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Assessment of Selected Stocks of Arctic Grayling in Streams of the Seward Peninsula, Alaska, during 1991

by

Alfred L. DeCicco

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Alaska Department of Fish and Game

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ABSTRACT

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

The estimated abundance of Arctic grayling greater than 339 millimeters of fork length (FL) in a 24 kilometer section of the Fish River was 2,900 fish (standard error = 424) or 121 fish/kilometer. Arctic grayling ranged from 168 to 460 millimeters FL and from one to 10 years.

The number of Arctic grayling over 269 millimeters FL was an estimated at 1,109 fish (standard error = 160) in a 28 kilometer section of the Snake River. The density was 40 fish/kilometer. Arctic grayling ranged from 21 to 492 millimeters FL and from 0 to 11 years.

The estimated abundance of Arctic grayling over 269 millimeters of FL in a 12 kilometer section of the Pilgrim River was 1,107 (standard error = 197) or 92 fish/kilometer. Arctic grayling ranged from 190 to 488 millimeters FL and from two to 13 years.

In a 24 kilometer section of the Nome River, the estimated abundance of Arctic grayling greater than 269 millimeters of fork length was 430 fish (standard error = 111) or 18 fish/kilometer. They ranged from 125 to 495 millimeters FL and from one to 12 years.

The estimated abundance of Arctic grayling greater than 324 millimeters FL of in a 40 kilometer section of the Sinuk River in 1990 was 1,453 fish (standard error = 296) or 36 fish/kilometer. Arctic grayling sampled in 1991 ranged from 206 to 511 millimeters FL and from two to 15 years. The estimated survival rate from 1989 to 1990 was 1.00 (standard error = 0.07).

The majority of fish (99, 49, 60, 60 and 50 percent) were in the "preferred" Relative Stock Density category in the Fish, Snake, Pilgrim, Nome and Sinuk rivers, respectively. "Memorable" fish comprised 45 percent of the Sinuk River sample. Mean length-at-age was greatest for Arctic grayling from the Sinuk River and least for fish from the Fish River.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, length composition, growth, Seward Peninsula, Fish River, Sinuk River, Nome River, Snake River, Pilgrim 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 1990, an average of 14,508 freshwater angler-days of fishing effort occurred in this area (Mills 1981-1991, Figure 1). 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 1989, Arctic grayling have comprised an average 21% of the harvest of these species; but in 1990, the harvest dropped to 7% (Table 1).

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 the Nome area is not connected by road to the state highway system, the Seward Peninsula contains 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: The Beam Road extending to the north, the Teller Road to the west and the Council Road to the east (Figure 2). This road system sets Nome apart from most other rural Alaskan communities and provides angler access to many streams on the Seward Peninsula.

As indicated by harvest statistics (Table 1), fishing pressure can be substantial at accessible streams. Subsistence harvests of Arctic grayling, although not monitored, have raised concern regarding stock status among local anglers who, along with ADF&G staff in Nome, 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 (380 mm).

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

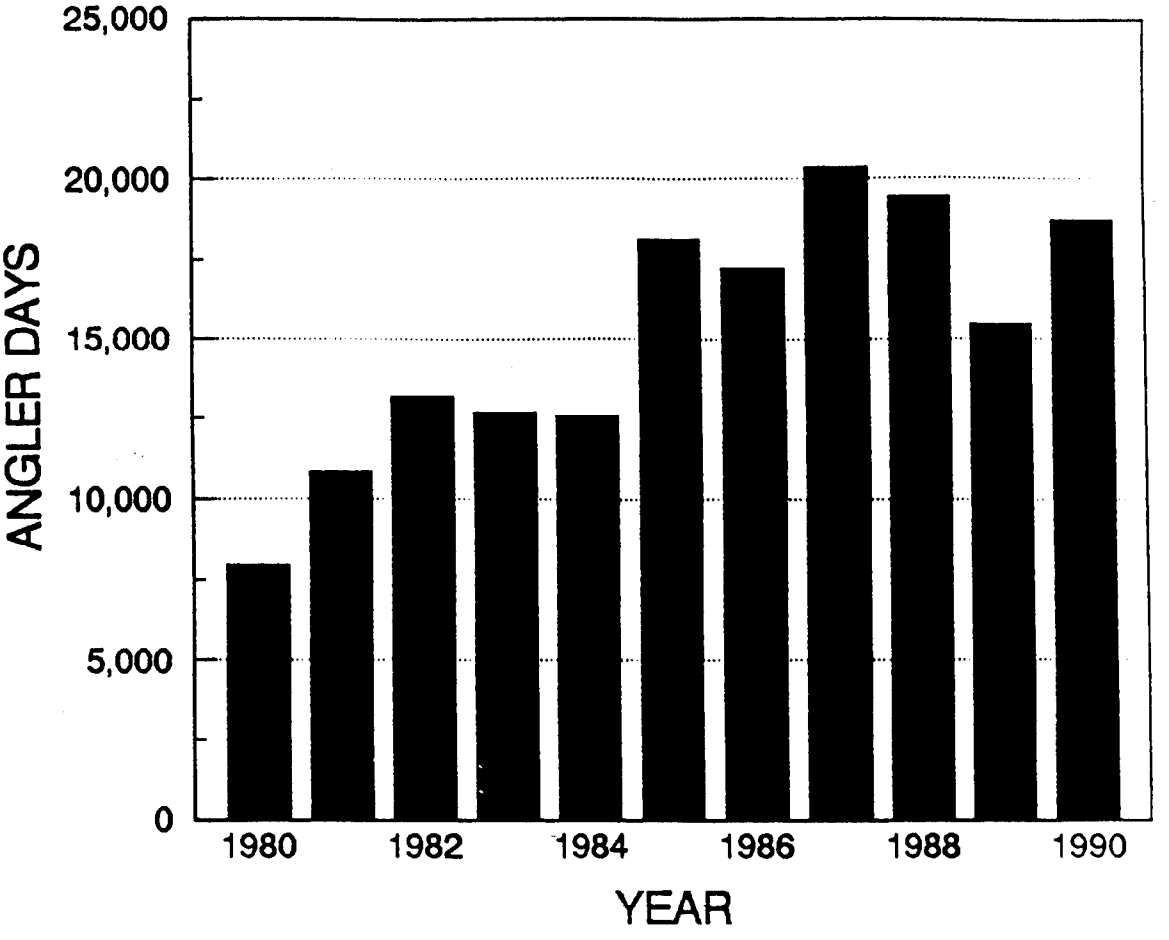

Figure 1. Freshwater sport fishing effort on Seward Peninsula and Norton Sound streams, 1980-1990.

Table 1. Freshwater sport fish harvests in Seward Peninsula and Norton Sound streams, 1980 to 1990[a].

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[b]	18,720	11,227 (24,705)	3,765 (9,118)	1,378 (6,119)	1,957 (4,145)	33 (33)	299 (315)
Mean	15,153	9,991 (24,705)	5,647 (9,118)	4,014 (6,119)	603 (4,145)	24 (33)	320 (315)

[a] Data from Alaska statewide sportfish harvest survey (Mills 1981 - 1991).
[b] The first year for which harvest and catch were both estimated.

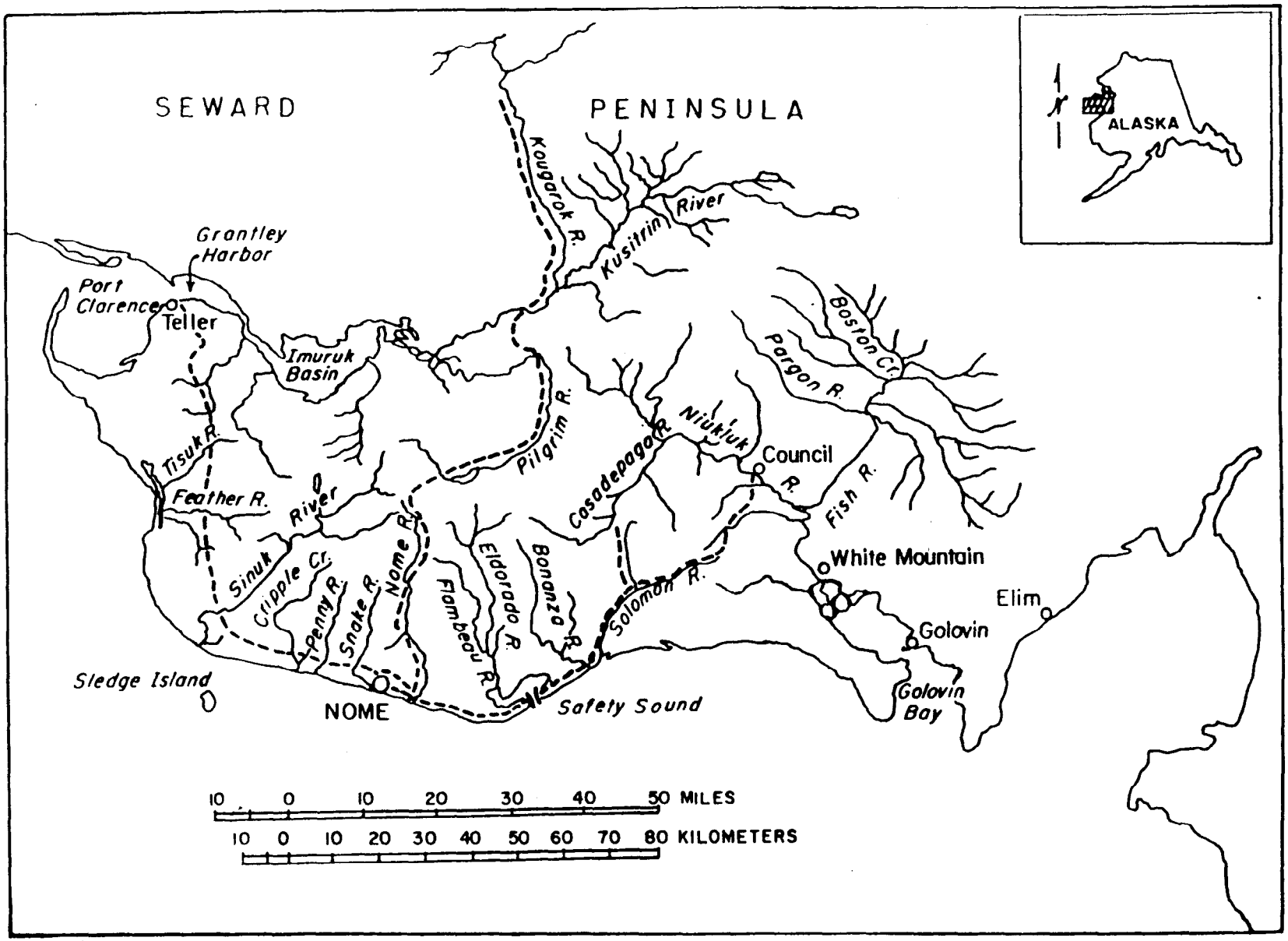

Figure 2. The southern Seward Peninsula showing roads and road accessible waters.

abundance was estimated for a section of the Niukluk River (DeCicco 1990). During 1990, population abundance as well as, age and size composition of Arctic grayling were estimated on the Niukluk, Fish, Pilgrim and Sinuk rivers (DeCicco 1991).

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 1991 were:

1) to estimate the abundance, age and length composition, and mean length-at-age of Arctic grayling greater than 149 mm FL in the following waters:

   a. a 24 km section of the Fish River upstream from its confluence with the Niukluk River;

   b. a 28 km section of the Snake River;

   c. a 12 km section of the Pilgrim River downstream of the Beam Road bridge; and,

   d. a 30 - 50 km section of the Nome River; and,

2) to estimate the abundance, age and length composition, and mean length-at-age of Arctic grayling greater than 249 mm FL in a 40-km section of the Sinuk River in 1990.

Additionally, estimates of survival from 1989 to 1990 were calculated for the Sinuk River stock.

METHODS

Sampling Gear and Techniques

Arctic grayling residing in the Fish and Snake rivers (Figures 3 and 4) were sampled using a pulse-DC electrofishing system mounted on a 5.4-m-long river boat. Input voltage (240 VAC) was provided by a 2,900 W single-phase Kawasaki Model GA 3200-A gas powered generator. A variable voltage pulsator (Coffelt Manufacturing Model VVP 3C) was used to generate output current. Six anodes were constructed of 9.5-mm diameter twisted steel cable 1.5 m long inside 19 mm diameter flexible conduit and attached equidistantly to the 3.5-m cross member of a 3.5-m-long retractable "T-boom" attached to a platform on the bow of the boat. The aluminum hull of the river boat was used as the cathode.

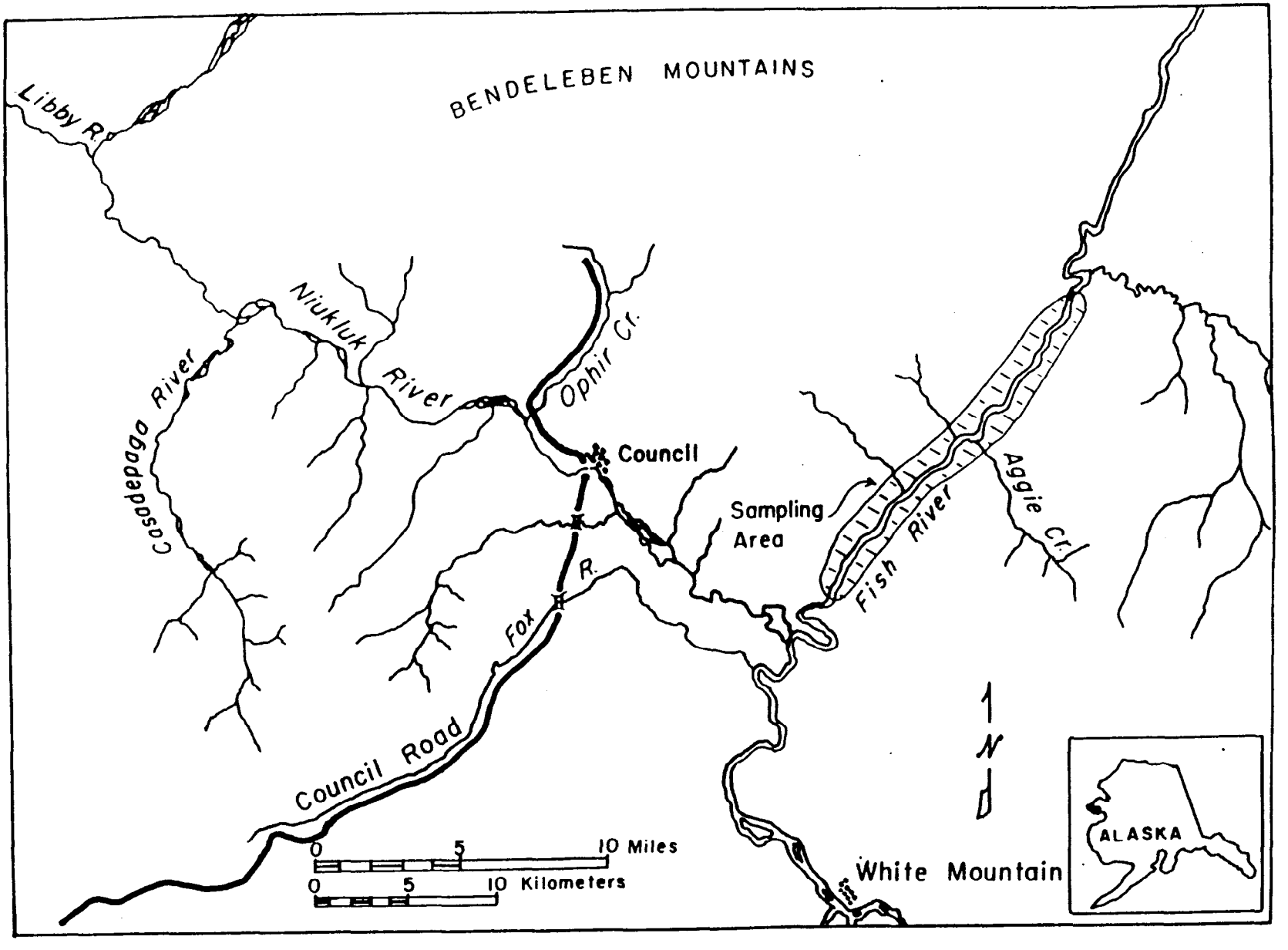

Figure 3. The Fish River with area sampled during 1991.

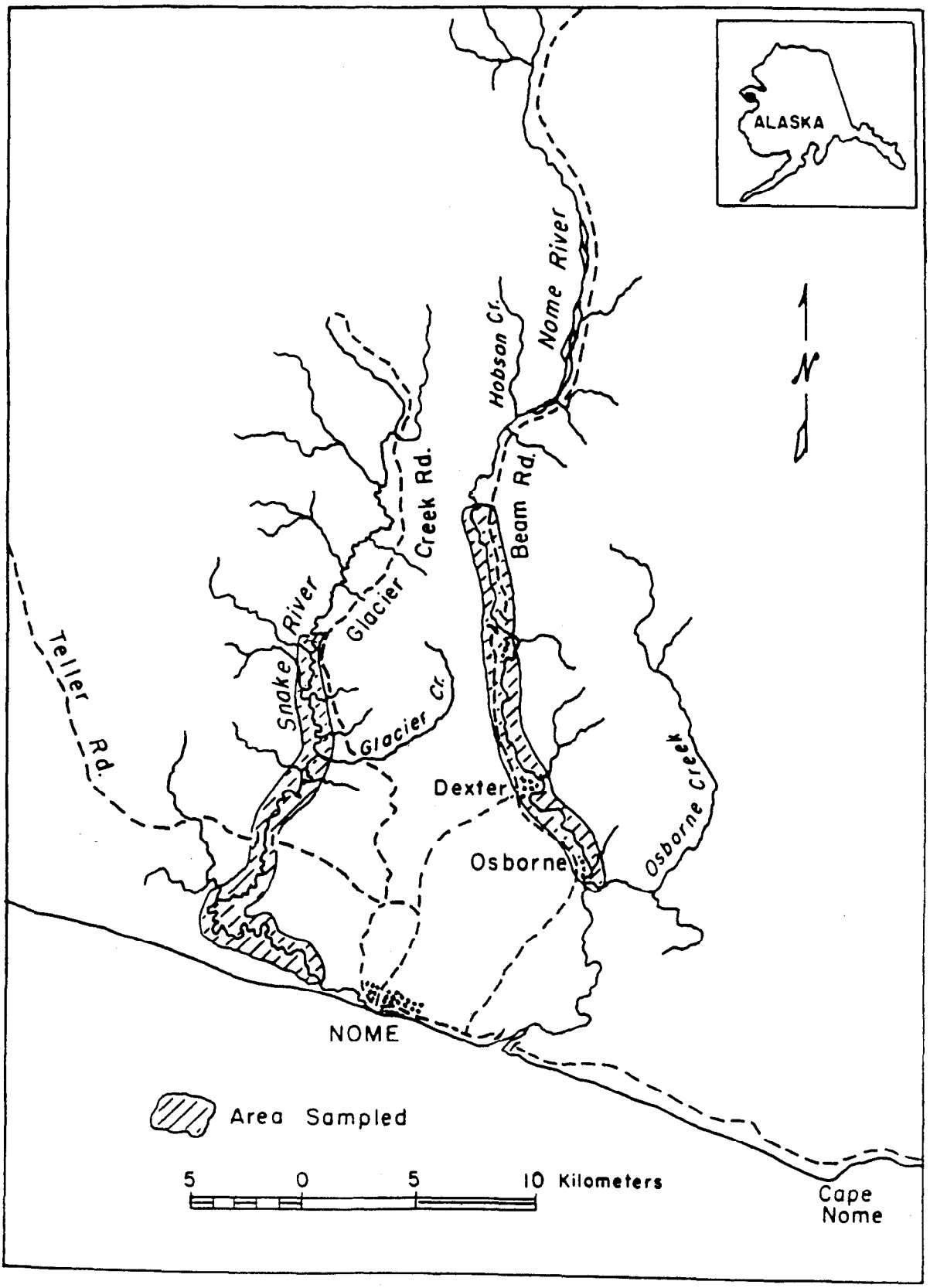

Figure 4. The Snake and Nome rivers with area sampled during 1991.

Output voltages varied between 180 and 240 VDC and amperage varied from 1.8 to 4 amp. The pulse rate was held around 80 Hz.

Sampling was conducted along the banks of each river. The electrofishing boat was directed downstream along each bank at a speed slightly above that of the current in order to maintain steerage of the vessel. All Arctic grayling seen were collected when possible by two technicians with dipnets located on the boat's bow platform which was equipped with a safety rail. Captured fish were immediately placed in one of two 142-L black plastic water-filled tubs. Fish were sampled after 20-30 had been captured or after a river subsection had been fully traversed. Each electrofishing run was timed and the catch of Arctic grayling per minute of electrofishing was calculated for each run. Fish were also sampled using hook and line in all rivers and using a 30 m x 2 m 6.5 mm mesh beach seine and a 15 m x 2 m x 12 mm mesh beach seine fished in tandem on the Snake, Nome and Pilgrim rivers (Figures 4 and 5).

Arctic grayling from a 40 km section of the Sinuk River (Figure 6) were sampled with hook and line during five days in early August. A Bell Jet Ranger helicopter, under contract to the Bureau of Land Management (BLM), was used to reach the headwaters. The river was floated using a 3.7 m Avon Redshank inflatable raft with oars.

Each Arctic grayling was measured to the nearest mm fork length (FL). Fish over 150 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 were taken for aging 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° C). Ages were determined by counting annuli from the acetate impressions using a microfiche reader. All scale impressions were read twice by the same reader. If readings were not the same, the scale was read a third time. When two readings agreed, this was taken to be the age of the fish. If the reader could not age the fish with three readings, 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 Fish, Snake, Pilgrim and Nome rivers (Figures 3, 4, and 5). A three year modified Jolly-Seber model was used to estimate the abundance of Arctic grayling in the study section of the Sinuk River (Figure 6).

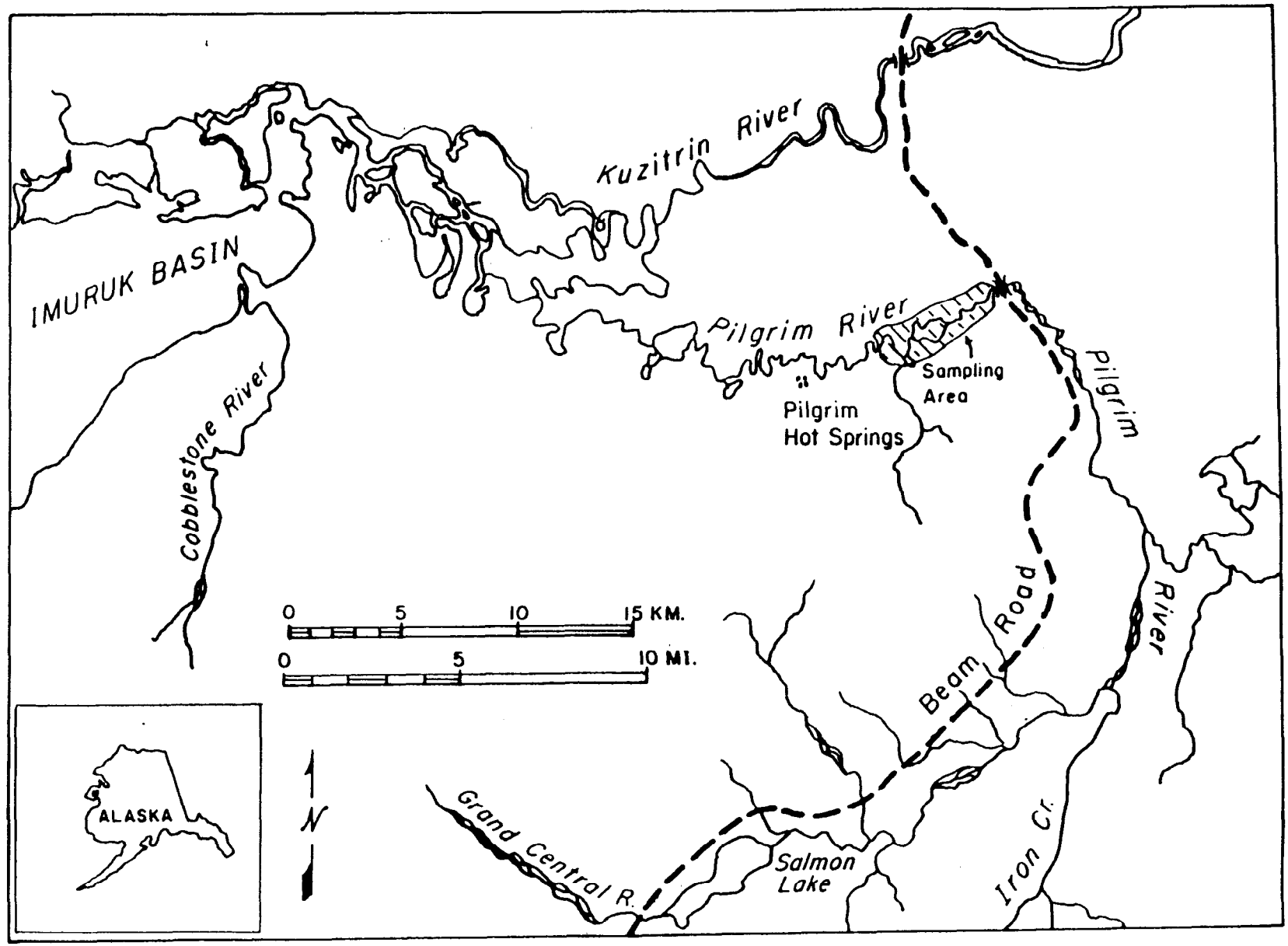

Figure 5. The Pilgrim River with area sampled during 1991.

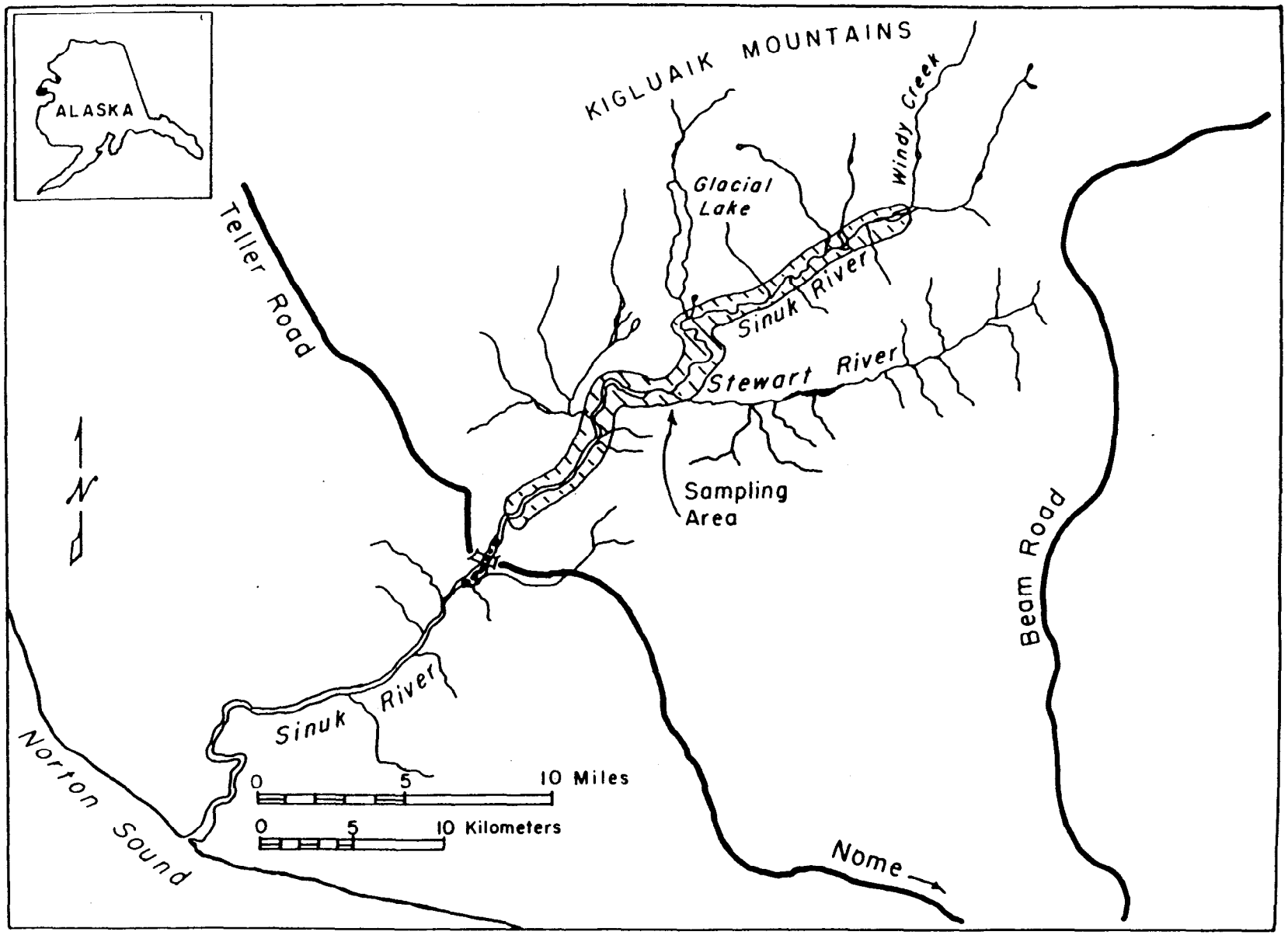

Figure 6. The Sinuk River with area sampled during 1990.

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 in the second sampling event (recapture event). In a second test, the cumulative length distribution of fish captured during the marking event was compared to that 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 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 fin clip (Appendix A1). Fin clips 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,

V = the approximate variance of the abundance estimate.

Rivers were divided into sections and the ratios of the number of recaptured fish to the number of fish examined during the second event by river section were examined for equal probability of capture using contingency table analysis. In rivers where the probabilities of capture were different by area, abundance estimates were stratified by area and compared to a single unstratified estimate using the goodness of fit method (Seber 1982, page 121) as follows:

$$z = \frac{\hat{N}_a - \hat{N}_b}{(V_a + V_b)^{1/2}} \qquad (3)$$

If the estimates were not different, i.e. $|z| < 1.96$, $\alpha = 0.05$, the estimate with the lowest variance was chosen.

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 and survival between 1989 and 1990. 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). 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.

Additionally, I evaluated possible gear selectivity bias by comparing the cumulative distribution of the lengths of fish marked and released in 1989 and 1990 to the cumulative distribution of the recaptured fish during the 1990 and 1991 sampling events. Two-sample Kolmogorov-Smirnov statistics were used to test the hypothesis of no difference in the distributions. These evaluations were similar to the first test described in Appendix A2. Similarly, I compared the cumulative distributions of the length of fish caught during each year's sampling. A K-sample Anderson Darling statistic (Scholz and Stephens 1987) was used to test the hypothesis of no difference among the three distributions.

Assumption 2 was also addressed using a Jolly-Seber model stratified by "size". These models cannot be directly stratified according to size, since the parameters of the model relate to ages of the fish. Therefore, I evaluated the age at size information, along with the cumulative distribution plots described above, to determine a size at which a majority of fish larger than the chosen size were expected to have homogenous survival rates (although possibly different than the larger fish). The age-stratified computer program JOLLYAGE (see Pollock, et al. 1990 for a description of this model and the computer program) was used to estimate the parameters of the age stratified model. Goodness-of-fit tests included with the program were used to evaluate the need for stratification according to "size".

Unfortunately, the effects of recruitment and mortality upon the distribution of the catch during each year, and on the recapture distributions cannot be separated from possible effects of gear selectivity. Therefore, the cumulative distribution plots, the associated tests, and the age stratified model tests were only used as general guidelines in evaluating the possible need to stratify estimates.

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 Arctic grayling with Floy tags and partial fin clips. Assumption 5 was met by restricting each sampling event to 10 days or less during the open water season; it is believed that additions and losses to and from the population were negligible during the sampling event.

The Jolly-Seber model parameter estimation procedures for abundance and survival rate were estimated for 1990 by first estimating the number of Arctic grayling marked in ith sample that survived to the $(i+1)$th sample:

$$\hat{M}_{1990} = \frac{R_{1990}\, z_{1990}}{r_{1990}} + m_{1990} \qquad (4)$$

where: R_{1990} = the number of marked Arctic grayling released after the 1990 sample;

z_{1990} = the number of different Arctic grayling caught before the 1989 sample, not seen during the 1990 sample, but subsequently recaptured during 1991;

r_{1990} = the number of Arctic grayling recaptured in 1991 that were released in the 1990 sample (recaptures from R_{1990}); and,

m_{1990} = the number of marked Arctic grayling caught during the 1990 sample (recaptures from 1989).

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

$$\hat{\phi}_{1989} = \frac{\hat{M}_{1990}}{R_{1989}} \qquad (5)$$

where: R_{1989} = the number of marked Arctic grayling released in 1989.

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

$$\hat{N}_{1990} = \frac{\hat{M}_{1990}\, n_{1990}}{m_{1990}} \qquad (6)$$

where: n_{1990} = the number of Arctic grayling caught during the 1990 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 non-parametric bootstrap estimates of the standard errors for the parameters.

Minimizing Length Bias:

Low numbers of small sized fish were marked and examined in most rivers. In order to minimize bias in estimates of small sized fish, the length of the smallest recaptured fish was used as a guideline for the minimum size for which the estimate would apply. A size smaller than the smallest recaptured fish was chosen as the minimum length of that RSD category in order to minimize bias introduced into estimates of small sized fish not represented in the recaptured sample and to get complete representation in a 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 Fish, Pilgrim, Snake, Nome, 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:

$$\hat{p}_j = \frac{n_j}{n} \tag{7}$$

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:

$$\hat{V}[p_j] = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \tag{8}$$

Abundance of Arctic grayling by age was estimated as follows:

$$\hat{N}_j = \hat{p}_j(\hat{N}); \tag{9}$$

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:

$$\hat{V}[\hat{N}_j] = (\hat{p}_j^2\hat{V}[\hat{N}])+(\hat{N}^2\hat{V}[\hat{p}_j])-(\hat{V}[\hat{p}_j]\hat{V}[\hat{N}]); \tag{10}$$

where:

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

Length Composition

Length composition of Arctic grayling residing in the Fish, Pilgrim, Snake, Nome, and Sinuk rivers was estimated 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 RSD categories followed the same procedures used for age composition (equations 7 and 8). Abundance estimates by RSD category were calculated using equations 9 and 10.

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 1991 was estimated in the Fish, Pilgrim, Snake, and Nome rivers. An abundance estimate germane to 1990 was calculated for Arctic grayling residing in the Sinuk River.

Fish River:

Both the mark and recapture runs on the Fish River (Figure 3) were conducted during four day periods in July with a three-day hiatus between events. A combination of electrofishing and hook and line fishing techniques were used to sample Arctic grayling. Adequate numbers of fish were sampled during both events and a sufficient number of marked fish were recaptured to calculate an abundance estimate within desired precision criteria. Of 395 Arctic grayling marked, the smallest was 206 mm FL; of 347 Arctic grayling examined in the second event, the smallest was 168 mm FL. The smallest recaptured fish was 348 mm FL. Following the rationale outlined to minimize length bias, the abundance estimate for the Fish River is for Arctic grayling > 339 mm fork length.

In the 24-km section of the Fish River upstream from its confluence with the Niukluk River, the estimated abundance of Arctic grayling greater than 339 mm FL was 2,900 fish (SE = 424 fish, CV = 14.6%) or 121 fish per km. A total of 358 Arctic grayling greater than 339 mm FL were marked during the first event (9 to 12 July). During the recapture event (15 to 19 July) 323 Arctic grayling greater than 339 mm FL were examined of which 39 had tags from

the marking event. No loss of tags placed during the marking event was detected during the recapture event, however four tag losses from 1990 (3%) were encountered.

Negligible movement was observed. Only three of 39 recaptured fish were caught in river sections other than those in which they were marked. The average distance moved was 0.82 km. Equal probability of capture by river section was examined by using contingency tables to compare the numbers of new fish examined in the second sampling event (total examined - recaptures) and of recaptured fish by river section. The four section test found no significant differences ($\chi^2 = 4.97$, df = 3, $0.10 < p < 0.20$). However when sections with the most similar ratios (C - R to R) were combined and compared (sections 1 and 2 vs sections 3 and 4), differences were found ($\chi^2 = 4.92$, df = 1, $0.025 < p < 0.050$). Therefore an abundance estimate stratified by area (two areas) and a single unstratified estimate were calculated. The estimates were not found to be different, z = 0.72. Therefore the unstratified estimate was chosen because it had the smallest variance.

Kolmogorov-Smirnov two sample tests of the cumulative length distributions of Arctic grayling greater than 339 mm FL marked versus those recaptured during the recapture event (test 1) and of those captured during the mark event versus those examined in the recapture event (test 2) failed to detect significant differences (test 1: D = 0.21, $p = 0.10$, $n_1 = 358$, $n_2 = 39$; test 2: D = 0.09, $p = 0.15$, $n_1 = 358$, $n_2 = 323$; Figure 7). Similar tests on entire samples did detect differences between the length distributions of marked and recaptured fish (Appendix A3). Length samples from both events were combined for age and length composition estimates and for length at age estimates (Appendix A4).

During 1991 sampling, the water in the Fish River was very low and clear which reduced the effectiveness of electrofishing. Only 10 Arctic grayling were captured during 95 minutes of electrofishing (0.105 per minute) and an additional 92 Arctic grayling were observed but not captured or stunned because they avoided the electrical field. Under these conditions, catch rates using hook and line were over four times higher (0.44 fish per minute) in the same river section. Similar observations were made in 1990. Unseasonably warm weather on the Seward Peninsula during the summer of 1991 caused water temperatures on the Fish River during sampling to range from 14 to 19° C. Arctic grayling were often observed in concentrations where small and cooler (3.4 to 13° C) tributary streams entered the river.

Snake River:

The marking run on the Snake River (Figure 4) was conducted during a four day period in late June using electrofishing, beach seine, and hook and line. The recapture event was conducted during a four day period in July after a three-day hiatus using the same gear types. Fishing success was good during both events. 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 209 Arctic grayling marked was 198 mm FL and the smallest of 267 Arctic grayling examined in the second event was 209 mm FL. The smallest fish recaptured from the

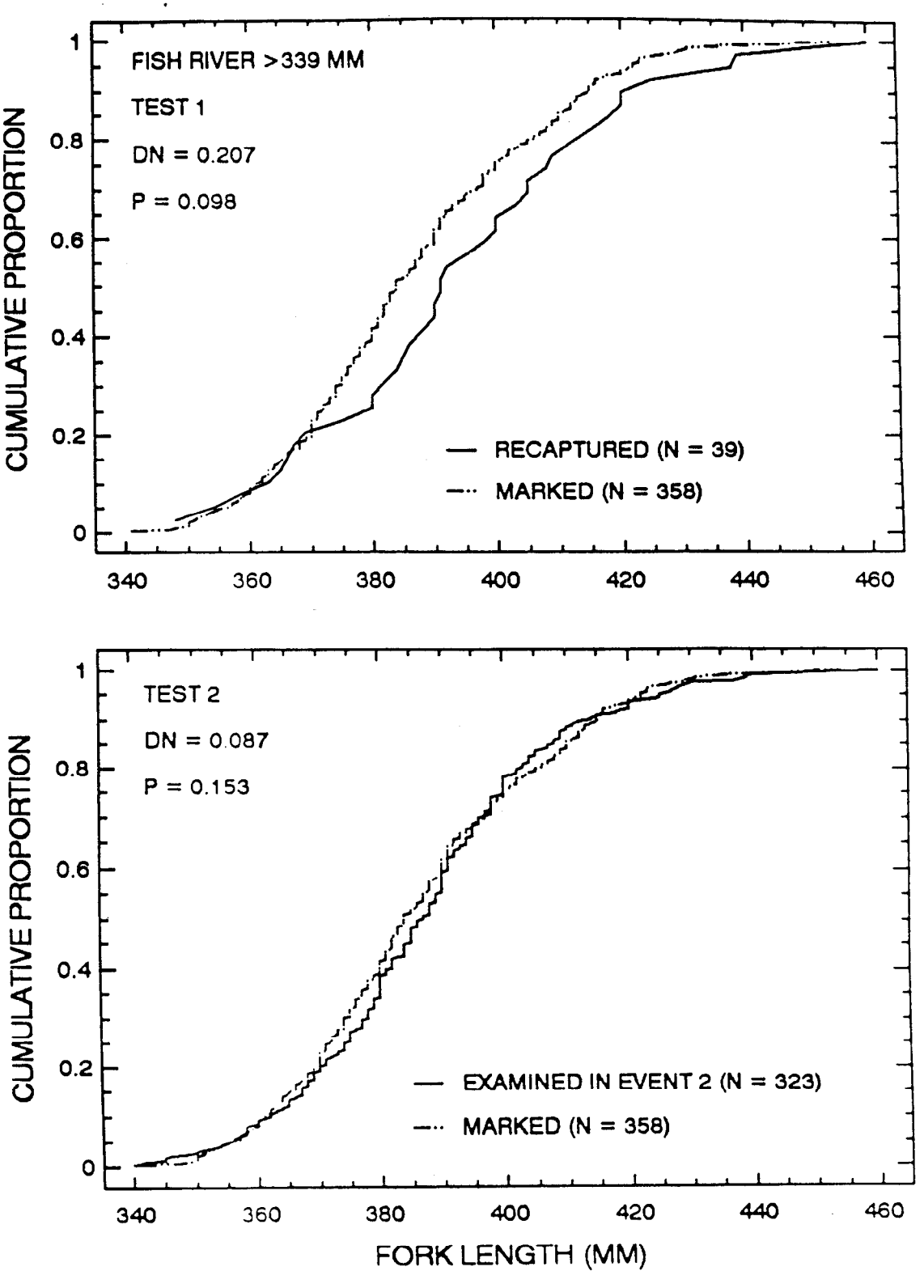

Figure 7. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling > 339 mm FL sampled from the Fish River in 1991.

Snake river was 277 mm FL. Following the rationale outlined to minimize length bias, the abundance estimate is germane to Arctic grayling >269 mm FL.

In the 28-km section of the Snake River from Boulder Creek downstream to the Nome airport, the estimated abundance of Arctic grayling greater than 269 mm FL was 1,109 (SE = 160 fish, CV = 14.1%). A total of 188 Arctic grayling greater than 269 mm FL were marked during the first sampling event (24 to 28 June). During the recapture event (1 to 5 July), 229 Arctic grayling were examined of which 38 had tags from the marking event. No fish with tag losses from the first event were encountered, however, six tag losses were noted of 11 fish which had been marked in 1988.

Arctic grayling were marked upstream of section three between the two sampling events and no fish from the first sampling event were encountered upstream from the sampling area. During the recapture event, 117 fish were examined in section three (the farthest upstream section). Three of these had been marked upstream of that section only one or two days before the sampling event. Since three times as many fish were examined in section three during the second event than marked during the first event in that section, and since fish later moved downstream into that section, it is probable that a downstream movement occurred prior to or during the second sampling event. Since there was no indication of upstream movement out of the section, the abundance estimate is germane to the second sampling event.

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 ($\chi^2 = 5.61$, df = 2, $0.05 < p < 0.10$), for all three sections. An abundance estimate stratified by area (three areas) and a single unstratified estimate were calculated. The two estimates were not found to be different, ($z = 0.44$). Therefore, the unstratified estimate was chosen because it had the smallest variance.

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 captured during the marking event versus those examined in the recapture event (test 2) failed to detect significant differences (test 1: $D = 0.15$, $p = 0.52$, $n_1 = 188$, $n_2 = 38$; test 2: $D = 0.07$, $p = 0.99$, $n_1 = 229$, $n_2 = 188$; Figure 8). Similar tests on entire samples also failed to detect significant differences. However upon inspection of the plots (Appendix A5) differences between fish marked and recaptured were apparent at lengths less than 330 mm. Length samples from both events were combined for age and length composition estimates, and additional fish marked outside the sampling area were included for length at age analysis (Appendix A6).

Pilgrim River:

The marking run on the Pilgrim River (Figure 5) was conducted during a three day period in August using beach seine and hook and line fishing techniques. The recapture event was conducted during a three day period after a four day

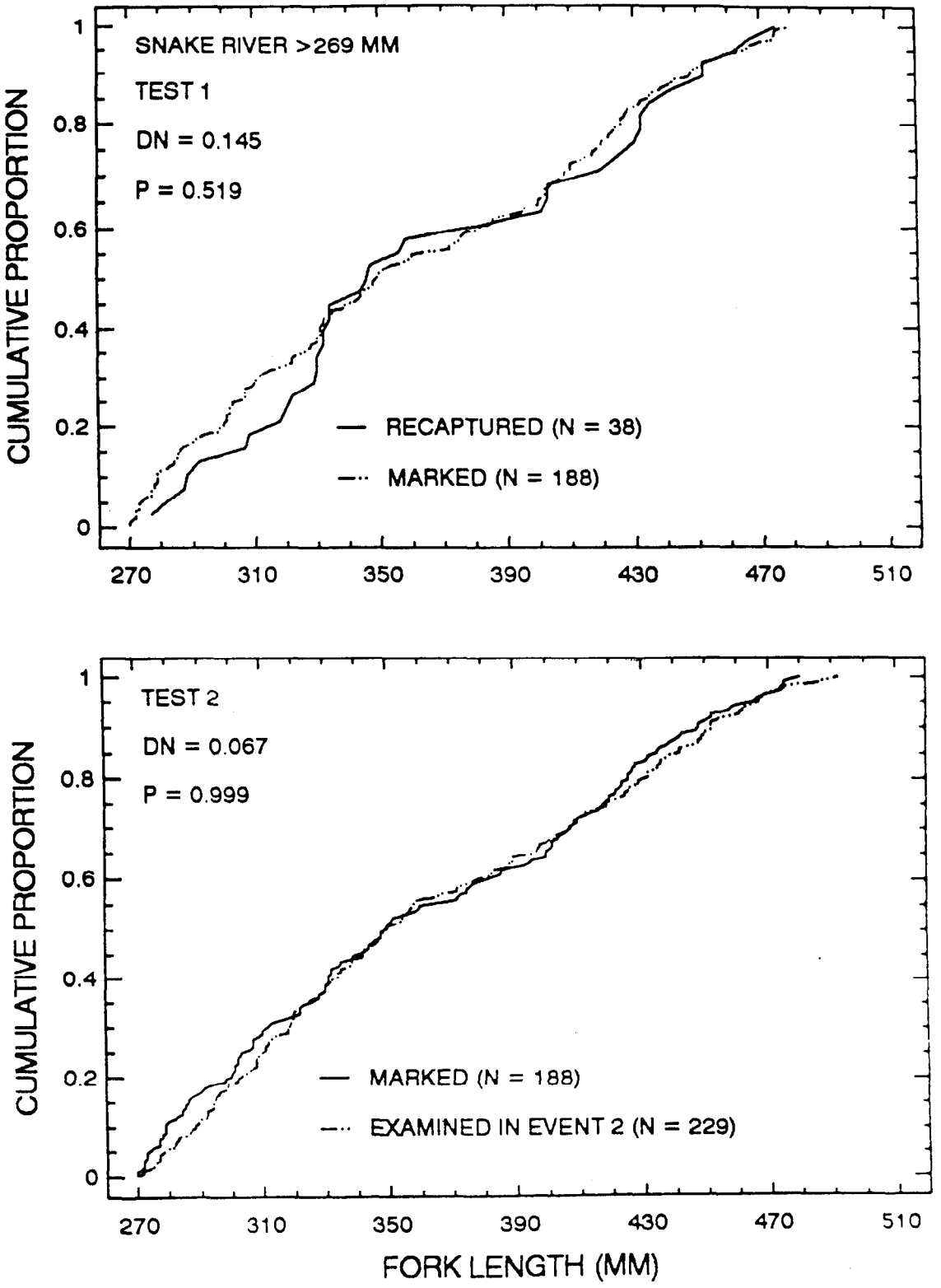

Figure 8. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >269 mm FL sampled from the Snake River in 1991.

hiatus. Beach seine and hook and line gear were used in combination to capture fish. Fishing success was good during both events. Enough fish were marked, examined and recaptured to calculate an abundance estimate within the desired precision criteria. The smallest of 186 Arctic grayling marked was 190 mm FL and the smallest of 194 Arctic grayling examined during the second event was 222 mm FL. The smallest marked fish recaptured from the Pilgrim River was 279 mm FL. Following the rationale provided earlier, the abundance estimate for the Pilgrim River applies only to Arctic grayling > 269 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 269 mm FL was 1,107 fish (SE = 197 fish, CV = 17.8%). A total of 159 Arctic grayling greater than 269 mm FL were marked during the first event (13 to 15 August). During the recapture event (19 to 21 August), 180 Arctic grayling were examined of which 25 had tags from the marking event. No tag loss was detected.

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: $D = 0.16$, $p = 0.99$, $n_1 = 159$, $n_2 = 25$; test 2: $D = 0.09$, $p = 0.54$, $n_1 = 180$, $n_2 = 159$; Figure 9). Similar tests on the entire samples did detect differences between the length distributions of marked and examined fish (Appendix A7). 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 (Appendix A8).

Nome River:

Arctic grayling residing in the Nome River (Figure 4) were marked during four days in late July using beach seine and hook and line fishing techniques. The recapture event was conducted during four days after a four day hiatus. Capture success ranged from moderate in the upstream reaches of the section to poor in the lower reaches. Fewer fish than anticipated were marked and examined, but sufficient numbers of fish were caught to calculate an abundance estimate within the desired precision criteria. The smallest Arctic grayling marked in the Nome River was 197 mm FL and the smallest Arctic grayling examined during the second event was 231 mm FL. The smallest fish recaptured from the Nome River was 280 mm FL. Following the rationale outlined to minimize length bias, the abundance estimate applies to Arctic grayling > 269 mm FL. Only four fish were marked in river section 1 (the most downstream section), and only three fish were caught in this section during the second sampling event. Since no marked fish were recaptured in the section, and the number of Arctic grayling sampled (and apparently present) was so small, these data were not included in the abundance estimate.

In the 24 km section of the Nome River from Iron Creek to Osborne, the estimated abundance of Arctic grayling greater than 269 mm FL was 430 fish (SE = 111 fish, CV = 25.8%). A total of 86 Arctic grayling greater than 269 mm FL were marked during the first event (22 to 26 July). During the recapture

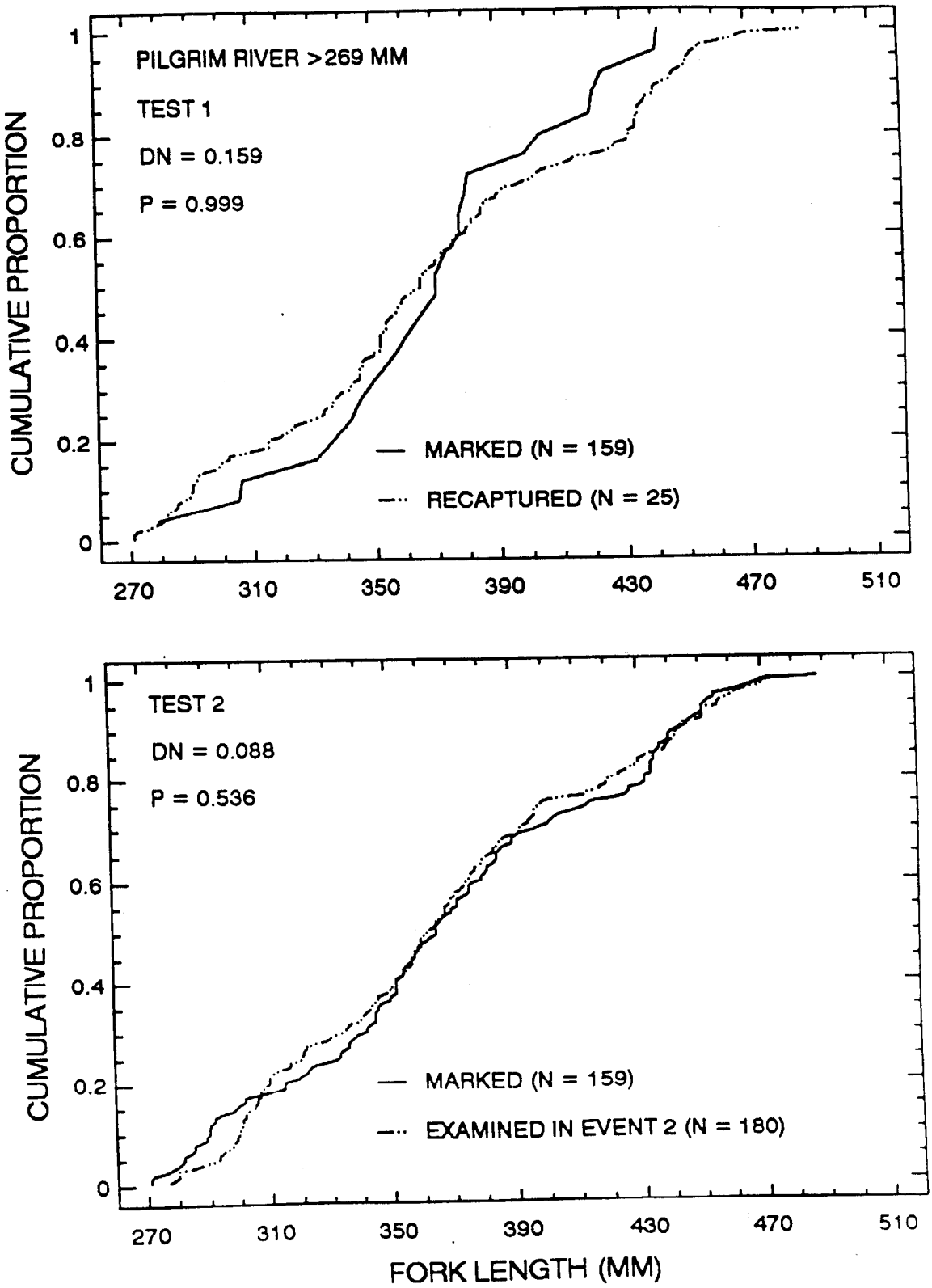

Figure 9. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >269 mm FL sampled from the Pilgrim River in 1991.

event (29 July to 1 August) 54 Arctic grayling were examined of which 10 had tags from the marking event. One tag loss was detected.

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 fish marked in the first event and those fish examined in the second event (test 2) failed to detect significant differences (test 1: $D = 0.26$, $p = 0.99$, $n_1 = 86$, $n_2 = 10$; test 2: $D = 0.18$, $p = 0.23$, $n_1 = 86$, $n_2 = 54$; Figure 10). Similar tests on the entire sample did not detect differences between the length distributions (Appendix A9). A single unstratified abundance estimate was calculated for Arctic grayling greater than 269 mm FL and fish from both sampling events were used to estimate age and length composition (Appendix A10).

Sinuk River:

The Sinuk River (Figure 6) was floated during seven days in August to collect Arctic grayling for a Jolly-Seber population abundance estimate germane to 1990. Hook and line gear was used to capture 325 Arctic grayling of which 40 carried 1990 marks and 31 carried 1989 marks. The smallest recaptured Arctic grayling at time of marking in 1989 and 1990 was 325 mm FL. The abundance estimate was therefore calculated for fish > 324 mm FL.

The abundance of Arctic grayling greater than 324 mm FL in a 40 km section of the Sinuk River in 1990, estimated from data collected during 1989, 1990 and 1991, was 1,453 fish (SE = 296, CV = 20.3%). During the marking event in 1989, 138 tagged Arctic grayling were released in the Sinuk River. During 1990, 236 Arctic grayling were examined, of which 22 were marked in 1989. Three fish had lost 1990 tags (7.5%) and no evidence of tag loss from 1989 was observed.

Three 2-sample Kolomgorov-Smirnov tests comparing the distributions of: (1A) fish marked and released in 1989 versus 1989 marked fish recaptured during 1990; (1B) fish marked and released in 1990 versus 1990 marked fish recaptured during 1991; and (test 2) fish examined in 1990 versus fish examined in 1991 all indicated no appreciable length selectivity for fish greater than 324 mm FL (test 1A: $DN = 0.13$, $p = 0.99$; test 1B: $DN = 0.10$, $p = 0.99$; test 2: $DN = 0.09$, $p = 0.19$; Figure 11). Similar results were obtained with tests conducted on the full range of lengths (Appendix A11). Cumulative length distributions of samples from 1989, 1990, and 1991 were compared with the K-Sample Anderson-Darling test and found to be different ($T_{akn} = 8.34$, $p < 0.01$; Appendix A12). Since there was only one sampling event each year, it is not known whether differences were due to selectivity or to legitimate differences in size composition among years. The program JOLLYAGE was therefore used to test the data with different models. Data were tested for two different size groups of fish (large and small) with bounds set at two different values (410 mm, and 435 mm). These tests failed to reject the hypothesis that probabilities of capture and survival were different by size group. Data were not stratified by size or age. Data were truncated by size using the smallest recaptured fish's fork length at marking (325 mm) as a lower bound. Abundance estimates were calculated using both truncated data and all data using the program RECAP. Unadjusted estimates and modified estimates using

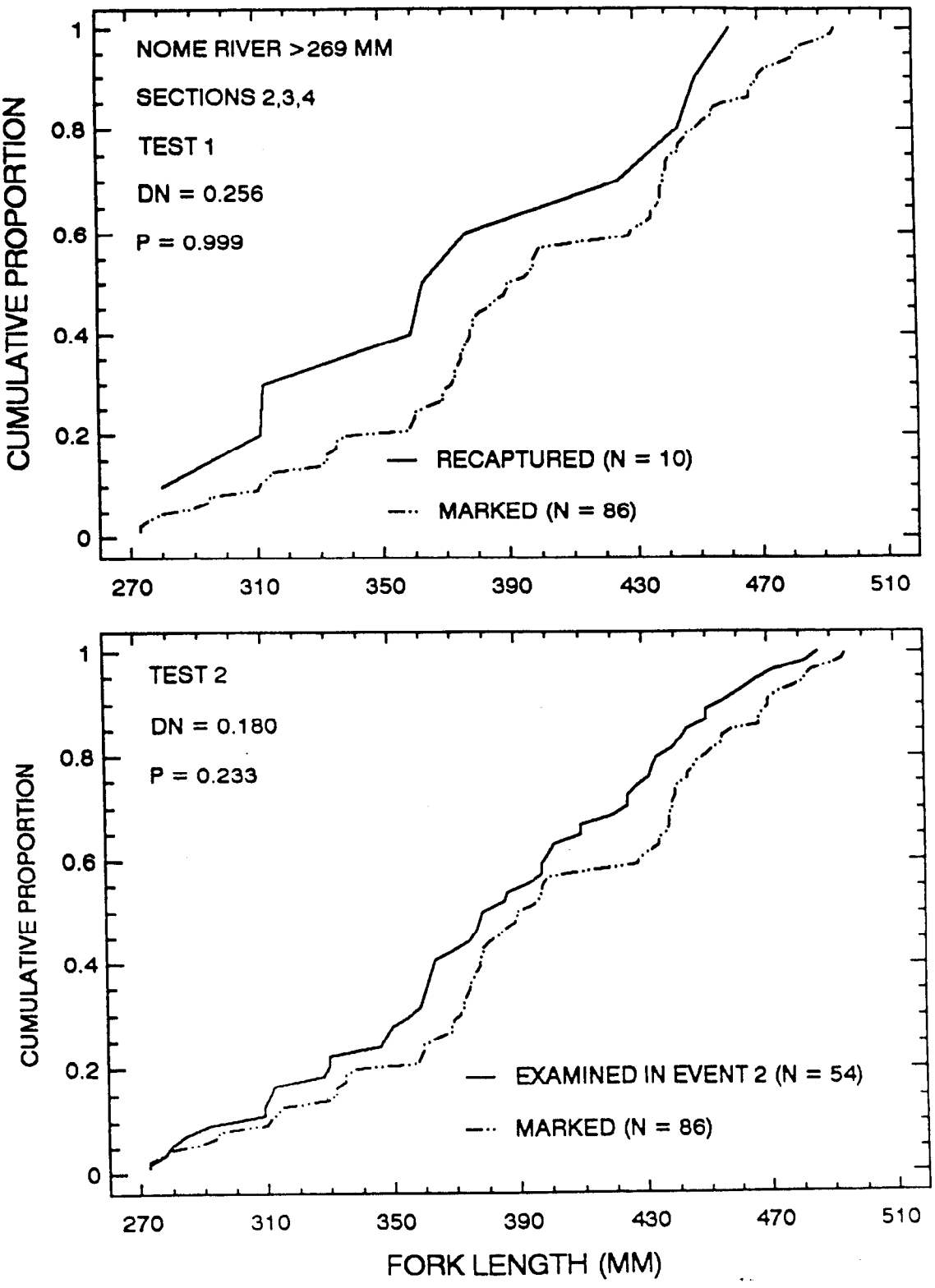

Figure 10. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling >269 mm FL sampled from the Nome River in 1991.

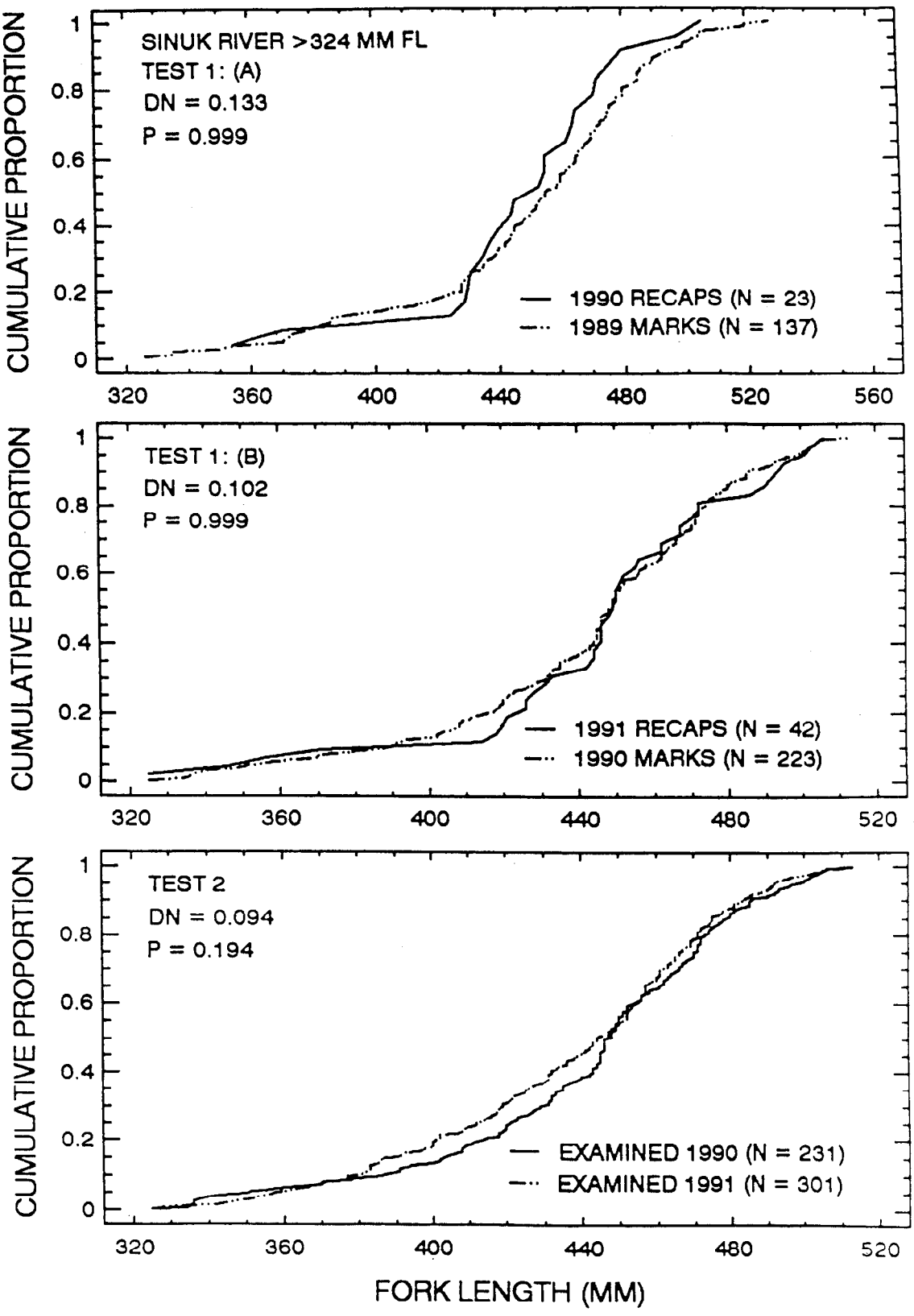

Figure 11. Cumulative length distribution plots (tests 1: A and B, and test 2) of Arctic grayling >324 mm FL in the Sinuk River.

bootstrapping in order to bring ϕ (survival) to 1.0 were calculated. Since the unadjusted estimate gave an unrealistic value for survival (ϕ = 1.109), and the modified estimate for truncated data had a smaller standard error than that for all non-truncated data, the modified estimate for truncated data was ultimately chosen (Appendix A13).

Age Composition

Although Arctic grayling sampled during 1991 ranged from age 0 fish collected from the Snake River to age 15 fish collected from the Sinuk River, estimates of age composition and abundance by age class were restricted to: (1) fish larger than 269 mm FL from the Snake, Nome and Pilgrim rivers; (2) fish larger than 339 mm FL from the Fish River; and, (3) fish larger than 325 mm FL from the Sinuk River in 1990 (Table 2). The numbers of fish in each age class from the Snake, Nome and Pilgrim rivers (rivers for which estimates were germane to the same length range) were compared and found to be significantly different (χ^2 = 64.17, df = 17, p <0.001). Age composition estimates for Sinuk River Arctic grayling aged 6 and older in 1990 were not different from those sampled in 1991 (adjusted by one year; χ^2 = 5.94, df = 5, 0.5> p >0.25). Age 7 and 8 fish dominated the population from the Fish River (73%) while ages of fish from other rivers were more evenly distributed (Figure 12). Higher proportions of Arctic grayling aged 10 years and older were found in the Sinuk River (12.9% in 1990, 20.3% in 1991) than in other rivers which ranged from 3.2% to 4.4%. The oldest Arctic grayling sampled during 1991 were: (1) 10 years from the Fish River; (2) 11 years from the Snake River; (3) 12 years from the Nome and Pilgrim rivers; and, (4) 15 years from the Sinuk River.

Length Composition

Length composition of Arctic grayling stocks sampled within the study area was estimated as Relative Stock Density categories (Figure 13). The majority of Arctic grayling sampled from all rivers were in the preferred or memorable categories (Table 3). Comparable data gathered from the Snake, Pilgrim, and Nome rivers indicated that Relative Stock Densities were significantly different among rivers (χ^2 = 32.07, df = 4, p <0.001). Arctic grayling in the preferred category comprised 49%, 60%, and 60% of the respective size compositions in those rivers in 1991. Memorable fish were not abundant in the Fish River (<1%), and moderately abundant in the Snake, Pilgrim, and Nome rivers (9%, 8% and 18%). The preferred category comprised 99% of the Arctic grayling greater than 339 mm FL in the Fish River. Preferred and memorable fish comprised 50% and 46% of the estimated size composition in the Sinuk River in 1990. No fish in the trophy category were encountered in any river. Few fish of stock size and smaller were sampled. The Arctic grayling sample from the Sinuk River during 1991 was composed of 1% stock, 8% quality, 47% preferred, and 43% memorable fish. Examination of size distribution of all Arctic grayling >101 mm FL sampled during 1991 (Table 4) shows that the majority of Arctic grayling sampled from some rivers represent limited length ranges. In the Fish River 85% of the Arctic grayling were between 351 and 425 mm FL. Arctic grayling in Sinuk River were larger with 51% being greater than 426 mm FL. Arctic grayling in the Snake, Nome, and Pilgrim rivers were more uniformly distributed by length (Appendix A14).

Table 2. Estimates of age composition and abundance of Arctic grayling sampled from the Fish, Snake, Pilgrim, and Nome rivers in 1991 and from the Sinuk River in 1990.

Statistic	Age 2	3	4	5	6	7	8	9	10	11	12	13	Totals
Fish R. (fish >339 mm FL)													
Sample Size	---	---	---	14	81	206	194	54	2	0	0	0	551
Est. Proportion	---	---	---	0.03	0.15	0.37	0.35	0.10	<0.01	0.00	0.00	0.00	1.00
SE of Proportion	---	---	---	<0.01	0.02	0.02	0.02	0.01	<0.01	0.00	0.00	0.00	
Est. Abundance	---	---	---	74	426	1,084	1,021	284	11	0	0	0	2,900
SE of Abundance	---	---	---	22	76	196	160	55	8	0	0	0	424
Snake R. (fish >269 mm FL)													
Sample Size	---	2	70	85	64	52	66	60	17	1	0	0	417
Est. Proportion	---	<0.01	0.17	0.20	0.15	0.12	0.15	0.14	0.04	<0.01	0.00	0.00	1.00
SE of Proportion	---	<0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	<0.01	0.00	0.00	
Est. Abundance	---	5	186	226	170	138	176	160	45	7	0	0	1,109
SE of Abundance	---	4	34	39	31	27	32	30	12	3	0	0	160
Pilgrim R. (fish >269 mm FL)													
Sample Size	---	13	43	29	74	54	36	32	10	2	1	0	294
Est. Proportion	---	0.04	0.15	0.10	0.25	0.18	0.12	0.11	0.03	<0.01	<0.01	0.00	1.00
SE of Proportion	---	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.01	<0.01	<0.01	0.00	
Est. Abundance	---	49	162	109	279	203	136	120	38	8	4	0	1,107
SE of Abundance	---	16	37	27	57	44	32	29	13	5	4	0	197
Nome R. (fish >269 mm FL)													
Sample Size	---	6	18	20	36	26	13	1	3	0	1	0	124
Est. Proportion	---	0.05	0.15	0.16	0.29	0.21	0.10	<0.01	0.02	0.00	<0.01	0.00	1.00
SE of Proportion	---	0.02	0.03	0.03	0.04	0.04	0.03	<0.01	0.01	0.00	<0.01	0.00	
Est. Abundance	---	21	62	69	125	90	45	3	10	0	3	0	430
SE of Abundance	---	10	21	23	36	28	16	3	6	0	3	0	111
Sinuk R. 1990 (fish >324 mm FL)													
Sample Size	---	1	3	4	32	62	42	18	11	10	1	2	186
Est. Proportion	---	<0.01	0.02	0.02	0.17	0.33	0.23	0.10	0.06	0.05	<0.01	0.01	1.00
SE of Proportion	---	<0.01	<0.01	0.01	0.03	0.03	0.02	0.02	0.02	0.02	<0.01	<0.01	
Est. Abundance	---	8	24	31	250	484	328	141	86	78	8	16	1,453
SE of Abundance	---	8	14	16	64	110	80	42	30	28	8	11	296

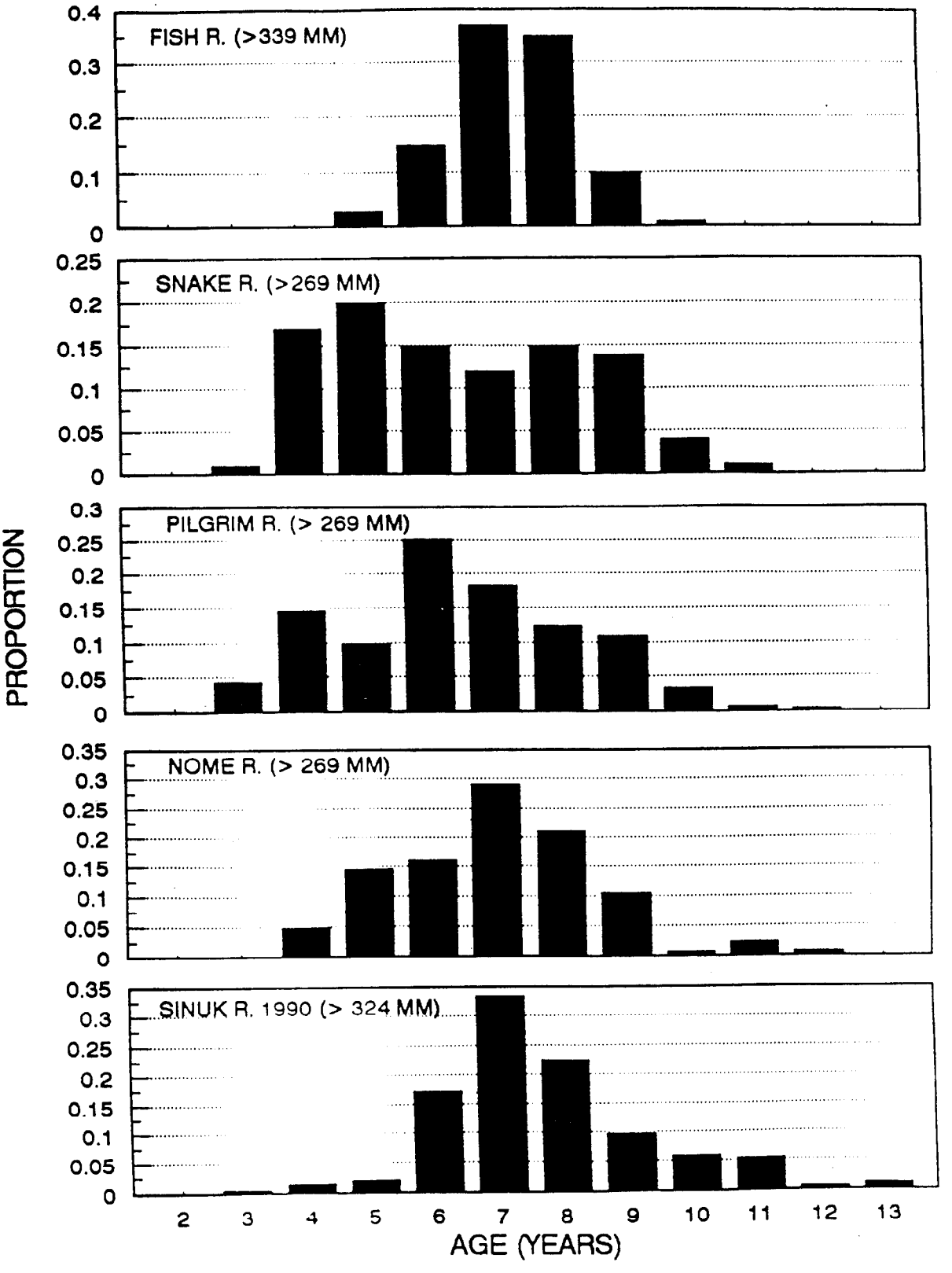

Figure 12. Age composition estimates of Arctic grayling from the Fish, Snake, Pilgrim and Nome rivers during 1991 and from the Sinuk River during 1990.

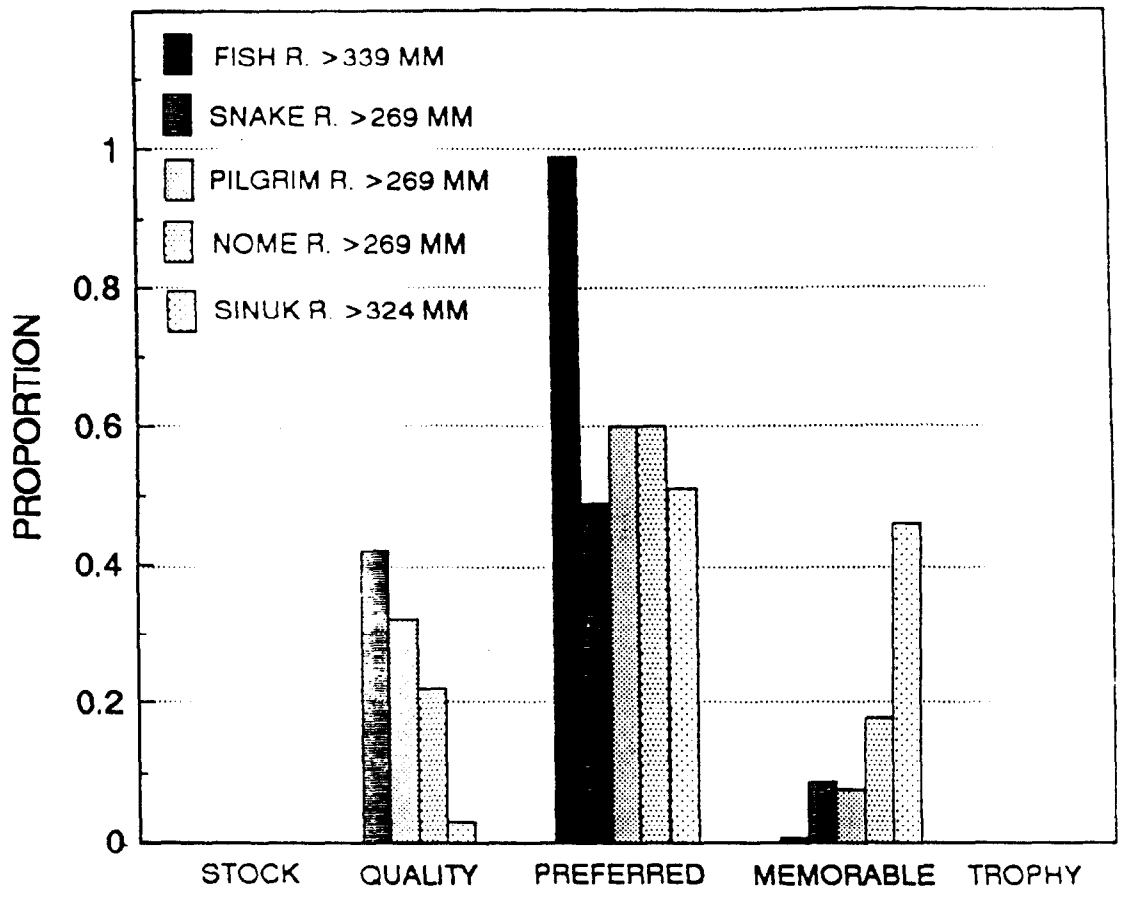

Figure 13. Length composition estimates as Relative Stock Density categories for Arctic grayling from the Fish, Snake, Pilgrim and Nome rivers in 1991 and the Sinuk River in 1990.

Table 3. Number and proportion of Arctic grayling sampled and estimated abundances by RSD category in the Fish, Snake, Pilgrim and Nome rivers during 1991 and the Sinuk River during 1990.

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
Fish River (fish >339 mm FL)					
Number sampled	---	---	694	3	0
RSD	---	---	0.99	<0.01	0.00
Standard Error	---	---	<0.01	<0.01	0.00
Abundance	---	---	2,888	12	0
Standard Error	---	---	422	7	0
Snake River (fish >269 mm FL)					
Number sampled	---	214	248	47	0
RSD	---	0.42	0.49	0.09	0.00
Standard Error	---	0.02	0.02	0.01	0.00
Abundance	---	466	540	102	0
Standard Error	---	71	82	20	0
Pilgrim River (fish >269 mm FL)					
Number sampled	---	110	210	29	0
RSD	---	0.32	0.60	0.08	0.00
Standard Error	---	0.02	0.03	0.01	0.00
Abundance	---	349	666	92	0
Standard Error	---	68	122	23	0
Nome River (fish >269 mm FL)					
Number sampled	---	33	90	84	0
RSD	---	0.22	0.60	0.18	0.00
Standard Error	---	0.04	0.04	0.03	0.00
Abundance	---	95	258	77	0
Standard Error	---	28	69	24	0
Sinuk River 1990 (fish >324 mm FL)					
Number sampled	---	8	118	106	0
RSD	---	0.03	0.51	0.46	0.00
Standard Error	---	0.01	0.03	0.03	0.00
Abundance	---	50	739	663	0
Standard Error	---	20	158	143	0

[a] Minimum lengths for RSD categories (Gablehouse 1984) are: Stock 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL; Memorable - 450 mm FL; and, Trophy - 560 mm FL.

Table 4. Length composition in 25 mm increments of Arctic grayling >101 mm fork length sampled from Seward Peninsula rivers during 1991.

Fork Length Range (mm)	Fish River Sampled Fish	Fish River Proportion	Fish River Standard Error	Snake River Sampled Fish	Snake River Proportion	Snake River Standard Error
101 - 125	1	0.001	0.001	14	0.014	0.004
126 - 150	0	0.000	0.000	14	0.014	0.004
151 - 175	1	0.001	0.001	0	0.000	0.000
176 - 200	0	0.000	0.000	1	0.001	0.001
201 - 225	8	0.011	0.004	28	0.028	0.005
226 - 250	15	0.020	0.005	76	0.075	0.008
251 - 275	5	0.007	0.003	96	0.094	0.009
276 - 300	8	0.011	0.004	124	0.122	0.010
301 - 325	18	0.024	0.006	132	0.130	0.011
326 - 350	27	0.036	0.007	118	0.116	0.010
351 - 375	187	0.246	0.016	86	0.085	0.009
376 - 400	330	0.435	0.018	64	0.063	0.008
401 - 425	131	0.173	0.014	97	0.095	0.009
426 - 450	25	0.033	0.006	104	0.102	0.010
451 - 475	3	0.004	0.002	53	0.052	0.007
476 - 500	0	0.000	0.000	9	0.009	0.003
Total 101 - 500	759	1.000		1,016	1.000	

Fork Length Range (mm)	Pilgrim River Sampled Fish	Pilgrim River Proportion	Pilgrim River Standard Error	Nome River Sampled Fish	Nome River Proportion	Nome River Standard Error	Sinuk River Sampled Fish	Sinuk River Proportion	Sinuk River Standard Error
101 - 125	2	0.005	0.004	2	0.012	0.008	0	0.000	0.000
126 - 174	3	0.008	0.004	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	1	0.003	0.003	1	0.006	0.006	0	0.000	0.000
201 - 225	6	0.015	0.006	0	0.000	0.000	1	0.003	0.003
226 - 250	17	0.043	0.010	6	0.036	0.014	1	0.003	0.003
251 - 275	19	0.048	0.011	12	0.072	0.020	3	0.009	0.005
276 - 300	45	0.114	0.016	11	0.066	0.019	4	0.012	0.006
301 - 325	45	0.114	0.016	8	0.048	0.017	14	0.043	0.011
326 - 350	42	0.107	0.016	13	0.078	0.021	8	0.025	0.009
351 - 375	70	0.178	0.019	24	0.144	0.028	16	0.050	0.012
376 - 400	49	0.124	0.017	29	0.174	0.029	33	0.102	0.017
401 - 425	21	0.053	0.011	7	0.042	0.016	46	0.142	0.019
426 - 450	46	0.117	0.016	30	0.180	0.030	60	0.186	0.022
451 - 475	27	0.069	0.013	14	0.084	0.021	94	0.291	0.018
476 - 500	1	0.003	0.003	10	0.060	0.018	36	0.111	0.018
501 - 525	2	0.006	0.004	0	0.000	0.000	7	0.022	0.008
151 - 550	394	1.000		167	1.000		323	1.000	

Mean Length-at-Age

Estimates of mean fork length-at-age were calculated for Arctic grayling sampled from the Fish, Snake, Pilgrim, Nome, and Sinuk rivers (Table 5). Where data were available, they were combined across years. Arctic grayling from the Sinuk River were larger at most age classes than fish of the same age classes sampled from other Seward Peninsula rivers. Fish in the Nome River reached the size of Sinuk River fish by age 8. Sinuk River fish increased in mean length at age faster after that age, although this observation is made from a small sample. Arctic grayling from the Fish River increased in mean fork length rapidly to age 6 slowing with the probable onset of sexual maturity. 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. Similar patterns of growth were less apparent for fish sampled from the Snake, Pilgrim, and Nome rivers where fish continued to increase in fork length with age. Age and length distributions of Arctic grayling sampled are provided in Appendices A4, A6, A8, A10 and A15.

Growth

Young of the year Arctic grayling were collected periodically after first being found in the Snake River. Mean fork length increased from 21.9 mm on 5 July 1991 to 42.0 mm by 30 July (Table 6). Fish reached 71.6 mm FL by 14 September 1991. The maximum growth rate achieved was 0.96 mm/day during the third week of July.

Mean annual increase in fork length of 119 marked Arctic grayling recaptured one year later from the Fish River was 8.1 mm. The annual increment ranged from 0 to 48 mm (Figure 14). The mean annual growth increment of 71 fish recaptured from the Sinuk River was 5.2 mm. Mean annual increases in fork length for Arctic grayling sampled from the Fish and Sinuk rivers was different (t = 1.88, p = 0.06).

DISCUSSION

Estimates of abundance of Arctic grayling residing in all study rivers were achieved within desired precision goals. The realized precision of estimates at α = 0.10 were as follows: Fish River ± 24%, Snake River ± 23%, Pilgrim River ± 29%, Nome River ± 42%, and Sinuk River ± 33%.

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 in all rivers subject to two event sampling and fish from both events were used for age and size composition estimates. 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. Small sized Arctic grayling (< 300 mm FL) were not common in any stretch of river sampled, yet fish of this size are commonly caught using similar gear types in the Tanana River

Table 5. Mean fork length-at-age of Arctic grayling in Seward Peninsula rivers sampled during 1991.

	Fish River			Snake River			Pilgrim River			Nome River			Sinuk River		
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	1	92	0	29	139	67	---	---	---	1	125	0	---	---	---
2	17	167	22	---	---	---	2	207	34	---	---	---	1	206	0
3	33	230	21	113	241	22	42	258	25	19	257	23	4	272	30
4	22	281	32	207	286	27	56	294	23	19	314	26	23	325	33
5	33	356	33	131	319	30	54	324	34	21	376	41	21	370	48
6	186	381	22	103	352	35	128	354	34	37	392	32	93	420	45
7	484	382	21	82	389	44	132	383	36	26	439	29	148	443	30
8	368	382	22	94	415	31	96	409	32	13	457	18	136	448	36
9	76	383	22	83	434	28	77	433	30	1	446	0	78	448	38
10	6	389	16	25	433	24	32	439	32	3	485	11	51	450	40
11	---	---	---	2	475	1	9	449	42	---	---	---	28	471	30
12	---	---	---	---	---	---	4	460	12	1	495	0	6	464	25
13	---	---	---	---	---	---	1	445	0	---	---	---	4	493	29
14	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
15	---	---	---	---	---	---	---	---	---	---	---	---	1	499	0

Table 6. Fork length and growth of young of the year Arctic grayling captured in the Snake River in 1991.

Date	Sample Size	Mean FL (mm)	Standard Deviation	FL Range (mm)	Growth Rate (mm/day)
5 July	12	21.910	0.9962	21 - 24	
					0.58
14 July	16	27.125	2.1871	24 - 30	
					0.88
20 July	69	32.391	2.6078	27 - 37	
					0.96
30 July	19	42.000	4.1230	36 - 51	
					0.74
4 August	27	45.740	5.3248	38 - 59	
					0.79
21 August	10	59.100	3.5730	52 - 62	
					0.52
14 September	8	65.500	1.6036	63 - 68	

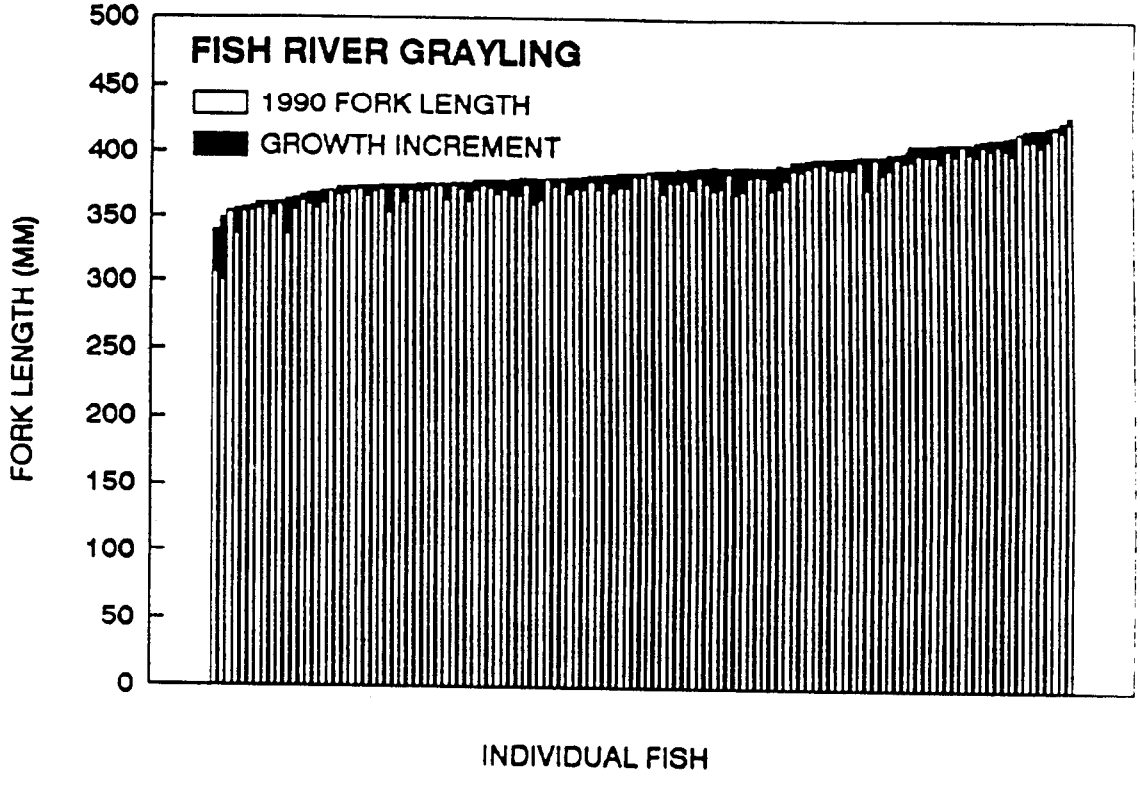

Figure 14. Annual increase in fork length of marked Arctic grayling recaptured after one year in the Fish Rivers during 1991.

drainage (Clark et al. 1991). For samples to represent the entire Arctic grayling population of a given river, either the entire river would have to be sampled or fish representative of the entire river's population would need to be present within the river section sampled. The latter case is likely untrue for the Fish, Pilgrim, Snake, and Sinuk rivers. The relative lack of small sized Arctic grayling in samples suggests that young fish occupy different areas or habitats than were sampled. Small Arctic grayling were found in the Snake River in small lower river tributary streams and in connected oxbow lakes outside the sampling area.

As suggested in 1990 (DeCicco 1991), continued sampling of Arctic grayling residing in the Fish River resulted in a similar length distribution of Arctic grayling. High recapture rate of fish tagged in 1990 suggests that Arctic grayling inhabit the same reach of the river each summer. Given these conditions, a single sampling event in 1992 should be sufficient to estimate abundance via the Jolly-Seber model, and is recommended as an alternate cost effective strategy.

In addition to planned sampling of Arctic grayling from the Snake River, Arctic grayling were sampled in an area which extended 20 km farther upstream. Good access is afforded to this entire area which, based on the relative abundance of Arctic grayling, is near the upper limit of their distribution in that river. Future work on Arctic grayling should include the entire river from Goldbottom Creek downstream. This would provide a whole river estimate and data on population dynamics for a complete river allowing recruitment and mortality processes to be followed over time.

The abundance of Arctic grayling in the Nome River as indicated by 1991 data was alarmingly low (430 fish, SE = 111). Additional data should be collected. Regulatory action to restrict the harvest of Arctic grayling in the Nome River should be considered.

The Sinuk River was the least exploited area sampled. Arctic grayling average size was large (445 mm FL), fish attained large maximum size (528 mm FL), lived long and had low mortality. This may be typical for unexploited populations on the Seward Peninsula. All other sampled rivers are exploited to a greater extent. The estimated density of Arctic grayling in the Sinuk River was relatively low (36 fish/km) and the population appears to be stable. The estimated density of Arctic grayling was greatest (121 fish/km) in the Fish River and least (18/km) in the Nome River. Density in the Pilgrim River was 92 fish/km and in the Snake River was 40 fish/km. These densities are lower than Tanana River drainage streams (Clark et al. 1991), but in general, Arctic grayling attain larger size in Seward Peninsula waters.

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APPENDIX A

Appendix A1. List of numbered tags and fin clips used to mark Arctic grayling sampled from the Fish, Snake, Pilgrim, Nome, and Sinuk rivers during 1991.

Location	Month	Total Fish	Tag Numbers	Color	Fin Clip
Fish River	July	574	28000 - 28573	Blue	Right Ventral
Snake River	June	280	27000 - 27279	Blue	Left Pectoral
	July	222	27280 - 27501	Blue	Left Pectoral
	July	9	27750 - 27758	Blue	Left Pectoral
	August	151	27759 - 27909	Blue	Left Pectoral
	August	48	27502 - 27549	Blue	Left Pectoral
	August	150	27600 - 27749	Blue	Left Pectoral
Pilgrim River	August	220	53302 - 53522	Green	Right Pectoral
	August	21	53524 - 53544	Green	Right Pectoral
	August	93	53546 - 53638	Green	Right Pectoral
Nome River	August	7	52672 - 52678	Green	Left Pectoral
	August	85	52687 - 52771	Green	Left Pectoral
	August	50	52850 - 52899	Green	Left Pectoral
	August	4	52950 - 52953	Green	Left Pectoral
Sinuk River	August	18	51352 - 51369	Green	Left Pectoral
	August	62	51371 - 51432	Green	Left Pectoral
	August	123	51434 - 51556	Green	Left Pectoral
	August	44	51558 - 51601	Green	Left Pectoral

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

Results of Hypothesis Tests (K-S and χ^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.

Case II: 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.

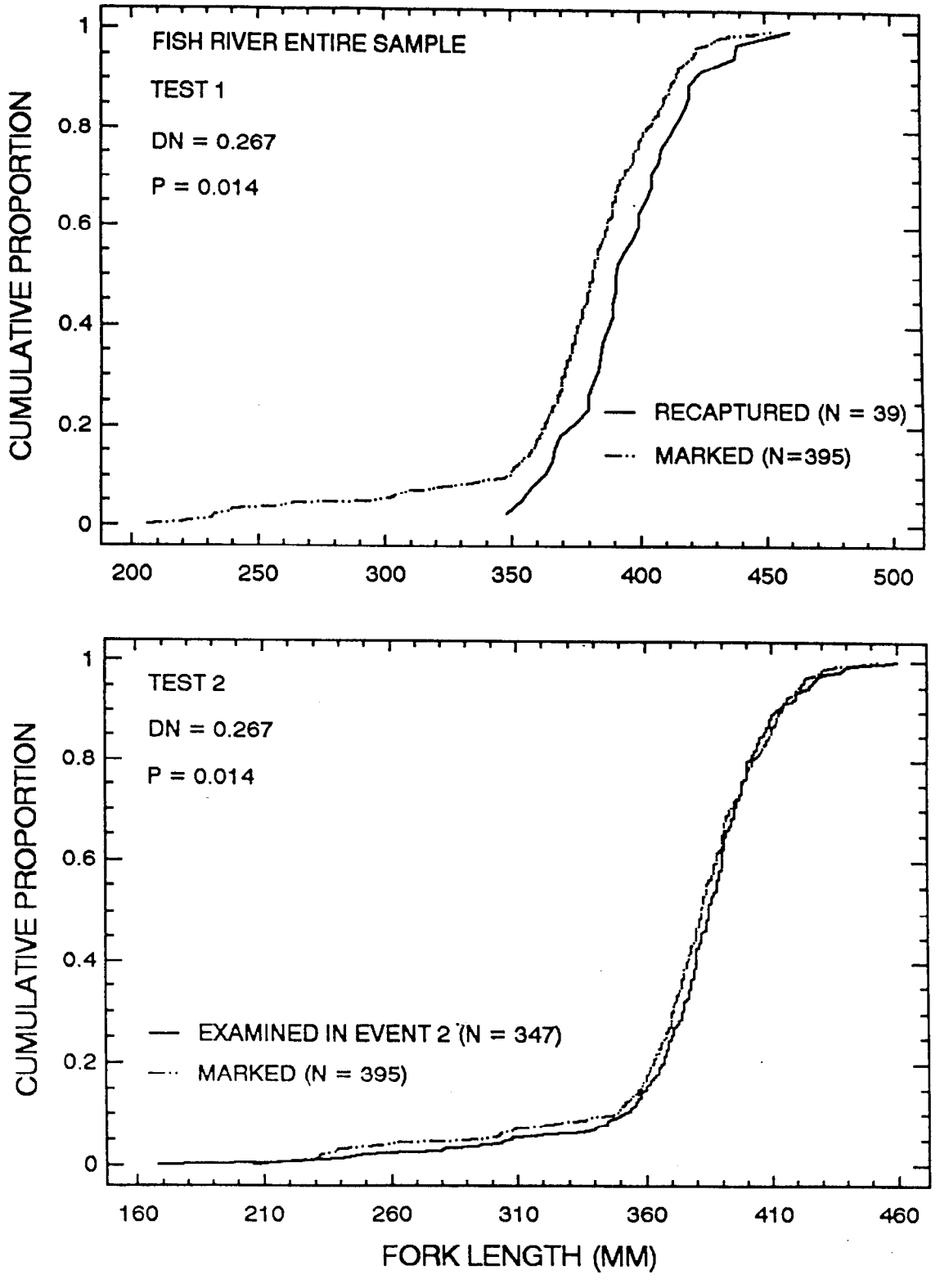
Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

-continued-

Appendix A2. (Page 2 of 2).

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.

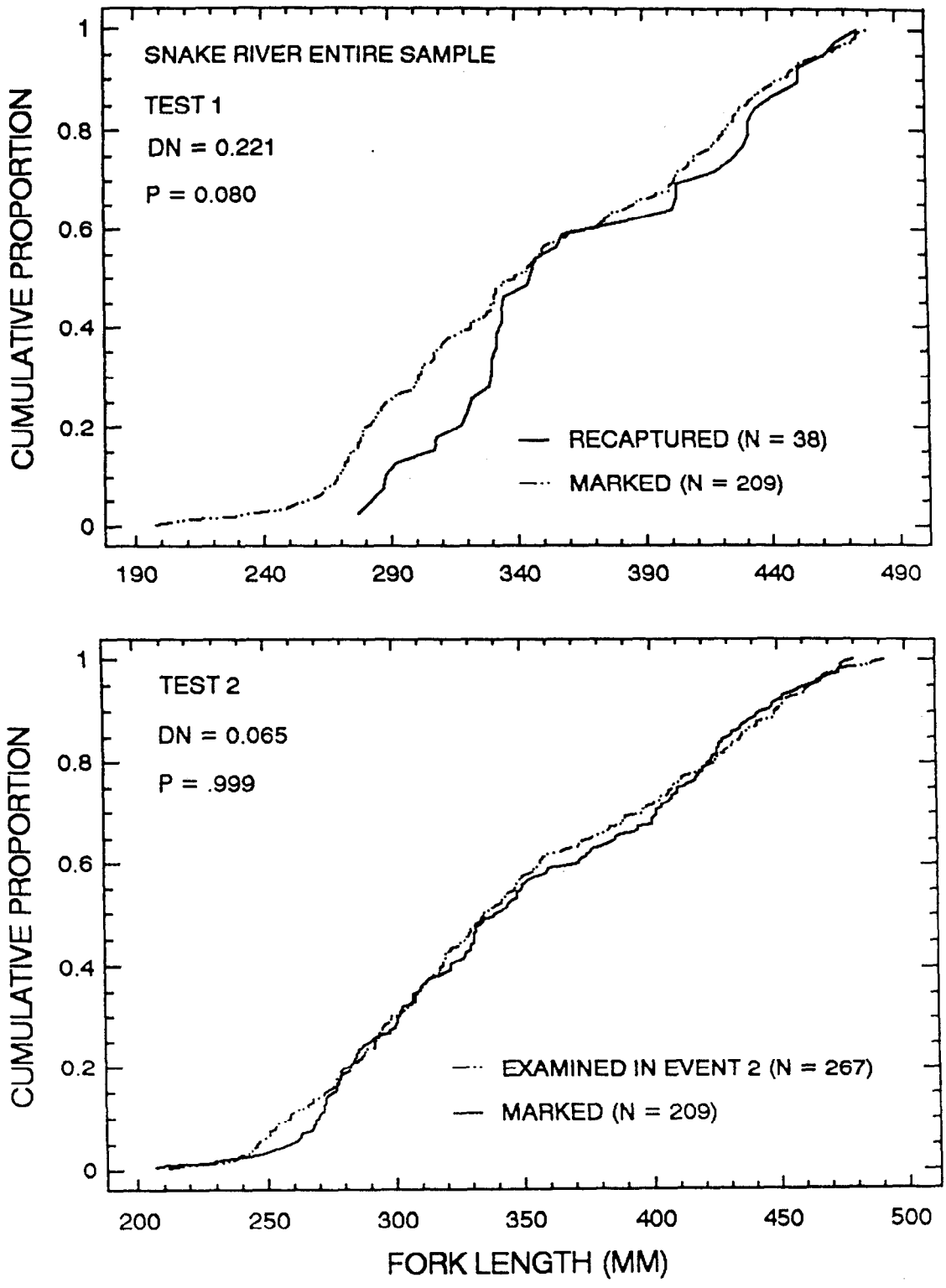
Case IVb: If the stratified and unstratified abundance estimates for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not apply formulae to correct for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



Appendix A3. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling sampled from the Fish River in 1991.

Appendix A4. Age-length distribution of Arctic grayling sampled from the Fish River during 1991.

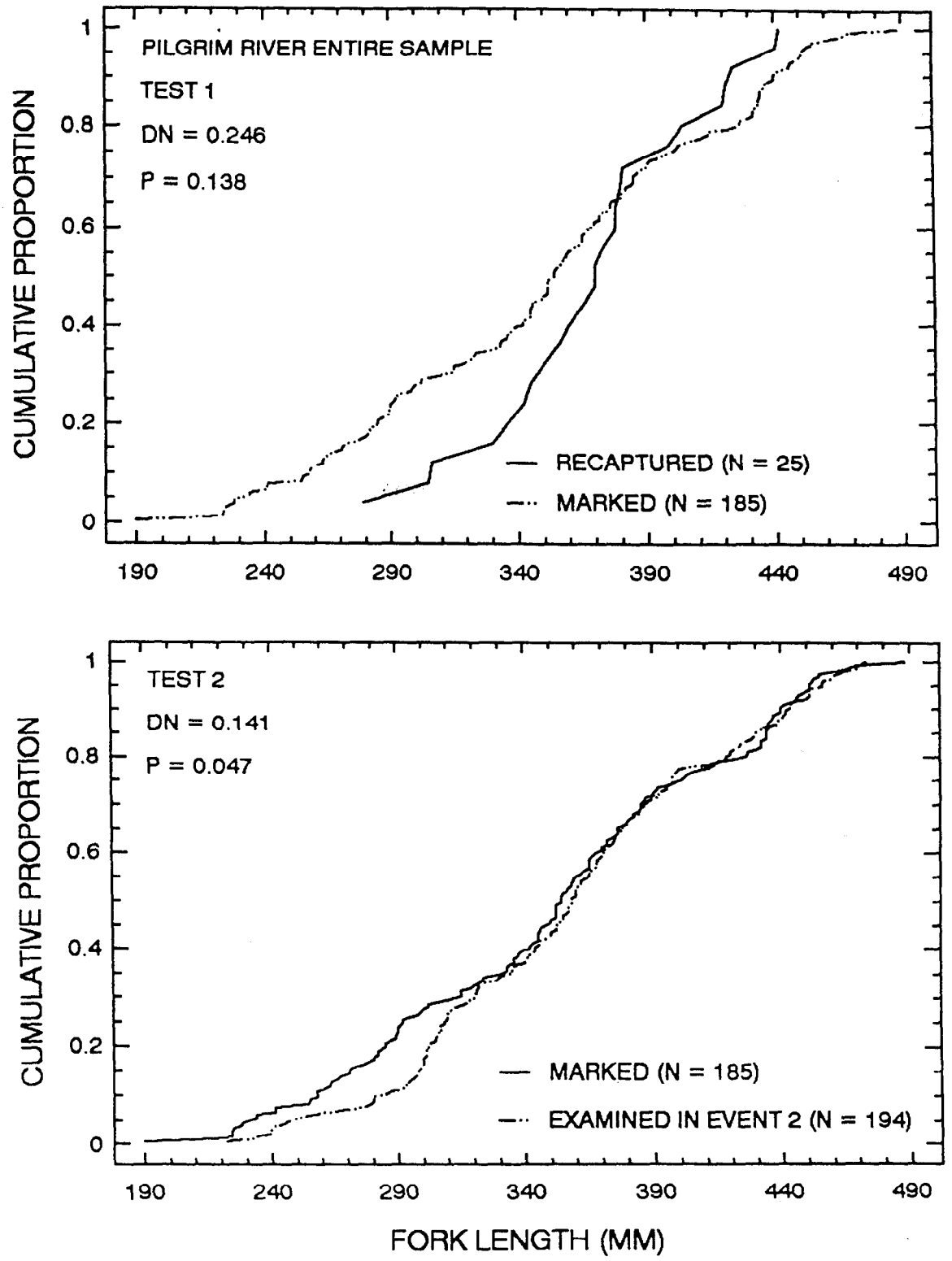
Fork Length (mm)	Age (Years)													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	1	0	0	0	0	0	0	0	0	0	0	0	1
176 to 200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201 to 225	0	0	8	0	0	0	0	0	0	0	0	0	0	8
226 to 250	0	0	15	0	0	0	0	0	0	0	0	0	0	15
251 to 275	0	0	4	1	0	0	0	0	0	0	0	0	0	5
276 to 300	0	0	0	7	0	0	0	0	0	0	0	0	0	7
301 to 325	0	0	0	7	3	2	1	1	0	0	0	0	0	14
326 to 350	0	0	0	0	2	5	8	6	0	0	0	0	0	21
351 to 375	0	0	0	0	5	17	47	63	16	0	0	0	0	148
376 to 400	0	0	0	0	7	38	115	76	28	2	0	0	0	266
401 to 425	0	0	0	0	1	19	33	43	8	0	0	0	0	104
426 to 450	0	0	0	0	0	4	6	6	1	0	0	0	0	17
451 to 475	0	0	0	0	0	0	0	1	1	0	0	0	0	2
476 to 500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	1	1	27	15	18	85	210	196	54	2	0	0	0	608



Appendix A5. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling sampled from the Snake River in 1991.

Appendix A6. Age-length distribution of Arctic grayling sampled from the Snake River during 1991.

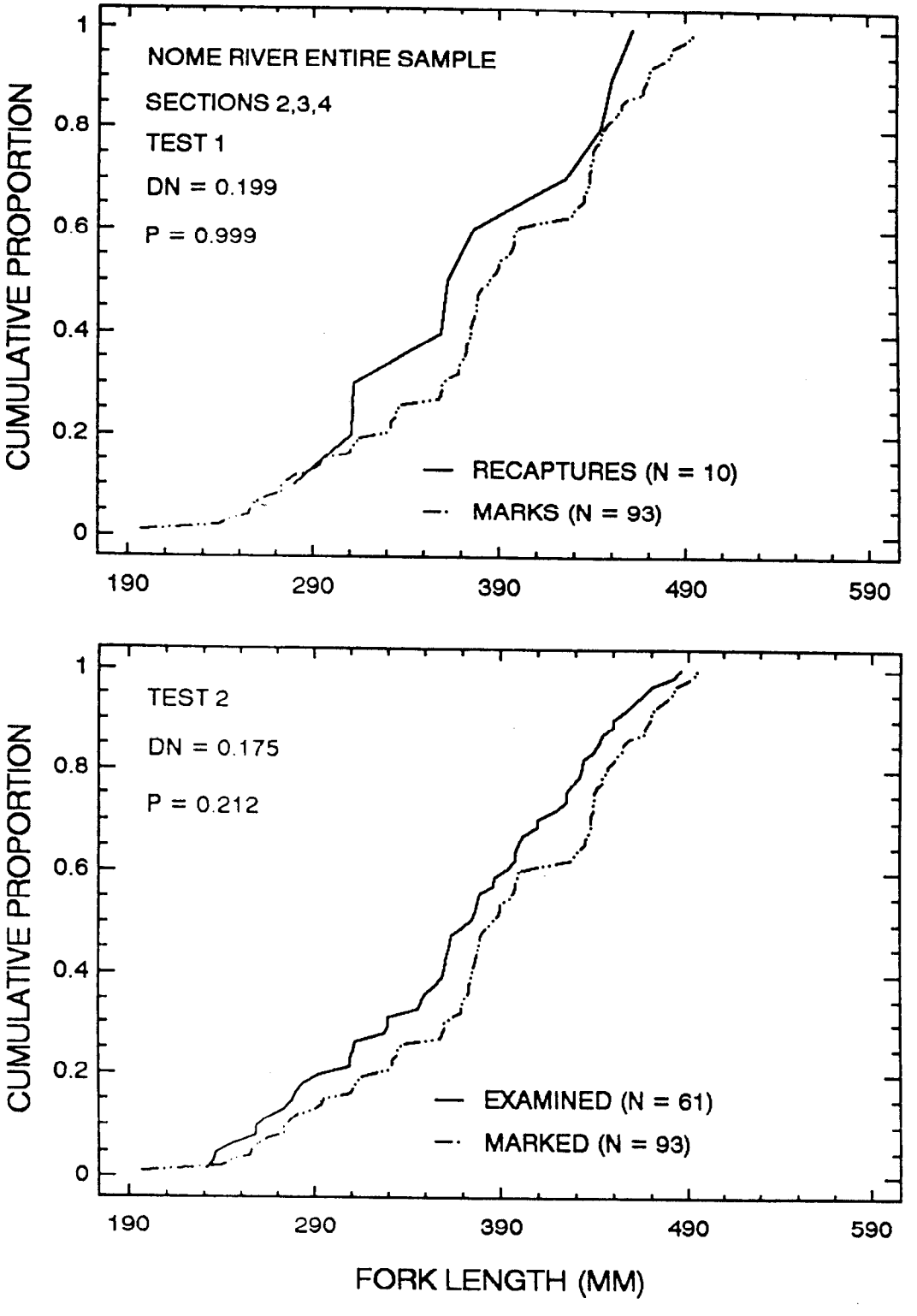
Fork Length (mm)	Age (Years)													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	14	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	14	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 to 200	0	0	1	0	0	0	0	0	0	0	0	0	0	1
201 to 225	0	0	26	2	0	0	0	0	0	0	0	0	0	28
226 to 250	0	0	50	20	1	2	0	0	0	0	0	0	0	73
251 to 275	0	0	28	48	8	1	1	0	0	0	0	0	0	86
276 to 300	0	0	6	70	25	1	2	0	0	0	0	0	0	104
301 to 325	0	0	2	56	45	10	4	0	0	0	0	0	0	117
326 to 350	0	0	0	11	31	40	9	3	0	0	0	0	0	94
351 to 375	0	0	0	0	16	30	18	8	2	0	0	0	0	74
376 to 400	0	0	0	0	4	11	13	17	7	2	0	0	0	54
401 to 425	0	0	0	0	1	2	16	31	23	6	0	0	0	79
426 to 450	0	0	0	0	0	6	13	25	27	11	0	0	0	82
451 to 475	0	0	0	0	0	0	6	10	20	5	1	0	0	42
476 to 500	0	0	0	0	0	0	0	0	4	1	1	0	0	6
Totals	28	0	113	207	131	103	82	94	83	25	2	0	0	840



Appendix A7. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling sampled from the Pilgrim River in 1991.

Appendix A8. Age-length distribution of Arctic grayling sampled from the Pilgrim River during 1991.

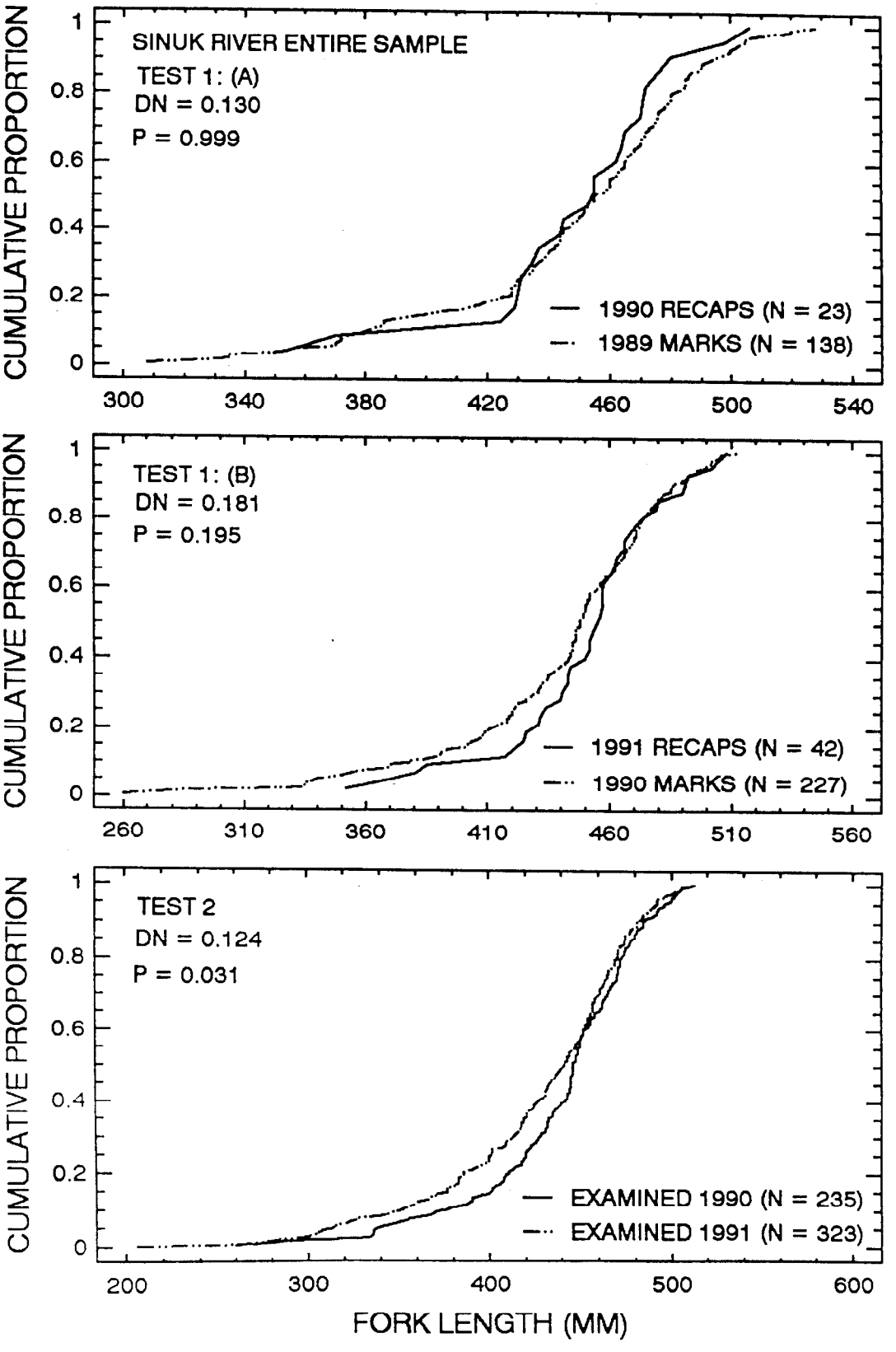
Fork Length (mm)	Age (Years)													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	
76 to 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101 to 125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126 to 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151 to 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 to 200	0	1	0	0	0	0	0	0	0	0	0	0	0	1
201 to 225	0	1	4	1	0	0	0	0	0	0	0	0	0	6
226 to 250	0	0	15	1	0	0	0	0	0	0	0	0	0	16
251 to 275	0	0	10	6	2	0	0	0	0	0	0	0	0	18
276 to 300	0	0	10	25	6	1	0	0	0	0	0	0	0	42
301 to 325	0	0	1	16	9	8	3	1	1	0	0	0	0	39
326 to 350	0	0	0	1	7	22	7	0	0	0	0	0	0	37
351 to 375	0	0	0	1	5	33	12	5	2	0	0	0	0	58
376 to 400	0	0	0	0	1	10	12	10	6	2	0	0	0	41
401 to 425	0	0	0	0	0	0	6	6	0	2	0	0	0	14
426 to 450	0	0	0	0	0	1	10	9	16	3	1	0	0	40
451 to 475	0	0	0	0	0	0	4	5	6	3	1	1	0	20
476 to 500	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Totals	0	2	40	51	30	75	54	36	32	10	2	1	0	333



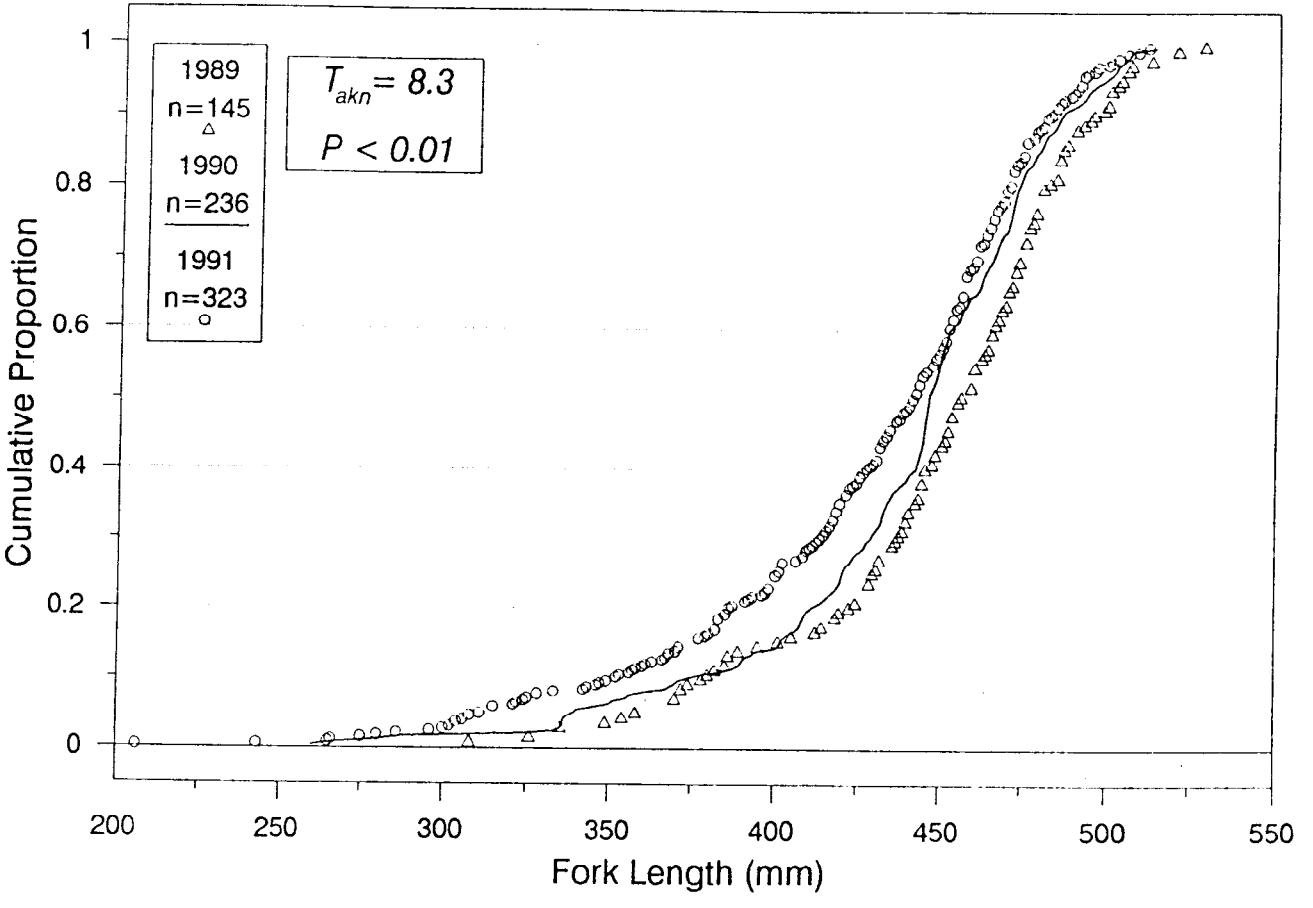
Appendix A9. Cumulative length distribution plots (tests 1 and 2) of Arctic grayling sampled from the Nome River in 1991.

Appendix A10. Age-length distribution of Arctic grayling sampled from the Nome River during 1991.

	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	1	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	1	0	0	0	0	0	0	0	0	0	0	1
201 to 225	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226 to 250	0	0	6	0	0	0	0	0	0	0	0	0	0	6
251 to 275	0	0	8	1	0	0	0	0	0	0	0	0	0	9
276 to 300	0	0	4	5	0	0	0	0	0	0	0	0	0	9
301 to 325	0	0	0	6	0	0	0	0	0	0	0	0	0	6
326 to 350	0	0	0	6	6	1	0	0	0	0	0	0	0	13
351 to 375	0	0	0	0	8	12	0	0	0	0	0	0	0	20
376 to 400	0	0	0	1	3	16	3	0	0	0	0	0	0	23
401 to 425	0	0	0	0	0	3	2	0	0	0	0	0	0	5
426 to 450	0	0	0	0	2	3	13	6	1	0	0	0	0	25
451 to 475	0	0	0	0	2	1	5	4	0	1	0	0	0	13
476 to 500	0	0	0	0	0	1	3	3	0	2	0	1	0	10
Totals	1	0	19	19	21	37	26	13	1	3	0	1	0	140



Appendix All. Cumulative length distribution plots (tests 1: A and B, and test 2) of Arctic grayling sampled from the Sinuk River.



Appendix A12. K-Sample Anderson-Darling cumulative length distribution plot of Arctic grayling sampled on the Sinuk River during 1989, 1990 and 1991.

Appendix A13. Program RECAP output for Sinuk River, 1991.

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

S= 3

	NS	MS	RR	R	G	Z	ALPHA	BETA	
1	142	0	48	136	0	0	1	0	Aug 1989
2	235	22	46	228	0	26	1	0	Aug 1990
3	303	71	0	296	1	1	1	0	Aug 1991

JOLLY-SEBER ESTIMATES:

	MP	NP	B	PHI
1				1.1093
2	150.87	1612.		

STANDARD ERRORS OF JOLLY-SEBER ESTIMATES:

	MP	NP	B	PHI
1				.2056
2	28.25	28.		

MODIFIED ESTIMATES:

I	MP	NP	B	PHI	P	NU	MU	ZETA
1				1.0000		.9577	.0000	
2	136.00	1453.			.1618	.9702		.0936

STANDARD ERRORS OF MODIFIED ESTIMATES ESTIMATED FROM 400 SIMULATIONS:

I	MP	NP	B	PHI	P	NU	MU
1				.0000		.0179	.0000
2	11.62	296.			.0319	.0103	

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

I	MP		NP		B		PHI	
	L	U	L	U	L	U	L	U
1							1.0000	1.0000
2	114.00	158.00	1048.	2223.				

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

I	MP		NP		B		PHI	
	L	U	L	U	L	U	L	U
1							1.0000	1.0000
2	116.00	159.00	998.	2132.				

ESTIMATED AVERAGE NUMBER OF ANIMALS ALIVE
BETWEEN CAPTURE 2 AND CAPTURE 2 = 1453. WITH STANDARD
ERROR 296. AND 95% CONFIDENCE INTERVAL (998. , 2132.)

ESTIMATED GEOMETRIC MEAN OF THE PROBABILITIES OF SURVIVAL
BETWEEN CAPTURE 1 AND CAPTURE 2 = .0000 WITH STANDARD
ERROR .0032 AND 95% CONFIDENCE INTERVAL (.0000 , .0000)

- continued -

Appendix A13. (Page 2 of 2).

Output 2: entire sample.

S= 3

	NS	MS	RR	R	G	Z	ALPHA	BETA	
1	143	0	48	137	0	0	0	0	Aug 1989
2	239	22	46	232	0	26	0	0	Aug 1990
3	325	71	0	316	1	1	0	0	Aug 1991

JOLLY-SEBER ESTIMATES:

	MP	NP	B	PHI
1				1.1177
2	153.13	1664.		

STANDARD ERRORS OF JOLLY-SEBER ESTIMATES:

	MP	NP	B	PHI
1				.2080
2	28.81	29.		

MODIFIED ESTIMATES:

I	MP	NP	B	PHI	P	NU	MU	ZETA
1				1.0000		.9580	.0000	
2	137.00	1488.			.1606	.9707		.0921

STANDARD ERRORS OF MODIFIED ESTIMATES ESTIMATED FROM 400 SIMULATIONS:

I	MP	NP	B	PHI	P	NU	MU
1				.0663		.0169	.0000
2	14.28	386.			.0375	.0112	

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

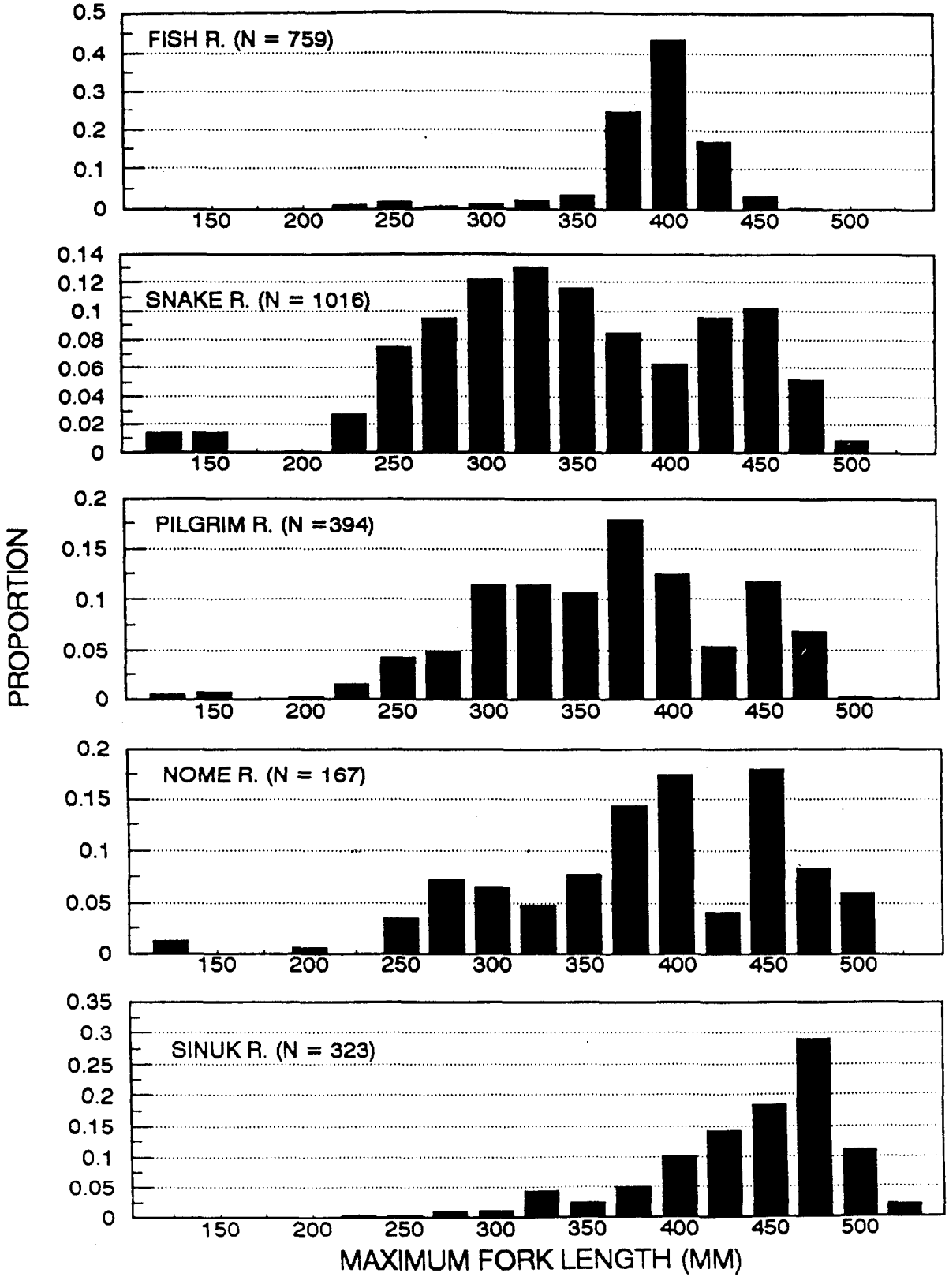
I	MP		NP		B		PHI	
	L	U	L	U	L	U	L	U
1							.7365	1.0000
2	102.17	159.00	943.	2511.				

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

I	MP		NP		B		PHI	
	L	U	L	U	L	U	L	U
1							.8094	1.0000
2	104.81	161.00	862.	2228.				

ESTIMATED AVERAGE NUMBER OF ANIMALS ALIVE
BETWEEN CAPTURE 2 AND CAPTURE 2 = 1488. WITH STANDARD
ERROR 386. AND 95% CONFIDENCE INTERVAL (862. , 2228.)

ESTIMATED GEOMETRIC MEAN OF THE PROBABILITIES OF SURVIVAL
BETWEEN CAPTURE 1 AND CAPTURE 2 = .0000 WITH STANDARD
ERROR .0032 AND 95% CONFIDENCE INTERVAL (.0000 , .0000)



Appendix A14. Length composition of Arctic grayling >101 mm sampled from Seward Peninsula rivers in 1991.

Appendix A15. Age-length distribution of Arctic grayling sampled from the Sinuk River during 1991.

	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	1	0	0	0	0	0	0	0	0	0	0	0	1
226 to 250	0	0	1	0	0	0	0	0	0	0	0	0	0	1
251 to 275	0	0	0	1	1	0	0	0	0	0	0	0	0	2
276 to 300	0	0	1	3	0	0	0	0	0	0	0	0	0	4
301 to 325	0	0	1	7	1	2	0	0	1	0	0	0	0	12
326 to 350	0	0	0	4	1	0	0	1	1	1	0	0	0	8
351 to 375	0	0	0	2	3	2	0	3	2	2	0	0	0	14
376 to 400	0	0	0	0	6	2	5	10	4	3	0	0	0	30
401 to 425	0	0	0	0	0	3	12	12	7	3	2	1	0	40
426 to 450	0	0	0	0	0	10	9	12	12	5	2	0	0	50
451 to 475	0	0	0	0	0	2	17	26	20	10	6	3	0	84
476 to 500	0	0	0	0	0	1	3	4	8	9	4	1	1	31
501 to 525	0	0	0	0	0	0	0	0	2	2	0	0	2	6
Totals	0	1	3	17	12	22	46	68	57	35	14	5	3	283

APPENDIX B

Appendix B1. Data files[a] used to estimate parameters of Arctic grayling populations on the Seward Peninsula in 1991.

Data file	Description
W005ALA1.DTA	Mark and recapture data for Arctic grayling captured from the Fish River during 1991.
W012ALA1.DTA	Mark and recapture data for Arctic grayling captured from the Snake River during 1991.
W0060LA1.DTA	Mark and recapture data for Arctic grayling captured from the Pilgrim River during 1991.
W004ALA1.DTA	Mark and recapture data for Arctic grayling captured from the Nome River during 1991.
W0020LA1.DTA	Mark and recapture data for Arctic grayling captured from the Sinuk River during 1991.

[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.