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Comparative Performance of Stocked Mixed-Sex and All-Female Rainbow Trout and Diploid and Triploid Coho Salmon in Landlocked Lakes in Southcentral Alaska, 1994 and 1995

by

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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

FISHERY DATA SERIES NO. 96-23

COMPARATIVE PERFORMANCE OF STOCKED MIXED-SEX AND ALL-FEMALE RAINBOW TROUT AND DIPLOID AND TRIPLOID COHO SALMON IN LANDLOCKED LAKES IN SOUTHCENTRAL ALASKA, 1994 AND 1995

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

Survival and growth of mixed-sex rainbow trout were compared to all-female rainbow trout by stocking the two treatment groups at equal densities in Long (Kepler-Bradley lakes complex), Johnson, and "X" lakes in Southcentral Alaska in July 1993. Rainbow trout were age 0+ and average weight was 1.1 g at stocking. Proportions and mean lengths at age 1+ and age 2+ were estimated for each group in May 1994, September 1994, and September 1995. Survival, from stocking in July 1993 to September 1994, of the two groups was also compared. Proportion of all-female rainbow trout remained near 50% for Long and Johnson lakes, but varied from 37% to 48% for "X" Lake. In May 1994 and September 1994, mixed-sex rainbow trout were significantly larger than all-female rainbow trout, but by less than 5 mm. In September 1995, mixed-sex rainbow trout were significantly larger in Johnson and Long lakes, but were significantly smaller in "X" Lake; the length differences for all lakes were less than 20 mm. Survival of rainbow trout from stocking in July 1993 to September 1994 was about 9% for Long Lake, about 11% for Johnson Lake, and about 2% for "X" Lake. In September 1994, abundance of mixed-sex and all-female rainbow trout was not significantly different for all three lakes.

Diploid and triploid coho salmon were stocked at equal densities in Johnson Lake during May 1994. Diploid coho salmon averaging 6.8 g and triploid coho salmon averaging 6.0 g at stocking were used for this experiment. Proportions and mean lengths of the two groups were compared in September 1994 and September 1995. Diploid coho salmon were significantly larger than triploid coho salmon in both years. In September 1994, 56% of the stocked coho salmon were diploid, 44% were triploid; in September 1995, 75% were diploid and 25% were triploid.

Key words: Southcentral Alaska, lake stocking practices, rainbow trout, *Oncorhynchus mykiss*, coho salmon, *Oncorhynchus kisutch,* mixed-sex, all-female, triploid, diploid, abundance, growth, survival, stocking evaluation.

INTRODUCTION

In Southcentral Alaska, selected landlocked lakes have been stocked on an annual or biannual basis with hatchery-reared sport fish since 1952. To date more than 60 lakes are stocked in the Matanuska-Susitna Valley alone. These stocked lakes benefit sport anglers and industries related to sport fishing by providing diverse, year-round fishing opportunities and by diverting pressure from natural stocks. The majority of these stocked lakes range in size from approximately 1 to 362 surface acres, and prior to stocking were either barren of fish or contained only threespined stickleback *Gasterosteus aculeatus* and longnosed suckers *Catostomus catostomus*. Most of these lakes are now stocked with rainbow trout *Oncorhynchus mykiss*, Arctic grayling *Thymallus arcticus*, landlocked salmon *Oncorhynchus*, or Arctic char *Salvelinus alpinus* depending on the nature of the water to be stocked, the availability of fish for stocking, and the desires of anglers for diversified fishing opportunities.

A study designed to provide information to improve lake stocking practices was initiated in 1973. The early phase of this project concentrated on collection of detailed physical and chemical data and indexing various plankton and invertebrate populations in stocked lakes. Since 1976, survival and growth of stocked sport fish have been estimated in lakes of known limnological characteristics. Accomplishments to date include but are not limited to: (1) selection of a native strain of rainbow trout from the Swanson River on the Kenai Peninsula as brood stock for Alaska's lake stocking program (Havens 1980), (2) implementation of early spawning of hatchery rainbow trout brood stock which resulted in rainbow trout fingerling being stocked in July when threespined stickleback densities are lowest (Havens 1985), and (3) recommendations for stocking densities of rainbow trout fingerlings (Havens and Sonnichsen 1992). In addition, experiments were performed in 1989 and 1990 comparing survival and mean length of mixed-sex triploid (sterile) and mixed-sex (normal) rainbow trout stocked as fingerlings in a landlocked lake. Results indicated a slightly higher survival for diploid rainbow trout but no significant difference between triploid or diploid mean length through age 2 (Havens 1991).

The Alaska Department of Fish and Game Broodstock Development Center (BDC) at Fort Richardson Hatchery began producing groups of all-female rainbow trout in 1991 in an effort to reduce the number of brood stock required to meet annual fingerling and subcatchable production needs. The hypothesized benefit of stocking all-female populations is to eliminate some of the problems associated with precocious males. These problems include sexual maturation, associated secondary characteristics, and mortality.

Long (Kepler-Bradley lakes complex or K/B), Johnson, and "X" lakes (Figure 1, Appendix A1), which were stocked with rainbow trout during these investigations, contained several age classes of rainbow trout that had been stocked as fingerlings in previous years. "X" and Long lakes have been closed to the retention of rainbow trout since 1989 and only unbaited, single-hook, artificial lures are allowed. Long Lake, located in a popular State Recreation Area, receives relatively heavy sport fishing pressure, while "X" Lake is less accessible and receives substantially less fishing effort. Johnson Lake is an experimental lake that is closed to public sport fishing.

Landlocked coho salmon are a popular sport fish in Southcentral Alaska's stocked lakes. However, the department terminated the stocking of landlocked coho salmon in lakes which, by nature, are usually landlocked (no inlet or outlet) but periodically experience high water events. These high water events may allow stocked coho salmon to escape these lakes and mix with wild fish. Success of the triploid rainbow trout program (Havens 1991) led us to test this technique with coho salmon.

Triploidization has yielded increased survival in interspecific hybrids when compared to their diploid counterparts in salmonids (Chevassus et al. 1983; Scheerer and Thorgaard 1983; Arai 1986; Sheerer et al. 1987; Seeb et al. 1988; Yamano and Yamazaki 1988). Triploid hybrids may also show increased growth (Stanley et al. 1984; Benfey et al. 1989) and disease resistance (Dorson and Chevassus 1984; Parsons et al. 1986; and Dorson et al. 1991). The Alaska Department of Fish and Game BDC at Fort Richardson Hatchery began producing triploid coho salmon in 1993.

In addition to preventing genetic mixing with native coho salmon stocks, we also hypothesize that triploidy will increase longevity. Almost all landlocked coho salmon reach sexual maturity and die prior to their third winter of lake residence. Triploidy may retard sexual maturation, allowing for greater longevity. Depending upon survival rates this would increase anglers' chances of catching larger, older fish. In addition to sterility, triploidy may also reduce the levels of precocity observed in male coho salmon (Silverstein and Hershberger 1992).

This report presents results from 2 years (1994 and 1995) of a study comparing survival and growth between all-female and mixed-sex rainbow trout, and between diploid and triploid coho salmon stocked in lakes. Triploid and diploid coho salmon were only stocked in Johnson Lake. Long, Johnson, and "X" lakes (Appendix A1) were stocked with rainbow trout during these investigations.

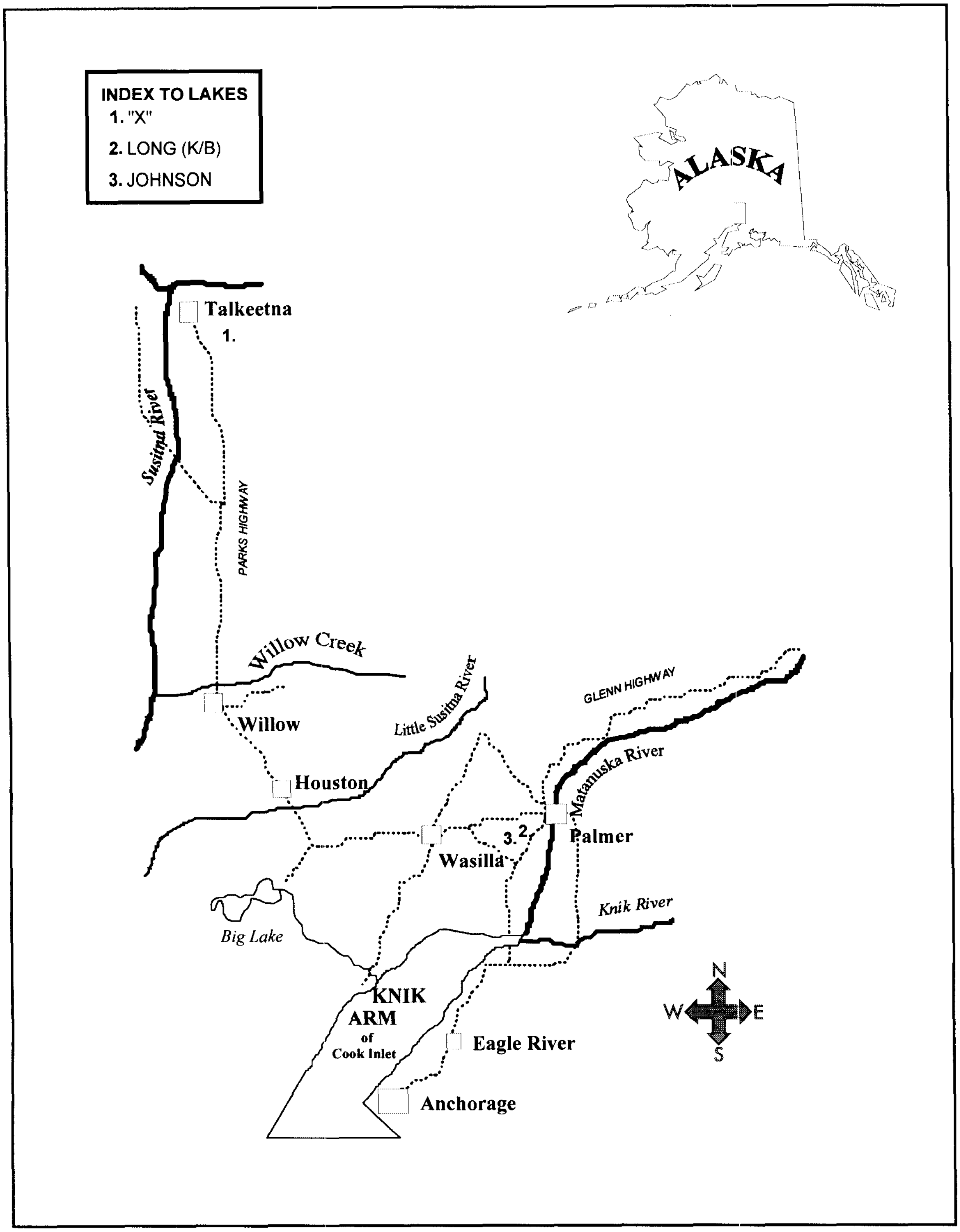

Figure 1.-Location of sampled lakes in the Matanuska-Susitna Valley.

The specific objectives for the 1994 and 1995 studies were:

1. To estimate the proportion and mean length of age-1 and age-2 mixed-sex rainbow trout and all-female rainbow trout captured in May and June 1994, that were stocked as fingerlings in Long, Johnson, and "X" lakes in the summer of 1993;
2. To test the null hypothesis that there is no difference in mean length in May and June, and in September and October 1994, between age-1+ all-female and mixed-sex rainbow trout stocked in Long, Johnson, and "X" lakes in 1993;
3. To estimate the proportion and mean length of age-1+ and 2+ mixed-sex and all-female rainbow trout captured in September 1994 and 1995, respectively, that were stocked as fingerlings in Johnson, Long, and "X" lakes during May 1994;
4. To test the null hypothesis that there is no difference in mean length in September 1995 between age-2+ all-female and mixed-sex rainbow trout stocked as fingerlings in Johnson, Long and "X" lakes in the spring of 1994;
5. To estimate the abundance and survival in September and October 1994 of age-1+ mixed-sex rainbow trout and all-female rainbow trout stocked as fingerlings in Long, Johnson, and "X" lakes in the summer of 1993;
6. To test the null hypothesis that there is no difference in survival from stocking to September and October 1994 between age-1+ all-female and mixed-sex rainbow trout stocked in Long, Johnson, and "X" lakes in 1993;
7. To test the null hypothesis that there is no difference in survival from stocking to September 1995 between age-1+ and age-2+ all-female and mixed-sex rainbow trout stocked in Long, Johnson, and "X" lakes in 1993 and 1995, respectively;
8. To estimate the proportion and mean length of age-1+ diploid and triploid coho salmon captured in September 1994 and 1995 that were stocked as fingerlings in Johnson Lake during May of 1994; and
9. To test the null hypothesis that there is no difference in mean length in September 1994 and 1995 between age-0+ and age-1+ triploid and diploid coho salmon stocked in Johnson Lake in the spring of 1994.

METHODS

Two experiments were conducted in this study, each with two different treatments. The first compared all-female rainbow trout to mixed-sex rainbow trout. The second compared triploid coho salmon to diploid coho salmon.

Comparison of Mixed-sex Versus All-female Rainbow Trout

Production and Rearing

All rainbow trout were raised at the Fort Richardson Hatchery. Mixed-sex rainbow trout were the result of matings between randomly selected females and males of Swanson River origin. All-female rainbow trout were the result of matings between randomly selected females and sex-reversed (XX) males, both of Swanson River origin. To make sex-reversed males, genetically-female rainbow trout were fed the male hormone testosterone immediately after emergence for a period of 50 days. At sexual maturity these sex-reversed (XX) males produced sperm that had only X sex chromosomes. All offspring of these males were female and it was these female offspring that comprised the all-female populations reared at Fort Richardson Hatchery. In all other aspects these fish appeared to be normal rainbow trout (Olito and Brock 1991).

During incubation and rearing, standard hatchery procedures were used for both mixed-sex and all-female rainbow trout populations. Each treatment group was kept in a separate raceway and were distinguished by a separate "lot number" on rearing records.

Stocking

All rainbow trout were stocked as age 0+ fingerlings weighing between 1.1 g and 1.4 g at stocking. All rainbow trout were marked at the hatchery prior to stocking: mixed-sex rainbow trout were given a left ventral finclip and all-female rainbow trout were marked with a right ventral finclip. In July 1993, Long, Johnson, and "X" lakes were stocked with mixed-sex and all-female rainbow trout fingerlings at ratios of 50:50 (100 fish per surface acre for each treatment for a total of 200 fish per surface acre). Long, Johnson, and "X" lakes contained no other fish with ventral finclips.

Rainbow trout recruit to the sport fishery at 165 mm FL (Al Havens, Alaska Department of Fish and Game, Palmer, personal communication). This length is reached in the fall, a year after stocking (age 1+). In 1994, all three lakes were sampled in the spring and fall; in 1995 all three lakes were sampled during the fall only.

Capture and Handling

Rainbow trout were captured using fyke nets baited with salmon eggs set parallel to the shoreline in randomly selected sites; direction of the trap opening (left or right) was also determined randomly. Nets were checked approximately every 24 hours. The fyke nets were 2.7 m (9 ft) in length, 0.8 m (30 in) in diameter, and included two 0.9 m (3 ft) by 6.1 m (20 ft) wings (two square aluminum frames and six steel or aluminum hoops supported the entrance and body of the fyke net). Internal throats, body, and wings were 4.8 mm (3/16 in) square mesh knotless nylon.

Captured rainbow trout were placed in a tub of water oxygenated with a portable 7.5 kg (20 lb.) oxygen bottle, and anesthetized with MS-222. After sampling, rainbow trout were placed in a 1.2 m (4 ft) by 1.2 m (4 ft) by 2.4 m (8 ft) covered holding pen made of plastic pipe enclosed with 4.8 mm (3/16 in) knotless nylon mesh.

Sampling and Marking

Three sampling events were conducted in each lake during 1994 (Table 1). In late May (and early June for "X" Lake), rainbow trout were captured to estimate mean length and proportion of each group. Presence and type of finclip (right or left ventral) was documented, and fork length was measured to the nearest millimeter on age-1+ rainbow trout with finclips. The possibility of multiple captures of the same fish during the event was eliminated by placing all fish in the holding pen. Upon completion of sampling, all fish were released from the holding pen.

To estimate abundance of each group, we conducted mark-recapture experiments in each lake. During the marking event in each lake in September 1994, all captured rainbow trout were examined for finclips, fork length was recorded, and the adipose fin was removed from each fish having a ventral finclip. Presence of right ventral (RV) or left ventral (LV) finclips was again documented, then all fish were released.

During the recapture events in September or early October, all rainbow trout captured were examined for finclips (right or left, ventral and adipose). Fork length and type(s) of finclip(s) were recorded for each fish having a finclip. Rainbow trout with finclips were held in the holding pen until all fish from all traps were sampled.

Table 1.-Sampling dates for mixed-sex and all-female rainbow trout in Long, Johnson, and "X" lakes, and diploid and triploid coho salmon in Johnson Lake, 1994 and 1995.

Species	Sampling Dates	Purpose Of Capture
	Long Lake	
Rainbow Trout	5/25/94-5/26/94	Length and Proportion Sampling
Rainbow Trout	9/12/94-9/14/94	Marking Event
Rainbow Trout	10/3/94-10/5/94	Recapture Event
Rainbow Trout	9/12/95-9/14/95	Length and Proportion Sampling
	Johnson Lake	
Rainbow Trout	5/25/94-5/26/94	Length and Proportion Sampling
Rainbow Trout	9/19/94-9/22/94	Marking Event
Rainbow Trout	10/5/94-10/7/94	Recapture Event
Rainbow Trout	9/19/95-9/21/95	Length and Proportion Sampling
Coho Salmon	9/19/94-9/21/94	Length and Proportion Sampling
Coho Salmon	9/19/95-9/21/95	Length and Proportion Sampling
	"X" Lake	
Rainbow Trout	5/31/94-6/3/94	Length and Proportion Sampling
Rainbow Trout	9/6/94-9/9/94	Marking Event
Rainbow Trout	9/26/94-9/30/94	Recapture Event
Rainbow Trout	9/26/95-9/29/95	Length and Proportion Sampling

Data collected during the marking event were used to estimate mean lengths and proportions by group for Long and Johnson lakes in September 1994. Data collected during the recapture event were used for length and proportion estimates for "X" Lake.

In September 1995, rainbow trout were again captured and sampled as in May 1994 to estimate mean lengths and proportions of each group.

Abundance Estimates

In 1994, abundance of age-1+ rainbow trout stocked in 1993 was estimated. Marking and recapture events were conducted in the fall of 1994 as described above.

Chapman's modification of the Petersen estimate (Seber 1982) was used to estimate abundance ($\hat{N}$) of rainbow trout of each group during the marking event:

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

and variance was estimated by:

$$\text{Var}\left(\hat{N}\right) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}, \tag{2}$$

where:

M = number of rainbow trout of a group marked and released during the marking event;

C = number of rainbow trout of a group examined for marks during the recapture event; and

R = number of marked rainbow trout of a group captured during the recapture event.

This estimator has the following assumptions:

1. There is no recruitment or mortality between events;
2. There is no loss of mark;
3. There is no mortality due to marking or handling;
4. Each fish has the same probability of capture in the first event or in the second event, or marked fish mix completely with unmarked fish between events; and
5. Marked and unmarked fish are subject to the same rates of mortality.

We could not assume that there was no mortality, because mark and recapture events occurred 3 weeks apart. Therefore, the Petersen method provided an estimate of abundance at the time of marking under the assumption that mortality was equal for marked and unmarked fish in the population between events. There was no evidence that this assumption was violated. The population of age-1+ rainbow trout with ventral finclips in these lakes was closed. Therefore no recruitment into the population of ventral finclipped fish occurred.

We did not test for loss of marks because fish would not lose finclips over the 3 weeks between mark and recapture events. We did not test for mortality due to handling and marking, but fish were carefully handled and examined during marking and recapture to minimize the potential for mortality.

To determine if marked fish mixed with unmarked fish between events, fyke net sets were organized into six contiguous groups in each lake. Chi-square statistics were used to test the null hypothesis that the ratio of marked to unmarked fish was equal among groups of fyke net sets.

Survival (S) from stocking in July 1993 to September 1994 was estimated by:

$$\hat{S} = \frac{\hat{N}}{N_S}, \tag{3}$$

where:

$\hat{N}$ = estimated cohort abundance, and

N_S = number stocked in 1993.

The variance of the survival estimate was calculated as:

$$\operatorname{Var}\left(\hat{S}\right) = \frac{\operatorname{Var}\left(\hat{N}\right)}{N_S^2}. \tag{4}$$

Because of the low abundance of age-2+ rainbow trout, survival from September 1994 to September 1995 was not estimated. Therefore, proportions of the two groups were compared to determine if survival was different for the two groups. For each lake in September 1994 and in September 1995, chi-square tests were used to test the null hypothesis that the proportion of mixed-sex rainbow trout was equal to the proportion of all-female rainbow trout.

Mean lengths with 95% confidence intervals were estimated using normal procedures. Parametric two-way analyses of variance were used to determine if mean length of mixed-sex rainbow trout was significantly different than mean length of all-female rainbow trout at age 1+ (September 1994) and age 2+ (September 1995).

COMPARISON OF DIPLOID VERSUS TRIPLOID COHO SALMON

Production and Rearing

All coho salmon for this experiment were raised at the Fort Richardson Hatchery. Eggs and sperm from Little Susitna strain coho salmon were collected from Nancy Lake, a lake system of the Little Susitna River, in August 1993. Fertilized eggs were divided into two lots. One lot of eggs was heat shocked postfertilization for 20 minutes at 26° C to induce triploidy (modification of Chourrout 1980). The other lot was not heat shocked (diploid coho salmon).

During incubation and rearing, standard hatchery procedures were used for both diploid and triploid coho salmon lots. Each treatment group was kept in a separate raceway and groups were distinguished by a separate "lot number" on rearing records.

Stocking

On 27 May 1994, Johnson Lake was stocked with diploid and triploid coho salmon fingerlings. All coho salmon were age 0+ fingerlings. Diploid fish weighed an average of 6.8 g and triploid fish weighed an average 6.0 g at stocking. All coho salmon were marked at the hatchery prior to stocking: diploid coho salmon were given a left ventral finclip and triploid coho salmon were marked with a right ventral finclip. Fish were stocked in approximately equal numbers into Johnson Lake at a density of 200 fish per surface acre or approximately 100 fish per surface acre for each group, for a total of 3,713 diploid and 3,718 triploid coho salmon fingerlings. Johnson Lake was sampled during the fall of 1994 and 1995.

Capture, Sampling, and Estimations

Capture and sampling methods for coho salmon were similar to those described above for rainbow trout.

Sampling events were conducted on Johnson Lake during September 1994 and September 1995 (Table 1). Presence and type of finclip (right or left ventral) was documented for all captured coho salmon. All fish were measured for fork length to the nearest millimeter. The possibility of multiple captures of the same fish during the event was eliminated by placing all fish into the holding pen. Fish were released from the holding pen upon completion of sampling all fish from all traps.

Chi-square tests were used to test the null hypothesis that the proportion of diploid coho salmon was equal to the proportion of triploid coho salmon in September 1994 and in September 1995. Mean lengths of diploid and triploid coho salmon with 95% confidence intervals were estimated using normal procedures. A two sample t-test was used to test the hypothesis that mean length of triploid coho salmon was not significantly different from mean length of diploid coho salmon.

RESULTS

MIXED-SEX AND ALL-FEMALE RAINBOW TROUT

Proportions

In September 1994, the proportion of all-female and mixed-sex rainbow trout was not significantly different in Long Lake and Johnson Lake, but treatment groups differed significantly at "X" Lake (Table 2, Figure 2). During 1995, however, there were no significant differences in proportions of all-female and mixed-sex rainbow trout (Table 2, Figure 2).

Mean Lengths and Length Distributions

Parametric analysis of variance was used to test the hypothesis that mean length of all-female rainbow trout was not significantly different from mean length of mixed-sex rainbow trout. A separate test was conducted

Table 2.-Number of rainbow trout stocked and percent of mixed-sex or all-female rainbow trout at three sampling times in Long, Johnson, and "X" lakes, 1993-1995.

Treatment Group	Number Stocked July 1993	Percent Stocked	Number Captured May 1994	Percent May 1994	Number Captured Sept 1994	Percent Sept 1994	χ^2, DF, P[a]	Number Captured Sept 1995	Percent Sept 1995	χ^2, DF, P[b]
					Long Lake					
Mixed-sex	7,355	50	210	52	473	49	0.24, 1, 0.62	33	47	0.22, 1, 0.64
All-female	7,383	50	195	48	490	51		37	53	
					Johnson Lake					
Mixed-sex	3,938	50	286	52	226	51	0.26, 1, 0.61	110	48	0.17, 1, 0.68
All-female	3,931	50	265	48	215	49		118	52	
					"X" Lake					
Mixed-sex	10,017	50	120	63	160	58	6.99, 1, 0.01	43	52	0.16, 1, 0.69
All-female	9,932	50	71	37	115	42		39	48	

[a] χ^2 test for significant difference between percent of mixed-sex and all-female rainbow trout in September 1994.

[b] χ^2 test for significant difference between percent of mixed-sex and all-female rainbow trout in September 1995.

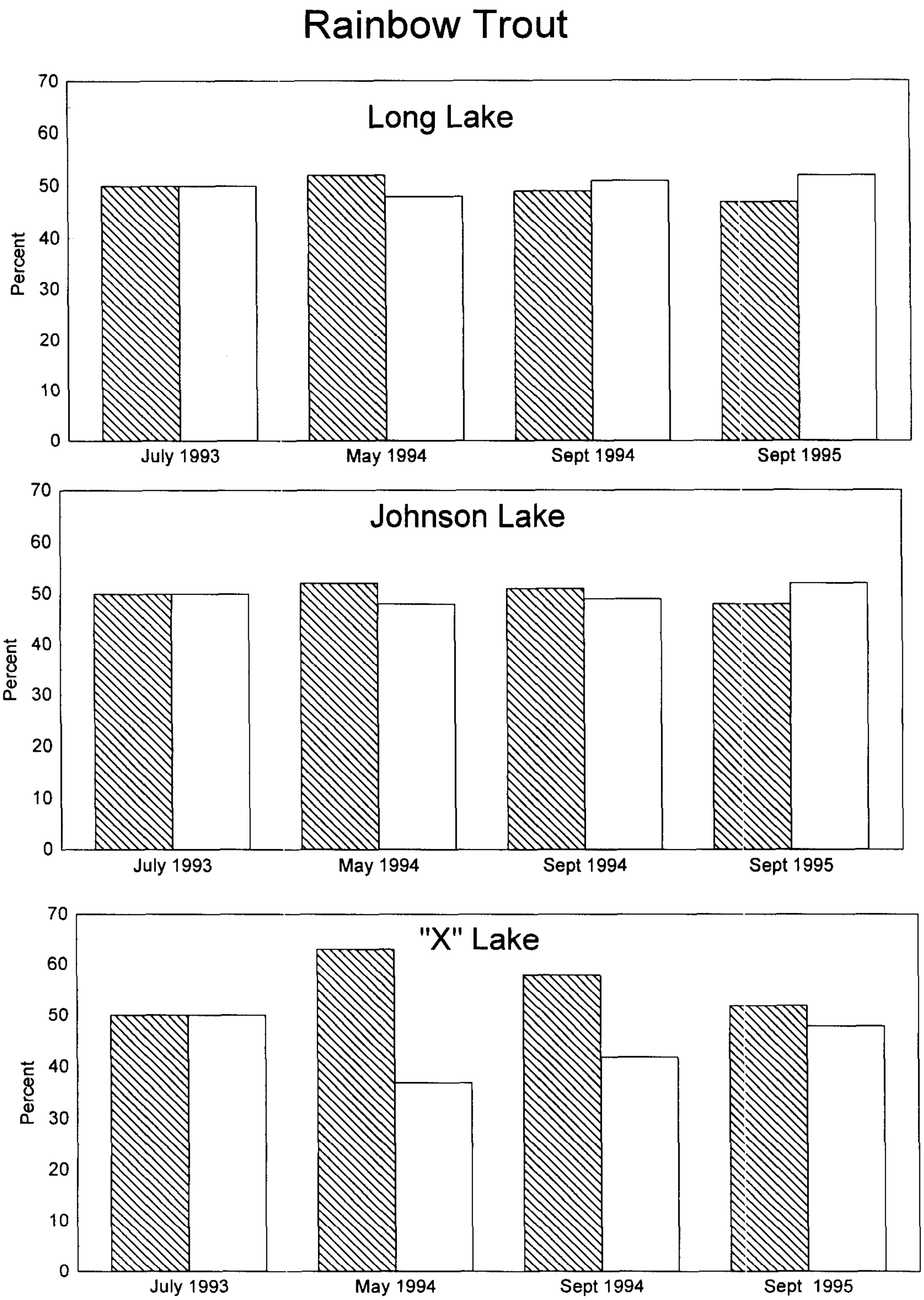

Figure 2.-Percent of rainbow trout that were mixed-sex (hatched bars) and all-female (clear bars) during four sampling periods in Long, Johnson, and "X" lakes, 1993-1995.

for each sampling period (May 1994 at age 1, September 1994 at age 1+, and September 1995 at age 2+). For the May 1994 and September 1994 periods, mixed-sex rainbow trout were significantly larger than all-female rainbow trout (Table 3 and Table 4). The same was true in September 1995, except that mixed-sex rainbow trout were smaller than all-female rainbow trout in "X" Lake (Table 3 and Table 4). The differences in mean length were small in all cases.

Abundance and Survival

During 1994 there was no significant difference in the length distributions of fish marked during the first event and those captured during the second event for the mixed-sex and all-female treatment groups in Johnson Lake (mixed-sex, P = 0.67; all-female, P = 0.16) and "X" Lake (mixed-sex, P = 0.49; all-female, P = 0.77) (Table 5, Appendices B1 and B2). However, there were significant differences in length distribution between events for both treatment groups in Long Lake (mixed-sex, P = 0.01; all-female, P = 0.08). The mixed-sex rainbow trout in Long Lake was the only case where there was a significant difference in the length distributions between fish captured in event 1 and those recaptured in event 2 (P = 0.01) (Table 5, Appendices B1 and B2). These differences may be more reflective of large sample sizes than actual biological differences and, therefore, we assumed that size selective sampling did not occur.

Chi-square tests of homogeneity of clip ratios among treatment groups of fyke nets of captured rainbow trout were not significant for Long and Johnson lakes, indicating that fish mixed throughout each lake between the marking and recapture events. However, there were significant differences for the mixed-sex group in "X" Lake, so abundance of mixed-sex rainbow trout was estimated using methods of Darroch (1958). Abundance estimated by the Darroch method was very close to that of the Peterson method (345 for mixed-sex, 332 all-female and 748 for the combined treatment groups) indicating that the lack of complete mixing did not bias the population estimate. Therefore, we used the Petersen estimate.

Estimated abundance ranged from 212 (SE = 30) all-female rainbow trout in "X" Lake to 681 (SE = 32) mixed-sex rainbow trout in Long Lake (Table 6). In all three lakes, abundance of mixed-sex rainbow trout was not significantly different than abundance of all-female rainbow trout (Table 6), indicating that survival of the two groups was not different.

Estimated survival from stocking in July 1993 to September 1994 of mixed-sex and all-female rainbow trout was about 9% in Long Lake (Table 6, Figure 3). In Johnson Lake, survival was about 11%-12%, and in "X" Lake, survival was about 2%.

TRIPLOID AND DIPLOID COHO SALMON

During September 1994, 599 coho salmon were caught in Johnson Lake; 676 were caught in the fall of 1995. During 1994, 56% (SE = 0.02) of the coho salmon were diploid and 44% (SE = 0.02) were triploid; during 1995, 75% (SE = 0.02) were diploid and 25% (SE = 0.02) were triploid (Table 7, Figure 4).

Coho salmon from both treatment groups ranged in size from 87 mm to 316 mm. During 1994, mean length of age 0+ diploid coho salmon in Johnson Lake was 170 mm (SE = 1) while mean length of triploid coho salmon was 142 mm (SE = 1) (Table 8). During September 1995, mean length of age-1+ diploid coho salmon was 229 mm (SE = 1) with the triploid group averaging 214 mm (SE = 1). The diploid group was significantly larger than the triploid group during 1994 ($t = 14.5$; $df = 524.3$; $P < 0.001$) and 1995 ($t = 15.1$; $df = 357.9$; $P < 0.001$).

Table 3.-Stocking history and mean lengths of age-1, age-1+, and age-2+ mixed-sex and all-female rainbow trout of Swanson River origin captured by fyke net in Long, Johnson, and "X" lakes, 1993-1995.

Treatment Group	Date Stocked	Number Stocked	Size (g)	Date Captured	Number Measured	Mean Length (mm)	SE	Range (mm)
				Long Lake				
Mixed-sex	07/23/93	7,355	1.15	May 1994	210	121	1	78-184
				Sept 1994	278	179	1	125-268
				Sept 1995	33	288	9	211-432
All-female	07/23/93	7,383	1.01	May 1994	195	113	2	76-154
				Sept 1994	283	181	1	113-274
				Sept 1995	37	285	6	219-383
				Johnson Lake				
Mixed-sex	07/20/93	3,938	1.11	May 1994	286	164	1	102-213
				Sept 1994	179	263	2	176-310
				Sept 1995	110	312	2	240-358
All-female	07/20/93	3,931	1.11	May 1994	265	158	1	114-200
				Sept 1994	164	256	2	178-319
				Sept 1995	118	306	2	232-358
				"X" Lake				
Mixed-sex	07/29/93	10,017	1.43	June 1994	120	106	1	78-137
				Sept 1994	103	174	3	117-248
				Sept 1995	43	304	7	173-381
All-female	07/29/93	9,932	1.09	June 1994	71	103	2	81-147
				Sept 1994	59	169	4	117-243
				Sept 1995	39	326	7	236-386

Table 4.-Results of three analyses of variance comparing mean length of mixed-sex rainbow trout to all-female rainbow trout stocked in Long, Johnson, and "X" lakes.

May 1994

Source	df	Mean Square	F	P
Lake	2	334,540	985.9	0.0001
Treatment	1	7,651	22.6	0.0001
Lake*Treatment	2	297	0.9	0.4176

Duncan Grouping	Mean	N	Treatment
A	138	616	Mixed-sex
B	134	531	All-female

Means with the same letter are not significantly different.

September 1994

Source	df	Mean Square	F	P
Lake	2	1,009,075	1,374.2	<0.0001
Treatment	1	8,569	11.7	0.0006
Lake*Treatment	2	174	0.2	0.7885

Duncan Grouping	Mean	N	Treatment
A	202	1,071	Mixed-sex
B	199	1,021	All-female

Means with the same letter are not significantly different.

September 1995

Source	df	Mean Square	F	P
Lake	2	11,099	10.58	<0.0001
Treatment	1	1,091	1.04	0.3086
Lake*Treatment	2	5,208	4.96	0.0075

Lake	Treatment	Mean	N
Johnson	Mixed-sex	311	113
Johnson	All-female	305	119
Long	Mixed-sex	300	33
Long	All-female	281	37
"X"	Mixed-sex	306	43
"X"	All-female	320	39

Table 5.-Results of Kolmogorov-Smirnov tests comparing length distributions of mixed-sex and all-female rainbow trout during the marking event (event 1) and recapture event (event 2) in Long, Johnson, and "X" lakes, 1994.

	Event 1 vs. Event 2				Event 1 vs. Recaptured Fish			
Treatment Group	Sample Size Event 1	Sample Size Event 2	D	P	Sample Size Event 1	Number of recaptured fish	D	P
Long Lake								
Mixed-sex	278	329	0.13	0.01	278	134	0.18	0.01
All-female	283	361	0.10	0.08	283	154	0.12	0.17
Johnson Lake								
Mixed-sex	179	76	0.10	0.67	179	29	0.24	0.26
All-female	164	80	0.15	0.16	164	29	0.18	0.56
"X" Lake								
Mixed-sex	103	106	0.11	0.49	103	49	0.11	0.89
All-female	59	77	0.11	0.77	59	21	0.14	0.89

Table 6.-Abundance estimates in September 1994 of age-1+ mixed-sex and all-female rainbow trout of Swanson River origin stocked in Long, Johnson, and "X" lakes, and survival estimates from stocking to September 1994.

Treatment	Number	Number	Total	Number	Abundance				95% CI			Survival	
Group	Stocked	Marked	Captured	Recaptured	Estimate	SE	Z[a]	P-value[a]	Lower	Upper	%RP[b]	Estimate	SE
					Long Lake								
Mixed-sex	7,355	278	329	134	681	32	0.45	0.3264	618	744	9	9.26	0.05
All-female	7,383	283	361	154	662	27			609	715	8	8.97	0.04
					Johnson Lake								
Mixed-sex	3,938	179	76	29	461	59	0.20	0.4207	345	577	25	11.71	0.13
All-female	3,931	164	80	29	445	57			332	557	25	11.31	0.13
					"X" Lake								
Mixed-sex	10,017	103	106	49	222	16	0.29	0.3859	189	254	14	2.21	0.07
All-female	9,932	59	77	21	212	30			153	270	28	2.13	0.14

[a] Z-test to test for significant difference in abundance of mixed-sex and all-female rainbow trout.

[b] Relative precision of 95% confidence interval.

Table 7.-Numbers of coho salmon stocked and percent of diploid and triploid coho salmon in Johnson Lake during two sampling periods.

		July 1993		September 1994				September 1995			
	Treatment	Number	Percent	Number				Number			
Year	Group	Stocked	Stocked	Captured	Percent	SE	χ^2, df, P[a]	Captured	Percent	SE	χ^2, df, P[b]
1994	Diploid	3,713	50	337	56	0.02	10.32, 1, 0.001	504	75	0.02	179.86, 1, <0.001
1994	Triploid	3,718	50	262	44	0.02		172	25	0.02	

[a] χ^2 test for significant difference between percent of mixed-sex and triploid coho salmon in September 1994.

[b] χ^2 test for significant difference between percent of mixed-sex and triploid coho salmon in September 1995.

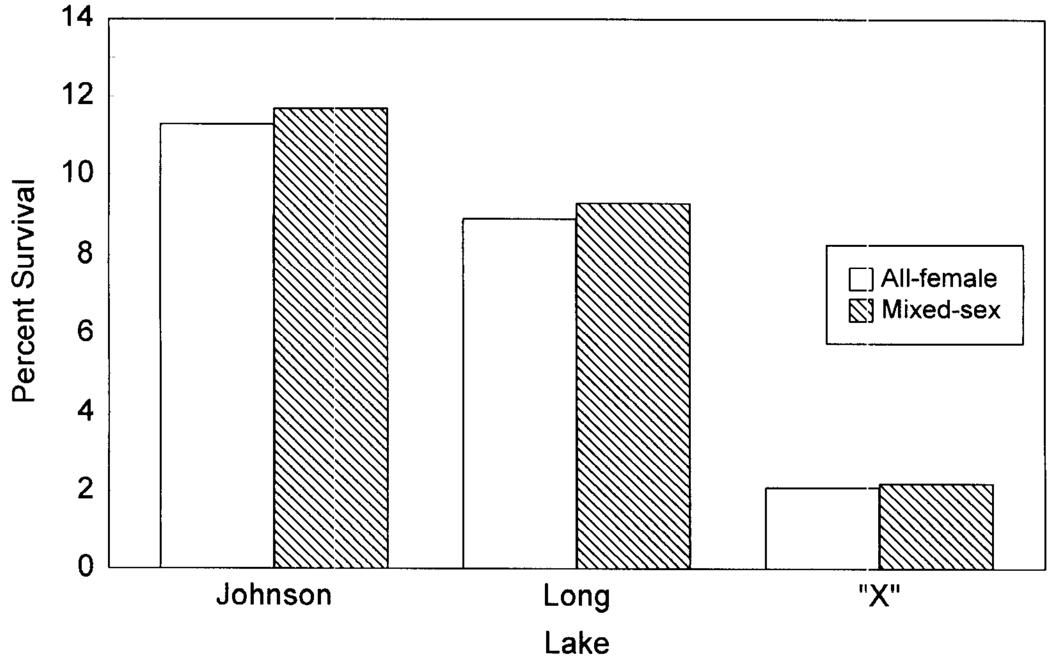

Figure 3.-Survival of all-female and mixed-sex rainbow trout in Johnson, Long and "X" lakes, from 1993 to September 1994.

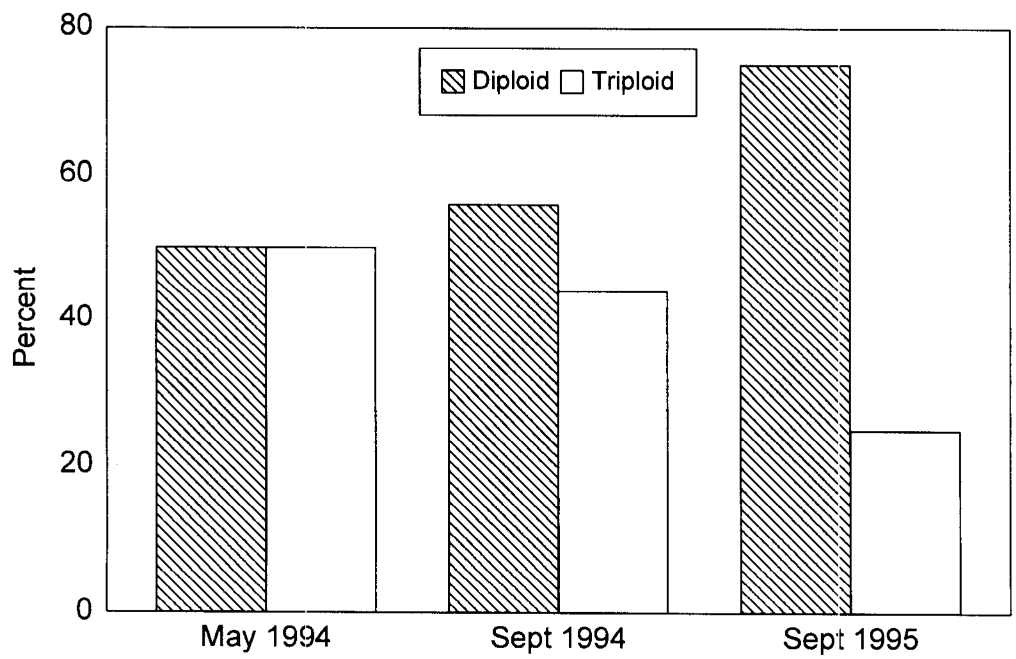

Figure 4.-Percent of coho salmon that were diploid and triploid during three sampling periods in Johnson Lake, 1994-1995.

Table 8.-Mean length in September 1994 and September 1995 of diploid and triploid coho salmon stocked in Johnson Lake in July 1993.

Treatment Group	Number Measured	Mean Length (mm)	SE	Range (mm)
		September 1994 (Age 0+)		
Diploid	337	170	1	119-201
Triploid	262	142	1	87-199
		September 1995 (Age 1+)		
Diploid	504	229	1	197-316
Triploid	172	214	1	188-277

DISCUSSION AND RECOMMENDATIONS

MIXED-SEX VERSUS ALL-FEMALE RAINBOW TROUT

Mixed-sex rainbow trout were equally divided between males and females at stocking. We hypothesized that a portion of the males from the mixed-sex group would become sexually mature and die in the spring of 1995, as is observed annually at the Fort Richardson Broodstock Development Center (Irv Brock, Fisheries Biologist, ADF&G, Sport Fish, Juneau, personal communication). If this was the case, we would expect that more than 50% of captured rainbow trout would be all-female, and that this proportion would increase over time.

We found that the proportion of all-female rainbow trout remained at about 50% throughout the 2 years of this study, except for "X" Lake in September 1994. In addition, survival rates for the two groups were very close, although survival for both groups at "X" Lake was much lower than at the other two lakes.

Mixed-sex rainbow trout were generally larger than all-female rainbow trout, but the small difference is inconsequential in making decisions about the stocking program.

We recommend that sampling continue for at least one more year to assess long-term differences in survival and size.

TRIPLOID VERSUS DIPLOID COHO SALMON

Stocked triploid coho salmon performed poorly compared to diploid coho salmon. The proportion of triploids dropped to only 25% the second year after stocking, indicating poor survival compared to diploid fish. Triploids were significantly smaller than diploid coho salmon at sampling in both 1994 and 1995, indicating that triploids grew slower than diploid coho salmon.

Stocking of triploid coho salmon will therefore have little application in our current stocking program. Coho salmon stocked in landlocked lakes seldom recruit to the sport fishery until their second year of lake residency (usually during that fall). Given the high mortality triploids experience, triploid coho salmon would probably not be able to support a viable fishery by the third year after stocking.

We do not know why triploid coho salmon were smaller than diploid fish. Some studies have found that triploid fish grow faster, while other studies have found that diploid fish grow faster. Simon et al. (1993) suggested that results of growth studies may be strain-dependent.

We recommend that coho salmon not be stocked in lakes that are likely to experience occasional high-water periods where there is a chance that stocked coho salmon could mix with wild strains. Based on past performance, stocking of triploid rainbow trout should be considered instead. Although triploid rainbow trout do not perform as well as their diploid counter parts (Havens and Sonnichsen 1993), they are sterile and seem to outperform triploid coho salmon. In addition, rearing triploid coho salmon is more costly than rearing triploid rainbow trout (Irv Brock, Alaska Department of Fish and Game, Juneau, personal communication) because coho salmon require more hatchery rearing time, which in turn requires additional man-hours, space, and food.

During fall 1996, the control group (diploid coho salmon) should be nearing 100% mortality due to sexual maturation. Theoretically, coho salmon remaining in Johnson Lake should be triploids. Though overall performance of triploid coho salmon is poor, we recommend that evaluation (relative abundance and length) of triploid coho salmon be continued in Johnson Lake for one additional year (September 1996). An additional year of data will provide important information on whether long-term survival of triploid coho salmon is better than survival of diploid coho salmon.

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APPENDIX A. SELECTED PHYSICAL AND CHEMICAL PARAMETERS OF MATANUSKA-SUSITNA VALLEY RESEARCH LAKES

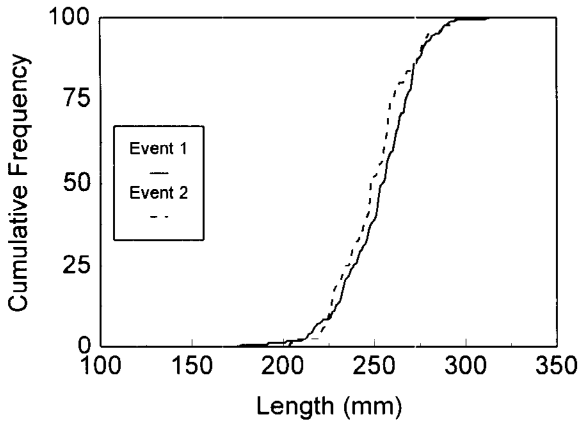
Appendix A1.-Selected physical and chemical parameters of Matanuska-Susitna Valley research lakes.

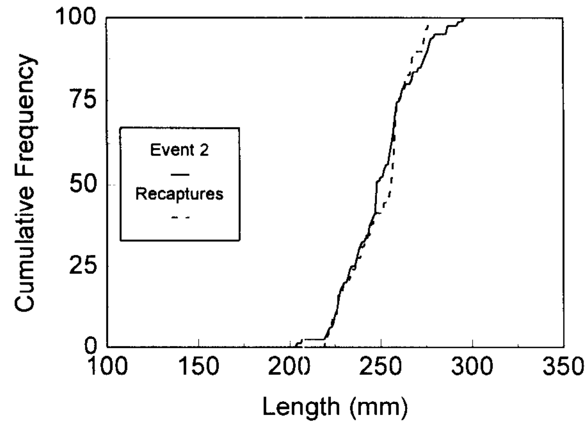
Lake	Surface Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Elevation (feet)	Morphoedaphic Index Value[a]	Species Present 1993-1995
Long (K/B)[b]	74.4	55	26.1	85	9.7	Rainbow Trout, Threespined Stickleback
Johnson[b]	40.3	46	20.0	80.0	7.4	Coho Salmon (landlocked), Rainbow Trout
"X"[b]	101.4	45	17.0	375	1.9	Rainbow Trout, Threespined Stickleback

[a] Morphoedaphic index value (MEI) derived by dividing specific conductance by mean depth, can give a gross measure of a lake's potential productivity (Ryder 1965). This can be related to other lakes within a region that are similar in respect to climate and general nature of the ionic composition of their waters.

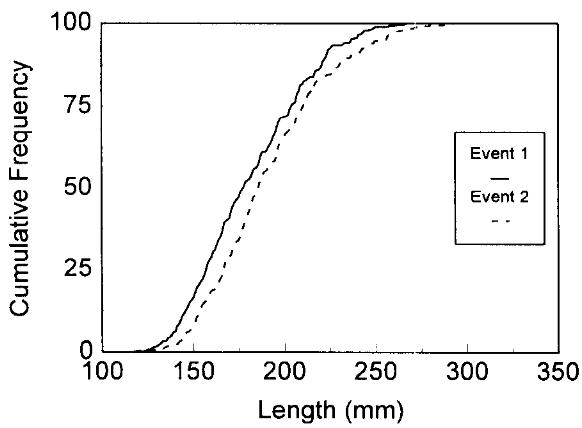
[b] Long and "X" are designated catch-and-release lakes by regulation. Johnson is an experimental lake, closed to sport fishing.

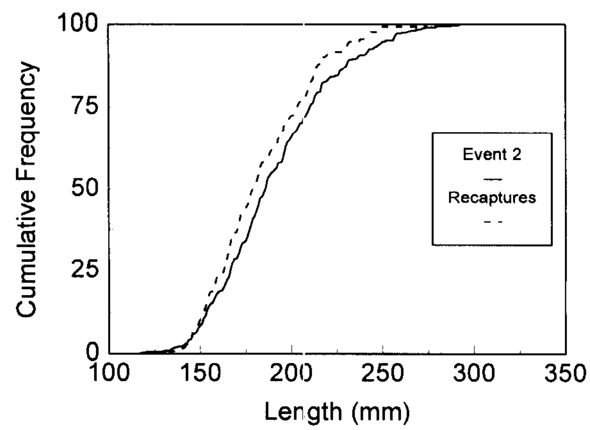
APPENDIX B. CUMULATIVE FREQUENCY PLOTS OF LENGTHS OF RAINBOW TROUT SAMPLED DURING EVENTS 1 AND 2 IN JOHNSON, LONG AND "X" LAKES DURING 1994



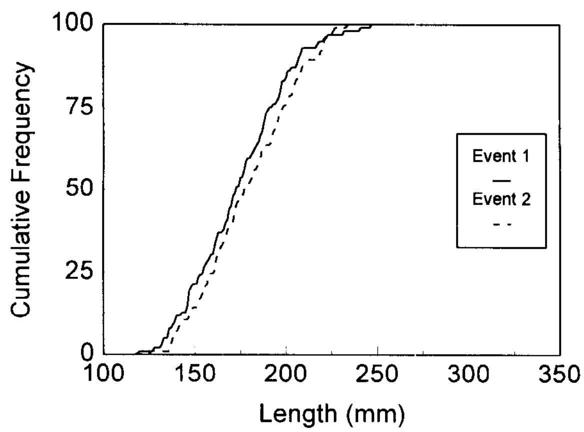


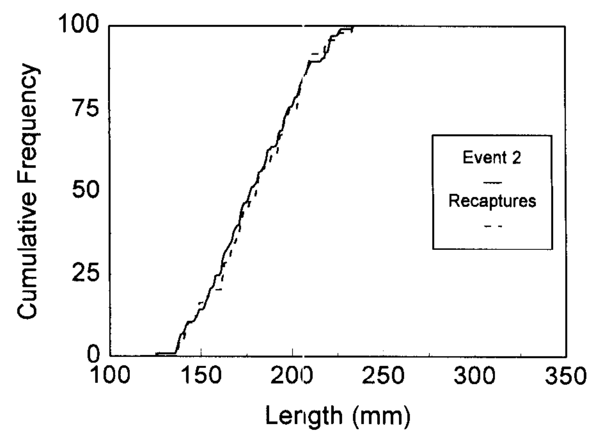
Johnson Lake





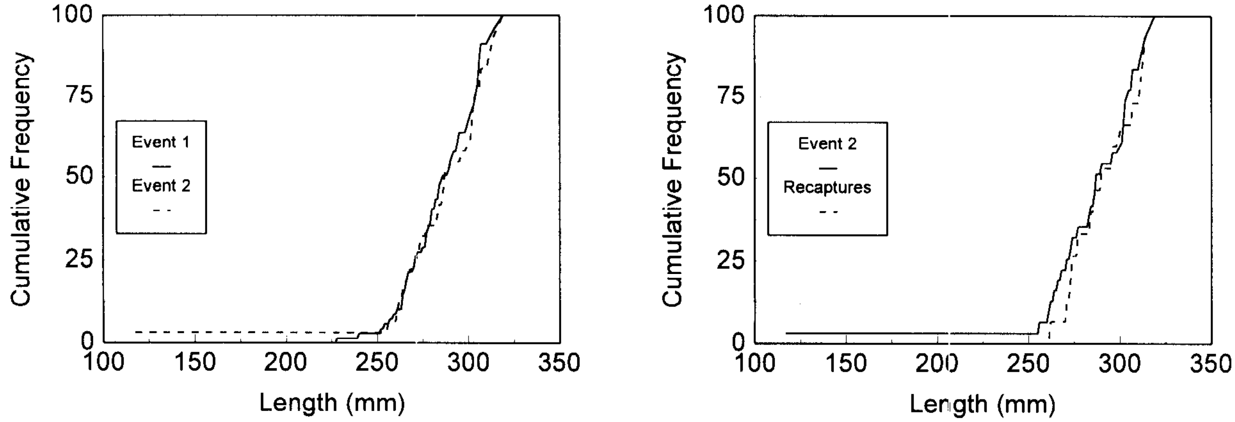
Long Lake



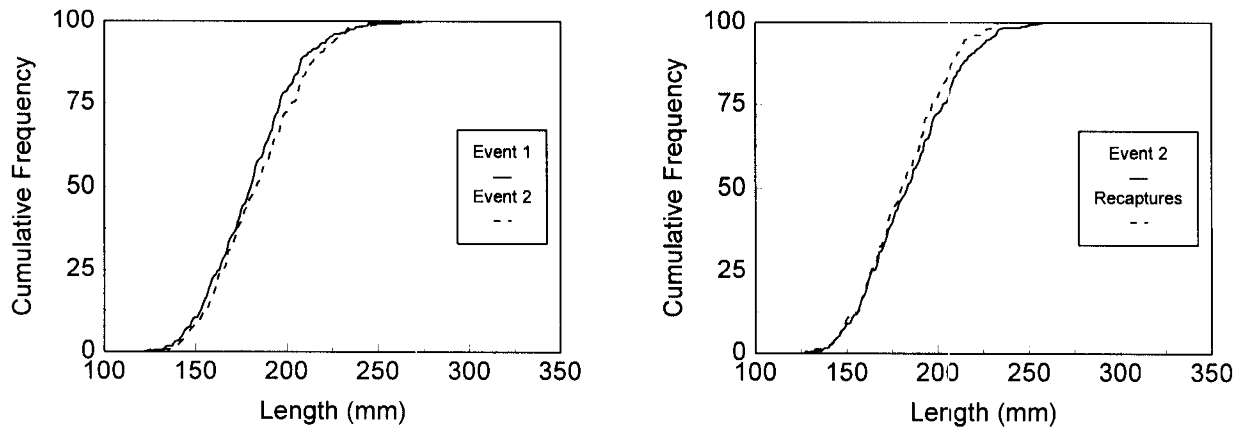


“X” Lake

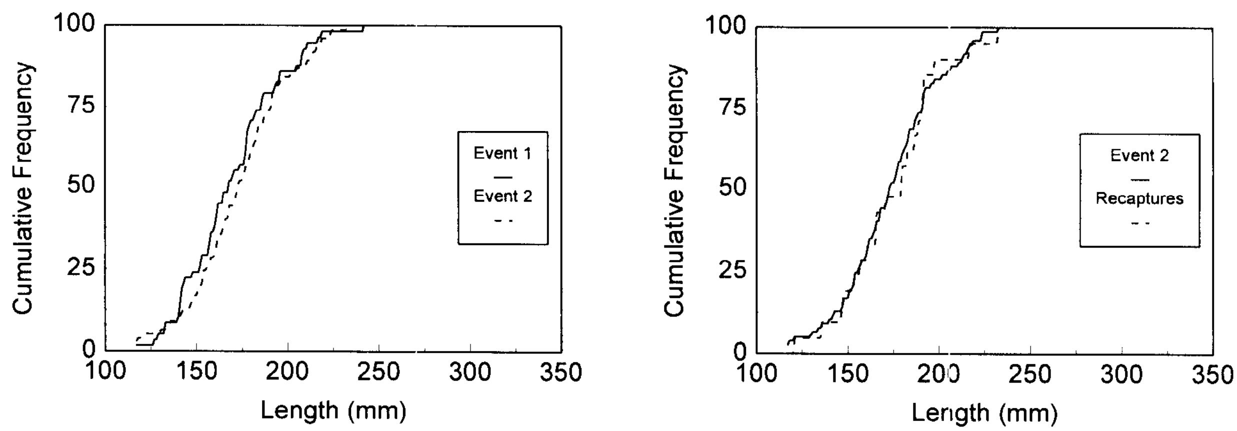
Appendix B1.-Cumulative frequency plots of lengths of mixed-sex rainbow trout sampled during events 1 and 2 in Johnson, Long and “X” lakes during 1994.



Johnson Lake



Long Lake



"X" Lake

Appendix B2.-Cumulative frequency plots of lengths of all-female rainbow trout sampled during events 1 and 2 in Johnson, Long and "X" lakes during 1994.