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Assessment of Selected Stocks of Arctic Grayling in Streams of the Seward Peninsula, Alaska, During 1993

by

Alfred L. DeCicco

July 1994

Alaska Department of Fish and Game

Division of Sport Fish

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ABSTRACT

Stock status of Arctic grayling *Thymallus arcticus* was investigated in the Snake, Nome, Pilgrim and Sinuk rivers of the Seward Peninsula during 1992. Population abundance, age composition, length composition and length-at-age were estimated. Survival rates from 1989 to 1990, from 1990 to 1991, and from 1991 to 1992 were estimated for Arctic grayling in the Sinuk River.

The number of Arctic grayling over 249 millimeters in fork length was estimated at 1,761 fish (SE = 129) in a 48 kilometer section of the Snake River. The density was 37 fish/kilometer. Arctic grayling ranged from 213 to 481 millimeters in fork length and in age from 2 to 12 years.

In a 12 kilometer section of the Pilgrim River, the estimated abundance of Arctic grayling greater than 239 millimeters in fork length was 708 fish (SE = 92) or 59 fish/kilometer. They ranged from 187 to 495 millimeters in fork length and from 2 to 13 years of age.

The estimated abundance of Arctic grayling greater than 324 millimeters fork length in a 40 kilometer section of the Sinuk River just prior to August 1992 was 1,782 fish (SE = 255) or 45 fish/kilometer. Arctic grayling sampled in 1993 ranged from 104 to 521 millimeters in fork length and from 1 to 15 years in age. The modified Jolly - Seber estimate of survival from 1989 to 1990 was 1.00 (SE = 0.06), from 1990 to 1991 was 0.77 (SE = 0.12), and from 1991 to 1992 was 1.00 (SE = 0.23).

In the Snake and Pilgrim rivers more fish (53 and 47 percent) were in the "preferred" Relative Stock Density category, while "memorable" fish comprised 52 percent of the Sinuk River sample in 1992. Mean length-at-age was greatest for Arctic grayling from the Sinuk River and least for fish from the Unalakleet River.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, length composition, growth, Seward Peninsula, Sinuk River, Snake River, Pilgrim River, Eldorado River, Unalakleet River, survival.

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 1992, an average of 16,012 freshwater angler-days of fishing effort occurred in this area (Mills 1981-1993). 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. In 1992, the estimated harvest of Arctic grayling was 492 (Table 1), which is 3.3% of the combined harvest of fish species for the Seward Peninsula-Norton Sound area.

The Seward Peninsula is the only area in Alaska outside of Bristol Bay which regularly produces trophy-sized Arctic grayling. Of 119 Arctic grayling registered with the Alaska Department of Fish and Game (ADF&G) Trophy Fish Program between 1967 and 1991, 30 (25%) were 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 gravel roads which are maintained by the Alaska Department of Transportation and Public Facilities from May through September. These roads originate in Nome and traverse the Seward Peninsula in three general directions (Figure 1). This road system sets Nome apart from most other rural Alaskan communities and provides angler access to many streams on the Seward Peninsula.

Subsistence harvests of river resident fish, although not monitored, have raised concern among local anglers regarding stock status of Arctic grayling. Angler reports indicated that the abundance of large-sized Arctic grayling appeared to be declining in some streams. These concerns 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 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 1978-1980). 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. In addition, 32 anglers were interviewed. 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 1990-1993).

Table 1. Estimated freshwater sport fish harvests for Seward Peninsula and Norton Sound streams, 1980 - 1992. Data from Alaska statewide sport fish harvest survey (Mills 1981 - 1993).

Year	Days Fished	Harvests (Catches) in Number of Fish: 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[a]	18,720	11,227 (24,705)	3,765 (9,118)	1,378 (6,119)	1,957 (4,145)	33 (33)	299 (315)
1991[a]	22,118	8,928 (15,561)	10,365 (25,425)	5,121 (23,160)	1,429 (4,257)	116 (116)	1,357 (1,409)
1992[a]	19,351	11,778 (35,473)	2,178 (5,726)	492 (5,772)	479 (3,742)	0 (0)	46 (165)
Mean	16,012	10,046 (25,246)	5,743 (13,423)	3,828 (11,684)	657 (4,048)	28 (50)	379 (630)

[a] Harvest and (catch) were both estimated.

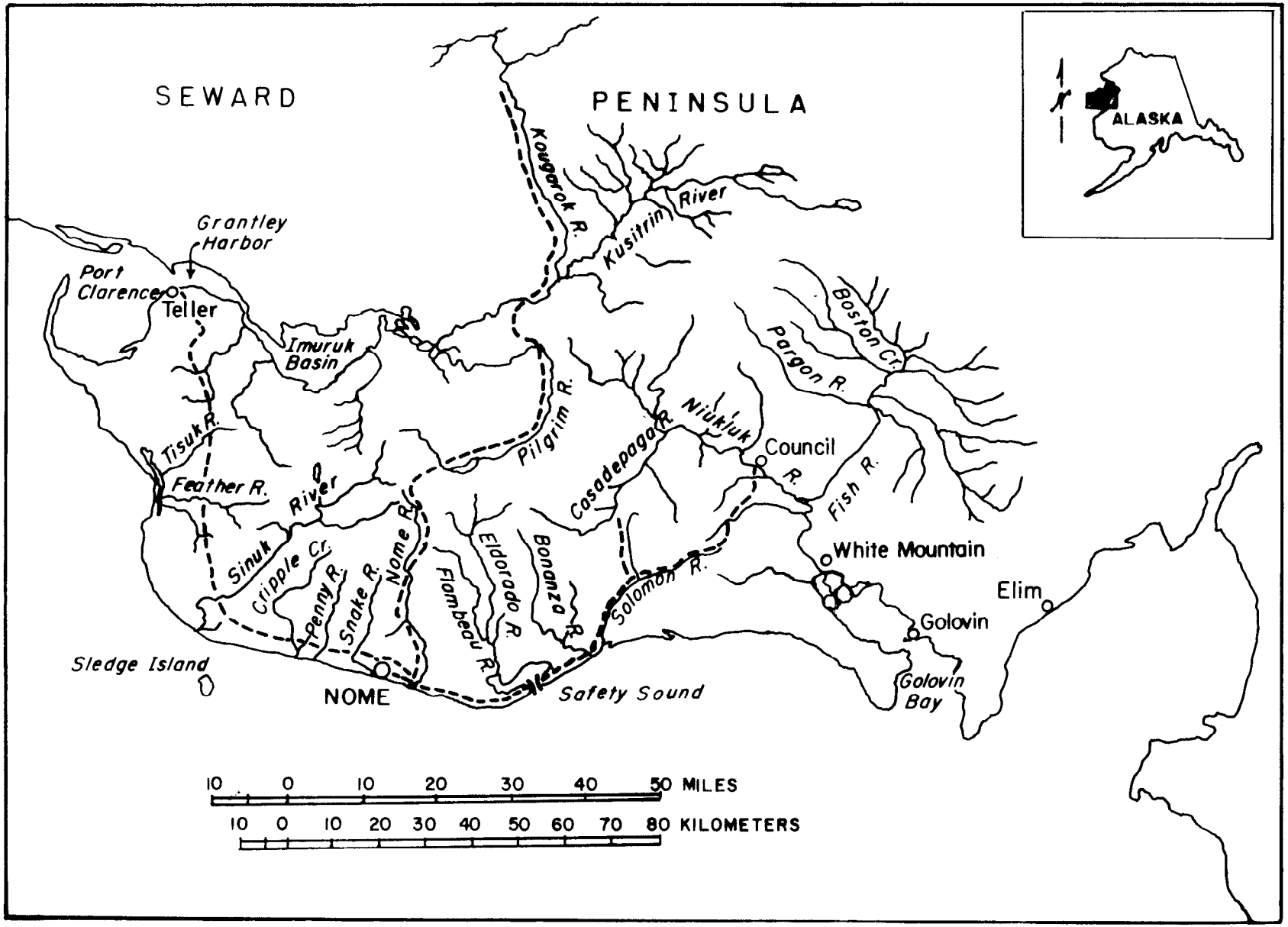

Figure 1. The southern Seward Peninsula showing roads and road accessible waters.

This project is a continuation of the work begun in 1988 by Merritt (1989). Long term goals of the project are:

1. to define sustainable yield for Arctic grayling stocks in Seward Peninsula drainages; and,

2. to achieve sustainable yield sport fisheries for Arctic grayling populations through regulation.

Project objectives in 1993 were to estimate:

1. the abundance of grayling greater than 149 mm FL in a 12 km section of the Pilgrim River downstream of the Beam Road Bridge;

2. the abundance of grayling greater than 149 mm FL in a 48 km section of the Snake River;

3. the age and length composition of grayling in the Snake, Pilgrim, Unalakleet and Eldorado rivers for given fork length ranges; and,

4. the mean length at age of grayling in the Unalakleet, Pilgrim, Eldorado, and Sinuk rivers.

The project tasks for study R-3-2(d) in 1993 were to estimate:

1. the abundance of graying greater than 324 mm FL in a 40 km section of the Sinuk River; and

2. the age and length composition of grayling greater than 324 mm FL in the Sinuk River.

Additionally, estimates of survival from 1991 to 1992 were calculated for the Sinuk River stock, and length-at-age data are presented for a sample of Arctic grayling from the upper Pilgrim River.

METHODS

Sampling Gear and Techniques

Arctic grayling were captured using hook and line in all rivers and using a 50-m x 2-m, 6.5-mm mesh beach seine on the Snake, Pilgrim and Sinuk rivers (Figures 2, 3 and 4). Access to the headwaters of the Sinuk river was gained using a Bell Jet Ranger helicopter under contract to the National Park Service. The river was floated using a 3.8-m Avon Scout inflatable raft and oars.

Each captured Arctic grayling was measured to the nearest mm in FL. Fish over 149 mm FL 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). 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.

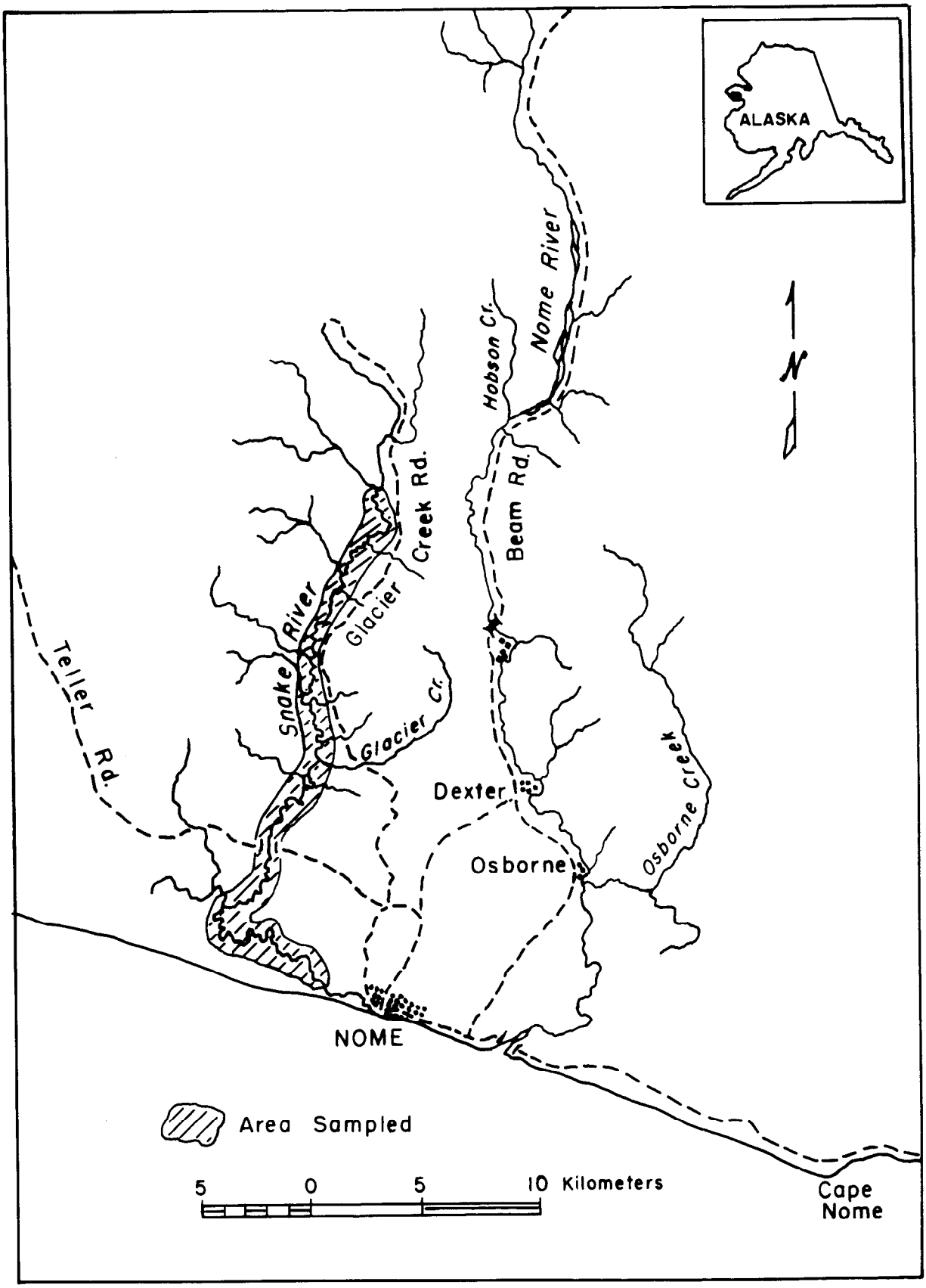

Figure 2. The Snake River with area sampled during 1993.

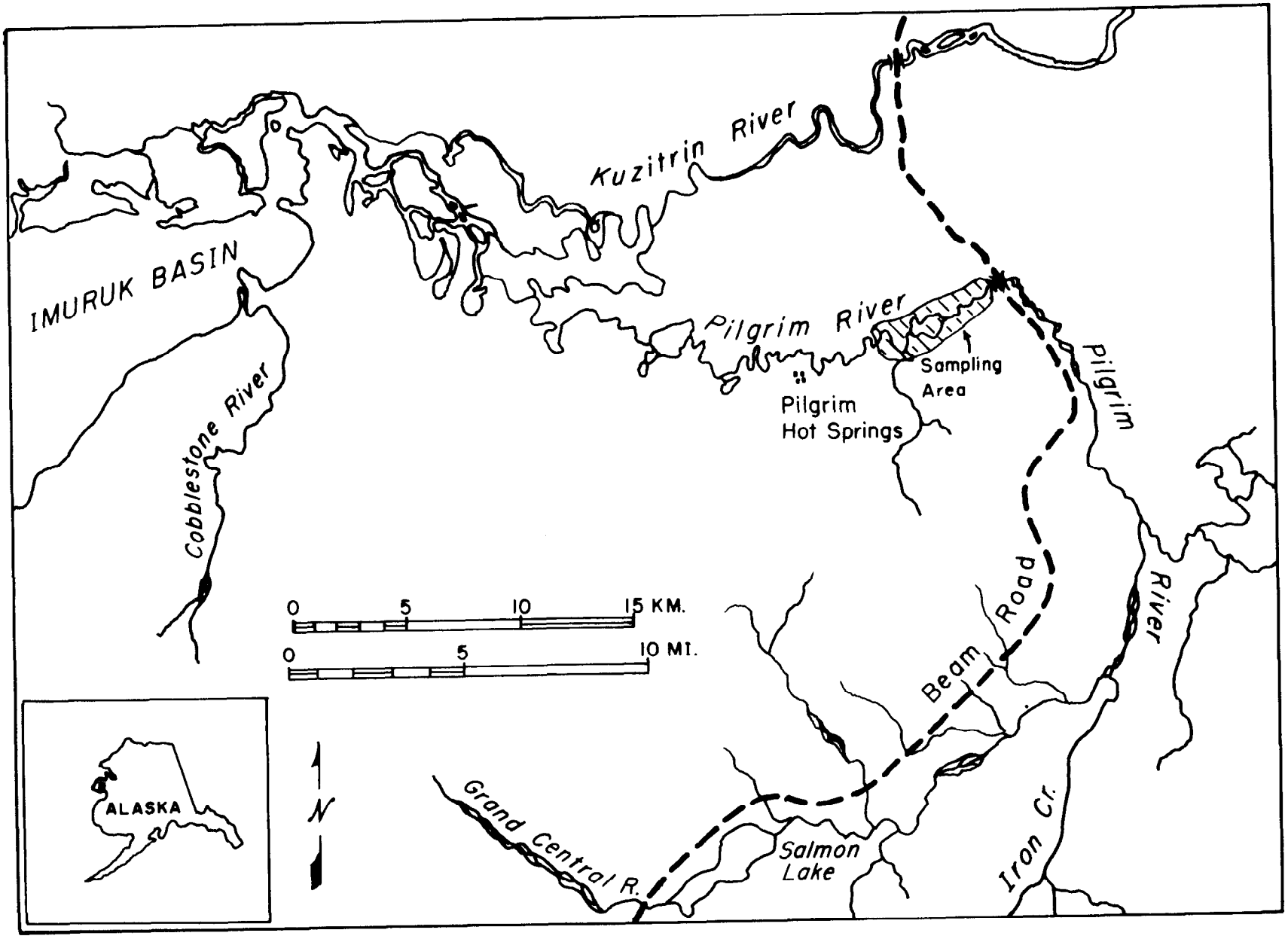

Figure 3. The Pilgrim River with area sampled during 1993.

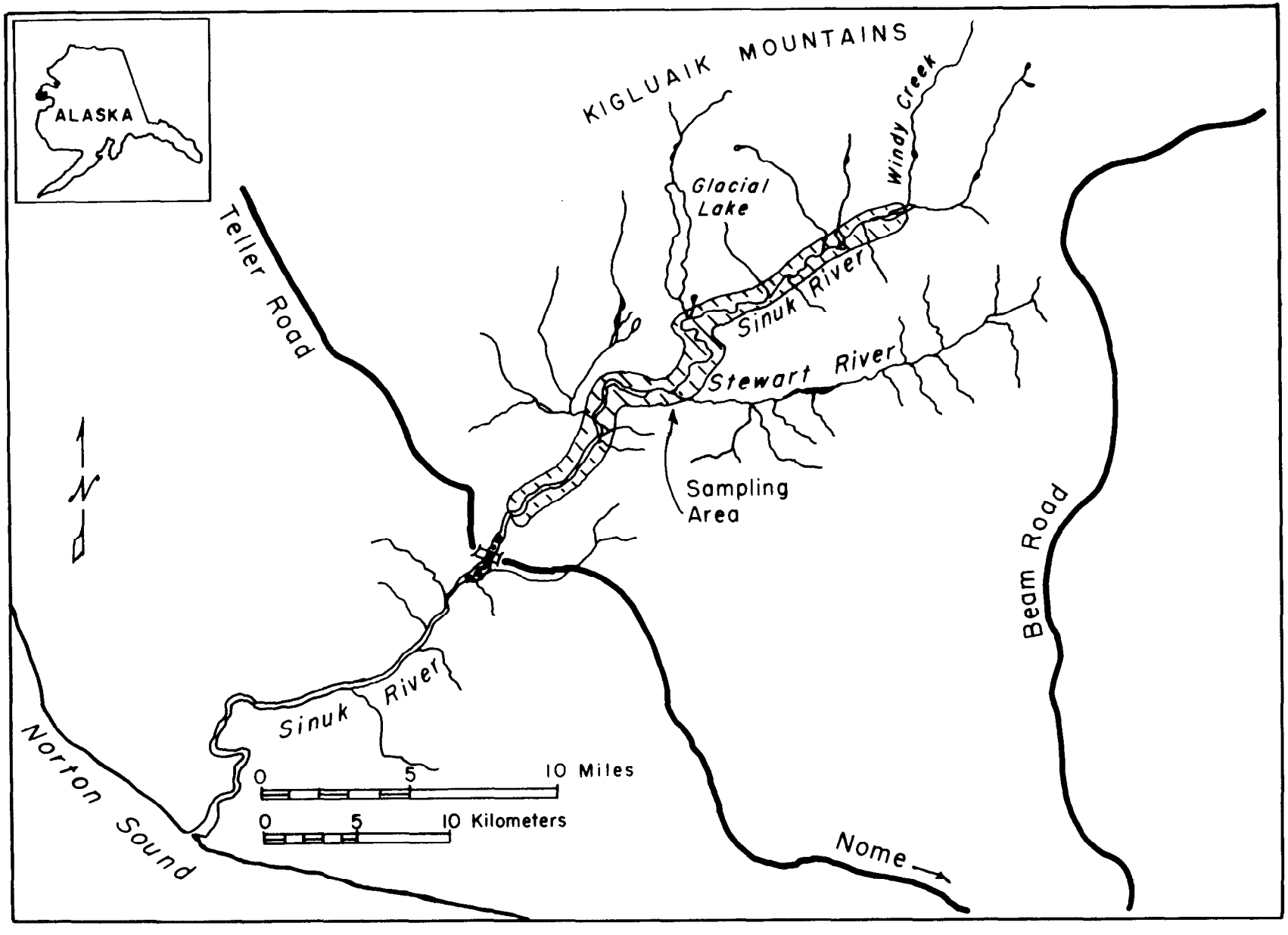

Figure 4. The Sinuk River with area sampled, 1989-1993.

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° C). Ages were determined by counting annuli from the acetate 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). A modified Jolly-Seber model was used to estimate the abundance of Arctic grayling in the study section of the Sinuk River (Figure 4).

Modified Petersen Mark-Recapture Estimates:

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 Appendix A2. All fish were released within the reach of the river in which they were captured. To meet conditions of assumption 4, all fish were double marked with a floy tag and an appropriate finclip (Appendix A1). Finclips 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 and by the presence of the double mark.

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

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

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

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,

$\hat{V}[N]$ = 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. The ratios of the number of recaptured fish to the number of marked fish by river section were also examined with contingency tables. Since the entire reach of the river inhabited by Arctic grayling was sampled, if either test was not significant, an unstratified estimate was used. The single section used for abundance estimation on the Pilgrim River was not divided into subsections.

Modified Jolly-Seber Mark-Recapture Estimates:

The Jolly-Seber model (Jolly 1965; Seber 1965) was used for estimating the abundance of Arctic grayling in the Sinuk River for the years 1990 through 1992; survival from 1989 to 1990, 1990 to 1991, and 1991 to 1992; and recruitment from 1991 to 1992 and 1992 to 1993. The assumptions necessary for accurate estimation of absolute abundance with the generalized Jolly-Seber model are as follows (taken from Seber 1982):

1) every fish in the population has the same probability of capture in the *i*th sample;

2) every marked fish has the same probability of surviving from the *i*th to the (*i* + 1) sample and being in the population at the time of the *i* + 1 sample;

3) every fish caught in the *i*th sample has the same probability of being returned to the population;

4) marked fish do not lose their marks between sampling events and all marks are reported on recovery; and,

5) all samples are instantaneous (sampling time is negligible).

Assumptions 1 and 2 were interrelated because differential vulnerability to sampling gear and changes in survival rate by size (or age) of fish cannot be separately detected. Both assumptions were simultaneously tested with a goodness-of-fit test to the Jolly-Seber model devised by Pollock et al. (1985) and implemented in a modified form in program JOLLY (Pollock et al. 1990). The test is composed of two sets of chi-square tables, the first compares the rate of recapture of fish first captured before the *i*th sample with those first captured in the *i*th sample. The second compares the rate of recapture of fish first captured before the (*i*-1)th sample with those captured in the (*i*-1)th sample. A nonsignificant test statistic would imply that the capture rates were consistent among samples. If the data fit the Jolly-Seber model (failure to reject the null hypothesis of goodness-of-fit), the complete data were used to estimate abundance, survival, and recruitment. If the data did not fit the Jolly-Seber model, probable causes of departure were investigated.

Assumption 3 was assumed to be valid because the number of fish killed while sampling, or released alive without a tag, has been less than 10 fish per year since 1989. Assumption 4 was met by double marking of Arctic grayling with Floy tags and partial fin clips. Assumption 5 was met by restricting each sampling event to 10 days or less, and it is believed that additions and losses to and from the population during each event were negligible.

The Jolly-Seber model parameter estimation procedures for abundance and survival rate were obtained by first calculating the number of Arctic grayling marked in *i*th sample that survived to the (*i*+1)th sample:

$$\hat{M}_i = \frac{R_i \, z_i}{r_i} + m_i, \text{ for } (_i = 1990, 1991, \text{ and } 1992) \qquad (3)$$

where: R_i = the number of marked Arctic grayling released after the ith sample;

z_i = the number of different Arctic grayling caught before the ith sample, not seen during the *i*th sample, but subsequently recaptured;

r_i = the number of Arctic grayling recaptured in years after year i that were released in the ith sample (that is recaptures from R_i); and,

m_i = the number of marked Arctic grayling caught during the ith 1991 sample.

With estimates of M_i, survival rate was calculated from the relation of those surviving to those initially marked and released:

$$\hat{\phi}_i = \frac{\hat{M}_{i+1}}{\hat{M}_i - m_i + R_i}, \text{ for } (i = 1990 \text{ and } 1991) \quad (4)$$

where: R_i = the number of marked Arctic grayling released in the ith year.

Abundance was then calculated by substituting estimated number of marked fish alive for the number of marked fish released in a standard Petersen estimate:

$$\hat{N}_i = \frac{\hat{M}_i \, n_i}{m_i} \quad (5)$$

where: n_i = the number of Arctic grayling caught during the ith sample.

Point estimates of the above parameters were calculated using the program RECAP (Buckland 1980) to estimate the parameters. Buckland's (1980) approach as applied in the program RECAP modifies the standard estimation equations so that parameter estimates fall within possible domain values (e.g. $0 \leq \phi \leq 1$). The program was also used to calculate nonparametric bootstrap (Efron 1982) estimates of the standard errors for the parameters using 400 bootstrap replications.

Minimizing Length Bias:

Few small fish were marked and examined in most rivers. In order to minimize bias in estimates of small fish, the length of the smallest recaptured fish was used as a guideline for the minimum size for which the estimate would apply. Relative Stock Density indices (RSD; Gabelhouse 1984) were used for size composition categories (see section on size composition) and when the smallest recaptured fish was close to a minimum RSD length category, that minimum RSD category size was chosen as the lower bound for the estimate. This allowed a minimum of bias to be introduced into estimates of small sized fish yet allowed complete (or nearly complete) representation in the smallest category for size composition estimates. Kolmgorov-Smirnov two sample tests were then run for those lengths of fish and the methods previously outlined were followed in the analyses.

Age Composition

Arctic grayling were collected and sampled to estimate age composition in conjunction with the abundance estimate experiments conducted on the Snake, Pilgrim, and Sinuk rivers. The proportions of fish in each age category were estimated as multinomial proportions (Cochran 1977).

The proportion in each category was estimated as:

$$\hat{p}_j = \frac{n_j}{n} \quad (6)$$

where:

n_j = the number in the sample from group j;

n = the sample size; and,

p_j = the estimated fraction of the population that is made up of group j.

The unbiased variance of this proportion was estimated as:

$$\hat{V}[p_j] = \frac{\hat{p}_j(1-\hat{p}_j)}{n - 1} \quad (7)$$

Abundance of Arctic grayling by age was estimated as follows:

$$\hat{N}_j = \hat{p}_j(\hat{N}); \quad (8)$$

where:

$\hat{N}_j$ = estimated number of fish in age category j;

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

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

Variances for Equation 4 were estimated using Goodman's (1960) formula:

$$\hat{V}[\hat{N}_j] = (\hat{p}_j^2\hat{V}[\hat{N}])+(\hat{N}^2\hat{V}[\hat{p}_j])-(\hat{V}[\hat{p}_j]\hat{V}[\hat{N}]); \quad (9)$$

where:

$\hat{V}[N]$ was obtained from the mark recapture analyses.

Length Composition

Length composition of Arctic grayling residing in the Snake, Pilgrim and Sinuk rivers was estimated as RSD categories. 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 RSD

categories followed the same procedures used for age composition (equations 6 and 7). Abundance estimates by RSD category were calculated using equations 8 and 9.

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 normal procedures.

RESULTS

Population Abundance Estimates

The abundance of Arctic grayling in 1993 was estimated in the Snake River and an index section of the Pilgrim River. An abundance estimate germane to 1992 and updated abundance estimates for 1990 and 1991 were calculated for Arctic grayling residing in the Sinuk River.

Snake River:

The marking run 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 essentially the entire river was sampled, the possibility that fish would leave the sampling area 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 with the desired precision. The smallest of 447 Arctic grayling marked was 222 mm FL and the smallest of 566 Arctic grayling examined in the second event was 213 mm FL. The smallest marked fish recaptured in the second event was 262 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.

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 1,761 fish (SE = 129 fish, CV = 7.3%). A total of 441 Arctic grayling greater than 249 mm FL were marked during the first sampling event (29 June to 3 July). During the recapture event (12 to 16 July), 554 Arctic grayling greater than 249 mm FL were examined of which 138 had tags from the marking event. One fish (<1%) had lost its tag from the first event. However, 31 fish out of 95 fish (33%) originally marked in 1991, 15 out of 180 fish (8.3%) and one fish originally marked in 1988 had lost their tags. 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 = 18.64, df = 3, $P < 0.005$), for the four sections. A lower number of fish marked in section 1 and 4 were recaptured than expected, and higher than expected numbers of fish were

recaptured in sections 2 and 3, very similar to data from 1992. However when the numbers of recaptured fish were compared to the numbers of marked fish by river section the probabilities of recapturing fish in relation to having marked them was not found to be different (χ^2 = 2.18, df = 3, 0.50 < P < 0.75). These tests suggest that even though fish moved toward the middle sections of the river between events, the capture probabilities during the second event were similar to those of the first event.

Kolmogorov-Smirnov two sample tests of the cumulative length distributions of Arctic grayling greater than 249 mm FL marked versus those recaptured during the recapture event (test 1) and of those captured during the marking event versus those examined in the recapture event (test 2) did not detect significant differences (test 1: D = 0.12, P = 0.10, n_1 = 441, n_2 = 138; test 2: D = 0.07, P = 0.21, n_1 = 441, n_2 = 554; Figure 5). Therefore, a single unstratified abundance estimate was calculated for Arctic grayling greater than 249 mm FL and fish from both samples were used to estimate age and length composition, and for length at age analysis (Appendix A3).

Pilgrim River:

The marking run 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. Beach seine and hook and line gear were used in combination to capture fish. The smallest of 196 Arctic grayling marked was 187 mm FL and the smallest of 193 Arctic grayling examined during the second event was 180 mm FL. The smallest marked fish recaptured from the Pilgrim River was 241 mm FL. The abundance estimate for the Pilgrim River was calculated for Arctic grayling > 239 mm FL.

In the 12 km section of the Pilgrim River downstream from the Beam Road bridge, the estimated abundance of Arctic grayling greater than 239 mm FL was 708 fish (SE = 92 fish, CV = 13%). A total of 173 Arctic grayling greater than 239 mm FL were marked during the first event (19 to 22 July). During the recapture event (26 to 29 July), 179 Arctic grayling (> 239 mm FL) were examined of which 43 had tags from the marking event. One tag loss from the first tagging event was detected. Of 32 fish originally marked in 1992 none had lost their tags while five of 34 fish originally marked in 1991 (14.7%) had lost their tags. No tag losses were found in the three fish originally marked in 1990, and three of five fish originally marked in 1988 (60%) had lost tags. One fish was killed during sampling during 1993.

Kolmogorov-Smirnov two sample tests of the cumulative length distributions of Arctic grayling greater than 239 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 = 0.09, P = 0.94, n_1 = 173, n_2 = 43; test 2: D = 0.07, P = 0.71, n_1 = 173, n_2 = 179; Figure 6). A single unstratified abundance estimate was calculated for Arctic grayling greater than 239 mm FL and fish from both samples were used to estimate age and length composition.

The upper Pilgrim River, from Salmon Lake to the Kugarok Road Bridge was also sampled during a river float in 1993. Arctic grayling were found throughout this section of the river and this sample was combined with the mark-recapture sample for the age-length distribution (Appendix A4).

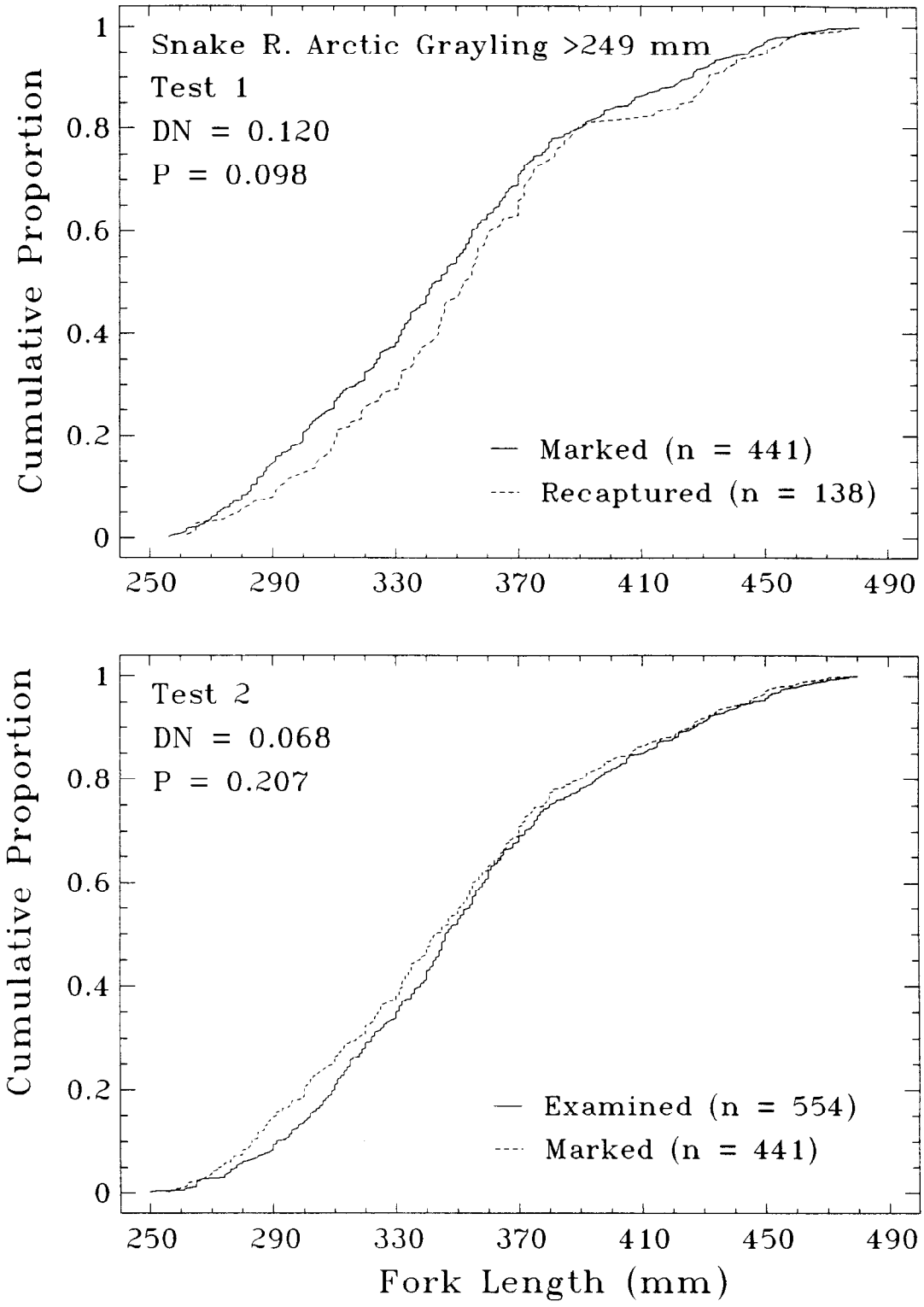

Figure 5. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >249 mm FL sampled from the Snake River in 1993.

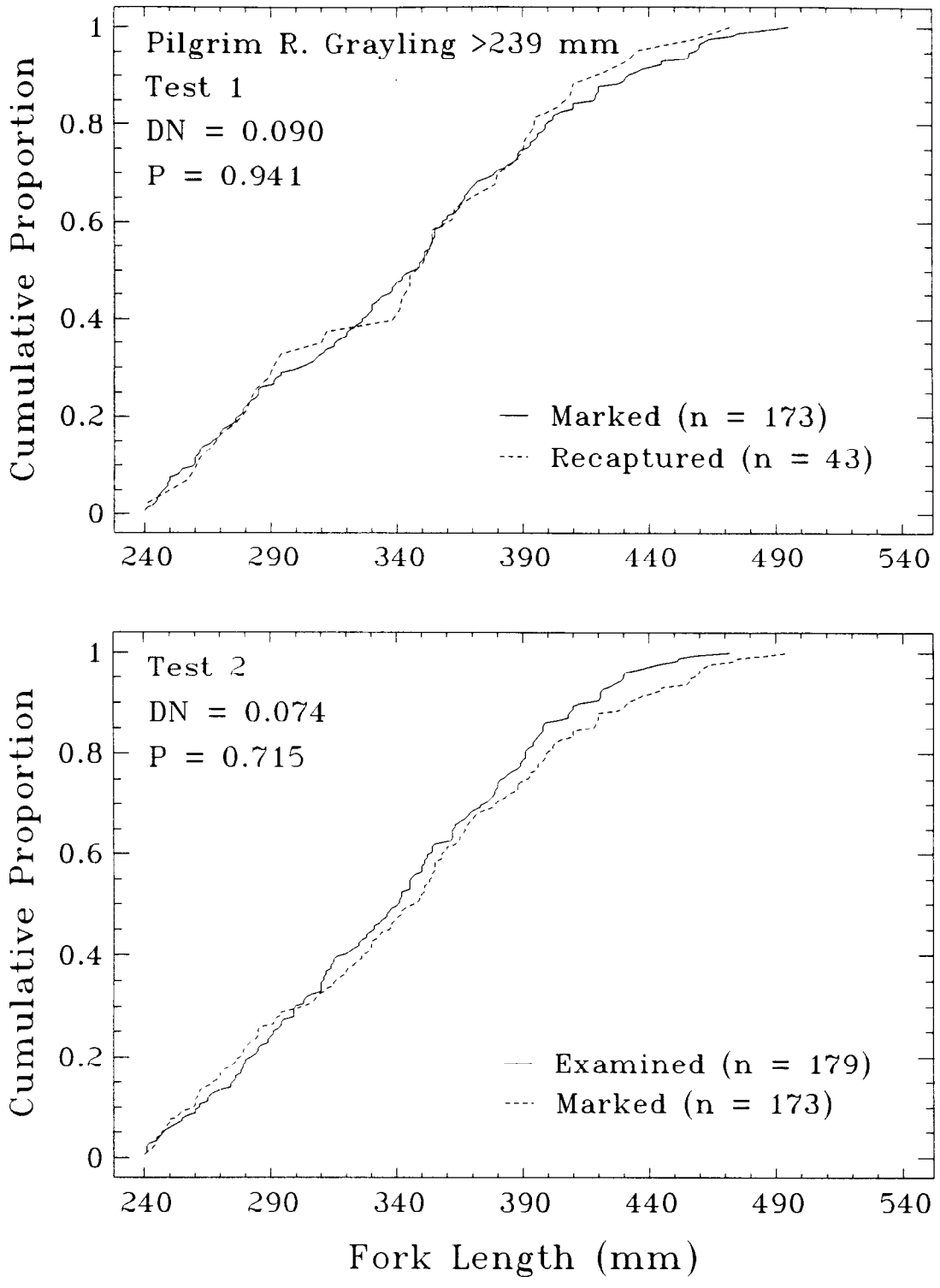

Figure 6. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >239 mm FL sampled from the Pilgrim River in 1993.

Sinuk River:

The Sinuk River (Figure 5) was floated during seven days in August to collect Arctic grayling for a Jolly-Seber population abundance estimate germane to 1992. Updated abundance estimates were also calculated for 1990 and 1991 (Appendix A5). Hook and line gear was used to capture 182 Arctic grayling of which four were captured last in 1992, 12 were captured last in 1991, eight were last captured in 1990, and two were last captured in 1989 (Appendix A6). A slightly significant test statistic ($\chi^2 = 4.099$, df = 1, P = 0.0429) in the first component test, indicated some dissimilarity in capture probabilities in 1991 (Table 2). However, the overall test statistic from the second test formulation was not significant ($\chi^2 = 5.417$, df = 5, P = 0.3672) suggesting that this shortcoming is only of minimal concern (Appendix A7), and that program RECAP was appropriate for this analysis. The smallest Arctic grayling recaptured in 1991 at time of marking in 1989 or 1990 was 325 mm FL. The abundance estimate germane to 1990 was therefore calculated for fish > 324 mm FL. In order for abundances to be comparable across years, abundance estimates for 1991 and 1992 were also calculated for fish > 324 mm FL.

The abundance of Arctic grayling greater than 324 mm FL in the 40 km section of the Sinuk River just prior to August 1992, estimated from data collected during 1989-1993 was 1,782 fish (SE = 255, CV = 14.3%). Unadjusted and modified estimates using bootstrapping in order to bring ϕ (survival) to 1.0 were calculated. The unadjusted model produced an unrealistic value of survival, so the modified bootstrapped estimate was chosen. The updated estimates of abundance for Arctic grayling greater than 324 mm FL were 1,290 fish (SE = 186, CV = 14.4%) in 1990, and 1,114 fish (SE = 198, CV = 17.8%) in 1991. The updated estimates of survival were 1.0 (SE = 0.0585, CV = 5.9%) for 1989 to 1990, 0.77 (SE = 0.1191, CV = 15.4%) for 1990 to 1991, 1.0 (SE = 0.0225, CV = 2.2%) for 1991 to 1992. The updated estimates of recruitment were 115 fish (SE = 165, CV = 143.5%) for 1991, and 671 fish (SE = 221, CV = 32.9%) for 1992 (Appendix A5).

The 1992 sample of Arctic grayling > 324 mm FL was used to estimate age and length composition for that year, and data from the 1993 sample are also presented (Appendix A8).

Age Composition

Although Arctic grayling sampled during 1993 ranged from age-2 fish collected from the Pilgrim River to age-14 fish collected from the Sinuk River, estimates of age composition and abundance by age class were restricted to fish larger than 249 mm FL on the Snake River, fish larger than 239 mm FL from the Pilgrim River, and fish larger than 324 mm FL from the Sinuk River in 1992 (Table 3). Age-5 and 6 Arctic grayling comprised 57% of the population in the Snake River in 1993 (Figure 7). The numbers of fish in each age class from age-6 through age-11+ from the Snake and Pilgrim rivers (rivers for which estimates were germane to about the same length ranges) were compared and found to be significantly different ($v^2 = 43.36$, df = 6, P <0.001). Most of the differences were in age-6 fish and age-10 and older fish. Age-6 fish were more abundant than expected in the Pilgrim River and less than expected in the Snake River. Age-10 and older fish were likewise more abundant than expected in the Pilgrim River and less abundant than expected in the Snake River.

Table 2. Goodness-of-fit tests of capture-recapture data from Arctic grayling (> 324 mm FL) in the Sinuk River to the Jolly-Seber model with death and immigration, 1989 - 1993.

Year of sampling (i)	Component 1[a]			Component 2[b]		
	χ^2	df	P	χ^2	df	P
1990	0.433	1	0.510	---	---	---
1991	4.099	1	0.043	0.483	2	0.785
1992	0.000	0	1.000	0.401	1	0.526
Totals	4.533	2	0.104	0.884	3	0.829
Overall	5.417	5	0.367	(Components 1 and 2)		

[a] Component 1 compares the frequency of first captures before the year of sampling ($<i$) with first captures from the year of sampling (i), stratified by whether these fish were subsequently recaptured versus not recaptured after the year of sampling (Pollock et al. 1985, 1990).

[b] Component 2 compares the frequency of first captures before the year i-1 ($<i$-1) that were not subsequently captured in year i-1, with those subsequently captured in year i-1; and, with those first captured in year i-1, stratified by whether these fish were captured in year i or they were not captured in year i, but captured after year i (Pollock et al. 1985, 1990).

Table 3. Estimates of age composition and abundance of Arctic grayling in the Snake and Pilgrim rivers in 1993 and in the Sinuk River in 1992.

Statistic	Age 2	3	4	5	6	7	8	9	10	11	12	13+	Totals
Snake R. (fish >249 mm FL)													
Sample Size	---	18	30	267	290	129	86	59	21	10	1	0	911
Est. Proportion	---	0.02	0.03	0.29	0.32	0.14	0.09	0.06	0.02	0.01	<0.01	0.00	1.00
SE of Proportion	---	<0.01	<0.01	0.02	0.02	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.00	
Est. Abundance	---	35	58	516	561	249	166	114	41	19	2	0	1,761
SE of Abundance	---	8	11	46	49	27	21	17	9	6	2	0	129
Pilgrim R. (fish >239 mm FL)													
Sample Size	---	38	45	78	44	24	18	19	15	8	6	1	296
Est. Proportion	---	0.13	0.15	0.26	0.15	0.08	0.06	0.06	0.05	0.03	0.02	<0.01	1.00
SE of Proportion	---	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.01	<0.01	<0.01	
Est. Abundance	---	91	108	187	105	57	43	45	36	19	14	2	708
SE of Abundance	---	18	20	30	20	13	11	12	10	7	6	2	92
Sinuk R. 1992 (fish >324 mm FL)													
Sample Size	---	0	7	18	8	21	43	44	20	11	0	1	173
Est. Proportion	---	0.01	0.04	0.10	0.05	0.12	0.25	0.25	0.12	0.06	0.00	<0.01	1.00
SE of Proportion	---	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.00	<0.01	
Est. Abundance	---	0	72	72	82	216	442	453	206	113	0	10	1,782
SE of Abundance	---	0	28	28	49	54	86	87	52	37	0	10	255

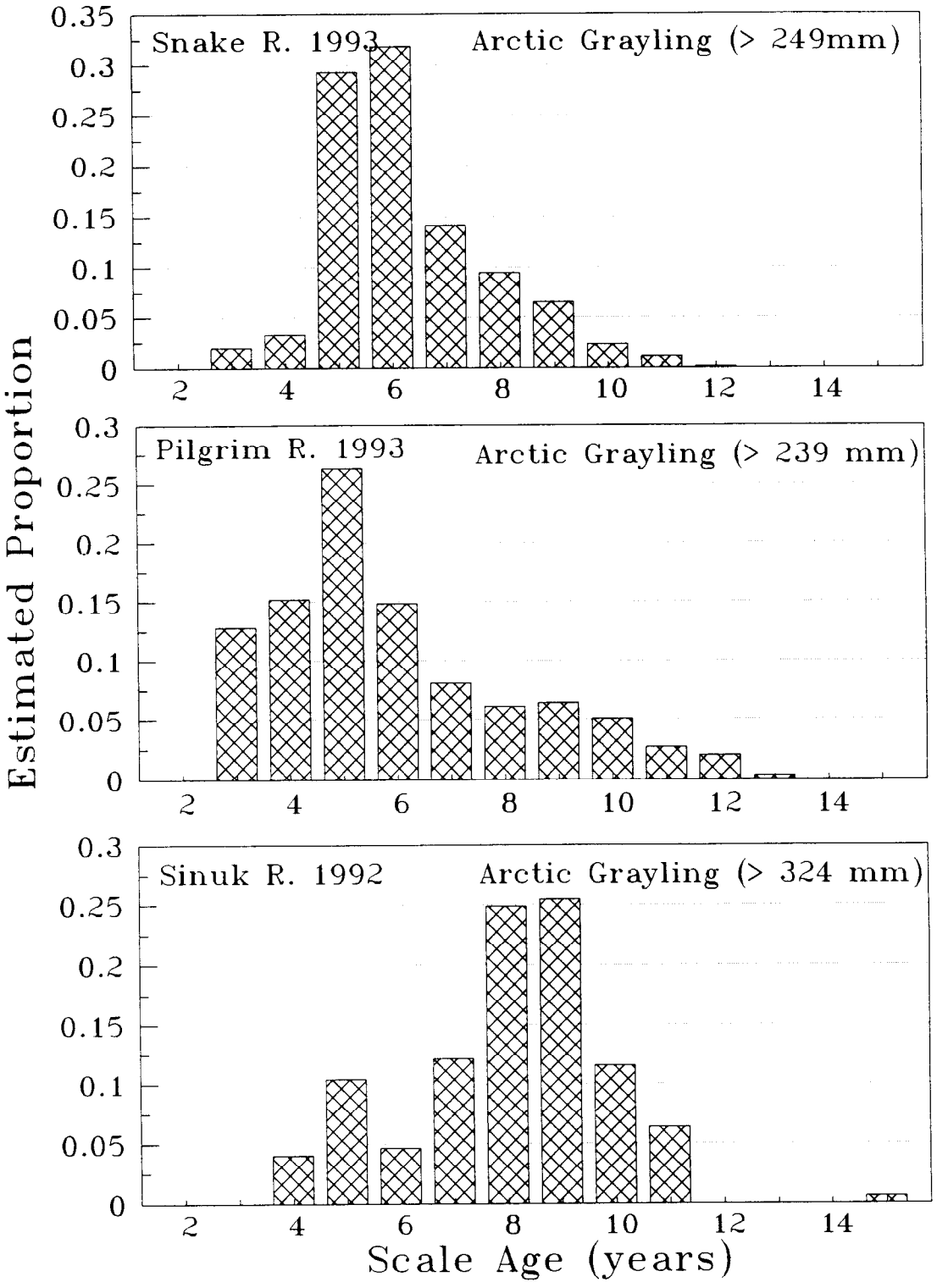

Figure 7. Age composition estimates of Arctic grayling from the Snake and Pilgrim rivers during 1993 and from the Sinuk River during 1992.

Arctic grayling aged 5, 6 or 7 comprised 57.6% of fish sampled from the Sinuk River in 1993 with age-5 fish being the most abundant. This is a shift from previous years when fish of age-7, 8 or 9 were most abundant. Higher proportions of Arctic grayling aged 10 years and older were found in the Sinuk River (12.9% in 1990, 20.3% in 1991, 15% in 1992, 19.2% in 1993) than in either the Snake (3.2%) or the Pilgrim (8.7%) rivers. As determined from scales, the oldest Arctic grayling sampled during 1993 were 12 years from the Snake River, 13 years from the Pilgrim River, and 14 years from the Sinuk River. Arctic grayling from the Unalakleet and the Eldorado rivers were also sampled for age in 1993 (Appendices A9 and A10). Unalakleet River Arctic grayling ranged in age to 13 years with ages 8 (20.4%) and 9 (24.2%) most strongly represented in the sample. Eldorado River Arctic grayling 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 as RSD categories (Figure 8). The majority of Arctic grayling sampled from all rivers were in the preferred or memorable categories (Table 4). Comparable data gathered from the Snake and Pilgrim rivers indicated that RSD's were not significantly different (χ^2 = 0.72, df = 2, 0.75> P >0.50). Arctic grayling in the preferred category comprised 53%, and 47% of the respective size compositions in the Snake and Pilgrim rivers in 1993. Memorable fish were weakly represented (4.2% and 4.6%) in the same rivers. Preferred and memorable fish comprised 42% and 53% of the estimated size composition of Arctic grayling >324mm FL in the Sinuk River in 1992. No fish in the trophy category were encountered in any river. Only small proportions of stock size and smaller Arctic grayling were captured in the Snake and Pilgrim rivers. The Arctic grayling sample from the Sinuk River during 1993 was composed of 1% stock, 9% quality, 62% preferred and 29% memorable. This is quite different from the 1992 sample which was composed of 2% stock, 17% quality, 35% preferred, and 45% memorable fish (χ^2 = 31.29, df = 3, p <0.01). Examination of size distribution of all Arctic grayling >101 mm FL sampled during 1992 (Table 5) shows that the majority of Arctic grayling sampled from some rivers represent limited length ranges. In the Snake River 55% of the Arctic grayling were between 301 and 375 mm FL while 72% of those sampled from the Unalakleet River were between 351 and 399 mm FL. Arctic grayling in Eldorado and Sinuk rivers were large with 87% and 53% being greater than 400 mm FL (Figure 8).

Mean Length-at-Age

Estimates of mean fork length-at-age were calculated for Arctic grayling sampled from the Snake, Pilgrim, Sinuk, Eldorado and Unalakleet rivers (Table 6). When data were available, they were combined across years. Arctic grayling in all rivers were approximately the same length at age through age 3 after which fish from the Sinuk River were larger at most age classes. Increases in mean fork length of Arctic grayling from the Sinuk River was very rapid through age 7, the probable age at first maturity for fish from that river. At age 8 and older, average annual increase in length was small. A similar pattern of length increase occurred in the Eldorado River with a slowing in annual growth at age 9. Fish sampled from the Snake, Pilgrim, and Unalakleet rivers continued to increase in fork length at older ages. Age and

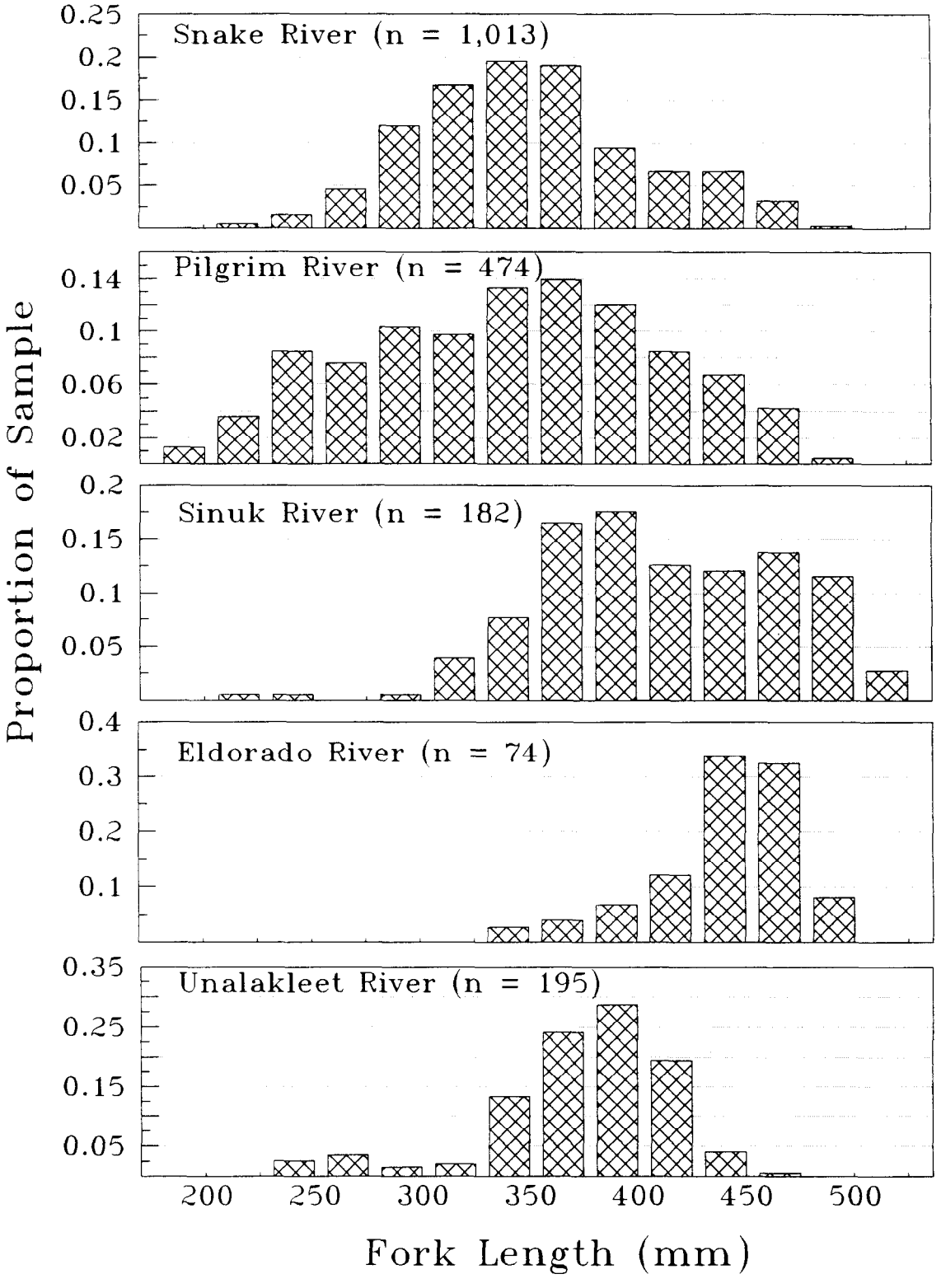

Figure 8. Length distributions in 25 mm increments of Arctic grayling sampled from the Snake, Pilgrim, Sinuk, Eldorado and Unalakleet rivers in 1993.

Table 4. Number and proportion of Arctic grayling sampled and estimated abundances by RSD category in the Snake and Pilgrim rivers during 1993 and the Sinuk River during 1992.

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
Snake River (fish >249 mm FL)					
Number sampled	30[b]	399	522	42	0
RSD	0.03	0.40	0.53	0.04	0.00
Standard Error	0.01	0.02	0.02	0.01	0.00
Abundance	53	708	926	74	0
Standard Error	10	58	73	12	0
Pilgrim River (fish >239 mm FL)					
Number sampled	50[c]	119	167	16	0
RSD	0.14	0.34	0.47	0.05	0.00
Standard Error	0.02	0.03	0.03	0.01	0.00
Abundance	101	239	336	32	0
Standard Error	18	36	47	9	0
Sinuk River 1992 (fish >324 mm FL)					
Number sampled	---	10	78	95	0
RSD	---	0.05	0.43	0.52	0.00
Standard Error	---	0.02	0.04	0.04	0.00
Abundance	---	97	760	925	0
Standard Error	---	33	126	148	0

[a] Minimum lengths for RSD categories (Gabelhouse 1984) are: stock 150 mm FL; quality - 270 mm FL; preferred - 340 mm FL; memorable - 450 mm FL; and, trophy - 560 mm FL.

[b] Estimate is only for fish >249 mm FL and <270 mm FL.

[c] Estimate is only for fish >239 mm FL and <270 mm FL.

Table 5. Length distribution in 25 mm increments of Arctic grayling >101 mm fork length sampled from Seward Peninsula rivers during 1993.

Fork Length Range (mm)	Snake River Sampled Fish	Snake River Proportion	Snake River SE	Pilgrim River Sampled Fish	Pilgrim River Proportion	Pilgrim River SE	Unalakleet River Sampled Fish	Unalakleet River Proportion	Unalakleet River SE	Sinuk River Sampled Fish	Sinuk River Proportion	Sinuk River SE	Eldorado River Sampled Fish	Eldorado River Proportion	Eldorado River SE
101 - 125	0	0.000	0.000	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	0	0.000	0.000			
151 - 175	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000			
176 - 200	0	0.000	0.000	6	0.013	0.005	0	0.000	0.000	0	0.000	0.000			
201 - 225	5	0.005	0.002	17	0.036	0.009	0	0.000	0.000	1	0.005	0.005	0	0	0
226 - 250	16	0.016	0.004	40	0.084	0.013	5	0.026	0.011	1	0.005	0.005	0	0	0
251 - 275	46	0.045	0.007	36	0.076	0.012	7	0.036	0.013	0	0.000	0.000	0	0	0
276 - 300	121	0.119	0.010	49	0.103	0.014	3	0.015	0.009	1	0.005	0.005	0	0	0
301 - 325	169	0.167	0.012	46	0.097	0.014	4	0.021	0.010	7	0.038	0.014	0	0	0
326 - 350	198	0.195	0.012	63	0.133	0.016	26	0.133	0.024	14	0.077	0.020	2	0.027	0.019
351 - 375	192	0.190	0.012	66	0.139	0.016	47	0.241	0.031	30	0.165	0.028	3	0.040	0.023
376 - 400	96	0.095	0.009	57	0.120	0.015	56	0.287	0.032	32	0.176	0.028	5	0.067	0.029
401 - 425	67	0.066	0.008	40	0.084	0.013	38	0.195	0.028	23	0.126	0.025	9	0.121	0.038
426 - 450	67	0.066	0.008	32	0.068	0.012	8	0.041	0.014	22	0.121	0.024	25	0.337	0.055
451 - 475	33	0.033	0.006	20	0.042	0.010	1	0.005	0.005	25	0.137	0.026	24	0.324	0.055
476 - 500	3	0.003	0.002	2	0.004	0.003	0	0.000	0.000	21	0.115	0.024	6	0.081	0.032
501 - 525							0	0.000	0.000	5	0.027	0.012	0	0	0
Total	1,013	1.000		474	1.000		195	1.000		182	1.000		74		

Table 6. Mean fork length-at-age of Arctic grayling in Seward Peninsula rivers sampled during 1993.

	Eldorado River 1988,1993			Unalakleet River 1993			Snake River 1991-1993			Pilgrim River 1990-1993			Sinuk River 1989-1993		
Age	Number of Fish	Fork Length (mm)	Standard Deviation (FL/mm)	Number of Fish	Fork Length (mm)	Standard Deviation (FL/mm)	Number of Fish	Fork Length (mm)	Standard Deviation (FL/mm)	Number of Fish	Fork Length (mm)	Standard Deviation (FL/mm)	Number of Fish	Fork Length (mm)	Standard Deviation (FL/mm)
1	---	---	---	---	---	---	29	139	67	---	---	---	3	109	12
2	---	---	---	---	---	---	14	208	16	7	200	19	3	209	29
3	3	263	23	10	263	15	149	266	25	124	253	30	11	280	26
4	16	285	35	1	252	0	512	285	31	185	293	29	49	322	39
5	19	325	40	34	345	14	574	319	30	189	326	31	111	361	39
6	11	356	46	11	364	18	485	344	37	220	354	33	127	412	44
7	8	398	33	16	377	18	279	380	39	207	381	39	200	440	32
8	18	427	13	32	389	20	297	407	35	165	404	35	190	448	37
9	25	442	23	38	394	21	204	429	30	140	422	34	140	451	35
10	12	457	17	13	411	20	79	435	23	67	427	31	80	452	38
11	6	457	13	1	412	0	24	445	19	24	437	44	49	471	26
12	3	474	9	---	---	---	4	442	29	12	461	17	12	470	21
13	---	---	---	1	425	0	---	---	---	1	495	0	6	490	25
14	---	---	---	---	---	---	---	---	---	---	---	---	2	492	4
15	---	---	---	---	---	---	---	---	---	---	---	---	2	497	3

length distributions of Arctic grayling sampled are provided in Appendices A3, A4, A8, A9 and A10.

Increase in Fork Length

Linear growth of Arctic grayling was examined in the Snake River using fish marked during the early summers of 1991 and 1992 that were recaptured during the early summers of 1992 and 1993 (Figure 9). Arctic grayling in three 25 mm initial length groups (226 to 300 mm) showed the greatest increase in length during both years (40 mm in 1991, and 44 mm in 1992) (Table 7, Figure 10). Arctic grayling, throughout most of their size range, showed a greater increase in length in 1992 than in 1991. The average length increase of Arctic grayling <325 mm FL was 11% greater in 1992 than in 1991 while that for Arctic grayling from 326 mm to 400 mm FL was 39% greater in 1992 than in 1991.

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 as follows: Snake River o 12%, Pilgrim River o 21%, and Sinuk River o 24%.

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. Equal probability of capture by size occurred during both sampling events in both the Pilgrim and Snake rivers. Both samples were used to estimate age and size composition for those rivers. A combination of gear types were used to sample fish in all rivers and it is thought that samples represent length ranges of fish present within the reach of each river sampled.

Based on observations during 1991 (DeCicco 1992), the sampling area on the Snake River was extended 20 km farther upstream in 1992 and 1993. This afforded the ability to sample the entire Arctic grayling population in this river. Continued sampling of the entire river is recommended. Data indicated that 1992 was a better year for growth of Arctic grayling in the Snake River than 1991. Strong pink salmon returns in Nome area streams during 1992 are thought to have provided a significant additional source of food for resident fish species. Although some pink salmon are present in all years, large runs have not occurred in the Nome area since 1984. If this was the cause of increased change in length between 1991 and 1992, it appears that larger fish, those between 326 and 400 mm, benefited most from this additional food source. 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, 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.

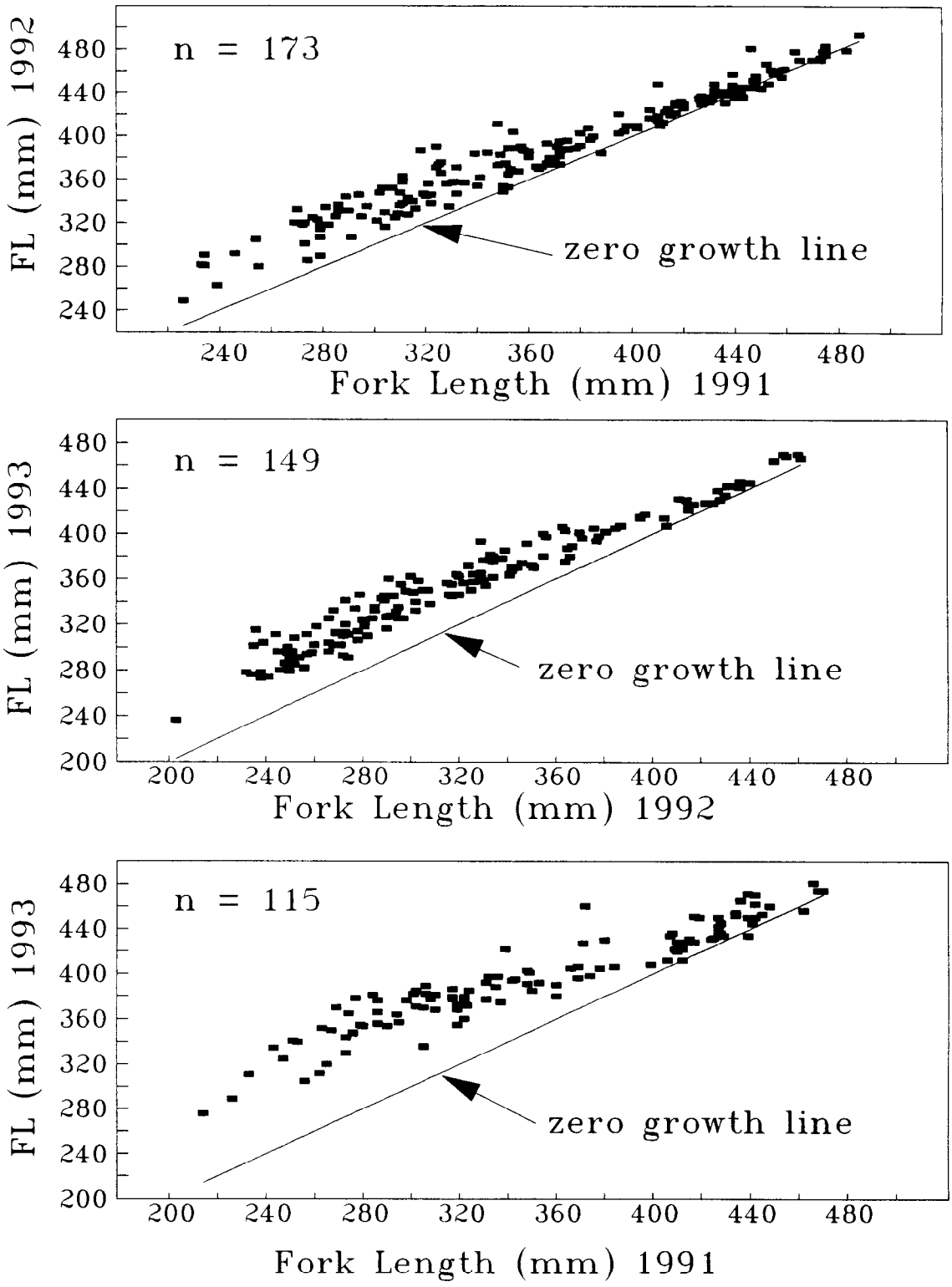

Figure 9. Annual change in measured fork length of Arctic grayling marked in the Snake River in 1991 and 1992 and recaptured in 1993.

Table 7. Average length increase in 25 mm length groups of Arctic grayling recaptured in the Snake River during 1992 and 1993.

Original Fork Length Group (mm)	1991-1992 Number	Average Length Increase	1992-1993 Number	Average Length Increase	1991-1993 Number	Average Length Increase
201 - 225	0		1	33.0	1	62.0
226 - 250	6	41.0	17	46.8	4	77.8
251 - 275	8	40.3	27	41.3	11	74.8
276 - 300	17	39.1	29	45.4	13	77.3
301 - 325	26	33.5	19	37.9	21	60.6
326 - 350	19	27.6	22	34.6	13	53.5
351 - 375	20	19.6	13	27.6	9	40.0
376 - 400	11	13.6	9	20.7	4	27.0
401 - 425	19	10.1	9	8.7	16	15.5
425 - 450	30	4.9	9	7.9	19	14.2
451 - 475	17	3.1	4	11.0	4	4.8

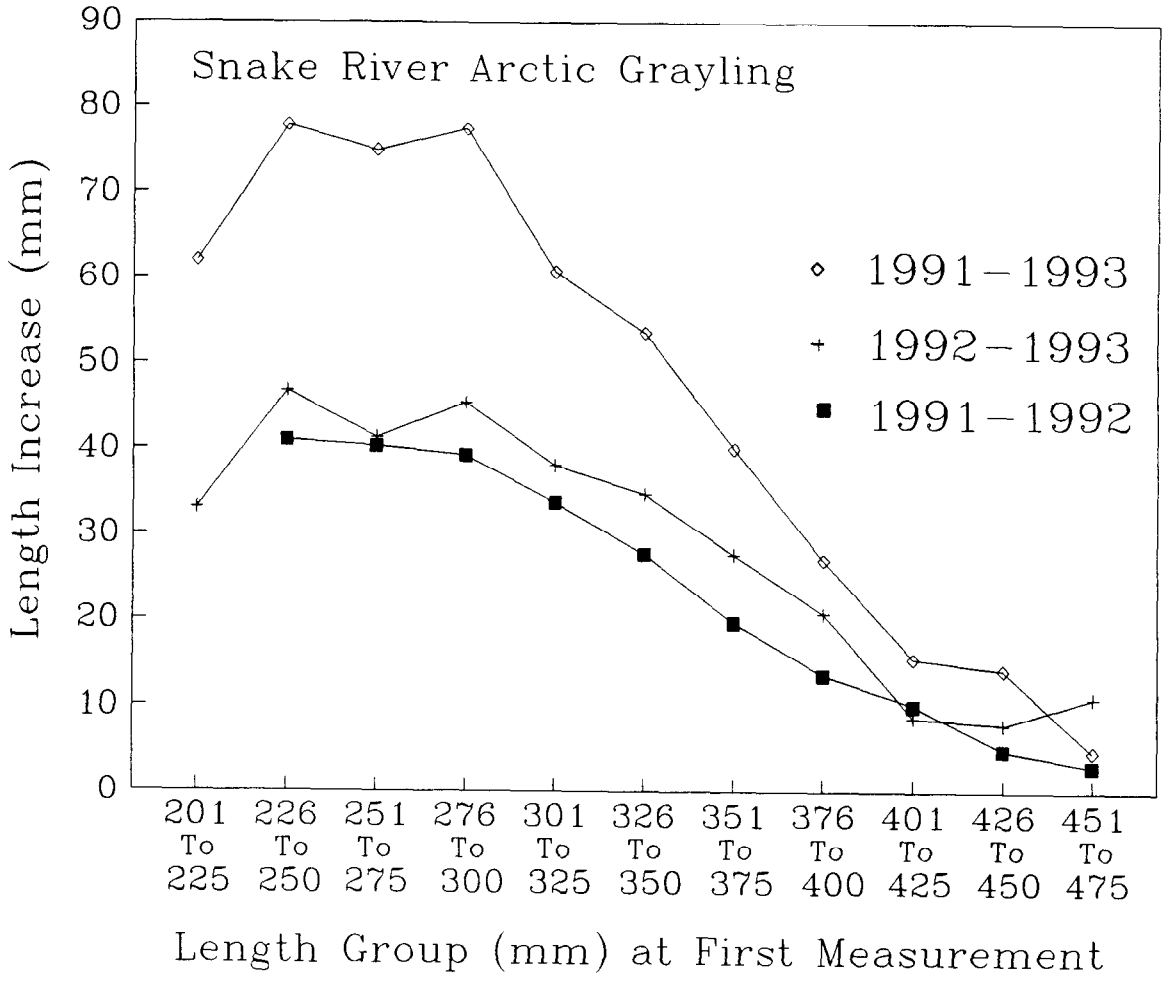

Figure 10. Average length change by 25 mm FL group of Arctic grayling marked in the Snake River in 1991 and 1992 and recaptured in 1992 and 1993.

The upper Sinuk River experiences very low sport fishing pressure. Arctic grayling from this river attain large maximum size with fish > 520 mm FL having been sampled each year. Although fish were aged to 15 years with scales, the few otolith samples available suggested that older fish may be under aged. Considering that age-9 (scale) fish were aged at 14 years using otoliths, and age-12 fish (scale) were aged at 18 years using otoliths, fish over 20 years of age may typically be present in this and other Arctic grayling populations on the Seward Peninsula. Scales from many recaptured fish showed no detectable growth after one year, and since recaptured Sinuk River grayling changed little in length after one year (< 7 mm), large fish may be commonly underaged using scales, and the age structure for large fish (> 430 mm FL) should be viewed with caution. There was a shift in the relative abundances of age classes in the Sinuk River. Age-5 fish were most abundant in the 1993 sample while older age classes dominated in earlier samples (ages-6 and 7 in 1989, age-7 in 1990, age-8 in 1991, and ages-8 and 9 in 1992). These data suggest that a strong year class moved through the population and that another strong age class was recruited in 1993. This is corroborated by a like shift in size composition, with smaller fish (< 400 mm) present in higher abundance in the 1993 sample than in past years.

It is recommended that studies on the Sinuk River not be continued, however, it is suggested that a lightly exploited population be selected in order to collect a matched set of scales and otoliths across the full size range of fish present in order to assess our ability to determine the ages of Arctic grayling using scales.

ACKNOWLEDGEMENTS

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APPENDIX A

Appendix A1. List of numbered tags and finclips used to mark Arctic grayling sampled from the Snake, Pilgrim, and Sinuk rivers during 1993.

Location	Month	Total Fish	Tag Numbers	Color	Fin Clip
Snake River	June/July	277	29281 - 29557	Blue	Adipose
	July	219	29559 - 29777	Blue	Adipose
	July	1	29782	Blue	Adipose
	July	15	29784 - 29798	Blue	Adipose
	July	70	29800 - 29869	Blue	Adipose
Pilgrim River	July	10	55190 - 55199	Green	Adipose
	July	92	55250 - 55341	Green	Adipose
	July	66	55343 - 55408	Green	Adipose
	July	57	55410 - 55466	Green	Adipose
	July	22	55468 - 55489	Green	Adipose
Sinuk River	August	50	51866 - 51915	Green	Adipose
	August	54	51917 - 51970	Green	Adipose
	August	1	51972	Green	Adipose
	August	26	51974 - 51999	Green	Adipose
	August	20	19000 - 19019	Gray	Adipose
	August	25	19200 - 19224	Gray	Adipose

Appendix A2. Inference as a means to detect bias due to gear selectivity.

Results of Hypothesis Tests (K-S and $\chi 2$) on Lengths of Fish Marked during First First Event and Recaptured during Second Event	Results of Hypothesis Tests (K-S) on Lengths of Fish Captured during First Event and during Second Event
Case I:	
"Accept" H_o	"Accept" H_o
There is no size-selectivity during either sampling event.	
Case II:	
"Accept" H_o	Reject H_o
There is no size-selectivity during the second sampling event but there is during the first.	
Case III:	
Reject H_o	"Accept" H_o
There is size-selectivity during both sampling events.	
Case IV:	
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.	

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

CaseII: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

-continued-

Case IVa: If the stratified and unstratified abundance estimates for the entire population are dissimilar, discard the unstratified estimate. Only use the lengths, ages, and sexes from the second sampling event to estimate proportions in composition, and apply formulae to correct for size bias to data from the second event.

Case IVb: If the stratified and unstratified abundance estimates for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not apply formulae to correct for size bias.

Appendix A3. Age-length distribution of Arctic grayling sampled from the Snake River during 1993.

	AGE (Years)													
	1	2	3	4	5	6	7	8	9	10	11	12	13+	
Fork Length(mm)														Total
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 to 200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201 to 225	0	0	4	1	0	0	0	0	0	0	0	0	0	5
226 to 250	0	0	8	5	0	2	0	0	0	0	0	0	0	15
251 to 275	0	0	5	6	14	11	0	0	0	0	0	0	0	36
276 to 300	0	0	1	8	58	39	2	0	0	0	0	0	0	108
301 to 325	0	0	0	7	78	55	13	0	1	0	0	0	0	154
326 to 350	0	0	0	2	83	65	20	4	2	0	0	0	0	176
351 to 375	0	0	0	1	31	81	42	21	1	0	0	0	0	177
376 to 400	0	0	0	0	1	26	31	21	7	2	0	0	0	88
401 to 425	0	0	0	0	1	6	16	17	14	5	1	0	0	60
426 to 450	0	0	0	0	1	3	4	16	24	8	4	0	0	60
451 to 475	0	0	0	0	0	1	1	6	8	6	5	1	0	28
476 to 500	0	0	0	0	0	1	0	0	2	0	0	0	0	3
Totals	0	0	18	30	267	290	129	85	59	21	10	1	0	910

Appendix A4. Age-length distribution of Arctic grayling sampled from the Pilgrim River during 1993.

	AGE (Years)													
Fork Length (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 to 200	0	3	3	0	0	0	0	0	0	0	0	0	0	6
201 to 225	0	2	13	0	0	0	0	0	0	0	0	0	0	15
226 to 250	0	0	33	2	0	0	0	0	0	0	0	0	0	35
251 to 275	0	0	12	17	2	0	0	0	0	0	0	0	0	31
276 to 300	0	0	9	15	11	4	1	0	0	0	0	0	0	40
301 to 325	0	0	0	11	24	6	1	0	0	0	0	0	0	42
326 to 350	0	0	1	4	29	13	2	2	0	0	0	0	0	51
351 to 375	0	0	0	0	17	19	5	6	2	0	0	0	0	49
376 to 400	0	0	0	0	5	14	13	4	8	3	2	0	0	49
401 to 425	0	0	0	0	0	1	8	7	6	7	0	0	0	29
426 to 450	0	0	0	0	0	0	2	3	9	4	2	2	0	22
451 to 475	0	0	0	0	0	0	0	2	2	4	4	4	0	16
476 to 500	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Totals	0	5	71	49	88	57	32	24	27	18	9	6	1	387

Appendix A5. Program RECAP output for Sinuk River, 1993.

Output 1: data truncated for fish >324 mm FL.

S= 5

	NS	MS	RR	R	G	Z	ALPHA	BETA	
1	137	0	59	137	0	0	0	0	Aug 1989
2	226	24	65	225	0	35	0	0	Aug 1990
3	302	71	50	300	0	29	0	0	Aug 1991
4	207	57	4	207	0	22	0	0	Aug 1992
5	169	26	0	168	0	0	0	0	Aug 1993

JOLLY-SEBER ESTIMATES:

	MP	NP	B	PHI
1				1.0595
2	145.15	1367.	75.	.7078
3	245.00	1042.	1718.	2.5222
4	1195.50	4342.		

STANDARD ERRORS OF JOLLY-SEBER ESTIMATES:

	MP	NP	B	PHI
1				.1549
2	21.42	314.	213.	.1183
3	37.08	182.	1044.	1.3048
4	612.83	2276.		

MODIFIED ESTIMATES:

I	MP	NP	B	PHI	P	NU	MU	ZETA
1				1.0000		1.0000	.0000	
2	137.00	1290.	115.	.7745	.1752	.9956	.0000	.1062
3	261.79	1114.	671.	1.0000	.2712	.9934	9.9999	.2351
4	490.79	1782.			.1161	1.0000		.2754

STANDARD ERRORS OF MODIFIED ESTIMATES ESTIMATED FROM 400 SIMULATIONS:

I	MP	NP	B	PHI	P	NU	MU
1				.0585		.0000	.0000
2	14.03	186.	165.	.1191	.0315	.0043	.0000
3	42.21	198.	221.	.0225	.0488	.0044	.0000
4	45.69	255.			.0186	.0000	

95% "EQUAL TAILS" CONFIDENCE INTERVALS ESTIMATED FROM 400 SIMULATIONS:

I	MP		NP		B		PHI	
	L	U	L	U	L	U	L	U
1							.7863	1.0000
2	105.16	159.00	889.	1566.	0.	633.	.5676	1.0000
3	185.72	341.91	791.	1543.	289.	1152.	.9316	1.0000
4	403.10	573.12	1390.	2343.				

-continued-

Appendix A5. (Page 2 of 2).

95% "MINIMUM LENGTH" CONFIDENCE INTERVALS ESTIMATED FROM 400 SIMULATIONS:

I	MP		NP		B		PHI	
	L	U	L	U	L	U	L	U
1							.8304	1.0000
2	105.16	159.00	891.	1567.	0.	463.	.5972	1.0000
3	185.72	341.91	789.	1499.	268.	1103.	1.0000	1.0000
4	405.60	575.00	1379.	2306.				

ESTIMATED AVERAGE NUMBER OF ANIMALS ALIVE
BETWEEN CAPTURE 2 AND CAPTURE 4 = 1395. WITH STANDARD
ERROR 150. AND 95% CONFIDENCE INTERVAL (1128. , 1676.)

ESTIMATED GEOMETRIC MEAN OF THE PROBABILITIES OF SURVIVAL
BETWEEN CAPTURE 1 AND CAPTURE 4 = .9184 WITH STANDARD
ERROR .0512 AND 95% CONFIDENCE INTERVAL (.8226 , 1.0000)

ESTIMATED AVERAGE NUMBER OF BIRTHS BETWEEN
CAPTURE 2 AND CAPTURE 4 = 393. WITH STANDARD
ERROR 115. AND 95% CONFIDENCE INTERVAL (174. , 618.)

Appendix A6. Summary of captures, fish released with marks, and recaptures of Arctic grayling (>324 mm FL) in the Sinuk River, 1989 through 1993.

Time of last capture	Time of Recapture				
	1989	1990	1991	1992	1993
1989	0	24	26	7	2
1990	0	0	45	12	8
1991	0	0	0	38	12
1992	0	0	0	0	4
1993	0	0	0	0	0
Marked	0	24	71	57	26
Unmarked	137	202	231	150	143
Caught	137	226	302	207	169
Released	137	225	300	207	168

Appendix A7. Cell values of Jolly-Seber model goodness-of-fit tests[a] performed on capture-recapture data collected from Arctic grayling in the Sinuk River, 1989 through 1993.

Component 1			Component 2			
Row elements	Column elements		Row elements	Column elements		
i = 2 (1990)	First captured before i	First captured in i				
Released and recaptured	8	57				
Expected value	6.6	58.4				
Not recaptured	15	145				
Expected value	16.4	143.6				
i = 3 (1991)	First captured before i	First captured in i		Captured before i-1 not captured in i-1	Captured before i-1 captured in i-1	First captured in i-1
Released and recaptured	6	44	Captured in i	26	5	40
Expected value	11.5	38.5	Expected value	25.9	5.7	40.5
Not recaptured	63	187	Captured after i	9	3	17
Expected value	57.5	192.5	Expected value	10.2	2.3	16.5
i = 4 (1992)	First captured before i	First captured in i		Captured before i-1 not captured in i-1	Captured before i-1 captured in i-1	First captured in i-1
Released and recaptured	2	2	Captured in i	19	5	33
Expected value	1.1	2.9	Expected value	20.9	4.3	31.8
Not recaptured	55	148	Captured after i	10	1	11
Expected value	55.9	147.1	Expected value	8.1	1.7	12.3

[a] The goodness-of-fit test was devised by Pollock et al. (1985).

Appendix A8. Age-length distribution of Arctic grayling sampled from the Sinuk River during 1993.

	AGE (Years)													
Fork Length (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 to 200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201 to 225	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226 to 250	0	0	1	0	0	0	0	0	0	0	0	0	0	1
251 to 275	0	0	1	0	0	0	0	0	0	0	0	0	0	1
276 to 300	0	0	3	0	0	0	0	0	0	0	0	0	0	3
301 to 325	0	0	0	0	2	0	0	0	0	0	0	0	0	2
326 to 350	0	0	0	1	10	2	0	0	0	1	0	0	0	14
351 to 375	0	0	0	0	15	7	2	0	0	1	0	0	0	25
376 to 400	0	0	0	0	12	8	4	2	2	0	0	0	0	28
401 to 425	0	0	0	0	2	6	7	2	3	0	0	0	0	20
426 to 450	0	0	0	0	0	3	7	4	1	1	1	1	0	18
451 to 475	0	0	0	0	0	0	0	2	7	2	4	3	1	19
476 to 500	0	0	0	0	0	0	0	1	5	4	2	2	2	16
501 to 525	0	0	0	0	0	0	0	0	0	0	3	0	1	4
Totals	0	0	5	1	41	26	20	11	18	9	10	6	4	151

Appendix A9. Age-length distribution of Arctic grayling sampled from the Eldorado River during 1993.

Fork Length (mm)	AGE (Years)													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13+	
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 to 200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201 to 225	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226 to 250	0	0	0	0	0	0	0	0	0	0	0	0	0	0
251 to 275	0	0	0	0	0	0	0	0	0	0	0	0	0	0
276 to 300	0	0	0	0	0	0	0	0	0	0	0	0	0	0
301 to 325	0	0	0	0	0	0	0	0	0	0	0	0	0	0
326 to 350	0	0	0	0	1	1	0	0	0	0	0	0	0	2
351 to 375	0	0	0	0	2	1	0	0	0	0	0	0	0	3
376 to 400	0	0	0	0	0	2	0	1	2	0	0	0	0	5
401 to 425	0	0	0	1	0	1	1	3	2	0	0	0	0	8
426 to 450	0	0	0	0	0	1	2	8	7	4	2	0	0	24
451 to 475	0	0	0	0	0	0	0	2	10	6	3	2	0	23
476 to 500	0	0	0	0	0	0	0	0	0	2	1	1	0	4
Totals	0	0	0	1	3	6	3	14	21	12	6	3	0	69

Appendix A10. Age-length distribution of Arctic grayling sampled from the Unalakleet River during 1993.

	AGE (Years)													
Fork Length (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13+	Total
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 to 200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201 to 225	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226 to 250	0	0	3	0	0	0	0	0	0	0	0	0	0	3
251 to 275	0	0	5	1	0	0	0	0	0	0	0	0	0	6
276 to 300	0	0	2	0	0	0	0	0	0	0	0	0	0	2
301 to 325	0	0	0	0	4	0	0	0	0	0	0	0	0	4
326 to 350	0	0	0	0	19	3	0	0	0	0	0	0	0	22
351 to 375	0	0	0	0	10	5	7	9	7	0	0	0	0	38
376 to 400	0	0	0	0	1	3	8	16	15	4	0	0	0	47
401 to 425	0	0	0	0	0	0	1	6	13	7	1	0	1	29
426 to 450	0	0	0	0	0	0	0	2	3	1	0	0	0	6
451 to 475	0	0	0	0	0	0	0	0	0	1	0	0	0	1
476 to 500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	0	0	10	1	34	11	16	33	38	13	1	0	1	158

APPENDIX B

Appendix B1. Data files used to estimate parameters of Arctic grayling populations on the Seward Peninsula in 1993.

Data file[a]	Description
W0120LA3.DTA	Mark and recapture data for Arctic grayling captured from the Snake River during 1993.
W0060LB3.DTA	Mark and recapture data for Arctic grayling captured from the Pilgrim River during 1993.
W0020LA3.DTA	Mark and recapture data for Arctic grayling captured from the Sinuk River during 1993.
W0110LA3.DTA	Sample data for Arctic grayling from the Eldorado River.
W0030LA3.DTA	Sample data for Arctic grayling from the Unalakleet River.

[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.