Fishery Data Series No. 06-53

Abundance and Age and Length Composition of Arctic Grayling in the North Fork Goodpaster River in 2003

by

James F. Parker

October 2006

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 SERIES NO. 06-53

ABUNDANCE AND AGE AND LENGTH COMPOSITION OF ARCTIC GRAYLING IN THE GOODPASTER RIVER IN 2003

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ABSTRACT

Arctic grayling *Thymallus arcticus* were sampled in July 2003 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 two 12.5 mile sections of river: the upper section, between Glacier Creek and Liese Creek, and the lower section, between Liese Creek and Barbara Creek. Abundance of Arctic grayling ≥240 mm FL could only be estimated for the lower section. Abundance of Arctic grayling ≥240 mm FL in the lower section, was estimated to be 2,063 fish (SE = 292). Abundance was estimated for Arctic grayling ≥300 mm FL in both sections. In the upper section the estimated abundance of Arctic grayling ≥300 mm FL was 1,168 fish (SE = 152). In the lower section, the estimated abundance of Arctic grayling ≥300 mm FL was 1,330 fish (SE = 198). Estimated abundance for fish ≥300 mm FL in both sections combined was 2,429 (SE = 237). Arctic grayling age-6 and older composed 98% of the population of Arctic grayling ≥300 mm FL sampled between Glacier Creek and Barbara Creek.

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

INTRODUCTION

The Goodpaster River, located in the upper Tanana River drainage (Figure 1), supports an important sport fishery for Arctic grayling *Thymallus arcticus*. The fishery occurs mostly in the lower 33 miles of the river and also targets other species such as northern pike, burbot, and whitefish; however, the majority of the harvest is Arctic grayling (Table 1). Although the Goodpaster River supports small runs of Chinook *Oncorhynchus tshawytscha* and chum salmon *O. keta*, fishing for salmon is closed. The average annual estimate of fishing effort for all species in the Goodpaster River from 1983-2002 was 1,542 angler days, while the average annual estimates of harvest and catch of Arctic grayling from 1983-2002 were 1,121 and 2,775, respectively (Table 1).

Recent development and future operation of the Pogo Creek gold mine (located in the drainage of the North Fork of the Goodpaster River; 68 miles from the mouth) by Teck-Pogo Incorporated (Teck) has the potential to impact the habitat of the Goodpaster River. While 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 (Appendix A), acquiring baseline information on fish populations is necessary to evaluate effects of any significant habitat alteration that may be caused by development and operation of the mine. While much has been learned about Arctic grayling in the lower portion of the Goodpaster River, little is known about abundance and composition of Arctic grayling in the upper river. The goal of this study was to obtain a multi-year baseline of abundance and distribution data for Arctic grayling in their summer feeding areas in the upper Goodpaster River. This information will provide fishery managers with a greater ability to assess fishery mortality and potential changes in the population associated with alterations to the watershed habitat. During 2003 a mark-recapture experiment was performed to estimate the abundance and the length and age compositions for Arctic grayling ≥ 240 mm FL in their summer feeding areas in a 25 mile reach of the North Fork Goodpaster River near the Pogo Mine site (Figure 2).

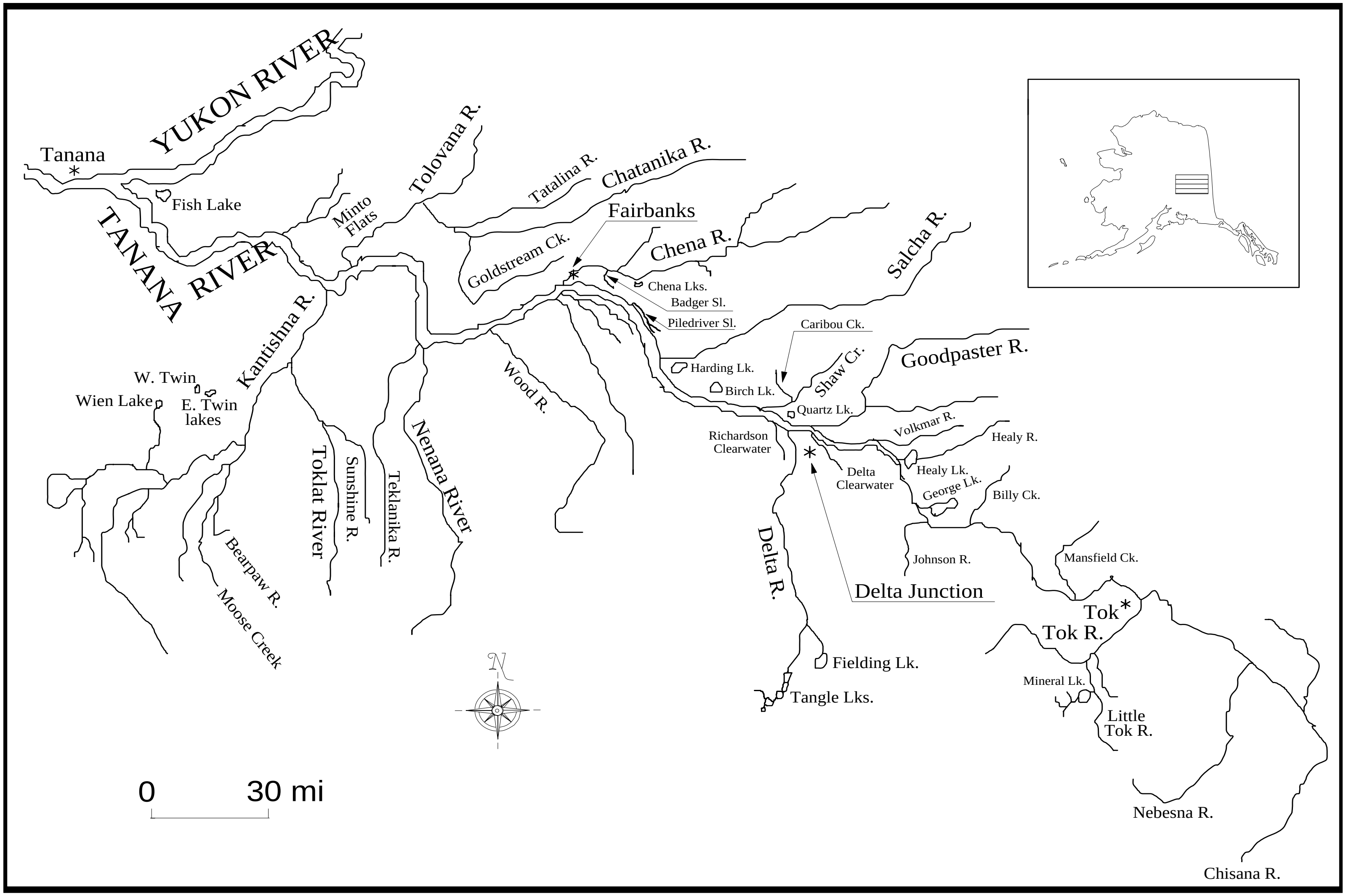


Figure 1.–The Tanana River drainage.

Table 1.–Estimates of effort, harvest, and catch for Arctic grayling and other species in the Goodpaster River, from the Alaska Statewide Harvest Survey, 1983-2002[a].

		Harvest						Catch					
Year	Anglers Days	AG <12"	AG >12"	AG All	NP	Burbot	WF	AG <12"	AG > 12"	AG All	NP	Burbot	WF
1983	1,989	...	...	3,021	0	0	0	...	...		...	...	...
1984	766	...	...	1,194	65	221	65	...	...		...	...	...
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
2000[b]													
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
Averages													
1983-2002	1,542	317	330	1,121	21	64	39	1,788	988	2,775	100	35	41
1999-2002	1,097	368	288	656	5	42	0	2,068	869	2,937	17	63	0

AG = Arctic grayling; NP = northern pike; WF = whitefish; ...=data not collected.

[a] Data from Mills 1984-1994, Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006 a-b.

[b] Data from 2000 not available, because too few responses were received for this location in the Statewide Harvest Survey (Walker et al. 2003).

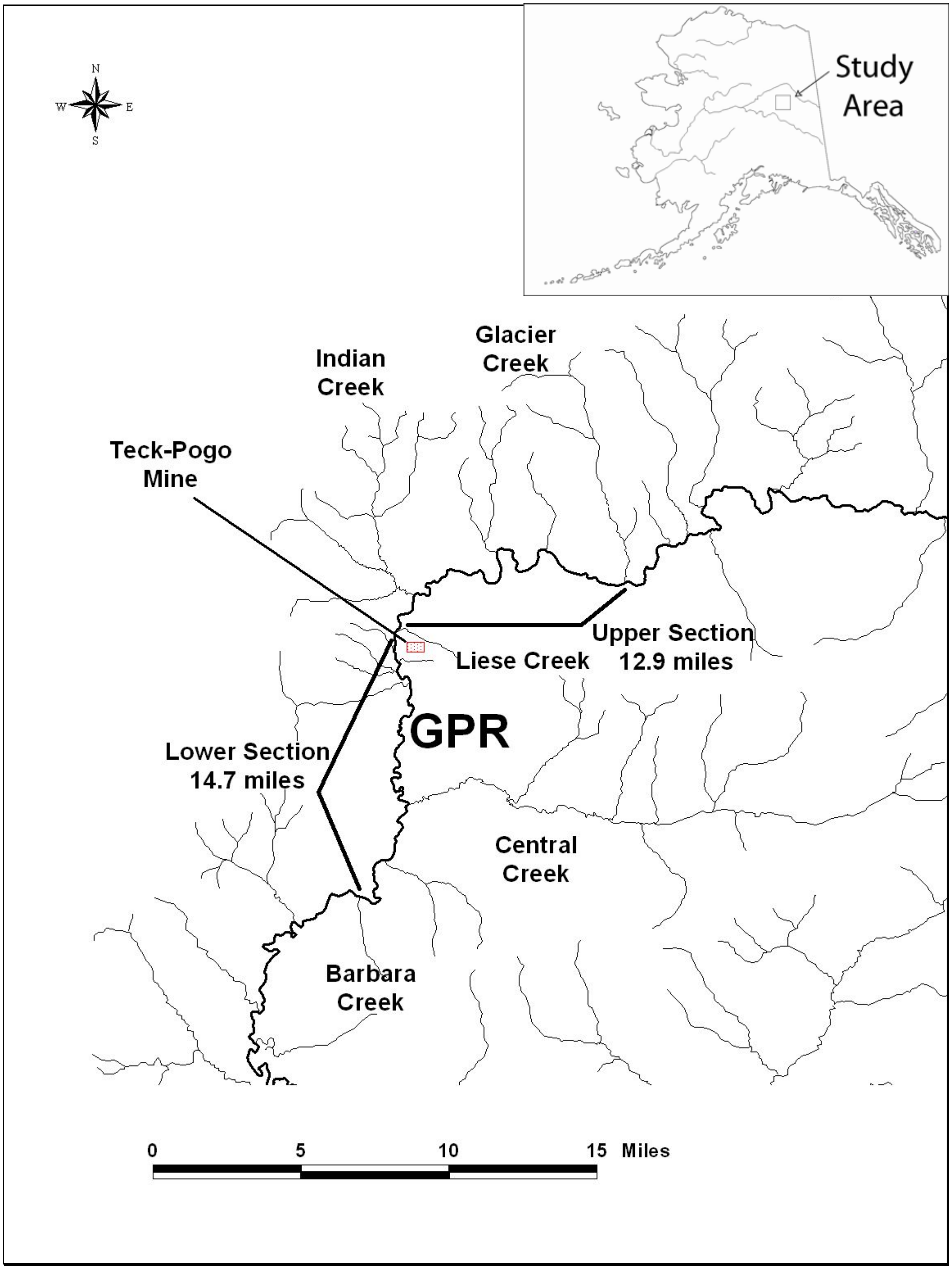


Figure 2.–The Goodpaster River study area, 2003.

BACKGROUND

The Goodpaster River serves as a spawning, summer feeding, overwintering, and nursery stream for Arctic grayling. Some of the spawning fish move to other streams such as the Richardson Clearwater and Delta Clearwater rivers for summer feeding (Reed 1961; Roguski 1967; Ridder 1998a, 1998b; 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 (river mile 33) to Central Creek (river mile 60), but predominately adult fish were found above Central Creek.

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). Studies from 1975-1987 were confined to two ~5 km sections in the lower 29 km of river. From 1988 to 1994, estimation was expanded to include the lower 53 km of river. More recent studies have focused on estimating abundance and composition of the spring spawning stock in the lower River. Mark-recapture studies were conducted in the lower 53 km of the river during 1995-2002 (Ridder 1998a; Parker 2002 and 2003).

The only previous work conducted in the upper Goodpaster River (above river km 53) to estimate abundance of the summer stock was done by Tack (1973 and 1974), who estimated abundance of Arctic grayling ≥150 mm FL in 184 km (115 mi) of the Goodpaster River. In this study, the Goodpaster River was stratified into 17 sections from its mouth to the lower part of Eisenmenger Fork. These sections were grouped into three areas based upon river characteristics. Area I was comprised of sections in the slow meandering portion of the river between the mouth and the confluence of the North and South forks (53 km**).** Area II was the lower 45 km (28 mi) of the North Fork from its confluence to Central Creek, and Area III was the upper North Fork from Central Creek to the lower part of Eisenmenger Fork (87 km). Tack 1974, described Area III as having relatively fewer pools and more long fast riffles than in Area II. Tack 1974, estimated 480 Arctic grayling/km (95% CI = 411-590) in Area I, 322 Arctic grayling/km (95% CI = 223-732) in Area II, 81 Arctic grayling/km (SE = 57-164) in Area III, and a combined estimate of 241 Arctic grayling/km (95% CI = 209-287) for the entire study area. It should be noted that very few fish < 240 mm FL (<3%) were caught in Tack's sampling effort. In 2003, a mark-recapture study was conducted to estimate abundance in 24.5 miles of the upper North Fork Goodpaster River (Figure 2). This study area in 2003 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.

OBJECTIVES

The objectives for 2003 were to:

1. estimate abundance of Arctic grayling ≥ 240 mm FL in two sections (12.9 mi and 14.7 mi, respectively) in the North Fork Goodpaster River near the Pogo Mine site in July 2003 such that the estimates are within 25% of the true abundance 95% of the time; and,
2. estimate age and length composition of Arctic grayling ≥ 240 mm FL in two sections in the North Fork Goodpaster River near the Pogo Mine site in July 2003 such that all proportions are within 10 percentage points of the true proportions 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 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. In the winter of 2003, construction of an all-season road began at the Richardson Highway at Shaw Creek. Boat launches are located at Big Delta on the Tanana River (14 mi downstream) and at Clearwater Lake (7 mi upstream). Riverboat navigation is possible in the lower 60 mi of the Goodpaster River and in the lower 10 mi of the South Fork Goodpaster River. Floatplane access is feasible in the lower 23 miles of the river. Private landing strips are located at Central Creek, at 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 66 recreational cabins on the river, and all but eight are located between river-mile 3 and 30. There is at least one recreational cabin above Central Creek.

SAMPLING DESIGN AND FISH CAPTURE

Arctic grayling were sampled in two events from July 7-11 and July 21-25. 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 crews of two persons each conducted all sampling and each crew worked exclusively in one section. During each event, sampling progressed from the upper end to the lower end of each section. Hook and line gear was used to capture most fish in both areas, although boat-mounted electrofishing gear (Clark 1985) was used for one day in the lower section during the first event. Electrofishing was conducted on June 7, but proved to be inefficient because of low water and the associated difficulty in navigating the drifting boat. Approximately 4-miles of river above Indian Creek were sampled and only 18 Arctic grayling were caught. Electroshocking efforts were abandoned at that point and hook and line gear was used exclusively thereafter. During the first event flies were used during the first day in the upper section and then 1/16 oz. rubber-bodied jig for the remainder of the experiment. Jigs were used exclusively in the lower section during both events. Arctic grayling in the upper Goodpaster River becomes summer resident to an area by approximately June 1 after most of the post-spawning migration is complete (Tack 1974). Sampling when Arctic grayling are occupying their summer feeding areas reduces the chance of fish leaving the study area during the course of the study. The two person crew, fishing the upper section (Figure 2), accessed the upper end by helicopter and used an inflatable canoe to haul their gear as they fished downstream to Pogo Mine site. The second crew, fishing the lower section, operated from the Pogo Mine site with a jet-powered boat and returned to the Pogo Mine site at the conclusion of each day. 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.

ESTIMATION OF ABUNDANCE

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 marking sample or in the recapture sample, or marked and unmarked Arctic grayling mixed completely between marking and recapture events;
3. marking of Arctic grayling did not affect the probability of capture in the recapture sample;
4. marked Arctic grayling were identifiable during the recapture events; and,
5. all marked Arctic grayling were reported when recovered in the recapture sample.

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 met.

The study design allowed the validity of these assumptions to be ensured or tested. 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 was expected but only on a localized scale (e.g., up to 2 river km). The short duration of the experiment also helped reduce occurrences of migration, recruitment and mortality. Location data for recaptured fish were examined for evidence of movement in order to evaluate the appropriateness of the assumption of closure.

To ensure Assumption 2 was met, an attempt was made to subject all fish to the same probability of capture within each sampling event. Specifically, within the constraint of sampling approximately 2.5 km/day, more time was spent in locations where fish were encountered as determined by visual sightings, strikes, and catches. In general, fishing was conducted for longer periods in areas below riffles at the upper end of pools, for example, where fish were congregated than in areas where few grayling appeared (e.g., wide shallow areas). 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 2-river km). 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 10 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

Each crew sampled 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. After fish were caught they were placed in a hand bucket (upper section) or an ice cooler aboard the boat (lower section). Fish were sampled after either 2-3 fish were caught or after a single fish was held for more than 5 min in the bucket. On average, sampling runs (points at which fish were marked and released) were spaced in approximately in 0.25 mile increments (Appendices C1).

All captured fish > 240 mm FL were sampled for age (two scales taken) and fork length (to the nearest millimeter). All captured fish were tagged with individually numbered internal anchor tags, and secondarily marked with a partial left ventral fin clip during the first (marking) event to detect tag loss and a partial right ventral fin clip during the second (recapture) event, to prevent double counting as captured fish were not tagged during that event. 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 (Appendices C1 and C2). The date and location of capture, finclips, 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 D).

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 gum cards were used to make triacetate impressions of the scales (30 seconds at 137,895 kPa, at a temperature of 97ºC). Ages were determined by counting annuli from the triacetate impressions magnified to 40X with a microfiche reader. Annuli were identified when: 1) complete circuli cut over incomplete circuli; 2) there were clear areas or irregularities in circuli along the anterior and posterior fields; or, 3) when a region of closely spaced circuli that was followed by a region of widely spaced circuli (Kruse 1959).

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. 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 B1; Bailey 1951, 1952) is preferred over the Chapman-modified Petersen estimator (Chapman 1951) for estimating abundance.

Violations of Assumption 2 relative to size effects were tested for using Kolmogorov-Smirnov (K-S) tests performed within each section (i.e., stratum). There were four possible outcomes of these tests relative to evaluating size selective sampling (either one of the two samples, both, or neither of the samples were biased) and two possible actions for abundance estimation (length stratify or not). The tests and possible actions for data analysis are outlined in Appendix B2. If stratification by size was required, capture probability by location were examined for each stratum, and total abundance and its variance estimate were calculated by summing strata estimates.

To check for spatiotemporal differences in capture probability, tests for consistency of the Petersen estimator (Seber 1982) were performed and the appropriate estimator selected (Appendix B3). Tests of consistency were used to determine which estimator among the following was appropriate: the pooled Bailey-modified Petersen estimator, the completely stratified Bailey-modified Petersen estimator, or a partially stratified estimator (Darroch 1961). Tests were performed by section, and each section was further divided into three subsections of roughly equal length to perform these tests. The closest landmark, for example, a stream tributary, defined the boundary of each subsection. 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). Documentation of release location for each fish permitted the examination of multiple geographic stratification schemes for purposes of assumption testing.

Length and Age Compositions

Length and age composition of the population were estimated using the procedures outlined in Appendix B4. Because the population of Arctic grayling in the Goodpaster River was defined as fish $\geq$ 240 mm FL, length composition are described in five length categories. The length categories used were, 240-269 mm FL, 270 to 299 mm FL, 300-349 mm FL, 350-399 mm FL, and fish >400 mm FL.

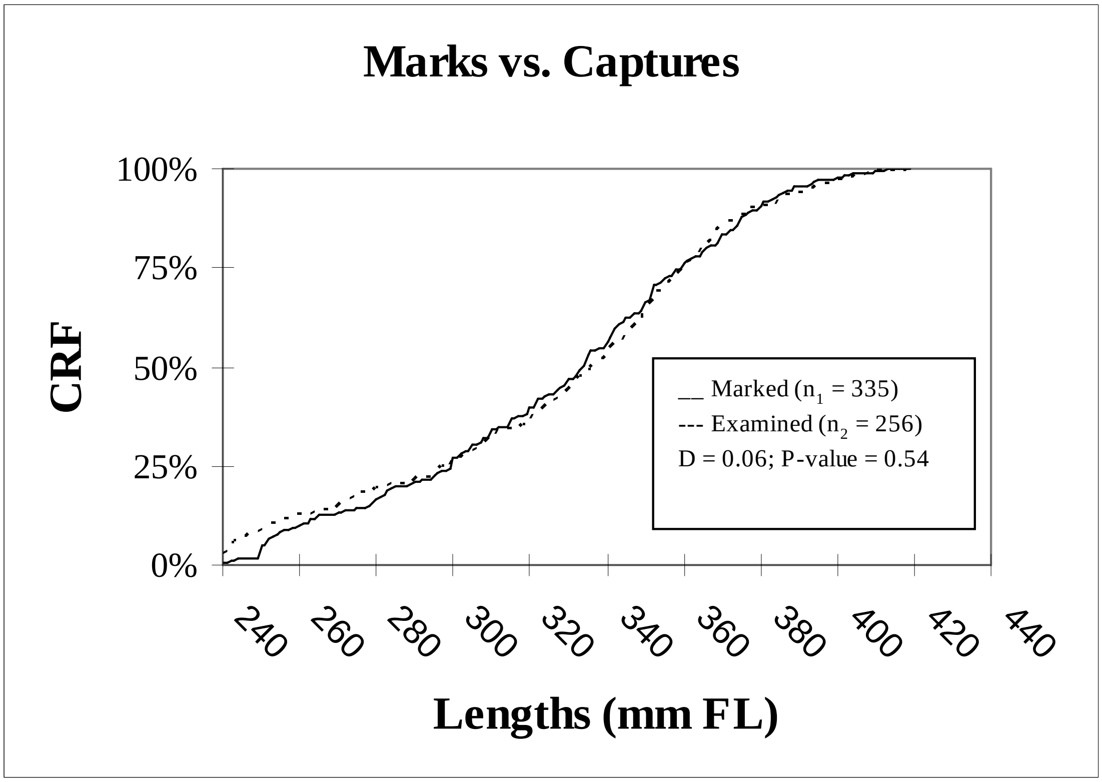
RESULTS

SUMMARY STATISTICS FOR THE CATCH

During the first event a total of 741 Arctic grayling were caught, of which 699 fish were ≥ 240 mm FL. Of these 699 fish, two were caught twice and seven died from handling. Thus, a total of 690 fish ≥ 240 mm FL were released live with marks (n_1), and of these, 361 were released in the upper section and 329 were released in the lower section. During the second event a total of 469 fish were sampled and 449 of these were fish ≥ 240 mm FL (n_2). All fish were caught only once during the second event and three died from handling. In the second event, 193 Arctic grayling >240 mm FL were caught and examined in the upper section and 256 Arctic grayling >240 mm FL were caught and examined in the lower section. During the second event 85 fish ≥240 mm FL marked in the first event and recaptured in the second event (m_2). Of these 85 recaptures, 40 were recovered in the lower section and 45 were recovered in the upper section. Three tagged fish moved from the lower section into the upper section between events. All fish ≥ 240 mm FL were used to estimate abundance in the lower section, but only fish ≥ 300 mm FL were used to estimate abundance in the upper section because few fish were captured or recaptured that were smaller ($n_1 = 42$; $n_2 = 19$; $m_2 = 0$). No tag loss was detected during the recapture event. Eighty-six fish from both events had tags from previous studies in the Goodpaster River.

ABUNDANCE ESTIMATE

The lengths of fish from the sample were subjected to the diagnostic testing procedures as outlined in Appendix B2, and testing indicated sampling was not size selective in either section during either event. In the lower section (below Pogo) cumulative relative length frequency distributions of fish ≥240 mm FL captured in the first event and those recaptured during the second event were not significantly different (D = 0.15; P-value = 0.28; Figure 3 lower panel), nor were distributions of fish captured in the first event and fish captured in the second event (D = 0.06; P-value = 0.55; Figure 3 upper panel). In the upper section cumulative relative length frequency distributions of fish ≥300 mm FL captured in the first event and those recaptured in the second event in were not significantly different (D = 0.15; P-value = 0.43; Figure 4 lower panel), nor were distributions of fish captured in the first event and fish captured in the second event (D = 0.08; P-value = 0.43; Figure 4 upper panel). Finally, when all fish ≥300 mm FL in both sections were combined, testing indicated there was no size-selectivity during either event (Test 1: lengths of fish captured in the first event and those recaptured in the second event-D = 0.08; P-value = 0.68; Figure 5 lower panel; and Test 2: lengths of fish captured in the first event and lengths of fish captured in the second event-, D = 0.05; P-value = 0.59; Figure 5 upper panel). First and second events lengths of recaptured fish were used to assess growth during the experiment. The mean growth was between 1 and 2 mm, which is insignificant relative to the objectives of this project.



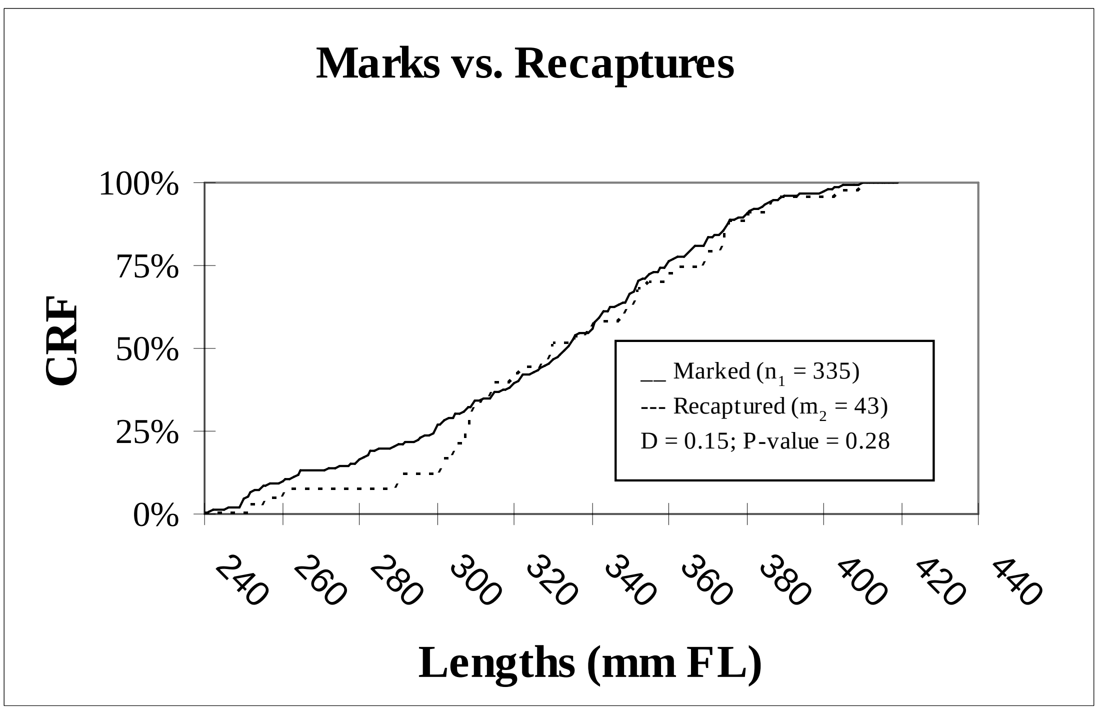
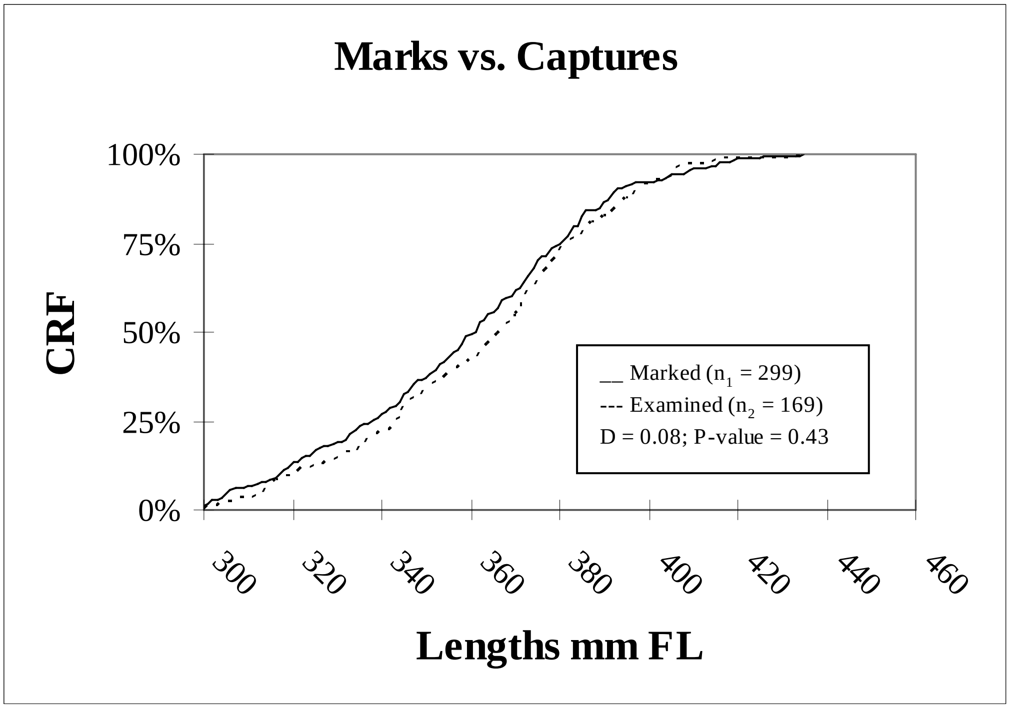


Figure 3.–Cumulative relative frequency (CRF) of Arctic grayling ≥240 mm FL marked and captured (upper panel) and marked and recaptured (lower panel), Lower section (below Pogo) North Fork Goodpaster River, July 2003.



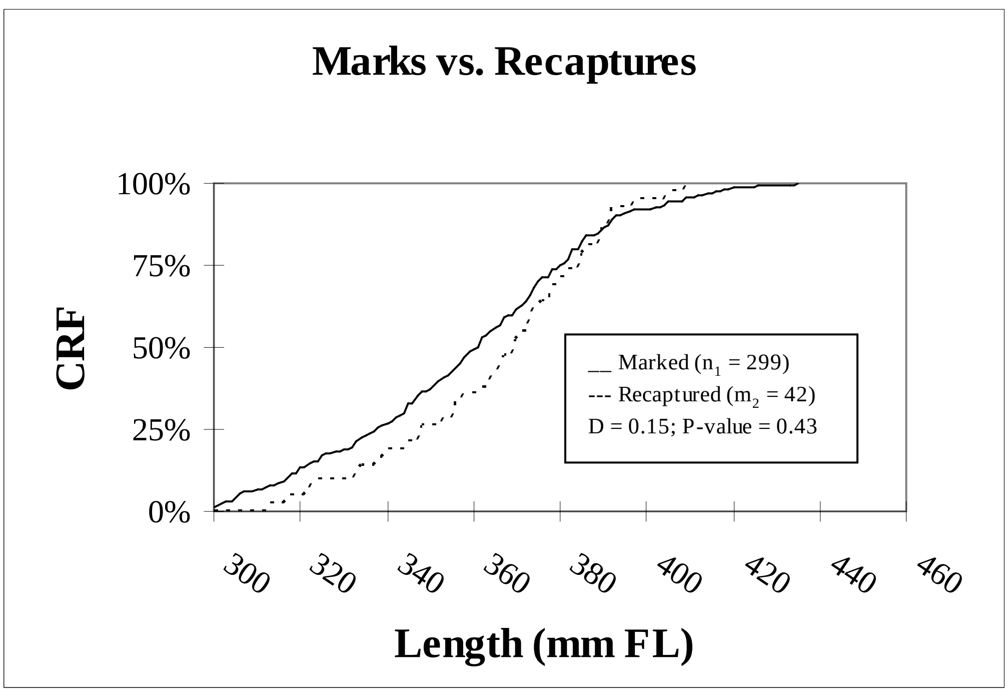
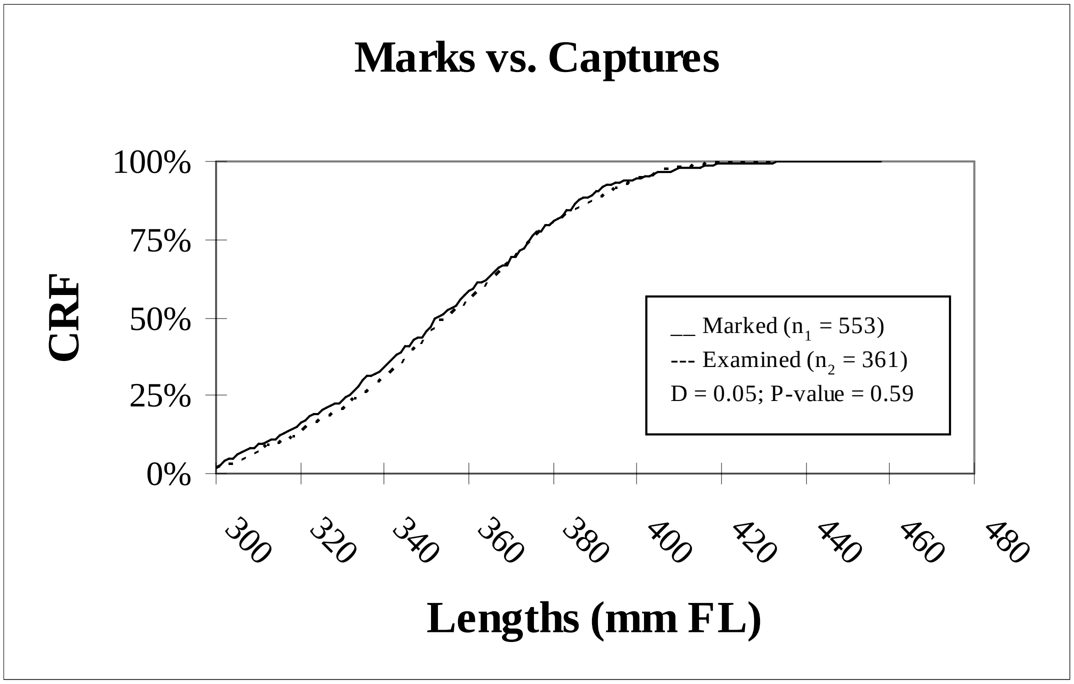


Figure 4.–Cumulative relative frequency (CRF) of Arctic grayling ≥300 mm FL marked and captured (upper panel) and marked and recaptured (lower panel), Upper section (above Pogo) North Fork Goodpaster River, July 2003.



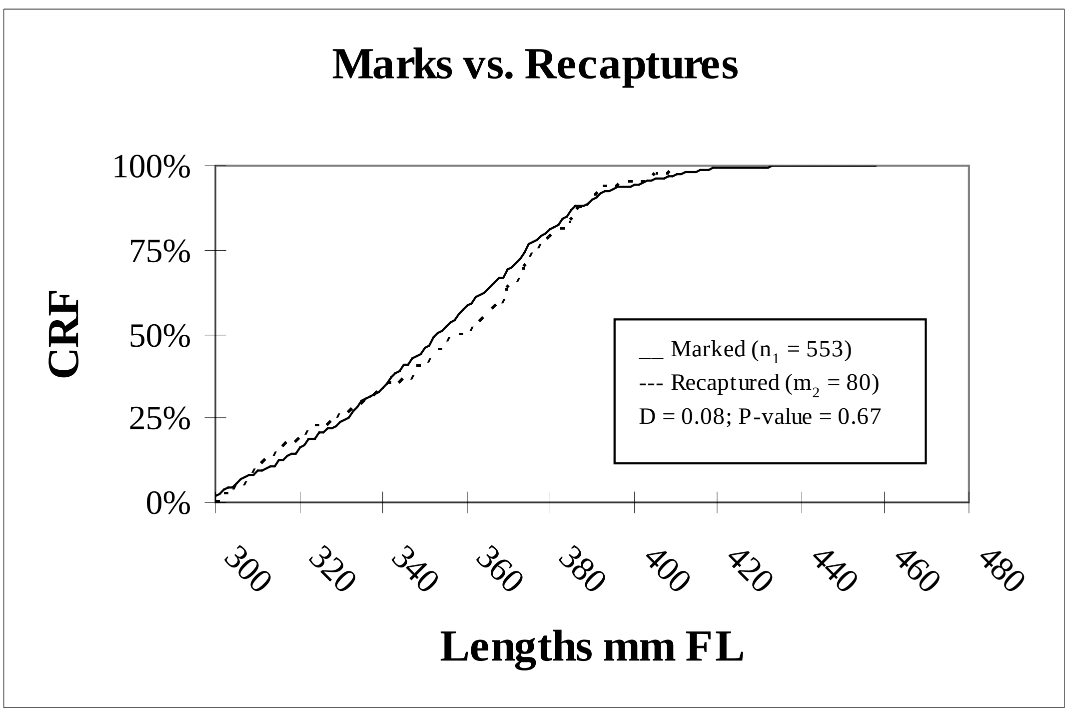


Figure 5.–Cumulative relative frequency (CRF) of Arctic grayling ≥300 mm FL marked and captured (upper panel) and marked and recaptured (lower panel), both Upper and Lower sections combined (~25 miles) North Fork Goodpaster River, July 2003.

Tests for consistency of the Petersen estimator (Appendix B3; Seber 1982) were performed to check for spatiotemporal differences in capture probability. For the upper section, 297 fish ≥300 mm FL were released with marks, and 169 fish were examined for marks, and 42 marks were detected. (The three marks released in the lower section that were recaptured in the upper section were not included in stratum specific tests and abundance estimates.) Tests of consistency indicated that mixing of fish between subsections (1, 2, & 3) of the upper section was not complete (P-value = <0.01; Table 2). However, the probabilities of being captured by area were not significantly different during the second event (P-value = 0.35; Table 3) and during the first event (P-value = 0.54; Table 4), which satisfied Assumption 2. Using the Bailey-modified Petersen estimate the population estimate for Arctic grayling ≥300 mm FL in the upper section was 1,168 (SE = 152).

For the lower section, 329 fish (≥240 mm FL) were released with marks, 256 fish examined for marks, and 40 marks were detected. Tests of consistency indicated that mixing of fish between subsections (4, 5 and 6) was not complete (P-value = <0.01; Table 5). The probabilities of being captured by area were not significantly different during the second event (P-value = 0.17; Table 6) and during the first event (P-value = 0.35; Table 7), which satisfied Assumption 2. The Bailey-modified Petersen estimate for fish ≥240 mm FL in the lower section was 2,063 (SE = 292). Also in the lower section 248 Arctic grayling ≥300 mm FL were released with marks and 192 fish examined for marks, of which 35 had marks. Tests of consistency indicated that mixing of fish between subsections (4, 5 & 6) were not complete (P-value = <0.01; Table 8). The probabilities of being captured by area were not significantly different during the second event (P-value = 0.23; Table 9) and during the first event (P-value = 0.42; Table 10), which satisfied Assumption 2. The Bailey-modified Petersen estimate for fish ≥300 mm FL in the lower section was 1,330 (SE = 198).

For the upper and lower sections combined, 545 Arctic grayling ≥300 mm FL were released with marks, 360 were examined for marks, and 80 marks were detected. Tests of consistency indicated that mixing of fish between subsections 1-6 were not complete (P-value = <0.01; Table 11) however, the probability of being captured by area were not significantly different during the second event (P-value = 0.16; Table 12) and during the first event (P-value = 0.27; Table 13) which satisfies Assumption 2. The Bailey-modified Petersen estimate for fish ≥300 mm FL for both sections combined was 2,429 (SE = 237).

During the course of the experiment, 77 of 80 fish with known release and recapture locations were recaptured within the same stratum (upper or lower section) in which marked. Three Arctic grayling moved from the lower stratum (subsection 2) into the upper stratum (subsection 5). At the subsection scale, 66 of the 80 recaptured Arctic grayling ≥ 300 mm FL were caught in the same subsection in both events. Of the 14 remaining only four moved more than one subsection (one moving two and movements of the other three were described above). Eleven of these 14 Arctic grayling moved upstream.

The estimated density of Arctic grayling (≥300 mm FL) in 2003 was 99 fish per mile (SE = 13.0) for the upper section, 105 fish per mile (SE = 15.5) for the lower section, and 99 fish per mile for both sections combined (SE = 9.6). The estimated density of Arctic grayling (≥240 mm FL) in 2003 for the lower section was 162 fish per mile (SE = 23.0).

Table 2.–Test for complete mixing. Number of Arctic grayling ≥ 300 mm FL marked in the upper section (subsections 1-3) and recaptured in subsections (1-3) of the North Fork Goodpaster River, July 2003.

	Subsection Where Recaptured			Not Recaptured	Marked
Subsection Where Marked	1	2	3	(n_1-m_2)	(n_1)
1	5	3	0	73	81
2	1	11	0	75	87
3	0	2	20	107	129
Total	6	16	20	297	297

χ^2 = 48.65, df = 6, P-value <0.01, reject H_o.

Table 3.–Test for equal probability of capture during the second event. Number of Arctic grayling ≥ 300 mm FL marked in the upper section by subsection (1-3) during the first event that were recaptured or not recaptured by subsections during the second event, North Fork Goodpaster River, July 2003.

	Subsection Where Marked			
Category	1	2	3	All Subsections
Marked (n_1)	81	87	129	297
Recaptured (m_2)	8	12	22	42
Not Recaptured (n_1-m_2)	73	75	107	255
$P_{capture}$ 2nd event (m_2/n_1)	0.10	0.14	0.17	0.14

χ^2 2.12, df = 2, P-value 0.35, accept H_o.

Table 4.–Test for equal probability of capture during the first event. Number of marked and unmarked Arctic grayling ≥ 300 mm FL examined during the second event in the upper section by subsections (1-3) of the North Fork Goodpaster River, July 2003.

	Subsection Where Examined			
Category	1	2	3	All Subsections
Examined (n_2)	31	69	69	169
Marked (m_2)	6	16	20	42
Unmarked (n_2-m_2)	25	53	49	127
$P_{capture}$ 1st event (m_2/n_2)	0.19	0.23	0.29	0.25

χ^2 1.23; df = 2; P-value 0.54; accept H_o.

Table 5.–Test for complete mixing. Number of Arctic grayling ≥ 240 mm FL marked in the lower section (subsections 4-6) and recaptured in subsections (4-6) of the North Fork Goodpaster River, July 2003.

Sub section Where Marked	Subsection Where Recaptured 4	5	6	Not Recaptured (n_1-m_2)	Marked (n_1)
4	5	0	0	59	64
5	2	17	0	96	115
6	1	2	13	134	150
Total	8	19	13	289	329

χ^2 = 50.68, df = 6, P-value <0.01, reject H_o.

Table 6.–Test for equal probability of capture during the second event. Number of Arctic grayling ≥ 240 mm FL marked in the lower section by subsection (4-6) during the first event that were recaptured or not recaptured by subsections during the second event North Fork Goodpaster River, July 2003.

Category	Subsection Where Marked 4	5	6	All Subsections
Marked (n_1)	64	115	150	329
Recaptured (m_2)	5	19	16	40
Not recaptured (n_1-m_2)	59	96	134	289
$P_{capture}$ 2st event (m_2/n_1)	0.08	0.17	0.11	0.12

χ^2 3.49, df = 2, P-value 0.17, accept H_o.

Table 7.–Test for equal probability of capture during the first event. Number of marked and unmarked Arctic grayling ≥ 240 mm FL examined during the second event in the lower section (4-6) of the North Fork Goodpaster River, July 2003.

Category	Subsection Where Examined 4	5	6	All Subsections
Examined (n_2)	48	99	109	256
Marked (m_2)	8	19	13	40
Unmarked (n_2-m_2)	40	80	96	216
$P_{capture}$ 1st event (m2/n2)	0.17	0.19	0.12	0.16

χ^2 2.13; df = 2; P-value 0.35; accept H_o.

Table 8.– Test for complete mixing. Number of Arctic grayling ≥ 300 mm FL marked in the Lower section (subsections 4-6) and recaptured in subsections (4-6) of the North Fork Goodpaster River, July 2003.

Sub section Where Marked	Subsection Where Recaptured 4	5	6	Not Recaptured (n_1-m_2)	Marked (n_1)
4	5	0	0	40	45
5	2	16	0	77	95
6	0	1	11	96	108
Total	7	17	11	213	248

χ^2 = 51.30, df = 6, P-value <0.01, reject H_o.

Table 9.–Test for equal probability of capture during the second event. Number of Arctic grayling ≥ 300 mm FL marked in the lower section by subsection (4-6) during the first event that were recaptured or not recaptured by subsection during the second event, North Fork Goodpaster River, July 2003.

	Subsection Where Marked			
Category	4	5	6	All Subsections
Marked (n_1)	45	95	108	248
Recaptured ($m_{2)}$	5	18	12	35
Not Recaptured (n_1-m_2)	40	77	96	213
$P_{capture}$ 1st event (m_2/n_1)	0.11	0.19	0.11	0.14

χ^2 2.97, df = 2, P-value 0.23, accept H_o.

Table 10.–Test for equal probability of capture during the first event. Number of marked and unmarked Arctic grayling ≥ 300 mm FL examined during the second event in the lower section by subsections (4-6) of the North Fork Goodpaster River, July 2003.

	Subsection Where Examined			
Category	4	5	6	All Subsections
Examined (n_2)	35	78	79	192
Marked ($m_{2)}$	7	17	11	35
Unmarked (n_2-m_2)	28	61	68	157
$P_{capture}$ 1st event (m_2/n_2)	0.25	0.28	0.16	0.18

χ^2 1.72; df = 2; P-value 0.43; accept H_o.

Table 11.–Test for complete mixing. Number of Arctic grayling ≥ 300 mm FL marked in both upper and lower sections and recaptured in each of six subsections (1-6) of the North Fork Goodpaster River, July 2003.

Subsection Where Marked	Subsection Where Recaptured 1	2	3	4	5	6	Not Recaptured (n_1-m_2)	Marked (n_1)
1	5	3	0	0	0	0	73	81
2	1	11	0	0	0	0	75	87
3	0	2	20	0	0	0	107	129
4	0	0	0	5	0	0	40	45
5	0	3	0	2	16	0	74	95
6	0	0	0	0	1	11	96	108
Total	6	19	20	7	17	11	465	545

χ^2 = 27568, df = 30, P-value <0.01, reject H_o.

Table 12.–Test for equal probability of capture during the second event. Number of Arctic grayling ≥ 300 mm FL marked in both sections by subsections (1-6) during the first event that were recaptured or not recaptured by subsection during the second event of the North Fork Goodpaster River, July 2003.

Category	Subsection Where Marked 1	2	3	4	5	6	All Subsections
Marked (n_1)	81	87	129	45	95	108	545
Recaptured (m_2)	8	12	22	5	21	12	80
Not Recaptured (n_1-m_2)	73	75	107	40	74	96	465
$P_{capture}$ 2nd event (m_2/n_1)	0.10	0.14	0.17	0.11	0.22	0.11	0.15

χ^2 7.87, df = 5, P-value 0.16, accept H_o.

Table 13.–Test for equal probability of capture during the first event. Number of marked and unmarked Arctic grayling ≥ 300 mm FL examined during the second event by upper and lower sections (1-6) of the North Fork Goodpaster River, July 2003.

Category	Section Where Examined 1	2	3	4	5	6	All Subsections
Examined (n_2)	31	69	69	35	78	79	361
Marked (m_2)	6	19	20	7	17	11	80
Unmarked (n_2-m_2)	25	50	49	28	61	68	281
$P_{capture}$ 1st event (m_2/n_2)	0.19	0.28	0.29	0.26	0.22	0.14	0.22

χ^2 6.37; df = 5; P-value 0.27; accept H_o.

LENGTH AND AGE COMPOSITIONS

The length of fish captured during both events ranged from 154 mm FL to 458 mm FL. However, due to low probability of capture of small fish, the catch statistics and estimates of length composition are for fish ≥240 mm FL in the lower section, for fish ≥300 mm FL in the upper section, and for fish ≥300 mm FL for both sections combined. The average length of Arctic grayling ≥240 mm FL captured in the mark and recapture events in the lower section was 327.6 mm FL (SD = 42.3) and 327.9 mm FL (SD = 44.8) respectively, and for fish ≥300 mm FL in the lower section was 346.9 mm FL (SD = 27.5) and 349.2 mm FL (SD = 26.9; Table 14). In the upper section captured fish ≥300 mm FL averaged 359.4 mm FL (SD = 29.5) during the mark event and 363.1 mm FL (SE = 29.0) in the recapture event (Table 14). The average length of fish caught in both events was 360.8 mm FL (SD = 29.3) for the upper section and 347.9 mm FL (SD = 27.2) for the lower section (Table 14). The average length of all captured Arctic grayling (≥300 mm FL) for both events was 354.5 mm FL (SD = 29.0; Table14).

Length composition estimates were calculated as described in Appendix B4 based on equal probability of capture of all lengths of fish (≥240 or ≥300 mm FL) in each event (Case I, Appendix B1). In the lower section, the proportion of Arctic grayling 240 - 300 mm FL was 26% and abundance was 531 fish (Table 15). The population of fish ≥300 in the lower section was nearly evenly split between the 300-349 mm FL category (50%) and the 350-399 mm FL category (46%; Table 16). Of fish ≥300 mm FL in the upper section, a greater percentage of fish (55%) were present in the 350-399 mm FL length category than in the 300-349 mm FL category (36%; Table 17). In both sections combined, of fish ≥300 mm FL fish from 350 to 399 mm FL comprised 51% of the population (Table 18).

The age composition like the length composition was estimated for the combined upper and lower areas for Arctic grayling ≥300 mm FL and also for Arctic grayling ≥240 mm FL in the lower section. Ages were obtained from 786 out of 823 fish ≥300 mm FL with the balance (37) not read due to scale regeneration. Ages of fish ≥300 mm FL ranged from ages 4–12. The abundance of age-6 and older Arctic grayling was estimated as 2,392, or 98% of the estimated abundance of fish ≥300 mm FL (Table 19). The abundance of age-6 and older Arctic grayling for the lower section (below pogo) was estimated as 1,614, or 78% of the estimated abundance of fish ≥240 mm FL (Table 20). Age-7 fish were the most abundant age class in the population ≥300 mm FL of both sections combined (abundance = 868; SE=94; Table 19). In the lower section (below pogo) Age 6 fish were the most abundance age class in the population ≥240 mm FL (abundance = 493; SE=76; Table 20).

Table 14.–Catch and length statistics for Arctic grayling ≥ 240 mm FL or ≥ 300 mm FL captured in the North Fork Goodpaster River during July 2003.

	Event			
Statistics	Mark	Capture	Recaptures	Total
		2003 Upper Section[a]		
Total fish captured ≥ 300 mm FL	297	169	42	466
Mean length (mm FL)	359.4	363.1	365.6	360.8
Standard deviation of lengths	29.5	28.9	24.0	29.3
Minimum length	300	301	313	300
Maximum length	435	458	409	458
		2003 Lower Section[b]		
Total fish captured ≥ 240 mm FL	329	256	40	585
Mean length (mm FL)	327.6	327.9	336.4	327.7
Standard deviation of lengths	42.3	44.8	39.0	43.4
Minimum length	240	240	252	240
Maximum length	413	419	410	419
		2003 Lower Section[b]		
Total fish captured ≥ 300 mm FL	248	192	35	440
Mean length (mm FL)	346.9	349.2	345.8	347.9
Standard deviation of lengths	27.5	26.9	31.0	27.2
Minimum length	300	300	302	300
Maximum length	413	419	410	419
		Combined Events 2003		
	Upper Section	Lower Section	Both events	
Total fish captured ≥ 300 mm FL	466	440	906	
Mean length (mm FL)	360.8	347.9	354.5	
Standard deviation of lengths	29.3	27.2	29.0	
Minimum length	300	300	300	
Maximum length	458	419	458	

[a] Upper Section (above Pogo Mine, approximately 11.8 miles in length from Glacier Creek to Liese Creek).

[b] Lower Section (below Pogo Mine, approximately 12.7 miles in length from Liese Creek to Barbara Creek).

Table 15.–Number 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 lower section, North Fork Goodpaster River, July 2003.

Length	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$
240-269	76	0.14	0.015	288	51
270-299	64	0.12	0.014	243	44
300-349	204	0.37	0.021	772	117
350-399	184	0.34	0.02	696	107
>400	17	0.03	0.007	64	18
Total	545	1.00		2,063	292

Table 16.–Number sampled (n), estimated proportion ($\hat{p}_k$), and estimated abundance ($\hat{N}_k$) by length category for the population of Arctic grayling (≥300 mm FL) in the lower section (below Pogo) of the North Fork Goodpaster River, July 2003.

Length	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$
300-349	204	0.50	0.025	670	105
350-399	184	0.46	0.025	604	95
>400	17	0.04	0.010	56	16
Total	405	1.00		1,330	152

Table 17.–Number sampled (n), estimated proportion ($\hat{p}_k$), and estimated abundance ($\hat{N}_k$) by length category for the population of Arctic grayling (≥300 mm FL) in the upper section (above Pogo) of the North Fork Goodpaster River, July 2003.

Length	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$
300-349	153	0.36	0.023	422	61
350-399	235	0.55	0.024	647	89
>400	36	0.09	0.013	99	20
Total	424	1.00		1,168	152

Table 18.–Number sampled (n), estimated proportion ($\hat{p}_k$), and estimated abundance ($\hat{N}_k$) by length category for the population of Arctic grayling (≥300 mm FL) in entire study area (~25 miles) of the North Fork Goodpaster River, July 2003.

Length	n	$\hat{p}_k$	$\hat{SE}[\hat{p}_k]$	$\hat{N}_k$	$\hat{SE}[\hat{N}_k]$
300-349	357	0.43	0.017	1,046	110
350-399	419	0.51	0.017	1,228	127
>400	53	0.06	0.008	155	26
Total	829			2,429	152

Table 19.–Number sampled (n), estimated proportion ($\hat{p}_k$), estimated abundance ($\hat{N}_k$), and length statistics by age for the population of Arctic grayling (≥300 mm FL) in ~25 miles of the North Fork Goodpaster River, July 2003.

		Age Composition		Abundance			Length Statistics			
Age	n	$\hat{p}_k$	SE[$\hat{p}_k$]	$\hat{N}_k$	SE[$\hat{N}_k$]	CV	Mean	SD	Min	Max
4	1	0.001	0.001	3	3.1	100%	367	…	367	367
5	11	0.014	0.004	34	10.7	31.4%	323	29	300	390
6	244	0.310	0.017	754	83.5	11.1%	326	17	300	391
7	281	0.360	0.017	868	94.0	10.8%	351	17	302	385
8	155	0.200	0.014	479	57.9	12.1%	375	12	330	399
9	64	0.080	0.010	198	30.4	15.4%	393	11	352	416
10	21	0.027	0.006	65	15.3	23.5%	410	7	393	420
11	7	0.009	0.003	22	8.4	38.7%	424	11	410	435
12	2	0.003	0.002	6	4.4	71%	419	1	418	420
All Ages	786	1.00		2,429	236.2	9.7%	354	29	300	435

Table 20.–Number sampled (n), estimated proportion ($\hat{p}_k$), estimated abundance ($\hat{N}_k$), and length statistics by age for the population of Arctic grayling (≥240 mm FL) in the Lower Section (below Pogo), North Fork Goodpaster River, July 2003.

		Age Composition		Abundance			Length Statistics			
Age	n	$\hat{p}_k$	SE[$\hat{p}_k$]	$\hat{N}_k$	SE[$\hat{N}_k$]	CV	Mean	SD	Min	Max
3	2	0.003	0.002	5	3.7	71.4%	241	1	240	242
4	31	0.039	0.007	81	18.3	22.5%	252	22	240	367
5	102	0.130	0.012	268	45.1	16.8%	272	24	240	390
6	188	0.239	0.015	493	76.4	15.5%	317	22	242	391
7	164	0.209	0.015	430	67.7	15.7%	346	17	297	378
8	95	0.121	0.012	249	42.5	17.1%	371	13	330	399
9	33	0.042	0.007	87	19.1	22.4%	393	13	352	409
10	5	0.006	0.003	13	6.1	46.4%	408	7	403	419
11	1	0.001	0.001	3	2.6	100.0%	413	…	413	413
All Ages	621	1.00		2,062	291.7	9.7%	327	43	240	419

DISCUSSION

Our objective to estimate abundance in ~25 miles of Arctic grayling ≥ 240 mm FL in two 12.5-mile sections of the river in the North Fork Goodpaster River near the Pogo Mine site such that the estimates were within 25% of the true abundance 95% of the time was partially attained. The relative precision in the upper section was 26% and for the lower section the relative precision was 29%, marginally close. Overall abundance of fish ≥ 300 mm FL for both sections combined met the level of precision in the objective (estimates were within 19% of the true abundance 95% of the time). In general, the movement of recaptured fish within the study area suggests a relatively low potential for a substantial positive bias in the abundance estimates due to combined immigration and emigration. The movement data, particularly that of three recaptured fish (all ≥ 300 mm FL) that moved three subsections from the lower to upper section, indicate that the system was not closed at the section scale. At the section scale (assuming closure for the study area), emigration from the lower section would have resulted in an abundance estimate for the lower section that was germane to the first event while immigration to the upper section would have resulted in abundance estimate for the upper section that was germane to the second event (positively biased for the first event). That these effects may be expected to be small can be seen by the close agreement between the sum of the stratum specific abundance estimates (2,498 Arctic grayling ≥ 300 mm FL) and the combined estimate (2,429 Arctic grayling ≥ 300 mm FL).

To compare our recent estimates of abundance to Tack (1974) we examined Tack's area III, which extends from Central Creek to Eisenmenger Fork. This area roughly corresponds to our study area. Tack (1974) reported a population density of Arctic grayling ≥ 150 mm FL in Area III at 131 fish/mile (95% CI = 92-264; Tack, 1974). The density estimate for the 2003 study area was 88 Arctic grayling ≥ 300 mm FL per mile (95% CI = 71-105). Data from 1973 were not available to directly estimate the proportion of Arctic grayling ≥ 150 mm FL that were also ≥300 mm FL; however, Figure 7 in Tack 1974 was used to approximate this proportion as 0.75 and the density of Arctic grayling ≥ 300 mm FL as 98 fish/mile. It appears that the density of Arctic grayling ≥ 300 mm FL 2003 was similar to that in 1973.

Timing of future stock assessments should be considered to avoid changes in Arctic grayling movement behavior due to the arrival of spawning Chinook salmon. During the initial mark effort (July 7-11) Chinook salmon were beginning to move up into the study area but were not actively spawning. However, during the recapture event (July 22-25) Chinook salmon were actively spawning and Arctic grayling were generally associated near salmon redds. To avoid the re-distribution of Arctic grayling between sampling events, a shift in sampling effort a week earlier is recommended.

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REFERENCES CITED

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

Bailey, N. T. J. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21:120-127.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131-160.

Clark, R. A. 1985. Evaluation of sampling gears for fish population assessment in Alaska lakes. Masters Thesis. University of Alaska Fairbanks, Alaska.

Cochran, W. G. 1977. Sampling techniques. Third Edition. John Wiley & Sons, New York.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series 97-29 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series 98-25 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition: Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series 99-41 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series 01-8, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and H. K. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04 -11, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and H. K. Sigurdsson. 2006a. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06-34, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and H. K Sigurdsson. 2006b. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-44, Anchorage.

Kruse, T. E. 1959. Grayling of Grebe Lake, Yellow-stone National Park, Wyoming. U. S. Fish and Wildlife Service Fishery Bulletin 59:307-351.

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

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

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

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series Number 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series Number 52, Juneau.

REFERENCES CITED (Continued)

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series Number 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series Number 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series Number 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series Number 92-40, Anchorage.

Mills, M. J. and A. L. Howe. 1992. An evaluation of estimates of sport fish harvest from the Alaska statewide mail survey. Alaska Department of Fish and Game, Special Publication No. 92-2, Anchorage, Alaska, USA.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-28, Anchorage.

Parker, J. F. 2002. Abundance and composition of Arctic grayling of the Goodpaster River, 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-06, Anchorage.

Parker, J. F. 2003. Abundance and age and length composition of Arctic grayling in the Goodpaster River in 2002. Memo to TECK-POGO Contract Report. Alaska Department of Fish and Game, Sport Fish Division, Delta Junction.

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

Ridder, W. P. 1998a. Abundance, composition, and emigration of Arctic grayling of the Goodpaster River, 1995 - 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-36, Anchorage.

Ridder, W. P. 1998b. Radio Telemetry of Arctic grayling in the Delta Clearwater River 1995 to 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-37, Anchorage.

Roach, S. M. 1995. Stock assessment of Arctic Grayling in the Salcha, Chatanika, and Goodpaster Rivers during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-9, Anchorage.

Robson, D. S., and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215-226.

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

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

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

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

Tack, S. L. 1980. Migrations and distribution of Arctic grayling, *Thymallus arcticus* (Pallas), in interior and arctic Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(R-I). Juneau.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41(1):42-46.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage.

APPENDIX A

Appendix A1.–Pogo project fishing policy.

APPLIES TO: All employees of Sumitomo and Teck and associated contractors.

POLICY: Teck, the operator of the Pogo gold exploration project, strictly forbids fishing on the Goodpaster River and its tributaries surrounding Pogo. This includes harvest and "capture and release" of grayling, burbot, northern pike, whitefish, salmon and any other aquatic species present in these watercourses.

EXCEPTIONS: With permission from Teck and the Alaska Department of Fish and Game, environmental scientists under contract to Teck and government employees may harvest aquatic species for scientific studies. Pogo employees may fish in these drainages only if they are off duty <u>and</u> have traveled to the area by their own efforts. Pogo employees who are off duty but are still on site may not fish.

RATIONALE: The Alaska Department of Fish and Game does not allow salmon fishing anywhere in the Goodpaster River and few of the other game species of fish are available in the upper river areas. A portion of the Goodpaster River Arctic grayling population migrates into the upper watershed, including the vicinity of the Pogo site, during the open water months. Historically, few fishermen access the upper watershed area. However, fishermen do utilize other portions of this grayling population, primarily in the lower Goodpaster River and the Delta Clearwater River. Past experience has shown that grayling population in the lower Goodpaster River and Delta Clearwater River has declined under heavy fishing pressure. Additional fishing pressure by Pogo project personnel would have the potential to further reduce this fish population. By not allowing fishing by project personnel at Pogo, we can help minimize Pogo project impact to this valuable resource.

PENALTIES: Adhering to Teck's no fishing policy is a condition of employment. Employees found violating this policy will be dismissed from the project.

AUTHORIZATION:

APPENDIX B

EQUATIONS AND STATISTICAL METHODOLOGY

Appendix B1.–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:

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

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):

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

Appendix B2.–Methodologies for alleviating bias due to size selectivity.

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

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_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 event for size and age composition estimates.

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

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

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Estimate length and age distributions from second event and adjust these estimates for differential capture probabilities.

Appendix B3.–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.

	First Event Sampling Area Released	Second Event				
		Sampling Area Recaptured				Not Recaptured
		A	**B**	**…**	**S**	(total)
TEST I[a]	**A**					
	B					
	…					
	S					

		Second Event: Sampling Area			
		A	**B**	**…**	**S**
TEST II[b]	Recaptured				
	Not Recaptured				

		Captured During Second Event			
		A	**B**	**…**	**S**
TEST III[c]	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 B4.–Equations for estimating length and age composition and their variances for the population.

For Arctic grayling > 240 mm FL in the lower stratum and >300 mm FL in the upper stratum, the diagnostic tests indicated that there was no size selective sampling during either event (Case I, Appendix B2). Therefore, stratification by size was not necessary and population compositions of lengths and ages were estimated for each geographic stratum using measurements from both sampling events. 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.

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; 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):

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

Four length categories (240-270, 271-300, 301-350, and >351 mm FL) were considered and Arctic grayling were also grouped into 10 mm FL length categories.

APPENDIX C
DATA SUMMARY FOR EACH SAMPLING RUN

Appendix C1.–Data summary for each consecutive sampling run for the mark and recapture efforts on the Goodpaster River, July 2003.

Date	Run Name	Consecutive Run Description	GPS Position	Survey Section	Sub-Sec	Run Dist.	Mile Post	Catch All	Old Tags	≥240FL Tagged	Recap	(K)
7/7/03	Start	Start of Mark and Recap	N64 28 04.2 W144 39 58.1	1	1		0					
	Glacier	Glacier Cr. Reference	N64 28 07.9 W144 40 22.5	1	1	0.2	0.2					
7/22/03	R1	Recap release location 1	N64 28 04.1 W144 40 51.4	1	1	0.3	0.5	5	0	5	0	0
7/22/03	R2	Recap release location 2	N64 28 13.5 W144 42 01.5	1	1	0.6	1.1	9	1	9	2	0
7/22/03	R3	Recap release location 3	N64 28 16.0 W144 42 07.7	1	1	0.1	1.2	8	0	7	1	0
7/22/03	R4	Recap release location 4	N64 28 23.2 W144 42 23.2	1	1	0.2	1.4	2	0	2	0	0
7/7/03	M0	Mark release location 0	N64 28 23.9 W144 42 21.2	1	1	0	1.4	34	1	31		0
7/8/03	M1	Mark release location 1	N64 28 23.8 W144 42 35.0	1	1	0.1	1.5	8	0	8		0
7/22/03	R5	recap release location 5	N64 28 32.1 W144 43 07.4	1	1	0.4	1.9	3	0	3	0	0
7/8/03	M2	Mark release location 2	N64 28 32.0 W144 43 08.5	1	1	0	1.9	5	0	5		0
7/8/03	M3	Mark release location 3	N64 28 31.7 W144 43 27.9	1	1	0.2	2.1	7	0	7		0
7/8/03	M4	Mark release location 4	N64 28 38.1 W144 43 57.0	1	1	0.3	2.4	7	1	3		0
7/8/03	M5	Mark release location 5	N64 28 43.5 W144 44 13.4	1	1	0.2	2.6	6	2	6		0
7/8/03	M6	Mark release location 6	N64 28 53.3 W144 44 36.2	1	1	0.2	2.8	5	0	4		0
7/8/03	M7	Mark release location 7	N64 29 00.5 W144 44 44.6	1	1	0.2	3	4	0	4		0
7/22/03	R6	Recap release location 6	N64 29 09.1 W144 44 53.1	1	1	0.2	3.2	3	0	3	0	0
7/8/03	M8	Mark release location 8	N64 29 15.7 W144 45 07.1	1	1	0.1	3.3	3	0	3		0
7/8/03	M9	Mark release location 9	N64 29 22.0 W144 45 28.0	1	1	0.3	3.6	5	0	5		0
7/22/03	R7	recap release location 7	N64 29 22.4 W144 45 29.3	1	1	0	3.6	1	0	1	1	0
7/8/03	M10	Mark release location 10	N64 29 24.0 W144 45 46.2	1	1	0.1	3.7	9	2	9		0
	End SUB I: Start of Subsection II		N64 29 23.9 W144 45 47.1				3.7					
7/8/03	M11	Mark release location 11	N64 29 07.0 W144 46 03.5	1	2	0.4	4.1	6	0	6		0

-continued-

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Date	Run Name	Consecutive Run Description	GPS Position	Survey Section	Sub-Sec	Run Dist.	Mile Post	Catch All	Old Tags	≥240FL Tagged	Recap	(K)
7/8/03	M12	Mark release location 12	N64 28 57.5 W144 46 25.2	1	2	0.3	4.4	5	0	5		0
7/22/03	R8	Recap release location 8	N64 28 54.0 W144 46 41.2	1	2	0.1	4.5	3	0	3	2	0
7/8/03	M13	Mark release location 13	N64 28 52.4 W144 46 50.8	1	2	0.1	4.6	3	0	3		0
7/22/03	R9	Recap release location 9	N64 28 49.9 W144 47 14.7	1	2	0.1	4.8	7	1	6	0	0
7/9/03	M14	Mark release location 14	N64 28 52.8 W144 47 35.4	1	2	0.2	5	4	0	4		0
7/9/03	M15	Mark release Location 15	N64 28 59.3 W144 47 39.4	1	2	0.1	5.1	5	0	5	0	0
7/22/03	R10	Recap release location 10	N64 29 01.5 W144 47 37.6	1	2	0.1	5.2	4	0	4	2	0
7/9/03	M16	Mark release location 16	N64 29 10.2 W144 47 31.5	1	2	0.2	5.4	4	0	4		0
7/9/03	M17	Mark release location 17	N64 29 09.0 W144 47 30.2	1	2	0	5.4	7	0	6	0	0
7/23/03	R11	Recap release location 11	N64 29 26.6 W144 47 43.8	1	2	0.3	5.7	9	1	9	0	0
7/23/03	R12	recap release location 12	N64 29 35.0 W144 48 06.1	1	2	0.3	6	4	2	4	0	0
7/23/03	R13	Recap release location 13	N64 29 34.5 W144 48 20.4	1	2	0.1	6.1	8	1	8	1	0
7/23/03	R14	Recap release location 14	N64 29 31.5 W144 48 41.2	1	2	0.2	6.3	13	0	12	1	0
7/9/03	M18	Mark release location 18	N64 29 30.9 W144 48 41.7	1	2	0	6.3	8	0	8		0
7/9/03	M19	Mark release location 19	N64 28 58.5 W144 48 39.8	1	2	0.7	7	8	1	7		1
7/23/03	R15	recap release location 15	N64 28 50.7 W144 48 44.0	1	2	0.2	7.2	4	0	4	0	0
7/9/03	M20	Mark release location 20	N64 28 42.0 W144 48 55.7	1	2	0.1	7.3	7	1	7		0
7/23/03	R16	Recap release location 16	N64 28 40.1 W144 48 58.7	1	2	0.1	7.4	5	1	4	0	0
7/23/03	R17	Recap release location 17	N64 28 37.5 W144 49 19.9	1	2	0.2	7.6	7	1	7	2	0
7/7/03	start	Start electroshocking	N64 28 38.0 W144 49 24.5	1	2	0	7.6					
7/9/03	M21	Mark release location 21	N64 28 38.2 W144 49 26.2	1	2	0	7.6	8	1	8		0
7/9/03	M22	Mark release location 22	N64 28 40.9 W144 49 40.7	1	2	0.2	7.8	8	0	7		1
7/23/03	R 18	Recap release location 18	N64 28 47.8 W144 49 52.5	1	2	0.1	7.9	4	0	4	1	0

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Date	Run Name	Consecutive Run Description	GPS Position	Survey Section	Sub-Sec	Run Dist.	Mile Post	Catch All	Old Tags	≥240FL Tagged	Recap	(K)
7/9/03	M23	Mark release location 23	N64 28 49.1 W144 49 52.3	1	2	0.1	8	4	1	4		0
7/10/03	M24	Mark release location 24	N64 29 02.5 W144 49 56.8	1	2	0.1	8.2	7	0	7		0
7/10/03	M25	Mark release location 25	N64 29 04.6 W144 50 03.8	1	2	0.1	8.3	9	1	9		0
7/23/03	R19	Recap release location 19	N64 29 04.7 W144 50 16.6	1	2	0.1	8.4	5	0	5	3	0
7/10/03	M26	Mark release location 26	N64 29 04.3 W144 50 17.0	1	2	0	8.4	7	0	6		0
7/24/03	R 20	Recap release location 20	N64 29 02.4 W144 50 19.1	1	2	0.1	8.5	4	0	4	3	0
7/10/03	M27	Mark release location 27	N64 28 59.7 W144 50 35.6	1	2	0	8.5	8	0	7		0
7/24/03	R21	Recap release location 21	N64 28 59.7 W144 50 37.6	1	2	0.2	8.7	4	0	2	2	0
	End SUBII start of Subsection III		N64 28 59.7 W144 50 38.7			0	8.7					
7/10/03	M28	Mark release location 28	N64 28 58.8 W144 50 59.7	1	3	0.1	8.8	11		10		0
7/10/03	M29	Mark release location	N64 29 02.5 W144 51 11.0	1	3	0.2	9	4		4		0
7/24/03	R 22	recap release location 22	N64 29 04.4 W144 51 17.5	1	3	0	9	7		7	3	0
7/24/03	R 23	recap release location 23	N64 29 07.1 W144 51 32.3	1	3	0.2	9.2	8	2	8	4	0
7/10/03	M30	Mark release location 30	N64 29 08.0 W144 51 41.8	1	3	0.1	9.3	15	2	15		0
7/24/03	R 24	recap release location 24	N64 29 08.8 W144 51 47.4	1	3	0	9.3	5	1	5	1	0
7/10/03	M31	Mark release location 31	N64 29 10.1 W144 51 57.2	1	3	0.1	9.4	4	0	4		0
7/24/03	R 25	recap release location 25	N64 29 04.5 W144 52 21.8	1	3	0.3	9.7	6	0	6	0	0
7/10/03	M32	Mark release location 32	N64 29 03.8 W144 52 19.8	1	3	0	9.7	10	2	10		0
7/24/03	R 26	Recap release location 26	N64 28 59.7 W144 52 33.7	1	3	0.1	9.8	4	1	3	1	0
7/10/03	M33	Mark release location 33	N64 28 58.3 W144 52 56.3	1	3	0.2	10	5	0	5		0
7/24/03	R 27	Recap release location 27	N64 28 52.7 W144 53 07.0	1	3	0.2	10.2	1	0	1	0	0
7/10/03	M34	Mark release location 34	N64 28 50.8 W144 53 14.6	1	3	0.1	10.3	11	0	11		0
7/10/03	M35	Mark release location 35	N64 28 48.8 W144 53 24.1	1	3	0	10.3	6	0	6		0

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Date	Run Name	Consecutive Run Description	GPS Position	Survey Section	Sub-Sec	Run Dist.	Mile Post	Catch All	Old Tags	≥240FL Tagged	Recap	(K)
7/10/03	M 36	Mark release location 36	N64 28 37.3 W144 53 37.7	1	3	0.3	10.6	1	0	1		0
7/24/03	R 28	recap release location 28	N64 28 33.2 W144 53 39.4	1	3	0.1	10.7	6	1	6	2	2
7/10/03	M37	Mark release Location 37	N64 28 29.0 W144 53 52.4	1	3	0.1	10.8	5	0	5		0
7/10/03	M38	Mark release location 38	N64 28 39.1 W144 54 26.2	1	3	0.4	11.2	4	1	4		0
7/24/03	R29	Recap location 29	N64 28 38.8 W144 54 32.6	1	3	0.1	11.3	7	2	3	1	0
7/7/03	end electroshocking, release site		N64 28 36.8 W144 54 38.4	1	3	0	11.3	18	2	16		0
7/7/03	M46	Mark start location for 46	N64 28 36.3 W144 54 39.7	1	3	0	11.3					
7/25/03	R30	Recap start location run30	N64 28 35.7 W144 54 41.1	1	3	0.1	11.4					
7/10/03	M39	Mark release location 39	N64 28 35.1 W144 54 41.5	1	3	0	11.4	13	0	13		0
7/21/03	R-Sup	start recapture	N64 28 33.1 W144 54 43.1	1	3	0	11.4					
7/10/03	M 40	Mark release location 40	N64 28 21.8 W144 54 56.0	1	3	0.3	11.7	14	2	12		0
7/25/03	R30	Recap release location 30	N64 28 11.6 W144 55 03.9	1	3	0.2	11.9	17	3	16	4	0
7/10/03	M 41	Mark release location 41	N64 28 10.0 W144 55 04.7	1	3	0	11.9	0	0	0		0
7/11/03	M42	Mark start location	N64 28 06.6 W144 55 08.6	1	3	0.1	12					
7/25/03	R31	Recap release location 31	N64 28 03.7 W144 55 38.0	1	3	0.2	12.2	18	2	18	4	0
7/11/03	M42	Mark release location 42	N64 27 59.3 W144 55 48.7	1	3	0.2	12.4	13	2	13		0
7/11/03	M43	Mark release location 43	N64 27 51.3 W144 56 02.2	1	3	0.2	12.6	10	1	9		0
7/11/03	M44	Mark release location 44	N64 27 47.7 W144 55 53.8	1	3	0.1	12.7	15	0	13		0
7/21/03	R Sup	end of supplemental recap	N64 27 41.7 W144 56 01.1	1	3	0.1	12.8	6	1	6	0	0
	Liese	end Sub III start of Sub IV	N64 27 39.0 W144 56 12.7				12.9					
7/25/03	R32	Recap release location 32	N64 27 34.0 W144 56 28.1	1	3	0.3	13.1	7	0	2	1	0
7/11/03	M45	Mark release location 45	N64 27 30.3 W144 56 31.2	1	3	0.1	13.2	7	0	5		0
7/7/03	M46	Mark release location	N64 26 56.8 W144 56 31.9	1	3	0.6	13.8	17	1	16		0

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Date	Run Name	Consecutive Run Description	GPS Position	Survey Section	Sub-Sec	Run Dist.	Mile Post	Catch All	Old Tags	≥240FL Tagged	Recap	(K)
	Pogo	South end Pogo Airstrip	N64 26 56.4 W144 56 31.2	1	3	0.1	13.9					
7/8/03	M47	start mark effort	N64 26 54.1 W144 56 29.0	2	4	0	13.9					
7/22/03	R33	start recap effort	N64 26 54.1 W144 56 29.0	2	4	0	13.9					
7/22/03	R33	recap release location 33	N64 26 36.9 W144 56 22.4	2	4	0.4	14.3	7	0	5		0
7/8/03	M47	mark release location 47	N64 26 32.8 W144 56 24.7	2	4	0.4	14.3	10	0	9		0
7/8/03	M48	mark release location 48	N64 26 01.8 W144 55 49.1	2	4	1.0	15.3	8	0	3		0
7/8/03	M49	mark release location 49	N64 25 48.1 W144 55 49.3	2	4	0.3	15.6	14	3	13		0
7/22/03	R34	recap release location 34	N64 25 35.0 W144 56 03.0	2	4	0.2	15.8	22	3	21	3	0
7/8/03	M50	mark release location 50	N64 25 22.1 W144 55 46.2	2	4	0.4	16.2	10	0	10		0
7/22/03	R35	recap release location 35	N64 25 07.1 W144 56 24.7	2	4	0.5	16.7	11	2	11	3	0
7/8/03	M51	mark release location 51	N64 25 07.1 W144 56 24.7	2	4	0.5	16.7	12	1	12		0
7/8/03	M52	mark release location 52	N64 25 05.3 W144 56 43.1	2	4	0.3	17	8	1	8		0
7/8/03	M53	mark release location 53	N64 24 38.0 W144 56 43.6	2	4	0.6	17.6	11	0	7		0
7/22/03	R36	recap release location 36	N64 24 30.0 W144 56 44.4	2	4	0.2	17.8	12	0	10	2	0
	End of Subsection IV		N64 24 29.5 W144 56 45.2				17.8					
7/9/03	M54	mark release location 54	N64 24 28.9 W144 56 46.1	2	5	0.1	17.9	12	0	12		0
7/9/03	M55	mark release location 55	N64 24 13.5 W144 57 21.0	2	5	0.4	18.3	11	0	11		0
7/22/03	R37	recap release location 37	N64 24 13.5 W144 57 21.0	2	5	0.4	18.3	7	0	7	3	0
7/9/03	M56	mark release location 56	N64 24 01.2 W144 57 33.1	2	5	0.3	18.6	18	1	17		0
7/22/03	R38	recap release location 38	N64 24 01.2 W144 57 33.1	2	5	0.3	18.6	13	0	13	6	0
7/9/03	M57	mark release location 57	N64 23 47.1 W144 57 15.2	2	5	0.3	18.9	14	2	13		0
7/9/03	M58	mark release location 58	N64 23 39.1 W144 57 31.9	2	5	0.3	19.2	11	1	8		1
7/23/03	R39	recap release location 39	N64 23 39.9 W144 57 43.2	2	5	0.1	19.3	11	1	11	2	0

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Date	Run Name	Consecutive Run Description	GPS Position	Survey Section	Sub-Sec	Run Dist.	Mile Post	Catch All	Old Tags	≥240FL Tagged	Recap	(K)
7/9/03	M59	mark release location 59	N64 23 36.4 W144 57 44.3	2	5	0	19.3	10	1	10		0
7/23/03	R40	recap release location 40	N64 23 29.4 W144 57 31.2	2	5	0.2	19.5	15	1	15	3	0
7/9/03	M60	mark release location 60	N64 23 27.2 W144 57 17.0	2	5	0.2	19.7	26	3	23		0
7/23/03	R41	recap release location 41	N64 23 21.4 W144 57 32.9	2	5	0.2	19.9	26	2	26	5	0
7/9/03	M61	mark release location 61	N64 23 06.9 W144 57 50.9	2	5	0.6	20.5	23	2	19		1
7/23/03	R42	recap release location 42	N64 23 02.9 W144 57 28.9	2	6	0.4	20.9	17	0	17	0	0
7/23/03	R43	recap release location 43	N64 22 14.8 W144 57 18.3	2	6	1.7	22.6	11	0	10	0	1
	End of SUBV start of SUBVI		N64 22 14.3 W144 57 25.0				22.6					
7/10/03	M62	mark release location 62	N64 22 15.5 W144 57 35.9	2	6	0.2	22.8	34	4	32		0
7/10/03	M63	mark release location 63	N64 21 58.4 W144 57 39.3	2	6	0.4	23.2	18	2	17		1
7/23/03	R44	recap release location 44	N64 21 48.0 W144 57 40.1	2	6	0.3	23.5	11	1	11	1	0
7/10/03	M64	mark release location 64	N64 21 36.0 W144 58 13.7	2	6	0.5	24	27	0	21		0
7/24/03	R45	recap release location 45	N64 21 36.0 W144 58 13.7	2	6	0.5	24	19	0	17	5	0
7/24/03	R46	recap release location 46	N64 21 13.5 W144 58 24.5	2	6	0.4	24.4	16	0	16	2	0
7/24/03	R47	recap release location 47	N64 21 03.1 W144 59 21.3	2	6	0.6	25	15	1	15	1	0
7/10/03	M65	mark release location 65	N64 20 55.0 W144 59 52.4	2	6	0.3	25.3	33	2	32		1
7/24/03	R48	recap release location 48	N64 20 31.2 W145 00 03.8	2	6	0.5	25.8	25	2	24	1	0
7/10/03	M66	mark release location 66	N64 20 11.1 W145 00 08.2	2	6	0.6	26.4	27	2	25		1
7/24/03	R49	recap release location 49	N64 20 01.4 W145 00 10.5	2	6	0.2	26.6	16	0	15	2	0
7/10/03	M67	mark release location 67	N64 19 56.0 W144 59 46.1	2	6	0.2	26.8	24	0	22		1
7/24/03	R50	recap release location 50	N64 19 58.6 W145 00 39.5	2	6	0.6	27.4	13	1	10	1	0
7/10/03	End of Subsection VI		N64 20 04.9 W145 01 07.4	2	6	0.2	27.6					
	Barbara Creek end of study area		N64 20 02.4 W145 01 10.9				27.6					

APPENDIX D
DATA SUMMARY

Appendix D1.–Data files[a] used to estimate parameters of the Arctic grayling population in the Goodpaster River, 2003.

Location	Project Leader	Storage Software and Version	
Region III	J.F. Parker	Comma delimited	
Delta Junction	895-4632	ASCII files Standard	
		RTS Archive format [a]	
Study Area	**File Name**	**Data Format**	**Software**
Goodpaster River	U-00800L012003.DTA	Tagging-Length	RTS-ASCII
	U-00800L022003.DTA	Tagging-Length	RTS-ASCII
	Goodpaster03 Analysis-012606.xls	Data and analysis in spreadsheets	Microsoft XL

Definitions of Data Formats:

Tagging Length: a mark-sense form developed by Alaska Department of Fish and Game, Division of Sport Fish Research and Technical Services (RTS) for the recording of length, sex, and tagging information.

[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.