Fishery Data Series No. 91-71

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by

Douglas F. Fleming

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ABSTRACT

A detailed assessment of the Arctic grayling *Thymallus arcticus* population was conducted at Piledriver Slough, near Fairbanks, Alaska during 1991. Several mark-recapture experiments were conducted to estimate abundance of Arctic grayling present in Piledriver Slough at the onset of the spring fishery and to estimate mixing rates of fish from other nearby streams that seasonally co-habit this spring-fed system. Fish were captured following spring break-up by pulsed direct current electrofishing and instream trap netting. An estimated 17,323 (standard error = 869) Arctic grayling greater than 149 millimeters of fork length were present during the May spawning period. The high density of Arctic grayling found within the 32 kilometer study area was noteworthy when compared to other interior Alaska populations. The stock was characterized by a high proportion of sub-legal sized Arctic grayling (less than 270 millimeters of fork length) and ages 4 and 5 fish predominated. Fish sampled in August exhibited strong in-season fidelity to Piledriver Slough and a substantial upstream shift in their distribution. Between 10 and 50 percent of Arctic grayling present in Moose Creek during summer were fish that had been in Piledriver Slough during spring. Arctic grayling in Piledriver Slough exhibited slower growth than other locally sampled populations of Arctic grayling. Arctic grayling may have become established in Piledriver Slough as recently as 15 years ago, and this short time frame may have influenced the population parameters observed in this study, relative to the dynamics of Arctic grayling populations resident in long-established streams.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Piledriver Slough, French Creek, Moose Creek, abundance estimation, mixing rates, age composition, size composition, maturity, Relative Stock Density, spawning stock, growth.

INTRODUCTION

The increased use of Piledriver Slough by anglers in recent years has led to the continued stock assessment and monitoring of Arctic grayling *Thymallus arcticus* and rainbow trout *Oncorhynchus mykiss*. The close proximity to Fairbanks, accessibility, and abundance of both Arctic grayling and stocked rainbow trout have led to a flourishing sport fishery. The Piledriver Slough fishery has experienced a six-fold increase in effort by area anglers since 1983 (Mills 1984, 1991), and currently it is estimated to receive roughly 15% of the Tanana drainage effort (days fished) and 20% of the drainage's total catches of Arctic grayling (Mills 1991). Following Piledriver Slough's establishment as a clearwater stream in 1976, it has been colonized by many of the indigenous species of freshwater fishes found in interior Alaska (Timmons and Clark 1991). In the 15 years following the original blocking of direct flow from the Tanana River, Arctic grayling have become well established in the slough, which is now more accurately described as a spring-fed stream. It is likely that Piledriver Slough was colonized by Arctic grayling straying from area streams and rivers. Life history accounts within the Tanana drainage have indicated that Arctic grayling do not utilize spring-fed systems for spawning (Clark and Ridder 1988; Ridder 1989). Contrary to these findings, concentrations of Arctic grayling continue to use Piledriver Slough for spawning, rearing, and feeding

In 1990, intensive stock assessments began at Piledriver Slough to determine the impact of the increasing sport fishery on the population of Arctic grayling. In 1991, the objectives of the Arctic grayling stock assessment program in Piledriver Slough included the estimation of:

1) abundance of Arctic grayling greater than 149 mm fork length (FL) in Piledriver Slough;

2) abundance of Arctic grayling greater than 149 mm FL in French Creek;

3) age composition of the Arctic grayling populations in Piledriver Slough and French Creek;

4) size composition of the Arctic grayling populations in Piledriver Slough and French Creek;

5) the mixing rate of Arctic grayling greater than 149 mm FL initially marked in Piledriver Slough in spring that stayed in Piledriver Slough or migrated to Moose Creek in summer; and,

6) the mixing rate of Arctic grayling greater than 149 mm FL initially marked in French Creek in spring that migrated to Piledriver Slough or Moose Creek in summer.

The estimation of abundance, age and size composition, and mixing rates were needed to facilitate management decisions that affect the recreational fishery for Arctic grayling and rainbow trout. The purpose of estimating mixing rates was to determine the component of the population seen in Piledriver Slough during May which are present there and elsewhere during the summer feeding period. This becomes important if fish emigrate to areas where differences in regulations may lead to over exploitation. Information on age and size at maturity and growth parameters for this stock of Arctic grayling were important for a drainage-wide perspective. The assessment program in Piledriver Slough offers a unique opportunity to document the stock dynamics of a recently formed (or forming) population of Arctic grayling.

METHODS

Field Sampling

A mark-recapture experiment began on 6 May 1991 in Piledriver Slough, following breakup, and was completed on 23 August (Appendix A1). Within this period, a two-week mark-recapture experiment ran from 6 through 16 May on the main stem of Piledriver Slough, and on French Creek from 14 through 30 May. Moose Creek was periodically sampled from May through August to estimate the rate of mixing of fish tagged in either Piledriver Slough or French Creek with those in Moose Creek. Piledriver Slough was sampled in August to estimate the marked proportion of the overall population.

Piledriver Slough:

The mark-recapture experiment in Piledriver Slough in 1991 was of shorter duration than that conducted in 1990. Sampling primarily occurred using two large crews which collected and marked fish in all areas of Piledriver Slough. Crews of five to seven people allowed an efficient and timely coverage of the entire area twice (mark and recapture events), minimizing the period during which immigration or emigration might occur. The marking event lasted eight days; the recapture event lasted four days. Piledriver Slough was divided into six areas delineated by landmarks, access points, or one crew-day's coverage (Figure 1). The areas of Piledriver Slough were as follows:

Area 1) Stringer Loop Road area: included the section between the large beaver dam downstream to the culverts . This was the headwaters of the slough; it was narrow, with alternating pools and riffles (one crew day).

Area 2) Culverts to Bailey Bridge: this section of Piledriver Slough was a remote section, accessed from the ends. The stream was generally small with alternating pools, riffles, and minor braiding. The lower portion of this section also included long runs and larger pools (two crew days).

Area 3) Bailey Bridge to 23-Mile Slough: this section was easily accessed by a road and a path, respectively. In this section, a habitat transition occurred; the variability seen in the upstream areas was reduced. This section was generally wide and slow moving, with an increased volume. (one crew day)

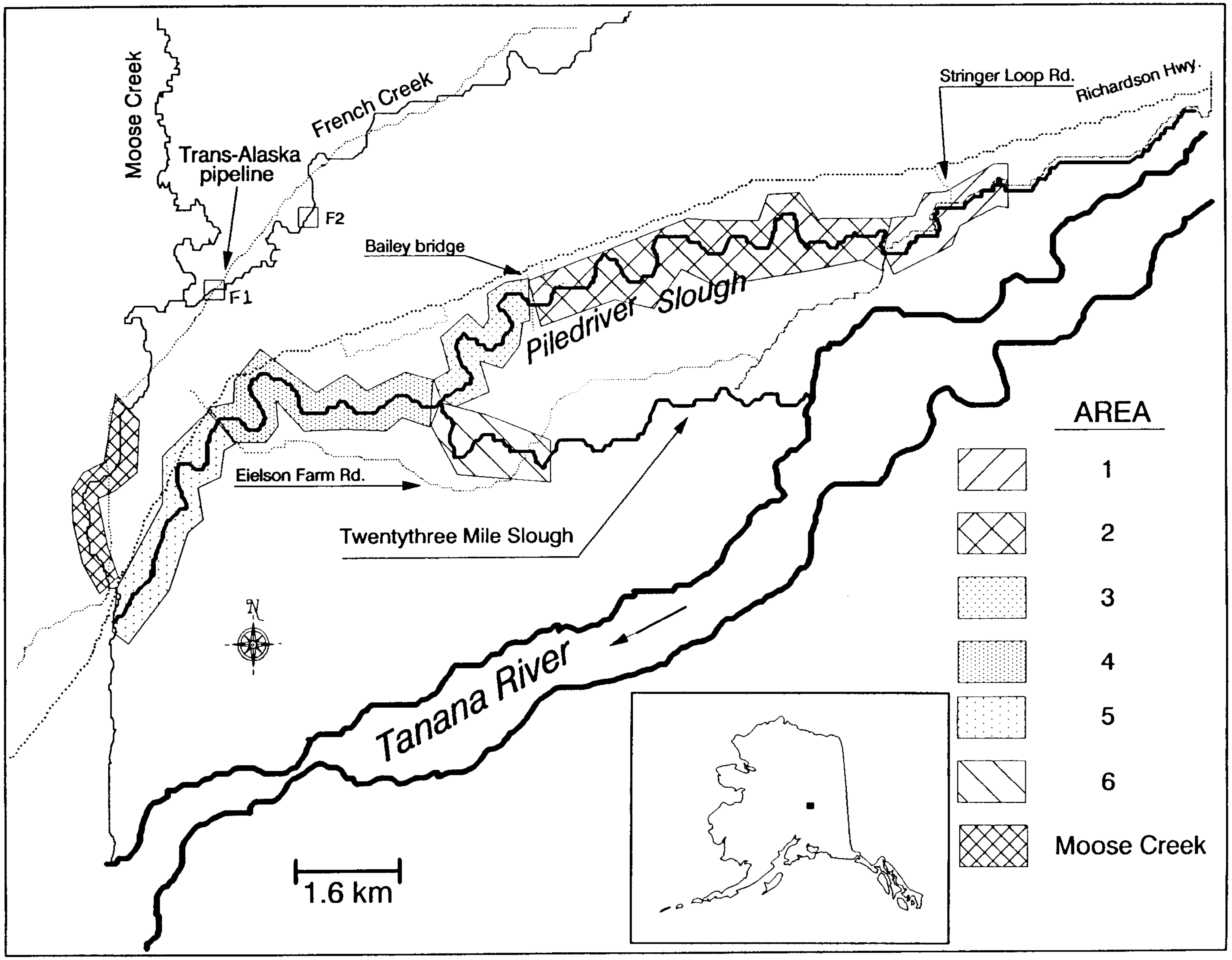

Figure 1. Map of study area encompassing Piledriver Slough, Moose Creek and French Creek.

Area 4) 23 Mile Slough to Eielson Farm Road: this section was easily accessed by a path and a road, respectively. This section was primarily broad and slow, with some deep pools (one and a half crew day).

Area 5) Eielson Farm Road to confluence with the Tanana River: this portion of the slough was accessed and sampled using a pulse-DC electrofishing boat. The area was evenly divided between broad and slow and narrow channelized habitats (one boat crew day).

Area 6) 23-Mile Slough: this tributary stream was accessed 2 km upstream of the Eielson Farm Rd. by a path, and exited by a path near the confluence with Piledriver Slough. The habitat in the tributary was similar to Area (1), but smaller in scale (one crew day).

The gear type primarily used to capture Arctic grayling was backpack electrofishing, but a pulse-DC electrofishing boat was also used in area (5) and Moose Creek (Figure 1). Efficient electrofishing capture techniques utilized in 1990 sampling were again used with success; two backpack shockers were fished in tandem within each large crew (Timmons and Clark 1991). In the smaller headwater areas (areas (1), (2), (6): Figure 1), one electrofishing team (one electrofisher and one dipnetter) blocked pool tail-outs as the other team worked downstream towards them. In the wider areas (Areas (3), (4): Figure 1), both teams worked either side-by-side, or in a staggered formation, fishing downstream. Variable voltage pulsator (VVP) settings were 60 Hz pulse DC ranging from 200 to 250 volts and amperage from 1.5 to 2.0 A. All initially captured fish greater than 149 mm FL were measured to the nearest 1 mm FL, fin clipped (partial left ventral clip), and tagged with an individually numbered blue Floy FD-67 internal anchor tag at the base of the dorsal fin. Sexual maturity was determined for each Arctic grayling by the release of eggs or milt. Several scales were collected from the preferred zone[1] of each Arctic grayling's left flank, and were later cleaned and mounted for ageing. Fork length, fin clip, tag number, and sex were recorded on Tagging-Length forms (Version 1.0). Fish with tag losses were given new tags, and previous fin-clips were noted. Scales from previously marked Arctic grayling were collected on the right side of the fish to avoid collection of regenerated scales. Data collection procedures from previously marked Arctic grayling were similar, but previous fin clips, tag losses, tag numbers, and colors were recorded.

August sampling proceeded in a similar manner, but only a single downstream pass by two crews was needed for the survey. Fork lengths, tag numbers, tag color, and fin clips were recorded, but no additional fish were marked.

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[1] The preferred zone for scale removal on Arctic grayling is located approximately six scale rows above the lateral line, just posterior to the dorsal fin's insertion.

French Creek:

A mark-recapture experiment to estimate the abundance of Arctic grayling in French Creek was planned using fyke nets and hoop traps. These traps were deployed along French Creek, at various stream crossings of the Trans-Alaskan Pipeline (Figures 1 and 2). Each trap was checked daily by a crew of two people. All captured fish were marked and sampled as previously stated. Several traps were later reversed, in an attempt to capture post-spawning Arctic grayling moving downstream to feeding areas.

Moose Creek:

Moose Creek was periodically sampled to gather information on Arctic grayling tagged in either Piledriver Slough or French Creek, that were either residing in or migrating through Moose Creek. A pulse DC electrofishing boat was used to sample the lower 3 km in May, July, and August (Figure 1, Appendix A1). Pulsed DC settings of the VVP at 60 Hz ranged from 200 to 225 volts and 2 to 5 amps.

Abundance Estimation

The use of a closed model to accurately estimate the abundance of Arctic grayling in Piledriver Slough in 1991 required differences to the approach used in 1990. The use of a closed model abundance estimator using mark-recapture experiments assumes the following (Seber 1982):

1) the population in the study area must be closed;

2) all Arctic grayling have the same probability of capture during the first sample or in the second sample or marked and unmarked Arctic grayling mix randomly between the first and second samples;

3) marking of Arctic grayling does not affect their probability of capture in the second sample, and:

4) Arctic grayling do not lose their mark between sampling events.

This year's sampling design attempted to lessen risks associated with closure (assumption 1) by shortening the duration of the mark-recapture experiment considerably. It was highly improbable that substantial mortality occurred during the seven day hiatus. Inclusion of all areas of Piledriver Slough in both events was desired to reduce any effects of recruitment during the experiment. Assumptions 2 and 3 were examined for size and geographic differences in capture probability. Size selectivity was tested with two Kolmogorov-Smirnov two-sample tests. The first test compared cumulative length frequency distributions of marked Arctic grayling from the first (mark event) and second (recapture event) samples. The second test examined the cumulative length frequency distributions of marked Arctic grayling with those recaptured. The results of these tests suggested methods to alleviate size biases (Appendix B1). Geographic or spatial differences in capture probability and mixing were evaluated through comparisons of area specific recapture-to-catch ratios, and examinations for the mixing of tagged fish.

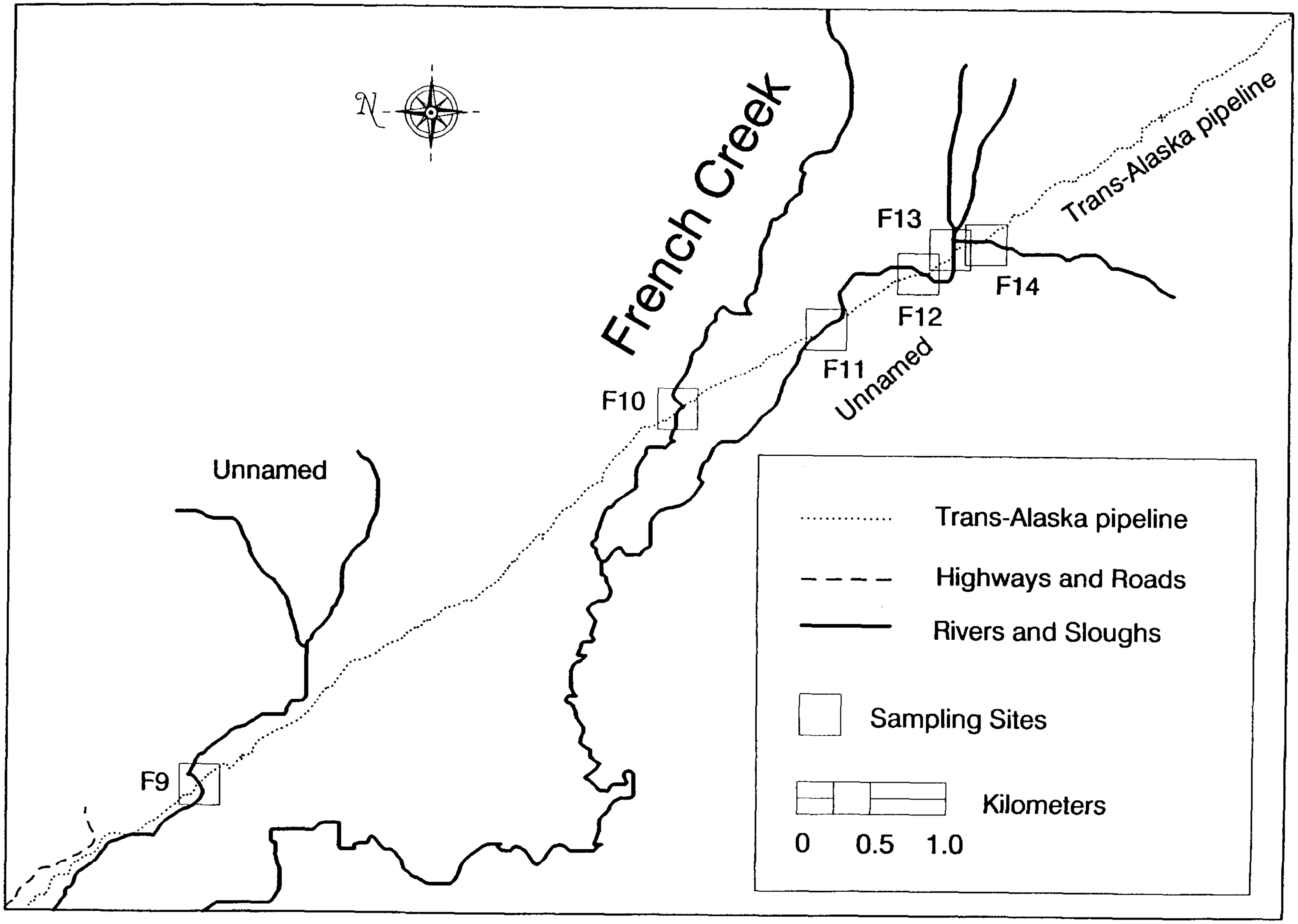

Figure 2. Map of upper French Creek showing locations of fyke nets and hoop traps, 14 through 30 May, 1991.

The results of these tests determined whether the abundance estimation model incorporated stratification by area. The last testable assumption was met by double marking each fish, with a tag and a fin-clip specific to the 1991 mark-recapture experiment.

Examination of the assumptions demonstrated that size selectivity was not detected, but differential capture probabilities by areas sampled, and incomplete mixing were evident. Incomplete mixing precluded use of the Petersen model (Bailey 1951, 1952) to estimate abundance, and methods by Darroch were selected for use (Darroch 1961). The Darroch estimator is a multidimensionally-expanded version of a Petersen model which: simultaneously estimates abundance by the selected strata (areas); accounts for movements between strata; and estimates stratified probabilities of movement and capture. Areas were stratified on the basis of differential capture probabilities; adjacent stream areas that shared statistically similar capture probabilities were grouped. The partially stratified (by area) estimate of abundance was then calculated from the model (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).

Variance of this estimator was approximated from bootstrapping the estimator 1,000 times, using the capture histories of all fish in the mark and recapture event samples (Efron 1982). The use of bootstrapping techniques is thought to more aptly estimate variation within the particular mark-recapture experiment, and help to describe underlying bias, whereas sole variance approximations (Seber 1982) do not. 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" × "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.

Point estimates of abundance were calculated using the sampled mark-recapture matrix and methods of Darroch (1961). Additionally, stratified and unstratified point estimates of abundance were calculated with the Bailey modification to the Petersen model (Bailey 1951, 1952):

$$\hat{N} = \frac{M\,(C + 1)}{(R + 1)} \qquad (2)$$

where:
- M = the number of Arctic grayling marked and released during the marking event sample;
- C = the number of Arctic grayling examined for marks during the recapture event;
- R = the number of Arctic grayling recaptured during the second sampling event (recapture); and,
- $\hat{N}$ = estimated abundance of Arctic grayling.

Variance of the abundance estimate was estimated by (Bailey 1951, 1952):

$$V[\hat{N}] = \frac{\hat{N}\,M\,(C - R)}{[(R + 1)(R + 2)]}. \qquad (3)$$

Age and Size Composition

Apportionment of the estimated abundance among age or size groupings depends upon the extent of sampling biases. The outcome of tests for length selectivity and chi-square tests, examining geographic differences in capture probabilities, determined the necessary adjustments. Because size selectivity was not detected, no adjustments were necessary to adjust the sampled age and size compositions by size-specific capture probabilities. The appropriate sample or samples (from the first event, second, or both events) was used to estimate the age and size compositions. When size selectivity could not be ascertained in some samples, such as from Moose and French Creeks, the proportion of fish at age *k* was estimated by:

$$\hat{p}_k = \frac{y_k}{n} \qquad (4)$$

where:
- $\hat{p}_k$ = the proportion of Arctic grayling that are age *k*;
- y_k = the number of Arctic grayling sampled that are age *k*; and,
- n = the total number of Arctic grayling sampled.

The unbiased variance of this proportion was estimated as:

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

Size composition was estimated in a similar manner, replacing age class with the RSD categories of Gabelhouse (1984) and incremental size categories. The RSD categories for Arctic grayling are: "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). Incremental size composition categories were 10 mm FL groupings with mid-points 155 to 395 mm FL.

The examination of, and finding of differential capture probability was first addressed by the "Darroch" estimation procedure. The estimators gave area-stratified abundances; the abundance was then apportioned by area-stratified estimates of age and size composition. To accurately assess the stock composition[2] in Piledriver Slough at the overall population level, additional steps were needed. First the conditional fractions based on the area-stratified samples were calculated:

$$\hat{p}_{ij} = n_{ij}/n_i \qquad (6)$$

where:

n_i = the number sampled from area i in the mark-recapture experiment;
n_{ij} = the number sampled from area i that belong to class j; and,
p_{ij} = the estimated fraction of the fish in class j in area i.

Note that $\sum_j p_{ij} = 1$. The variance for p_{ij} was estimated as:

$$V[\hat{p}_{ij}] = \frac{\hat{p}_{ij}(1 - \hat{p}_{ij})}{n_i - 1} \qquad (7)$$

The estimated abundance of class j in the population ($\hat{N}_j$) was calculated as:

$$\hat{N}_j = \sum_i \hat{p}_{ij} \hat{N}_i \qquad (8)$$

where: $\hat{N}_i$ = the estimated abundance in area i of the mark-recapture experiment.

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

$$V[\hat{N}_j] = \sum_i (V[\hat{p}_{ij}]\hat{N}_i^2 + V[\hat{N}_i]\hat{p}_{ij}^2 - V[\hat{p}_{ij}]V[\hat{N}_i]) \qquad (9)$$

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[2] Composition here refers to age, RSD, and incremental size composition.

The estimated fraction of the population that belongs to class j (p_j) was:

$$\hat{p}_j = \hat{N}_j/\hat{N} \qquad (10)$$

where: $\hat{N} = \Sigma \hat{N}_i$.

The variance of the estimated fraction was approximated with the delta method (see Seber 1982; ignoring the hat symbols, all quantities were estimated):

$$V[p_j] \approx \sum_i V[p_{ij}] \left\{ \frac{N_i}{N} \right\}^2 + \frac{\sum_i \{V[N_i]\ (p_{ij} - p_j)^2\}}{N^2} \qquad (11)$$

Each stock assessment category utilized the above approach, where substitutions for class were: age classes; RSD categories, and 10 mm FL incremental size groupings.

Mixing Rates

From abundance estimation experiments conducted in spring, the proportions of fish marked in Piledriver Slough and French Creek were estimated by:

$$\hat{p}_t = \frac{m_t}{\hat{N}_t} \qquad (12)$$

where:

$\hat{p}_t$ = the estimated proportion of Arctic grayling marked in system t;
m_t = the number of unique Arctic grayling marked in system t; and,
$\hat{N}_t$ = the estimated abundance of Arctic grayling in system t.

The variance of $\hat{p}_t$ was approximated by:

$$\hat{V}[\hat{p}_t] \approx \frac{m_t^2\ \hat{V}[\hat{N}_t]}{\hat{N}_t^4} \qquad (13)$$

where:

$\hat{V}[\hat{N}_t]$ = the variance of abundance of Arctic grayling in system t.

Upon recovery, the marked-to-unmarked ratio was the ratio of marks to those examined for marks:

$$\hat{p}_m = \frac{m_c}{n_2} \tag{14}$$

where:

$\hat{p}_m$ = the estimated proportion of Arctic grayling originally marked in system *t* and recovered in system *m*;

m_c = the number of marked Arctic grayling originally from system *t* that are recovered in system *m*; and,

n_2 = the number of Arctic grayling examined for marks in system *m*.

The variance of p_m is the variance of a binomial, or:

$$\hat{V}[\hat{p}_m] = \frac{\hat{p}_m (1 - \hat{p}_m)}{n_2 - 1} \tag{15}$$

Mixing rate of fish from each release system that were recovered at Piledriver Slough or Moose Creek was then estimated with these two ratios:

$$\hat{p}_c = \frac{\hat{p}_m}{\hat{p}_t} \tag{16}$$

Variance of mixing rate was then approximated with the delta method (Seber 1982; ignoring the hat symbols, all quantities were estimated):

$$V[p_c] \approx \left[\frac{p_m}{p_t}\right]^2 \left[\frac{V[p_m]}{p_m^2} + \frac{V[p_t]}{p_t^2}\right] \tag{17}$$

Growth

Information was collected to estimate growth parameters particular to Arctic grayling present in Piledriver Slough. Size and age data collected from the mark and recapture events were pooled, resulting in 2,156 age-length combinations. These were reduced to mean length at age (arithmetic mean) and their standard deviations (based upon standard estimating equations). These data were fitted to the von Bertalanffy growth equation (Ricker 1975), in which three parameters were estimated for the sampled stock:

1) L_∞ is the length an average fish could attain if life and growth continued indefinitely (Ricker 1975);

2) K is the Brody growth coefficient, which is a dimensionless variate that regulates incremental growth; and,

3) t_0 represents the hypothetical age at which a fish would have zero length (Ricker 1975).

The parameter estimates were obtained from use of the Marquardt (1963) compromise within a nonlinear least square procedure. Input values for the parameters ranged from 350 to 700 mm FL by 50 mm increments for L_∞ ; from 0.0 to 0.4 by 0.01 for K and -2.0 to 2.0 by 0.5 for t_0. The model was fit initially 360 times, using all permutations of input variables. Secondarily, the best fitting combination of L_∞, K, and t_0 input parameters, as denoted by the smallest sum of squared deviations, were used as initial values for iterative solution of the equation.

RESULTS

Field Sampling

A total of 2,980 Arctic grayling (≥ 150 mm FL) were captured over a 11-day period in May and used in the mark-recapture experiment at Piledriver Slough. Fair weather conditions persisted, and water temperatures ranged between 3° and 8°C. The maximum daily change observed was 3.5°C. During the marking event, 1,772 fish were marked and released alive over the 32 km of Piledriver Slough, in the six areas. From this sample, 327 fish retained tags from 1990, while 13 others had tag losses. During the recapture event, 1,208 fish were captured in a single downstream pass, which included the recovery of 231 tagged Arctic grayling. This sampling event included an additional 244 fish captured with 1990 tags, 17 fish marked in 1990 with tag losses, and one fish with a current tag loss from the recent marking. An overwinter tag loss rate was estimated to be 5%, stemming from 30 tags shed and 588 Arctic grayling bearing tags and or finclips from the 1990 sampling. The tag shedding rate from the marking to the recapture event was 0.4%, based upon one tag shed in 231 recaptures examined. The overall acute mortality rate from the experiment was 13 out of 2,762 individual Arctic grayling handled, or 0.5%. During the May sampling, the sex was determined for 913 Arctic grayling (412 females and 501 males) from a sample of 2,747 individuals. The smallest incremental size class and age class to achieve 50% or greater sexual maturity was 250 to 259 mm FL, and age 6, respectively (Table 1). The smallest mature individual (female) occurred in the 170 to 179 mm FL size grouping, and was age 2.

Catches in French Creek (Appendix A1) totalled 87 Arctic grayling, which included six mortalities and 67 fish that were greater than 149 mm FL and that were marked for the estimation of abundance and mixing rates. The timing of sampling with passive gears (fyke nets and hoop traps) coincided with the mean annual flood from an all time record snowpack. Difficulties in the deployment and maintenance of gear and its efficiency in such high water led to the unsatisfactory catches, thereby not attaining the sampling objectives, which were targeted at 2,000 fish.

Table 1. Proportions of Arctic grayling that were mature, by age and size categories (≥ 150 mm FL) collected from Piledriver Slough, 6 through 16 May 1991.

Age	Number examined	Proportion mature	SE	Size class	Number examined	Proportion mature	SE
1	0	---	---	150-159	63	0.00	---
				160-169	84	0.00	---
2	60	0.02	0.01	170-179	114	<0.01	<0.01
				180-189	123	<0.01	<0.01
3	341	<0.01	<0.01	190-199	137	0.00	---
				200-209	155	0.02	0.01
4	487	0.16	0.02	210 219	144	0.07	0.02
				220-229	149	0.13	0.03
5	686	0.38	0.02	230-239	221	0.24	0.03
				240-249	273	0.35	0.03
6	335	0.56	0.03	250-259	289	0.53	0.03
				260-269	259	0.49	0.03
7	175	0.65	0.04	270-279	244	0.55	0.03
				280-289	198	0.57	0.03
8	64	0.70	0.06	290-299	126	0.71	0.04
				300-309	80	0.59	0.05
9	9	0.55	0.17	310-319	35	0.71	0.08
				320-329	28	0.79	0.08
10	0	---	---	330-339	9	0.78	0.15
				340-349	8	0.50	0.18
11	0	---	---	350-359	4	0.75	0.25
				360-369	2	1.00	---
12	0	---	---	370-379	0	---	---
				380-389	2	1.00	---
Totals	2,157				2,747		

Periodic sampling occurred in Moose Creek using a pulse-DC electrofishing boat during May, July and August. During the several sampling days, a total of 539 Arctic grayling were captured and examined for marks given to fish at either Piledriver Slough or French Creek. A total of four Arctic grayling were killed during the several sampling events. The sampling objectives were attained, and mixing rates could be calculated for fish marked in Piledriver Slough.

Abundance Estimation

Inter-area movements tabulated for recaptured fish (Table 2) showed that marked Arctic grayling mixed incompletely, and that a non-random pattern of movements occurred when fish released in area 6 (Figure 1) were recovered in other areas of Piledriver Slough. Capture probability was found to vary among areas when the recapture-to-catch ratios were examined (M/U ratio; Table 2) by chi-square goodness of fit tests ($\chi^2 = 94.1$, df = 5, $P < 0.001$). Statistical similarity as determined through chi-square testing allowed grouping of the adjacent areas(3),(4),(5) into area (3-4-5) ($\chi^2 = 3.8$, df = 2, $0.10 < P < 0.25$).

A Kolmogorov-Smivnov comparison of cumulative distribution functions (CDF's) from the mark-recapture experiment showed that no significant size selectivity was present in the second event, but selectivity existed in the first event (mark vs recaptures: DN = 0.05, P = 0.75; mark vs catch: DN = 0.08, $P < 0.01$). As a result the abundance could be calculated without adjustments for size selectivity, but stock composition estimates would be based on the second event sample (Case II; Appendix B1).

The results of assumption testing led to the selection of the Darroch estimator of abundance. The Darroch point estimate based upon a 4 × 4 mark-recapture matrix [area groupings (1), (2), (3-4-5), and (6)] resulted in an estimate of 13,666 Arctic grayling. The estimate of capture probability in area 6 was -0.25, which indicated a model fitting problem with the present experiment. A bootstrapping run of the Darroch estimator, with 1,000 iterations was run using the same input matrix; negative capture probabilities resulted in approximately 95% of the simulations for area (6).

A closer examination of the inter-area movements indicated fish tagged in area (6) did not mix reciprocally with equal propensities as those marked in area (3-4-5). Arctic grayling marked in area (3-4-5) mixed into areas (3-4-5) and (6) at similar rates based upon binomial confidence interval testing of recapture-to-catch ratios ($\alpha = 0.05$). Alternatively, those fish marked in area (6) did not mix evenly among area (3-4-5) and area (6); R/C ratios were 0.04 and 0.27, respectively. The 361 Arctic grayling marked in area (6) were then removed from the study, but because fish from area (3-4-5) mixed into areas (6) and (3-4-5) at similar rates, the recapture event sampling in area (6) was retained.

The removal of area (6) from the marking event resulted in 86 fewer recaptures (Table 3). Testing of assumptions germane to abundance estimates once again indicated capture probability varied between areas (M/U ratio: Table 3). Chi-square goodness of fit tests led to grouping of the adjacent areas (3), (4),

Table 2. Numbers of marked and recaptured Arctic grayling (≥ 150 mm FL), and tabulation of catches and recaptures by area in Piledriver Slough, 6 through 16 May 1991.

	Marking event		Area recaptured[a]						Recovered	
	Number marked	Area	1	2	3	4	5	6	Yes	No
	235	1	50	3	2	0	0	2	57	178
	224	2	5	19	6	0	0	2	32	192
	382	3	0	1	14	4	0	5	24	358
	558	4	0	0	2	24	1	4	31	527
	12	5	0	0	0	1	0	0	1	11
	361	6	0	2	7	19	1	57	86	275
Total	1,772	Marked (M)	55	25	31	48	2	70	∑ = 231	1,541
		Unmarked (U)	91	91	248	351	56	140	∑ = 977	
		Catch	146	116	279	399	58	210	∑ = 1,208	
		M/U Ratio	0.60	0.27	0.12	0.14	0.03	0.50		

[a] Areas for the mark-recapture experiment were delineated from existing landmarks (see Figure 1) and or access points to more remote sections.

Table 3. Numbers of marked and recaptured Arctic grayling (≥ 150 mm FL), and tabulation of catches and recaptures by area, collapsed into groupings by similar capture probability[a].

	Marking event		Area recaptured[b]			Recovered	
	Number marked	Area	1	2	3-4-5-6	Yes	No
	235	1	50	3	4	57	178
	224	2	5	19	8	32	192
	952	3-4-5	0	1	55	56	896
Total	1,411	Marked (M)	55	23	67	∑ = 145	1,266
		Unmarked (U)	91	93	879	∑ = 1,063	
		Catch	146	116	946	∑ = 1,208	
		M/U Ratio	0.60	0.25	0.08		

[a] Capture probabilities were tested for statistical similarity using chi-square tests on numbers of marked and unmarked grayling. Failure to reject the null hypothesis of similarity between adjacent areas allowed grouping.

[b] Areas for the mark-recapture experiment were delineated from existing landmarks (see Figure 1) or, access points to more remote sections.

(5), (6) into combined area (3-4-5-6) (χ^2 = 3.0, df = 1, 0.10 < P < 0.25). The comparison of cumulative frequency distributions from the mark-recapture experiment resulted in the finding that no significant size selectivity was present in the second event, but selectivity existed in the first (mark vs recaptures: DN = 0.08, P = 0.29, Figure 3A ; mark vs catch: DN = 0.11, P < 0.01, Figure 3B). As a result, abundance was calculated without adjustments for size selectivity, but stock composition estimates were based on the second event sample.

The Darroch point estimate based upon a 3 × 3 mark-recapture matrix [area groupings (1), (2), (3-4-5-6)] was 17,194 Arctic grayling (SE = 1,976, CV = 11.5%; Table 4) greater than 149 mm FL in Piledriver Slough. Stratified estimates of capture probabilities were: 0.32, 0.27, and 0.06 which correspond to areas (1), (2), and (3-4-5-6), respectively. The bootstrapped estimate was 17,323 Arctic grayling (SE = 869, CV = 5%; Table 4) for Piledriver Slough. Negative capture probabilities were only found in area (2), and occurred in 28% of the simulations. The stratified point estimate of the Petersen estimator using the Bailey modification was 18,087 Arctic grayling (SE = 2,086, CV = 11.5%; Table 4). Abundance estimates stratified by area (Table 4) indicate that 90% of the population in Piledriver Slough at the time of the second sampling event, were below the Bailey Bridge (areas (3), (4), (5), (6); Figure 1).

Age and Size Composition

Ages observed for Arctic grayling in Piledriver Slough ranged from 2 to 9 years, with 5 years as the median age of fish in the second (recapture) sampling event. The predominant age class present in Piledriver Slough was age 5 (34% of the stock; Table 5) followed by age 4 (25% of the stock). The upper reaches of the slough (area 1) had a greater proportion of younger fish (Table 6) than areas downstream. Overall, Piledriver Slough was predominated by stock-sized fish, with 247 mm FL as the median size, but a greater proportion were of quality size than observed in 1990 (Table 7). Size composition, RSD, and incremental size composition also varied by area (Tables 8 and 9). Apportioning the estimated abundance over the incremental size composition (Figure 4) indicated that very few of the 4,600 harvestable-sized Arctic grayling (≥ 270 mm FL) were in the preferred RSD class. A combination of area stratified abundances with incremental size composition showed the majority of individual Arctic grayling within the population to be of a median size, distributed in the lower half of Piledriver Slough during the May sampling (Figure 5).

Estimates of age and size composition for French Creek were based on an unadjusted sample of 87 Arctic grayling. The most common ages in the sample were ages 5 and 6 (24% and 32% of the sample, respectively; Appendix C1). Stock-sized Arctic grayling made up 80% of the sample, while the quality size class made up the remaining 20%. The onset of maturity for a small sample (n=50) of fish was age 4 (Appendix C2).

Estimates of age and size composition of Arctic grayling in Moose Creek were based on unadjusted samples collected during May, July, and August. Ages 4, 5, and 6 were the most common ages collected from Arctic grayling sampled in

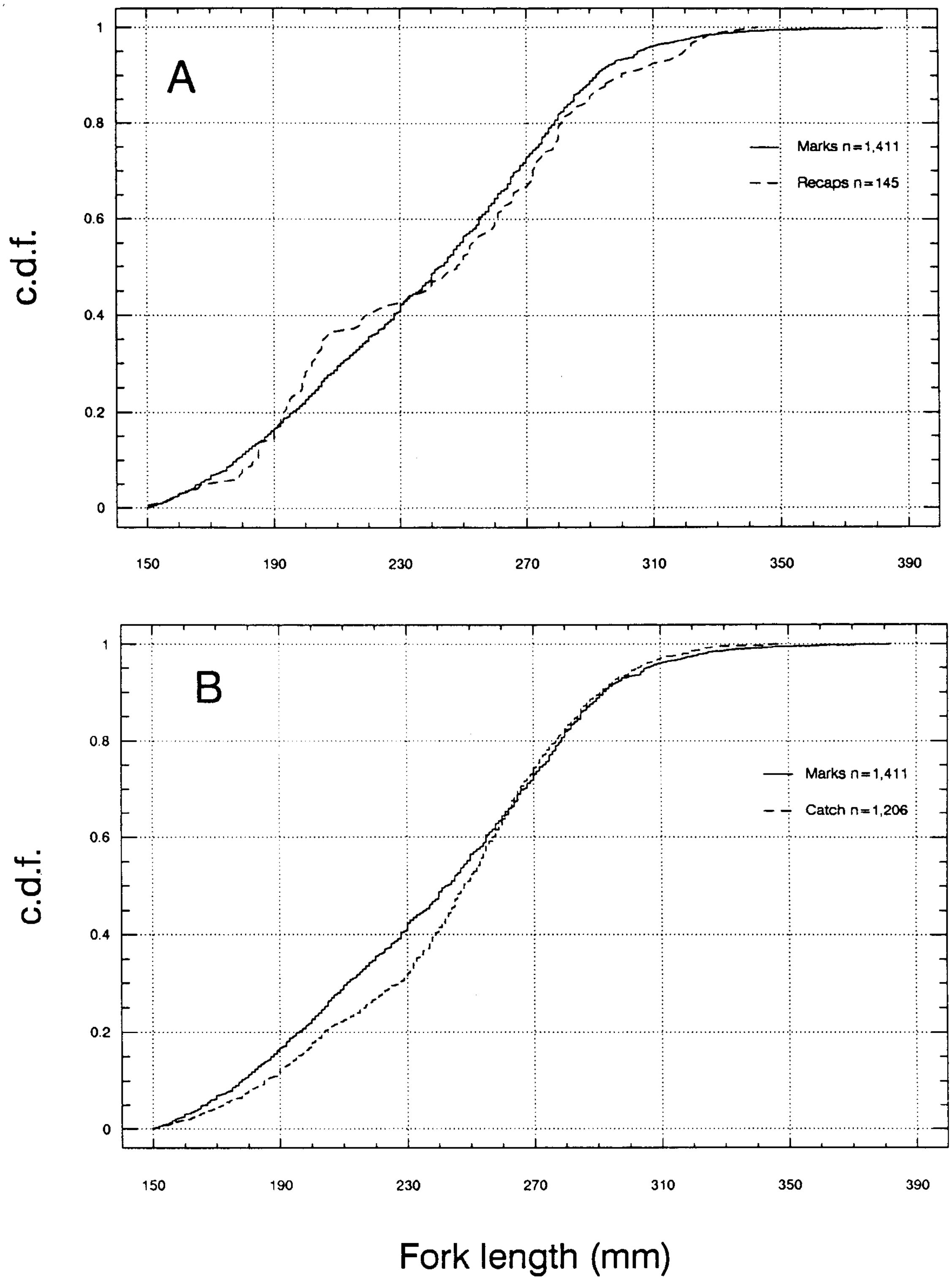

Figure 3. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) in Piledriver Slough, 6 through 16 May, 1991.

Table 4. Abundance estimates of Arctic grayling (≥ 150 mm FL) in Piledriver Slough, stratified by area.

Abundance estimator	Area[a]	N_{pt}[b]	$SE[N_{pt}]$[c]	N_b[d]	$SE[N_b]$[e]	Bias[f]
Petersen[g]						
	1	677	76	---	---	Yes
	2	1,310	261	---	---	"
	3-4-5-6	16,099	2,069	---	---	"
Total	(stratified)	18,087	2,086	---	---	Yes
Total	(unstratified)[h]	11,684	904	---	---	"
Darroch[i]						
	1	517	---	561	89	No
	2	570	---	1,171	304	"
	3-4-5-6	16,107	---	15,591	844	"
Total	(stratified)	17,194	1,976	17,323	869	No

[a] Areas for the abundance estimate were delineated by both established landmarks along Piledriver Slough and access points. Eventually, the areas were collapsed on a basis of similar capture probabilities.

[b] N_{pt} is the point estimate for the area specific abundance.

[c] $SE[N_{pt}]$ is the standard error of the point estimated abundance.

[d] N_b is the mean bootstrapped abundance estimate.

[e] $SE[N_b]$ is the standard error of the mean bootstrapped estimate.

[f] Bias is in reference to the appropriateness of the particular estimation model to the population being enumerated, i.e. the meeting or failure to meet the assumptions inherent to different estimator models.

[g] Petersen model for estimating abundance, used here with the Bailey modification (Bailey 1951, 1952).

[h] Unstratified is interpreted as a single Petersen estimate using the summed values of marks, catch, and recapture from the individual areas.

[i] Darroch's method (Darroch 1961) was selected for use due to incomplete mixing of tagged and untagged fish, and unequal capture probabilities.

Table 5. Estimates of the sampled and adjusted contributions by each age class for Arctic grayling (≥ 150 mm FL) captured in Piledriver Slough, 13 through 16 May 1991.

	Sampled						Adjusted[a]		
Age	n[b]	p[c]	SE[d]	FL[e]	SD[f]	n[g]	N[h]	p[i]	SE[j]
1	0	0.00	---			0	0	0.00	---
2	14	0.02	<0.01	168	27	60	274	0.02	<0.01
3	121	0.15	0.01	185	19	341	2,373	0.14	0.01
4	207	0.25	0.01	224	24	486	4,366	0.25	0.01
5	265	0.33	0.02	250	24	686	5,919	0.34	0.02
6	127	0.16	0.01	273	27	335	2,833	0.16	0.01
7	56	0.07	<0.01	287	24	175	1,186	0.07	0.01
8	18	0.02	<0.01	299	21	64	371	0.02	<0.01
9	0	---	---	309	34	9	0	---	---
	808	1.00					17,322	1.00	

[a] Age composition was adjusted only by the apportionment of the estimated abundance among the areas sampled.

[b] n = sample size.

[c] p = pooled proportion of sampled Arctic grayling from recapture event.

[d] SE = standard error of the sampled proportion.

[e] FL= mean fork length-at-age based upon 2,156 age:length combinations from both mark and recapture events, 6 through 16 May 1991.

[f] SD = sample standard deviation.

[g] n = sample size for mean fork length at age.

[h] N= estimated abundance by age classes at the time of recapture event.

[i] p = adjusted proportion of Arctic grayling (≥ 150 mm) in stock.

[j] SE = standard error of the adjusted proportion, as calculated using the bootstrapped variance and the delta method (Seber 1982).

Table 6. Summary of sampled age composition and standard errors for Arctic grayling in areas[a] of Piledriver Slough, 13 through 16 May 1991[b].

	Area 1 Stringer Loop Road area			Area 2 Culverts to Bailey Bridge			Areas 3, 4, 5, 6 pooled Below Bailey Bridge		
Age class	n[c]	p[d]	SE[e]	n	p	SE	n	p	SE
1	0	---	---	0	---	---	0	---	---
2	3	0.04	0.02	1	0.02	---	10	0.01	<0.01
3	28	0.34	0.05	1	0.02	---	92	0.14	0.01
4	28	0.34	0.05	7	0.11	0.03	172	0.26	0.02
5	14	0.17	0.04	16	0.25	0.04	235	0.35	0.02
6	3	0.04	0.02	21	0.33	0.04	103	0.16	0.01
7	4	0.05	0.02	13	0.21	0.05	39	0.06	0.01
8	2	0.02	0.02	4	0.06	0.02	12	0.02	<0.01
9	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---
Total	82	1.00		63	1.00		663	1.00	

[a] Areas in Piledriver slough were grouped by similar capture probabilities for purposes of estimating abundance.

[b] Arctic grayling were captured for a mark-recapture experiment using back-pack electrofishing units. This sample corresponds to the ages of fish collected in the recapture event only due to size selectivity in the marking event.

[c] n = the sample size of estimated ages.

[d] p = proportion.

[e] SE = standard error of the proportion.

Table 7. Summary of Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) captured at Piledriver Slough in 1990 and 1991.

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
1990[b]					
Number sampled	1,217	150	1	0	0
Adjusted RSD[c]	0.85	0.14	<0.01	---	---
Standard Error	0.03	0.03	<0.01	---	---
CV(%)	4	23	66	---	---
1991					
Number sampled	882	320	4	0	0
Adjusted RSD[d]	0.73	0.26	<0.01	---	---
Standard Error	0.01	0.01	<0.01	---	---
CV (%)	2	6	50	---	---

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

[b] Arctic grayling were sampled from several sites in Piledriver Slough in a 1990 mark-recapture study (Timmons and Clark 1991) between 25 April and 5 October 1990. In 1991, a mark-recapture study was conducted in the same area but over a shorter duration, from 6 through 16 May.

[c] The adjustments made in the 1990 analysis were to correct for size selectivity and a differential capture probability by area.

[d] The required adjustment made in the 1991 analysis involved a differential capture probability by area, but no changes were made to the RSD sample proportion by size specific capture probabilities.

Table 8. Summary of Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) by area in Piledriver Slough, 13 through 16 May 1991.

	RSD Category[a]				
Area[b]	Stock	Quality	Preferred	Memorable	Trophy
<u>Area 1 (Stringer Loop Road area)</u>					
Number sampled	127	19	0	0	0
Sample RSD[c]	0.87	0.13	---	---	---
Standard Error	0.03	0.03	---	---	---
CV(%)	3	23	---	---	---
<u>Area 2 (Culverts to Bailey Bridge)</u>					
Number sampled	37	79	0	0	0
Sample RSD	0.32	0.68	---	---	---
Standard Error	0.04	0.04	---	---	---
CV (%)	12	6	---	---	---
<u>Area 3,4,5,6 (Below Bailey Bridge)</u>					
Number sampled	718	222	4	0	0
Sample RSD	0.76	0.23	<0.01	---	---
Standard Error	0.01	0.01	<0.01	---	---
CV(%)	1	4	50	---	---
<u>Areas pooled (Total Piledriver Slough)</u>					
Number sampled	882	320	4	0	0
Sample RSD	0.73	0.26	<0.01	---	---
Standard Error	0.01	0.01	<0.01	---	---
CV (%)	1	4	66	---	---

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

[b] Arctic grayling were sampled over the entire length of Piledriver Slough which was divided into six sections, corresponding to established landmarks and/or area covered in one crew-day of sampling.

[c] Sample RSD was calculated for lengths gathered during the recapture event sample only, as size selectivity was present in the mark-event sample.

Table 9. Summary of incremental size composition and standard error for Arctic grayling, stratified by areas of Piledriver Slough with similar capture probabilities, 13 though 16 May 1991.

	Area 1 Stringer Loop Road area			Area 2 Culverts to Bailey Bridge			Area 3,4,5,6 below Bailey Bridge			Areas pooled Total Piledriver Slough		
Size class	n[a]	p[b]	SE[c]	n	p	SE	n	p	SE	n	p	SE
150-159	7	0.05	0.02	0	---	---	14	0.01	<0.01	21	0.02	<0.01
160-169	9	0.06	0.02	1	<0.01	<0.01	18	0.02	<0.01	28	0.02	<0.01
170-179	11	0.07	0.02	0	---	---	30	0.03	<0.01	41	0.03	<0.01
180-189	20	0.14	0.03	0	---	---	25	0.03	<0.01	45	0.04	<0.01
190-199	29	0.20	0.03	0	---	---	39	0.04	<0.01	68	0.06	0.01
200-209	21	0.14	0.03	2	0.02	0.01	41	0.04	<0.01	64	0.05	0.01
210-219	4	0.03	0.01	3	0.03	0.01	47	0.05	<0.01	54	0.05	0.01
220-229	3	0.02	0.01	0	---	---	50	0.05	<0.01	53	0.04	0.01
230-239	4	0.03	0.01	6	0.05	0.02	102	0.11	0.01	112	0.09	0.01
240-249	7	0.05	0.02	10	0.09	0.02	111	0.12	0.01	128	0.11	0.01
250-259	8	0.05	0.02	6	0.05	0.02	125	0.13	0.01	139	0.12	0.01
260-269	4	0.03	0.01	9	0.08	0.02	116	0.12	0.01	129	0.11	0.01
270-279	3	0.02	0.01	16	0.14	0.03	82	0.09	<0.01	101	0.08	0.01
280-289	4	0.03	0.01	24	0.21	0.03	63	0.07	<0.01	91	0.07	0.01
290-299	2	0.01	0.01	16	0.14	0.03	36	0.04	<0.01	54	0.05	0.01
300-309	4	0.03	0.01	11	0.09	0.02	25	0.03	<0.01	40	0.03	<0.01
310-319	3	0.02	0.01	4	0.03	0.01	9	0.01	<0.01	16	0.01	<0.01
320-329	3	0.02	0.01	7	0.06	0.02	7	<0.01	<0.01	17	0.01	<0.01
330-339	0	---	---	1	<0.01	<0.01	0	---	---	1	<0.01	<0.01
340-349	0	---	---	0	---	---	4	<0.01	<0.01	4	<0.01	<0.01
350-359	0	---	---	0	---	---	0	---	---	0	---	---
Total	146	1.00		116	1.00		944	1.00		1,206	1.00	

[a] n = sample size.
[b] p = proportion.
[c] SE = standard error of the proportion, except for areas combined, which uses the delta method approximation (Seber 1982).

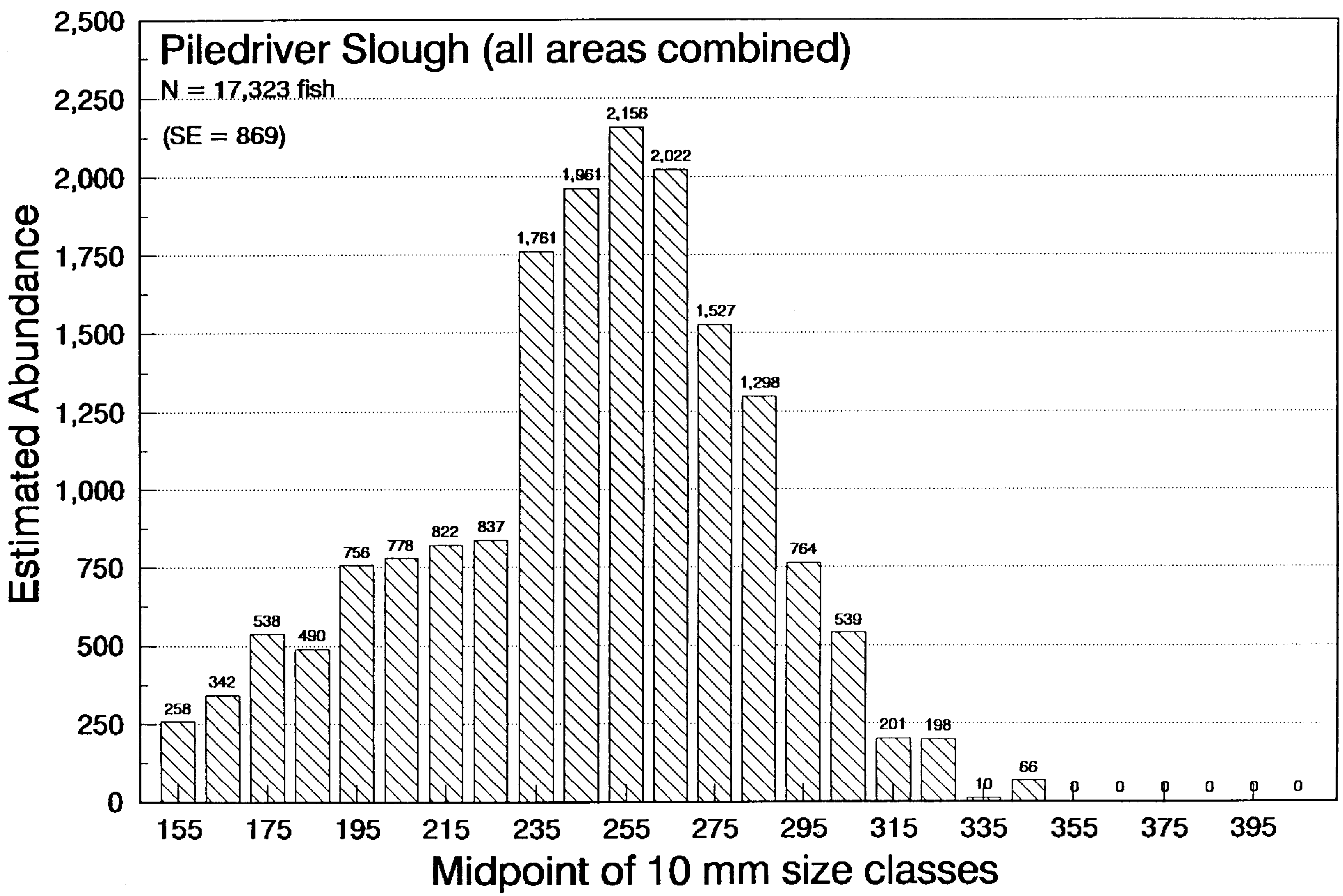

Figure 4. Apportionment of estimated abundance across 10 mm FL incremental size categories for Arctic grayling (≥150 mm FL) present in Piledriver Slough from 13 through 16 May, 1991.

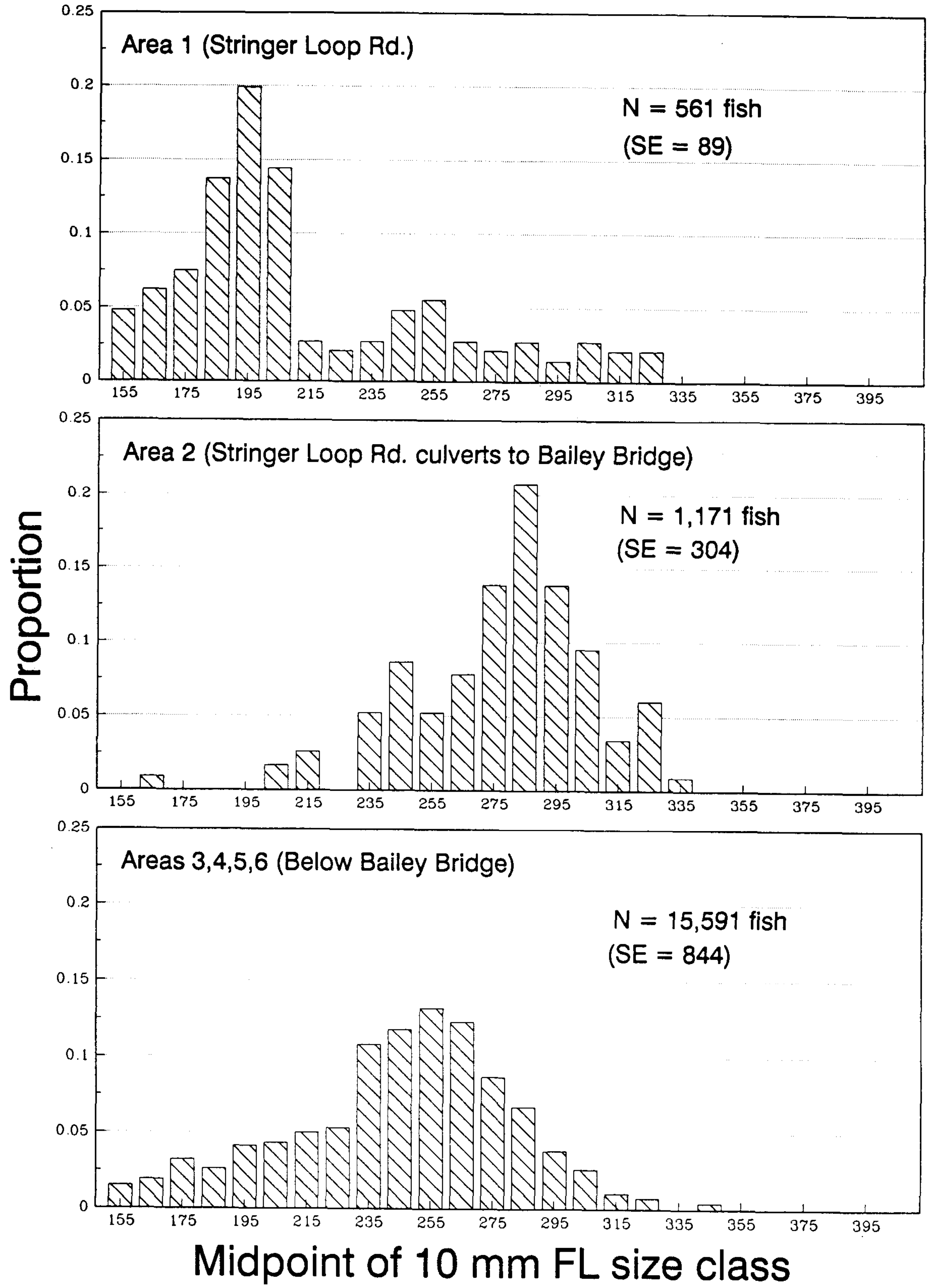

Figure 5. Spatial distribution of the estimated population of Arctic grayling (≥150 mm FL) from 13 to 16 May, 1991, with corresponding size composition.

May and July (Appendix C3). Stock-sized Arctic grayling made up 60% of the size composition, based on May, July, and August samples pooled; quality-sized Arctic grayling composed the balance. The onset of maturity for a small sample (n=52) of fish was age 4 (Appendix C4).

Mixing Rates

In order to estimate the mixing rates of fish released in spring spawning areas and recaptured later in summer feeding areas, surveys of tagged fish were conducted in Moose Creek in May, July, and August, and Piledriver Slough in August (Appendix A1). During the Moose Creek surveys, 66, 97, and 377 Arctic grayling were captured using an electrofishing boat and examined for tags in May, July, and August, respectively. Of these catches, 22 fish were previously sampled in Moose Creek, two fish were previously sampled in French Creek, and 21 fish were previously sampled in Piledriver Slough in May.

In the later half of August, 1,167 Arctic grayling were captured in a single downstream pass in Piledriver Slough, which included the recovery of 178 Arctic grayling tagged in the May sampling, and one fish from Moose Creek (May sample). The spatial distribution of August catches varied from those in May; catches above Bailey Bridge (areas (1), (2); Figure 1) made up 85% of the August sample, while only comprising 26% and 22% of the catches in May. In this sample, 29% of the captured Arctic grayling belonged in the quality RSD category, a slight increase from 26% estimated in May.

Because estimates of the abundance and subsequent marked proportion could not be attained in French Creek, mixing rates could only be estimated for Arctic grayling moving between Piledriver Slough and Moose Creek, and Piledriver Slough (May) to Piledriver Slough (August). The marked proportion of the estimated abundance in Piledriver Slough was 0.158 (SE = 0.025 ; CV = 16%). Mixing rates (P) from Piledriver Slough (PDS) to Moose Creek and to Piledriver Slough, based upon the movement and subsequent recapture of 21 and 178 tagged Arctic grayling, respectively, were:

$PDS_{(MAY)}$ to Moose $Creek_{(MAY)}$ (1 fish) P = 0.09 (SE = 0.09)

$PDS_{(MAY)}$ to Moose $Creek_{(JULY)}$ (8 fish) P = 0.52 (SE = 0.19)

$PDS_{(MAY)}$ to Moose $Creek_{(AUGUST)}$ (12 fish) P = 0.20 (SE = 0.06)

$PDS_{(MAY)}$ to $PDS_{(AUGUST)}$ (178 fish) P = 0.97 (SE = 0.17)

Some Arctic grayling present during the spawning period in Piledriver Slough migrated into Moose Creek to feed during summer. These fish are estimated to have comprised 9%, 20%, and 52% of Moose Creek's population, with respect to May, July, and August.

Growth

Mean length-at-age information from 1991 (Table 5) was used to successfully model growth of Arctic grayling present in Piledriver Slough. All three parameters of the von Bertalanffy equation were estimated with sufficient precision (Appendix C5). The best fitting combination of input parameters L_∞, K, and t_0 were found to be 367 mm FL, 0.19, and -1.0 year, respectively. Growth parameters taken from this and other studies of interior Alaska Arctic grayling stocks were plotted, and suggested slower growth for Piledriver Slough Arctic grayling (Figure 6).

DISCUSSION

This year's investigations at Piledriver Slough indicated a very dense population of Arctic grayling, approximately 17,323 fish greater than 149 mm FL, or 541 fish per kilometer. At this time several inconsistencies hinder comparisons with other lotic populations. In other studies, high densities have been detected, but the standardizing unit of measure has been based on linear measurement, river miles (or kilometers). If the measurement was based on area or average discharge, for the system-specific populations, then comparison or indexing of population density would be more meaningful. Additionally, abundances during the spring may be influenced by spawning behaviors by Arctic grayling, which differ from those during the summer feeding period.

An increased number of harvestable quality-sized grayling were found this year (26%) which was a significant increase (α = 0.05) from estimates in 1990 (14%). This was likely caused by growth recruitment from the stock size category in 1990, as the estimated abundance in 1991 was similar to 1990. Again, as in 1990, very few age 9 and preferred size Arctic grayling were sampled in the Piledriver Slough system. Reasons for this may be directly related to the population's short residence time (15 years) within Piledriver Slough. If initial establishment of the population followed Piledriver Slough's inception as a clear-running stream in 1976, then the population is still young and maturing after 15 years. This becomes important when parameter estimates are compared between years or among populations present in other local clearwater drainages. For example, growth parameters estimated for Arctic grayling in Piledriver Slough indicated slower growth potential than in other Tanana drainage stocks assessed to date. It is not known whether this rate is of a compensatory nature, given the observed high density; is specific to this, or its parental stock; or, the estimation of growth is premature for Arctic grayling in Piledriver Slough. Implications of the population's short history may result in confounding effects in present and future assessments, as well as management of the fishery.

During the marking event, an additional spawning area, 23-Mile Slough or area (6), was discovered at the end of one sampling section, and added in to the sampled areas. The new area was initially sampled several days later than the other areas, and this may have led to the observed differences in mixing behaviors. The finding that fish released in area (6) failed to mix equally between areas (6), and (3-4-5) was most likely caused by a hiatus in area (6) of only two days, while the hiatus for fish marked in areas (3), (4), (5) was eight, seven, six days, respectively. As a result, the mark event in this area was not used for the estimate of abundance, but was sampled for tagged fish during the recapture event. Given this finding, future investigations should be conducted to allow equivocal mixing periods.

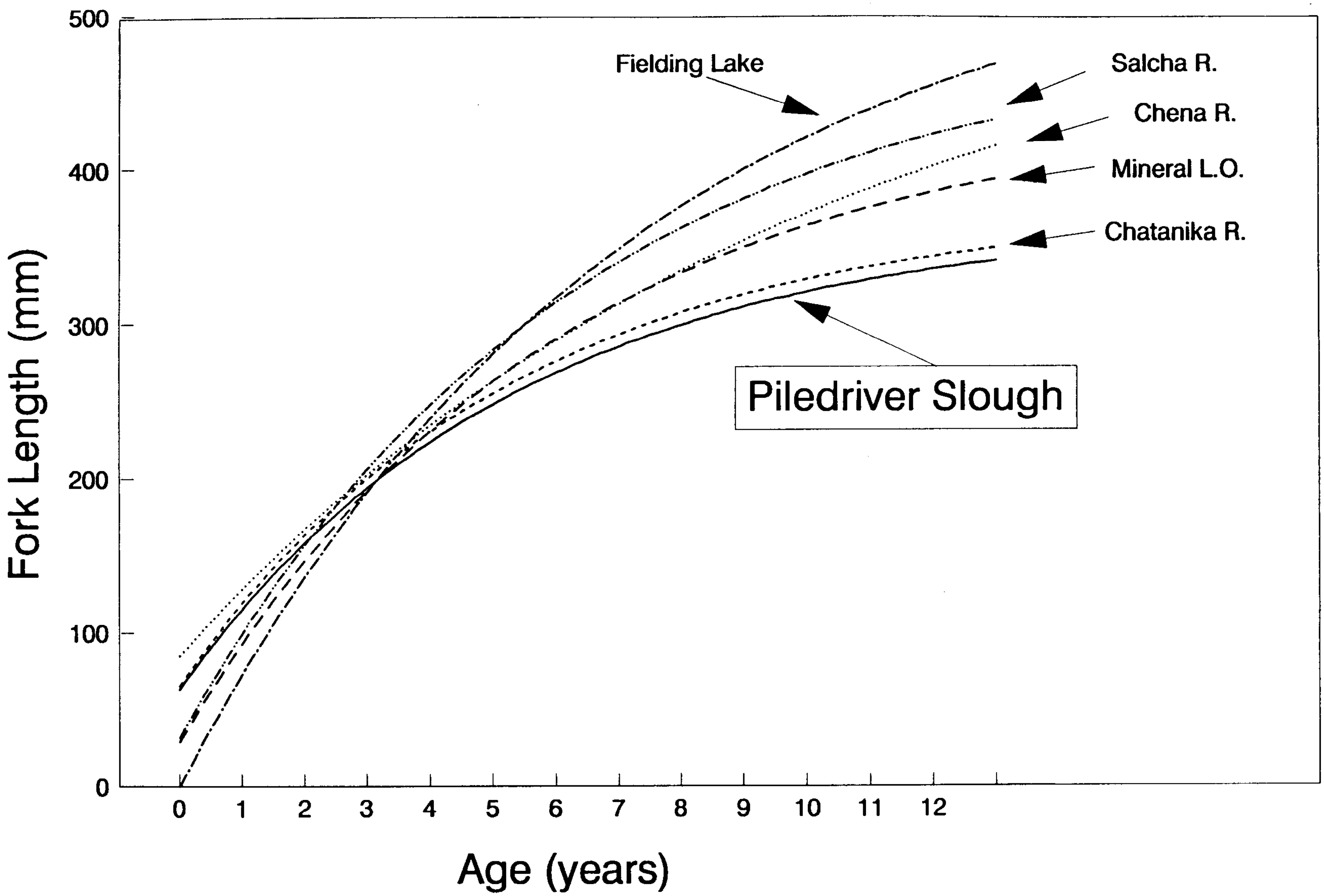

Figure 6. Von Bertalanffy growth functions estimated for Arctic grayling in Fielding Lake, Salcha River, Chena River, Mineral Lake Outlet, and Chatanika River, for comparison with 1991 estimates from Piledriver Slough.

Some of the stock resident to Piledriver Slough in spring moved into Moose Creek and made up a significant proportion of the stock present there during the summer months. Although sampling efforts to estimate abundance in French Creek were compromised by high water conditions, some inferences about movements were drawn from the available information. First, the August sampling in Piledriver Slough revealed that 97% of the fish present were also present during the May mark-recapture experiment. This suggests minimal emmigration from Piledriver Slough from May through August and leaves only 3% to have immigrated from outside the sampling area, i.e. French or Moose Creek. Secondarily, two tagged fish out of 67 fish released with tags in French Creek were recaptured in Moose Creek, which indicated the existence of a French Creek component in Moose Creek. Lack of movement of Arctic grayling between spring and late summer in Piledriver Slough may have implications for future sampling strategies. Abundance estimation could be conducted in August when the population is more likely to be migrationally static than expected following break-up, amidst spawning migrations and behaviors. Additionally, the concentration of August catches in the upper areas (~85% above Bailey Bridge) suggests a smaller-scale approach in terms of manpower needs. Trade-offs for this would include uncertainty of post-winter, and pre-season abundances of Arctic grayling, and the loss of maturity sampling opportunities.

First-time estimates of catch and estimates of harvest in the Alaska Statewide Harvest Survey (Mills 1991) for 1990, indicate a high utility for each Arctic grayling angled in the sport fishery. An estimated 34,840 catches were made upon a stock of 16,435 Arctic grayling (Timmons and Clark 1991), yielding a harvest of 2,380 Arctic grayling greater than 270 mm FL. This indicates that on average, each Arctic grayling in the estimated population was handled twice by anglers, and, for every Arctic grayling harvested, about 15 others were released. This represents a 93% probability of catch and release, or survival through the 1990 fishery. Using the apportionment of the 1991 estimated abundance by incremental size composition (Figure 4) and growth increment between mean lengths-at-age, it is likely that between 5,000 and 6,000 Arctic grayling will enter the harvestable stock by growth recruitment in 1992. If the ratio between catch and harvest remains stable with an increasing presence of harvestable-sized Arctic grayling, Piledriver Slough will likely continue to be a high quality fishery.

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APPENDIX A

Appendix A1. Distribution and characteristics of sampling effort for Arctic grayling stock assessment in Piledriver Slough, French Creek, and Moose Creek in 1991.

	Piledriver Slough			Moose Creek		French Creek		
Date	Area[a]	Gear[b]	Catch[c]	Gear[b]	Catch[c]	Area[a]	Gear[b]	Catch[c]
5/6	1,2/3	BP	236, 159					
5/7	2,3	BP	65, 383					
5/8	4	BP	426					
5/9	4	EB	132					
5/10	5	EB	12					
5/13	1,6	BP	146, 361					
5/14	2,3	BP	27, 279			F-11,14	F,H	3, 1
5/15	2,4	BP	89, 399			F-11,13,14	F,H,F	8, 1, 1
5/16	5,6	EB,BP	58, 210	EB	66	F-11	F	12
5/17						F-9,11,15	H,F,H	1, 9, 6
5/18								
5/19								
5/20						F-15	H	25
5/21								
5/22						F-1	F	3
5/23								
5/24								
5/25								
5/26						F-1,2,11	F,F,F	1, 5, 4
5/27								
5/28								
5/29						F-11,14	F,F	4, 1
5/30						F-11,13	F,H	1, 1
7/3				EB	97			
8/19	5	EB	17	EB	115			
8/20	1,2	BP	153, 610					
8/21	2	BP	235					
8/22	3,4	BP	91, 61					
8/23				EB	261			
Total			4,149		539			87

[a] See Figures 1 and 2.

[b] F=fyke net; H= hoop trap; BP= backpack electrofishing; EB= electro-fishing boat.

[c] Catches reported are raw counts.

APPENDIX B

Appendix B1. Methodologies for alleviating bias due to gear selectivity by means of statistical inference.

Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]	
Fail to reject H_0	Fail to reject H_0
Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]	
Fail to reject H_0	Reject H_0
Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event	
Case III[e]	
Reject H_0	Fail to reject H_0
Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]	
Reject H_0	Reject H_0
Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.
If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.
If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

APPENDIX C

Appendix C1. Estimates of the sampled proportional contribution of each age class for Arctic grayling (≥ 150 mm FL) captured in French Creek[a], 14 through 30 May 1991.

	Sampled:		
Age	n[b]	p[c]	SE[d]
2	5	0.10	0.04
3	5	0.10	0.04
4	9	0.18	0.05
5	12	0.24	0.06
6	16	0.32	0.07
7	3	0.06	0.03
8	0	---	---
9	0	---	---
10	0	---	---
Total	50	1.00	

[a] Data from unadjusted catches from fyke nets and hoop traps at several sites along French Creek.
[b] n = sample size.
[c] p = proportion of sampled Arctic grayling.
[d] SE = standard error of the sample proportion.

Appendix C2. Proportion of Arctic grayling that were mature, by age and size categories (≥ 150 mm FL) collected from French Creek, 14 through 30 May 1991.

Age	Number examined	Proportion mature	SE	Size class	Number examined	Proportion mature	SE
1	0	---	---	150-159	0	---	---
				160-169	1	---	---
2	5	0.00	---	170-179	1	0.00	---
				180-189	2	0.00	---
3	5	0.00	---	190-199	1	0.00	---
				200-209	1	0.00	---
4	9	0.11	0.11	210 219	2	0.00	---
				220-229	3	0.33	0.33
5	12	0.66	0.14	230-239	4	0.75	0.25
				240-249	11	0.64	0.15
6	16	0.81	0.10	250-259	11	0.45	0.16
				260-269	9	0.66	0.17
7	3	1.00	---	270-279	12	0.66	0.14
				280-289	5	0.40	0.24
8	0	---	---	290-299	2	1.00	---
				300-309	0	0.00	---
9	0	---	---	310-319	1	1.00	---
				320-329	0	---	---
10	0	---	---	330-339	1	1.00	---
				340-349	0	---	---
11	0	---	---	350-359	0	---	---
				360-369	0	---	---
12	0	---	---	370-379	0	---	---
				380-389	0	---	---
Totals	50				67		

Appendix C3. Estimates of the sampled proportional contribution of each age class for Arctic grayling (≥ 150 mm FL) captured in Moose Creek in 1991[a].

	May 16 Sample:			July 3 Sample:		
Age	n[b]	p[c]	SE[d]	n[b]	p[c]	SE[d]
2	0	---	---	0	---	---
3	7	0.13	0.05	0	---	---
4	14	0.27	0.06	10	0.13	0.04
5	13	0.25	0.06	24	0.30	0.05
6	12	0.23	0.06	26	0.32	0.05
7	2	0.04	0.03	15	0.19	0.04
8	4	0.08	0.04	3	0.04	0.02
9	0	---	---	1	0.01	0.01
10	0	---	---	1	0.01	0.01
Total	52	1.00		80	1.00	

[a] Moose Creek was sampled using a pulse DC electrofishing boat in May, July, and August, but no scales were collected in the August sample.
[b] n = sample size.
[c] p = proportion of sampled Arctic grayling.
[d] SE = standard error of the sampled proportion.

Appendix C4. Proportion of Arctic grayling that were mature, by age and size categories (≥ 150 mm FL) collected from Moose Creek, 16 May 1991.

Age	Number examined	Proportion mature	SE	Size class	Number examined	Proportion mature	SE
1	0	---	---	150-159	0	---	---
				160-169	0	---	---
2	0	---	---	170-179	1	0.00	---
				180-189	1	0.00	---
3	7	0.00	---	190-199	1	0.00	---
				200-209	2	0.00	---
4	14	0.50	0.14	210 219	5	0.00	---
				220-229	3	0.00	---
5	13	0.53	0.14	230-239	9	0.11	0.11
				240-249	6	0.66	0.21
6	12	0.83	0.11	250-259	6	1.00	---
				260-269	6	1.00	---
7	2	0.50	0.50	270-279	5	0.80	0.20
				280-289	8	0.88	0.13
8	4	1.00	---	290-299	6	0.83	0.17
				300-309	3	0.66	0.33
9	0	---	---	310-319	2	1.00	---
				320-329	0	---	---
10	0	---	---	330-339	0	---	---
				340-349	0	---	---
11	0	---	---	350-359	0	---	---
				360-369	0	---	---
12	0	---	---	370-379	0	---	---
				380-389	0	---	---
Totals	52				64		

Appendix C5. Parameter estimates and standard errors of the von Bertalanffy growth model[a] for Arctic grayling sampled in Piledriver Slough during May 1991.

Parameter	Estimate	Standard Error
L_∞[b]	367	22
K[c]	0.19	0.03
t_0[d]	-1.01	0.28
$Corr(L_\infty, K)$[e]	-0.97	---
$Corr(L_\infty, t_0)$	-0.82	---
$Corr(K, t_0)$	0.92	---
Sample size	2,156	

[a] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_\infty (1 - exp(-K (t - t_0)))$. The parameters of this model were estimated with data collected during 1988 and 1990. This model was fitted to the data by nonlinear regression utilizing the Marquardt compromise (Marquardt 1963). The range of ages used to model growth was age 1 through age 9.

[b] L_∞ is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[c] K is a constant that determines the rate of increase of growth increments (Ricker 1975).

[d] t_0 represents the hypothetical age at wich a fish would have zero length (Ricker 1975).

[e] $Corr(x,y)$ is the correlation of parameter estimates x and y.