Fishery Data Series No. 00-13

Evaluation of Stocked Game Fish in the Tanana Valley, 1999

by
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and
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August 2000

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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Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Projects F-10-13, Job E-3-1(a) and F-10-16, Job No. E-3-1(a).

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This document should be cited as:
Skaugstad, C., and J. Fish. 2000. Evaluation of stocked game fish in the Tanana Valley, 1999. Alaska Department of Fish and Game, Fishery Data Series No. 00-13, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

A popular rainbow trout, *Oncorhynchus mykiss,* fishery occurs at Quartz Lake in spring as the ice withdraws from shore. The fishery is gaining popularity because large fish are concentrated in a small, easily accessible area. Anglers believe that a significant portion of the rainbow trout population is harvested during the spring fishery which reduces the number of large fish available the rest of the year. The Alaska Department of Fish and Game (ADF&G) initiated a study to determine if sterile all-female rainbow trout would avoid the spring fishery and provide a source of large fish available for harvest during the remainder of the year. Marked cohorts of normal male and female rainbow trout, and sterile all-female rainbow trout, were stocked in 1996 and again in 1997. In 1999, out of 600 rainbow trout examined during catch sampling, we found 36 normal and eight sterile fish were captured in the spring fishery and 11 normal and 22 sterile fish were captured in the summer fishery. The proportions of sterile fish captured in the spring and summer fisheries were 0.18 (SE = 0.059) and 0.67 (SE = 0.083). Mean lengths of normal and sterile fish were 397 mm (SE = 5.61) and 393 mm (SE = 7.97), respectively. Our results show sterile rainbow trout were less likely to be captured in the spring fishery than in the summer fishery, and there was no size difference between the sterile and normal fish.

The rainbow trout population in Little Harding Lake is managed to provide angling opportunities for large-sized rainbow trout. The estimated abundance in 1999 was 2,191 (SE = 329). Sizes of fish captured in September ranged from 243 to 458 mm FL. Due to a protracted mark-recapture experiment, we were unable to estimate the abundance by age or size cohort. The rainbow trout population in Little Harding Lake has not met our original goals for a trophy rainbow trout lake, based on size criteria. However, anglers consider the fishery acceptable. We plan to continue our current stocking method, but we have no need for further evaluation work.

Key words: Little Harding Lake, Quartz Lake, rainbow trout, *Oncorhynchus mykiss*, trophy, stocking evaluation, stocking method, triploid, diploid, survival, growth, harvest.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) stocks game fish in numerous lakes and one stream in the Tanana River Valley within Alaska's interior (Figure 1). Our goal is to provide more angling opportunities near population centers along the road system and to offer alternatives to the harvest of wild stocks. The stocking program began in the early 1950's, when lakes along the road system were stocked with rainbow trout *Oncorhynchus mykiss*, or coho salmon *O. kisutch*. Today, the stocking program provides diverse year-round sport fishing opportunities for rainbow trout, coho salmon, chinook salmon *O. tshawytscha*, Arctic grayling *Thymallus arcticus*, Arctic char *Salvelinus alpinus*, and lake trout *S. namaycush*.

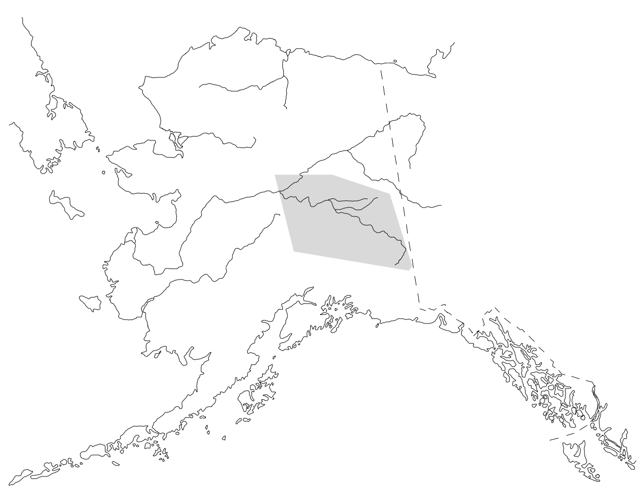

Figure 1.-The Tanana Valley (shaded area).

The stocking program supports consumptive fisheries along the road system where fishing effort and harvests are highest, and as a conservation measure, serves to divert harvest away from wild populations. In 1998, an estimated 24,893 anglers fished in the Tanana Valley, and they generated an estimated 137,599 angler-days of effort[1] (Howe et al. 1999). An estimated 53,445 angler-days of effort were directed toward stocked fish. The estimated harvests of stocked and wild fish in the Tanana Valley in 1998 were 57,173 and 20,307, respectively. Since 1990, stocked fish have represented 51 to 74% of the estimated harvest of game fish in the Tanana Valley and about 33 to 44% of the total estimated fishing effort. During 1998, about 65% of the total harvest of wild and stocked fish in the Tanana Valley was attributed to just two stocked species: rainbow trout and landlocked coho salmon (Howe et al. 1999).

This report addresses one objective for Project F-10-13, Job E-3-1(a) and five objectives for Project F-10-16, Job E-3-1(a).

Project F-10-13, Job E-3-1(a):

Objective 1 Test the null hypothesis that the proportion of triploid rainbow trout harvested in the spring fishery is not less than (*i.e.*, is equal to or greater than) the proportion of triploid rainbow trout harvested in the summer fishery. The alternative hypothesis is the proportion of triploid rainbow trout harvested in the spring is less than the proportion of triploid rainbow trout harvested in the summer fishery. Test H_o: $p_{spring} \geq p_{summer}$ vs H_a: $p_{spring} < p_{summer}$ such that at least a difference of 0.25 can be detected with 0.10 and 0.11 probabilities of Type I and Type II errors, respectively.

Project F-10-16, Job E-3-1(a):

Objective 1 Estimate the abundance of rainbow trout in Little Harding Lake such that $\Pr\left(\left|\frac{\hat{N} - N}{N}\right| \geq 0.25\right) = 0.05$.

Objective 2 Estimate the age and size compositions of rainbow trout in Little Harding Lake such that $\Pr(|\hat{P} - P| \geq 0.05) = 0.05$.

Age categories are: Age 2 and older than age 2. Size categories (FL) are: Less than 350 mm (<350 mm) and 350 mm or larger (≥350 mm).

Objective 3 Test the null hypothesis that rainbow trout caught in event 1 by fyke net have the same recapture rate as those caught by sport gear. The alternative hypothesis is the recapture rates are different for rainbow trout originally captured with fyke nets compared to that for rainbow trout originally captured with sport gear. Test H_o: $p_F \geq p_S$ vs H_a: $p_F < p_S$ with $\alpha = 0.10$ such that $\beta = 0.1$ for $p_s - p_f = 0.083$.

Objective 4 Test the null hypothesis that the proportion of hybrid salmon caught during the winter fishery is not less than (*i.e.*, is equal to or greater than) the

[1] Fishing effort (angler-days) for a location is defined as the estimated number of days fished by all anglers for that location (Mills 1990-1994; Howe et al. 1995-1999). Any part day fished by an angler is considered one angler-day.

proportion of chinook salmon caught in the same fishery. The alternative hypothesis is the proportion of hybrid salmon captured during the winter fishery is less than the proportion of chinook salmon caught in the same fishery. Test H_o: $p_H \geq 0.5$ vs H_a: $p_H < 0.5$ with $\alpha = 0.10$ such that $\beta = 0.1$ if the true proportion is 0.4; and,

Objective 5 Test the null hypothesis that the mean size of hybrid salmon caught during the winter fishery is not less than (*i.e.*, is equal to or greater than) the mean size of chinook salmon caught in the same fishery. The alternative hypothesis is the average size of hybrid salmon captured during the winter fishery is less than the average size of chinook salmon caught in the same fishery. Test H_o: $L_H \geq L_C$ vs H_a: $L_H < L_C$ such that at least a difference of 10% (~ 20 mm) can be detected with 0.05 probability of Type I error and 0.10 probability of Type II error.

Objectives 3, 4, and 5 for Project F-10-16, Job E-3-1(a) were not met. Objective 3 was to evaluate recapture rates between fyke nets and sport gear. It was not achieved due to inclement weather. We intend to modify the study design so the project will not be affected by adverse weather and conduct the study during Summer 2000. Objectives 4 and 5 were to evaluate the use of hybrid salmon in the stocking program under actual angling situations. The study was not conducted because the health of the hybrid salmon was poor at the time of stocking. This would have potentially biased a comparison with healthy chinook salmon. We intend to conduct this experiment during Winter 2000 using healthy hybrid fish.

COMPARISON OF DIPLOID AND TRIPLOID RAINBOW TROUT STOCKED IN QUARTZ LAKE

A popular rainbow trout fishery occurs at Quartz Lake (Figure 2) in the spring. As the ice on Quartz Lake recedes, rainbow trout attempt to spawn in the shallow, near shore water. The fishery is gaining popularity because large fish are concentrated in a small, easily-accessed area and are readily caught. The fishery occurs along the beach at the state recreation area, between the two boat launch sites which are about 100 m apart. Anglers line up along the shore and even walk out on the ice to catch fish. Rainbow trout are probably attracted to this and other similar sites due to the presence of upwelling ground water.

Anglers believe that a significant portion of the population of large rainbow trout is harvested in the spring fishery, reducing the number of large fish available for harvest during the rest of the year. They are concerned that the quality of fishing has recently declined due to the increasing popularity of the spring fishery. Although an increasing number of large fish are probably removed during the spring fishery, there is no conservation problem because all fish in Quartz Lake are stocked, and there is no natural trout reproduction in the lake.

ADF&G was asked if it is possible to develop a group of fish that avoid the spring fishery and provide for angling opportunities for large numbers of fish during the rest of the year. We have elected to conduct an experiment to determine if triploid all-female rainbow trout will provide such a fishery. Triploid rainbow trout are sterile. Because they do not become sexually mature they should not be attracted to a spawning site where they would be exposed to intense fishing. We decided to not use triploid males because they do show external signs of sexual maturation and a portion do attempt to spawn.

METHODS

About 400,000 diploid rainbow trout fingerlings are stocked annually into Quartz Lake along with 80,000 coho salmon fingerlings. In 1996 and 1997 we stocked marked cohorts of triploid (3N) and diploid (2N) rainbow trout (Table 1).

Table 1.-Stocking and marking summary of rainbow trout in Quartz Lake, 1996 and 1997.

Stocking Date	Ploidy[a]	Sex[b]	Number	Life Stage	Average Weight (g)	Mark
7 Aug 96	3N	AF	30,208	Fingerling	2.2	Left Ventral
7 Aug 96	2N	MF	20,706	Fingerling	2.2	Right Ventral
5, 7 Aug 96	2N	MF	361,985	Fingerling	2.2	
Aug 97	3N	AF	50,000	Fingerling	2.2	Left Ventral
Aug 97	2N	MF	50,000	Fingerling	2.2	Right Ventral
Aug 97	2N	MF	300,000	Fingerling	2.2	

[a] 3N = triploid; 2N = diploid.

[b] AF = all-female; MF = male and female.

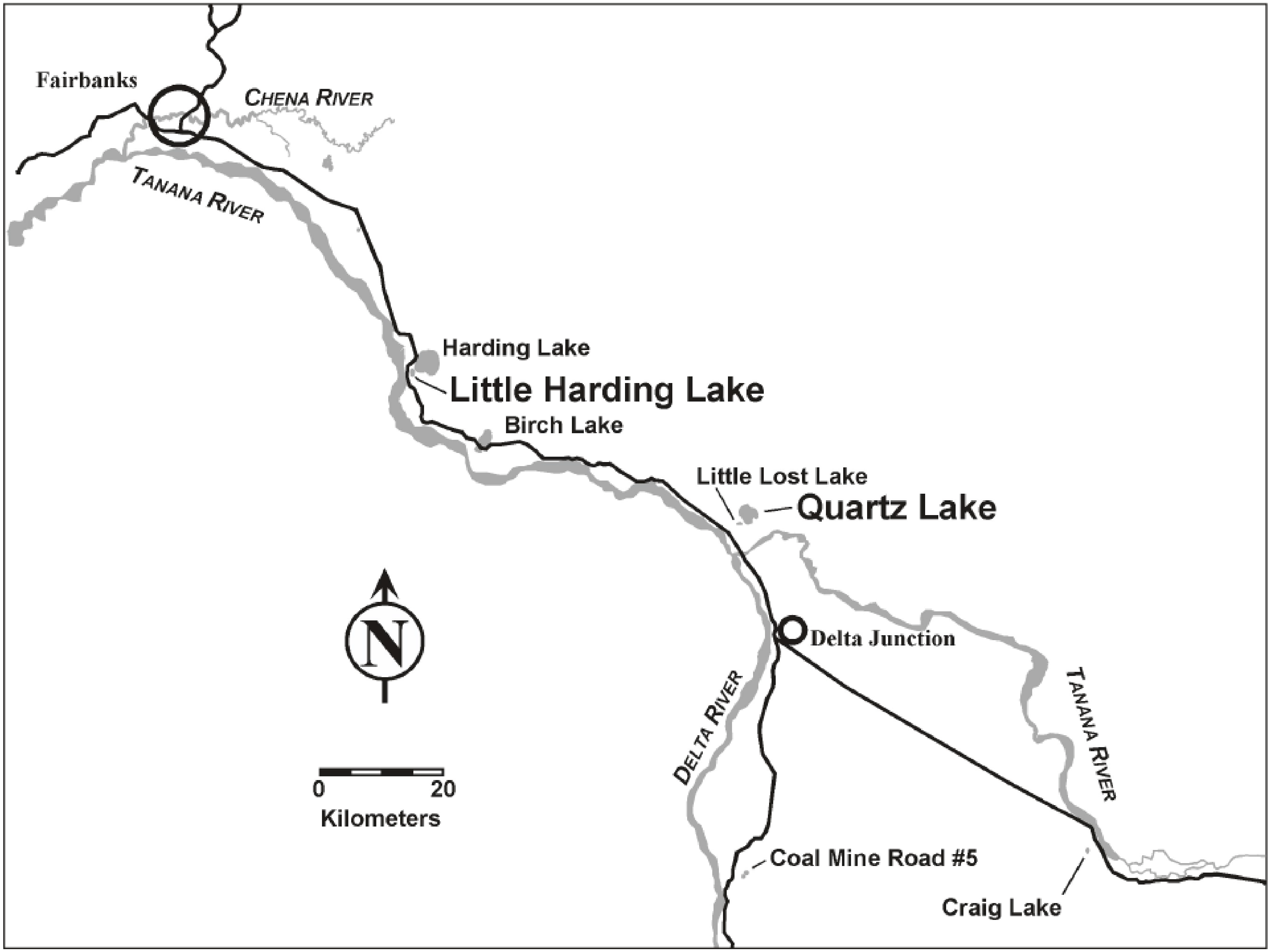

Figure 2.-Lake location in the Tanana Valley.

The cohorts were identified with left (3N) and right (2N) ventral fin clips. One month prior to stocking, the ventral fin of each fish was excised at the base. The fish were marked at Ft. Richardson Hatchery in Anchorage. Unmarked 2N rainbow trout were also stocked both years. Each year the number of marked and unmarked rainbow trout stocked into Quartz Lake totaled about 400,000. All rainbow trout stocked into Quartz Lake since 1990 originated from broodstock kept at Ft. Richardson Hatchery.

During the spring fishery in 1999 an ADF&G employee was positioned at the Quartz Lake State Recreational Area. This person examined harvested rainbow trout for missing left or right ventral fins. Sampling started 24 April and continued through 20 June 1999 (Table 2). Initially, sampling was planned for every weekend, but we adjusted the schedule to avoid periods when few or no anglers were present (such as during adverse weather). Sampling generally lasted from 0900 to 1700 hrs. When a second person was available an additional shift ran from 1700 to 2200 hrs.

Table 2.-Number of rainbow trout observed during creel sampling at Quartz Lake, 1999.

Date	3N	2N	Unmarked	Total
24 April	2	4	61	67
25 April		1	31	32
1 May			5	5
8 May	4	10	49	63
9 May	1	7	57	65
13 May		5	47	52
15 May		5	80	85
16 May		2	34	36
22 May	1	2	32	35
23 May			5	5
29 May	6		12	18
20 June	16	11	110	137
Total	30	47	523	600

The marked fish examined in the fishery were summarized in a 2 x 2 contingency table by ploidy (3N vs 2N) and by fishery (spring vs summer). We used a one-tailed Fisher exact test to determine if capture rates for the 3N and 2N were different by fishery. A one-tailed t-test was used to test the null hypothesis that the mean length of diploid rainbow trout was not greater than the mean length of triploid rainbow trout.

RESULTS AND DISCUSSION

Most of the ice was gone by 23 May and anglers began to disperse their fishing effort across the lake. We selected this time to separate the spring and summer fisheries because anglers were no longer restricted to the recreational area where a large number of spawning rainbow trout was concentrated. We inspected and measured 600 rainbow trout and found 30 fish with left ventral clips (3N) and 47 fish with right ventral clips (2N) (Table 2). The proportions of 3N fish captured in the spring and summer fisheries were 0.18 (SE = 0.059) and 0.67 (SE = 0.083), respectively (Table 3). The proportions of 2N fish captured in the spring and summer fisheries were 0.82 (SE = 0.059) and 0.33 (SE = 0.083), respectively (Table 3).

Results of the Fisher exact test were significant ($p < 0.0001$) and we inferred that 3N fish were less likely to be harvested in the spring fishery. Mean lengths of diploid and triploid rainbow trout were about 397 and 393 mm FL, respectively (Table 4, Figure 3) and diploid rainbow trout were not significantly larger than triploid rainbow trout (p-value = 0.66).

Our results suggest that 3N fish were less likely to contribute to the spring fishery compared to marked 2N fish. However, after the lake was ice free, anglers disperse across the lake and 3N fish contributed more to the fishery. This may be the result of having harvested a large proportion of the marked 2N fish during the spring fishery, leaving less marked 2N fish available for harvest during the summer fishery. Conversely, most 3N fish may have simply avoided the spring fishery, without an impetus to spawn.

Some of the anglers that fished Quartz Lake recorded their catches. They also noted that 2N fish made up less of the catch compared to 3N fish within a month of the lake being ice free. Their records also show that the proportions of 2N and 3N fish in their catches became more equal as the season progressed.

Table 3.-Summary of marked fish captured by fishery at Quartz Lake, 1999.

Fishery	Ploidy	Sample Size	Proportion	Lower 95% CI	Upper 95% CI
Spring	Diploid	36	0.82	0.68	0.90
	Triploid	8	0.18	0.10	0.32
Summer	Diploid	11	0.33	0.20	0.50
	Triploid	22	0.67	0.50	0.80

Table 4.-Length (FL) statistics of harvested rainbow trout examined at Quartz Lake, 1999.

	Sample Size	Mean (mm)	Standard Error (mm)	Minimum (mm)	Maximum (mm)
Diploid	47	397	5.61	295	464
Triploid	30	393	7.97	285	479

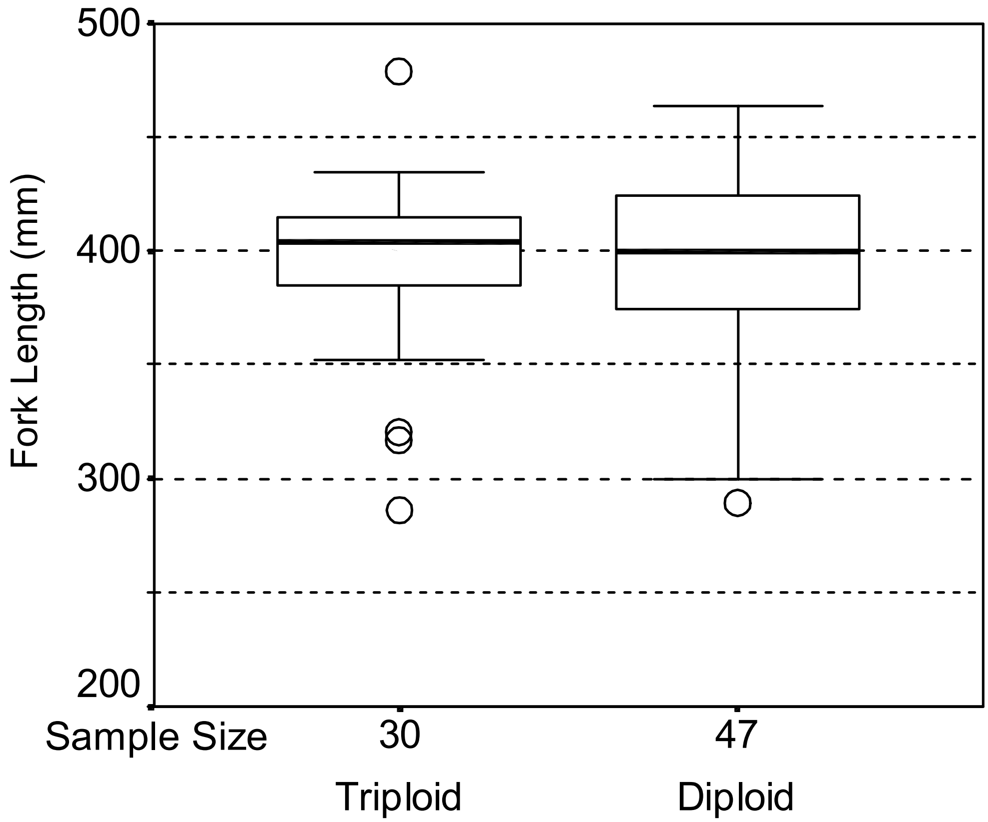

Figure 3.-Summary plot of lengths of harvested rainbow trout inspected at Quartz Lake, 1999.

The box represents the interquartile range which contains 50% of values. The whiskers extend to the highest and lowest values, excluding outliers. The line across the box indicates the median. Outlier values are between 1.5 and 3 box lengths (interquartile range) from the upper or lower edge of the box. Extreme values are more than three box lengths from the upper or lower edge of the box. Outlier and extreme values are represented with circles.

ABUNDANCE AND COMPOSITION OF RAINBOW TROUT IN LITTLE HARDING LAKE

In 1994 ADF&G initiated a program to create fisheries for trophy size rainbow trout in Little Harding Lake (22 ha), Craig Lake (7 ha) and Coal Mine #5 Lake (5 ha) (Figure 2). Special regulations were adopted for these lakes to increase the likelihood of creating successful fisheries. These lakes are open to fishing from 15 May through 30 September. Only unbaited, single-hook, artificial lures may be used. The daily bag and possession limit for rainbow trout is one fish which must be 18 inches TL (457 mm) or larger.

Success in establishing fisheries for trophy rainbow trout in Little Harding Lake, Craig Lake, and Coal Mine #5 Lake is based on size and relative abundance. For these fisheries to be considered successes, at least half of an age cohort must exceed 14 in. FL (350 mm) by age 4. When stocked, these fish are age 1 and average 150 to 180 mm FL. Prior to 1994, Little Harding Lake was stocked previously with rainbow trout and coho salmon (Appendix A). Now, only rainbow trout are stocked. Lake chubs *Couesius plumbeus* are also present in the lake. To date, only Little Harding Lake is approaching the criteria for a successful fishery. We have dropped Craig Lake and Coal Mine #5 Lake from the trophy rainbow trout program because these two lakes have not provided acceptable fisheries (Skaugstad 1999).

The purpose of this study is to estimate the abundance and size structure of the rainbow trout population in Little Harding Lake. This information will be used to evaluate progress towards achieving abundance and size criteria.

METHODS

To estimate the abundance of rainbow trout we conducted a two-sample mark-recapture experiment using fyke nets. The fyke net openings were either 1.2 or 0.9 m sq., hoop size was 0.9 m diameter, mesh size was 9 mm sq., wings were 7.5 m long by 1.2 m deep, and center leads were 30 m long by 1.2 m deep. The center lead, when used, was attached to the center vertical post on the first square frame. We distributed six to eight fyke nets roughly equidistant to each other around the lake perimeter. We used two methods to set the fyke nets. With the first method, we positioned the body of the net parallel to shore with the wings forming a "V". One wing was anchored to shore and a weight was attached to the other wing and positioned offshore. A center lead was not used. Each fyke net was pulled taut from the cod end which was weighted. The fyke nets rested on the lake bottom. Water depth at these sites varied from 1 to 1.8 m. When water depth was less than 2 m out to about 30 m from shore we used a center lead attached to the frame of a fyke net. The other end of the center le was anchored to shore. The fyke nets were set with the center lead perpendicular to shore and wings parallel to shore. The fyke nets rested on the lake bottom in 1 to 2 m of water.

Each captured fish was marked to identify the event in which it was captured. For marking we used a paper punch (which produces a 7 mm diameter circular hole) to remove a half disk of tissue from the caudal fin from each captured fish. During the marking event fish were marked in the lower lobe of the caudal fin. All fish captured in the recapture event were marked in the upper lobe. Any fish captured in the recapture event without a mark in the lower lobe was classified as unmarked (captured for the first time). Any fish captured more than once during either the marking or recapture events was counted only once per event. We measured all captured fish to the nearest millimeter FL. All length measurements are FL unless noted otherwise.

The assumptions necessary for accurate estimation of abundance in a closed population and the test of these assumptions are described in Appendices B and C. To test for size bias we first separated fish into age/size groups by visual inspection of the length frequency distribution of fish captured only once in both events. Generally, these distributions have only two modes that represent small (usually age 2) and large fish (usually age 3 and older). We then divided the sample between the modes at the category that had the lowest count, and then evaluated size bias using contingency tables. Although not as precise as using Kolmogorov-Smirnov (K-S) tests this method is preferred because it eliminates the problem when growth occurs between sampling events (which the K-S test is sensitive to). It also provides an appropriate rational for dividing the population because we have found that capture probabilities are sometimes different for smaller and larger fish. Depending on the outcome of the tests for size bias, we made appropriate adjustments as outlined in Appendix C. This year, due to protracted sampling and small sample sizes, we were not able to separate the data into categories for small and large fish. Instead we examined the data by plotting cumulative frequency distributions and evaluating size bias with K-S tests.

Chapman's modification of the Petersen estimate (Chapman 1951; Seber 1982, p.60) was used to estimate the abundance of the rainbow trout population:

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

where: $\hat{N}$ = the abundance of rainbow trout in a lake; n_1 = the number of rainbow trout marked and released during the marking event; n_2 = the number of rainbow trout examined for marks during the recapture event; and, m_2 = the number of rainbow trout recaptured in the recapture event.

Variance of this estimator was calculated by (Seber 1970; Wittes 1972):

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

RESULTS AND DISCUSSION

We captured and marked 332 Arctic grayling during sampling event 1, 1-4 June (Table 5, Figure 4). However, during the second sampling event 14-18 June we captured too few fish (n=57) for an adequate sample size to use as the recapture event (Figure 4). We decided to stop sampling after this event because catches were low (Table 5) and water temperature was increasing which caused increased stress to the fish (Table 6). We also suspect that there was a change in the probability of capture of large fish between the first and second sampling events. This assessment was based on our observations during this experiment and our experience with similar experiments and situations with other rainbow trout populations. Doxey (1992) found that larger rainbow trout in a population were less likely to be captured with fyke nets in near shore waters when water temperatures were warm. However, after the near shore waters cooled, larger fish were again captured in fyke nets. Our data suggest that large fish were less likely to be captured than small fish during sampling event 2. The upper tail for the recaptured fish in

Table 5.-Number of marked and unmarked fish captured by sampling event at Little Harding Lake, 1999.

Sampling Events				
1-4 Jun	14-18 Jun	16-20Aug	20 Sep – 1 Oct	Recapture History
332	34	66	131	Unmarked
	23	13	10	Recaptured from 1st
		2	4	Recaptured from 2nd
			14	Recaptured from 3rd
			3	Recaptured from 1st and 2nd
			0	Recaptured from 1st and 3rd
			0	Recaptured from 2nd and 3rd
			0	Recaptured from 1st, 2nd, and 3rd
332	57	81	162	Total

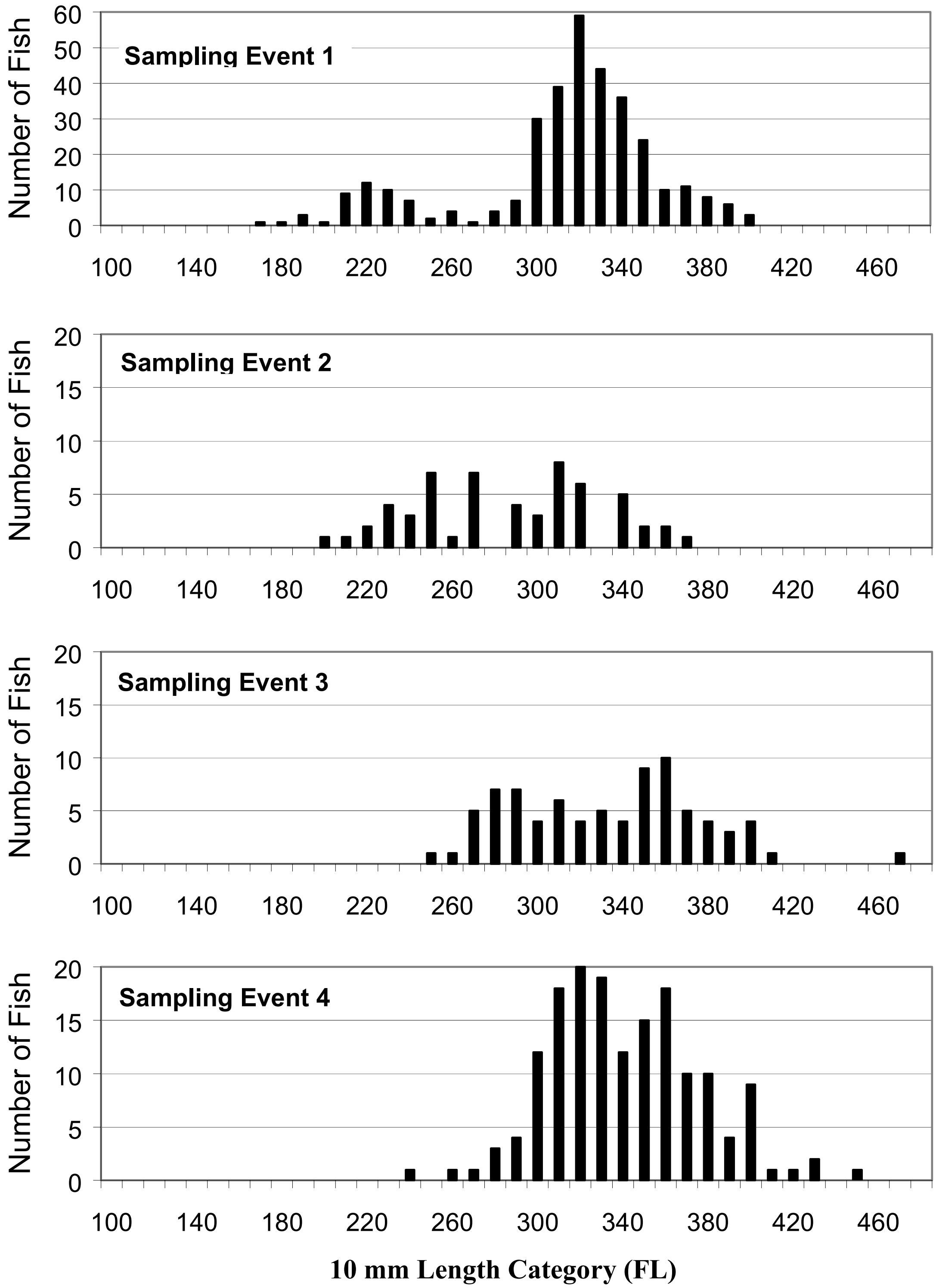

Figure 4.-Length frequency distribution rainbow trout captured by sampling event at Little Harding Lake, 1999.

Table 6.-Water temperature during mark-recapture experiment at Little Harding Lake, 1999.

Date	Depth	Temperature °C
6/15/99	Surface	21.9
	~2 M	15.4
8/20/99	Surface	17.6
	~3 M	16.4
9/23/99	Air Temp	4.8
	Surface	9.2
9/27/99	Surface	7.8

Figure 5(A) is shifted toward smaller fish which means that larger fish were less likely to be recaptured than smaller fish. Results of hypothesis tests for size selective sampling (Appendix C) were significant (P-value < 0.001) for all sampling events.

In August we attempted another recapture event, but water temperatures were still high and catches were low (n=81, Figure 4). During sampling event 3 we could not determine if the larger fish were more or less likely to be captured because all fish had grown during the experiment (Figure 5B). Growth would result in a shift to the right of the cumulative length frequency distribution curve (cfd) for recaptured fish. This would mask any indication that larger fish were less likely to be recaptured than smaller fish. In September, water temperatures were cooler and we were able to obtain adequate sample sizes (Table 5, Figure 4).

To estimate abundance we combined data from sampling events 1, 2, and 3 for our marking event (n=432). Sampling event 4 was our recapture event (n=162 with 31 recaptured fish; Table 5).

Due to the protracted sampling period some of our assumptions were challenged. We do know that there was no immigration, no births, nor recruitment because the lake was closed and there was no natural trout reproduction. There probably was natural mortality, but this would have no effect on the estimate if marked and unmarked fish had the same rate of mortality. Fishing regulations allowing only one fish over 18 inches per day should reduce mortality. We don't know if anglers kept fish smaller than the legal size but we assumed that the number was negligible. The assumption that every fish in the marking event have an equal probability of capture most likely was not achieved because as the water warmed the larger fish avoided the near shore water where the fyke nets were set. It is not known if fish had an equal probability of capture during the recapture event (sampling event 4). But, given that these last two assumptions may be invalid, we can still assume that the marked and unmarked fish mixed due to the extended marking event (three months) and the one month hiatus between the end of the marking event and the start of the recapture event. Examination of the cfds (Figure 5C) shows that the curves have similar shape but the curves for the marked/recaptured and unmarked fish in the recapture event (sampling event 4) are shifted to the right of the curve for the fish released in event 1. This was most likely the result of growth. Any size bias that may have occurred during the experiment (such as changes in the probability of capture for different sizes of fish) was likely masked by growth. We suspect that size bias likely occurred but we were unable to determine where to stratify the data because of growth of the fish during the experiment. We did not estimate the proportion of the population by age or size category for the same reason. The unstratified estimated abundance of rainbow trout was 2,191 (SE = 329).

Experiments such as this are designed to avoid problems associated with growth and changes in the likelihood of capture due to temperature changes. Sampling was supposed to have occurred during a three-week period sometime in May and June when water temperatures were cool and to minimize the affect of growth. This did not happen. This year water temperatures increased more rapidly than we expected and which resulted in low catches during sampling events 2 and 3, and larger fish avoiding areas where we set the fyke nets. Due to the protracted sampling period we also had to deal with significant fish growth during the study. In previous mark-recapture experiments we were able to separate the age-2 cohort from older cohorts using length frequency analysis. This was not the situation this year because growth during summer resulted in overlapping lengths between age cohorts. By September, the faster growing age-2 fish were larger than slower growing older fish.

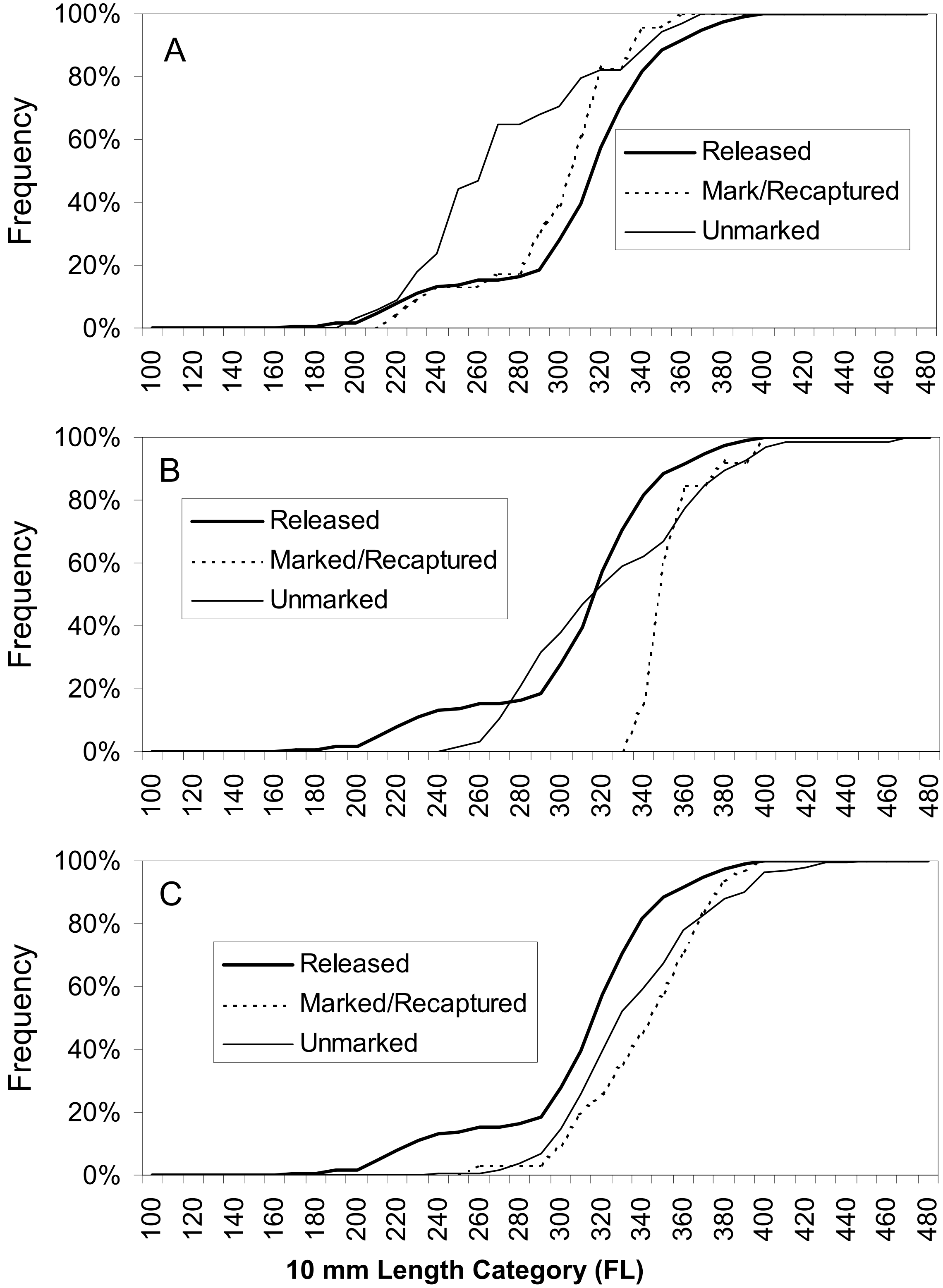

Figure 5.-Cumulative length-frequency distribution of rainbow trout captured in event 1 and event 2 (A); captured in event 1 and event 3 (B); and captured in event 1 and event 4 (C).

ACKNOWLEDGMENTS

Becky Kelleyhouse, Tony Roof, David Stoller, Ted Lambert, Doug Edwards, and Fronty Parker assisted with field work and data summaries. The U.S. Fish and Wildlife Service provided partial funding for this study through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Projects F-10-13 and F-10-16, Studies E, Job No. 3-1(a).

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APPENDIX A

Appendix A.-Stocking history for Little Harding Lake, 1990-1999.

Species	Stocking Date	Number Stocked	Age[a]	Sex[b]	Weight (g)	Brood Year	Mark
Coho Salmon	16-Jul-90	3,600	F	MF	2.7	89	
Rainbow Trout	24-Jul-90	1,000	F	MF	1.6	90	
Rainbow Trout	24-Jul-91	3,600	F	MF	1.8	91	
Rainbow Trout	22-Jul-92	11,000	F	MF	1.1	92	
Coho Salmon	21-Jun-93	7,700	F	MF	0.9	92	
Coho Salmon	24-Jun-93	14,300	F	MF	0.8	92	
Rainbow Trout	18-May-94	2,838	S	MF	42.0	94	
Rainbow Trout	21-Jun-95	1,300	S	MF	54.0	94	AD
Rainbow Trout	11-Jul-96	100	B	MF	800.0	93	
Rainbow Trout	18-Jul-96	1,750	S	MF	67.0	95	RV
Rainbow Trout	8-Jul-97	1,400	S	MF	65.0	96	
Rainbow Trout	8-Jul-97	74	B	MF	800.0	94	
Rainbow Trout	13-Jul-98	1,497	S	MF	37.2	97	LV
Rainbow Trout	22-Aug-99	1,385	S	MF	48.0	98	

[a] B = broodstock; F = fingerling; S = subcatchable.

[b] MF = male and female.

APPENDIX B

Appendix B.-Assumptions necessary for accurate estimation of abundance in a closed population.

The assumptions necessary for accurate estimation of abundance in a closed population are as follows (taken from Seber 1982):

1. the population is closed (no change in the number of rainbow trout in the population during the estimation experiment; i.e. there is no immigration, emigration, births or deaths);
2. all rainbow trout have the same probability of capture in the marking sample or in the recapture sample, or marked and unmarked rainbow trout mix completely between marking and recapture events;
3. marking of rainbow trout does not affect their probability of capture in the recapture sample;
4. rainbow trout do not lose their mark between the marking and recapture events; and,
5. all marked rainbow trout are reported when recovered in the recapture sample.

For assumption 1 no immigration or emigration is assured because the lakes do not have inlets or outlets. The second half of assumption 1 is also assured because rainbow trout do not reproduce in these lakes. If during the study the probability of death is equal for each fish then the abundance estimate is germane to the first event. To minimize the likelihood of higher mortality rates for marked fish, all captured fish were handled carefully and any fish that showed signs of severe stress was marked by excising a small portion of the upper caudal lobe prior to release. Any fish given such a mark was not considered part of the mark-recapture experiment. A hiatus of at least ten days should have been sufficiently long to minimize the effect of previous capture on capture probability as related to assumption 3. Validity of assumptions 2 and 3, relative to sampling induced selectivity of fish, was tested with either Kolmogorov-Smirnov (K-S) or Chi-squared tests generated from length data collected during the marking and recapture events (Appendix C). A length frequency histogram was used to distinguish size classes. The first hypothesis tested was that all marked rainbow trout have the same probability of capture in the recapture sample. Probability of capture usually differs by the size of rainbow trout, especially when a size selective gear is used. Fyke nets should not be size selective, however, they are typically placed near shore in shallow water where part of the population may not frequent. Given this situation the probability of capture will not be the same for all fish. If this test was significant, the recapture sample was biased and the data were partitioned into size classes. Population estimates were generated for each size class and these independent estimates were summed to estimate the abundance of the entire population. If the test did not detect a significant difference, the data were not partitioned and a single population estimate sufficed.

The second hypothesis tested was that rainbow trout captured during the first event had the same length frequency distribution as fish captured in the second event. There were four possible outcomes of these two tests; either one or both of the samples were biased or neither were biased. Possible actions for data analysis are outlined in Appendix C.

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Assumption 4 was assured because there is not sufficient time for excised tissue to grow back.

Assumption 5 was assured because of rigorous examination of all fish for fin clips.

Complete mixing of marked and unmarked rainbow trout between the first and second events was assumed to be occurring during the experiment. To promote mixing and give each fish an equal chance of being captured there was a hiatus of at least 10 days between the first and second events, and fish handled during any events were released towards the middle of the lake.

APPENDIX C

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

	Result of first K-S (or χ^2) test[a]	Result of second K-S (or χ^2) test[b]
Case I[c]		
	Fail to reject H_o	Fail to reject H_o
	Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]		
	Fail to reject H_o	Reject H_o
	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_o	Fail to reject H_o
	Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]		
	Reject H_o	Reject H_o
	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 χ^2 test is based on a contingency table to examine the effect of variable catchability of marked fish captured during the second event for various size/age categories. The contingency table is made up of marked fish that are captured and not captured in the second event. H_o for this test is: The probability of capture in the second event for marked fish is constant across the various categories.

or

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_o 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 χ^2 test is based on a contingency table to examine the effect of variable catchability in the first event for given size/age categories. The contingency table is made up of marked and unmarked fish captured in the second event. H_o for this test is: The probability of capture in the first event is constant across the various categories.

or

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_o 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 events 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.

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Testing of assumptions necessary for accurate abundance estimation may also reveal biases in age and size composition samples. Because age and length information are collected during mark-recapture sampling, bias in mark-recapture samples also indicates bias in age and size data that are collected. Age and size composition are used to apportion the population estimate into age classes or size categories, so that age and length information collected during either the marking sample, the recapture sample, or both samples may be used to calculate age and size composition.

If case I is indicated by tests (Appendix B), no adjustments to age and size data are necessary and data from both events may be pooled. If case II occurs, age and size data from the second event must be used to estimate compositions. If the population is closed between sampling events the abundance estimate is germane to both sampling events. For these two scenarios the proportion of fish at age is calculated as:

$$\hat{p}_i = \frac{y_i}{n} \tag{3}$$

where: $\hat{p}_i =$ the proportion of rainbow trout that are age *i*; y_i = the number of rainbow trout sampled that are age *i*; and, n = the total number of rainbow trout sampled.

The unbiased variance of this proportion is estimated as:

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

Size composition is estimated in a similar manner, replacing age class with the two size categories (less than 355 mm and 355 mm or larger).

If case III or case IV from inference testing occurs, either the first and second events are biased or the second event is unbiased and the status of the first event is unknown. If case III occurs, age and size data from both events can be pooled and adjustments made to these data. If case IV occurs and the partitioned and un-partitioned abundance estimates are dissimilar, age and size data from the second event must be used to estimate compositions. These data must also be adjusted for bias due to size-selectivity. 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 are calculated:

$$\hat{p}_{ji} = {n_{ji}}/{n_j} \tag{5}$$

where: n_j = the number sampled from size class *j* in the mark-recapture experiment; n_{ji} = the number sampled from size class *j* that are age *i*; and, $\hat{p}_{ji} =$ the estimated proportion of age *i* fish in size class *j*. The variance calculation for $\hat{p}_{ji}$ is identical to equation 6 (with appropriate substitutions).

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

$$\hat{N}_i = \sum_{j=1}^{s} \hat{p}_{ji} \hat{N}_j \tag{6}$$

where: N_i = the estimated abundance in size class *j* and s = the number of size classes.

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

$$\hat{V}\left[\hat{N}_i\right] = \sum_{j=1}^{s} \left(\hat{V}\left[\hat{p}_{ji}\right] \hat{N}_j^2 + V\left[\hat{N}_j\right] \hat{p}_{ji}^2 \right) \tag{7}$$

The estimated proportion of the population that are age *i* $(\hat{p}_i)$ is then:

$$\hat{p}_i = \hat{N}_i / \hat{N} \tag{8}$$

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

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

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

APPENDIX D

Appendix D.-Archive files for data collected during studies covered in this report.

File Name	Description
Little Harding 1999.xls	Rainbow trout captured during mark-recapture experiment at Little Harding Lake, 1999.
Quartz Lake 1999.xls	Game fish examined during catch sampling at Quartz Lake, 1999.

Data files are available from the Alaska Department of Fish and Game, Sport Fish Division, Policy and Technical Services, 333 Raspberry Road, Anchorage, Alaska, 99518-1599.