Fishery Data Series No. 97-35

Evaluation of Stocked Game Fish in the Tanana Valley, 1996

by

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and

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November 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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November 1997

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 Project F-10-12, Job No. E-3-1(a).

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This document should be cited as:
Skaugstad, C., and M. Doxey. 1997. Evaluation of stocked game fish in the Tanana Valley, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-35, Anchorage.

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ABSTRACT

Estimation of reproduction of Arctic char *Salvelinus alpinus* in Harding Lake, population structure of rainbow trout *Oncorhynchus mykiss* in three lakes, evaluation of visual implant tags as marks, habitat use by Arctic char, and analysis of the cost effectiveness of the stocking program in the Tanana Valley are described here. No juvenile Arctic char were captured in Harding Lake during two weeks of sampling. The abundance of rainbow trout in Little Harding Lake was estimated at 2,950 (SE = 443) of which 353 (SE = 59) were ≥ 250 mm. The abundance estimate for rainbow trout in Craig Lake was 429 (SE = 29) of which 106 (SE = 18) were ≥240 mm. For Coal Mine #5 Lake the rainbow trout abundance estimate was 67 (SE = 9). The proportion of visual implant tags that were shed increased to slightly more than 50% about one year after stocking. A second group of fish had shed 11% their tags a few months after stocking. During summer ten Arctic char affixed with sonic depth tags were observed in water warmer than 12°C on only one of 144 observations. As summer progressed Arctic char became more dispersed in the water column but still avoided near surface water warmer than 12°C. None of the fishery management objectives for cost-per-angler-day or harvest rates were achieved for any location in 1995. The average cost-per-angler-day for the stocking program was $8.49. Arctic grayling *Thymallus arcticus* provided the best cost/benefit in 1995 for dollar spent ($1.18) in contrast to Arctic char which had the worst ($19.72).

Key words: Birch Lake, Chena Lake, Quartz Lake, Harding Lake, stocking evaluation, Arctic char, *Salvelinus alpinus*, rainbow trout, *Oncorhynchus mykiss*, Arctic grayling, *Thymallus arcticus*, lake trout, *Salvelinus namaycush*, coho salmon, *Oncorhynchus kisutch*, chinook salmon *Oncorhynchus tshawytscha*, catch per unit effort, growth, cost-per-day of fishing, stocking cost, days fished, fishing effort, cost-to-the-creel, cost/benefit, visual implant tag, tag loss.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) stocks game fish in numerous lakes and one stream in the Tanana River Valley (a portion of interior Alaska; Figure 1) to provide more angling opportunities near population centers and 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 for rainbow trout, coho salmon, chinook salmon *O. tshawytscha*, Arctic grayling *Thymallus arcticus*, Arctic char *Salvelinus alpinus*, and lake trout *S. namaycush*.

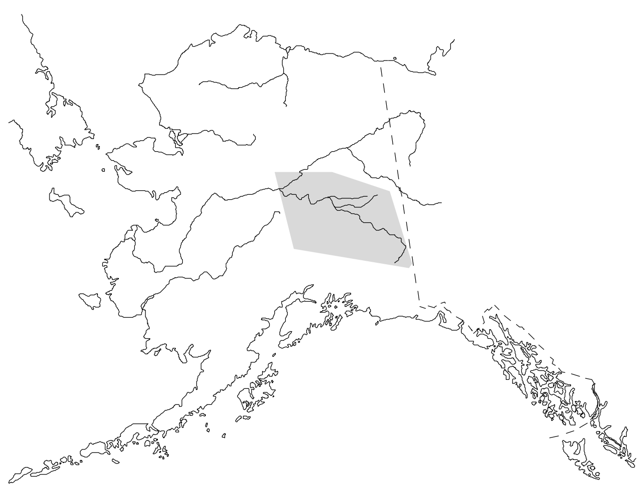

Figure 1.-The Tanana Valley (shaded area).

The stocking program provides consumptive fisheries along the road system where fishing effort and harvests are highest. The estimated total annual net economic value for major stocked waters (Chena, Birch, Quartz, and Harding lakes and Piledriver Slough) based on 1995 use and net economic values was $2,289,393 (SE = $226,681) (Bioeconomics 1996). In 1995, an estimated 41,654 anglers fished in the Tanana Valley and they generated an estimated 201,389 angler-days of effort[1] (Howe et al. 1996), second only to the Kenai Peninsula for number of angler-days. In 1995, harvests of populations of wild fish in the Tanana Valley were estimated at 37,284 fish (Howe et al. 1996). The stocking program provides alternative fisheries so as to direct harvests from wild fish as a conservation measure. Since 1991 stocked fish represent 51 to 69% of the estimated harvest of game fish in the Tanana Valley and about 35 to 49% of the total estimated fishing effort. During 1995, about 57% 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. 1996).

In 1991, to make the stocking program more efficient, ADF&G developed Fishery Management Plans (FMP) and significantly changed species, numbers, and sizes of game fish stocked in the Tanana Valley. These changes were based on a review of fishery studies, angler surveys, and creel surveys conducted since the 1970's. FMPs were developed for fisheries at Birch, Quartz, Chena, and Harding lakes, Piledriver Slough, and across an aggregation of more than 80 small lakes (ADF&G 1993). The FMPs list objectives that provide for minimum annual mean catch rates, limit stocking costs and serve to guide and evaluate the stocking program.

In 1995 we initiated an investigation to determine if Arctic char were reproducing in Harding lake. If Arctic char are producing significant numbers of offspring then we can reduce the number of Arctic char stocked in Harding lake and stock the surplus fish in other lakes.

In 1994, in response to a request from anglers, ADF&G identified three lakes (Craig Lake, Coalmine #5 Lake, and Little Harding Lake) where we would establish a fishery for trophy size rainbow trout. Trophy size was defined as 18 inches (457 mm) or longer. To accomplish this objective, the Alaska Board of Fisheries established special regulations and we developed a special management plan and modified the stocking program.

To evaluate the progress towards meeting objectives relating to growth rate of rainbow trout in trophy lakes, the feasibility of using visual implant tags (VITs) as unique marks was investigated beginning in 1995. A continuation of this study in 1996 is discussed in this report.

Arctic char stocked into small, shallow, low altitude lakes and gravel pits in the Interior usually do not survive. The population may be constrained by a water body’s thermal characteristics. During summer the size of the hypolimnion decreases and the epilimnion may approach or exceed the thermal tolerance of Arctic char. To determine if the current strategy for stocking Arctic char (stocking density based on lake surface area) should be amended to provide for consideration of the size of the hypolimnion, an estimate of how much lake volume becomes unsuitable for Arctic char in summer is needed.

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[1] Fishing effort (angler-days) for a location is defined as the estimated number of days fished by all anglers for that location (Mills 1980-1995). Any part day fished by an angler is considered one whole day or one angler-day.

The studies summarized in this report are intended to provide fishery managers with information to assess how well ADF&G is progressing toward achieving the objectives in the management plans for the major fisheries and for special fisheries such as those for trophy rainbow trout.

Following are the objectives and one task of studies addressed in this report for Project F-10-12, Job E-3-1(a).

Objective 1: For Harding Lake, estimate the proportion of Arctic char from natural reproduction in the population of Arctic char less than 300 mm such that $\Pr(|p - P| \geq 0.1) = 0.05$.

Objective 2: Estimate the abundance of rainbow trout in Craig, Coal Mine #5, and Little Harding lakes such that $\Pr\left(\left|\frac{\hat{N} - N}{N}\right| \geq 0.25\right) = 0.05$.

Objective 3: Estimate the age and size compositions of rainbow trout in these three lakes such that $\Pr(|p - P| \geq 0.05) = 0.05$. Age categories are: Age 1 and older than age 1. Size categories are: Less than 350 mm and 350 mm and larger.

Objective 4: Test the null hypothesis that large Arctic char are found as often or less often in the hypolimnion than in the epilimnion. The alternative hypothesis is that large Arctic char are found more often in the hypolimnion. H_o: $p \leq 0.5$ vs H_a: $p > 0.5$. This test is performed with the probabilities of Type I and Type II errors being 0.055 and 0.323 respectively for the alternative p=0.8.

Task 1: Calculate the cost-per-angler-day for Birch Lake, Quartz Lake, Chena Lake, Harding lake, Small Lakes, and Piledriver Slough. These data are used to monitor and assess the stocking program;

In addition, the rate that Visual Implant Tags (VITs) are lost one year after marking such that $\Pr(|p - P| \geq 0.1) = 0.1$ was estimated.

ARCTIC CHAR REPRODUCTION IN HARDING LAKE

Arctic char *Salvelinus alpinus* have been stocked into Harding Lake since 1988. In 1995, the estimated catch and harvest of Arctic char in Harding Lake was 1,610 and 245, respectively (Howe et al. 1996). The purpose of this project was to determine if stocked Arctic char have produced offspring. Some of the Arctic char captured during population studies in Harding Lake are old enough to reproduce and show signs of sexual maturation (developed kype, spawning coloration, gamete development). We want to know if stocked Arctic char have produced a significant number of offspring. Significant reproduction by stocked Arctic char could result in reduced stocking levels and subsequent reduced cost of the Harding Lake Arctic char stocking program. The stocking rate should be reduced if Arctic char from natural reproduction comprises one fifth or more of the population of Arctic char less than 300 mm. The current annual stocking for Harding Lake is 10,000 subcatchable (20-60 g) Arctic char.

METHODS

All Arctic char stocked in 1994 and 1995 were marked with adipose fin clips to distinguish them from similar size unmarked Arctic char that are the offspring of fish stocked in prior years. Fish stocked in 1993 were not marked and all Arctic char stocked before 1994 should now be larger than 300 mm. The average weight of Arctic char stocked in 1993 was 106 g (about 200 mm), in 1994 was 59 g (about 170 mm), and in 1995 was 73 g (about 183 mm) (see Appendix A).

We attempted to catch juvenile Arctic char (<300) from 15 - 17 July and 19 - 23 August 1996. For sampling we divided the lake into quadrants and 30 to 40 hoop traps were placed in each quadrant for 24 h. After 24 h we pulled the traps, examined, rebaited, and set them in another quadrant. The sampling order of the quadrants was selected randomly without replacement. General trap placement is shown in Figure 2. In water less than 15 m deep we attached a single trap to a line about one-third the depth from the bottom. In deeper water (34 m maximum depth) we attached a second trap on the line about two-thirds the distance from the bottom. Each line was held stationary with an anchor and marked with a buoy. We suspended the hoop traps so their long axis was horizontal and we baited the traps with unsalted frozen salmon roe.

The traps were made of Vexar with a mesh of 13 mm bar measure. They measured 1 m long x 0.4 m diameter. The interior funnel opening was 50 mm diameter which excluded large predators such as burbot *Lota lota*. Small steel or plastic rings were sewn to the opening to prevent large predators from expanding the size of the opening.

RESULTS AND DISCUSSION

No fish were captured. We do know that juvenile Arctic char are present because they have been stocked for a number of years (Appendix A) and adults from these stockings support a growing fishery. However, lack of captures indicate that the abundance of juvenile Arctic char (from stocking and natural reproduction) is too low to detect with our level of sampling effort – 161 trap days (number of hoop traps used and number of days the traps were fished). During earlier studies at Harding Lake, juvenile Arctic char were captured using gillnets (Viavant and Clark, 1991; Doxey 1991; Skaugstad et al. 1994). However, a review of these studies suggests these fish were likely stocked within a few weeks of sampling. Our sampling was scheduled about one month prior to stocking to avoid catching newly stocked fish. During another project we used the Vexar hoop traps in Little Harding Lake and captured 33 rainbow trout (125-421 mm) in 10 trap days (10 traps; each set for 1 day).

POPULATION STRUCTURE OF RAINBOW TROUT IN LAKES MANAGED FOR TROPHY SIZE FISH

In 1994 Region III 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). 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 (457 mm) or larger.

Success in establishing fisheries for trophy rainbow trout in Little Harding Lake, Craig Lake, and Coal Mine #5 Lake have criteria based on size. For these fisheries to be considered successes, at

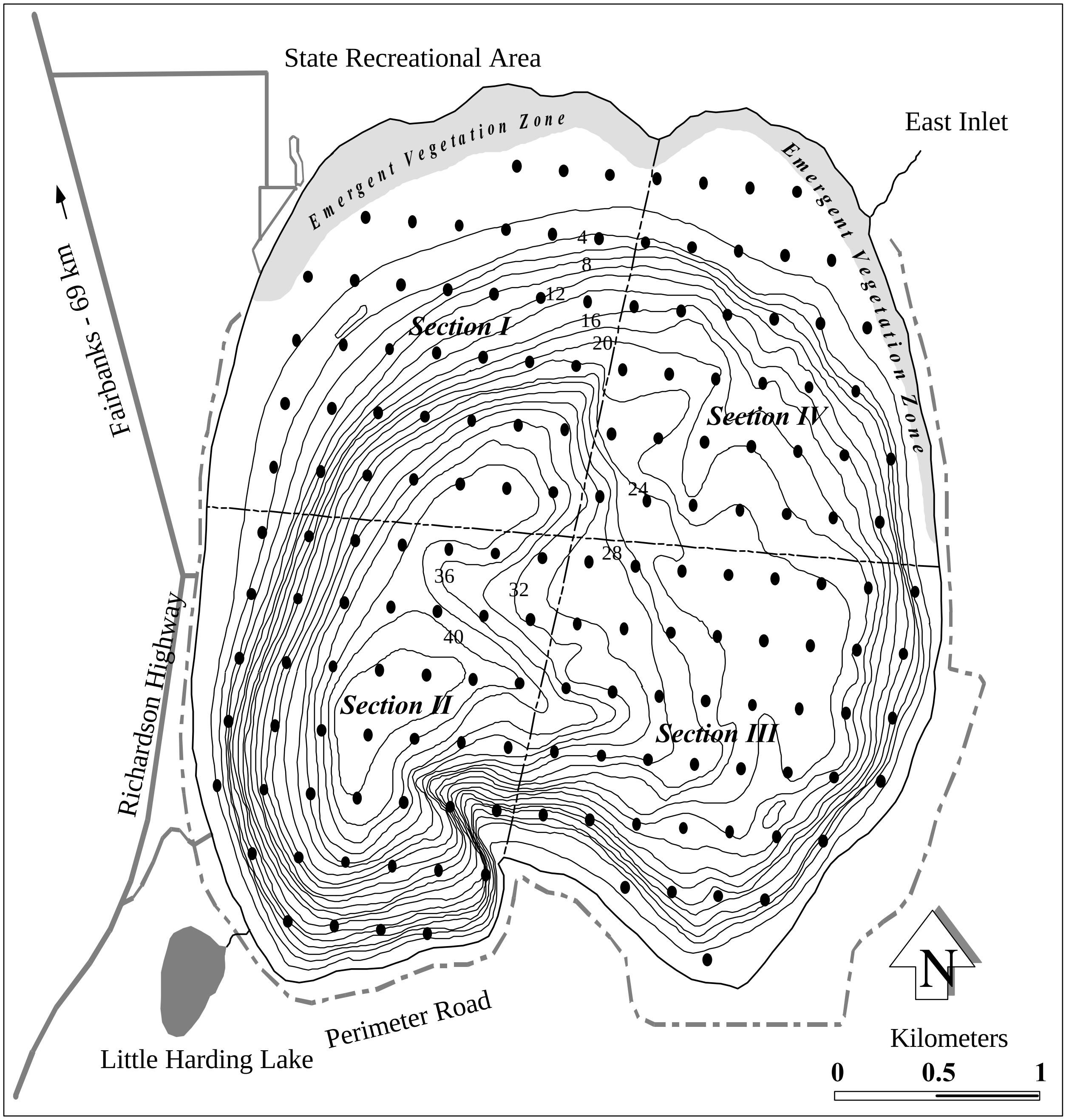

Figure 2.-General location of hoop traps in Harding Lake.

least half of an age cohort must exceed 14 inches (350 mm) by age 4. When stocked these fish are age 1 and averaged 42 to 70 g. These three lakes were stocked previously with rainbow trout and other species (Appendix B). Initially, landlocked coho salmon were present in Little Harding Lake. Lake trout and slimy sculpins *Cottus cognatus* are in Coal Mine #5 Lake and lake chubs *Couesius plumbeus* are present in Craig Lake and Little Harding Lake.

The purpose of this study was to estimate the size structure of the rainbow trout populations in these three lakes. This information will be used to evaluate progress towards achieving size criteria.

METHODS

Capture

We used a two sample mark-recapture experiment to estimate abundance during 29 July - 23 September. Prior to stocking we marked all rainbow trout by completely excising the right ventral fin of fish stocked in 1996 and the adipose fin in 1995. Rainbow trout stocked before 1995 were not marked. Fish were captured with fyke nets and marked to identify the capture event. We tried to have a hiatus of at least two weeks between the end of the capture and recapture events. Due to time constraints during sampling at Craig Lake we had a hiatus of two days before commencing the recapture event.

We distributed the fyke nets roughly equidistant to each other around the lake perimeters. The fyke nets were set with the center lead perpendicular to shore and wings parallel to shore. The unattached end of the center lead was anchored to shore and a weight was attached to the cod end to prevent the fyke net collapsing. A second method we used was to position 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 off shore. No center lead was used. In Craig Lake we set one fyke net in the middle of the lake. Metal tubing was used to stretch the fyke net and maintain proper shape. The wings of this fyke net were not used. We used unsalted salmon roe to bait the fyke nets. The openings of the fyke nets were 1.2 m sq., mesh size was 9 mm sq., wings were 7.5 m long, and the center leads were 30 m long by 1.2 m deep.

For marking we used a paper punch (which produces a 7 mm diameter circular hole) to remove a half circle 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. We marked all fish with a punch in the upper lobe that were captured during the recapture events. Any fish captured more than once during either the marking or recapture events was counted only once per event. Any fish captured in the second event without a mark in the lower lobe was classified as unmarked (captured for the first time). All captured fish were measured to the nearest millimeter from tip-of-snout to fork-of-tail (FL).

Data Analysis

The assumptions necessary for accurate estimation of abundance in a closed population and the test of these assumptions are described in Appendix C and Appendix D. If significant size bias was detected, separate population estimates were calculated for each size category. The resulting independent estimates were then summed to produce an estimate of abundance.

The modified Petersen estimator of Bailey (1951, 1952) was used to estimate the abundance of the entire population or a size category of the rainbow trout population in each of the three lakes:

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

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

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

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

A length frequency distribution of fish with adipose and right ventral fin clips was used to separate the sample into two age/size categories. Only fish captured for the first time were used to generate the distribution. The distribution was examined and an arbitrary point was chosen between the two modes representing the small and large fish that gave the lowest number of misclassified individuals. When the data were adequate, abundance was also estimated for the population equal to or larger than 350 mm (14 in). Only the abundance estimate and the length data from fish in the larger size category were used to estimate the abundance of fish equal to or larger than 350 mm. Fish in the larger size category were divided into two sub categories - those less than 350 mm and those equal to or greater than 350 mm. These new size categories were examined for size bias following the same procedures already described. The estimated proportion of fish equal to or larger than 350 mm was calculated as:

$$\hat{p} = \frac{y}{n} \tag{3}$$

where: $\hat{p} =$ the proportion of rainbow trout that were equal to or larger than 350 mm; y = the number of rainbow trout sampled that were equal to or larger than 350 mm; and, n = the total number of rainbow trout sampled in the larger size category.

The unbiased variance of this proportion was estimated as:

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

The abundance of rainbow trout in the population equal to or larger than 350 mm was then:

$$\hat{N}_k = \hat{p}\hat{N} \tag{5}$$

where: N_j = the estimated abundance of fish in the larger size category.

The variance for $\hat{N}_k$ in this case was estimated by (Goodman 1960):

$$\hat{V}\left[\hat{N}_k\right] = [\hat{p}]\hat{N}^2 + V\left[\hat{N}\right]\hat{p}^2 - \hat{V}[\hat{p}]xV\left[\hat{N}\right]. \tag{6}$$

RESULTS

Little Harding Lake

During the mark-recapture experiment 819 individual rainbow trout were captured in both events (Table 1, Figure 3). Of these, 447 had adipose fin clips (fish stocked in 1996) and 76 had right ventral fin clips (fish stocked in 1995). A length frequency distribution by age cohort showed almost complete separation of fish stocked in 1996 from those stocked in 1995 (Figure 4). The sample was divided at 250 mm which separated the age 1 fish from the rest of the population. Tests for size bias inferred there was size-selectivity during both the mark and recapture events (Table 2). However, tests for size bias found no significant size-selectivity between the size categories 250 mm ≤ x <350 mm and ≥350 mm. We estimated 2,597 rainbow trout less than 250 mm and 353 fish equal to or larger than 250 mm and 104 fish equal to or larger than 350 mm (Table 3). We also captured 25 coho salmon that ranged in size from 294 to 370 mm FL (Appendix E1). Lake chub were present in the catch, but they were not enumerated.

Craig Lake

During the mark-recapture experiment 293 individual rainbow trout were captured in both events (Table 4, Figure 5). Of these, 34 had adipose fin clips (fished stocked in 1995) and 34 had right ventral fin clips (fish stocked in 1996). Length frequency distributions of these marked cohorts showed some overlap (Figure 6). We chose to divide the sample at 240 mm for separating the sample into two age cohorts. Tests for size bias inferred there was size-selectivity during the marking event (Table 5). We estimated 323 rainbow trout less than 240 mm and 106 fish equal to or larger than 240 mm (Table 6). None of the captured fish were 350 mm or larger.

Coal Mine #5 Lake

During the mark-recapture experiment 48 individual rainbow trout were captured in both events (Table 7, Figure 7). Of these, four had adipose fin clips (fished stocked in 1995) and 36 had right ventral fin clips (fished stocked in 1996). None of the captured fish were 350 mm or larger. Length frequency distributions of these marked cohorts did not overlap (Figure 8). We chose not to divide the sample into two age cohorts using length frequencies because too few older fish were captured. Tests for size bias inferred there was no size-selectivity during the marking event or the recapture event (Table 8). We estimated 67 rainbow trout in the population (Table 9). We also captured 58 lake trout that ranged in size from 267 to 605 mm FL (Appendix E2). Slimy sculpin were also present in the catch; however, they were not enumerated.

DISCUSSION

The rainbow trout population in Little Harding Lake will most likely achieve the criteria for a successful trophy fishery. The populations in Coal Mine #5 Lake and Craig Lake will not achieve the criteria because large fish are missing from these populations. We had anticipated catching fish that had been stocked prior to 1995 but few were present in our samples. Fish stocked prior to 1995 could be identified because they lacked marks and would generally be larger than the 1995 and 1996 cohorts. However, length frequency histograms for fish sampled from Coal Mine #5 Lake and Craig Lake show no fish larger than 340 mm while there were several fish in the sample from Little Harding Lake larger than 340 mm. It is possible that the rainbow trout population in Coal Mine #5 Lake and Craig Lake suffered high mortality due to

Table 1.-Rainbow trout captured at Little Harding Lake during mark-recapture experiment, 1996.

	Marking Event		Recapture Event		
	Date	Number Marked	Date	Number Unmarked	Number with Marks
	29 Jul - 9 Aug	692	19 - 23 Aug	127	42
<250 mm		582		94	24
≥250 mm		110		33	18
250≤ x <350 mm		79		29	11
≥350 mm		34		11	7

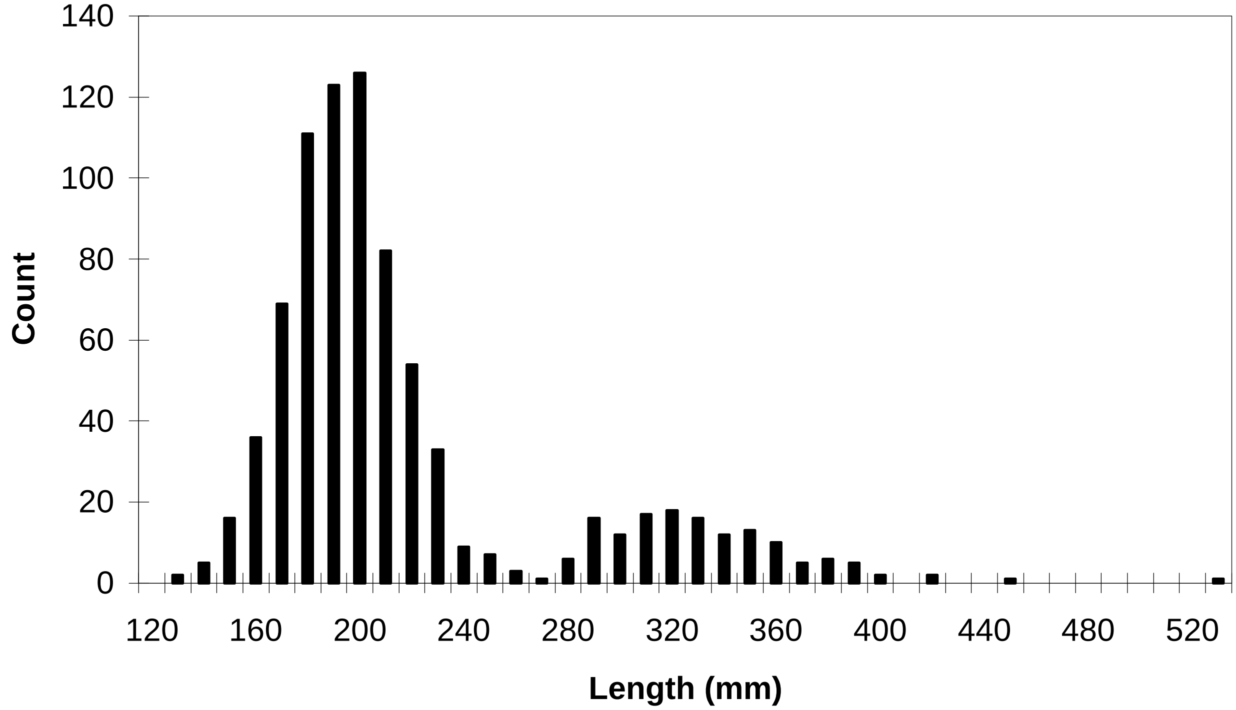

Figure 3.-Length frequency histogram for rainbow trout captured for the first time during the mark-recapture experiment at Little Harding Lake, 1996.

Table 2.-Evaluation of size bias during the mark-recapture experiment at Little Harding Lake.

	Test 1		Test 2	
	Recaptured	Not Recaptured	Marked	Not Marked
Size Category:				
<250 mm	24	555	24	87
≥250 mm	18	95	18	40
Results:				
χ^2	23.08		1.81	
p-value	0		0.18	

Table 3.-Abundance estimates for the rainbow trout population in Little Harding Lake, 1996.

			95% Confidence Limits	
	Abundance	SE	Lower	Upper
Size Category:				
<250 mm	2,597	439	1,736	3,459
≥250 mm	353	59	236	470
Combined	2,950	443	2,081	3,819
≥350 mm	104	22	61	147

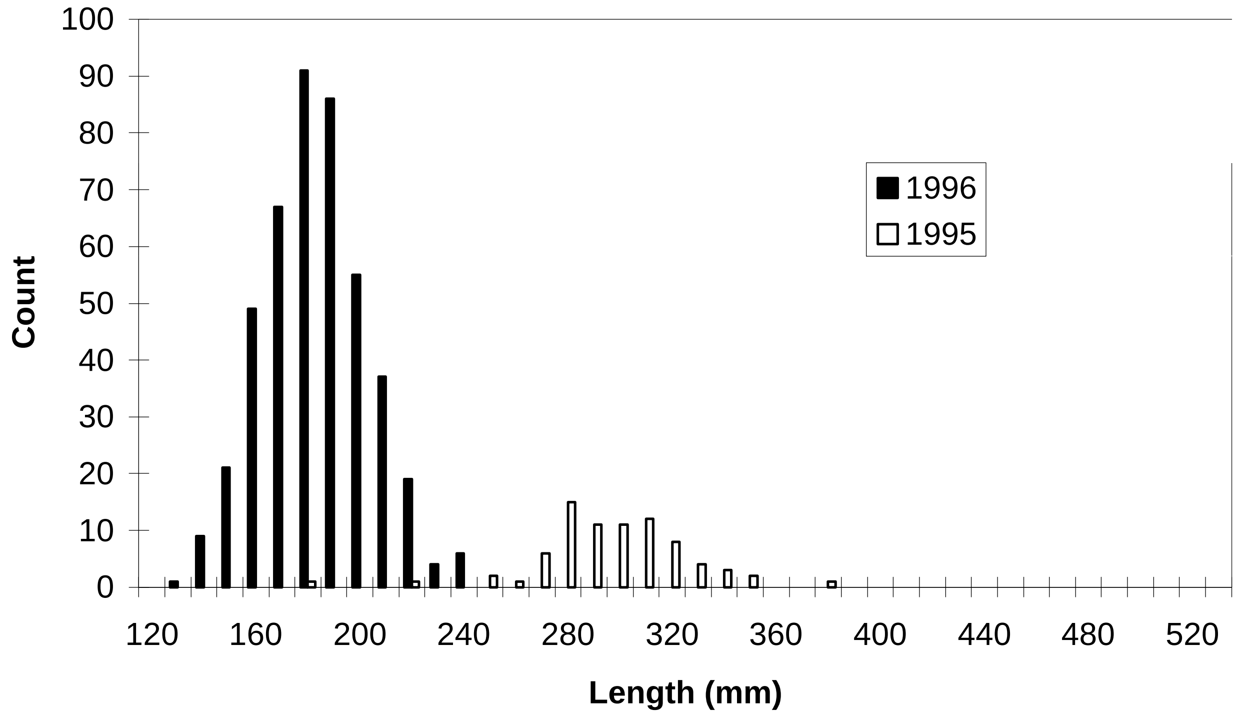

Figure 4.-Length frequency histogram by age class for rainbow trout captured for the first time during the mark-recapture experiment at Little Harding Lake, 1996. Black bars represent fish stocked in 1996 and white bars are fish stocked in 1995.

Table 4.-Rainbow trout captured at Craig Lake during mark-recapture experiment, 1996.

	Marking Event		Recapture Event		
Size Category	Date	Number Marked	Date	Number Unmarked	Number with Marks
All	19 - 22 Aug	236	26 - 30 Aug	57	69
<240 mm		202		35	60
≥240 mm		34		22	9

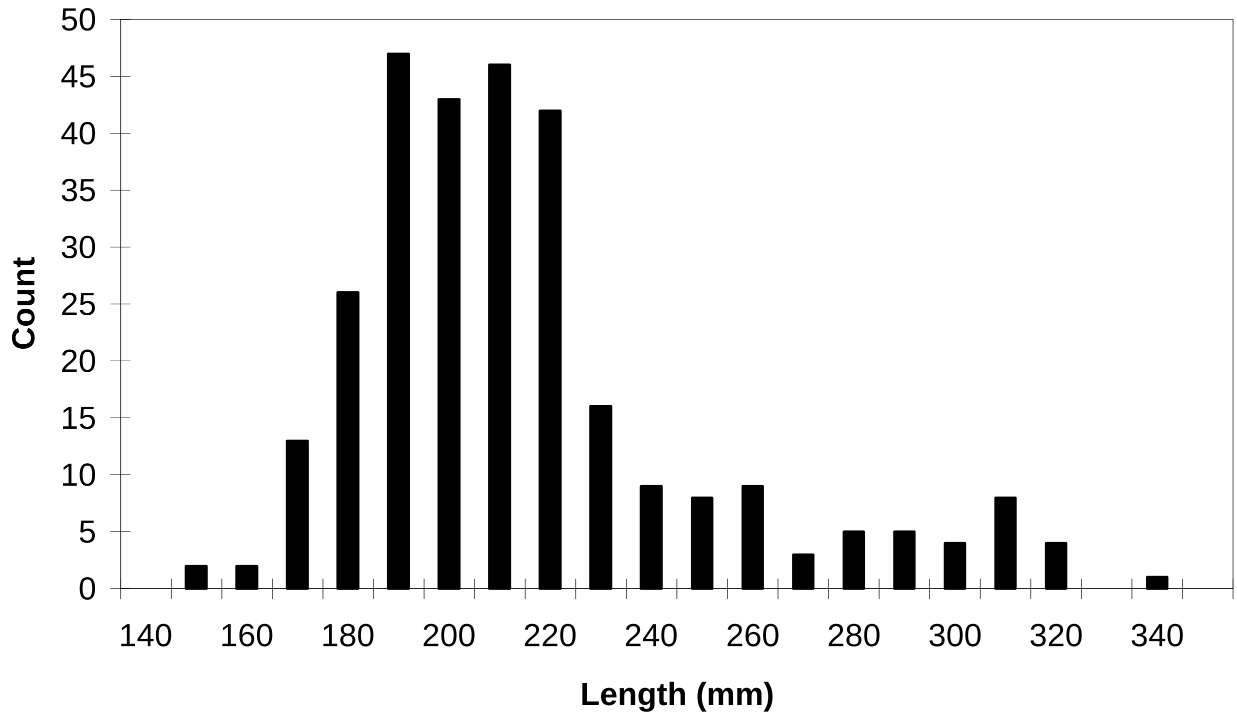

Figure 5.-Length frequency histogram for rainbow trout captured for the first time during the mark-recapture experiment at Craig Lake, 1996.

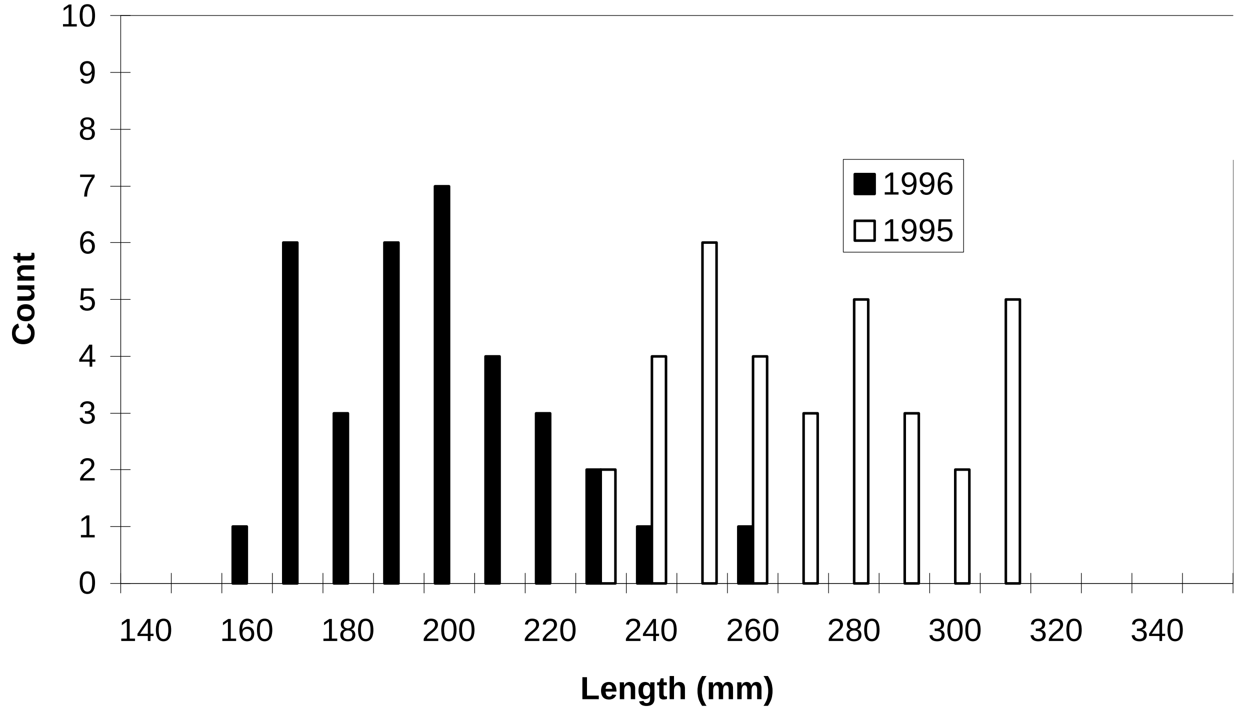

Figure 6.-Length frequency histogram by age class for rainbow trout captured for the first time during the mark-recapture experiment at Craig Lake, 1996. Black bars represent fish stocked in 1996 and white bars are fish stocked in 1995.

Table 5.-Evaluation of size bias during the mark-recapture experiment at Craig Lake.

	Test 1		Test 2	
	Recaptured	Not Recaptured	Marked	Not Marked
Size Category:				
<240 mm	60	142	60	35
≥240 mm	9	25	9	22
Results:				
χ^2	0.15		10.99	
p-value	0.70		0.001	

Table 6.-Abundance estimates for the rainbow trout population in Craig Lake, 1996.

			95% Confidence Limits	
Size Category	Abundance	SE	Lower	Upper
<240 mm	323	27	270	377
≥240 mm	106	18	70	141
Pooled	429	29	373	485

Table 7.-Rainbow trout captured at Coal Mine #5 Lake during mark-recapture experiment, 1996.

	Marking Event		Recapture Event		
Size Category	Date	Number Marked	Date	Number Unmarked	Number with Marks
All	19 - 23 Aug	31	26 Aug- 23 Sep	17	14

Table 8.-Results of Kolmogorov-Smirnov tests used to evaluate size bias during the mark-recapture experiment at Coal Mine #5 Lake.

All Fish in Event 1 vs All Fish in Event 2		All Fish in Event 1 vs All Marked Fish in Event 2	
DN	p-value	DN	p-value
0.21	0.34	0.22	0.62

Table 9.-Abundance estimates for the rainbow trout population in Coal Mine #5 Lake, 1996.

			95% Confidence Limits	
Size Category	Abundance	SE	Lower	Upper
Pooled	67	9	49	85

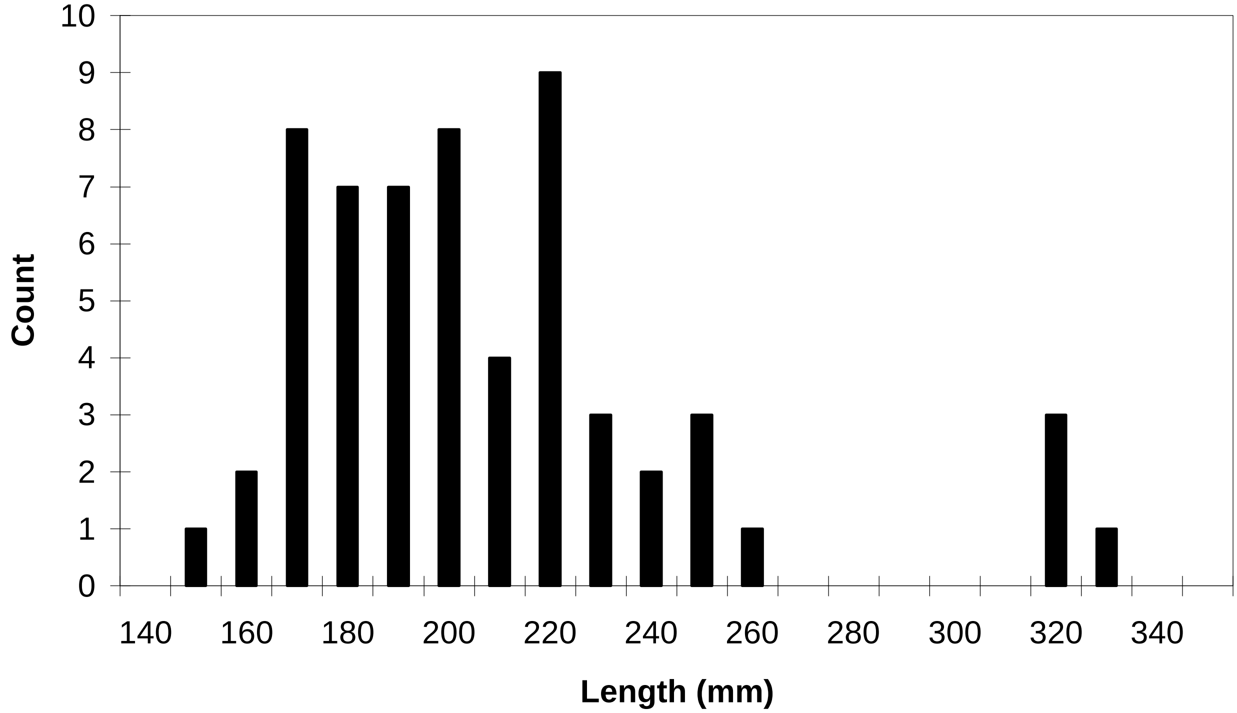

Figure 7.-Length frequency histogram for rainbow trout captured for the first time during the mark-recapture experiment at Coal Mine #5 Lake, 1996.

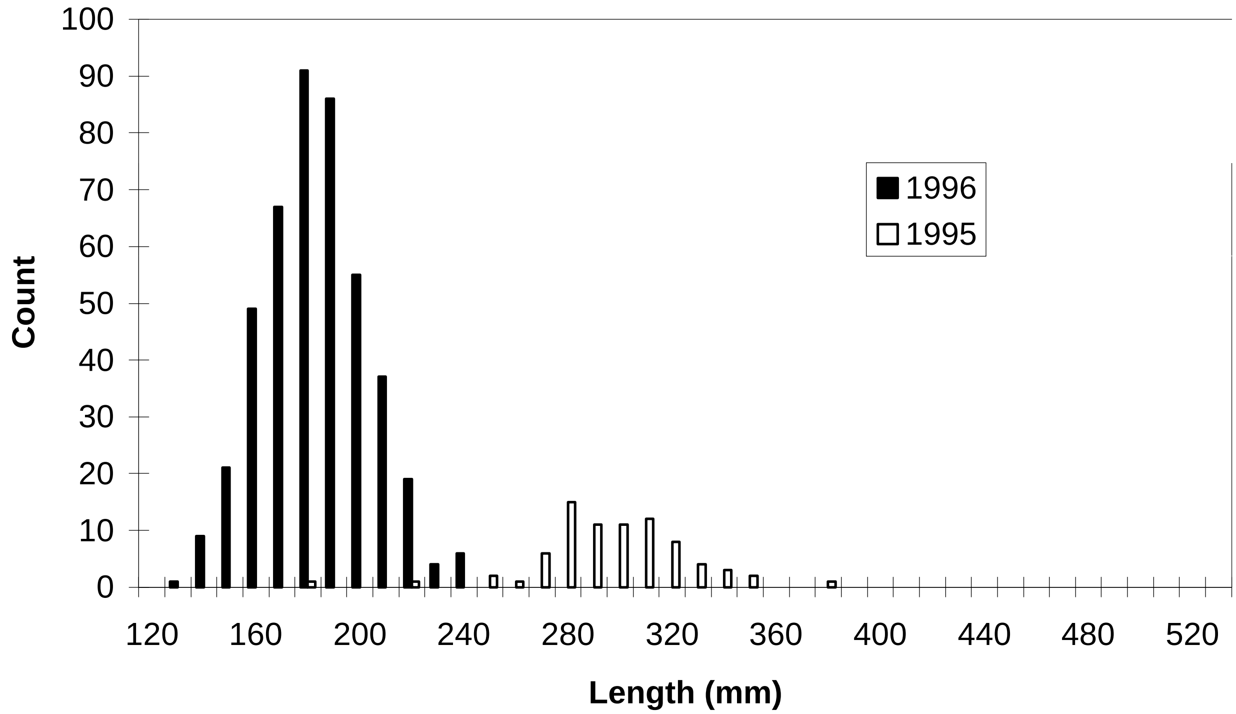

Figure 8.-Length frequency histogram by age class for rainbow trout captured for the first time during the mark-recapture experiment at Coal Mine #5 Lake, 1996. Black bars represent fish stocked in 1996 and white bars are fish stocked in 1995.

weather or these fish were illegally harvested. Anecdotal information from anglers suggest that fish stocked in 1995 in Coal Mine #5 Lake and Craig Lake were present until the fishery closed in fall 1995 but were missing the following spring. In spring 1996 at Quartz Lake we also found very few large rainbow trout in our catch samples. Similar observations have been made in the past at Quartz Lake and other productive lakes and probably result from low levels of dissolved oxygen which often occur in the spring when ice breakup is delayed. In 1996, ice breakup at Quartz Lake was later than normal which may have resulted in low dissolved oxygen levels. This same situation may have occurred at Coal Mine #5 and Craig Lake. We don't know if ice breakup was delayed at Little Harding Lake.

While we have no direct evidence of illegal harvests, anglers have reported that people were using bait and keeping fish less than the legal size limit (18 in) length. We have captured rainbow trout during sampling that have treble and bait hooks imbedded in their mouths. This gear is illegal. Illegal harvests probably account for some but not all of the missing large rainbow trout.

VISUAL IMPLANT TAG LOSS

The purpose of this study was to evaluate visual implant tags (VITs) loss one year after stocking. In an earlier study at Ft. Richardson hatchery in 1995 we showed 30% of VITs were lost 72 days after marking (Skaugstad and Doxey 1996). A follow up check of another group of fish with VITs in Little Harding Lake in September 1995 (97 days after stocking and 111 days after marking) found 26% of fish with VITs had lost their tags.

Rainbow trout used in this study were marked with VITs in 1995 and 1996 prior to stocking. Fish released in 1995 were also marked with an adipose fin clip and in 1996 the fish were given a right ventral fin clip. Data were collected 29 July through 23 September 1996 during mark-recapture experiments to estimate the population abundance of rainbow trout.

We captured 117 rainbow trout with adipose fin clips and 61 of these fish had lost VITs (Table 10). We also captured 678 rainbow trout with right ventral fin clips and 77 ($p = 0.11$, SE $= 0.012$) of these fish had lost VITs (Table 10).

Table 10.-Rainbow trout captured with and without visual implant tags (VITs).

No. Captured	Fin Clip	Stocking Date	Number of fish with VITs	Number of fish without VITs	Proportion of Tags Lost	SE
117	Ad	21-Jun-95	56	61	0.52	0.046
678	RV	10,18-Jul-96	601	77	0.11	0.012

The high loss rate of VITs from fish marked in 1995 makes this marking method unacceptable for future use in capture-recapture experiments. This follow up study demonstrates that VITs were still being lost 72 days after the tags were inserted. We believe that the lower loss rate for fish marked in 1996 is due to less time having elapsed since marking. Given more time a greater number of VITs will probably be lost from the 1996 cohort.

HABITAT USE BY ARCTIC CHAR IN HARDING LAKE

Arctic char used for stocking in Tanana Valley lakes were originally from Lake Aleknagik in the Bristol Bay area. These fish are adapted to large, deep lakes that provide cold water habitat all year. When we stock the progeny of these fish into small (<20 ha), shallow (< 4 m maximum depth), low altitude (<200 m) lakes and gravel pits in the Tanana Valley they usually do not survive (Skaugstad 1991). Near surface temperatures in these lakes often exceed 24°C in the summer and are probably too shallow to stratify. However, Arctic char stocked into low altitude but deeper lakes or shallow but higher altitude lakes in the Tanana Valley provide acceptable fisheries. A reasonable explanation is that some portion of the water body of small, shallow, high altitude lakes does not exceed lethal temperatures while lakes with similar morphology but at lower altitude exceed lethal temperatures throughout the water body. Large, deep, low altitude lakes do stratify during the summer with suitable temperatures in the hypolimnion.

The population size for Arctic char may be constrained by a lake’s thermal characteristics. This may become more apparent and critical to the population during summer stratification when the epilimnion approaches or exceeds biological limits for thermal tolerance and the size of the hypolimnion decreases. If suitable habitat during summer only exists in water cooler than 13°C (ADF&G 1976), the amount of suitable habitat may decrease to less than one half the size of large deep lakes and approach zero for small shallow lakes.

We base stocking densities for Arctic char in Tanana Valley lakes on surface area. But, if useable habitat is restricted to the hypolimnion during summer then stocking densities should be calculated based on the amount of useable habitat provided by the hypolimnion. This will result in reduced stocking densities yet provide about the same number of fish for anglers.

This study was designed to investigate Arctic char movements with respect to thermal strata in Quartz Lake and Harding Lake. Only two Arctic char were captured in Quartz Lake and both were smaller than the minimum acceptable size for attaching sonic tags. Therefore, habitat use by Arctic char could not be investigated in Quartz Lake. This report discusses the portion of the study conducted at Harding Lake.

METHODS

Arctic char were captured with gill nets at several different locations that represent diverse habitat. We used sinking, multi-filament gill nets that measured 38 m x 2 m and were triple-hung with 50 mm mesh (bar measure). Eight nets were fished in four pairs by joining two nets end to end. All nets were set on the lake bottom. Gill nets were checked every 30 min and moved to a new location every 2 h. Most Arctic char, however, were captured at sites A and B (Figure 9). All captured fish were measured to the nearest millimeter fork-length (FL). We selected and attached sonic tags to five fish larger than 550 mm but less than 650 mm and five fish equal to or larger than 650 mm. After attaching the tags all captured fish were held in a holding tank for about 15 min for observation. We did not use any fish with obvious injuries, that were lethargic, or had problems maintaining equilibrium. Tagged fish were released at least 200 m from the capture site after they regained equilibrium (usually within 15 min after tagging).

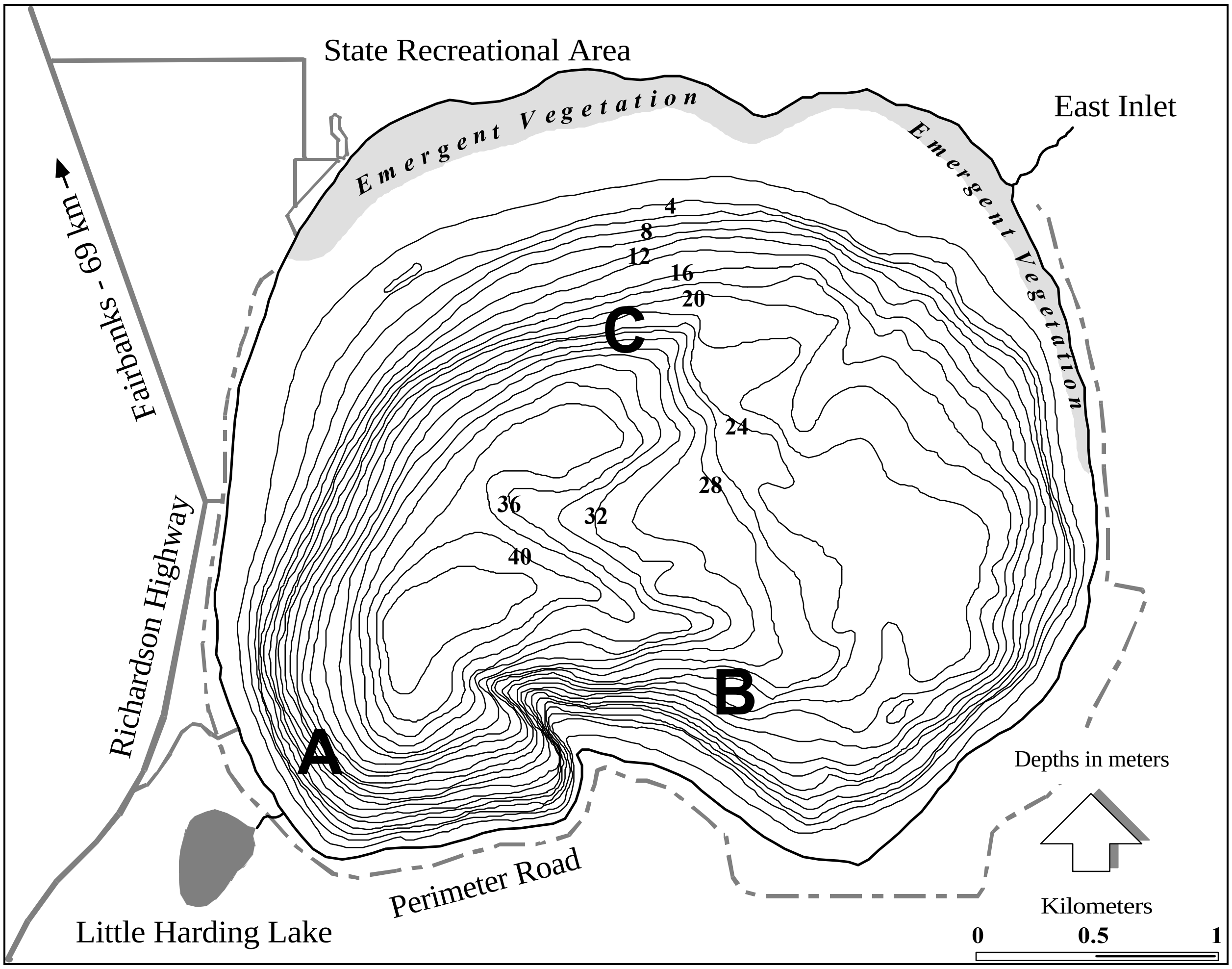

Figure 9.-Capture sites in Harding Lake.

The sonic tags (model DT-96) and ultrasonic receiver (model USR-5W) were manufactured by Sonotronics, Tucson, AZ. Tag size is 18 mm diameter by 90 mm long, out of water weight is 12 g and battery life is 12 mo. Maximum range is 3,000 m and depth accuracy is about 2% of full scale. Full scale for Harding Lake is 100 PSI (at 75 m depth the accuracy is about 61 cm). Tags are preset to separate frequencies. Depth information is encoded by altering the pulse interval. We used the ultrasonic receiver and directional hydrophone (model DH-2) to detect the tags and display the pulse interval. Each tag was checked to verify operation and frequency before attaching to a fish.

We attached the sonic tags along the base of the dorsal fin using a method similar to attaching a Petersen disk. Stainless steel wires (22 gage) attached to each end of a tag were inserted through the musculature about 10 mm below the line where the dorsal fin joins the back. Two small disks (about 20 mm diameter) were slid onto the wire on the side of the fish opposite the tag. We then twisted the protruding wire into a loop to prevent it from pulling back through the disk.

We measured the water temperature with a YSI model 51B oxygen analyzer at 1.3 m (5 ft) intervals once in the afternoon during each 24 h period. All measurements were made in the southwest basin over the deepest area.

We recorded the depth and approximate location of tagged Arctic char once every 6 h during a 24-hour period. We determined the bearing to a fish by rotating the hydrophone until we received the strongest signal and then recorded the listening site and signal direction on a map. When possible the point on the lake directly over a tagged fish was determined by the intersection of compass bearings obtained from two or more sites.

RESULTS

Ten Arctic char were captured and fitted with sonic tags from 3 to 7 June 1996 (Table 11). We identified each tagged Arctic char by the frequency of the attached sonic tag. While we were capturing and tagging Arctic char an angler caught Fish 75 and returned the sonic tag to us. We attached the tag to another fish on 7 June.

All fish were released about 15 min after receiving a tag and none displayed problems with equilibrium or swimming. We determined that Fish 78 had died or shed its sonic tag sometime after 26 June but prior to 9 July 1996 based on constant depth readings and no horizontal movement.

Temperature Profiles

During summer water temperature near the surface exceeded 20°C on 24 July 1996 but cooled to less than 5°C about 20 m from the surface (Figure 10). The lake became isothermal at 6°C on 2 October 1996.

Tracking (Depth and Location)

During a 24-h period we made four observations for each of nine tagged fish which equaled 36 observations per period. Initially, Arctic char were found near the surface but as the surface water warmed the sonic tagged fish were found further from the surface (Appendix F). From 25 June through 28 August 1996, 143 Arctic char were found in hypolimnion, water cooler than 12°C (proportion = 0.993, $z = 11.8$, $P < 0.0001$). As summer progressed the fish became more dispersed in the water column but still avoided near surface water warmer than 12°C. The 12°C

Table 11.-Arctic char captured and affixed with sonic tags, Harding Lake, 1996.

Date	Capture Location	Length (mm)	Frequency (KHz)	Floy Tag	Comments
3 Jun	A	760	76		
3 Jun	A	660	79		
3 Jun	A	560	78		
3 Jun	B	572	75		Tag returned by angler 6 Jun.
3 Jun	B	585	73	946 Yellow	
3 Jun	C	650	70	947 Yellow	
6 Jun	A	670	71		
7 Jun	A	620	75		Tag 75 attached to new fish.
7 Jun	A	561	72		
7 Jun	B	695	74		
26 Jun	B	590	77		

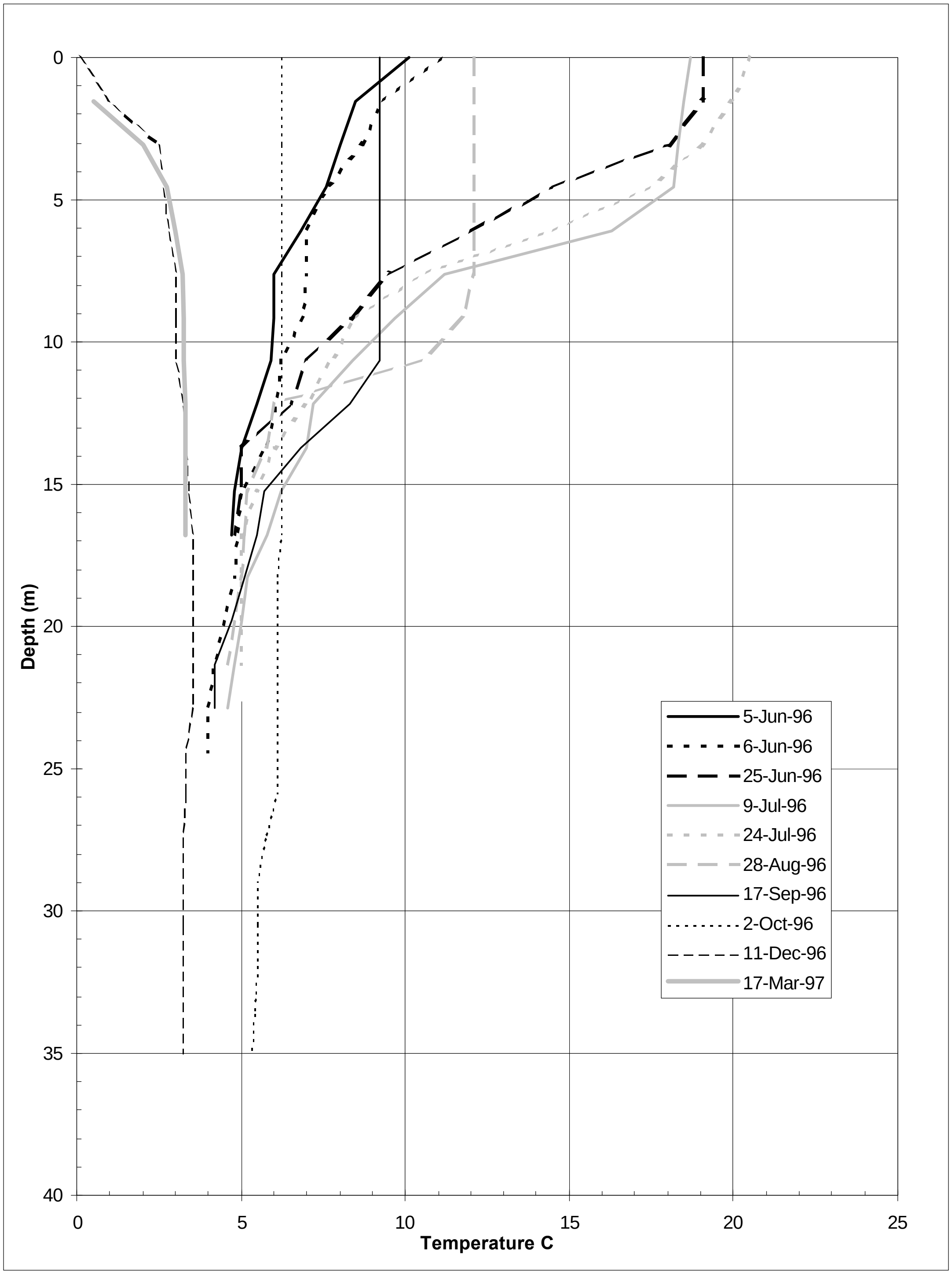

Figure 10.-Temperature profiles for Harding Lake 5 June 1996 through 17 March 1997.

profile was near 6 m on 25 June, 7.5 m on 9 July, 7 m on 24 July, and 9 m on 28 August 1996. On 17 September when the lake was about 9°C or cooler only two fish on just one occasion (two observations out of 36) were found within 10 m of the surface. Not until 17 October when the lake was isothermal were Arctic char observed about one-half of the time within 10 m of the surface (16 out of 36 observations). The sonic tagged Arctic char were found throughout the water column on 11 December 1996 and 17 March 1997.

Sonic tagged Arctic char did not display any obvious horizontal movement patterns as individuals or in groups (Appendix F). Fish were dispersed across the lake and some were quite mobile during a 24-h period moving between opposite shores. Others did not move much during one 24-h period but would sometimes move more than 2 km during another 24-h period.

DISCUSSION

It is apparent that Arctic char prefer temperatures less than 12°C. All of our other lakes stocked with Arctic char are much more shallow (<12 m) than Harding Lake. A review of temperature profiles and bathometric maps for several lakes show 12°C temperatures extend down to 9 m leaving about one-fourth of the lake volume cooler than 12°C during summer. Some lakes are even more shallow and exceed 12°C throughout the water column. If Arctic char are stressed at temperatures 12°C or warmer then prior to stocking it should be determined if there is water cooler than 12°C during summer and its extent. Adjusting stocking levels based on the extent of the refuge may or may not be necessary unless the refuge is a small fraction of the lake volume.

During June through August as we attempted to establish the horizontal location of the sonic tagged fish we found it difficult to hear the sonic tags more than 0.5 km from the source due to water craft activity and wind and wave action. During periods when water craft were not active and there was little or no wind we could hear some tags for a distance up to 2 km. During winter we could hear each sonic tag from any point on the lake (maximum width for the lake is about 4 km). During winter the lake is completely covered with ice which eliminated surface noise from wind and waves.

The horizontal location of Arctic char during summer are approximate because we found it too difficult to use triangulation to more accurately determine location. We found that surface noise reduced the distance that the sonic tags could be heard and movement of the boat while taking bearings hampered accurate observations. Triangulation was easily accomplished during winter while working on the ice. We could not determine distance moved from one observation to the next with any accuracy because we were limited to using bearings that provided only a general location. These observations do provide information for a general area where the fish was present.

ASSESSMENT OF FISHERY MANAGEMENT OBJECTIVES FOR STOCKED WATERS

Since 1992 the stocking program accounts for an average 26% of effort and 61% of the harvest for all sport fisheries in the Tanana Valley. Over the years we have modified our stocking program for the major fisheries to adapt to changing fisheries, increased hatchery capacity, and to take advantage of new research. We have found the lowest cost-to-a-catchable fish was dependent on the size of fish used for stocking and the best size was different for each of our three major stocked lakes (Skaugstad, Hansen and Doxey 1995). Costs refer to expenditures at state hatcheries. For example, fingerling [2](1-10 g) rainbow trout stocked in Quartz Lake produce the lowest cost-to-a-catchable fish while stocking subcatchable (15-75 g) rainbow trout in Birch Lake give the lowest cost. In Chena Lake we stock catchable (>90 g) rainbow trout because growth and survival rates are low for fish stocked as fingerlings or subcatchables. To reduce stocking costs but maintain fishing effort in Piledriver Slough, ADF&G decreased the number of rainbow trout that are stocked but increased their size. To provide more fishing opportunities we are emphasizing small lakes in urban areas with easy road access. We have diverted more resources toward these lakes by stocking more fish and/or larger fish, and providing additional promotion through informational handouts to anglers and news releases.

In 1995 we started stocking catchable sized fish in early spring in lakes with popular fisheries. Prior to altering our stocking strategy, anglers were expressing frustration with these fisheries because by spring there were too few large fish. Most of the catchable fish had been harvested by winter. We still stock catchable fish in late spring/early summer as we have done in the past which provides catchable fish for the remaining season. Because our hatcheries have expanded their capacity to produce catchable fish, we now stock lakes which can not produce or sustain sufficient numbers of large fish to support a desirable fishery. In these lakes we stock only what we anticipate will be harvested. This stocking strategy increases the number of lakes that we can stock and provides new fisheries in urban areas where potential use is high.

METHODS

Assessment of the management objectives for each fishery requires the collation of data from several sources. Fishery management objectives were obtained from Fishery Management Plans (FMPs) for Piledriver Slough, and Birch, Quartz, Chena, Harding, and the Small lakes (ADF&G 1993). Fish production and its cost for 1995 and 1996 were obtained from audits of hatchery records. Prior to 1995, costs and production data were obtained from the Recreational Fishery Program Maintenance of Effort report (CFMD 1984-1994). Hatchery operating costs are based on a fiscal year that begins 1 July and ends 30 June (i.e., FY95 is for the period 1 July 1994 through 30 June 1995) while stockings are scheduled on a calendar year (CY). Hatchery production is the total weight of fish stocked from 1 January through 31 December. Costs and production include all costs and all production for the hatchery, even though some portion of the fish were not destined for release in the Tanana Valley, were for commercial fisheries, or were

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[2] The weight intervals that are used for classifying fish as fingerling, subcatchable, or catchable are arbitrary. Generally, fish stocked as fingerlings do not reach catchable size (about 90 g) until the second year after stocking and most fish stocked as subcatchables reach catchable size one year after stocking.

used for the rehabilitation of the Arctic grayling population in the Chena River. Estimates of the number of anglers, fishing effort (angler days) and total harvest of game fish by species for each location were obtained from the Statewide Harvest Survey (SWHS; Mills 1980-1995, Howe et al. 1996). Some of these data required further manipulation to allocate effort between stocked and wild fish populations for certain locations, to calculate stocking costs by location and species, and to calculate cost-per-day-fished (CDF).

Stocking costs for calendar year 1995 (CY95) were based on operating costs for FY95 and fish production for CY95. We obtained estimates of average weight and number of fish for each released cohort from the Ft. Richardson and Clear AFB hatcheries. Stocking costs for individual cohorts were then summed by location and species.

We calculated stocking costs for each cohort and cost-per-day of fishing (CDF),

$$\hat{c}_i = \frac{C}{\hat{W}}(\hat{n}_i \hat{\bar{w}}_i) \tag{7}$$

$$C\hat{D}F = \frac{\sum \hat{c}_i}{\hat{E}} \tag{8}$$

where:

C	=	hatchery operating cost in a fiscal year;
W	=	weight of fish stocked in a calendar year;
n_i	=	number of fish stocked in cohort *i*;
$\bar{w}_i$	=	average weight of fish stocked in cohort *i*,
c_i	=	cost of fish stocked in cohort *i*,
E	=	total annual angler days of fishing effort by location; and,
CDF	=	cost per angler day by location.

We defined a cohort as a group of similar size fish of the same species and age that were stocked at the same time in the same location. For example: a cohort of 4 g rainbow trout stocked in 1991 was considered different from a cohort of 24 g rainbow trout stocked in 1991. Both of these cohorts are different from a cohort of 4 g rainbow trout stocked in 1992. Annual cost for a stocking location was calculated as the sum of all costs associated with stocking fish for that location. We used similar methods to calculate the total annual stocking costs by species. Estimates of fishing effort were obtained with some modification from the SWHS for fisheries at Harding Lake, Piledriver Slough, and small lakes. For Harding Lake and Piledriver Slough, estimates of fishing effort were arbitrarily divided by two because of wild game fish which also contribute to the total effort for these locations. In the SWHS effort is not apportioned between species. There are no wild fish in the other major lakes (Birch, Quartz, and Chena). Some of the small lakes were listed individually in the SWHS and effort was estimated for each lake. However, due to small sample sizes, most of the small lakes were grouped and a single estimate of effort was made for the group. Within this group of small lakes is another group called “other lakes”. Some of these “other lakes” have stocked game fish, others have only wild game fish, and some have both. Because wild fish made a significant contribution to the harvest for these fisheries, the effort for these “other lakes” was apportioned using the proportion of stocked and wild fish harvested from these lakes (Table 12). All rainbow trout, coho salmon, chinook salmon, Arctic char, and Arctic grayling were considered to have come from stocked populations. Fish that were listed as either Arctic char or Dolly Varden in the SWHS were considered to be stocked Arctic char because only a few lakes in the Tanana Valley have small populations of wild Dolly Varden. All other harvested fish were considered wild.

RESULTS

Management objectives from the FMPs are summarized in Table 13 along with the actual fishery statistics for 1993-95. Generally, effort for all fisheries in 1995 increased or were similar to levels in 1993 and 1994. Harvest levels for only two locations in 1995 were higher than those in 1994 but harvest levels in 1995 were less than those in 1993 except for one location. Mean harvest rates for all locations in 1995 were less than those in 1993 and 1994. Stocking costs were higher 1995 than in 1994 and 1993 (except for one location). The CDF was higher for all locations in 1995 than in 1994 and were higher than those in 1993 except for two locations. In 1995 the fishery management objectives for effort were obtained for the small lakes and were close for Chena Lake. None of the fishery management objectives for CPD was achieved for any location in 1995. Arctic grayling provided the best cost/benefit in 1995 for dollar spent ($1.18) in contrast to Arctic char which had the worst ($19.72; Table 14).

DISCUSSION

Costs and the Number of Days Fished

The method we used to calculate CDF oversimplified the relation between stocking costs, cohort contribution, and effort. We attributed stocking costs to the year that a cohort of fish was stocked; but, the fish usually do not significantly contribute to a fishery until at least one year after stocking. The time between stocking and when a cohort of fish make a significant contribution to the fishery depends on the size of the fish and when they were stocked. The CDF calculated for any year was based on the stocking cost and effort for that year. However, the fish that may have attracted anglers to the fishery and those harvested probably were from fish stocked in prior years.

We also realize that the number of angler days for a location was not entirely dependent on stocking methods, stocking costs, or the quality of the fishery. Stocking methods were designed to maintain acceptable stocking costs while creating fisheries that were acceptable to anglers. Even for an acceptable fishery, weather and major events may affect anglers and their decision to participate in fisheries. Given this situation, effort will most likely fluctuate with environmental and social conditions regardless of the quality of the fishery. The relationship between stocking costs and effort was very apparent in 1992 when stocking costs hit a historical high and effort was the lowest since 1986. This combination resulted in a record high CDF (Skaugstad 1996). While we can account for the high stocking cost, we can not determine the cause for the large decrease in fishing effort in 1992. Although we can manipulate stocking costs, our influence on anglers and their decision to participate in a fishery is usually indirect and limited to the few factors that we can control. Some of these factors include improving public access to fishing locations, informing anglers of various and unique fishing opportunities, and managing our fisheries to provide an attractive incentive to go fishing.

Table 12.-Portion of total effort attributed to game fish stocked in Tanana Valley lakes that were classified as other lakes in the Alaska Statewide Harvest Survey.

	Number of Days Fished (effort)			
Year	All Small Lakes	"Other Lakes"	Adjustment Factor[a]	Adjusted effort
1993	23,950	3,576	0.60	22,516
1994	22,308	1,089	0.59	21,859
1995	23,112	2,034	0.63	22,369

[a] The adjustment factor for effort was calculated from the harvest data for "Other Lakes". The adjustment factor is calculated as the number of stocked fish harvested from "Other Lakes" divided by the total number of fish harvested (stocked and wild) from "Other Lakes". The adjusted effort was calculated using:

$$(\text{All Small Lakes} - \text{"Other Lakes"}) + \text{"Other Lakes"} \times \text{Adjustment Factor}$$

Cost/benefit for each species was calculated by dividing stocking cost by catch.

Table 13.-Objectives from Fishery Management Plans and statistics from major fisheries in 1992, 1993, and 1994.

Management Plan	Objective	1993	1994	1995
Birch Lake:				
Days fished	15,000	10,447	9,880	11,702
Harvest		15,373	10,781	6,758
Mean harvest rate	2	1.47	1.09	0.83
Stocking cost		$70,368	$52,777	$109,240
Cost-per-day of fishing	$2.00	$6.73	$5.34	$9.34
Quartz Lake:				
Days fished	20,000	17,613	14,031	17,569
Harvest		27,676	17,262	17,688
Mean harvest rate	2	1.57	1.23	1.01
Stocking cost		$45,706	$29,026	$68,160
Cost-per-day of fishing	$2.50	$2.60	$2.07	$3.88
Chena Lake:				
Days fished	10,000	6,668	2,828	9,317
Harvest		7,629	3,915	7,652
Mean harvest rate	2	1.14	1.38	0.82
Stocking cost		$60,480	$37,755	$107,998
Cost-per-day of fishing	$2.00	$9.07	$13.35	$11.59
Piledriver Slough:				
Days fished	20,000[a]	8,627	5,685	6,307
Harvest[b]		6,007	2,673	1,199
Mean harvest rate	2[c]	0.70	0.47	0.19
Stocking cost		$91,726	$42,985	$93,764
Cost-per-day of fishing	$2.00	$10.63	$7.56	$14.87

-continued-

Table 13.-Page 2 of 2.

Management Plan	Objective	1993	1994	1995
Small Lakes:				
Days fished[d]	20,000	22,516	21,859	22,369
Harvest[e]		22,557	15,141	11,484
Mean harvest rate		1.00	0.69	0.51
Stocking cost		$213,291	$114,574	$191,832
Cost-per-day of fishing	$3.00	$9.47	$5.24	$8.58
Harding Lake:				
Days fished[f]		2,443	2,457	3,372
Harvest[g]		586	152	245
Mean harvest rate		0.24	0.06	0.07
Stocking cost		$29,937	$15,555	$32,446
Cost-per-day of fishing	$3.00	$12.25	$6.33	$9.62

[a] The goal for effort in management plan is 40,000 angler-days, however, only one-half of the goal is attributed to stocked rainbow trout.

[b] Piledriver Slough has wild Arctic grayling and stocked rainbow trout. The reported harvest numbers are for rainbow trout only.

[c] Mean harvest rate includes Arctic grayling.

[d] Some of these lakes have wild and stocked fish populations. Reported effort was adjusted to account for stocked fish only.

[e] Reported harvest is for stocked fish only.

[f] Only one-half the estimated effort from the SWHS was attributed to fish that were stocked into Harding Lake.

[g] Reported harvest is for stocked fish only.

Table 14.-Cost/benefit for species stocked in the Tanana drainage in 1993-95.

Year	Arctic Grayling	Coho and Chinook Salmon	Rainbow Trout	Dolly Varden and Arctic Char	Lake Trout[a]	Total
1993[a]						
Harvest	2,722	15,734	49,693	3,505	789	72,443
Catch	61,528	31,017	144,699	9,737	2,987	249,968
Stocking Cost	$21,843	$85,411	$210,637	$197,893	$0	$515,784
Cost/Benefit	**$0.36**	**$2.75**	**$1.46**	**$20.32**	**$0.00**	**$2.06**
1994[a]						
Harvest	3,810	10,404	33,249	1,590	817	49,870
Catch	25,633	23,379	90,254	4,540	2,009	145,815
Stocking Cost	$16,460	$44,992	$142,087	$72,128	$14,835	$290,502
Cost/Benefit	**$0.64**	**$1.92**	**$1.57**	**$15.89**	**$7.38**	**$1.99**
1995						
Harvest	1,360	8,304	35,625	2,075	477	47,841
Catch	28,837	21,422	102,410	6,327	939	159,935
Stocking Cost	$33,989	$170,502	$274,192	$124,756	$0	$603,440
Cost/Benefit	**$1.18**	**$7.96**	**$2.67**	**$19.72**	**$0.00**	**$3.77**
Average						
Harvest	3,266	13,069	41,471	2,548	803	61,157
Catch	43,581	27,198	117,477	7,139	2,498	197,892
Stocking Cost	19,152	65,202	176,362	135,011	7,418	$403,143
Cost/Benefit	**$0.62**	**$3.97**	**$1.86**	**$19.16**	**$2.50**	**$2.54**

[a] These data were updated from Skaugstad (1996) to correct an error.

[b] Lake trout were not stocked in 1993 or 1995 but fish were harvested in 1993 and 1995 from previous stockings.

Hatchery Operation Costs and Fish Production

Stocking cost and in turn CDF are dependent on the cost of producing fish and the quantity of fish produced. Low costs and high production yield the lowest cost per kilogram of fish produced. To reduce production costs for Arctic char and lake trout we will conduct egg takes for these species biennially but in different years. We also have eliminated the Arctic char brood stock to further reduce costs. Both species are long-lived with low harvest levels which make them suited to alternate year stockings. Better planning between hatchery managers and fishery managers can take advantage of species and fishery characteristics and available hatchery resources to make the stocking program more efficient.

Management Objectives

While we did not anticipate meeting these objectives in one or two years, now it appears that we can not meet most of the objectives until effort increases dramatically. We may reasonably expect effort to increase in the future and should manage the stocking program to meet angler demand while minimizing costs. Some examples of reducing or minimizing stocking costs while maintaining or improving fisheries follow. 1) Stock fingerling rainbow trout in Quartz Lake and subcatchable rainbow trout in Birch Lake. Although cost per fish for stocking at Birch Lake was less for fingerlings, cost-per-survivor to a catchable size was less for fish stocked as subcatchables. Apparently, in Birch Lake the higher rate of survival for subcatchables offset their higher stocking cost. Wiley et al. (1993) found similar results for the cost of stocked fish returned to the creel in Wyoming. 2) Conduct multiple stockings of catchable rainbow trout in urban ponds. The small urban ponds are close to Fairbanks and North Pole which makes them easily accessible for a large number of anglers. As a result we think these lakes receive a lot of fishing pressure for their size and are probably quickly fished out. Havens et al. (1995) recommends similar stocking methods for lakes along the roadside in south-central Alaska. Stocking more fingerling-size fish is not a workable option because small ponds and lakes probably can not produce or sustain sufficient numbers of catchable rainbow trout to meet demand. Nehring (no date) reports a similar situation for some Colorado streams where the production of quality size rainbow trout and brown trout is limited by environmental constraints. For these reasons, we plan to stock catchable size fish in our urban ponds two or more times during spring and summer to provide better fisheries close to town. Although stocking cost for these ponds will increase, we expect the cost-to-the-creel and CDF will decrease. 3) Conduct biennial egg takes and stockings for some species. By going to alternate year stockings for Arctic char and lake trout we will reduce hatchery costs while maintaining acceptable fisheries. Of course, to reduce stocking costs we can also drastically reduce the number and size of fish that are stocked. But we risk losing fishing effort because anglers may no longer be drawn to smaller fish populations. While we have modified the stocking program to minimize costs, it also is our intent to make the fisheries on stocked game fish attractive to anglers. These two goals sometimes are not compatible because in some instances to make fisheries more attractive we stock greater numbers of larger more expensive fish which drives up stocking costs. If anglers find these fisheries and their higher costs acceptable then we should consider revising the existing management objectives.

ACKNOWLEDGEMENTS

Pat Houghton and Kirsten Bagne assisted with the field work. Gary Wall and Dave Parks provided operational costs and fish production data for the hatcheries. 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 Project F-10-12, Study E, Job No. 3-1(a).

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APPENDIX A

Appendix A.-Summary of Arctic char stockings in Harding Lake, 1988-1995.

Date	Number Stocked	Weight (g)
15-Sep-88	5,736	44
15-Sep-88	5,849	44
19-Sep-88	4,771	47
5-Oct-88	3,465	72
5-Oct-88	200	42
1-Nov-88	4,077	53
2-Nov-88	3,262	53
3-Nov-88	3,460	53
6-Feb-89	2,125	122
7-Feb-89	2,112	122
8-Feb-89	2,137	122
9-Feb-89	2,017	122
22-May-89	418	739
23-May-89	418	739
24-May-89	418	739
18-Jul-89	12,635	19
11-Oct-89	8,055	112
12-Oct-89	8,055	112
13-Oct-89	3,100	112
16-Oct-89	9,255	98
17-Oct-89	5,786	98
21-Mar-90	437	653
22-Mar-90	438	653
23-Mar-90	437	653
28-Aug-90	49,900	20
29-Aug-90	20,614	35
31-Aug-90	15,159	35
19-Sep-90	11,230	56
20-Sep-90	7,331	50
29-May-91	1,044	761
30-May-91	522	761
18-Jul-91	49,296	11
19-Jul-91	49,095	11
23-Jul-91	7,659	11
21-Aug-91	22,967	31
22-Aug-91	24,030	34
23-Aug-91	20,452	35
3-Sep-91	22,888	43
4-Sep-91	23,386	42
5-Sep-91	7,992	42
9-Sep-91	29,967	33
10-Sep-91	7,010	35
11-Sep-91	12,684	40
16-Jun-92	60,603	9
17-Jun-92	60,603	9
18-Jun-92	60,000	9
19-Jun-92	8,928	10
23-Jun-92	11,190	9
8-Sep-92	17,836	56
9-Sep-92	16,012	63
10-Sep-92	18,412	56
11-Sep-92	17,627	54
29-Sep-92	17,408	60
30-Sep-92	16,614	64
1-Oct-92	10,692	61
15-Sep-93	7,500	106
16-Sep-93	2,500	106
20-Sep-94	10,000	58
14-Sep-95	9,990	73

APPENDIX B

Appendix B.-Stocking history for the Trophy Lakes, 1990-1996.

Location	Species	Stocking Date	Number Stocked	Age	Sex[a]	Weight (g)	Brood Year	Mark
Craig L	LT	31-May-91	3,500	F		3.9	90	
Craig L	RT	6-Aug-91	4,086	F		2.0	91	
Craig L	RT	20-Jul-93	3,500	F		1.6	93	
Craig L	RT	14-Jun-94	850	C	AF	70.0	94	
Craig L	RT	21-Jun-95	949	S	MF	54.0	94	AD
Craig L	RT	10-Jul-96	550	S	MF	66.1	95	RV
Coal Mine #5 L	LT	29-May-91	2,600	F		3.6	90	
Coal Mine #5 L	RT	16-Jul-92	2,600	F		1.6	92	
Coal Mine #5 L	AC	1-Jul-93	2,600	F		12.0	92	
Coal Mine #5 L	RT	14-Jun-94	750	C	AF	70.0	94	
Coal Mine #5 L	RT	21-Jun-95	450	S	MF	54.0	94	AD
Coal Mine #5 L	RT	10-Jul-96	450	S	MF	77.1	95	RV
L Harding L	SS	16-Jul-90	3,600	F		2.7	89	
L Harding L	RT	24-Jul-90	1,000	F		1.6	90	
L Harding L	RT	24-Jul-91	3,600	F		1.8	91	
L Harding L	RT	22-Jul-92	11,000	F		1.1	92	
L Harding L	SS	21-Jun-93	7,700	F		0.9	92	
L Harding L	SS	24-Jun-93	14,300	F		0.8	92	
L Harding L	RT	18-May-94	2,838	S		42.0	94	
L Harding L	RT	21-Jun-95	1,300	S	MF	54.0	94	AD
L Harding L	RT	11-Jul-96	100	B	MF	800.0	93	
L Harding L	RT	18-Jul-96	1,750	S	MF	67.0	95	RV

[a] AF = All female; MF = male and female.

APPENDIX C

Appendix C.-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 two weeks was sufficiently long to minimize the effect of previous capture on capture probability as related to assumption 2. Validity of assumptions 2 and 3, relative to sampling induced selectivity of fish, was tested with Chi-squared tests generated from length data collected during the marking and recapture events (Appendix D). 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 does 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 D.

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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 two week hiatus between the first and second events (except for Craig Lake) and fish captured in the first event were released towards the middle of the lake.

APPENDIX D

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

	Result of first χ^2 (or K-S) test[a]	Result of second χ^2 (or K-S) 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 event for size and age composition estimates.

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

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

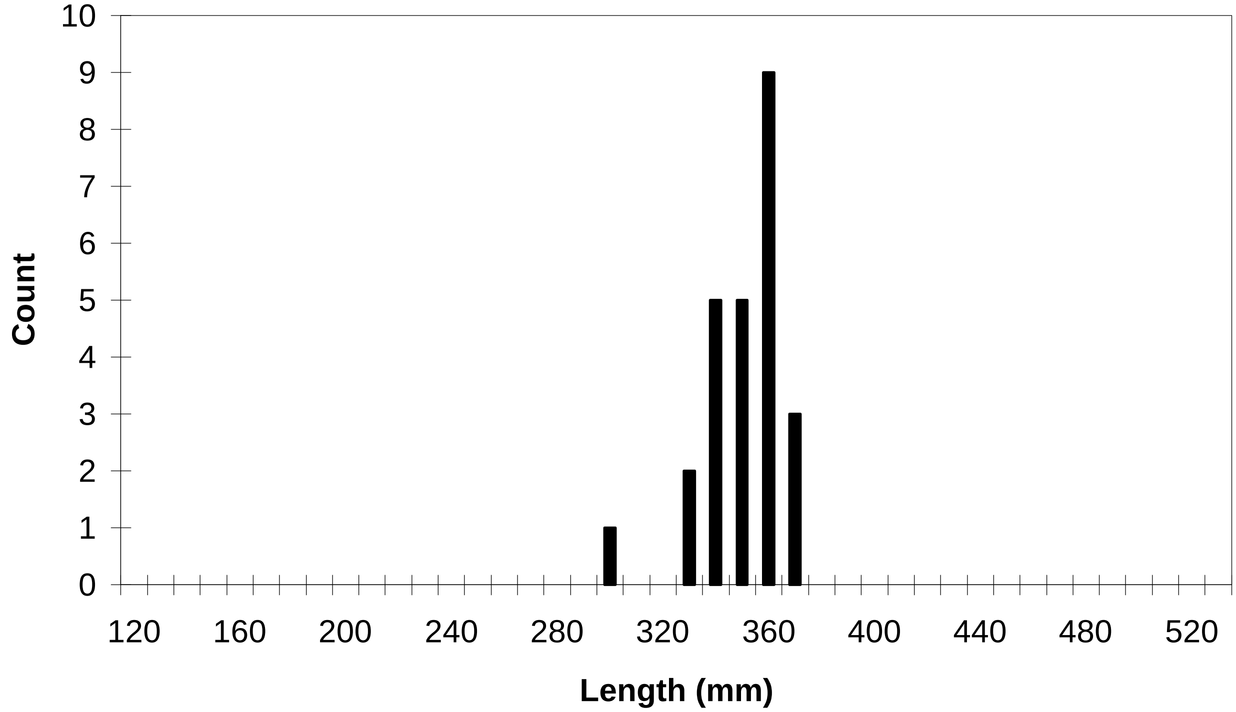
[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

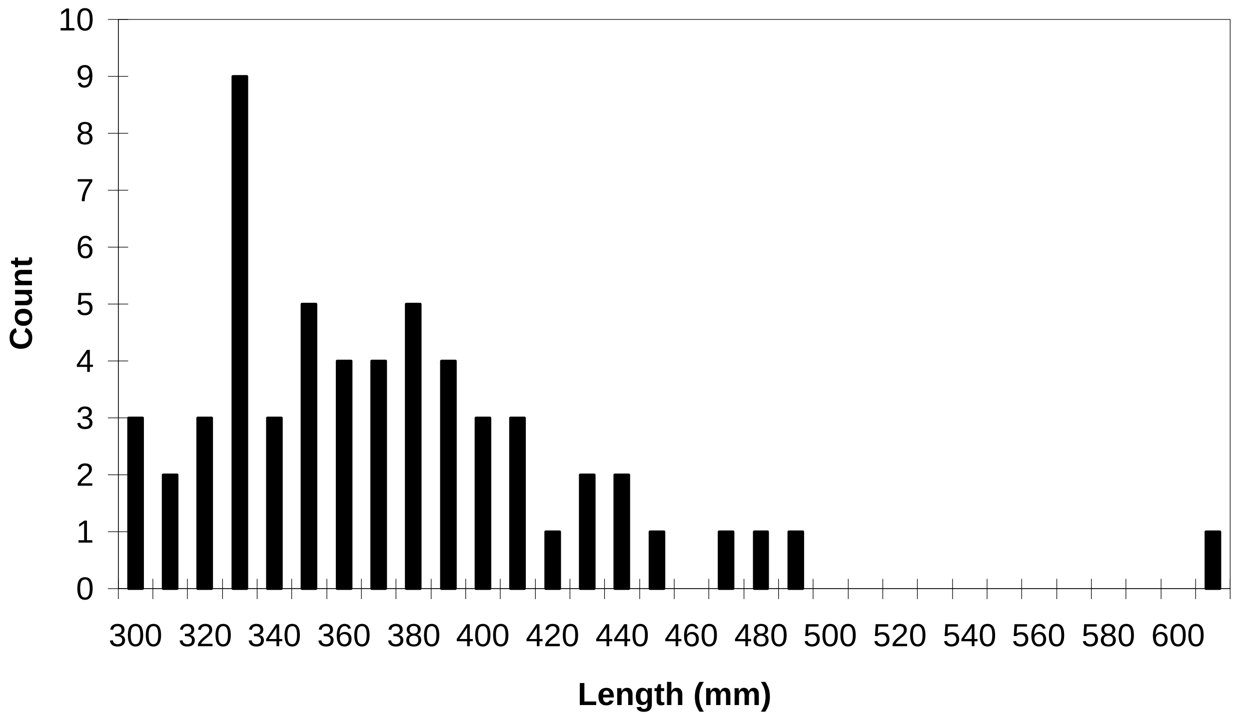
If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

Appendix E
Other Species Captured During Mark-Recapture Experiments

Appendix E1.-Length frequency histogram for coho salmon captured for the first time during mark-recapture experiment at Little Harding Lake, 1996.

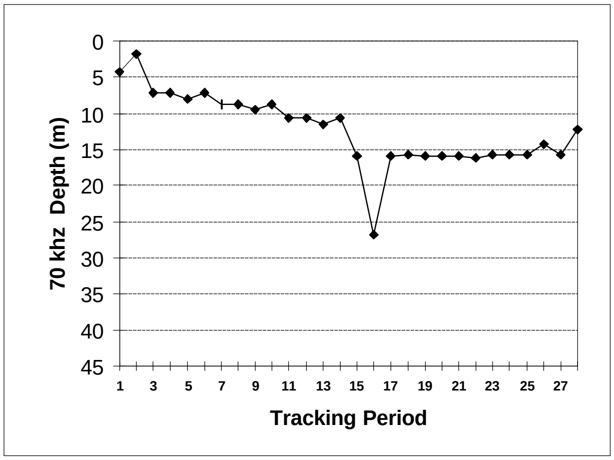


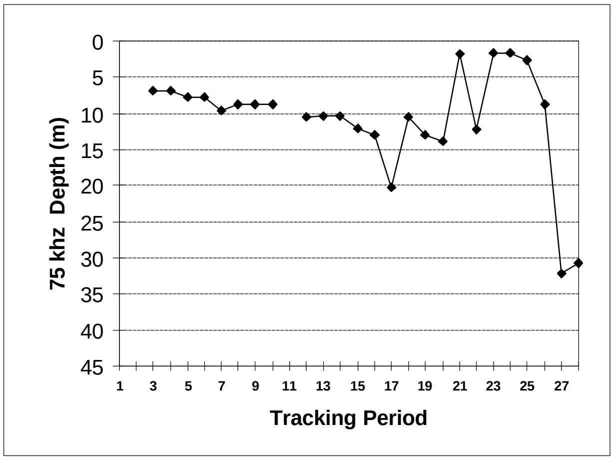
Appendix E2.-Length frequency histogram for lake trout captured for the first time during mark-recapture experiment at Coal Mine #5 Lake, 1996.

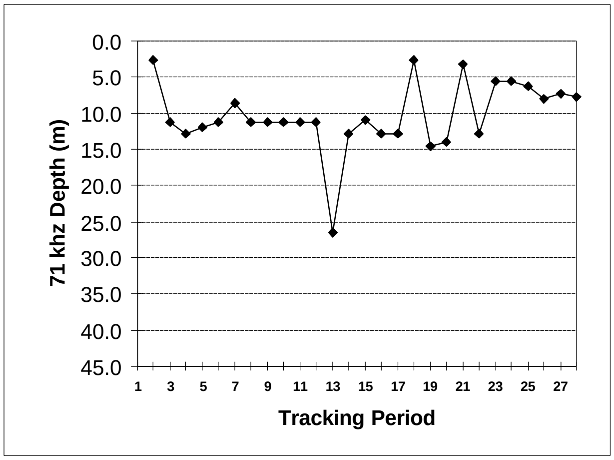


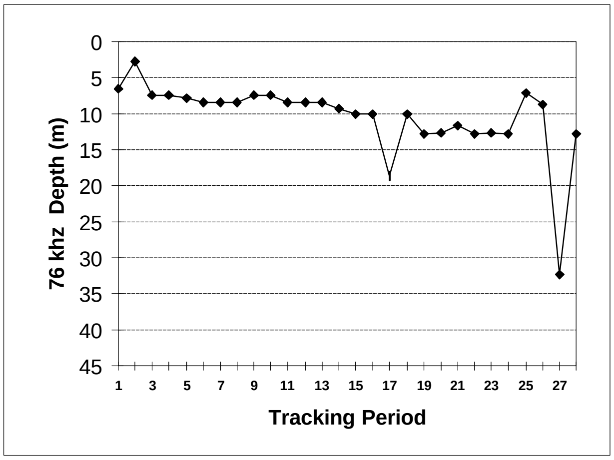
APPENDIX F

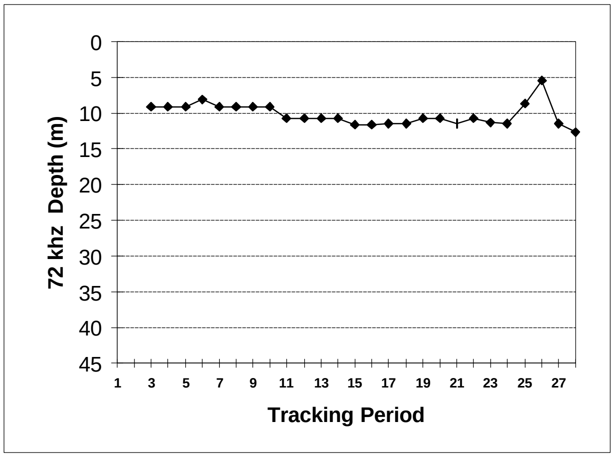
Appendix F.-Depth profile of Arctic char by tag frequency in Harding Lake, 5 June 1996 through 17 March 1997.

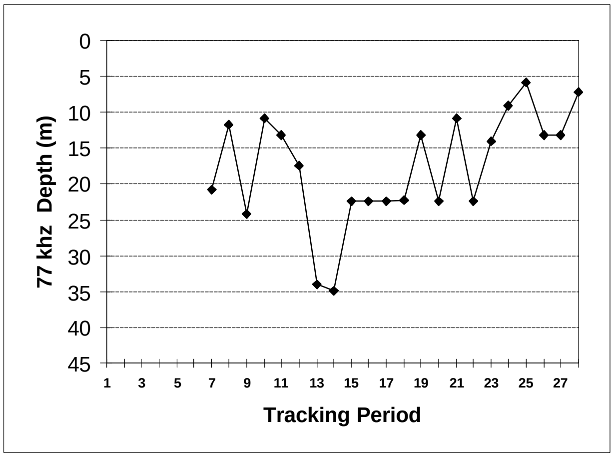












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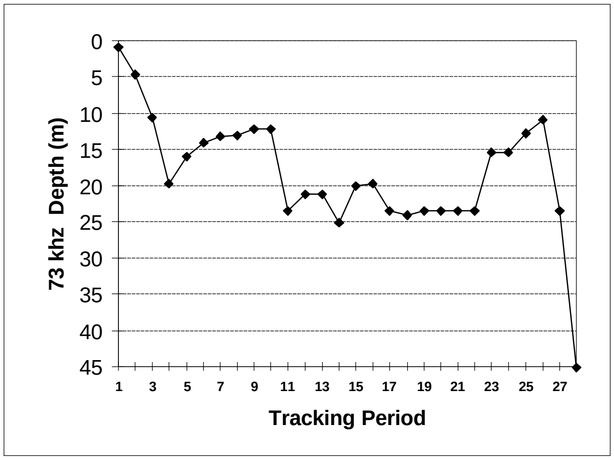

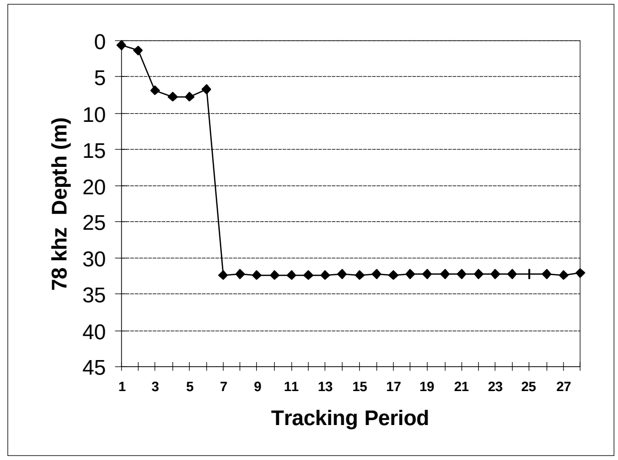

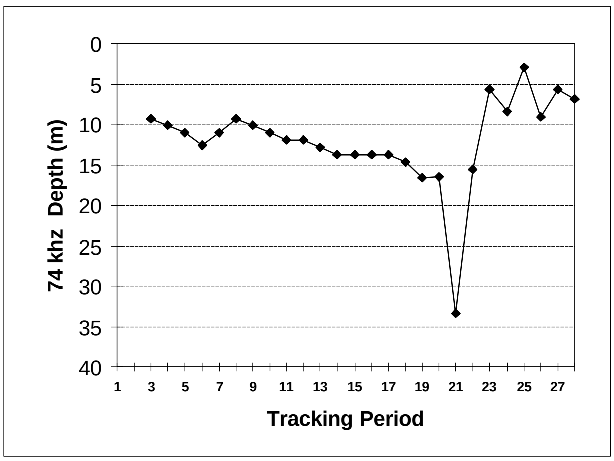

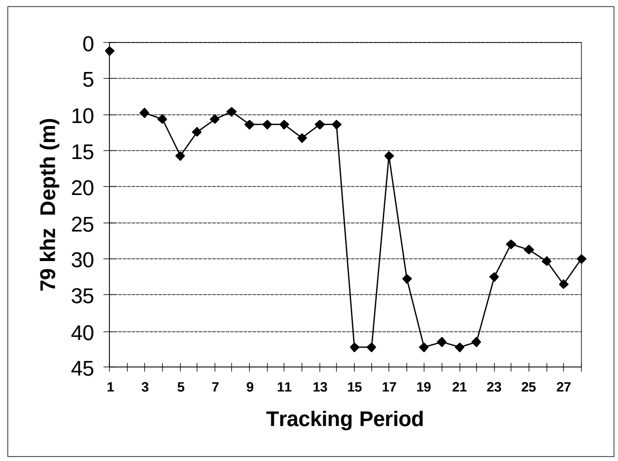

Tracking Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Date	5 Jun 96	6 Jun 96	25 Jun 96	25 Jun 96	26 Jun 96	26 Jun 96	9 Jul 96	9 Jul 96	10 Jul 96	10 Jul 96	24 Jul 96	24 Jul 96	24 Jul 96	25 Jul 96	28 Aug 96	28 Aug 96	28 Aug 96	29 Aug 96	17 Sep 96	17 Sep 96	17 Sep 96	18 Sep 96	2 Oct 96	2 Oct 96	3 Oct 96	3 Oct 96	11 Dec 96	17 Mar 97
Time	1043-1214	1038-1422	1336-1517	2120-2232	0530-0653	1023-1244	1309-1447	2009-2121	0433-0540	1028-1124	1132-1146	1736-1904	2328-0047	0520-0632	1118-1207	1722-1828	2350-0038	0620-0717	1104-1143	1645-1725	2336-0206	0535-0623	1257-1326	1917-1947	0107-0134	0705-0726	1226-1247	1206-1318

APPENDIX G
Location of Sonic Tagged Arctic Char

Appendix G.-Location of sonic tagged Arctic char, ranging from June of 1996 through March of 1997.

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APPENDIX H

Appendix H.-Archive files for data collected during investigations in 1996.

File Name	Description
U189AC97.XLS	Data file of location, depth, gear type, and biological information for Arctic char captured in Harding Lake, 1996.

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