Fishery Data Series No. 93-41

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by

Dan O. Dunaway

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[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-8, Job No. R-2-1.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Mark and recapture methods and the Chapman modified Petersen estimator were used to estimate the abundance of rainbow trout *Oncorhynchus mykiss* in two rivers near Bristol Bay in southwestern Alaska during 1992. Rainbow trout were captured with hook and line gear from 5 September to 6 October on the Agulowak River and 18 September to 1 October on the Agulukpak River. Over 1,300 fish were captured and 32 tagged fish were recaptured on the Agulowak River to produce an estimate of 13,689 (Standard error = 2,231) rainbow trout > 250 millimeters in length. On the Agulukpak River, 601 rainbow trout were captured and 36 fish were recaptured; but the estimate of 2,446 (Standard error = 348) fish was restricted to fish > 340 millimeters in length. The numbers of rainbow trout per kilometer of river (1,287-2,489 fish/kilometer) estimated in the Agulukpak and Agulowak rivers were much higher than the 54-274 rainbow trout/kilometer estimated in the Kenai River. Comparisons between age compositions of rainbow trout sampled in the Agulowak River in 1992 and 1988 were significantly different ($v2 = 60.19$, $df = 5$, $P = 0.00$) with the 1992 sample containing larger proportions of older aged fish. The change in the age distribution of rainbow trout in the Agulowak River was attributed to harvest and gear restrictions enacted in February 1990. A comparison of age compositions of Agulukpak River rainbow trout sampled in 1992 and 1987 found no changes ($v2 = 3.43$, $df = 5$, $P = 0.64$). The condition factor as described by the natural log of weight as a function of the natural log of length showed significant linear relationships for fish in both rivers. Comparisons between the condition factors of hook-marked fish versus nonmarked fish showed no difference in either river. A system to train personnel to make consistent age determinations from rainbow trout scales was developed.

KEY WORDS: Rainbow trout, *Oncorhynchus mykiss*, population abundance, age, age determination, length, weight, condition, Agulowak River, Agulukpak River.

INTRODUCTION

Wild rainbow trout stocks of Southwest Alaska are a cornerstone of Southwest Alaska's multimillion dollar sport fishing industry. In the Wood River drainage near Dillingham, the two best known and most heavily fished waters are the Agulowak and Agulukpak rivers (Figure 1). These two short, swift, and clear rivers contain substantial numbers of rainbow trout and annually support 4,000 to 10,000 angler-days of recreational fishing effort (Mills 1979-1992). Both rivers have seen their popularity enhanced by the growing public use of the surrounding Wood/Tikchik State Park.

Rainbow trout stocks throughout Southwest Alaska are managed under the guidance of the *Southwest Alaska Rainbow Trout Management Plan* (Minard 1990a), adopted by the Alaska Board of Fisheries in February of 1990. The overriding philosophy of that plan is conservative wild stock management. During implementation of the plan, the Division of Sport Fish presented to the Board an assessment of rainbow trout stocks in Southwest Alaska (Minard 1990b). The report indicated that rainbow trout stocks of the Agulukpak River were in excellent health, but the Agulowak River stocks appeared to be suffering from overharvest. The Board reacted by reducing bag and possession limits from two to one rainbow trout per day and limited gear to single-hook artificial lures on the Agulowak River. The Agulukpak River was selected for special management and is one of 13 fly-fishing-only, catch-and-release waters in Southwest Alaska, a distinction intended to provide diverse sport fishing opportunity while ensuring adequate protection for rainbow trout.

The rainbow trout plan requires periodic evaluation of the general health of the area's rainbow trout stocks and monitoring the recovery of any depressed stocks. Additionally, as part of a regionwide comprehensive management planning exercise, the Division of Sport Fish is developing concise, and measurable, management objectives for these two important fisheries. Establishment of management objectives will direct the department's efforts and clarify for the angling public the goals associated with management of specific waters. This project was designed to evaluate the status of the Agulowak and Agulukpak rivers rainbow trout stocks, to provide information necessary to maintain the fisheries, and to provide the basis to develop specific management objectives for these fisheries.

The objectives of the studies on the Agulowak and Agulukpak rivers were:

1. To estimate the abundance of rainbow trout $\geq$ 250 mm in length in the Agulowak River during September 1992.

2. To estimate the abundance of rainbow trout $\geq$ 250 mm in length in the Agulukpak River during September 1992.

3. To estimate the age, length, and weight compositions of rainbow trout in the Agulowak and Agulukpak rivers during September 1992.

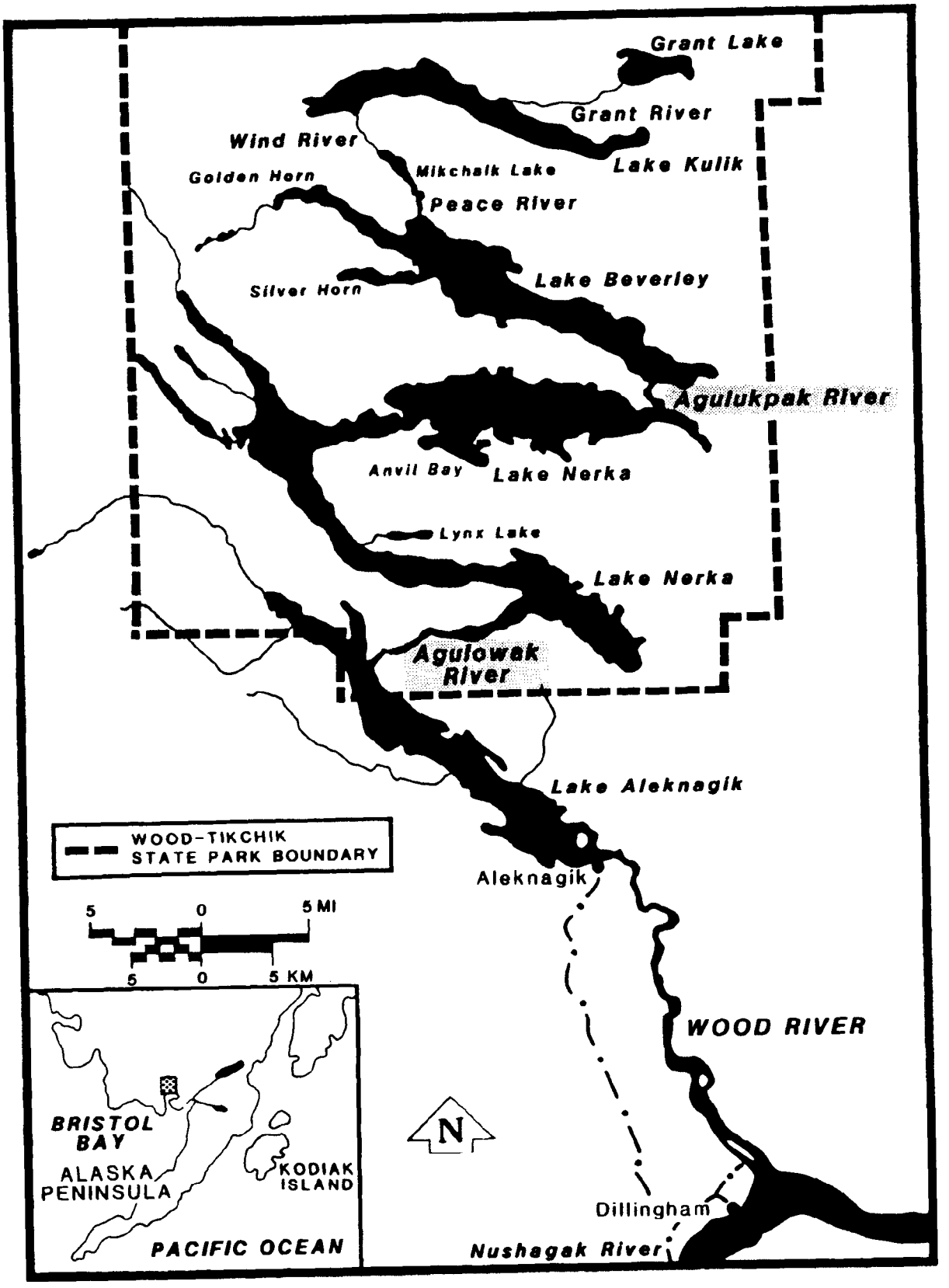

Figure 1. The Wood River lake system.

METHODS

Study Design

Abundance Estimates:

Mark-recapture methods were used to estimate the number of rainbow trout $\geq$ 250 mm in length in the Agulowak and Agulukpak rivers. The Agulowak River was divided into three geographic strata and the Agulukpak River was divided into two strata (Figures 2 and 3). All strata were fished during the marking and recovery periods on the Agulowak River. Because extremely low water levels made sampling on the Agulukpak River too hazardous below the island, sampling was limited to the upstream section (Figure 3).

The marking period on the Agulowak River occurred from 5 September through 19 September and on the Agulukpak River from 18 through 23 September. Due to low temperatures which threatened to close access to the Agulukpak River, the recovery period on the Agulukpak River occurred from 27 September to 1 October. The recovery period on the Agulowak River occurred from 1 October to 6 October. The 11-day hiatus between marking and recovery periods on the Agulowak River and the 4-day hiatus on the Agulukpak River likely allowed marked fish to recover the stress of handling during the marking period (Favro et al. 1986).

Biological Composition:

To attain the desired precision for age, weight and length composition, a minimum of 150 rainbow trout were sampled from each river (Thompson 1987). All captured rainbow trout were measured for length, and all rainbow trout captured during the marking periods were weighed and sampled for age.

Data Collection

Rainbow trout were captured with hook and line gear from drift boats and riverbanks. During the marking period, fish were measured for fork length to the nearest millimeter, weighed to the nearest 10 grams, and scales collected for age. All fish $\geq$ 250 mm in length were marked with a Floy T-Anchor tag, and the adipose fin was clipped to allow estimation of tag loss. During the recovery period, each captured fish was measured for length, carefully examined for indications of tag loss, tag numbers recorded from recaptured trout, and unmarked fish $\geq$ 250 mm in length marked with Floy T-anchor tags and the adipose fin clipped. Fish captured during both periods were examined for hook marks, then released near the point of capture. Sex could not be reliably determined for most rainbow trout and was recorded only when absolutely known. Injured or lethargic fish that appeared unlikely to survive tagging were sampled for length, weight, and age but were not tagged. To reduce handling time and stress to the fish, anesthesia was not used.

During the marking period on each river, scales were collected from each fish captured. Smears of six to 12 scales were taken from the area above the lateral line and along a line from the rear insertion of the dorsal fin to the anterior insertion of the anal fin (Alvord 1954, Maher and Larkin 1955). The scale smears were sorted under a microscope and three or four scales mounted on adhesive-coated cards. The mounted scales were pressed against acetate

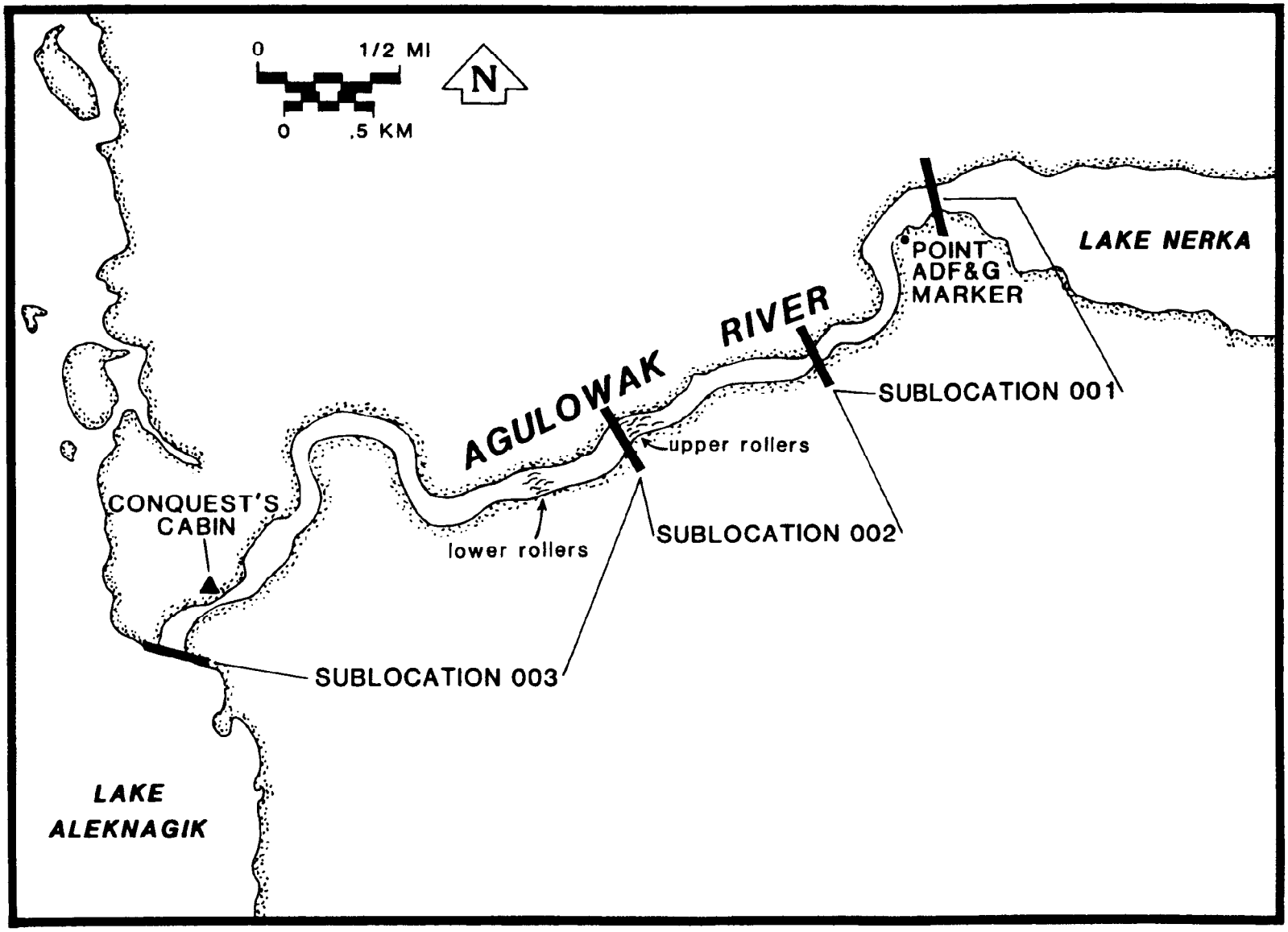

Figure 2. The Agulowak River study area.

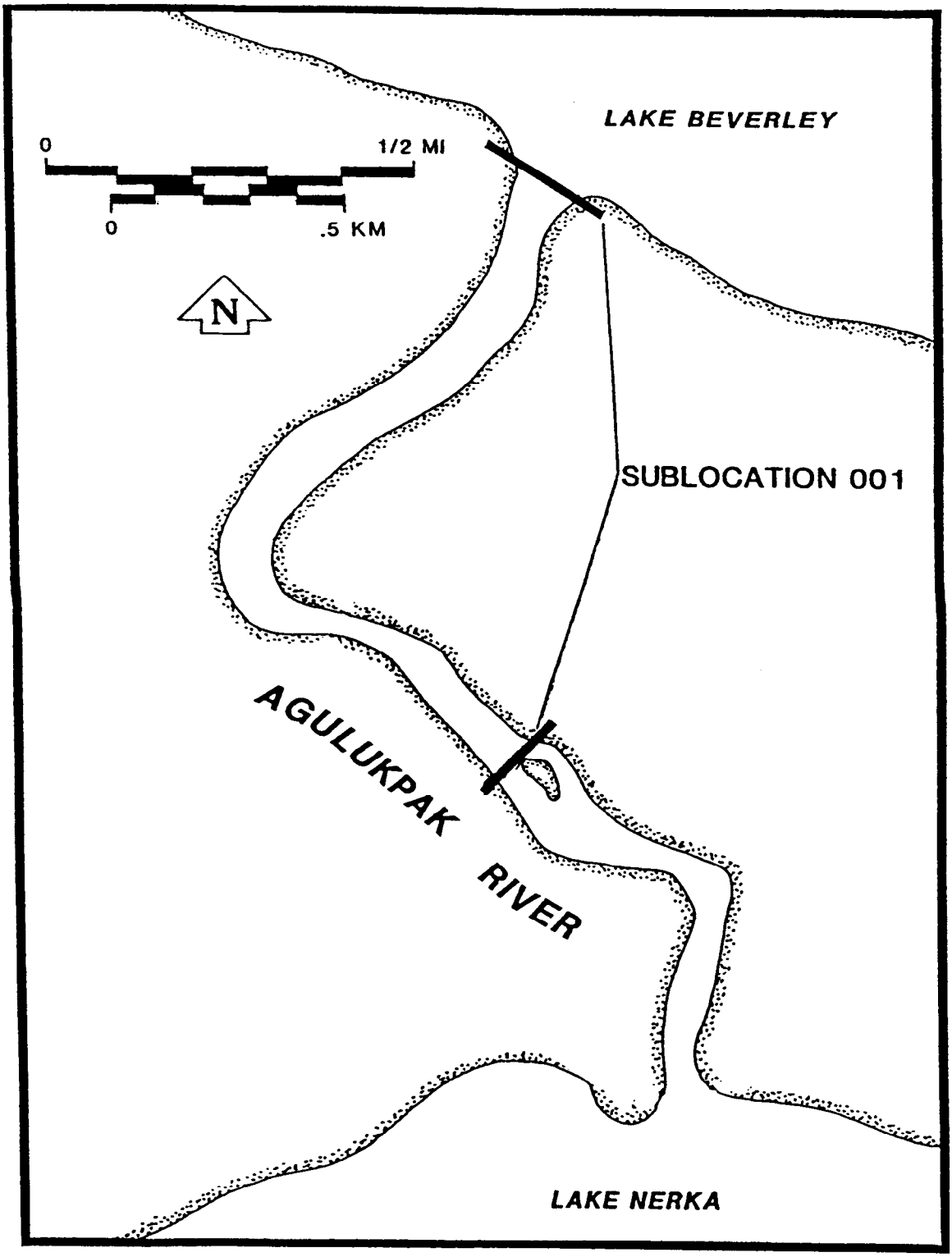

Figure 3. The Agulukpak River study area.

cards in a heated hydraulic press and the resulting scale impressions displayed on a microfiche projector for age determination (Jerald 1983). For a more extensive discussion of scale collection and the age determination process used in this study see Appendix A.

All data were recorded on coin envelopes containing individual scale samples or in waterproof notebooks while in the field. Later, the data were transferred to Alaska Department of Fish and Game (ADF&G) standard age, weight, and length mark-sense forms, version 1.1, to permit the creation of electronic data files (Heineman 1991).

Data Analysis

Abundance Estimates:

The first step of estimating abundance was to test assumptions of a simple Chapman modification of the Petersen two-sample mark-recapture model (Seber 1982, page 59). Results of the tests would indicate whether the estimate required stratification or whether another estimator (Darroch 1961) was more appropriate.

The assumptions related to the Petersen estimator are:

1. The population must be closed, with no additions (recruitment or immigration) or losses (mortality or emigration) between sampling periods.

2. Marking did not affect capture probability during the recovery period.

3. All trout $\geq$ 250 mm in length must have an equal capture probability in the marking period or the recovery period; or marked fish mix completely with unmarked fish prior to the recovery period.

4. Marks (tags) were not lost between sampling periods.

5. All marked fish recaptured during the second sampling period were correctly identified and recorded.

Though the two rivers were not closed to migration, and mortality or removal was possible, the first assumption was likely met by the limited duration of the study period. It was also assumed that growth related recruitment did not occur. While harvest mortality may have occurred on the Agulowak River and hook-and-release mortality may have occurred on both rivers, we assumed that mortality would equally affect the marked and unmarked portions of the population. Additionally, the fish captured during the study were handled with utmost care to avoid injury or stress related mortality.

The second assumption could not be tested directly; however, results of tests examining violation of the third assumption provided indirect evidence of whether the second assumption was violated. Careful handling of the fish and uniform fishing effort throughout the study area on each river should have minimized problems in violating this assumption.

To test the third assumption, a contingency table and chi-square test were used to examine the probability of capture among geographic strata on the Agulowak River. The table consisted of the number of marked and unmarked fish > 250 mm in length captured at each sampling location during the recovery period. To determine if marked fish mixed among geographic strata, a matrix was constructed consisting of marked fish released during the marking period and those recovered during the recovery period by capture location. These tests were not conducted for the Agulukpak River because all sampling occurred in one geographic stratum.

Two 2-sample Kolmogorov-Smirnov (K-S) tests were done to examine equal probability of capture by length. The first test compared the cumulative length frequency distribution of all fish > 250 mm captured during the marking period with marked fish recaptured during the recovery period. The second K-S test compared the cumulative length distribution of all fish > 250 mm captured during the marking period with all fish > 250 mm captured during the recovery period. In addition, a chi-square test was used to test for equal probability of capture among length classes. These length classes were determined by dividing the length frequency distribution into distinct modes. The distinct modes likely corresponded to broad age class categories. Age data were not collected during the recovery period, so differences in capture rate among length classes may indicate capture rate differed due to age.

The estimated abundance and variance of rainbow trout > 250 mm in length were calculated using the following equations for the Chapman modified Petersen estimate (Seber 1982):

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

$$\widehat{Var}\ (N) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)2\ (R+2)} \qquad (2)$$

where:

M = the total number of trout > 250 mm captured and tagged during the marking period,

C = the total number of trout > 250 mm examined for marks during the recovery period, and

R = the total number of trout > 250 mm tagged during the marking period and recaptured during the recovery period.

Biological Composition:

Mean length, weight, length-at-age, and their associated variances were calculated using normal procedures for rainbow trout > 250 mm in length during the marking period on both rivers.

The proportion of each age class (pi) was estimated as a binomial proportion by:

$$\hat{pi} = \frac{ni}{nt} \qquad (3)$$

where:

ni = the number of trout of age class i, and

nt = the total number of trout examined,

and its variance by:

$$\widehat{Var(pi)} = \frac{\hat{(pi)}\ \hat{(1-pi)}}{nt - 1} \quad . \qquad (4)$$

Using values from equations (3) and (4), abundance for each age class was estimated by:

$$\hat{Ni} = \hat{N}\ \hat{pi} \qquad (5)$$

and its variance was estimated by:

$$\widehat{Var(Ni)} = \hat{pi}2\ \widehat{Var(N)} + \hat{N}2\ \widehat{Var(pi)} - \widehat{Var(N)}\ \widehat{Var(pi)} \quad . \qquad (6)$$

Length Weight Relationship:

The relationship of the natural log of weight as a function of the natural log of length (condition, or measure of "fatness") was estimated for each river using standard regression procedures (Draper and Smith 1981). Analysis of covariance was used to determine if condition (i.e. regression slope estimates) differed between trout with hook marks and those with no visible hook marks.

Evaluation of Regulation Changes:

Age, weight, and length data of rainbow trout collected from Agulowak River in 1988 were compared to the data collected in 1992. A K-S test was used to detect whether there were differences in the length distributions of the two samples. In addition, a chi-squared test was used to determine if the age distribution was equal between the 1988 and 1992 samples. The same tests were used to compare data from Agulukpak River rainbow trout > 250 mm collected in 1992 and 1987.

RESULTS

Agulowak River

Abundance Estimate:

During the marking period on the Agulowak River, 757 rainbow trout > 250 mm in length were released with tags (Table 1). There were 563 unmarked rainbow trout > 250 mm in length and 32 marked fish captured during the recovery period. No evidence of lost marks was found during the study. Two fish that had been marked in 1989 were captured, and one of these fish was caught in both periods. Several other fish were caught with fully healed adipose fin clips administered during sampling activities in previous years (an exact count was not made). A summary of all fish captured each day by location appears in Appendix B, and a summary of tag releases and recoveries by date appears in Appendix D.

Probability of capture was not significantly different ($v2 = 1.56$, $df = 2$, $P = 0.46$) among geographic strata on the Agulowak River (Table 2). There was also some mixing of marked trout among locations, with marked trout tending to move upstream (Table 2). The K-S test detected no difference ($D = 0.148$, $n1 = 757$, $n2 = 29$, $P = 0.56$) in the cumulative length distribution between fish marked in the first event and recaptures in the second event (Figure 4), but there was a difference ($D = 0.089$, $n1 = 757$, $n2 = 591$, $P = 0.009$) in the distribution between fish captured in the marking period and those captured in the recovery period (Figure 5). However, the distributions in Figure 5 are not functionally different and the significant test statistic is likely due to the large sample size. In addition, there was no significant difference ($v2 = 0.54$, $df = 1$, $P = 0.46$) in the capture probability of fish 250 mm-354 mm in length and those > 355 mm (Table 3).

The test results indicated there was no need to stratify the data and that the Chapman modified Petersen model would provide the best estimate of abundance. The number of rainbow trout > 250 mm in length in the Agulowak River was estimated to be 13,689 (SE = 2,231). The 95% confidence interval associated with the point estimate ranged from a low of 9,316 to a high of 18,062 fish.

Biological Composition:

Of the 764[1] Agulowak River rainbow trout > 250 mm in length sampled during the marking period of the study, most were age 4 (20.9%, SE = 1.59), age 5 (41.4%, SE = 1.92) or age 6 (22.2%, SE = 1.62, Table 4). Overall mean length was 387 mm (SE = 2.30) and overall mean weight was 714 g (SE = 12.33). The biggest fish caught from the Agulowak River was 515 mm (20.3 in) long and weighed 1,920 grams (4.2 lb). The longest fish caught was 556 mm (21.9 in) in length and weighed 1,050 grams (2.3 lb).

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[1] All rainbow trout > 250 mm captured, including 12 mortalities, were used to calculate the biological composition in the Agulowak River. However, five fish were excluded from the calculation of mean length because of discrepancies between the length recorded at initial capture versus the length recorded at recapture.

Table 1. Summary of tag releases and recoveries by date for Agulowak and Agulukpak rivers, 1992.

	Agulowak River fish ≥ 250 mm			Agulukpak River fish ≥ 340 mm		
Date	New Marks Released	Fish Captured	Marks Recovered	New Marks Released	Fish Captured	Marks Recovered
9/05	9					
9/06						
9/07						
9/08						
9/09	13					
9/10	52					
9/11	89					
9/12	51					
9/13	93					
9/14	191					
9/15	103					
9/16	126					
9/17						
9/18				9		
9/19	30			61		
9/20				68		
9/21				49		
9/22				57		
9/23				38		
9/24						
9/25						
9/26						
9/27					6	2
9/28					127	14
9/29					103	11
9/30					37	6
10/01		54	1		46	3
10/02		29	2			
10/03		126	8			
10/04		122	8			
10/05		181	11			
10/06		51	2			
Total	757	563	32	282	319	36

Table 2. Summary of rainbow trout (≥ 250 mm FL) tagging data by event and sublocation, Agulowak River, 1992.

Marking Event 9/5 - 9/19		Recapture Event 10/1 - 10/6					
		Tag Recoveries By Sublocation					
Sub-location	Number of Tags Released	001	002	003	Total	Not Recovered	Percent Recovered
001	207	12	0	0	12	195	5.8%
002	270	4	5	0	9	261	3.3%
003	280	3	3	5	11	269	3.9%
Total Tagged	757	19	8	5	32	725	
Number Untagged		383	94	86	563		
Number Examined		402	102	91	595		
Percent Tagged		4.7%	7.8%	5.5%	5.4%		

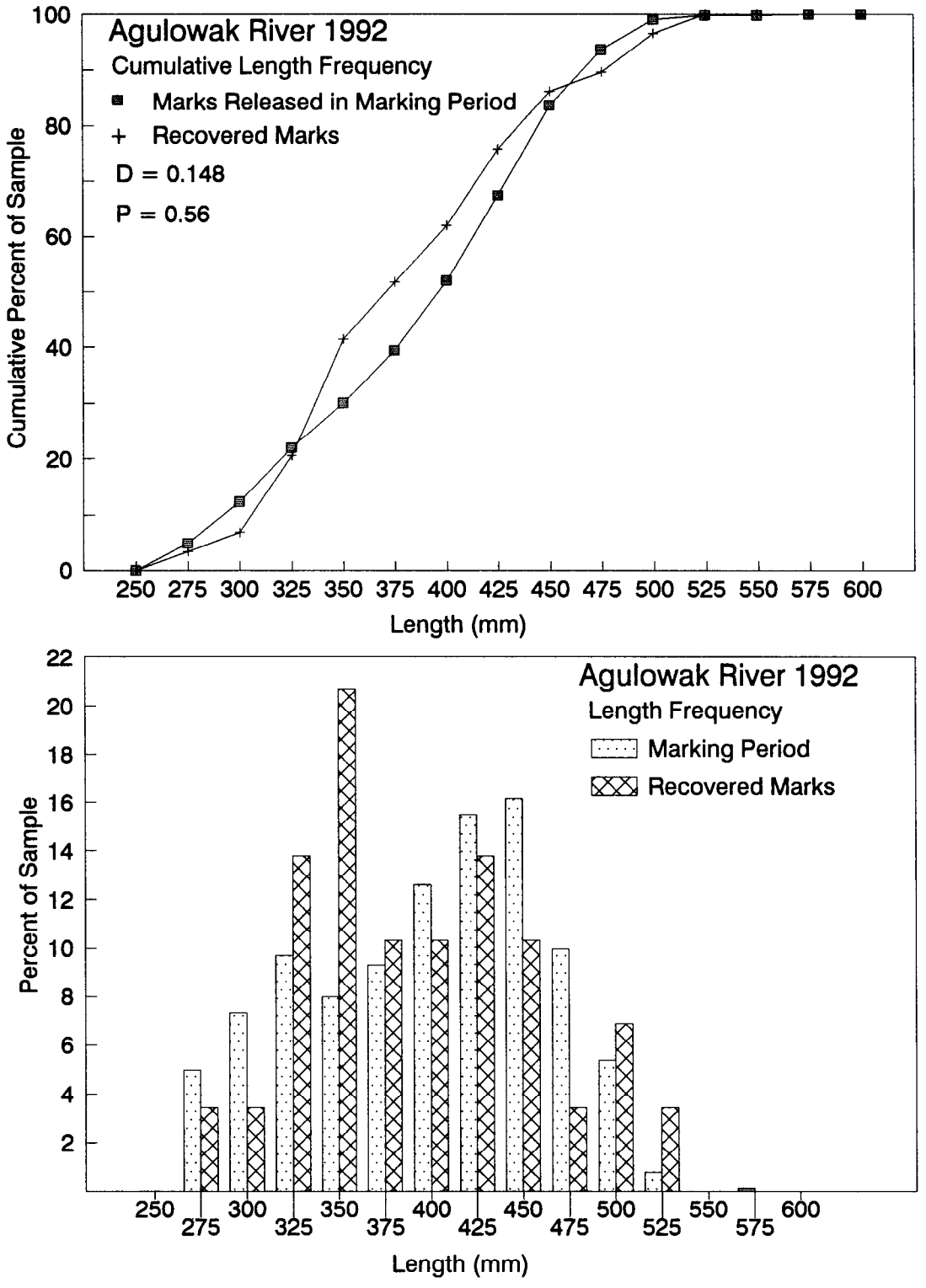


Figure 4. Length frequency distributions of rainbow trout ≥ 250 mm tagged in the marking period and recaptured in the recovery period in the Agulowak River, 1992.

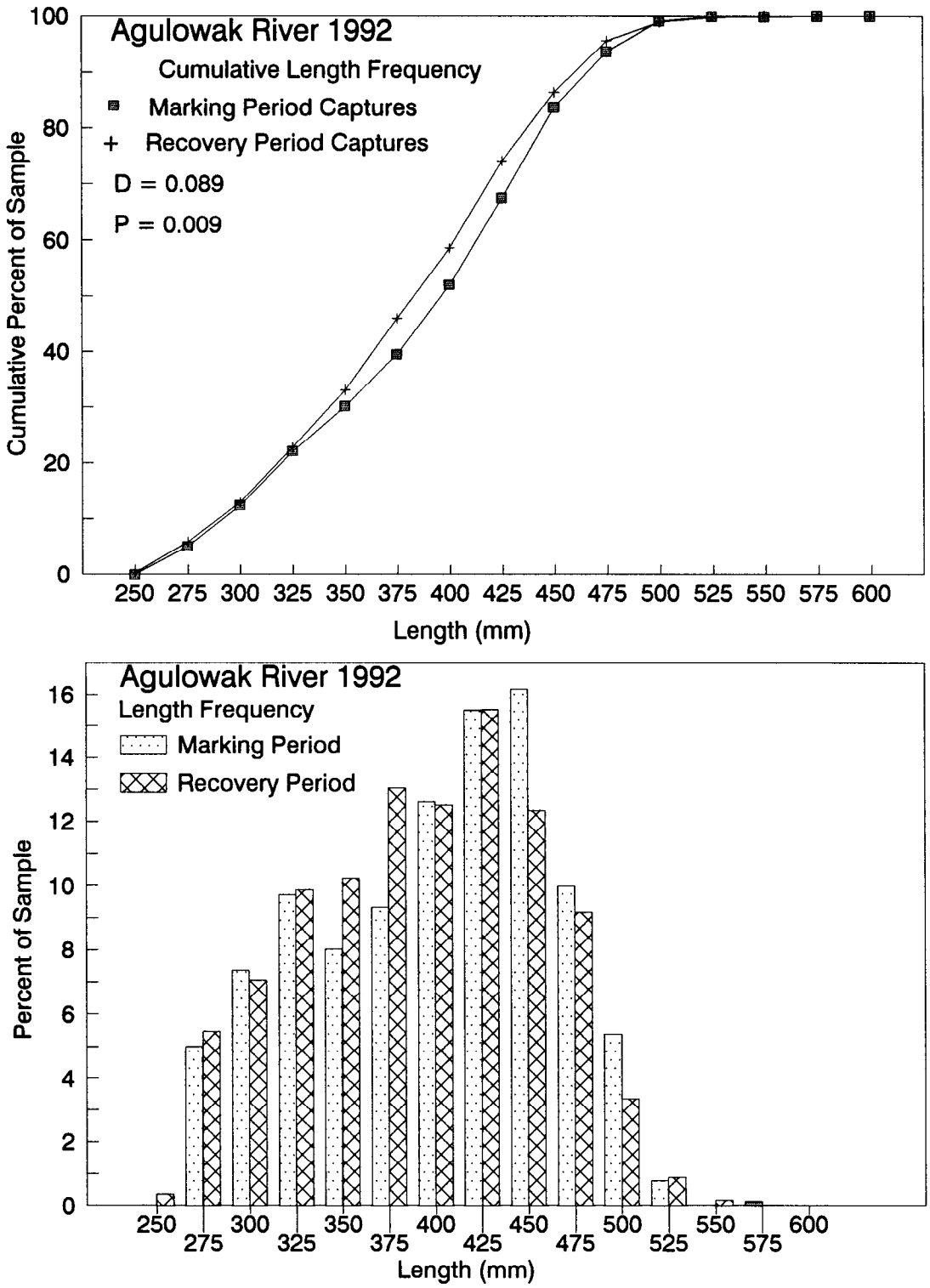


Figure 5. Length frequency distributions of rainbow trout ≥ 250 mm captured in the marking and recovery periods on the Agulowak River, 1992.

Table 3. A comparison among length classes of rainbow trout captured from the Agulowak and Agulukpak rivers, 1992.

Agulowak River	Captures in Recovery Period.		
	250-355 mm	≥ 355 mm	Total
Unmarked	195	367	562
Marked	12	17	29[a]
Total	207	884	591[b]

Agulukpak River	Captures in Recovery Period.		
	340-405 mm	≥ 405 mm	Total
Unmarked	64	219	283
Marked	5	31	36
Total	69	250	319

[a] A total of 32 fish marked in the marking period were recovered in the recovery period. Three recovered fish were incorrectly measured for length and were not used in this test.

[b] Total fish examined in the recovery period = 595. Four were not measured for length and could not be used in this test.

Table 4. Mean lengths (mm) and weights (g) of rainbow trout ≥ 250 mm by age group from samples collected with hook and line gear on the Agulowak River in 1992 and 1988.

Sample period: 9/5/92 to 9/19/92.

	Age Group								
	UNKNOWN	3	4	5	6	7	8	9	TOTAL
Percent		2.0	20.9	41.4	22.2	11.6	1.8	0.2	100.0
SE		0.54	1.59	1.92	1.62	1.25	0.52	0.15	
Sample Size		13	137	272	146	76	12	1	657
Mean Length	437	261	298	373	423	458	482	512	387
SE	4.42	3.24	1.93	2.17	1.95	2.51	5.78		2.30
Sample Size	109	13	137	270	146	76	12	1	764[a]
Mean Weight	915	244	338	631	887	1121	1296		714
SE	27.00	8.97	6.63	11.48	16.27	25.38	78.58		12.33
Sample Size	98	9	120	228	114	56	11	0	636[b]

Sample period: 6/27/88 to 9/17/88.

	Age Group						
	UNKNOWN	3	4	5	6	7	TOTAL
Percent		16.0	37.3	36.0	8.0	2.7	100.0
SE		4.26	5.62	5.58	3.15	1.87	
Sample Size		12	28	27	6	2	75
Mean Length	373	303	350	372	392	431	368
SE	4.11	11.51	8.57	6.07	17.95	1.50	3.34
Sample Size	148	12	28	27	6	2	223
Mean Weight	539						539
SE	24.63						24.63
Sample Size	44	0	0	0	0	0	44

[a] Sample includes 12 fish (mortalities or untagged) not used in the 1992 mark and recapture abundance estimate. Five fish were excluded from the calculation of mean length because of discrepancies between the length recorded at initial capture versus the length recorded at recapture.

[b] Due to a shortage of scales, 133 fish were not weighed during the marking period.

Calculating abundance of fish $\geq$ 250 mm in length by age class resulted in an estimated 2,859 (SE = 513) age-4 fish, 5,634 (SE = 955) age-5 fish, and 3,047 (SE = 543) age-6 fish (Table 5).

Incidence of Hook Marks:

Over 18% of the fish captured during the Agulowak River study showed hook marks or evidence of previous capture (Table 6).

Length Weight Relationship:

There was a significant ($F = 9,402.38$; $df = 1, 632$; $P < 0.001$) linear relationship between the natural log of weight as a function of the natural log of length (Table 7). Trout with hook marks did not have a lower body weight at a given length than fish with no visible hook marks.

Comparison Between 1992 and 1988 Data:

A K-S test found that fish sampled in 1992 ($n = 764$) were significantly larger ($D = 0.262$, $P = 0.00$) than those ($n = 223$) sampled in 1988 (Figure 6). At least part of this difference can be attributed to the significantly ($\chi^2 = 60.19$, $df = 5$, $P = 0.00$) older age composition in 1992 relative to 1988 (Table 4).

Agulukpak River

Abundance Estimate:

On the Agulukpak River, 282 tagged rainbow trout $\geq$ 340 mm in length were released during the marking period (Table 1). There were 283 unmarked rainbow trout $\geq$ 340 mm in length and 36 marked fish captured during the recovery period. Because no marked trout 250 mm-340 mm in length were recaptured during the recovery period, the data sets were truncated, tests were conducted, and the abundance was estimated only for trout $\geq$ 340 mm in length. There was no evidence of tag loss. A summary of all fish captured each day by location appears in Appendix C, and a summary of tag releases and recoveries by date appears in Appendix D.

Fifteen fish were caught twice during the marking period and 11 fish marked during the recovery period were caught a second time. One fish was recovered three times after it was tagged. One fish was caught bearing a tag from a previous year, and several fish bore healed scars where their adipose fin had been clipped during sampling in previous years.

For fish $\geq$ 340 mm in length, a K-S test detected no significant difference ($D = 0.187$, $n_1 = 292$, $n_2 = 36$, $P = 0.19$) between the cumulative length distributions of fish marked during the marking period and recaptures during the recovery period (Figure 7). In addition, there was no significant difference ($D = 0.70$, $n_1 = 318$, $n_2 = 292$, $P = 0.41$) between cumulative length distributions of all fish captured in the marking period and all fish captured in the recovery period (Figure 8). During the recovery period, the probability of capture of marked and unmarked fish in size classes 340 mm-405 mm and $\geq$ 405 mm was not significantly different ($\chi^2 = 1.27$, $df = 1$, $P = 0.26$, Table 3).

Table 5. Estimates of abundance by age class for rainbow trout in the Agulowak and Agulukpak rivers during September and October 1992.

Age Group	Number Sampled	Proportion	SE of the Proportion	Estimated Abundance	Standard Error[a]
Agulowak River rainbow trout ≥ 250 mm in length.					
3	13	0.020	$5.4 * 10^{-3}$	271	86
4	137	0.209	$15.9 * 10^{-3}$	2,859	513
5	270	0.412	$19.2 * 10^{-3}$	5,634	955
6	146	0.222	$16.3 * 10^{-3}$	3,047	543
7	77	0.117	$12.6 * 10^{-3}$	1,607	312
8	12	0.018	$5.2 * 10^{-3}$	250	82
9	1	0.002	$1.5 * 10^{-3}$	21	21
Agulukpak River rainbow trout ≥ 340 mm in length					
4	3	0.015	$8.8 * 10^{-3}$	38	21
5	79	0.405	$35.2 * 10^{-3}$	991	85
6	56	0.287	$32.5 * 10^{-3}$	703	79
7	42	0.215	$29.5 * 10^{-3}$	527	71
8	11	0.056	$16.6 * 10^{-3}$	138	40
9	4	0.021	$10.1 * 10^{-3}$	50	25

[a] Goodman 1960.

Table 6. Incidence of hook marks observed in rainbow trout sampled from the Agulowak and Agulukpak rivers, 1992.

Location	Period	Hook Mark[a]	Frequency	Percent
Agulowak River				
	Marking	Y	169	22.2
		N	593	77.8
	Recovery	Y	78	13.9
		N	484	86.1
	Total	Y	247	18.7
		N	1,077	81.3
Agulukpak River				
	Marking	Y	119	40.6
		N	174	59.4
	Recovery	Y	98	34.6
		N	185	65.4
	Total	Y	217	37.7
		N	359	62.3

[a] A fish was determined to be hook-marked when mouth parts were missing or damaged; when hooks were present; or when scars, or injuries were observed around the mouth and head of a fish. The determination was subjective and a crude indicator of fish surviving capture and subsequent release.

Table 7. Parameter estimates of the relationship of natural log of weight as a function of natural log of length for rainbow trout $\geq$ 250 mm with hook marks and those with no hook marks captured from the Agulowak and Agulukpak rivers during September 1992.

System[a]	Hook Mark	n	R^2	MSE[b]	$\hat{\beta}_0$	$SE(\hat{\beta}_0)$	$\hat{\beta}_1$	$SE(\hat{\beta}_1)$
Agulowak River	Yes	144	0.93	0.0146	-10.562	0.396	2.862	0.066
	No	490	0.94	0.0140	-9.111	0.179	2.622	0.030
	Total	634	0.94	0.0144	-9.343	0.163	2.660	0.027
Agulukpak River	Yes	122	0.91	0.0122	-8.837	0.455	2.582	0.075
	No	219	0.93	0.0164	-7.998	0.270	2.445	0.045
	Total	341	0.93	0.0149	-8.139	0.218	2.468	0.036

[a] Relationship is of the form $\ln(\text{weight}) = \ln(\beta_0) + \beta_1[\ln(\text{length})]$.

[b] Mean square error.

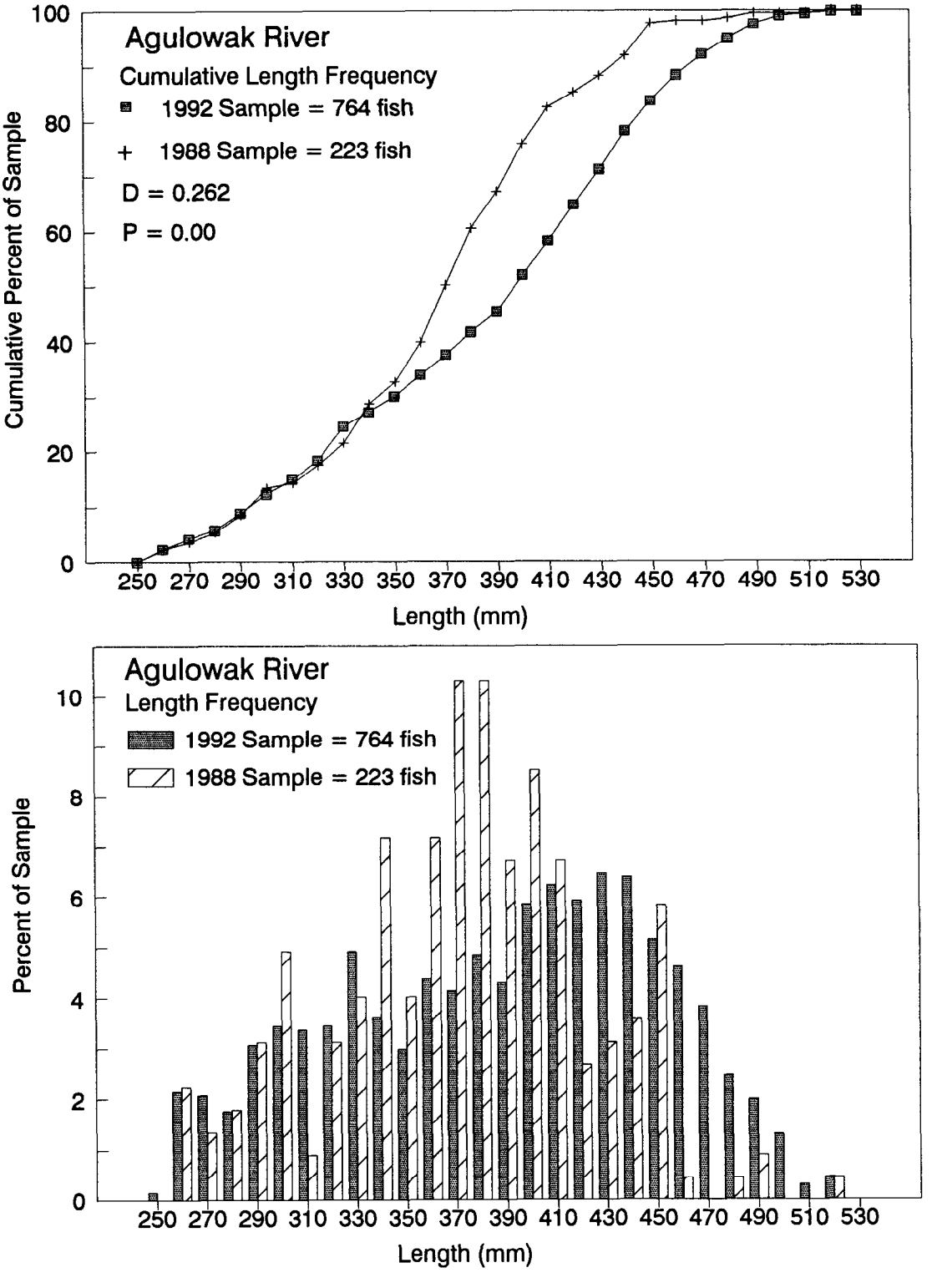
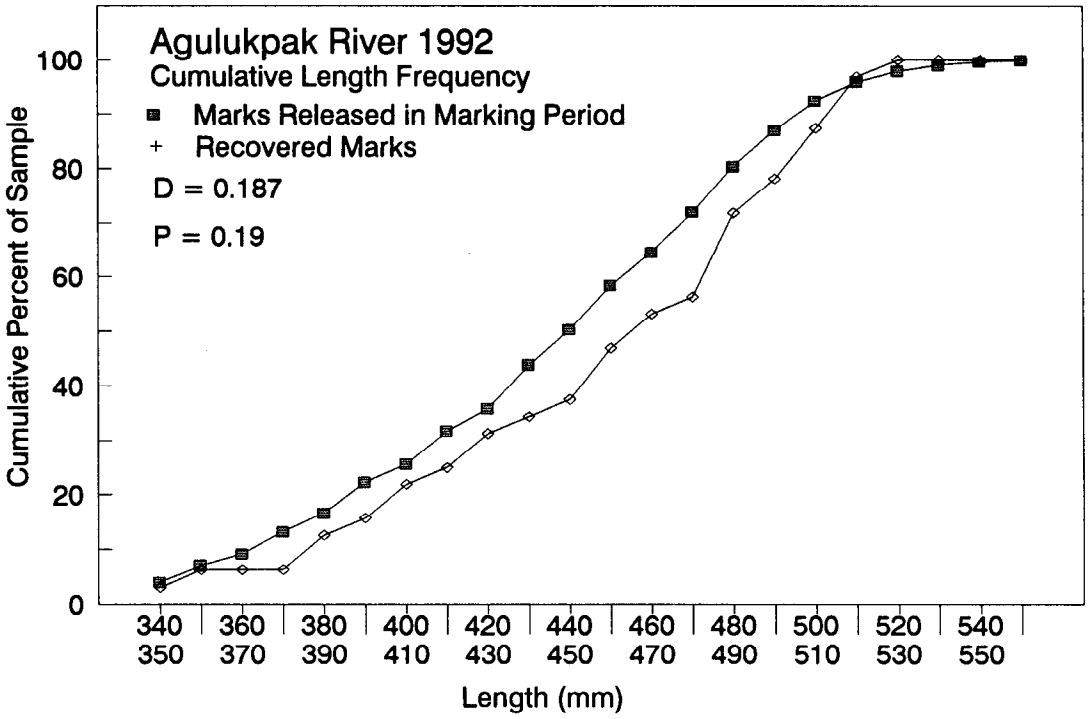


Figure 6. Length frequency distributions of rainbow trout ≥ 250 mm captured in the Agulowak River in 1992 and 1988.



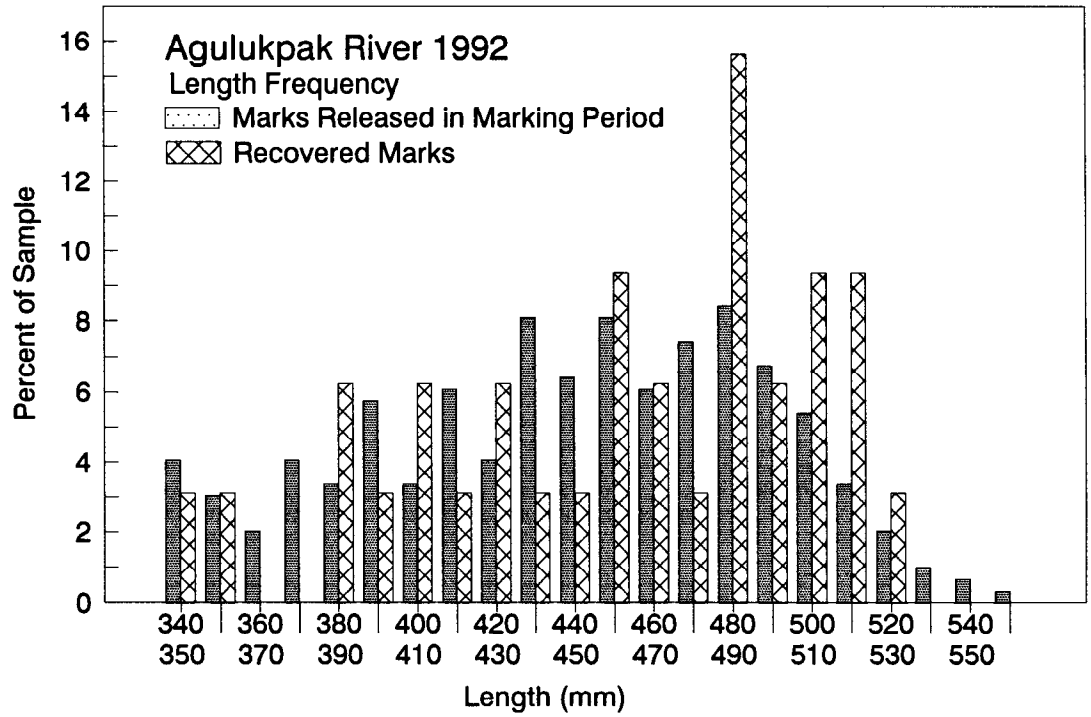


Figure 7. Length frequency distributions of rainbow trout ≥ 340 mm captured in the marking period and recaptured in the recovery period in the Agulukpak River, 1992.

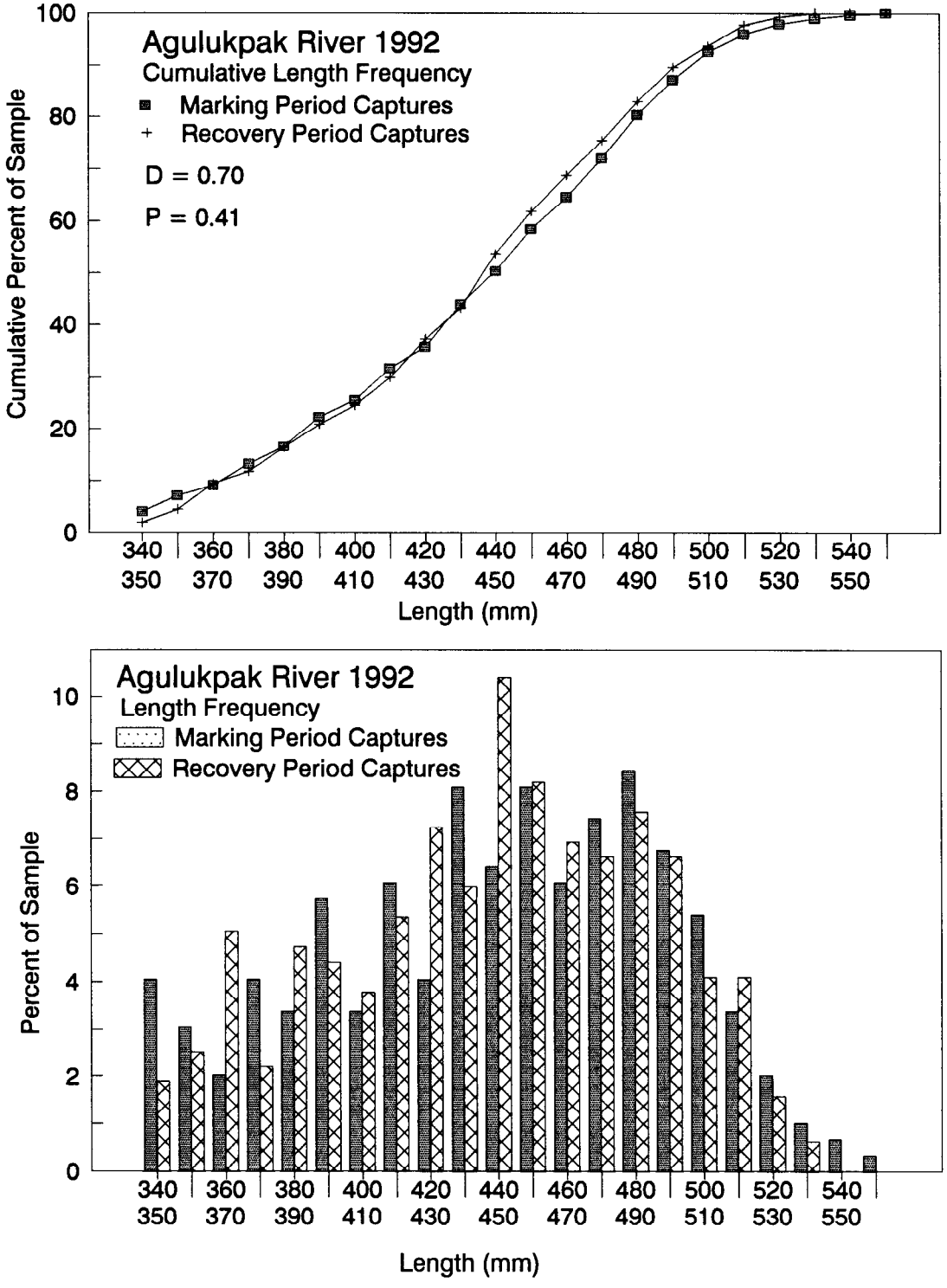


Figure 8. Length frequency distributions of rainbow trout ≥ 340 mm captured in the marking and recovery periods in the Agulukpak River, 1992.

Results of the tests indicated stratification was not necessary and that the Chapman modified Petersen estimator (Seber 1982) would provide the best estimate of abundance. At a 95% confidence interval, the number of rainbow trout $\geq$ 340 mm in length in the Agulukpak River was estimated to range from 1,764 to 3,128 fish with a point estimate of 2,446 fish (SE = 348).

Biological Composition:

Of the rainbow trout $\geq$ 250 mm in length captured in the marking period, age determination was possible from 255 scale samples, 351 length measurements were collected, and 344 fish were weighed (Table 8). Nearly 41% (SE = 3.08) of the fish were age 5, 22% (SE = 2.60) were age 6, followed by age 7 (16%, SE = 2.33) and age 4 (14%, SE = 2.16). The mean length for all fish measured was 422 mm (SE = 3.78) and the mean weight was 931 g (SE = 19.67). The biggest fish caught from the Agulukpak River was 535 mm (21 in) long and weighed 1,910 grams (4.2 lb). The longest fish caught was 554 mm (21.8 in) in length and weighed 1,430 grams (3.1 lb).

The abundance of rainbow trout $\geq$ 340 mm in length by age class was estimated to be 991 (SE = 85) fish of age 5, 703 (SE = 79) of age 6, and 527 (SE = 71) of age 7 (Table 5).

Incidence of Hook Marks:

Hook marks or other evidence of previous capture were observed in 37.7% of the fish sampled (Table 6).

Length Weight Relationship:

There was a significant ($F = 4,669.48$; $df = 1, 339$; $P < 0.001$) linear relationship between the natural log of weight as a function of the natural log of length (Table 7). There was no difference ($F = 2.16$; $df = 1, 337$; $P = 0.14$) in the condition factor (i.e. slope estimate) between fish with hook marks and fish without hook marks.

Comparison Between 1992 and 1987 Data:

A K-S test between the cumulative length distribution of Agulukpak River rainbow trout $\geq$ 250 mm sampled in 1992 and 1987 found no significant difference ($D = 0.084$, $n_1 = 358$, $n_2 = 172$, $P = 0.35$, Figure 9). There was also no significant difference detected between the 1992 and 1987 age distributions ($\chi^2 = 3.43$, $df = 5$, $P = 0.64$, Table 8).

Computerized data files used to generate these analyses are listed in Appendix E.

DISCUSSION

The estimates of 13,689 rainbow trout in the Agulowak River ($\geq$ 250 mm in length) and 2,446 rainbow trout in the Agulukpak River ($\geq$ 340 mm in length) appear reasonable and will serve as good benchmarks for evaluating management actions. The assumptions of the Petersen estimator were apparently not violated except that both systems were open and fish movement could have

Table 8. Mean lengths (mm) and weights (g) of rainbow trout ≥ 250 mm by age group from samples collected with hook and line gear on the Agulukpak River in 1992 and 1987.

Sample period: 9/18/92 to 9/23/92.

	Age Group								
	UNKNOWN	3	4	5	6	7	8	9	TOTAL
Percent		1.2	13.7	40.8	22.0	16.5	4.3	1.6	100.0
SE		0.68	2.16	3.08	2.60	2.33	1.27	0.78	
Sample Size		3	35	104	56	42	11	4	255
Mean Length	477	274	299	377	435	469	502	521	422
SE	3.93	12.20	4.70	4.45	3.87	3.23	3.90	18.46	3.78
Sample Size	97	3	35	103	56	42	11	4	351
Mean Weight	1209	273	383	682	983	1160	1352	1360	931
SE	28.28	31.80	16.68	21.61	24.04	30.43	39.89	81.55	19.67
Sample Size	95	3	34	99	56	42	11	4	344

Sample period: 9/17/87 to 9/20/87.

	Age Group							
	UNKNOWN	3	4	5	6	7	8	TOTAL
Percent		1.0	11.8	41.2	32.4	10.8	2.9	100.0
SE		0.98	3.21	4.90	4.66	3.09	1.68	
Sample Size		1	12	42	33	11	3	102
Mean Length	465	300	309	404	438	480	509	435
SE	7.43		12.79	6.61	4.62	7.61	11.39	5.04
Sample Size	71	1	12	41	33	11	3	172
Mean Weight	1126		528	785	960	1294		991
SE	35.07		70.53	45.15	32.89	122.21		29.73
Sample Size	35	0	5	16	19	5	0	80

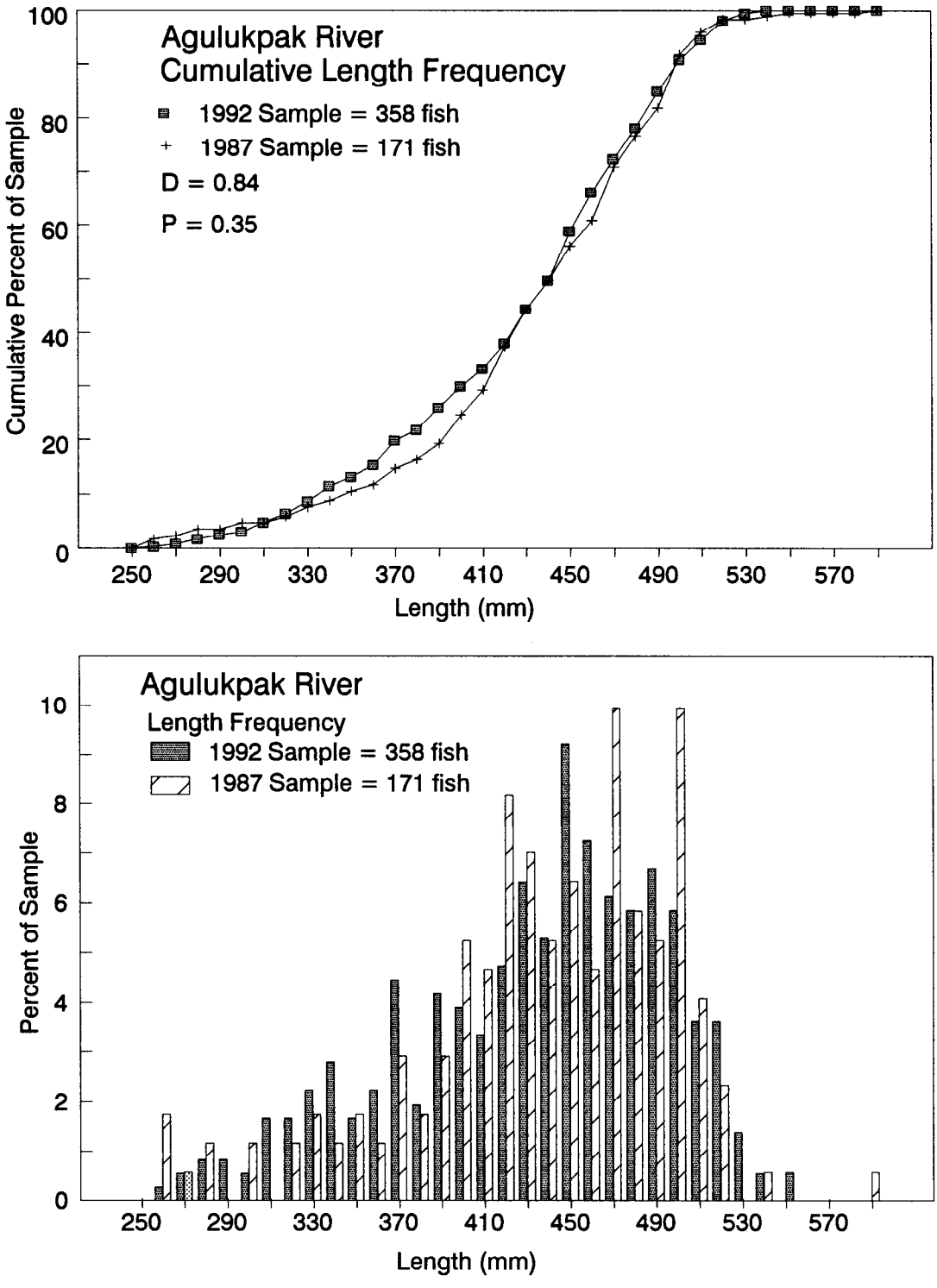


Figure 9. Length frequency distributions of rainbow trout ≥ 250 mm captured in the Agulukpak River in 1992 and 1987.

introduced some error. While the estimate of abundance of rainbow trout in the Agulukpak River is useful, the failure to recover tagged fish 250 mm to 340 mm in length left the estimate short of the project objectives. It is not clear why smaller fish were not recaptured from the Agulukpak River.

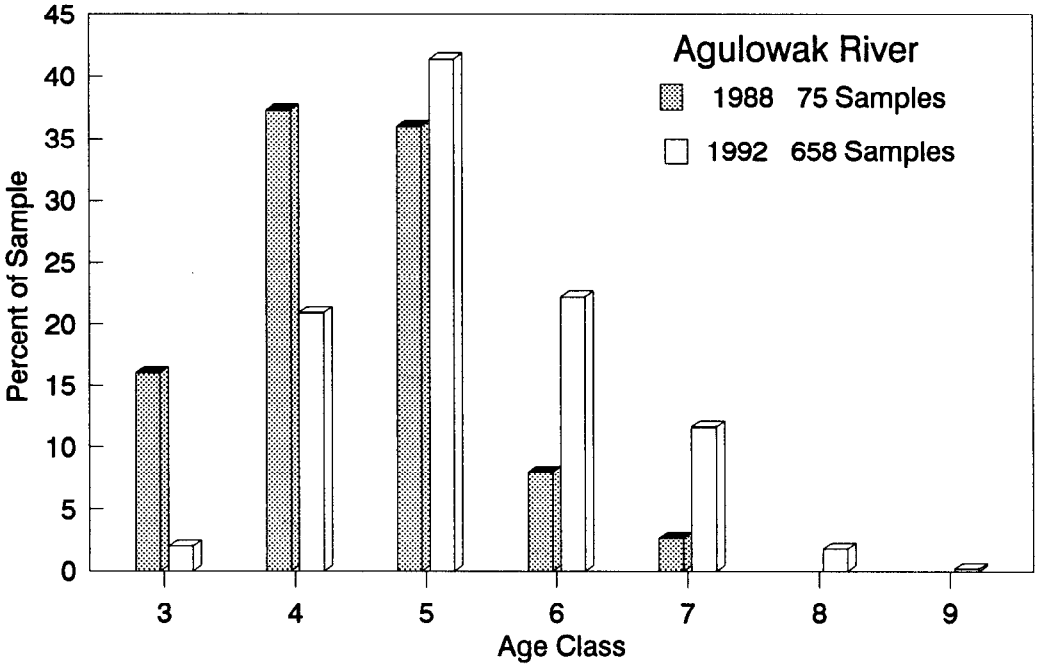
From the estimates of abundance, the average density of rainbow trout was calculated to be 2,489 fish/km (4,026 fish/mi) in the Agulowak River and 1,287 fish/km (2,041 fish/mi) in the Agulukpak River. Whether such large numbers of fish reside in these small rivers the entire year or whether the fish temporarily congregate to feed on the salmon spawn and carcasses is unknown. Though the size ranges were narrower (250 mm to 560 mm), both systems showed much greater densities than the 54-280 rainbow trout (150 mm to 800 mm) per kilometer (86-448 fish/mi) estimated in portions of the Kenai River (Lafferty 1989). In the future, recoveries of tagged fish still at large may provide insight into the movements and life histories of rainbow trout using the Agulowak and Agulukpak rivers.

The regulatory changes adopted in 1990 had the desired effect of increasing the proportions of older aged rainbow trout in the Agulowak River (Figure 10). The relatively unchanged age structure observed between 1987 and 1992 in the nearby Agulukpak River rainbow trout, where voluntary catch-and-release fly angling was the norm for many years prior to the adoption of the 1990 regulations, lends support to this conclusion. If the proportion of older aged fish continues to increase, there should be more spawning age fish (age 5 and older) to perpetuate the fishery. On an anecdotal note, several anglers with experience on the Agulowak River agree that the rainbow trout population has improved since 1990.

Weight as a function of length, or condition factor, is a measure of a fish's "fatness." In both rivers, the rainbow trout without hook marks were not found to be in significantly better condition than those with hook marks (Table 7) even though some hook marked fish were missing mouth parts, eyes, or suffered other damage. Condition factor does not address survival rates, but it is apparent that fish surviving capture and release apparently had no trouble maintaining body weight during the period of this study. It is interesting to note that many of the fish with relatively severe injuries had survived long enough for the damage to heal.

ACKNOWLEDGEMENTS

Many people contributed to the success of this project. The author is indebted to Jim Hasbrouck for the help catching the fish, his guidance and patience during the data analysis, and for his assistance in writing portions of the report. Lew Coggins, Don Perrin, and Andy O'Brien tolerated an anxious supervisor to catch tremendous numbers of fish in a very short time. Everett Evans caught his share of fish and distinguished himself in the lab by mounting and reading over 1,000 scales in a very efficient and consistent manner. Ranger Dan Hourihan of DNR, Wood Tikchik State Park, is thanked for his generosity in providing lodging, boats, and volunteers to assist with the Agulukpak River work. Thanks to Mac Minard for his guidance and steady supply of volunteers. The volunteers Ron Evans, Jim Woolington, Joan Mitchell, and others were a great help during the project as well.



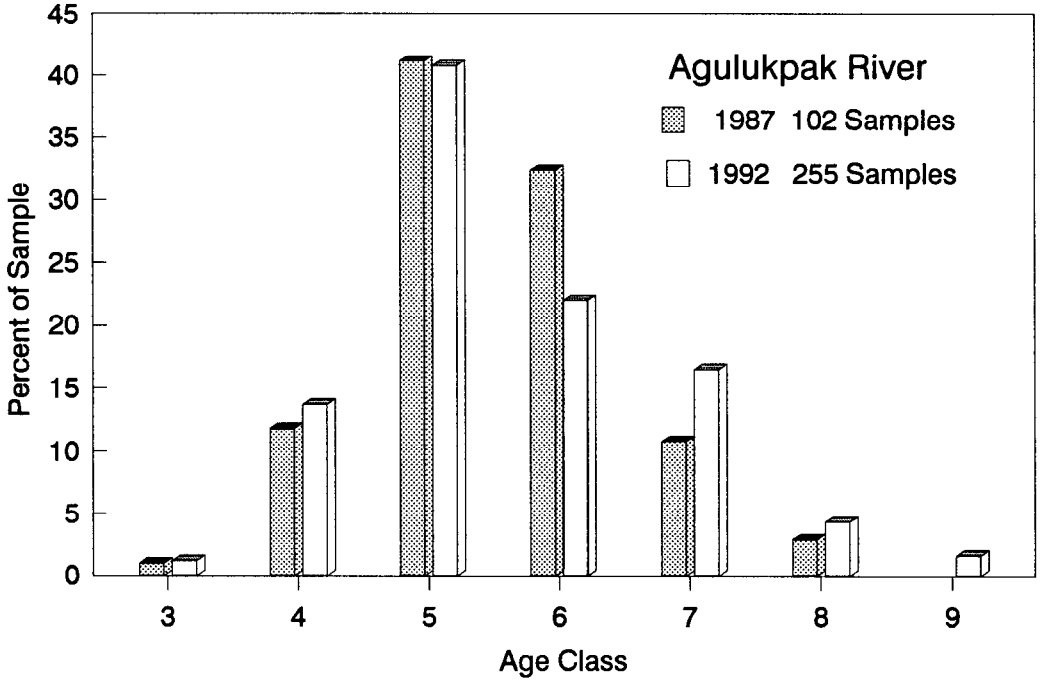


Figure 10. Age distributions of rainbow trout $\geq$ 250 mm captured in the Agulowak River in 1988 and 1992, and in the Agulukpak River in 1987 and 1992.

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APPENDIX A

Techniques Used to Determine Age from the Scales of Rainbow Trout Captured in the Agulowak and Agulukpak Rivers in 1992.

Appendix A. Techniques used to determine age from the scales of rainbow trout captured in the Agulowak and Agulukpak rivers in 1992.

Fish scales have long been a popular structure to use to determine the age of fish (Alvord 1954). Scales can be collected quickly and in large numbers without killing or severely harming fish. Preparation and determination of approximate age from scales is relatively easy and inexpensive compared to the processes required for aging other bony structures. For these reasons, ADF&G prefers to use scales for age determination in its monitoring and management of rainbow trout stocks in Southwest Alaska.

Determining ages of fish from scales can be a highly subjective process. To provide useful data requires a consistent method of collecting and "reading" scales. A measure of consistency exists in the historical collection of Southwest Alaska rainbow trout scales (over 30,000 samples) because the vast majority of the age determinations were made by only two ADF&G employees, Richard Russell and Dan Bosch (Minard and Dunaway 1991). The following methods were adopted to assure that age determinations of the 1992 rainbow trout scale samples were consistent with the historical database.

A short review of the available literature was conducted to develop a set of criteria for aging the scales. During the review, the aging technician became familiar with the general principles of scale age determination. Dan Bosch, ADF&G Anchorage, provided a list of criteria and observations he had used when working with Southwest Alaska rainbow trout scales. In addition to the authors cited throughout this text, Circular 317 by Mosher (1969) was found to be helpful.

Criteria

Some general observations of fish scale growth and development followed by specific interpretations of characteristics found in Southwest Alaska rainbow trout scales were combined to form the following set of criteria:

The first scales to be formed on larval fish appear along the length of the lateral line and then spread dorsally and ventrally outward (Paget 1920). According to Paget, the "process develops far more rapidly in the region posterior to the insertion of the dorsal fin than elsewhere" (page 4, 1920).

Individual scale growth begins with the formation of the focus, or area enclosed by the first circulus (Mosher 1969). The scale grows outward from the focus with the greatest growth occurring toward the anterior margin of the scale. Fine ridges called circuli are laid down in a circular pattern around the focus as the scales grow and many circuli are added to the scale each year. When magnified, the circuli appear as light and dark rings around the scale. The first few circuli of most species completely encircle the focus. After the complete circuli, the others appear as arcs that tend to end abruptly at the junction with the exterior (posterior) portion of the scale (Mosher 1969). In some species of salmon and trout, the bases of the circuli may not end abruptly, but may extend posterior for varying distances, or the circuli may be broken or enlarged in this area (Mosher 1969; Lux 1971).

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The growth rate of a fish is reflected in scale growth (Lux 1971). Circuli are widely spaced when fish growth is rapid and closely spaced when growth is slow and appears to be most related to the availability of food, and to a lesser degree by temperature (Bhatia 1932). "Since fish continue to grow throughout their lives, this pattern [of annuli] is repeated each year" (Lux 1971, page 4). "The age of a fish is determined by counting the number of annuli or year-marks." Bosch (ADF&G, Anchorage, personal communication) speculated that "nonspawning rainbow trout from the Kvichak River and Naknek River drainages produced detectable annuli in April as growth seemed to occur through the winter. Spawning rainbow trout from the same systems appeared to produce a detectable annulus as late as the end of June when their growth rate apparently increases."

Choosing a Scale:

For accurate age determination, the scale may not be regenerated beyond the fourth or fifth circuli. When a scale is lost, a replacement (regenerated) scale grows rapidly to reach the size of the original. Regenerated scales do not form circuli during the period of rapid growth and often appear clear or irregularly formed compared to an original scale. When the regenerated scale reaches the size of the original, further growth occurs and circuli are formed at a rate similar to the original scales.

Annual Mark or "Check":

Under magnification, groups of closely packed circuli associated with annually reduced rates of growth appear as dark bands compared to groups of circuli generated during rapid growth. An annulus was defined as a concentrated group of unbroken circuli running forward from the posterior margin on one side of a scale around to the posterior margin on the other side. Age was determined by counting annual marks on the anterior portion of the scale from the focus to the margin along a line no more than 30 degrees from the anterior-posterior axis of the scale. Sometimes the appearance of circuli along the anterior-most margin of the scale was used to help define the location of annuli.

Rainbow trout from the Agulowak and Agulukpak rivers may not have the same life history as Naknek or Kvichak drainage fish, but for this study annuli were assumed to be formed in April if the fish did not spawn and in mid to late June if the fish spawned.

First Annual Mark:

Rainbow trout may not produce an annual mark their first year of life (Lentsch and Griffith 1987). If there was no distinct first year annulus within the first 20 circuli, an annulus was assumed to be within the seventh to fourteenth circuli (D. Bosch, ADF&G, Anchorage, personal communication).

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Early growth:

Usually a large band of late summer growth was observed between the second, third, and fourth annuli. Summer growth regions between subsequent annuli were generally smaller and less distinct.

Spawning Mark or "Check":

During spawning, rainbow trout may reabsorb the margins of their scales. Reabsorption may consume the scale through one or two annuli. However, reabsorption is more pronounced on the dorsal and ventral margins of the scale and usually leaves crescent-shaped portions of annuli on the anterior margin of the scale. After spawning the fish resume their growth and spawning year annulus deposition occurs. Once formed, the new annulus has an unusual "split" appearance along its anterior portion while appearing as a normal, single annulus along the dorsal and ventral portions of the scale. Called a spawning check, the reader counted the inner portion of the "split" annulus as one year's annulus and the outer or more distal annulus as the subsequent, spawning year's annulus.

Counting annuli along a line no further than 30 degrees from the anterior-posterior axis of the scale insures that spawning checks will be properly counted as annual marks. Spawning checks were commonly found at age classes 4 through 6 in Agulowak and Agulukpak rivers samples. In scales with more than six annuli, spawning checks were much harder to differentiate, and were often observed as a very wide check combining the sixth, seventh, and eighth annuli.

False Annuli or "Check":

False annual marks may occur during a period of reduced growth, injury, or shock (Lux 1971), and scale readers should be aware of their existence. The standard characteristics of false checks include a much thinner than normal annulus or an apparent annulus which is only visible on one side of the anterior-posterior axis of the scale.

Plus Growth:

Plus growth is the growth occurring after the production of the last annulus until the collection of the sample. A "reader" must be aware when samples were collected to avoid counting plus growth as an additional annulus. As the samples in this study were collected during a time of abundant food, the outer margin of the scales often showed a large amount of plus growth.

Selection of Training Data Set

In addition to establishing age criteria, another step to maintain consistent age determinations was training the scale reader with a carefully selected set of data.

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Data collected from the Agulowak and Agulukpak rivers in the late 1980s and aged by Dan Bosch was used as the standard. Data sets collected before 1986

did not have an adequate number of acetates with scale impressions, or the data printouts did not correspond to the few available acetate impressions. The data sets used for the training test were:

File	River	Year	Selected
T01110BB	Agulowak R.	1986	*
T1110BA8		1988	*
T1110B89		1989	*
T1280BB8	Agulukpak R.	1986	*
T1280BA7		1987	
T1280BA8		1989	*

Next, a test was conducted to see whether the length-at-age was consistent between years within each river. Mean lengths at age 4 and 5 (which covered a large portion of each data set) were compared using the one-way ANOVA test in Minitab (Scheaffer and Anderson 1989). When the results of the ANOVA test were compared visually, the mean length and associated variances of age classes 4 and 5 in the data set T1280BA7 Agulukpak River 1987 were shown to differ significantly from the other data sets. The other data sets (* above) were merged to provide a pool from which to draw training samples. Though some of the remaining data sets were barely within acceptable limits, this was often a result of very small sample sizes. While it would have been better to use very similar data sets, there would not have been sufficient records for a reasonably sized pool of training data.

Only records with length and actual ages were included in the pool. The intention was to include samples of regenerated and illegible scales but it was discovered that regenerated and illegible scales were not mounted when the scale impressions were made. The final data pool consisted of 266 records.

Training and Testing With Data Set
The aging technician viewed several hundred scales from the training set to learn aging techniques and to help refine the criteria above.

After the technician learned to make age determinations, he was tested for consistency with the established ages. Three subsamples of 128 scales (Thompson 1987) were drawn randomly from the training data pool and aged by the trainee. The established age frequencies were compared to the frequencies of trainee's determinations using a chi-squared test in Minitab. The groups tested were age 3 or younger, 4, 5, 6, 7, and age 8 or older. The null hypothesis in these tests was: Established age composition = trainee's age composition at a = 0.05.

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The chi-squared tests showed the trainee to be within limits to accept the null hypothesis ($v2 = 7.2$, $df = 5$, $P > 0.10$; $v2 = 7.6$, $df = 5$, $P > 0.10$; $v2 = 9.0$, $df = 5$, $P > 0.1$). In another chi-squared test, the technician's determinations were compared against each other. The second test also found the trainee's age determinations to be consistent between subsamples ($v2 = 7.9$, $df = 10$, $P > 0.1$).

After the training and testing, the technician proceeded to determine ages from the rainbow trout scales collected on the Agulowak and Agulukpak rivers.

APPENDIX B

Appendix B. Summary of tag releases and recoveries by date and sublocation from the Agulowak River, 1992.

		Location 001			Location 002			Location 003			Captured But Not Marked						Subtotals					
			Recap	Recap of		Recap	Recap of		Recap	Recap of	001		002		003					Not Marked		
		New	In Same	Pd 1[a] Marks in	New	In Same	Pd 1 Marks in	New	From Same	Pd 1 Marks in							New	Same Period	Recap of Pd 1 Marks in	Over	Under	
Period	Date	Marks	Period	Pd 2[b]	Marks	Period	Pd 2	Marks	Period	Pd 2	250+	<250	250+	<250	250+	<250	Marks	Recap	Pd 2	250	250	Total
	9/05	3			4			2						1			9	0		0	1	10
	9/09	9			4			0									13	0		0	0	13
MARKING	9/10	12			29			11									52	0		0	0	52
(Pd 1)	9/11	48			18			23			1	1					89	0		1	1	91
	9/12	33			9			9			3						51	0		3	0	54
	9/13	20	1		8			65	1				1	1	1	6	93	2		2	7	104
	9/14	42	4		58			91	3		1	1		3	1		191	7		2	4	204
	9/15	0			52			51	6					2	3	1	103	6		3	3	115
	9/16	40	3		58	3		28	6				1	2		3	126	12		1	5	144
	9/19	0			30	1		0									30	1		0	0	31
Total		207	8		270	4		280	16		5	2	2	9	5	10	757	28		12	21	818
	10/01	23			22		1	9									54	0	1	0	0	55
RECOV-	10/02	15		2				12							2		27	0	2	2	0	31
ERY	10/03	87	1	5	33		3				6	3					120	1	8	6	3	138
(Pd 2)	10/04	81		2	16	1	3	22		3			2		1	1	119	1	8	3	1	132
	10/05	123	6	9	12			35		2	8	3			3	2	170	6	11	11	5	203
	10/06	34	3	1	8		1	2			6		1				44	3	2	7	0	56
Total		363	10	19	91	1	8	80	0	5	20	6	3	0	6	3	534	11	32	29	9	615
Total		570	18	19	361	5	8	360	16	5	25	8	5	9	11	12	1291	39	32	41	29	1433

[a] Period 1, the marking period.
[b] Period 2, the recovery period.

APPENDIX C

Appendix C. Summary of tag releases and recoveries of rainbow trout by date from the Agulukpak River, 1992.

Period	Date	Marks Released ≥ 340 mm	Marks From Period 1 Recovered in Period 2 ≥ 340 mm	Captured but not Marked	Marks Recaptured in Same Period as Released	Marked Fish < 340 mm	Total
	9/18	9				4	13
	9/19	61		5		10	76
Marking	9/20	68		1	2	10	81
	9/21	49			3	13	65
	9/22	57		2	6	11	76
	9/23	38		2	4	11	55
Total		282		10	15	59	366
	9/27	5	2			1	8
	9/28	111	14	1	2	16	144
Recovery	9/29	87	11	4	3	16	121
	9/30	34	6			3	43
	10/01	41	3		7	5	56
Total		278	36	5	12	41	372
Total		560	36	15	27	100	738

APPENDIX D

Appendix D. Tag recoveries summarized by date of release and date of recapture from the Agulowak and Agulukpak rivers, 1992.

Agulowak River Rainbow Trout ≥ 250 mm.

Date of Release	Number of Tags Released	Date and Number of Tags Recovered						
		Oct 1	Oct 2	Oct 3	Oct 4	Oct 5	Oct 6	Total
Sep 5	9			1				1
Sep 9	13		1			2		3
Sep 10	52							0
Sep 11	89		1			1	1	3
Sep 12	51					2		2
Sep 13	93			2	1	2		5
Sep 14	191			2	3			5
Sep 15	103			2	2	1	1	6
Sep 16	126	1		1	1	3		6
Sep 19	30				1			1
Total	757	1	2	8	8	11	2	32

Agulukpak River Rainbow Trout ≥ 340 mm.

Date of Release	Number of Tags Released	Date and Number of Tags Recovered					
		Sep 27	Sep 28	Sep 29	Sep 30	Oct 1	Total
Sep 18	9						0
Sep 19	61		4	1		3	8
Sep 20	68		4	3	3		10
Sep 21	49		2	2	3		7
Sep 22	57		4	3			7
Sep 23	37	2		2			4
Total	282	2	14	11	6	3	36

APPENDIX E

Appendix E. Computer files and software used to produce this report.

Data Files:	
T111ABA2.DTA	Agulowak River rainbow trout tag release and recovery, and biological data.
T128ABA2.DTA	Agulukpak River rainbow trout tag release and recovery, and biological data.
Analysis programs:	
KS2M.EXE	A program developed by ADF&G Sport Fish Division, Research and Technical Services staff for conducting Kolmogorov-Smirnov two sample tests.
BBXPEXE	A series of programs that uses biological files to produce tables of mean length and weights by sex and age group. The program also produces a data set which may be used in Lotus 1-2-3 (tm) to create graphs.