Fishery Data Series No. 91-7

Lake Trout Population Studies in Interior Alaska, 1990, Including Abundance Estimates of Lake Trout in Glacier, Sevenmile, and Paxson Lakes During 1989

by

John M. Burr

May 1991

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 91-7

LAKE TROUT POPULATION STUDIES IN INTERIOR ALASKA, 1990, INCLUDING ABUNDANCE ESTIMATES OF LAKE TROUT IN GLACIER, SEVENMILE, AND PAXSON LAKES DURING 1989[1]

By

John M. Burr

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

May 1991

1 This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-6, Job Number R-3-3(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 TABLES (Continued)

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

During 1990, lake trout *Salvelinus namaycush* were sampled from Paxson Lake of the Copper River system, and from Fielding, Glacier, and Sevenmile lakes of the Tanana River system. Size composition of lake trout estimated as Relative Stock Density varied widely between lakes. Most large lake trout (greater than 715 millimeters fork length) were found in Paxson Lake. A few large fish were captured from Fielding Lake. Most other lake trout sampled from the Tanana River system were less than 500 millimeters. Ages of lake trout ranged from 0 to 33 years, with most between 4 and 20 years. No fish greater than age 15 were found in Fielding or Sevenmile lakes. Age at which 50 percent of all lake trout were mature ranged from 4.8 years for males in Paxson Lake to 9.2 years for females in Glacier Lake. Males typically matured at younger ages than females. Lengths at which 50 percent of lake trout were mature were similar for all lakes sampled and ranged from 351 millimeters for males in Paxson Lake to 448 millimeters for females in Fielding Lake.

Lake trout abundance for 1989 was estimated using mark-recapture experiments in Sevenmile, Glacier, and Paxson lakes. Abundance estimates are germane to the year of marking, which is 1989. The abundance estimate of lake trout greater than 275 millimeters was 1,665 fish (50 fish per hectare) in Sevenmile Lake and 3,142 fish (18 fish per hectare) for lake trout 250 mm and larger in Glacier Lake. Estimated abundance of spawning lake trout in Paxson Lake was 5,066 fish (three fish per hectare). Estimated density of lake trout of mature size was 32 fish per hectare in Sevenmile Lake, and eight fish per hectare in Glacier Lake.

KEY WORDS: Lake trout, *Salvelinus namaycush*, population abundance, age, growth, maturity, yield, Fielding Lake, Glacier Lake, Paxson Lake, Sevenmile Lake.

INTRODUCTION

Lake trout *Salvelinus namaycush* support important recreational fisheries in both roadside and remote waters of interior Alaska. Most fishing for lake trout occurs in easily accessible waters. However, since lake trout are often considered a trophy species, anglers seek guided and other fly-in fishing opportunities in remote areas of the state. Since 1977, the statewide harvest of lake trout has averaged about 18,000 fish annually with this level of harvest remaining relatively constant (Mills 1990). Over one half of the total Alaskan harvest comes from the combination of lakes located in the Tanana River drainage and the Glennallen area. In the Glennallen area, harvest has remained at a level of 7,000 to 8,000 lake trout annually since 1977. In the Tanana River drainage, lake trout harvests increased 5% annually up through 1985 to a level of approximately 5,000 fish harvested per year.

Due to a number of biological attributes, lake trout populations may be easily overharvested. This species is long lived and slow growing. Records of fish older than 25 years are not unusual, and lake trout older than 50 years have been captured in Alaska. A trophy size lake trout weighing 8.7 kg (20 lbs) in Alaska would typically be 20 or more years old. In interior Alaska, lake trout spawn for the first time at ages of 5 to 10 and at fork lengths (FL) of 350 mm to 450 mm (14 to 18 in). Mature lake trout may not spawn every year. Healey (1978) suggests that average maximum sustainable yield of lake trout populations is less than 0.5 kg of fish per surface hectare of lake per year.

Burr (1987a) concluded that knowledge of population abundance, size structure, population dynamic rates, and harvest levels for Alaska lake trout populations was limited. Based on harvest estimates (Mills 1986) and the average size of lake trout obtained from creel sampling and test netting, it was found that the average maximum sustainable harvest rate recommended by Healey was being exceeded for all populations in the Tanana River drainage and Glennallen area for which harvest estimates were available. Harvest in these waters was as much as seven times maximum sustainable yield recommended by Healey (1978). Based on this information, the Alaska Board of Fisheries in 1987 reduced bag limits from 12 to two fish per day in all waters in the Tanana River drainage and Glennallen area. In addition, a minimum length limit of 450 mm total length (TL) (18 in) was instituted for several high use roadside lakes. For the Tangle Lakes system, which has received the highest harvest rates of any lake trout fishery in Alaska in recent years, a one fish daily bag limit and a 450 mm minimum length limit was instituted.

This research project began in 1986 and this report represents the fifth in a series of annual data reports. The long-term goal of the project is to quantify dynamic rates of lake trout populations in Alaska and to accurately estimate sustainable yield for lake trout fisheries. However, management experience in North America indicates that estimates of sustainable yield for lake trout populations are decades in the making. Therefore, the short term goal of this program is to refine our ability to promulgate effective regulations for fisheries in interior Alaska which will keep harvests at or below levels shown to be sustainable for other lake trout populations (see Healey 1978).

The specific project objectives during the 1990 field season were to:

1. estimate population abundance of lake trout in Glacier Lake and Sevenmile Lake for 1989;

2. estimate population abundance of spawning lake trout in Paxson Lake for 1989;

3. estimate the length composition of lake trout populations in Glacier Lake, Sevenmile Lake, and Paxson Lake for 1989;

4. estimate age at maturity (AM_{50}) and length at maturity (LM_{50}) of both sexes of lake trout in Glacier Lake, Sevenmile Lake, and Fielding Lake;

5. estimate mean length at age for populations of lake trout in Glacier Lake, Sevenmile Lake, Paxson Lake, and Fielding Lake;

6. identify spawning locations of lake trout in Fielding Lake; and,

7. test the hypothesis that ages of lake trout from West Twin Lake as determined from otoliths, opercular bones, and scales are true ages.

METHODS

Site Descriptions

Data were collected from populations of lake trout from four lakes in central Alaska: Paxson Lake of the Copper River drainage; Fielding, Sevenmile, and Glacier lakes in the Tanana River drainage (Figure 1). The lakes range widely in size from Sevenmile Lake (surface area 32 ha) to Paxson Lake (surface area 1,575 ha). All lakes are located in the Alaska Mountain Range at elevations ranging from 778 to 1,124 m, and with the exception of Paxson Lake, within alpine tundra/scrub birch habitat. Paxson Lake is in a mixed spruce forest.

Sevenmile Lake is located adjacent to the Denali Highway at an elevation of 975 m (Figure 1). The estimated surface area of this lake is 33 ha and the maximum recorded depth is 12.5 m. There are no active inlet or outlet streams, so it is closed to immigration and emigration.

The estimated surface area of Glacier Lake is 177 ha, and the maximum depth is 27 m. The lake is located at an elevation of 1,124 m (Figure 1). There are numerous small inlets which drain the hillsides around the lake. A single outlet (Rock Creek) flows from the south end of the lake to Upper Tangle Lake approximately 10 km downstream.

Fielding Lake is located at an elevation of 906 m (Figure 1). It has an estimated surface area of 536 ha and a maximum recorded depth of 23 m. Numerous small inlets drain the hillsides around the lake and a single outlet flows to the south into Phelan Creek.

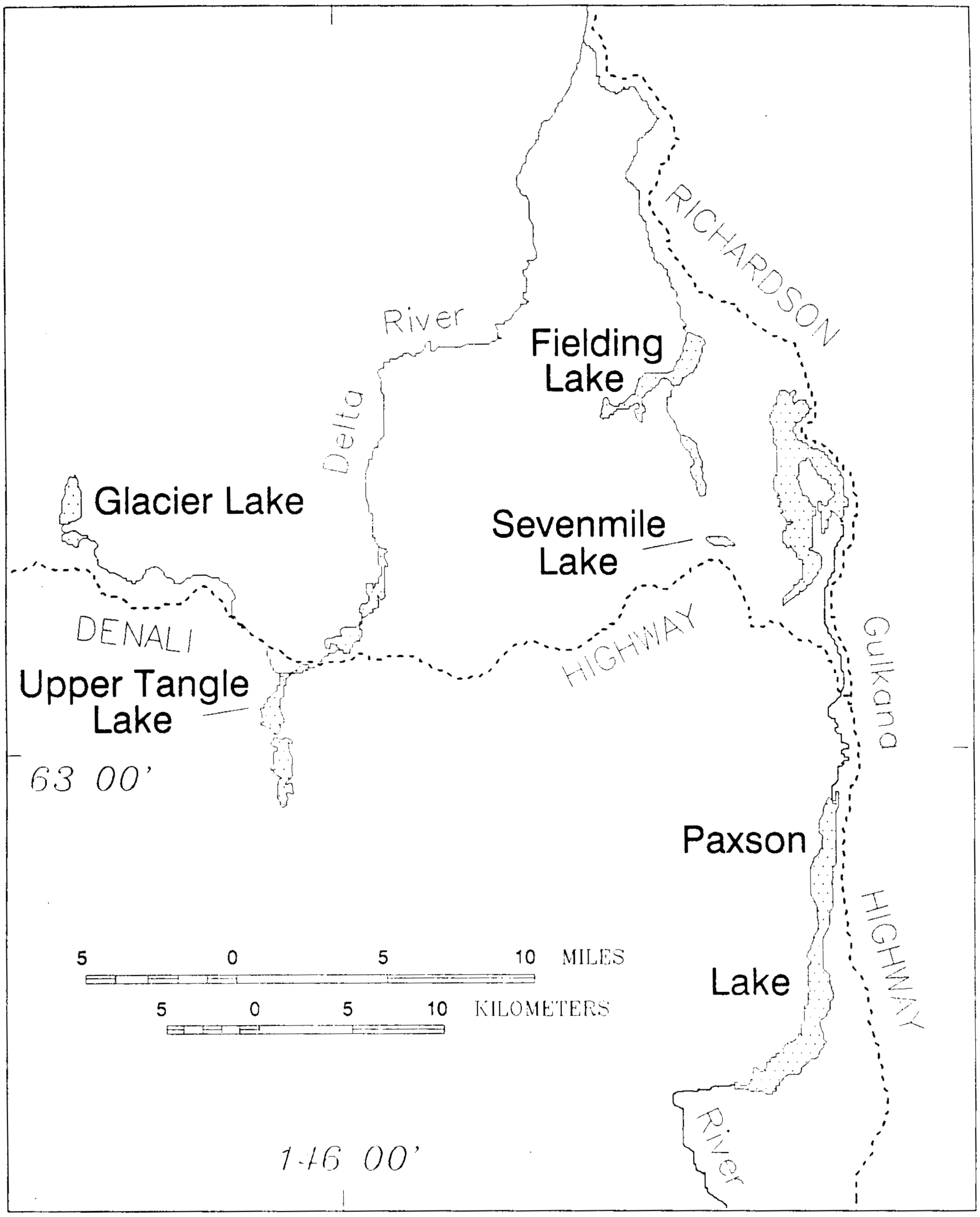

Figure 1. Study area near Paxson, Alaska.

Paxson Lake is located at an elevation of about 778 m within the Gulkana River System (Figure 1). The estimated surface area is 1,575 ha, and the maximum recorded depth is 26 m. There are numerous small inlet streams in addition to the Gulkana River which flows through the lake from north to south.

Abundance Estimates

Mark-recapture experiments were conducted to estimate the population abundance of lake trout larger than 250 mm FL in Sevenmile Lake and Glacier Lake and for spawning lake trout in Paxson Lake. For Glacier Lake and Sevenmile Lake, a modified Petersen mark-recapture estimator was selected (Chapman 1951) with marking events and recapture events performed in separate years (Seber 1982). Marking events were conducted in 1989 and recapture events were performed in 1990. The Petersen estimator was selected because of small sample sizes (less than 1,000) and because it was believed feasible to adjust for growth recruitment in these otherwise closed populations. Since the population of spawning lake trout in Paxson Lake cannot be considered closed, and large numbers of fish were captured and recaptured, the Jolly Seber estimator was selected. This model allows for immigration and mortality and the multi-year design allows for greater mixing of marked and unmarked fish. The estimated abundance of lake trout in each lake is germane to the time of marking. Abundance and the approximate variance of the estimates of abundance of lake trout in Glacier and Sevenmile lakes were evaluated as follows:

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

$$V[\hat{N}] = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \tag{2}$$

where:

M = the number of lake trout marked during the first sampling event (1989);

C = the number of lake trout captured during the second sampling event (1990); and,

R = the number of lake trout captured during the recapture event with marks from the first event.

Conditions for the accurate application of the Petersen mark-recapture estimator to these two lake trout populations include:

1. closed population (no change in the number of lake trout in the populations during the experiment);

2. all lake trout had the same probability of capture in the marking event (1989) or in the recapture event (1990), or marked and

unmarked lake trout mixed completely between marking and recapture events;

3. marking of lake trout did not affect their probability of capture in the recapture event;

4. lake trout did not lose their mark between the marking and recapture events; and,

5. all marked lake trout were reported when recovered in the recapture event.

Efforts were made to meet these requirements. To promote mixing of marked fish with the unmarked population, marked fish were released throughout the lake. Since one year lapsed between sampling events, it is assumed that mixing of marked and unmarked fish occurred. To measure potential tag loss, all fish were given an adipose fin clip as well as a uniquely numbered tag. To minimize differential mortality between marked and unmarked fish, only fish which appeared to be in good condition were released as marked fish. Handling induced "net shyness" should have been minimized by the one year hiatus between sampling events.

Growth recruitment in these lake trout populations was considered likely between the marking and recapture events. The Petersen estimator is valid for multi-year experiments if either mortality or recruitment (but not both) occurs between sampling events (Seber 1982). To evaluate recruitment through growth between the marking recapture events, a nonparametric method of testing for recruitment was used (Robson and Flick 1965). When growth recruitment was found, the length beyond which no significant growth recruitment is detectable (L_r) was determined and separate estimates of abundance for each portion of the population were made. The abundance of fish larger than L_r was calculated with the Petersen estimator. The abundance of fish below L_r was calculated with the model from Robson and Flick (1965):

$$\hat{N} = (m + 1)(\bar{u}_r) - 1 \quad \text{and,} \tag{3}$$

$$V[\hat{N}] = (m + 1)^2 \, V[\bar{u}_r]; \tag{4}$$

where:

$\hat{N}$ = estimated abundance of lake trout smaller than the upper extent of growth recruitment (L_r);

m = number of marked lake trout from the first event that were smaller than the upper extent of growth recruitment (L_r); and,

$\bar{u}_r$ = frequency of unmarked lake trout averaged over the cells formed by the fish recaptured in the second event beyond the upper extent of growth recruitment (L_r).

The variance of $\bar{u}_r$ was calculated using standard normal procedures to estimate the variance of a mean over the u_i where i is from r to M.

The Jolly-Seber model (Seber 1982) was used for estimating the abundance and survival of spawning lake trout in Paxson Lake. This approach was also used for lake trout 250 mm and larger in Sevenmile Lake. The estimated abundance calculated with the Jolly-Seber model was compared with the results from the Petersen estimator and the most precise estimate was accepted. The number of lake trout marked in 1988 and surviving to 1989 was estimated by:

$$\hat{M}_{87,88} = \frac{R_{87,89}M_{88}}{R_{88,89}} + R_{87,88} + D_{87,88} \qquad (5)$$

where:

$\hat{M}_{87,88}$ = number of marked lake trout released alive into the population in 1987 and still alive just prior to sampling in 1988;

M_{88} = number of marked lake trout released alive in 1988;

$R_{87,88}$ = number of marked lake trout released in 1987 and recaptured in 1988;

$R_{87,89}$ = number of marked lake trout released in 1987 and recaptured in 1989;

$R_{88,89}$ = number of marked lake trout released in 1988 and recaptured in 1989; and,

$D_{87,88}$ = number of marked lake trout released in 1987, recaptured during 1988, and not returned to the population (usually due to death).

An estimate of survival rate between 1988 and 1989 was then calculated as:

$$\hat{S}_{87,88} = \frac{\hat{M}_{87,88}}{M_{87}} \qquad (6)$$

Population abundance just prior to sampling in 1989 was estimated as :

$$\hat{N}_{89} = \frac{C_{89}\hat{M}_{88,89}}{R_{88,89}} \tag{7}$$

where:

N_{89} = abundance just prior to sampling in 1989; and,

C_{89} = number of lake trout captured in 1989.

All the conditions for the use of the Jolly-Seber method (Seber 1982) are the same as those for the Petersen mark-recapture procedure except that the population need not be closed (i.e., mortality and recruitment are permitted between sampling events). The Jolly-Seber method requires at least three sampling events and is unbiased only for situations with large overall sample sizes including large numbers of recaptured fish.

Variances for abundance estimates and for survival rates were calculated by bootstrapping capture histories of lake trout marked in 1987 through 1990 400 times according to the procedures of Efron (1982) and Buckland (1980, 1982).

For all mark-recapture experiments, the hypothesis of equal probability of capture during each sampling event for fish of different sizes was tested with the Kolmogorov-Smirnov (K-S) two-sample test (Conover 1980) and contingency table analysis. The data were grouped by length classes for the contingency table analysis. One test compared the frequencies of tagged fish recaptured versus those not recaptured by size group. Frequencies of fish captured during the marking event were compared with fish captured during the recapture event (Seber 1982).

Sevenmile Lake:

In 1987, a mark-recapture experiment was conducted to estimate abundance of lake trout larger than 250 mm FL in Sevenmile Lake (Burr 1988). Starting in 1988, lake trout were sampled annually during late July with the goal of estimating lake trout abundance (Burr 1989, 1990). Between 18 and 27 July, 1990, lake trout were captured with 25 mm (square measure) x 3 m x 46 m sinking gill nets, baited hoop nets, and fyke nets. Gill nets were checked at one half hour intervals. The hoop nets were baited with cut Pacific herring *Clupea harengus* placed in perforated bait containers. These nets were set throughout the lake at various depths ranging from 1 to 12 m. Fyke nets were set near shore at depths of about 1.2 m with center lead nets attached to shore.

Glacier Lake:

In 1986, the abundance of lake trout 250 mm FL and larger in Glacier Lake was estimated with a mark-recapture experiment (Burr 1987b). A second mark-recapture experiment was conducted in 1989 but too few marked fish were recaptured to provide a meaningful estimate (Burr 1990). Between 17 and 26 August 1990 lake trout were again sampled from this population with the goal of estimating abundance from fish marked in 1989 and recaptured in 1990. Lake trout were captured with 25 mm and 38 mm (square measure) x 3 m x 46 m sinking gill nets. Nets were set throughout the lake at various depths ranging from 0.5 m to more than 25 m. To minimize mortality of lake trout, gill nets were checked every half hour.

Paxson Lake:

Beginning in 1987, lake trout on spawning sites have been captured during September at Paxson Lake. In 1987 the fish were captured with gill nets and a beach seine. Since 1988, all lake trout have been captured by beach seine. All seining was conducted after dark and before 04:30.

Population Structure

Age, weight, length, sex, and maturity data were obtained from captured lake trout from the four study lakes. When a lake trout was captured in good condition, it was measured to the nearest mm FL, the adipose fin was removed, and the fish was tagged with an individually numbered Floy anchor tag before being released. When killed, lake trout were weighed and dissected to obtain otoliths for age determination and to obtain information concerning sex and maturity. These data were obtained from lake trout while conducting abundance estimates at Sevenmile, Glacier, and Paxson lakes and from test netting conducted at Fielding Lake.

Age Determination:

All age and growth data presented in this report are based on ages obtained from otoliths. Otoliths were collected from all lake trout dissected during the various field activities. Whole otoliths were prepared by hand grinding surfaces on a carborundum honing stone and were viewed with a compound microscope under reflected light. Sets of opaque and hyaline bands were counted as years of growth with the hyaline bands used as "annuli".

Relative Stock Density:

The proportions (and variances) of the populations corresponding to each size category were estimated as follows (Cochran 1977):

$$\hat{p}_j = \frac{n_j}{n}; \text{ and,} \tag{8}$$

$$\hat{V}[p_j] = \frac{\hat{p}_j(1-\hat{p}_j)}{n - 1}; \qquad (9)$$

where:

n_j = the number of lake trout in the sample from group j;

n = the sample size; and,

p_j = the estimated fraction of the lake trout population that is made up of group j.

Relative Stock Density (RSD) was estimated for lake trout populations from the samples collected. The categories of "stock", "quality", "preferred", "memorable", and "trophy" were determined as outlined by Gabelhouse (1984).

Length at Maturity and Age of Maturity:

The maturity of all dissected lake trout was recorded. Fish of both sexes were classified as mature if the fish would have spawned in the season of capture or if it had spawned in the past. Females containing eggs with diameters greater than 1 mm and ovaries with stretched, fragmented mesovarium were considered mature (Martin and Olver 1980). The presence of retained eggs was also used to identify females which had spawned in prior years. Females with tightly compacted and granular ovaries that contained eggs less than 1 mm in diameter were considered immature. Males with flattened testes with a maximum width 3 mm or more were considered mature. Males with testes which were cylindrical in cross section and less than 3 mm in diameter were considered immature. The percentage of mature fish in 25 mm length categories was calculated. Since more than one length category generally had mature and immature fish, probit analysis was used to estimate the LM_{50} (the length at which 50% of the fish are mature; Finney 1971). The procedure PROBIT from SAS Institute Inc., Cary, NC 27511 was used for this analysis.

The age at maturity, AM_{50}, was estimated using the same procedures as described in the previous paragraph, except that ages rather than lengths were used as variables. The same lake trout were used for both analyses.

To compare densities of mature lake trout from lakes for which estimates have been made, abundance estimates were reduced by the proportion of the fish sampled which were less than the LM_{50} for that population of lake trout. The proportion of mature fish in each sample was estimated with formula (8) and the variance of the proportion with formula (9). Abundance of mature fish (and the corresponding variance) was calculated as follows (Goodman 1960):

$$\hat{N}_m = \hat{p}\,\hat{N}; \text{ and,} \qquad (10)$$

$$V[\hat{N}_m] = \hat{p}^2 V[\hat{N}] + V[\hat{p}] \hat{N}^2 - V[\hat{p}] V[\hat{N}]; \quad (11)$$

where:

$\hat{N}$ = estimate of abundance of lake trout;

$\hat{N}_m$ = estimate of abundance of lake trout of mature size; and,

$\hat{p}$ = estimate of the proportion of mature fish in $\hat{N}$.

Size at Age:

Estimates of mean length at age were calculated with standard normal procedures. Simple averages and squared deviations from the mean were used to calculate means and variances of the means.

Fielding Lake Spawning Sites

Radio telemetry was used to locate fish of mature size during the spawning season with the goal of identifying spawning sites. During the summer, fish larger than 500 mm FL were fitted with 49 MHz radio transmitters manufactured by Advanced Telemetry Systems of Isanti, MN. Between June 19 and June 22 lake trout were captured with 25 mm and 38 mm gill nets and by electrofishing. In July (6-13) lake trout were caught with 25 and 38 mm gill nets. The fish were anesthetized with CO_2 and the transmitters were externally attached with Petersen discs and pins. The pins passed through the musculature just below the dorsal fin. All lake trout which were considered to be in good condition were either radio tagged or were marked with numbered Floy tags and adipose clips. During the spawning season in September, the radio tagged fish were located and these sites were sampled for the presence of spawning fish. Sampling was conducted in areas where radio transmitters were present. Fish were sampled with 38 mm gill nets and where possible with a 25 mm x 3 m x 30 m beach seine.

Age Validation, West Twin Lake

During August 1989, 25,575 young-of-the-year lake trout were stocked into West Twin Lake. These fish came from eggs taken in September of 1988 from Paxson Lake and reared in Clear Hatchery. At the time of stocking, the lake trout were approximately 20 g in weight. West Twin Lake is 680 ha (1,680 acres) in area and contains populations of northern pike *Esox lucius*, burbot *Lota lota*, humpback whitefish *Coregonus clupeaformis*, and least cisco *Coregonus sardinella*.

Annual samples from this known age population of lake trout should provide data to test the hypothesis that ages as determined from otoliths, opercular bones and scales are the true ages. Sampling was first conducted during 1990. Between 7 and 10 August, six variable mesh (19, 25, 38, 50, and 64 mm) gill nets (2.4 x 38 m) were fished for a total of 210 net hours. Hoop nets measuring 2.4 x 0.6 m with 12 mm mesh were fished a total of 552 net hours. Hoop nets were baited with cut Pacific herring. Both gear types were set in depths from 3 to 33 m and in all parts of the lake.

RESULTS

Sevenmile Lake Abundance Estimate

The abundance of lake trout larger than 275 mm FL in Sevenmile Lake at the end of sampling in 1989 was estimated to be 1,665 fish (SE = 210; Table 1). Estimated density was 50.5 lake trout per hectare (20.5 LT/ac). Abundance of mature lake trout in Sevenmile Lake in 1989 was estimated to be 1,054 (SE = 138) and density of mature lake trout per hectare was estimated to be 31.9 fish (12.9 LT/ac; Table 2).

During sampling in 1989, 141 lake trout 250 mm (FL) or larger were marked in Sevenmile Lake. Of these 141 lake trout, 136 were caught in gill nets, three in fyke nets, and two in hoop nets (Appendix A1). During the recapture event in 1990, 271 lake trout 250 mm (FL) and larger were captured; 269 in gill nets, two in hoop nets, and three in fyke nets. Eighteen of the 271 lake trout had been marked in 1989 (Appendix A2). No lake trout smaller than 280 mm FL at time of marking in 1989 were recaptured in 1990 (Table 3). Two hundred forty-two were captured alive, tagged if not previously tagged, and released. Twenty-eight died in the sampling gear. Twelve additional lake trout were captured with missing adipose fins. We were unable to determine if these fish were clipped in 1989 or in a previous year. Hence, they were not counted as recaptures.

Comparison of lengths of fish marked in 1989 with lake trout recaptured in 1990 failed to detect any difference in the distribution of lengths (K-S Two Sample Test; DN = 0.21, P = 0.52; Appendices A1, A2). In addition, comparison of lengths of all fish captured in 1989 with fish captured in 1990 failed to show any difference between the two samples (K-S Two Sample Test; DN = 0.05, P = 0.92;). Hence, no size selectivity in either sampling event was detected.

Since lake trout were marked in 1989 and recaptured in 1990, recruitment through growth is likely. Growth recruitment was indicated by comparison of lengths of fish recaptured from 1989 with fish captured without tags in 1990 (K-S Two Sample Test; DN = 0.31, P = 0.03) and by examination of plots of these data (Figure 2). Although the number of fish recaptured is small (Table 3) the technique of Robson and Flick (1965) indicated that the upper extant of growth recruitment was 402 mm FL. Annual growth information of fish marked and recaptured one year later provides additional information on the upper extant of growth recruitment. Lake trout between 280 and 398 mm FL grew on average 33 mm between 1989 and 1990 (Table 3), while fish 402 mm and larger grew an average of 5 mm during the same period. Pooled annual growth data from 1987 through 1990 indicated average annual growth for lake trout between 200 and 399 mm FL to be 51 mm while fish 400 mm FL and larger grew an average of 7 mm (Table 4). Hence the upper extant of growth recruitment for lake trout in Sevenmile Lake is estimated to be 399 mm FL.

Table 1. Estimated abundance of lake trout larger than 275 mm FL in Sevenmile Lake in 1989.

Length Strata	Number of Lake Trout Marked	Recaptured	Examined	$\bar{u}_r$[a]	Abundance Estimate	SE	Lake Trout per Hectare
275 - 399 mm	65	3	121	12.3	877	133	26.6
> 399 mm	81	15	153		788	163	23.9
Total	146	18	274		1,665	210	50.5

[a] Average number of unmarked to marked lake trout 400 mm FL and larger in 1989.

Table 2. Estimated abundance and density of mature lake trout in Paxson, Glacier, Sevenmile lakes, 1989.

Lake (surface area)	Abundance	SE	Lake Trout Per Hectare	LM_{50}
Paxson (1,575 ha)	5,066	318	3.2	362 mm
Glacier (177 ha)	1,474	324	8.3	375 mm
Sevenmile (33 ha)	1,054	138	31.9	386 mm

Table 3. Length (mm FL) of lake trout sampled from Sevenmile Lake at time of marking in 1989 and at recapture in 1990 with growth increments (mm) between sample periods.

Length at Marking	Length at Recapture	Growth	Length at Marking	Length at Recapture	Growth
Part A:					
nd	440	nd	447	453	6
nd	417	nd	450	460	10
nd	417	nd	455	458	3
nd	386	nd	tag loss	388	nd
280	332	52	tag loss	392	nd
295	348	53	tag loss	394	nd
386	405	19	tag loss	396	nd
391	418	27	tag loss	404	nd
395	402	7	tag loss	413	nd
398	435	37	tag loss	418	nd
402	402	0	tag loss	420	nd
414	416	2	tag loss	420	nd
420	422	2	tag loss	436	nd
422	433	11	tag loss	460	nd
434	440	6	tag loss	460	nd

Length Category[a]	Mean Growth	Length Category[a]	Mean Growth
Part B:		Part C:	
280 to 398	33	300	53
		325	
402 to 455	5	350	
		375	
		400	23
		425	4
		450	7
		475	3

[a] Upper limit of length category

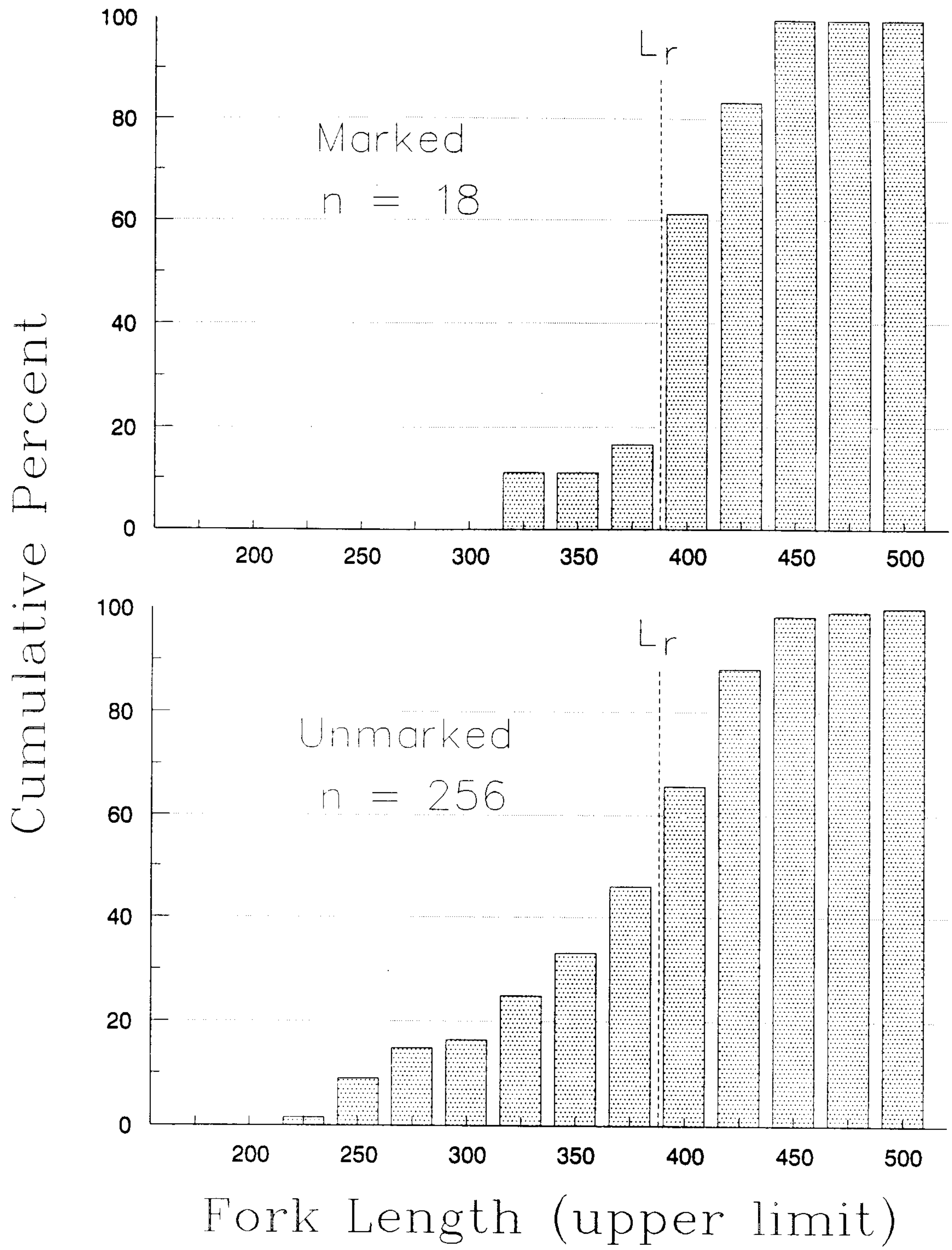

Figure 2. Cumulative distribution of lengths of marked (recaptured) and unmarked lake trout captured during 1989 from Sevenmile Lake. L_r indicates upper extant of growth recruitment.

Table 4. Length (mm FL) of lake trout from Sevenmile Lake at time of marking and at recapture with growth increments (mm) between sample periods, 1987-1990.

Period	Length at Marking	Length at Recapture	Growth	Period	Length at Marking	Length at Recapture	Growth
Part A:							
1987-88	200	274	74	1989-90	398	435	37
1987-88	231	325	94	1988-89	399	401	2
1987-88	234	345	111	1988-89	400	412	12
1987-88	240	340	100	1989-90	402	402	0
1987-88	244	332	88	1988-89	410	434	24
1987-88	245	349	104	1988-89	412	420	8
1987-88	246	353	107	1989-90	414	416	2
1987-88	247	351	104	1988-89	416	430	14
1987-88	253	355	102	1987-88	418	420	2
1989-90	280	332	52	1988-89	418	426	8
1989-90	295	348	53	1987-88	418	426	8
1987-88	317	371	54	1987-88	418	429	11
1987-88	320	394	74	1987-88	420	421	1
1988-89	347	382	35	1989-90	420	422	2
1987-88	347	391	44	1989-90	422	433	11
1988-89	352	390	38	1988-89	431	436	5
1988-89	357	386	29	1988-89	433	441	8
1988-89	361	391	30	1988-89	434	443	9
1988-89	361	395	34	1989-90	434	440	6
1989-90	386	405	19	1987-88	435	440	5
1987-88	390	416	26	1989-90	447	453	6
1989-90	391	418	27	1989-90	450	460	10
1987-88	392	409	17	1988-89	451	453	2
1987-88	395	395	0	1988-89	454	466	12
1989-90	395	402	7	1989-90	455	458	3
1987-88	395	405	10	1987-88	462	463	1
1987-88	397	415	18	1988-89	463	478	15

Length Category [a]	Mean Growth	Length Category [a]	Mean Growth
Part B:		Part C:	
200 to 399	51	200	74
		225	
400 to 478	7	250	101
		275	102
		300	53
		325	64
		350	40
		375	33
		400	16
		425	8
		450	7
		475	7
		500	

[a] Upper limit of length category

Since no size selectivity of the sampling gear was detected, the data were divided into two strata, fish 275 mm to 399 mm and fish larger than 399 mm. With the assumption that recruitment through growth for lake trout 400 mm and larger is negligible, an unbiased estimate of abundance for fish larger than 399 mm was obtained with the modified Petersen estimator (Table 1). The abundance of lake trout 275 to 399 mm was made after growth recruitment was removed. The abundance of fish in the smaller size category was estimated with procedures of Robson and Flick (1965).

Since lake trout have been marked annually in Sevenmile Lake, the Jolly-Seber model was used with the goal of estimating recruitment and mortality for this population. However, the model failed to provide realistic estimates of these parameters; survival was estimated at 100% and recruitment at zero (Appendix A3). The estimate of population abundance provided by the model for 1989 was 1,837 (SE = 307) and is similar to the abundance estimated described above. Since the Petersen estimate is more precise and is likely less biased than the Jolly-Seber model for situations with small sample sizes and low numbers of recaptures, the Petersen estimate is preferred and is believed by the author to best represent abundance of lake trout of mature size.

Glacier Lake Abundance Estimate

Abundance of lake trout larger than 250 mm FL in Glacier Lake at the end of sampling in 1989 is estimated to have been 3,142 fish (SE = 669; Table 5). Density is estimated to have been 17.8 lake trout per hectare (7.2 LT/ac). The estimate of the abundance of lake trout of mature size (LM_{50} and larger) in Glacier Lake in 1989 was 1,474 fish (SE = 324). Density of mature lake trout is estimated to have been 8.3 fish per hectare (3.4 LT/ac; Table 2).

During sampling in 1989, 333 lake trout 250 mm (FL) or larger were marked in Glacier Lake (Appendix A4). During the recapture event in 1990, 373 lake trout 250 mm (FL) or larger were captured, sixteen of which had been marked in 1989. No lake trout smaller than 265 mm FL at time of marking in 1989 were recaptured in 1990 (Table 6). Two hundred sixty-five lake trout were captured alive, tagged if not previously tagged, and released. One hundred eight died in the sampling gear. In addition to the 16 fish recaptured from 1989, three lake trout were captured with missing adipose fins indicating tag loss. We were unable to determine if these fish were marked in 1989 or in a previous year. Hence, they were not counted as recaptures. One of the tagged lake trout captured during 1990 was marked in Upper Tangle Lake during 1988. This is the only known inter-lake movement of lake trout in this area. Such movement is assumed to be minimal. This fish was not considered in the abundance estimate.

Comparison of lengths of fish marked in 1989 with lake trout recaptured in 1990 failed to detect any difference in the distribution of lengths (K-S Two Sample Test; DN = 0.24, P = 0.27; Appendix A4). However, comparison of lengths of all fish captured in 1989 with fish captured in 1990 did detect a difference (K-S Two Sample Test; DN = 0.13, P = 0.001). Hence, no size selectivity was detected in the 1990 sample, but selectivity was detected in the sample from 1989.

Table 5. Estimated abundance of lake trout larger than 250 mm FL in Glacier Lake in 1989.

Length Strata	Number of Lake Trout Marked	Recaptured	Examined	$\bar{u}_r$[a]	Abundance Estimate	SE	Lake Trout per Hectare
250 - 411 mm	204	5	267	8.6	1,975	44	11.2
> 411 mm	130	11	106		1,167	291	6.6
Total	334	16	373		3,142	669	17.8

[a] Average number of unmarked to marked lake trout 412 mm FL and larger in 1989

Table 6. Length (mm FL) of lake trout from Glacier Lake at time of marking in 1989 and at recapture in 1990 with growth increments (mm) between sample periods.

Length at Marking	Length at Recapture	Growth	Length at Marking	Length at Recapture	Growth
Part A:					
nd	311	nd	407	411	4
nd	415	nd	407	418	11
nd	421	nd	422	429	7
nd	428	nd	451	456	5
nd	465	nd	469	470	1
nd	470	nd	475	495	20
265	275	10	tag loss	414	nd
328	351	23	tag loss	421	nd
333	378	45	tag loss	430	nd
404	434	30			

Length Category[a]	Mean Growth	Length Category[a]	Mean Growth
Part B:		Part C:	
265 to 404	27	275	10
		300	
407 to 475	8	325	
		350	34
		375	
		400	30
		425	7
		450	5
		475	11
		500	

[a] Upper limit of length category

Inspection of plots of length frequencies of lake trout recaptured in 1990 and fish captured without marks in 1990 indicate that growth recruitment occurred between 1989 and 1990 (Figure 3). Comparison of the distribution of these lengths indicated a significant difference (K-S Two Sample Test; DN = 0.48, $P < 0.01$). Although sample size is small, the technique of Robson and Flick (1965) indicated that the upper extant of growth recruitment was 411 mm FL. Growth of fish marked in 1989 and recaptured in 1990 provide additional information. Lake trout between 265 mm and 404 mm FL grew on average 27 mm (10 mm minimum); while fish 407 mm and larger grew an average of 8 mm (20 mm maximum; Table 6). Hence, the upper extant of growth recruitment for lake trout in Glacier Lake is likely between 404 mm and 412 mm. Because of the small sample size and because of variability in annual growth for fish in this population, 411 mm FL was selected as the upper extant of growth recruitment (L_r).

Since no size selectivity of the sampling gear was detected in the sample from 1990, the data were divided into two strata: fish 250 mm to 411 mm; and fish larger than 411 mm. With the assumption that recruitment through growth for lake trout 412 mm and larger is negligible, an unbiased estimate of abundance for fish larger than 411 mm was obtained. The abundance of lake trout 250 to 411 mm was made with procedures recommended by Robson and Flick (1965).

Paxson Lake Abundance Estimate

Estimated abundance of spawning lake trout in Paxson Lake in 1989 was 5,066 fish (SE = 318; Table 7). Estimated density of spawning lake trout was 3.2 fish per hectare (1.3 per acre; Table 2).

Lake trout have been sampled annually in Paxson Lake during September since 1987. In 1987, 351 lake trout were caught of which 267 were marked and released. In 1988, 1,025 lake trout were caught and 964 were tagged and released. In 1989, 982 lake trout were caught and 949 were released with tags. In 1990, 834 lake trout were caught and 752 were released with tags. All lake trout were in spawning condition. The proportion of lake trout captured with tags (recaptured) has steadily increased; 4% in 1988, 29% in 1989, and 53% in 1990 (Table 7). Females have comprised a minor portion of those recaptured: 1% in 1988, 9% in 1989, and 14% in 1990 (Table 8).

The distribution of lengths of fish caught in 1989 and 1990 were compared and no significant difference was detected (K-S two-sample test $D = 0.06$, $P = 0.09$). Length distributions of fish by sex which were caught in 1989 and in 1990 were also compared and no significant differences were detected (K-S two-sample test: males $D = 0.05$, $P = 0.29$; females $D = 0.11$, $P = 0.30$). Growth of individual fish was evident but the Jolly-Seber model allows for recruitment, and no adjustment was necessary.

A large number of individual male lake trout and a lesser number of individual female lake trout were captured in consecutive years (Table 9). Five hundred fifty-three males were captured in more than one year, 389 (70%) were caught in consecutive years, 70 (13%) in three consecutive years and three (0.5%) in all four years. One hundred fifty-six (28%) males were caught after skipping

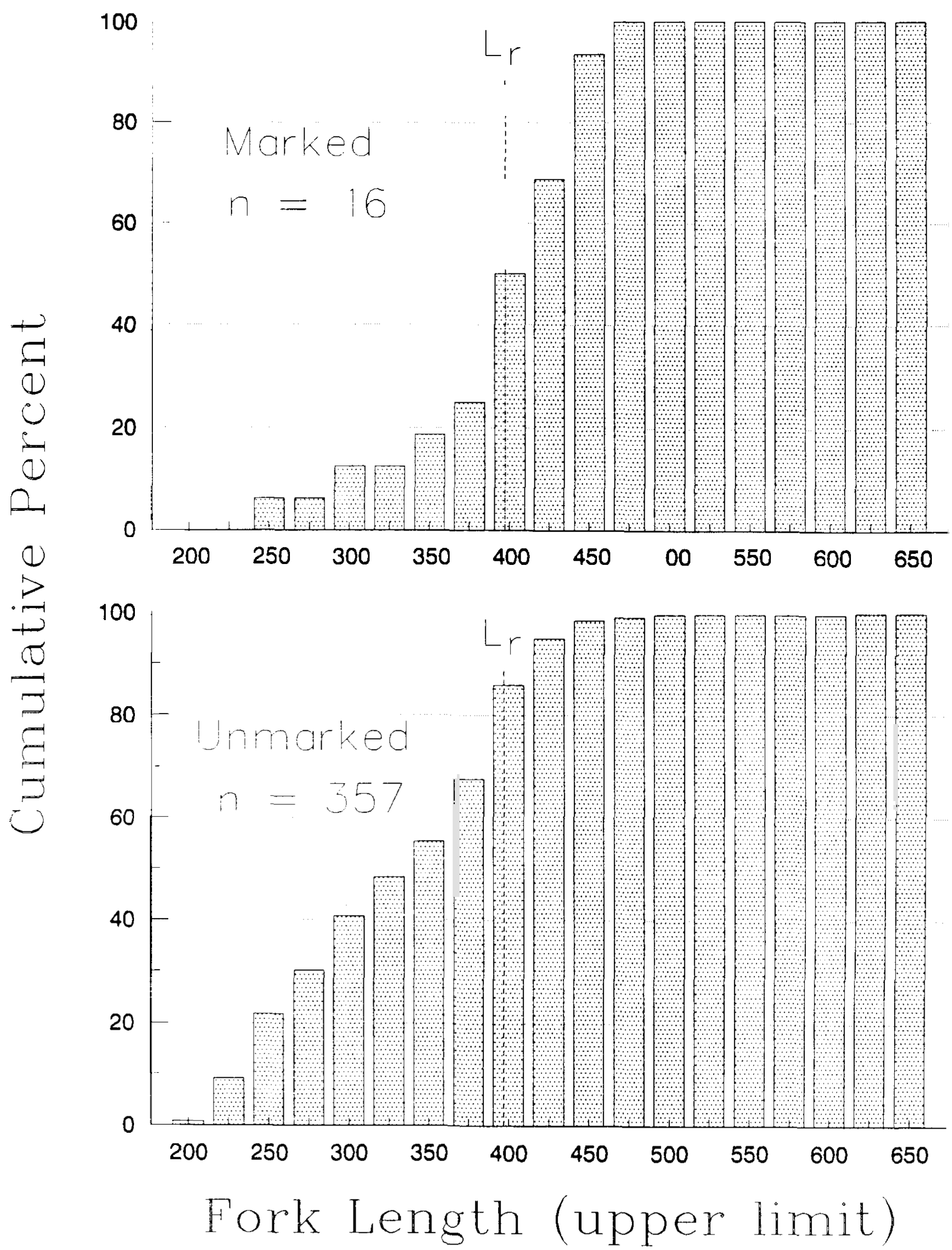

Figure 3. Cumulative distribution of lengths of marked (recaptured) and unmarked lake trout captured during 1989 in Glacier Lake. L_r indicates upper extant of growth recruitment.

Table 7. Spawning lake trout (both sexes) captured, marked and recaptured in Paxson Lake with estimates of abundance and survival, 1987-1990.

Category	Number of Lake Trout 1987	1988	1989	1990
Originally marked in 1987	0	40	50	28
Originally marked in 1988	0	0	231	199
Originally marked in 1989	0	0	0	217
Captured with tags	0	40	281	444
Captured without tags	351	985	701	390
Total captured	351	1,025	982	834
Released with tags	267	964	949	752
Released without tags	1	0	0	0
Total released	268	964	949	752
Abundance estimate		4,105[a]	3,324[a]	
SE of abundance estimate		409	303	
Lake trout per hectare		2.6	2.1	
Survival estimate	0.61[a]	0.82[a]		
SE of survival estimate	0.07	0.06		
Adjusted estimates				
Abundance estimate		6,308	5,066	
SE of abundance estimate		458	318	
Lake trout per hectare		4.0	3.2	
Survival rate estimate			0.81	
SE of survival rate estimate			0.06	

[a] Biased estimate, see text.

Table 8. Male and female lake trout captured, marked and recaptured in Paxson Lake with estimates of abundance and survival, 1987-1990.

Sex		Number of Lake Trout			
		1987	1988	1989	1990
Males	Originally marked in 1987	0	39	48	27
	Originally marked in 1988	0	0	214	184
	Originally marked in 1989	0	0	0	212
	Captured with tags	0	39	262	423
	Captured without tags	259	803	588	274
	Total captured	259	842	850	697
	Released with tags	215	813	821	657
	Released without tags	0	0	0	0
	Total released	215	813	821	657
	Abundance estimate		3,154	2,533	
	SE of abundance estimate		324	225	
	Lake trout per hectare		2	1.6	
	Survival estimate	0.68	0.81		
	SE of survival estimate	0.07	0.06		
Females	Originally marked in 1987	0	1	2	1
	Originally marked in 1988	0	0	10	15
	Originally marked in 1989	0	0	0	4
	Captured with tags	0	1	12	20
	Captured without tags	83	181	116	119
	Total captured	83	182	128	139
	Released with tags	43	150	124	97
	Released without tags	0	0	0	0
	Total released	43	150	124	97
	Abundance Estimate		2,792[a]	2,760[a]	
	SE abundance estimate		1,732	1,503	
	Lake trout per hectare		1.8	1.8	
	Survival rate estimate	0.55[a]	1.00[a]		
	SE of survival rate estimate	0.29	0.02		

[a] biased estimate, see text

Table 9. Number of spawning lake trout sampled in Paxson Lake from 1987 through 1990 that were captured in two or more years.

Sex	Number of Years	Consecutive	Skip
Female Lake Trout	1	--	18
	2	14	1
	3	1	--
	4	--	--
Sub Total	one or more	15	19
Male Lake Trout	1	--	156
	2	316	8
	3	70	--
	4	3	--
Sub Total	one or more	389	164
Both Sexes	1	--	172
	2	337	9
	3	71	--
	4	3	--
Total	one or more	411	181

one year and eight (1%) skipped two years. Male lake trout probably spawn annually in Paxson Lake since 70% of the males which were recaptured on the spawning grounds were caught in consecutive years. The frequency of spawning for females is less clear. Thirty-four individual female lake trout were caught in more than one year, 15 (44%) were captured in consecutive years, 18 (53%) skipped one year and one (3%) skipped two years. The number of females captured during each sampling event is much lower than males: 3.1 males/female in 1987, 4.6 males/female in 1988, 6.6 males/female in 1989, and 4.9 males/female in 1990 (Table 8). This is believed to be a result of the fish's behavior and not a reflection of the population sex ratio which is likely to be balanced (Martin and Olver 1980). It is difficult to argue for annual spawning for females in Paxson Lake with the low sample size and with less than 50% of females being captured consecutively.

The Jolly-Seber model does not provide a reliable estimate of the abundance of female lake trout in Paxson Lake from these samples. The number of females and males are disproportionate and lake trout of both sexes are apparently not equally catchable on the spawning sites. The result is that every fish does not have the same probability of capture and an assumption of the model is violated. The estimate of abundance from the pooled samples of males and females is therefore biased. To obtain an estimate of abundance for both sexes the estimate of abundance for males was doubled. This estimate is believed to be less biased since lake trout stocks are likely to have balanced sex ratios and because there is no evidence of differential mortality between sexes (Martin and Olver 1989).

Estimates of survival from the Jolly-Seber model for lake trout in Paxson Lake were meaningful only for males (Table 8). The estimated survival rate for males between 1987 and 1988 is 0.82 (SE = 0.06). Because no evidence of differential mortality between sexes is reported for other lake trout populations (Martin and Olver 1989), the estimate for males was used for lake trout of both sexes. The instantaneous rate of total mortality ($Z = \ln S$) is calculated to be 0.21.

<u>Population Structure</u>

Proportions of lake trout in various size categories and mean size-at-age were estimated for various populations. Maturity estimates were limited to lake trout residing in Sevenmile, Fielding, and Glacier lakes. Estimates of length and age at maturity for lake trout from Paxson Lake are included in the report for reference purposes and are taken from Burr 1990.

Relative Stock Density:

Length data were obtained from lake trout from all four study lakes during 1990. Size selectivity of the sampling gear was not detected in the samples from Sevenmile or Paxson lakes so the Relative Stock Densities were estimated from pooled samples of fish collected in 1989 and 1990. The data from Paxson Lake are for the spawning portion of the population. As a result, the number of fish in the smallest size category (stock, 240 - 453 mm) is biased low. The RSD for lake trout in Glacier Lake was estimated from the 1990 sample only. Comparison of lengths of fish marked in 1989 and recaptured in 1990 failed to detect size selectivity in the 1990 sample (K-S two sample test; DN = 0.24, P = 0.53). Comparison of the distribution of lengths of lake trout captured in 1989 with those captured in 1990 showed that they were not the same (K-S two sample test; DN = 0.42, $P < 0.01$), indicating that the Glacier Lake sample from 1989 was biased. It was not possible to determine if the lake trout sample from Fielding Lake was size selective without a completed mark-recapture experiment. Consequently, the RSD data calculated for this population may or may not be biased.

Only one lake trout captured from the four lakes sampled in 1990 was of trophy size (> 895 mm FL; Table 10, Figure 4). This fish was captured from Paxson Lake. A small portion of the lake trout sampled from Paxson Lake (0.7%) and Fielding Lake (6.9%) were of memorable size (715-894 mm FL). Twenty-one percent of the lake trout caught in Paxson Lake and 14% of lake trout caught in Fielding Lake were of preferred size (546-714 mm FL). Few lake trout sampled from Glacier Lake (0.3%) and none from Sevenmile Lake were in the preferred category. The highest proportion of lake trout of quality size (454-545 mm FL) were found in Paxson (60.3%) and Fielding (41.4%) lakes; lake trout of quality size were less common in Sevenmile, and Glacier lakes. Most of the lake trout sampled from these two lakes (91 to 94%) were of stock size (240-453 mm FL) or smaller.

Maturity:

Estimates of the length at which 50% of the lake trout were mature (LM_{50}) ranged from 362 mm FL for lake trout from Paxson Lake to 448 mm FL for fish from Fielding Lake (Table 11; Figure 5a). Lake trout mature at similar size in Sevenmile Lake (LM_{50} = 386 mm), Glacier Lake (LM_{50} = 375 mm), and Paxson Lake (LM_{50} = 362 mm). The limited sample from Fielding Lake indicates that 50% of lake trout mature at a larger size than other lake trout populations studied in Alaska. In most lakes, males matured at a smaller size than did females. However, females were statistically different from males only in Paxson and Fielding lakes as shown by overlaps in fiducial limits (Table 11).

The age at which 50% of the lake trout were mature (AM_{50}) in the sample from Paxson Lake is 5.4 years (males = 4.8, females = 6.2; Table 12, Figure 5b). The AM_{50} for lake trout in Fielding Lake was 6.9 years (males = 6.2, females = 7.7). For Glacier Lake the AM_{50} was 9.2 years (males = 9.3, females = 9.2). Because probit analysis requires two or more data pairs with percentages other than 0 or 100 (all fish age 4 and younger were immature, and all fish age 6 and older were mature) it was not possible to estimate fiducial limits for the AM_{50} for lake trout from Sevenmile Lake. However, the estimated AM_{50} for both sexes was 4.9 years (males = 4.5, females = 5.0) for lake trout of Sevenmile Lake.

Size at Age:

Estimates of mean length at age were calculated for lake trout sampled from Paxson, Fielding, Glacier, and Sevenmile lakes (Tables 13-16). Lake trout from Paxson Lake grew fastest and attained the largest size. Growth of lake trout from Fielding Lake was similar to growth demonstrated by younger fish from Paxson Lake, but no fish older than age 13 were sampled. Lengths at age

Table 10. Relative Stock Density of lake trout in Glacier, Sevenmile, Fielding, and Paxson lakes, 1989.

Lake	Statistic[a]	Stock (240 mm)	Quality (454 mm)	Preferred (546 mm)	Memorable (715 mm)	Trophy (895 mm)
	$\hat{N}$	3,054	185	9	0	0
Glacier	%	94.0	5.7	0.3	0	0
	SE	648	55	9	0	0
	$\hat{N}$	1,514	152	0	0	0
7-Mile	%	90.9	9.1	0	0	0
	SE	192	30	0	0	0
	$\hat{N}$	591	2,003	704	24	2
Paxson	%	17.8	60.3	21.2	0.7	0.1
	SE	61	186	71	6	1
	n	44	48	16	8	0
Fielding	%	37.9	41.4	13.8	6.9	0
	SE(%)	4	4	3	2	0

[a] N = abundance estimate, SE = standard error of estimate; n = sample size

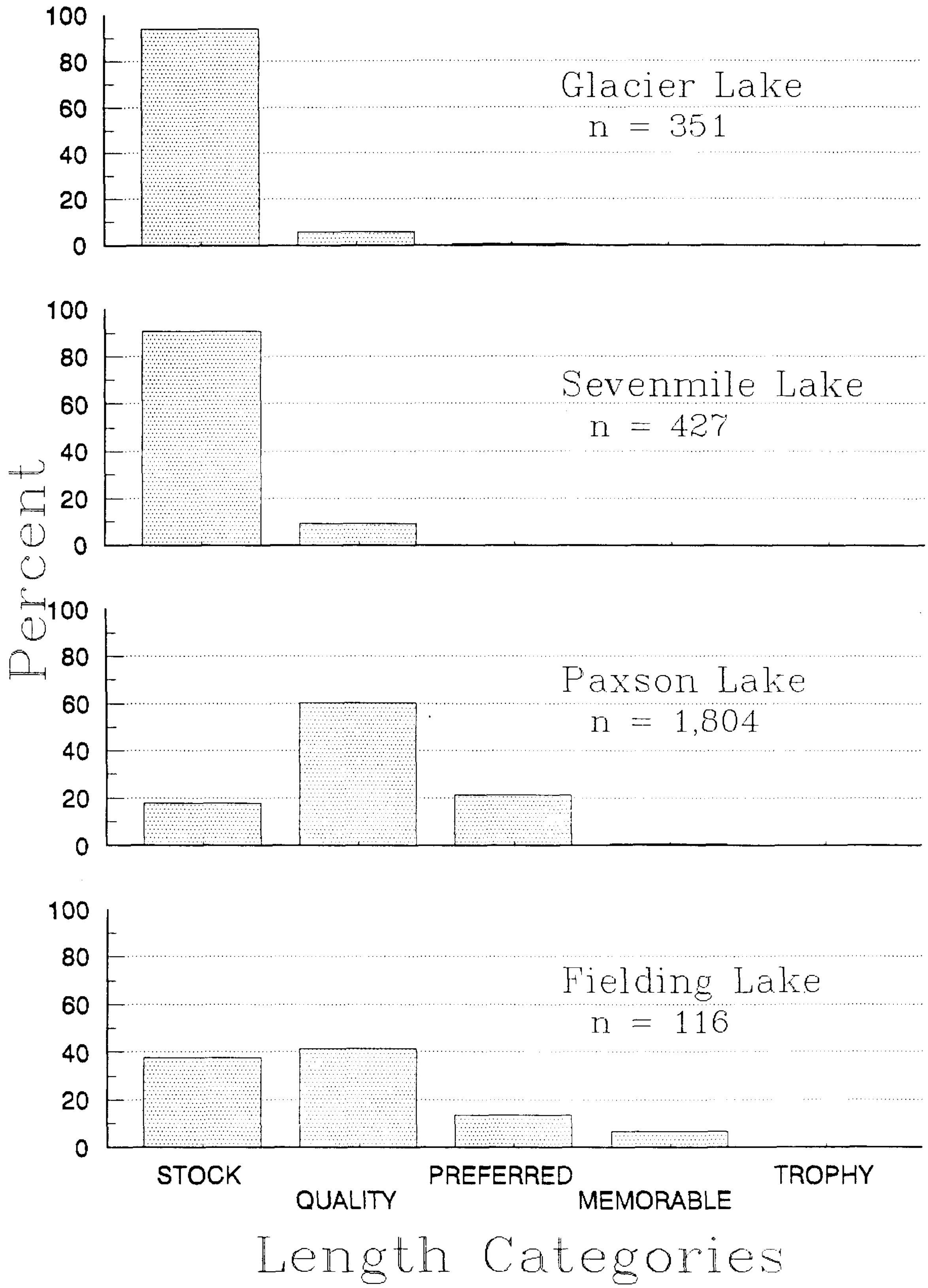

Figure 4. Relative Stock Density of lake trout sampled in Paxson, Sevenmile, Glacier and Fielding lakes, 1989.

Table 11. Estimated lengths (mm FL) at which 50% (LM_{50}), 1% (LM_1) and 99% (LM_{99}) of lake trout are mature for four populations in Alaska.

Lake (Sex)	Sample Size	LM_{50}	95% Fiducial Limits Lower	95% Fiducial Limits Upper	LM_1	95% Fiducial Limits Lower	95% Fiducial Limits Upper	LM_{99}	95% Fiducial Limits Lower	95% Fiducial Limits Upper
PAXSON										
(Both)	1,620	362	341	376	289	250	314	454	443	471
(Females)	382	426	410	436	373	336	393	486	471	516
(Males)	1,234	351	310	370	286	218	320	429	418	451
SEVENMILE										
(Both)	139	386	377	397	346	321	358	431	413	472
(Females)	49	391	377	413	353	312	368	432	410	516
(Males)	43	367	343	389	327	235	348	411	388	562
FIELDING										
(Both)	108	448	428	464	368	311	396	547	517	619
(Females)	34	481	451	524	408	260	440	567	522	935
(Males)	71	428	384	449	354	241	391	519	486	648
GLACIER										
(Both)	483	375	370	381	312	300	322	451	440	466
(Females)	235	377	368	384	310	291	323	457	441	483
(Males)	221	377	369	384	322	303	334	440	428	462

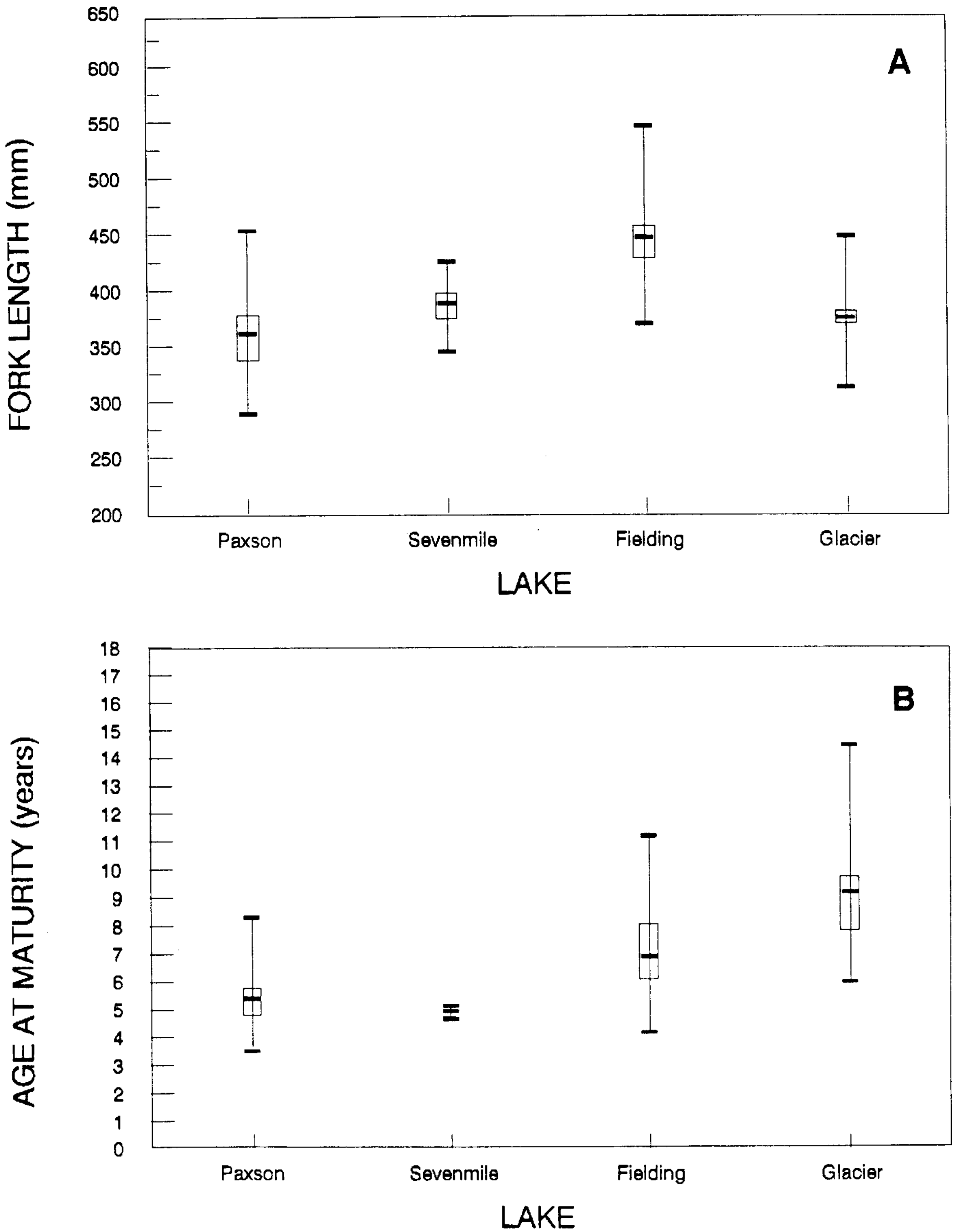

Figure 5. Length at maturity (A) and age at maturity (B) of lake trout from four populations in Alaska. Lengths (LM_{50}) ang ages (AM_{50}) at 50% maturity are shown as solid bars inside rectangles which show 95% fiducial limits around the estimates. Lower ends of the vertical lines show length and age at 1% maturity and upper ends length and age at 99% maturity.

Table 12. Estimated ages at which 50% (AM_{50}), 1% (AM_1) and 99% (AM_{99}) of lake trout are mature for four populations in Alaska.

Lake (Sex)	Sample Size	AM_{50}	95% Fiducial Limits Lower	95% Fiducial Limits Upper	AM_1	95% Fiducial Limits Lower	95% Fiducial Limits Upper	AM_{99}	95% Fiducial Limits Lower	95% Fiducial Limits Upper
PAXSON										
(Both)	223	5.4	4.9	5.7	3.5	2.6	4.0	8.3	7.5	10.2
(Females)	114	6.2	5.6	6.6	4.4	3.0	5.0	8.7	7.7	11.9
(Males)	102	4.8	3.9	5.3	3.1	1.3	3.9	7.5	6.5	12.6
SEVENMILE										
(Both)	110	4.9	-	-	4.6	-	-	5.2	-	-
(Females)	48	5.0	-	-	4.7	-	-	5.3	-	-
(Males)	42	4.5	-	-	4.3	-	-	4.6	-	-
FIELDING										
(Both)	50	6.9	6.1	8.0	3.9	2.0	4.9	11.2	9.5	24.6
(Females)	22	7.7	6.6	13.4	5.4	0.6	6.4	11.0	8.9	234.7
(Males)	25	6.2	4.6	7.6	3.4	0.4	4.6	11.1	8.5	70.5
GLACIER										
(Both)	402	9.2	8.8	9.7	5.9	5.2	6.4	14.5	13.2	16.5
(Females)	203	9.2	8.7	9.7	6.0	5.2	6.6	14.0	12.7	16.4
(Males)	181	9.3	8.5	10.1	6.2	4.7	7.0	14.0	12.3	18.5

Table 13. Estimated length (mm FL) at age (from otoliths) of lake trout from Paxson Lake, data combined from 1987 through 1990.

	Female Lake Trout			Male Lake Trout			All Lake Trout[a]		
Age	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE
0		0			0			0	
1		0			0			0	
2		0			0			0	
3		0			0			0	
4	390	1		364	2	14	377	4	9
5	397	8	9	420	19	6	411	33	5
6	444	18	11	439	19	5	445	44	5
7	485	12	11	455	31	6	465	44	6
8	517	27	7	478	23	8	498	53	6
9	526	15	9	487	21	8	504	37	6
10	535	6	21	494	9	16	506	16	13
11	553	9	16	524	8	11	540	18	10
12	571	5	16	475	5	13	523	10	19
13	541	4	8	632	7	50	599	11	34
14	584	8	27	543	2	15	575	10	22
15	566	14	8	556	9	5	564	24	5
16	609	8	17	573	4	12	597	12	12
17	571	7	10	577	6	8	574	13	6
18	577	2	3	563	5	12	569	8	8
19	632	5	55	579	4	15	607	11	25
20	621	3	6		0		621	3	6
21	583	1		563	6	13	564	8	10
22	579	3	12	589	2	17	583	5	9
23	655	5	59	553	1		638	6	51
24	681	6	58	625	1		673	7	50
25		0		548	1		548	1	
26	610	1		532	1		602	3	39
27	637	1		571	1		604	2	33
28	652	1		596	2	50	614	3	34
29	573	3	3		0		579	4	6
30		0			0			0	
31		0			0			0	
32		0			0			0	
33	610	1			0		610	1	
34		0			0			0	
All	540	174	6	494	189	5	514	391	4

[a] Includes fish of unknown sex.

Table 14. Estimated length (mm FL) at age (from otoliths) of lake trout from Fielding Lake, data combined from 1987 through 1990.

Age	Female Lake Trout			Male Lake Trout			All Lake Trout		
	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE
0		0			0			0	
1		0			0			0	
2		0			0			0	
3	284	3	1	280	1		283	7	4
4	327	4	23	305	3	3	317	10	9
5	378	2	23	437	2	34	372	9	17
6	420	7	18	421	9	10	412	25	8
7	463	4	12	410	1		439	15	9
8	492	3	55	495	6	17	482	15	14
9	547	1			0		537	3	28
10	519	2	10	486	2	4	502	4	10
11		0		458	1		553	2	95
12		0		660	1		660	1	
13	705	1			0		700	2	6
14		0			0			0	
All	425	27	20	436	26	16	423	93	10

Table 15. Estimated length (mm FL) at age (from otoliths) of lake trout from Glacier Lake, data combined from 1986 through 1990.

Age	Female Lake Trout			Male Lake Trout			All Lake Trout		
	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE
0		0			0			0	
1		0			0		127	3	2
2		0			0		160	2	3
3		0			0		203	2	2
4	255	5	13	273	5	12	265	12	8
5	286	18	6	269	10	7	275	35	4
6	292	24	6	296	23	7	293	48	4
7	325	28	5	322	19	4	324	47	3
8	347	20	5	351	26	5	349	46	4
9	361	16	6	364	16	7	362	33	5
10	403	7	8	393	12	8	397	19	6
11	409	14	6	397	13	5	403	27	4
12	413	10	4	404	9	5	410	20	3
13	449	13	17	432	13	16	440	26	11
14	407	13	9	425	5	10	414	19	7
15	430	8	6	424	5	9	428	13	5
16	435	5	9	439	2	9	436	7	7
17	435	4	6	414	3	10	426	7	7
18	461	5	34	428	2	18	452	7	25
19	423	2	10	426	4	8	425	7	5
20	415	3	4	410	1		414	4	3
21	447	1		424	1		436	2	12
22	423	1		422	3	4	423	4	3
23	443	1		416	4	4	421	5	6
24	436	1			0		436	1	
25		0			0			0	
26	432	2	5	421	2	1	427	4	4
27	441	1			0		441	1	
28	430	1			0		430	1	
29		0		435	1		435	1	
30		0			0			0	
31		0		435	1		435	1	
32	441	1			0		441	1	
33		0		418	1		418	1	
34		0			0			0	
All	366	204	5	364	181	4	359	406	3

Table 16. Estimated length (mm FL) at age (from otoliths) of lake trout from Sevenmile Lake, data combined from 1987 through 1990.

	Female Lake Trout			Male Lake Trout			All Lake Trout		
Age	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE
0		0			0			0	
1		0			0		93	12	4
2	173	2	3	218	2	37	188	8	10
3	296	9	10	296	7	8	296	16	6
4	335	18	8	341	17	5	338	35	5
5	371	6	15	390	7	7	382	14	7
6	403	3	4		0		403	3	4
7	430	3	4	411	3	13	421	6	8
8	425	2	5	416	3	13	419	5	8
9	450	3	7	364	1		429	4	22
10	425	2	8	418	1		422	3	5
11		0		418	2	5	418	2	5
12		0		412	1		412	1	
13	429	1			0		429	1	
14	462	2	10	445	1		456	3	8
15	430	1			0		430	1	
16		0			0			0	
ALL	358	52	10	355	45	8	325	116	10

for lake trout from Sevenmile Lake indicate growth rates similar to rates for lake trout from Fielding Lake up to age 6, but slower for older fish. Estimates of length at age for fish from Glacier lake indicate slower growth than fish from Paxson, Fielding, or Sevenmile lakes.

Fielding Lake Spawning Sites

During June, all gill netted lake trout were caught at depths of 4 to 15 m. Lake trout captured by electrofishing were netted in water less than 4 m near shore. During June, 32 lake trout were captured and six were fitted with radio transmitters. In July, an additional 46 lake trout were captured and four were fitted with radio transmitters. During July, all lake trout were caught at depths greater than 12 m. All lake trout that had been radio tagged in June had moved into deep water (> 15 m) areas in the large southern basin of the lake by July.

In September, radio-tagged fish were located in shallow water. Three of the 10 transmitters were located in the northern end of the lake (Figure 6). One radio tagged fish was found dead and washed up on the northern shore. No movement was detected between September 6 and 19 for the other two transmitters found in this portion of the lake and these fish are presumed to have died. One other tagged fish showed no movement during September and it was also presumed to be dead. This transmitter was located in the middle portion of the lake at a depth of 9 m. It is unlikely that the radio transmitters were shed due to the method of attachment. The other six transmitters were found in two general areas and daily movement of these signals indicated that the fish were alive and moving. Four of these six fish were regularly located at various points along the southern shore of the large northern basin in 1 to 10 m of water (Site A, Figure 6). One of the radio tagged fish was found either in the western most portion of this area (Site A) or in another area farther south along the eastern shore (Site B). The last of these 6 fish was always located in the second area (Site B).

Night-time visual surveys using lights to illuminate the two potential spawning areas (sites A and B) found large fish (>500 mm FL) in groups of four to 20 along the shore at site A but failed to locate fish at site B. The water clarity was poor; hence it was difficult to see to a depth greater than 1.5 m. Both of these sites are located adjacent to deep water and are characterized by variable sized substrate ranging from gravel to large boulders.

Attempts at capturing these fish with a beach seine were frustrated by the large rocks and steep gradient of the bottom slope. On September 17-19, 32 lake trout were caught along the shore at site A with gill nets. These fish were all in spawning condition and ranged in size from 430 to 855 mm FL. Seven of these 32 fish were females. Sampling at site B with gill nets failed to catch large lake trout. The single lake trout that was caught at site B was of mature size (512 mm) but was not in spawning condition. None of the fish fitted with radio transmitters were recaptured.

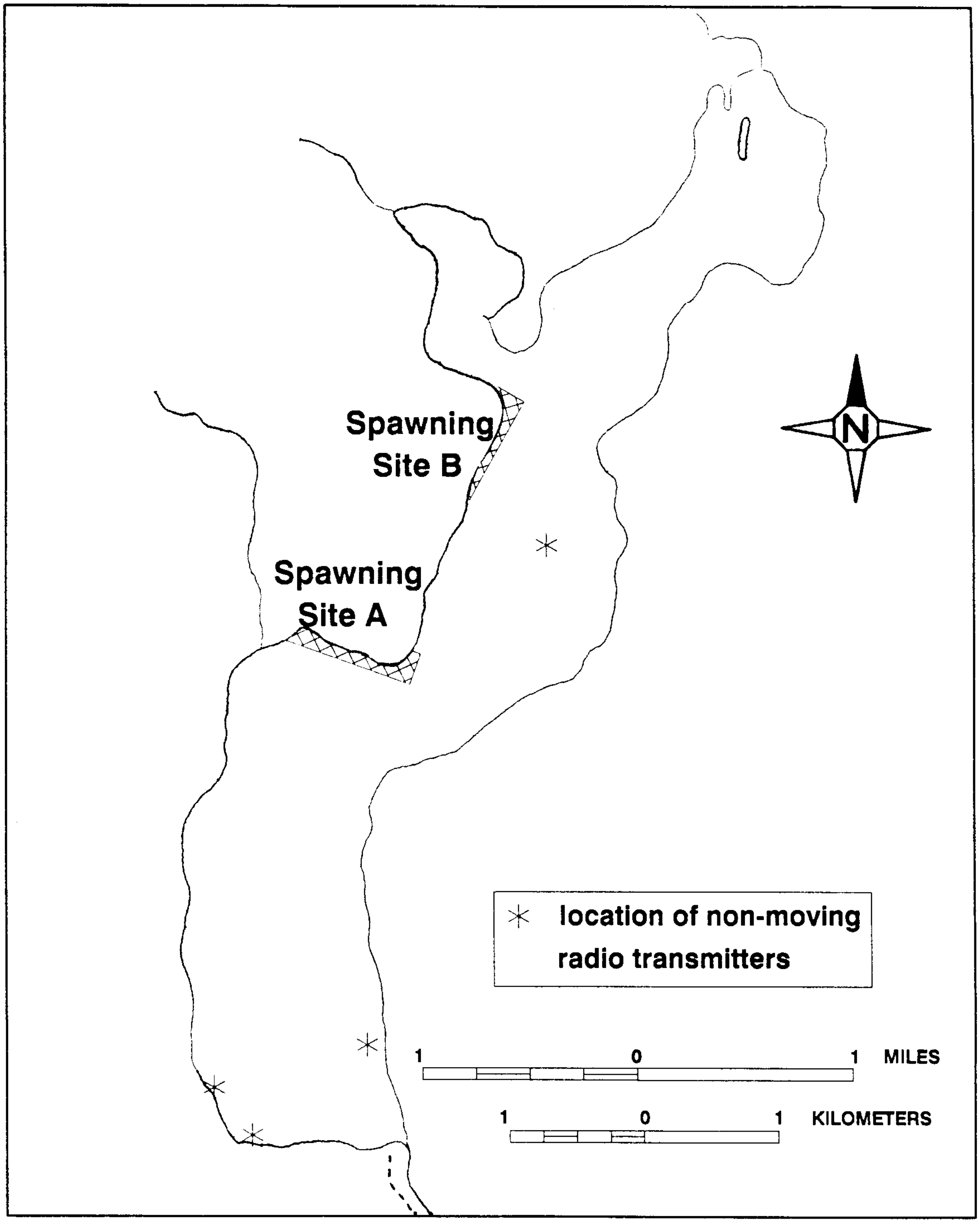

Figure 6. Location of possible spawning sites in Fielding Lake.

Age Validation, West Twin Lake

During the netting effort at West Twin Lake, no lake trout were captured. All other species of fish which were known to be present in the lake were caught. Northern pike were caught in gill nets in depths ranging from the surface to 10 m. Burbot were caught in both gill nets and in hoop nets in depths from 5 m to 34 m. Whitefish were caught in gill nets at all depths with most in depths less than 25 m. Burbot and pike which were killed in the sampling gear were dissected and the stomachs were examined. Although whitefish were found in many of the stomachs, no lake trout were detected. The lake trout age validation study at West Twin Lake was suspended because no lake trout were found during the sampling at West Twin Lake.

DISCUSSION

Abundance Estimates

Lake trout of mature size in Sevenmile Lake in 1989 were more abundant than in prior years. Previous estimates of abundance of mature lake trout in Sevenmile Lake were 459 fish in 1987 (Burr 1989) and 791 fish in 1988 (Burr 1990). While lack of precision is undoubtedly responsible for some of the difference, it is unlikely that population abundance increased. The estimate from the 1989-1990 data is believed to be inflated due to bias introduced by tag loss. Of the 31 fish recaptured in 1988 from the 166 marked in 1987, 6 (19%) had shed their tags. In 1989, 17 fish were recaptured with tags from the marked population of 156 in 1988. Five additional fish were caught without adipose fins indicating tag loss from either 1987 or 1988. In 1990, 12 fish were captured that had shed tags from previous years. Since fish which had shed tags were not counted as recaptures, the result is an inflated abundance estimate. Increased attention has been devoted to tag insertion by field personnel.

In 1986 a similar mark-recapture experiment estimated population abundance for lake trout 250 mm FL and larger in Glacier Lake to be 2,686 (SE = 612; Burr 1987). The present estimate of 3,248 (SE = 689) is similar. From sampling in 1989, it was noted that catch rates were higher in August than they were in June and July and that this difference was probably due to the movement of lake trout into shallow areas prior to spawning in September (Burr 1990). The presence of an outlet accessible to fish in Glacier Lake introduced the possibility that some fish captured in August may not have been present in the lake during June and July. The capture of a lake trout which was tagged in Upper Tangle Lake in 1988, a distance of about 10 km, supports this possibility. This type of movement is assumed to be minimal, but illustrates the importance of validating the assumptions necessary for conducting mark-recapture experiments. Seasonal differences in catch rates indicate that sampling for lake trout in the same part of the season is advisable for these types of experiments.

The assumption of equal probability of capture for all spawning lake trout at Paxson Lake was likely violated. The capture rate for females was lower than for males. A disproportionate number of males is common in other lake trout stocks. Martin and Olver (1980) found that sex ratios on spawning beds ranged from 2:1 to 4:1 males/female. In addition to the fact that fewer females were generally present on spawning grounds, their probability of being recaptured was less than that for males. The rate of recapture for males in 1989 and 1990 was 31% and 62%, respectively, contrasted with 9% and 14%, respectively, for females.

Two possible causes for the discrepancy in numbers of fish of each sex that were captured are offered. Either some of the females are not present at the time of sampling in any one season or all females do not spawn every year.

In other studies, males are reported to arrive earlier and remain longer on the spawning beds than females (Martin and Olver 1980). Consequently, a particular male may be present at a spawning site for most of the spawning season, while an individual female may be present for only a small portion of that time. It is possible that the sampling schedule may have exacerbated this problem. Sampling was limited to a relatively small portion of the spawning season, particularly in 1990 when all of the fish sampled were caught in three nights.

Intermittent spawning is not uncommon for lake trout, particularly at northern latitudes. While most of the mature male lake trout in Paxson Lake appear to spawn every year, it is not clear if this is the case for females. Although sample size is small, less than half of the females which have been captured in more than one year were caught in successive years. Though this does not rule out the possibility that the females which were not recaptured in successive years were simply missed, it becomes less likely.

In an attempt to correct for the bias introduced by different capture probabilities for males and females in Paxson Lake, the estimate for males was assumed to be representative of the number of females and was doubled to provide an estimate of the total number of spawning fish. Estimates of sex ratio available in the literature reflect the portion of the populations which were captured. Lake trout exhibit little sexual dimorphism and, except during spawning, are probably equally vulnerable to capture. Since there is no evidence of differential natural mortality, lake trout stocks probably have balanced sex ratios (Martin and Olver 1980). If most of the females are spawning each year once they are mature, and the lower rate of recapture is caused by the short time that females spend on spawning beds, then the adjusted estimate of abundance is reasonable. If, on the other hand, some portion of the population is not spawning each year, then the estimated number of spawning fish is too high, and over estimates the reproductive potential for Paxson Lake.

Abundance of mature lake trout in lakes studied in 1990 ranged from 3.2 fish per hectare in Paxson Lake to 31.9 fish per hectare in Sevenmile Lake. The estimated density of mature lake trout in Glacier Lake in 1989 is 8.3 fish per hectare as compared to 9.7 fish per hectare in 1986 (Burr 1988). Other estimates of density of lake trout of mature size from Alaska are: Butte Lake (318 ha) 6.7 fish/ha (Burr 1990); Landlocked Tangle Lake (241 ha), 6.8 fish/ha (Burr 1988) and Twobit Lake (109 ha) 10.2 fish/ha (Burr 1989). The few estimates available from outside Alaska indicate that most lake trout densities are between one and 14 fish per hectare (Martin and Olver 1980).

Densities of lake trout in lakes which have been studied in Alaska show an inverse relationship with lake surface area. An inverse relationship between density and or yield with lake area is consistent with reports by Carlander (1977), Goddard et al. (1987) and Carl et al. (1990). This implies that smaller lakes produce more fish than do larger lakes on a per unit area basis. Most lake trout populations in smaller lakes are benthivorous/planktivorous contrasted with a greater degree of piscivory with increasing lake size (Carl et al. 1990). Planktivorous and piscivorous populations of lake trout of equivalent biomass may differ widely in abundance because of the typical small average size of the planktivorous fish. In addition to greater numbers of fish in smaller lakes, Carl et al. (1990) found that a higher standing stock (greater biomass) of lake trout tends to occur in smaller lakes. The greater biomass of lake trout in the small lakes is likely due to the more efficient energy transfer from lower trophic level prey compared with a diet of higher trophic level prey (fish) found in large lakes. Martin and Oliver (1980) report that the densest stocks of lake trout generally occur in those lakes where fish mature at a small size, are planktivorous, and where the average size of fish is between 300 and 400 mm. Thus, the relatively high densities of lake trout found in most of the lakes which have been studied in Alaska are likely due to the small surface area of the lakes studied, the small average size of fish, and the small size at maturity for lake trout in these populations.

Population Structure

Data collected in 1990 have provided estimates of size composition from four populations of lake trout as well as estimates of maturity for these populations. However, in some cases, the sample sizes were too small to provide conclusive comparisons, particularly for estimates of age composition and size at age. ADFG will continue to collect data from lake trout residing in these lakes. Such data will be accumulated across years and added to the existing data base to improve accuracy and precision of estimates of population structure.

The size composition of lake trout estimated as RSD is similar for the populations of lake trout residing in Sevenmile and Glacier lakes. In each of these lakes, very few fish of large size were found and nearly all of the lake trout sampled were less than 453 mm FL (stock). A much higher proportion of large lake trout occurred in the sample from Fielding Lake (62% $\geq$ 454 m FL) and from Paxson Lake (82% $\geq$ 454 m FL). The apparent large size of lake trout in Fielding Lake is likely due to the sample collected. Once spawning sites were located, effort was directed at catching spawning fish from those sites. This combined with the overall small sample size (N = 116), would bias the sample from Fielding Lake toward large fish. The relatively large size of lake trout from Paxson Lake is probably because these fish were captured from spawning concentrations.

The estimates of length at which lake trout of both sexes in Paxson, Sevenmile, and Glacier lakes mature are very similar; LM_{50}'s ranged from 362 to 369 mm. A similar estimate for lake trout residing in Fielding Lake was much higher (440 mm) but samples were too few for complete analysis. Female lake trout from fast growing populations (e.g. Paxson and Fielding lakes) matured at a relatively larger size. For slower growing populations, less difference was documented between males and females. Estimates of length at maturity of lake trout from lakes in Alaska are in general less than what has been reported from other areas. Healey (1978) noted that lake trout from lakes north of 60° appear to mature at smaller size than do fish from populations farther south. The similarity in the size at maturity in these lake trout populations may indicate a threshold size for maturity for the species.

The estimated LM_{50} for the lake trout population of Sevenmile Lake is 386 mm. Information from growth of marked and recaptured fish showed that growth slows for fish larger than 400 mm. Similarly, in Glacier Lake, growth of lake trout slowed for fish between 375 to 411 mm; the estimated LM_{50} for the Glacier Lake population is 375 mm. Other researchers have noted that lake trout growth slows markedly once maturity is reached (Healey 1978). In contrast, growth of lake trout from Paxson and Fielding lakes does not slow as markedly once they reach mature size.

Though data are too few to estimate age composition of the populations that were sampled, the limited age data, together with size composition of samples, provide information on the age structure of these lake trout populations. No fish older than age 15 have been sampled from Sevenmile and Fielding lakes. In addition, estimates of mean length at age have been calculated for the entire range of lengths encountered indicating that there are very few, if any, old age fish in these populations. In contrast, relatively old lake trout (age > 25) were well represented in the samples from the populations of Paxson and Glacier lakes. All populations sampled, with the exception of Glacier Lake, show a dominance of younger age (age < 10) fish. All of these lakes except for Glacier Lake have direct road access. The absence of significant proportions of older fish in most of these populations may be a result of the fishery targeting larger, older-aged fish

Lake trout from Paxson Lake (Copper River system) are larger, grow faster, and mature at a younger age than do lake trout from the other lakes sampled in 1990. The faster growth of lake trout in Paxson Lake is probably a result of the availability of large numbers of sockeye salmon *Oncorhynchus nerka* fry and smolt and, to a lesser degree, round and humpback whitefish *Prosopium cylindraceum, Coregonus pidschian* and Arctic grayling *Thymallus arcticus* which provide a diverse forage base. The forage base in the Tanana drainage lakes is less diverse. Whitefish and other fish species are present in most of the other lakes sampled, but sockeye salmon are absent. Lake trout from Glacier lake are mostly small, grow slowly and mature at relatively old age. Lake trout in Sevenmile Lake are small, although growth is good and fish mature at a young age. The good growth, the absence of older age classes, and young age at maturity suggests a response by lake trout in Sevenmile Lake to fishing pressure. This small lake has excellent road access. The stock status at Fielding Lake is less clear. Relative to the other lakes studied, lake trout grow to large size, are larger at age, demonstrate a large size at maturity and a medium age at maturity. All of these factors except for medium age at maturity would point to a fast growing population that attains large size. The large size distribution documented in the 1990 sample may be a result of small sample size coupled with bias for large fish as suggested earlier. Such a population structure might also be explained by a limited rate of recruitment and low abundance coupled with significant harvest.

Fielding Lake Spawning Sites

It is unclear whether site B at Fielding Lake is used by lake trout for spawning. All lake trout fitted with radio tags were of mature size and the lake trout that was always located in this area was large (640 mm). The fish that was captured in gill netting from this area was released. It was not in spawning condition, its state of maturity could not be ascertained. It is possible that the mature sized fish were using this area for feeding. If the fish spawn intermittently in Fielding Lake, these may have been fish that did not spawn in 1990. It is also possible that Site A is the only spawning area in Fielding Lake. The habitat, when compared to known spawning areas in other lakes, appears ideal. The steep slope allows wave action to clean the areas between the angular rocks of various sizes and the large size of the rocks would provide large amounts of interstitial spaces.

Age Validation, West Twin Lake

The lack of lake trout in samples from West Twin Lake indicates that the stocking probably failed. The presence of two predatory species, burbot and northern pike, in the lake may be largely responsible for the apparent failure. Either burbot or pike or both were found at all depths during gill net sampling and little cover for the juvenile lake trout is present. A few of the stocked lake trout may have survived but the level of sampling should have been enough to detect significant survival.

ACKNOWLEDGEMENTS

The author extends his thanks to Mike Amberg who assisted with field work associated with this study. Thanks also to Patricia Hansen and David R. Bernard for assistance with statistical procedures, data analysis, and editing and to Terry Bendock for thoughtful editorial comments. Thanks to Peggy Merritt for editorial comments and overall support. Appreciation is extended to John H. Clark for support in all aspects of this project. I also thank the U. S. Fish and Wildlife Service for funding support through the Federal Aid in Fish Restoration Act, (16 U.S.C. 777-777K) under Project F-10-6, Job Number R-3-3(b).

LITERATURE CITED

Buckland, S.T. 1980. A modified analysis of the Jolly-Seber capture-recapture model. Biometrics 36:419-435.

____. S.T. 1982. A mark-recapture survival analysis. Journal of Animal Ecology 51:833-847.

Burr, J. M. 1987a. Synopsis and bibliography of lake trout, *Salvelinus namaycush*, in Alaska. Alaska Department of Fish and Game, Sport Fish Division, Juneau. Fishery Manuscript No. 5. 50 pp.

_____. 1987b. Stock assessment and biological characteristics of lake trout populations in Interior Alaska, 1986. Alaska Department of Fish and Game, Sport Fish Division, Juneau. Fishery Data Series No. 35. 65 pp.

_____. 1988. Stock assessment and biological characteristics of lake trout populations in Interior Alaska, 1987. Alaska Department of Fish and Game, Sport Fish Division, Juneau. Fishery Data Series No. 66. 53 pp.

_____. 1989. Stock assessment and biological characteristics of lake trout populations in Interior Alaska, 1988. Alaska Department of Fish and Game, Sport Fish Division, Juneau. Fishery Data Series No. 99. 57 pp.

_____. 1990. Stock assessment and biological characteristics of lake trout populations in Interior Alaska, 1989. Alaska Department of Fish and Game, Sport Fish Division, Juneau. Fishery Data Series No. 90-33. 50 pp.

Carl, L., M. F. Bernier, W. Christie, L. Deacon, P. Hulsman, D. Loftus, D. Maraldo, T. Marshall, and P. Ryan. 1990. Fish community and environmental effects on lake trout. Lake Trout Synthesis, Ont. Min. Nat. Resour., Toronto. 47 pp.

Carlander, K. D. 1977. Biomass, production, and yields of walleye (*Stizostedion vitreum*) and yellow perch (*Perca flavescens*) in North American Lakes. Journal of the Fisheries Research Board of Canada. 34:1602-1612.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1, 131-60.

Cochran, W. G. 1977. Sampling techniques, 3rd ed. John Wiley & Sons, Inc. New York. 428 pp.

Conover, W. J. 1980. Practical nonparametric statistics. John Wiley and Sons, New York. 493 pp.

Efron, B. 1982. The jackknife, the bootstrap, and other resampling plans. Society of Industrial and Applied Mathematics, Philadelphia. 92pp.

Finney, D. J. 1971. Statistical methods in biological analysis, 2nd ed. Charles Griffin & Company, Ltd. London. 668 pp.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management. 4:273-285.

Goddard, C. I., D. H. Loftus, J. A. MacLean, C. H. Olver, and B. J. Shuter. 1987. Evaluation of the effects of fish community structure on observed yields of lake trout (*Salvelinus namaycush*). Canadian Journal of Fisheries and Aquatic Sciences. 44(Suppl. 2): 239-248.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association. 66:708-713.

Healey, M. C. 1978. Dynamics of exploited lake trout populations and implications for management. Journal of Wildlife Management. 42:307-328.

Martin, N. V. and C. H. Olver. 1980. The lake charr, *Salvelinus namaycush*. in E. K. Balon, ed. "Charrs: Salmonid Fishes of the Genus *Salvelinus*. D. W. Junk, Publishers, The Hague, Netherlands. 925 pp.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1. 27(SW-I). 137 pp.

____. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Sport Fish Division, Juneau. Fisheries Data Series No. 90-44. 152 pp.

Paterson, R. J. 1968. The lake trout (*Salvelinus namaycush*) of Swan Lake, Alberta. Alberta Department of Lands Forests. Fish and Wildlife Division of Research Report. 2: 1-149.

Robson, D. S. and W. A. Flick. 1965. A non-parametric statistical method for culling recruits from a mark-recapture experiment. Biometrics 21: 936-947.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd ed. Charles Griffin & Company, Ltd. London. 624 pp.

APPENDIX A

Appendix A1. Length frequencies (listed by gear type) of all lake trout captured and marked during 1989 in Sevenmile Lake.

	Captured								Marked							
Fork Length[a]	Gill Nets		Fyke Nets		Hoop Nets		All Gear		Gill Nets		Fyke Nets		Hoop Nets		All Gear	
	n[b]	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	4	3	0	0	4	1	0	0	0	0	0	0	0	0
100	0	0	19	16	0	0	19	7	0	0	0	0	0	0	0	0
125	0	0	70	58	0	0	70	26	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175	0	0	11	9	0	0	11	4	0	0	0	0	0	0	0	0
200	0	0	13	11	0	0	13	5	0	0	0	0	0	0	0	0
225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
250	7	5	0	0	0	0	7	3	7	5	0	0	0	0	7	5
275	10	7	1	1	0	0	11	4	9	6	1	33	0	0	10	7
300	8	5	1	1	0	0	9	3	7	5	1	33	0	0	8	5
325	4	3	0	0	0	0	4	1	2	1	0	0	0	0	2	1
350	5	3	0	0	0	0	5	2	3	2	0	0	0	0	3	2
375	10	7	0	0	0	0	10	4	9	6	0	0	0	0	9	6
400	26	17	1	1	0	0	27	10	25	18	1	33	0	0	26	18
425	30	20	0	0	0	0	30	11	30	21	0	0	0	0	30	21
450	32	21	0	0	2	100	34	13	31	22	0	0	2	100	33	23
475	11	7	0	0	0	0	11	4	11	8	0	0	0	0	11	8
500	7	5	0	0	0	0	7	3	7	5	0	0	0	0	7	5
525	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
550	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	150		120		2		272		141		3		2		146	

[a] Upper limit length category
[b] Sample size

Appendix A2. Length frequencies (listed by gear type) of all lake trout captured in 1990 in Sevenmile Lake.

Fork Length[a]	Captured								Recaptured From 1989							
	Gill Nets		Fyke Nets		Hoop Nets		All Gear		Gill Nets		Fyke Nets		Hoop Nets		All Gear	
	n[b]	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
50	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	2	11	0	0	2	1	0	0	0	0	0	0	0	0
125	0	0	12	63	0	0	12	4	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175	0	0	3	16	0	0	3	1	0	0	0	0	0	0	0	0
200	1	0	2	11	0	0	3	1	0	0	0	0	0	0	0	0
225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
250	5	2	0	0	0	0	5	2	0	0	0	0	0	0	0	0
275	19	7	0	0	0	0	19	6	0	0	0	0	0	0	0	0
300	14	5	0	0	0	0	14	5	0	0	0	0	0	0	0	0
325	4	1	0	0	0	0	4	1	0	0	0	0	0	0	0	0
350	25	9	0	0	0	0	25	8	2	11	0	0	0	0	2	11
375	21	8	0	0	0	0	21	7	0	0	0	0	0	0	0	0
400	36	13	0	0	0	0	36	12	1	6	0	0	0	0	1	6
425	58	21	0	0	1	50	59	20	8	44	0	0	0	0	8	44
450	58	21	0	0	1	50	59	20	4	22	0	0	0	0	4	22
475	28	10	0	0	0	0	28	9	3	17	0	0	0	0	3	17
500	2	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0
525	2	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0
550	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	273		19		2		295		18		0		0		18	

[a] Upper limit length category
[b] Sample size

Appendix A3. Lake trout captured, marked, and recaptured in Sevenmile Lake with estimates of abundance, survival and recruitment, 1987-1990.

	Number of Lake Trout			
	1987	1988	1989	1990
Originally marked in 1987	--	24	16	21
Originally marked in 1988		--	17	13
Originally marked in 1989		--	--	18
Captured with tags	3	27	33	56
Captured without tags	220	151	126	219
Total captured	223	178	159	275
Released with tags	189	159	150	247
Released without tags	0	5	0	0
Total Released	189	164	150	247
Abundance estimate	--	1,839	1,837	--
SE of abundance estimate	--	317	307	--
Lake trout per hectare	--	55.7	55.7	--
Survival rate estimate	--	1.0	1.0	--
SE of survival rate estimate	--			--
Recruitment estimate	--	0	--	--
SE of recruitment estimate		261	--	--

Appendix A4. Length frequencies of lake trout captured, marked and recaptured in Glacier Lake during 1989 and 1990.

Fork Length[a]	1989				1990			
	Captured		Marked		Captured		Recaptured	
	n[b]	%	n	%	n	%	n	%
200	1	0.2	0	0.0	0	0.0	0	0.0
225	1	0.2	0	0.0	3	0.8	0	0.0
250	20	4.3	6	1.8	30	8.0	0	0.0
275	31	6.7	26	7.8	46	12.3	1	6.3
300	33	7.1	19	5.7	30	8.0	0	0.0
325	38	8.2	21	6.3	39	10.4	1	6.3
350	46	9.9	20	6.0	27	7.2	0	0.0
375	42	9.1	29	8.7	26	6.9	1	6.3
400	68	14.7	56	16.8	45	12.0	1	6.3
425	90	19.5	75	22.5	69	18.4	4	25.0
450	59	12.7	49	14.7	35	9.4	3	18.7
475	18	3.9	18	5.4	17	4.5	4	25.0
500	3	0.7	3	0.9	3	0.8	1	6.3
525	3	0.7	3	0.9	2	0.5	0	0.0
550	1	0.2	1	0.3	0	0.0	0	0.0
575	2	0.4	2	0.6	0	0.0	0	0.0
600	0	0.0	0	0.0	0	0.0	0	0.0
625	0	0.0	0	0.0	0	0.0	0	0.0
650	1	0.2	1	0.3	1	0.3	0	0.0
675	3	0.7	3	0.9	0	0.0	0	0.0
700	1	0.2	1	0.3	0	0.0	0	0.0
Total	461		333		373		16	

[a] Upper limit of length category.
[b] Sample size.