Fishery Data Series No. 01-28

Stock Assessment of Arctic Grayling in Beaver and Nome Creeks

by
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Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition.

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
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	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

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

Mathematics, statistics, fisheries

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

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

In July 2000, we assessed Arctic grayling inhabiting a portion of Beaver Creek which is a nationally designated "Wild" river, located north of Fairbanks. This population, unlike most previously assessed grayling populations in interior Alaska, has been considered a pristine, unexploited population. Alaska Department of Fish and Game and the U.S. Bureau of Land Management staff conducted the mark-recapture assessment along a 30½ mile section of Beaver Creek that has become more accessible following construction of a new road. During the two 10-day sampling trips a total of 3,671 Arctic grayling were captured by angling and sampled. An estimated 40,421 Arctic grayling (≥150 mm FL) were present in the study area during the mid-summer feeding period. In the study area we estimated the population density to include 1,325 Arctic grayling per mile, which is higher than in other reported studies on summer feeding populations of Arctic grayling in Alaskan rivers. Age-3 (29%) and age-4 (30%) fish were estimated to be the predominant age classes after the sampled age composition was adjusted for size-selectivity. It was estimated that grayling between 220 and 250 mm FL predominated the size composition following adjustments for size selectivity. Separate stock assessments were conducted during June and July 2000, in two portions of Nome Creek, which is the large road accessible tributary used by anglers and recreational floaters entering the Beaver Creek Wild River corridor. Difficulty with the timing of mark-recapture experiments in this tributary is discussed.

Key Words: Beaver Creek, Nome Creek, Arctic grayling, *Thymallus arcticus*, hook-and-line angling, age composition, length composition, stock assessment.

INTRODUCTION

The Beaver Creek watershed, located in the eastern interior of Alaska, is approximately 50-air miles north of Fairbanks. It was designated a National Wild River on December 2, 1980 when Congress amended the Wild and Scenic Rivers Act (P.L. 90-542) as part of the Alaska National Interest Lands Conservation Act (P.L. 96-487). The Bureau of Land Management (BLM), in its River Management Plan for the Beaver Creek National Wild River (BLM 1983), proposed to "conduct an inventory of fish, wildlife and habitat within the river corridor and continue to monitor the effects of river management actions, population trends and habitat use". The headwaters of Beaver Creek include Bear, Champion, and Nome creeks and many other tributaries enter along its course before entering the Yukon River about 290 miles downstream (Figure 1). It is similar to other runoff streams in the Fairbanks area such as the Chena, Chatanika, and Salcha rivers, which drain upland areas and terminate in glacially influenced rivers such as the Tanana. Fish species found in Beaver Creek include Arctic grayling *Thymallus arcticus*, round whitefish *Prosopium cylindraceum*, northern pike *Esox lucius*, burbot *Lota lota*, sheefish *Stenodus leucichthys*, longnose sucker *Catostomus catostomus*, slimy sculpin *Cottus cognatus*, chum salmon *Oncorhynchus keta*, and chinook salmon *O. tshawytscha*. The relative abundance of each species varies over its length as the river's hydrologic characteristics change. Arctic grayling are the most sought after species by sport fisherman accessing areas located in the upper half of the drainage, including the mainstem of Beaver Creek and adjacent tributaries (BLM 1983).

The watershed is generally considered pristine, but it also includes previously disturbed habitats such as Nome Creek, which enters Beaver Creek near river-mile 6½. Nome Creek was extensively placer mined from the early 1900s to the late 1980s, and recreational gold panning still occurs. Approximately 8 miles of streambed and associated floodplain were disturbed. Since 1991, BLM has reclaimed 4 miles of the Nome Creek channel and rehabilitated 500 acres of adjacent floodplain. This continuing work has focused on increasing the Arctic grayling

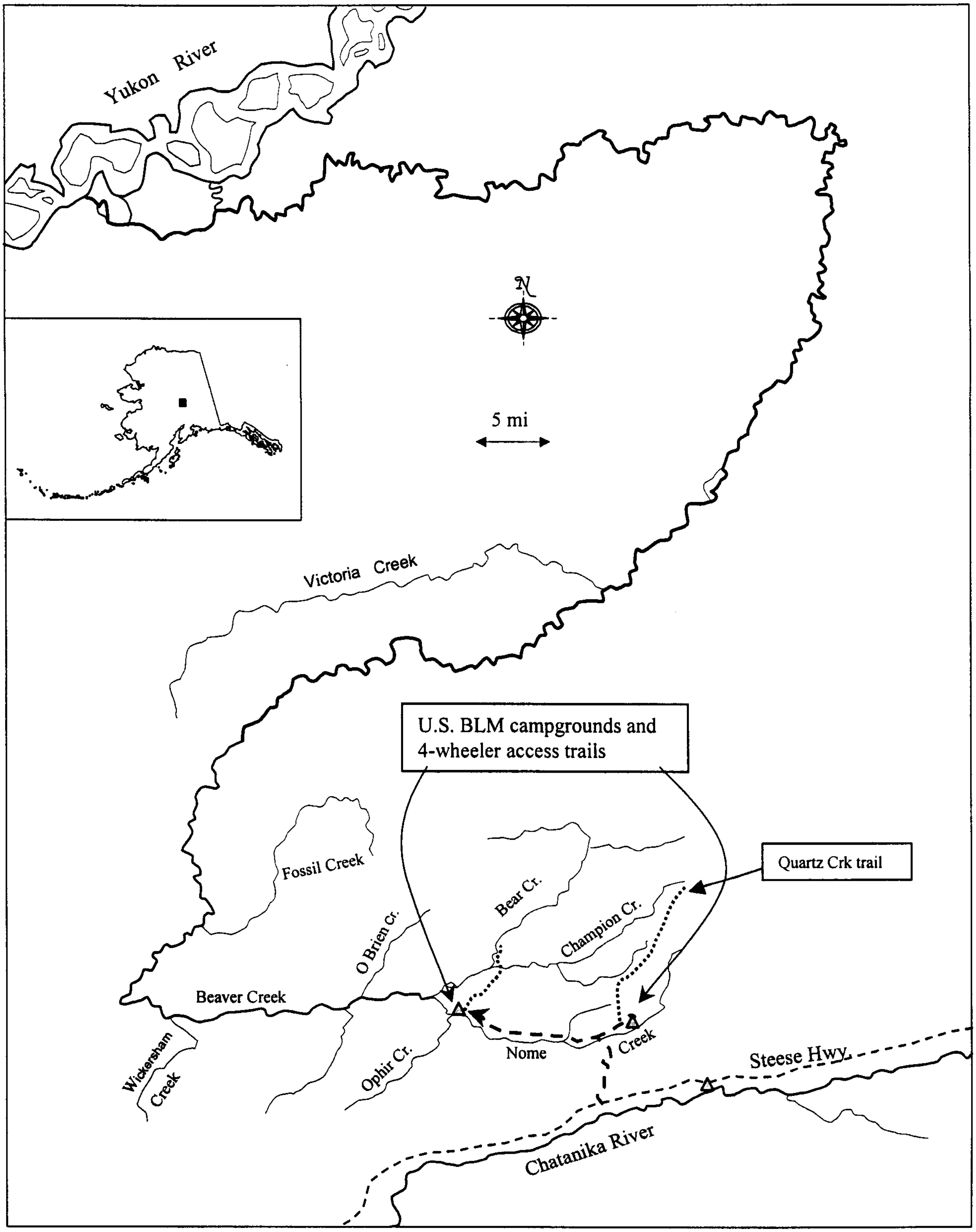

Figure 1.-The Beaver Creek drainage, including locations of access roads, trails, and campgrounds (triangles).

population through habitat enhancement, construction of pool habitat, and monitoring limnological parameters resulting from the restoration activities.

Nome Creek has been the most frequently used route to gain floating access to Beaver Creek from the Steese Highway and U.S. Creek Road. Excellent access for anglers and floaters has recently been provided to lower Nome Creek by way of road improvements and new construction. In 1997, a 15 mi two-lane gravel road was constructed along Nome Creek. Two public campgrounds were also constructed at the time: one near the confluence of Ophir and Nome creeks and the other near the Quartz Creek trail (Figure 1). Statewide sport fisheries surveys conducted by the Alaska Department of Fish and Game (ADF&G) have indicated increased use of the Nome and Beaver creek sport fisheries in recent years (Table 1; Mills 1992-1994; Howe et al. 1995-2000; Walker *In prep*). Between 1991 and 2000, estimates of angler-days increased from 149 to a peak of 1,101 in 2000. In the same period, estimated catches of Arctic grayling increased from about 200 in 1991 to 4,000 fish in 1996 and 1997, and estimates of harvest ranged to over 600 in 1996 and 2000. Concern over increased fishing effort and a potentially high level of exploitation of the Arctic grayling prompted ADF&G and BLM to propose increasingly restrictive regulations for Nome Creek in 1994. At that time, it was expected that the access improvement and development surrounding Nome Creek would lead to greater recreational use of both creeks. These concerns culminated in the current catch and release regulation for Nome Creek that was adopted in the winter 1994-95.

It is anticipated that recreational fishing in Nome and Beaver Creeks will continue to increase as the improved access and new campgrounds become more popular and attractive to the public seeking new opportunities in the Fairbanks area. Even though catch-and-release regulations protect fish that reside or spawn in Nome Creek, angling regulations in Beaver Creek prior to 2001 had allowed a 10 fish daily bag limit with no size restrictions. This regulation has usually been applied as a background regulation for remote areas, without road access, and where effort levels are low.

The Bureau of Land Management has periodically fielded studies on Arctic grayling in both Nome and Beaver creeks since 1988. These studies have included biological sampling, influences of habitat and habitat enhancements, and life history studies. Carufel (1988; 1989) conducted studies along Beaver Creek that included collection of age and size sample data from Arctic grayling at index sites, water quality measurements, aerial surveys of river users, and habitat enhancement in areas disturbed by mining. Between 1991-1995, baseline length and weight samples from Beaver Creek indicated Arctic grayling were of similar sizes and weights to other Interior Alaska rapid-runoff rivers near Fairbanks. In 1994, a study was conducted on winter habitats utilized by Arctic grayling in the Beaver Creek watershed (Lubinski 1995). Overwintering habitats were identified within the upper 30 mi of Beaver Creek using radiotelemetry. The purpose of this study was to characterize the physical attributes of overwintering areas used by adult Arctic grayling. In 1996, BLM conducted an investigation on Arctic grayling in Nome Creek to examine population abundance and structure. The project incorporated 50 permanent stations for stratified sampling along Nome Creek in a 13 mi section upstream of Ophir Creek (Ingrid McSweeney, BLM, Steese White Mtn. District, personal communication). A combination of this stratified approach of sub-sampling and the likely movements by marked Arctic grayling resulted in an estimate of about 9,500 fish, which was

Table 1.-Summary of angling effort and Arctic grayling catches and harvests from Beaver and Nome Creeks.[a]

Year	Fishing Effort[b]	Catch	Harvest
1991	149	219	141
1992	929	1,375	338
1993	535	2,711	171
1994	952	2,621	326
1995	886	957	53
1996	752	4,030	665
1997	1,059	4,065	122
1998	446	1,747	371
1999	966	1,427	311
2000	1,101	2,405	672

[a] Estimates for Nome and Beaver creeks have been combined since 1991.

[b] Number of angler-days fished.

believed to be biased high. The most recent BLM sampling on Nome and Beaver creeks has focused on collecting length and sex data from Arctic grayling migrating between Beaver and Nome creeks during the early spring spawning period. A cursory examination indicated that male and female Arctic grayling may initiate spawning at lengths near 200 mm FL (Ingrid McSweeney, BLM, Steese White Mtn. District, personal communication). In addition to assessing Beaver Creek Arctic grayling, there has been interest in the stock status in Nome Creek following effects from past mining and the more recent habitat enhancement.

Aside from immediate management actions on Beaver Creek, information on this lightly exploited, or nearly pristine population of Arctic grayling will be of value as the department develops a regional Arctic grayling management plan, or evaluates other grayling fisheries. Few populations of Arctic grayling have had historical baseline population data collected prior to increases in angler use and impact. An additional assessment of the Nome Creek grayling population was also sought to relate to its no-harvest regulation to habitat rehabilitation efforts by BLM. ADF&G and BLM entered into a Challenge Cost Share agreement (CCS) to collectively undertake these stock assessments in 2000.

The research objectives for 2000 to be addressed in this report under Federal Aid contract were to estimate:

1. abundance of Arctic grayling (≥150 mm FL) in the upper 34 mi of Beaver Creek, such that this estimate is within 25% of the true abundance 95% of the time;
2. age composition of the Arctic grayling (≥150 mm FL) in the upper 34 mi of Beaver Creek, such that all proportions are within 5 percentage points of the true proportions 95% of the time; and,
3. length composition of the Arctic grayling (≥150 mm FL) in the upper 34 mi of Beaver Creek, such that all proportions are within 5 percentage points of the true proportions 95% of the time.

Additional research objectives associated with a Challenge Cost Share agreement with BLM, were to estimate:

4. abundance of Arctic grayling (≥150 mm FL) in the lower 13 mi of Nome Creek, such that this estimate is within 25% of the true abundance 95% of the time;
5. age composition of the Arctic grayling (≥150 mm FL) in the lower 13 mi of Nome Creek, such that all proportions are within 5 percentage points of the true proportions 90% of the time; and,
6. length composition of the Arctic grayling (≥150 mm FL) in the lower 13 mi of Nome Creek, such that all proportions are within 5 percentage points of the true proportions 90% of the time.

The results of the Beaver Creek study are reported in the body of this report, while results from the Nome Creek study are reported in Appendix B.

METHODS

BEAVER CREEK STUDY AREA

The Beaver Creek study area is located within a Wild River corridor and administered by the BLM's Northern Field Office White Mountains Team. The river corridor and the surrounding area provides a large and popular year-round recreational area, that includes multi-use trails and public-use cabins. The river and stream corridor is used for angling, hunting, boating, and in some cases recreational gold panning.

Beaver Creek is formed at the confluence of Bear and Champion creeks. In the first 20 mi, Beaver Creek's channel is approximately 1 to 3 ft deep, 50 to 150 ft wide, and flows through a gravel streambed at an average river gradient of 20 ft/mi. Except for occasional shallow riffles, sufficient water levels are present throughout the summer for canoes and rafts. Major tributaries entering Beaver Creek along this segment include Nome, O'Brien, and Trail creeks. At several locations, Beaver Creek splits into two main channels that flow separately for nearly a mile before rejoining.

From river-mile 20 to 100, Beaver Creek's channel depth ranges from 1 to 9 ft, widens to over 200 ft, and flows with a similar river gradient. Major tributaries entering Beaver Creek along this segment include Wickersham, Fossil, and Victoria creeks. The majority of angling and floating parties using this area exit by wheel-plane at an airstrip near Victoria Creek. The remaining 190 mi of Beaver Creek flows slowly through the Yukon Flats National Wildlife Refuge before entering the Yukon River.

The 30½ mi study area that we selected for Arctic grayling stock assessment included two distinctive segments of Beaver Creek: one segment was remote and is believed to be accessed by overland travel, while the other segment was in the commonly floated portion of Beaver Creek (Figure 2). The remote portion was located between the confluence of Bear and Champion creeks and the confluence with Nome Creek, and was 6 ½ mi in length (Figure 2). In this section, unofficial trails allow anglers to access areas where bag limits[1] have allowed the sport harvest of 10 fish per day. A generally accepted life history paradigm for Arctic grayling is that larger and older fish spend the summer feeding period in headwater areas and tributaries of rapid runoff rivers of interior Alaska (Armstrong 1982). This pattern has previously been observed during BLM sampling conducted during surveys of the Beaver Creek headwater areas (N. Collins, BLM, Steese White Mtn. District, personal communication). The inclusion of this section allowed assessment of a relatively remote population of larger adult fish, which could be more sensitive to angling exploitation with increased use of overland trails.

[1] Bag limits of Arctic grayling in portions of Beaver Creek have been reduced following the 2001 Alaska Board of Fish meeting, which occurred after the stock assessment was completed, but prior to this report's completion. Bag and possession limits were reduced to five (5) Arctic grayling per day in the upper 13 mi of the Beaver Creek study area, while anglers can harvest 10 fish daily in areas further downstream.

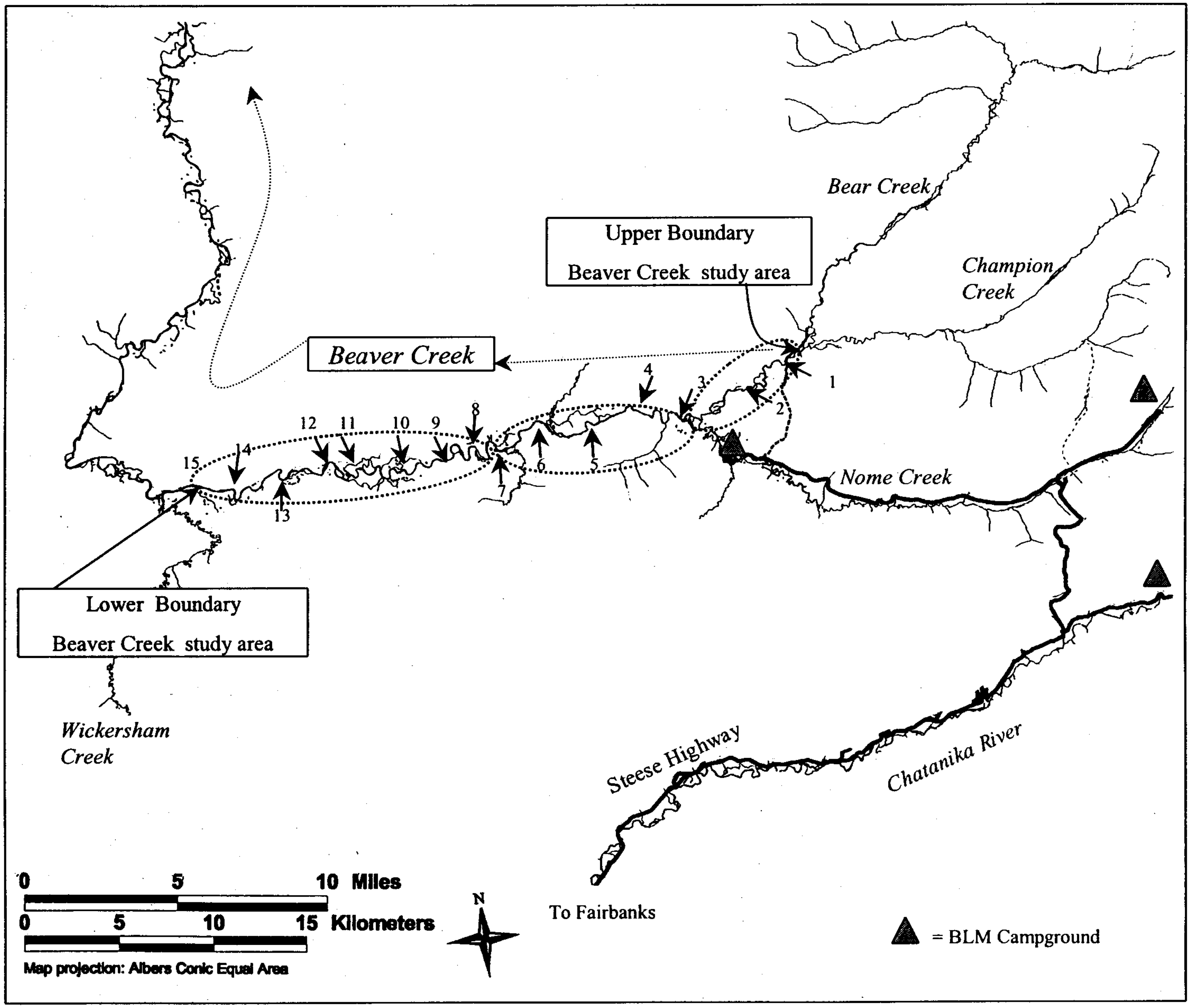

Figure 2.-Map of the Beaver Creek study area showing sequentially numbered two-mile sampling sections, sampling boundaries, and geographic sampling strata (circled).

The commonly floated portion of the study area started at the confluence of Beaver and Nome creeks, where floaters first enter Beaver Creek after floating down lower Nome Creek. This part of the study area extended downstream an additional 24 mi. The lower sampling boundary coincided with a seldom used airstrip located 1 mi upstream of Wickersham Creek near a public access cabin erected by BLM, known as the Borealis Le Fevre Cabin.

SAMPLING ACTIVITIES

To address the study objectives, a single-sample mark-recapture sampling study was conducted along Beaver Creek and timed to correspond with the summer feeding period of Arctic grayling. Past stock assessment and tagging studies on fluvial stocks of grayling have found that they move little during the summer feeding period, and thereby support assumptions of closed-population abundance models (Fleming et al. 1992; Ridder et al. 1993; Roach 1995). This project was undertaken in two 10-day sampling trips that were separated by a 20-day sampling hiatus. As part of the CCS agreement, ADF&G and BLM each supplied a crew of three persons, and necessary field equipment and supplies for the project. Additionally, ADF&G prepared and provided a detailed Operational Plan and biometric support for the project while BLM provided remote helicopter transportation, mapping expertise, historical information, and past biological data for the Operational Plan.

On July 5, 2000, an ADF&G crew of three first traveled by vehicle to Nome Creek and then on to Beaver Creek in a Bell 212 helicopter contracted by BLM's Alaska Fire Service. At the confluence of Bear and Champion creeks, the crew assembled an inflatable raft and started the marking event sampling (Figure 2). Hook-and-line gear was used throughout the project to capture Arctic grayling for mark-recapture sampling. The ADF&G crew traveled downstream and systematically sampled Arctic grayling in the upper 6½ mi of Beaver Creek over a three-day period. In this portion of Beaver Creek, the field crew generally traveled on foot, while the raft was tended by one of the crew members. Fishing pressure was deliberately spread over available habitat, and not concentrated in locations believed to contain fish. To achieve this, crew members started angling at locations about 50 meters apart, and moved downstream covering the water between their starting locations. Captured fish were briefly held in 6.5 gallon plastic buckets fitted with aeration vents. After the passage of either 20 minutes of holding time for 1 or more fish, or upon the capture of 5 fish by the crew members, angling was suspended and the catches were sampled. After each batch of fish was sampled, the crew moved downstream about 100 m before they resumed angling. This measure was taken to avoid recapturing previously sampled fish.

On July 8, 2000, a three-person BLM crew joined the ADF&G crew at the confluence of Beaver and Nome creeks to sample the remaining 24 mi portion of Beaver Creek. The two crews sampled downstream in an offset, or staggered fashion through this portion of the study area. At the start of each day, the two crews were each assigned a predetermined 2-mi section to sample as they moved downstream. Starting and stopping locations, and intermediate waypoints were found using topographic maps and hand-held Global Positioning System (GPS) units. One crew (alternating daily) initially traveled downstream about 2 mi to a predetermined location to start sampling. After flagging the location, the crew started sampling for the day. Sampling was terminated when this crew reached a predetermined location where both crews could camp during the upcoming night. The other crew started the day's sampling immediately downstream of the previous night's campsite. This crew sampled in a downstream fashion until they had reached the other crew's flagged starting location, which was approximately 2 mi downstream. The crew then suspended sampling and traveled downstream to the campsite location. Collectively, the two sampling crews sampled fish in about 4 mi of Beaver Creek each day, until reaching the lower sampling boundary near Wickersham Creek on July 13, 2000. Crews sampled a total of 15 sections that were approximately 2 mi in length (Figure 2).

As the overall size of Beaver Creek increased with additional inputs of water from tributaries and changes in its channel morphology (width, length of runs and pools, and depth), the distribution of angling effort required adjustment. The raft was actively used to allow the spread of sampling effort to both shorelines and mid-river habitat. Often the crew member that was rowing the raft would sequentially drop-off crew members, then land the raft further downstream. After the crew had angled and sampled fish between the drop-off locations and the raft, the cycle was repeated. After reaching the lower sampling boundary, the crews were flown by helicopter to either the Nome Creek road, or directly to the Alaska Fire Service Helibase, located at Ft. Wainwright, in Fairbanks.

During the first sampling trip, each fish was measured, tagged, and given an upper caudal finclip before release. To lessen the impacts of marking with anchor tags, small fine-fabric Floy™ FD-68b anchor tags were used. The tag color was dark green, and tag numbers ranged between 1 and 2,999. After a 20-day sampling hiatus, the second sampling trip was conducted in identical fashion, with changes only to the sampling protocol and several staff members. The second sampling trip was conducted between July 25 and August 2, 2000. During this sampling event, commonly referred to as the recapture event, fish were measured, examined for tags and clips, and scale samples were collected. Two to three scales were taken from each fish sampled for age. Scales came from an area on the fish approximately six scale rows above the lateral line and just posterior to the insertion of the dorsal fin (W. Ridder *Unpublished;* Brown 1943). Scales were placed on gum cards in the field and retained for age determination.

Because of the high catch rates in the first sampling event, scale samples were collected by geographically sub-sampling in the lower 24 mi of the study area. Each day, one crew collected scales to efficiently gather sufficient age information. This was to reduce time spent sampling fish in the field, preparing scale samples in the laboratory, and assigning estimated ages to sampled fish. After the completion of field activities, impressions of the scales were made on triacetate film using a scale press (30 s; 137,895 kPa; 97°C). Ages were determined by counting annuli from impressions of scales magnified to 40X with the aid of a microfiche reader. Criteria for determining the presence of an annulus were: 1) when complete circuli cut across incomplete circuli; 2) when clear areas or irregularities in circuli along the anterior and posterior fields were present; and, 3) when regions of closely spaced circuli were followed by a region of widely spaced circuli (Kruse 1959). Determination of age was performed at least twice for each readable set of scales, and one reader read all scales.

ABUNDANCE ESTIMATION

The assumptions necessary for accurate estimation of abundance in Beaver Creek were (Seber 1982):

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

2. all grayling had the same probability of capture in the marking sample, or in the recapture sample, or marked and unmarked grayling mixed completely between marking and recapture events;
3. marking of grayling did not affect their probability of capture in the recapture sample;
4. grayling did not lose their mark between the marking and recapture events; and,
5. all marked grayling were reported when recovered in the recapture sample.

To meet assumption 1, the study was conducted during the summer feeding period when Arctic grayling are less prone to migrate. To further reduce the risk of significant immigration or emigration (a violation of population closure) we selected a large study area (30 ½ miles). In order to lessen risks of gear avoidance during the second sampling event (assumption 2), a 20-day sampling hiatus separated sampling events. However, this could increase the likelihood of movement, particularly if the study's sampling period overlapped with the timing of an unknown, late-summer, or early fall migration toward overwintering areas. To validate use of the longer hiatus, information on movements were gathered from the mark-recapture data. Movements by recaptured fish and emigration/immigration were inferred through the examination of tagging histories from recovered fish, recapture-to-catch (R/C) ratios, and recapture-to-mark (R/M) ratios.

The study addressed assumption 2 in several ways. First, the hook-and-line gear included small-sized feather and plastic jigs, spinners, and flies so that all sizes of Arctic grayling could be caught. Second, we spread angling effort over much of the available habitat in each section (including pools, riffles, runs, inside and outside bends) and regulated downstream progress during each day to achieve more uniform sampling effort through the section. Assumptions 2 and 3 were addressed by the long sampling hiatus (20 d). This allowed time for marked and unmarked fish to mix locally or completely, as well as time to reduce effects such as gear shyness or avoidance following initial hooking.

The validity of assumptions 2 and 3 were examined by statistical inference using the mark-recapture data. A series of two-sample Kolmogorov-Smirnov (KS) tests examined difference in size selectivity within the mark-recapture experiment (Appendix A1). The first KS test compared the cumulative length frequency distributions of marked and recaptured Arctic grayling. This tested the hypothesis that the distribution of length of fish sampled during the first event was similar to the distribution of lengths recaptured during the second event. The second KS test examined the length frequency of fish captured during the first (marking) sample compared to fish captured in the second (recapture) sample. This tested the hypothesis that fish captured during the marking sample have the same length frequency distribution as fish captured in the recapture sample. The results from these tests then determined whether size stratification of the mark-recapture experiment was necessary (Appendix A1). Since size selectivity was detected in the mark-recapture data, the next step was to partition the mark-recapture data into appropriate size strata. A series of chi-square tests determined the length strata where the differences in capture probabilities were greatest, as indicated by the largest significant chi-square test statistic.

Since capture probabilities can differ significantly among sampled areas because of differential population density or by movements of marked fish, assumption 2 was further examined with chi-square tests on recapture-to-catch ratios (R/C), recapture-to-mark (R/M) ratios, and tests for mixing. These three tests for consistency of a Petersen estimate (Appendix A2) were performed following Seber (1982: page 438).

Assumptions 4 and 5 were ensured by the sampling methods. Assumption 4 was ensured because all fish were double marked using a tag and a partial finclip, which could not grow back during the study. Assumption 5 was ensured through examination of all captured fish for tags and finclips.

If any of the three tests for consistency (R/C, R/M, or mixing) were not significant, Bailey's estimator would remain as an appropriate estimator of abundance. The modified Petersen estimator of Bailey (1951, 1952), when used to estimate abundance of Arctic grayling in Beaver or Nome creeks, was calculated as:

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

where: $\hat{N}$ = the abundance of Arctic grayling in Beaver or Nome creeks (≥150 mm FL); 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 Arctic grayling recaptured in the second event.

Variance of this estimator was calculated as (Seber 1982):

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

If all three tests were significant (meaning the null hypothesis of equal r/m, r/c, or complete mixing was rejected), abundance would be estimated by the Darroch stratified estimator. Maximum likelihood (ML) estimates of the Darroch likelihood would be found by a direct searching algorithm (M. Wallendorf, Alaska Department of Fish and Game, Fairbanks, personal communication). The ML estimator required that for each tagging location, the movement probabilities were restricted to sum to 1 (consistent with the closure assumption). The objective function for the natural log of the Darroch likelihood was:

$$L = \sum_i \{(a_i - c_{i\cdot})\log[1 - \sum_j \Theta_{ij} p_j]\} + \sum_i \sum_j c_{ij} \log(\Theta_{ij} p_j), \tag{3}$$

where:

a_i = number of fish tagged at location i;

c_{ij} = number tagged fish from location i recaptured at location j;

$c_{i\cdot} = \sum_j c_{ij}$;

p_j = second sample capture probability for location j; and,

Θ_{ij} = probability of movement from tagging location i to recapture location j.

The estimate of untagged fish in the jth location of the second sample was:

$$\tilde{n}_j = b_j \,/\, \hat{p}_j \tag{4}$$

where b_j was the number of untagged fish caught in the second sample.

Total abundance was:

$$\tilde{N} = \sum_j \tilde{n}_j + \sum_i a_i \,. \tag{5}$$

The covariance matrix for the capture probabilities and movement probabilities were estimated using the observed information matrix. The variance for the abundance estimate was then approximated using the delta method (Seber 1982).

Population estimates were generated based on the appropriate choices of each size or area strata when necessary, before summing the independent estimates to yield an estimate of the entire population.

AGE AND SIZE COMPOSITION

Apportionment of fish populations among age or size groupings depends on the extent of sampling biases and needed adjustments. When adjustments are not required, the proportion of fish at age would be calculated as:

$$\hat{p}_k = \frac{y_k}{n} \tag{6}$$

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

The unbiased variance of this proportion would be estimated as:

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \,. \tag{7}$$

Size composition is estimated in a similar manner, replacing age class with 10 mm FL incremental size classes.

When size-selectivity or area differences in capture probability resulted in the use of stratification for the mark-recapture experiment, age and size composition estimates for the overall population would be adjusted or corrected. To adjust age and size estimates, the proportion of fish at age would be calculated by summing independent abundances for each age or size class and then dividing by the summed abundances for all size strata. First, the conditional proportions from the sample are calculated:

$$\hat{p}_{jk} = n_{jk} \big/ n_j \tag{8}$$

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 were age k; and, $\hat{p}_{jk}$ = the estimated proportion of age k fish in size stratum j. The variance calculation for $\hat{p}_{jk}$ would be identical to equation 7 (with appropriate substitutions).

The estimated abundance of age k fish in the population would then be:

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk}\hat{N}_j \tag{9}$$

where: N_j = the estimated abundance in size stratum j and s = the number of size strata.

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

$$\hat{V}\left[\hat{N}_k\right] \approx \sum_{j=1}^{s}\left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + V\left[\hat{N}_j\right]\hat{p}_{jk}^2\right) \tag{10}$$

The estimated proportion of the population that were age k $\left(\hat{p}_k\right)$ would then be:

$$\hat{p}_k = \hat{N}_k / \hat{N} \tag{11}$$

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

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

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

Equations 8 through 12 are also used to adjust biased size composition estimates, replacing the number sampled at age k that were also in size strata j (n_{jk}) with the number sampled per 10 mm FL incremental size category k (k = 155,165,175...395) that were also in size strata j.

RESULTS

FIELD SAMPLING

ADF&G and BLM crews, each with three persons, conducted two 10-day sampling trips in a 30½ mi study area during July and early August 2000. On July 5, the marking event began at the confluence of Bear and Champion creeks, and was completed on July 14, 2000. During the nine sampling days, a total of 1,589 fish were captured and sampled, of which 1,547 were released with individually numbered tags and upper caudal finclips. In the upper 6 ½ mi section of Beaver Creek, the crew's downstream sampling progress was briefly impaired by downed trees and an impassable channel. The crew resorted to dragging the raft and equipment through the previous main channel, which was mostly dry gravel bed. Travel in the remaining 24 mi of the study area was not impaired. During the marking event unsettled weather conditions prevailed with frequent rain showers. Water conditions were moderately low and clear through the first 7 days. However, on July 12, sampling was impaired for part of the day when rising water levels and poor water clarity impaired angling success, but conditions improved by the start of the next day.

On July 25, the second sampling event was initiated. During the second event, the crews captured and inspected 2,229 fish in nine days of sampling which included the recovery of 146 grayling that were tagged during the earlier sampling event. Weather conditions were variable, but water conditions remained lower than those experienced during the marking event.

In the course of the overall mark-recapture sampling project, 70 Arctic grayling were significantly wounded or died from hooking injuries, which represented a 1.9% acute rate of mortality for Arctic grayling captured in the study.

ABUNDANCE ESTIMATION

The relative ease of catching grayling throughout the study area allowed the crews to meet sample size objectives for the closed population model. During the marking event, daily sampling catches for the crews ranged from 58 to 145 fish and median daily catch was 107 fish. In the recapture sampling event daily catches ranged from 66 to 212 fish and the median daily catch was 146 fish. The pattern of gear use and sampling effort was consistent between sampling events.

Of the 146 fish recovered during the second sampling event, 29 fish had moved between 2 and 16 mi downstream, and 5 fish moved 2 to 10 mi upstream (Table 2). However, of the 29 fish that moved, 22 (76%) were within 4 mi of the area of initial release after 20 days. The movements and redistribution following the 20-day sampling hiatus indicated that some mixing occurred, although a large-scale seasonal migration had not occurred, thereby suggesting closure was maintained.

The mark-recapture data from the 15 sections were collapsed into three areas or strata based on similar capture probability (R/C). Resulting strata included an upper strata (sections 1-3: R/C = 0.15), a middle strata (sections 4-7: R/C = 0.08), and a lower strata (sections 8-15: R/C = 0.04). Examination of Seber's three tests for consistency for these strata indicated unequal mixing among strata ($\chi^2 = 393$, df = 6, $P < 0.0001$), recapture rates (R/M) varied by area ($\chi^2 = 64.3$, df = 2, $P < 0.0001$), and probabilities of marking also varied by area (R/C: $\chi^2 = 56.1$, df = 2, $P < 0.0001$). These results indicated that Darroch's partially stratified estimator would be appropriate to use, unless size selectivity was present in the mark-recapture experiment.

Kolmogorov-Smirnov (KS) two-sample tests were conducted within each of the three area-based strata (Figure 3). The resulting interpretation of the test statistics (Appendix A1) suggested that size-stratified estimates would not be required in the upper strata (Appendix A1: Case I) or the middle strata (Appendix A1: Case II), but would be necessary for the lower strata (Appendix A1: Case IV).

The size strata selected for further examination included small fish (<250 mm) and large fish ($\geq$ 250 mm). This was based on differences in recapture-to-catch ratios ($\chi^2_{250mm} = 61.7$, df = 1, $P < 0.01$) and the observation that no fish smaller than 250 mm were sampled in the upper strata.

Table 2.-Numbers of recovered and not recovered Arctic grayling ($\geq$ 150 mm FL) marked over a 30½ mi portion of upper Beaver Creek that were captured, released, and recaptured in 15 sequentially sampled sections during the 2000 Beaver Creek stock assessment.

Marking	Recovery Section															Not	
Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Recovered	Total
1	7															17	24
2	7	10														65	82
3		1	21	2				1								77	102
4		2	1	4		1										50	58
5				1	14		1									129	145
6				1	1	9										116	127
7				1	1	2	9									105	118
8								2								116	118
9									9							130	139
10					1	1		1		5						99	107
11					1			2			2					94	99
12							1				1	2				122	126
13										1		1	5			85	92
14														12		105	117
15												1		1		92	94
																1,402	1,548

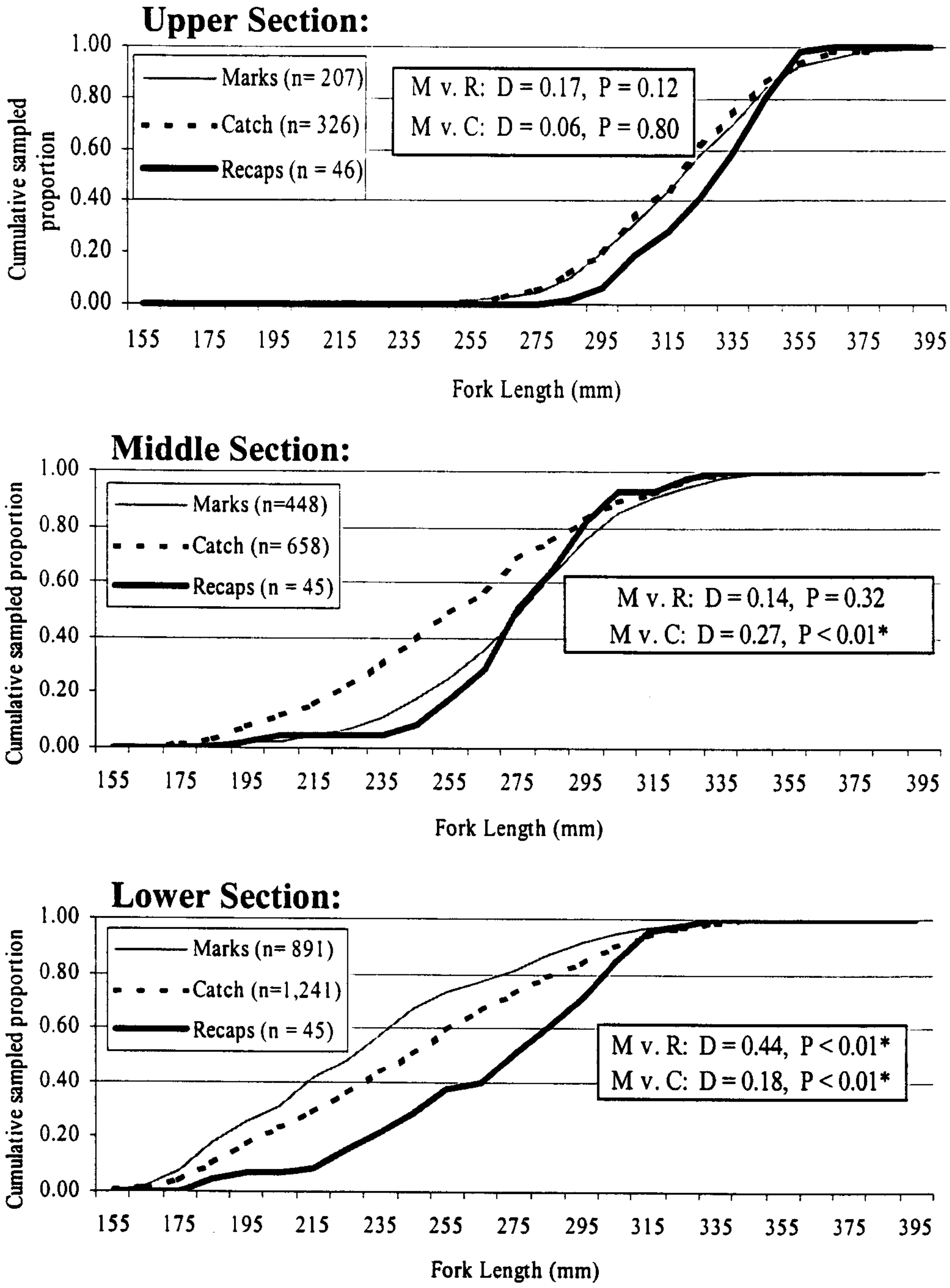

Figure 3.-Cumulative sampled proportions and resultant Kolmogorov-Smirnov (KS) test statistics for comparisons of lengths of Arctic grayling that were marked, examined for marks, and recaptured within upper, middle, and lower geographic strata.

Each of the two size strata were then reexamined by the three tests for consistency (Seber 1982) using the previously determined geographic strata (upper, middle, and lower):

Size-Stratum	Mark (M)	Catch (C)	Recap (R)	Consistency test results:
150 to 249 mm FL	682	895	19	**Test 1 mixing**: $\chi^2 = 19.0$, df = 2, P < 0.01
				Test 2 (R/M): $\chi^2 = 1.57$, df = 1, P = 0.21
				Test 3 (R/C): $\chi^2 = 0.04$, df = 1, P = 0.83
≥ 250 mm FL	863	1,330	127	**Test 1 mixing**: $\chi^2 = 239$, df = 6, P < 0.01
				Test 2 (R/M): $\chi^2 = 16.2$, df = 2, P < 0.01
				Test 3 (R/C): $\chi^2 = 26.3$, df = 2, P < 0.01
Total	1,545	2,225	146	

Within the small fish stratum, the unstratified Petersen estimator was selected, since at least one test of consistency was not significant. The estimated abundance of small fish was 30,554 fish (SE = 6,592 fish; 21.5% CV) in sampling sections 4 through 15, corresponding to a 24 mi portion of Beaver Creek. The estimated density of smaller Arctic grayling for this section of Beaver Creek was 1,273 fish per mile. Since the size of the smallest recaptured fish was 180 mm FL, the estimate represents fish ≥ 180 mm FL, roughly 8 inches total length (TL).

However, since all three test statistics corresponding to the large fish strata were significant, a partially stratified approach (Seber 1982) was selected to estimate abundance of the larger fish. The similarity of estimates of capture probabilities for the middle and lower section (0.11, 0.12) allowed pooling these two sections, which resulted in a simpler estimation model. The final ML estimate of abundances for large fish (≥ 250 mm FL) and capture probabilities were based on the history of recovery:

	Recovery History		Marked Fish	
Marking Area	**Upper**	**Lower**	Recovered	Not Recovered
Upper (6.5 mi):	46	2	48	157
Lower (24 mi):	3	76	79	323
Total	49	78	127	256
Unmarked	325	973		

The partially-stratified ML estimate for large Arctic grayling (≥ 250 mm FL) in the upper area strata was 1,328 fish (SE = 159 fish; CV =12%) and a capture probability of 0.24 (SE= 0.03). This portion of the estimate was germane to the 6½ mi section between the start of Beaver Creek, at the confluence of Bear and Champion creeks, downstream to the confluence with Nome Creek (Figure 2). In this section the estimated density was 204 fish per mile. The partially-stratified ML estimate for large Arctic grayling (≥ 250 mm FL) in the pooled middle and lower strata was 8,539 fish (SE = 959 fish; CV =11%) with a capture probability of 0.12 (SE= 0.01). This portion of the estimate was applicable to the section of river between the Nome Creek confluence and the lower study boundary, approximately 1 mi upstream of Wickersham Creek (Figure 2). The estimated density was 356 fish per mile (≥ 250 mm FL) in the lower 24 mi of the study area.

Combined estimates of abundance across size (small and large fish) and area strata indicate the presence of an estimated 40,421 Arctic grayling (SE = 6,663 fish; CV = 16.4%) ≥ 180 mm FL in the 30½ mi study section of Beaver Creek at the time of the second sampling event in late-July, 2000. The overall averaged estimated density for fish ≥ 180 mm FL was 1,325 fish per mile.

AGE AND SIZE COMPOSITION

Scale samples were collected by only one sampling crew each day in order to sub-sample the catch. However, due to a misunderstanding on sampling protocols relevant age information was only available from 6 of the 15 sections. Scale samples were successfully collected from all fish in the upper 6½ mi (sections 1-3), but only gathered from fish sampled within three sections (5, 9, 13) downstream of the confluence of Beaver Creek with Nome Creek (Figure 2). To examine whether the age data was representative of the entire study area, lengths of sampled fish were compared from sections with, or without complete age samples. Results of a two-sample KS test did not indicate a statistically significant difference (D = 0.03; P = 0.73), which gave reason to believe that the two samples were similar. As a result of this ad-hoc test, the age sample was believed to characterize the assessed population.

Ages determined from scale patterns ranged from 2 to 12 years. The final number of useable age samples was 714, after accounting for 93 scale samples that were either regenerated or illegible. The median age was 6 years, the average length of which was 283 mm FL. Ages were determined from 710 fish ≥ 150 mm FL, of which 274 represented fish in the upper 6½ mi, and the remaining represented fish in the lower 24 mi.

Estimates of size and age composition were adjusted following the process of stratifying the abundance estimates. After adjustment, the predominant age classes were age-4 (30%) followed by age-3 fish (28%) and age-5 fish (19%; Table 3).

The lengths measured from the 3,671 sampled Arctic grayling ranged from 115 to 386 mm FL. The median (and mean) sized grayling sampled during the second sampling event was 263 mm FL. Individual lengths and the median lengths from each of the 15 sections clearly indicated a predominance of larger fish in the upper areas and a wider range of sizes were elsewhere (Figure 4).

Estimates of the length composition of Arctic grayling within the 30½ mi study area were adjusted for size selectivity. Three strata were selected for adjusting the length composition. They included small fish (middle and lower), and two strata for large fish which were the pooled middle and lower areas (sections 4-15), and the upper area (section 1-3). The adjustment calculation led to a doubling of the proportional contributions (100% relative increase) for fish smaller than 250 mm FL, and a halving of the proportions associated with larger fish (Figure 5). Moreover, it was estimated that fish smaller than 12 in Total length (TL) make-up 85% of the population within the 30.5 mi assessment area, while fish > 12 in (≥ 270 mm FL) represent only 15%. The total estimated density of Arctic grayling was 1,325 fish per mile, which included 204 fish per mile that were 12 in or larger (≥ 270 mm FL).

Table 3.-Sampled and adjusted[a] composition and abundance by age class for Arctic grayling 3 150 mm FL in Beaver Creek during July 2000.

Age	Number Sampled	Proportion (p')	SE[p']	Abundance N'	SE[N']
2	8	0.03	0.01	456	454
3	80	0.29	0.03	4,561	2,255
4	98	0.30	0.03	5,587	2,310
5	105	0.19	0.02	5,986	1,515
6	134	0.10	0.02	7,640	942
7	126	0.05	0.01	7,183	527
8	94	0.03	0.01	5,359	348
9	44	0.01	0.00	2,508	171
10	9	0.00	0.00	513	58
11	8	0.00	0.00	456	40
12	3	0.00	0.00	171	3
Totals:	709	1	na	40,421	na

[a] Adjusted proportions (p') resulted from corrections made to the sampled composition because of differential capture probability by size (size selectivity bias) and geographic area within the mark-recapture experiment.

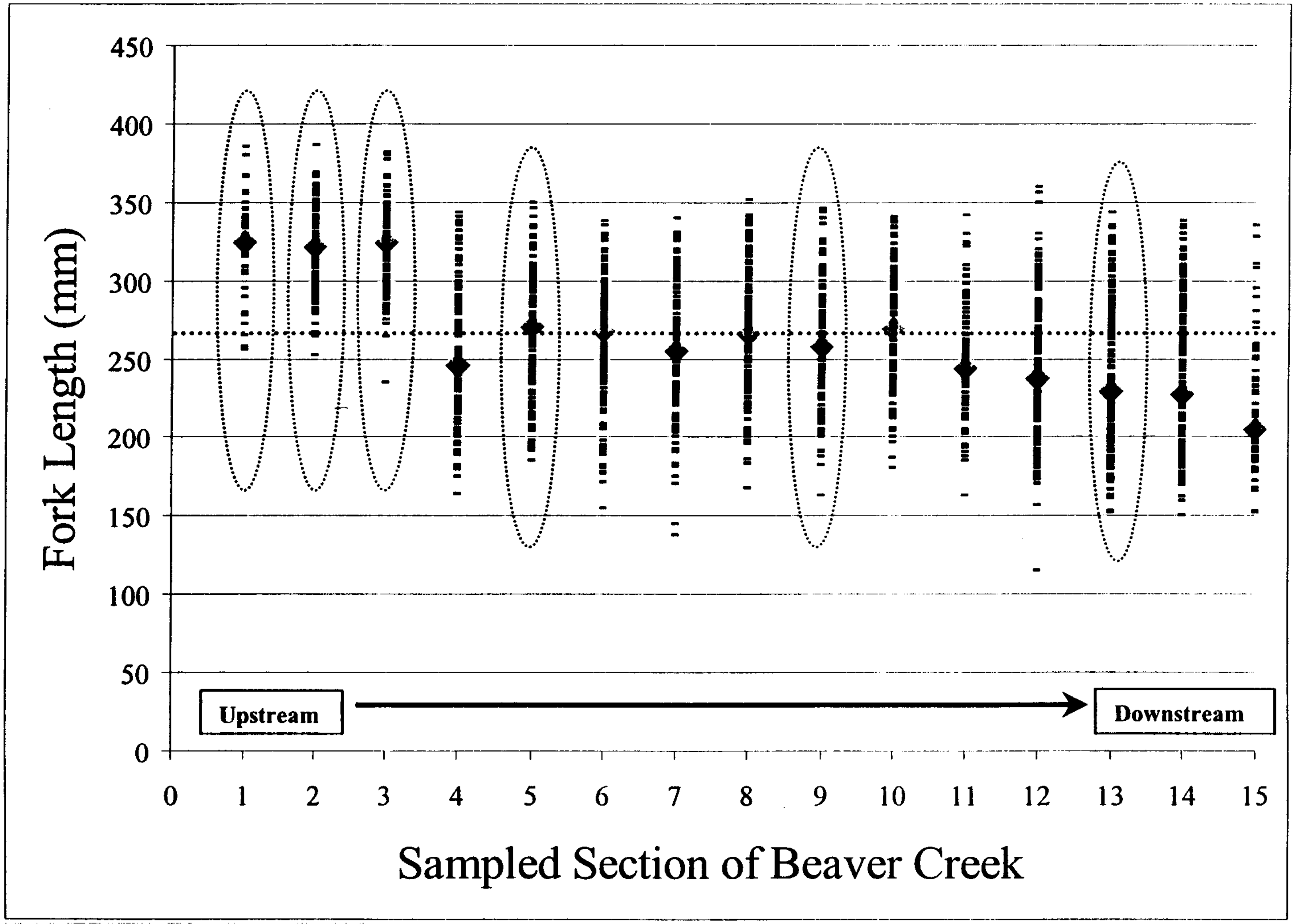

Figure 4.-Sampled lengths and median lengths of Arctic grayling for each approximately two-mile sampling section (crew-day), from upstream to downstream, within the 30.5 mi study area. Circled data denote fish that were successfully sampled for age throughout the study area.

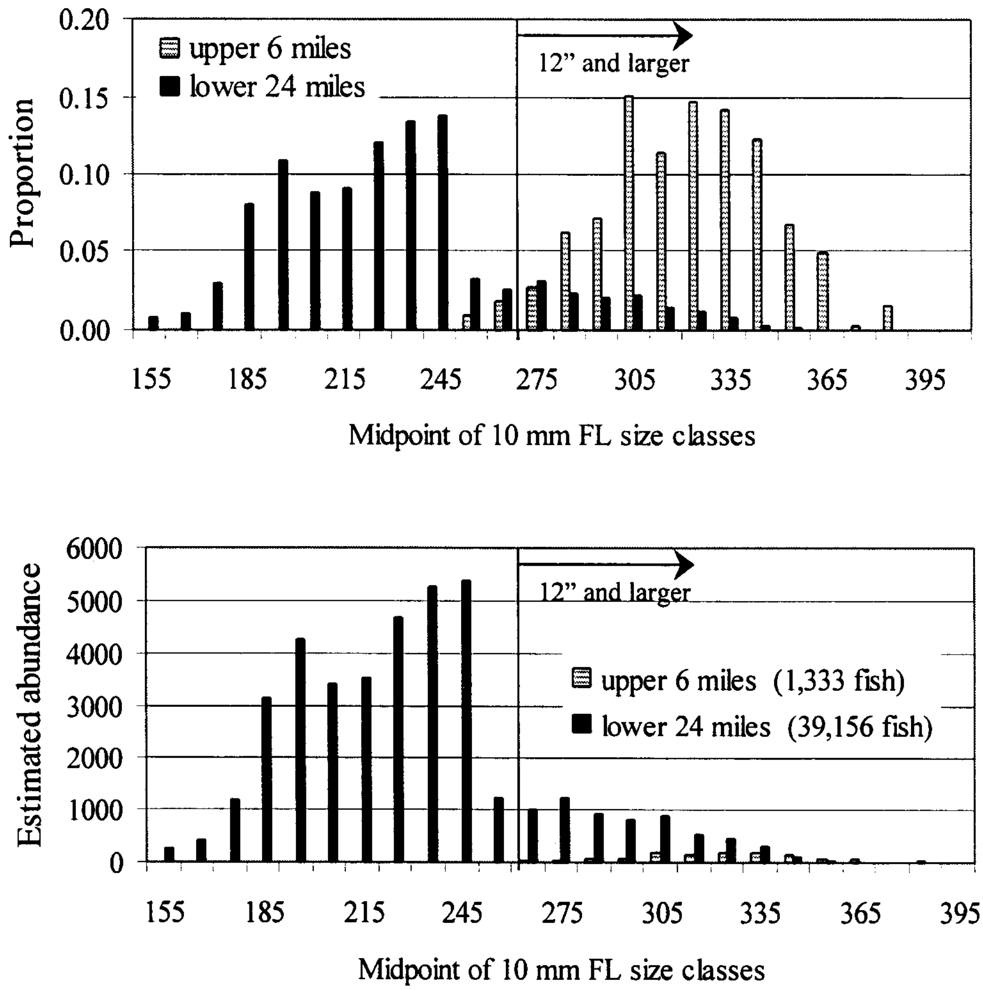

Figure 5.-Length composition of Arctic grayling by size class, plotted by adjusted proportion and by estimated abundance within the upper six and the lower 24 miles of the Beaver Creek study area, July 2000.

DISCUSSION

The mark-recapture stock assessment at Beaver Creek will be valuable in several ways for the management of Arctic grayling within interior Alaskan waters. Fishery and land managers now have baseline population data to include in their evaluations of the effects of increased public access through road and campground construction into this area. At the 2001 meeting, the Board of Fish supported a proposal by the Fairbanks Advisory Committee to reduced the daily bag and possession limit to 5 Arctic grayling. This regulation applies to all areas of the Beaver Creek drainage upstream of O'Brien Creek, except in Nome Creek. Prior regulations for Arctic grayling (10 fish per day, and in possession) will remain in effect downstream of O'Brien Creek, and catch-and-release fishing will remain in Nome Creek, which is road accessible. The Challenge Cost Share (CCS) project between ADF&G and BLM allowed both agencies to participate and ultimately share resulting information for a smaller investment than could be otherwise accomplished. Distributing field work between the two agencies permitted stock assessment to occur over a large enough study area to reduce the likelihood of violating the closure assumption during the mark-recapture study. However, in the process of conducting the assessments in Beaver and Nome creeks study over a broad time scale, we could not successfully estimate abundance in Nome Creek. In the Nome Creek study (Appendix B), we found that we could not maintain geographic closure in the 5 mi lower Nome Creek study area over the 19-day sampling hiatus. In the future, stock assessment along Nome Creek should be designed with a shorter sampling hiatus, and not be conducted in conjunction with a large project such as Beaver Creek.

The average population density we estimated in Beaver Creek (1,325 fish per mile) appears to have been higher than other reported densities for fluvial, summer-feeding populations of Arctic grayling. There have been instances when similar or higher densities of summer feeding grayling were observed in short sections of Alaskan streams, but only in areas between or downstream from productive lakes (Roguski and Tack 1970). This population may be near or at its carrying capacity and largely removed from influences that might adversely impact the population, such as habitat losses or increasing levels of exploitation by anglers. Within the Tanana River basin, other populations of grayling inhabiting clear runoff rivers have been assessed, such as the Chena River, near Fairbanks. Populations of Chena River Arctic grayling have cycled in response to factors including heavy exploitation rates and significant variations in recruitment levels. Annual stock assessments of Arctic grayling conducted during the summer feeding period between 1991 and 1997 tracked a recovery following a significant decline in abundance from the late 1980s (Clark 1993, 1994, 1995; Ridder and Fleming 1997; Ridder 1998). The upper 50 mi of the past Chena River study area is physically similar to the Beaver Creek study area, however, recent densities have ranged from 360 to 580 fish per mile, or approximately 27 to 44% of the Beaver Creek density (1,325 fish per mile). It is unknown whether the contrast in densities is based on greater production of sub-adult grayling in Beaver Creek, or suppressed production within the Chena. In the future it may be of interest to compare other stock assessment findings with the estimated stock density observed in Beaver Creek, using the pristine population as a benchmark. However, it would be advisable to repeat the Beaver Creek stock assessment to characterize interannual variation of the adult population before using it as an evaluation tool.

In the course of the two sampling trips, crew members were aware of declining sizes of grayling as they moved from the headwaters of Beaver Creek to areas downstream of Nome Creek. Estimates of mean length-at-age indicated the growth of Beaver Creek grayling may be similar to other assessed interior Alaska stocks, including the Chena, Jim, and Chatanika rivers (Figure 6). Upstream of Nome Creek, all but one of the captured fish were $\geq$ 250 mm FL. This observation mirrored a commonly held paradigm about inherent size distribution patterns for Arctic grayling populations in interior Alaska. This pattern includes a predominance of larger individual grayling feeding in the headwaters of rapid-runoff streams and rivers, with increased presence of smaller fish rearing in areas downstream. The pattern has been examined and reported within the Chena and Goodpaster rivers (Hughes 1999), observed during assessments along the Chatanika (Fleming 1998), and reported by anglers fishing the headwaters of the Salcha. Although we did not set out to test or examine this pattern, we observed the change in sampled lengths. Knowledge of a size-stratified distribution pattern may be useful for anglers in the Beaver Creek fishery seeking different opportunities whether harvesting a bag limit of pan-size grayling, or those seeking an opportunity to fish in the more remote headwater areas to catch larger fish.

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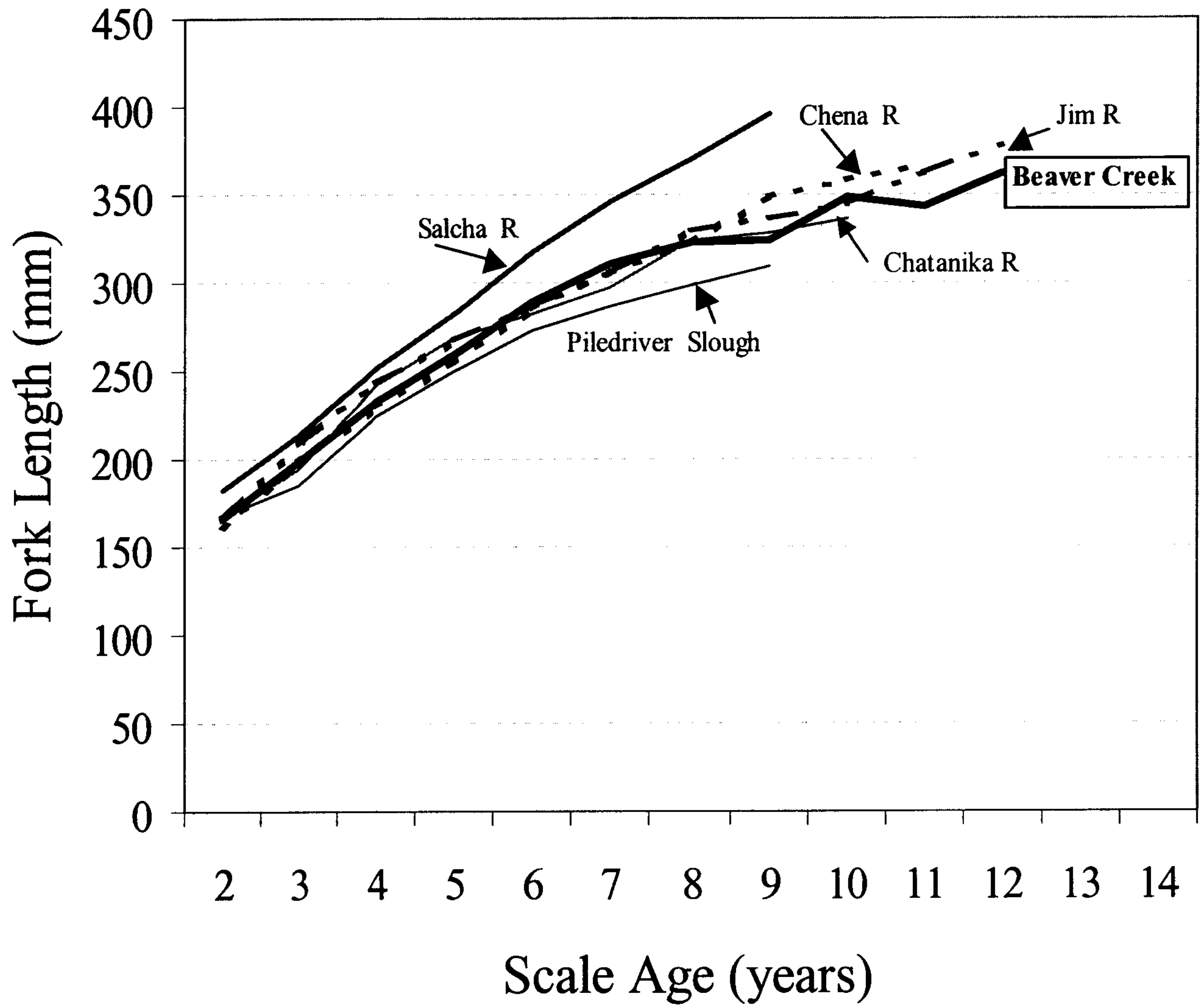

Figure 6.-Mean length at age estimates for Arctic grayling sampled in Beaver Creek and from other interior Alaska grayling stocks.

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Appendix A
STATISTICAL EXAMINATION AND CORRECTION FOR SAMPLING BIAS IN MARK-RECAPTURE STUDIES

Appendix A1.-Methodologies to compensate for bias due to unequal catchability by length.

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 A2.-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. Every fish has an equal probability of being marked and released during event 1;
2. Every fish has an equal probability of being captured during event 2; or,
3. Marked fish mix completely with unmarked fish between events.

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 (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	Second Event		
River Section	River Section Recaptured		
Released	Upper	Lower	Not Recaptured
Upper			
Lower			

TEST II[b]

	Second Event: River Section	
	Upper	Lower
Recaptured		
Not Recaptured		

TEST III[c]

	Captured During Second Event	
	Upper	Lower
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: $\Sigma_i a_i \theta_{ij} = k U_j$. Theta only applies to marked fish.

Appendix B
NOME CREEK ASSESSMENT STUDY

Appendix B1.-Stock assessment of Nome Creek Arctic grayling stock during June and July 2000.

The U.S. Bureau of Land Management's White Mountains Team has been working towards improving stream and riparian habitat conditions along Nome Creek, with the intent of allowing Arctic grayling populations to expand and colonize previously mined areas. These activities are consistent with a mandate to provide for outdoor recreation and to conserve the fish, wildlife, and scientific values of Nome Creek as required by ANILCA (title XIII; sec. 1312).

NOME CREEK STUDY AREA

The headwaters of Nome Creek flow from a relatively narrow, steep valley draining the 3,900 to 5,200 ft high ridges and slopes abutting Mt. Prindle. Further downstream, Nome Creek enters a broader valley where post-mining reclamation has been initiated. At this point the stream is relatively shallow, has a high stream gradient, and is composed of coarse cobble and boulders. Farther downstream, an undisturbed section of Nome Creek flows 12½ mi through a narrow twisting channel that is 1 to 6 ft deep, approximately 5 to 20 ft wide, and hosts numerous over-hanging trees, adjacent riparian growth consisting of willow *Salix* sp., and isolated stands of spruce *Picea* sp. Most of the Nome Creek study area is accessed from the recently constructed gravel road that runs parallel to Nome Creek and terminates at Ophir Creek. Within this upper portion of the study area, BLM has continued efforts to rehabilitate degraded habitat from past mining activities. This has included riparian vegetation plantings and current efforts to improve the active channel habitat. Downstream of Ophir Creek, the channel straightens and widens for much of the remaining 3 mi before entering Beaver Creek.

Anglers utilize Nome Creek to fish for Arctic grayling either by accessing it directly from the road, or from canoe or raft trips to and along Beaver Creek. The recently constructed public campgrounds will likely attract increasing numbers of anglers and campers to this area. The study area selected in 2000 included all portions of Nome Creek beginning about one-half mile below Moose Creek and ending at the confluence of Nome and Beaver creeks.

Sampling Activities

Arctic grayling stock assessment was completed by BLM personnel from June 19 to July 27, 2000. Due to logistical restraints, the project was completed in two parts. Nome Creek was divided into upper and lower sampling reaches. The upper portion of the Nome Creek study area included an 11 mi segment of river that started one-half mile from the confluence of Nome and Moose creeks (latitude 65 20.059 north, longitude 146 50.037 west) and ended at an airstrip located along the river (latitude 65 21.914 north, longitude 147 02.715 west). The lower portion of the study area included a 5 mi segment of river that started at the airstrip and ended at the confluence of Nome and Beaver creeks (latitude 65 23.319 north, longitude 147 08.168 west).

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The upper Nome Creek mark-recapture sampling was completed in June by a two-person crew. The mark event began on June 19 and ended June 22, 2001. The recapture event ran from June 26-29, 2000. There was a seven-day sampling hiatus between events. In the month of July, a three-person crew completed the lower Nome Creek mark-recapture study before joining the ADF&G crew at Beaver Creek. The mark event was conducted on July 7-8, 2000 and the recapture event occurred July 26-27, 2000. There was a 19-day sampling hiatus between sampling events.

For all sampling events, an inflatable raft was used to float the stream and carry sampling gear. All fish were collected by angling with light spinning rods rigged with small spinners or mini jigs. All habitats in the drainage were sampled (pool, riffle, and glide). Sampling effort was determined by a fixed-time schedule that called for angling to cease at a location after the passage of 5 min without capturing a fish. All post-capture sampling methods were identical to those detailed in the previous Methods Section, however, data was recorded in a DURA Rite Waterproof notebooks and later transferred to ADF&G mark/sense forms.

RESULTS

Upper portion of Nome Creek: During the initial sampling event, the two-person crew captured a total of 95 grayling, of which 93 fish were released with tags after sampling. Anchor tag numbers for this sample of grayling ranged between 2,001 and 2,091. Three fish had been previously tagged during past efforts to sample. Following a 7-day sampling hiatus, 89 fish were captured during the recapture sampling event, that included the recover of 19 previously tagged grayling. Weather conditions were mild and clear, except for the last day of the marking event, in which it rained. No fish died as a result of hooking injuries during sampling in the upper portion of Nome Creek.

Of the 19 tagged fish that were later recovered during the recapture event, 12 fish were captured in the same general location and the remaining 7 fish had moved downstream. No size selectivity was indicated from Kolmogorov-Smirnov (KS) two-sample tests (marks v. recaptures: D = 0.21; P = 0.51; catch v. marks: D = 0.10; P = 0.66). The resulting interpretation of the test statistics (Appendix A1) suggested that size-stratified estimates would not be required (Appendix A1: Case I). The mark-recapture data set was then tested for consistency (Seber 1982; page 438). The three consistency tests resulted in findings that suggested unequal mixing (χ^2 = 15.2; df = 6; P = 0.02), and unequal recapture rates (R/M) by area (χ^2 = 7.7; df = 2; P = 0.02), but capture probabilities during the marking event that were similar by area (R/C: χ^2 = 5.2; df = 2; P = 0.07). The unstratified Petersen estimator was selected, since at least one test statistic was not significant at α = 0.05 (Appendix A2). The estimated abundance of Arctic grayling was 419 fish (SE = 81fish; 19.2% CV) $\geq$ 250 mm FL in the 11-mi upper section of Nome Creek, which indicated a density of 38 fish per mile. The sampled population was composed of older Arctic

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grayling, and 74% of the sampled fish were determined age-6 and 8 (n=105 ages). Nearly all grayling captured during the mid-to-late June sampling period were in excess of 250 mm FL (Appendix B2).

Lower portion of Nome Creek: On July 6, the BLM crew started mark-recapture sampling in the lower 5 mi section of Nome Creek, as they traveled downstream to join ADF&G for the Beaver Creek project. A three-person sampling crew captured 146 grayling, of which 140 were released with tags after sampling. Sampling effort was split between two sections, corresponding to the two days sampling required to reach the confluence with Beaver Creek. The first day's section paralleled the road along Nome Creek, while the second day of sampling was located between the road end and Beaver Creek. Anchor tag numbers for this sample of grayling ranged between 2,100 and 2,248. Following a 19-day sampling hiatus, 132 fish were captured and sampled during the recapture sampling event, that included the recover of 6 previously tagged grayling. Weather conditions were mixed through sampling activities along the lower portion of Nome Creek, and no substantial rainfall occurred. Four fish died as result of hooking injuries during this part of the study.

After the 19-day sampling hiatus, four of the recaptured fish were captured in the same section in which they were marked and released. The remaining two recovered fish were located upstream of their initial sampling section. Given the low number of recaptured fish, meaningful examinations for size selectivity, or resulting stratification for abundance and composition estimates was not possible. By default, the unstratified Petersen estimator was selected. Due to the low number of recaptures a point estimate of abundance is not given here. However, the 95% confidence interval suggests that there was between 878 and 4,522 grayling $\geq$ 180 mm FL. Only 17 useable ages were available from sampling conducted in the lower section of Nome Creek, which precluded any meaningful information about age composition. Unlike the upper section of Nome Creek, many fish were smaller than 250 mm FL; 235 mm was the median length sampled during the marking event and 196 mm was the smallest length of a recaptured fish (Appendix B2).

DISCUSSION

In the process of planning a large-scale stock assessment project for Nome and Beaver creeks, we introduced several problems that could not be resolved, and resulted in only partial success with the Nome Creek study. The mid-late June timing of sampling in the upper 11 mi area of Nome Creek corresponded to the time when a portion of the adults remained after spawning, yet the smaller juvenile grayling may not have entered the area for summer feeding. The study timing resulted in what is likely to be a partial estimate of the spawning population. In effect, the estimate did not include the summer feeding population that was the target population. In the future, summer feeding populations of Arctic grayling of Nome Creek should be assessed in mid-July to allow sufficient time for the summer feeding population assemble.

A second problem occurred in the lower portion of Nome Creek when we allowed a long sampling hiatus (19-day). Sampling in the lower section of Nome Creek was conducted by the BLM crew as they traveled downstream to join the ADF&G sampling crew at Beaver Creek.

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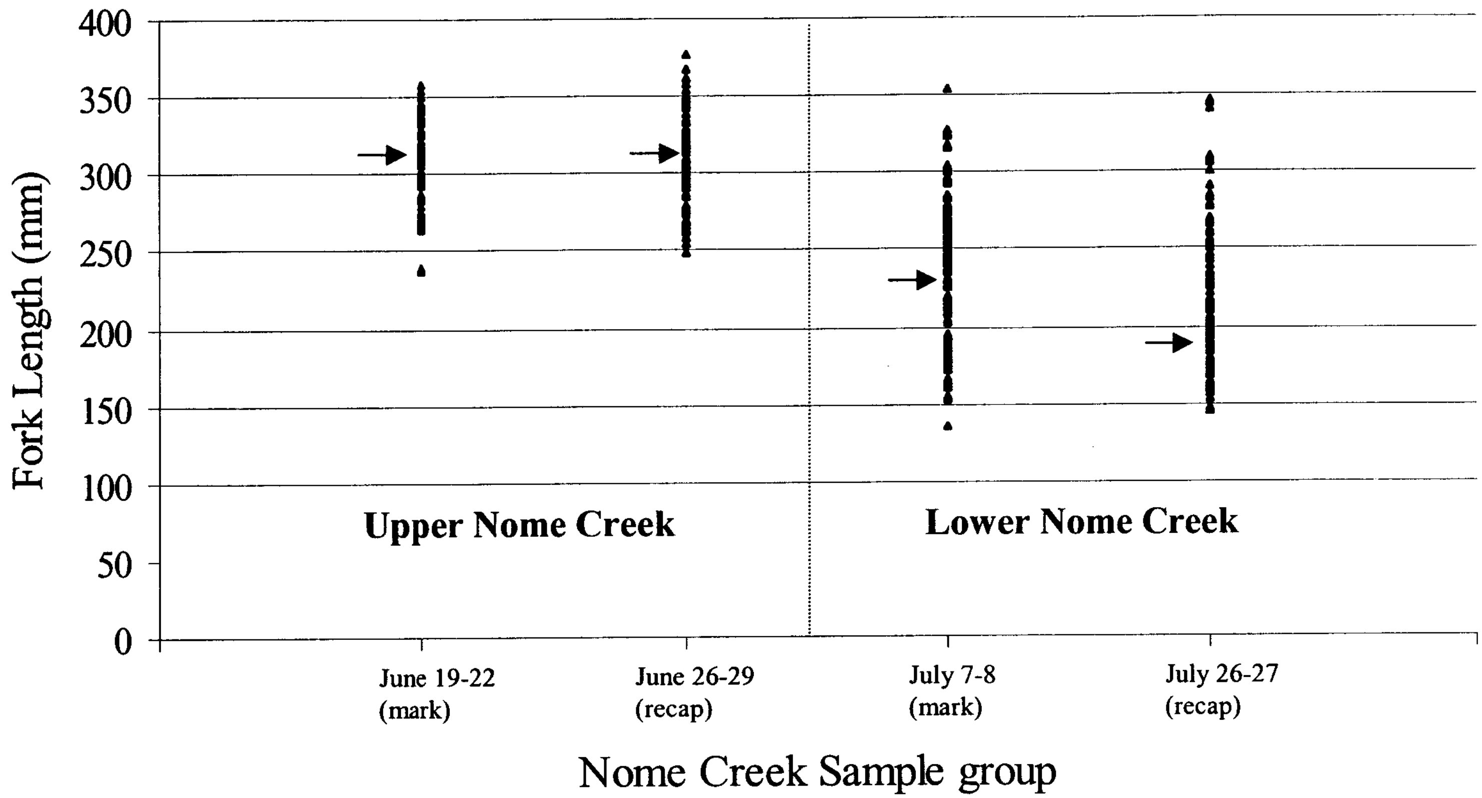
This was undertaken because no road access is available to the lower 3 mi of Nome Creek, and crews otherwise would have had to drag rafts or canoes back upstream to the Ophir Creek campground. It is likely that smaller fish were actively entering or moving upstream through the lower portions of Nome Creek. Since the lower Nome Creek sampling area was small (5 mi) and the hiatus was long (19 days), it is possible that marked fish migrated outside of the small study area, unmarked fish moved into the study area, or both. The limited number of recaptured fish and the change in median length between sampling events hampered the estimation process. Future assessments should be conducted in mid-July.

Current regulations at Nome Creek should continue to afford protection to fish that are seasonally present for spawning, and those remaining during the summer months. This regulation will also protect fish that may colonize areas reclaimed after mining.

Appendix B2.-Sampled lengths of Arctic grayling plotted for upper and lower Nome Creek study areas by sampling event during June and July 2000 (arrows denote median sampled length).



Appendix C
DATA FILE LISTING

Appendix C1.-Data file listing for Arctic grayling captured in Beaver and Nome creeks during 2000.

Year	Files	Contents
2000	Y-020201L012000	Beaver Creek, early July marking sample
2000	Y-020202L012000	Beaver Creek, late July recapture sample
2000	Y-020201L022000	Nome Creek mark recapture data from June (upper section) and July (lower section) sampling trips.