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Abundance and Length and Age Composition of Arctic Grayling in the North Fork Goodpaster River in 2004

by

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November 2007

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
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	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
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.
minute (angular)	'
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
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 07-73

ABUNDANCE AND LENGTH AND AGE COMPOSITION OF ARCTIC GRAYLING IN THE NORTH FORK GOODPASTER RIVER IN 2004

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ABSTRACT

Arctic grayling *Thymallus arcticus* were sampled in July 2004 to estimate abundance, and age and length composition in the North Fork Goodpaster River. A two-sample mark-recapture experiment was used to estimate abundance of Arctic grayling in a 27.6-mile reach of river, roughly centered on a developing gold mine. In the upper section (12.9 miles from Glacier Creek to Liese Creek) the estimated abundance of Arctic grayling ≥240 mm FL was 1,411 fish (SE = 208). The abundance of Arctic grayling ≥240 mm FL in the lower section (14.7 miles from Liese Creek to Barbara Creek) was estimated to be 4,058 fish (SE = 436). Estimated abundance for fish ≥240 mm FL in both sections combined was 5,356 (SE = 481). Arctic grayling age-6 and older composed 96% of the population of Arctic grayling ≥240 mm FL sampled between Barbara Creek and Glacier Creek.

Key words: Arctic grayling, *Thymallus arcticus*, spawning, mark-recapture, age composition, size composition, Goodpaster River.

INTRODUCTION

The Goodpaster River, located in the upper Tanana River drainage (Figure 1), supports an important sport fishery that primarily occurs in the lower 33 miles of the drainage with a large majority of the angler effort directed at Arctic grayling *Thymallus arcticus.* Other targeted sport fishes include northern pike *Esox lucius* and burbot *Lota lota* and fishing is closed to the river's small runs of Chinook *Oncorhynchus tshawytscha* and chum salmon *O. keta*. The average annual estimate of fishing effort for all species in the Goodpaster River from 1983-2004 was 1,423 angler days, while the average annual estimates of harvest and catch of Arctic grayling from 1983-2004 were 981 and 2,560, respectively (Table 1).

Recent development and future operation of the Pogo Creek gold mine (located in the drainage of the North Fork Goodpaster River; 68 miles from the mouth) by Teck-Pogo Incorporated (Teck) has the potential to impact the habitat of the Goodpaster River. It is not likely that sport fishing effort will increase as a result of the mine operations because company policy prohibits employees from fishing while working; however, acquiring baseline information on fish populations was considered prudent given planned mining operations. While much has been learned about Arctic grayling in the lower portion of the Goodpaster River, little is known about the abundance and composition of Arctic grayling in the upper river, near the mine. The goal of this study was to obtain a second year of baseline abundance and composition (length and age) data for Arctic grayling ≥ 240 mm FL in their summer feeding areas in a 27.6-mile reach of the North Fork Goodpaster River roughly centered on the developing mine, essentially repeating the mark-recapture study performed in 2003 (Parker 2006).

BACKGROUND

The Goodpaster River provides habitat to Arctic grayling for spawning, summer feeding, and overwintering. A portion of the spring spawning population in the Goodpaster River migrates to other streams such as the Richardson Clearwater and Delta Clearwater rivers for summer feeding (Reed 1961; Roguski 1967; Ridder 1998a-b; Figure 1). Within the Goodpaster River, Tack (1974, 1980) described an upstream, pre-spawning movement prior to and during ice-out, an upstream post-spawning movement in late May and early June, and a mid-summer period of little movement. During the mid-summer period, predominately juveniles and sub-adults occupied the lower 33 miles of the river. Both adults and juveniles were found in the middle drainage from the Forks (confluence of South and North Forks, river mile 33) to Central Creek (river mile 60), but predominately adult fish were found above Central Creek.

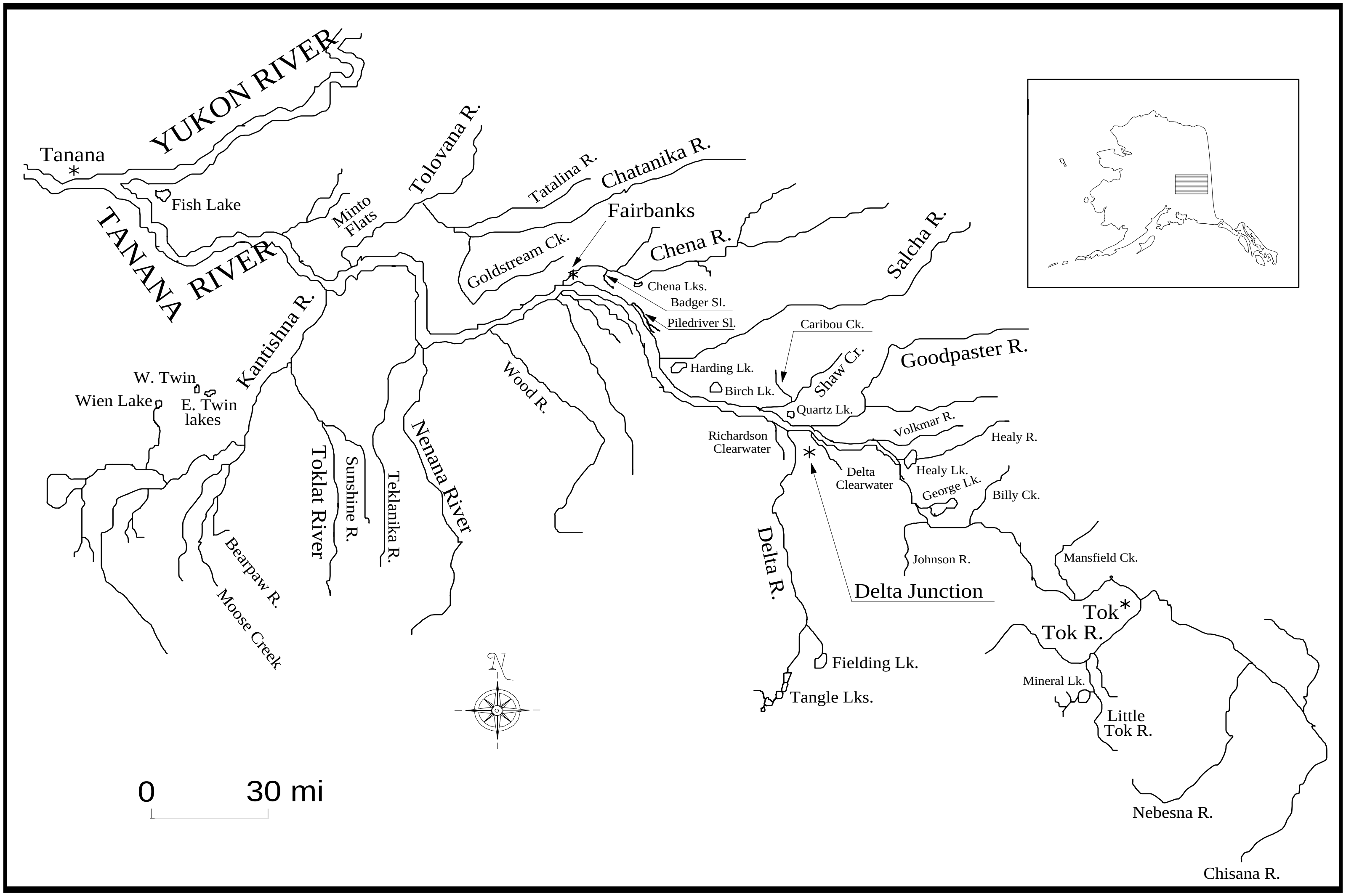

Figure 1.–The Tanana River drainage.

Table 1.–Estimates of effort, harvest, and catch for Arctic grayling and other species in the Goodpaster River, from the Alaska Statewide Harvest Survey, 1983-2004.

		Harvest						Catch					
Year	Angler Days	Arctic Grayling <12"	Arctic Grayling >12"	Arctic Grayling All	Northern Pike	Burbot	Whitefish	Arctic Grayling <12"	Arctic Grayling > 12"	Arctic Grayling All	Northern Pike	Burbot	Whitefish
1983	1,989	...	...	3,021	0	0	0	...	...		...	...	...
1984	766	...	...	1,194	65	221	65	...	...	78	...	...	...
1985	2,844	...	...	2,757	0	350	175	...	...		...	...	...
1986	933	...	...	1,508	16	88	0	...	...		...	...	...
1987	3,061	...	...	1,702	0	13	0	...	...		...	...	...
1988	1,037	...	...	1,273	36	109	0	...	...		...	...	...
1989	1,930	...	...	1,964	10	120	0	...	...		...	...	...
1990	2,083	...	...	760	17	0	186	...	...	3,342	34	0	186
1991	786	196	440	636	0	0	0	440	465	905	0	0	0
1992	1,430	281	485	766	26	17	0	2,399	1,200	3,599	120	17	0
1993	1,692	461	127	588	9	86	0	1,217	706	1,923	66	86	0
1994	825	342	358	700	0	0	309	945	864	1,809	66	0	309
1995	2,028	0	325	325	106	23	0	1,673	1,504	3,177	408	23	0
1996	1,244	484	351	835	33	16	0	2,167	754	2,921	142	35	0
1997	2,266	246	398	644	60	0	0	2,552	1,896	4,448	292	0	0
1998	774	206	462	668	0	109	0	2,878	1,827	4,705	34	109	0
1999	1,915	677	175	852	18	51	0	3,297	585	3,882	26	137	0
2001	787	548	325	873	0	7	0	1,403	412	1,815	9	7	0
2002	912	41	188	229	0	0	0	693	653	1,346	0	0	0
2003	925	0	56	56	22	11	0	942	557	1,499	34	11	0
2004	612	33	143	176	0	0	0	1,592	143	1,735	0	0	0
Averages													
1983-2004	1,423	253	277	981	19	56	33	1,637	867	2,560	88	28	33
1999-2004	743	129	151	279	4	4	0	1,070	467	1,537	28	4	0

Source: (Mills 1984-1994; Howe et al. 1995; 1996, 2001a-d; Walker et al. 2003; Jennings et al. 2004, 2006 a-b.)

Abundance and length and age compositions of the summer feeding stock in the lower river were estimated nearly annually from 1972-1994 (summarized in Roach 1995). Mark-recapture experiments performed from 1975-1987 were confined to two ~3 mile sections in the lower 18 miles of river. From 1988 to 1994, the experiments were expanded to include the lower 33 miles of river. More recently (1995-2002) mark-recapture studies were conducted in the lower 53 miles of the river during to estimate the abundance and composition of the spring spawning stock (Ridder 1998a; Parker 2002 and 2003).

Prior to 2003, the only work conducted in the upper Goodpaster River (above river mi 33) to estimate abundance of the summer stock was done by Tack (1973 and 1974), who estimated the abundance of Arctic grayling ≥150 mm FL in 115 miles of the Goodpaster River. Tack divided his study area into three sections based upon river characteristics. Area I was comprised of slow meandering portions of river between the mouth and the confluence of the North and South forks (33 mi). Area II was the lower 28 mi of the North Fork Goodpaster River from its confluence to Central Creek, and Area III was the upper North Fork from Central Creek to the lower part of Eisenmenger Fork (54 mi). Tack (1974), described Area III as having relatively fewer pools and more long fast riffles than in Area II.

The study area for the experiment in 2004 included parts of Area II and III as described by Tack (1974): approximately 3.9 miles from Central Creek to Barbara Creek were in Area II and the remaining 20.6 miles were in Area III. Parker (2006) used Tack's data to estimate the density of Arctic grayling ≥ 300 mm FL in Area III as 98 fish/mile and noted that it was similar to the density estimate of 88 Arctic grayling ≥ 300 mm FL per mile (95% CI = 71-105) calculated for 2003 (Figure 2).

OBJECTIVES

The research objectives for 2004 were to:

1. estimate the abundance of Arctic grayling ≥ 220 mm FL in two sections (12.9 mi and 14.7 mi) of the North Fork Goodpaster River near the Pogo Mine site for June-July 2004 such that the estimates are within 25% of the true abundance 95% of the time;
2. estimate the length composition (in 10-mm intervals) of the Arctic grayling ≥ 220 mm FL in two sections (12.9 mi and 14.7 mi) of the North Fork Goodpaster River near the Pogo Mine site for June-July 2004 such that the estimates are within 10 percentage points of the true value 95% of the time; and,
3. estimate the age composition (age-1 to -6 and ≥ age-7) of the Arctic grayling ≥ 220 mm FL in two sections (12.9 mi and 14.7 mi) of the North Fork Goodpaster River near the Pogo Mine site for June-July 2004 such that the estimates are within 10 percentage points of the true value 95% of the time.

METHODS

STUDY AREA

The Goodpaster River is a large, rapid run-off tributary of the Tanana River. It has a drainage area of approximately 1,600 mi^2, and flows southwest for 140 miles to its confluence with the Tanana River 10 miles north of Delta Junction (Figure 1). The Goodpaster River has 13 named tributaries, the largest of which is the South Fork Goodpaster River (40 mi long). The Pogo

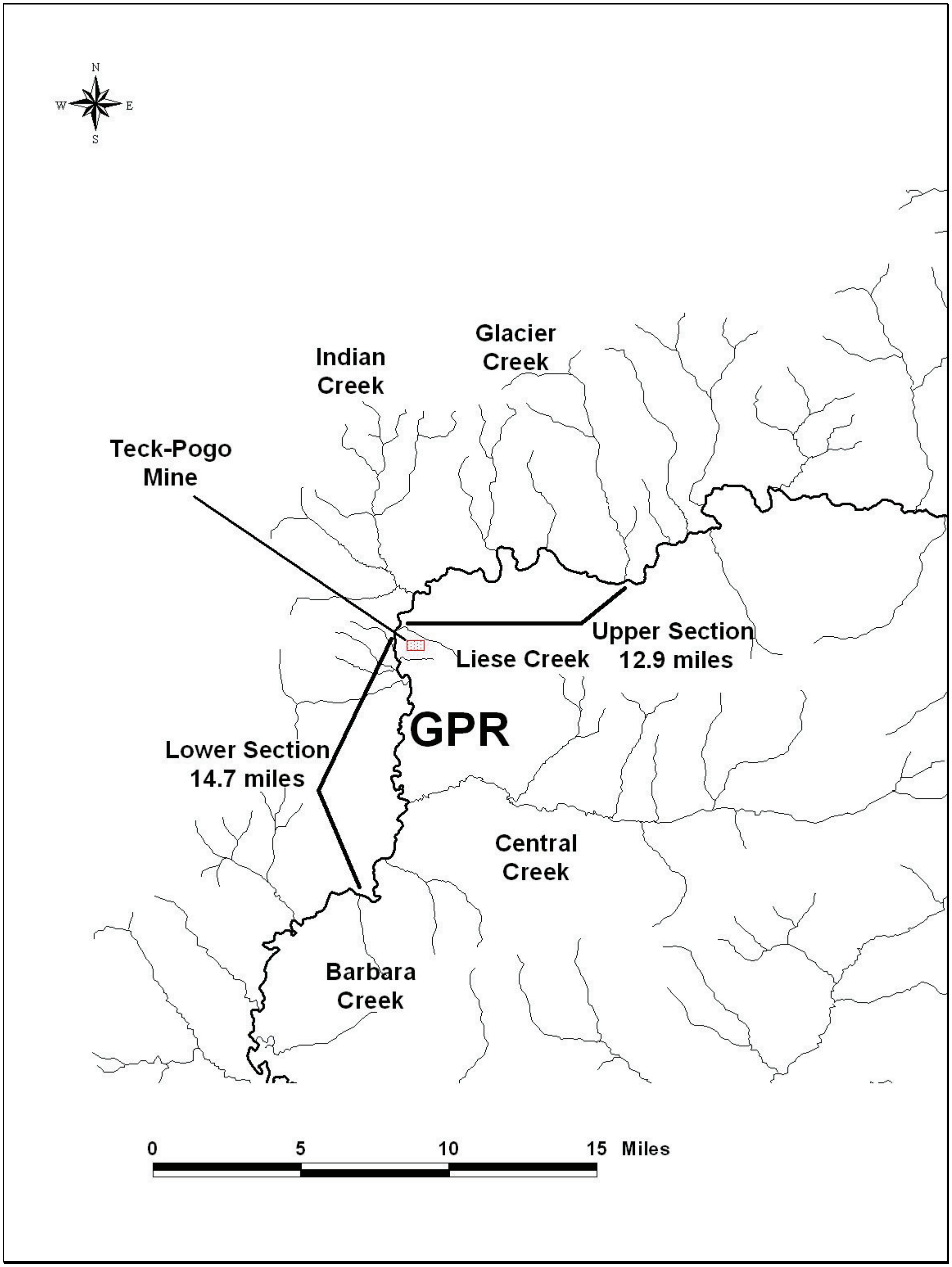

Figure 2.–The Goodpaster River (GPR) study area, 2004.

mine site is located in the North Fork Goodpaster River approximately 35 miles upstream from the confluence of the South Fork Goodpaster River. The study area extends approximately 12.9 miles upstream from the Liese Creek to Glacier Creek and 14.7 miles downstream from the Liese Creek site to Barbara Creek (Figure 2).

The river is accessible by riverboat or airplane during the summer. The mine can also be accessed by an all-season road that starts at the Richardson Highway at Shaw Creek, but is closed to the public. Boat launches are located at Big Delta on the Tanana River (14 mi downstream from the mouth of the Goodpaster River) and at Clearwater Lake (7 mi upstream from the mouth of the Goodpaster River). During average summer flow conditions, navigation using a jet-powered boat is possible in the lower 60 mi of the Goodpaster River and in the lower 10 mi of the South Fork. Floatplane access is feasible in the lower 23 miles of the river. Private landing strips are located at Central Creek (river-mile 60), at Pogo Creek (at river-mile 68), and at Tibbs Creek, which is a tributary of the Eisenmenger Fork of the Goodpaster River. There are approximately 66 recreational cabins on the river, and all but eight are located between river-mile 3 and 30, and at least one recreational cabin is located above Central Creek.

EXPERIMENTAL DESIGN

Arctic grayling were sampled during two events from July 6-14 and July 21-28, when Arctic grayling were relatively stationary during occupation of their summer feeding areas, to minimize the effects of immigration and emigration. The study area was divided into two sections. The upper section was 12.9 miles in length and the lower section was 14.7 miles in length (Figure 2). Two two-person crews conducted sampling with each crew assigned to one section for the duration of the experiment. Within each section sampling was conducted in a downstream progression covering approximately 1.5 to 2 miles of river per day. The crew on the upper section was transported each day by helicopter from the mine site and an inflatable boat was used to carry gear while wading downstream. The lower section was accessed using a jet-powered boat and both crews returned to the Pogo Mine site at the conclusion of each day for lodging.

Arctic grayling were captured using hook-and-line gear, and 1/16 oz rubber-bodied jigs were used as terminal gear. Each crew fished the river systematically, actively searching for suitable areas where Arctic grayling could be found. With the low water levels, riffle and pool areas were easily distinguishable and Arctic grayling were most often sighted and captured in the bottom of riffle areas or at the head of pools. On occasion concentrations of Arctic grayling were found in long stretches of narrow riffle area associated with large rocks and fast current. In areas where the river was divided into two channels, both channels were sampled in attempt to subject all fish to a non-zero probability of capture. Captured fish were temporarily held in a water-filled container until sampled. All Arctic grayling were sampled and released within 0.25 mi of their capture location. Sample size objectives for estimating abundance were established using methods in Robson and Regier (1964) and for length and age compositions using criteria developed by Thompson (1987) for multinomial proportions.

The mark-recapture experiment was designed to satisfy the assumptions of a Petersen mark-recapture experiment (Seber 1982). These assumptions were that:

1. the population was closed (i.e., Arctic grayling did not enter or leave the population during the experiment);

2. all Arctic grayling had a similar probability of capture in the first event or in the second event, or marked and unmarked Arctic grayling mixed completely between the first and second events;
3. marking of Arctic grayling did not affect the probability of capture in the second event;
4. marked Arctic grayling were identifiable during the second event; and,
5. all marked Arctic grayling were reported when recovered in the second event.

The estimator used was a modification of the general form of the Petersen estimator:

$$\hat{N} = \frac{n_1 n_2}{m_2}, \quad (1)$$

where:

n_1 = the number of Arctic grayling marked and released during the first event;

n_2 = the number of Arctic grayling examined for marks during the second event; and,

m_2 = the number of marked Arctic grayling recaptured during the second event.

The specific form of the estimator was determined from the experimental design and the results of diagnostic tests performed to evaluate if the assumptions were satisfied (see Data Analysis Section). The experiment was designed to allow the validity of these assumptions to be insured or tested because failure to satisfy the assumptions could result in substantially biased estimates.

To help ensure that the movement of fish did not violate the assumption of closure (Assumption 1), the experiment was conducted during the summer feeding period when Arctic grayling were not expected to be migrating (Tack 1974, 1980; Ridder 1998a; Parker 2002). Movement within the study area was expected, but only on a localized scale (e.g., up to 1.5 river miles) as was observed in 2003 (Parker 2006). The short duration of the experiment also helped reduce occurrences of migration, recruitment and mortality. Marking and recovery locations of recaptured fish were examined for evidence of movement in order to evaluate the appropriateness of the assumption of closure.

To help ensure Assumption 2 was met, the crews tried to subject all Arctic grayling to the same probability of capture within the constraints of the duration of an event (6 days) and length of river being sampled (27.6 miles). Specifically, relative densities were assessed from direct observations and from numbers of strikes and fish landed. Based on these assessments, attempts were made to expend more fishing effort fishing in high density areas such as in heads of pools and less in low density areas such as wide, shallow areas, while fishing the entire river. Because Arctic grayling move little during the summer, complete mixing of marked and unmarked fish within the study area was not expected; rather Arctic grayling were expected to mix on a smaller scale (within approximately 1.5 river mile). Diagnostic tests to identify heterogeneous capture probabilities and methods to correct for potential biases are presented in the Data Analysis section.

Relative to Assumption 3, a hiatus of 8 days between the first and second sampling events was thought to be ample time for Arctic grayling to recover from the effects of hooking and handling and to resume normal feeding behavior.

Relative to Assumptions 4 and 5, Arctic grayling captured during the first event were double marked with an internal anchor tag and a single fin clip, and all fish caught in the second event were carefully examined for marks.

DATA COLLECTION

Two scales for aging and a length measurement (mm FL) were taken from all captured fish ≥240 mm FL during both sampling events. In the first event, all captured fish were tagged with individually numbered internal anchor tags and secondarily marked with a partial left ventral fin clip to detect tag loss. In the second event, unmarked fish were only given a partial right ventral fin clip to prevent double-counting. Arctic grayling captured with tags from previous experiments were given the appropriate secondary mark and the tag number of each and the number caught per run were recorded. The date and location of capture, fin clips, tag numbers and colors, and fate of fish were recorded in water-resistant field notebooks. These data were later transferred to optical scanning forms and transformed into an electronic (ASCII) data file for analysis and archival (Appendix C).

The two scales used for aging were taken from an area approximately six scale rows above the lateral line and just posterior to the insertion of the dorsal fin. Each scale was immediately cleaned and mounted on a gummed card. The scales on gummed cards were used to make triacetate impressions of the scales (30 seconds at 137,895 kPa, at a temperature of 97ºC). Ages from impression were determined as described by Yole (1975).

DATA ANALYSIS

Abundance Estimate

A stratified design was used to estimate the abundance and size composition of Arctic grayling for the two adjacent river sections within the study area. Although not specifically listed as an objective, these parameters were also estimated for the entire study area (upper and lower sections combined) hereafter referred to as the “combined’ estimates.

It is inherently difficult to approximate the taking of a simple random sample (i.e., a random sample without replacement) in a river. Therefore, samples from the Goodpaster River were taken systematically in the sense of progressively moving downstream and sampling proportionally to the abundance of fish present (discussed above with respect to Assumption 2). Under these circumstances the Bailey-modified Petersen estimator (Appendix A; Bailey 1951, 1952) is preferred over the Chapman-modified Petersen estimator (Chapman 1951) for estimating abundance.

Violations of Assumption 2 relative to length were tested for using Kolmogorov-Smirnov (K-S) tests performed within each section (i.e., stratum). The tests and possible outcomes and actions for data analysis are outlined in Appendix A2. The tests for consistency of the Petersen estimator (Seber 1982; Appendix A3) were used to determine if, for each identified length stratum, stratification by location was required due to spatiotemporal effects and to determine the appropriate abundance estimator: the pooled Bailey-modified Petersen estimator, the completely stratified Bailey-modified Petersen estimator, or a partially stratified estimator (Darroch 1961). To perform these tests, each section was divided into three subsections of roughly equal length using the nearest landmark (e.g., a stream tributary) to define subsection boundaries. The subsections were consistent with those used when analyzing data from the 2003 experiment (Parker 2006). Criteria considered when defining geographic strata included number of recaptures per stratum, hydrology, and stratum length relative to anticipated movements. When estimating abundance, a minimum number of recaptures (approximately seven fish) were preferred to permit reliable diagnostic testing and to ensure negligible statistical bias in $\hat{N}$ (Seber 1982). Sections longer than approximately 2 km were preferred to accommodate localized movements of Arctic grayling (e.g., approximately 1-2 km).

Length and Age Compositions

Length and age composition of the population were estimated using the procedures outlined in Appendix A2 and A4. Length composition was estimated in 10-mm length categories. Length composition was estimated in 10-mm length categories. Age composition was described for individual age classes 1-6, but fish 7 years and older were lumped into a single age category (7+) because of error associated with assigning ages to older Arctic grayling (DeCicco and Brown 2006).

RESULTS

A total of 1,884 Arctic grayling were captured and measured for length, of which 1,793 were ≥ 240 mm FL and included in the analysis. Of the fish ≥ 240 mm FL, 1,164 were marked and released in the first event (n_1) and 629 were captured and examined for marks in the second event (n_2), and 153 were marked fish recaptured in the second event (m_2). No tag loss was detected between sampling events. The smallest recaptured fish was 252 mm FL in the lower section and 268 mm FL in the upper section. The lower length limit of 240 mm FL was selected to facilitate comparisons to abundance estimates attained in 2003 and because K-S diagnostic tests (see below) did not reject the hypothesis of equal probability of capture regardless of length for Arctic grayling between 240 and 319 mm FL indicating that fish ≥ 240 mm FL were sufficiently recruited to the capture gear.

Based on the diagnostic procedures outlined in Appendix A2, K-S test results indicated that for the upper section, stratification by length was not required because sampling was not size selective during the first event (Table 2, Figure 3). For the lower section, sampling was size selective during both events and two length strata were identified, 240-319 mm FL and ≥ 320 mm FL (Table 2). The strata break at 320 mm FL was chosen because it was in a range of lengths that were related/linked to: 1) more extreme vertical separation between cumulative relative length frequency curves (Figure 3); and, 2) more extreme differences in first and second event capture probability (as determined by contingency table analysis) when selected as break points defining large and small fish categories. For the combined estimate, stratification at 320 mm FL was required (Table 2). Within length strata, K-S tests confirmed selected strata and identified appropriate sampling events for use in estimating length composition (Table 2).

Table 2.–Results of diagnostics used to detect and correct for size selective sampling (Appendix A) for estimating length composition of Arctic grayling in the Goodpaster River for the upper and lower sections and for the upper and lower sections combined, 2004.

	Comparison and Test Statistic		
Section and length strata	**M vs. R**	**C vs. R**	**Result**
Upper Section			
≥ 240 mm FL	D = 0.16 P-value = 0.01 Reject Ho	D = 0.12 P-value = 0.66 Fail to reject H_0	Case II, do not stratify, use first event lengths for composition analysis
Lower Section			
≥ 240 mm FL	D = 0.25 P-value = 0.00 Reject Ho	D = 0.21 P-value = 0.00 Reject Ho	Case IV, stratify; 320 mm selected as break point
240-319 mm FL	D = 0.23 P-value = 0.05 Fail to reject H_0	D = 0.19 P-value = 0.15 Fail to reject H_0	Case I, do not stratify, use lengths from both events for composition analysis
≥ 320 mm FL	D = 0.06 P-value = 0.96 Fail to reject H_0	D = 0.07 P-value = 0.83 Fail to reject H_0	Case I, do not stratify, use lengths from both events for composition analysis
Combined			
≥ 240 mm FL	D = 0.23 P-value = 0.00 Reject Ho	D = 0.15 P-value = 0.01 Reject Ho	Case IV, stratify
240-319 mm FL	D = 0.22 P-value = 0.04 Reject Ho	D = 0.19 P-value = 0.08 Fail to reject H_0	Case II, do not stratify, use first event lengths for composition analysis
≥320 mm FL	D = 0.06 P-value = 0.93 Fail to reject H_0	D = 0.07 P-value = 0.80 Fail to reject H_0	Case I, do not stratify, use lengths from both events for composition analysis

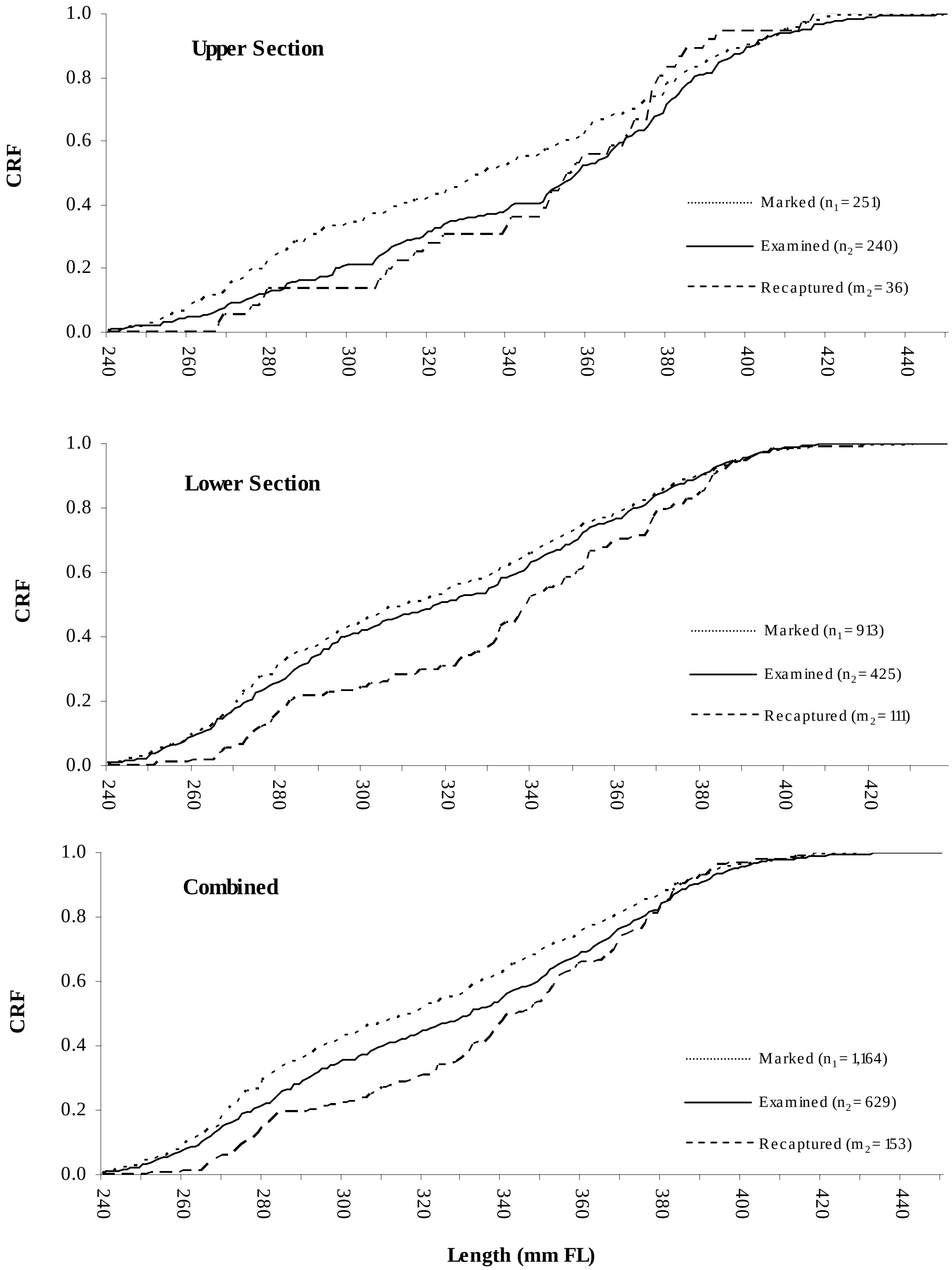

Figure 3.–Cumulative relative frequency (CRF) of Arctic grayling ≥ 240 mm FL marked, examined and recaptured for the upper and lower sections of the study area and the two sections combined in the North Fork Goodpaster River, 2004.

Within each identified length stratum, tests for consistency of the Petersen estimator (Appendix A3; Seber 1982) were performed to check for spatiotemporal differences in capture probability. For testing and estimating abundance in the upper and lower sections, the fates of the six fish that were recaptured after having moved between sections (three fish for each section) were not counted as recaptured but rather as examined (n_2**;** Tables 3 and 4). For fish ≥ 240 mm FL in the upper section, capture probabilities among subsections were not significantly different for both the first and second events (Table 5). For both length strata (240 – 319 and ≥320 mm FL) in the lower section and when combining the upper and lower sections, geographic stratification was not required (Table 5). For all identified length and geographic strata, mixing was not complete (Table 5).

Using the Bailey-modified Petersen estimate, the population estimates for Arctic grayling were:

1) 1,411 (SE = 208) ≥240 mm FL in the upper section;
2) 4,058 (SE = 436) ≥ 240 mm FL in the lower section;
    a. 2,858 (SE = 422) 240 – 319 mm FL in the lower section;
    b. 1,200 (SE = 110) ≥320 mm FL in the lower section;
3) 5,356 (SE = 481) ≥ 240 mm FL in the entire study area;
    a. 3,471 (SE = 457) 240 – 319 mm FL in the entire study area; and,
    b. 1,885 (SE = 150) ≥320 mm FL in the entire study area.

During the course of the experiment, 147 of 153 fish with known release and recapture locations were recaptured within the same stratum (upper or lower section) in which marked. At the subsection scale, 121 of the 153 recaptured Arctic grayling ≥ 240 mm FL were caught in the same subsection in both events. Of the 32 remaining, only six moved more than one subsection, four of which moved two subsections. Twenty-three of these 32 Arctic grayling moved upstream. The tendency of Arctic grayling 240 – 319 mm FL to move at least one subsection (15 of 46 fish) was significantly greater than for Arctic grayling ≥320 mm FL (17 of 107 fish).

An analysis of the actual distances moved showed that 88 fish moved upstream and 57 moved downstream (7 did not move). For fish moving greater than 2 km, 19 moved upstream and six moved downstream. Most (77%) of the recaptured fish moved less than one kilometer, only 16% moved greater than 2 km, and only 10% moved greater than 4 km (Figure 4). Four fish were captured at or near the limits of detection after having moved greater than 5 km.

LENGTH AND AGE COMPOSITIONS

Arctic grayling in the upper section of the study area were on average larger and older than fish in the lower section of the study area (Figure 5, Appendices B1 and B2); nevertheless, the abundance of large fish (e.g., ≥320 mm FL) and fish age-6 and older in the lower section was greater than in the upper.

Table 3.–Number of Arctic grayling 240-319 mm FL marked (**n_1**), examined (**n_2**), and recaptured (**m_1**) by location relative to the upper (subsections 1-3) and lower sections (subsections 4-6) of the study area in the North Fork Goodpaster River, July 2004.

		Subsection where recaptured						Total Recaptured	Total Marked	$P_{capture}$ 2nd Event
		1	2	3	4	5	6	(m_2)	(n_1)	(m_2/n_1)
Subsection where marked	1	1	1	0	0	0	0	2	11	0.18
	2	1	2	0	0	0	0	3	30	0.10
	3	1	0	1	1[a]	0	0	3	63	0.05
	4	0	1[a]	0	11	0	0	12	133	0.09
	5	0	0	1[a]	4	8	2	15	185	0.08
	6	0	0	0	0	3	8	11	167	0.07
Total Recaptured (m_2)		3	4	2	16	11	10			
Total Examined (n_2)		17	26	18	67	73	75			
$P_{capture}$ 1st Event		0.18	0.15	0.11	0.24	0.15	0.13			

[a] Fish that moved between the lower and upper section and were not included in the testing procedures or in calculating abundance estimates within a geographic strata.

Table 4.–Number of Arctic grayling≥320 mm FL marked **n_1**), examined (**n_2**), and recaptured (**m_1**) by location relative to the upper (subsections 1-3) and lower sections (subsections 4-6) of the study area in the North Ford Goodpaster River, July 2004.

		Subsection where recaptured						Total Recaptured	Total Marked	Pcapture 2nd Event
		1	2	3	4	5	6	(m_2)	(n_1)	(m_2/n_1)
Subsection where marked	1	8	1	0	0	1[a]	0	10	41	0.24
	2	2	7	0	0	0	0	9	49	0.18
	3	1	0	10	0	0	1[a]	12	57	0.21
	4	0	0	1[a]	19	1	0	21	117	0.18
	5	0	0	0	5	26	1	32	172	0.19
	6	0	0	0	0	3	20	23	139	0.17
Total Recaptured (m_2)		11	8	11	24	31	22			
Total Examined (n_2)		61	48	34	66	68	76			
$P_{capture}$ 1st Event		0.18	0.17	0.32	0.36	0.46	0.29			

[a] Fish that moved between the lower and upper section and were not included in the testing procedures or in calculating abundance estimates within a geographic strata.

Table 5.–Results of consistency tests for the Petersen estimator (Appendix A2) for estimating abundance of Arctic grayling in the Goodpaster River for the upper and lower sections and for the upper and lower sections combined, 2004

	Consistency Test		
	I	II	III
Length and geographic strata	**Complete Mixing**	**Equal probability of Capture, 2nd Event**	**Equal probability of Capture, 2nd Event**
Upper Section			
≥240	χ^2 = 43.19	χ^2 = 0.74	χ^2 = 3.21
	P-value = 0.00	P-value = 0.69	P-value = 0.20
Lower Section			
240 - 319 mm FL	χ^2 = 33.50	χ^2 = 2.16	χ^2 = 0.31
	P-value = 0.00	P-value = 0.34	P-value = 0.85
>320 mm FL	χ^2 = 98.55	χ^2 = 4.22	χ^2 = 0.25
	P-value = 0.00	P-value = 0.12	P-value = 0.88
Combined			
240 - 319 mm FL	χ^2 = 104.67	χ^2 = 3.69	χ^2 = 3.30
	P-value = 0.00	P-value = 0.60	P-value = 0.65
>320 mm FL	χ^2 = 373.79	χ^2 = 17.38	χ^2 = 1.56
	P-value = 0.00	P-value = 0.00	P-value = 0.91

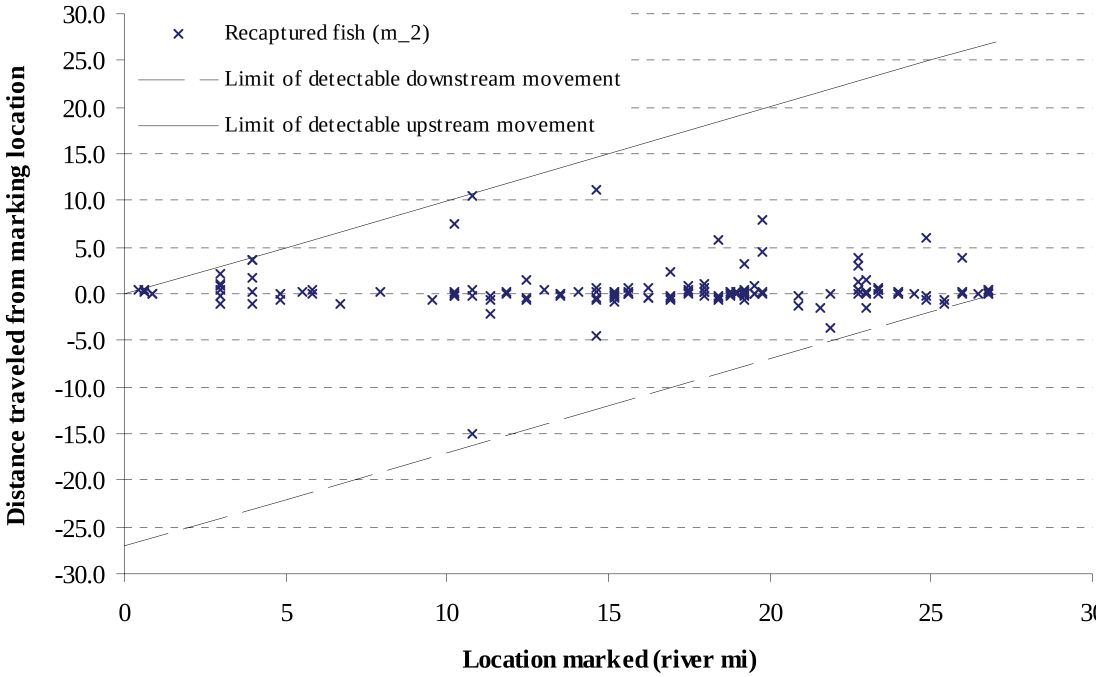

Figure 4.–Distance traveled of recaptured Arctic grayling between the first and second events of the mark-recapture experiment within the 42-kilometer study area in the North Fork Goodpaster River, 2004.

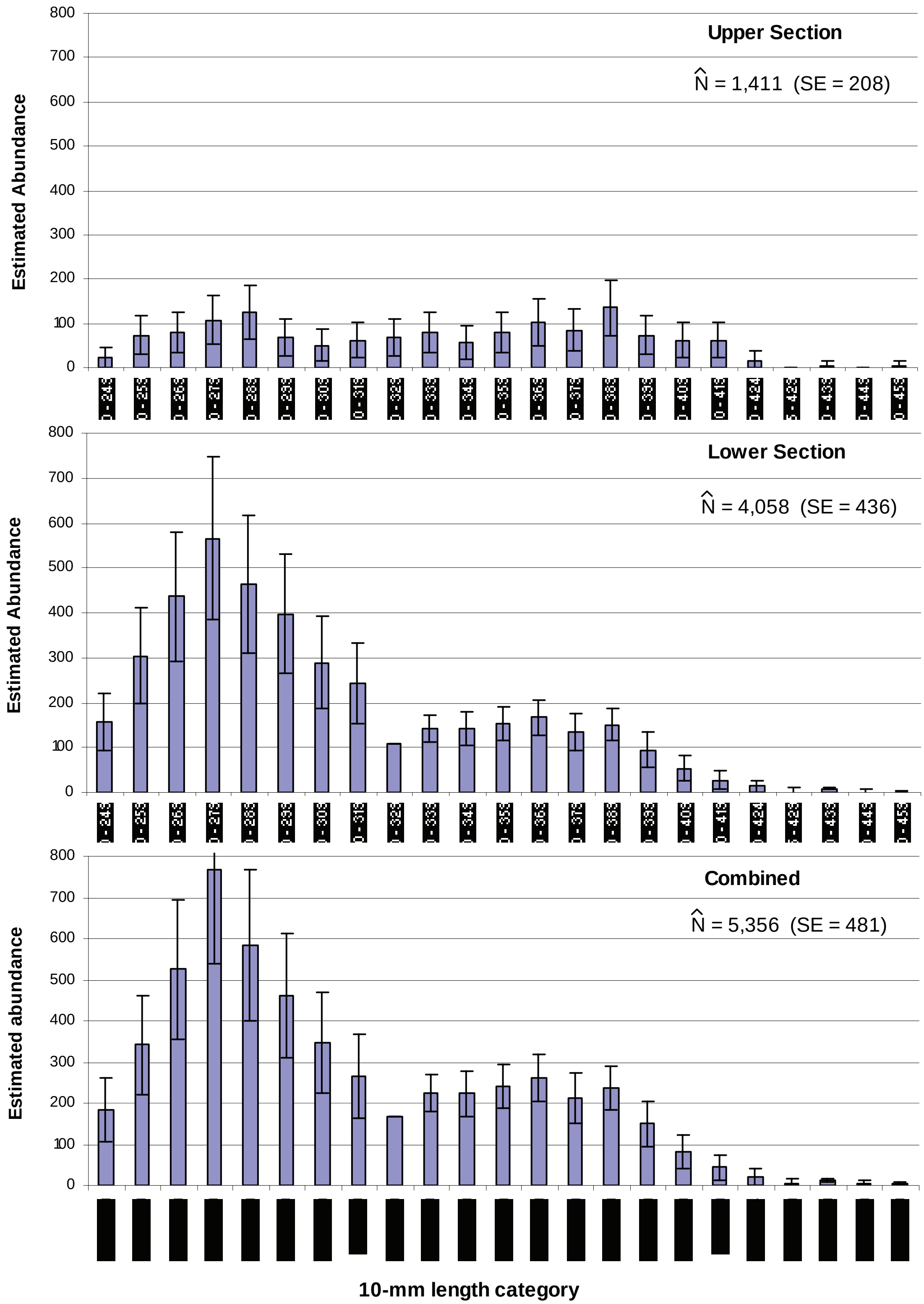

Figure 5.–Estimated of Arctic grayling length composition by 10-mm length category for the upper and lower sections of the study area and the two sections combined in the North Fork Goodpaster River, 2004.

DISCUSSION

Positive bias in estimated abundance resulting from combined immigration and emigration (closure violations) was thought to be minor because a large majority of fish movements occurred on a small scale relative to the size of the study area and there was only a weak indication of net upriver movement. That the positive bias may be expected to be small (i.e., ≤ 5%) can be seen by the close agreement between abundance estimates calculated for the entire study area without stratifying into upper and lower sections with those calculated by stratifying by these sections. For Arctic grayling ≥ 320 mm FL, these abundance estimates were 1,885 (not stratified by section) compared to 1,910 (stratified by section), and for fish between 240 and 319 mm FL the abundance estimates were 3,471 (not stratified by section) and 3,676 (stratified by section). The increase was greater for the smaller fish, which is consistent with their movements being greater. These results were confirmed by further dividing the study area into three then six subsections and comparing these stratified estimates with the non-stratified estimate.

Results of this study in 2004 demonstrated that there were notable differences in the abundance and length compositions of Arctic grayling above and below the mine site. Above the mine site the fish tended to be larger in size on average and few smaller sized fish (i.e., ≤ 320 mm FL) were present (Figure 5). This pattern of low densities of smaller sized fish in the upper section was also observed in 2003 (Parker 2006). In 2003, too few small fish were captured in the upper section to be able to estimate abundance.

Interannual comparisons showed potentially consistent and inconsistent patterns in abundance. To facilitate comparisons between years (2003 and 2004; Figure 6), estimates in 2004 were adjusted to length strata identified in 2003 (i.e., ≥300 mm FL). During both years, the abundance of larger sized fish (i.e., ≥300 mm FL) in the upper section and in the entire study area were markedly similar. However, there was a notable difference in the abundance of fish ≥240 mm FL in the lower section.

The differences in fish densities above and below the mine observed during both years of study suggest that this pattern of higher fish densities in the lower section may be related to habitat and therefore temporally stable. However, the large difference in the abundance of fish ≥240 mm FL in the lower section between 2003 and 2004 despite similar estimates of for fish ≥ 300 mm FL underscores the fact that temporal variation in fish densities within a given section may be substantial.

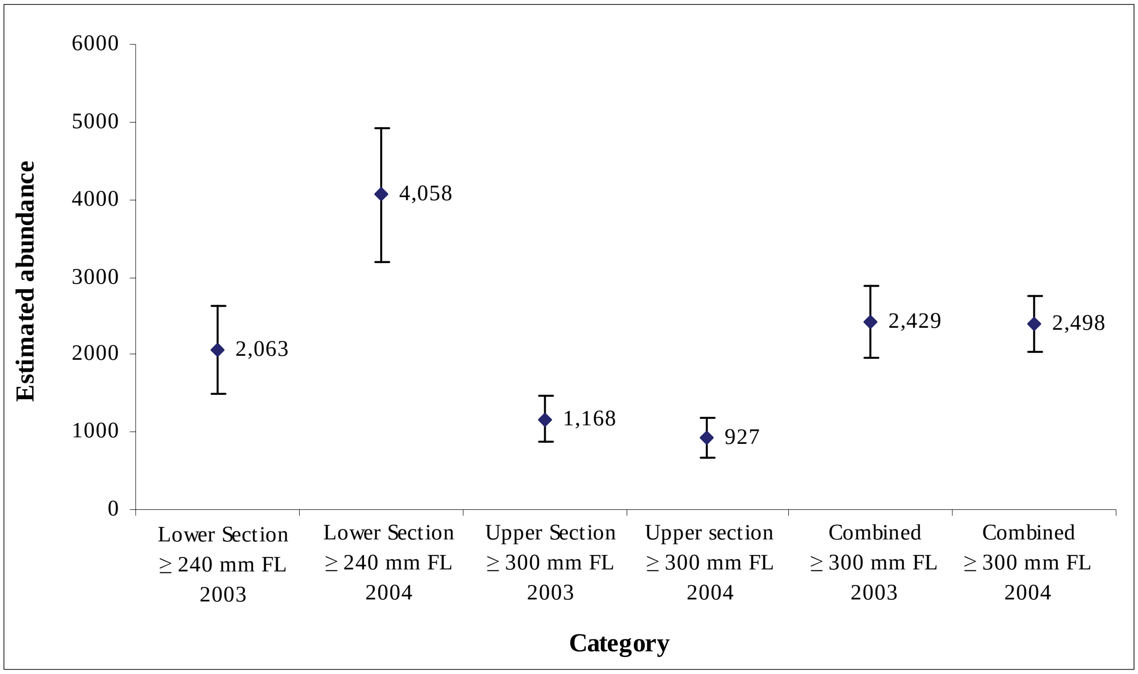

Figure 6.–Estimated abundance of Arctic grayling by category (section and length strata) within the 43-km study area of the North Fork Goodpaster River, 2003 and 2004.

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APPENDIX A
EQUATIONS AND STATISTICAL METHODOLOGY

Appendix A1.–Equations for calculating estimates of abundance and its variance using the Bailey-modified Petersen estimator.

The Bailey-modified Petersen estimator (Bailey 1951 and 1952) was used because the sampling design called for a systematic downstream progression, fishing each pool and run and attempting to subject all fish to the same probability of capture while sampling with replacement. The Bailey modification to the Petersen estimator may be used even when the assumption of a random sample for the second sample is false when a systematic sample is taken provided:

1) there is uniform mixing of marked and unmarked fish; and,
2) all fish, whether marked or unmarked, have the same probability of capture (Seber 1982).

The abundance of Arctic grayling was estimated as:

$$\hat{N} = \frac{n_1(n_2+1)}{m_2+1}, \tag{1}$$

where:

n_1 = the number of Arctic grayling marked and released alive during the first event;

n_2 = the number of Arctic grayling examined for marks during the second event; and,

m_2 = the number of Arctic grayling marked in the first event that were recaptured during the second event; and

The variance was estimated as (Seber 1982):

$$\hat{V}[\hat{N}] = \frac{n_1^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)}. \tag{2}$$

Appendix A2.–Procedures for detecting and adjusting for size or sex selective sampling during a 2-sample mark recapture experiment.

Overview

Size and sex selective sampling may result in the need to stratify by size and/or sex in order to obtain unbiased estimates of abundance and composition. In addition, the nature of the selectivity determines whether the first, second or both event samples are used for estimating composition. The Kolmogorov-Smirnov two sample (K-S) test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first or second sampling events and contingency table analysis (Chi-square test) is generally used to detect significant evidence that sex selective sampling occurred during the first or second sampling events.

K-S tests are used to evaluate the second sampling event by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R), using the null test hypothesis (H_o) of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. Chi-square tests are used to compare the counts of observed males to females between M&R and C&R according to the null hypothesis that the probability that a sampled fish is male or female is independent of the sample. When the proportions by gender are estimated for a subsample (usually from C), rather than observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are compared between samples using a two sample test (e.g., Student's t-test).

Mark-recapture experiments are designed to obtain sample sizes sufficient to 1) achieve precision objectives for abundance and composition estimates and 2) ensure that the diagnostic tests (i.e., tests for selectivity) have power adequate for identifying selectivity that could result in significantly biased estimates. Despite careful design, experiments may result in inadequate sample sizes leading to unreliable diagnostic test results due to low power. As a result, detection and adjusting for size and sex selectivity involves evaluating the power of the diagnostic tests.

The protocols that follow are used to classify the experiment into one of four cases. For each case the following are specified: 1) whether stratification is necessary, 2) which sample event's data should be used when estimating composition, and 3) the estimators to be used for composition estimates when stratifying. The first protocols assume adequate power. These are followed by supplemental protocols to be used when power is suspect and guidelines for evaluating power.

Protocols given Adequate Power

Case I:

M vs. R	**C vs. R**
Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events but do not include recaptured fish twice.

Case II:

M vs. R	**C vs. R**
Reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula.

-continued-

Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III:

M vs. R	**C vs. R**
Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV:

M vs. R	**C vs. R**
Reject H_o	Reject H_o

There is size/sex selectivity detected during both the first and second sampling events. The ratio of the probability of captures for size of sex categories can either be the same or different between events. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

Protocols when Power Suspect (re-classifying the experiment)

When sample sizes are small (guidelines provided in next section) power needs to be evaluated when diagnostic tests fail to reject the null hypothesis. If this failure to identify selectivity is due to low power (that is, if selectivity is actually present) data will be pooled when stratifying is necessary for unbiased estimates. For example, if the both the M vs. R and C vs. R tests failed to identify selectivity due to low power, Case I may be selected when Case IV is true. In this scenario, the need to stratify could have been overlooked leading to biased estimates. The following protocols should be followed when sample sizes are small.

Case I:

M vs. R	**C vs. R**	**Implication**
Fail to reject Ho	Fail to reject Ho	re-evaluate both tests
Power OK/retain test result	Power OK/retain test result	Case I
Power suspect/change to Reject Ho	Power OK/retain test result	Case II
Power OK/retain test result	Power suspect/change to Reject Ho	Case III
Power suspect/change to Reject Ho	Power suspect/change to Reject Ho	Case IV

-continued-

Case II:

M vs. R	**C vs. R**	**Implication**
Reject Ho	Fail to reject Ho	re-evaluate C vs. R
	Power OK/retain test result	Case II
	Power suspect/change to Reject Ho	Case IV

Case III:

M vs. R	**C vs. R**	**Implication**
Fail to reject Ho	Reject Ho	re-evaluate M vs. R
Power OK/retain test result		Case III
Power suspect/change to Reject Ho		Case IV

Guidelines for evaluating power:

The following guidelines to assess power are based upon the experiences of Sport Fish biometricians; they have not been comprehensively evaluated by simulation. Because some "art" in interpretation remains these guidelines are not intended to be used in lieu of discussions with biometricians when possible. When the evaluation does not lead to a clear choice, a stratified estimator should be selected (i.e., the experiment should be classified as Case IV) in order to minimize potential bias.

The reliability of M vs. R and C vs. R tests that fail to reject H_o are called into question when 1) sample sizes M or C are < 100 and the sample size for R is < 30, 2) p-values are not large (~0.20 or less), and the D statistics are large (≥ 0.2). If sample sizes are small, the p-value is not large, and the D statistic is large then the power of the test is suspect and, when re-classifying the experiment, the test should be considered as having rejected the null hypothesis. If for example, sample sizes are marginal (close to the recommended values), the p-value is large, and the D-statistic is not large then the test result may be considered reliable. It is when results are close to the recommended "cutoffs" that interpretation becomes somewhat more complicated.

Apparent inconsistencies between the combination of the M vs. R and C vs. R test results and the M vs. C test results may also arise from low power. For example, if one of the tests involving R rejects the null hypothesis and the other fails to reject one could infer a difference between M & C; however, the M vs. C test may still fail to reject the null indicating no difference between the M & C. In this case, the apparent inconsistency may be due to low power in the test involving R that failed to reject the null. Finally, an additional Case I scenario is flagged by an apparent inconsistency between test results, this time resulting from power being too high. Under this scenario both the M vs. R and C vs. R tests fail to reject the null hypothesis and their power is thought to be sufficient; however, the M vs. C test rejects H_o: no difference between the M & C. The apparent inconsistency may result from the M vs. C test being so powerful as to detect selectivity that would result in insignificant bias when estimating abundance and composition. The reliability of M vs. C tests that reject are called into question when 1) sample sizes M or C are > 500, 2) p-values are not extremely small (~0.010-0.049), and the D statistics are small (<0.08). In general all three K-S tests should be performed to permit these evaluations.

Appendix A3.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

The following two assumptions must be fulfilled:

1. catching and handling the fish does not affect the probability of recapture; and,
2. marked fish do not lose their mark.

Of the following assumptions, only one must be fulfilled:

1. marked fish mix completely with unmarked fish between events;
2. every fish has an equal probability of being marked and released during event 1; or,
3. every fish has an equal probability of being captured during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

TEST I[a]

First Event Sampling Area Released	Second Event				
	Sampling Area Recaptured				Not Recaptured
	A	**B**	**…**	**S**	(total)
A					
B					
…					
S					

TEST II[b]

	Second Event: Sampling Area			
	A	**B**	**…**	**S**
Recaptured				
Not Recaptured				

TEST III[c]

	Captured During Second Event			
	A	**B**	**…**	**S**
Marked				
Unmarked				

[a] This tests the hypothesis that movement probabilities are the same among sections: H_1: $\theta_{ij} = \theta_j$. Theta applies to both marked and unmarked fish.

[b] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities between the three river areas: H_2: $\Sigma_j \theta_{ij} p_j = d$. Theta applies to both marked and unmarked fish.

[c] This tests the homogeneity on the columns of the 2-by-t contingency table with respect to the probability of movement of marked fish in stratum *i* to the unmarked fraction in *j*: H_4: $\Sigma_i a_i \theta_{ij} = kU_j$. Theta only applies to marked fish.

Appendix A4.–Equations for estimating length and age composition and their variances for the population.

For Case I-III scenarios (Appendix A2), the proportions of Arctic grayling within each age or length class *k* were estimated:

$$\hat{p}_k = \frac{n_k}{n} \tag{1}$$

where:

n_k = the number of Arctic grayling sampled within age or length class *k* and,

n = the total number of Arctic grayling sampled.

When calculating n and n_k the diagnostic test results were used to determine the fish were included (Appendix A2). For Case I, used fish from both events and for Case II used first event fish.

The variance of each proportion was estimated as (from Cochran 1977):

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

The abundance of Arctic grayling in each length or age category, *k*, in the population was then estimated:

$$\hat{N}_k = \sum_{k=1}^{s} \hat{p}_k \hat{N}, \tag{3}$$

where:

$\hat{N}$ = the estimated overall abundance (Appendix A1); and,

s = the number of age or length classes.

The variance for $\hat{N}_k$ was then estimated using the formulation for the exact variance of the product of two independent random variables (Goodman 1960):

$$\hat{V}[\hat{N}_k] \approx \sum_{k=1}^{s} \left(\hat{V}[\hat{p}_k]\hat{N}^2 + \hat{V}[\hat{N}]\hat{p}_k^2 - \hat{V}[\hat{p}_k]\hat{V}[\hat{N}] \right). \tag{4}$$

For the Case IV scenario (Appendix A2), that requiring stratification by size or sex, the proportions of Arctic grayling within each age or length class *k* were estimated by first calculating:

$$\hat{p}_{jk} = \frac{n_{jk}}{n_j} \tag{5}$$

-continued-

where:

n_j = the number sampled from size stratum *j* in the mark-recapture experiment;

n_{jk} = the number sampled from size stratum *j* that are in length or age category *k*; and,

$\hat{p}_{jk}$ = the estimated proportion of length or age category *k* fish in size stratum *j*.

When calculating n_j and n_{jk} the within stratum diagnostic test results were used to determine which fish were included in the analysis following the rules for *n* and n_k provided above.

The variance calculation for $\hat{p}_{jk}$ is equation 2 substituting $\hat{p}_{jk}$ for $\hat{p}_k$ and n_j for *n*.

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

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk} \hat{N}_j \tag{6}$$

where:

$\hat{N}_j$ = the estimated abundance in size stratum *j*; and,

s = the number of size strata.

The variance for $\hat{N}_k$ will be estimated using the formulation for the exact variance of the product of two independent random variables (Goodman 1960):

$$\hat{V}\left[\hat{N}_k\right] = \sum_{j=1}^{s} \left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + \hat{V}\left[\hat{N}_j\right]\hat{p}_{jk}^2 - \hat{V}\left[\hat{p}_{jk}\right]\hat{V}\left[\hat{N}_j\right] \right). \tag{7}$$

The estimated proportion of the population in length or age category *k* $(\hat{p}_k)$ is then:

$$\hat{p}_k = \hat{N}_k \big/ \hat{N} \tag{8}$$

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

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

$$\hat{V}\left[\hat{p}_k\right] \approx \sum_{j=1}^{s} \left\{ \left(\frac{\hat{N}_j}{\hat{N}} \right)^2 \hat{V}\left[\hat{p}_{jk}\right] \right\} + \frac{\sum_{j=1}^{s} \left\{ \hat{V}\left[\hat{N}_j\right]\left(\hat{p}_{jk} - \hat{p}_k\right)^2 \right\}}{\hat{N}^2} . \tag{9}$$

APPENDIX B

Appendix B1.–Number of representative fish sampled (n), estimated proportion ($\hat{p}_k$), and estimated abundance ($\hat{N}_k$) by length category for the population of Arctic grayling (≥240 mm FL) in the upper section (above Pogo Mine), lower section (below Pogo Mine), and both sections combined in the North Fork Goodpaster River, July 2004.

Length	Upper Section					Lower section					Combined				
(mm FL)	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$
240 - 249	4	0.016	0.008	22	12	45	0.000	0.000	157	32	31	0.034	0.006	183	40
250 - 259	13	0.052	0.014	73	22	87	0.079	0.009	304	54	58	0.064	0.008	342	62
260 - 269	14	0.056	0.015	79	23	125	0.114	0.011	436	74	89	0.098	0.011	525	86
270 - 279	19	0.076	0.017	107	28	162	0.147	0.012	565	92	130	0.143	0.013	766	117
280 - 289	22	0.088	0.018	124	31	133	0.121	0.011	464	78	99	0.109	0.011	583	93
290 - 299	12	0.048	0.013	67	21	114	0.104	0.010	398	68	78	0.086	0.010	460	77
300 - 309	9	0.036	0.012	51	18	83	0.076	0.009	290	52	59	0.065	0.009	348	63
310 - 319	11	0.044	0.013	62	20	70	0.064	0.008	244	45	45	0.050	0.007	265	51
320 - 329	12	0.048	0.013	67	21	73	0.026	0.003	107	15	73	0.031	0.004	168	23
330 - 339	14	0.056	0.015	79	23	98	0.035	0.004	143	19	98	0.042	0.005	225	28
340 - 349	10	0.040	0.012	56	19	97	0.035	0.004	142	19	97	0.042	0.005	223	28
350 - 359	14	0.056	0.015	79	23	105	0.038	0.004	153	20	105	0.045	0.005	241	29
360 - 369	18	0.072	0.016	101	27	114	0.041	0.004	167	21	114	0.049	0.005	262	31
370 - 379	15	0.060	0.015	84	24	93	0.033	0.004	136	18	93	0.040	0.004	213	27
380 - 389	24	0.096	0.019	135	33	103	0.037	0.004	150	19	103	0.044	0.005	236	29
390 - 399	13	0.052	0.014	73	22	65	0.023	0.003	95	14	65	0.028	0.004	149	21
400 - 409	11	0.044	0.013	62	20	36	0.013	0.002	53	10	36	0.015	0.003	83	15
410 - 419	11	0.044	0.013	62	20	19	0.007	0.002	28	7	19	0.008	0.002	44	10
420 - 424	3	0.012	0.007	17	10	9	0.003	0.001	13	5	9	0.004	0.001	21	7

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Appendix B1.-Page 2 of 2.

Length (mm FL)	n	$\hat{p}_k$	$\hat{S}E[\hat{p}_k]$	$\hat{N}_k$	$\hat{S}E[\hat{N}_k]$	n	$\hat{p}_k$	$\hat{S}E[\hat{p}_k]$	$\hat{N}_k$	$\hat{S}E[\hat{N}_k]$	n	$\hat{p}_k$	$\hat{S}E[\hat{p}_k]$	$\hat{N}_k$	$\hat{S}E[\hat{N}_k]$
425 - 429	0	0.000	0.000	0	0	1	0.000	0.000	1	1	1	0.000	0.000	2	2
430 - 439	1	0.004	0.004	6	6	6	0.002	0.001	9	4	6	0.003	0.001	14	6
440 - 449	0	0.000	0.000	0	0	1	0.000	0.000	1	1	1	0.000	0.000	2	2
450 - 459	1	0.004	0.004	6	6	1	0.000	0.000	1	1	1	0.000	0.000	2	2
460 - 469	0	0.000	0.000	0	0	0	0.000	0.000	0	0	0	0.000	0.000	0	0

Appendix B2.–Number of representative fish sampled (n), estimated proportion ($\hat{p}_k$), and estimated abundance ($\hat{N}_k$) by age category for the population of Arctic grayling (≥240 mm FL) in the upper section (above Pogo Mine), lower section (below Pogo Mine), and both sections combined in the North Fork Goodpaster River, July 2004.

	Upper Section					**Lower section**					**Combined**				
Age	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$
2	0	0.000	0.000	0	0	0	0.000	0.000	0	0	0	0.000	0.000	0	0
3	0	0.000	0.000	0	0	0	0.000	0.000	0	0	0	0.000	0.000	0	0
4	0	0.000	0.000	0	0	6	0.006	0.003	25	11	7	0.007	0.003	37	15
5	69	0.049	0.014	69	22	319	0.328	0.019	1,329	203	347	0.381	0.022	2,041	277
6	60	0.043	0.013	60	20	423	0.369	0.016	1,496	198	376	0.298	0.016	1,598	185
≥7	122	0.086	0.018	122	31	573	0.298	0.022	1,208	102	786	0.314	0.034	1,679	131

APPENDIX C

Appendix C1.–Data files for all Arctic grayling captured in the Goodpaster River, 2004.

File Name	Description
AG-Goodpaster River-2004.xls	Data and analysis Excel workbook

[a] Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, 1300 College Road, Fairbanks, Alaska 99701-1599.

b Data files are archived at and are available from Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska, 99518-1565.