Fishery Data Series No. 99-23

Niukluk River Arctic Grayling Stock Assessment, Seward Peninsula, Alaska 1998

by
Alfred L. DeCicco

September 1999

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. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

FISHERY DATA SERIES NO. 99-23

NIUKLUK RIVER ARCTIC GRAYLING STOCK ASSESSMENT, SEWARD PENINSULA, ALASKA 1998

by

Alfred L. DeCicco
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

September 1999

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-14, Job No. R-3-2(e).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or a group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

Alfred L. DeCicco
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599,USA

This document should be cited as:
DeCicco, A. L. 1999. Niukluk River Arctic grayling stock assessment, Seward Peninsula, Alaska 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-23, Anchorage.

The Alaska Department of Fish and Game administers all programs and activities free from discrimination on the basis of sex, color, race, religion, national origin, age, marital status, pregnancy, parenthood, or disability. For information on alternative formats available for this and other department publications, contact the department ADA Coordinator at (voice) 907-465-4120, or (telecommunication device for the deaf) 1-800-478-3648.

TABLE OF CONTENTS

Page

LIST OF TABLES ii

LIST OF FIGURES ii

LIST OF APPENDICES ii

ABSTRACT 1

INTRODUCTION 1

METHODS 4

Design 4
Sampling Gear and Techniques 6
Niukluk River Population Abundance 6
Age Composition 8
Length Composition 9
Mean Length-at-Age 9
Eldorado River Age Validation 9
Nome River Arctic Grayling Restoration 10

RESULTS 10

Niukluk River Population Abundance 10
Age and Length Compositions 15
Mean Length-At-Age 20
Eldorado River Age Validation 20
Nome River Arctic Grayling Restoration 20

DISCUSSION 20

ACKNOWLEDGMENTS 22

LITERATURE CITED 23

APPENDIX A 27

APPENDIX B 31

APPENDIX C 33

LIST OF TABLES

Table **Page**

1. Estimated freshwater sport fish harvests (catches) for Seward Peninsula and Norton Sound streams, 1980-1997. 2
2. Frequency of large Arctic grayling marked and recaptured in areas 1 and 2 of the Niukluk River with R/C and R/M ratios..... 13
3. Estimated proportion and abundance of Arctic grayling in the Niukluk River by scale age class, 1998..... 17
4. Estimates of length composition and abundance of Arctic grayling from sections 1 and 2 of the Niukluk River by 25 mm FL increments, 1998. 19

LIST OF FIGURES

Figure **Page**

1. The southern Seward Peninsula..... 3
2. Area sampled in the Niukluk River during 1998. 5
3. The Nome River drainage showing the location of the Banner Creek gravel pit..... 11
4. The Banner Creek gravel pit..... 12
5. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >249 mm FL sampled from sections 1 and 2 of the Niukluk River in 1998. 14
6. Movement in km between mark and recapture of Arctic grayling in the Niukluk River in 1998. 15
7. Age composition estimates of Arctic grayling from sections 1 and 2 of the Niukluk River in 1998. 16
8. Length composition estimates in 25 mm increments of Arctic grayling in sections 1 and 2 of the Niukluk River, 1998. 18

LIST OF APPENDICES

Appendix **Page**

A1. List of numbered tags and finclips used to mark Arctic grayling from the Niukluk River in 1998 28
A2. Age-length distribution of Arctic grayling sampled from sections 1 and 2 of the Niukluk River in 1998..... 29
B1. Data files used to estimate parameters of Arctic grayling populations on the Seward Peninsula in 1998 32
C1. Methodoligies to compensate for bias due to unequal catchability by length..... 34
C2. Methodoligies to compensate for bias due to unequal catchability by river section..... 35

ABSTRACT

The number of Arctic grayling *Thymallus arcticus* over 249 mm in FL was estimated at 4,975 fish (SE = 611) in a 17 km section of the Niukluk River. Arctic grayling captured from the Niukluk River ranged in length from 172 mm to 501 mm FL and in age from 4 to 15 years. Arctic grayling aged 7 and 8 years comprised 55% of the estimated population, and fish from 400 to 450 mm FL comprised 62% of the estimated population. The estimated population in this section of the Niukluk River was approximately twice that estimated in 1990. In the Nome River, 670 young-of-the-year Arctic grayling were captured and moved to an experimental rearing pond as part of a restoration effort.

Key words: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, length composition, Seward Peninsula, Niukluk River.

INTRODUCTION

The Seward Peninsula-Norton Sound area of western Alaska supports the second largest amount of recreational fishing effort in the Arctic-Yukon-Kuskokwim (AYK) region. Over the past 10 years, annual sport fishing effort has ranged from an estimated 15,443 angler days in 1989 to 22,118 in 1991, with an annual average of 16,117 angler-days (Mills 1988-1994, Howe et al. 1995-1998). Reported freshwater fish harvests consisted primarily of Dolly Varden *Salvelinus malma*, Arctic grayling *Thymallus arcticus*, pink, coho, chum and chinook salmon *Oncorhynchus spp.*, northern pike *Esox lucius*, whitefish *Coregonus spp.*, and burbot *Lota lota*. From 1980 through 1991, Arctic grayling had comprised an average of 19.1% of the harvest of these species, but dropped to an average of 8.5% over the past 5 years (Table 1; Mills 1981-1994, Howe et al. 1995-1998). The annual harvest has remained fairly consistent at about 1,100 Arctic grayling over the past five years.

The Seward Peninsula is the only area in Alaska outside of Bristol Bay that regularly produces trophy-sized Arctic grayling. Since 1983, 25% of the Arctic grayling registered in the Alaska Department of Fish and Game (ADF&G) Trophy Fish Program have come from the Seward Peninsula (ADF&G *Unpublished*).

Although not connected by road to the state highway system, the Nome area has approximately 420 km of maintained gravel roads which traverse the Seward Peninsula in three general directions from Nome (Figure 1). This road system provides angler access to many waters. Local concerns about the stock status of Arctic grayling and angler reports that the abundance of large-sized Arctic grayling appeared to be declining in some streams led the Alaska Board of Fisheries to promulgate a regulation in 1988 that reduced the daily bag limit of Arctic grayling on the Seward Peninsula to five per day, five in possession, with only one over 15 in (381 mm).

The first studies conducted by ADF&G on the basic life history and angler utilization of fish in the freshwaters of Seward Peninsula began in 1977 and continued through 1979. Nine streams were surveyed for fish presence and 147 Arctic grayling were sampled for age, weight and length. Angler counts were conducted periodically on 15 different streams (Alt 1978, 1979, 1980). Between 1979 and 1984, 88 Arctic grayling from the Fish/Niukluk rivers were sampled for age, length and weight (Alt 1986). During 1988, a project was initiated to survey Arctic grayling stocks on Seward Peninsula rivers and to estimate average catch and harvest per unit effort on surveyed streams (Merritt 1989). A total of 887 Arctic grayling were tagged and sampled for length and age on the Nome, Snake, Sinuk, Solomon, Eldorado, Pilgrim, Kuzitrin,

Table 1.-Estimated freshwater sport fish harvests (catches) for Seward Peninsula and Norton Sound streams, 1980-1997.

	Harvests (Catches) in Number of Fish [a]						
Year	Days Fished	Salmon All Species	Dolly Varden	Arctic Grayling	Northern Pike	Burbot	Whitefish
1980	7,968	10,840	5,811	1,635	284	0	353
1981	10,879	6,564	3,981	2,104	303	0	123
1982	13,198	19,757	6,498	6,225	210	0	597
1983	12,678	10,189	9,779	8,241	798	0	148
1984	12,558	13,881	4,260	2,349	208	13	39
1985	18,141	3,401	5,695	4,501	56	175	70
1986	17,257	9,610	5,381	4,042	699	0	510
1987	20,381	5,415	5,506	4,600	906	0	272
1988	19,456	10,460	4,437	4,873	564	36	655
1989	15,443	8,548	7,003	4,205	648	10	453
1990	18,720	11,227	3,765	1,378	1,957	33	299
		(24,705)	(9,118)	(6,119)	(4,145)	(33)	(315)
1991	22,118	8,928	10,365	5,121	1,429	116	1357
		(15,561)	(25,425)	(23,160)	(4,257)	(116)	(1,409)
1992	19,351	11,778	2,178	492	479	0	46
		(35,473)	(5,726)	(5,772)	(3,742)	(0)	(165)
1993	17,055	6,634	5,702	1,378	537	96	95
		(16,920)	(21,961)	(13,223)	(2,117)	(107)	(196)
1994	16,777	12,215	2,981	1,200	376	0	67
		(21,048)	(7,254)	(6,853)	(1,731)	(0)	(172)
1995	17,334	5,316	2,908	1,037	215	45	247
		(14,250)	(7,806)	(5,788)	(1,856)	(56)	(321)
1996	16,777	12,138	3,662	1,192	410	0	27
		(29,208)	(7,140)	(6,342)	(1,747)	(0)	(54)
1997	14,023	5,703	2,551	802	386	46	84
		(15,930)	(8,808)	(17,422)	(709)	(46)	(323)
MEAN	16,117	9,589	5,296	3,210	593	25	459
		(21,910)	(11,655)	(10,585)	(2,538)	(45)	(369)

[a] Data from the Alaska statewide sport fish harvest survey (Mills 1981-1994, Howe et al. 1995, 1998).

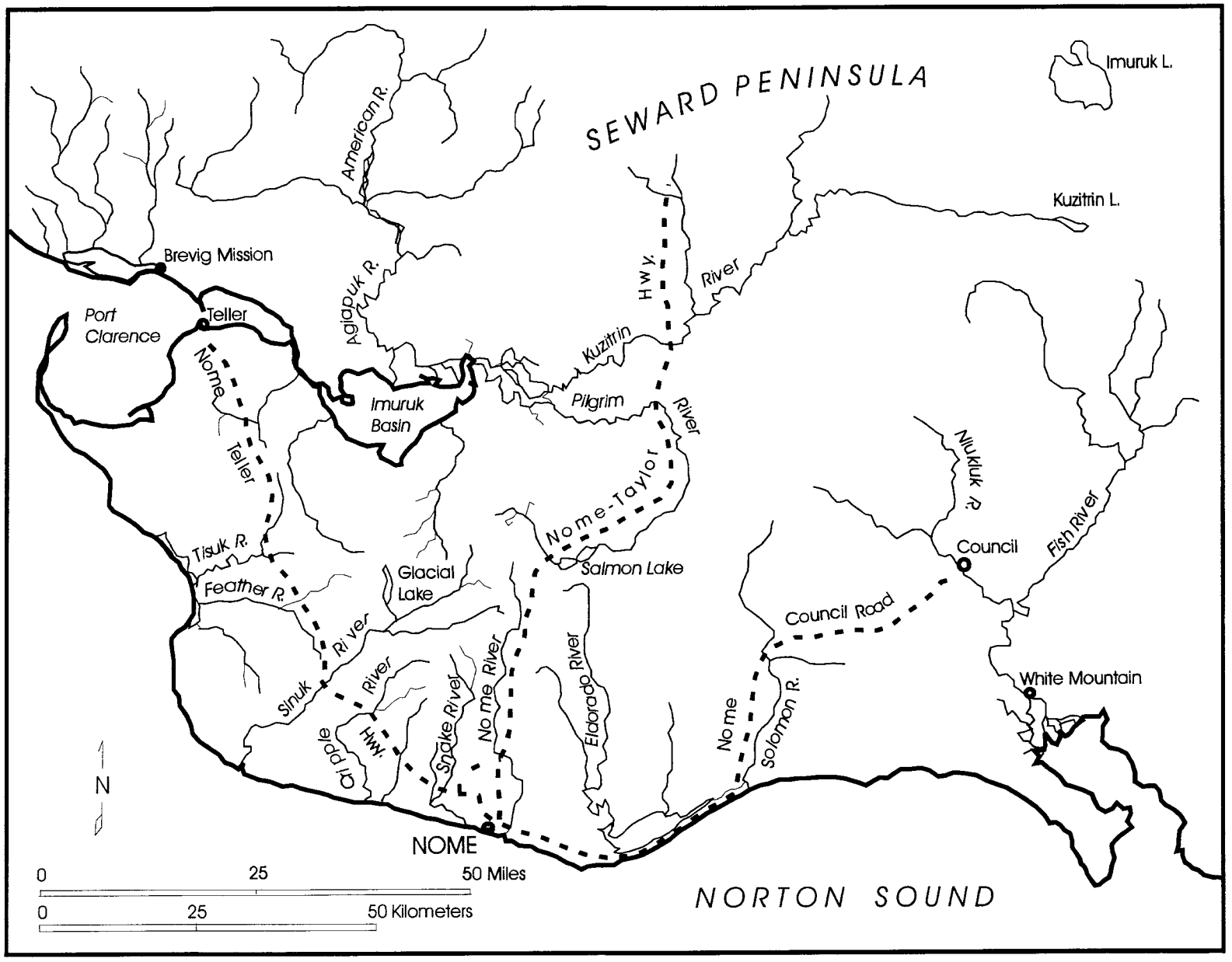

Figure 1.-The southern Seward Peninsula.

Niukluk and Fish rivers and Boston Creek. Since 1989, population abundance, age at length, size and age composition have been estimated for Arctic grayling on the Niukluk, Fish, Pilgrim, Nome, Snake and Sinuk rivers (DeCicco 1990-1998). Problems with assigning ages to large Arctic grayling have been noted in recent years (DeCicco 1993-1995). Consequently, an age validation component using oxytetracycline was added to this project in 1994.

Several regulatory changes have recently been implemented based on data collected from these studies. The daily bag and possession limits for Arctic grayling in both the Snake and Pilgrim rivers have been reduced to two per day, only one of which may be over 15 in (381 mm) in length. Very low abundances in the Nome and Solomon rivers resulted in the closure of these waters to Arctic grayling fishing by emergency order in 1992. These rivers were closed to fishing for Arctic grayling by the Board of Fisheries in December 1997 after it was found that abundances had not changed with five years of closure to sport fishing. Base line data have been collected on most road accessible Arctic grayling populations and this project has taken on a population monitoring function with a long term goal to achieve sustained yield fisheries for Arctic grayling populations through appropriate regulation.

The Arctic grayling population in the Nome River is depressed; even with the sport fishery closed the last five years, the population has not increased. A preliminary study was initiated to determine if restoration of the Arctic grayling population in the Nome River by enhancing young-of-the-year (YOY) survival is a feasible approach to increasing recruitment.

Project objectives for stock assessment (R-3-2e part 1) in 1998 were to estimate:

1. the abundance of Arctic grayling greater than 249 mm FL in a 25 km section of the Niukluk River upstream from Council;
2. age and length compositions of Arctic grayling for given length ranges in the Niukluk River; and,
3. the proportion of correctly aged otoliths from Arctic grayling marked with oxytetracycline and recaptured in the Eldorado River.

In addition, mean length-at-age for Arctic grayling in the Niukluk River was estimated. A task of this study was to examine gonads of fish collected from the Eldorado River for age validation.

Project objectives for the Nome River restoration study (R-3-2e part 2) were to:

1. capture up to 600 YOY Arctic grayling in the Nome River and move them to rear in the Banner Creek gravel pits;
2. collect zooplankton biomass data from the pond during the summer; and,
3. collect dissolved oxygen data from the pond during the winter.

METHODS

DESIGN

A two event mark-recapture experiment was used to estimate the abundance of Arctic grayling ≥250 mm FL in a 25 km section of the Niukluk River upstream from the village of Council (Figure 2). The river section was divided into three geographic areas identical to those used previously (DeCicco 1990). The upstream area extended from the confluence of the Casadepaga

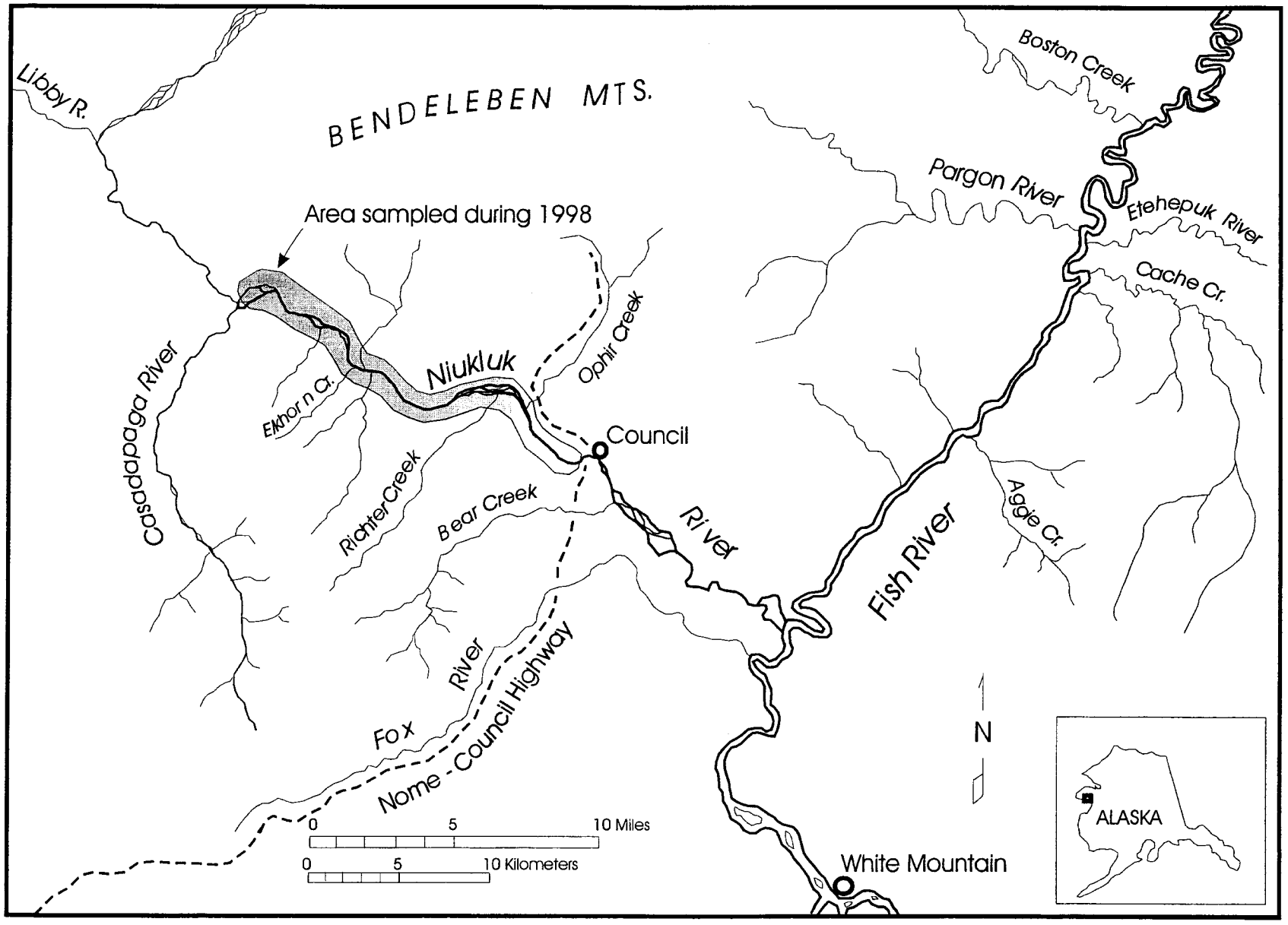

Figure 2.-Area sampled in the Niukluk River during 1998.

River downstream to Elkhorn Creek (8 km); the middle area extended from Elkhorn Creek downstream to Richter Creek (9 km); and the downstream area extended from Richter Creek downstream to Council (8 km). Sampling for the population estimate was performed along the entire length of each river section during both the mark and recapture events. The marking event, working downstream through the three sections of the Niukluk River, was conducted for eight days from June 24 through July 1. The recapture event was conducted during eight days from July 9 and July 16. The sequence of sampling was the same in both events, resulting in a 14 day hiatus between sampling events in a given location of the river.

SAMPLING GEAR AND TECHNIQUES

Arctic grayling in the Niukluk River were sampled using hook and line with 1/8 oz mini-jigs as terminal gear, and a 65-m x 2-m, 6.5-mm mesh beach seine. Access to the river was by a 4.8 m outboard jet-powered riverboat. Each Arctic grayling was measured to the nearest mm in fork length. Fish over 249 mm FL in the first sample were tagged with sequentially numbered Floy FD-67 internal anchor tags which were inserted such that the "T" anchor locked between the base of adjacent dorsal fin rays. Each fish was also marked with a partial fin clip (Appendix A1). Scales for age determination were taken from the left side of the fish approximately midway between the dorsal fin and the lateral line down from the posterior insertion of the dorsal fin in accordance with Scarneccia (1979). Data were recorded on standard ADF&G Tagging-Length forms (version 1), and electronically transferred to EXCEL spreadsheets for analysis. Scales were cleaned with detergent and water, mounted on gummed cards and acetate impressions were made (30 s at 7,000 kg/cm^2, at 100° C) as described by Clutter and Whitesel (1956). Ages were determined by counting annuli from the acetate impressions using a microfiche reader. Scale impressions were read by a trained scale reader and the project leader. Age determinations follow procedures outlined by Yole (1975). Scale impressions with questionable readings were read a third time as necessary. If the age assignment was still in question, the age sample was discarded. Regenerated scales were not aged. Data files were archived with ADF&G Research and Technical Services (RTS) in Anchorage (Appendix B1).

NIUKLUK RIVER POPULATION ABUNDANCE

A two sample approach using a Petersen mark-recapture estimator as modified by Bailey (1951, 1952) and Darroch (1961) were used to estimate the abundance of Arctic grayling in the upper two areas of the Niukluk River. The assumptions necessary for the accurate estimation of abundance in a closed population are (from Seber 1982):

1. there is neither mortality nor recruitment between sampling events (closed population);

2. fish have an equal capture probability in the first event or the second event, or marked fish mix completely with unmarked fish during the second sampling event;

3. marking does not affect capture probability in the second event;

4. marks are not lost between events; and,

5. marked fish can be recognized from unmarked fish.

Assumption 1 could not be tested directly. It was assumed that neither mortality nor recruitment occurred between events because both events were close together in time. Assumptions 2 and 3 were tested with two Kolmogorov-Smirnov two-sample tests (Conover 1980). The first test compared the cumulative length distribution of fish marked in the first sampling event (mark event) with the cumulative length distribution of marked fish recaptured during the second sampling event (recapture event). In the second test, the cumulative length distribution of fish captured during the marking event was compared to the cumulative length distribution of all fish captured during the recapture event. If the results of the first test showed that the samples were different ($P < 0.05$), size selectivity between samples was indicated. If the results of the second test showed that the samples were different ($P < 0.05$), recruitment, migration, or some other factor affecting the size distribution of the two samples was indicated. A more complete tracking of test results and consequences is contained in Appendix C1. All fish were released within the reach of the river in which they were captured. To meet conditions of assumption 4, all tagged fish were also marked with a fin clip (see Appendix C2). Assumption 5 was met by the close examination of all fish for the presence of the double mark or fin punch.

Diagnostic tests for consistency of a Petersen estimate (Seber 1982, page 438) were also conducted. If all tests were significant ($P<0.05$) incomplete mixing or unequal probability of capture by geographic area were indicated. In this case, the use of a Darroch two-sample stratified estimate was indicated.

The population abundance estimate and the approximate variance of the estimate were calculated with Bailey's modified Petersen estimator (Seber 1982):

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

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

where:

M = the number marked during the first event;

C = the number captured during the second event;

R = the number captured during the second event with marks from the first event; and,

N = population abundance.

Tests indicated that there was unequal capture probabilities among the river sections during the second event. The reasons for this are addressed in the discussion section of this report. Abundance was therefore estimated for only the two upstream river sections. Tests also indicated that length stratification was necessary. A suitable bound for the two length strata determined by visual inspection of the CDF's of the marked and recaptured Arctic grayling. Further tests indicated that a Darroch estimator of abundance (Darroch 1961) was appropriate for the large length stratum while the Bailey modification of the Petersen estimator was appropriate for the small length stratum. For the large fish, a numeric search of the log likelihood function for Darroch's stratified model provided maximum likelihood estimates of movement and capture

probabilities and N. Variances were calculated using the inverse information matrix and the delta method (Seber 1982).

AGE COMPOSITION

Scales were collected from Arctic grayling sampled in conjunction with the abundance and age experiments. Ages were assigned to scales in order to estimate age composition for the population in the assessed area of the Niukluk River. The proportions of fish in each age category were estimated as multinomial proportions (Cochran 1977, Thompson 1987).

The proportion in each category when no adjustments were needed was estimated as:

$$\hat{p}_i = \frac{n_i}{n} \tag{3}$$

where:

$n_i =$ the number in the sample from age category i;

$n =$ the sample size; and,

$\hat{p}_i =$ the estimated fraction of the population that is made up of age category i.

The unbiased variance of this proportion was estimated as:

$$V\left[\hat{p}_i\right] = \frac{\hat{p}_i\left(1-\hat{p}_i\right)}{(n-1)}. \tag{4}$$

Abundance of Arctic grayling by age was estimated as follows:

$$\hat{N}_i = \hat{p}_i(\hat{N}); \tag{5}$$

where:

$\hat{N}_i =$ estimated number of fish in age category i;

$\hat{p}_i =$ estimated proportion of fish in age category i; and,

$\hat{N} =$ estimated abundance of Arctic grayling.

Variances for Equation 5 were estimated using Goodman's (1960) formula:

$$V[\hat{N}_i] = \left(\hat{p}^2{}_i\, V\left[\hat{N}\right]\right) + \left(\hat{N}^2 V\left[\hat{p}_i\right]\right) - \left(V\left[\hat{p}_i\right] V\left[\hat{N}\right]\right); \tag{6}$$

where:

$V[\hat{N}]$ was obtained from the mark recapture analyses (see equation 2).

When stratification was necessary, length and age proportions and variances of proportions for Arctic grayling was estimated using the delta method (Seber 1982):

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \text{ , and} \tag{7}$$

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}}\right)^2 \hat{V}[\hat{p}_{ik}] \tag{8}$$

where:

$\hat{N}_i$	=	the abundance of Arctic grayling in stratum i;
$\hat{N}$	=	total abundance of Arctic grayling; and,
$\hat{p}_{ik}$	=	the proportion of Arctic grayling in stratum i that were age or size k.

LENGTH COMPOSITION

Length composition of Arctic grayling residing in the assessed area of the Niukluk River was estimated in 25 mm length increments. Estimates of the proportion of fish in size categories followed the same procedures used for age composition (equations 3 and 4). Abundances and their variances by length category were estimated using equations 5 and 6. The proportion and its variance estimator approximated by the delta method were used when adjustments were needed because of stratification (equations 7 and 8).

MEAN LENGTH-AT-AGE

Mean length-at-age was calculated as the arithmetic mean length of all fish assigned the same age. Samples were combined across years to increase sample sizes. Standard deviations of lengths of each age class were calculated.

ELDORADO RIVER AGE VALIDATION

Arctic grayling have been captured in the Eldorado River as part of an ongoing study to validate aging using oxytetracycline (OTC). Injected into the body cavity of a fish, OTC marks bony structures that can be used to validate ages in fish (Frost et al. 1961; McFarlane and Beamish

1987). Fish with Floy tags or adipose fin clips indicating that they carried (OTC) marks were collected, kept cool and frozen at the first opportunity. Scales were collected from each fish not carrying a fin clip or tag. Frozen fish were transported to Fairbanks where otoliths were taken from all dead fish.

Upon completion of this study in 1999, otoliths will be imbedded in thermoplastic resin and ground in cross section through their origin on a horizontal diamond wheel. The otoliths will be placed flat ground side against a glass slide, stabilized in thermoplastic resin and thin sections (approximately 0.5 mm) prepared using a thin section grinder. Otolith sections will be photographed under the same magnification using both visible and ultraviolet light. Paired photographs of each otolith will be compared to locate the position of the fluorescent mark in relation to the visible annual growth rings. In order to validate the passage of time (age), the numbers of annual growth rings past the fluorescent mark will be compared to the known passage of time between the OTC injection and the capture of the fish from which the otoliths were taken. Final results of this analysis will be presented in a subsequent report.

NOME RIVER ARCTIC GRAYLING RESTORATION

In an attempt to enhance survival of Arctic grayling fry during their first winter, young-of-the-year Arctic grayling were captured with beach seines in the Nome River just upstream from Osborne (Figure 3) and transferred to an arm of the Banner Creek gravel pit (Figure 4). This arm of the gravel pit was isolated from main part with a small mesh plastic fence prior to the introduction of fry. In addition, the arm was sampled with baited minnow traps and 419 potential competitors for food and oxygen were removed. These included 367 juvenile coho, 48 slimy sculpin, three juvenile Dolly Varden and one nine-spine stickleback. During June 1999, surviving fry will be removed from the pit, marked and placed in the Nome River. Survival will be estimated at that time and a decision will be made whether to proceed with this experiment on a larger scale. Water samples were taken from the Banner Creek gravel pit in July to examine zooplankton biomass and in late November to test for dissolved oxygen. Zooplankton were sampled using a 0.2 m plankton net with 153 μ mesh. Zooplankton were washed into a 125 ml polypropylene bottle containing 10 ml straight formaldehyde, resulting in a mixed 10% formalin solution. Dissolved oxygen was measured using a standard Hach kit.

RESULTS

NIUKLUK RIVER POPULATION ABUNDANCE

The abundance of Arctic grayling >249 mm FL in the upper two sections (17 km) of the 25 km index section of the Niukluk River (Figure 2) in 1998 was estimated to be 4,975 fish (SE = 611 fish, CV - 12.29%). This section includes the area from the mouth of the Casadapaga River downstream to Richter Creek. The abundance of Arctic grayling in the downstream section (below Richter Creek, hereafter referred to as the downstream section) could not be estimated because movement of Arctic grayling in association with a very large run of pink salmon into this section of the river confounded attempts at analysis and resulted in reduced capture probabilities during the second sampling event in this river section.

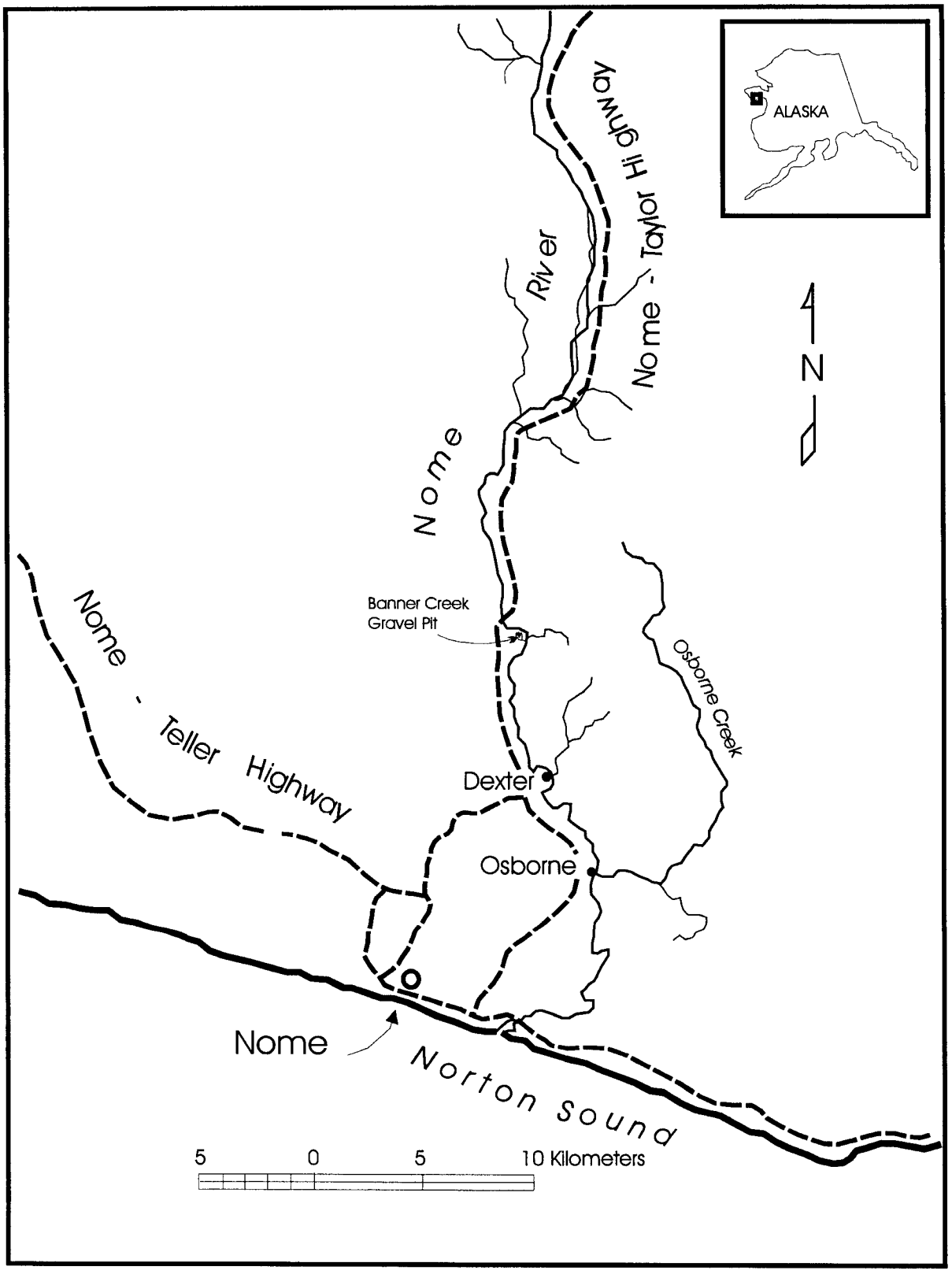

Figure 3.-The Nome River drainage showing the location of the Banner Creek gravel pit.

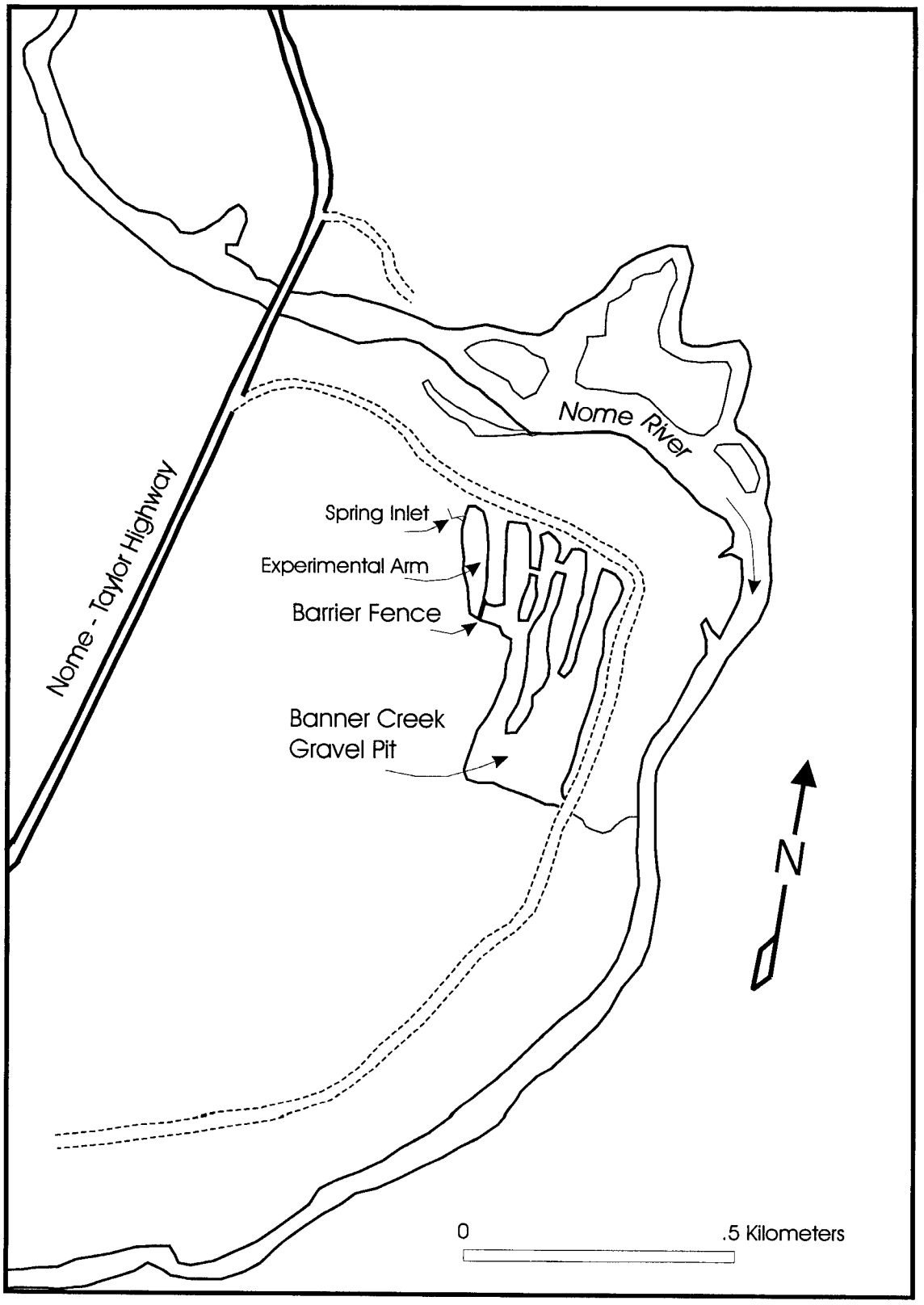

Figure 4.-The Banner Creek gravel pit.

The smallest of 546 Arctic grayling >249 mm FL marked and released in sections 1 and 2 of the Niukluk River was 261 mm FL and the smallest of 651 Arctic grayling >249 mm FL examined during the second event was 250 mm FL. The smallest of the 84 marked fish recaptured from sections 1 and 2 of the Niukluk River was 275 mm FL. No tag losses were detected, and only five fish out of 1,549 unique fish examined in the Niukluk River were killed during sampling in 1998.

A Kolmogorov-Smirnov two sample test of the cumulative length distributions of Arctic grayling > 249 mm FL marked in sections 1 and 2 versus those recaptured during the second sampling event (test 1) detected significant differences (D = 0.19, P = 0.012, n_1 = 546, n_2 = 84) between the samples. A similar test of those marked in the first event and those examined in the second event (test 2) failed to detect significant differences (D = 0.05, P= 0.41, n_1 = 546, n_2 = 651; Figure 5). The results of the first test suggest that the data be stratified, and abundance estimates be calculated for Arctic grayling in two length strata. Examination of the plot of cumulative length distributions suggested a division of the sample with fish <428 mm FL in the small size stratum and fish >427 mm FL in the large size stratum.

Since test 2 (above) failed to detect significant differences in the length distributions of the first and second samples, fish from both samples were combined and used for the length-at-age, length composition, age composition, and age-length distribution (Appendix A2).

Recapture rates for each size stratum as a measure of capture probability were examined among the two river sections using contingency tables that compared the number of marked fish (R) with the number of fish unmarked fish (C-R) in the second sample and by comparing the number of marked fish not recaptured (M-R) with the number recaptured (R). Neither of Darroch's tests showed significant differences for the small size stratum between river sections (Test 1: χ^2 = 0.41, df = 1, P = 0.52; Test 2: χ^2 = 0.0006, df = 1, P = 0.98). However, tests showed significant differences for the large size stratum between sections (Test 1: χ^2 = 11.57, df = 1, P < 0.001; Test 2: χ^2 = 7.558, df = 1, P 0.006). These results indicated that geographic stratification was unnecessary for small Arctic grayling (<428 mm FL in sections 1 and 2), consequently, a Bailey estimator was used to estimate abundance of small Arctic grayling, and a Darroch estimator was used to estimate abundance of large Arctic grayling >427 mm FL (Table 2).

Table 2.-Frequency of large Arctic grayling marked and recaptured in areas 1 and 2 of the Niukluk River with R/C and R/M ratios.

Large fish >437 mm		Recaptured		Not	
	Marked	Area 1	Area 2	Recaptured	R/M
	Area 1	38	1	97	0.29
	Area 2	2	11	88	0.13
Examined	No mark	128	128		
	R/C	0.24	0.09		

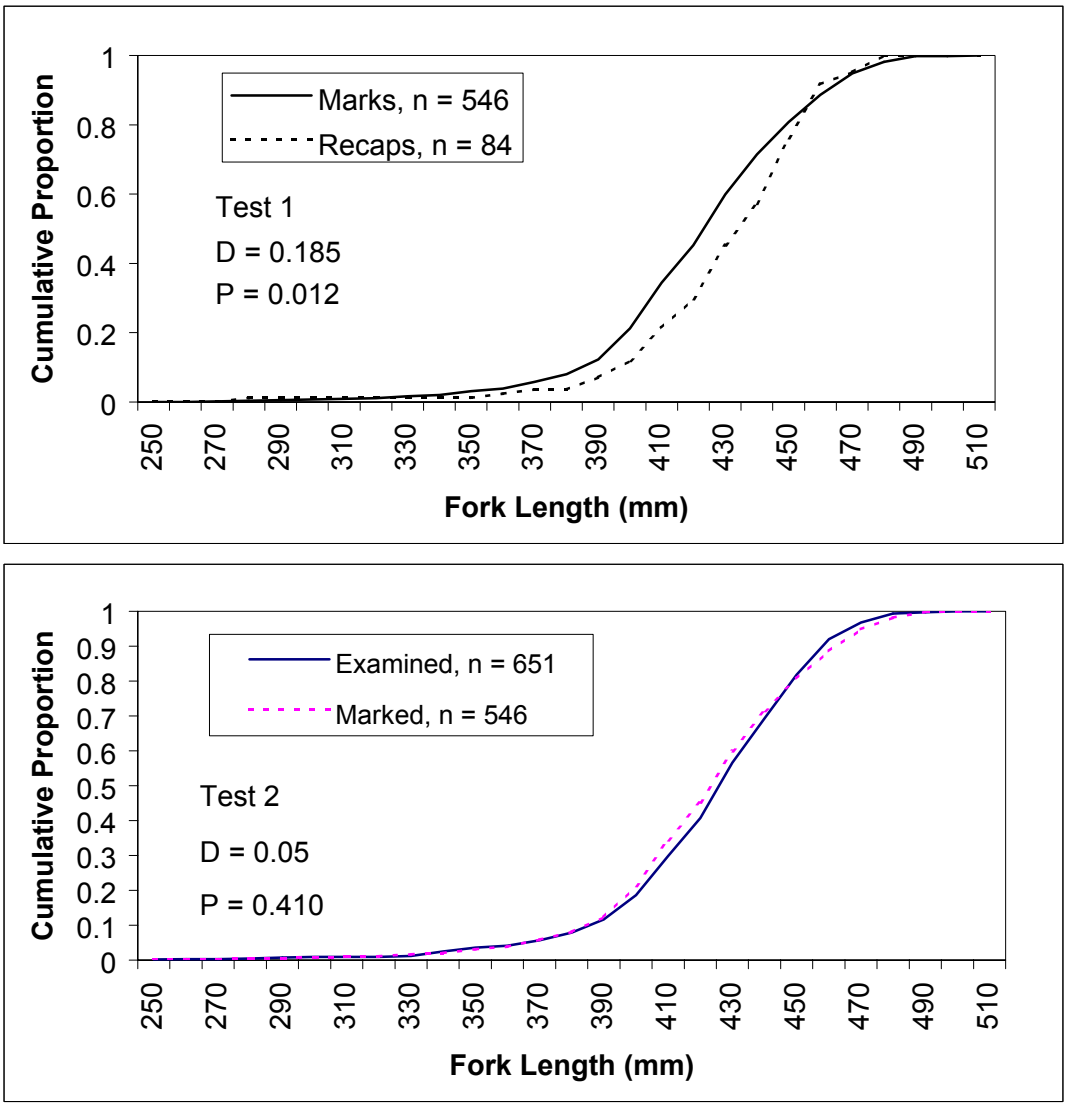

Figure 5.-Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >249 mm FL sampled from sections 1 and 2 of the Niukluk River in 1998.

To determine if movement of Arctic grayling between sampling events might have influenced the estimate of abundance, both the river sections and the locations (river km), where fish were marked and subsequently recaptured, were examined. Out of 84 recaptured fish in sections 1 and 2, only five were recaptured from a river section other than where marked (two fish were recaptured in the section upstream and three were recaptured downstream from where marked). Three of these were in the large size stratum and influenced the choice of the Darroch estimator for large Arctic grayling. When movement was examined with location data by river km from mark to recapture, it was found that 81 of the 84 fish with recapture location data had moved 5 km or less, and three moved between 5 and 11 km (Figure 6).

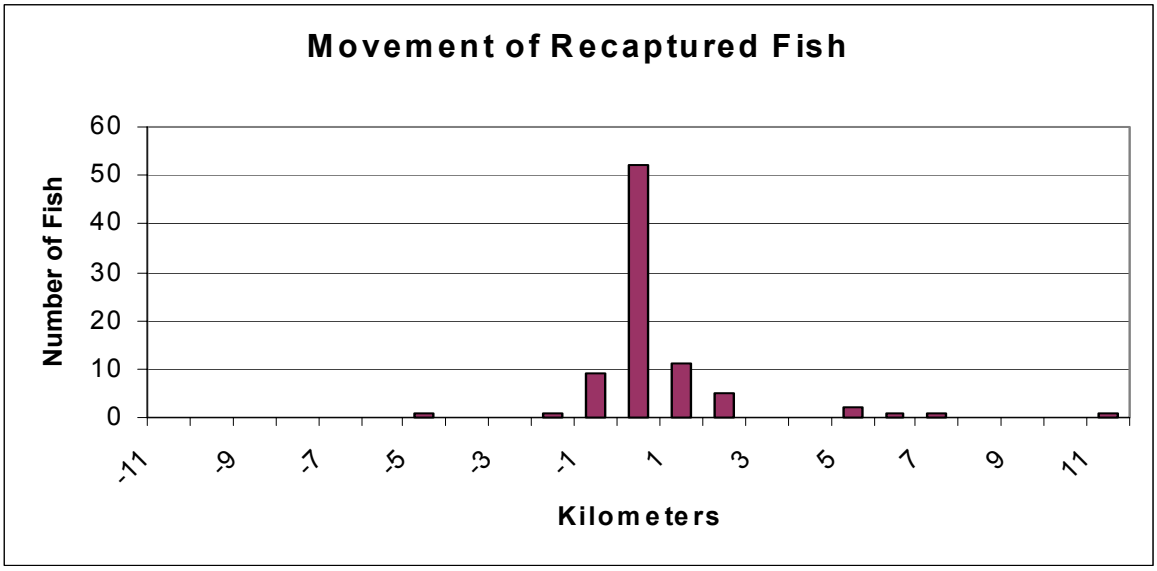

Figure 6.-Movement in km between mark and recapture of Arctic grayling in the Niukluk River in 1998.

AGE AND LENGTH COMPOSITIONS

Age and length composition and abundances by age and size category of Arctic grayling were estimated for the Niukluk River in 1998. Estimates of ages from scale reading of Arctic grayling from the Niukluk River ranged from 4 to 15 years. Fish aged 7 and 8 years comprised 55% of the population, and fish aged 9 – 11 years comprised an additional 30% of the population in sections 1 and 2 of the river (Figure 7, Table 3).

The majority of the population comprised the three 25 mm length categories from 400 to 475 mm (75%) with 38% in the 400 – 425 mm FL category (Figure 8, Table 4). The estimates were germane to those fish >249 mm FL and may be biased high in relation to the entire population. However, very few Arctic grayling smaller than 249 mm FL were captured or observed in the river, and it is thought that if size bias exists, it is small and that composition estimates are representative of the population.

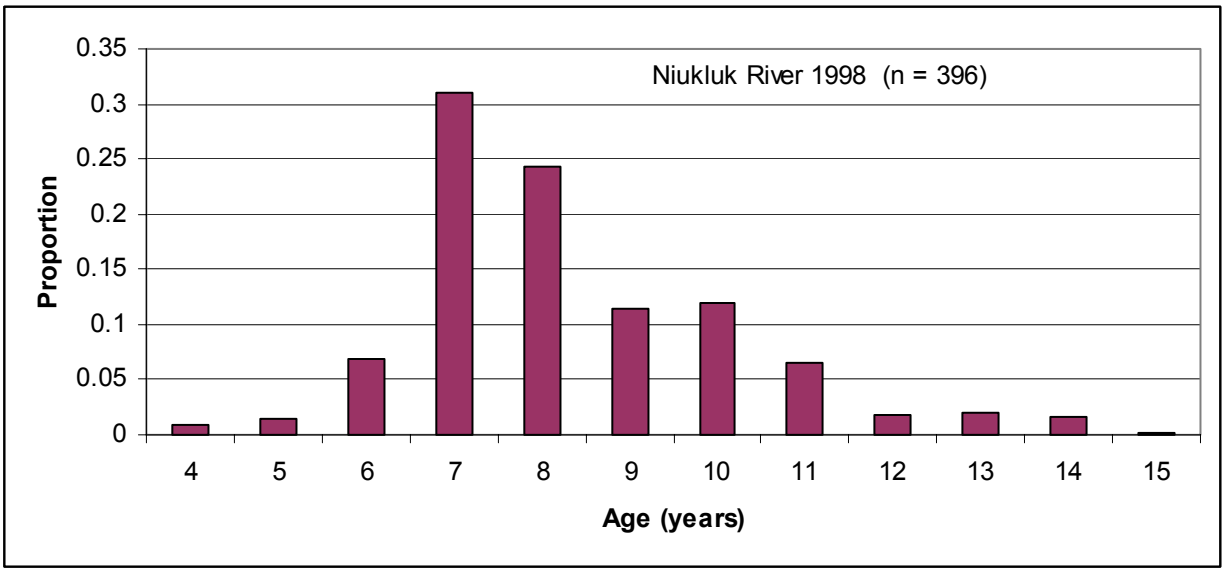

Figure 7.-Age composition estimates of Arctic grayling from sections 1 and 2 of the Niukluk River in 1998.

Table 3.-Estimated proportion and abundance of Arctic grayling in the Niukluk River by scale age class, 1998.

Statistic	Scale Age												Total
	4	5	6	7	8	9	10	11	12	13	14	15	
Niukluk R.													
Sample Size	3	5	24	110	93	50	53	30	9	10	8	1	396
Estimated P (adj)	0.009	0.015	0.070	0.310	0.243	0.115	0.119	0.065	0.018	0.020	0.016	0.002	1.00
SE of adjusted P	0.005	0.007	0.015	0.030	0.023	0.017	0.018	0.013	0.007	0.007	0.006	0.002	
Est. Abundance	44	73	345	1,540	1,205	570	591	324	91	101	81	10	4,975
SE of Abundance	26	34	84	241	186	110	115	77	34	37	32	10	986

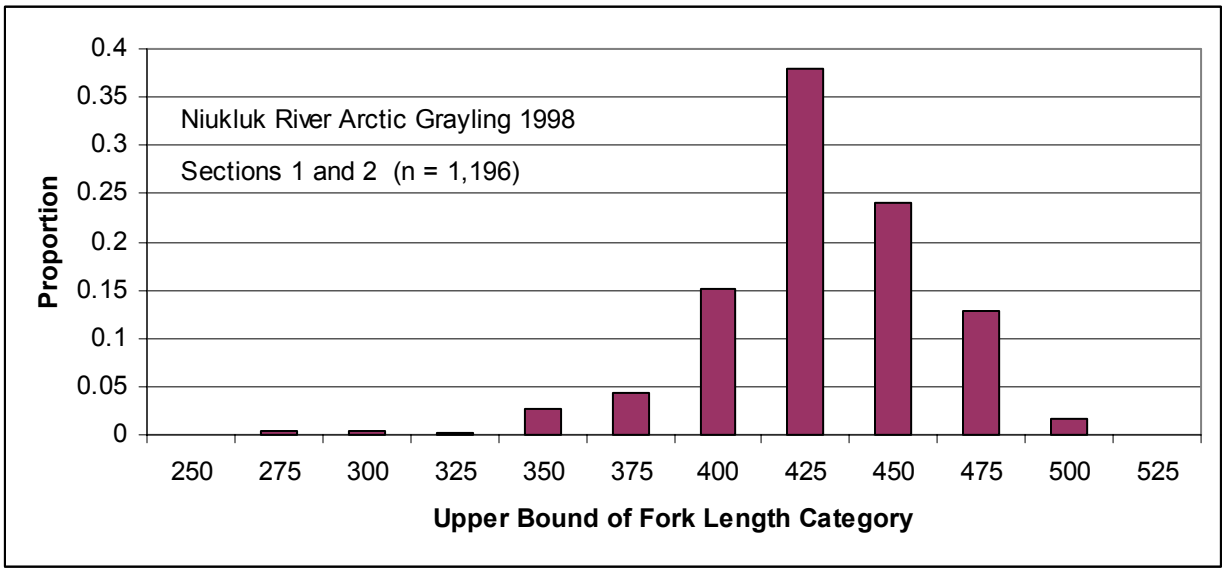

Figure 8.-Length composition estimates in 25 mm increments of Arctic grayling in sections 1 and 2 of the Niukluk River, 1998.

Table 4.-Estimates of length composition and abundance of Arctic grayling from sections 1 and 2 of the Niukluk River by 25 mm FL increments, 1998.

Statistic	Upper Bound of Fork Length Category												Total
	250	275	300	325	350	375	400	425	450	475	500	525	
Sample Size	1	4	5	3	27	44	153	383	353	197	25	1	1,196
Estimated Proportion	0.001	0.004	0.005	0.003	0.027	0.044	0.152	0.380	0.240	0.128	0.016	0.001	1.00
SE of Proportion	0.001	0.002	0.002	0.002	0.006	0.007	0.017	0.035	0.032	0.021	0.004	0.001	
Estimated Abundance	5	20	25	15	133	217	755	1,889	1,194	638	81	3	4,975
SE of Abundance	5	10	12	9	32	45	125	289	214	131	22	3	888

MEAN LENGTH-AT-AGE

Estimates of mean fork length-at-age were calculated for Arctic grayling sampled from the Niukluk River (Table 5). When data were available, they were combined across years. Like most Arctic grayling populations in Seward Peninsula waters, fish in the Niukluk River appear to grow rapidly in their early years. The age - length distribution of Arctic grayling sampled in the Niukluk River during 1998 is provided in Appendix A2.

ELDORADO RIVER AGE VALIDATION

During 1994, 60 Arctic grayling in the Eldorado River were measured, weighed and injected with OTC for age validation. During 1995, 43 additional Arctic grayling captured and marked for age validation. In 1996, 11 of 75 Arctic grayling that were captured carried OTC marks. In 1997, 6 of 93 Arctic grayling captured from the Eldorado River carried tetracycline marks from 1994 or 1995, including one fish which had lost its tag. All recaptured fish were killed and frozen whole for later analysis. Otoliths will not be analyzed until the remainder of the sample is collected. Approximately 23 otoliths must be analyzed to validate aging techniques. No OTC marked fish were captured during 1998.

NOME RIVER ARCTIC GRAYLING RESTORATION

On July 22 and 23, a total 670 YOU Arctic grayling were introduced into the experimental arm of Banner Creek gravel pit. The mean length of 98 fry sampled from those captured for introduction in 1998 was 29.1 mm (SD = 1.69 mm).

Dissolved oxygen was measured from a sample taken from the gravel pit in late November; 6 in of ice covered the pit at the time of sampling. The dissolved oxygen level was 11.6 mg/l. The zooplankton found were: 46 Chironomidae, 19 Oligochaeta and 1 Coleoptera (G. Todd, Alaska Department of Fish and Game, Commercial Fisheries, Soldotna Lab, personal communication). These lake benthic organisms are expected in non-moving water with mud substrate. Biomass was not estimable, given the small sampling scheme.

DISCUSSION

The abundance estimate reported for the Niukluk River in 1998 applies only to Arctic grayling >249 mm FL in sections 1 and 2 and is thought to be unbiased. Age and size composition estimates similarly apply only to fish larger than 249 mm FL. They are thought to be unbiased for the range of sizes covered, but may be biased high in relation to the Arctic grayling population of the entire Fish/Niukluk river system. Since very few small fish were captured or observed in the Niukluk River, it is thought that if size bias exists, its extent is small.

Both hook and line and beach seines were used to capture fish during both sampling events. However, mechanical problems with the reverse mechanism of the outboard motor prevented the use of the beach seine in much of the river during 1998. The question of hook-shyness affecting recapture rates has been raised. If this condition occurs, it would result in an abundance estimate that is biased high. Sampling will be designed to test whether hook-shyness affects the recapture rate of Arctic grayling during work planned for 1999 in the Fish River.

The estimate of abundance in the lower section of the sampling area were made difficult by a massive run of pink salmon in 1998, many of which moved into this section between sampling

Table 5.-Mean fork length-at-age of Arctic grayling from the Niukluk River, 1989, 1990 and 1998 samples combined.

	Niukluk River 1989, 1990, 1998		
Scale Age	Number of Fish	Mean Length (mm/FL)	Standard Deviation (mm/FL)
1	---	---	---
2	11	132	21
3	46	200	20
4	24	267	20
5	49	339	19
6	299	357	18
7	483	373	27
8	241	392	30
9	75	419	31
10	57	439	22
11	30	448	24
12	9	459	9
13	10	466	15
14	8	470	14
15	1	478	---

events. Over 700,000 pink salmon passed the counting tower located about 8 km downstream from the lower bound of the river section, and many of these moved into the lower part of our assessed area. The presence of so many spawning pink salmon affected the distribution of Arctic grayling in this river section, and reduced our ability to capture them during the second sampling event. It is also thought that some Arctic grayling from the area of the river downstream from our sampling area traveled with the pink salmon into the lower river section and were available during the second sampling event but not available during the first.

In previous stock assessment work on the Niukluk River during 1990, abundance for the upper two sections of the river was about half what was found in 1998. I believe that both of these estimates are valid and that the higher level of abundance found in 1998 resulted from a combination of factors. Prior to 1979 a small cable-drawn ferry that only could carry a few cars was used to cross the entrance to Safety Sound. This effectively limited traffic between Nome and Council until 1979 when the bridge was completed over Safety Sound allowing easy access to Council and the Niukluk River. The daily bag limit during the 1970's and into the mid 1980's was 15 Arctic grayling per day with a possession limit of 30 fish. Sport fishing for Arctic grayling was very good and the liberal limit combined with improved access resulted in high harvests. In addition, there were targeted subsistence fisheries for Arctic grayling in the upper Fish River. In 1986 the daily bag limit was reduced to its current level of five fish per day with only one allowed greater than 15 in in length. Hook and release fishing for Arctic grayling has been gaining in popularity in the Nome area. During the past three years, reports have been received that fishing for Arctic grayling in the Niukluk River was improving. The results of this project support this contention. I believe that we are just now seeing population level effects of the combination of changes in fishing practices (more hook and release) and from the more restrictive regulations put into place in 1986.

The success of the experimental project to restore the Nome River Arctic grayling population will be evaluated during 1999. If we are able to capture at least 134 fry from the experimental arm of the Banner Creek gravel pit, then we will assume that survival was at least 20% and we will proceed with this experiment on a larger scale with about 6,000 fry in 1999. However, if survival is poor, and we capture fewer than 134 fry, we will reevaluate this project and either find a different pond in which to rear fry, or abandon this effort. If the natural recruitment process in the Nome River can successfully be enhanced, the population may recover to the point that some fishing can be allowed in the future.

It is recommended that the status of Nome area Arctic grayling populations continue to be assessed on a rotational basis in order to determine population trends. The Arctic grayling population in the upper part of the Fish River will be assessed in 1999. Collection of additional OTC marked Arctic grayling from the Eldorado River is desired, and should be carried out in 1999.

ACKNOWLEDGMENTS

I would like to thank Michael "Wolf" Cartusciello and Patrick Lewis for their amiable and able assistance in the field and the staffs of the Commercial Fisheries and Wildlife Conservation Divisions in Nome for their logistical support. Mike Wallendorf contributed significantly to this study with biometric support.

LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). *Unpublished*. Trophy fish program history (1967-1995). Alaska Department of Fish and Game, Juneau.

Alt, K. T. 1978. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1977-1978, Project F-9-10, 19(G-I).

Alt, K. T. 1979. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1978-1979, Project F-9-11, 20(G-I).

Alt, K. T. 1980. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1979-1980, Project F-9-12, 21(G-I).

Alt, K. T. 1986. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Part B: Nowitna and Fish\Niukluk River study, western Alaska creel census, and sheefish enhancement assessment. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(G-I), Juneau.

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

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

Clutter, R. I., and L. E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin IX of the International Pacific Salmon Fisheries Commission, New Westminster, British Columbia, Canada.

Cochran, W. J. 1977. Sampling techniques, third edition. John Wiley and Sons, New York, New York.

Conover, W. J. 1980. Practical nonparametric statistics, second edition. John Wiley and Sons, New York.

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

DeCicco, A. L. 1990. Seward Peninsula Arctic grayling study 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-11, Anchorage.

DeCicco, A. L.. 1991. Seward Peninsula Arctic grayling study 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-24, Anchorage.

DeCicco, A. L. 1992. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-13, Anchorage.

DeCicco, A. L. 1993. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-36, Anchorage.

DeCicco, A. L. 1994. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, During 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-12, Anchorage.

DeCicco, A. L. 1995. Assessment of selected stocks of Arctic grayling in streams and a survey of Salmon Lake, Seward Peninsula, Alaska, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-19, Anchorage.

DeCicco, A. L. 1996. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-21, Anchorage.

DeCicco, A. L. 1997. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-15, Anchorage.

LITERATURE CITED (Continued)

DeCicco, A. L. 1998. Assessment of selected stocks of Arctic grayling in streams of the Seward Peninsula, Alaska, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-19, Anchorage.

Frost, H. and 3 co-authors. 1961. Tetracycline bone labelling. Journal of New Drugs. 1(5):206-216.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association. 66:708-713.

Howe, A. H., 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. H., G. Fidler, A. E. Bingham and M. J. Mills. 1996. Harvest, catch and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage.

Howe, A. H., G. Fidler, C. Olnes, A. E. Bingham and M. J. Mills. 1997. Harvest, catch and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29, Anchorage.

Howe, A. H., G. Fidler, C. Olnes, A. E. Bingham and M. J. Mills. 1998. Harvest, catch and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25, Anchorage.

McFarlane, G. and R. Beamish. 1987. Selection of dosages of oxytetracycline for age validation studies. Canadian Journal of Fisheries and Aquatic Sciences, 44:905-909.

Merritt, M. F. 1989. Age and length studies and harvest surveys of Arctic grayling on the Seward Peninsula, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 79, Juneau.

Mills, M. J. 1981. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A), Juneau.

Mills, M. J. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23(SW-I-A), Juneau.

Mills, M. J. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24(SW-I-A), Juneau.

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), Juneau.

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 fish harvest studies (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fish harvest studies (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fish harvest studies (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 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 No. 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 No. 92-40, Anchorage.

LITERATURE CITED (Continued)

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 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 No. 94-28, Anchorage.

Scarnecchia, D. L. 1979. Variation of scale characteristics of coho salmon with sampling location on body. Progressive Fish Culturist 41(3): 132-135.

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

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

Yole, F. 1975. Methods of aging fish species common to rivers and lakes of the northern Yukon Territory, 1972-1974. *in* L. Steigengerger, M. Elson, P. Bruce, Y. Yole editors. Northern Yukon Fisheries Studies 1971-1974. Volume 2. Prepared for Environmental Social Program, Northern Pipelines.

APPENDIX A

Appendix A1.-List of numbered tags and finclips used to mark Arctic grayling from the Niukluk River in 1998.

Location	Month	No. Fish	Tag Numbers	Color	Fin Clip
Niukluk Sect. 1	June	237	36000-36236	Gray	Left Ventral
Niukluk Sect. 2	June	305	36237-36541	Gray	Right Ventral
Niukluk Sect. 3	June	258	36542-36799	Gray	Left Pectoral

Appendix A2.-Age-length distribution of Arctic grayling sampled from sections 1 and 2 of the Niukluk River in 1998.

Length	Age												
(mm)	4	5	6	7	8	9	10	11	12	13	14	15	Total
101-125													
126-150													
151-175													
176-200													
201-225													
226-250													
251-275	1												1
276-300	1												1
301-325	1		1										2
326-350		3	4										7
351-375			6		3								9
376-400			7	23	9	1	2	1					43
401-425			5	38	37	12	9	4					105
426-450				19	19	20	21	8	2	2	1		92
451-475				1	6	6	20	16	7	5	4		65
476-500						1	1	1		3	3	1	10
501-525													
Total	3	3	23	81	74	40	53	30	9	10	8	1	335

APPENDIX B

Appendix B1.-Data files used to estimate parameters of Arctic grayling populations on the Seward Peninsula in 1997.

Data File[a]	Description
W0050LA8.DTA	Data for Arctic grayling captured from the Nome River during 1998.

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

APPENDIX C

Appendix C1.- Methodologies to compensate for bias due to unequal catchability by length.

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

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling events for size and age composition estimates.

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

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

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

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

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

Appendix C2.-Methodologies to compensate for bias due to unequal catchability by river section.

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

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

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

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

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

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

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