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Assessment of Arctic Grayling in Selected Streams and a Survey of Salmon Lake, Seward Peninsula, 1994

by

Alfred L. DeCicco

September 1995

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

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ASSESSMENT OF ARCTIC GRAYLING IN SELECTED STREAMS AND A SURVEY OF SALMON LAKE, SEWARD PENINSULA, 1994

by

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September 1995

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ABSTRACT

The number of Arctic grayling *Thymallus arcticus* over 249 mm in FL was estimated at 1,379 fish (SE = 166) in a 48 km section of the Snake River. The density was 29 fish/km. Arctic grayling ranged from 210 to 485 mm in FL and from 2 to 12 years of age. In a 12 km section of the Pilgrim River, the estimated abundance of Arctic grayling greater than 269 mm in FL was 353 fish (SE = 77) or 29 fish/km. They ranged from 235 to 486 mm in FL and from 2 to 13 years of age. The majority of Arctic grayling (50 and 52%) were in the "preferred" Relative Stock Density category in the Snake and Pilgrim rivers, while "memorable" fish comprised 35% of the Snake River sample and 34% of the Pilgrim River sample. Sixty Arctic grayling were captured on the Eldorado River and injected with OTC for later recapture in order to validate aging techniques.

Salmon Lake was sampled using variable mesh gillnets and baited hoop and minnow traps in order to assess species presence and catch per unit of effort. Although a total of 309 fish comprising nine species were captured, numbers of fish were insufficient to estimate proportions of occurrence. Based on this study, few fish appear to inhabit Salmon Lake in mid-July.

Key words: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, length composition, Seward Peninsula, Snake River, Pilgrim River, Eldorado River, Salmon Lake.

CHAPTER 1: ARCTIC GRAYLING STUDIES IN SELECTED STREAMS

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. From 1980 to 1993, an average of 16,085 freshwater angler-days of fishing effort occurred in this area (Mills 1981-1994). 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 to 1991, Arctic grayling have comprised an average of 19.4% of the harvest of these species, but dropped to 3.3% in 1992, and was 9.0% in 1993 (Table 1).

The Seward Peninsula is the only area in Alaska outside of Bristol Bay which regularly produces trophy-sized Arctic grayling. Of 116 Arctic grayling registered with the Alaska Department of Fish and Game (ADF&G) Trophy Fish Program between 1967 and 1994, 31 (27%) were from the Seward Peninsula (ADF&G *Unpublished*). Since 1984, 17 of 33 Arctic grayling registered in this program (52%) came from the Seward Peninsula.

Although not connected by road to the state highway system, the Nome area has approximately 420 km of maintained gravel roads which originate in Nome and traverse the Seward Peninsula in three general directions (Figure 1). This road system provides angler access to many streams on the Seward Peninsula.

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 which reduced the daily bag limit of Arctic grayling on the Seward Peninsula to five per day, five in possession, with only one over 15 inches (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

Table 1.-Estimated freshwater sport fish harvests (catches are in parentheses) for Seward Peninsula and Norton Sound streams, 1980-1993. Data from the Alaska statewide sport fish harvest survey (Mills 1981-1994).

	Harvests (Catches) in Number of Fish						
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)	(12,158)	(2,117)	(107)	(196)
MEAN	16,085	9,802	5,740	3,653	648	34	358
		(23,165)	(15,558)	(11,802)	(3,565)	(64)	(521)

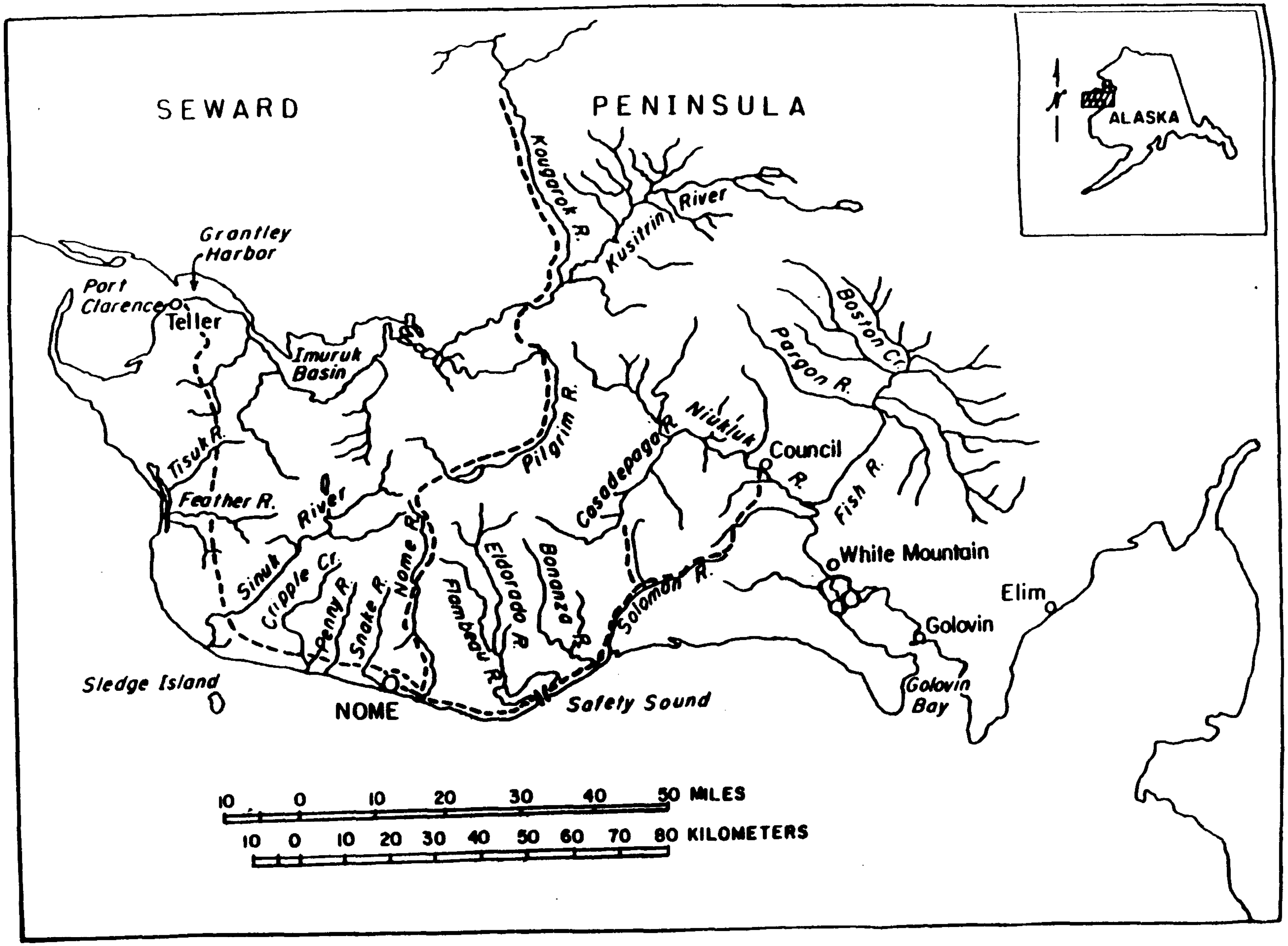

Figure 1.-The southern Seward peninsula showing roads and road accessible waters.

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, 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 1990-1994). Problems assigning ages to large Arctic grayling have been noted in recent years (DeCicco 1993, 1994). Consequently, an age validation component was added to this project in 1994.

Several regulatory changes have recently been implemented based on data collected from this study. The Nome and Solomon rivers have been closed to Arctic grayling fishing by emergency order and will remain closed until it is determined that the populations have recovered. 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 inches (381 mm) in length.

The long term goal of this project is to achieve sustained yield fisheries for Arctic grayling populations through regulation. Project objectives in 1994 were to:

1) estimate the abundance and age and length compositions of Arctic grayling greater than 249 mm FL in a 48-km section of the Snake River and a 12-km section of the Pilgrim River downstream of the Beam Road bridge; and,
2) validate age estimates from scales and otoliths for Arctic grayling in the Eldorado River. This objective will be ongoing for several years.

In addition, mean length-at-age for Arctic grayling in the Snake, Pilgrim and Eldorado rivers was estimated.

METHODS

Sampling Gear and Techniques

Arctic grayling were sampled using hook and line, and a 50-m x 2-m, 6.5-mm mesh beach seine on the Snake and Pilgrim rivers (Figures 2 and 3). Access to the upper Snake River was by foot, while the lower Snake and the Pilgrim rivers were sampled using a 4.8 m outboard jet powered riverboat.

Each Arctic grayling was measured to the nearest mm in fork length. Fish over 149 mm FL in the Pilgrim River were tagged with individually 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). Arctic grayling in the Snake River were marked by punching a hole in the upper or lower lobe of the caudal fin. 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.

Data were recorded on standard ADF&G Tagging-Length forms (version 1). Scales were cleaned with detergent and water, mounted on gummed cards and acetate impressions were made (30 seconds at 7,000 kg/cm^2, at 100^{o} C). Ages were determined by counting annuli from the acetate

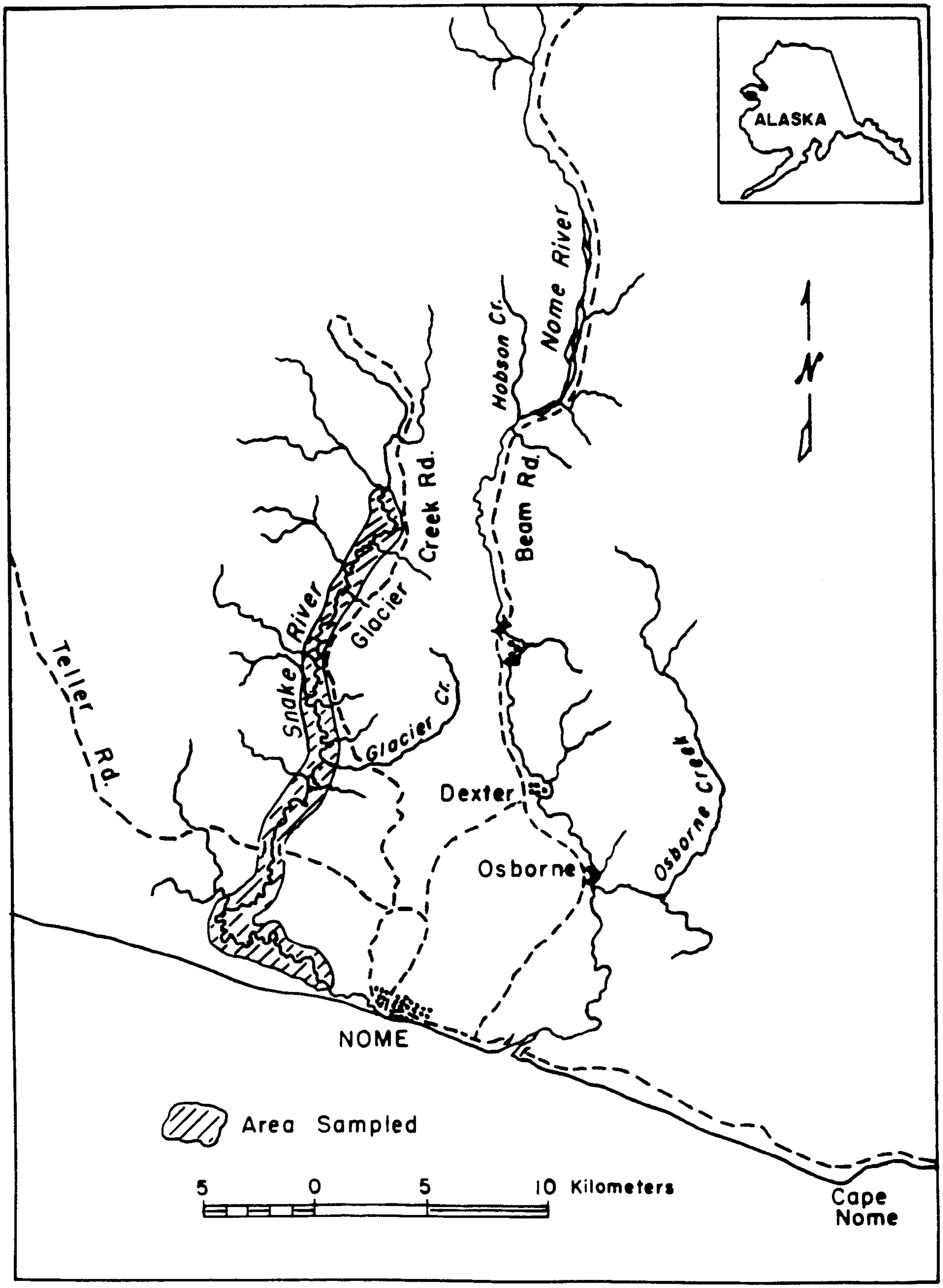

Figure 2.-The Snake River with area sampled during 1994.

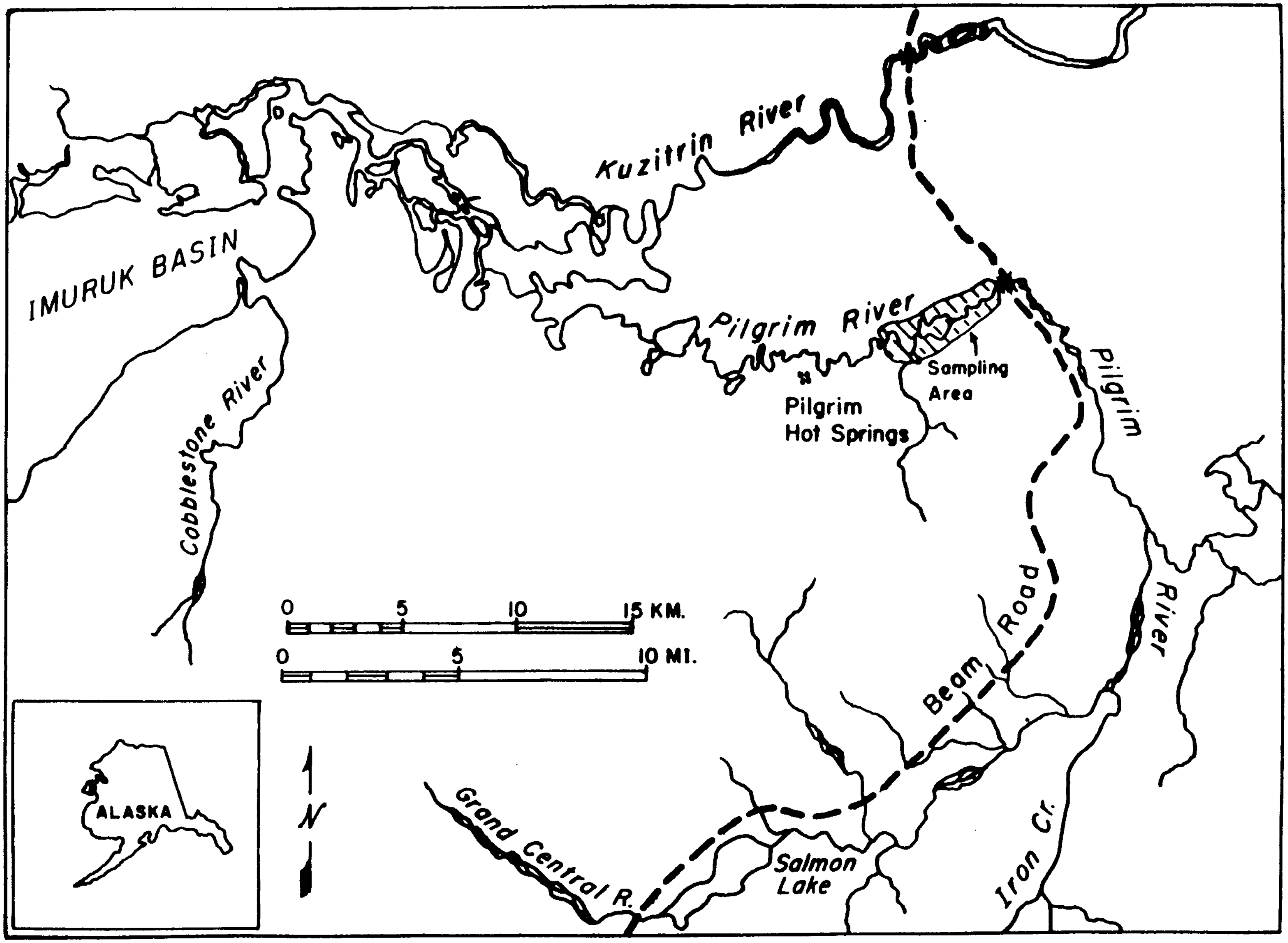

Figure 3.-The Pilgrim River with area sampled during 1994.

impressions using a microfiche reader. All scale impressions were read by the project leader. Scale impressions for which questionable ages were assigned were read a second or 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).

Population Abundance Estimates

A modified Petersen mark-recapture experiment (Bailey 1951, 1952) was used to estimate the abundance of Arctic grayling in sections of the Snake and Pilgrim rivers (Figures 2 and 3). Sampling for the two-event population estimates was performed in each of the river sections. The entire length of each river section was sampled during both the mark and recapture events. 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 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 (Seber 1982). 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 Bernard and Hansen (1992). 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 an appropriate finclip (Appendix A1). Finclips or hole punches were chosen so as to not duplicate those used for fish from a given river in previous years. Assumption 5 was met by the close examination of all fish for the presence of the double mark or fin punch.

Population abundance and the approximate variance of the estimate were calculated with the following formulas (Seber 1982):

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

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

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;
- $\hat{N}$ = the estimated abundance of Arctic grayling during the first event; and,
- V = the approximate variance of the abundance estimate.

The Snake River was divided into sections and the ratios of the number of recaptured fish to the number of fish examined during the second event (minus the recaptures) by river section were examined for equal probability of capture using contingency table tests. Incomplete mixing of fish has occurred between sampling events in the Snake River in past years (DeCicco 1992-1994), but it has never been shown to adversely influence the estimate of abundance, and since the entire reach of the river inhabited by Arctic grayling was sampled, the sections were combined and treated as a single sampling unit in 1995.

Age Composition

Scales were collected from Arctic grayling sampled in conjunction with the abundance estimate experiments. Ages were assigned to scales as indicated above to estimate age composition for the populations in the Snake and Pilgrim rivers. The proportions of fish in each age category were estimated as multinomial proportions (Cochran 1977).

The proportion in each category was estimated as:

$$\hat{p}_i = \frac{n_i}{n} \qquad (3)$$

where:

- n_i = the number in the sample from group i;
- n = the sample size; and,
- p_i = the estimated fraction of the population that is made up of group i.

The unbiased variance of this proportion was estimated as:

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

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).

Length Composition

Length composition of Arctic grayling residing in the Snake and Pilgrim rivers was estimated in 25 mm length increments and as Relative Stock Density (RSD) categories (modified from Gabelhouse 1984). The RSD categories used for Arctic grayling were: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and "trophy" (greater than 559 mm FL). Estimates of the proportion of fish in size categories followed the same procedures used for age composition (equations 3 and 4). Abundance estimates by RSD category were calculated using equations 5 and 6.

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 the mean lengths of each age class were calculated using standard . procedures.

Age Validation

Arctic grayling were captured in the Eldorado River in order to validate aging techniques. Each fish was anesthetized by bubbling CO_2 into the holding water, measured to the nearest mm FL, weighed to the nearest 25 gm using a Chatillion spring scale, and given an interperitoneal injection of oxytetracycline (OTC) in order to permanently mark bony structures (Bumguardner 1991, Campagna and Neilson 1982). Each fish was injected with 25mg/kg OTC (Beamish and McFarlane 1987), and tagged with an individually numbered Floy tag. In addition, the adipose fin was removed to allow for later identification of marked fish.

RESULTS

Population Abundance Estimates

The abundance of Arctic grayling in 1994 was estimated in the Snake River and in an index section of the Pilgrim River.

Snake River

The marking event on the Snake River (Figure 2) was conducted during five days in late June and early July. The recapture event was conducted during a five day period in mid-July, after a one week hiatus. Since nearly the entire river was sampled, the possibility that fish would leave the sampling area between sampling events was minimized. Adequate numbers of fish were sampled during both events and a sufficient number of marked fish were recaptured to calculate an abundance estimate within the desired precision criteria. The smallest of 246 Arctic grayling marked in the first sampling event was 210 mm FL and the smallest of 323 Arctic grayling examined in the second sampling event was 234 mm FL. The smallest marked fish recaptured in the second event was 275 mm FL. The abundance estimate was calculated for Arctic grayling >249 mm FL because it is close to the smallest recapture, and the same lower bound was used in 1992 and 1993, for the same section of the river.

In the 48 km section of the Snake River from Goldbottom Creek downstream to the Nome airport, the estimated abundance of Arctic grayling greater than 249 mm FL was 1,379 fish (SE = 166 fish, CV = 12%). A total of 246 Arctic grayling greater than 249 mm FL were marked during the first sampling event. During the recapture event, 313 Arctic grayling greater than 249 mm FL were examined of which 55 had fin clips from the marking event. One fish (<1%) had lost its tag from the first event. Two fish were killed during sampling.

The river was divided into four sampling sections. Equal probability of capture of Arctic grayling by river section was examined through contingency tables comparing the numbers of new fish examined in the second sampling event (total examined - recaptures) and numbers of recaptured fish by river section. Probabilities of capture were found to be different (χ^2 = 9.37, df = 3, P = 0.025) for the four sections. A lower number of marked fish were recaptured in section 4 than expected. This accounted for most of the total χ^2 value (6.05). Numbers of recaptured fish from each section could not be compared to the numbers of marked fish in each river section because individually numbered tags were not used in 1994. However, in past years even though movement of fish between sampling events was detected in each year (DeCicco 1992-1994), a single nonstratified estimate was chosen as the best estimate for this river. It was therefore decided to treat this river as a single sampling section in 1994 and numbered tags were not used.

Kolmogorov-Smirnov two sample tests of the cumulative length distributions of Arctic grayling greater than 249 mm FL marked during the first sampling event versus those recaptured during the second sampling event (test 1) did not detect significant differences (D = 0.14, P = 0.35, n_1 = 246, n_2 = 53). A similar test of those marked during the first sampling event versus those examined in the second sampling event (test 2) did detect significant differences (D = 0.13, P = 0.02, n_1 = 312, n_2 = 246; Figure 4). Therefore, a single unstratified abundance estimate was calculated for Arctic grayling greater than 249 mm FL and only fish from the second sample were used to estimate age and length composition. Samples from both events were used for the age-length distribution (Appendix A2).

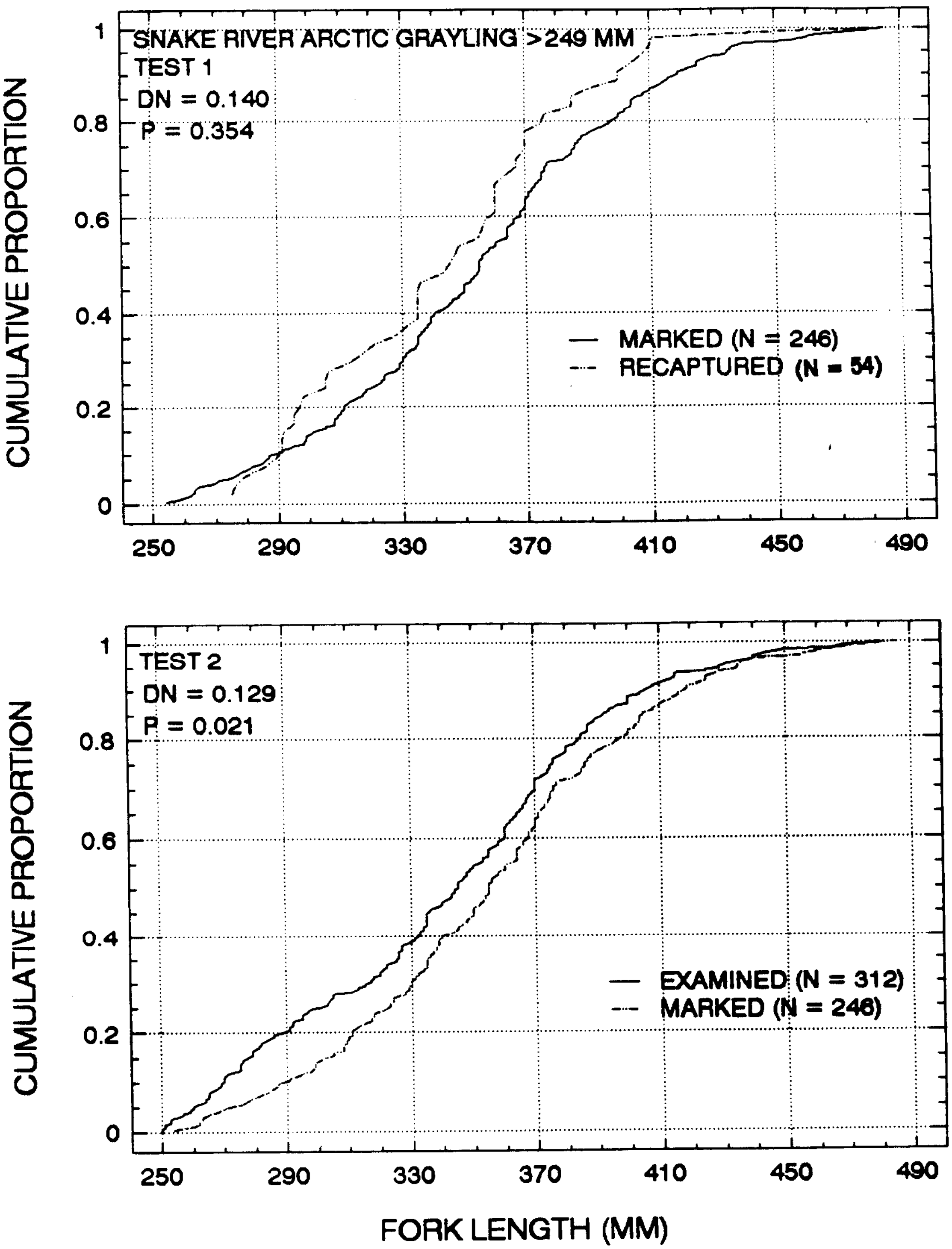

Figure 4.-Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >249 mm FL sampled from the Snake River in 1994.

Pilgrim River
The marking event on the Pilgrim River (Figure 3) was conducted during a four day period in July and the recapture event was conducted during a four day period in July after a four day hiatus. The smallest of 75 Arctic grayling marked was 235 mm FL and the smallest of 90 Arctic grayling examined during the second event was 251 mm FL. The smallest marked fish recaptured from the Pilgrim River was 282 mm FL. The abundance estimate for the Pilgrim River was calculated for Arctic grayling > 269 mm FL since this was the lower bound of the RSD category nearest the smallest sized recapture.

In the 12 km section of the Pilgrim River downstream from the Beam Road bridge, the estimated abundance of Arctic grayling greater than 269 mm FL was 353 fish (SE = 77 fish, CV = 22%). A total of 65 Arctic grayling greater than 269 mm FL were marked during the first event (19 to 22 July). During the recapture event (26 to 29 July), 86 Arctic grayling > 269 mm FL were examined of which 15 had tags from the marking event. One fish from the first sampling event had lost its tag when recaptured in the second event, and one fish was killed during sampling in 1994.

Kolmogorov-Smirnov two sample tests of the cumulative length distributions of Arctic grayling greater than 269 mm FL marked versus those recaptured during the recapture event (test 1) and of those marked in the first event and those examined in the second event (test 2) failed to detect significant differences (test 1: $D = 0.14$, $P = 0.96$, $n_1 = 65$, $n_2 = 15$; test 2: $D = 0.09$, $P = 0.90$, $n_1 = 86$, $n_2 = 65$; Figure 5). A single unstratified abundance estimate was calculated for Arctic grayling greater than 269 mm FL and fish from both samples were used to estimate age and length composition, and for the age-length distribution (Appendix A3).

Age Composition

Although Arctic grayling sampled during 1994 ranged from age 3 fish collected from the both the Snake and Pilgrim rivers to an age 12 fish collected from the Snake River, estimates of age composition and abundance by age class were restricted to fish larger than 249 mm FL on the Snake River and fish larger than 269 mm FL from the Pilgrim River (Table 2). Age-4,5 and 6 Arctic grayling comprised 86% of the population in the Snake River (Figure 6) and 60% of the population in the Pilgrim River in 1994. Age-5 fish were most abundant in the Snake River (47%), while age-4 fish were most abundant (28%) in the Pilgrim River. The numbers of fish in each age class <5 through 8+ from the Snake and Pilgrim rivers were compared and found to be significantly different ($\chi^2 = 62.05$, df = 4, $P < 0.001$). Most of the differences were in age-5 fish and age-7 and older fish. Age-5 fish were more abundant than expected in the Snake River and less than expected in the Pilgrim River, while older fish (age-7 and older) were more abundant than expected in the Pilgrim River and less abundant than expected in the Snake River. Arctic grayling from the Eldorado River were also sampled for age in 1994 (Appendix A4). They ranged to age-12 with ages 8 (20.3%) and 9 (30.4%) most strongly represented in the sample.

Length Composition

Length composition of Arctic grayling stocks sampled within the study area was estimated in 25 mm increments (Table 3; Figure 7) and as Relative Stock Density (RSD) categories (Table 4; Figure 6). The majority of Arctic grayling sampled from the Snake and Pilgrim rivers were in the quality and preferred categories. Comparable data gathered from the Snake and Pilgrim rivers indicated that RSDs were not significantly different ($\chi^2 = 5.24$, df = 3, $P = 0.155$). Arctic

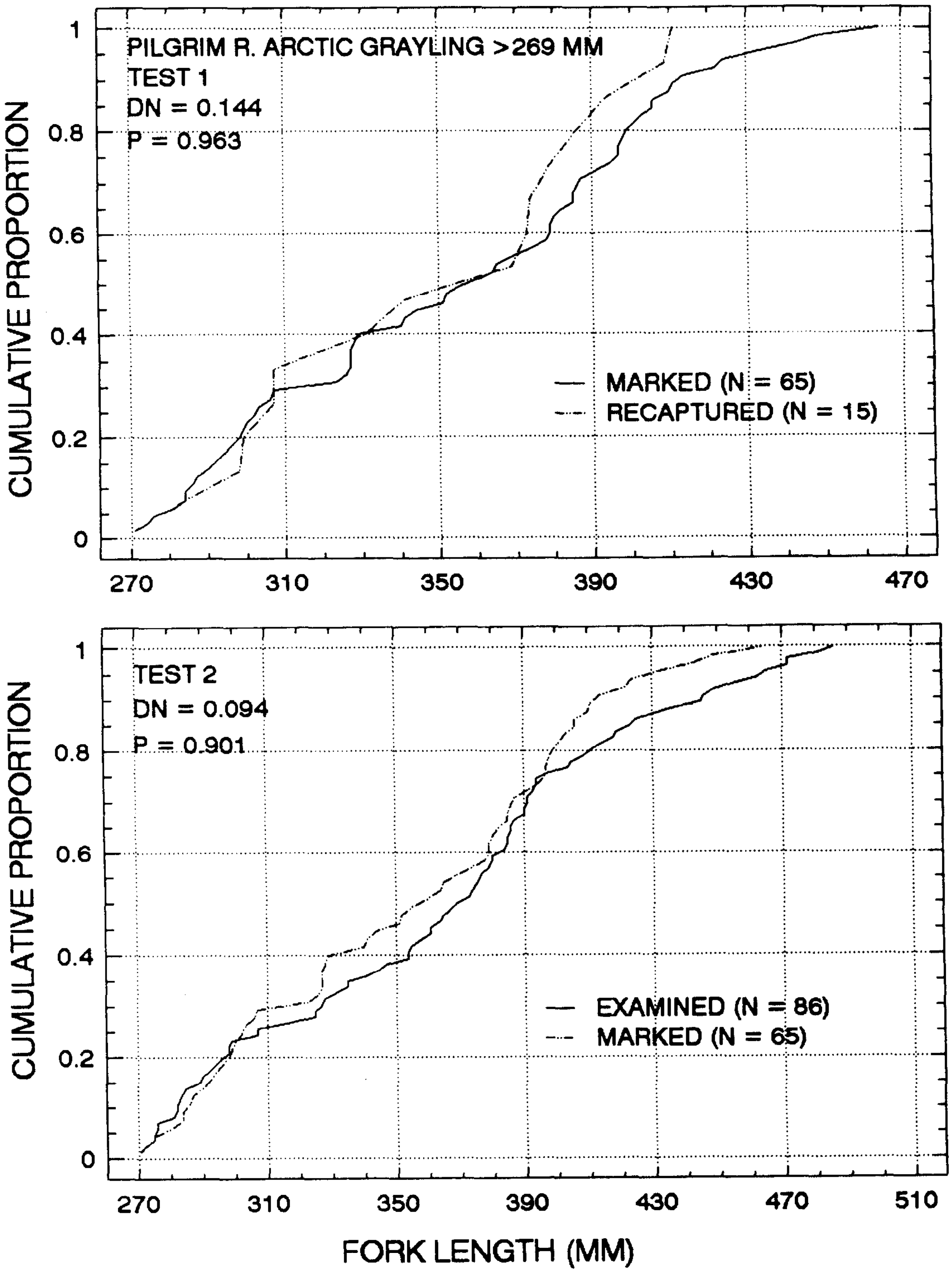

Figure 5.-Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >269 mm FL sampled from the Pilgrim River in 1994.

Table 2.-Estimated proportion and abundance of Arctic grayling in the Snake and Pilgrim rivers by age class, 1994.

	Age										
Statistic	3	4	5	6	7	8	9	10	11	12	Total
Snake R. (fish >249 mm FL)											
Sample Size	4	70	120	32	14	7	9	0	0	1	257
Estimated Proportion	0.02	0.27	0.47	0.12	0.05	0.03	0.04	0	0	>0.01	1.00
SE of Proportion	0.01	0.03	0.03	0.02	0.01	0.01	0.01	0	0	>0.01	
Estimated Abundance	21	376	644	172	75	38	48	0	0	5	1,379
SE of Abundance	12	110	183	55	28	17	20	0	0	5	431
Pilgrim R. (fish > 269 mm FL)											
Sample Size	2	34	19	29	25	11	8	6	5	0	139
Estimated Proportion	0.14	0.24	0.14	0.21	0.18	0.08	0.06	0.04	0.04	0	1.00
SE of Proportion	0.01	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0	
Estimated Abundance	5	86	48	74	63	28	20	15	13	0	353
SE of Abundance	4	23	15	20	18	10	8	7	6	0	110

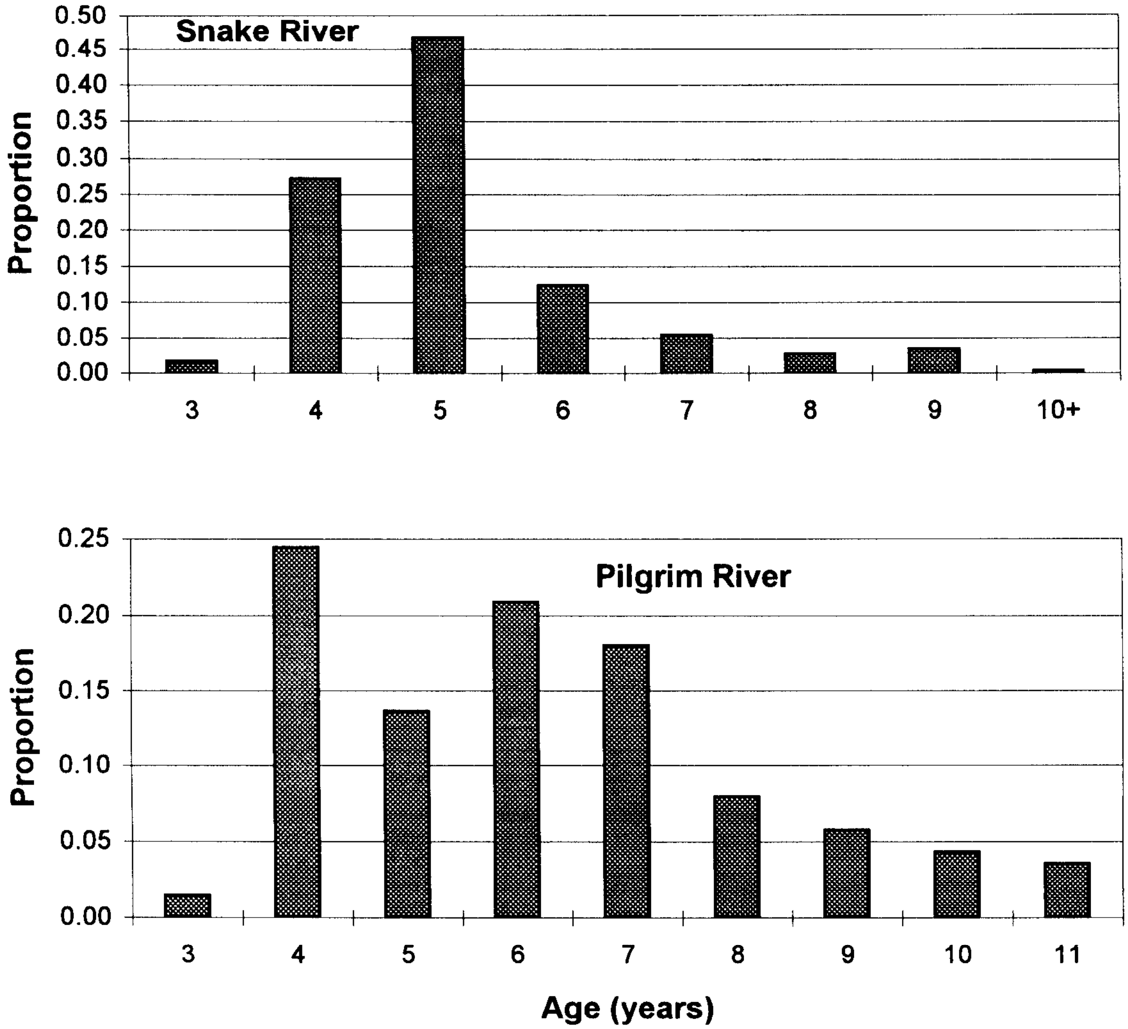

Figure 6.-Age composition estimates of Arctic grayling from the Snake and Pilgrim rivers in 1994.

Table 3.-Estimated proportion and abundance of Arctic grayling in the Snake and Pilgrim rivers by 25 mm FL increments, 1994.

	Length Category (mm)											
Statistic	250	275	300	325	350	375	400	425	450	475	500	Total
Snake River (fish > 249 mm FL)												
Sample Size	12	41	35	31	61	63	44	17	13	4	1	322
Estimated Proportion	0.04	0.13	0.11	0.10	0.19	0.20	0.14	0.05	0.04	0.01	>0.01	1.00
SE of Proportion	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	>0.01	
Estimated Abundance	51	176	150	133	261	270	188	73	56	17	4	1,379
SE of Abundance	20	55	47	43	78	80	58	26	21	9	4	442
Pilgrim R. (fish > 269 mm FL)												
Sample Size	---	6	29	10	17	21	34	18	8	6	2	151
Estimated Proportion	---	0.04	0.19	0.07	0.11	0.14	0.26	0.12	0.05	0.04	0.01	1.00
SE of Proportion	---	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.01	
Estimated Abundance	---	14	68	23	40	50	79	42	19	14	5	353
SE of Abundance	---	6	17	9	12	15	21	13	8	6	3	112

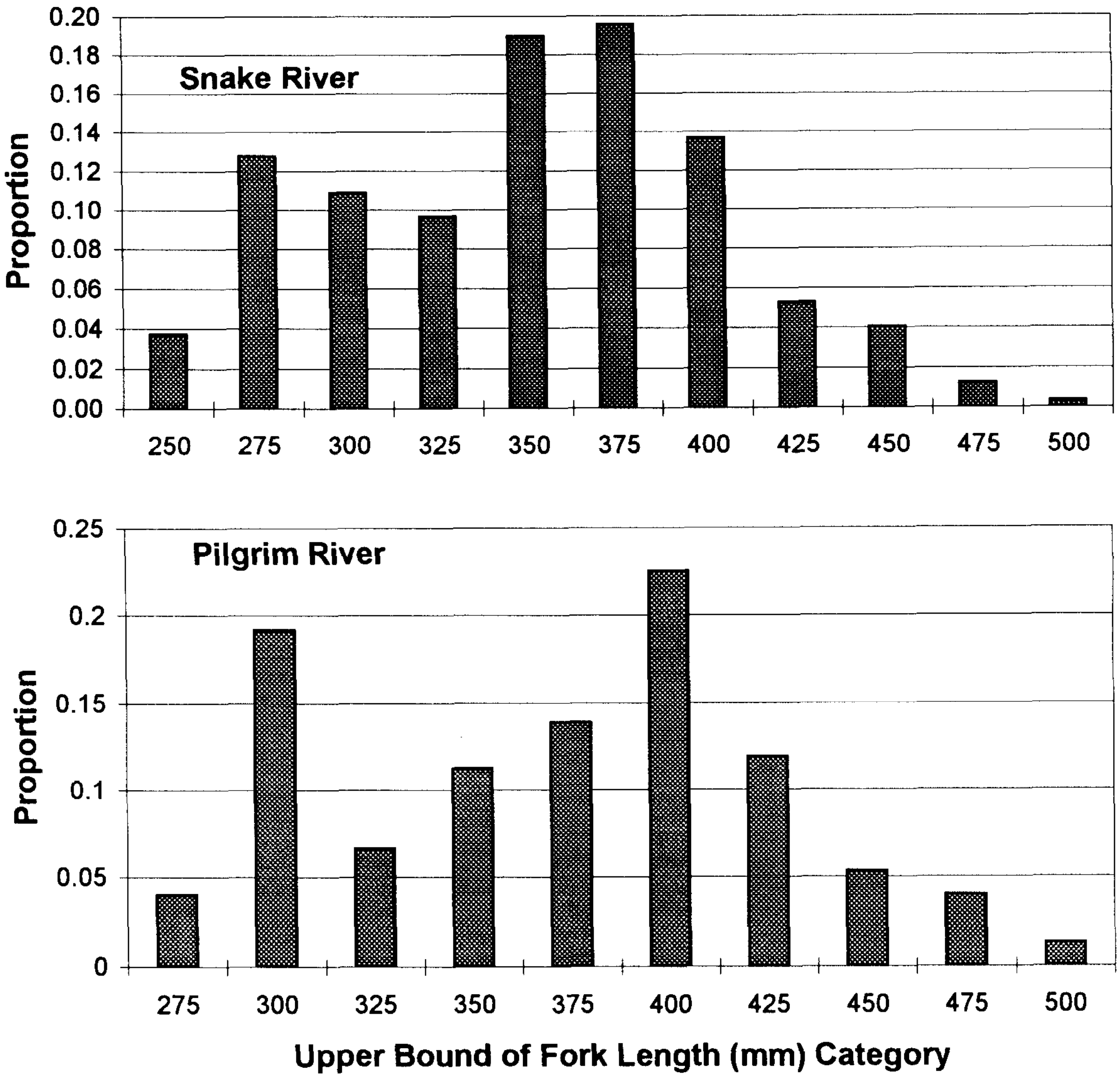

Figure 7.-Length composition estimates in 25 mm increments of Arctic grayling sampled from the Snake and Pilgrim rivers in 1994.

Table 4.-Estimated proportion and abundance of Arctic grayling in the Snake and Pilgrim rivers by RSD category, 1994.

	RSD Category				
	Stock	Quality	Preferred	Memorable	Trophy
Snake River (fish >249 mm FL)					
Number sampled	41	113	162	6	0
Proportion	0.13	0.35	0.50	0.02	0
SE of proportion	0.02	0.03	0.03	0.01	0
Abundance	175	484	694	26	0
SE of abundance	54	138	196	12	0
Pilgrim R. (fish >269 mm FL)					
Number sampled	14	56	86	8	0
Proportion	0.09	0.34	0.52	0.05	0
SE of proportion	0.02	0.04	0.04	0.02	0
Abundance	30	121	185	17	0
SE of abundance	10	29	43	7	0

grayling in the preferred category comprised 50%, and 52% of the respective size compositions in the Snake and Pilgrim rivers in 1994. The quality category was also strongly represented (35% and 34%, respectively) in the Snake and Pilgrim rivers. Memorable fish were weakly represented (2% and 5%) in the same rivers. No fish in the trophy category were encountered in either river. Only small proportions of stock size and smaller Arctic grayling were sampled in the Snake and Pilgrim rivers (13% and 9%, respectively). Examination of the size distribution of all Arctic grayling >101 mm FL sampled during 1994 (Table 5) shows a bimodal length distribution of Arctic grayling sampled from both the Snake and Pilgrim rivers during 1994. In the Snake River 52% of the Arctic grayling were between 326 and 400 mm FL with a smaller length mode (250-300 mm FL) comprising 24% of the population. In the Pilgrim River, 48% of the Arctic grayling were from 350 to 425 mm FL and a smaller mode (275-300 mm FL) comprised 19% of the population. Arctic grayling sampled from the Eldorado River were larger with 91% being greater than 400 mm FL.

Mean Length-at-Age

Estimates of mean fork length-at-age were calculated for Arctic grayling sampled from the Snake, Pilgrim, and Eldorado rivers (Table 6). When data were available, they were combined across years. Arctic grayling in the Snake and Pilgrim rivers had similar mean lengths throughout their entire age range, while those in the Eldorado River were larger at all ages greater than five years. Age and length distributions of Arctic grayling sampled are provided in Appendices A2-A4.

Eldorado River Age Validation

Sixty Arctic grayling were captured on the Eldorado River, tagged, and injected with OTC for later recapture in order to validate aging techniques. The fish ranged from 292 to 507 mm FL, but most (91%) were greater than 400 mm FL.

DISCUSSION

Estimates of abundance of Arctic grayling residing in all study rivers except the Sinuk River were achieved within desired precision goals. The realized precision of estimates at $\alpha = 0.10$ were 20% for the Snake River, and 36% for the Pilgrim River.

Abundance estimates reported for the rivers apply only to the size ranges indicated and are thought to be unbiased. Age and size composition estimates similarly apply only to the indicated size ranges. These are biased high in relation to the entire Arctic grayling population residing in a given river because small fish were not adequately sampled. Equal probability of capture by size occurred during both sampling events in both the Pilgrim River, however and size selectivity was indicated during the first sampling event on the Snake River. Both samples were used to estimate age and size composition for the Pilgrim River, but only those fish sampled during the second sampling event were used on the Snake River. A combination of beach seine and rod and reel were used to sample fish in both rivers and it is thought that samples represent length ranges of fish present within the reach of each river sampled.

DeCicco (1994) suggested that strong pink salmon returns in Nome area streams during 1992 may have provided a significant additional source of food for resident fish species resulting in increased annual growth increments for Arctic grayling between 326 and 400 mm FL. A similar benefit to the Arctic grayling populations is expected from the large runs of pink salmon which also occurred in 1994. Although some pink salmon are present in all years, large runs have not

Table 5.-Length distribution in 25 mm increments of Arctic grayling >101 mm FL sampled from Seward Peninsula rivers during 1994.

Fork Length (mm)	Snake River Number Sampled	Proportion	SE	Pilgrim River Number Sampled	Proportion	SE	Eldorado River Number Sampled	Proportion	SE
101-125	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
126-150	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
151-175	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
176-200	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000
201-225	1	0.002	0.002	0	0.000	0.000	0	0.000	0.000
226-250	16	0.028	0.007	8	0.048	0.017	0	0.000	0.000
251-275	54	0.094	0.012	12	0.073	0.020	0	0.000	0.000
176-300	57	0.099	0.012	29	0.176	0.030	1	0.015	0.015
301-325	63	0.110	0.013	10	0.061	0.019	0	0.000	0.000
326-350	108	0.188	0.016	17	0.103	0.024	0	0.000	0.000
351-375	120	0.209	0.017	21	0.127	0.026	0	0.000	0.000
376-400	75	0.131	0.014	34	0.206	0.032	5	0.075	0.034
401-425	44	0.077	0.011	18	0.109	0.024	9	0.134	0.045
426-450	23	0.040	0.008	8	0.048	0.017	20	0.299	0.067
451-475	10	0.017	0.005	6	0.036	0.015	17	0.254	0.062
476-500	3	0.005	0.003	2	0.012	0.009	14	0.209	0.056
501-525	0	0.000	0.000	0	0.000	0.000	1	0.015	0.015
Total	574	1.000		165	1.000		67	1.000	

Table 6.-Mean fork length-at-age of Arctic grayling in Seward Peninsula rivers sampled during 1994.

	Snake River 1991-1994			Pilgrim River 1990-1994			Eldorado R.1988, 1993, 1994		
Age	Number of Fish	Fork Length (mm)	Standard Deviation (mm/FL)	Number of Fish	Fork Length (mm)	Standard Deviation (mm/FL)	Number of Fish	Fork Length (mm)	Standard Deviation (mm/FL)
1	29	139	67						
2	14	208	16	7	200	19			
3	156	265	25	127	254	30	3	263	23
4	612	283	30	226	292	29	17	285	6
5	625	320	30	209	326	32	20	326	43
6	639	345	34	249	356	34	16	369	43
7	355	378	37	232	381	37	18	411	28
8	334	407	35	176	405	35	36	437	22
9	220	430	30	149	422	34	38	449	24
10	93	433	23	73	428	31	17	462	17
11	25	447	20	29	435	42	10	458	18
12	5	433	32	4	442	29	4	477	9

occurred in the Nome area since 1984. Skopets and Prokop'yev (1990) found that Arctic grayling in their second year of life had considerably higher growth rates in years of high pink salmon abundances in the Bol'shaya River, Russia. They also found that when strong alternate year runs of pink salmon continued for several cycles, that significant growth differences in the fourth year of life were not found, and proposed that productivity from strong returns of pink salmon carried over to the next year providing an overall increase in productivity of the ecosystem. If strong Nome area pink salmon runs continue in alternate years, it may be found that Arctic grayling populations will show benefits for several successive years. It is suggested that a sample of marked fish be collected from the Snake River in 1995 in order to assess growth in relation to the large pink salmon run of 1994.

Length samples in 1994 were the first which suggested a bimodal length distribution in Arctic grayling populations in both the Snake and Pilgrim rivers. Age data show a strong four year old age class comprising the lower length mode in both streams, however overall population abundance in the index section of the Pilgrim River was the lowest estimated during the last five years of study.

During 1994, 60 Arctic grayling in the Eldorado River were injected with OTC for age validation. It is recommended that we return to this river in 1995 and inject more fish with OTC. This will give us two cohorts of injections, allowing more possible outcomes when the final sample is collected. It will also provide an indication of the proportion of marked fish which we can expect to encounter with we return to collect the final sample.

It is recommended that studies on the Pilgrim River be expanded to encompass the entire upper reach of the river from Salmon Lake through the present index area in order to assess the Arctic grayling population throughout most of the river inhabited by this fish. It is also recommended that assessment of the Snake River Arctic grayling population be terminated. This river should be assessed intermittently every four or five years into the future to detect any negative trends in abundance which may require future regulatory action.

CHAPTER 2: FISHERIES SURVEY OF SALMON LAKE

INTRODUCTION

Salmon Lake (Figure 8) is an oligotrohpic lake with a surface area of 750 ha, a shoreline distance of approximately 24,242 m, and a maximum depth of 40 m. It is located approximately 64 km north of Nome and is the only lake on the Seward Peninsula with road access. The lake has two basins defined by a narrows where Fox Creek enters from the northwest. Its major tributary, the Grand Central River, enters the south end of the lake. Salmon Lake is drained by the Pilgrim River which flows north and then west eventually joining with the Kuzitrin River and flowing into Imuruk Basin. The Nome - Taylor Highway parallels its northwestern shore for approximately 6 km and provides access to the lake outlet where a Bureau of Land Management campground is located.

Salmon Lake has never supported enough sport fishing effort to be included as a separate entry in the Statewide Harvest Survey (Mills 1979 - 1993), and it has been closed to salmon fishing for many years.

Until now, a complete species inventory of Salmon Lake had never been conducted. During July 1969, Ken Alt (ADF&G *Unpublished*) set gillnets in the lake capturing round whitefish *Prosopium cylindraceum*, least cisco *Coregonus sardinella*, Dolly Varden, Arctic grayling and sockeye salmon. I have observed Dolly Varden, sockeye salmon, coho salmon, and round whitefish in the Grand Central River, and Arctic char have been captured in small alpine lakes at the headwaters of this stream (Kretsinger 1987). A single known specimen of Arctic char has been captured in Salmon Lake (McPhail 1961). Anecdotal evidence suggested that northern pike, humpback whitefish *Coregonus pidscian*, burbot and lake trout *Salvelinus namaycush* may occur in the lake. Because of their general distribution throughout the Seward Peninsula, slimy sculpin *Cottus cognatus*, nine spine stickleback *Pungitius pungitius* and Alaska blackfish *Dallia pectoralis* were also thought to occur in Salmon Lake.

Salmon Lake was one of two lakes on the Seward Peninsula named in 1990 as candidates for lake fertilization in the hope of increasing sockeye salmon production in the area. To this end, the first limnological data were collected on the lake in 1994. The Norton Sound Regional Planning Team has recommended that efforts to increase sockeye salmon production in Salmon Lake be undertaken.

This report contains the results of a fisheries survey to estimate species composition and mean gillnet catch per unit of effort (CPUE) by species conducted on Salmon Lake from July 12 to July 15, 1994.

METHODS

Salmon lake was sampled using 38 m variable mesh gillnets with panels of 13 mm, 25 mm, 32 mm, 38 mm, 51 mm and 64 mm bar measure mesh. Nets varied slightly in the order of different mesh panels and only one net contained 38 mm mesh. Each net had five panels of different mesh size. One of the two crews, each with three gillnets, sampled the each of the two basins of the lake. Each crew set two nets from randomly selected sites along the margin of the lake and one net in an off shore location. Nets were checked at approximately 30 min intervals and moved to a new location or reset nearby. In addition, each crew set four baited minnow traps and three baited hoop traps each day. Minnow traps were baited with salmon eggs and hoop traps were

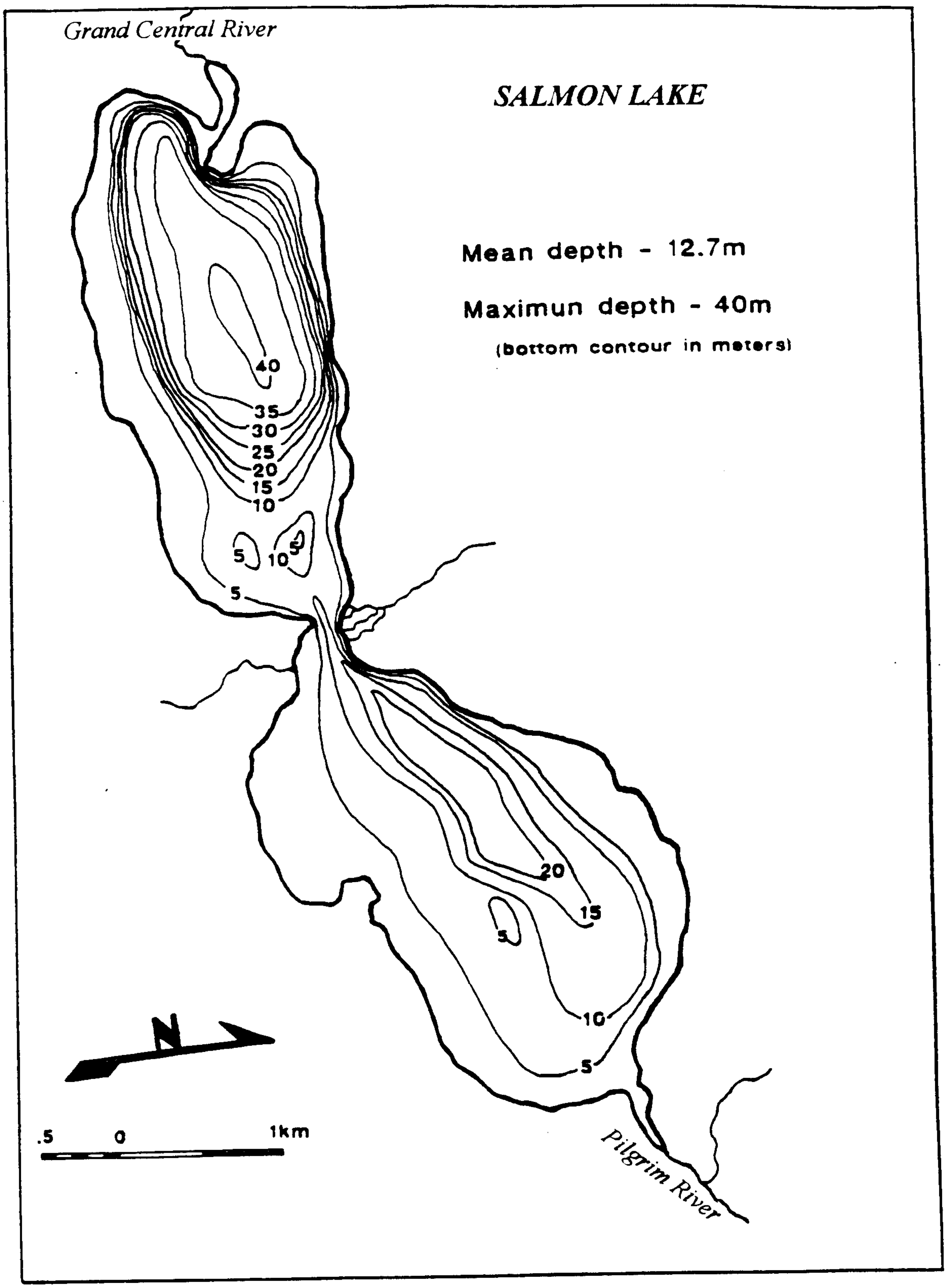

Figure 8.-Salmon Lake with bottom contours.

baited with cut whitefish (sampling mortalities from gillnet catches). Each fish captured was identified (species), measured to the nearest millimeter in fork length (total length for burbot), and weighed to the nearest 25 g using a Chatillion spring scale and a weighing net. The mesh size was recorded in which each fish was captured. Scales were collected for age determination from each live fish returned to the water, and otoliths were collected from all fish killed in gillnets. Each live fish was given a lower caudal fin punch to eliminate the possibility of repeat sampling. Acetate impressions were made from scales and ages were determined as described by Yole (1975). Otoliths were surface read as described by Nordeng (1961). Otoliths were also ground through the focus, burned over an alcohol flame and read in cross section as described by Power (1978).

The unit of effort for catch per unit of effort (CPUE) was standardized to one gillnet fished for a 30 min interval. The actual duration of each set was divided by 30 min to arrive at "units fished". Actual catches were then adjusted by this factor to arrive at CPUE. Median CPUE and 90% confidence limits were computed as described by Zar (1984).

RESULTS

A total of 309 fish of all species were captured using gillnets, hoop traps and minnow traps including 214 ninespine stickleback, 50 round whitefish, 14 least cisco, 14 slimy sculpin, seven Arctic grayling, five Dolly Varden, two sockeye salmon, two coho salmon fry and one burbot.

Ninety eight gillnet sets were fished throughout both basins of the lake (Figure 9). Gillnet catches comprised 25% of the total catch (50 round whitefish, 14 least cisco, seven Arctic grayling, three Dolly Varden adults, and two sockeye salmon adults).

Minnow traps baited with salmon eggs were fished around the margin of the lake and in the lower reaches of two small inlet streams (Figure 10). Minnow trap catches comprised 72% of the total catch (213 ninespine stickleback, five slimy sculpin, two coho salmon fry, and two Dolly Varden juveniles).

Hoop traps baited with cut whitefish were fished in deeper waters of the lake (Figure 10). Hoop traps caught the remaining 3% of the sample (nine slimy sculpin, one ninespine stickleback, and one burbot).

An insufficient number of fish were captured to estimate species composition, however, gillnet catches suggest that round whitefish and least cisco make up the majority of the standing crop of fish in Salmon Lake prior to the arrival of sockeye salmon adults. Minnow trap catches indicate that ninespine stickleback are the most numerous species in the lake, but two traps set near a small inlet stream accounted for 172 stickleback suggesting that this species was not evenly distributed among trapping sites.

Catch per Unit of Effort

The overall CPUE with gillnets (one net fished for 30 min) was very low for all fish species. The median CPUE for all fish was 0.00 with an upper 90% confidence limit of 1.72 fish and a lower limit of 0.00 fish (Table 7). The median CPUE for each species captured was also 0.00 fish with an upper 90% confidence limit of 1.20 for round whitefish; 0.52 for least cisco; and 0.00 for Arctic grayling; Dolly Varden and adult sockeye salmon.

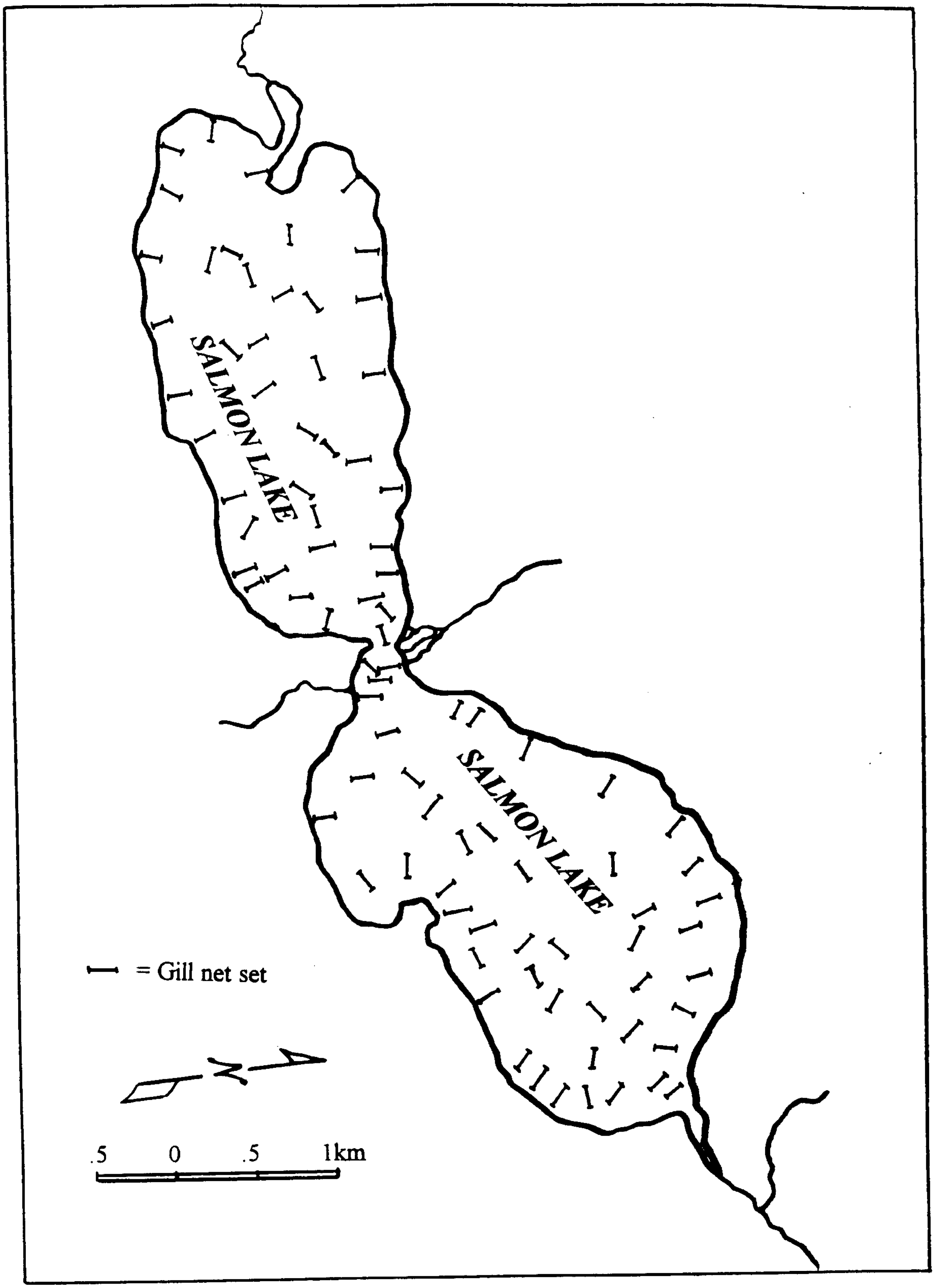

Figure 9.-Salmon Lake showing the location of gillnet sets.

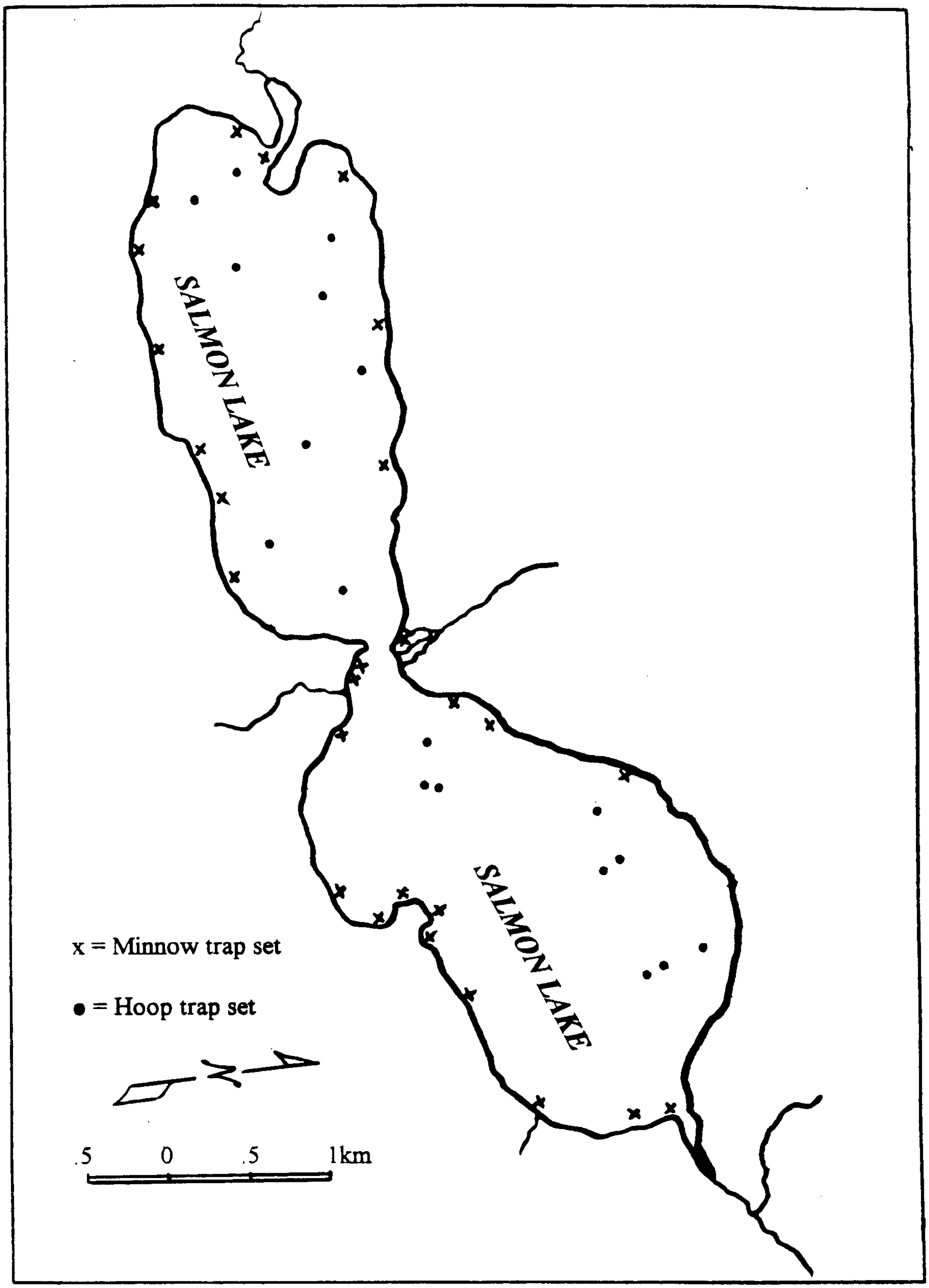

Figure 10.-Salmon Lake showing the location of hoop trap and minnow trap sets.

Table 7.-Median gillnet catches by species in Salmon Lake.

	SPECIES[a]					
Gillnet CPUE	RWF	LCI	AG	DV	SS	Total
Mean	0.35	0.10	0.10	0.02	0.03	0.06
SE	0.65	0.29	0.89	0.01	0.10	1.14
Median	0.00	0.00	0.00	0.00	0.00	0.00
LOWER 90% CI	0.00	0.00	0.00	0.00	0.00	0.00
UPPER 90% CI	1.20	0.52	0.00	0.00	0.00	1.72

[a] RWF = round whitefish, LCI = least cisco, AG = Arctic grayling, DV = Dolly Varden SS = sockeye salmon.

Catches by mesh size varied considerably with 25 mm bar measure mesh catching the most fish (n=38), and 38 mm mesh the next most successful (n=23) (Table 8). The largest mesh (64 mm) caught no fish.

Catches in minnow traps set for 24 h each varied from 0.00 to >100 fish per set. The majority (96%) of the catch was nine-spine stickleback (n=213), the remainder was composed of five slimy sculpin, two juvenile Dolly Varden and two coho salmon fry (the only catches of this species).

Baited hoop trap catches were consistently low. One 24 h set contained four slimy sculpin and one ninespine stickleback, all other sets were either empty or contained one fish. A single burbot, 693 mm TL, was captured in the north basin of the lake, the only example of this species taken.

Biological Data

Fifty round whitefish ranged in length from 279 mm FL to 472 mm FL (mean = 362 mm FL, SE = 41 mm; Figure 11). They ranged in weight from 150 g to 1,150 g (mean = 462 g, SE = 199 g). Scale ages ranged from 6 to 20 years of age. Sectioned and burned otoliths from seven dead round whitefish consistently gave greater ages than scales, ranging from 10 (9 years scale age) to 33 years of age (12 and 14 years scale age). Sectioned and burned otoliths consistently gave older ages than surface-read otoliths. The weight-to-fork length relationship of round whitefish sampled from Salmon Lake was represented by the equation $W = 1X10^{-8} L^{4.1457}$ ($R^2 = 0.93$) (Figure 12).

Least cisco (n = 14) ranged in length from 279 mm FL to 432 mm FL (mean =354 mm FL, SE = 41 mm) (Figure 11). They ranged in weight from 200 g to 725 g (mean = 424 g, SE = 138 g). Scale ages ranged from 7 to 16 years of age. Surface read otoliths gave older ages than scales for two of the three fish from which both structures were obtained, but in only one fish was there a large disparity in otolith and scale ages (16 years scale age vs 31 years surface-read otolith). Sectioned and burned otoliths gave an older age in one of the four fish from which otoliths were obtained (20 years versus 18 years). The surface-read otolith gave an older age by one year in one case (31 years vs 30 years of age), and both readings were the same in the two others (9 and 12 years of age). The weight to fork length relationship for least cisco from Salmon Lake was represented by the equation $W = 1X10^{-5} L^{2.2936}$ ($R^2 = 0.99$) (Figure 13).

Arctic grayling were not numerous in our sample (n = 7); they ranged in length from 212 mm FL to 352 mm FL (mean = 279 mm FL, SE = 44 mm). They ranged in weight from 90 g to 552 g (mean = 285 g, SE = 145 g). Scale ages ranged from 3 to 7 years of age. Otolith ages were not obtained from Arctic grayling.

Ninespine stickleback were the most numerous species captured in Salmon Lake (n = 214). Ninety stickleback ranged in length from 42 mm FL to 66 mm FL (mean = 53 mm FL, SE = 6 mm) (Figure 11). Counts of dorsal spines from 14 ninespine stickleback ranged from 9 to 12 (mean = 10.3, SE = 0.96). Ninespine stickleback were most common in shallow water areas, however, several were taken in hoop traps set at a depth of 40 m. Ages were not determined for ninespine stickleback.

Fourteen slimy sculpin ranged in length from 43 mm TL to 92 mm TL (mean = 61 mm TL, SE = 16 mm) (Figure 11). Slimy sculpin were collected in shallow water areas and in depths to 40 m. Ages were not determined for slimy sculpin.

Table 8.-Number and size of fish caught by different gillnet mesh sizes in Salmon Lake.

		Mesh Size (mm, bar measure)					
		13	25	32	38	51	64
Round Whitefish	Number	3	29	1	16	1	0
	Avg FL	338	350	384	385	384	0
	SE of FL	54	37	0	37	0	0
	Smallest	279	285	384	332	384	0
	Largest	410	468	384	472	384	0
Least Cisco	Number	1	4	4	5	0	0
	Avg FL	380	313	382	360	0	0
	SE of FL	0	27	14	44	0	0
	Smallest	380	279	365	295	0	0
	Largest	380	352	400	431	0	0
Arctic Grayling	Number	1	4	0	2	0	0
	Avg FL	212	271	0	330	0	0
	SE of FL	0	24	0	22	0	0
	Smallest	212	236	0	308	0	0
	Largest	212	305	0	352	0	0

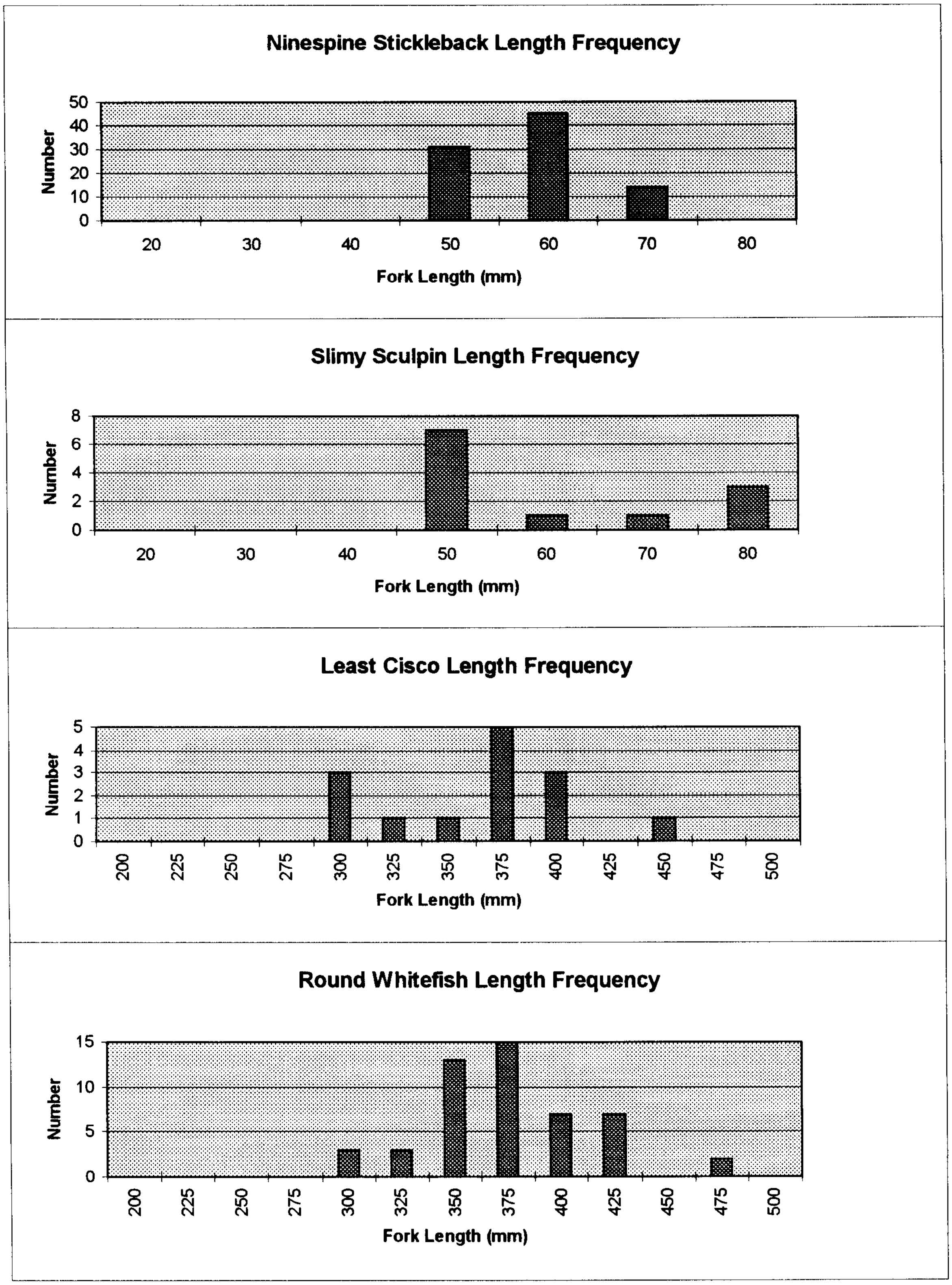

Figure 11.-Length frequencies of fish captured in Salmon Lake.

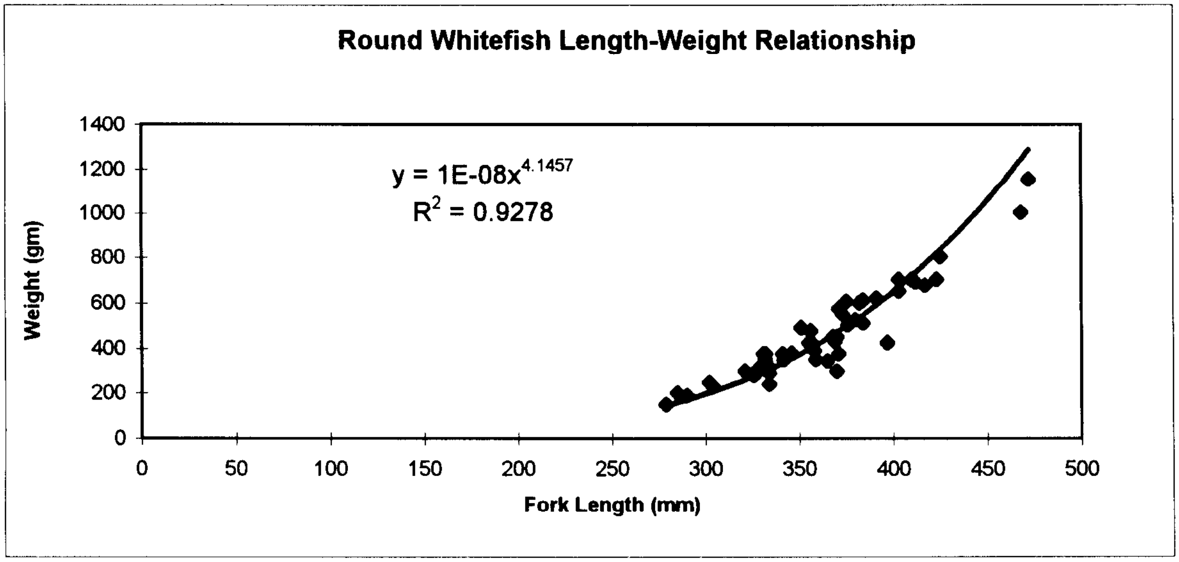

Figure 12.-Length-weight relationship for round whitefish sampled from Salmon Lake.

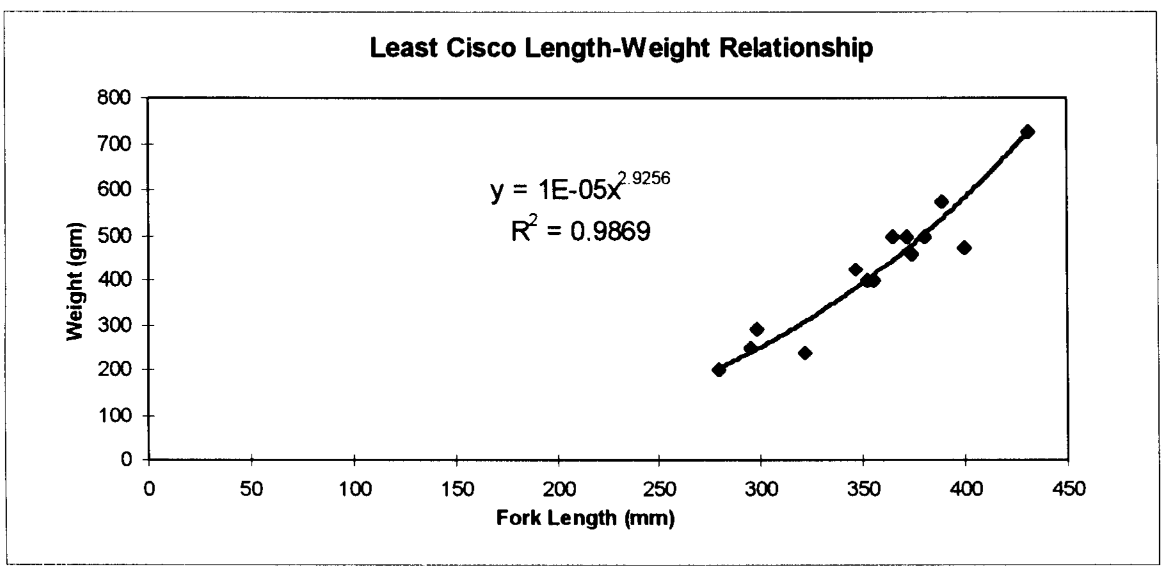

Figure 13.-Length-weight relationship for least cisco sampled from Salmon Lake.

Three adult Dolly Varden were captured ranging in length from 401 mm FL to 583 mm FL. These fish were probably traveling to the Grand Central River where they are known to spawn. Two juvenile Dolly Varden (not measured) were captured in a minnow trap set in the lower reaches of Fox Creek.

Two coho salmon fry (59 mm and 61 mm FL) were captured in a minnow trap at the entrance of a small slough near the mouth of the Grand Central River where coho salmon are known to spawn.

DISCUSSION

Insufficient numbers of fish were sampled in order to estimate proportions of occurrence with any reliability. Based on our catches and catch rates, few fish inhabit Salmon Lake. Both basins of the lake are relatively featureless and the observable bottom was composed primarily of sand and silt. The lake is oligotrophic and very clear. A secchi disk was observable to 11 m on 13 July, water temperatures ranged from 11° C on the surface to 8° C at a depth of 11 m, and dissolved oxygen ranged from 11.7 ppm on the surface to 11.9 ppm at 11 m (Tom Simpson, Alaska Cooperative Fish and Wildlife Unit, University of Alaska, personal communication).

Our survey indicated that ninespine stickleback numerically dominate the fish community of Salmon Lake. They are probably followed in abundance by sockeye salmon fry, but these were not available to our gear. Round whitefish were the most common large sized fish captured, but our net catches indicated that these were present only in low numbers. Least cisco were present, but not common. Very few predatory fish are present in Salmon Lake. Only one burbot was captured, and no pisciverous salmonids other than three adult Dolly Varden were caught. Based on their physical appearance, I believe that the Dolly Varden are not resident in the lake, but were anadromous fish migrating through the lake in order to spawn in the Grand Central River. It was surprising that no resident Arctic char were captured. This species is known to occur in small alpine lakes at the headwaters of the Grand Central River (Kretsinger 1987), and one example of *S. alpinus* has been collected in Salmon Lake (McPhail 1961). Arctic char are known to inhabit highly oligotrophic lakes such as Salmon Lake and are sometimes the only species present (Johnson 1980). This species may be present in Salmon Lake in very low numbers but was not captured in our sampling.

Examination of a small number of otoliths from round whitefish indicated that they gave considerably older ages than were obtained from scales and may be the preferred method for determining age in this species. Sectioned and burned otoliths gave the highest ages because in older fish, calcium layers were deposited as caps on the ventral surfaces of the lower otolith lobes and were not visible when observed from the dorsal surface. This condition has been described for lake whitefish by Power (1978) but has not been noted in round whitefish. Round whitefish to 22 years of age have been captured from the Chandalar River (Craig and Wells 1975) and from Galbraith Lake (J. M. Burr, Alaska Department of Fish and Game, Fairbanks, personal communication). Least cisco otoliths could be surface read successfully, and agreed with both sectioned readings and scales in most cases, but scales of older fish were difficult to interpret. Least cisco from Lake C-62 on Alaska's North Slope have been aged to 20 years using scales (J. M. Burr, Alaska Department of Fish and Game, Fairbanks, personal communication).

The Norton Sound Regional Planning Team has identified Salmon Lake as a candidate for lake fertilization in order to boost production of sockeye salmon. Aerial counts of sockeye salmon escapements into Salmon Lake averaged 591 fish during the 1960's and 1970's (ADF&G 1994). Recently, they have ranged from 413 in 1984 to 4,645 in 1987, and during the 1990's have averaged 3,471 fish. Similar increases have been observed in the Grand Central River where counts have ranged from 30 sockeye in 1984 to 1,520 in 1991. Limnological studies conducted in 1994 and extrapolations from other sockeye producing lakes indicate that if zooplankton biomass could be maintained at 200 mg m^{-2}, Salmon Lake could potentially produce a return of 90,000 adult sockeye (Gary Kyle, Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional limnologist, Memorandum to Tim Linley, Bering Sea Fishermen's Association, November 22, 1994).

ACKNOWLEDGMENTS

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APPENDIX A

Appendix A1.-List of numbered tags and finclips used to mark Arctic grayling from the Pilgrim River in 1994.

Location	Month	No. Fish	Tag Numbers	Color	Fin Clip
Pilgrim River	July	116	55490 - 55605	Green	Lower Caudal

Appendix A2.-Age-length distribution of Arctic grayling sampled from the Snake River in 1994.

	AGE													
Length (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
101-125														
126-150														
151-175														
176-200														
201-225			1											1
226-250			2	12										14
251-275			4	45	1									50
276-300				38	11	4	1							54
301-325				2	9	42	5							58
326-350				1	11	70	13	4						99
351-375				1	18	61	22	5						107
376-400				1	1	25	25	8		2			1	63
401-425						6	10	10	4	5				35
426-450							1	8	7	5				21
451-475								1	4	2				7
476-500								1	1		1			3
501-525														
Total			7	100	51	208	77	37	16	14	1		1	512

Appendix A3.-Age-length distribution of Arctic grayling sampled from the Pilgrim River in 1994.

	AGE													
Length (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
101-125														
126-150														
151-175														
176-200														
201-225														
226-250														
251-275				6	1									7
276-300			2	18	5	2								27
301-325				6	2	1								9
326-350				3	2	7	2							14
351-375				1	5	3	9							18
376-400					3	14	12	2	1	1				33
401-425						1	2	6	4	1	3			17
426-450						1		1	1	2	1			6
451-475								2	2	1	1			6
476-500						1				1				2
501-525														
Total			2	34	18	30	25	11	8	6	5			139

Appendix A4.-Age-length distribution of Arctic grayling sampled from the Eldorado River in 1994.

	AGE													
Length (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
101-125														
126-150														
151-175														
176-200														
201-225														
226-250														
251-275														
276-300				1										1
301-325														
326-350														
351-375														
376-400					1	2	1	1						5
401-425						3	4	1			1			9
426-450							5	7	5	1				18
451-475								6	5	2	2			15
476-500						1		3	2	4	1	1		11
501-525									1					1
Total				1	1	5	10	18	13	7	4	1		60

APPENDIX B

Appendix B1.-Data files used to estimate parameters of Arctic grayling populations on the Seward Peninsula in 1994.

Data File[a]	Description
W012ALA4.DTA	Mark and recapture data for Arctic grayling captured from the Snake River during 1994.
W0060LB4.DTA	Mark and recapture data for Arctic grayling captured from the Pilgrim River during 1994.
W0110LA4.DTA	Data for Arctic grayling captured from the Eldorado River during 1994.

[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.