Fishery Data Series No. 98-36

Abundance, composition, and emigration of Arctic grayling in the Goodpaster River, 1995-1997

by

William P. Ridder

December 1998

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

FISHERY DATA SERIES NO. 98-36

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by

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ABSTRACT

Mark-recapture experiments were conducted in the Goodpaster River over a six day period soon after ice-out in early May of 1995 – 1997 to estimate abundance, composition, and post-spawning emigration of Arctic grayling, *Thymallus arcticus*. Study area encompassed the lower 70 miles in 1995 and the lower 33 miles in 1996 and 1997. Over the three years, 8,025 Arctic grayling were captured. Estimated abundance of Arctic grayling ≥230 mm FL in 1995 was 23,194 fish (SE = 3,257) in the 70 mile reach and 13,445 fish (SE = 1,445) in the 33 mile reach. Estimated abundance in 1996 was 25,364 fish (SE = 3,093) ≥150 mm FL and 12,893 fish ≥230 mm FL (SE = 1,839) in 1997. In all years, quality-sized and larger fish (≥270 mm FL) predominated as did the 1990 year class. Age 6 and older fish comprised the majority of yearly age compositions. Relative contribution rates based on tag recoveries of these fish the following July in the Delta Clearwater River ranged from 22% (SE 5%) to 34% (SE 6%) in three length groups over the three years of estimates.

Key words: Arctic grayling, *Thymallus arcticus*, spawning, abundance, age composition, size composition, movements, emigration, contribution rates, Goodpaster River, Delta Clearwater River, Richardson Clearwater River, Tanana River drainage.

INTRODUCTION

Seasonal migrations and stratified summer populations are common in riverine Arctic grayling populations (Tack 1980, Northcote 1995) and must be considered in setting programs and policy. The most extensive migrations occur in fall with fish moving to overwintering areas and again in the spring when fish move to spawning areas before dispersing to summer feeding areas. The migrations can be simple, from point A to point B within a river, or complex involving tributaries of one or more drainages (Ridder 1991). These latter migrations can result in mixed stock populations in waters supporting popular summer fisheries (Reed 1961). Designing management programs and setting regulatory policy for such fisheries without quantifiable knowledge of migrations, the number of stocks involved, and their respective recruitment, may result in a loss of opportunity for anglers or over exploitation of the stocks. In 1995, a three year program was begun to investigate the movements and contributions of Goodpaster River (GPR) spawners to the Delta Clearwater River (DCR) harvest. The DCR is a major Arctic graying fishery in interior Alaska.

BACKGROUND

The DCR is a 21 mi long spring-fed system located 110 mi southeast of Fairbanks and 14 mi northeast of Delta Junction in the middle Tanana River drainage (Figure 1). It is the largest of a number of spring-fed systems that support Arctic grayling that enter the Tanana River and the only one that is road-accessible. These spring-fed systems provide quality summer feeding habitat for Arctic grayling that neither spawn or overwinter there (Reed 1961, Tack 1980, Ridder 1991). The DCR's Arctic grayling fishery is unique among the major road accessible fisheries in the Interior because it is a mixed stock fishery. Immigration to the DCR begins in April with juvenile fish, followed by adults, and lasts into June. Emigration begins in August and is complete by December.

Since 1953, the river has offered a popular Arctic grayling fishery known for its high catch rates, the largest fish in the Tanana drainage, and pristine water quality. Adult fish of ages 5 and older have predominated in the harvest. Historical harvests of Arctic

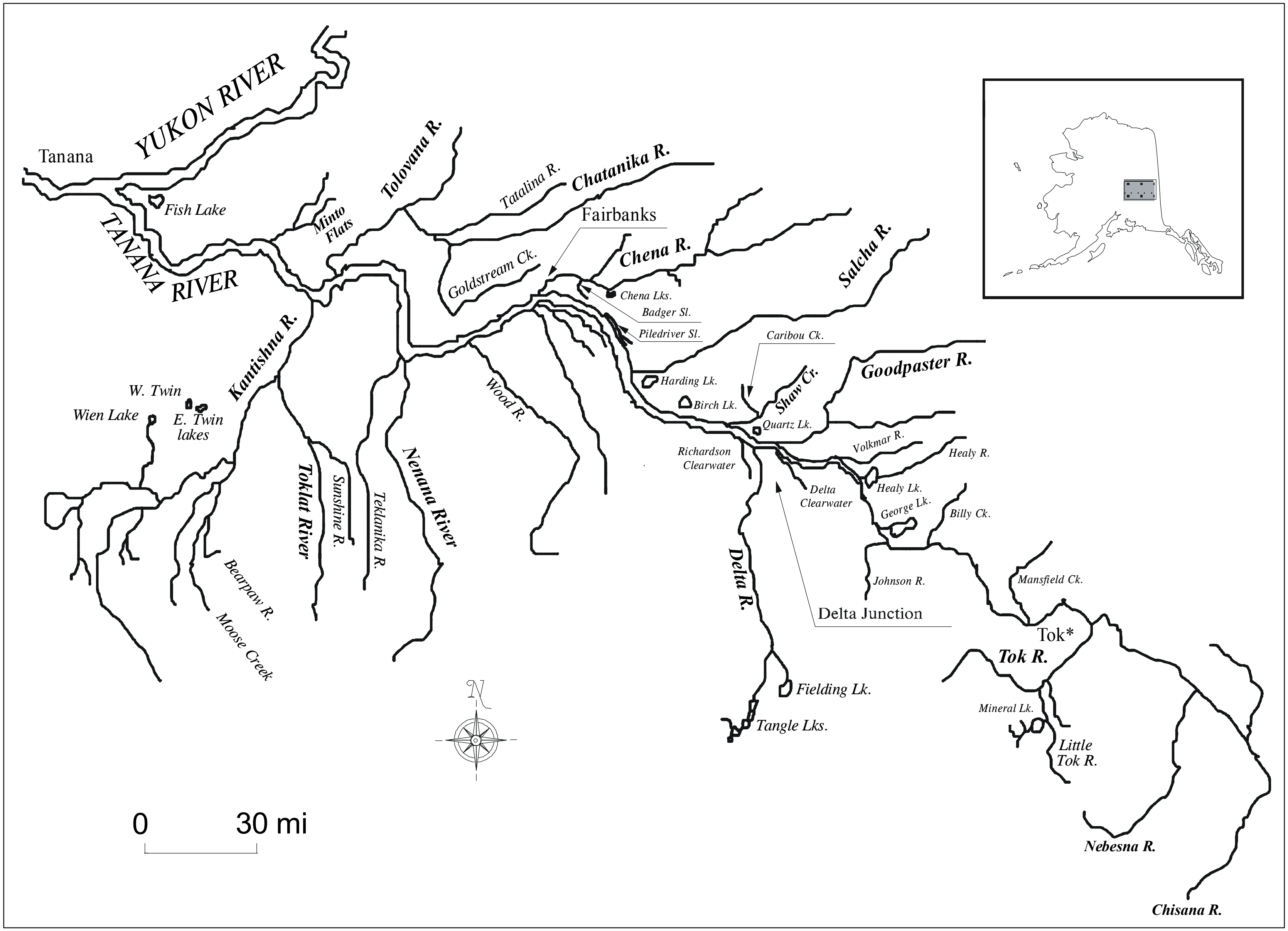


Figure 1.-The Tanana River drainage.

grayling in the DCR have ranked in the top five Arctic grayling fisheries in the Tanana drainage. Average annual harvests prior to 1987 exceeded 5,000 fish but have since fallen to 30 fish through 1997 (Table 1). A drainage wide decline in abundance indices led to restrictive regulations enacted in 1987 for the DCR and some other drainage fisheries. Regulations included the imposition of a catch and release season until the first Saturday in June, a 12 in TL minimum size limit, a no bait restriction, and a five fish daily bag and possession limit (limits were 10 fish daily and 20 fish in possession prior to 1977 and five and 10, respectively, through 1986). Results from catch-age modeling of the fishery from 1977-1990 showed population declines with exploitation rates averaging 34%; these results led to further restrictions to the fishery (Clark and Ridder 1994). A two fish bag and possession limit was imposed in July of 1995 through 1996 and the fishery became catch and release in June of 1997.

The GPR is the largest of eight spawning streams for the Arctic grayling population in the DCR and thus its largest recruitment source (Ridder 1983, 1985, and *In press*). Spawners in the GPR also feed in the Richardson Clearwater, Tanana, and Salcha rivers and Clear Creek during summer (Ridder 1991). While the proportion of GPR spawners that feed in these streams during summer is unknown, the respective fisheries, excepting the Salcha River, are small. As in the DCR (see below), harvest and abundance of Arctic grayling in the GPR are at historical lows. The fishery in the GPR, which predominantly targets fish less than 12 in TL in the lower 33 mi (50 km) of the river (Tack 1974), had an average yearly harvest of 1,221 Arctic grayling from 1983 through 1997 but harvest declined to 325 Arctic grayling in 1995. The fishery is under no season or size restrictions and operates under general regulations with a five fish daily bag and possession limit. From 1977 to 1986, Arctic grayling abundance in the lower 33 mi of the river averaged 576 fish ≥ 150 mm FL per mi (360 fish per km) versus 253 fish ≥ 150 mm FL per mi (158 fish per km) from 1987 to 1994 (Roach 1995).

Recaptures of GPR spawners in other rivers have been dependent on when the fish were tagged and at what size. Tagging in the GPR generally occurred in two time periods: during spawning in May (1982, 1985-1987) and during summer feeding in August (1988-1994). The large-sized fish tagged during spawning in May were recaptured in higher proportions in the DCR than the smaller fish tagged in August (Ridder 1991). Fish tagged in the GPR in May were recovered in the DCR in higher proportions (17%) than fish tagged in August (0-5%; unpublished data). Given these data, and the predominantly adult population present in the DCR, the focus of this study was on the GPR population during spawning in May.

OBJECTIVES

The research objectives for 1995 were to estimate:

1. the May abundance of Arctic grayling (≥150 mm FL) in the lower 60 mi (96 km) of the Goodpaster River and lower 10 mi (16 km) of the South Fork of the Goodpaster River;

Table 1.-Estimates of effort and harvest for Arctic grayling in the Delta Clearwater and Goodpaster rivers from the Statewide Harvest Survey, 1977-1997 (Mills 1978-1994; Howe et al. 1995-1998).

	Delta Clearwater River			Goodpaster River		
Year	Angler days[a]	Harvest	Catch	Angler days	Harvest	Catch
1977	6,881	6,118	nd[b]	nd	nd	nd
1978	7,210	7,657	nd	nd	nd	nd
1979	8,398	6,492	nd	nd	nd	nd
1980	4,240	5,680	nd	nd	nd	nd
1981	4,673	7,362	nd	nd	nd	nd
1982	4,231	4,779	nd	nd	nd	nd
1983	5,867	6,546	nd	1,989	3,021	nd
1984	5,139	4,193	nd	766	1,194	nd
1985	8,722	5,809	nd	2,844	2,757	nd
1986	10,137	2,343	nd	933	1,508	nd
1987	5,397	2,005	nd	3,061	1,702	nd
1988	5,184	2,910	nd	1,037	1,273	nd
1989	5,368	3,016	nd	1,930	1,964	nd
1990	4,853	1,772	12,424	2,083	760	2,083
1991	5,594	2,165	7,998	786	636	786
1992	3,756	797	6,086	1,430	766	1,430
1993	4,909	437	5,712	1,162	588	1,162
1994	3,984	1,411	9,306	825	700	825
1995	6,261	926	5,974	2,028	325	2,028
1996	4,622	957	9,448	1,737	595	1,737
1997	2,925	30	4,665	2,996	532	2,996
Averages: All	5,636	3,495	7,702	1,707	1,221	1,631
1995-1997	4,603	638	6,696	2,254	484	2,254

[a] Angler days = effort for all species.

[b] nd = no data.

2. the age composition of Arctic grayling (≥150 mm FL) in the lower 60 mi (96 km) of the Goodpaster River and lower 10 mi (16 km) of the South Fork of the Goodpaster River;
3. the size composition of Arctic grayling (≥150 mm FL) in the lower 60 mi (96 km) of the Goodpaster River and lower 10 mi (16 km) of the South Fork of the Goodpaster River; and,
4. the relative contribution of Arctic grayling (≥150 mm FL) that were marked and released in the lower 60 mi (96 km) of the Goodpaster River and lower 10 mi (16 km) of the South Fork of the Goodpaster River during May and recovered in the Delta Clearwater River in May and June.

The study area of the GPR and the timing of DCR sampling were changed for the 1996 and 1997 research objectives based on 1995 sampling results. The 1996 and 1997 research objectives were to estimate:

1. the May abundance of Arctic grayling (≥150 mm FL) in the lower 33 mi (53 km) of the Goodpaster River;
2. the age composition of Arctic grayling (≥150 mm FL) in the lower 33 mi (53 km) of the Goodpaster River;
3. the size composition of Arctic grayling (≥150 mm FL) in the lower 33 mi (53 km) of the Goodpaster River; and,
4. the relative contribution of Arctic grayling (≥150 mm FL) that were marked and released in the lower 33 mi (53 km) of the Goodpaster River during May and recovered in the Delta Clearwater River in July.

In addition to these objectives, sampling was conducted in late July and early August 1995 and 1996 in the Goodpaster and Richardson Clearwater rivers to estimate the relative contribution of the May (spawning) population of the Goodpaster River to these populations.

METHODS

Arctic grayling were sampled with an electrofishing boat in the Goodpaster River over a six to seven day period in May of 1995-1997 and in a three day period in early August 1995-1996. In each year, the May sampling occurred within eight days of initial ice break-up and within one to two days of complete ice-out (Appendix A1-A3). The August sampling coincided with past assessment programs. The timing of the May sampling is critical since Arctic grayling commence spawning at temperatures of 4 C° (Tack 1980), water temperatures can rise rapidly after ice-out (Appendix A2), and occupation of spawning sites can range from four to 18 days depending on water temperatures (Tack, 1980; Ridder 1985; Beauchamp 1990).

The May 1995 study area (Figure 2) encompassed approximately 70 river mi (112 km) and included three physically different but contiguous sections of the river: the 33 mi (52.8 km) of the mainstem from the mouth upstream to the confluence of the North and

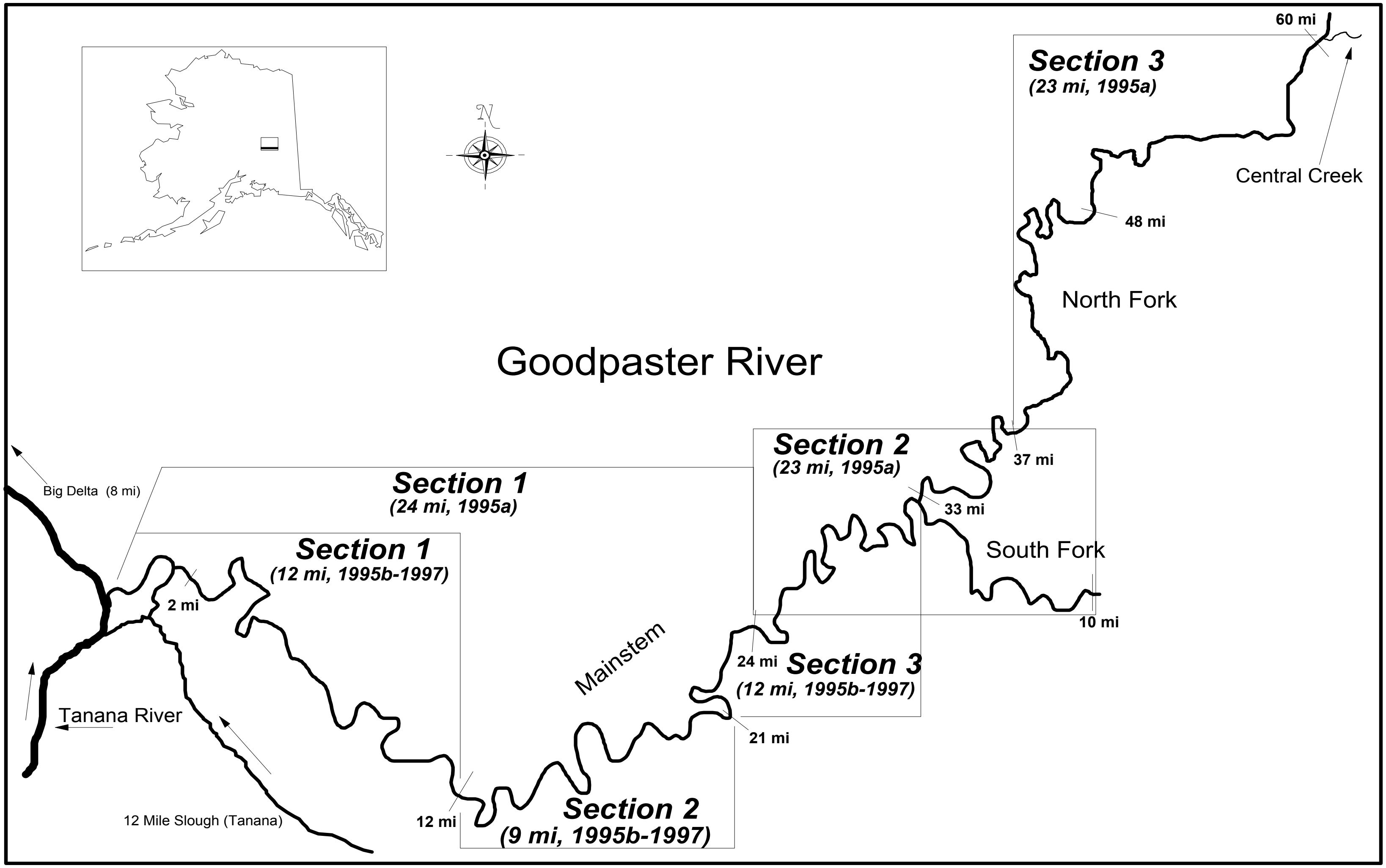


Figure 2.-The Goodpaster River study area, 1995-1997.

South forks (the same study section as in prior August stock assessments), the lower 27 mi (43.2 km) of the North Fork from the forks upstream to Central Creek (the normal limit of jet boat access), and the lower 10 mi (16 km) of the South Fork from the forks upstream. Based on results of the 1995 sampling, the study area was reduced to include only the 33 mi mainstem in May 1996 and 1997. To accommodate this reduction, two sets of parameter estimates were produced for 1995: 1995a represents the 70 mi reach while 1995b represents only the mainstem (33 mi). The August samples also came from the mainstem.

While two pulsed-DC electrofishing boats were used in the May 1995 sampling of the GPR, only one boat sampled each section. The mainstem and North Fork sections were sampled concurrently followed by the South Fork. During all other sampling, one boat was used. Sampling during each event began at the upstream end of a section and proceeded downstream in approximately 20 min intervals hereafter referred to as runs. During the spawning period, these habitats were associated with riffle areas. At the end of each run, approximately equal to 1.4 mi of river, all captured fish $\geq$150 mm FL were sampled for age and length as described below, finclipped, tagged, and released. For the August sample, fish were sampled only for length and tag recaptures.

The electrofishing boat had a crew of three; two captured fish with dip nets and one piloted the boat and operated the electrofishing gear. The boat was equipped with a pulsed DC variable voltage pulsator (Coffelt Model VVP-15) powered by a 3,500 watt single phase gasoline generator. Anodes consisted of four 15 mm diameter steel cables (1.5 m long) spaced 1 m apart and arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the boat served as the cathode. Settings on the pulsator were set at 50% duty cycle and 60Hz. While amperage at a given voltage varied due to conductivity, substrate, and water depth, the boat operator attempted to keep amperage constant to minimize injury to fish. Voltage was adjusted (250 - 300 V) to keep output at between 2 to 4 amperes. Water conductivity during the 1995 experiment ranged from 65 μS on 4 May at river mile 33 to 74 μS on 8 May at river mile 28. No conductivity measurements were taken in 1996 or 1997.

In 1995, sampling in the DCR (Figure 3) for fish tagged and released in the GPR was with the pulsed-DC electrofishing boat and hook and line methods from 1 May through 15 June. The majority of the electrofishing was expended in the lower mile of the river while the majority of hook and line sampling was between miles 2 and 3. Samples were also taken during harvest surveys from 3 June through 29 July and during collections for a radio telemetry study from 19 through 27 July. In 1996 and 1997, the sampling occurred over the last two weeks of July in conjunction with a mark-recapture experiment and used hook and line gear exclusively (see Ridder 1998b). Recapture rates of GPR fish in 1995 were found to be biased by gear type, reach sampled, and timing. These biases were minimized by restricting samples to mid summer when inter-stream movements of Arctic grayling are minimal (Tack 1980) and by sampling the entire river with one gear type. All captured Arctic grayling were sampled as described below.

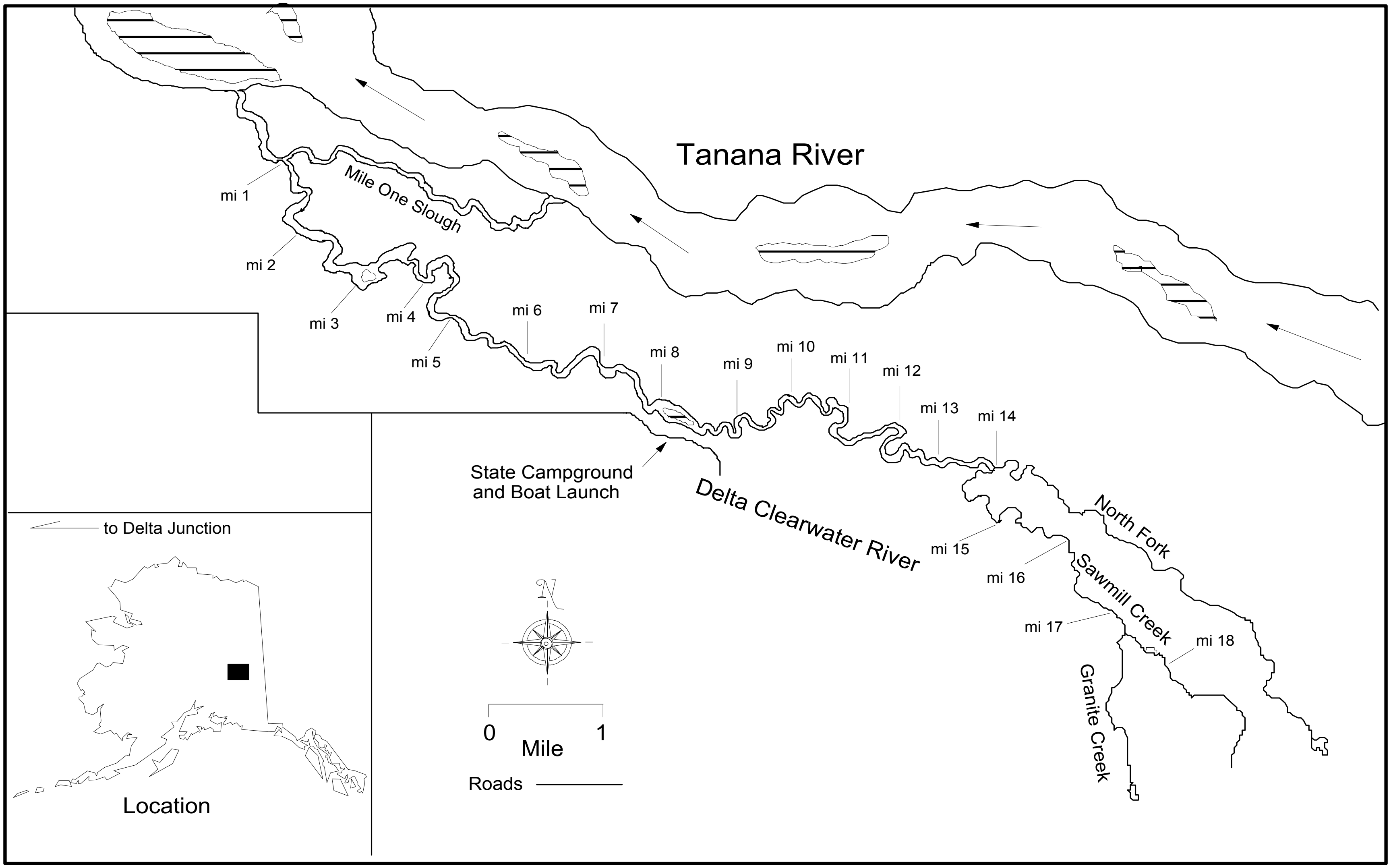


Figure 3.-The Delta Clearwater River study area, 1995-1997.

Sampling the lower 8 mi (13 km) of the Richardson Clearwater River for fish tagged and released in the GPR was accomplished with a pulsed-DC electrofishing boat 25 July 1995 and 1 August 1996. All captured Arctic grayling were sampled as described below.

In all waters, data on age, length, and sex (May GPR samples only) of captured Arctic grayling ≥150 mm FL, date and location of capture, finclips, tag numbers and colors, and fate of fish were recorded on optical scanning forms and transformed into an electronic (ASCII) data file for analysis and archival (see listing of data files in Appendix C1). All Arctic grayling ≥150 mm FL were measured to the nearest 1 mm FL, finclipped, and tagged with individually numbered Floy internal anchor tags (GPR May sampling and 1995 DCR sampling only). Sex was determined by sexual dimorphism and the extrusion of milt or eggs, or, in the case of "green" females, a swollen vent and abdomen. Dimorphism is evident in differences in length of the dorsal fin (in fish greater than 300 mm FL, the male dorsal fin usually extends to the adipose fin whereas the female dorsal fin is noticeably shorter; Wojcik 1955). Data on the state of maturity of females was also gathered. Female maturity was characterized into one of three stages: Green = few or no eggs extruded with slight pressure and a "full" abdomen; Ripe = eggs easily extruded; and, Spent = few or no eggs extruded and a flaccid abdomen. Age and size compositions of GPR fish as sampled in 1995-1997 and of DCR fish in 1995 are presented in Appendix A. Age and size compositions and abundance estimates for the 1996 and 1997 DCR samples can be found in Ridder 1998b.

ABUNDANCE ESTIMATION

The modified Peterson estimator of Bailey (1951, 1952) was used to estimate the May abundance in the GPR in 1995 and 1997. The modified Peterson estimator of Evenson (1988) was used in May 1996. Since movements and differential capture probabilities along the study reach can bias the estimate, the river was divided into three, nearly equal sections for each data set (Table 2; Figure 2).

The objective was to estimate abundance for fish ≥150 mm FL, the minimum length for age 3 Arctic grayling beginning their fourth growing season. This size category has been the target of studies of Arctic grayling in the Tanana drainage dating back to 1973 (Tack 1974) based upon the low end selectivity of boat-mounted electrofishing gear. However, in this study, the minimum length of recaptured fish determined the component of the population being estimated. The capture probability of Arctic grayling is dependent not only on the size selectivity of the sampling gear but also on the availability of the fish. Numerous authors have presented data noting the stratification of Arctic grayling by size and/or maturity that is dependent on time and place (Wojick 1955; Reed 1961; Tack 1980; Armstrong 1986; Ridder 1991; Northcote 1995).

The assumptions necessary for accurate estimation of absolute abundance in a closed population are as follows (taken from Seber 1982):

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

Table 2.-Summary of timing, reach, duration, marks, catch, recaptures, and capture probabilities for Arctic grayling in three sections of the Goodpaster River, May 1995-1997.

1995a:	Reach	Timing					Recaptures[b]				
Section (i)	(miles)	Mark	Catch	Hiatus	Mark[a]	Catch[a]	R_{i1}	R_{i2}	R_{i3}	ΣR_i	$\Sigma R_x/C$[c]
Upper	23	5/4-6	5/8, 5/10	3-4d	443	506	0	3	43	46	0.10
Middle	23	5/4, 5/6-7	5/7, 5/9-10	2-3d	535	425	1	51	2	54	0.13
Lower	24	5/4-6	5/7-9	3d	837	690	53	2	4	59	0.08
Totals	70	---	---	---	1,815	1,621	54	56	49	159	0.11

1995b:	Reach	Timing					Recaptures				
Section (i)	(miles)	Mark	Catch	Hiatus	Mark	Catch	R_{i1}	R_{i2}	R_{i3}	ΣR_i	$\Sigma R_x/C$
Upper	12	5/4	5/7	3d	398	220	0	2	23	25	0.10
Middle	9	5/5	5/8	3d	307	321	0	20	0	20	0.07
Lower	12	5/6	5/9	3d	563	398	30	2	0	32	0.08
Totals	33	---	---	---	1,268	939	30	24	23	77	0.08

1996:	Reach	Timing					Recaptures[d]				
Section (i)	(miles)	Mark	Catch	Hiatus	Mark	Catch	R_{i1}	R_{i2}	R_{i3}	ΣR_i	$\Sigma R_x/C$
Upper	12	5/10	5/13	3d	286	360	0	4	10	14	0.05
Middle	9	5/11	5/14-15	3d	500	463	5	25	7	37	0.07
Lower	12	5/12	5/15-16	3d	747	534	46	3	1	50	0.10
Totals	33	---	---	---	1,533	1,357	51	32	18	101	0.08

1997:	Reach	Timing					Recaptures				
Section (i)	(miles)	Mark	Catch	Hiatus	Mark	Catch	R_{i1}	R_{i2}	R_{i3}	ΣR_i	$\Sigma R_x/C$
Upper	12	5/6	5/9	3d	269	208	2	0	11	13	0.06
Middle	9	5/7	5/10	3d	273	302	1	18	2	21	0.06
Lower	12	5/8	5/11	3d	455	384	28	1	0	29	0.08
Totals	33	---	---	---	997	894	31	19	13	63	0.07

a Data reflect Arctic grayling ≥150 mm FL for all data sets except 1995a where it is ≥230 mm FL.

b Recaptures of fish marked in each section are stratified into area of recapture. R_{ix} = the number of fish marked in section i during the first (mark) event and recaptured in section x during the second (recap) event. Totals reflect all recaptures within in a section regardless of where the fish was released.

c $\Sigma R_x/C$ = capture probability; the total of all recaptures within a section divided by the catch (second event) in that section.

d Excludes two recaptures that lost tags.

2. all Arctic grayling have the same probability of capture in the marking sample or in the recapture sample, or marked and unmarked Arctic grayling mix completely between marking and recapture events;
3. marking of Arctic grayling does not affect their probability of capture in the recapture sample;
4. Arctic grayling do not lose their mark between the marking and recapture events; and,
5. all marked Arctic grayling are reported when recovered in the recapture sample.

Assumption 1 was not tested directly but inferred from an examination of the movement of recaptured fish between three approximately equal sections of the study area. If more than 10% of recaptured fish moved between sections, the assumption of closure was violated and the methodology outlined in Appendix B1 was followed. While mortality and growth may also contribute to the violation of closure, these were assumed negligible because of the short duration of the experiment (approximately six days from beginning to end).

Complete mixing of marked and unmarked Arctic grayling between mark and recapture events was assumed to have occurred during the experiment. All sections of the river were fished with equal intensity and all captured fish were released at the end of the run where captured, so that movement of Arctic grayling over a small distance would have promoted mixing and gave each fish within a small area an equal chance of being captured. However, morphology of river sections may result in unequal catchability and movement over long distances may violate the assumption of closure. To detect this, a chi-square test was performed on the number of marked and unmarked fish caught in the second event by study section and was coupled with the empirical inspection of movements of recaptures between study sections. If unequal catchability and/or movement was detected, the methodology of Appendix B1 was followed. Also, tests for consistency of the Peterson estimator were performed (Seber 1982, p. 438). Biologically significant movement occurred if inter-sectional movement exceeded 10% of all recaptures.

Validity of assumptions 2 and 3, relative to sampling induced selectivity of fish, was tested with a series of two-sample Kolmogorov-Smirnov tests generated from the mark-recapture data (Appendix B2). The first hypothesis tested was that all marked Arctic grayling have the same probability of capture in the recapture sample. Probability of capture usually differs by the size of Arctic grayling, especially when a size selective gear (electrofishing) is used (see Clark and Ridder 1988). If this test is significant, the recapture sample was biased and the data are partitioned into size classes. To maximize the difference in capture probability between size classes, a series of chi-squared tests was performed to determine optimal size classes for stratification. The length at stratification that produces the largest chi-squared test statistic is used to delimit the size classes. Population estimates are generated for each size class and these independent estimates summed to estimate the entire population. If the test does not detect a significant difference, the data need not be partitioned and a single population estimate will suffice.

The second hypothesis tested was that Arctic grayling captured during the first sample, or mark event, have the same length frequency distribution as fish captured in the second sample, or recapture event. There are four possible outcomes of these two tests; either one or both of the samples are biased or neither are biased. Possible actions for data analysis are outlined in Appendix B2.

Assumption 4 was assured because all fish are double marked. Assumption 5 was assured because of rigorous examination of all fish for fin clips and tags.

The modified Petersen estimator of Bailey (1951, 1952) was used to estimate abundance in 1995 and 1997:

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

where: $\hat{N}$ = the abundance of Arctic grayling in a section of GPR (≥150 mm FL); M = the number of Arctic grayling marked and released during the first event; C = the number of Arctic grayling examined for marks during the second event; and, R = the number of Arctic grayling recaptured in the second event.

Variance of this estimator is calculated by (Bailey 1951, 1952):

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

The Evenson' modification of the Peterson (Evenson 1988) was used in 1996:

$$N = \frac{\{M_1(1-p_d) + M_2 + M_3(1-p_u)\}\{C+1\}}{R+1}. \tag{3}$$

The probabilities of movements are estimated by:

$$\hat{p}_d = \frac{M_2(R_{32} + R_{21})}{R_2(M_3 + M_2)} \text{ and} \tag{4}$$

$$\hat{p}_u = \frac{M_2(R_{12} + R_{23})}{R_2(M_1 + M_2)} \tag{5}$$

where:

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

R = the number of fish recaptured during the second event;

p_z = 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 catch made during the second event;

N = the abundance of fish in <u>all</u> sections at the start of the second event;

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_2 = the number of fish that were marked in the midstream section during the first event and were recaptured during the second event.

The variance of these parameters were approximated with bootstrapping (500 iterations):

<u>Bootstrap mean</u>

$$\hat{N}_B = \frac{\sum_{i=1}^{j} \hat{N}_i}{j} \tag{6}$$

<u>Bootstrap variance</u>

$$\hat{V}[\hat{N}_B] = \frac{\sum_{i=1}^{j} (\hat{N}_i - \hat{N}_B)^2}{j-1} \tag{7}$$

where:

j = the number of bootstrap replicates;

$\hat{N}_B$ = the bootstrap mean of *j* replicates of the mark-recapture experiment;

N_i = the ith bootstrap replicate of the mark-recapture experiment; and,

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

If significant size bias was detected, separate population estimates were calculated for each size class. The resulting independent estimates were then summed to produce an estimate of abundance. If unequal catchability was found between study sections, the estimate of Arctic grayling abundance in the GPR was calculated as the sum of the section estimates. Section variances were also summed to produce a variance for this estimate.

Abundance was also estimated for the population of fish ≥270 and ≥340 mm FL. Comparisons of parameter estimates between years and rivers and to historical data necessitated a common target population. The former size category approximates the adult component of Arctic grayling populations in the study area as well as the minimum length for harvest in the DCR (see Clark and Ridder 1994). This category also represents the predominant size range found in the fish sampled in the DCR. The latter size category represented the size of fish used in a radio telemetry study in the DCR, a component of the same program as this study. The availability of parameter estimates from different size categories would detect if contributions are dependent on size. These estimates were derived proportionately if no area or size selectivity was found. If area and size bias were found, estimates were derived with equations 10 through 15 substituting area and/or size class *k* for age *k*.

AGE AND LENGTH COMPOSITIONS

For aging, scales were taken from the area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin. Scales were processed by wiping slime and dirt off each scale and mounting on gummed cards in the field. The gum cards were used to make triacetate impressions of the scales (30 s at 137,895 kPa, at a temperature of 97ºC). Ages were determined in a single reading using a microfiche reader according to criteria outlined by Yole (1975).

Testing of assumptions necessary for accurate abundance estimation may also reveal biases in age and size composition samples. Because age and length information are collected during mark-recapture sampling, bias in mark-recapture samples also indicates bias in age and size data that are collected. Age and size composition are used to apportion the population estimate into age classes or RSD categories, so that age and length information collected during either the marking sample, the recapture sample, or both samples may be used to calculate age and size composition.

If case I from inference testing occurs (Appendix B2), no adjustments to age and size data are necessary and data from both events may be pooled. If case II occurs, age and size data from the recapture event must be used to estimate compositions. If the population is closed between sampling events the abundance estimate is germane to both sampling events. For these two scenarios the proportion of fish at age is calculated as:

$$\hat{p}_k = \frac{y_k}{n} \tag{8}$$

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

The unbiased variance of this proportion is estimated as:

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1}. \tag{9}$$

Size composition is estimated in a similar manner, replacing age class with the RSD categories of Gabelhouse (1984). The RSD categories are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and, "trophy" (> 559 mm FL).

If case III or case IV from inference testing occurs, either mark and recapture samples are biased or the recapture sample is unbiased and the status of the mark sample is unknown. If case III occurs, age and size data from both samples can be pooled and adjustments made to these data. If case IV occurs and the partitioned and unpartitioned abundance estimates are dissimilar, age and size data from the recapture sample must be used to estimate compositions. These data must also be adjusted for bias due to size-selectivity. To adjust age and size data, the proportion of fish at age is calculated by summing independent abundances for each age or size class and then dividing by the summed abundances for all age or size classes (see Bernard and Hansen 1992, page 18). First the conditional proportions from the sample are calculated:

$$\hat{p}_{jk} = {n_{jk}}\Big/{n_j} \qquad (10)$$

where: n_j = the number sampled from size class *j* in the mark-recapture experiment; n_{jk} = the number sampled from size class *j* that are age *k*; and, $\hat{p}_{jk}$ = the estimated proportion of age *k* fish in size class *j*. The variance calculation for $\hat{p}_{jk}$ is identical to equation 4 (with appropriate substitutions).

The estimated abundance of age *k* fish in the population is then:

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk} \hat{N}_j \qquad (11)$$

where: N_j = the estimated abundance in size class *j* and s = the number of size classes.

The variance for $\hat{N}_k$ in this case is estimated by the delta method (Seber 1982):

$$\hat{V}\left[\hat{N}_k\right] = \sum_{j=1}^{s}\left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + V\left[\hat{N}_j\right]\hat{p}_{jk}^2\right). \qquad (12)$$

The estimated proportion of the population that are age *k* $\left(\hat{p}_k\right)$ is then:

$$\hat{p}_k = \hat{N}_k / \hat{N} \qquad (13)$$

where: $\hat{N} = \sum_{j=1}^{s} \hat{N}_j$.

Variance of the estimated proportion can be approximated with the delta method (Seber 1982):

$$\hat{V}\left[\hat{p}_k\right] \approx \sum_{j=1}^{s}\left\{\left(\frac{\hat{N}_j}{\hat{N}}\right)^2 \hat{V}\left[\hat{p}_k\right]\right\} + \frac{\sum_{j=1}^{s}\left\{V\left[\hat{N}_j\right]\left(\hat{p}_{jk} - \hat{p}_k\right)^2\right\}}{\hat{N}^2}. \qquad (14)$$

Equations 10 through 14 are also used to adjust biased RSD estimates, replacing the number sampled at age *k* that are also in size class *j* (n_{jk}) with the number sampled in RSD category *k* (*k* = 1, 2, 3, 4, and 5 RSD categories) that are also in size class *j*.

CONTRIBUTIONS

Contribution is estimated in two parts. First the proportion marked and released in the GPR is estimated from mark-recapture data:

$$\hat{p}_{jt} = \frac{m_{jt}}{\hat{N}_j} \qquad (15)$$

where p_{jt} is the estimated proportion of size class *j* released in the GPR bearing a mark, m_{jt} is the number marked of size class *j*, and N_j is the estimated abundance of size class *j* in the GPR. Variance of p_{jt} is estimated with the delta method (Seber 1982):

$$\hat{V}[\hat{p}_{jt}] \approx \frac{m_{jt}^2 \hat{V}[\hat{N}_j]}{\hat{N}_j^4} \tag{16}$$

where $V[\hat{N}_j]$ is the estimated variance of the abundance estimate of size class *j* (from equation 2).

In the DCR during immigration, the proportion of fish originally released in the GPR that are now in the DCR is estimated by:

$$\hat{p}_{jm} = \frac{c_{jm}}{n_{jm}} \tag{17}$$

where p_{jm} is the estimated proportion of fish of size class *j* in the DCR that were originally marked in the GPR, c_{jm} is the number examined of size class *j* bearing a mark from the GPR experiment, and n_{jm} is the number examined of size class *j* in the DCR. GPR marked fish were treated as recaptures only if they fell within particular length groups <u>at</u> time of marking. Variance of equation 12 is the variance of a binomial (as in equation 4).

The contribution (p_{jc}) of size class *j* is then estimated from the ratio of these two proportions:

$$\hat{p}_{j_c} = \frac{\hat{p}_{j_m}}{\hat{p}_{j_t}}. \tag{18}$$

Variance of p_{jc} is then estimated with the delta method:

$$\hat{V}[\hat{p}_{jc}] \approx \left[\frac{\hat{p}_{jm}}{\hat{p}_{jt}}\right]^2 \left[\frac{\hat{V}[\hat{p}_{jm}]}{\hat{p}_{jm}^2} + \frac{\hat{V}[\hat{p}_{jt}]}{\hat{p}_{jt}^2}\right]. \tag{19}$$

RESULTS

GOODPASTER RIVER

In the three years of this study, over 8,000 Arctic grayling were captured in the GPR during the spawning period. In each year, sampling commenced within two days of ice-out and predominantly adult sized fish 270 mm FL and larger were captured (Figure 4). The inability to capture significant numbers of small fish prevented meeting the objective of estimating the population of fish ≥150 mm in two of the three years. Movement of fish was prevalent in all years with an average of 36% of recaptured fish moving at least 1.4 mi in three days (Table 3). This inter-run movement was greater for females (59%) and fish of unknown sex (44%) than for males (19%; Table 4). However, in only one year, 1996, did movement significantly affect the abundance experiment when 18% (SE = 4%) of recaptured fish moved between study sections (Table 3).

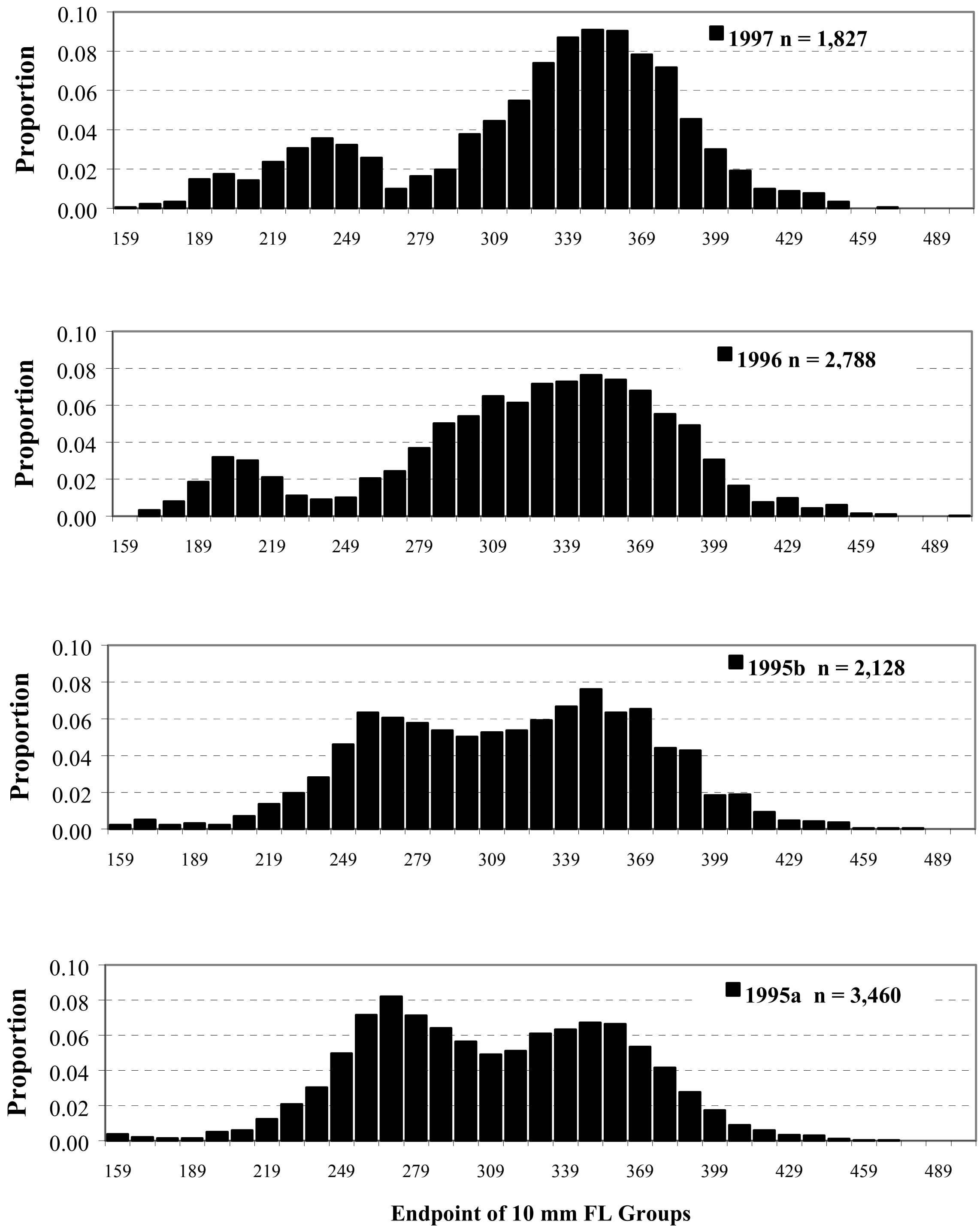


Figure 4.-Length frequencies of Arctic grayling captured during spawning in the lower 33 miles of the Goodpaster River, May 1995b-1997 and the lower 70 miles, May 1995a.

Table 3.-Movement of recaptured Arctic grayling three days after release by run and section, Goodpaster River, 1995-1997.

By run[a]:		No Movement			Moved			Upstream			Downstream		
Year	Total	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
1995a[b]	159	92	0.58	0.04	67	0.42	0.04	44	0.28	0.04	23	0.14	0.03
1995b[c]	77	55	0.71	0.05	22	0.29	0.05	9	0.12	0.04	13	0.17	0.04
1996	101	65	0.64	0.05	36	0.36	0.05	23	0.23	0.04	13	0.13	0.03
1997	63	43	0.68	0.06	20	0.32	0.06	16	0.25	0.06	4	0.06	0.03
Totals	400	255	0.64	0.02	145	0.36	0.02	92	0.23	0.02	53	0.13	0.02
By section[d]:		No Movement			Moved			Upstream			Downstream		
Year	Total	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
1995a	159	147	0.92	0.02	12	0.08	0.02	10	0.06	0.02	2	0.01	0.01
1995b	77	73	0.95	0.03	4	0.05	0.03	0	0.00	0.00	4	0.05	0.03
1996	101	83	0.82	0.04	18	0.18	0.04	11	0.11	0.03	7	0.07	0.03
1997	63	58	0.92	0.03	5	0.08	0.03	3	0.05	0.03	2	0.03	0.02
Totals	400	361	0.90	0.01	39	0.10	0.01	24	0.06	0.01	15	0.04	0.01

[a] a run covers approximately 1.4 mi of river. Movement occurred if fish moved at least 1 run upstream or two runs downstream from release (fish were released at downstream boundaries of runs).

[b] 1995a = the study area covered 70 river miles.

[c] 1995b = the study area covered 33 river miles.

[d] a section was approximately 23 river mi in 1995a and 11 river mi in 1995b-1997. Fish released at the downstream boundary of a section and recaptured in the first run of the next downstream section were considered not to have moved.

Table 4.-Inter-run movement of Arctic grayling stratified by sex, Goodpaster River, May 1995-1997.

1995	Total			Female			Male			Unknown		
	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
Upstream	43	0.27	0.04	29	0.51	0.07	6	0.11	0.04	8	0.17	0.06
Downstream	20	0.13	0.03	8	0.14	0.05	3	0.05	0.03	9	0.19	0.06
No Movement	96	0.60	0.04	20	0.35	0.06	46	0.84	0.05	30	0.64	0.07
Total	159	---	---	57	---	---	55	---	---	47	---	---
1996	Total			Female			Male			Unknown		
	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
Upstream	23	0.23	0.04	12	0.48	0.10	3	0.05	0.03	8	0.47	0.12
Downstream	13	0.13	0.03	4	0.16	0.07	6	0.10	0.04	3	0.18	0.10
No Movement	64	0.64	0.05	9	0.36	0.10	49	0.84	0.05	6	0.35	0.12
Total	100	---	---	25	---	---	58	---	---	17	---	---
1997	Total			Female			Male			Unknown		
	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
Upstream	16	0.25	0.06	4	0.21	0.10	9	0.24	0.07	3	0.50	0.22
Downstream	4	0.06	0.03	2	0.11	0.07	2	0.05	0.04	0	0.00	0.00
No Movement	43	0.68	0.06	13	0.68	0.11	27	0.71	0.07	3	0.50	0.22
Total	63	---	---	19	---	---	38	---	---	6	---	---
All Years:	Total			Female			Male			Unknown		
	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]	n	p	SE[p]
Upstream	82	0.25	0.02	45	0.45	0.05	18	0.12	0.03	19	0.27	0.05
Downstream	37	0.11	0.02	14	0.14	0.03	11	0.07	0.02	12	0.17	0.05
No Movement	203	0.63	0.03	42	0.42	0.05	122	0.81	0.03	39	0.56	0.06
Total	322	---	---	101	---	---	151	---	---	70	---	---

1995a Abundance

From 4 through 10 May 1995, 3,481 unique Arctic grayling ≥150 mm FL were caught in the 70 mi study area. With the smallest recaptured fish being 235 mm FL, the target population was reduced from fish ≥150 mm FL to fish ≥230 mm FL. Fish less than 230 mm FL comprised 6% of the sample (Figure 4). For the larger study area, truncating the population reduced marked fish to 1,815 (excludes two fish whose lengths were not recorded) and fish examined for marks to 1,621 (excludes one fish whose length was not recorded) while recaptures (n = 159) remained the same (Table 2).

Within the 70 mi study area, an examination of capture probabilities and movement of recaptured fish dictated the experiment be stratified by river section following the methodology of Appendix B1. Capture probabilities differed significantly among the three river sections ranging from 0.08 in the upper Section to 0.13 in the middle Section ($\chi^2 = 8.52$, df = 2, p = 0.01; Table 2). Although 42% of the recaptured fish (67 of 159, Table 3) moved during the experiment, only 8% of the recaptures (12 of 159, Table 3) moved between sections. This inter-sectional movement was considered insignificant since it was less than 10%. With section stratification, the number of recaptures was reduced by 12.

Lower Section

There was no indication of size selective sampling bias in the lower river section based upon comparisons of length frequencies of marked fish with length frequencies of recaptured fish (D = 0.16, P ≈ 0.16). Following the methodology of Appendix B2, the data needed no further stratification. The abundance of Arctic grayling ≥230 mm FL in the lower section (river mi 0-24 of the mainstem) was 10,711 fish (SE = 1,387; Table 5).

Middle Section

There was significant size selective sampling bias in the middle river section based upon comparisons of length frequencies of marked fish with length frequencies of recaptured fish (D = 0.32, P < 0.01) and the data needed stratification by length group. The maximal chi-square statistic occurred at a stratification of 230 -319 mm for small fish and >319 mm for large fish. Summing the abundance estimates for the two strata, abundance of fish ≥ 230 mm in the middle section was 5,816 (SE = 1,100; Table 5). The middle section encompassed the lower 5 mi of the North Fork, the lower 10 mi of the South Fork, and the upper 8 mi of the mainstem.

Upper Section

There was also significant size selective sampling bias in the upper river section based upon comparisons of length frequencies of marked fish with length frequencies of recaptured fish (D = 0.32, P < 0.01). The maximal chi-square statistic occurred at a stratification of 230 -309 mm for small fish and >309 mm for large fish. Summing the abundance estimates for the two strata, abundance of fish ≥230 mm in the upper section was 6,670 (SE = 1,375 fish; Table 5). The upper section encompassed the upper 22 mi of the North Fork study area (from 5 mi above the forks to Central Creek).

Table 5.-Estimated abundance of Arctic grayling (≥230 mm FL) in A, the lower 70 miles, of Goodpaster River stratified by river section and size category and B, the lower 33 miles, 4 through 10 May 1995.

A:

Section	Strata	Mark	Catch	Recap	R/M[a]	R/C[b]	N[c]	SE[N][d]	cv[e]
Upper	230 - 309	272	277	13	0.05	0.05	5,401	1,359	25%
	≥310	171	229	30	0.18	0.13	1,269	209	16%
	subtotal	443	506	43	0.09	0.10	6,670	1,375	21%
Middle	230 - 319	334	243	16	0.05	0.07	4,794	1,090	23%
	≥320	201	182	35	0.17	0.19	1,022	151	15%
	subtotal	535	425	51	0.10	0.12	5,816	1,100	19%
Lower	≥230	837	690	53	0.06	0.08	10,711	1,387	13%
All	Total	1,815[f]	1,621[g]	147[h]	0.08	0.09	23,196	2,241	10%

B:

Section	Strata	Mark	Catch	Recap	R/M	R/C	N	SE[N]	cv
All	≥230	1,185	884	77	0.07	0.09	13,445	1,445	11%

[a] R/M is the recapture rate (Recap divided by marks).

[b] R/C is the probability of capture (Recap divided by catch).

[c] N is the estimated abundance.

[d] SE[N] is the standard error of N.

[e] cv is the coefficient of variation of N expressed as a percentage.

[f] Excludes two fish whose lengths was not recorded.

[g] Excludes one fish whose length was not recorded.

[h] Excludes 12 fish who were recaptured in sections other than those in which they were marked.

All Sections
Summing estimated abundance from the three sections, there were 23,196 Arctic grayling ≥230 mm FL (SE = 2,241 fish) in the 70 mi study area (Table 5). The Bailey estimate without stratification is 19,900 (SE = 1,600).

1995b Abundance
In the mainstem study area, a total of 2,130 Arctic grayling ≥150 mm FL were caught (Table 2). The data was truncated to fish ≥230 mm as in the larger study area resulting in 1,185 fish marked, 884 fish examined with 77 recaptures. Unlike the larger study area, the data did not need area stratification since inter-sectional movement was 5% and capture probabilities were similar (χ^2 = 2.27, df = 2, P = 0.32). While significant size bias was found both between marked and recaptured fish (D = 0.17, P = 0.03) and between marked and examined fish (D = 0.08, P < 0.01), abundance was similar between the length stratified estimate (13,950 fish, SE = 1,574 fish) and the unstratified estimate (13,445 fish, SE = 1,445 fish). Following the methodology of Appendix B2 (Case IVb), the unstratified estimate was appropriate and there were 13,445 Arctic grayling ≥230 mm FL in the mainstem study area (SE = 1,445 fish; Table 5).

1996 Abundance
From 10 through 16 May 1996, 2,787 unique Arctic grayling ≥150 mm FL were caught in the 33 mi study area. With the smallest recaptured fish at 168 mm FL, abundance was estimated for fish ≥150 mm FL. Marks totaled 1,533 and 1,357 fish were examined for marks with 103 fish recaptured (two recaptured fish lost tags; Table 2). Significant movement of recaptured fish across section boundaries (18%; Table 3) as well as unequal capture probabilities between sections (χ^2 = 6.48, df = 2, P = 0.04) required stratification of the study area and a comparison of two estimators (Appendix B1, Case IV). Since movement out of the study area was probable, the Bailey estimator was compared to Evenson's modification of the Bailey (Appendix B1; Case IV). Significant gear bias was also detected (marked fish vs recaptured fish, D = 0.23, P < 0.01) and the data was stratified at 303 mm FL prior to estimation. With a difference of 14% between the Bailey (29,482 fish) and Evenson estimates (25,364 fish), the latter was the more appropriate estimator. For small sized fish, 150 – 303 mm FL, abundance was 16,653 (SE = 2,990 fish) and for large fish, abundance was 8,711 (SE = 791 fish). Summed, there were 25,364 fish ≥150 mm FL (SE = 3,093 fish) in the mainstem in 1996 (Table 6).

1997 Abundance
From 6 through 11 May 1997, 1,828 unique Arctic grayling ≥150 mm FL were caught in the 33 mi study area (Table 2). With the smallest recaptured fish at 237 mm FL, abundance was estimated for fish ≥230 mm FL. Marks totaled 881 fish and 814 fish were examined for marks with 63 fish recaptured (Table 7). With inter-sectional movement at 8% (Table 3) and capture probabilities between sections similar (χ^2 = 1.08, df = 2, P = 0.58), area stratification was not necessary. Comparisons of marked fish to recaptured and examined fish were both significantly different (D = 24, P = 0.03 and D = 0.07, P < 0.01, respectively) and inferred size selectivity in the experiment. Length stratification of the data was set at 368 mm FL. There was a 15% difference between the length stratified estimate (12,893 fish) and the unstratified estimate (11,219 fish). Following the

Table 6.-Data (A) and bootstrapped parameter estimates (B) of Evenson's modification of the Bailey estimator for Arctic grayling (≥150 mm FL) in the lower 33 miles of Goodpaster River stratified by size group, 10 through 16 May 1996.

A:

Group	M_1[a]	M_2	M_3	R_{oo}[b]	p(ds)[c]	p(us)	R_{3-2}[d]	R_{2-1}	R_{1-2}	R_{2-3}	R_{2o}[e]	C[f]
150-303	247	212	70	15	0.00	0.10	0	0	0	2	9	495
≥304	500	288	216	88	0.17	0.11	4	5	4	5	30	862
Total	747	500	286	103	0.09	0.11	4	5	4	7	39	1,357

B:

Group	N[g]	SE[N]	cv	p(ds)	SE[p(ds)]	P(us)	SE[p(us)]
150-303	16,653	2,990	18%	0.00	---	0.13	0.08
≥304	8,711	791	9%	0.18	0.06	0.11	0.05
Total	25,364	3,093	12%	0.09	0.10	0.12	0.07

[a] M_x = the number of fish marked in the first event in section x (x = 1, 2, and 3 for the downstream, midstream, and upstream sections, respectively).

[b] R_{oo} = the number of fish recaptured during the second event.

[c] P_{zz} = the probability that a fish will move out of an area in the z direction (us = upstream; ds = downstream).

[d] R_{x-y} = 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,

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

[f] C = the catch made during the second event.

[g] N = the abundance of fish in all sections at the start of the second event.

Table 7.-Estimated abundance of Arctic grayling (≥230 mm FL) in the lower 33 mi of the Goodpaster River stratified by size category, 6 through 11 May 1997.

Strata	Mark	Catch	Recap	R/M[a]	R/C[b]	N[c]	SE[N][d]	cv[e]
230 - 368	679	605	35	0.05	0.06	11,430	1,822	16%
≥369	202	209	28	0.14	0.13	1,463	248	17%
Total	881	814	63	0.07	0.08	12,893	1,839	14%

[a] R/M is the recapture rate (Recap divided by marks).

[b] R/C is the probability of capture (Recap divided by catch).

[c] N is the estimated abundance.

[d] SE[N] is the standard error of N.

[e] cv is the coefficient of variation of N expressed as a percentage.

methodology of Appendix B2 (Case IVa), the stratified estimate was appropriate. In 1997, there were 11,430 fish 230-368 mm FL (SE = 1,822) and 1,463 fish greater than 368 mm FL (SE = 248 fish) for a total of 12,893 fish (SE = 1,839; Table 7) in the mainstem.

Age and Length Compositions

Age and length compositions for four of the above six abundance estimates were adjusted for size bias due to the selectivity of the sampling gear. The composition data from the lower section of 1995a and from 1995b, which shared data, needed no adjustments (Table 8). Ages ranged from age 2 to age 14. The 1990 year class was the predominant age class in all three years first as age 5 fish in both 1995 study areas (Tables 9 and 10), then at age 6 in 1996 (Table 11), and as age 7 in 1997 (Table 12). Fish of age 6 and older comprised the majority of fish in every sample, 51% to 87%, whether in the truncated and adjusted compositions in Tables 9 through 12 or in the compositions estimated directly from sampled fish greater than ≥150 mm (Appendices A4 through A6). Clark (1992) estimated the age at 99% maturity for the GPR stock as age 6.

Truncation of the data sets to fish ≥ 230 mm FL somewhat alters the utility of the RSD index which has a minimum length of 150 mm FL. However, the adjusted RSD's were similar to the sampled RSD's with the exception of 1996 (Table 13). Quality-sized fish (270-339 mm FL) were the predominant category in all adjusted RSD's. Abundance of quality-sized fish in the mainstem were similar in 1995 and 1997 (≈6,000 fish) but were nearly twice as numerous in 1996 (≈11,000 fish; Table 13).

Proportion Marked

The proportion of marked fish released alive into the population in each of the three years was remarkably similar among three length groups (≥230 mm, ≥270 mm, and ≥340 mm) with a median value of 0.15. Proportions ranged from 0.12 (SE = 0.02) for fish ≥ 230 mm to 0.20 (SE = 0.03) for fish ≥ 340 mm (Table 14). The ≥ 340 mm group generally had the higher proportions but overlapping confidence intervals among length groups indicated that no proportion was significantly different from any other.

TAG RECOVERIES

A total of 131 marked fish released in the GPR in May 1995-1997 were recaptured in the DCR in the same year as marking from 1995 through 1997. All but one of the recaptures were originally released in the mainstem and 122 recaptures (93%, SE = 2%) were released below river mi 15 (Figure 5). This selective pattern of lower river fish emigrating to the DCR was similar for all tagging years.

In the 1995 DCR sample, 1,231 Arctic grayling ≥150 mm FL were captured by three methods within six sample events (defined by area and method of capture) between 1 May and 29 July 1995 (Appendix A7). Fish ≥ 270 mm comprised from 89% to 100% of all but the electrofishing sample (60%) from the river's lower mile. Recaptures of GPR fish were made in all samples (Appendix A7) and totaled 38 fish of which 34 fish were unique. (With the exception of the harvest sample, all sampling was done with replacement and four fish were recaptured twice.) Anglers reported harvesting eight GPR

Table 8.-Summary of treatments for estimated age and size compositions of Arctic grayling in the Goodpaster River, May 1995-1997.

	1995a						
Category	Lower	Middle	Upper	All	1995b	1996	1997
Reach (mi)	24	23	23	70	33	33	33
Length Category (mm FL)	≥230	≥230	≥230	≥230	≥230	≥150	≥230
Size selectivity KS tests:							
First event vs recaptured	P=0.16	P<0.01	P<0.01	Sum	P<0.0	P<0.01	P<0.01
First event vs second	P=0.02	P=0.02	P=0.12	Of	P<0.0	P=0.23	P=0.04
Stratify by length?	No	Yes	Yes	Section	No[a]	Yes	Yes
Length Break (mm FL)	---	319	309	---	---	303	368
Adjust composition?	No	Yes	Yes	---	No	Yes	Yes
Event for compositions	Second	Second	Pooled	Second	First	Pooled	Second

[a] From Case IVb in Appendix B2, estimates from data unstratified by length were the most appropriate.

[b] na = not applicable.

Table 9.-Estimates of adjusted age composition and abundance at age with standard errors for Arctic grayling (≥230 mm FL) captured in the lower 70 miles of the Goodpaster River, 7 through 10 May 1995.

	Age Composition			Abundance		
Age	n[a]	p'[b]	SE[p']	N[c]	SE[N]	CV
4	73	0.07	0.05	1,606	256	15.9%
5	412	0.42	0.09	9,693	1,324	13.6%
6	159	0.14	0.06	3,304	428	13.0 %
7	199	0.13	0.05	3,049	350	11.5%
8	215	0.13	0.05	3,080	358	11.6%
9	93	0.05	0.04	1,167	167	14.3%
10	56	0.03	0.03	792	137	17.3%
11	24	0.01	0.02	323	79	24.6%
12	9	0.01	0.02	140	52	37.1%
13	4	<0.01	0.01	41	23	56.1%
Totals	1,244	1.00		23,196	2,241	9.7%

[a] n = number of Arctic grayling sampled at age.

[b] p' = estimated adjusted proportion of Arctic grayling at age in population.

[c] N = estimated population abundance of Arctic grayling at age.

Table 10.-Estimates of age composition and abundance at age with standard errors for Arctic grayling (≥230 mm FL) captured in the lower 33 miles of the Goodpaster River, 7 through 9 May 1995.

	Age Composition			Abundance		
Age	n	p	SE[p']	N	SE[N]	CV
4	45	0.06	0.01	853	153	18%
5	196	0.28	0.02	3,717	458	12%
6	107	0.15	0.01	2,029	283	14%
7	120	0.17	0.01	2,276	309	14%
8	135	0.19	0.01	2,560	338	13%
9	48	0.07	0.01	910	160	18%
10	36	0.05	0.01	683	132	19%
11	15	0.02	0.01	284	78	28%
12	6	0.01	0.00	114	48	42%
13	1	0.00	0.00	19	19	100%
Totals	709	1.00	---	13,445	1,445	11%

Table 11.-Estimates of adjusted age composition and abundance at age with standard errors for Arctic grayling (≥150 mm FL) captured in the lower 33 miles of the Goodpaster River, 13 through 16 May 1996.

	Age Composition			Abundance		
Age	n[a]	p'[b]	SE[p']	N[c]	SE[N]	CV
2	3	0.00	0.00	114	68	59%
3	131	0.20	0.02	4,981	964	19%
4	34	0.05	0.01	1,293	313	24%
5	79	0.12	0.01	3,004	618	21%
6	238	0.26	0.02	6,651	1,067	16%
7	202	0.14	0.01	3,580	436	12%
8	152	0.08	0.01	1,911	220	12%
9	164	0.08	0.01	2,032	230	11%
10	87	0.04	0.01	1,064	144	14%
11	37	0.02	0.00	453	83	18%
12	18	0.01	0.00	220	55	25%
13	4	0.00	0.00	49	25	51%
14	1	0.00	0.00	12	12	100%
Totals	1,150			25,364	3,093	12%

[a] n = number of Arctic grayling sampled at age.

[b] p' = estimated adjusted proportion of Arctic grayling at age in population.

[c] N = estimated population abundance of Arctic grayling at age.

Table 12.-Estimates of adjusted age composition and abundance at age with standard errors for Arctic grayling (≥230 mm FL) captured in the lower 33 miles of the Goodpaster River, 9 through 11 May 1997.

	Age Composition			Abundance		
Age	n[a]	p'[b]	SE[p']	N[c]	SE[N]	CV
3	1	0.00	0.00	21	21	100%
4	69	0.11	0.01	1,434	279	19%
5	12	0.02	0.01	249	81	32%
6	74	0.12	0.01	1,505	286	19%
7	212	0.33	0.02	4,217	688	16%
8	137	0.19	0.02	2,492	402	16%
9	110	0.14	0.01	1,831	292	16%
10	59	0.06	0.01	827	145	18%
11	21	0.02	0.01	259	66	26%
12	3	0.00	0.00	29	17	59%
13	3	0.00	0.00	29	17	59%
Totals	701	1.00	---	12,893	1,839	14%

[a] n = number of Arctic grayling sampled at age.

[b] p' = estimated adjusted proportion of Arctic grayling at age in population.

[c] N = estimated population abundance of Arctic grayling at age.

Table 13.-Estimates of Relative Stock Density (RSD) indices of Arctic grayling captured in the Goodpaster River, May 1995-1997.

1995a, lower 70 mi:		Sampled[a]		Adjusted[b]		Abundance (≥230 mm)	
Category	Length	n	RSD	RSD	SE[RSD]	N	SE[N]
Stock	150-269	572	0.27	0.28	0.03	6,564	941
Quality	270-339	935	0.43	0.46	0.02	10,754	1,155
Preferred	340-449	649	0.30	0.25	0.05	5,846	1,183
Memorable	449-559	2	0.00	0.00	0.00	32	24
Trophy	≥ 560	0	---	---	---	0	0
		2,158	1.00	1.00	---	23,196	

1995b, lower 33 mi:		Sampled		Adjusted		Abundance (≥230 mm)	
Category	Length	n	RSD	RSD	SE[RSD]	N	SE[N]
Stock	150-269	378	0.30	0.23	0.01	3,110	357
Quality	270-339	493	0.39	0.42	0.01	5,662	626
Preferred	340-449	396	0.31	0.35	0.01	4,659	521
Memorable	449-559	0	---	0.00	0.00	13	10
Trophy	≥ 560	0	---	---	---	0	0
		1,267	1.00	1.00	---	13,445	

1996, lower 33 mi:		Sampled		Adjusted		Abundance (≥150 mm)	
Category	Length	n	RSD	RSD	SE[RSD]	N	SE[N]
Stock	150-269	523	0.19	0.34	0.03	8,615	1,233
Quality	270-339	1,149	0.41	0.44	0.01	11,277	1,409
Preferred	340-449	1,109	0.40	0.21	0.03	5,433	978
Memorable	449-559	8	0.00	0.00	0.00	39	15
Trophy	≥ 560	0	---	---	---	0	0
		2,789	1.00	1.00	---	25,364	

1997, lower 33 mi:		Sampled		Adjusted		Abundance (≥230 mm)	
Category	Length	n	RSD	RSD	SE[RSD]	N	SE[N]
Stock	150-269	384	0.21	0.15	0.01	1,916	316
Quality	270-339	610	0.33	0.46	0.02	5,991	883
Preferred	340-449	832	0.46	0.39	0.02	4,984	745
Memorable	449-559	1	0.00	0.00	0.00	2	2
Trophy	≥ 560	0	---	---	---	0	0
		1,827	1.00	1.00	---	12,893	

[a] Sampled = captured Arctic grayling ≥150 mm FL from both sample events in the Upper Section and from the second event in the Middle and Lower Sections.

[b] Adjusted = is the RSD corrected for the length bias found in the above sample events from electrofishing and applicable only to the length range specified for abundance.

Table 14.-Estimated abundance and proportion marked of Arctic grayling in three length groups in the Goodpaster River, May 1995-1997.

Year	Reach (mi)	Group	N[a]	SE[N]	m_t[b]	p_t[c]	SE[p_t]
1995	0-70	≥230	23,194	2,459	3,257	0.14	0.01
1995	0-70	≥270	16,636	1,827	2,458	0.15	0.02
1995	0-70	≥340	5,873	734	1,026	0.17	0.02
1995	0-33	≥230	13,445	1,445	1,990	0.15	0.02
1995	0-33	≥270	10,095	1,097	1,529	0.15	0.02
1995	0-33	≥340	4,478	515	694	0.15	0.02
1996	0-33	≥230	19,305	2,484	2,427	0.12	0.02
1996	0-33	≥270	16,436	2,124	2,257	0.13	0.02
1996	0-33	≥340	5,389	737	1,114	0.20	0.03
1997	0-33	≥230	12,893	1,900	1,687	0.13	0.02
1997	0-33	≥270	11,364	1,682	1,499	0.13	0.02
1997	0-33	≥340	5,822	899	874	0.15	0.02

[a] N = estimated abundance of Arctic grayling in length group.

[b] m_t = number of marked Arctic grayling released alive in length group.

[c] p_t = estimated proportion of marked Arctic grayling in population in length group.

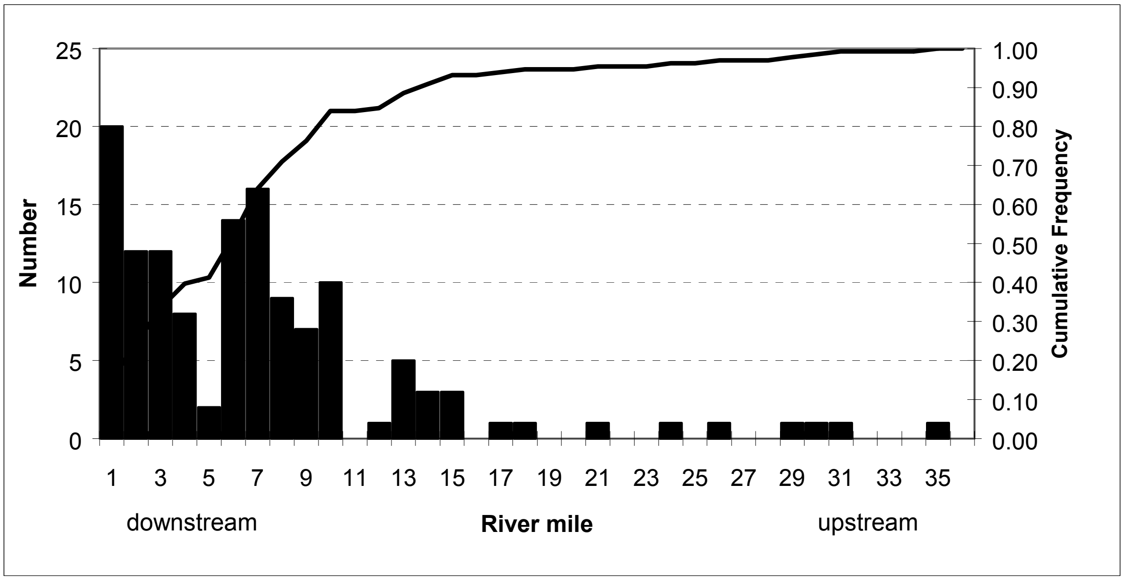


Figure 5.-Release locations in the Goodpaster River by number and cumulative frequency of 131 Arctic grayling from three tagging years (i…i+3) recaptured in year i in the Delta Clearwater River, 1995-1997.

tags representing an additional two unique fish. These 36 unique recaptures ranged from 213 to 424 mm at time of marking and averaged 348 mm (SD = 54 mm).

Recapture rates among the events differed and, although not significant due to some small sample sizes, appeared dependent on a combination of sample timing and method. Grouped by month, rates for fish ≥340 mm tended to decrease over time while rates for fish ≥270 mm remained relatively static (Table 15). Hypothetically, the recapture rates of any length group should be the same in any sample provided that not only sampling and distribution of marked fish were random but also that emigration of fish from other "donor streams", regardless of maturity, occurred concurrently with those of the GPR. Recapture rates in two length groups (≥270 mm and ≥340 mm) within five of the six sample events were nearly identical (Table 15). Only in the electrofishing sample from the lower mile were rates, 0.02 for fish ≥270 mm and 0.14 for fish ≥340 mm, significantly different (χ^2= 32.8 = 1, P = 0.001). Although there was a relatively wide range in rates for each length group among the six events, no rates were significantly different between samples: 0.02 to 0.07 for fish ≥270 mm (χ^2 = 10.64, df = 5, p = 0.06) and 0.04 to 0.14 for fish ≥340 mm (χ^2= 8.08, df = 5, p = 0.15). However, the large electrofishing sample from the lower mile influenced the combined sample estimates where rates were nearly twice as great for the 340 mm group than the 270 mm group (0.07 versus 0.04, , respectively, Tables 15 and 16).

When combining the samples into three categories by either method (electrofishing, hook and line, and harvest sample) or month, no significant differences in recapture rates were found among the length groups within each category (Table 16A). However, tests within the groups showed significant differences in rates between length categories in three of the six tests, the electrofishing, May and June groups (Table 16B). The majority of the electrofishing fish are the same fish as are in the May group (Table 15).

The above tests infer that recapture rates from the May electrofishing sample from the lower river are likely biased. The extreme recapture rates for each length category in the sample are likely biased by differing emigration rates between donor streams and between juvenile and adult fish. Those streams that offer early spawning, such as the GPR, would provide the first emigration of adult fish to the DCR whereas juvenile fish from all stocks, which precede the arrival of adults, would not be affected. In estimating recapture and contribution rates, it appears that July sampling would offer the least bias since movement of fish is considered minimal during the feeding period of mid-summer. This conclusion led to changing sample timing in 1996 and 1997 to July. Also, the May electrofishing sample was excluded from estimates of recapture and contribution rates for 1995.

In 1996, 796 Arctic grayling ≥150 mm FL were captured in the DCR between 15 and 31 July. Fish ≥ 230 mm comprised 97% of the sample and fish ≥ 270 mm were 88% of the sample (Appendix A8; Figure 6). Recaptures of GPR fish totaled 34 fish. The 1996 harvest survey recovered six GPR fish in a sample of 251 fish. Anglers reported harvesting 14 GPR tags. These recaptures ranged from 206 to 445 mm at the time of marking and averaged 346 mm (std = 58 mm). The majority of recaptures, excluding

Table 15.-Recapture rate (p_m) estimates for Arctic grayling tagged in the Goodpaster River and recaptured in the Delta Clearwater River in 1995 stratified by length and grouped by sample method and month.

			≥270 mm					≥340 mm				
Method[a]	Area[b]	Dates	n[c]	m[d]	p_m[e]	SE[f]	cv(%)[g]	n	m	p_m	SE	cv(%)
EB	0-1	5/1-6/15	369	8	0.02	0.01	35	49	7	0.14	0.05	35
EB	3-12	5/26-6/15	55	4	0.07	0.04	49	48	3	0.06	0.04	56
EB	12-14	7/19-7/20	52	3	0.06	0.03	57	42	2	0.05	0.03	70
Total EB:			476	15	0.03	0.01	25	139	12	0.09	0.02	28
H&L	2-12	6/5-6/15	149	11	0.07	0.02	29	89	9	0.10	0.03	32
H&L	2-7	7/21-7/27	72	2	0.03	0.02	70	23	1	0.04	0.04	100
Total H&L:			221	13	0.06	0.02	27	112	10	0.09	0.03	30
Harvest	2-14	6/3-7/29	273	9	0.03	0.01	33	168	7	0.04	0.02	37
All	All	May	363	10	0.03	0.01	31	75	8	0.11	0.04	34
All	All	June	305	16	0.05	0.01	24	179	14	0.08	0.02	26
All	All	July	302	11	0.04	0.01	30	165	7	0.04	0.02	37
Totals	All		970	37	0.04	0.01	16	419	29	0.07	0.01	18
	w/o mi 1 EB		601	27	0.05	0.01	20	370	19	0.05	0.01	20

[a] Method: EB = electrofishing boat; H&L = hook and line; Harvest: exit samples of angler harvest.

[b] Area: sampled reach designated by location (river mile).

[c] n = sample size

[d] m = number of recaptures

[e] p_m = proportion of recaptures in catch.

[f] SE = standard error of the proportion

[g] cv = coefficient of variation.

Table 16.-Contingency tests on recapture rates for 1995 Delta Clearwater River sample events grouped by method and month A:) within length groups and, B:) between length groups.

A:

	≥270 mm FL			≥330 mm FL		
Test	chi-sq	df	P	chi-sq	df	P
Method	3.346	2	0.188	3.312	2	0.191
Month	2.865	2	0.239	3.710	2	0.157

B:

Test	chi-sq.	df	P
EB	16.9	1	0.001
H&L	2.77	1	0.096
Harvest	0.45	1	0.5
May	18.5	1	0.001
June	4.59	1	0.03
July	0.09	1	0.76

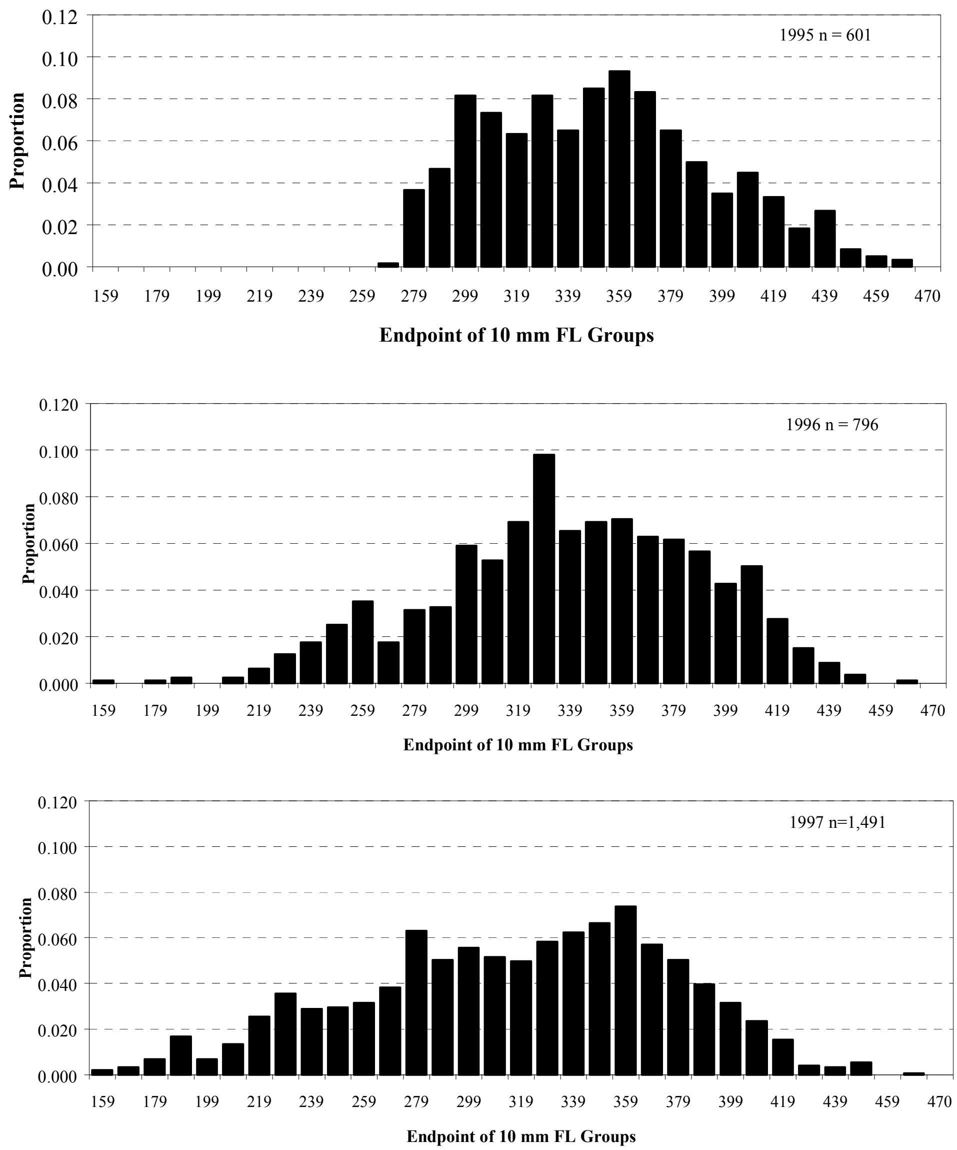


Figure 6.-Length frequencies of Arctic grayling captured in the Delta Clearwater River, May through July 1995 and July 1996-1997.

angler reports, (37 of 40 fish or 93%; Appendix A8), were ≥ 270 mm at the time of marking.

In 1997, 1,491 Arctic grayling ≥150 mm FL were captured in the DCR between 14 and 25 July. Fish ≥ 230 mm comprised 89% of the sample and fish ≥ 270 mm were 76% of the sample (Appendix A8; Figure 6). Recaptures of GPR fish totaled 38 fish. Anglers reported catching (and releasing) nine GPR tags. The 38 recaptures ranged from 212 to 429 mm at time of marking and averaged 343 mm (SD = 55 mm). The majority of recaptures, excluding angler reports, (33 of 38 fish or 87%; Appendix A8), were ≥ 270 mm at time of marking.

In the Richardson Clearwater River 237 fish were captured on 25 July 1995, and 172 fish were captured on 1 August 1996 ≥ 150 mm (Appendix A8). As in the DCR, the majority of the samples, 98% and 84%, respectively, were ≥ 270 mm. Two GPR fish, 335 mm and 352 mm, were recaptured in 1995 and one GPR fish, 346 mm, was recovered in 1996.

In August, 638 fish ≥ 150 mm were captured in the mainstem GPR in 1995, and 617 fish ≥ 150 mm were captured in 1996 (Appendix A8). Unlike the clearwater streams, the majority of the catches were less than 270 mm (77% and 78%, respectively). August samples typically consist of smaller and younger fish than those in May (Roach 1995). Eleven GPR fish were recaptured in 1995 with lengths at marking ranging from 236 mm to 347 mm and an average of 292 mm (SD = 38). Seventeen GPR fish were recovered in 1996 (206 mm - 358 mm with an average of 275 mm, SD = 34 mm). Unlike the total catches, the majority of these recaptures were ≥ 270 mm (64% and 78%, respectively).

Recapture rates of GPR fish in the above samples were quite small but similar among length groups of each sample and between years for each sample with one obvious exception (Table 17). The August sample, drawn from the 'home' stream, would be expected to have higher proportions than extant waters. However, this occurred only in all length groups of the 1996 sample and with fish ≥ 340 mm in 1995.

CONTRIBUTION RATES

Contribution rates of GPR fish to the DCR estimated from the three length groups ranged from 0.22 in 1997 to 0.34 in 1996 for fish ≥ 230 mm (Table 18). The range of rates for fish ≥ 270 mm and ≥ 340 mm were similar, 0.23 to 0.33 and 0.24 to 0.32, respectively. Average rates for each length group were near identical, 0.29 for fish ≥ 230 mm and 270 mm, and 0.28 for fish ≥ 340 mm. No rate was significantly different from another due to poor precision (Figure 7). The similarities between groups and sample years suggests that there is no differential contribution dependent on size class or time. Rates derived from harvest sampling were generally lower, but not significantly (Table 18; Figure 6). This tendency may be related to angler bias towards keeping tagged fish.

The GPR's contribution to the Richardson Clearwater was consistent as in the DCR but much lower ranging from 0.05 to 0.06 for all length groups (Table 18). The contribution to the summer population in the GPR had the largest range and the highest of estimates. Rates ranged from 0.27 for fish ≥ 230 mm in 1995 to 0.76 for fish ≥ 270 mm in 1996

Table 17.-Recapture rate (p_m) estimates for Arctic grayling of three length groups tagged in the Goodpaster River and recaptured in the Delta Clearwater (DCR), Richardson Clearwater (RCR), and Goodpaster (GPR) rivers, 1995-1997.

				≥230 mm FL				≥270 mm FL				≥340 mm FL			
River	Gear[a]	Area(mi)[b]	Dates	n[c]	m[d]	p_m[e]	SE[p_m]	n	m	p_m	SE[p_m]	n	m	p_m	SE[p_m]
DCR	EB,HL,Hv	2-14	5/26-7/29/95	615	27	0.04	0.01	601	27	0.04	0.01	331	15	0.05	0.01
DCR	HL	2-14	7/15-7/31/96	775	32	0.04	0.01	699	31	0.04	0.01	374	18	0.05	0.01
DCR	HL	2-14	7/14-7/25/97	1,271	36	0.03	<0.01	1086	33	0.03	0.01	529	25	0.05	0.01
DCR	Hv	2-14	6/3-7/29/95	273	8	0.03	0.01	273	8	0.03	0.01	143	5	0.03	0.02
DCR	Hv	2-14	6/1-8/17/96	251	6	0.02	0.01	251	6	0.02	0.01	185	4	0.02	0.01
RCR	EB	0-8	7/25/95	237	2	0.01	0.01	233	2	0.01	0.01	143	1	0.01	0.01
RCR	EB	0-8	8/1/96	167	1	0.01	0.01	145	1	0.01	0.01	101	1	0.01	0.01
GPR	EB	2-33	8/1-8/3/95	279	11	0.04	0.01	146	7	0.05	0.02	9	1	0.11	0.11
GPR	EB	1-33	8/5-8/8/96	209	17	0.08	0.02	137	14	0.10	0.03	18	2	0.11	0.08

[a] Gear: EB = electrofishing boat; HL = hook and line; Hv: exit samples of angler harvest.

[b] Area: sampled reach designated by location (river mile).

[c] n = sample size

[d] m = number of recaptures

[e] p_m = proportion of recaptures in catch.

Table 18.-Contribution rate (p_c) estimates for Arctic grayling of three length groups tagged in the Goodpaster River and recaptured in the Delta Clearwater (DCR), Richardson Clearwater (RCR), and Goodpaster (GPR) rivers, 1995-1997.

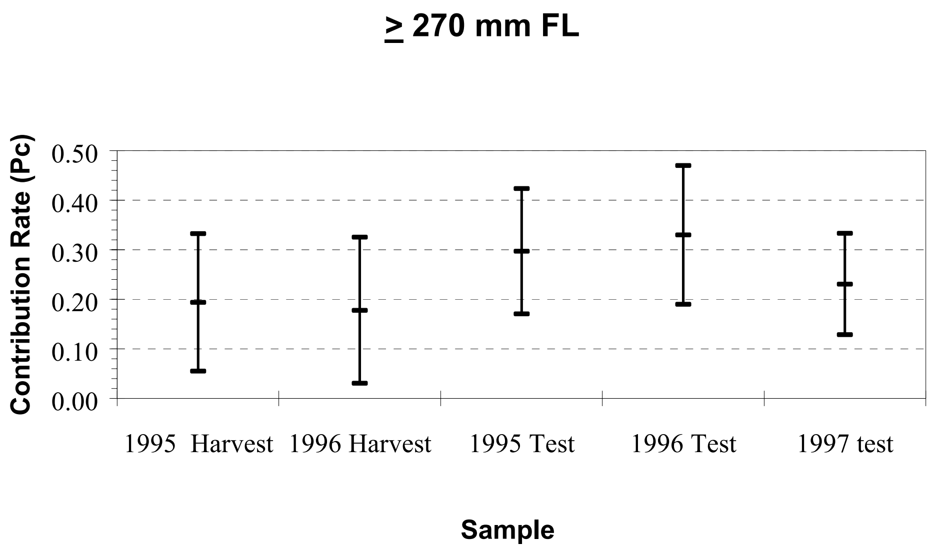
				≥230 mm FL			≥270 mm FL			≥340 mm FL		
River	Gear[a]	Area(mi)[b]	Dates	p_c[c]	SE[p_c]	cv[d]	p_c	SE[p_c]	cv	p_c	SE[p_c]	cv
DCR	EB,HL,Hv	2-14	5/26-7/29/95	0.30	0.06	22%	0.30	0.06	22%	0.29	0.08	28%
DCR	HL	2-14	7/15-7/31/96	0.34	0.07	21%	0.33	0.07	22%	0.24	0.06	27%
DCR	HL	2-14	7/14-7/25/97	0.22	0.05	22%	0.23	0.05	23%	0.32	0.08	25%
DCR	Hv	2-14	6/3-7/29/95	0.20	0.07	37%	0.19	0.07	37%	0.23	0.10	46%
DCR	Hv	2-14	6/1-8/17/96	0.19	0.08	42%	0.18	0.08	42%	0.11	0.05	51%
RCR	EB	0-8	7/25/95	0.06	0.04	71%	0.06	0.04	71%	0.05	0.05	101%
RCR	EB	0-8	8/1/96	0.05	0.05	101%	0.05	0.05	101%	0.05	0.05	101%
GPR	EB	2-33	8/1-8/3/95	0.27	0.08	31%	0.32	0.12	39%	0.72	0.72	101%
GPR	EB	1-33	8/5-8/8/96	0.66	0.17	26%	0.76	0.22	28%	0.55	0.38	70%

[a] Gear: EB = electrofishing boat; HL = hook and line; Hv: exit samples of angler harvest.

[b] Area: sampled reach designated by location (river mile).

[c] p_c = contribution rate.

[d] cv = coefficient of variation.



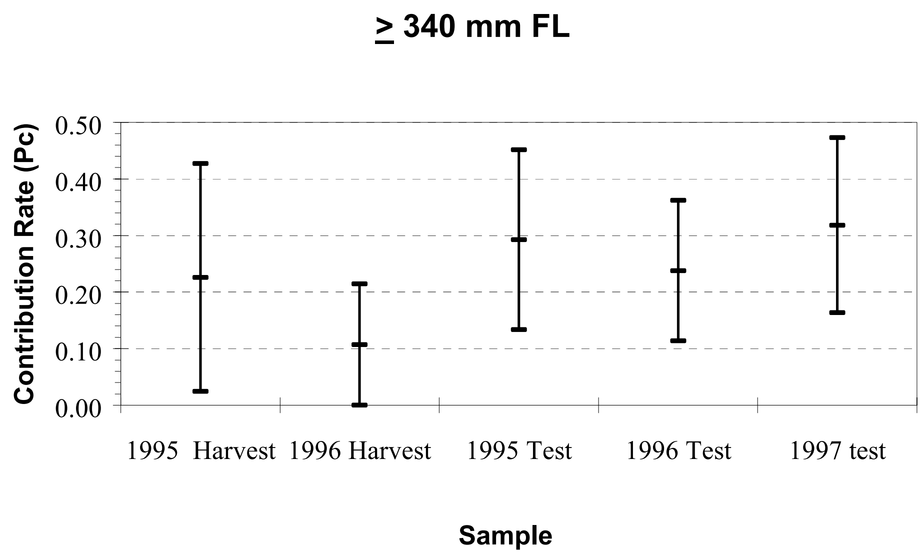


Figure 7.-Estimates of contributions of Goodpaster River Arctic grayling from two sample methods to the Delta Clearwater River by length group, 1995-1997.

(Table 18). However, due to small sample sizes and poor precision, no rate was significantly different from another.

DISCUSSION

This study presented the first estimates of abundance of a spawning assemblage of Arctic grayling in a large river system. While the abundance estimates were precise with coefficient of variations from 11% to 14%, movement of fish was problematical in 1996 and likely biased the 1996 estimate. The significantly higher abundance of fish ≥ 270 mm in 1996 would have been expected to increase abundance in the DCR given the same contribution rates. However, abundance in the DCR in 1996 was 2,775 fish ≥ 270 mm (SE = 342 fish) compared to 6,493 fish (SE = 806) in 1997 (Ridder 1998b). The 1996 contribution rate (0.33) was not significantly different from those in 1995 (0.30) and 1997 (0.23).

Movements of fish can be a potential bias in any abundance experiment on Arctic grayling, particularly during the spawning period. Movement in this study was significantly less evident in adult males than adult females and unknowns (19% vs 59% and 44%, respectively; $\chi^2 = 38.5$, df = 1, $P < 0.01$; Table 4). This finding is consistent with Arctic grayling reproductive behavior reported in the literature. Estimating Arctic grayling abundance by sex would have been helpful in assessing the apparent bias found in the 1996 data and may have afforded a more accurate and precise estimate of spawner abundance and trend.

The study showed not only the importance of the lower reaches of a clear water tributary as spawning habitat but also that estimates of abundance and composition can be significantly different depending on time of sampling. Previous population assessments in the GPR were conducted in early August and averaged 8,050 fish (≥150 mm FL, SE = 1,099 fish) from 1990 to 1994 with adult-sized fish (≥270 mm FL) averaging 1,191 fish (SE = 434; Table 19). In this study, abundance of adult-sized fish averaged 12,745 fish (SE = 1,689). These adult-sized fish comprised >75% of the population in May while they were only 20% of the population in August. It is likely that similar rivers in the Tanana drainage would show comparable changes in composition of fish between May and August.

The relative contribution rates of GPR Arctic grayling to the DCR do not represent the entire population but rather just that segment residing in the study area. Given the number of marked fish released in this study and an estimate of the entire population, the estimates of the proportion marked, p_t, would be much lower resulting in a higher contribution rate. Relative contribution rates should thus be viewed as minimum estimates.

Table 19.-Estimates of abundance of Arctic grayling for two size classes in the lower 33 miles of the Goodpaster River, August 1990-1994 and May 1995-1997.

	≥150 mm FL		≥270 mm FL	
Year[a]	N	SE	N	SE
1990	7,113	489	1,138	196
1991	7,836	859	1,019	310
1992	6,886	809	1,308	353
1993	10,841	1,340	976	402
1994	7,574	1,617	1,515	723
1995	na[b]	na	10,095	1,097
1996	25,364	3,093	16,775	2,127
1997	na	na	11,364	1,682
Average:				
August	8,050	1,099	1,191	434
May	25,364	3,093	12,745	1,689
% difference	215%	---	970%	---

a Data for 1990-1994 taken from Roach 1995.

b na = not available.

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APPENDIX A
Data Summaries and Additions

Appendix A1.-Summary of ice break-up conditions and water temperatures °C in the Goodpaster River, 28 April to 10 May, 1995.

Date	Time	Section[a]	Mile	Temperature °C
4/28/95	nd	One third open water from mouth to forks.		
4/29/95	nd	Lots of ice flowing past Big Delta.		
4/30/95	nd	Ice jams at mile 7-9.		
5/1/95	nd	Large ice jam at mile 15.		
5/2/95	nd	River open for boat travel.		
5/2/95	1000	MS	1	4.8
5/2/95	1300	MS	1	5.9
5/4/95	1700	MS	30	4.9
5/5/95	900	MS	23	4.0
5/5/95	1600	MS	11	5.0
5/6/95	840	MS	11	4.5
5/6/95	1530	MS	2	5.5
5/7/95	900	MS	33	3.8
5/7/95	1500	MS	23	4.0
5/8/95	830	MS	23	3.8
5/8/95	1600	MS	11	5.8
5/9/95	930	MS	11	5.4
5/9/95	1600	MS	1	7.7
5/4/95	1300	NF	nd	3.2
5/4/95	1600	NF	nd	4.0
5/5/95	1300	NF	nd	3.9
5/5/95	1700	NF	nd	5.4
5/6/95	1200	NF	nd	3.5
5/6/95	1600	NF	nd	3.5
5/8/95	930	NF	nd	2.7
5/8/95	1600	NF	17	5.2
5/10/95	1000	NF	17	5.1
5/10/95	1300	NF	13	6.0
5/10/95	1600	NF	8	7.2
5/7/95	930	SF	10	2.5
5/7/95	1500	SF	1	3.0

[a] Section = MS = Mainstem, mouth to forks (mile 0-33); NF = North Fork, forks to Central Creek (miles 0-27); SF = South Fork, forks to 10 miles upstream.

[b] nd = not done.

Appendix A2.-Summary of ice break-up conditions and water temperatures (°C) in the Goodpaster River, 7-16 May 1996.

Date	Time	Mile	Ave	Min	Max
7-May	---	Ice jams above mile 5			
7-May	1500	2	1.0	---	---
9-May	1300	Last ice jam above mouth broken up; river open for boats			
9-May	1600	2	3.8	---	---
10-May	0000-2400	2	5.5	3.5	6.7
11-May	0000-2400	2	6.8	4.8	8.8
12-May	0000-2400	2	8.3	6.7	10.2
13-May	0000-2400	2	8.5	7.1	10.1
14-May	0000-2400	2	6.4	5.0	8.2
15-May	0000-2400	2	4.9	4.0	5.7
16-May	0000-2400	2	4.8	3.9	6.8

Appendix A3.-Summary of ice break-up conditions and water temperatures (^{o}C) in the Goodpaster River, 2-11 May 1997.

Date	Time	Mile	Ave	Min	Max
2-May	1300	Numerous ice jams along river (aerial survey)			
3-May	---	---	---	---	---
4-May	---	---	---	---	---
5-May	1100	River free of ice (aerial survey)			
6-May	0900	2	4.0	---	---
6-May	0000-2400	33	2.1	1.1	2.7
7-May	0000-2400	33	2.2	0.8	3.3
8-May	1800	2	4.2	---	---
8-May	0000-2400	33	3.6	2.1	5.5
9-May	1700	22	4.8	---	---
9-May	0000-2400	33	3.1	2.2	4.4
10-May	1700	12	5.0	---	---
11-May	1700	2	6.0	---	---

Appendix A4.-Estimates of age composition and mean length at age for Arctic grayling ≥150 mm FL captured by electrofishing in the lower 70 miles of the Goodpaster River, 7 - 10 May 1995.

	Mainstem (river mi 0 – 33)							South Fork (river mi 0 – 10)							North Fork (river mi 0 – 27)						
	Age Composition			Length (mm FL)				Age Composition			Length (mm FL)				Age Composition			Length (mm FL)			
Age	n	p	SE	ave	std	min	max	n	p	SE	ave	std	min	max	n	p	SE	ave	std	min	max
2	10	0.01	<0.01	159	7	151	175	3	0.01	0.01	209	15	194	224	0	---	---	---	---	---	---
3	18	0.02	0.01	198	16	167	228	5	0.02	0.01	203	7	195	211	2	<0.01	<0.01	199	1	198	199
4	69	0.09	0.01	236	15	207	284	20	0.09	0.02	234	16	208	263	35	0.07	0.01	239	17	197	271
5	197	0.26	0.02	269	18	221	327	61	0.28	0.03	258	14	226	300	212	0.42	0.02	272	16	227	317
6	107	0.14	0.01	303	22	261	360	24	0.11	0.02	305	16	278	339	53	0.10	0.01	307	20	243	346
7	120	0.16	0.01	334	20	272	388	29	0.13	0.02	330	20	289	365	74	0.15	0.02	331	20	284	378
8	135	0.18	0.01	351	24	284	418	36	0.17	0.03	355	20	314	395	71	0.14	0.02	347	24	218	386
9	48	0.06	0.01	364	22	302	408	21	0.10	0.02	364	17	341	424	31	0.06	0.01	366	19	330	400
10	36	0.05	0.01	384	20	354	438	13	0.06	0.02	371	14	353	396	14	0.03	0.01	378	16	347	408
11	15	0.02	0.01	392	19	353	420	3	0.01	0.01	370	1	369	370	12	0.02	0.01	377	16	349	410
12	6	0.01	<0.01	421	29	385	465	2	0.01	0.01	386	3	384	388	2	<0.01	<0.01	388	8	380	396
13	1	<0.01	<0.01	396	---	---	---	0	---	---	---	---	---	---	3	0.01	<0.01	409	17	385	424
	762	1.00	---	313	55	151	465	217	1.00	---	305	53	194	424	509	1.00	---	305	45	197	424

Appendix A5.-Estimates of age composition and mean length at age for Arctic grayling ≥150 mm FL captured by electrofishing in the lower 33 miles of the Goodpaster River, 14 - 16 May 1996.

	Age Composition			Length (mm FL)			
Age	n[a]	p[b]	SE[p]	ave	std	min	max
2	3	<0.01	<0.01	202	10	192	211
3	131	0.11	0.01	199	14	164	250
4	34	0.03	0.01	240	20	203	303
5	79	0.07	0.01	267	14	236	300
6	238	0.21	0.01	301	23	255	372
7	202	0.18	0.01	321	21	252	399
8	152	0.13	0.01	344	22	288	453
9	164	0.14	0.01	358	19	303	412
10	87	0.08	0.01	375	21	330	426
11	37	0.03	0.01	386	20	352	442
12	18	0.02	<0.01	425	29	381	498
13	4	<0.01	<0.01	420	23	388	443
14	1	<0.01	<0.01	460	---	---	---
	1,150			337	55	171	441

[a] n = number of Arctic grayling sampled at age.

[b] p = proportion of Arctic grayling at age in sample.

Appendix A6.-Estimates of age composition and mean length at age for Arctic grayling ≥150 mm FL captured by electrofishing in the lower 33 miles of the Goodpaster River, 9 - 11 May 1997.

	Age Composition			Length (mm FL)			
Age	n[a]	p[b]	SE[p]	ave	std	min	max
2	1	<0.01	<0.01	150	0	150	150
3	29	0.04	0.01	190	17	160	243
4	113	0.15	0.01	235	17	198	280
5	14	0.02	<0.01	260	26	212	304
6	74	0.10	0.01	313	25	270	380
7	212	0.27	0.02	331	24	240	397
8	137	0.18	0.01	351	24	241	414
9	111	0.14	0.01	360	38	18	416
10	59	0.08	0.01	376	24	335	437
11	21	0.03	0.01	381	19	341	430
12	3	<0.01	<0.01	399	11	391	414
13	3	<0.01	<0.01	409	7	408	427
	777	1.00	----	322	57	18	437

[a] n = number of Arctic grayling sampled at age.

[b] p = proportion of Arctic grayling at age in sample.

Appendix A7.-Summary of catches and Goodpaster River tag recaptures in Arctic grayling samples stratified by length category (mm FL) and grouped by event, capture method, and month), Delta Clearwater River, 1995.

				Catch (n)				Recaptures (m)			
Group	Gear[a]	Area[b]	Dates	≥150	≥230	≥270	≥340	≥150	≥230	≥270	≥340
Event	EB	0-1	5/1-6/15	613	574	369	25	9	8	8	5
	EB	3-12	5/26-6/15	62	60	55	47	4	4	4	3
	H&L	2-12	6/5-6/15	151	151	149	79	11	11	11	5
	H&L	2-7	7/21-7/27	78	78	72	21	2	2	2	1
	EB	12-14	7/19-7/20	54	53	52	41	3	3	3	1
	Harvest	2-14	6/3-7/29	273	273	273	143	9	9	9	5
Method	EB	---	---	729	687	476	123	16	15	15	9
	H&L	---	---	229	229	221	100	13	13	13	6
	Harvest	---	---	273	273	273	143	9	9	9	5
Month	---	---	May	560	530	363	61	10	10	10	7
	---	---	June	360	349	305	156	17	16	16	14
	---	---	July	309	308	302	148	11	11	11	6
Totals[c]:	with replacement			1,231	1,189	970	366	38	37	37	20
	w/o replacement			1,172	1,130	912	336	34	33	33	18

[a] Gear: EB = electrofishing boat; H&L = hook and line; Harvest = exit samples of angler harvest.

[b] Area: sampled reach designated by location (river mile).

[c] Totals: with replacement = sampling with replacement; w/o replacement = sampling without replacement. All fish captured in the Delta Clearwater, except those from the harvest sample, were released with marks. This total culled recaptures of those marked fish.

Appendix A8.-Summary of catches and Goodpaster River tag recaptures in Arctic grayling samples stratified by length category (mm FL) Delta Clearwater River (DCR), Richardson Clearwater River (RCR), and Goodpaster River (GPR) 1995-1997.

				Catch (n)				Recaptures (m)			
Group	Gear[a]	Area[b]	Dates	≥150	≥230	≥270	≥340	≥150	≥230	≥270	≥340
DCR 1995	H&L,EB ,Harvest	2-14	5/26-7/29	618	615	601	331	27	27	27	15
DCR 1996	H&L	2-14	7/15-7/31	796	775	699	374	34	32	31	18
DCR 1997	H&L	2-14	7/14-7/25	1,434	1272	1087	529	38	36	33	25
DCR 1995	Harvest	2-14	6/3-7/29	273	273	273	143	8	8	8	5
DCR 1996	Harvest	2-14	6/1-8/17	251	251	251	185	6	6	6	4
RCR 1995	EB	0-8	7/25	237	237	233	143	2	2	2	1
RCR 1996	EB	0-7	8/1	172	167	145	101	1	1	1	1
GPR 1995	EB	2-33	8/1-8/3	638	279	146	9	11	11	7	1
GPR 1996	EB	1-33	8/5-8/8	617	209	137	18	17	17	14	2

[a] Gear: EB = electrofishing boat; H&L = hook and line; Harvest = exit samples of angler harvest.

[b] Area: sampled reach designated by location (river mile).

Appendix A9.-Relative Stock Density (RSD) indices of Arctic grayling (≥150 mm) by capture method and location, Delta Clearwater River, 1995.

				RSD Category[c]				
Date	Gear[a]	Reach[b]		Stock	Quality	Preferred	Memorable	Trophy
5/1 -	EB	0 - 1	Number	244	335	35	0	0
6/15			RSD	0.40	0.55	0.04	---	---
			SE	0.02	0.02	0.01	---	---
6/01 -	EB	3 - 12	Number	1	2	45	2	0
6/15			RSD	0.02	0.04	0.90	0.04	---
			SE	0.02	0.03	0.04	0.03	---
6/01 -	H&L	2 - 10	Number	2	62	50	1	0
6/15			RSD	0.02	0.54	0.43	0.01	---
			SE	0.01	0.05	0.05	0.01	---
7/19 -	EB	4 - 14	Number	2	11	41	0	0
7/21			RSD	0.04	.020	0.76	---	---
			SE	0.03	0.06	0.06	---	---
7/21 -	H&L	2 - 7	Number	6	51	21	0	0
7/27			RSD	0.08	0.65	0.27	---	---
			SE	0.03	0.05	0.05	---	---

[a] Gear: EB = electrofishing boat; H&L = hook and line.

[b] Reach = river mile.

[c] Length ranges (FL) for RSD categories (adapted fron Gabelhouse 1984): stock (150 - 269 mm); quality (270-339 mm); preferred (340-449 mm); memorable (450-559); and trophy (≥560 mm).

Appendix A10.-Estimates of age composition and mean length at age for Arctic grayling ≥150 mm FL captured by electrofishing in the lower mile of the Delta Clearwater River, 1 May -15 June 1995.

	Age composition			Length			
Age Class	n[a]	p[b]	SE[p']	mean	std	min	max
2	3	0.01	<0.01	182	35	154	221
3	27	0.05	0.01	224	22	175	270
4	166	0.31	0.02	257	21	210	323
5	223	0.42	0.02	282	34	240	341
6	81	0.15	0.02	307	21	251	351
7	7	0.01	<0.01	339	11	333	362
8	15	0.03	0.01	363	30	316	401
9	2	<0.01	<0.01	407	22	391	401
10	3	0.01	<0.01	395	22	379	420
11	3	0.01	<0.01	416	18	397	432
12	1	<0.01	<0.01	418	---	---	---
Totals	308	1.00		279	43	154	432

[a] n = number of Arctic grayling sampled at age.

[b] p = proportion of Arctic grayling at age in sample.

Appendix A11.-Estimates of age composition and mean length at age for Arctic grayling ≥150 mm FL captured by hook and line in the lower 12 miles of the Delta Clearwater River, 5 - 15 June 1995.

	Age composition			Length			
Age Class	n[a]	p[b]	SE[p']	mean	std	min	max
4	13	0.14	0.04	296	20	262	328
5	41	0.44	0.05	316	22	274	362
6	24	0.26	0.05	351	20	312	396
7	20	0.22	0.04	355	24	295	397
8	11	0.12	0.03	379	22	345	420
9	6	0.16	0.03	394	23	372	431
10	2	0.02	0.02	410	12	401	460
Totals	117	1.00	---	344	39	262	460

[a] n = number of Arctic grayling sampled at age.

[b] p = proportion of Arctic grayling at age in sample.

APPENDIX B
STATISTICAL METHODOLOGY

Appendix B1.-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 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 fish did not mix completely with unmarked fish within at least river section.
IV[f]	Reject H_o	Movement between sections	Inferred cause: There is differential capture probability by section or marked fish did not mix completely with unmarked 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 B2.-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, 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 C
DATA FILE LISTING

Appendix C1.-Data files[a] used to estimate parameters of the Arctic grayling population in the Goodpaster, Delta Clearwater, and Richardson Clearwater rivers, 1995 - 1997.

Data file	Description
U008ALA5	First event, mainstem, Goodpaster River, May 1995.
U008ALB5	Second event, mainstem, Goodpaster River, May 1995.
U008BLB5	Both events, South Fork, Goodpaster River, May 1995.
U008CLB5	Both events, North Fork, Goodpaster River, May 1995.
U0080LA5	One event, Goodpaster River, 1-3 August 1995.
U008ALA6	First event, mainstem, Goodpaster River, May 1996.
U008ALB6	Second event, mainstem, Goodpaster River, May 1996.
U0080LC6	One event, mainstem, Goodpaster River, 5-8 August 1996.
U008ALAA	First event, mainstem, Goodpaster River, May 1997.
U008ALBA	Second event, mainstem, Goodpaster River, May 1997.
U0060LA5	Test sample, Delta Clearwater River, 1 May through 9 June 1995.
U0060LB5	Harvest sample, Delta Clearwater River, 1995.
U0060LC5	Test sample, Delta Clearwater River, 12 through 15 June 1995.
U0060LD5	Test sample, Delta Clearwater River, 19 through 27 July 1995.
U006ALA6	Test sample, Delta Clearwater River, 15 through 31 July 1996.
U0060LAA	Test sample, Delta Clearwater River, 14 through 25 July 1997.
U0070LA5	One event, Richardson Clearwater River, 25 July 1995.
U0070LA6	One event, Richardson Clearwater River, 1 August 1996.

[a] Data files are 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.