1973); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); and, 1994 (present report).

[b] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984): stock (150 - 169 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

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

[d] 28.8 km section from 3.2 km above the Elliott Highway bridge downstream to below Any Creek.

[e] 83.2 km section from 25.6 km below the Elliott Highway bridge to Murphy Dome Extension Rd.

[f] 35.2 km section from 9.6 km above the Elliott Highway bridge downstream to below Any Creek.

[g] 73.8 km section from 25.6 km below the Elliott Highway bridge to Murphy Dome Extension Rd.

[h] 50 km section from 25.6 km below the Elliott Highway bridge to 24 km above Murphy Dome Extension Rd.

Appendix B6.-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_o[e]	-0.42	0.16	-1.01	0.2
Corr(L_∞,K)[f]	-0.99	---	-0.98	---
Corr(L_∞,t_o)	-0.88	---	-0.89	---
Corr(K,t_o)	0.94	---	0.96	---
Sample size	1,198		1,469	

[a] The von Bertalanffy growth model (Ricker 1975) used was $l_t = L_\infty (1 - exp(-K (t - t)))$. 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* 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 C

Historic Data Summaries - Goodpaster River

Appendix C1.-Summary of abundance estimates of Arctic grayling (150 mm FL) in the Goodpaster River, 1972 - 1993[a].

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

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Year	Day/Month	River km	M	C	R	Fish/km[b] N	95% CI[c] or (SE)
1985	25-27 Jun	4.8 - 9.6	189	213	7	459	238-966
1985	6-13 Aug	4.8 - 9.6	307	455	42	400	296-554
		24 - 28.8	303	424	45	328	245-450
		combined	610	879	87	364	271-502
1986	11-15 Aug	4.8 - 9.6	230	312	15	403	250-686
		24 - 28.8	293	389	42	256	193-352
		combined	523	701	57	305	234-397
1987	4-10 Aug	4.8 - 9.6	138	191	14	188	115-324
		24 - 28.8	158	213	24	133	91-203
		combined	274	363	35	134	97-191
1988	8-18 Aug	4.8 - 53	1,130	1,002	139	158	(12)
1989	8-17 Aug	3 - 53	955	984	124	161	(15)
1990	8-16 Aug	3 - 53	1,051	554	82	145	(15)
1991	7-14 Aug	3 - 53	780	429	42	157	(17)
1992	4-14 Aug	3 - 53	922	562	80	138	(16)
1993	3-13 Aug	3 - 53	730	890	59	219	(27)
1994	2-11 Aug	3 - 53	668	294	29	151	(32)

[a] Data sources: 1972 - 1974 (Tack 1973, 1974, 1975); 1975 - 1978 and 1980 (Peckham 1976, 1977, 1978, 1979, 1981); 1982 and 1984 (Ridder 1983, 1985); 1985 (Holmes et al. 1986); 1986 - 1987 (Clark and Ridder 1987, 1988; Ridder 1989); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994) and, 1994 (this report).

[b] Schnabel estimator was used in 1972, 1973, 1985 through 1987; modified Petersen (Bailey 1951, 1952) estimator in 1974 through 1984 and 1992 through 1994; modified Petersen (Evenson 1988) in 1988; and bootstrapped modified Petersen (Bailey 1951, 1952) in 1989, 1990, and 1991.

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

[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 C2.-Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1994[a].

	1955			1956			1957			1958					
	29 July-15 Sept.			summer			11 June-15 Aug			7 May-25 July			1969		
Age	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		1,104	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	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	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			1990[e] 8-10 August		
Age	n	p	SE	n	p	SE	n	p	SE	n	p[f]	SE[f]	n	p[f]	SE[f]
1	0	---	---	6	0.02	0.01	1	<0.01	<0.01	0	---	---	46	0.05	<0.01
2	80	0.14	0.02	55	0.15	0.02	144	0.18	0.01	364	0.47	0.02	79	0.08	<0.01
3	360	0.63	0.02	51	0.14	0.02	58	0.07	0.01	165	0.21	0.01	562	0.59	0.01
4	26	0.05	0.01	165	0.46	0.03	86	0.11	0.01	37	0.04	0.01	94	0.10	<0.01
5	37	0.07	0.01	9	0.03	0.01	317	0.40	0.02	104	0.09	0.01	36	0.04	<0.01
6	56	0.10	0.01	22	0.06	0.01	34	0.04	0.01	134	0.11	0.02	55	0.05	<0.01
7	8	0.01	0.01	32	0.09	0.02	67	0.09	0.01	44	0.03	<0.01	60	0.06	0.01
8	2	<0.01	<0.01	12	0.03	0.01	45	0.06	0.01	29	0.02	0.01	13	0.01	<0.01
9	2	<0.01	<0.01	5	0.01	0.01	20	0.03	0.01	7	0.01	<0.01	8	0.01	<0.01
10	0	---	---	1	<0.01	<0.01	8	0.01	<0.01	4	<0.01	<0.01	4	<0.01	<0.01
11	0	---	---	0	---	---	3	<0.01	<0.01	1	<0.01	0.00	0	---	---
12	0	---	---	0	---	---	1	<0.01	<0.01	0	---	---	0	---	---
Total	571	1.00		358	1.00		784	1.00		889	1.00		957	1.00	

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Age	1991[e] 7-9 August n	p	SE	1992[e] 4-6 August n	p	SE	1993[e] 3-5 August n	p	SE	1994[e] 9-11 August n	p	SE
1	8	0.01	<0.01	1	0.01	<0.01	0	---	---	3	0.01	0.01
2	393	0.53	0.02	319	0.39	0.02	213	0.33	0.02	33	0.11	0.02
3	72	0.10	0.02	199	0.24	0.02	288	0.45	0.02	90	0.33	0.03
4	186	0.25	0.02	81	0.10	0.02	68	0.11	0.01	107	0.39	0.03
5	27	0.04	0.01	179	0.22	0.02	19	0.03	0.01	14	0.05	0.01
6	18	0.02	<0.01	23	0.03	0.02	43	0.07	0.01	10	0.04	0.01
7	27	0.03	0.01	12	0.01	<0.01	4	0.01	<0.01	9	0.03	0.01
8	13	0.02	0.01	9	0.01	<0.01	3	<0.01	<0.01	0	0.00	0.00
9	5	0.01	<0.01	1	<0.01	<0.01	2	<0.01	<0.01	5	0.02	0.01
10	2	<0.01	<0.01	3	<0.01	<0.01	4	0.01	<0.01	3	0.01	0.01
11	0	---	---	1	<0.01	<0.01	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---
Total	751	1.00		828	1.00		644	1.00		274	1.00	

[a] Data sources and gear type: 1955 - 1956 (hook and line (H&L); Warner 1957); 1957 (H&L; Warner 1958); 1958 (seine; Warner 1959a); 1969 (electrofishing boat (EB); Roguski and Tack 1970); 1973 - 1974 (EB; Tack 1973; 1974); 1975 - 1980 (EB; Peckham 1976; 1977; 1978; 1979; 1980; 1981); 1982 - 1984 (EB; Ridder 1983; 1985); 1985 (EB; Holmes et al. 1986); 1986 - 1987 (EB; Clark and Ridder 1987; 1988); 1988 (EB, Ridder 1989); 1989 (EB; Clark and Ridder 1990); 1990 (EB; Clark et al. 1991); 1991 (EB; Fleming et al. 1992); 1992 (EB; Ridder et al. 1993); 1993 (EB; Roach 1994); and, 1994 (present report).

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

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

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

Appendix C3.-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	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 section - electrofishing boat; upper section - 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 C4.-Estimated age composition[a] for Arctic grayling within the 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		277	1	

[a] Age proportions estimated from three river sections were combined using estimated abundance from each section as a weighting factor (Tack 1974; 1975).

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

[e] ND = no data in citation.

Appendix C5.-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	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 C6.-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			1985			1986			1987					
	15-16 May			22-23 May			16-17 May			12-13 May			Total		
Age	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 C7.-Summary of mean length at age data for Arctic grayling sampled in the Goodpaster River, summer, 1969 - 1994[a].

	1969			1973			1975			1976			1977		
	summer			15 Jun-15 Aug			23-24 June			21-22 June			21-22 June		
Age	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			1979			1980			1982			1984		
	21-22 June			25-28 June			24-25 June			29-30 June			27-28 June		
Age	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	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	0	---	---	6	166	17	1	155	---	0	---	---
2	3	160	6	56	164	15	80	164	9	55	183	15	144	187	13	364	171	11
3	44	190	12	27	208	10	360	193	19	51	206	14	58	221	14	165	220	14
4	33	224	14	22	236	14	26	235	15	165	233	13	86	243	16	37	253	17
5	79	245	19	69	253	17	37	261	12	9	264	15	317	268	17	104	277	19
6	25	269	20	18	284	13	56	281	22	22	276	14	34	296	17	134	296	18
7	16	284	21	15	292	20	8	305	23	32	288	17	67	307	20	44	315	19
8	4	323	25	1	295	---	2	301	8	12	296	17	45	321	22	29	332	17
9	0	---	---	0	---	---	2	387	27	5	341	34	20	336	33	7	354	19
10	0	---	---	0	---	---	0	---	---	1	311	---	8	352	15	4	384	21
11	0	---	---	0	---	---	0	---	---	0	---	---	3	376	33	1	378	---
12	0	---	---	0	---	---	0	---	---	0	---	---	1	391	---	0	---	---
Total	204	236	37	208	227	47	571	211	72	358	233	38	784	254	46	889	230	59

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	1990[f] 8-10 August			1991[f] 7-9 August			1992[f] 4-6 August			1993[f] 3-5 August			1994[f] 9-11 August		
Age	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	46	156	5	8	163	12	1	152	---	0	---	---	3	153	1
2	79	182	11	393	189	11	319	176	12	213	176	11	33	189	11
3	562	214	15	72	217	14	199	224	17	288	214	15	90	222	12
4	94	252	20	186	245	15	81	256	17	68	252	19	107	253	16
5	36	278	23	27	276	14	179	273	15	19	281	19	14	295	15
6	55	297	26	18	294	21	23	308	24	43	295	24	10	303	16
7	60	311	24	27	313	18	12	318	28	4	275	35	9	319	17
8	13	321	28	13	328	27	9	339	26	3	313	12	0	---	---
9	8	345	18	5	348	19	1	318	---	2	350	8	5	360	23
10	4	365	57	2	386	4	3	383	6	4	351	10	3	363	35
11	0	---	---	0	---	---	1	392	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	957	228	45	751	220	43	828	225	48	828	225	48	274	246	

[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 (EB; Ridder 1989); 1989 (EB; Clark and Ridder 1990); 1990 (EB; Clark et al. 1991); 1991 (EB; Fleming et al. 1992); 1992 (EB; Ridder et al. 1993); 1993 (EB; Roach 1994); and, 1994 (EB; present report).

[b] n = sample size.

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

[d] SD = sample standard deviation of FL.

[e] ND = no data in citation.

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

Appendix C8.-Summary of mean length at age data for 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		
Age	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD
1	2	96	11	0	---	---	0	---	---	0	---	---
2	4	137	21	0	---	---	9	133	23	4	183	12
3	26	195	9	11	193	9	67	175	20	2	160	10
4	30	217	10	32	224	15	31	221	15	49	224	21
5	29	262	20	136	250	21	34	252	16	11	280	21
6	45	293	31	53	279	17	92	276	21	28	303	21
7	29	311	36	85	301	28	48	305	18	72	328	22
8	33	337	29	25	323	21	32	317	22	53	338	27
9	16	349	24	31	355	23	10	378	25	45	363	21
10	7	368	24	10	365	28	5	385	25	16	379	23
11	1	383	---	7	381	16	2	405	24	15	393	20
12	0	---	---	0	---	---	3	414	26	3	418	10
13	0	---	---	0	---	---	2	416	14	2	371	4
14	0	---	---	0	---	---	0	---	--	1	472	---
Total	222	278	63	390	280	48	335	259	64	301	320	59

[a] All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al. 1986) and are from office files.

[b] n = sample size.

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

[d] SD = sample standard deviation of FL.

Appendix C9.-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	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	8	276	11	2	304	49	0	---	---	1	339	---	11	286	30
6	21	298	35	7	291	17	21	292	19	15	308	24	64	297	27
7	16	311	42	19	321	30	19	313	17	49	332	22	103	323	28
8	26	337	30	5	329	13	14	318	18	36	344	28	81	336	28
9	11	351	24	11	360	21	4	361	22	37	364	21	63	361	22
10	7	368	24	4	379	35	4	385	23	12	383	25	27	379	27
11	1	383	---	2	394	7	2	405	24	12	390	20	17	391	20
12	0	---	---	0	---	---	3	414	26	3	418	10	6	416	20
13	0	---	---	0	---	---	2	416	14	2	371	4	4	393	25
14	0	---	---	0	---	---	0	---	---	1	472	---	1	472	---
Total	90	322	41	50	333	39	69	325	42	168	350	36	377	337	41

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

[b] n = sample size.

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

[d] SD = sample standard deviation of FL.

Appendix C10.-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			1985			1986			1987					
	15-16 May			22-23 May			16-17 May			12-13 May			Total		
Age	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	6	280	11	1	248	---	1	253	---	1	296	---	9	275	17
6	20	296	24	18	283	18	22	287	22	7	298	9	67	290	21
7	13	310	25	43	301	26	24	302	16	19	320	19	99	306	24
8	7	334	23	18	322	23	18	317	24	16	326	19	59	323	23
9	5	345	25	20	352	24	6	344	24	8	360	22	39	351	24
10	0	---	---	6	356	17	1	351	---	4	367	13	11	360	16
11	0	---	---	5	376	16	0	---	---	3	405	12	8	387	20
Total	51	307	30	111	316	37	72	304	27	58	333	33	292	313	34

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

[b] n = sample size.

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

[d] SD = sample standard deviation of FL.

Appendix C11.-Summary of estimated RSD categories for Arctic grayling (≥ 150 mm FL) within the lower Goodpaster River by year[a].

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

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Year		RSD Category[b] Stock	Quality	Preferred	Memorable	Trophy
1982	Number	112	102	37	0	0
May	RSD	0.45	0.41	0.15	---	---
	SE	0.03	0.03	0.02	---	---
1982	Number	314	11	0	0	0
Jun	RSD	0.97	0.03	---	---	---
	SE	0.01	0.01	---	---	---
1984	Number	443	39	0	0	0
Jun	RSD	0.92	0.08	---	---	---
	SE	0.01	0.01	---	---	---
1985	Number	217	210	80	0	0
May	RSD	0.43	0.41	0.16	---	---
	SE	0.02	0.02	0.02	---	---
1985	Number	169	35	1	0	0
Jun	RSD	0.82	0.17	0.01	---	---
	SE	0.03	0.03	0.01	---	---
1985	Number	322	60	0	0	0
Aug	RSD	0.84	0.16	---	---	---
	SE	0.02	0.02	---	---	---
1986	Number	167	151	28	0	0
May	RSD	0.48	0.44	0.08	---	---
	SE	0.03	0.03	0.02	---	---
1986	Number	560	80	6	0	0
Aug	RSD	0.87	0.12	0.01	---	---
	SE	0.01	0.01	<0.01	---	---
1987	Number	58	128	130	1	0
May	RSD	0.18	0.4	0.41	<0.01	---
	SE	0.02	0.03	0.03	<0.01	---
1987	Number	290	66	2	0	0
Aug	RSD	0.81	0.18	0.01	---	---
	SE	0.02	0.02	<0.01	---	---

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Year		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1988	Number	1,213	725	73	0	0
Aug	RSD	0.6	0.36	0.04	---	---
	SE	0.01	0.01	<0.01	---	---
1989	Number	1,239	515	62	0	0
Aug	RSD[c]	0.78	0.2	0.02		
	SE	0.02	0.02	<0.01	---	---
1990	Number	1,234	244	46	0	0
Aug	RSD[c]	0.84	0.14	0.02		
	SE	0.02	0.02	<0.01	---	---
1991	Number	686	90	11	0	0
Aug	RSD	0.87	0.12	0.01	---	---
	SE	0.01	0.01	<0.01	---	---
1992	Number	454	97	11	0	0
Aug	RSD	0.81	0.17	0.02	---	---
	SE	0.02	0.02	0.01	---	---
1993	Number	809	71	9	0	0
Aug	RSD	0.91	0.08	0.01	---	---
	SE	0.01	0.01	<0.01	---	---
1994	Number	771	165	26	0	0
Aug	RSD	0.80	0.18	0.02	---	---
	SE	0.01	0.01	<0.01	---	---

[a] Data Sources: 1955-1956 (Warner 1957); 1970 and 1972 (Tack 1971; 1973); June 1975-1982: (Peckham 1976, 1977, 1978, 1979, 1983); 1984 (Ridder 1985); May 1982, 1985, 1986, May 1987, (office files); August 1987 (Clark and Ridder 1988); 1988 (Ridder 1989); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994) and, 1994 (present report).

[b] Minimum lengths (FL) for RSD categories were (adapted from Gabelhouse 1984): stock (150 -269 mm FL); quality (270 -339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

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

[d] Standard error of the adjusted RSD.

Appendix C12.-Summary of estimated RSD categories for Arctic grayling (≥ 150 mm FL) within the lower 16 km of the Goodpaster River in the spring by year.

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

[a] Minimum lengths (FL) for RSD categories were (adapted from Gabelhouse 1984): stock (150 - 269 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

Appendix C13.-Summary of estimated RSD categories for Arctic grayling (≥ 150 mm FL) within the lower 16 km of the Goodpaster River in the spring by sex and year.

Year		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Males:					
	Number	10	51	30	0	0
	RSD	0.11	0.56	0.33	---	---
	Standard	0.03	0.05	0.05	---	---
1982	Females:					
	Number	7	48	7	0	0
	RSD	0.11	0.77	0.11	---	---
	Standard	0.04	0.05	0.04	---	---
1985	Males:					
	Number	4	39	44	0	0
	RSD	0.05	0.45	0.51	---	---
	Standard	0.02	0.05	0.05	---	---
1985	Females:					
	Number	16	102	36	0	0
	RSD	0.1	0.66	0.23	---	---
	Standard	0.03	0.04	0.03	---	---
1986	Males:					
	Number	2	56	20	0	0
	RSD	0.03	0.72	0.26	---	---
	Standard	0.02	0.05	0.05	---	---
1986	Females:					
	Number	7	66	8	0	0
	RSD	0.09	0.82	0.1	---	---
	Standard	0.03	0.04	0.03	---	---
1987	Males:					
	Number	1	68	110	1	0
	RSD	0.01	0.38	0.61	0.01	---
	Standard	0.01	0.04	0.04	0.01	---
1987	Females:					
	Number	0	40	20	0	0
	RSD	---	0.67	0.33	---	---
	Standard	---	0.06	0.06	---	---
Total	Males:					
	Number	17	214	204	1	0
	RSD	0.04	0.49	0.47	<0.01	---
	Standard	0.01	0.02	0.02	<0.01	---
Total	Females:					
	Number	30	256	71	0	0
	RSD	0.08	0.72	0.2	---	---
	Standard	0.02	0.02	0.02	---	---

[a] Minimum lengths (FL) for RSD categories were (adapted from Gabelhouse 1984): stock (150 - 269 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

Appendix C14.-Estimated Arctic grayling abundance, harvest, and exploitation for the Goodpaster River by year.

Year	Month	Abundance[a]		Harvest	Exploitation[b]	
		0-53km	0-152km		0-53 km	0-152 km
1972	JUNE	10,017	20,034	NDc	---	---
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	0.07
1986	AUGUST	16,165	32,330	1,508	0.09	0.05
1987	AUGUST	7,102	14,204	1,702	0.19	0.11
1988	AUGUST	8,374	16,748	1,273	0.13	0.07
1989	AUGUST	8,033	16,066	1,964	0.20	0.11
1990	AUGUST	7,113	14,226	760	0.10	0.05
1991	AUGUST	7,836	15,672	636	0.08	0.04
1992	AUGUST	6,886	15,304	766	0.10	0.05
1993	AUGUST	10,841	21,682	588	0.05	0.03
1994	AUGUST	7,573	15,146	ND	---	---
Average		14,555	29,110	1,705	0.10	0.05

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

[b] Exploitation rate is harvest divided by abundance. Harvests were added to estimated abundance to give an approximation of abundance at the start of season prior to calculating exploitation rates

[c] ND = no data.

APPENDIX D

Equations and Statistical Methodology

Appendix D1.-Methodology to compensate for bias due to unequal catchability by river section.

Case	Result of χ^2 Test[a]	Inspection of Fish Movement[b]	Inferred Cause
I[c]	Fail to reject H_o	No movement between sections	There is no differential capture probability by river section or marked fish completely mixed with unmarked fish within each river section.
II[d]	Fail to reject H_o	Movement between sections	There is no differential capture probability by river section or marked fish completely mixed with unmarked fish across river sections.
III[e]	Reject H_o	No movement between sections	There is differential capture probability by river section or marked fish did not mix completely with unmarked fish within at least one river section.
IV[f]	Reject H_o	Movement between sections	Inferred cause: There is differential capture probability by river section or marked fish did not mix completely with unmarked fish across river sections.

[a] The chi-squared test compares the frequency of marked fish recaptured during the second event in each river section with the frequency of unmarked fish examined in the second event in each river section. H_o for this test is: capture probability of marked fish in the second event is the same in all river sections.

[b] Inspection of fish movement is a visual comparison of the frequency of marked fish recaptured in the second event that moved from one river section to another with the frequency of unmarked fish examined in the second event in each river section.

[c] Case I: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator.

[d] Case II: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator and calculate one unstratified abundance estimate using the "movement" (Evenson 1988) estimator. If estimates are dissimilar, discard the Bailey estimate and use the movement estimate as the estimate of abundance. If estimates are similar, discard the movement estimate and use the Bailey estimate as the estimate of abundance.

[e] Case III: Completely stratify the experiment by river section, calculate abundance estimates for each using the Bailey (1951, 1952) estimator, and sum abundance estimates.

[f] Case IV: Completely stratify the experiment by river section. Calculate abundance estimates for each using the Bailey (1951, 1952) estimator and sum estimates. If movement out of the sample area is neither probable nor possible, calculate abundance with the partially stratified model of Darroch (1961) and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the Darroch estimate as the estimate of abundance. If estimates are similar, discard the estimate with the largest variance. If movement out of the sample area is probable, calculate abundance with the movement (Evenson 1988) estimator and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the movement estimate as the estimate of abundance (note: this estimate will be biased). If estimates are similar, discard the movement estimate and proceed as if movement were neither probable nor possible.

Appendix D2.-Methodology to compensate for bias due to gear selectivity by means of statistical inference.

Case	Result of First K-S Test	Result of second K-S test[b]	Inferred Cause
I[c]	Fail to reject H_o	Fail to reject H_o	There is no size-selectivity during either sampling event.
II[d]	Fail to reject H_o	Reject H_o	There is no size-selectivity during the second sampling event, but there is during the first sampling event.
III[e]	Reject H_o	Fail to reject H_o	There is size-selectivity during both sampling events.
IV[f]	Reject H_o	Reject H_o	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_o 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_o 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 events for size and age composition estimates.

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

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

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

Case IVa: If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

Case IVb: If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

Appendix D3.-Equations used to estimate abundance and variance.

Abundance ($\hat{N}$)and Variance of Abundance($\hat{V}[\hat{N}]$)

Bailey (1951,1952) estimate of abundance as modified by Seber (1982):

$$\hat{N} = \frac{M(C + 1)}{R + 1} \qquad \text{(D3.1)}$$

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,
- $\hat{N}$ = estimated abundance of Arctic grayling during the first sample.

Variance estimated by (Seber 1982):

$$\hat{V}[\hat{N}] = \frac{M^2(C + 1)(C - R)}{(R + 1)^2(R + 2)}. \qquad \text{(D3.2)}$$

Bailey (1951, 1952) estimate of abundance as modified by Evenson (1988)for movement out of the study area:

$$\hat{N} = \frac{\left[M_1\left(1-\hat{\theta}_d\right)+M_2+M_3\left(1-\hat{\theta}_u\right)\right]\left[C+1\right]}{R_{oo}+1} \qquad \text{(D3.3)}$$

where:
- M_x = the number of Arctic grayling marked and released alive during the first sample in section x; downstream section (x = 1), midstream section (x = 2), or upstream section (x =3);
- $\hat{\theta}_d$ = the probability that a fish will move out of an area in the *z* direction (<u>u</u>pstream or <u>d</u>ownstream);
- C = the number of Arctic grayling examined for marks during the second sample;
- R_{oo} = the number of fish recaptured during the second event; and,
- $\hat{N}$ = the abundance of fish in <u>all</u> sections at the start of the second event.

-continued-

Abundance ($\hat{N}$)and Variance of Abundance($\hat{V}[\hat{N}]$)

The probabilities of movements were estimated as:

$$\hat{\theta}_d = \frac{M_2(R_{32} + R_{21})}{R_{2o}(M_3 + M_2)}, \text{ and} \quad \text{(D3.4)}$$

$$\hat{\theta}_u = \frac{M_2(R_{12} + R_{23})}{R_{2o}(M_1 + M_2)} \quad \text{(D3.5)}$$

where:

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

R_{2o} = the number of fish that were marked in the midstream section during the first event and were recaptured during the second event.

Appendix D4.-Equations used to estimate age and length compositions when no adjustments were needed and when adjustments were needed to compensate for bias due to differential capture probability by size of fish or river section.

Proportions by Length or Age ($\hat{p}_k$)and Variance of Proportions ($\hat{V}[\hat{p}_k]$)

Proportion and variance estimator used when no adjustments were needed:

$$\hat{p}_k = \frac{x_k}{n}, \text{ and} \tag{D4.1}$$

$$\hat{V}[\hat{p}_k] = \frac{p_k(1 - p_k)}{n - 1} \tag{D4.2}$$

where: $\hat{p}_k$ = the proportion of fish that are age or size *k*;

x_k = the number of fish sampled that are age or size *k*; and,

n = the number of fish sampled that were aged or measured.

Proportion and variance estimator used when adjustments were needed:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik}, \text{ and} \tag{D4.3}$$

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}}\right)^2 \hat{V}[\hat{p}_{ik}] \tag{D4.4}$$

where: $\hat{N}_i$ = the abundance of Arctic grayling in stratum *i*;

$\hat{N}$ = total abundance; and,

$\hat{p}_{ik}$ = the proportion of fish in stratum *i* that were age or size *k*.

APPENDIX E

Data File Listing

Appendix E1.-Data files used to estimate parameters of Arctic grayling populations in the Salcha, Chatanika, and Goodpaster rivers, 1994.

Data file[a]	Description
U005ALA4.DTA	Population and marking data for Arctic grayling captured during the first marking event at the Salcha River, 13 through 14 June 1994.
U005BLA4.DTA	Population and marking data for Arctic grayling captured during the second marking event at the Salcha River, 15 through 16 June 1993.
U005CLA4.DTA	Population and marking data for Arctic grayling captured during the recapture event at the Salcha River, 29 through 30 June 1993.
U004BLC4.DTA	Population and marking data for Arctic grayling captured during the marking event at the Middle Chatanika River, 15 through 17 August 1994.
U004ALD4.DTA	Population and marking data for Arctic grayling captured during the recapture event at the Middle Chatanika River, 22 through 24 August 1994.
U0080LA4.DTA	Population and marking data for Arctic grayling captured during the marking event at the Goodpaster River, 2 through 4 August 1994.
U0080LB4.DTA	Population and marking data for Arctic grayling captured during the recapture event at the Goodpaster River, 9 through 11 August 1994

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