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STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF LAKE TROUT POPULATIONS IN INTERIOR ALASKA, 1989[1]

By

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ABSTRACT

During 1989, lake trout *Salvelinus namaycush* were from sampled Paxson Lake of the Copper River system, Butte Lake of the Susitna River system, Fielding, Glacier, and Sevenmile lakes of the Tanana River system and Island Lake on the North Slope. 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 fish in this size category were captured from Fielding Lake. Most other lake trout sampled from the Tanana River system and from Butte Lake and Island Lake were smaller, with most less than 500 millimeters. Ages of lake trout determined with otoliths (sagitta) ranged from 0 to 33 years, with most between 4 and 20 years. No fish greater than age 16 were found in Island, 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. Length 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 426 millimeters for females in Paxson Lake.

Population abundance of lake trout was estimated with mark-recapture experiments from Sevenmile, Glacier, Butte, and Paxson lakes. The abundance estimate of lake trout greater than 345 millimeters was 942 (29 fish per hectare) in Sevenmile Lake and 4,440 (14 fish per hectare) for lake trout 250 mm and larger in Butte Lake. The mark recapture experiment failed at Glacier Lake. The estimated abundance of spawning lake trout in Paxson Lake was 4,895 (3 fish per hectare). The estimated density of lake trout of mature size was 24 fish per hectare in Sevenmile Lake, and 7 fish per hectare in Butte Lake.

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

INTRODUCTION

Lake trout *Salvelinus namaycush* support important recreational fisheries in both roadside and remote waters. Most fishing for lake trout occurs on easily accessible waters. In addition, 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 1988). Over one half of the total 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 and the Arctic-Yukon-Kuskokwim region (AYK), 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) found that the 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 maximum sustainable harvest rate 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 the recommended maximum sustainable yield (Healy 1978). Based on this information, the Alaska Board of Fisheries reduced bag limits from 12 to two fish per day in all waters in the Tanana River drainage and Glennallen area in 1987. In addition, a minimum length limit of 450 mm total length (TL) (18 in) was included 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 fourth 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, the experience of management of lake trout fisheries in North America is that estimates of sustainable yield 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 1989 field season were to:

1. estimate population abundance of lake trout in Glacier Lake, Butte Lake, Sevenmile Lake, and Island Lake;

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

3. estimate the Relative Stock Density (RSD Gabelhouse categories) of lake trout populations in Glacier Lake, Butte lake, Sevenmile Lake, Paxson Lake, and Island Lake (or Summit Lake);

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

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

METHODS

Site Descriptions

Data were collected from populations of lake trout from five lakes in central Alaska: Paxson Lake of the Copper River drainage; Butte Lake of the Susitna River drainage; Fielding, Sevenmile, and Glacier lakes in the Tanana River drainage. The lakes range widely in size from Sevenmile Lake (surface area 32 ha) to Paxson Lake (surface area 1,575 ha; Figure 1). All lakes are located in the Alaska Mountain Range at elevations from 778 to 1,006 m, and with the exception of Paxson Lake, within alpine tundra/scrub birch habitat. Paxson Lake is in a mixed spruce forest. Data were also collected from Island Lake (62 ha) of the Kuparuk River drainage on the North Slope of the Brooks Range.

Sevenmile Lake is located at an elevation of 975 meters and the lake is located adjacent to the Denali Highway (Figure 1). The estimated surface area of the lake is 32 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 meters (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 5 km downstream.

Butte Lake is in the Susitna River system at 1,022 m and has an estimated surface area of 318 ha and a maximum recorded depth of 24 m (Figure 2). Numerous small inlets drain the hillsides around the lake and a single outlet flows to the south into Butte Creek.

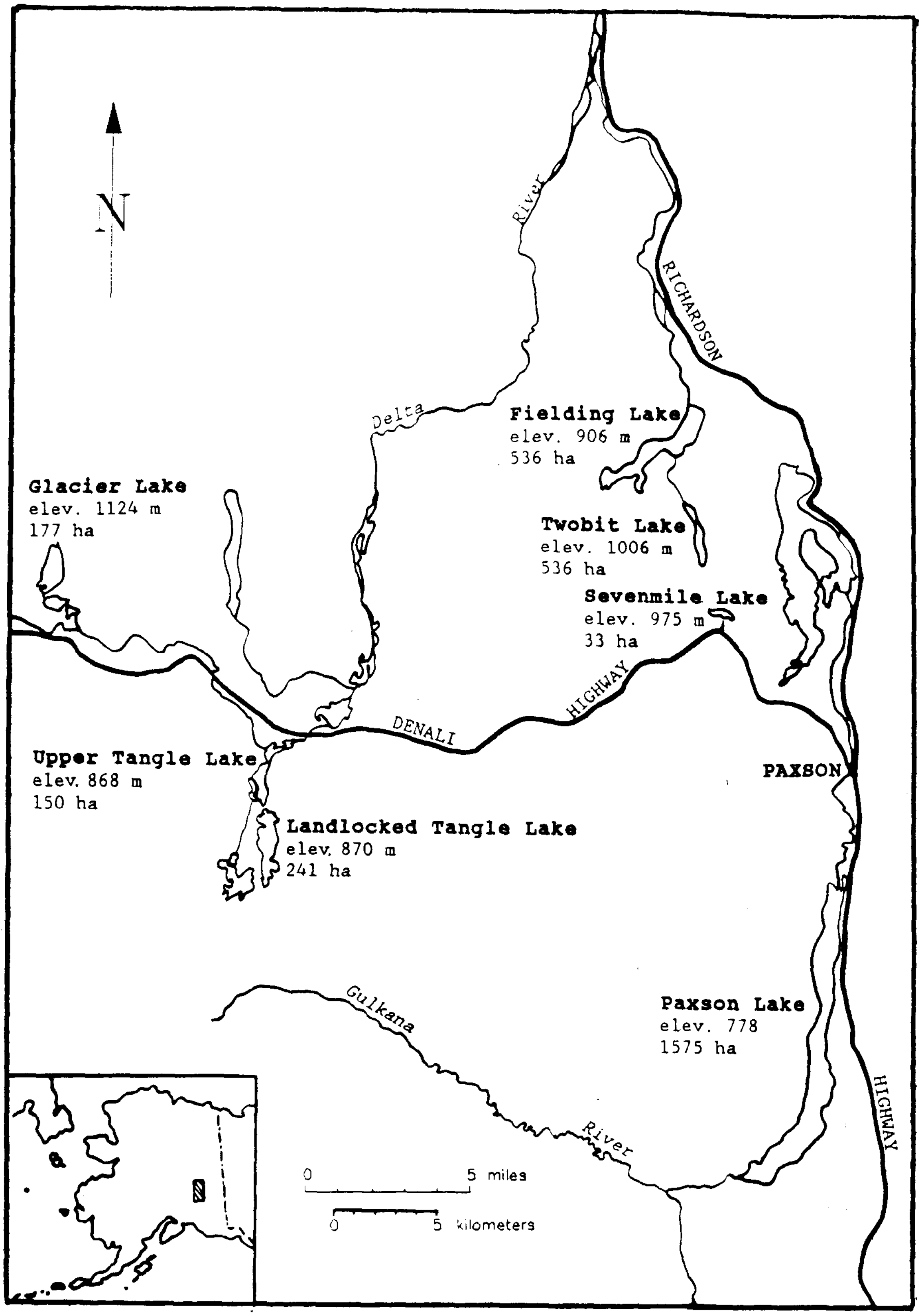

Figure 1. Study area near Paxson Alaska. Elevations of lakes are given in meters and approximate surface areas are in hectares.

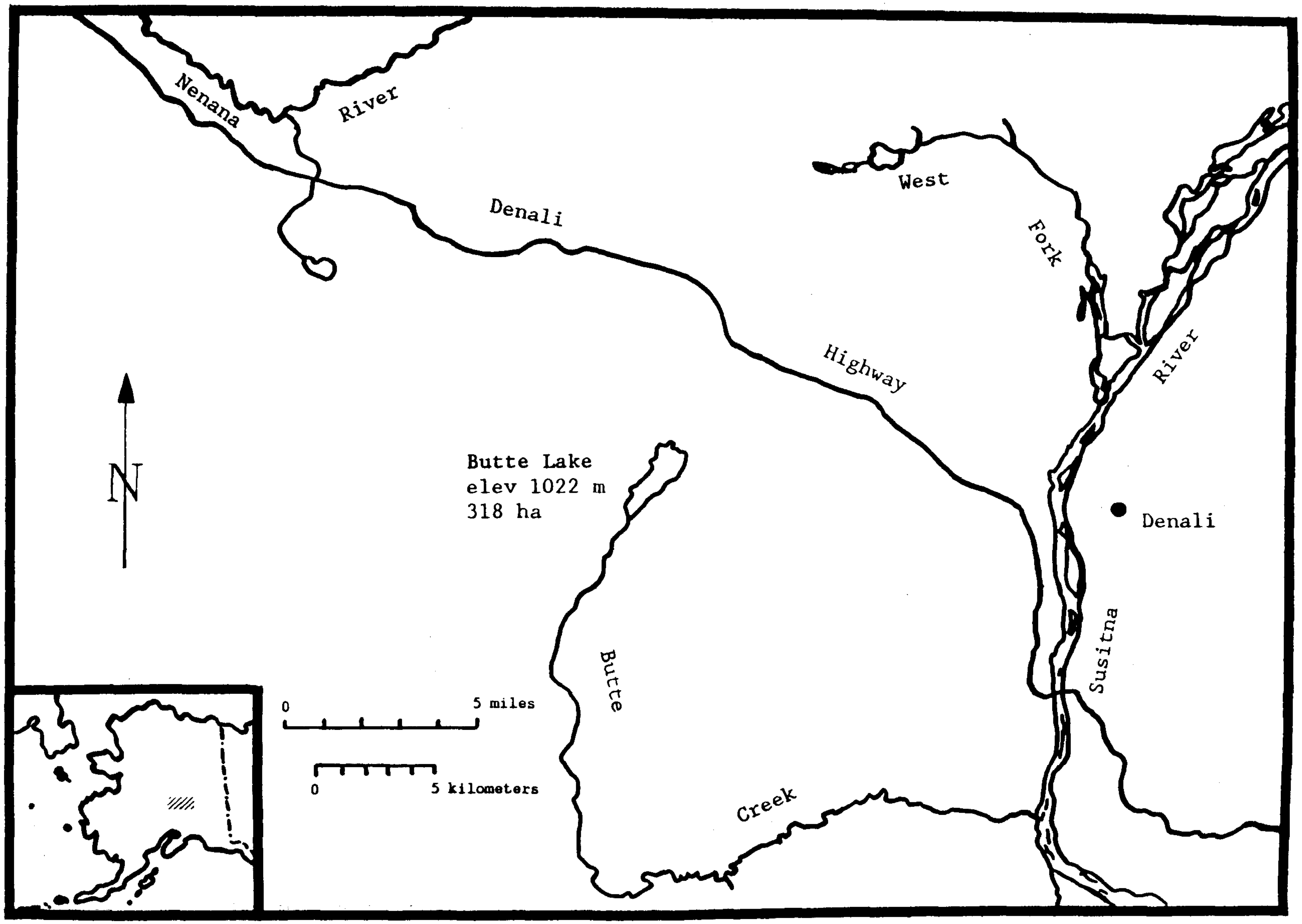

Figure 2. Map of Butte Lake, Alaska. Elevation of the lake is in meters and approximate surface area is in hectares.

Island Lake is located at an elevation of 881 meters and the lake is located adjacent to the Dalton Highway (not shown on map). The estimated surface area of the lake is 62 ha and the maximum recorded depth is 14.5 m. There are no active inlet or outlet streams, so it is closed to immigration and emigration.

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, Glacier Lake, Butte Lake and Island Lake during 1989 and for spawning lake trout in Paxson Lake. For Glacier Lake and Island Lake, a modified Petersen mark-recapture estimator was selected (Chapman 1951) with both sampling events conducted during 1988. Abundance of lake trout in Butte and Sevenmile lakes was estimated with marking events and recapture events performed in separate years (Seber 1982). The marking events were conducted in 1988 and the recapture events were performed in 1989. The Petersen estimator was selected because of the relatively smaller sample sizes (less than 1000) from these four lakes and because it was deemed 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, the Jolly Seber estimator was selected because it allows for immigration and mortality and the multiyear design should provide mixing of marked and unmarked fish. The estimated abundance in each lake is germane to the time of marking. Population abundance and the approximate variance of this estimate were calculated for all populations except for Paxson Lake with the following formulas (Seber 1982):

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

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

where:

M = the number marked during the marking sample period;

C = the number captured during the recapture sample period; and,

R = the number captured during the recapture period with marks from the marking period.

Conditions for the accurate use of the Petersen mark-recapture estimator include (Seber 1982):

1. a closed population (no change in the number of fish in the population during the experiment);

2. all lake trout have the same probability of capture in the marking sample or in the recapture sample, or marked and unmarked lake trout mix completely between marking and recapture events;

3. marking of lake trout does not affect their probability of capture in the recapture sample;

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

5. all marked lake trout are reported when recovered in the recapture sample.

In all sampled lakes, efforts were made to meet these requirements. To promote mixing of marked fish with the unmarked population, marked fish were released throughout the lake. The length of time between the capture events (one month minimum) was deemed sufficient to permit mixing of marked and unmarked fish. As a test of mixing, each lake was divided in half and numbers of fish recaptured and not recaptured in each half was tested with chi-square analysis. To measure 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. Handling induced "net shyness" should have been minimized by the period of time between the marking and recapture events.

Growth recruitment in these lake trout populations was assumed to be minimal when marking and recapture events were performed within a season but not so when the experiment was conducted over more than one year. The Petersen estimator is valid for multiyear experiments if either mortality or recruitment (but not both) occurs between sampling events (Seber 1982). To evaluate recruitment through growth between the marking period and the subsequent recapture period, 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):

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

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

where:

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

m = number of marked fish from the marking period that are smaller than the upper extent of growth recruitment (L_r); and,

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

The variance of $\bar{u}_r$ was calculated using standard normal procedures to find 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 of spawning lake trout in Paxson Lake in 1988. The number of lake trout marked in 1987 and surviving to 1988 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 1987 and 1988 was then calculated as:

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

Population abundance just prior to sampling in 1988 was estimated as :

$$\hat{N}_{88} = \frac{C_{88}\hat{M}_{87,88}}{R_{87,88}} \quad (7)$$

where:

N_{88} = abundance just prior to sampling in 1988; and,

C_{88} = number of lake trout captured in 1988.

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 (ie, 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.

Point estimates and variances of population size and survival rate were calculated by bootstrapping the 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 two-sample test (Conover 1980) and contingency table analysis. The data were grouped by length classes for the contingency table analysis. The first 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 for the second test (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). During late July 1988, lake trout were again sampled (Burr 1989). Similarly, between 23 and 28 July, 1989, 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 herring *Clupea harengus* which was placed in perforated bait containers. These nets were set in all parts of the lake in various depths from 1 to more than 12 meters. Fyke nets were set near shore at depths of about 1.2 m with center lead nets attached to shore.

Glacier Lake:

In 1986, lake trout were captured in Glacier Lake during two sampling events with variable mesh sinking gill nets, baited hoop nets, and by angling. An estimate of abundance for lake trout 250 mm FL and larger was calculated from these data (Burr 1987b). A second mark-recapture experiment was conducted in 1989. Between 21 June and 12 July 1989 lake trout were captured with 25 mm (square measure) x 3 m x 46 m sinking gill nets, and by angling. Nets were set in all parts of the lake in various depths from 0.5 to more than 25 m. During the recapture period (21 to 30 August), lake trout were captured with 25 mm mesh sinking gill nets. All portions of the lake were netted as were various depths. To minimize mortality of lake trout, gill nets were checked every half hour.

Butte Lake:

In 1988 and 1989 a mark recapture experiment was conducted at Butte Lake. During 16-23 June and 18-25 August of 1988, lake trout were marked with Floy anchor tags. The recapture sampling period was conducted during 20-27 June and 21-29 August 1989. During the sampling periods, lake trout were captured with 25 mm mesh sinking gill nets. Nets were set in all parts of the lake in various depths from 0.5 to 18 m.

Island Lake:

Between 7 and 13 July, lake trout were captured in Island Lake with 25 mm mesh sinking gill nets. Initially, gill nets were checked at one half hour intervals, but because of very low catch rates toward the end of the marking period, the intervals increased up to three hours. Nets were set in all parts of the lake in various depths from 0.5 to 14 m. Due to the low number of lake trout captured, the recapture event which would have taken place in August was canceled.

Paxson Lake:

In September of 1987, 1988, and 1989, lake trout were captured while on spawning sites at Paxson Lake. In 1987 the fish were captured with 25 mm gill nets and with a 90 m beach seine. In 1988 and 1989 the lake trout were captured with the beach seine only.

<u>Population Structure</u>

Age, weight, length, sex, and maturity data were obtained from captured lake trout in all six 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 captured, lake trout were not in good condition, they were weighed and dissected to obtain otoliths for age determination and to obtain information on sex and maturity. These data were obtained from sampling for the abundance estimates at Sevenmile, Glacier, Island, Butte and Paxson lakes and from test netting at Fielding Lake.

Age Determination:

All age and growth data presented in this report are based on ages obtained from otoliths. Sharp and Bernard (1988) found that scales provided lower estimates of age than did otoliths, particularly for lake trout older than age 5. The estimates of age obtained from the scale samples are not presented in this report. They will be used for validation of age determination with tagged lake trout recaptured in future years. Otoliths (sagitta) 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". A scale sample was taken from all lake trout handled during various project activities. Scales were cleaned and placed between glass slides and were archived for future analysis.

Relative Stock Density:

The proportions of the populations corresponding to each size category were estimated with formula (8) and the variances of the proportions with formula (9) (Cochran 1977):

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

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

where:

n_j = the number in the sample from group j;

n = the sample size; and,

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

Relative Stock Density (RSD) was estimated for lake trout from the samples collected from each lake. The categories of "stock", "quality", "preferred", "memorable", and "trophy" were determined as outlined by Gablehouse (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 or if it had spawned in the past. Females containing eggs with diameters greater than 1 mm and ovaries with streched, fragmented mesovarium were considered mature (Martin and Olver 1980). The presence of retained eggs was also used to identify females which had spawned before. 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 analysed. 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 of 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 samples were used for both analyses.

To compare densities of mature lake trout from lakes for which estimates have been made, the abundance estimates were reduced by the proportion of the fish sampled which were less than the LM_{50} for the population from each lake. The proportion of mature fish in each sample was estimated with formula (8) and the variance of the proportion with formula (9). The estimated abundance of mature fish was calculated with formula (10) and the variance of the estimate (formula 11) is the variance of a product (Goodman 1960):

$$\hat{N}_m = \hat{p}\,\hat{N}; \text{ and,} \tag{10}$$

$$V[\hat{N}_m] = \hat{p}^2\, V[\hat{N}] + V[\hat{p}]\,\hat{N}^2 - V[\hat{p}]\,V[\hat{N}]; \tag{11}$$

where:

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

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

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

Size at Age:

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

RESULTS

Abundance Estimates

Abundance of lake trout was estimated in Sevenmile, Butte, and Paxson lakes. Too few lake trout were captured in Glacier and Island lakes to estimate abundance in those lakes.

Sevenmile Lake:

The abundance of lake trout larger than 345 mm FL in Sevenmile Lake at the end of 1988, estimated from data collected in 1988 and 1989, was 942 fish (SE = 186; Table 1). The estimated density was 28.6 lake trout per hectare (11.6 LT/acre). The estimate of the abundance of lake trout of mature size (LM_{50} and larger) in Sevenmile lake in 1987 was 791 (SE = 158) giving a density of 23.9 mature lake trout per hectare (9.8 LT/acre; Table 2).

During sampling in 1988, 156 lake trout 250 mm (FL) or larger were marked in Sevenmile Lake. Of these 156 lake trout, 151 were caught in gill nets, two in fyke nets, and three in hoop nets (Appendix A1). During the recapture event in 1989, 155 lake trout 250 mm (FL) or larger were captured; 150 in gill nets, two in hoop nets, and three in fyke nets. Seventeen of the 155 lake trout had been marked in 1987. One hundred forty-six were captured alive, tagged, and released, and nine died in the sampling gear. Five additional lake trout were captured with missing adipose fins. We were unable to determine if these fish were clipped in 1988 or in a previous year. Hence, they were not counted as recaptures.

Comparison of lengths of marked and recaptured fish (test 1) and lengths of all fish captured during the marking event in 1987 and during the recapture event in 1989 (test 2) failed to detect significant difference between capture rates among length categories (test 1: D = 0.15, P = 0.81; test 2: D = 0.11, P = 0.24; Appendices A2 - A3). Therefore, a single nonstratified abundance estimate was calculated for Sevenmile Lake.

Inspection of plots of length frequencies of lake trout recaptured during 1989 and unmarked fish captured in 1989 indicate that growth recruitment occurred between 1988 and 1989 (Figure 3). Due to small sample size, the technique of Robson and Flick (1965) was inconclusive. Growth of fish recaptured in 1989 and marked in 1988 provides some information on the upper extent of growth recruitment. Lake trout between 347 and 361 mm FL grew, on average, 33 mm (minimum 29 mm) between 1988 and 1989 (Table 3) while fish 399 mm and larger grew an average of 10 mm (maximum 24 mm) during the same period. No data are available for growth of fish smaller than 347 mm between 1988 and 1989. However, tag recoveries between 1987 and 1988 showed that growth of lake trout between 200 mm and 245 mm averaged 97 mm during that annual period (Table 4). Hence, the upper extent of growth recruitment for lake trout in Sevenmile Lake appears to be between 347 and 399 mm FL.

The Petersen estimator is valid if either mortality or recruitment (but not both) occurs. Since sampling was conducted in different years, mortality undoubtedly occurred between sampling events and recruitment through growth is

Table 1. Abundance estimates for lake trout larger than 345 mm FL in Sevenmile Lake in 1988.

Year	Gear	Number of Lake Trout Marked	Number of Lake Trout Recaptured	Number of Lake Trout Examined	Abundance Estimate	SE	Lake Trout per Hectare
1988	Gill Net	133	--	142			
	Fyke Net	1	--	1			
	Hoop Net	3	--	3			
	Total	137	--	146			
1989	Gill Net	115	17	119			
	Fyke Net	1	0	1			
	Hoop Net	2	0	2			
	Total	118	17	122	942	186	28.6

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

Lake (Surface Area)	Abundance	SE	Density (Lake Trout Per Hectare)	LM_{50}
Paxson (1,575 ha)	4,895	953	3.1	362 mm
Butte (318 ha)	2,124	347	6.7	369 mm
Glacier[a] (177 ha)	1,724	403	9.7	373 mm
Sevenmile (33 ha)	791	158	23.9	368 mm

[a] Data are from Burr 1988.

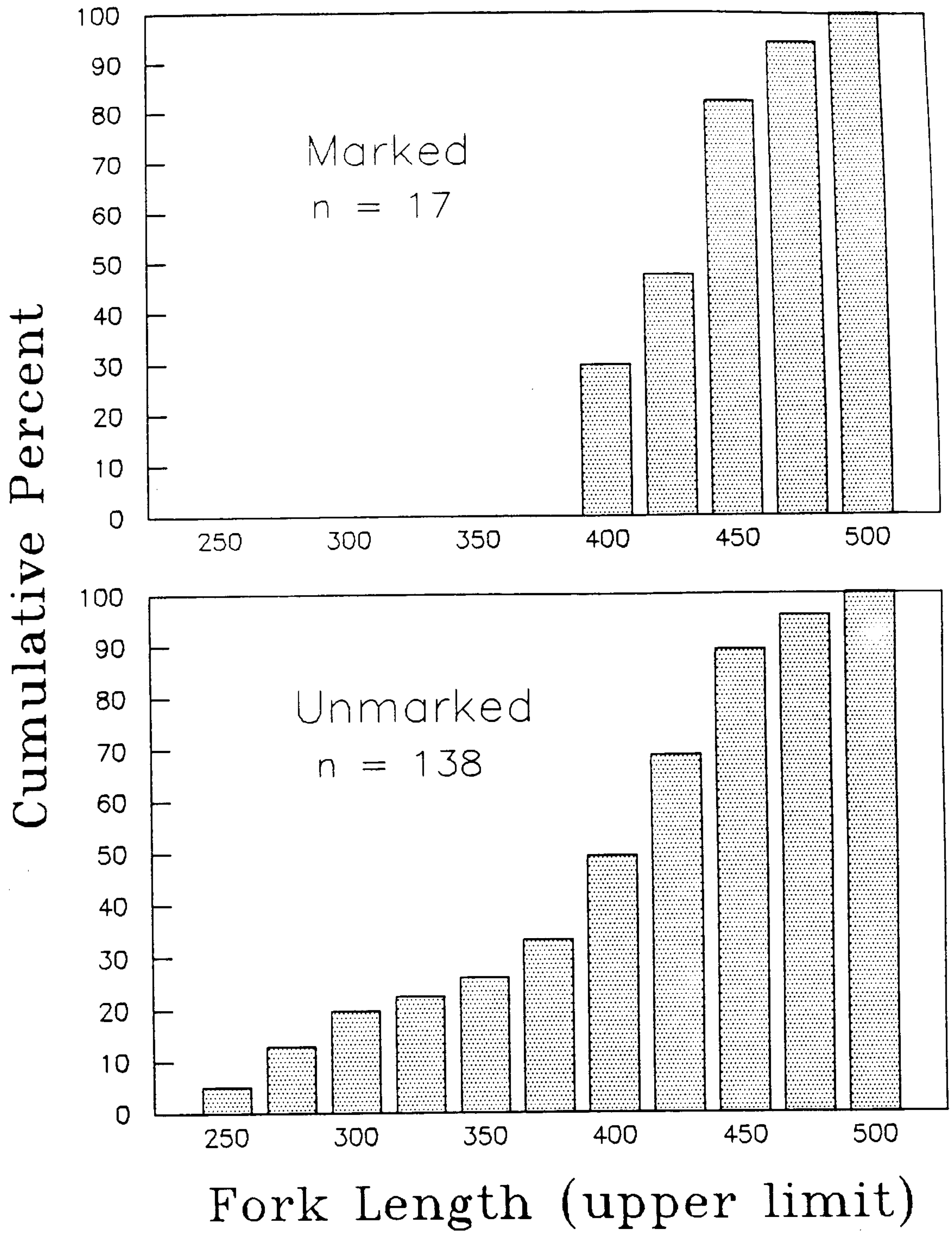

Figure 3. Cumulative distribution of lengths of marked (recaptured) and unmarked lake trout captured during 1989 in Sevenmile Lake.

Table 3. Length (mm FL) of lake trout from Sevenmile Lake at time of marking in 1988 and recapture in 1989 and growth (mm) between sample periods.

Length at:						
Marking	Recapture	Growth	Length Category	Mean Growth	Length Category[a]	Mean Growth
347	382	35	347 to 361	33	350	35
352	390	38			375	33
357	386	29	399 to 463	10	400	7
361	391	30			425	14
361	395	34			450	7
399	401	2			475	10
400	412	12				
410	434	24				
412	420	8				
416	430	14				
418	426	8				
431	436	5				
433	441	8				
434	443	9				
451	453	2				
454	466	12				
463	478	15				

[a] Upper limit of length category.

Table 4. Length (mm FL) of lake trout from Sevenmile Lake at time of marking in 1987 and recapture in 1988 and growth (mm) between sample periods.

Length at:						
Marking	Recapture	Growth	Length Category	Mean Growth	Length Category[a]	Mean Growth
200	274	74	200 to 320	92	200	74
231	325	94			225	
234	345	111	347 to 462	12	250	101
240	340	100			275	102
244	332	88			300	
245	349	104			325	64
246	353	107			350	44
247	351	104			375	
253	355	102			400	14
317	371	54			425	6
320	394	74			450	5
347	391	44			475	1
390	416	26				
392	409	17				
395	395	0				
395	405	10				
397	415	18				
418	420	2				
418	426	8				
418	429	11				
420	421	1				
435	440	5				
462	463	1				

[a] Upper limit of length category.

likely. The use of the Petersen estimator over more than one year is predicated on the ability to detect growth recruitment and to cull those recruits from the estimate. Since it was not possible to precisely determine the upper extant of growth recruitment and because no lake trout were recaptured that were smaller than 347 mm at the time of marking in 1988, a single abundance estimate was calculated for fish larger than 345 mm FL. This estimate was subsequently used to calculate the abundance of lake trout of mature size.

Butte Lake:

The estimated abundance of lake trout 250 mm FL and larger in Butte Lake at the end of the 1988 season was 4,440 (SE = 710; Table 5). The surface area of Butte Lake is 318 ha (786 acres) hence the estimated density of lake trout 250 mm and larger in the lake was 14.0 lake trout per hectare (5.6 LT/acre). The estimated abundance of lake trout of mature size (LM_{50} and larger) in Butte Lake in 1988 was 2,124 (SE = 347) for a density of 6.7 lake trout per hectare (2.7 LT/acre; Table 2).

During 1988, 417 lake trout 250 mm or larger were captured marked and released in Butte Lake; 255 in June, and 163 in August (Table 6). In 1989, 433 lake trout 250 mm or larger were captured in gill nets; 180 in June and 253 in August. Four hundred twenty-three were captured in good condition, tagged and released. The remaining 10 fish were killed by the sampling gear.

Thirty-four of the 433 lake trout caught in 1989 were recaptured from 1988. Six of the lake trout captured during 1989 lost the floy tags from 1988, but since all tagged fish were also marked with a clipped adipose fin, the fish were recognized as recaptures.

Comparison of the lengths of lake trout marked in 1988 with lake trout recaptured from this marked group in 1989 (Appendix A4.) showed that the length distributions were not the same (Kolomogorov-Smirnov Two Sample Test; DN = 0.30, P = 0.02). This indicated that there was size selectivity in the sampling gear in 1989. Contingency table analysis comparing fish recaptured in 1989 and fish released with marks in 1988 (event 1) showed that capture rates were different for fish greater than and less than 425 mm FL (χ^2= 17.56, 1 df).

Since lake trout were marked in 1988 and recaptured in 1989, recruitment through growth was likely. Due to the small sample size involved (34 recaptured fish, Figure 4), the technique of Robson and Flick (1965) was inconclusive. However, growth of fish recaptured in 1989 from those marked in 1988 provided an estimate of length of recruitment. Lake trout 408 mm FL and smaller grew, on average, 35 mm (minimum 17 mm) between 1988 and 1989 (Table 7). In contrast, fish 438 mm and larger grew, on average, 3 mm (maximum 11 mm) during the same period. While the growth of fish between 408 and 438 mm FL is unknown, growth of lake trout larger than 438 mm FL was negligible between the sampling events. Hence, the length beyond which growth recruitment was negligible between sampling periods for lake trout in Butte Lake is between 408 and 438 mm FL.

Table 5. Estimated abundance of lake trout larger than 249 mm FL in Butte Lake in 1988.

Strata	Marked	Recaptured	Examined	$\bar{u}_r$[a]	Abundance Estimate	SE	Lake Trout per Hectare
250 - 425 mm	353	19	283	9.88	3,827	700	12
> 425 mm	64	15	150		613	122	2
Total	417	34	433		4,440	710	14

[a] Average number of unmarked to marked lake trout 425 mm FL and larger in 1988.

Table 6. Number of lake trout caught in gill nets at Butte Lake during 1988 and 1989.

Year	Period	Number of Lake Trout		
		Marked	Recaptured	Examined
1988	June	255	--	308
	August	163	3	204
	Total	417	3	512
1989	June	177	15	180
	August	246	20	253
	Total	423	34[a]	433

[a] One fish recaptured in both June and August.

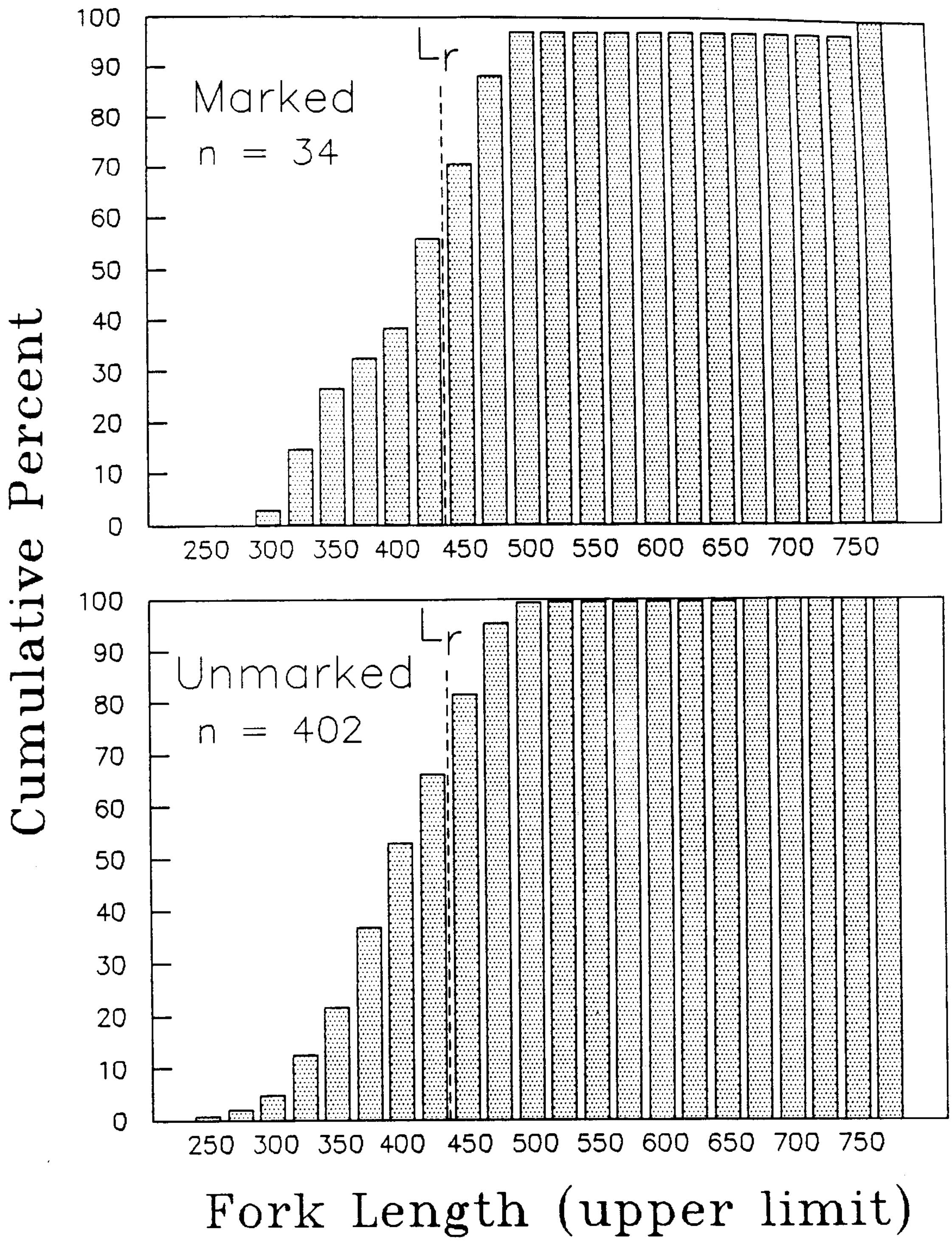

Figure 4. Cumulative distribution of lengths of marked (recaptured) and unmarked lake trout captured during 1989 in Butte Lake. L^r indicates length of upper extant of growth recruitment.

Table 7. Length (mm FL) of lake trout from Butte Lake at time of marking and recapture and growth (mm) between periods.

Length at: Marking	Length at: Recapture	Growth	Length Category	Mean Growth	Length[a] Category	Mean Growth
288	308	20	288 to 408	35.6	275	
292	323	31			300	25.5
305	347	42	438 to 765	2.9	325	35.2
306	331	25			350	57.0
308	325	17			375	
318	340	22			400	27.3
318	388	70			425	28.0
325	360	35			450	3.6
332	365	33			475	0.8
337	406	69			500	6.0
340	409	69			525	
380	410	30			550	
384	404	20			575	
387	424	37			600	
391	413	22			625	
408	436	28			650	
438	438	0			675	
445	447	2			700	
446	448	2			725	
448	457	9			750	
450	455	5			775	2.0
455	453	-2			800	
457	465	8				
466	466	0				
473	470	-3				
476	487	11				
489	490	1				
765	767	2				
tag loss	295					
tag loss	319					
tag loss	329					
tag loss	384					
tag loss	445					
tag loss	481					

[a] Upper limit of length category.

To give consideration to both size selectivity of the sampling gear and growth recruitment, the data were divided into two strata, fish 250 mm to 425 mm and fish larger than 425 mm. With the assumption that recruitment through growth for lake trout 426 mm to 437 mm FL is negligible (Table 7), an unbiased estimate of abundance for fish larger than 425 mm was obtained with the modified Petersen estimator (Table 5). The abundance of fish between 250 mm and 425 mm was made after growth recruitment was removed. The abundance of fish in the smaller size category is estimated with the estimator of Robson and Flick.

Glacier Lake:

Too few lake trout were recaptured during the sampling period in August from fish marked in June and July of 1989 to yield a meaningful abundance estimate.

During the marking period, 154 lake trout were captured in gill nets. Of these fish, 120 were marked and released while 34 were killed in the sampling gear. During August 1989, catch rates were higher and 298 lake trout were captured in gill nets. Only six of the fish caught in August were recaptured from the marking period in 1989 (Appendix A5).

Comparison of lengths of fish marked during the sampling period in June and July with the fish recaptured during August failed to detect a difference (Kolmogorov-Smirnov two-sample test $D = 0.27$, $P = 0.70$); but, the sample size is very small. Comparison of lengths of fish captured during the marking period with those from the recapture period detected a difference (Kolmogorov-Smirnov two-sample test $D = 0.14$, $P = 0.03$). This indicates size selectivity in the marking event.

The catch rates of lake trout were higher in August than they were in June and July. The higher catch rates are probably due to the movement of lake trout into shallow areas prior to the spawning season. However, since Glacier Lake has an outlet which will pass fish at various times in the summer, it is possible that a portion of the fish captured in August were not present in the lake during June and July.

In 1986 a similar mark-recapture experiment was successfully conducted at Glacier Lake (Burr 1987b). At the end of sampling in 1986, 255 lake trout were marked in the population. During sampling in 1989, 21 of these 255 fish were recaptured; six in June and July and 15 during August. Additional sampling at Glacier Lake is planned during August of 1990 to estimate the abundance of lake trout during 1989.

Island Lake:

The abundance estimate for lake trout at Island lake was abandoned at the end of the first sampling period due to extremely low catch rates. Between 6 July and 13 July only 34 lake trout were caught in gill nets in Island Lake (Appendix A6).

Paxson Lake:

The estimated abundance of spawning lake trout in Paxson Lake in 1988 was 4,895 (SE = 955; Table 8). The surface area of Paxson Lake is 1,575 ha hence the estimated density of spawning lake trout is 3.1 per hectare (1.3 per acre).

Lake trout have been sampled annually in September since 1987. In 1987, 349 lake trout were caught of which 265 were marked. In 1988, 1,025 lake trout were caught and 964 were tagged. In 1989, 980 lake trout were caught and 947 were released with tags. All lake trout were in spawning condition.

The distribution of lengths of fish caught in 1988 and in 1989 were compared and no significant difference was detected (Kolmogorov-Smirnov two-sample test D = 0.06, P = 0.08). Growth of individual fish was evident but since the Jolly-Seber model allows for recruitment no adjustment was necessary.

A large number of male lake trout and a few female lake trout were captured in consecutive years. Fifteen percent of the fish captured in 1987 were again captured in 1988. Twenty-four percent of the fish marked in 1988 were recaptured in 1989. Nineteen percent of the fish captured in 1989 were seen in 1987. Of the 980 fish captured in 1989, 12 were caught all three years. Approximately 75% of the fish captured each year were males. It is interesting to note that the largest female (910 mm) that was captured in 1988 was again captured in 1989. This fish was live spawned in both years. Eggs were stripped from this fish in both years and she was released in good condition.

Population Structure

Proportions of lake trout in various size categories and mean size-at-age were estimated. Maturity estimates were limited to lake trout populations in Paxson, Sevenmile, Fielding, Butte, and Glacier lakes.

Relative Stock Density:

Although data on RSD were obtained from the six lake trout populations sampled in 1989, the estimate of RSD from the lake trout population in Butte Lake was the only estimate that was unbiased. It was not possible to determine if the gear used to capture lake trout in Island, Glacier and Fielding lakes was size selective without completed mark-recapture experiments. Hence, the RSD data collected from these populations may be biased. The data from Sevenmile and Paxson lakes are for only a portion of the populations. Since the length biases, if any, in the samples from Island, Glacier and Fielding lakes are unknown, the RSD from these samples are included here as the number sampled in each category.

The sample of lake trout from Butte Lake collected in 1989 was biased as a result of size selectivity of sampling gear. In addition, comparison of the distribution of lengths of lake trout captured in 1988 with those captured in 1989 showed that they were not the same (Kolmogorov-Smirnov two sample test;

Table 8. Spawning lake trout captured, marked, and recaptured in Paxson Lake, 1987 through 1989, and estimated abundance in September 1988.

	Number of Lake Trout		
	1987	1988	1989
Recaps from 1987	--	40	50
Recaps from 1988	--	--	231
Recaps from 1989	--	--	--
Captured with tags	--	42	281
Captured without tags	348	983	699
Total captured	349	1,025	980
Released with tags	265	964	947
Released without tags	1	0	0
Total Released	266	964	947
Abundance Estimate	--	4,895	--
SE	--	955	--
Lake trout per hectare	--	3.1	--

DN = 0.42, P < 0.01). Therefore, the status of size selectivity during 1988 (the first period) is unknown. The proportions of lake trout in size categories in the lake trout population from Butte Lake were therefore estimated only from data collected during 1989 and were adjusted for length bias (Table 9).

Only one lake trout captured from the six lakes sampled in 1989 was of trophy size (> 895 mm FL; Table 9, Figure 4). This fish was captured in Paxson Lake during the spawning season. A small portion of the lake trout sampled from Paxson Lake (0.7%), Fielding Lake (3.0%), and from Butte Lake (0.1%) were memorable (715-894 mm FL). Twenty-three percent of the lake trout caught in Paxson Lake and 11% of lake trout in Fielding Lake were of preferred (546-714 mm FL) size. Few lake trout sampled from Glacier Lake (2.0%) and Butte Lake (0.1 %) were in the preferred category. The highest proportion of lake trout of quality size (454-545 mm FL) were found in Paxson (57.0%) and Fielding (58.0%) lakes; lake trout of quality size were less common in Butte, Sevenmile, Island, and Glacier lakes. Most of the lake trout sampled from these four lakes (78 to 93%) were of stock size (240-453 mm FL) or smaller.

Maturity:

Length at Maturity. Estimates of the length at which 50% of the lake trout mature (LM_{50}) ranged from 362 mm FL for lake trout from Paxson Lake to 440 mm FL for fish from Fielding Lake (Table 10; Figure 6). Lake trout mature at similar size in Butte Lake (LM_{50} = 369 mm), Sevenmile Lake (LM_{50} = 368 mm), Glacier Lake (LM_{50} = 363 mm), and Paxson Lake (LM_{50} = 362 mm). The limited sample from Fielding Lake indicates that 50% of the lake trout are mature at a larger size than is the case for other studied lake trout populations in Alaska. In most lakes, males matured at somewhat smaller size than did females. However, females were statistically different from males only in Paxson Lake as shown by overlap in fiducial limits (Table 10).

The samples were too few from Island Lake to estimate length at 50% maturity. However the samples indicate that lake trout in this population mature at lengths in excess of 400 mm; all lake trout 460 mm and larger were mature and lake trout 338 mm and smaller were immature (Appendix A6).

Age of Maturity. 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 11, Figure 6). In Fielding Lake, the AM_{50} was 6.8 years. The AM_{50} for lake trout in Butte Lake was 8.5 years (males = 8.4, females = 7 - 9). 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, it was not possible to estimate the AM_{50} for lake trout from Sevenmile Lake. However, all fish age 4 and younger were immature, and all fish age 6 and older were mature. Approximately 70% of the age 5 fish were mature. No estimate of age at maturity was possible for lake trout in Island Lake. Lake trout age 12 and older sampled from the Island Lake were mature and lake trout age 5 years and younger were immature.

Table 9. Relative Stock Density of the lake trout population in Butte Lake and of lake trout sampled in Sevenmile, Island, Glacier, Fielding and Paxson lakes (after Gabelhouse 1984).

Lake		Length Group[a]				
		Stock (240 mm)	Quality (454 mm)	Preferred (546 mm)	Memorable (715 mm)	Trophy (895 mm)
	$\hat{N}$	4138	294	4	4	0
Butte[b]	%	93	6.6	0.1	0.1	0
	SE(%)	7.1	7.1	1.1	1.1	
	n	136	17	0	0	0
Sevenmile	%	88.9	11.1	0	0	0
	SE(%)	2.5	2.5			
	n	45	12	0	0	0
Island	%	78.9	21.1	0	0	0
	SE(%)	5.5	5.5			
	n	421	24	7	0	0
Glacier	%	93.1	5.3	1.6	0	0
	SE(%)	1.2	1.1	0.6		
	n	27	57	11	3	0
Fielding	%	27.5	58.2	11.2	3.1	0
	SE(%)	4.5	5.0	3.2	1.8	
	n	186	553	225	7	1
Paxson	%	19.1	56.9	23.2	0.7	0.1
	SE(%)	1.3	1.6	1.4	0.3	0.1

[a] Lower limit of length category in parenthesis.
[b] Adjusted for size selectivity.

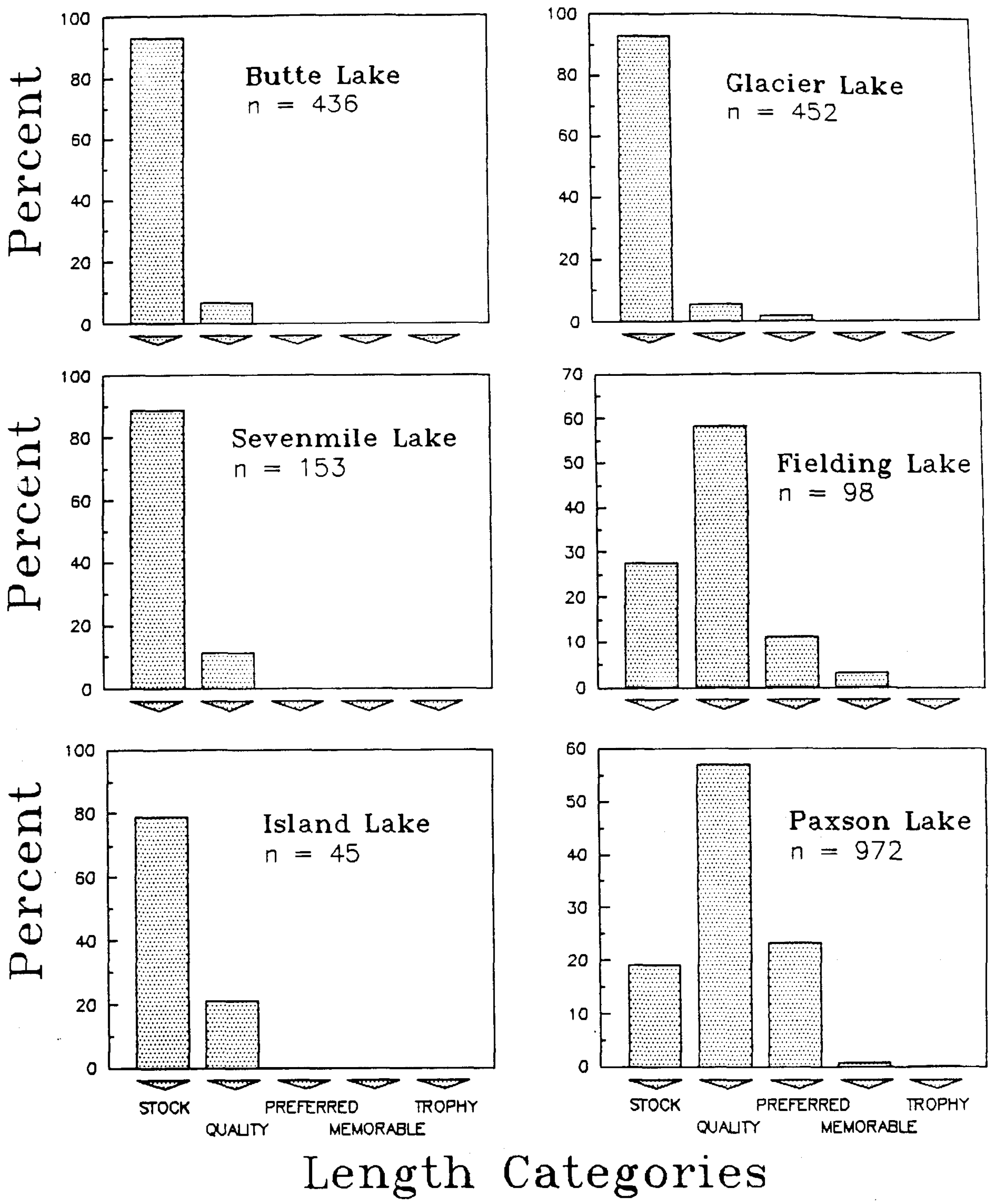

Figure 5. Relative Stock Density of the lake trout population in Butte Lake and Relative Stock Density of lake trout sampled from Paxson, Sevenmile, Fielding, Glacier, and Island lakes in 1989.

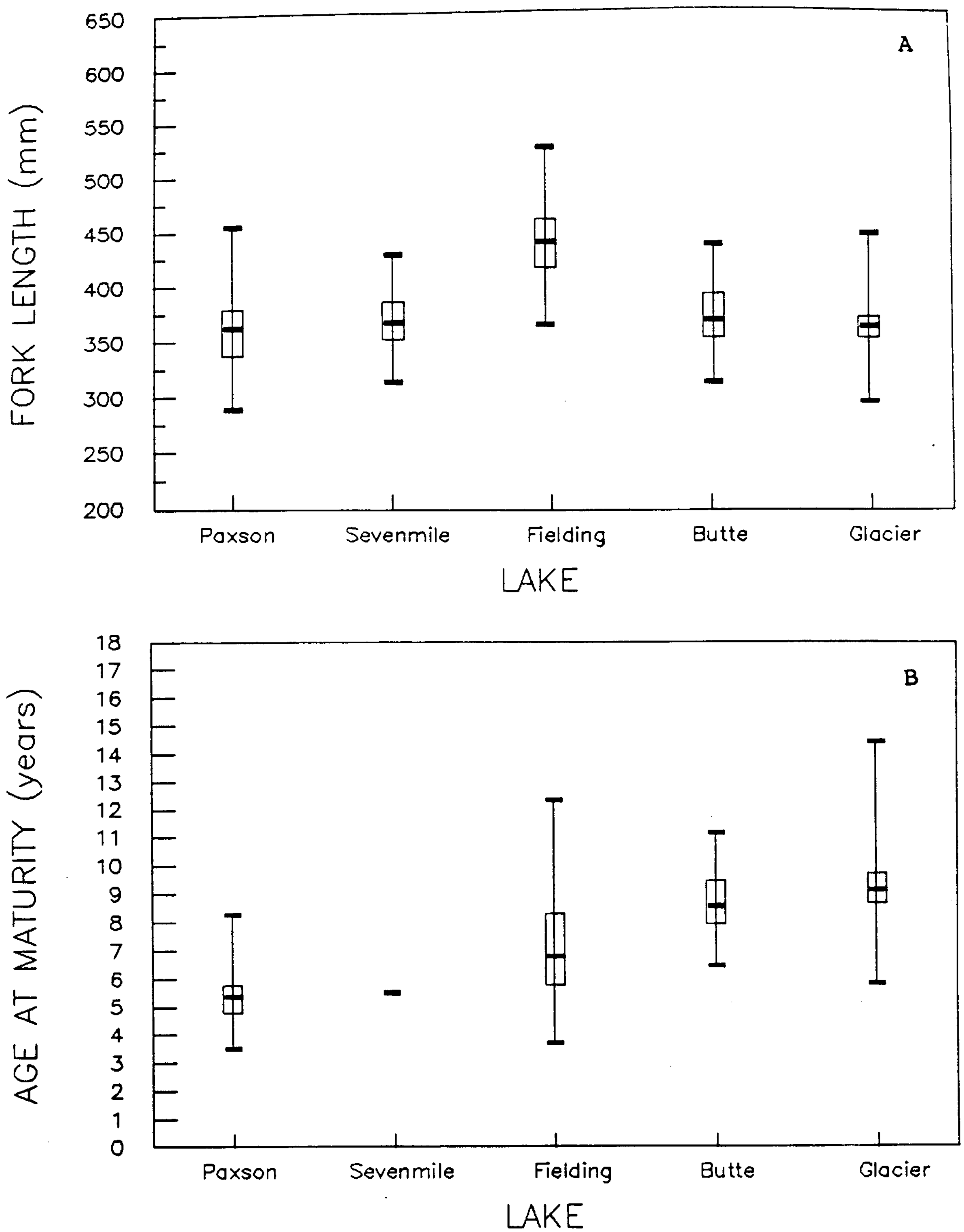

Figure 6. Length at maturity (A) and age at maturity (B) of lake trout from five populations in Alaska. Lengths (LM_{50}) and ages (AM_{50}) at 50% maturity are shown as solid bars inside rectangles which show 95% fiducial limits around the estimates. Lower ends of the vertical lines show length and age at 1% maturity and upper ends length and age at 99% maturity.

Table 10. Estimated lengths (mm FL) at which 50% (LM_{50}), 1% (LM_1) and 99% (LM_{99}) of lake trout are mature for five 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)	111	368	355	383	315	276	332	429	406	496
(Females)	38	375	355	401	322	258	344	436	405	563
(Males)	27	367	343	389	327	235	348	411	388	562
FIELDING										
(Both)	60	440	418	457	367	299	395	526	495	622
(Females)	21	450 - 500								
(Males)	39	419	362	441	352	200	389	499	466	706
BUTTE										
(Both)	114	369	357	389	313	283	328	436	408	508
(Females)	60	375	355	423	311	244	332	452	408	683
(Males)	52	363	345	393	312	264	332	452	392	535
GLACIER										
(Both)	373	363	357	370	296	281	307	446	432	465
(Females)	171	361	350	371	285	261	302	456	434	492
(Males)	175	368	358	376	312	290	327	432	419	457

Table 11. Estimated ages of maturity at which 50% (AM_{50}), 1% (AM_1) and 99% (AM_{99}) of lake trout are mature for five 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)	89	5 - 6	(NO AM_{50}'s are possible, all Age 4 and younger were immature; all Age 6 and older were mature; partial maturity at Age 5)							
(Females)	37									
(Males)	27									
FIELDING										
(Both)	34	6.8	5.9	8.3	3.7	1.1	4.8	12.4	9.4	49.6
(Females)	16	7 - 8								
(Males)	18	5 - 8								
BUTTE										
(Both)	111	8.5	8.0	9.3	6.4	5.6	6.9	11.1	10.0	14.1
(Females)	57	7 - 9								
(Males)	42	8.4	7.8	9.5	6.3	5.0	7.0	11.2	9.8	16.2
GLACIER										
(Both)	294	9.2	8.8	9.7	5.9	5.2	6.4	14.5	13.2	16.5
(Females)	141	9.2	8.6	9.8	5.6	4.5	6.4	14.9	13.1	18.6
(Males)	135	9.3	8.5	10.1	6.2	4.7	7.0	14.0	12.3	18.5

Size at Age:

Estimates of the mean length at age were calculated for lake trout sampled from Paxson, Butte, Fielding, Glacier, Sevenmile, and Island lakes (Tables 12-17). Lake trout in the samples from Paxson Lake grew fastest and attained the largest size. Growth of lake trout from Fielding Lake was similar to the growth seen in the younger age classes of fish from Paxson Lake, but no fish older than age 13 were sampled. Lengths at age for lake trout from Sevenmile Lake indicate growth rates similar to the 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 and Butte lakes are very similar, showing slower growth than fish from Paxson, Fielding, or Sevenmile lakes.

DISCUSSION

Abundance Estimates

Abundance of mature lake trout in lakes for which estimates were performed in 1989 ranged from 3.1 fish per hectare in Paxson Lake to 23.9 fish per hectare in Sevenmile Lake. The estimated density of mature lake trout in Butte Lake is 6.7 fish per hectare. Burr (1989) previously estimated abundance of mature lake trout in Sevenmile Lake to be 13.9 fish per hectare. Abundance of mature lake trout in Glacier Lake in 1986 was estimated to be 1,724 fish or 9.7 fish per hectare and in Landlocked Tangle Lake (241 ha) to be 1,645 lake trout or 6.8 fish per hectare Burr (1988). Comparable estimates of lake trout density from other areas of Alaska are not available. The few estimates available from outside Alaska indicate that most lake trout stock densities are between one and 14 fish per hectare (Martin and Olver 1980). The estimated stock of mature lake trout (age 6 and older) in Swan Lake, Alberta, calculated from mark-recapture experiments, was 226 fish or 1.13 fish per hectare for this 200 ha lake (Paterson 1968). In the much larger Thompson Lake, Maine (1,791 ha), the estimated abundance of lake trout larger than 356 mm was 19,252, or 10.7 fish per hectare (De Roche unpublished, from Martin and Olver 1980). The estimates of lake trout densities from these five lakes in Alaska lie in the middle to upper range of reported densities.

Densities of lake trout in the five lakes from Alaska show an inverse relationship with lake surface area (Table 2). An inverse relationship with density and or yield and lake area is consistent with reports by Carlander (1977), Goddard et al. (1987) and others. This implies that smaller lakes produce more fish than larger lakes on a per unit area basis. Such a trend is intuitively reasonable since larger oligotrophic lakes in which lake trout are typically found, generally have a greater proportion of deep, relatively less productive habitat than do smaller lakes.

Abundance in numbers does not necessarily correlate well with the biomass of a population. For example, planktivorous and piscivorous populations of lake trout of equivalent biomass may differ widely in abundance because of the typically small average size of the planktivorous fish. Martin and Olver (1980) report that the densest stocks of lake trout generally occur in those

Table 12. Estimated mean length (mm FL) at age (from otoliths) of lake trout from Paxson Lake, 1988-1989.

Age	All Lake Trout			Female Lake Trout			Male 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		0			0			0	
4	377	4	9	390	1		364	2	14
5	410	32	5	397	8	9	420	19	6
6	444	42	5	444	18	11	437	17	5
7	463	39	6	483	9	14	455	29	7
8	495	40	7	526	17	11	471	20	7
9	491	19	7	508	5	11	480	13	7
10	510	8	23	568	3	32	475	5	18
11	556	12	10	568	6	20	545	5	6
12	514	7	22	570	3	13	471	4	16
13	604	10	37	541	4	8	646	6	57
14	594	7	29	600	6	34	558	1	
15	565	20	5	567	12	7	557	7	7
16	600	8	13	606	6	16	581	2	9
17	572	10	6	565	4	11	577	6	8
18	583	5	5	577	2	3	588	2	13
19	607	11	25	632	5	55	579	4	15
20	621	3	6	621	3	6		0	
21	568	7	11	583	1		569	5	15
22	577	4	8	579	3	12	572	1	
23	638	6	51	655	5	59	553	1	
24	673	7	50	681	6	58	625	1	
25	548	1			0		548	1	
26	638	2	28	610	1			0	
27		0			0			0	
28	649	2	4	652	1		645	1	
29	579	4	6	573	3	3		0	
30		0			0			0	
31		0			0			0	
32		0			0			0	
33	610	1		610	1			0	
34		0			0			0	
ALL	512	311	5	542	133	8	488	152	6

Table 13. Estimated mean length (mm FL) at age (from otoliths) of lake trout from Butte Lake, 1988-89.

	All Lake Trout			Female Lake Trout			Male 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			0	
2		0			0			0	
3		0			0			0	
4	274	1			0		274	1	
5	285	7	5	285	6	5		0	
6	300	48	2	300	27	3	301	21	3
7	323	36	3	330	17	6	316	18	3
8	386	3	8		0		395	2	2
9	416	5	20	397	1		397	3	14
10	395	8	13	374	4	10	415	4	18
11	400	1			0		400	1	
12	438	1			0		438	1	
13	426	1		426	1			0	
14		0			0			0	
15	466	1		466	1			0	
16		0			0			0	
17		0			0			0	
18		0			0			0	
19	496	1			0		496	1	
20		0			0			0	
ALL	327	113	4	319	57	5	332	52	7

Table 14. Estimated mean length (mm FL) at age (from otoliths) of lake trout from Fielding Lake, 1987-1989.

	All Lake Trout			Female Lake Trout			Male 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			0	
2		0			0			0	
3		0			0			0	
4	327	4	20	332	2	48		0	
5	372	9	17	378	2	23	437	2	34
6	409	23	8	414	6	20	421	8	11
7	436	14	9	456	3	15	410	1	
8	504	15	27	492	3	55	495	6	17
9	537	3	28	547	1			0	
10	486	2	4		0		486	2	4
11		0			0			0	
12		0			0			0	
13	700	2	6	705	1			0	
14		0			0			0	
15		0			0			0	
ALL	439	73	11	439	19	22	452	19	11

Table 15. Estimated mean length (mm FL) at age (from otoliths) of lake trout from Glacier Lake, 1986-1989.

	All Lake Trout			Female Lake Trout			Male Lake Trout		
Age	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE
0		0			0			0	
1	127	3	2		0			0	
2	160	2	3		0			0	
3	203	2	2		0			0	
4	264	11	9	249	4	14	273	5	12
5	274	29	5	293	13	6	264	9	5
6	292	28	7	289	14	9	298	13	11
7	324	33	4	326	19	7	321	14	5
8	345	37	4	340	15	4	349	22	6
9	356	23	5	357	13	6	357	9	10
10	392	10	8	395	4	9	391	6	13
11	405	23	4	410	12	6	399	11	5
12	409	15	4	414	6	7	404	8	6
13	439	22	13	446	10	22	432	12	17
14	422	13	4	420	8	4	422	4	11
15	430	9	7	438	4	10	424	5	9
16	430	4	8	430	3	11	430	1	
17	431	4	6	438	2	8	423	2	7
18	459	5	35	471	4	42	410	1	
19	424	6	6	413	1		426	4	8
20	414	3	4	416	2	6	410	1	
21	447	1		447	1			0	
22	423	3	4	423	1		423	2	8
23	425	3	9	443	1		416	2	2
24	436	1		436	1			0	
25		0			0			0	
26	426	3	5	437	1		421	2	1
27	441	1		441	1			0	
28	430	1		430	1			0	
29	435	1			0		435	1	
30		0			0			0	
31		0			0			0	
32	441	1		441	1			0	
33	418	1			0		418	1	
34		0			0			0	
ALL	358	298	4	367	142	6	364	135	5

Table 16. Estimated mean length (mm FL) at age (from otoliths) of lake trout from Sevenmile Lake, 1987-1989.

	All Lake Trout			Female Lake Trout			Male Lake Trout		
Age	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE	Mean Length	Sample Size	SE
0		0			0			0	
1	93	12	4		0			0	
2	188	8	10	173	2	3	218	2	37
3	301	7	12	313	4	18	284	3	10
4	334	24	6	330	14	9	340	10	7
5	378	10	10	371	6	15	388	4	13
6	403	3	4	403	3	4		0	
7	421	6	8	430	3	4	411	3	13
8	409	3	7	420	1		404	2	7
9	426	3	31	458	2	1	364	1	
10	422	3	5	425	2	8	418	1	
11	422	1			0		422	1	
12	412	1			0		412	1	
13	429	1		429	1			0	
14	456	3	8	462	2	10	445	1	
15	430	1		430	1			0	
ALL	315	86	12	364	41	11	365	29	11

Table 17. Estimated mean length (mm FL) at age (from otoliths) of lake trout from Island Lake, 1989.

	All Lake Trout			Female Lake Trout			Male 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			0	
2		0			0			0	
3	265	1		265	1			0	
4	284	1			0		284	1	
5	320	2	19		0		320	2	19
6		0			0			0	
7		0			0			0	
8		0			0			0	
9		0			0			0	
10		0			0			0	
11		0			0			0	
12	464	1			0			1	
13		0			0			0	
14		0			0			0	
15		0			0			0	
16	460	1					460	1	
ALL	352	6	36	265	1	0	369	5	35

lakes where fish mature at a small size, are planktivorous, and where the average size of fish is between 300-400 mm. Hence the relatively high densities of lake trout found in four of the five lakes in Alaska is likely related 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 1989 have provided estimates of size composition from five populations of lake trout in the study area as well as estimates of maturity for these populations. However, in many cases the sample sizes were too small to provide conclusive comparisons, particularly for estimates of age composition and size at age. ADF&G will continue to collect data from the populations in each of these lakes from creel census contacts and from test netting. These data will be accumulated across years and added to the existing data base to improve the accuracy and precision of the estimates of population structure.

The size composition of lake trout estimated as RSD is similar for the populations of lake trout from Butte, Sevenmile, Glacier and Island 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 (72% ≥ 454 m FL) and from Paxson Lake (81% ≥ 454 m FL). However this difference in the size composition of lake trout from Paxson Lake is probably because these fish were captured from spawning concentrations.

The estimate of the RSD for the population in Butte Lake in 1989 was adjusted for bias. Separation of the data on lengths of fish captured in 1989 into two strata to adjust for bias from gear selectivity and growth recruitment is based on the size structure in the population in 1988. The distributions of lengths of fish sampled in the two years are not the same, and there is no independent evidence that 425 mm is the best length at which to split the data. Thus, this division at 425 mm is not necessarily optimal, and the estimate of length composition could be slightly biased. However, with the information available it is the best estimate of population size structure in 1989, and, although it may be biased, it is less biased than an estimate in which no adjustments are made.

The estimates of length at which lake trout of both sexes mature are very similar for the four lakes for which there are sufficient sample sizes; LM_{50}'s ranged from 362 to 369 mm (Table 10). The estimate from Fielding Lake (440 mm) was much higher but samples were too few for complete analysis. Female lake trout from fast growing populations (eg. Paxson and Fielding lakes) matured at a relatively larger size. For slower growing populations, less difference was seen between males and females. Estimates of length at maturity from these 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 minimum necessary size for maturity for the species.

The estimated LM_{50} for the lake trout population of Butte Lake is 368 mm. Information from growth of marked and recaptured fish showed that growth slows for fish larger than 408 mm FL. Similarly, in Sevenmile Lake, growth of lake trout slowed for fish between 345 to 390 mm; the estimated LM_{50} for the Sevenmile Lake population is 368. Other researchers have noted that lake trout growth slows markedly once maturity is reached (Healey 1978).

Mature lake trout do not necessarily spawn every year. Intermittent or nonconsecutive spawning is common in lake trout populations in northern latitudes (eg. Great Bear Lake, Great Slave Lake, and Keller Lake; Martin and Olver 1980). Annual spawning is more common in more southern locations. Nearly all populations of lake trout which have been investigated in Alaska demonstrate intermittent spawning once maturity is reached (Burr 1987a). The cause for the apparent clinal relationship between frequency of spawning and latitude is not known but has been suggested to be linked to photoperiod and to the unproductive nature of far northern lakes. The environmental effect of the availability of suitable forage would seem to be the most critical factor controlling frequency of reproduction. In contrast to other studies, we now have evidence that females from Paxson Lake spawn on an annual basis. This is likely due to the productive nature of this lake and the enhanced population of sockeye salmon *Oncorhynchus nerka* in the lake.

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 Butte Lake, no fish older than age 19 were found. However, in this lake, lake trout were captured that were larger than those for which we have estimates of age. This indicates that a few older fish are present in this population. In contrast, relatively old lake trout (age > 25) were well represented in the samples from the populations of Paxson and Glacier lakes. All lakes sampled, with the exception of Glacier Lake, show a dominance of younger age (age 4-8) fish. All of these lakes except for Glacier and Butte lakes have direct road access. The absence of significant proportions of older fish in most of these populations appears to be a result of fishing having cropped off the older age classes.

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 1989. The faster growth of lake trout in Paxson Lake is probably a result of the availability of large numbers of sockeye salmon fry and smolt and, to a lesser degree, round and humpback whitefish *Coregonus pidschian* and Arctic grayling *Thymallus arcticus* which provide an excellent forage base. The forage base in Butte Lake and in the Tanana drainage lakes is lower. Whitefish and other fish species are present in most of the other lakes sampled, but sockeye salmon are absent. Lake trout from Butte and Glacier lakes 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 young age. The good growth, the absence of older age classes, and young age at maturity suggests a response by the lake trout population in Sevenmile Lake to fishing pressure in this small lake which has excellent road access

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APPENDIX A

Appendix A1. Lake trout sampled larger than 250 mm FL in Sevenmile Lake in 1988 and 1989.

		Number of Lake Trout		
Year	Gear	Marked	Recaptured	Examined
1988	Gill Net	151	--	165
	Fyke Net	2	--	2
	Hoop Net	3	--	3
	Total	156	--	170
1989	Gill Net	141	17	150
	Fyke Net	3	0	3
	Hoop Net	2	0	2
	Total	146	17	155

Appendix A2. Length frequencies (listed by gear type) of all lake trout captured and marked during 1988 in Sevemile Lake.

Fork Length[a]	Captured								Marked							
	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	3	10.0	0	0.0	3	1.5	0	0.0	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	0.0	0	0.0	0	0.0
100	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
125	0	0.0	11	36.7	0	0.0	11	5.5	0	0.0	0	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	0.0	0	0.0	0	0.0
175	0	0.0	4	13.3	0	0.0	4	2.0	0	0.0	0	0.0	0	0.0	0	0.0
200	0	0.0	6	20.0	0	0.0	6	3.0	0	0.0	0	0.0	0	0.0	0	0.0
225	0	0.0	4	13.3	0	0.0	4	2.0	0	0.0	0	0.0	0	0.0	0	0.0
250	2	1.2	1	3.3	0	0.0	3	1.5	2	1.3	1	50.0	0	0.0	2	1.3
275	6	3.6	0	0.0	0	0.0	6	3.0	6	3.9	0	0.0	0	0.0	6	3.8
300	9	5.4	0	0.0	0	0.0	9	4.5	7	4.6	0	0.0	0	0.0	7	4.5
325	2	1.2	0	0.0	0	0.0	2	1.0	2	1.3	0	0.0	0	0.0	2	1.3
350	15	9.0	0	0.0	0	0.0	15	7.5	9	5.9	0	0.0	0	0.0	9	5.7
375	29	17.4	0	0.0	0	0.0	29	14.5	28	18.3	0	0.0	0	0.0	28	17.8
400	19	11.4	0	0.0	0	0.0	19	9.5	18	11.8	0	0.0	0	0.0	18	11.5
425	37	22.2	0	0.0	2	66.7	39	19.5	35	22.9	0	0.0	2	66.7	37	23.6
450	32	19.2	1	3.3	0	0.0	33	16.5	31	20.3	1	50.0	0	0.0	32	20.4
475	15	9.0	0	0.0	0	0.0	15	7.5	14	9.2	0	0.0	0	0.0	14	8.9
500	1	0.6	0	0.0	1	33.3	2	1.0	1	0.7	0	0.0	1	33.3	2	1.3
525	0	0.0	0	0.0	0	0.0	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	0.0	0	0.0	0	0.0
Total	167		30		3		200		153		2		3		157	

[a] Upper limit length category.

[b] Sample size.

Appendix A3. Length frequencies (listed by gear type) of all lake trout captured in 1989 and recaptured from 1988 during 1989 in Sevemile Lake.

Fork Length[a]	Captured								Recaptured From 1988							
	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	0	0	0	0	0.0
75	0	0.0	4	3.3	0	0.0	4	1.5	0	0.0	0	0	0	0	0	0.0
100	0	0.0	19	15.8	0	0.0	19	7.0	0	0.0	0	0	0	0	0	0.0
125	0	0.0	70	58.3	0	0.0	70	25.7	0	0.0	0	0	0	0	0	0.0
150	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0.0
175	0	0.0	11	9.2	0	0.0	11	4.0	0	0.0	0	0	0	0	0	0.0
200	0	0.0	13	10.8	0	0.0	13	4.8	0	0.0	0	0	0	0	0	0.0
225	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0.0
250	7	4.7	0	0.0	0	0.0	7	2.6	0	0.0	0	0	0	0	0	0.0
275	10	6.7	1	0.8	0	0.0	11	4.0	0	0.0	0	0	0	0	0	0.0
300	8	5.3	1	0.8	0	0.0	9	3.3	0	0.0	0	0	0	0	0	0.0
325	4	2.7	0	0.0	0	0.0	4	1.5	0	0.0	0	0	0	0	0	0.0
350	5	3.3	0	0.0	0	0.0	5	1.8	0	0.0	0	0	0	0	0	0.0
375	10	6.7	0	0.0	0	0.0	10	3.7	0	0.0	0	0	0	0	0	0.0
400	26	17.3	1	0.8	0	0.0	27	9.9	5	29.4	0	0	0	0	5	29.4
425	30	20.0	0	0.0	0	0.0	30	11.0	3	17.6	0	0	0	0	3	17.6
450	32	21.3	0	0.0	2	100.0	34	12.5	6	35.3	0	0	0	0	6	35.3
475	11	7.3	0	0.0	0	0.0	11	4.0	2	11.8	0	0	0	0	2	11.8
500	7	4.7	0	0.0	0	0.0	7	2.6	1	5.9	0	0	0	0	1	5.9
525	0	0.0	0	0.0	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	0	0	0	0	0.0
Total	150		120		2		272		17		0		0		17	

[a] Upper limit length category.

[b] Sample size.

Appendix A4. Length frequencies of lake trout captured at Butte Lake and recaptured during sampling in 1988 and 1989.

Fork Length[a]	June 1988				August 1988				All 1988				June 1989				August 1989		All 1989					
	Captured		Marked		Captured		Recaptured		Captured		Marked		Captured		Marked		Captured		Captured		Marked		Recaptured	
	n[b]	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
200	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.6	1	0.6	0	0.0	1	0.2	1	0.2	0	0.0
225	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.6	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0
250	3	1.0	3	1.2	3	1.5	0	0.0	6	1.2	6	1.4	2	1.1	0	0.0	0	0.0	2	0.5	0	0.0	0	0.0
275	18	5.8	16	6.3	17	8.3	0	0.0	35	6.8	31	7.4	5	2.8	5	2.8	1	0.4	6	1.4	6	1.4	0	0.0
300	53	17.2	34	13.3	33	16.2	1	33.3	86	16.8	54	12.9	12	6.7	12	6.8	0	0.0	12	2.8	12	2.8	1	2.9
325	90	29.2	66	25.9	41	20.1	0	0.0	131	25.6	93	22.2	32	17.8	32	18.1	3	1.2	35	8.0	34	8.0	4	11.8
350	47	15.3	43	16.9	16	7.8	1	33.3	63	12.3	53	12.7	37	20.6	37	20.9	4	1.6	41	9.4	40	9.4	4	11.8
375	27	8.8	24	9.4	15	7.4	0	0.0	42	8.2	37	8.9	35	19.4	35	19.8	28	10.9	63	14.4	62	14.6	2	5.9
400	32	10.4	32	12.5	18	8.8	0	0.0	50	9.8	48	11.5	16	8.9	16	9.0	50	19.5	66	15.1	63	14.9	2	5.9
425	13	4.2	13	5.1	19	9.3	0	0.0	32	6.3	32	7.7	15	8.3	15	8.5	44	17.2	59	13.5	57	13.4	6	17.6
450	12	3.9	11	4.3	15	7.4	0	0.0	27	5.3	26	6.2	13	7.2	13	7.3	54	21.1	67	15.4	67	15.8	5	14.7
475	9	2.9	9	3.5	17	8.3	1	33.3	26	5.1	24	5.7	9	5.0	9	5.1	52	20.3	61	14.0	61	14.4	6	17.6
500	3	1.0	3	1.2	8	3.9	0	0.0	11	2.1	11	2.6	2	1.1	2	1.1	17	6.6	19	4.4	18	4.2	3	8.8
525	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4	1	0.2	1	0.2	0	0.0
550	0	0.0	0	0.0	1	0.5	0	0.0	1	0.2	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
575	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
600	0	0.0	0	0.0	1	0.5	0	0.0	1	0.2	1	0.2	0	0.0	0	0.0	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	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
650	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
675	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4	1	0.2	1	0.2	0	0.0
700	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
725	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
750	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
775	1	0.3	1	0.4	0	0.0	0	0.0	1	0.2	1	0.2	0	0.0	0	0.0	1	0.4	1	0.2	1	0.2	1	2.9
800	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	308		255		204		3		512		418		180		177		256		436		424		34	

[a] Upper limit length categories.

[b] Sample size.

Appendix A5. Length frequencies of lake trout captured and recaptured in Glacier Lake during 1989.

Fork Length[a]	June				August			
	Captured		Marked		Captured		Recaptured	
	n[b]	%	n	%	n	%	n	%
225	0	0.0	0	0.0	0	0.0	0	0.0
250	3	1.9	3	2.5	5	1.7	0	0.0
275	10	6.5	8	6.7	21	7.0	1	16.7
300	12	7.8	8	6.7	21	7.0	0	0.0
325	12	7.8	7	5.8	26	8.7	0	0.0
350	19	12.3	8	6.7	27	9.1	0	0.0
375	19	12.3	16	13.3	25	8.4	2	33.3
400	28	18.2	26	21.7	41	13.8	1	16.7
425	24	15.6	19	15.8	66	22.1	0	0.0
450	17	11.0	15	12.5	42	14.1	0	0.0
475	6	3.9	6	5.0	14	4.7	2	33.3
500	1	0.6	1	0.8	2	0.7	0	0.0
525	2	1.3	2	1.7	1	0.3	0	0.0
550	0	0.0	0	0.0	1	0.3	0	0.0
575	0	0.0	0	0.0	2	0.7	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	0	0.0	0	0.0	1	0.3	0	0.0
675	0	0.0	0	0.0	3	1.0	0	0.0
700	1	0.6	1	0.8	0	0.0	0	0.0
Total	154		120		298		6	

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

Appendix A6. Lake trout captured in gill nets from Island Lake.

Fork Length	Total Weight	Sex	Maturity	Age	Tag Number
265	200	F	Immature	3	
284	220	M	Immature	4	
301	270	M	Immature	5	
338	420	M	Immature	5	
460	1250	M	Mature	16	
464	1250	M	Mature	12	
422					35165
486					35166
491					35167
458					35168
500					35169
570					35170
483					35171
475					35172
448					35173
560					35174
444					35178
514					35181
440					35182
457					35183
489					35184
510					35186
437					35188
508					35189
549					35190
475					35191
501					35193
469					35194
477					35195
481					35199
521					38000
590					38001
439					38004
531					38006