Fishery Data Series No. 93-16

Abundance and Length-Age Composition of Northern Pike Near the Confluence of the Pilgrim and Kuzitrin Rivers, 1992

by

Alan Burkholder

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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, Study R, Job No. 3-4c.

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ABSTRACT

Estimated abundance of northern pike *Esox lucius* $\geq$ 450 millimeters near the confluence of the Pilgrim and Kuzitrin rivers was 9,998 fish (SE = 2,307). For northern pike $\geq$ 450 millimeters, 40% were "quality" size, 30% were "preferred" size, 21% were "stock" size, and 8% were "memorable" size in Relative Stock Density categories. The age 7 cohort was the most abundant. The oldest fish sampled was age 22. Since northern pike moved between the two rivers, the Pilgrim River cannot be considered as closed to immigration or emigration.

KEY WORDS: Northern pike, *Esox lucius*, mark-recapture, Darroch estimator, bootstrap, abundance, Relative Stock Density, age, composition, length-at-age, Pilgrim River, Kuzitrin River.

INTRODUCTION

An estimated 1,194 northern pike *Esox lucius* were harvested from the Pilgrim River by anglers in 1990, the second largest sport harvest of northern pike in Alaska during 1990 (Mills 1991). This is substantially higher than the estimated sport harvest of 415 and 91 in 1989 and 1988, respectively (Mills 1989 and 1990). Current regulations for the sport fishery are 10 northern pike per day bag limit, 10 northern pike in possession, no size limit, and no closed season.

In addition to the sport harvest, there is a subsistence fishery for northern pike by the residents of Teller and Nome. No estimates of subsistence harvest are available. Limited anecdotal accounts suggest that the subsistence harvest of northern pike occurs primarily in the winter and spring by setting gill nets under the ice. No permit is required for subsistence fishing and there is no bag limit for subsistence-caught northern pike.

Increased sport harvest and very limited information on northern pike population abundance, structure and dynamics in the Pilgrim River coupled with the assumption that northern pike are susceptible to overharvest, prompted the Department of Fish and Game (ADF&G) to initiate a stock assessment program of northern pike in the Pilgrim River. This is the first documented northern pike study conducted by ADF&G on the Seward Peninsula.

Objectives

The goal of this research is to assess the abundance, structure, and dynamics of the stocks of northern pike in the Pilgrim River drainage and to improve the management of the sport fishery. This report summarizes research conducted in 1992 on the composition, and abundance of northern pike in the Pilgrim and Kuzitrin rivers. Project objectives in 1992 were:

1. to estimate the population abundance and age and length composition of northern pike in the Pilgrim River; and,

2. to test the hypothesis that the northern pike in the Pilgrim River are a geographically closed population.

Study Area

The Pilgrim River is located on the Seward Peninsula. It originates in Salmon Lake and flows north and east for approximately 72 km before entering the Kuzitrin River (Figure 1). Access to these rivers is either by aircraft, the Beam Road from Nome, or by boat from Teller via Imuruk Basin. The specific study area (Figure 2) was near the confluence of the Pilgrim and Kuzitrin rivers.

METHODS

Study Design

The study design consisted of a mark-recapture experiment with two sampling events: 27 June to 3 July 1992 and 7 July to 17 July 1992. The primary

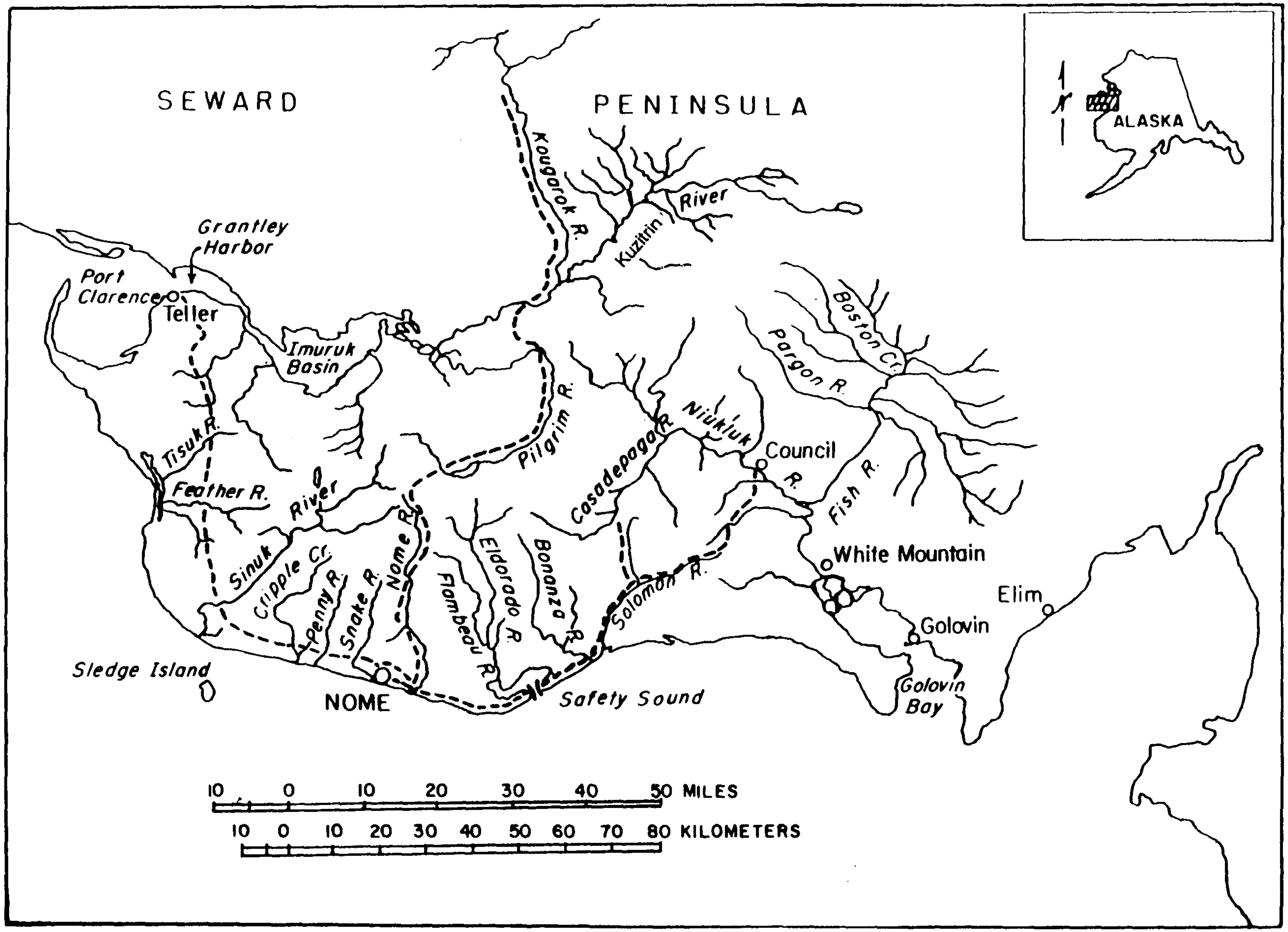

Figure 1. Pilgrim/Kuzitrin study area.

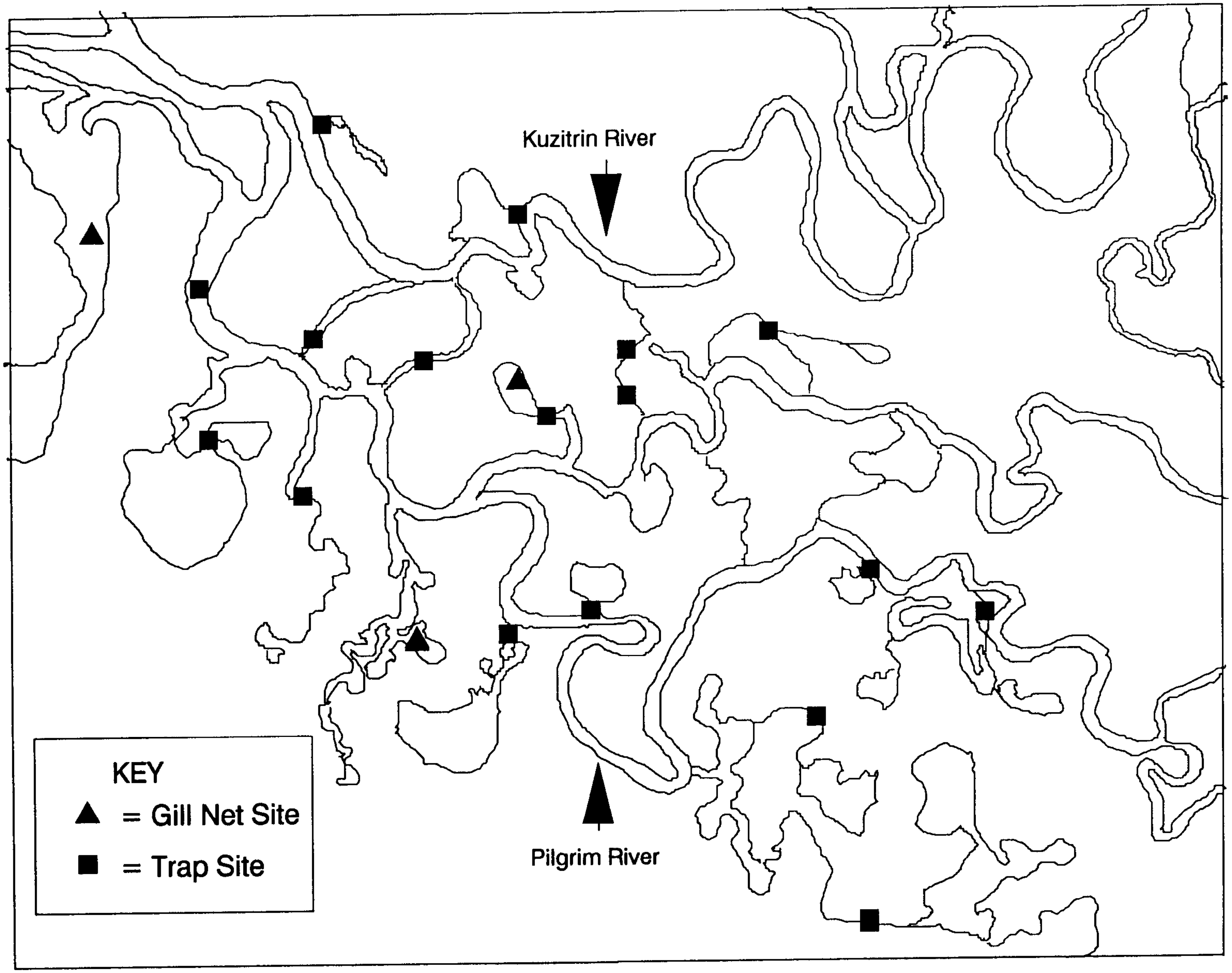

Figure 2. Sampling sites in the Pilgrim and Kuzitrin river, 1992.

sampling gear during both events was hoop traps with wings and leads (Table 1). These traps were used to block off sloughs and entrances to lakes adjacent to the main channels of both the Pilgrim and Kuzitrin rivers (Figure 2). During each event traps were fished continuously except for brief periods of time when they were moved to different locations. Variable mesh gill nets (Table 1) were also fished in similar areas, in connected lakes, and in the main river channels during both events. All sampling was conducted by a two person crew.

Data Collection

During both sampling events, northern pike were examined for marks; marked; and sampled for age, sex, and length. Captured northern pike were measured to the nearest mm fork length (FL). Untagged northern pike > 299 mm FL and in healthy condition were marked with a Floy FD-68 internal anchor tag inserted posterior to the left base of the dorsal fin and released. Fish marked in the Pilgrim River received a partial left pectoral fin clip and fish marked in the Kuzitrin River received a partial right pectoral fin clip. Because determination of sex using external characteristics (Casselman 1974) proved unreliable, sex was recorded only for northern pike extruding sexual products. At least three scales were taken from the preferred zone adjacent to but not on the lateral line above the pelvic fins (Williams 1955). Age determined from scales, sagittal otoliths, and cleithra are similar (Peckham and Bernard 1987). Scales were directly mounted onto gum cards. Gum cards were used to make impressions on 20 mil acetate using a Carver press at 137,895 kPa (20,000 psi) heated to 93^{0}C for 30 s. Annuli were counted along their dorsal radius using a Micron 770 Microfiche reader. All data was recorded onto Tagging Length Mark-sense forms (Version 1.0).

Data Analysis

Abundance Estimation:

After investigating results of the mark-recapture experiment with a battery of statistical tests (Appendix A), a Darroch estimator stratified by geographical location was selected as the appropriate estimator. The Darroch estimator (Darroch 1961, cited in Seber 1982) is:

$$\hat{\underline{U}} = D_u M^{-1} \underline{a} \qquad (1)$$

where:

$\hat{\underline{U}}$ = a vector with the estimated number of unmarked northern pike in each recovery stratum;

D_u = a vector of the number of unmarked fish examined by area during the second event;

$\underline{M}^{-1}$ = a matrix of tag recoveries by river sections where the fish were marked and then recovered; and,

$\underline{a}$ = a vector of the number of fish marked and released in the Pilgrim and Kuzitrin rivers.

Table 1. Description of gear used to capture northern pike in the Pilgrim and Kuzitrin rivers, 1992.

Gear Type	Description
Traps:	
1) Hoop Traps	1 m diameter by 4 m long with 25 mm square mesh nylon netting on 7 fiberglass hoops and with finger-style throats on second and fourth hoops. Attached leads and wings were of various depths from 2.4 m to 3.6 m with mesh sizes of 10 or 25 mm.
Gill Nets:	
1) Six panel (floating and sinking)	46 m long with 7.6 m panels of 25, 38, 51, 25 38, and 51 mm bar mesh multifilament netting.

The number of northern pike in each stratum at the time of recovery is the sum of the estimated number of untagged fish present and the number of tagged fish released in that stratum.

The variance-covariance matrix of $\hat{U}$ was estimated with (Seber 1982):

$$E[(\hat{U}-U)(\hat{U}-U)'] \approx D_N B^{-1} D_u D_a^{-1} B'^{-1} D_N + D_N(D_p - I) \quad (2)$$

where,

D_N = diagonal matrix of estimated abundance in each stratum;

D_p = diagonal matrix of reciprocals of p_i, the estimated probability of an animal being caught;

D_a = a diagonal matrix of marked fish;

B = matrix of b_{ij}, the probability that a northern pike marked and released in stratum $i(a_i)$ is in stratum j at sampling; and,

$$= D_a^{-1} M D_p \quad . \quad (3)$$

Bootstrap procedures (Efron and Gong 1983) were used to investigate statistical bias in the estimate of abundance. One thousand bootstrap samples were drawn randomly from all capture histories in the experiment. Each bootstrap sample was built by randomly drawing samples with replacement from the body of capture histories. An estimate of abundance was calculated for each bootstrap sample with Equation 1 giving 1,000 estimates of abundance. A measure of the statistical bias was the difference between the point estimate from the original sample and the average of the bootstrap estimates. The generalized bootstrap procedure was as follows:

1. generate a pseudorandom number (between 0 and 1) from a uniform distribution;

2. sample capture history of fish number "random number" x "total number of fish" + 1;

3. repeat 1 and 2 until a sample of "total number of fish" is taken;

4. generate abundance estimate from randomly sampled capture histories;

5. repeat 1 through 4 for 1,000 iterations; and,

6. calculate mean of 1,000 iterations of abundance estimate.

Composition Estimation:

After a review of Gabelhouse (1984), categories of Relative Stock Density were defined as: "stock" size, 300 to 524 mm (FL); "quality" size, 525 to 654 mm; "preferred" size, 655 to 859 mm; "memorable" size, 860 to 1,079 mm; and "trophy" size, 1,080 mm and longer.

The proportions and associated variances of the northern pike of each age and length category were estimated with (Cochran 1977):

$$\hat{p}_j = n_j/n \text{ , and} \quad (4)$$

$$\hat{V}[\hat{p}_j] = \frac{\hat{p}_j(1 - \hat{p}_j)}{n - 1} \quad (5)$$

where:

n = the number of fish sampled to estimate length, or age composition;

n_j = the number of sampled fish in group j; and

$\hat{p}_j$ = the estimated proportion of the fish in group j.

The estimated abundance of northern pike of group $_j$ was calculated as:

$$\hat{N}_j = \hat{p}_j \hat{N} \quad (6)$$

The variance for $\hat{N}_j$ is a sum of the exact variance of a product (Goodman 1960):

$$\hat{V}[\hat{N}_j] = \hat{V}[\hat{p}_j]\hat{N}^2 + \hat{V}[\hat{N}]\hat{p}_j^2 - \hat{V}[\hat{p}_j]\hat{V}[\hat{N}] \quad (7)$$

Length-at-age:

Mean length-at-age was calculated as the arithmetic mean length of each age cohort for which ages were determined from both sampling events. Variances and standard errors of mean lengths were calculated using standard normal procedures.

RESULTS

During the first event 577 northern pike were captured and lengths from 575 fish were obtained. Of these fish 546 were marked and released. During the second event 961 northern pike were captured and examined for marks, and 959 fish were measured (Figure 3). Of these fish 48 had been marked in event one. A total of 826 newly captured northern pike were marked and released during event two. During both events 57 sampling-related mortalities (3.7%) occurred and 1,372 fish were marked. Of the fish marked, 97.5% were captured using traps, and only 34 fish (2.5%) in the mark and recapture experiment were captured using gill nets. It was assumed that spawning had taken place prior

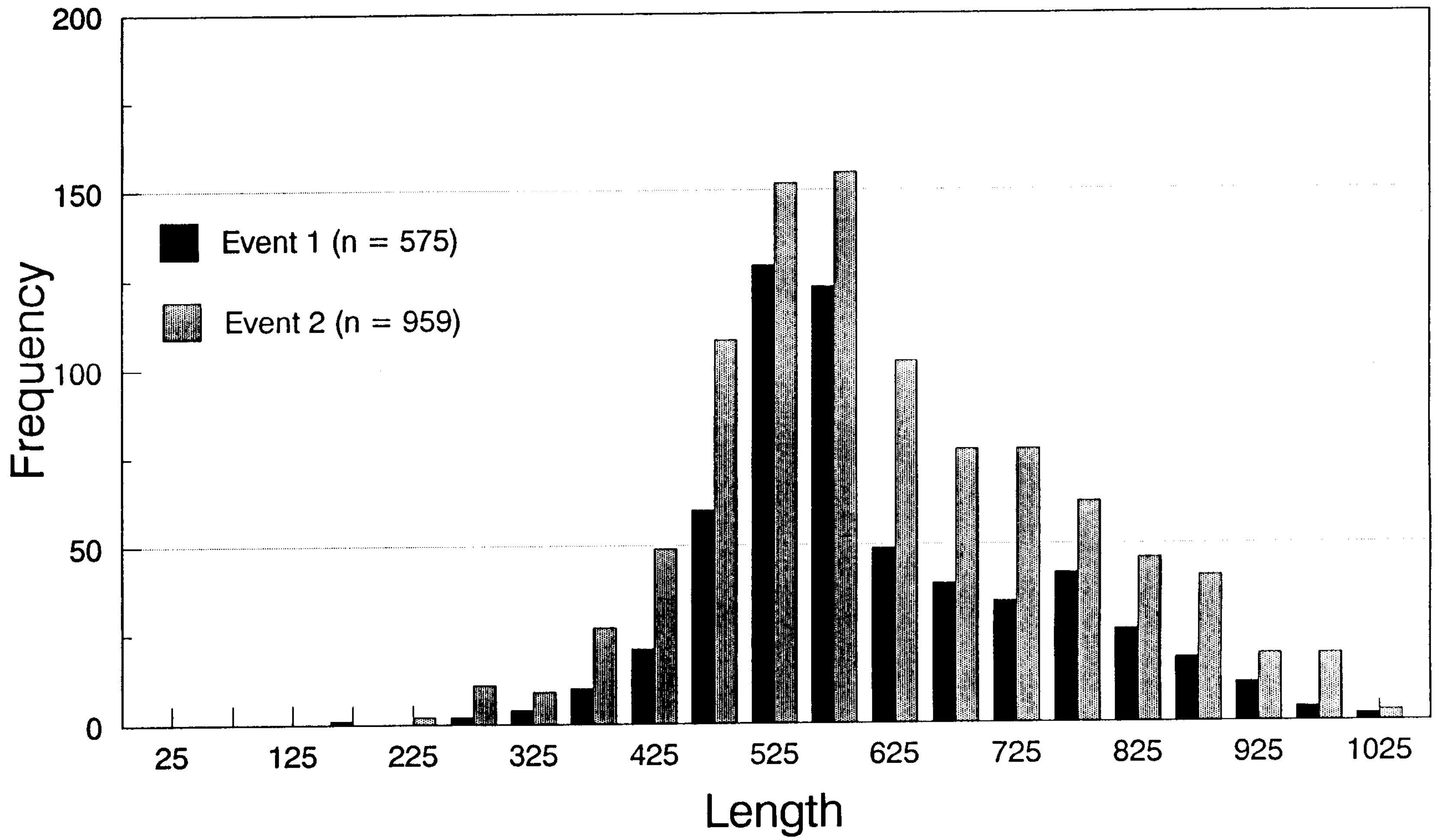

Figure 3. Length frequency of northern pike caught in the Pilgrim and Kuzitrin rivers, 1992 during Event 1 and Event 2 of a mark and recapture experiment.

to sampling because no sex products were extruded. Therefore, sex was not determined for the fish sampled.

Tests of Assumptions for Abundance Estimator

No northern pike < 450 mm were recaptured in the second event, therefore only fish ≥ 450 mm were used in the mark-recapture experiment. The following results were based on a series of statistical tests (Appendix A) on data from the mark-recapture experiment.

Gear Bias:

Differences in length distributions of all fish ≥ 450 mm (both events combined) were tested between traps and gill nets. While significant difference was suggested (DN = 0.23, P = 0.056), northern pike captured with both gear types were pooled. No bias from pooling fish captured with the two gear types should result, because both gear types were used in each event, and the probability of capture with each gear type was assumed to be the same. In addition, proportionally few fish were caught with gill nets.

No selectivity in the second event was indicated. No statistical difference was found (DN = 0.09, P = 0.86; Figure 4) between the length distributions of fish marked in event one versus fish recaptured in event two that were marked in event one. Since length distributions of fish marked in event one and fish captured in event two were significantly different (DN = 0.10, P < 0.01; Figure 4), size selectivity may have occurred in the first event. Therefore, the estimate of abundance was not stratified by size categories, but only those northern pike captured during the second event were used for estimating length and age compositions.

Closed Population:

The marked-to-unmarked ratio of northern pike was significantly different in the Pilgrim and Kuzitrin rivers during the second sampling event ($\chi^2 = 26.18$, df = 1, P < 0.01; Table 2). Therefore, all fish did not have an equal probability of capture during either sampling event, or marked northern pike did not completely mix with unmarked fish between the two sampling events. Mixing was not complete, but did occur to some extent (Table 3).

Abundance Estimate

Based on the results of the above tests, abundance was estimated using the Darroch method to adjust for unequal recapture rates between the two rivers. The estimated abundance for northern pike ≥ 450 mm in the study area was 9,998 fish (SE = 2,307). The bootstrap methods detected a negative statistical bias of the abundance estimate of 1,990 fish (Figure 5).

Tag Loss

No tag loss was observed during the experiment. Since the northern pike were double marked (tag and fin clip) any tag loss would have easily been identified.

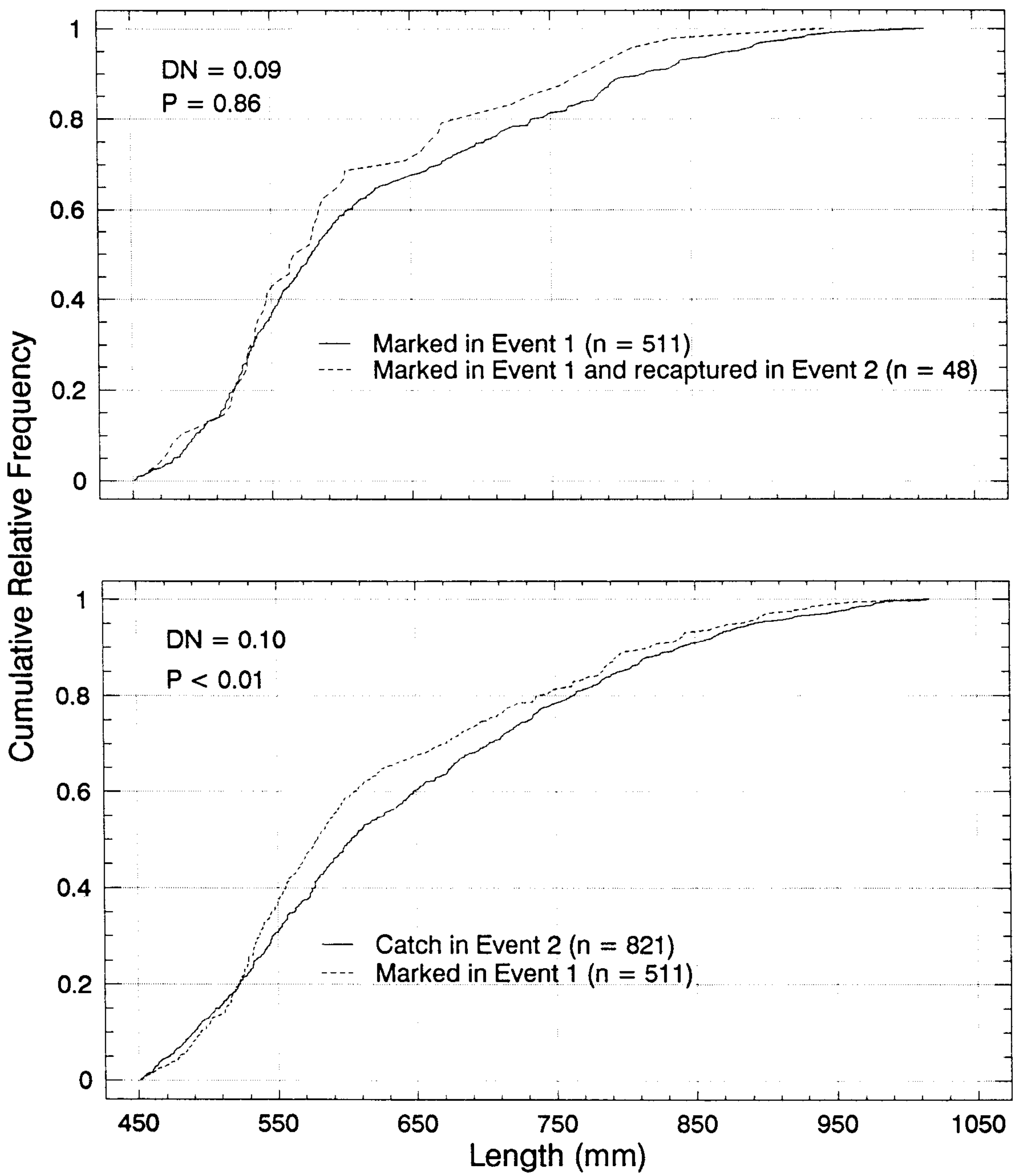

Figure 4. Cumulative relative frequency of northern pike in the Pilgrim and Kuzitrin rivers > 449 mm, marked in Event 1, captured in Event 2, and marked in Event 1 and recaptured in Event 2.

Table 2. Number of northern pike caught during the second sampling event (7-17 July 1992) in the Pilgrim and Kuzitrin rivers.

	River		
	Pilgrim	Kuzitrin	Total
Marked	39	9	48
Unmarked	336	437	773
Total Catch	375	446	821
Recovery rate	0.10	0.02	0.06

Table 3. Capture history of northern pike in the Pilgrim and Kuzitrin rivers, July 1992[a].

River Where Marked Fish Were Released	River Where Marked Fish Were Recaptured: Pilgrim	Kuzitrin	Total	Number Marked	Number Not Recaptured
Pilgrim	36	1	37	369	332
Kuzitrin	3	8	11	142	131
Total	39	9	48	511	463
Unmarked Event 2	336	437	773		
Total Event 2	375	446	821		

[a] These data were used to estimate abundance of northern pike with Darroch's estimator.

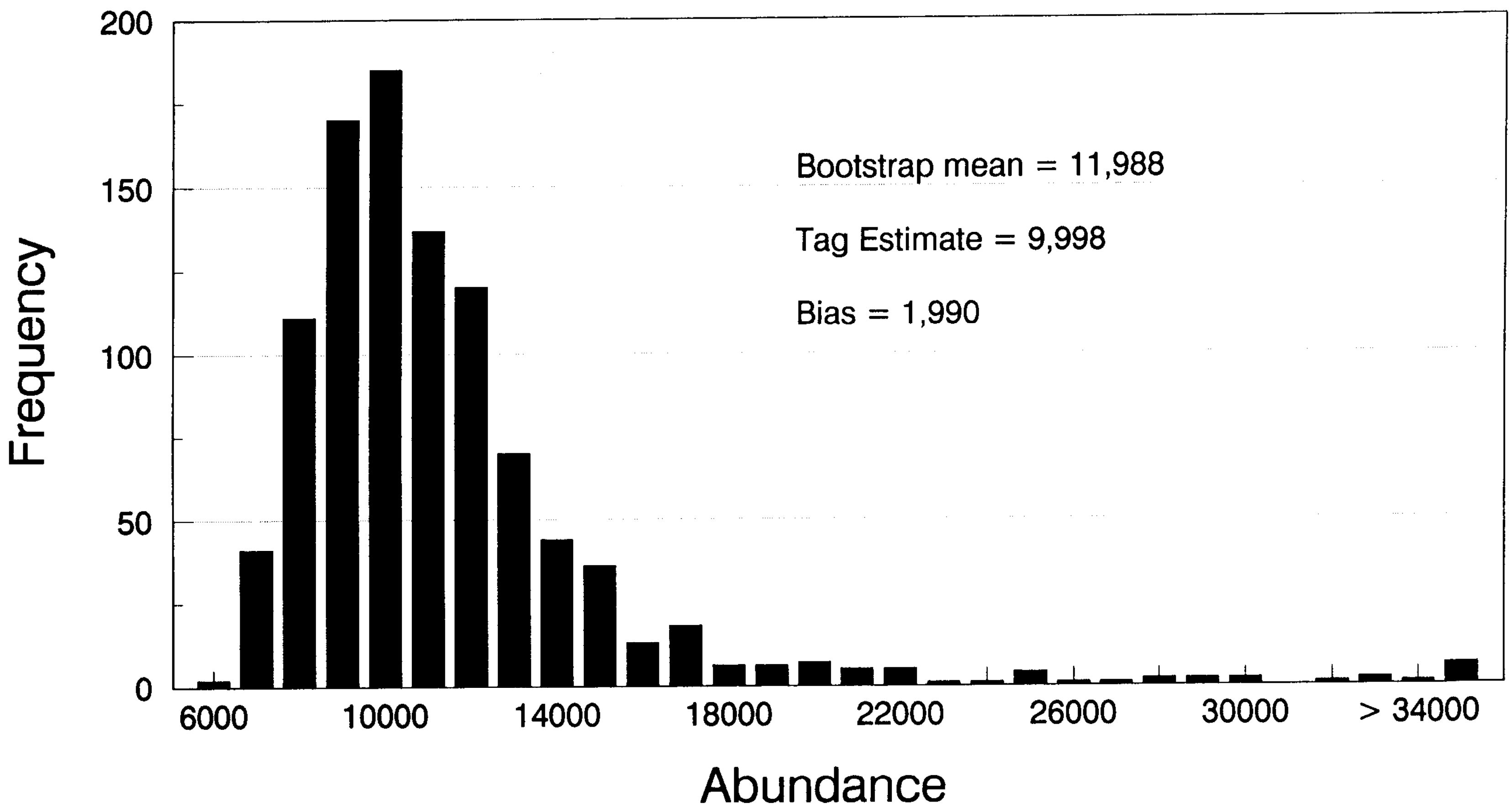

Figure 5. Frequency of the 1,000 bootstrap abundance estimates using capture history data of northern pike captured in the Pilgrim and Kuzitrin rivers, July 1992.

Length and Age Compositions

No trophy size northern pike were captured. For northern pike $\geq$ 450 mm, 40% were quality size, 30% were preferred size, 21% were stock size and 8% were memorable size (Table 4). However, the proportion of fish in the quality and larger size categories are overly represented because we were unable to recapture tagged fish < 450 mm.

The age 7 cohort was the most abundant (1,649, Table 5). Because the lower range of length-at-age for age 4 through 7 northern pike (Table 6) was < 450 mm, the estimated abundance of age 4 - 7 fish (Table 5) represents only those fish $\geq$ 450 mm. In general, estimated abundance of northern pike decreased from age 7 through age 22 (Table 5).

Length-At-Age

Relative increases in mean length-at-age were greatest between ages 2 and 3, and ages 3 and 4 (Table 6). Mean length-at-age for age 7 fish (the most abundant cohort) was 550 mm (SE = 4).

DISCUSSION

While northern pike of lengths < 450 mm were tagged in the first event, and sampled during the recapture event, no marked fish < 450 mm were recaptured. The lack of recapture of small northern pike was also reported by Burkholder (1991), Clark (1988), and Clark and Gregory (1988) at Harding, T, and Volkmar lakes, respectively.

Since partial mixing occurred between the Pilgrim and Kuzitrin rivers, abundance and composition were estimated for the entire study area which included areas of both rivers instead of treating each river separately. The bias (1,990) associated with the abundance estimate (9,998) is large, a result of low numbers of fish that were marked in one river and recaptured in the other. Since northern pike moved between the two rivers it is assumed that fish also moved in and out of the study area, therefore violating the assumption of a closed system. A second year of sampling is planned to occur in 1993, and this will constitute a third sampling event. Three sampling events will allow the use of an open population abundance estimator, which should produce an unbiased estimate for northern pike in the Pilgrim River.

The oldest northern pike sampled in the Pilgrim/Kuzitrin study area was an estimated 22 years old, which is older than estimated ages reported from other northern pike populations studied since 1985 in the AYK region. The oldest estimated ages for other northern pike populations studied in the AYK region are: age 16 for T Lake (Clark 1988), age 19 for Volkmar Lake (Clark and Gregory 1988), age 14 for George Lake (Pearse 1990), age 12 for Harding Lake (Skaugstad and Burkholder 1992), age 16 for Minto Flats (Holmes and Burkholder 1988), and age 14 for the Dall River (Arvey and Burkholder 1990). Because, in general, scale age estimates become increasingly unreliable with increasing age of the fish (Beamish and McFarlane 1987), and inaccuracy in aging northern pike scales has been found (Pearse and Hansen 1992), it cannot be assumed that the fish aged as 22 years was its true age.

Table 4. Percentage of northern pike captured in the Pilgrim and Kuzitrin rivers, July 1992, by Relative Stock Density category.

Category	Gabelhouse Minimum Length (mm)	Relative Stock Density[a]	SE	Abundance	SE
Stock	300	21.0	1.4	2,095	503
Quality	525	40.3	1.7	4,031	945
Preferred	655	30.4	1.6	3,044	720
Memorable	860	8.3	1.0	828	213
Trophy	1,080	—	—	—	—
Total		100.0		9,998	

[a] Relative Stock Density expressed as a percentage with categories from Gabelhouse (1984).

Table 5. Estimated proportions and abundance of northern pike captured in the Pilgrim and Kuzitrin rivers, July 1992 by age class.

Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
4	17	0.022	0.005	217	71
5	60	0.077	0.010	767	200
6	103	0.132	0.012	1,317	326
7	129	0.165	0.013	1,649	402
8	115	0.147	0.013	1,470	361
9	87	0.111	0.011	1,112	279
10	77	0.098	0.011	985	247
11	42	0.054	0.008	537	147
12	59	0.075	0.009	754	197
13	36	0.046	0.007	460	129
14	17	0.022	0.005	218	71
15	15	0.019	0.005	192	65
16	9	0.012	0.004	115	46
17	6	0.008	0.003	77	35
18	8	0.010	0.004	102	42
19	0	0	0	0	0
20	1	0.001	---	13	---
21	0	0	0	0	0
22	1	0.001	---	13	---
Total	782	1.000		9,998	

Table 6. Estimated length-at-age of northern pike captured in the Pilgrim and Kuzitrin rivers during July 1992.

Age	Sample Size	Length (mm)		
		Mean	SE	Range
1	1	158		
2	12	292	10	242 - 365
3	28	359	6	282 - 432
4	56	435	7	346 - 568
5	109	482	5	377 - 617
6	158	514	4	359 - 650
7	191	550	4	402 - 700
8	144	585	5	458 - 803
9	124	622	7	458 - 804
10	117	659	9	486 - 965
11	78	710	10	518 - 865
12	83	775	10	548 - 947
13	64	783	13	539 - 980
14	46	779	17	442 - 977
15	36	818	20	453 - 1017
16	21	852	20	693 - 985
17	11	930	22	783 - 1015
18	11	917	23	762 - 1010
19	1	840	--	
20	2	971	--	967 - 947
21	1	956	--	
22	1	1,010	--	

ACKNOWLEDGEMENTS

The author thanks N. F. Hughes and Matt Evenson for assistance with the 1992 field work. The author is grateful to John Clark, Dave Bernard, Pat Hansen, and Peggy Merritt for various aspects of planning and reporting. Thanks to Sara Case for assisting with finalization of the manuscript.

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APPENDIX A

Appendix A. Statistical tests for analyzing data from a mark-recapture experiment for gear bias and evaluating the assumptions of a two-event mark-recapture experiment.

The following statistical tests will be used to analyze the data for significant bias due to gear selectivity and length:

1. Tests for significant gear bias by size will be based on: (A) Kolmogorov-Smirnov goodness of fit test comparing the distributions of the lengths of all fish that were marked during electrofishing and all marked fish that were collected during the carcass survey; and, (B) Kolmogorov-Smirnov two sample test comparing the distributions of the lengths of all fish that were captured during electrofishing and all fish that were collected during the carcass survey. The null hypothesis is no difference between the distributions of lengths for Test A or for Test B.

For these two tests there are four possible outcomes:

Case I:

Accept $H_o(A)$ Accept $H_o(B)$

There is no size-selectivity during the first sampling event (when fish were marked) or during the second sampling event.

Case II:

Accept $H_o(A)$ Reject $H_o(B)$

There is no size-selectivity during the second sampling event but there is size-selectivity during the first sampling event.

Case III:

Reject $H_o(A)$ Accept $H_o(B)$

There is size-selectivity during both sampling events.

Case IV:

Reject $H_o(A)$ Reject $H_o(B)$

There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

-continued-

Depending on the outcome of the tests, the following procedures will be used to estimate the abundance of the population:

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

Case II: Calculate one unstratified estimate of abundance, 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 the abundance for each stratum. Add the estimates of abundance 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 the abundance for each stratum. Add the estimates of abundance across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

Case IVa: If the stratified and unstratified estimates of abundance 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 (*See* Adjustments in Compositions for Gear Selectivity) to data from the second event.

Case IVb: If the stratified and unstratified estimates of abundance 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.

-continued-

Closed Population

The following two assumptions must be fulfilled:

1. Catching and handling the fish does not affect the probability of recapture; and,

2. Marked fish do not lose their mark.

If the floy tag is lost, the fin clip given to each fish will identify from what area the fish was marked.

Of the following assumptions, only one must be fulfilled:

1. Every fish has an equal probability of being marked and released during event one;

2. Every fish has an equal probability of being collected during event two; or,

3. Marked fish mix completely with unmarked fish between event one and event two.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency table. The results will be used to determine the appropriate abundance estimator and if the estimate of abundance should be stratified by river section or period:

1. Null hypothesis is that marked-to-unmarked ratio is the same at all sites. Columns 1, 2, and 3 in the table will be the corresponding river section where the fish were recovered. Row 1 will be the number of marked fish collected during event two and row 2 will be the number of unmarked fish collected during event two. The column totals will be equal to the number of fish collected during the carcass event two.

-continued-

If the test statistic is not significant, then either every fish had an equal probability of being marked (caught in event one) or marked fish mixed completely with unmarked fish between sampling events. In this case a Petersen estimate will be used to estimate abundance. If the test statistic is significant the following matrix will be created:

River Section of Release	River Section of Recapture	
	Pilgrim	Kuzitrin
Pilgrim		
Kuzitrin		

If all the off-diagonal elements are zero, then a Petersen estimate will be calculated for each river section. The sum of the three estimates will be the overall abundance estimate. If the off-diagonal estimates are not zero, then Darroch's method will be used to estimate abundance. With these tests it is unknown whether the second assumption was fulfilled. Darroch's method will be used to insure an unbiased estimate.