Fishery Data Series No. 92-10

Abundance of Rainbow Trout in Birch and Quartz Lakes, 1991

by

Michael Doxey

May 1992

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 92-10

ABUNDANCE OF RAINBOW TROUT IN BIRCH AND QUARTZ LAKES, 1991[1]

By

Michael Doxey

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

May 1992

1 This investigation was partially financed by the Federal aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-7, Study E, Job No. 3-1(a).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This report presents the results of fisheries studies conducted during 1991 at Birch and Quartz Lakes, near Fairbanks in interior Alaska. Abundance, survival, and cost-per-fish to catchable size of two stocking cohorts of age 1 rainbow trout *Oncorhynchus mykiss* in each lake were estimated from mark-recapture experiments and length frequency analysis. Abundance and mean length of older rainbow trout cohorts were also estimated, along with collection of length composition data on cohorts of coho salmon *Oncorhynchus kisutch* and Arctic char *Salvelinus alpinus*.

Total abundance of rainbow trout in Birch Lake in August 1991 was 18,839 fish. Two cohorts of age 1 rainbow trout were present in Birch Lake in August, 1991. Abundance of age 1 rainbow trout that had been stocked in October, 1990 was 3,527 fish, and of age 1 rainbow trout that had been stocked in June, 1991 was 6,269 fish. Survival and corresponding cost to August 1991 was 0.14 ($1.72 per fish) for the rainbow trout stocked in October 1990, and was 0.25 ($1.18 per fish) for rainbow trout stocked in June 1991. Abundance of age 2 and older rainbow trout in Birch Lake was 9,043.

In Quartz Lake, total abundance of rainbow trout in August was 22,650. Abundance of rainbow trout stocked as fingerlings in summer 1990 was 7,534, and for those stocked as age 1 rainbow trout in June, 1991 was 7,394. Rainbow trout stocked as fingerlings in summer 1990 had a survival to August 1991 of 0.05 ($1.61 per fish) and rainbow trout stocked as subcatchables had a survival of 0.17 ($1.73 per fish).

Mortality of age 1 rainbow trout and coho salmon was documented at the Birch Lake weir during the heavy stream-flow event in May, 1991. About 5 percent of the subcatchable rainbow trout stocked in October, 1990 were dead at the outlet structure on 13 May, 1991.

KEY WORDS: Rainbow trout, *Oncorhynchus mykiss*, coho salmon, *Oncorhynchus kisutch*, stocking evaluation, Birch Lake, Quartz Lake, interior Alaska.

INTRODUCTION

To provide diverse angling opportunities and reduce the harvest of native fish stocks, the Alaska Department of Fish and Game (ADF&G) has undertaken a lake stocking program providing year-round sport fishing for rainbow trout *Oncorhynchus mykiss*, coho salmon *Oncorhynchus kisutch*, Arctic grayling, *Thymallus arcticus*, lake trout *Salvelinus namaycush*, and Arctic char *Salvelinus alpinus* in interior Alaska. The Birch Lake and Quartz Lake rainbow trout and coho salmon sport fisheries continue to be a very important component of this stocking program and of the Tanana River drainage sport fishery as a whole (Doxey 1991). These two lakes with the two stocked species absorbed 19% of the entire effort expended by anglers in the Tanana drainage in 1990 (35,287 days fished). A total of 17,352 of the Tanana drainage anglers visited the two lakes, catching 109,483 fish and harvesting 36,748 fish (Mills 1991).

Birch and Quartz lakes are located along the road system between Fairbanks and Delta Junction in the Tanana River Valley of central Alaska (Figure 1). Quartz Lake is landlocked. Birch Lake has an outlet blocked by the Birch Lake Weir. The weir consists of concrete piers dividing the stream into two channels. Each channel is blocked by a self-cleaning rotary screen, allowing stream-flow and yet blocking fish passage. The screens are turned by electric motors. Debris carried against the screens by the current is picked up on the screens, carried over the top, and washed off the downstream side of the screen by water passing through. A detailed physical description of the lakes, the ADF&G fish stocking programs for them, and historical research and evaluations through 1990 are contained in the report entitled "Evaluation of rainbow trout and coho salmon stocking programs in Birch, Chena, and Quartz Lakes, Alaska" (Doxey 1991).

Quartz Lake (Figure 2) was stocked in 1990 and 1991 with a combination of fingerling and subcatchable rainbow trout (subcatchables) and coho salmon, and Birch Lake (Figure 3) was stocked in 1990 and 1991 with subcatchable rainbow trout and coho salmon. Fingerling rainbow trout are stocked in midsummer at age 0 with a mean weight of 1-2 g. Subcatchable rainbow trout are normally fish that have been held in the hatchery until early in the following summer when they are stocked at age 1 and a mean weight of about 20 g. Previous research has shown that both fingerlings stocked at 1 - 2 g and subcatchables stocked at 20-25 g begin to recruit to the sport fishery at age 1 and a fork length of about 180 mm in late summer. Survival to recruitment of rainbow trout stocked as subcatchables is much higher than survival of rainbow trout stocked as fingerlings (Doxey 1991). In 1990 an experiment was conducted to test the cost effectiveness of stocking subcatchable rainbow trout much earlier, which reduces initial cost and makes hatchery raceway space available for other production. About 50% of the planned 1991 stocking of 50,000 subcatchable rainbow trout for Birch Lake were put on an accelerated feeding schedule, reared to 18 g and stocked in October, 1990. The remainder were held in the hatchery and reared at a much slower growth rate until they were stocked in June, 1991.

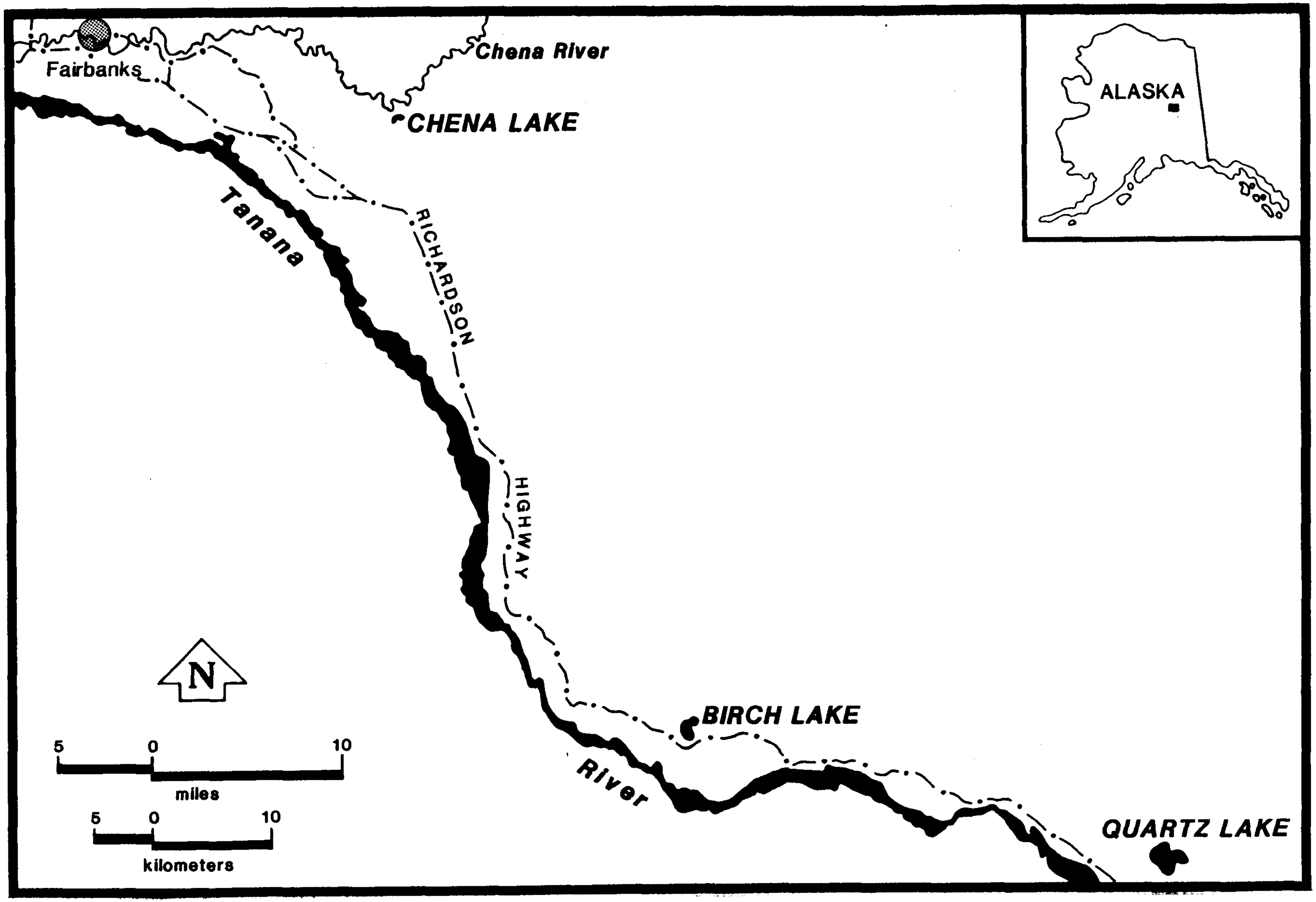

Figure 1. Location of Birch and Quartz lakes near Fairbanks, Alaska.

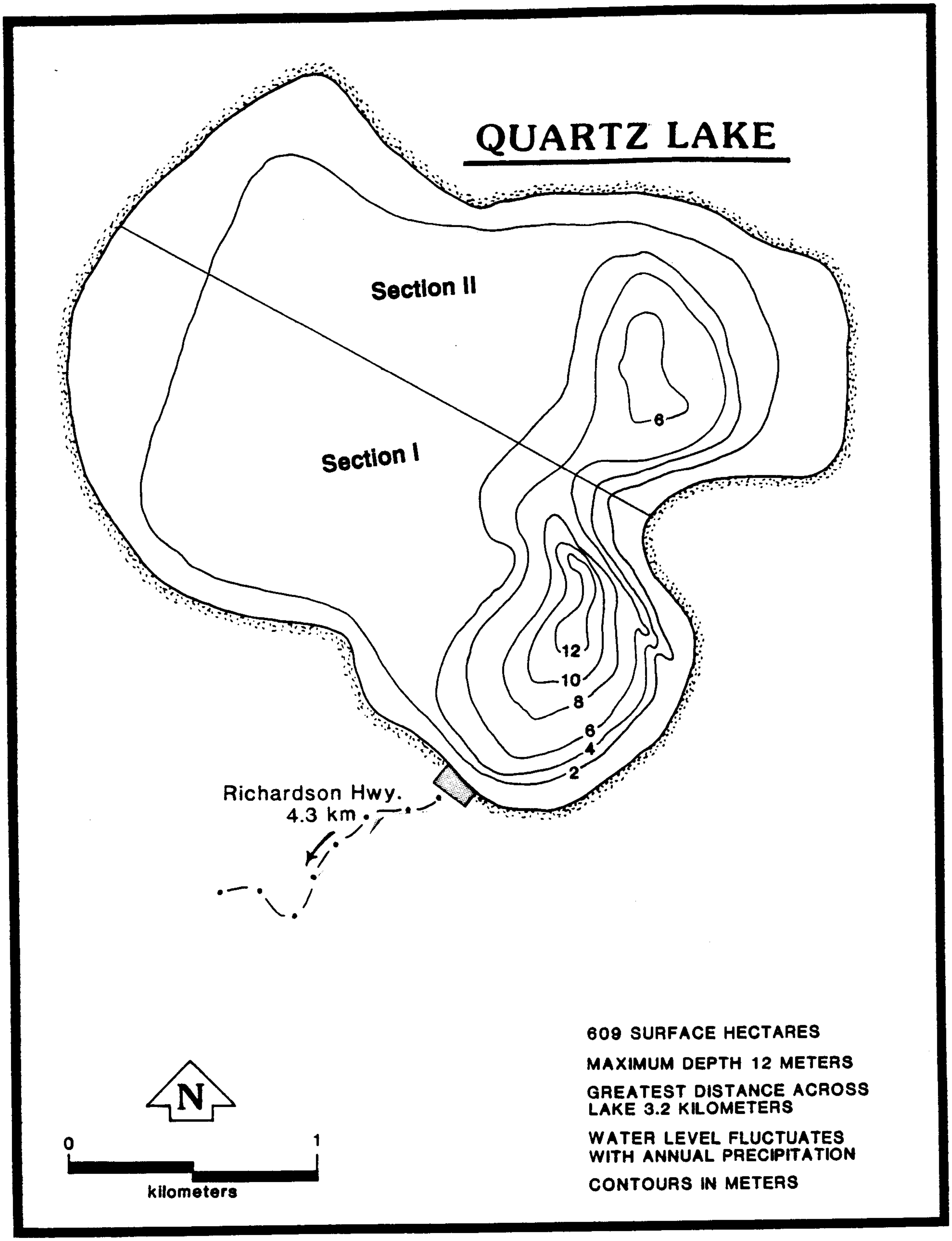

Figure 2. Depth contour map of Quartz Lake.

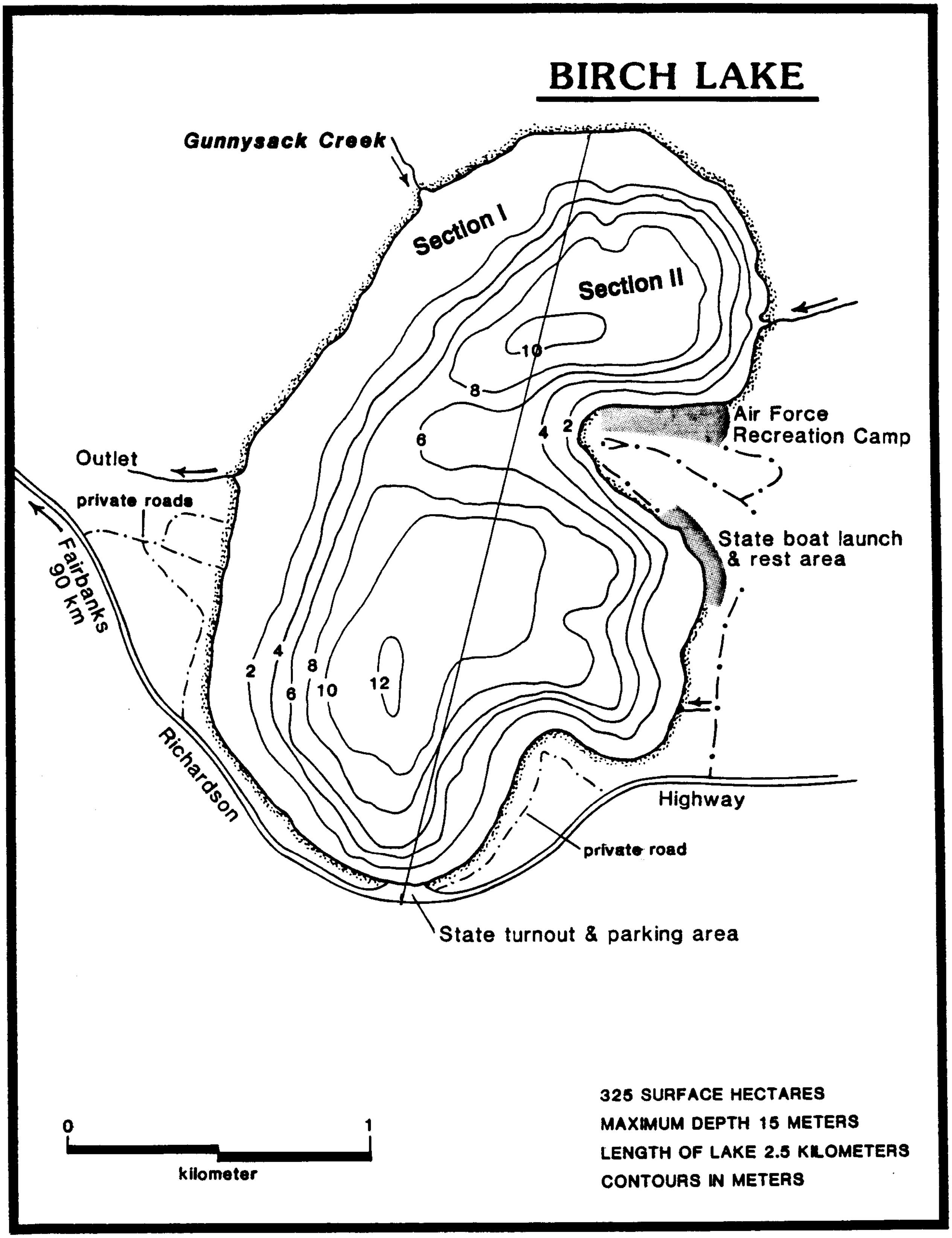

Figure 3. Depth contour map of Birch Lake.

This report summarizes the results of the rainbow trout enhancement evaluations in Birch and Quartz lakes in 1991.

Project objectives addressed in this report for the 1991 (F-10-7) Federal Aid contract were as follows:

Quartz Lake

1. Estimate the abundance of age 1 rainbow trout that were stocked as fingerlings in August 1990.

2. Estimate the abundance of age 1 rainbow trout that were stocked as subcatchables in June 1991.

3. Estimate the abundance of age 2 and older rainbow trout.

4. Estimate mean lengths of age 1 rainbow trout that were stocked as fingerlings in August 1990, and as subcatchables in June 1991.

Birch Lake

1. Estimate the abundance of age 1 rainbow trout that were stocked as age 0 subcatchables in October 1990.

2. Estimate the abundance of age 1 rainbow trout that were stocked as age 1 subcatchables in June 1991.

3. Estimate the abundance of age 2 and older rainbow trout.

4. Estimate the mean lengths of age 1 rainbow trout that were stocked as subcatchables in October 1990 and June 1991.

METHODS

Stocking and Marking

Recent stocking and marking histories of fish released into Birch Lake and Quartz Lake are summarized in Tables 1 and 2. Portions of some cohorts of rainbow trout were marked for future identification by complete removal of a fin. When the fish were stocked, sufficient numbers were held in a net pen, anesthetized with carbon dioxide and marked with a fin clip.

Rainbow trout subcatchables were stocked in Birch Lake on 24 October 1990 (fall) and 4 June 1991 (spring; Table 1). These cohorts were identified by removal of the right ventral (RV) fin from 2,500 fish during the fall stocking and the left ventral (LV) fin from 5,000 fish during the spring stocking (Table 1).

Table 1. Recent stocking history of Birch Lake.

Species[a]	Date	Number Stocked	Size (g)	Number Marked	Mark[b]	Hatchery
RT	5/87	34,039	23-30	0	--	Clear
SS	6/87	40,000	4.8	0	--	Clear
RT	3/88	10,000	32	10,000	Ad	Clear
RT	5/88	44,723	25	0	--	Clear
SS	6/88	40,000	4.2	0	--	Clear
RT	4/89	50,000	16	0	--	Clear
RT	8/89	4,045	112	0	--	Fort Richardson
SS	6/89	40,000	4.2	0	--	Clear
RT	6/90	48,345	23	0	--	Fort Richardson
RT	10/90	25,000	18	2,500	RV	Fort Richardson
SS	7/90	131,000	2.7	0	--	Big Lake
RT	6/91	25,153	23	5,000	LV	Fort Richardson
SS	7/91	40,303	1.0	0	--	Big Lake
AC	7/91	13,365	11	0	--	Clear
GR	9/91	40,000	5.0	0	--	Clear

[a] RT = Rainbow Trout, SS = Coho Salmon, GR = Arctic Grayling.
[b] Ad = Adipose Fin Clip, RV = Right Pelvic Fin Clip, LV = Left Pelvic Fin Clip.

Table 2. Recent stocking history of Quartz Lake.

Species[a]	Date	Number Stocked	Size (g)	Number Marked	Mark[a]	Hatchery
RT	5/87	10,000	28	0	--	Clear
RT	8/87	227,917	2.4	0	--	Fort Richardson
RT	8/87	180,000	2.2	0	--	Clear
SS	4/87	85,089	2.3	0	--	Clear
SS	6/87	83,400	4.9	0	--	Clear
RT	5/88	48,094	25	48,094	AD	Clear
RT	8/88	150,000	1.0	0	--	Clear
SS	5/88	150,000	3.4	0	--	Clear
RT	4/89	22,966	17-36	22,966	AD	Clear
RT	5/89	24,037	26	0	--	Clear
RT	8/89	150,000	1.2	0	--	Clear
SS	6/89	150,000	4.0	0	--	Clear
RT	6/90	33,843	23	0	--	Fort Richardson
RT	7/90	150,632	1.2	0	--	Fort Richardson
RT	9/90	52,914	2.4	0	--	Fort Richardson
SS	7/90	150,000	2.7	0	--	Big Lake
RT	5/91	25,005	20	0	--	Fort Richardson
RT	6/91	17,711	25	5,000	RV	Fort Richardson
RT	7/91	152,000	2.0	0	--	Fort Richardson
SS	7/91	151,785	1.1	0	--	Big Lake
AC	7/91	75,000	10	0	--	Clear

[a] RT = Rainbow Trout, SS = Coho Salmon, GR = Arctic Grayling.
[b] Ad = Adipose Fin Clip, RV = Right Pelvic Fin Clip, LV = Left Pelvic Fin Clip.

During spring and early summer of 1991, 42,716 subcatchable rainbow trout were stocked into Quartz Lake. A total of 5,000 were marked by removing the right ventral fin (Table 2).

Length Comparison of Birch Lake Age 1 Rainbow Trout in June

At Birch Lake on 20 June 1991, rainbow trout were captured with fyke nets (see below for net specifications), examined for ventral fin clips, and measured to the nearest millimeter from tip-of-snout to fork-of-tail (FL). The Kolmogorov-Smirnov statistic was used to test the null hypothesis that there was no difference between length frequency distributions of fish with RV and LV fin clips. The results determined whether one cohort would enter the sport fishery before the other.

Mark Recapture Experiment

The abundance of rainbow trout in Birch Lake and Quartz Lake was estimated using a two-event mark-recapture experiment. During the first event a sample of the population was captured, marked, and released back into the population. During the second event, after allowing time for the marked and unmarked fish to mix, another sample was collected and examined for marks.

In both events, fish were captured with fyke nets set along the lake perimeter. Each fyke net had a 15 to 30 m center lead and two 7.5 m wings. The fyke nets were set with the center leads perpendicular to shore and wings approximately parallel to shore, and were inspected daily. Captured fish were anesthetized with carbon dioxide during marking and measuring. Both lakes were arbitrarily divided into two sampling sections along an approximate north-south axis (Figures 2 and 3) as an aid to evaluating the assumptions underlying a two-event mark-recapture experiment. Western and eastern sections were designated Sections I and II respectively.

Event 1 - Capture and Marking

Fish were captured from 6-10 August in Birch Lake and from 11-20 August in Quartz Lake. All captured rainbow trout were examined for ventral marks, marked with a caudal clip, measured, and released. The caudal clips consisted of removing a portion of the upper (UC) or lower (LC) lobe of the caudal fin. UC and LC marks identified fish initially captured along the western (Section I) or eastern (Section II) shoreline, respectively. Fork length was measured to the nearest millimeter.

Event 2 - Collection and Mark Recovery

The second event occurred in both lakes during the period 21-30 August. All captured rainbow trout were examined for marks, measured, and released. Data was recorded by trap location, defining the section of the lake where marked fish were recaptured.

Test of Assumptions for Abundance Estimator

The mark-recapture experiment required the satisfaction of a set of assumptions to prevent a biased estimate (Seber 1982).

The assumptions are:

1. every fish has an equal probability of being marked and released alive during the first sampling event; *or* every fish has an equal probability of being captured during the second sampling event; *or* marked fish mix completely with unmarked fish between sampling events;

2. marking does not affect the catchability of fish;

3. marked fish do not lose their marks between sampling events; and,

4. recruitment to the cohorts being sampled and significant differential mortality of marked and unmarked fish do not occur between sampling events (after Seber 1982).

The following tests were used to determine if these assumptions were satisfied. Results from these tests were used to select both an appropriate abundance estimator and methods for estimating age and length compositions of the rainbow trout populations.

Gear Bias:

Three tests were used to evaluate gear bias by size (length of the fish). Length distributions were compared for: (Test 1) rainbow trout marked in the first event and marked rainbow trout recaptured in the second event; and, (Test 2) all rainbow trout captured in the first event and all rainbow trout captured in the second event. The Kolmogorov-Smirnov statistic was used to test for significant differences between length distributions. The null hypothesis was that the distributions were identical. However, these tests often show that small differences are significant due to large sample sizes, or slightly different rates of recovery of small and large marked rainbow trout, and growth during the experiment. Rates of recovery were assessed using a contingency table comparing numbers of marked rainbow trout that were captured and not captured by size (small and large) during the second event (Test 3). The chi-square statistic was used to determine if there was a significant difference between rates of recovery. The null hypothesis was that rates of recovery were similar for small and large fish. The fork length at which the length distributions were divided into cohorts of small and large fish was determined through examination of length frequency histograms of rainbow trout captured in the second event. The first two large modes in length frequency histograms of rainbow trout populations sampled in late summer in the two lakes have been shown to correspond to age 1 and age 2 fish (Doxey 1991). Age 0 rainbow trout stocked as fingerlings were not given marks. The length ranges typically overlap for age 1 fish stocked as fingerlings and subcatchables. The relatively few fish older than age 2 are to the right of the large mode of age 2 fish. For the purposes of the abundance estimate these fish were combined with age 2 rainbow trout into a single cohort characterized as age 2+ fish.

Location:

Rates of capture were evaluated with a contingency table using numbers of marked and unmarked rainbow trout captured by section during Event 2. The chi-square statistic was used to determine if rates of capture by section were significantly different. The null hypothesis was that the rates of capture were similar.

Likewise, mixing of marked fish between sections was evaluated with a contingency table using numbers of marked rainbow trout that were and were not captured during Event 2. The null hypothesis was that section of capture in Event 2 was independent of section of capture in Event 1.

Loss of Marks:

Ventral fins were completely excised, preventing fin regeneration. Some regeneration of caudal fin clips occurs, but the short period between sampling events minimized the amount of regeneration, and it is believed that all marked fish were recognized upon recapture. In addition, the regenerated area was less pigmented and the original straight scissor cut through the fin rays was plainly discernable. No loss of marks occurred.

Recruitment and Mortality:

Abundance of fish age 1 and older was being estimated. The only recruitment into these cohorts in these landlocked lakes could be through stocking of more fish of the same age during the experiment. Such stockings did not occur.

While some angling and natural mortality probably occurred during the experiment, it was minimized by the short time between events. The mortality rate of marked and unmarked fish was assumed to be similar.

Abundance Estimator

Based on the results of these tests, abundance was estimated using an unstratified Petersen estimator (described by Chapman 1951, cited in Seber 1982).

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

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

where:

$\hat{N}$ = estimated abundance of rainbow trout;
n_1 = number of rainbow trout marked in Event 1;
n_2 = number of rainbow trout captured in Event 2; and,
m_2 = number of marked rainbow trout captured in Event 2.
$V(\hat{N})$ = variance of $\hat{N}$

Age Composition

In both Birch Lake and Quartz Lake, length frequency histograms were used to separate rainbow trout captured during Events 1 and 2 into age 1 and age 2+ (age 2 and older) cohorts. Length frequency histograms were bi-modal. Because age 1 rainbow trout marked with a ventral fin clip were present in only the left mode it was assumed that the left mode was comprised of age 1 and the right mode was comprised of age 2+ fish. The division between the cohorts was made at the lowest frequency between the modes. Proportions of each cohort in the population were estimated using:

$$\hat{p}_a = n_s/n \quad \text{and,} \tag{3}$$

$$\hat{V}(\hat{p}_a) = \hat{p}_a(1-\hat{p}_a)/(n-1) \tag{4}$$

where:

$\hat{p}_a$ = proportion of age 1 (p_1) or age 2+ (p_2) fish in the population;
n_s = number of age 1 or age 2+ fish in the sample;
n = total number of fish in sample; and,
$\hat{V}(p_a)$ = variance of $\hat{p}_a$.

The abundance of age 1 and age 2+ rainbow trout in the population was estimated using:

$$\hat{N}_a = \hat{N}(\hat{p}_a) \tag{5}$$

Variance of the product N_a was estimated using the exact variance of products (Goodman 1960):

$$\hat{V}(N_a) = \hat{N}^2\hat{V}(\hat{p}_a)+\hat{p}_a^2\hat{V}(\hat{N})-\hat{V}(\hat{p}_a)\hat{V}(\hat{N}) \tag{6}$$

Stocking Cohort Composition for Age 1 Fish

In both Birch Lake and Quartz Lake, the population of age 1 rainbow trout was comprised of two cohorts stocked at different times and sizes (Table 1). In Birch Lake, rainbow trout were stocked as subcatchables in the fall (1990) and spring (1991).

In Quartz Lake, age 1 rainbow trout had been stocked as fingerlings (summer 1990) and subcatchables (spring 1991). A portion of the subcatchables were marked with an RV fin clip. No rainbow trout stocked as fingerlings were marked prior to Event 1.

To begin calculating the proportions of the two age 1 stocking cohorts present in Birch Lake, the numbers marked with an RV or LV fin clip captured during the 20 June 1991 sampling event and Events 1 and 2 of the August mark - recapture experiment were summed. These were summations of fish with each mark, not of all marked fish summed together. Because 2,500 of the 25,000 rainbow trout stocked in the fall were marked with an RV clip, while 5,000 of 25,153 stocked in the spring received an LV clip, the number of rainbow trout sampled having RV marks was multiplied by 2 for making comparisons. The proportion of each stocking cohort within the total population of age 1 fish was then estimated using Formula 3 and Formula 4. Abundance of each cohort in the population was estimated using Formula 5 and Formula 6.

For Quartz Lake rainbow trout, the abundance of age 1 rainbow trout marked with an RV fin clip was estimated using:

$$\hat{p}_{rv} = \frac{n_{rv}}{n_1 + n_2} \qquad (7)$$

$$\hat{V}(\hat{p}_{rv}) = \frac{\hat{p}_{rv}(1-\hat{p}_{rv})}{n-1} \qquad (8)$$

$$\hat{N}_{rv} = \hat{N}\,\hat{p}_{rv} \qquad (9)$$

$$\hat{V}(\hat{N}_{rv}) = \hat{N}^2\,\hat{V}(\hat{p}_{rv}) + \hat{p}_{rv}^2\,\hat{V}(\hat{N}) - \hat{V}(\hat{p}_{rv})\,\hat{V}(\hat{N}) \qquad (10)$$

where:

n_{rv} = number of rainbow trout with an RV fin clip captured in Events 1 and 2;
n_1 = total number of fish in Event 1;
n_2 = total number of fish in Event 2;

$\hat{p}_{rv}$ = proportion of rainbow trout in the population with an RV finclip;

N_{rv} = estimated number of fish in the population with an RV fin clip;

$V(\hat{p}_{rv})$ = variance of $\hat{p}_{rv}$; and,

$V(\hat{N}_{rv})$ = variance of N_{rv}.

The abundance of age 1 rainbow trout in Quartz Lake that were stocked as subcatchables was estimated using:

$$\hat{N}_{sc} = \frac{N_{st}\,\hat{N}_{rv}}{N_m} \qquad (11)$$

$$V(\hat{N}_{sc}) = k^2\,V(\hat{N}_{rv}) \qquad (12)$$

where:

N_{st} = number of rainbow trout stocked as subcatchables;
N_m = number of rainbow trout marked at the time of stocking;
k = N_{st}/N_m;

$\hat{N}_{sc}$ = estimated number of surviving age 1 rainbow trout that were stocked as subcatchables; and,

$V(\hat{N}_{sc})$ = variance of $\hat{N}_{sc}$.

The abundance of age 1 rainbow trout in Quartz Lake that were stocked as fingerlings was estimated using:

$$\hat{N}_f = \hat{p}_1\,\hat{N} - \frac{N_{st}}{N_m}\,\hat{N}\,\hat{p}_{rv} \qquad (13)$$

$$V(\hat{N}_f) = V[\hat{N}]\,(p_1 - k\,\hat{p}_{rv})^2 + V[\hat{p}_{rv}]\,\hat{N}^2 - V[\hat{p}_{rv}]V[\hat{N}] \qquad (14)$$

where:

The statistics p_{rv} and $V[p_{rv}]$ are calculated as described before with Equations 3, 4, and 6.

$\hat{N}_f$ = estimated number of surviving age 1 rainbow trout that were stocked as fingerlings;

$\hat{p}_1$ = proportion of age 1 rainbow trout in population (variance of $\hat{p}$ is negligible); and,

$V(\hat{N}_f)$ = variance of $\hat{N}_f$.

Survival

Rates of survival of different cohorts of age 1 rainbow trout were estimated using:

$$\hat{S}_c = \frac{\hat{N}_c}{N_{st}} \tag{15}$$

$$V(\hat{S}_c) = \frac{V(\hat{N}_c)}{(N_{st})^2} \tag{16}$$

where:

$\hat{N}_c$ = estimated abundance of a cohort (defined by size, or stocking time);

$V(\hat{S}_c)$ = variance of $\hat{N}_c$.

Cost per Survivor

Costs per survivor of different cohorts of age 1 rainbow trout stocked in Birch Lake and Quartz Lake were estimated using:

$$\hat{CPS}_c = \frac{CPF_c\ N_{stc}}{\hat{N}_c} \tag{17}$$

$$V(\hat{CPS}_c) = \frac{b^2\ V(\hat{N}_t)}{\hat{N}_c^{\,4}} \tag{18}$$

where:

CPF_c = cost per fish when stocked for cohort c;
N_{stc} = number of fish stocked of cohort c;
$\hat{N}_c$ = estimated abundance of cohort c;

$\hat{CPS}_c$ = estimated cost per survivor for cohort c; and,

b = $(CPF_c)\ (N_{stc})$

$V(\hat{CPS}_c)$ = variance of CPS_c using the Delta Method (Seber 1982).

Length Composition

Length ranges for the various cohorts (by age and stocking time as determined by size and mark) were determined by examination of length frequency distributions. The population means and variances were estimated from the sample means and variances. Fish older than age 2 were either combined with age 2 fish into a single age 2+ cohort describing the length range and mean of all of the fish older than age 1, or where possible separated and described as age 2 and age 3+ fish (all fish age 3 and older).

Spring Mortality at the Weir

When dead and dying rainbow trout and coho salmon were found at the Birch Lake Weir on 12 May, all of the moribund fish against one of the screens were collected and later counted. Subsamples of 100 rainbow trout and 100 coho salmon were sampled for fork length and the rainbow trout were examined for fin clips.

Coho Salmon

Coho salmon were sampled for length in Birch Lake three times during 1991. The first sampling event was at the outlet on 12 May, as described above. The next two sampling events took place on 20 June and 8 August. Coho salmon captured on 12 August in Quartz Lake were sampled for length. Up to 100 coho salmon were measured per sampling event. Age 0 fingerling coho salmon stocked in July, 1991 were not sampled.

Arctic Char

Arctic char fingerlings (age 0, Tables 1,2) were first stocked into Birch and Quartz lakes during July 1991. All Arctic char fingerlings captured in fyke nets during rainbow trout sampling events were measured (FL). These data are included in this report as summary information on the length composition of these cohorts, providing a starting point for the database documenting the performance of stocked Arctic char in each lake.

RESULTS

Birch Lake

Rainbow trout in Birch Lake were examined during four sampling events in 1991. The first sampling event was during a period of mass mortality at the outlet on 13 May. The second sampling event was when cohorts of rainbow trout were sampled for length composition in June. The last two sampling events were during Events 1 and 2 of the mark-recapture experiment during August. Coho salmon were sampled for length during the first three events, and Arctic char were sampled for length during the third event.

Length Comparison of Age 1 Rainbow Trout Captured in June:

In June, 669 rainbow trout were captured in Birch Lake and examined for ventral fin clips. Of these, 13 had right ventral (RV) fin clips and 38 had left ventral (LV) fin clips.

The length frequency distribution of rainbow trout sampled in Birch Lake in June was bi-modal (Figure 4B). Fish with ventral fin clips were present among only the smaller fish comprising the left mode. Mean lengths of fish marked with either an RV or LV fin clip were 140 mm (SE = 4) and 146 mm (SE = 2; Table 3), respectively. Length distributions of these marked fish generally overlapped (Figure 5A) and were not significantly different (P = 0.24, Figure 5B).

Mark-Recapture Experiment:

During the mark-recapture experiment in August, 1,027 rainbow trout were captured, measured, marked with a caudal fin clip, and released during the first event. During the second event, 1,007 rainbow trout were captured, measured, examined for marks, and released. Of these, 54 had a caudal fin clip. The estimated abundance of rainbow trout in Birch Lake in early August of 1991 was 18,839 (SE = 2,472; Table 4).

Tests of Assumptions for the Abundance Estimate of Birch Lake Rainbow Trout:

In Event 1 in Birch Lake, 599 rainbow trout were marked in Section I and 428 rainbow trout were marked in Section II. During Event 2, there were 28 fish recaptured with Section I marks and 26 fish recaptured with Section II marks (Table 5).

Gear Bias. The length frequency distributions of rainbow trout captured during Event 1 and Event 2 were bi-modal (Figures 6A, 6B). Fish marked with ventral fin clips were again only present in the left mode. From Event 1 to Event 2 both modes shifted to the right. Length distributions were different for rainbow trout captured in Event 1 versus <u>marked</u> rainbow trout captured in Event 2 (P = 0.004; Figure 7A). Also, length distributions were different for rainbow trout captured in Event 1 versus <u>all</u> rainbow trout captured in Event 2 (P = 0.001, Figure 7B). However, rates of recovery for small (0.04) and large (0.06) rainbow trout were not different (P = 0.24; Table 6).

Capture Location. Rates of recovery of marked rainbow trout for Section I and Section II were 0.06 and 0.05 and were not different (P = 0.32; Table 7). However, equal mixing of marked fish between sections did not occur (P < 0.0001; Table 5).

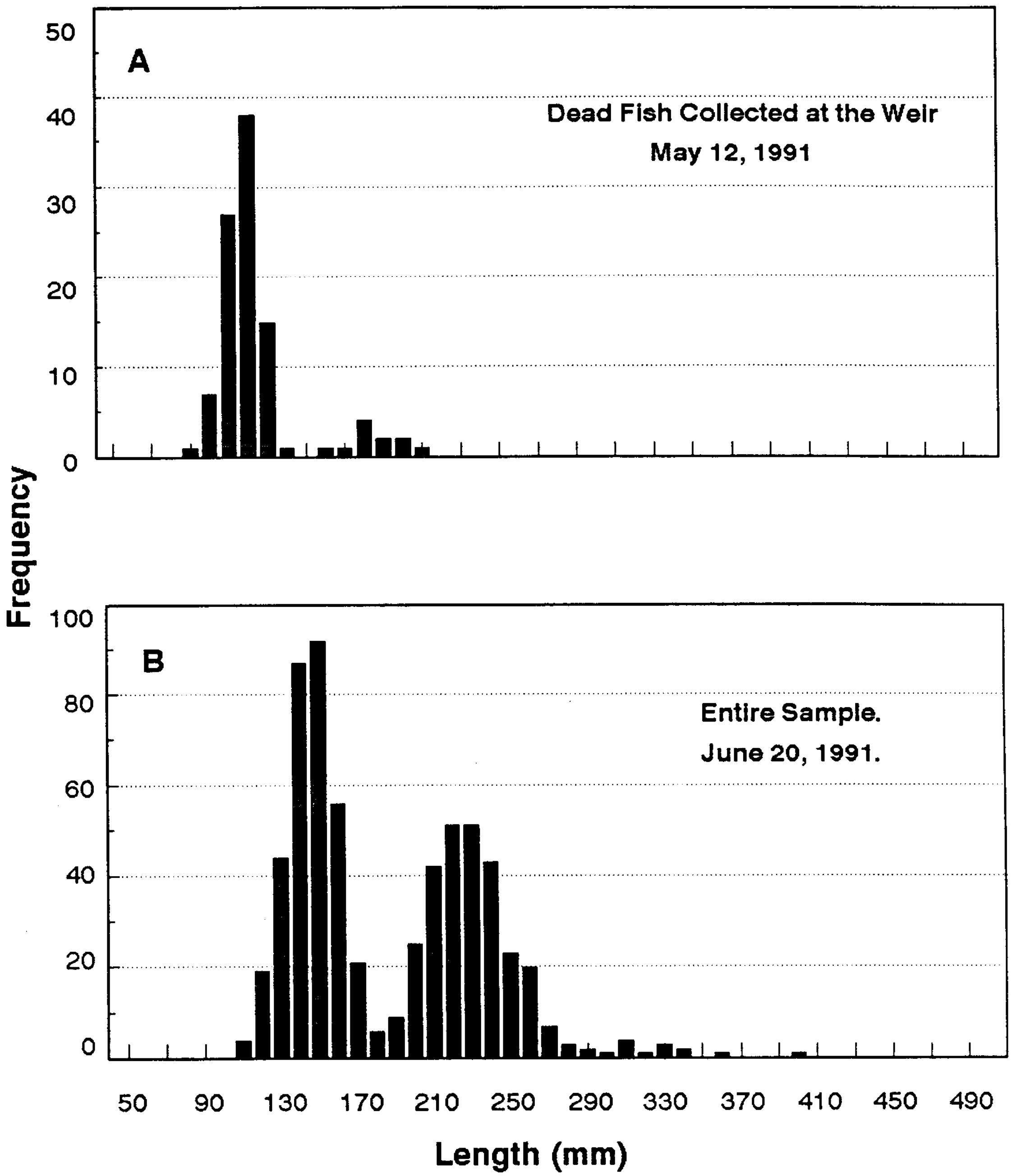

Figure 4. Length frequency histograms of Birch Lake rainbow trout sampled in: (A) May; and, (B) June 1991.

Table 3. Range and mean length of rainbow trout cohorts sampled from Birch Lake, May - June 1991.

Date	Stocking Cohort (Fin Clip)[a]	Number Sampled	Length (mm) Range	Mean (SE)
12 May	Fall 1990 (RV) Age 1	89[b]	90-131	112 (1)
12 May	Age 2	11[b]	157-203	180 (4)
20 June	Fall 1990 (RV) Age 1	13	120-160	140 (4)
20 June	Spring 1991 (LV) Age 1	38	121-170	146 (2)
20 June	All (Marked and Unmarked) Age 1	323	102-170	140 (1)
20 June	Age 2 Rainbow Trout	280	171-276	222 (1)
20 June	Older Rainbow Trout	15	283-399	321 (29)

[a] RV = Right Pelvic Fin Clip; LV = Left Pelvic Fin Clip.
[b] Subsample from mortalities at the Birch Lake Weir.

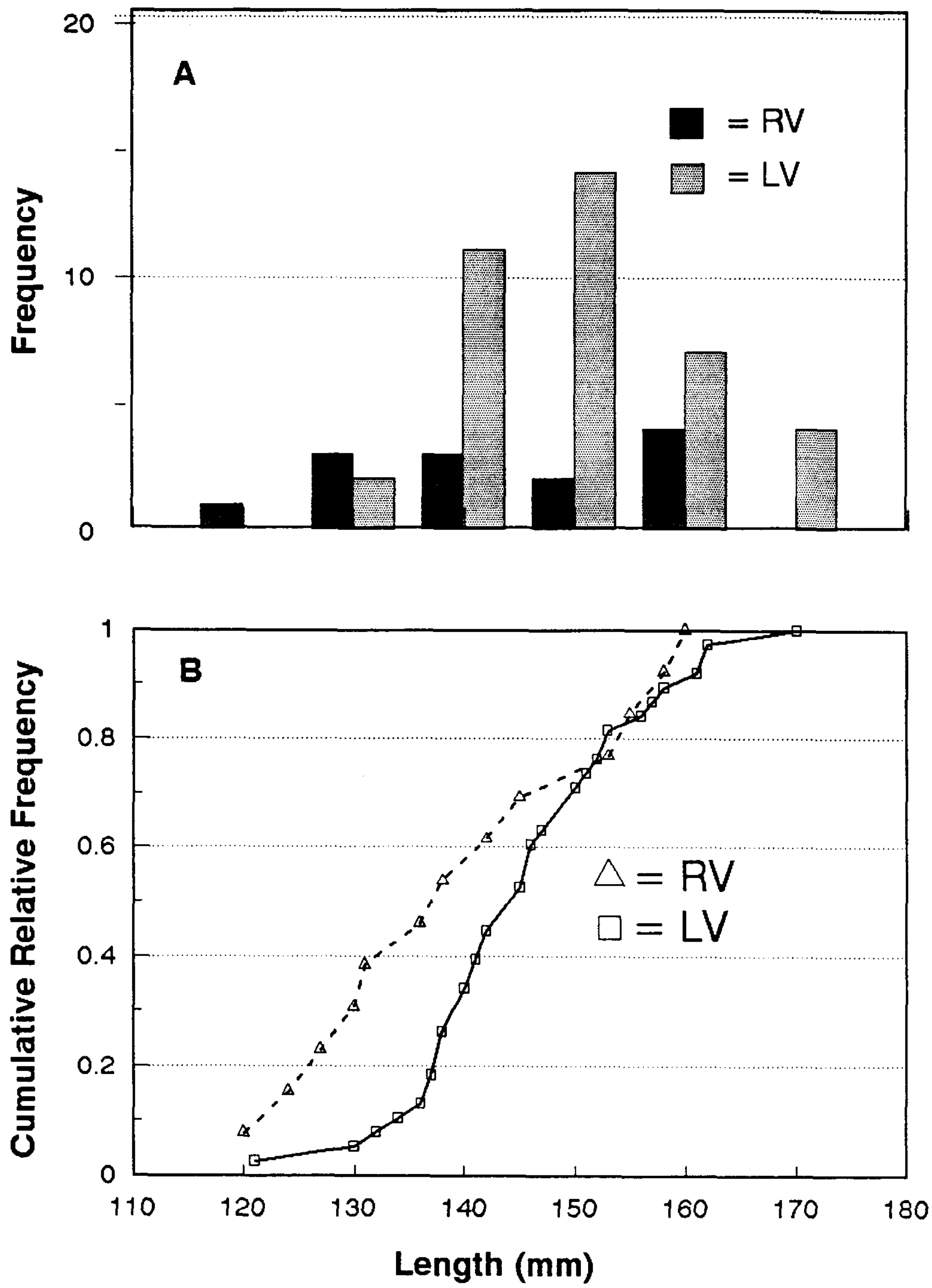

Figure 5. Birch Lake rainbow trout, 20 June 1991: (A) Length frequency histogram of rainbow trout with right (RV) or left (LV) pelvic fin clips; and, (B) Cumulative length frequency of rainbow trout with right (RV) or left (LV) pelvic fin clips.

Table 4. Estimated rainbow trout abundance, Birch Lake, August 1991.

Cohort	Proportion	Standard Error	Estimated Abundance	Standard Error
Age 1	0.52	0.011	9,796	1,302
Fall 1990	0.36	0.015	3,527	441
Spring 1991	0.64	0.015	6,269	846
Age 2 and older	0.48	0.011	9,043	1,204
Total Abundance			18,839	2,472

Table 5. Mixing of marked and unmarked rainbow trout during the abundance estimate in Birch Lake, August 1991.

	Event 2		Not	Total
	Section I	Section II	Recovered	Marked
Event 1:				
Section I	24	5	570	599
Section II	4	21	403	428
Unmarked	428	525		
Total	456	551	970	1,027

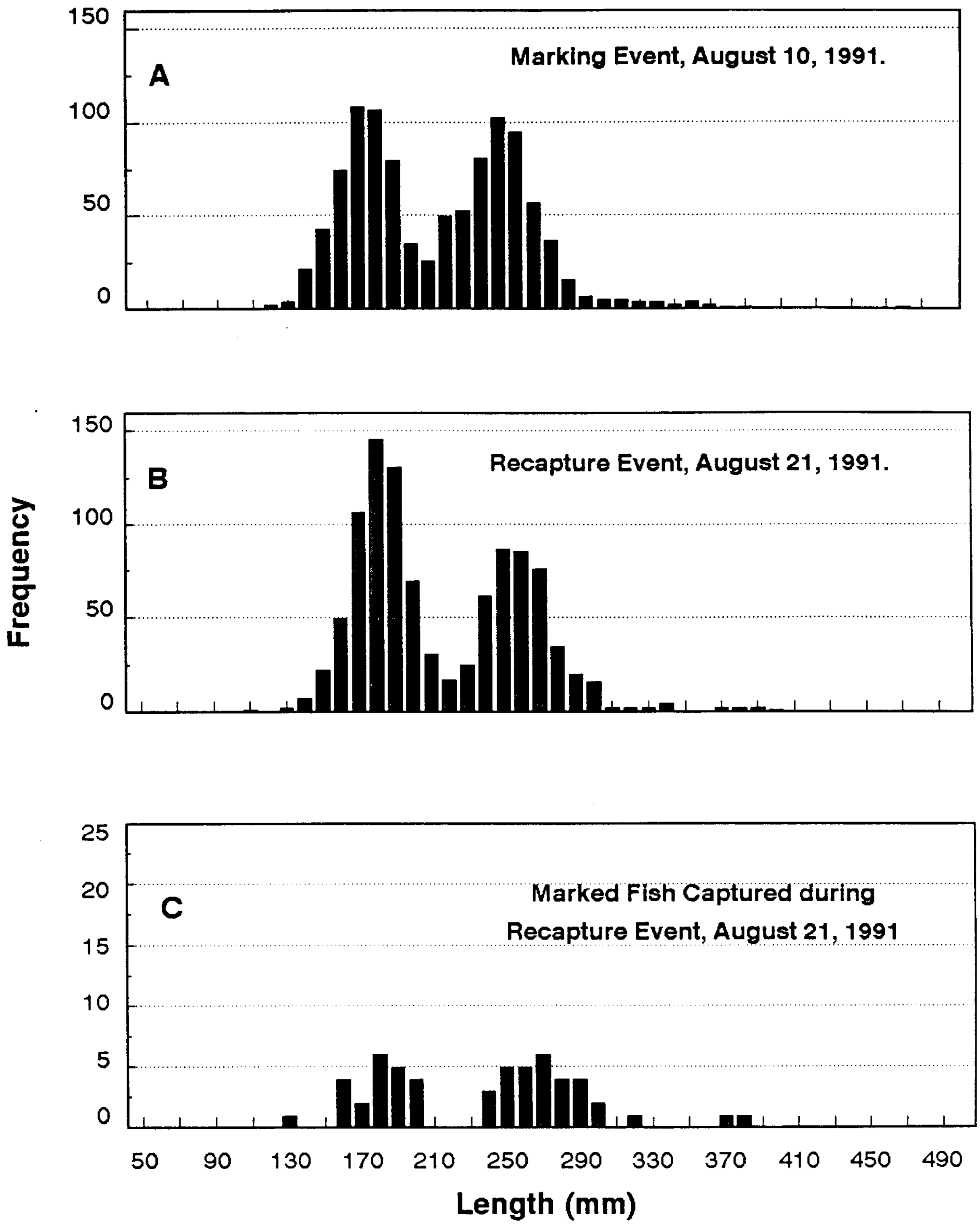

Figure 6. Length frequency histograms of Birch Lake rainbow trout during the abundance estimate sampling, August 1991.

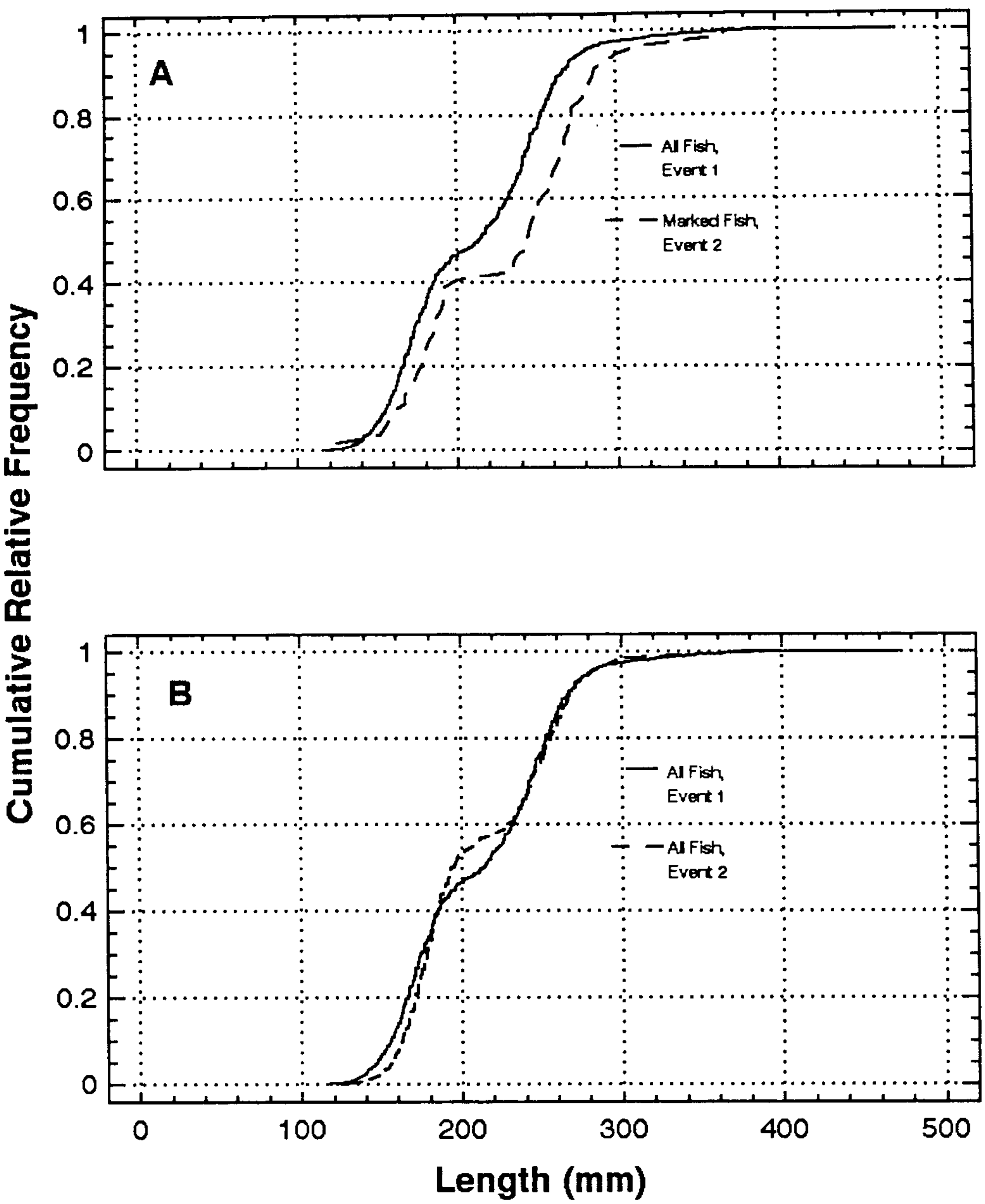

Figure 7. Birch Lake rainbow trout cumulative length frequency distributions: (A) All fish sampled in Event 1 versus marked fish recaptured in Event 2; and, (B) All fish sampled in Event 1 versus all fish sampled in Event 2.

Table 6. Contingency table of rates of recovery by size cohort for the Birch Lake rainbow trout abundance estimate, August 1991.

	Size Cohort	
	Small	Large
Recovered	22	32
Not Recovered	476	497
Total Marked	498	529
Proportion Recovered	0.04	0.06

Table 7. Rates of capture by lake section for the Birch Lake rainbow trout abundance estimate, August 1991.

	Section I	Section II
Marked	28	26
Unmarked	428	525
Total	456	551
Proportion Marked	0.06	0.05

Age Composition:

Proportions of age 1 and age 2+ rainbow trout in the population were 0.52 and 0.48 (SE = 0.01). Corresponding abundances of the age 1 and age 2+ cohorts were 9,796 fish (SE = 1,302) and 9,043 fish (SE = 1,204), respectively (Table 4).

Stocking Cohort Composition for Age 1:

When catches of rainbow trout from June and August were combined, 35 had RV fin clips and 123 had LV fin clips. Rainbow trout from stockings in fall 1990 and spring 1991 comprised 0.36 and 0.64 (SE = 0.015) of the age 1 population. Corresponding abundances were 3,527 fish (SE = 441) and 6,269 fish (SE = 846), respectively (Table 4).

Survival:

Rates of survival for rainbow trout stocked as subcatchables in fall 1990 and spring 1991 were 0.14 (SE = 0.03) and 0.25 (SE = 0.05).

Cost per Survivor:

Costs per surviving fish for subcatchable rainbow trout stocked in the fall and spring were $0.25 and $0.30 per fish, bringing the total costs of producing and stocking each cohort of 25,000 fish to $6,250 and $7,500. The costs per survivor to August for the fall and spring stocking cohorts were $1.72 (SE = 0.10) and $1.18 (SE = 0.04), respectively.

Length Composition:

Mean lengths for age 1, age 2, and age 3+ rainbow trout sampled during Event 1 were 169 mm (SE = 1), 246 mm (SE = 1), and 345 mm (SE = 7); and for the corresponding cohorts sampled during Event 2 were 176 mm (SE = 1), 255 mm (SE = 1), and 353 mm (SE = 7; Table 8). Mean lengths of age 1 rainbow trout stocked in fall 1990 and marked with an RV fin clip or stocked in spring 1991 and marked with an LV fin clip were 140 mm (SE = 4) and 146 mm (SE = 2) in June (Table 3); 169 mm (SE = 3) and 170 mm (SE = 2) during Event 1 of the abundance estimate; and, 173 mm (SE = 5) and 175 mm (SE = 2) during Event 2 of the abundance estimate (Table 8).

Spring Mortality:

Dead and dying rainbow trout and coho salmon were found against the two rotating, self cleaning weir screens at the outlet on 13 May. Approximately equal masses of small dead fish were against each of the screens. Larger rainbow trout and Arctic grayling were attempting to spawn in the 40 m of stream between the weir and the lake.

Totals of 694 rainbow trout and 630 coho salmon were collected from one of the screens. Length distribution of the dead rainbow trout was in a small right mode and a strong left mode (Figure 4). Length range of rainbow trout in the right mode (larger fish) was 157-203 mm (n=11) and mean

Table 8. Range and mean length (mm) of rainbow trout cohorts sampled from Birch Lake during the mark-recapture experiment, August 1991.

	Marking Event 10 August			Recapture Event 23 August		
		Length (mm)			Length (mm)	
Stocking Cohort	Number Sampled	Range	Mean (SE)	Number Sampled	Range	Mean (SE)
Fall Age 1	15	141-191	169 (3)	7	170-196	173 (5)
Spring Age 1	51	132-201	170 (2)	34	146-205	175 (3)
All Age 1	488	118-204	169 (1)	572	103-213	176 (1)
Age 2	515	205-308	246 (1)	421	214-311	255 (1)
Age 3+[a]	24	315-471	345 (7)	14	314-392	353 (7)

[a] All rainbow trout in the lake older than Age 2.

length was 180 mm (SE = 4)(Table 3). These lengths are within the length range (89 - 249 mm) of the rainbow trout from the 1990 subcatchable cohort that were sampled in September, 1990, and fish within this mode were judged to be from that cohort. Length range of fish in the left mode (n = 89) was 90 - 131 mm and mean length was 112 mm. A total of seven of the rainbow trout in the left mode had been marked with RV fin clips. The length range and marks indicated that fish within the left mode were from the cohort of subcatchable rainbow trout that were stocked during October, 1991.

In the subsample of 100 coho salmon, 99 fish were in a distinct cohort (Figure 8A) with a length range of 102-138 mm and a mean length of 123 mm (SE=1; Table 9). These fish were probably stocked as fingerlings in 1990. In September 1990 they had a length range of 85 - 121 mm (n=102) and a mean length of 105 mm (Doxey 1991). One coho salmon in the sample had a length of 186 mm and was probably an age 2 fish.

Birch Lake Coho Salmon and Arctic Char Collected during Rainbow Trout Sampling Events:

On 20 June, coho salmon of the 1990 fingerling stocking cohort (age 1) had a length range of 136 - 163 mm (n = 98) and a mean length of 150 mm (SE = 0). Age 2 coho salmon from the 1989 fingerling stocking cohort had a length range of 211 - 235 mm (n = 14) and a mean length of 223 mm (SE = 2). In August, a sample of 116 age 1 fish had a length range of 142 - 196 mm with a mean length of 174 mm (SE = 1). Age 2 and older fish (n = 11) had a length range of 205 - 314 mm and a mean length of 238 mm (SE = 10; Table 9; Figure 8 B,C).

A sample of 42 age 0 Arctic char fingerlings (Table 10) had a length range of 78 - 123 mm (Figure 9A) and a mean length of 102 mm (SE = 2).

<u>Quartz Lake</u>

Rainbow trout were captured, sampled and released in Quartz Lake during the first and second sampling events of the abundance estimate in August, 1991. Coho salmon and Arctic char were sampled during the first event of the abundance estimate.

Mark - Recapture Experiment:

During the first event of the mark-recapture experiment in August, 990 rainbow trout were captured, measured, marked with a caudal fin clip, and released. During the second event, 1,119 were captured, measured, and examined for marks. Of these, 48 had a caudal fin clip. The estimated abundance of rainbow trout in Quartz Lake was 22,650 fish (SE = 3,184; Table 11).

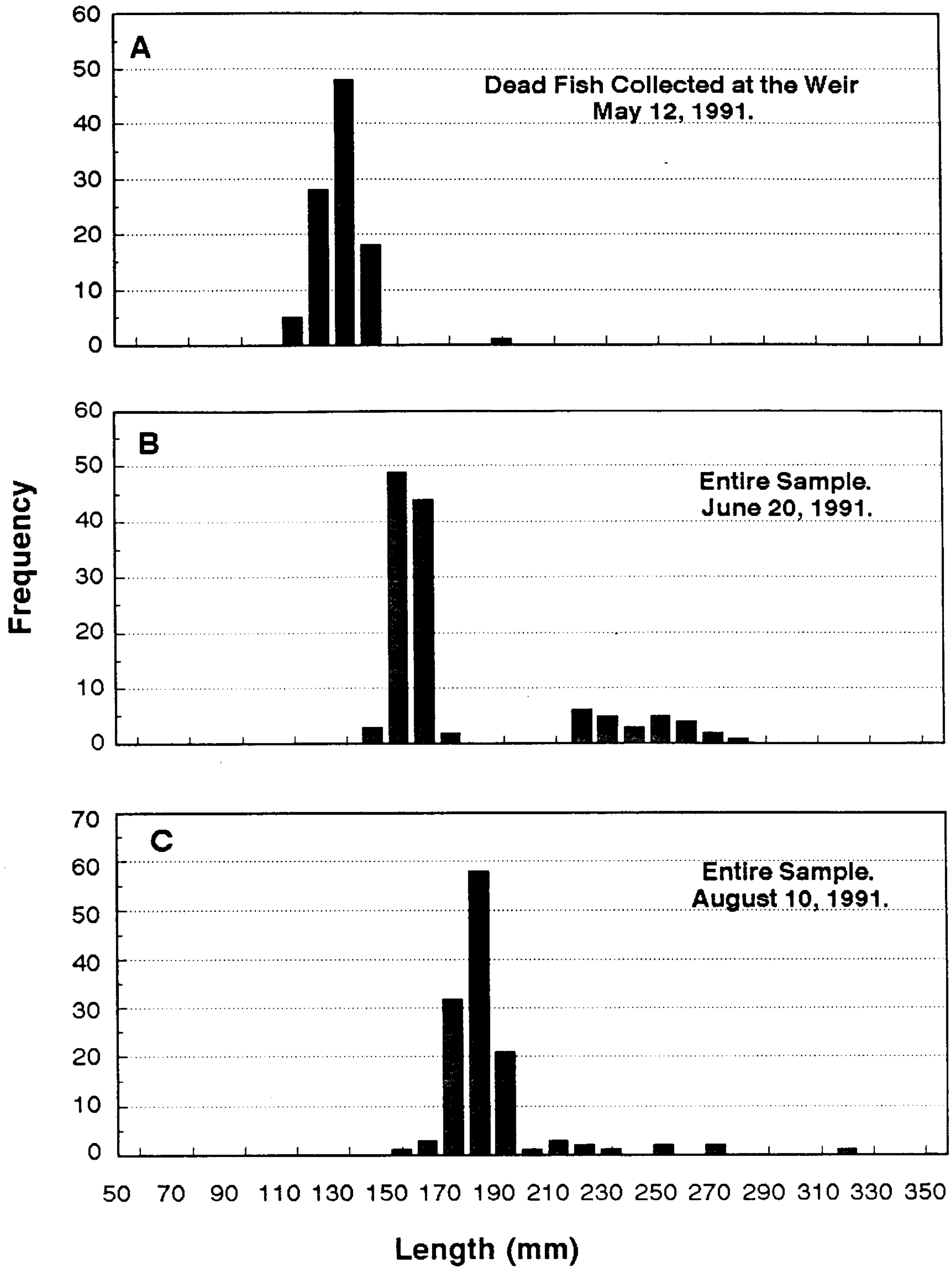

Figure 8. Length frequency histograms of coho salmon sampled from Birch Lake in: (A) May; (B) June; and, (C) August 1991.

Table 9. Range and mean length of coho salmon cohorts sampled from Birch Lake, 1991.

Date	Stocking Cohort	Number Sampled	Length (mm)	
			Range	Mean (SE)
12 May	1990 Fingerling	99[a]	102-138	123 (1)
12 May	1989 Fingerling	1[a]	186	- (-)
20 June	1990 Fingerling	98	136-163	150 (0)
20 June	1989 Fingerling	14	211-235	223 (2)
8 Aug	1990 Fingerling	116	142-196	174 (1)
8 Aug	1989 Fingerling and Older Fish	11	205-314	238 (10)

[a] Mortalities at the Birch Lake weir.

Table 10. Range and mean length of Arctic char sampled from Birch and Quartz Lakes, August 1991.

Water	Stocking Cohort	Number Sampled	Length (mm)	
			Range	Mean (SE)
Birch Lake	1991 Fingerling	42	78-123	102 (2)
Quartz Lake	1991 Fingerling	16	87-116	99 (16)

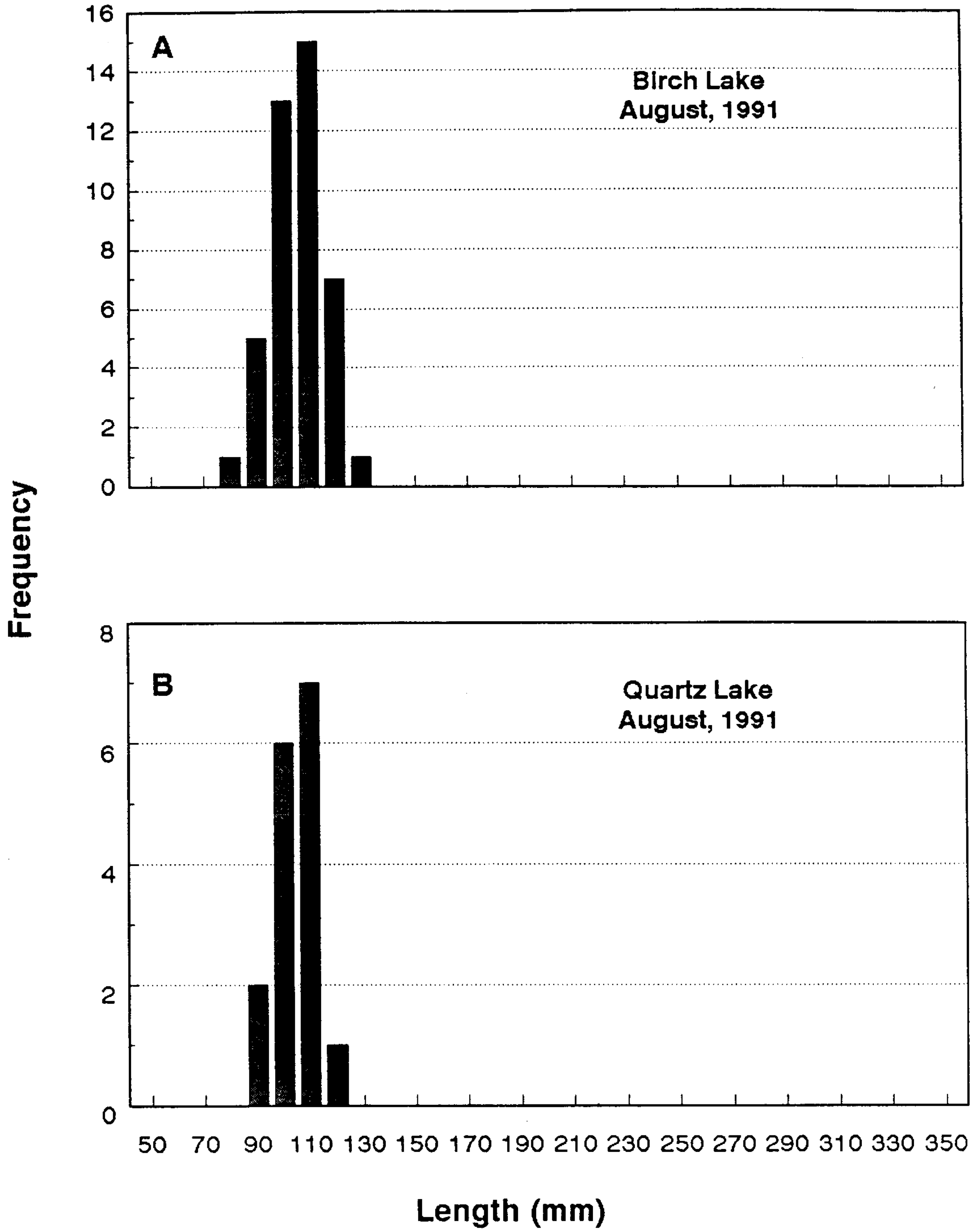

Figure 9. Length frequency histograms of age 0 Arctic char sampled from: (A) Birch Lake; and, (B) Quartz Lake, August 1991.

Table 11. Estimated rainbow trout abundance, Quartz Lake, August 1991.

Cohort	Proportion	Standard Error	Estimated Abundance	Standard Error
Age I	0.66	0.010	14,928	2,585
1990 Fingerlings			7,534	2,884
1991 Subcatchables			7,394	1,280
Age 2 and older	0.34	0.010	7,722	1,859
Total Abundance			22,650	3,184

Tests of Assumptions for the Abundance Estimate of Quartz Lake Rainbow Trout:

In Event 1 in Quartz Lake, 332 rainbow trout were marked and released in Section I and 658 were marked and released in Section II. During Event 2 there were 32 fish recaptured with the Section I marks and 16 fish recaptured with Section II marks (Table 12).

Gear Bias. The length frequency distributions of rainbow trout captured during Event 1 and Event 2 were bi-modal (Figure 10), with fish marked with an RV fin clip present only in the left mode. From Event 1 to Event 2 both modes shifted right. Distributions of lengths were different for rainbow trout captured in Event 1 versus marked rainbow trout captured in Event 2 ($P = 0.023$; Figure 11). Also, distributions of lengths were different for rainbow trout captured in Event 1 versus rainbow trout captured in Event 2 ($P < 0.001$, Figure 11). However, rates of recovery for small (0.05) and large (0.04) rainbow trout were not different ($P = 0.59$; Table 13).

Capture Location. Rates of recovery of marked rainbow trout in Section I and Section II were 0.03 and 0.05 and were not different ($P = 0.08$; Table 14). Equal mixing of marked fish between sections did occur ($P = 0.06$; Table 12). Although these two tests were not rejected at the $P = 0.05$ level, potential bias associated with the Petersen estimate of abundance due to P levels of 0.08 and 0.06 is indicated. To investigate this potential bias, a stratified estimate of abundance (Darroch 1961) was calculated. The stratified estimate of abundance was 23,155 (SE - 4,061) rainbow trout. Because the difference between the stratified (unbiased) abundance estimate and the unstratified abundance estimate was only 505 fish (2%), potential bias associated with the Petersen estimate was determined to be negligible.

Age Composition:

Proportions of age 1 and age 2+ rainbow trout in the population were 0.66 and 0.34 (SE = 0.010). Corresponding abundances of age 1 and age 2+ fish were 14,928 (SE = 2,585) and 7,722 (SE = 1,859) (Table 11).

Stocking Cohort Composition for Age 1 Fish:

In August, 81 of the rainbow trout captured had been marked with an RV fin clip. The abundance of age 1 rainbow trout in the population with an RV fin clip was 870 (SE = 151). The abundance of rainbow trout in the population that were stocked as subcatchables in spring 1991 and as fingerlings in summer 1990 was 7,394 fish (SE = 1,280) and 7,534 fish (SE = 2,884; Table 11).

Survival:

Rates of survival for rainbow trout stocked as subcatchables in spring 1991 and as fingerlings in summer 1990 were 0.17 (SE = 0.0009) and 0.05 (SE = 0.0004).

Table 12. Mixing of marked and unmarked rainbow trout during the abundance estimate in Quartz Lake, August 1991.

		Event 2		Not	Total
		Section I	Section II	Recovered	Marked
Event 1:					
	Section I	9	7	316	332
	Section II	7	25	626	658
	Unmarked	496	575		
	Total	512	607	942	990

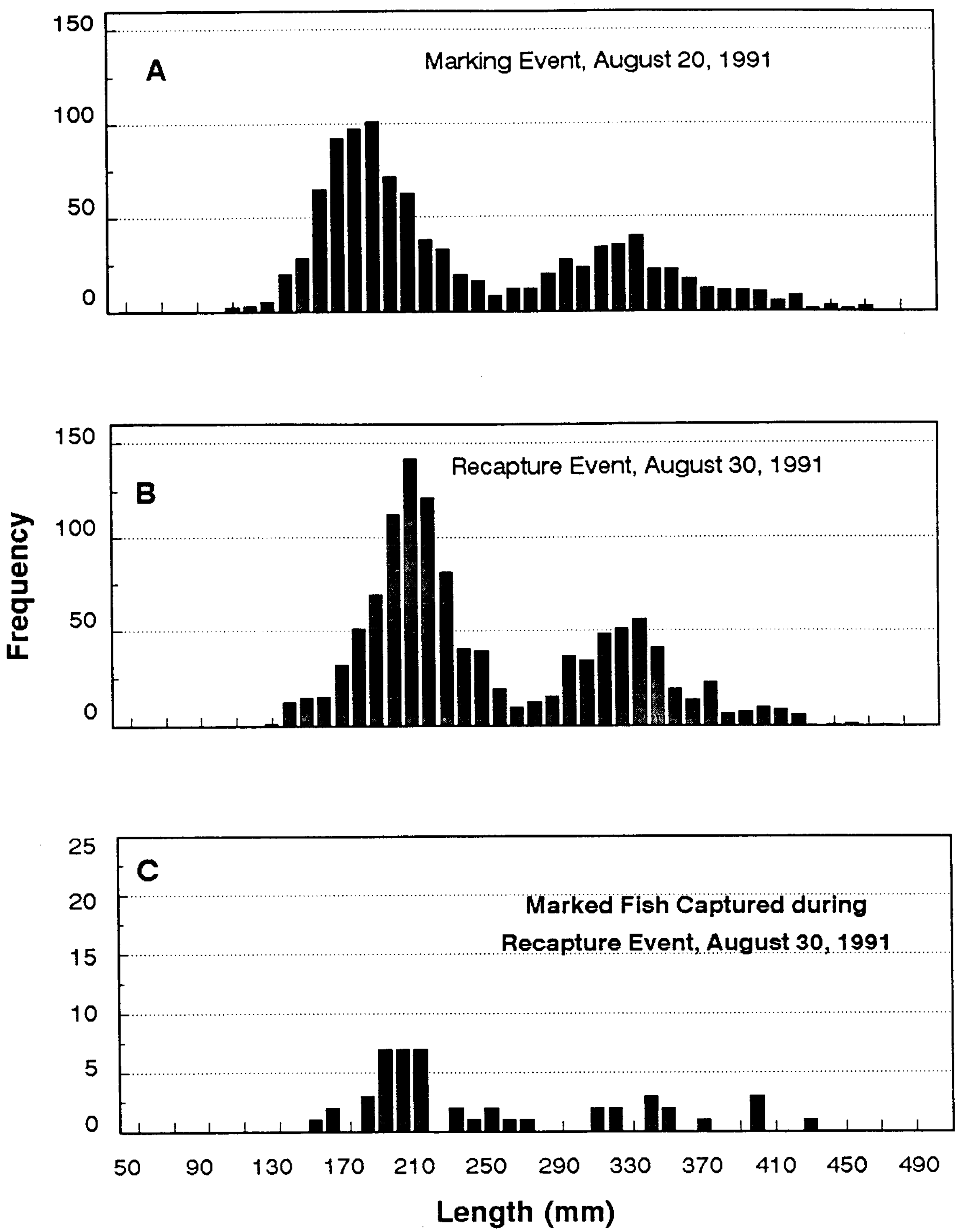

Figure 10. Length frequency histograms of Quartz Lake rainbow trout sampled during the abundance estimate, August 1991.

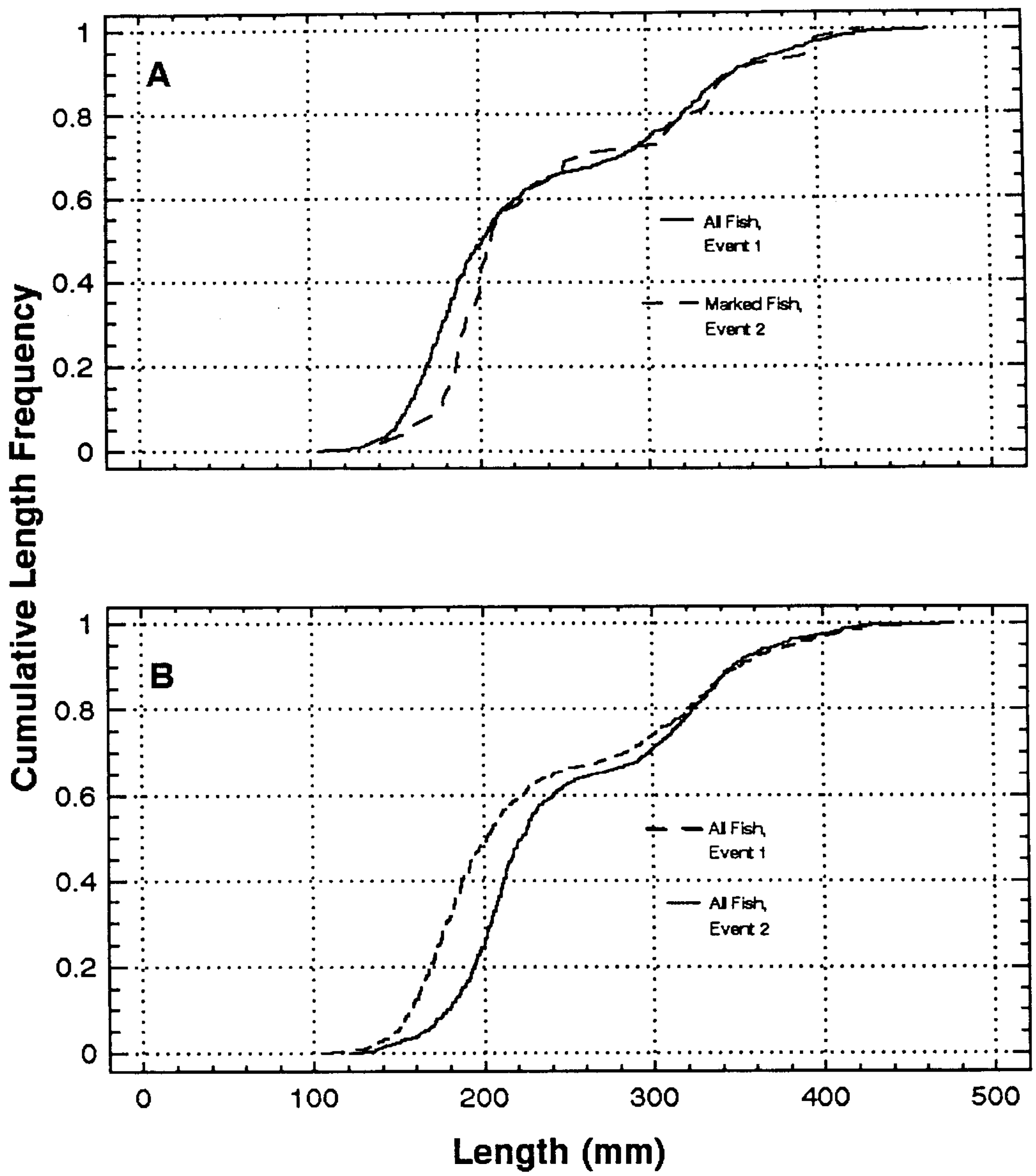

Figure 11. Quartz Lake rainbow trout cumulative length frequency distributions: (A) All fish sampled in Event 1 versus marked fish recaptured in Event 2; and, (B) All rainbow trout sampled in Event 1 versus all rainbow trout sampled in Event 2.

Table 13. Contingency table of rates of recovery by size cohort for the Quartz Lake rainbow trout abundance estimate, August 1991.

	Size Cohort	
	Small < 262 mm	Large > 263 mm
Recovered	34	14
Not Recovered	632	310
Total Marked	666	324
Proportion Recovered	0.05	0.04

Table 14. Rates of capture by lake section for the Quartz Lake rainbow trout abundance estimate, August 1991.

	Section I	Section II
Marked	16	32
Unmarked	496	575
Total	512	607
Proportion Marked	0.03	0.05

Cost per Survivor:

Costs per fish for subcatchable and fingerling rainbow trout were $0.30 and $0.08. The total cost of producing and stocking the cohort of 42,716 subcatchables was $12,815, and the 152,000 fingerlings cost $12,160. The costs per survivor for rainbow trout stocked as subcatchables and fingerlings were $1.73 (SE = $0.09) and $1.61 (SE = $0.38).

Length Composition:

Mean lengths for age 1 and age 2+ rainbow trout during Event 1 were 184 mm (SE = 1) and 335 mm (SE = 2) respectively; and during Event 2 were 204 mm (SE = 1) and 334 mm (SE = 2; Table 15) respectively. Mean length of age 1 rainbow trout stocked in summer 1991 and marked with an RV fin clip was 180 mm (SE = 3) during Event 1 and 201 mm (SE = 3) during Event 2 (Table 15).

Quartz Lake Coho Salmon and Arctic Char:

Coho salmon were sampled for length at Quartz Lake on 12 August (Table 16 and Figure 12). Age 1 fish (n = 82) from the 1990 fingerling stocking cohort had a mean length of 183 mm (SE = 18) and a length range of 140 - 227 mm. Length range of a sample of six age 2 fish from the 1988 fingerling cohort was 239 - 262 mm and mean length was 250 mm (SE = 10). A sample of three age 3 coho salmon from the 1988 stocking cohort had a length range of 303 - 334 mm and a mean length of 320 mm (SE = 16).

Arctic char (n = 16) from the 1991 fingerling stocking (age 0) had a mean length of 99 mm (SE = 16; Table 10) and a length range of 87 - 116 mm (Figure 9B).

DISCUSSION

This study was primarily conducted to answer two fishery management questions: (1) Would the stocking of Birch Lake with age 0 rainbow trout subcatchables in the fall be a cost effective alternative to the prior practise of stocking age 1 rainbow trout subcatchables in June?; and, (2) Would the stocking of Quartz Lake with age 1 subcatchable rainbow trout in June be a cost-effective alternative to the prior practice of stocking age 0 fingerlings in the fall? During the planning of this research, it was decided that mark-recapture estimates of abundance of rainbow trout at the time these fish recruit to the fisheries of Birch and Quartz lakes in 1991 would be elements needed to answer these two fishery management questions.

When planning of the mark-recapture experiments took place (April 1991), it was decided that the marking events for the mark-recapture estimates would take place in August and the recapture events would take place in late September and early October. The planned long hiatus between events was due to an observed phenomena that occurred during a mark-recapture experiment that took place in Birch Lake in 1988. In 1988, rainbow trout were marked in Birch Lake in August and recaptured in September and in

Table 15. Range and mean length of rainbow trout cohorts sampled from Quartz Lake, 1991.

	Marking Event 20 August			Recapture Event 30 August		
		Length (mm)			Length (mm)	
Stocking Cohort	Number Sampled	Range	Mean(SE)	Number Sampled	Range	Mean(SE)
Combined Age 1[a]	663	105-261	184 (1)	730	121-263	204 (1)
Marked Age 1[b]	55	131-226	180 (3)	29	175-225	201 (3)
Age 2 and Older	327	265-465	335 (2)	389	265-476	334 (2)

[a] Overlapping cohorts of Age 1 rainbow trout stocked as fingerlings in fall, 1990 and as subcatchables in spring 1991.
[b] 1991 subcatchables marked with a right pelvic fin clip.

Table 16. Range and mean length of coho salmon cohorts sampled from Quartz Lake, 1991.

Date	Stocking Cohort	Number Sampled	Length (mm) Range	Length (mm) Mean (SE)
12 Aug	1990 Fingerling	82	140-227	183 (18)
12 Aug	1989 Fingerling	6	239-262	250 (10)
12 Aug	1988 Fingerling	3	303-334	320 (16)

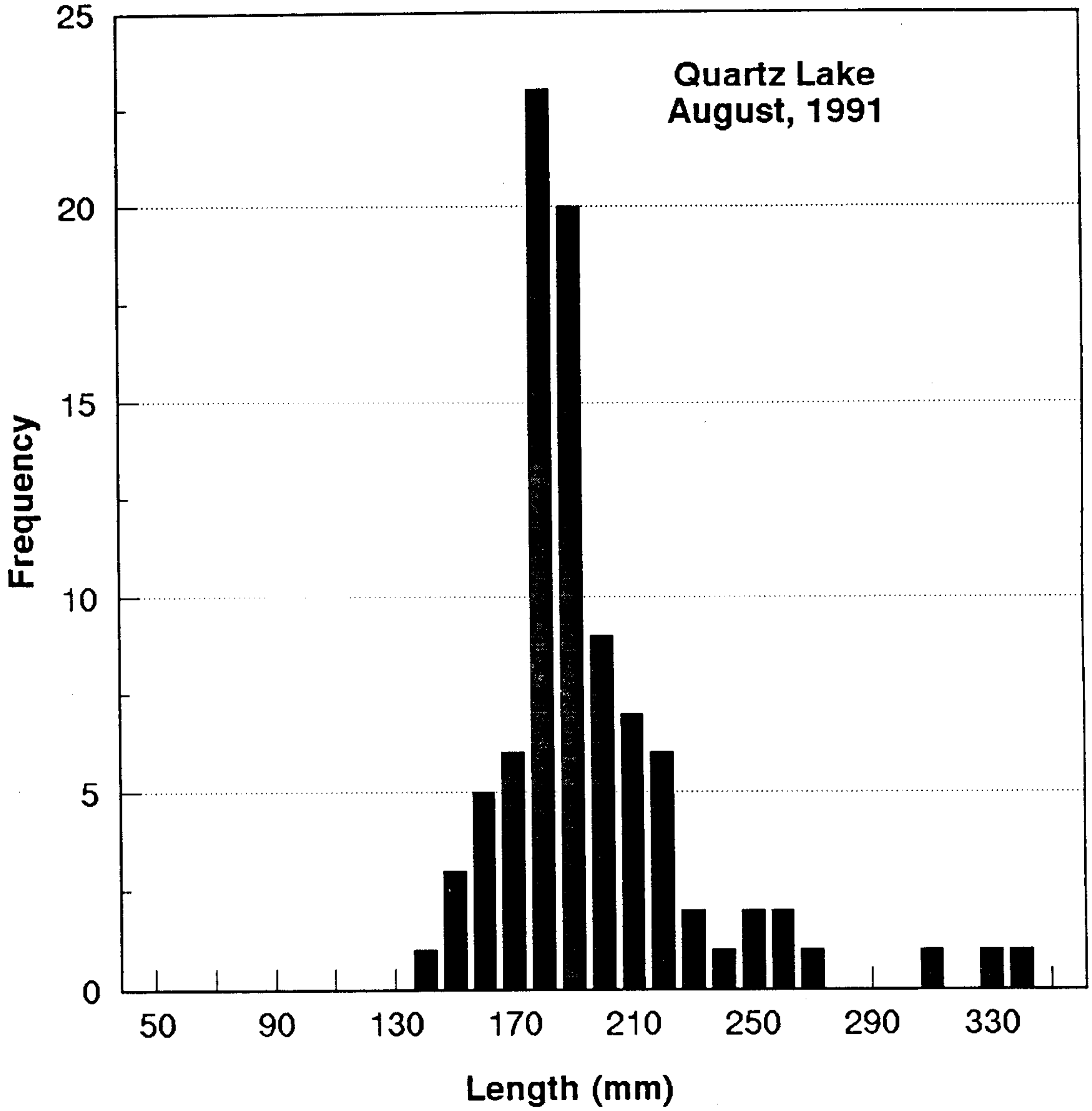

Figure 12. Length frequency histogram of coho salmon sampled from Quartz Lake, 1991.

October. The proportion of fish with marks from the August 1988 sampling event were significantly higher in the recapture sample collected in September 1988 than was the case in the October 1988 sampling, implying that between September and October of 1988, an influx of unmarked fish that had resided in the limnetic zone had moved inshore where the fyke net sampling was taking place. Havens et al (1991) observed a similar phenomena in Big Lake when they were studying a lake population of rainbow trout. A judgement call, due to budgetary limitations, was made during the summer of 1991 to schedule the recapture sampling events for these two mark-recapture experiments shortly after the marking events. The effect of this in-season scheduling decision was to dramatically shorten the hiatus between 1991 sampling events. As a result, the abundance estimates of rainbow trout residing in Birch and Quartz lakes may be biased low because of an inadequate time allowed for fish residing in the limnetic zone to completely mix with fish residing in the littoral zone where sampling took place. Direct evidence of this potential bias cannot be gleaned from the 1991 sampling program but can be gleaned from the 1988 experiment wherein the net effect was a bias that represented about one third of the overall population. On the positive side, the effect of this bias would be the same for all cohorts of the overall population (fish with a RV versus LV fin clip in Birch Lake; and, fish resulting from the stocking of fingerlings versus subcatchables in Quartz Lake) and thus the net effect of this potential bias when addressing the two primary fishery management questions is negligible. Further, an action that is cost effective at an artificially low estimate of abundance will be cost-effective at the real level of abundance. Although I recognize that the 1991 abundance estimates for rainbow trout residing in Birch and Quartz lakes may be biased low due to the short hiatus periods, I am using these estimates without further qualification throughout the remainder of this discussion.

Birch Lake

The total abundance (18,839) of rainbow trout in Birch Lake in August, 1991, was the lowest since estimates of total abundance of the rainbow trout population began in 1986. Abundance from 1986 to 1990 ranged from an estimated 19,551 to 58,269 fish. However, total abundances were probably much lower in 1984 and 1985, when the sport fishery was supported by the stockings of fingerlings and a single stocking of larger fish, and when the abundance of age 1 fish ranged from 0 to 3,779 fish (Doxey 1991).

The 14% total survival to catchable size of the subcatchable rainbow trout stocked at 18 g in October, 1990 is the poorest ever measured for a cohort of subcatchable rainbow trout stocked into Birch Lake, including the 8 g fish that were stocked in June, 1982. Survival of the 1982 cohort was 27.2%, and survivals of early summer stockings of 20 g subcatchables have been as high as 67.4% in 1986 and are typically over 50%. Cohorts of 32 g subcatchables stocked in March, 1988 and 16 g subcatchables stocked in April, 1989 (both prior to breakup) had survivals of 40.6% and 28.3% (Doxey 1991).

The October 1990 cohort took 9.5 months to grow to catchable size, (six of those months under ice cover), compared to the 2.5 - 3 months it typically takes 20 g subcatchables stocked in the spring to reach catchable size (Doxey 1991). By late June, the mean length of the October cohort was slightly less than that of the 20 g subcatchables stocked in June (Table 3). Daily mortality reduced the October cohort at an unknown rate during the additional seven months that it was present in the lake (prior to the catastrophic short term die-off at the outlet in May). A winter mortality accumulating to 20% combined with the slow growth rate would have resulted in poorer cost effectiveness of the fall cohort in the lake before the spring cohort was even stocked. This 20% total mortality over a nine month period is not unlikely, since the typical mortality of a cohort of 20 g subcatchable rainbow trout stocked in spring is over 40% by fall of that year, when they enter the fishery (Doxey 1991).

The 25% survival to fall of the cohort of subcatchable rainbow trout stocked in June, 1991 was about one half of the typical survival (in excess of 50%) of such a cohort (Doxey 1991). While no cause of this lower survival was identified during the study, predation and competition for food from other fish already in the lake when these fish were stocked is a possibility. From 1986 (when older fish were first included in the Birch Lake rainbow trout abundance estimates) through 1990, abundance of age 2 and older rainbow trout has ranged from 955 in 1988 to 7,966 in 1987 (Doxey 1988, 1989). Abundance of this cohort in 1991 was 9,796 (Table 4), and comprised 48% of the entire rainbow trout population. While this percentage is inversely proportional to the abundance of the age 1 fish, age 2 fish were still at their greatest documented abundance. The greater abundance of this cohort may be due to the record snowfall during the winter of 1990 - 1991, which covered Birch Lake with a layer of deep snow underlain by overflow (water standing on top of the ice). Birch Lake was virtually impassible to ice fishermen, and winter harvest was greatly reduced, ensuring a greater abundance of age 2 rainbow trout in summer 1991. These older fish could have preyed upon and competed for food with the spring subcatchables. In addition, the coho salmon stocking density was more than tripled from an annual stocking of about 40,000 fish to 131,000 fish in 1990 (Table 1). The survivors of this large cohort of coho salmon, along with the survivors of the October subcatchable rainbow trout stocking, were present in Birch Lake when the spring subcatchable rainbow trout cohort was stocked.

Due to the record snowfall during the winter of 1990-1991, there were extremely high flows through the structure (weir) at the outlet of Birch Lake during spring breakup of 1991. Spring runoff in May attracted rainbow trout to the outlet of Birch Lake in past years resulting in the deaths of fish stocked as fingerlings the summer before (in the mid-1980's) or of fish stocked as subcatchables through the ice the previous two months (in March 1988 and April 1989). Death was caused by physical damage as the smaller rainbow trout were forced against the rotating screens by the current (Doxey 1991). Swanson River rainbow trout are spring spawners, and move to areas of the river with a gravel bottom during May (Hammarstrom 1975). Hatchery personnel had noted sexual maturity of male age 1 Swanson strain subcatchable rainbow trout and spring mortalities resulting from subcatchables attempting to get out of the raceways by ramming into or attempting to jump over and hitting the raceway headboards (Wall pers. comm.[1]). It is probable that spawning behavior attracted the rainbow trout to the outlet of Birch Lake.

Since the totals of 694 rainbow trout and 630 coho salmon were all of the fish from only one side of the outlet structure, and the other side appeared to have as many dead fish, it is likely that there were over 1,000 of each species against the two screens. In addition, the rotating self-cleaning screens were carrying dead fish over the top and dropping them into the water on the downstream side along with stream-born detritus every one to two minutes. It is therefore mathematically possible, given the near 50/50 split between the two species and assuming a fairly constant supply of 2,000 dead fish, that up to 720 of each species were being carried over during each 24 hour period of peak flows. Since the bodies of the fish had to deteriorate somewhat before the screen could pick them up, this disposal rate would probably increase with warming water temperatures, which would speed the decomposition rate of the fish.

The 1,000 plus subcatchable rainbow trout dead against the weir screens on 13 May represent about 5% of the original cohort of 25,000 fish stocked in October. This is likely a minimum estimate of mortality for a single day. Additionally, about 2.5% of the original number stocked may have been passing dead over the structure each day. The flows in 1991 were higher and the mortality was probably at a greater magnitude than the event which occurred in 1989 (Doxey 1991). This 1991 short term catastrophic die-off undoubtedly contributed to the low survival of the October 1990 subcatchable stocking cohort in Birch Lake. Conversely, rainbow trout held in the hatchery to be stocked after spring runoff are not subjected to this event until the following year, by which time they are generally large and strong enough to avoid being pulled against the screens. In addition, such a cohort has already contributed to the sport fishery (Doxey 1991). The outlet of Birch Lake can rise rapidly to high flow rates during the summer in response to heavy rains. Rainbow trout are apparently not as attracted to the outlet in the summer, and no mass mortalities of the magnitude of the spring events have been noted. None of the much larger rainbow trout (approximately 300 - 500 mm) congregated upstream from the outlet structure were found dead on 13 May.

The subcatchable stocking experiment (stocking numerically identical cohorts of similarly sized subcatchable rainbow trout in early winter and in early summer) reduced hatchery raceway crowding through the winter, and because less hatchery resources were consumed during the shorter rearing time, the initial cost of the October fish was less. It was expected that overwinter survival of subcatchables stocked in October might be lower. Whether the expected decreased survival was offset by lower initial cost was tested. Even with the lower than expected survival of the cohort of rainbow trout stocked in June, the cost per survivor ($1.18) in August was 32% lower than that of the October cohort ($1.72), though the initial cost

---

[1] Wall, Gary. 1991. Personal Communication. ADF&G, PO Box 5-337, Ft. Richardson, Ak 99505-0337.

of the October cohort ($0.25) was 17% lower than that of the June cohort ($0.30). The stocking of 20 g subcatchable rainbow trout into Birch Lake in October could be cost effective if it enabled an increase in hatchery production at such a low cost that the sport fishery could be sustained or improved at Birch Lake and at the same time the cost per fish in the overall program was reduced or the hatchery space could be better allocated to another project.

Quartz Lake

The total abundance of rainbow trout in Quartz Lake (22,650) is slightly low in the historical range of rainbow trout abundance estimates for 1986 - 1990 (9,489 - 43,251). Survival to fall of the 1991 subcatchable rainbow trout cohort (17%) is midrange of three similar cohorts, evaluated in 1987, 1988, and 1989, that had survivals of 14%, 28%, and 9%. The 5% survival of the 1990 fingerling rainbow trout cohort is lower but comparable to the only other estimate available (7% in 1987; Doxey 1991).

The reason is unclear for the apparent lower survival in Quartz Lake of cohorts of subcatchable rainbow trout compared to Birch Lake, but the cost per survivor ($1.73) is essentially the same as that of the October cohort of subcatchable rainbow trout stocked into Birch Lake, and is 7% greater than that of survivors of the Quartz Lake 1990 fingerling cohort ($1.61). However, growth rate of subcatchable rainbow trout cohorts in Quartz Lake is similar to that of Birch Lake, meaning that subcatchable cohorts stocked at 20 g or larger in the spring will recruit to the fishery by fall.

Recruitment to the Fishery

Length frequency distributions of rainbow trout in Birch and Quartz lakes shifted to the right (Figures 6 and 10, respectively) and mean length of cohorts of age 1 fish increased (Tables 8 and 15) in both lakes between sampling events. This is typical and is due to growth. Mean lengths of cohorts of age 1 fish in Birch Lake (176 mm) and Quartz Lake (204 mm) were within historical length ranges for those cohorts during late August (Doxey 1991). Mean length of cohorts of age 1 rainbow trout can be expected to increase by up to 22 mm in Quartz Lake and 29 mm in Birch Lake by early October (Doxey 1988). Rainbow trout begin to recruit to the sport fishery as their length exceeds a minimum "catchable size" of 180 mm (Doxey 1991). Mean length of the Quartz Lake age 1 rainbow trout had already exceeded this minimum length and the anticipated growth of the age 1 fish in Birch Lake ensured the availability of these fish during the upcoming ice fishing season.

Similarly, age 1 cohorts of coho salmon in Birch and Quartz lakes were at or near catchable size (Tables 9 and 16; Figures 8 and 12, respectively) and can be expected to contribute to the winter fishery of 1991-1992.

Based on the results of this study and the information reported in Doxey 1991, the following conclusions are drawn:

1. Rainbow trout reared to subcatchable size can be a cost effective substitute for fingerling stockings.

2. In lakes with blocked outlets having heavy flow from snow-melt runoff, such as Birch Lake, subcatchable sized rainbow trout should not be stocked until flow drops to normal summer levels.

3. The use of subcatchable sized rainbow trout to maintain a sport fishery in lakes such as Quartz Lake may cost as much or more than fingerlings.

ACKNOWLEDGEMENTS

My thanks to Cal Skaugstad, John Clark, Peggy Merritt and Dave Bernard for advice and editing of this report, and to Sara Case for her patience in responding to the demands of producing the final product. Cal Skaugstad, Tim Viavant, Roy Perry, Kelly Krueger, and Larry King assisted with the field work. This project and report were made possible by partial funding provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-7, Study No. E, Job No. 3-1(a).

LITERATURE CITED

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Publications in Statistics 1: 131-160.

Darroch, J. N. 1961. The two sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Doxey, M.R.. 1988. Evaluation of Stocked Waters in the Tanana drainage, 1987. Alaska Department of Fish and Game, Fishery Data Series No. 73. 53 pp.

_____. 1989. Evaluation of Stocked Waters in the Tanana drainage, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 106. 49 pp.

_____. 1991. Evaluation of Rainbow Trout and Coho Salmon Stocking Programs in Birch, Chena, and Quartz Lakes, Alaska. Alaska Department of Fish and Game, Fisheries Data Series 91-66.

Goodman, L.A. 1960. On the exact variance of products. Journal of American Statistical Assoc., Vol 55:708-713.

Hammarstrom, S.L. 1975. Inventory and Cataloging of Kenai Peninsula, Cook Inlet, and Fish Stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1974-1975, Project F-9-7, 16:27-66.

Havens, A. C., M. Alexandersdottir, and S. Sonnichsen. 1991. Evaluation of Rainbow Trout Populations in Big Lake, Alaska, 1989-1990. Alaska Department of Fish and Game, Fisheries Data Series No. 91-27.

Mills, M. J. 1991. Harvest, Catch, and Participation in Alaska Sport Fisheries During 1990. Alaska Department of Fish and Game. Fishery Data Series No. 91-58. 184 pp.

Seber, G. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., London, U.K. 654 p.