Fishery Data Series No. 97-18

Stock Assessment of Arctic Grayling in Piledriver Slough During 1996

by

Douglas F. Fleming

September 1997

Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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by

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In 1996, a mark-recapture investigation was conducted to assess the stock of Arctic grayling *Thymallus arcticus* in Piledriver Slough, near Fairbanks, Alaska. The timing of the investigation corresponded with an exceptionally late spring breakup. A total of 808 Arctic grayling were captured with backpack electrofishing gear, marked, and released during late-May. During the late-June recapture sampling, 1,009 Arctic grayling were captured using the same methods and examined for marks, yielding 91 recaptures. An estimated 9,981 (SE = 1,256) Arctic grayling ≥ 150 mm FL were present during late June. The 1996 stock was characterized by a high proportion of young Arctic grayling, and the age composition was predominated by age-3 fish. Significantly fewer Arctic grayling ≥ 270 mm FL were present in 1996 than at the last assessment in 1994. Densities of Arctic grayling have continued to remain at high levels (722 fish per km), but beaver dams have blocked migrations to headwater areas and reduced the total area of habitat by as much as 60%.

Key words: Arctic grayling, *Thymallus arcticus*, Piledriver Slough, abundance estimation, age composition, size composition, spawning stock, beaver dams.

INTRODUCTION

Arctic grayling *Thymallus arcticus* and other fish species common to interior Alaska colonized Piledriver Slough (Timmons and Clark 1991) after its establishment as a clearwater slough in 1976. At this time a flood control project consisting of several small dykes blocked inputs of silty, glacial water from the Tanana River. Subsequently, clear water entered approximately 45 km of the slough by upwelling from the Tanana aquifer. It is likely that Arctic grayling straying from area streams and rivers colonized Piledriver Slough. Limited information on the movements of tagged fish has suggested donor stocks were from the adjoining Moose and French creeks watersheds (Figure 1; Fleming 1991), and the more distant Chena and Salcha rivers. In the ensuing years, Arctic grayling populated the slough at higher densities than other assessed Tanana River drainage populations (Fleming 1991). Hydrologically, the slough is unlike spring-fed and rapid run-off streams and rivers in the area. Water temperature at Piledriver Slough fluctuates substantially through the season and throughout the day (Fleming 1995), unlike the Delta Clearwater and other spring-fed streams (Wojcik 1955, Tack 1980). The combination of nearly-constant flow, low velocity (low gradient), and the generally early spring breakup and warming created suitable habitat for Arctic grayling spawning, rearing, and feeding.

Since 1987, Piledriver Slough has been stocked with rainbow trout *Oncorhynchus mykiss* to provide stream fishing opportunities close to Fairbanks. Prior to the stocking program, Piledriver Slough received between 1 and 3% of the total Tanana drainage effort in angler-days (Table 1). Since the 1987 inception of the stocking program, fishing effort in Piledriver Slough increased by as much as five-fold, and in 1990 it received approximately 15% of the fishing effort within the Tanana River drainage (Mills 1991). The fishery has provided as much as 20% of the total Arctic grayling catches in the Tanana River drainage during 1990 and 1991 (Mills 1991, 1992) and as much as 16% of the drainage harvest of rainbow trout in 1988 (Mills 1989).

The popularity of the fisheries indicated the need for annual stock assessment of Arctic grayling to ensure proper sustainable harvests at Piledriver Slough. A stock assessment program was initiated in 1990 to characterize the Arctic grayling stock in Piledriver Slough and adjoining

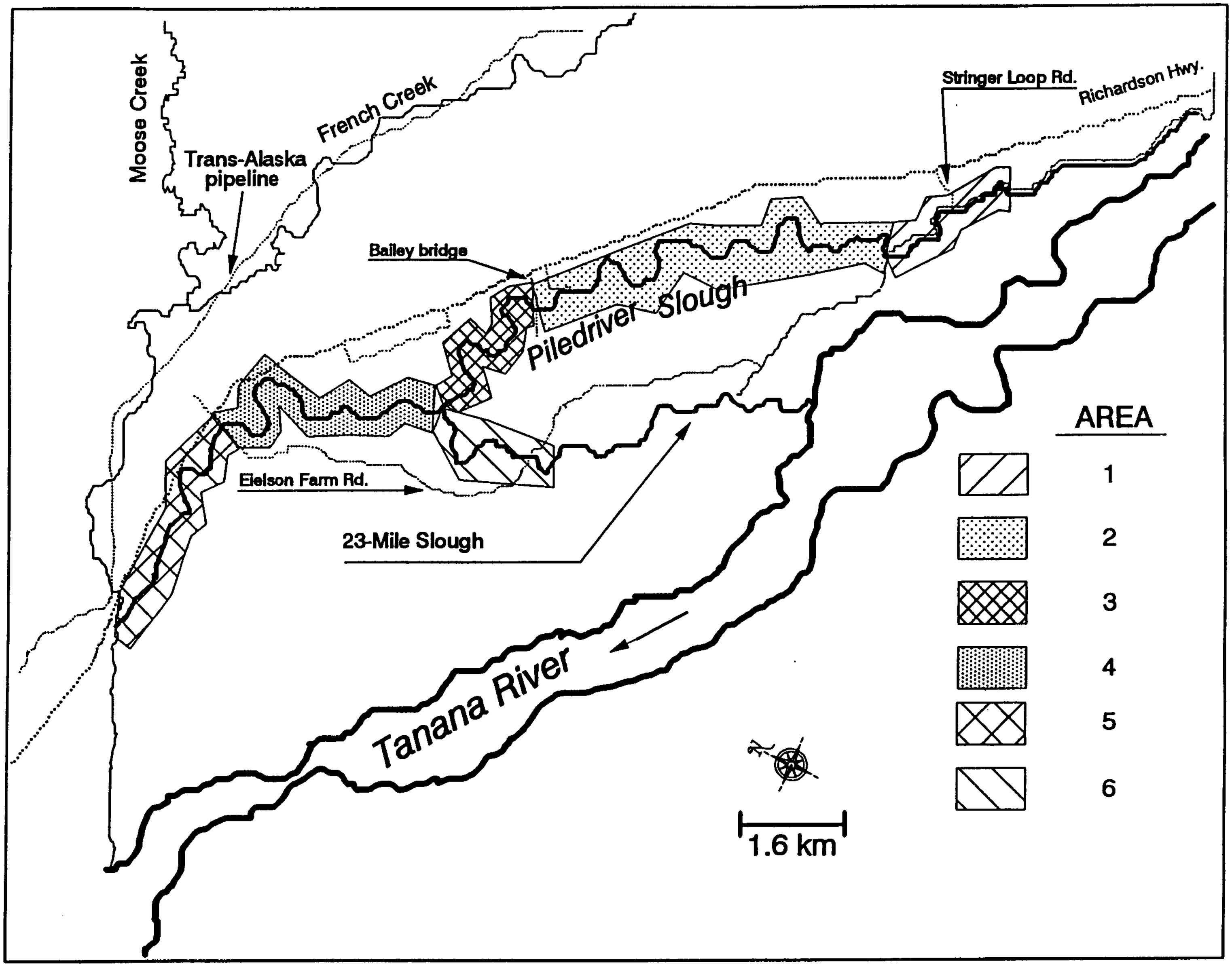

Figure 1.-Piledriver Slough and adjoining creeks.

Table 1.-Effort, catch, and harvest of Arctic grayling from Piledriver Slough and in the Tanana River drainage, 1983 to 1995[a].

	Piledriver Slough			Tanana River Drainage			% Tanana River Drainage[b]		
Year	Days Fished	Catch	Harvest	Days Fished	Catch	Harvest	Days Fished	Catch	Harvest
1983[c]	4,148	N/A	5,822	144,981	N/A	91,682	2.8	N/A	6.3
1984[d]	4,651	N/A	3,751	145,142	N/A	82,548	3.2	N/A	4.5
1985[d]	2,133	N/A	2,133	135,745	N/A	62,433	1.6	N/A	3.4
1986[d]	2,079	N/A	2,312	144,814	N/A	45,780	1.4	N/A	5.0
1987[e]	13,247	N/A	4,907	155,346	N/A	38,230	8.5	N/A	12.8
1988[f]	24,375	N/A	8,095	173,706	N/A	51,803	14.0	N/A	15.6
1989[g]	22,746	N/A	4,459	185,715	N/A	53,791	12.2	N/A	8.3
1990[h]	27,705	34,840	2,380	184,887	171,058	28,414	14.9	20.4	8.4
1991[i]	17,703	30,012	3,987	155,662	146,892	33,778	11.4	20.4	11.8
1992[j]	13,607	15,252	1,030	120,848	115,633	14,983	11.3	13.2	6.9
1993[k]	17,263	32,036	759	160,117	193,088	17,658	10.8	16.6	4.3
1994[l]	11,369	31,324	57	148,633	243,906	24,741	7.6	12.8	0.1
1995[m]	12,613	17,431	0	201,389	156,611	16,089	6.2	11.1	0.0

[a] Statewide harvest estimates for Arctic grayling in Piledriver Slough began with the 1983 fishery.

[b] Percent of Tanana River drainage fishery represented by Piledriver Slough.

[c] Mills 1984.

[d] Mills, unpublished data *taken from* Timmons 1992.

[e] Mills 1988.

[f] Mills 1989.

[g] Mills 1990.

[h] Mills 1991.

[i] Mills 1992.

[j] Mills 1993.

[k] Mills 1994.

[l] Howe et al. 1995.

[m] Howe et al. 1996.

watersheds (Timmons and Clark 1991). Since 1991 the trend in abundance of Arctic grayling ≥ 150 mm FL has indicated a decline as shown below:

Assessment Year (source)	Estimated Abundance	Standard Error
1990 (Timmons and Clark 1991)	16,435	1,396
1991 (Fleming 1991)	17,323	869
1992 (Fleming and Schisler 1993)	14,030	1,860
1993 (Fleming 1994)	10,587	1,351
1994 (Fleming 1995)	11,747	1,297

This decline in abundance led to a catch-and-release angling regulation by emergency order in 1993.

In 1995, the stock was not assessed after findings from 1994 indicated signs of stock rebuilding and other assessment priorities within the AYK Region. Estimates of angling effort and catches (Howe et al. 1996) indicated a low level fishery occurred in 1995.

OBJECTIVES

The research objectives for 1996 were to:

1. estimate abundance of Arctic grayling ≥ 150 mm fork length (FL) in Piledriver Slough;
2. estimate age composition of Arctic grayling in Piledriver Slough; and,
3. estimate size composition of Arctic grayling in Piledriver Slough.

METHODS

SAMPLING

In 1996, the study area comprised a 13.8 km section of Piledriver Slough (Figure 2) that was accessible to Arctic grayling. The study area was divided among three sections of the slough which have been delineated by landmarks, access points, or one crew-day's coverage (Fleming 1991). The 1996 study geographic delineations were consistent with all previous assessments. The sections of Piledriver Slough examined in 1996 are described as follows (from Fleming 1991):

Section {2} — Culverts to Bailey Bridge. This section of Piledriver Slough is a remote section, accessed from the ends. The stream is generally small with alternating pools, riffles, and minor braiding. The lower portion of this section also includes long runs and larger pools.

Section {3} — Bailey Bridge to 23-Mile Slough. This section is easily accessed by a road and a path, respectively. In this section, a habitat transition occurs; the variability seen in the upstream areas is reduced. This section is generally wide and slow moving, with an increased volume.

Section {4} 23-Mile Slough to Eielson Farm Road. This section is easily accessed by a path and a road, respectively. This section is primarily broad and slow, with some deep pools and few riffle areas.

In several headwater segments comprising 21 km of Piledriver Slough (sections {1}, {6} and part of {2}) fish were absent at the time of assessment, owing to aufeis accumulations and several unbreached beaver dams (Figure 2). No fish were located upstream of the blockages during foot surveys. The upstream limit of fish distribution and the 1996 study area boundary was located at a new unbreached beaver dam, 13.8 km above the Bailey Bridge Rd (Figure 2). The downstream sampling boundary was at the Eielson Farm Road (Figure 2).

Mark-recapture sampling in 1996 occurred over a longer duration than in earlier assessment years. Sampling began on May 21 and finished on June 27. Three four-day sampling events were completed by a single electrofishing crew of five to seven people. Each sampling event began at the upstream boundary (beaver dam) and was conducted systematically downstream to the lower study area boundary. The backpack electrofishing techniques were identical to previous assessments (Timmons and Clark 1991, Fleming 1991, Fleming and Schisler 1993, Fleming 1994) but were supplemented with the use of block-nets (10 m beach seines composed of 20 mm braided mesh) to increase capture efficiency. First, two crew members proceeded downstream of the electrofishing crew and stretched the beach seine across the channel, in the tail-out areas of pools. After the block-net was in place, the electrofishing crew fished downstream towards the net.

All initially captured Arctic grayling $\geq$ 150 mm FL were dipped from the water, measured to the nearest 1 mm FL, and examined for finclips and tags. Fish captured during the first sampling event were given an upper caudal finclip, tagged with an individually numbered Floy™ FD-67 internal anchor tag, and released. Fish captured during the second sampling event were given a lower caudal finclip, tagged, and released. Fish captured during the third sampling event were given a left pelvic finclip and released.

Scales were collected from all fish for aging. Scales were collected from the area approximately six scale rows above the lateral line, just posterior to the dorsal fin's insertion of each Arctic grayling's left flank, and were mounted directly on gum cards.

Ages were determined by counting annuli from impressions of scales magnified to 40X with the aid of a microfiche reader. Criteria for determining the presence of an annulus are: 1) complete circuli cutting over incomplete circuli; 2) clear areas or irregularities in circuli along the anterior and posterior fields; and, 3) regions of closely spaced circuli followed by a region of widely spaced circuli (Kruse 1959).

In 1994, a picket weir was used to assess the stock of Arctic grayling in Piledriver Slough (Fleming 1995). The investigation characterized Arctic grayling immigration and emigration to- and from the study area at the time of mark-recapture sampling. Approximately 90% of the stock was determined to have entered the slough prior to the set-up of the weir on April 12, 1994. By completion of the weir project in early June 1994, only 3% of the Arctic grayling had moved downstream of the study area. Ultimately, the weir passage findings helped validate assumptions of closure during mark-recapture sampling conducted at Piledriver Slough, generally between late-April and late-May.

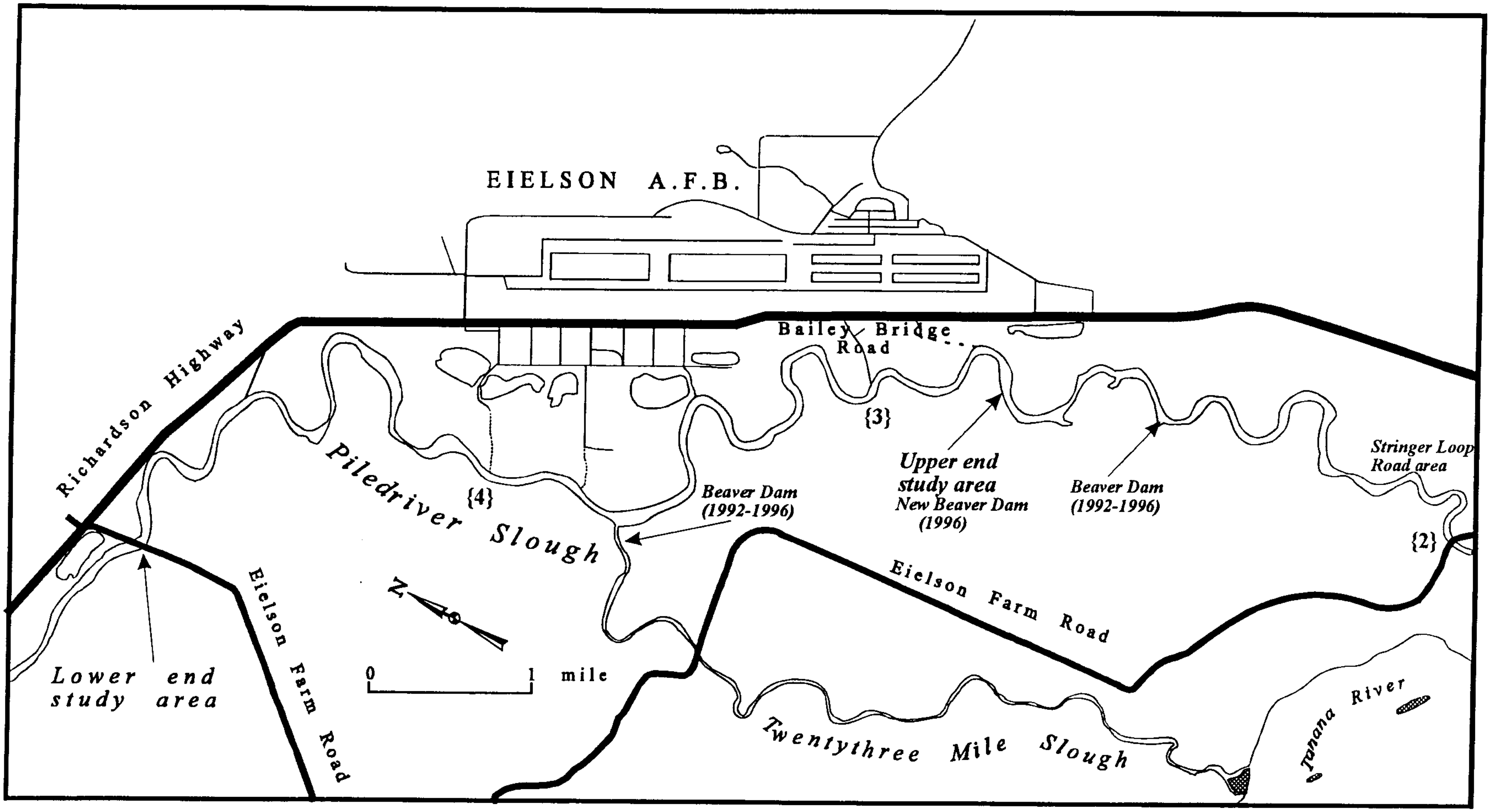

Figure 2.-Map of Piledriver Slough study area. Numbers delineate the upper boundary of each sampling section.

Fork length, finclips, and tag numbers were recorded on Tagging-Length forms (Version 1.0). Data collection procedures from previously marked Arctic grayling were similar, but previous tag numbers, and colors were recorded.

ABUNDANCE ESTIMATION

A closed-model mark-recapture experiment was used to estimate the abundance of Arctic grayling in Piledriver Slough in 1996, similar to the approach used in 1992, 1993 and 1994. The use of a closed-model mark-recapture abundance estimator assumes the following (Seber 1982):

1. the population in the study area must be closed, i.e. the effects of migration, mortality, and recruitment are negligible;
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 completely 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 the first and second sampling events.

Assumption 1 could not be fully validated because of the prolonged study duration. A second sampling event was added after catches from the first sampling event were insufficient to meet marking objectives. Higher catches throughout the study area and observations of immigrating fish near the completion of the second sampling event indicated not all Arctic grayling were present after the first sampling event.

Although additional unmarked fish entered the study area, weir passage data (Fleming 1995), summer fidelity detected during 1991 (Fleming 1991), and the examination of lengths from marked and recaptured grayling in 1996 indicated that large-scale emigration (outmigration) was unlikely.

Assumptions 2 and 3 were then examined by testing for differences in capture probability by geographic area and by size. Spatial differences in capture probability were evaluated through comparisons of area-specific recapture-to-catch ratios. Results of this test determined whether the abundance estimation model should be stratified by area. Size selectivity was tested with two Kolmogorov-Smirnov (KS) two-sample tests. The first KS test compared the cumulative length frequency distributions of marked and recaptured Arctic grayling. The second KS test compared cumulative length frequency distributions of Arctic grayling from the first (mark event) and second (recapture event) samples. The results of these tests suggested methods to alleviate size biases (Appendix A1). Assumption 4 was satisfied by using easily identified finclips that could not be shed during the study.

Capture probabilities varied significantly between sampled areas. Separate population estimates were calculated for each resulting stratum (area). The resulting independent estimates were then summed to produce an estimate of abundance. Additionally, an unstratified estimate of abundance was calculated for comparison.

The two KS tests indicated that only first event sampling was size selective, not requiring further stratification of the data. Abundance of Arctic grayling was estimated using the modified

Petersen estimator of Bailey (1951, 1952). Bailey's modification was used because of the systematic sampling approach and the level of mixing (localized, not complete; Seber 1982) of marked and unmarked fish over the length of the sampling area (Seber 1982). Stratified and unstratified point estimates of abundance were calculated as:

$$\hat{N} = \frac{n_1(n_2+1)}{(m_2+1)} \tag{1}$$

where:

$\hat{N}$ = the abundance of Arctic grayling in Piledriver Slough (≥150 mm FL);

n_1=the number of Arctic grayling marked and released during the first event;

n_2=the number of Arctic grayling examined for marks during the second event; and,

m_2=the number of Arctic grayling recaptured in the second event.

Variance of this estimator was calculated by (Bailey 1951, 1952):

$$V\left[\hat{N}\right] = \frac{(n_1)^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \tag{2}$$

AGE AND SIZE COMPOSITIONS

Apportionment of the estimated abundance among age or size groupings depends on the extent of sampling biases. The outcome of tests (for size selectivity, and chi-square tests to detect geographic differences in capture probabilities), determined the necessary adjustments. Because adjustments were required for geographic differences in capture probability, the proportion of fish at age *k* (or length class *k*) was estimated using the appropriate sample (Appendix A1: from the first event, second, or both events) by:

$$\hat{p}_k = \frac{y_k}{n} \tag{3}$$

where:

$\hat{p}_k$ = the proportion of Arctic grayling that were age *k*;

y_k = the number of Arctic grayling sampled that were age *k*; and,

n = the total number of Arctic grayling sampled.

*The unbiased variance of this proportion was estimated as:

$$\hat{V}\left[\hat{p}_k\right] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \tag{4}$$

To adjust age and size data, the proportion of fish at age is calculated by summing independent abundances for each age or size class and then dividing by the summed abundances for all age or size classes. First the conditional proportions from the sample were calculated:

$$\hat{p}_{jk} = {n_{jk}}/{n_j} \qquad (5)$$

where:

n_j = the number sampled from area stratum *j* in the mark-recapture experiment;

n_{jk} = the number sampled from area stratum *j* that are age *k*; and,

$\hat{p}_{jk}$ = the estimated proportion of age *k* fish in area stratum *j*.

The variance calculation for $\hat{p}_{jk}$ was identical to equation 4 (with appropriate substitutions).

The estimated abundance of age *k* fish in the population is then:

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk}\hat{N}_j \qquad (6)$$

where:

N_j = the estimated abundance in area stratum *j,* and ;

s = the number of area strata.

The variance for $\hat{N}_k$ in this case is approximated by the delta method (Seber 1982):

$$\hat{V}\left[\hat{N}_k\right] \approx \sum_{j=1}^{s}\left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + V\left[\hat{N}_j\right]\hat{p}_{jk}^2\right). \qquad (7)$$

The estimated proportion of the population that are age *k* $\left(\hat{p}_k\right)$ is then:

$$\hat{p}_k = \hat{N}_k / \hat{N} \qquad (8)$$

where: $\hat{N} = \sum_{j=1}^{s} \hat{N}_j$

Variance of the estimated proportion can be approximated with the delta method (Seber 1982):

$$\hat{V}\left[\hat{p}_k\right] \approx \sum_{j=1}^{s}\left\{\left(\frac{\hat{N}_j}{\hat{N}}\right)^2 \hat{V}\left[\hat{p}_k\right]\right\} + \frac{\sum_{j=1}^{s}\left\{V\left[\hat{N}_j\right]\left(\hat{p}_{jk} - \hat{p}_k\right)^2\right\}}{\hat{N}^2} \qquad (9)$$

Equations 5 through 9 are also used to adjust biased size composition estimates, replacing the number sampled at age *k* that are also in are strata *j* (n_{jk}) with the number sampled per 10 mm FL incremental size category *k* (*k* = 155,165,175...395) that are also in area strata *j*.

RESULTS

SAMPLING

Mark-recapture sampling was conducted over 13.8 km of Piledriver Slough. A new unbreached beaver dam shortened the accessible portion of the slough by 2.3 km (Table 2). The electrofishing crew captured and sampled 298 Arctic grayling ($\geq$ 150 mm FL) of which 292 were released with gray tags and upper caudal finclips during the first downstream sampling event. In the second downstream sampling event, an additional 519 fish were sampled and 516 were released with gray tags and lower caudal finclips. The total marking sample included 808 Arctic grayling, which were released between May 21 and May 31. Water temperatures ranged between 3° and 13°C during the 11-day period.

On June 24, the electrofishing crew resumed sampling after a 23-day hiatus. This third downstream sampling event constituted the recapture sampling event. The crew captured and examined 1,012 Arctic grayling (1,009 fish $\geq$ 150 mm FL) for marks over the four day period. This sample yielded the recovery of 91 marked Arctic grayling released during the marking event. The overall acute mortality rate from mark-recapture sampling in 1996 was 12 fish out of 1,738 individual Arctic grayling handled, or 0.6%.

ABUNDANCE ESTIMATION

Unequal capture probabilities (recapture-to-catch rate) were detected from three different sections which comprise the Piledriver Slough study area (χ^2 = 7.09, df = 2, P = 0.03). Similar capture probabilities in the upper and middle sections (0.12 and 0.11, respectively) allowed pooling. After pooling, two 6.9 km sections of differing capture probabilities resulted: pooled section {2, 3} and section {4} (χ^2 = 6.95, df = 1, P = 0.008). The capture probabilities, expressed as the recapture-to-catch rate, in pooled section {2, 3} was 0.11 and 0.06 in section {4}.

The KS tests on the upstream section data suggest that size selectivity was present during the June sampling event (Figure 3A - mark vs recaptures: D = 0.14, P = 0.172; and, Figure 3B - mark vs catch: D = 0.28, P < 0.001). The KS tests on the ***downstream*** section data inferred that size selectivity was present during the June sampling event (Figure 4A -mark vs recaptures: D = 0.11, P = 0.92; and, Figure 4B - mark vs catch: D = 0.25, P < 0.001).

As a result, abundance was estimated using a stratified approach with respect to two discrete sampling sections (strata), and stock composition estimates were based on the second sampling

Table 2.-Tabulated statistics from the Piledriver Slough Arctic grayling fishery and assessed stock, 1990-1996.

Fishery Year	Fishery status	Abundance ≥ 150 mm	Harvest (Mills)	Habitat[a] available	Proportion[b]		Density (fish per km)	
					Ages 1-4	Ages 5+	< 270 mm	≥ 270 mm
1990	Open	16,435	2,380	31.0	0.54	0.46	442	72
1991	Open	17,323	3,987	34.6	0.41	0.59	365	135
1992	Open	14,030	1,030	16.1	0.42	0.58	619	253
1993	C&R[c]	10,587	759	16.1	0.51	0.49	526	131
1994	C&R	11,747	57	16.1	0.53	0.47	455	275
1995	C&R	nd	0	nd	nd	nd	nd	nd
1996	C&R	9,981	nd	13.8	0.66	0.34	534	188
Average	----	11,392	---	---	0.51	0.49	500	196

[a] Habitat available refers to the number of stream kilometers that are accessible to immigrating fish.

[b] The summed proportions for the age groupings and densities are calculated from past assessments (1990: Timmons and Clark 1991, 1991: Fleming 1991, 1992: Fleming and Schisler 1993, 1993: Fleming 1994, 1994: Fleming 1995, and; 1996: the present study.

[c] In 1993 the fishery was open until it was closed to harvest by Emergency Order on June 26, 1993.

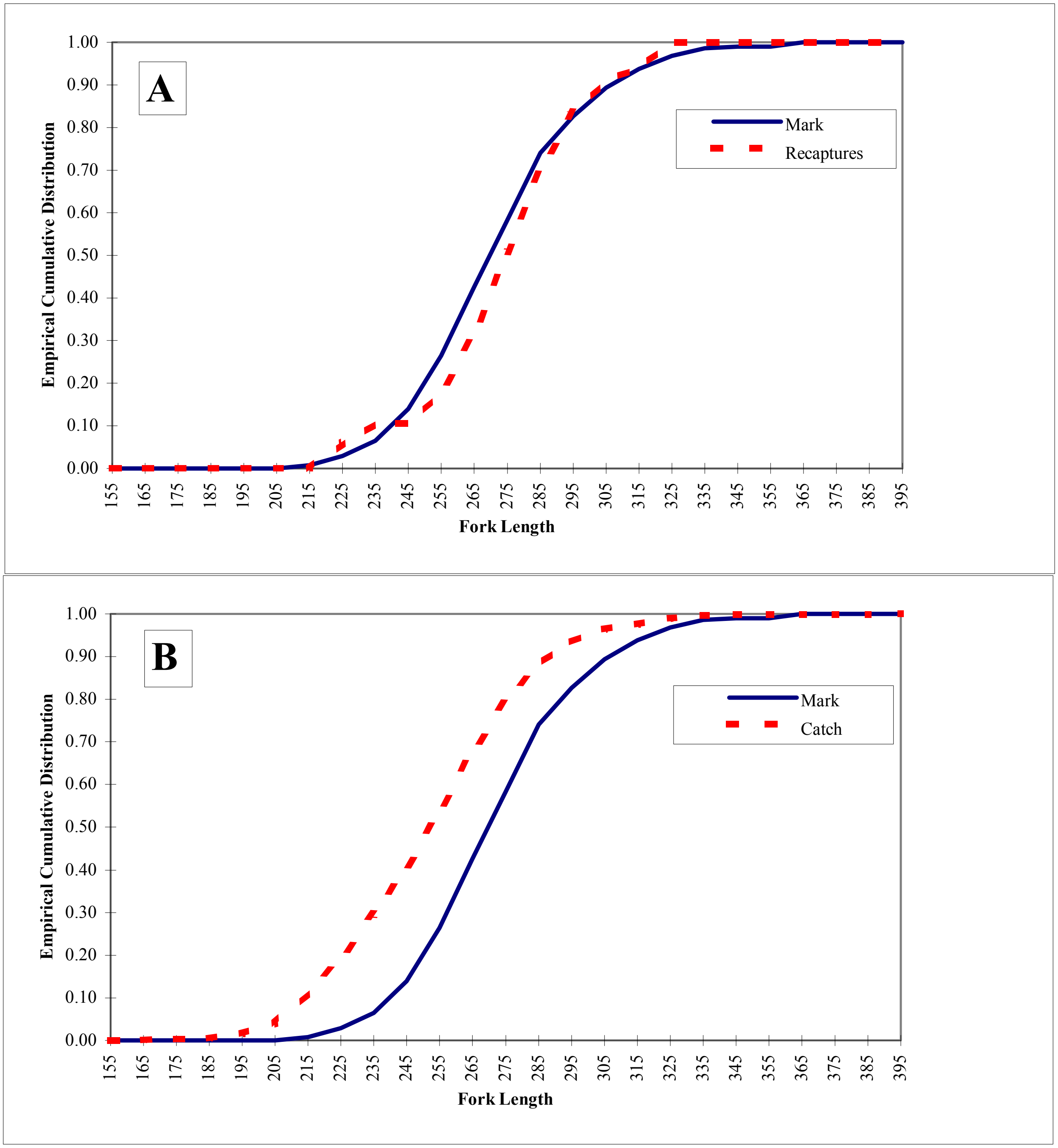

Figure 3.-Empirical cumulative distribution of lengths of Arctic grayling marked (n=416) versus lengths of Arctic grayling recaptured (n=67) in the upstream strata (A) and, versus lengths of Arctic grayling examined for marks (n=613) in the upstream strata (B) in Piledriver Slough, May 21 through June 27, 1996.

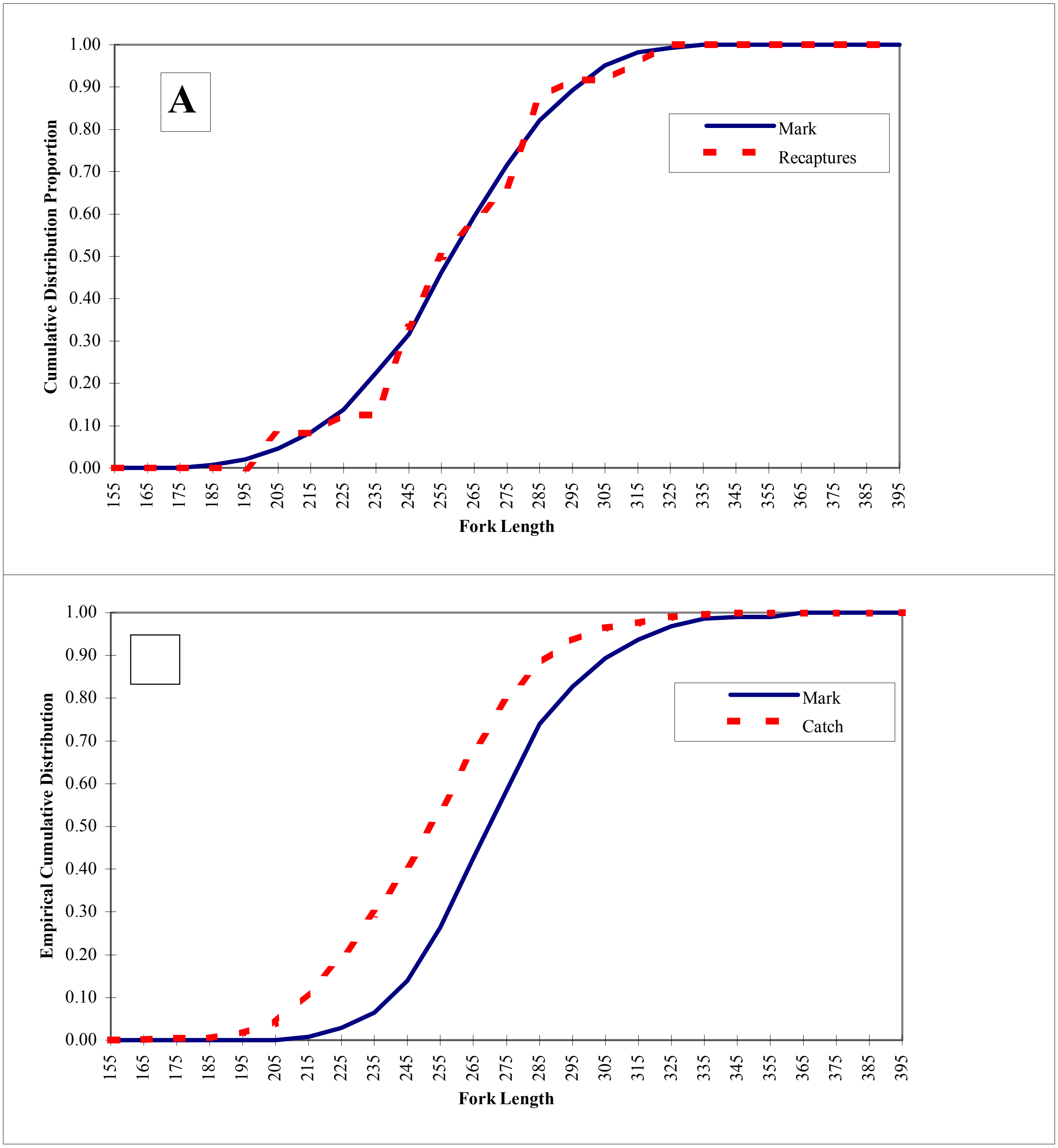

Figure 4.-Empirical cumulative distribution of lengths of Arctic grayling marked (n=392) versus lengths of Arctic grayling recaptured (n=24) in the downstream strata A) and, versus lengths of Arctic grayling examined for marks (n=396) in the downstream strata (B) in Piledriver Slough May 21 through June 27, 1996.

event (Case II; Appendix A1). The estimated abundance was germane to the second sampling event (June) after unmarked fish were observed migrating upstream into the study area, at the end of the marking event (May). The examination of assumptions led to the selection of the Bailey modification of the Petersen estimate as the appropriate estimator:

Strata {section}	Mark M	Catch C	Recap R	Capture Probability	Abundance N-hat	Standard Error
Upstream {2, 3}	416	613	67	0.11	3,756	426
Downstream {4}	392	396	24	0.06	6,225	1,182
Total	808	1,009	91	----	9,981	1,256

The estimated abundance of Arctic grayling (≥ 150 mm FL) was 9,981 fish (summed stratified: SE = 1,256, CV = 11%) that were resident in the 13.8 km study area at the time of the second sampling event (June) in 1996. The total density of all Arctic grayling (≥ 150 mm FL) in Piledriver Slough during 1996 was 722 fish/km. This estimate includes 534 fish/km < 270 mm FL (Table 2) and 188 fish/km ≥ 270 mm FL[1] (Table 2).

AGE AND SIZE COMPOSITIONS

Arctic grayling ranged from ages 2 to 11, with age-4 as the median age. The predominant age class was age-3 (38% of the stock; Table 3) followed by age-4 (24% of the stock). The size distribution of past and present assessed stocks (Figure 5) indicated recent decreases in the estimated abundance of Arctic grayling 12 in TL (≥ 270 mm FL) or larger (legal-sized). In 1996, the estimated abundance of Arctic grayling (≥ 270 mm FL) had decreased (Z test: Z= 3.01, P = 0.001) from 4,422 fish (SE = 487 fish) in 1994 to 2,607 fish (SE = 355 fish). In 1996, the estimated recruitment was 1,512 fish (SE = 230 fish) that were age-5 (Figure 6), and the proportion of the assessed stock that included partially recruited age classes (ages 1-4) was 0.66 (Table 2).

DISCUSSION

In 1996, the timing of the Arctic grayling migrations into Piledriver Slough was later than all previous assessments, and added risks to violation of assumptions of the mark-recapture sampling project. During the initial downstream sampling event, we found complete channel blockages formed from aufeis accumulation that were up to 2.5 m thick, and many ice bridges which spanned the slough channel. Electrofishing catches were well below average and it took two downstream sampling events (with supplementing 20 mm mesh beach seines used as block nets) to approximate the lowest catch in past mark-recapture sampling (887 fish; Fleming 1994). Near completion of the second event, small schools of unmarked Arctic grayling were directly observed moving upstream through a breached beaver dam into the study area. At this time we determined that an additional sampling event would be necessary to accurately assess the late-

[1] The Arctic grayling legal size limit in Piledriver Slough was 12 in or larger in total length (which corresponds to 270 mm FL) during previous years when the fishery was open to harvest.

Table 3.-Estimates of the sampled contributions by each age class and 10 mm FL incremental size groupings for Arctic grayling (≥150 mm FL) captured in Piledriver Slough, 24 through 26 June 1996[a].

Age	Count[b]	$\hat{P}$[c]	SE[d]	Length	Count[b]	$\hat{P}$[c]	SE[d]
1	0	0.00	----	155	3	<0.01	<0.01
				165	6	0.01	<0.01
2	25	0.04	0.01	175	7	0.01	<0.01
				185	11	0.02	<0.01
3	319	0.38	0.02	195	16	0.02	<0.01
				205	35	0.04	0.01
4	213	0.24	0.02	215	65	0.06	0.01
				225	91	0.09	0.01
5	145	0.15	0.01	235	117	0.12	0.01
				245	127	0.13	0.01
6	107	0.10	0.01	255	118	0.11	0.01
				265	127	0.12	0.01
7	49	0.05	0.01	275	108	0.10	0.01
				285	80	0.07	0.01
8	21	0.02	< 0.01	295	43	0.04	0.01
				305	25	0.02	<0.01
9	12	0.01	< 0.01	315	11	0.01	<0.01
				325	11	0.01	<0.01
10	4	<0.01	< 0.01	335	4	<0.01	<0.01
				345	1	<0.01	<0.01
11	3	<0.01	< 0.01	355	2	<0.01	<0.01
				365	0	----	----
12	0	---	----	375	0	----	----
				385	0	----	----
				395	1	<0.01	<0.01
Total	898	1.00	----	Total	1,009	1.00	----

[a] Age and size compositions estimates were germane to the second event, June 24 through 26, 1996.

[b] Number of sampled individuals which yielded age or size information in each age or 10 mm FL incremental size class.

[c] $\hat{P}$ = adjusted proportion of Arctic grayling in the assessed stock at the time of the second sampling event, June 24 through 26, 1996.

[d] SE = standard error of the proportional contribution.

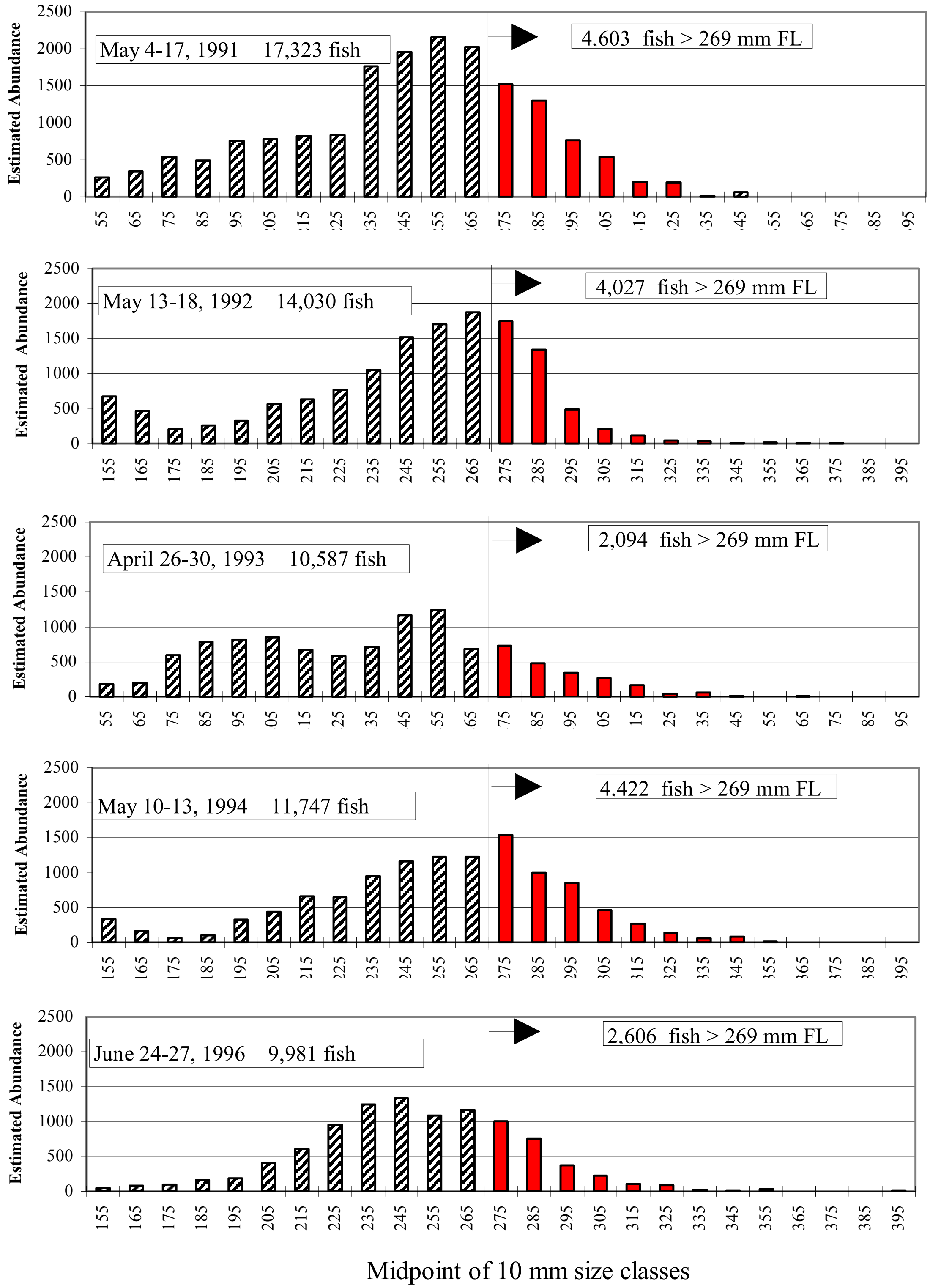

Figure 5.-Apportionment of estimated abundance across 10 mm FL incremental size categories for Arctic grayling (≥ 150 mm FL) in Piledriver Slough stock assessments between 1991 and 1996.

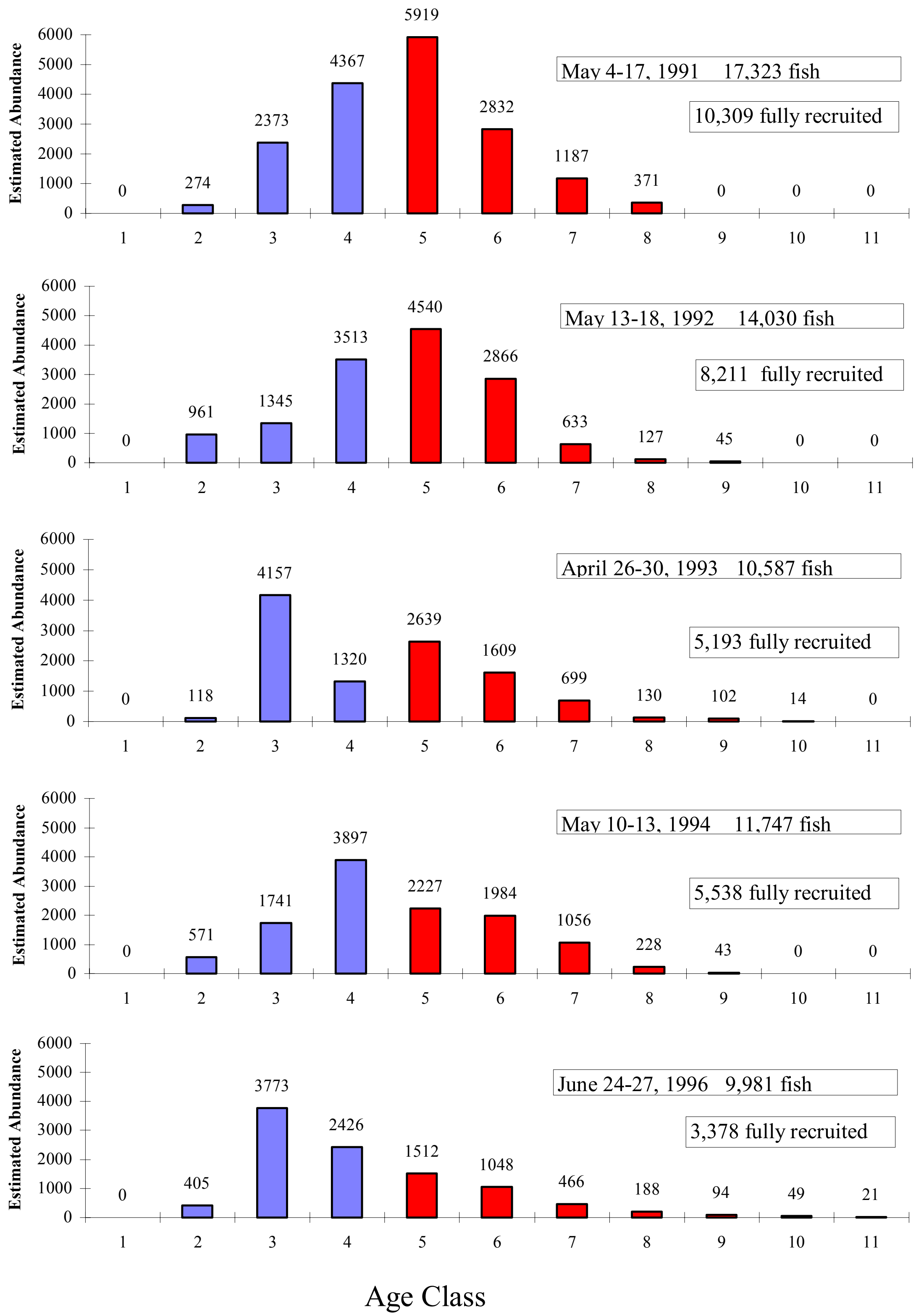

Figure 6.-Distribution of estimated abundance across age classes for Arctic grayling ≥ 150 mm FL) in Piledriver Slough stock assessments between 1991 and 1996.

arriving population. We based this on the facts that the marking sample size was not achieved during the first sampling event (n=292), and the continued immigration at the end of the second sampling event indicated that estimates using only the first two sampling events would not estimate abundance of the whole stock.

After a longer-than-usual hiatus (23 days), the size composition in the recapture sampling event had shifted towards smaller fish. Statistical comparisons of length distributions of May and June catches supported this observation (Figures 3b and 4b). There also was a risk that given the longer hiatus, a post-spawning outmigration of larger fish may have occurred, leading to the observed size-shift. Although past investigations (Timmons and Clark 1991, Fleming 1991, Fleming 1994), and summertime angling reports indicate larger Arctic grayling remain after spawning, it is possible that some level of emigration occurred. However, assumption testing on the lengths of fish marked and recaptured did not indicate that large fish left between the first and second sampling events (Figures 3a and 4a). Although results of the mark-recapture experiment appeared to be relatively free of bias, future mark-recapture experiments should coincide with completion of the pre-spawning immigration of Arctic grayling into Piledriver Slough.

Results from the assessment study did not indicate stock rebuilding had occurred between 1994 and 1996 at Piledriver Slough, following nearly three years of catch-and-release regulation. Although the 1996 estimated abundance was statistically similar to recent year abundances (1992-1994), a downward trend in abundance exists. However, the overall density of Arctic grayling has remained high (Table 2).

Age composition data indicated the presence of a strong age-3 year class during the 1996 assessment. The combined strength of pre-recruit year classes (fish younger than age-5; Fleming and Schisler 1993) have suggested an increasing trend or tendency towards a stock composed of younger fish (Table 2). Unfortunately, the 1996 estimated recruitment (1,512 age-5 Arctic grayling) was the lowest point estimate in six years of assessment, and the observed recruitment trend has been downward. This has also been expressed by fewer legal-sized (≥ 270 mm FL) Arctic grayling (Figure 5).

Reductions in quantity and quality of available Arctic grayling habitat may limit the stock's ability to return to former abundance levels. Beaver dams have been built and maintained in the headwater areas of the slough since 1990, when assessment began. This has led to a 60% reduction in available Arctic grayling habitat in Piledriver and 23-Mile sloughs (Table 2). Moreover, the expected stock rebuilding from conservative management has not occurred. The no-harvest policy may be conserving legal-sized (270 mm FL or 12 in TL) fish at abundance levels dictated by a new (reduced) carrying capacity for Piledriver Slough.

Although Piledriver Slough's remaining habitat may be optimal for spawning and juvenile rearing, the same available habitat may not be of sufficient quantity and quality for summer feeding adults. In several locations, beaver dams have forced water out of the active channel into adjacent areas of sedge meadow *Carex* spp. and riparian stands of alder *Alnus* spp. and willow *Salix* spp. (D. Fleming- ADF&G, unpublished data). These shallow areas can modify (heat or cool) the water temperature before it moves downstream of the beaver dam. Although warming may benefit the production of smaller fish, adult Arctic grayling often leave spawning areas when water temperatures reach 11°C or more, and seek out cooler feeding areas (MacFee and Watts 1976, Craig and Poulin 1975, Tack 1980, Ridder 1983, 1991). Badger Slough, which is also a blocked Tanana River slough with groundwater upwelling, has numerous road culverts and beaver dams. The channel and riffle areas have become filled in, and water temperatures have been found to exceed those at Piledriver Slough (Wuttig, *In prep*). Following spawning, most adult Arctic grayling are believed to migrate to the Chena River (Clark 1996). It would follow that post-spawning emigration and a corresponding decrease in summer angling opportunities may occur in Piledriver Slough, with continued losses or modifications to Piledriver Slough's habitat.

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APPENDIX A

Appendix A1.-Methods for detection of gear selectivity and bias reduction.

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.