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Stock Status of Piledriver Slough Arctic Grayling

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L. Saree Timmons
and
Robert A. Clark

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ABSTRACT

The stock status of Arctic grayling *Thymallus arcticus* in Piledriver Slough, Tanana River drainage, near Fairbanks, Alaska, was investigated in 1990. Abundance, Relative Stock Density, and age composition were estimated. French Creek, Moose Creek, and Garrison Slough, which are interconnected with Piledriver Slough, were also sampled during 1990. Abundance of Arctic grayling in Piledriver Slough in 1990 was estimated to be 16,435 fish over 149 millimeters fork length (standard error = 1,396). Most Arctic grayling in Piledriver Slough were ages 3 to 6 years. Over 50 percent of Arctic grayling sampled in French Creek were age 5. Most Arctic grayling in Moose Creek were ages 4 to 6. About 85 percent of Arctic grayling in Piledriver Slough fell into the stock category of the Relative Stock Density index. There was some movement of Arctic grayling among the four creeks.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, abundance, age composition, size composition, Relative Stock Density.

INTRODUCTION

Piledriver Slough, a clearwater stream located near Fairbanks, Alaska has historically supported a small sport fishery for Arctic grayling *Thymallus arcticus*. Angler effort for the period from 1983 through 1986 average 3,253 angler-days annually and the sport harvest of Arctic grayling averaged 3,548 fish annually during this same period (Table 1; Mills 1984-1987). Sport effort and harvest in Piledriver Slough from 1983 through 1986 represented 2.3% and 4.9%, respectively, of the total effort and harvest in the Tanana River drainage. Beginning in 1987, the Alaska Department of Fish and Game (ADFG) experimentally stocked Piledriver Slough with rainbow trout *Oncorhynchus mykiss* in an effort to increase area sport fishing opportunities. As a result of the stocking program, angler effort increased to an average of 20,126 angler-days annually for the period from 1987 through 1989 which represented over 12% of the total Tanana drainage sport fishing effort (Table 1; Mills 1988-1990). Coupled with the increased effort was a concurrent increase in the sport harvest of Arctic grayling which peaked at 8,095 fish in 1988. However, the Arctic grayling sport harvest decreased 45% to 4,459 fish in 1989.

In response to the increasing sport fishing effort at Piledriver Slough since the inception of the rainbow trout stocking program coupled with the significant decrease in the Arctic grayling sport harvest observed in 1989, a stock assessment study of Arctic grayling was begun at Piledriver Slough in 1990. Specific objectives for 1990 were to:

1. estimate the age and length compositions of Arctic grayling in Piledriver Slough; and,

2. estimate the abundance of Arctic grayling greater than 149 mm fork length (FL) in Piledriver Slough.

Data collected prior to 1990 are also presented in this report.

Study Area

Located near Fairbanks, Alaska, the largest urban area in interior Alaska, Piledriver Slough can be accessed at many locations along the Richardson Highway (Figure 1). Although there are no developed recreational areas along the slough, there are several gravel pull-offs and parking areas along the Richardson Highway and at gravel road crossings. Piledriver Slough is also easily accessed at its upper end from a residential area along the Old Richardson Highway at Stringer Road.

Contrary to its name, Piledriver Slough is no longer a slough. In 1976, the slough was blocked off from the Tanana River as part of a flood control project. As a result, Piledriver Slough became a clear-water stream fed primarily from run-off and ground-water instead of the Tanana River. It is still directly influenced by fluctuations of the Tanana River, with occasional flooding of the slough during high water events.

Table 1. Angler effort and sport harvest of Arctic grayling at Piledriver Slough, 1983-1990.

	Piledriver Slough				Tanana Drainage		% of Tanana Drainage[a]	
Year	Number of Anglers	Number of Trips	Days Fished	Harvest of Arctic Grayling	Days Fished	Harvest of Arctic Grayling	Days Fished	Harvest of Arctic Grayling
1983[b]			4,148	5,822	146,386	92,363	2.8	6.3
1984[c]	470	2,334	4,651	3,751	145,752	83,626	3.2	4.5
1985[c]	648	3,019	2,133	2,306	136,422	63,560	1.6	3.6
1986[c]	342	1,870	2,079	2,312	144,937	45,981	1.4	5.0
1987[d]	4,686	15,236	13,257	4,907	156,061	38,480	8.5	12.8
1988[e]	4,981	21,936	24,375	8,095	174,554	52,659	14.0	15.4
1989[f]	5,268	19,512	22,746	4,459	186,418	54,823	12.2	8.1

[a] Percent of Tanana drainage fishery represented by Piledriver Slough.
[b] Mills 1984.
[c] Mills, unpublished data.
[d] Mills 1988.
[e] Mills 1989.
[f] Mills 1990.

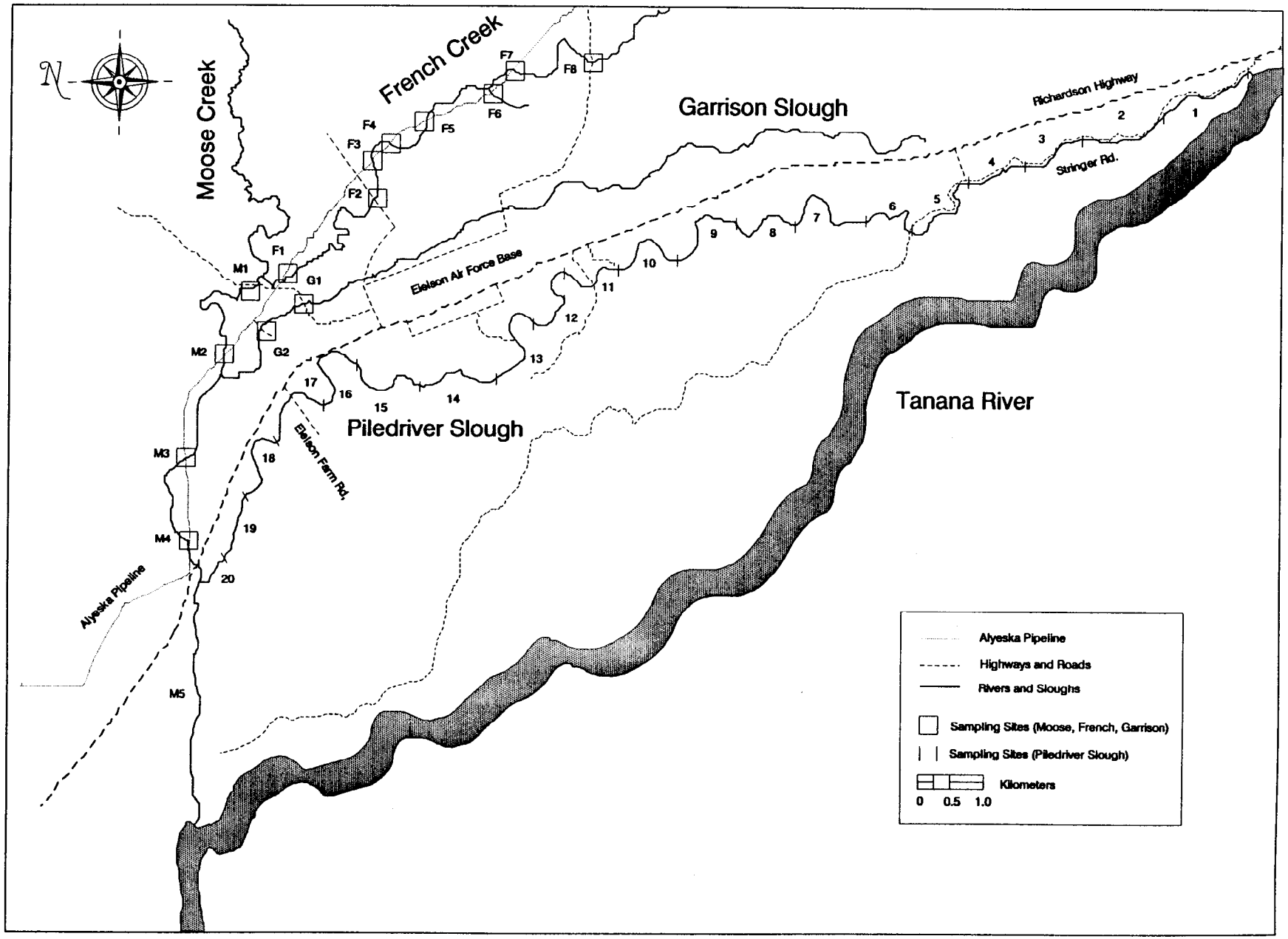

Figure 1. Map of study sites on Piledriver Slough, Moose Creek, French Creek, and Garrison Slough, 1990.

Numerous riffles and pools characterize the upper reaches of Piledriver Slough, while slower, deeper water is more common near its confluence with Moose Creek. Substrate of the slough varies from gravel to mud, and in the summer the lower reaches are choked with a variety of aquatic vegetation. After completion of the flood control project in 1976, Piledriver Slough was quickly inhabited by most fish species indigenous to interior Alaska, including Arctic grayling, round whitefish *Prosopium cylindraceum*, least cisco *Coregonus sardinella*, humpback whitefish *Coregonus pidschian*, northern pike *Esox lucius*, burbot *Lota lota*, and coho salmon *Oncorhynchus kisutch*. Other fish inhabiting the slough include slimy sculpin *Cottus cognatus* and longnose suckers *Catostomus catostomus*.

Moose Creek, French Creek and Garrison Slough were included in the 1990 sampling because they are interconnected with Piledriver Slough (Figures 1 and 2). Lower Moose Creek, from Eielson Air Force Base to its confluence with the Tanana River, is primarily a meandering stream with steep cut-banks and muddy bottom. Access to Moose Creek can be gained from the Richardson Highway and several bridge crossings on Eielson Air Force Base. French Creek, a tributary to Moose Creek, varies from a small creek with gravel and mud substrate to a small river nearly the size of Moose Creek. Access to French Creek is primarily limited to bridge and pipeline crossings on Eielson Air Force Base. Garrison Slough is also a small tributary to Moose Creek, contained almost entirely on Eielson Air Force Base. Because the Alyeska oil pipeline crosses French and Moose creeks at numerous locations, these water bodies were the subjects of habitat and fish surveys conducted by the Division of Habitat, ADFG, prior to construction of the oil pipeline. Physical characteristics of these streams are presented in Appendix A. Water temperatures during the 1990 study are presented in Appendix B.

METHODS

Field Sampling

Field sampling of Piledriver Slough fishery resources in 1988 and 1989 was limited to a few days. In 1990, extensive field sampling was conducted throughout Piledriver Slough, and in Moose Creek, French Creek, and Garrison Slough.

Sampling in 1988 and 1989:

In 1988, Piledriver Slough was sampled with minnow traps and seines in early June. On June 2, three minnow traps were set at Piledriver Slough, site 20, and one minnow trap was set at Moose Creek site 5 (Figure 1). The minnow traps were baited with salmon roe and allowed to fish overnight. Also on June 2, 1988, three seine hauls were made just downstream of the confluence of Moose Creek and Piledriver Slough (Moose Creek Site 5), and one seine haul was made at Piledriver Slough site 17. On June 3, 1988, Moose Creek site 5 was sampled with boat mounted electrofishing equipment. In 1989, field sampling was limited to one day. Sites 4 and 16 were sampled with seines on May 19, 1989.

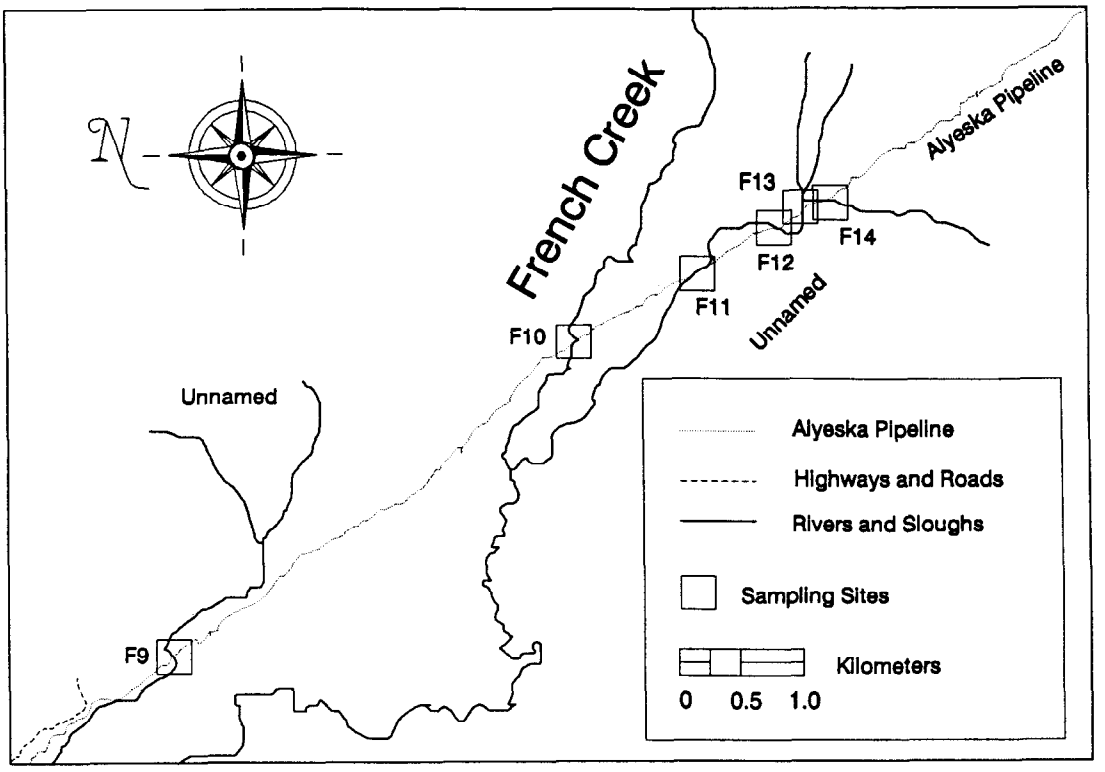

Figure 2. Map of study sites on upper French Creek, 1990.

Sampling in 1990:

In 1990, sampling for Arctic grayling occurred throughout Piledriver Slough, in lower Moose Creek, and at bridge and pipeline crossings of Moose Creek, French Creek, and Garrison Slough (Figures 1 and 2). Using a variety of gear types, including backpack and boat electrofishers, hoop traps, minnow traps, and seines, Arctic grayling were captured from April 25 through October 5, 1990 (Table 2). In the upper areas of Piledriver Slough, and in narrow riffle areas of lower Piledriver Slough, backpack shockers were used in pairs. Two crew members, one manning the shocker and one manning a dip net, worked downstream to two other crew members manning another shocker and another dip net. In the broad, lower areas of Piledriver Slough, crew members worked side-by-side with two backpack shockers and two dippers, attempting to cover as much of the width of the slough as possible. Backpack electrofishing was used in French Creek on only one day at sites 9-12. The boat electrofisher was used from site M4 in Moose Creek to the confluence with the Tanana River, and in Piledriver Slough from site 17 to the confluence with Moose Creek. Hoop traps, with 2.54 mm (1 in) mesh and with 0.64 mm (0.25 in) mesh, and minnow traps baited with salmon roe, were employed in all four water bodies. Beach seines were used to capture fish in Piledriver Slough only.

A single-season mark-recapture method was used to estimate abundance of Arctic grayling in Piledriver Slough. Piledriver Slough was initially stratified into four areas: sites 1-5 (Area A), sites 6-9 (Area B), sites 10-12 (Area C), and sites 13-20 (Area D) (Figure 1). The marking event was April 4, 1990 to May 31, 1990. The recapture event was June 20, 1990 to August 16, 1990.

Captured Arctic grayling from all four water bodies were measured to the nearest 1 mm fork length. Spawning condition and sex were noted during the mark event by extrusion of eggs or milt when possible. Arctic grayling larger than 149 mm were double marked with an individually numbered Floy tag and an adipose fin clip. Tags were inserted on the left side of the fish at the base of the dorsal fin.

Several scales, taken from an area above the lateral line just posterior to the insertion of the dorsal fin, were removed from Arctic grayling for determination of age. Two scales from each fish were later mounted on gummed scale cards and mounted scales were impressed on acetate cards with a Carver hydraulic press at a temperature of 93°C and pressure of 137,895 kPa for 30 seconds. Scale impressions were viewed with a microfiche reader at about 40× to count annuli.

Statistical Analysis

Data on lengths and ages of Arctic grayling sampled in 1988 and 1989 were very limited and were briefly summarized. Data collected in 1990 were analyzed more rigorously.

Table 2. Dates and areas sampled, gear used, and numbers of Arctic grayling sampled during 1990.

Date	Piledriver Slough			French Creek			Moose Creek			Garrison Slough		
	Site[a]	Gear[b]	Number Sampled	Site[a]	Gear[b]	Number Sampled	Site[a]	Gear[b]	Number Sampled	Site[a]	Gear[b]	Number Sampled
4/25	4-6	HM	3									
4/26	4-6	HM	2									
4/27	4-5	HM	9									
4/30	4-5	HM	78									
5/02	4-5	HM	28									
5/03	4-16	ES	740				3-5	E	39	1-2	H	1
5/04	5,11,16	ES	611									
5/11				1-14	H	77	1-4	H	8	1-2	H	5
5/14				1-14	H	75	1-5	H	46	1-2	H	1
5/16				1-14	H	22	1-4	H	6	1-2	H	0
5/17				1-7	H	4						
5/21	16	S	60									
5/22				1-14	H	64	1-4	H	4	1-2	H	1
5/23	11	S	30									
5/25				1-14	H	4	2-4	H	10	1-2	H	1
5/28				6	H	0						
5/29	16	S	19	8,12	H	0	1-4	H	0			
5/31	11	S	79									
6/01							2-4	H	0	2	H	0
6/05							2-4	H	5	2	H	0
6/08							2-4	H	0	2	H	0
6/20	4	E	370									
6/21	5	E	260									
6/22	11	E	179	10-14	H	5						
6/25				10-14	H	7						
6/26	11-12	E	205									
6/27				10-14	H	4						
6/28	11-13	E	180									

-continued-

Table 2. (Page 2 of 2).

Date	Piledriver Slough			French Creek			Moose Creek			Garrison Slough		
	Area[a]	Gear[b]	Number Sampled	Area[a]	Gear[b]	Number Sampled	Area[a]	Gear[b]	Number Sampled	Area[a]	Gear[b]	Number Sampled
6/29	11-14	E	126	10-14	H	0						
7/02				10-14	H	0						
7/11				10-14	H	7						
7/12							3-5	E	133			
7/31	10	E	189									
8/01	12	E	62									
8/02	15	E	15									
8/03	4	E	430									
8/09				9	E	4						
8/13	13	E	29									
8/15	6	E	502									
8/16	6-8	E	686									
9/10	16-19	E	30				1-2	E	110			
9/27[c]	5-16	M	13									
9/29[c]	5-16	M	8									
10/01[c]	5-11	M	16	1-7	M	0						
				9-14	M	4						
10/03[c]				1-14	M	0	17-20	M	1	1	M	0
10/05[c]							1	M	0			
							17-20	M	0	1	M	0
Total			4,959			277			362			9

[a] See Figures 1 and 2.
[b] H=hoop trap; M=minnow trap; E=electrofishing; S=seine.
[c] Arctic grayling were enumerated but not sampled.

Abundance Estimate:

The Bailey (1951, 1952) modification of the Petersen single-mark method was to be used to estimate the abundance of Arctic grayling in Piledriver Slough. Conditions for the accurate use of this method are:

1. marking does not affect the catchability of Arctic grayling;

2. marked Arctic grayling do not lose their marks between sampling events;

3. recruitment *and* death of Arctic grayling do not occur between sampling events; and,

4. every Arctic grayling has an equal probability of being marked and released alive during the first sampling event; *or* every Arctic grayling has an equal probability of being captured during the second sampling event; *or* marked Arctic grayling mix completely with unmarked Arctic grayling between sampling events (Seber 1982).

Frequent processing of captured Arctic grayling ensured that there was little difference in mortality between marked and unmarked Arctic grayling (Condition 1). Double marking of Arctic grayling permitted correction of abundance estimates for any tag loss that may have occurred (Condition 2). Because of the lengthy recapture period, there was the potential for growth recruitment and mortality (Condition 3).

Condition 4 was examined in two ways: by testing for sampling bias by area and by testing for sampling bias by size. To detect sampling bias by area, two contingency tables were constructed (Seber 1982). The first table, which compared the recapture to catch ratios by area strata, tested for complete mixing of Arctic grayling or that every Arctic grayling had the same probability of being tagged during the marking event. The second table, which compared numbers by area strata of Arctic grayling released and recaptured, was employed to detect mixing of Arctic grayling between area strata. To detect sampling bias by size group, two Kolmogorov-Smirnov tests were conducted. The first compared the distribution of lengths of fish marked during the first event to lengths of fish recaptured during the second event. The second test compared the distribution of lengths of fish marked during the first event to lengths of fish captured during the second event. The outcome of the tests determined whether or not the estimates of abundance would be stratified by size (Appendix C).

Based on the results of the contingency table analyses, capture probability differed by area and mixing was incomplete. Therefore, a single abundance estimate was performed using Darroch's partially stratified modification (Darroch 1961). The Kolmogorov-Smirnov tests revealed that capture probability also differed by size of fish. Therefore, the mark-recapture data were stratified into size classes and abundance was estimated separately for each size strata.

The partially stratified (by area) estimate of abundance was calculated by (using the notation of Seber 1982):

$$\hat{N} = \underline{u}'\underline{M}^{-1}\underline{a} + A \qquad (1)$$

where:

- $\underline{u}$ = a vector of the number of unmarked Arctic grayling examined by area during the recapture event;
- $\underline{M}$ = a matrix of the number of recaptures partitioned by area marked and area recaptured;
- $\underline{a}$ = a vector of the number of Arctic grayling marked and released by area; and,
- A = the total number of Arctic grayling marked and released (a scalar).

The variance of this estimator was calculated by bootstrapping the capture histories of all fish in both events 1,000 times (Efron 1982). The bootstrap procedure also permitted examination of bias in the abundance estimate by generating a bootstrap estimate in addition to a bootstrap variance. The 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" × "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 and variance of 1,000 iterations of abundance estimate.

Abundance estimates and variances for the two size strata were then summed to obtain a final estimate of abundance. An unstratified estimate and variance were also calculated. The variance of the stratified estimate was compared to the variance of the unstratified estimate and the estimate with the smaller variance was used as the final estimate.

Age and Size Compositions:

Testing of assumptions necessary for accurate abundance estimation may also reveal biases in samples collected for estimation of age and size compositions. Because age and length data were collected during both mark and recapture events, sampling bias during mark or recapture events also implies bias in age and length data that were collected. Age and size compositions were used to apportion the population estimate into age classes or Relative

Stock Density (RSD) categories (Gabelhouse 1984), thus, age and length data collected during the mark event, the recapture event, or both events may be used to calculate age and size compositions, depending on which events were biased.

Based on the Kolmogorov-Smirnov tests for size selectivity, the chi-squared test for equal probability of capture by area, and the rationale presented in Appendix C, sampling bias in the recapture event was detected. Therefore, age and length data from the first event were used to estimate age and size compositions, and age and size compositions were adjusted to compensate for the area and size sampling biases. These adjustments were performed during bootstrapping of the capture histories.

Because abundance was estimated with mark-recapture data that were partially stratified by area (two areas) and completely stratified by size (two size classes), probabilities of capture were estimated for each area/size combination (a total of four combinations). These capture probabilities, or more exactly the inverse of these capture probabilities, were then used to alleviate bias in age composition data due to unequal capture probabilities. First, the inverse of capture probabilities were estimated from the Darroch (1961) model for small Arctic grayling:

$$\hat{\underline{\rho}}^{-1} = \underline{M}^{-1}\underline{a} \qquad (2)$$

where: $\hat{\underline{\rho}}^{-1}$ = a vector of inverse capture probabilities (the ratio of marks to recaptures) of small Arctic grayling in areas A and BCD; and,

$\underline{M}^{-1}$ and $\underline{a}$ are as defined in equation 1.

These same quantities were then estimated for large Arctic grayling in areas A and BCD using equation 2. The resulting two vectors (for small and large fish) each have two elements, the first element is the inverse of capture probability for area A and the second element is the inverse of capture probability for area BCD.

Next, these vectors were reduced to their scalar elements and the elements inverted to make them "capture probabilities:"

$$\hat{\rho}_{j1} = 1/\hat{\rho}_{j1}^{-1} \qquad (3)$$

where: $\hat{\rho}_{j1}$ = the capture probability of Arctic grayling in area j that were also in size class 1; and,

$\hat{\rho}_{j1}^{-1}$ = the inverse of capture probability of Arctic grayling in area j that were also in size class 1 (from the vector $\hat{\underline{\rho}}$).

After inversion, the adjustment factors for effects due to size selectivity and unequal probability of capture by area were calculated as the ratios of

the largest of the four capture probabilities to each of the capture probabilities:

$$\hat{A}_{jl} = \frac{\hat{\rho}_{max}}{\hat{\rho}_{jl}} \qquad (4)$$

where: $\hat{A}_{jl}$ = the adjustment factor for all Arctic grayling in area j that are also in size class l, regardless of age class k; and,
ρ_{max} = the largest among all four capture probabilities.

There were then four adjustment factors, corresponding to the four area/size combinations. One of the adjustment factors was one (1) because it corresponded to the largest capture probability; all other adjustment factors were greater than one.

The number of fish sampled, by age class k, that were also from area j and size class l was then multiplied by the adjustment factor:

$$\hat{x}_{jlk} = \hat{A}_{jl}\, n_{jlk} \qquad (5)$$

where: $\hat{x}_{jlk}$ = the adjusted number of Arctic grayling of age k that were also from area j and in size class l; and,
n_{jkl} = the actual number of Arctic grayling sampled that were age k and also from area j and size class l.

The proportion of Arctic grayling that were age k was then reevaluated to:

$$\hat{p}_k = \frac{\sum_{j=1}^{2}\sum_{l=1}^{2}\hat{x}_{jlk}}{\sum_{j=1}^{2}\sum_{l=1}^{2}\sum_{k=1}^{o}\hat{x}_{jlk}} = \frac{\hat{x}_{..k}}{\hat{x}_{...}} \qquad (6)$$

where: p_k = the adjusted proportion of Arctic grayling that were age k;
k = 1, 2, ..., o age classes.

The variances of these adjusted proportions were estimated by bootstrap techniques (Efron 1982). The inverse capture probabilities were produced from bootstrap runs of the mark-recapture data, in conjunction with abundance estimation. Variance of the proportions was estimated from the 1,000 iterations of the inverse capture probabilities (using steps 1 through 6 as outlined for abundance estimation).

The same adjustment technique (equations 2 through 6) was use to adjust biased RSD indices, replacing the number sampled at age *k* that were also from area j and in size class l (n_{jlk}) with the number sampled in RSD category k (K =1, 2, 3, 4, and 5 RSD categories) that were also from area j and in size class l. The RSD categories were taken from Gabelhouse (1984): "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).

RESULTS

Prior to 1988, the only information collected on Arctic grayling in Piledriver Slough was length and age of the catch, sampled during creel surveys. This limited information is presented in Appendix D.

Sampling in 1988 and 1989

No Arctic grayling were captured in Moose Creek using minnow traps and a beach seine in 1988, although these sampling efforts were very limited. Forty-four Arctic grayling were captured with boat-mounted electrofishing equipment. Of the 44 fish sampled, 29 were aged. The mean length of fish captured was 239 mm (SE = 6), and the range of lengths was 125 to 305 mm. The mean age of 29 fish was 6 years (SE = 0.1). The sample was comprised of fish of ages 5 (21%), 6 (55%), 7 (21%), and 8 (3%). In 1989, 90 Arctic grayling were captured using beach seines, and of these fish, 55 were aged. No record of catch-per-unit of effort was kept. The mean length of fish captured was 210 mm (SE = 3.8), and the range of lengths was 150 mm to 274 mm. The mean age of 55 fish was 4 years (SE = 0.1). The sample was comprised of fish of ages 2 (2%), 3 (22%), 4 (24%), 5 (40%), 6 (11%), and 7 (2%).

Sampling in 1990

Backpack electrofishing was the most effective means of capturing Arctic grayling in Piledriver Slough. Seines also worked well in shallow areas having little bottom debris. Hoop traps, when set in the narrow channels of upper French Creek, acted as fyke traps and were very effective in capturing Arctic grayling that were moving upstream. Boat electrofishing was effective in lower Moose Creek (below site 3). Capturing Arctic grayling above Moose Creek site 3 was difficult because the stream was too small for boat electrofishing, but the deep water and cut banks made backpack shocking, seining, and hoop traps ineffective.

During the mark event, 1,367 Arctic grayling were tagged and released alive in Piledriver Slough. During the recapture event, 2,793 Arctic grayling were captured, of which 313 were recaptures from the mark event. During the recapture event, a total of 12 Arctic grayling were captured which had lost their tags. Due to the long recapture event, it was unknown if those fish had been tagged during the mark event or during the recapture event. Also, tag losses represented less that 5% of the recaptures. Therefore, abundance estimates were not adjusted for tag loss.

The proportions of recaptured Arctic grayling in the four area strata during the recapture event were significantly different ($\chi^2 = 230.74$, df = 3, $P < 0.01$). Arctic grayling had a much higher probability of capture in Area A than in the other three areas (Table 3). Some mixing of Arctic grayling occurred among the four areas (Table 4). Because the probability of capture varied by area strata and some mixing occurred between areas, the methods of Darroch were necessary to calculate abundance. Because the probability of capture in Area A was much higher than the other three areas, Areas B, C, and D were pooled for the Darroch estimate, resulting in two areas: Area A and Area BCD.

In addition, length compositions of Arctic grayling were very different by month and location of capture (Figure 3). Kolmogorov-Smirnov tests were rejected ($P < 0.01$ for both tests; Figure 4), indicating that there was size selectivity during the mark event; the status of size-selectivity during the recapture event was unknown (Appendix C). Therefore, both events were stratified by size, and abundance was estimated for each size stratum. The two size groups were chosen as fish 150-224 mm in length (small) and fish larger than 224 mm (large; Table 5). Abundance estimates were then added across strata to obtain an estimate of abundance for the entire population over 149 mm. A single, unstratified estimate of abundance was also calculated. The stratified and unstratified estimates were similar, and the variance for the stratified estimate was smaller (Table 6). Therefore, a stratified estimate was generated by bootstrapping, and only lengths, ages, and sexes from the first event were used for composition estimates. Based on t-tests, mean lengths-at-age of Arctic grayling of ages 5, 6, and 7 were significantly different for Area A and Area BCD (Table 7; Figure 5). Therefore, age and length compositions and age and length at maturity were adjusted for area and size strata. These adjustments were made during the bootstrapping for the Darroch estimates.

The abundance of Arctic grayling in Piledriver Slough was estimated to be 4,816 small Arctic grayling (SE = 518) and 11,619 large Arctic grayling (SE = 1,296), for a total estimate of abundance of 16,435 (SE = 1,396).

Most Arctic grayling in Piledriver Slough were ages 3 to 6. Most Arctic grayling in French Creek and Moose Creek were ages 4 to 6. The estimates of age composition for French Creek and Moose Creek were not adjusted for potential sampling bias (Table 8; Figure 6). Arctic grayling in all three creeks were mostly in the RSD stock category (Table 9; Figure 7). Because only nine Arctic grayling were captured in Garrison Slough (Table 10), age and size compositions were not estimated for Garrison Slough. Thirty-seven percent of age 5 and 70% of age 6 Arctic grayling sampled at Piledriver Slough were mature (Table 11). Of the Arctic grayling in length category 250-259 mm, about 77% were mature (Table 12). Of age 5 Arctic grayling sampled in Moose Creek, about 64% were mature; about 63% of Arctic grayling in length category 250-259 mm were mature. In French Creek, about 87% of the age 5 Arctic grayling were mature; about 95% of Arctic grayling in length category 250-259 mm were mature.

There was some mixing of Arctic grayling between Piledriver Slough, French Creek, Moose Creek, and Garrison Slough (Table 13). One Arctic grayling,

Table 3. Proportion of marked Arctic grayling captured in four areas of Piledriver Slough during the recapture event, 1990.

Area	Number Marked	Number Unmarked	Proportion with Tags
A	202	613	0.25
B	40	1,019	0.04
C	60	531	0.10
D	11	317	0.03

Table 4. Numbers of Arctic grayling marked and recaptured by area in Piledriver Slough in 1990.

Area Released	Area Recaptured				Not Recaptured	Total Released
	A	B	C	D		
A	184	24	13	7	532	760
B	0	0	0	0	0	0
C	7	13	45	0	220	285
D	11	3	2	4	302	322
Total	202	40	60	11	1,054	1,367

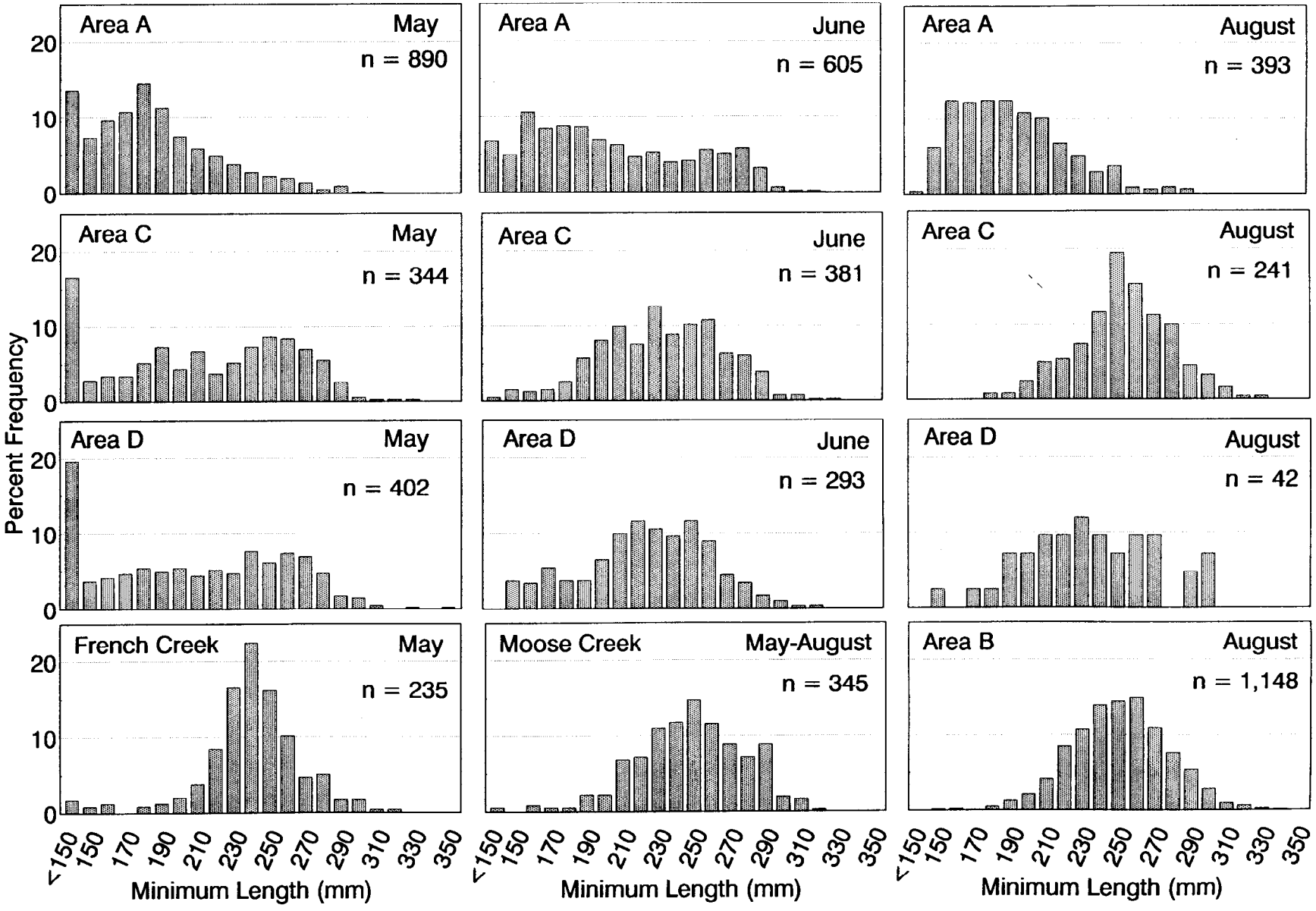

Figure 3. Length distributions of Arctic grayling captured in four sections of Piledriver Slough, in French Creek, and in Moose Creek, during 1990.

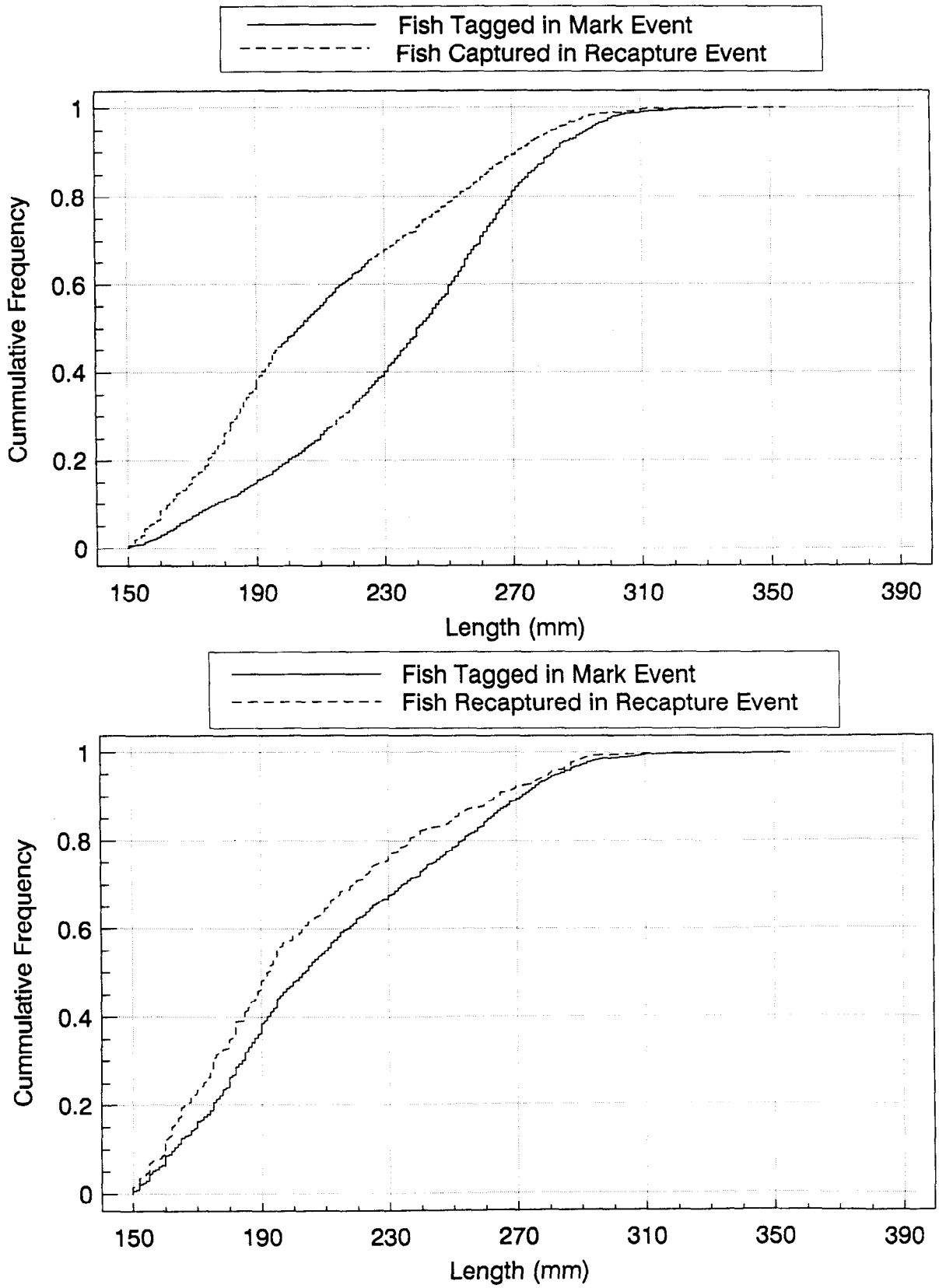

Figure 4. Cumulative length frequencies of Arctic grayling tagged during the mark event, captured during the recapture event, and recaptured during the recapture event in Piledriver Slough in 1990.

Table 5. Determination of size groups for stratification of the abundance estimate of Arctic grayling in Piledriver Slough, 1990.

Size Group (mm)	Number Tagged	Number Not Tagged	Total	Proportion With Tags
150-174	85	208	293	0.29
175-199	94	217	311	0.30
200-224	49	366	415	0.12
225-249	36	573	609	0.06
250-274	26	704	730	0.04
275-299	21	331	352	0.06
≥ 300	2	81	83	0.02

Table 6. Stratified and unstratified estimates of abundance of Arctic grayling in Piledriver Slough, and variances of estimates, 1990.

	Abundance	Variance
Stratified		
Small	5,668	528,843
Large	12,115	2,723,437
Total Stratified	17,783	3,252,280
Unstratified	18,516	3,365,781

Table 7. Mean length by age of Arctic grayling captured during the mark event in two areas of Piledriver Slough in 1990.

	Area A			Area BCD			
Age	n	Mean	SE	n	Mean	SE	*P-value*[a]
4	336	187	1.1	139	212	2.0	<0.01
5	117	209	1.9	93	247	2.3	<0.01
6	62	236	3.1	102	265	1.7	<0.01
7	37	262	3.8	50	278	2.8	<0.01

[a] Two-sample t-test.

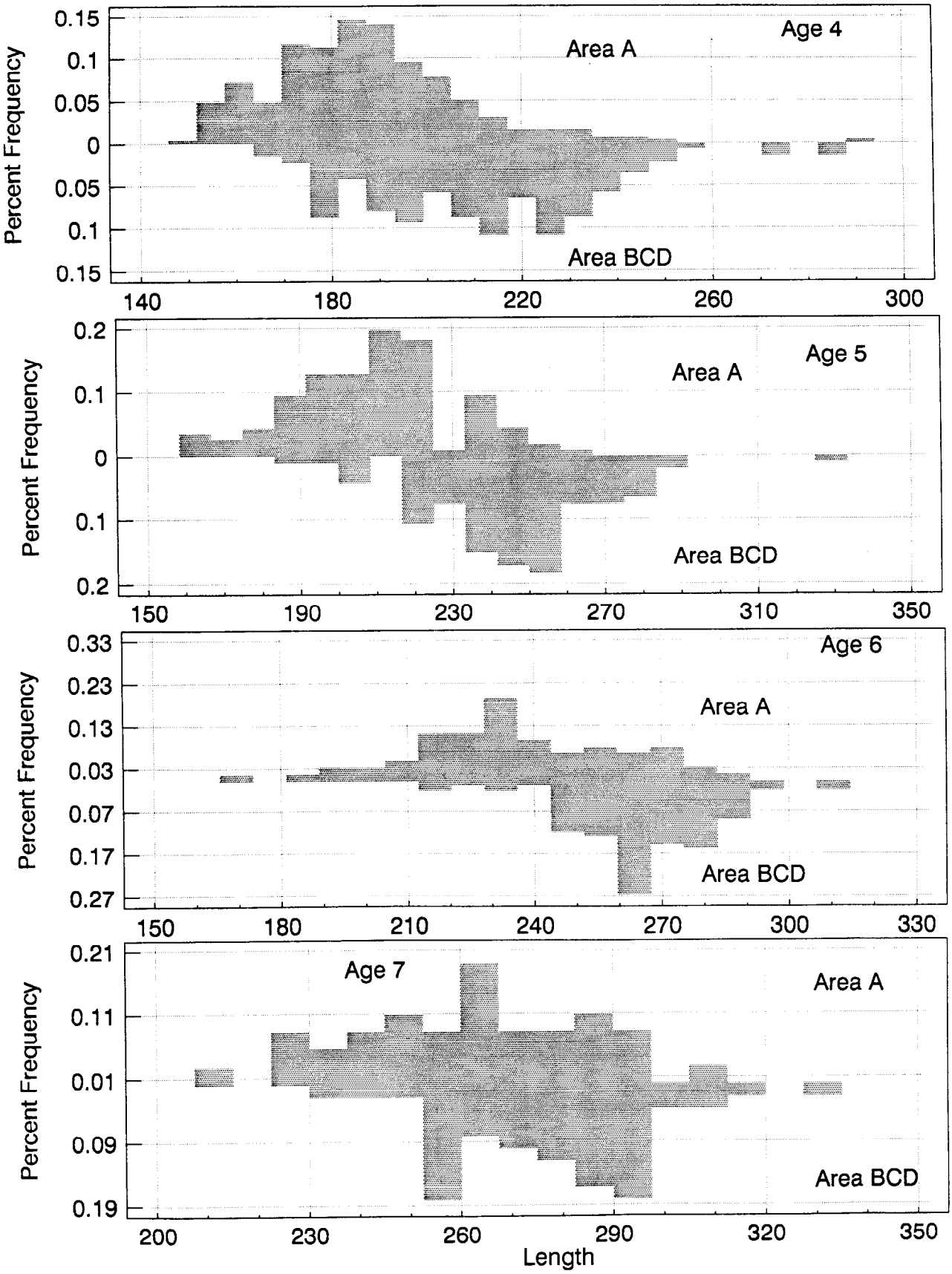

Figure 5. Length distributions, by age, of Arctic grayling captured in Area A and in Area BCD in Piledriver Slough in 1990.

Table 8. Estimated age composition of Arctic grayling in Piledriver Slough, French Creek, and Moose Creek, 1990.

	Piledriver Slough[a]			French Creek			Moose Creek		
Age	Percent	SE	n	Percent	SE	n	Percent	SE	n
1	0.00	0.00	0	1.02	0.72	2	0.00	0.00	0
2	1.07	4.60	11	1.53	0.88	3	0.54	0.54	1
3	17.17	3.32	214	1.53	0.88	3	8.15	2.02	15
4	35.99	2.38	475	11.22	2.26	22	22.28	3.08	41
5	18.28	1.83	210	52.55	3.58	103	30.43	3.40	56
6	16.95	3.38	164	22.45	2.99	44	24.46	3.18	45
7	8.98	1.40	87	8.67	2.02	17	11.41	2.35	21
8	1.15	0.19	13	0.51	0.51	1	2.72	1.20	5
9	0.40	0.16	4	0.51	0.51	1	0.00	0.00	0
Total	99.99		1,178	99.99		196	99.99		184

[a] Estimated proportions for Piledriver Slough were adjusted for area and size biases, and were estimated by bootstrapping.

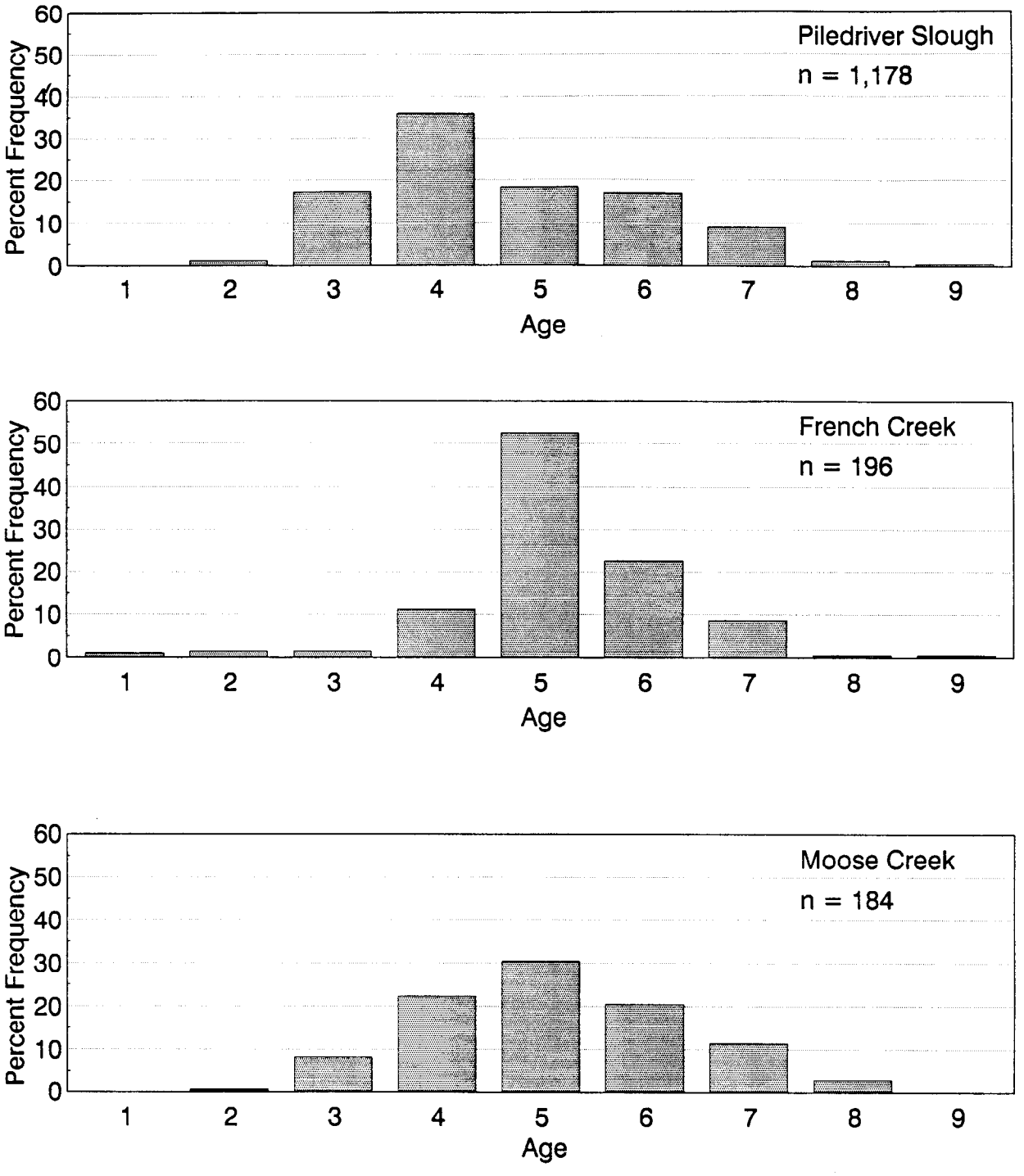

Figure 6. Age distributions of Arctic grayling captured in Piledriver Slough, French Creek, and Moose Creek in 1990. Estimates for Piledriver Slough were adjusted for area and size biases and were estimated by bootstrapping.

Table 9. Estimated percentages of Arctic grayling in Relative Stock Density (RSD) categories for Piledriver Slough, French Creek, and Moose Creek, 1990.

	Piledriver Slough[a]			French Creek			Moose Creek		
RSD[b]	Percent	SE	n	Percent	SE	n	Percent	SE	n
Stock	85.62	3.34	1,217	85.71	2.31	198	70.55	2.46	242
Quality	14.28	3.34	150	14.29	2.31	33	29.45	2.46	101
Preferred	0.09	0.06	1	0.00	0.00	0	0.00	0.00	0
Memorable	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
Trophy	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
Total	99.99		1,368	100.00		231	100.00		343

[a] Estimated proportions for Piledriver Slough were adjusted for area and size biases, and were estimated by bootstrapping.

[b] Stock = 150 - 269 mm; Quality = 270 - 339 mm; Preferred = 340 - 449 mm; Memorable = 450 - 559 mm; Trophy > 559 mm.

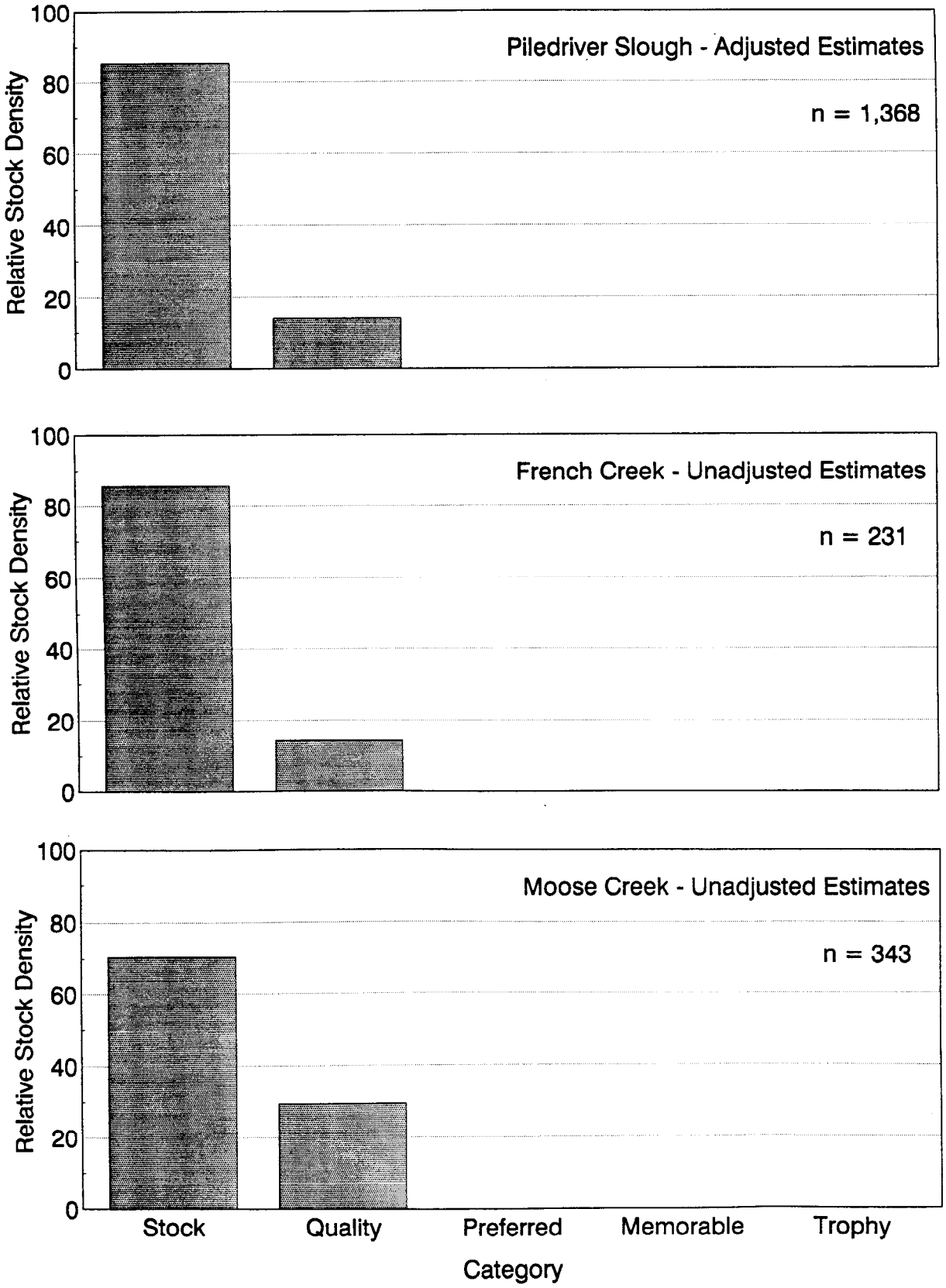

Figure 7. Relative Stock Densities of Arctic grayling captured in Piledriver Slough, French Creek, and Moose Creek in 1990. Estimates for Piledriver Slough were adjusted for area and size biases and were estimated by bootstrapping.

Table 10. Arctic grayling captured in Garrison Slough, 1990.

Tag Number	Date Sampled	Length (mm)	Age
82561	5-11	263	[b]
83849	5-11	212	[b]
83848	5-11	216	[b]
83869	5-14	262	6
81823	5-25	245	4
[a]	5-3	132	2
[a]	5-11	237	5
[a]	5-11	206	5
[a]	5-22	230	4
Total Sampled: 9		Mean Length: 223	

[a] Not tagged.
[b] Age not available.

Table 11. Proportions (p) of Arctic grayling, by age category, that were mature in Piledriver Slough, Moose Creek, and French Creek in 1990.

	Piledriver Slough			French Creek			Moose Creek		
Age	p	SE	n	p	SE	n	p	SE	n
1	0.00	0.00	0	-	-	0	-	-	0
2	0.00	0.00	7	0.00	-	1	0.00	-	1
3	0.00	0.00	144	-	-	0	0.14	0.14	7
4	0.09	0.03	321	0.86	0.14	7	0.50	0.19	8
5	0.37	0.03	130	0.87	0.04	67	0.64	0.15	11
6	0.70	0.04	85	0.88	0.06	26	0.88	0.13	8
7	0.88	0.07	37	0.91	0.09	11	1.00	0.00	5
8	1.00	0.00	5	1.00	-	1	1.00	-	1
9	0.71	0.45	1	1.00	-	1	-	-	0
Total			730			114			41

Table 12. Proportions (p) of Arctic grayling, by length category, that were mature in Piledriver Slough, Moose Creek, and French Creek in 1990.

Length Category	Piledriver Slough			French Creek			Moose Creek		
	p	SE	n	p	SE	n	p	SE	n
150-159	0.00	0.00	59	-	-	0	-	-	0
160-169	0.00	0.00	81	-	-	0	-	-	0
170-179	0.00	0.00	80	-	-	0	0.00	-	1
180-189	0.00	0.00	107	-	-	0	0.00	0.00	2
190-199	0.01	0.01	91	-	-	0	0.00	0.00	2
200-209	0.06	0.03	62	0.00	-	1	0.00	-	1
210-219	0.15	0.05	57	1.00	0.00	2	0.00	0.00	2
220-229	0.20	0.04	49	0.80	0.13	10	0.40	0.24	5
230-239	0.51	0.08	41	0.87	0.07	23	0.60	0.24	5
240-249	0.66	0.06	44	0.86	0.06	35	0.71	0.18	7
250-259	0.77	0.05	39	0.95	0.05	22	0.63	0.18	8
260-269	0.88	0.05	32	0.94	0.06	18	0.80	0.20	5
270-279	0.73	0.07	34	1.00	0.00	8	1.00	0.00	4
280-289	0.57	0.05	24	0.75	0.25	4	1.00	0.00	2
290-299	0.84	0.10	10	1.00	0.00	3	1.00	-	1
300-309	1.00	0.00	3	1.00	0.00	2	-	-	0
310-319	0.95	0.22	2	-	-	0	1.00	-	1
320-329	-	-	0	1.00	-	1	-	-	0
330-339	1.00	0.00	2	-	-	0	-	-	0
340-349	-	-	0	-	-	0	-	-	0
350-359	0.77	0.42	1	-	-	0	-	-	0
360-369	-	-	0	-	-	0	-	-	0
Total			818			129			46

Table 13. Arctic grayling recaptured outside creek in which marked, 1990.

Tag Number	Marked			Recaptured		
	Creek	Site	Date	Creek	Site	Date
82513	Piledriver Slough	16	5-3	French Creek	1	5-11
82690	Piledriver Slough	16	5-4	French Creek	1	5-14
82561	Piledriver Slough	16	5-3	Garrison Slough	2	5-11
82578	Piledriver Slough	16	5-3	Moose Creek	20	5-14
82613	Piledriver Slough	16	5-4	Moose Creek	4	7-12
82681	Piledriver Slough	16	5-4	Moose Creek	4	7-12
81674	Piledriver Slough	4	5-4	Moose Creek	4	7-12
82546	Piledriver Slough	16	5-3	Lower Chena River		7-18
80801	Moose Creek	5	7-12	Piledriver Slough	10	7-31
81812	Moose Creek	2	5-25	Piledriver Slough	6	8-16
81322	Moose Creek	20	5-14	French Creek	13	5-16
82173	French Creek	14	5-22	Piledriver Slough	12	6-26
83858	French Creek	14	5-11	Piledriver Slough	14	6-29
83878	French Creek	1	5-14	Piledriver Slough	10	7-31
83880	French Creek	1	5-14	Piledriver Slough	6	8-15
81353	French Creek	11	5-14	Moose Creek	4	7-12
81394	French Creek	13	5-16	Moose Creek	4	7-12
81402	French Creek	14	5-16	Moose Creek	3	5-25
83814	French Creek	14	5-11	Moose Creek	4	7-12
83886	French Creek	1	5-14	Moose Creek		9-10
83889	French Creek	1	5-14	Moose Creek	1	5-22
83807	French Creek	14	5-11	Moose Creek	3	5-25

which was tagged at Piledriver Slough site 16 on May 3, 1990, was recaptured in the lower Chena River on July 17, 1990.

DISCUSSION

Differing capture probabilities between area A and area BCD, and size selectivity during the sampling activities, presented the major obstacles in estimating abundance of Arctic grayling in Piledriver Slough. Different capture probabilities, as well as size selectivity, were probably due to a combination of two primary factors: behavior of Arctic grayling and gear effectiveness. Density of fish was much higher in the upper sections of Piledriver Slough than in the lower sections. Arctic grayling were segregated by size in Piledriver Slough, with larger fish in the lower sections while smaller fish were more numerous in the upper sections. Backpack electrofishing was extremely efficient in area A, where, because of the small stream size, a very high proportion of the fish that were present could be captured. As stream size increased in the lower portion of the river (area BCD), capture of fish became more difficult. Although an assortment of sampling gear was used in the lower sections of Piledriver Slough, none were as effective as backpack shocking in Area A.

Density of Arctic grayling in Piledriver Slough (514 fish per kilometer) was high compared to other rivers in interior Alaska. However, most of those fish were small. For example, almost 50% of the Arctic grayling sampled in the Chatanika River in 1989 fell into the quality category of RSD (Clark and Ridder 1990) and 38% of the Chena River Arctic grayling were quality sized, while only 14% of the Piledriver Slough Arctic grayling were quality size in 1990.

Compared to other rivers in interior Alaska, mean length at age of Arctic grayling in Piledriver Slough was generally smaller. For example, mean lengths of age 4 and 5 Arctic grayling in the Goodpaster River were 253 and 277 mm, respectively (Clark and Ridder 1990) compared to 212 and 247 mm for age 4 and 5 Arctic grayling respectively in Piledriver Slough.

Prior to the rainbow trout stocking program, harvest of Arctic grayling and recreational fishing effort at Piledriver Slough were relatively negligible. Days fished at Piledriver Slough increased twelve-fold with the initiation of the stocking program, from 2,079 in 1986 to 24,375 in 1988. Despite its short length (only about 32 km long), in 1988, the second year of the stocking program, Piledriver Slough absorbed almost 14% of the recreational fishing effort expended in the Tanana River drainage, making it the most popular stocked water in interior Alaska in terms of days fished. The increased popularity of Piledriver Slough over the last four years is probably due almost entirely to the rainbow trout stocking program. Concurrent with the increasing effort at Piledriver Slough has been increased harvest of Arctic grayling. At this time, data are insufficient to determine additional effects of the experimental stockings of rainbow trout on Arctic grayling in Piledriver Slough. Monitoring of the stock status of Arctic grayling in Piledriver Slough, such as abundance, and age and length compositions, will continue. As recommended in the evaluation of the experimental stocking

program (Timmons *in press*), a long-term, controlled experiment to study the effects of stocking rainbow trout on Arctic grayling should be designed.

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APPENDIX A

Appendix A. Physical characteristics of Moose Creek and French Creek measured during Alyeska Pipeline surveys, 1979-1980[a].

Date	Site	DO mg/ℓ	Temp °C	Conductivity μmhos/cm	pH	Discharge m^3/s	Substrate
Moose Creek							
3/26/79	3	3.6	0.8	220	7.5	0.10	mud
6/27/79	2	7.8	10.0	145	7.7	-	mud
6/27/79	3	8.4	13.0	155	7.5	-	mud
6/28/79	1	7.2	10.0	120	7.5	-	mud
9/20/80	0	14.0	2.5	45	7.5	0.45	mud
9/24/79	1	9.2	4.5	85	7.2	-	mud
9/24/79	2	8.6	4.5	75	7.4	-	mud
9/24/79	3	8.2	4.5	125	7.5	-	mud
12/3/79	1	0.8	0.5	110	6.8	-	mud
12/3/79	3	1.0	0.0	135	6.9	0.82	mud
French Creek							
3/25/79	1	3.0	0.5	270	7.7	0	mud
3/27/79	5	3.4	0.0	435	7.5	0.02	mud
9/24/79	5	7.8	3.5	105	7.5	1.0	sand/mud
12/3/79	3	0.2	0.0	-	7.5	<0.01	mud
12/3/79	5	0.2-0.4	0.0	30	6.9	0.32	gravel/mud
12/5/79	1	0.2	0.2	-	6.8	0.27	sand/gravel

[a] Unpublished data, Division of Habitat, Alaska Department of Fish and Game 1300 College Road, Fairbanks, AK 99701.

APPENDIX B

Appendix B. Water temperatures (°C) of Piledriver Slough, Moose Creek, French Creek, and Garrison Slough during 1990.

Piledriver Sites 1-5			Piledriver Sites >5			Moose/French/Garrison		
Date	Site	Temp	Date	Site	Temp	Date	Site	Temp
4/11	5	2	4/11	16	0	5/16	Moose	6
4/24	1	4	4/24	6	4	6/08	Moose	10
4/24	5	4	4/26	16	4	5/17	Garrison	10
4/24	2	4	5/29	16	17	6/08	Garrison	10
4/27	3	5	6/26	11	11	5/16	French	10
4/30	5	4	6/27	11	16	5/17	French	8
5/02	5	4	6/27	16	18	6/22	French	11
6/20	5	11	9/20	16	4	6/25	French	7
6/21	5	10				6/27	French	10

APPENDIX C

Appendix C. Detection of size-selectivity in sampling and its effects on estimation of size composition.

Results of Hypothesis Tests (K-S and χ^2) on Lengths of Fish Marked during the First Event and Recaptured during the Second Event	Results of Hypothesis Tests (K-S) on Lengths of Fish Captured during the First Event and Captured during the 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-

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 D

Appendix D1. Age composition of Arctic grayling sampled during creel surveys at Piledriver Slough, 1986, 1987[a], 1989, and 1990[a].

	1986[b]		1987[c]		1989[d]		1990[e]	
Age	Sample Number	Percent	Sample Number	Percent	Sample Number	Percent	Sample Number	Percent
1	0	0	1	1	0	0	0	0
2	1	1	8	10	3	10	0	0
3	7	6	22	28	5	17	1	2
4	69	60	38	48	6	21	23	38
5	35	30	9	11	11	38	19	32
6	3	3	2	3	2	7	17	24
7	0	0	0	0	2	7	4	5
Total	115	100	80	101	29	100	64	101

[a] Only six Arctic grayling were sampled in the creel survey in 1988. Because of the small sample size, those fish were not aged.
[b] From Clark and Ridder (1987).
[c] From Baker (1988).
[d] From Merritt et al. 1990.
[e] From Hallberg and Bingham *in press*.

Appendix D2. Percent of Arctic grayling sampled during creel surveys in Relative Stock Density (RSD) categories, 1986 - 1990.

Category	Minimum Length (mm)	1986[a] RSD	1987[b] RSD	1988[c] RSD	1989[d] RSD	1990[e] RSD
Stock	150	85	70	50	46	38
Quality	270	15	30	50	54	62
Preferred	340	0	0	0	0	0
Memorable	450	0	0	0	0	0
Trophy	560	0	0	0	0	0

[a] n = 118 (Clark and Ridder 1987).
[b] n = 84 (Baker 1988).
[c] n = 6 (Baker 1989).
[d] n = 28 (Merritt et al. 1990).
[e] n = 76 (Hallberg and Bingham *in press*).