Fishery Data Series No. 95-40

# Evaluation of Lake Trout Stock Status and Abundance in Selected Lakes in the Upper Copper and Upper Susitna Drainages, 1994

by

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and

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December 1995

Alaska Department of Fish and Game

Division of Sport Fish

## Symbols and Abbreviations

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**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| metric ton | mt |
| milliliter | ml |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |
| Spell out acre and ton. | |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| hour (spell out for 24-hour clock) | h |
| minute | min |
| second | s |
| Spell out year, month, and week. | |

**Physics and chemistry**

| | |
|---|---|
| all atomic symbols | |
| alternating current | AC |
| ampere | A |
| calorie | cal |
| direct current | DC |
| hertz | Hz |
| horsepower | hp |
| hydrogen ion activity | pH |
| parts per million | ppm |
| parts per thousand | ppt, ‰ |
| volts | V |
| watts | W |

**General**

| | |
|---|---|
| All commonly accepted abbreviations. | e.g., Mr., Mrs., a.m., p.m., etc. |
| All commonly accepted professional titles. | e.g., Dr., Ph.D., R.N., etc. |
| and | & |
| at | @ |
| Compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| Copyright | © |
| Corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| et alii (and other people) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g., |
| id est (that is) | i.e., |
| latitude or longitude | lat. or long. |
| monetary symbols (U.S.) | $, ¢ |
| months (tables and figures): first three letters | Jan,...,Dec |
| number (before a number) | # (e.g., #10) |
| pounds (after a number) | # (e.g., 10#) |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S. state and District of Columbia abbreviations | use two-letter abbreviations (e.g., AK, DC) |

**Mathematics, statistics, fisheries**

| | |
|---|---|
| alternate hypothesis | $H_A$ |
| base of natural logarithm | e |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | F, t, $\chi^2$, etc. |
| confidence interval | C.I. |
| correlation coefficient | R (multiple) |
| correlation coefficient | r (simple) |
| covariance | cov |
| degree (angular or temperature) | ° |
| degrees of freedom | df |
| divided by | ÷ or / (in equations) |
| equals | = |
| expected value | E |
| fork length | FL |
| greater than | > |
| greater than or equal to | ≥ |
| harvest per unit effort | HPUE |
| less than | < |
| less than or equal to | ≤ |
| logarithm (natural) | ln |
| logarithm (base 10) | log |
| logarithm (specify base) | $log_2$, etc. |
| mideye-to-fork | MEF |
| minute (angular) | ' |
| multiplied by | x |
| not significant | NS |
| null hypothesis | $H_O$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | α |
| probability of a type II error (acceptance of the null hypothesis when false) | β |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| standard length | SL |
| total length | TL |
| variance | Var |

# *FISHERY DATA SERIES NO. 95-40*

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# ABSTRACT

Mark-recapture experiments were conducted to estimate the abundance, survival rates and recruitment to lake trout *Salvelinus namaycush* populations in Paxson Lake in the Copper River drainage, and Lake Louise in the Susitna River drainage. Maximum sustainable yields and carrying capacities of populations in Paxson Lake and Lake Louise were estimated with thermal habitat volume (THV) measurements: the average volume of water between 8° and 12° C. The mark-recapture experiment conducted at Paxson Lake in 1994 generated an estimate of abundance for 1993 of 2,262 (SE = 126) mature male lake trout on the sampled spawning beds, an increase from 1992 levels. An estimated 2,077 (SE = 112) mature males were present on the sampled spawning beds of Lake Louise in 1993. The number of mature lake trout in Paxson Lake in 1993, estimated from hook and line sampling, was of 45,427 (SE = 22,148), an increase over 1992 levels. The maximum sustainable yield of lake trout from Paxson Lake was 0.92 kg ha-1 y-1, 0.89 kg ha-1 y-1 from Lake Louise, and 0.73 kg ha-1 y-1 for Susitna Lake. The current harvest from Paxson Lake is near estimates of sustainable yield while the harvest from Lake Louise is below sustainable levels.

Key words: Lake trout, *Salvelinus namaycush*, population abundance, age, thermal habitat volume, yield, harvest, homing behavior, Lake Louise, Paxson Lake, Susitna Lake.

# INTRODUCTION

Lake trout *Salvelinus namaycush* are a popular target of sport anglers in Alaska. Sought in many lakes and some streams, the number of lake trout harvested annually from Alaska has averaged about 17,000 fish since 1977 (Mills 1993) (Figure 1a). Over 40% of the annual harvest has been taken from the lakes and streams which drain into the upper Copper and upper Susitna rivers; 18% from the Gulkana drainage and 11% from the Tyone drainage (Mills 1979-1993) (Figure 1b). Since 1984, harvest statistics have been available for the state's two largest lake trout sport fisheries: Paxson Lake, through which the Gulkana River flows on its way to the upper Copper River; and Lake Louise, a major source of the Tyone River, a tributary to the Susitna River (Figure 2). Together, these two lakes have produced an average of 19% of the annual statewide harvest. The annual harvest from both lakes has been relatively stable since 1984. The average annual harvest from Paxson Lake is estimated at 1,314 fish. The average harvest estimate from Lake Louise since 1984 is 1,672 lake trout. Other major sport fisheries for lake trout in the area occur at Summit Lake (near Paxson Lake), Crosswind Lake (also in the Gulkana drainage) and Susitna Lake (downstream of Lake Louise) (Figure 2). These lakes contribute between 2% and 4% of the statewide harvest of lake trout.

Lake trout are a slow growing, long-lived species. Lake trout as old as 25 years are common and fish older than 50 years have been recorded in Alaska (Burr 1987). Age at complete maturity ranges from 7 to 20 years in Alaska; maturity is later in more northerly latitudes (Burr 1987). Generally, female lake trout do not spawn every year (Healy 1978). Sustainable yields are suggested to be less than 0.5 kg per surface hectare per year (Healy 1978). As a result of their life history characteristics and their allure to anglers, the species is vulnerable to overharvest.

A study by the Alaska Department of Fish and Game (ADF&G) of the structure, abundance and sustainable yield of the lake trout populations in 11 interior lakes commenced in 1986. In 1987, bag limits for lake trout were reduced in the Tanana, upper Copper and upper Susitna river drainages upon determination that the harvest exceeded the maximum sustained yield by as much as seven times in some of the study lakes. A minimum harvestable size of lake trout was also established in 1987 to allow female lake trout to spawn once, on average, before they were subject to harvest. During 1994, the Board of Fisheries voted to increase the minimum size limit

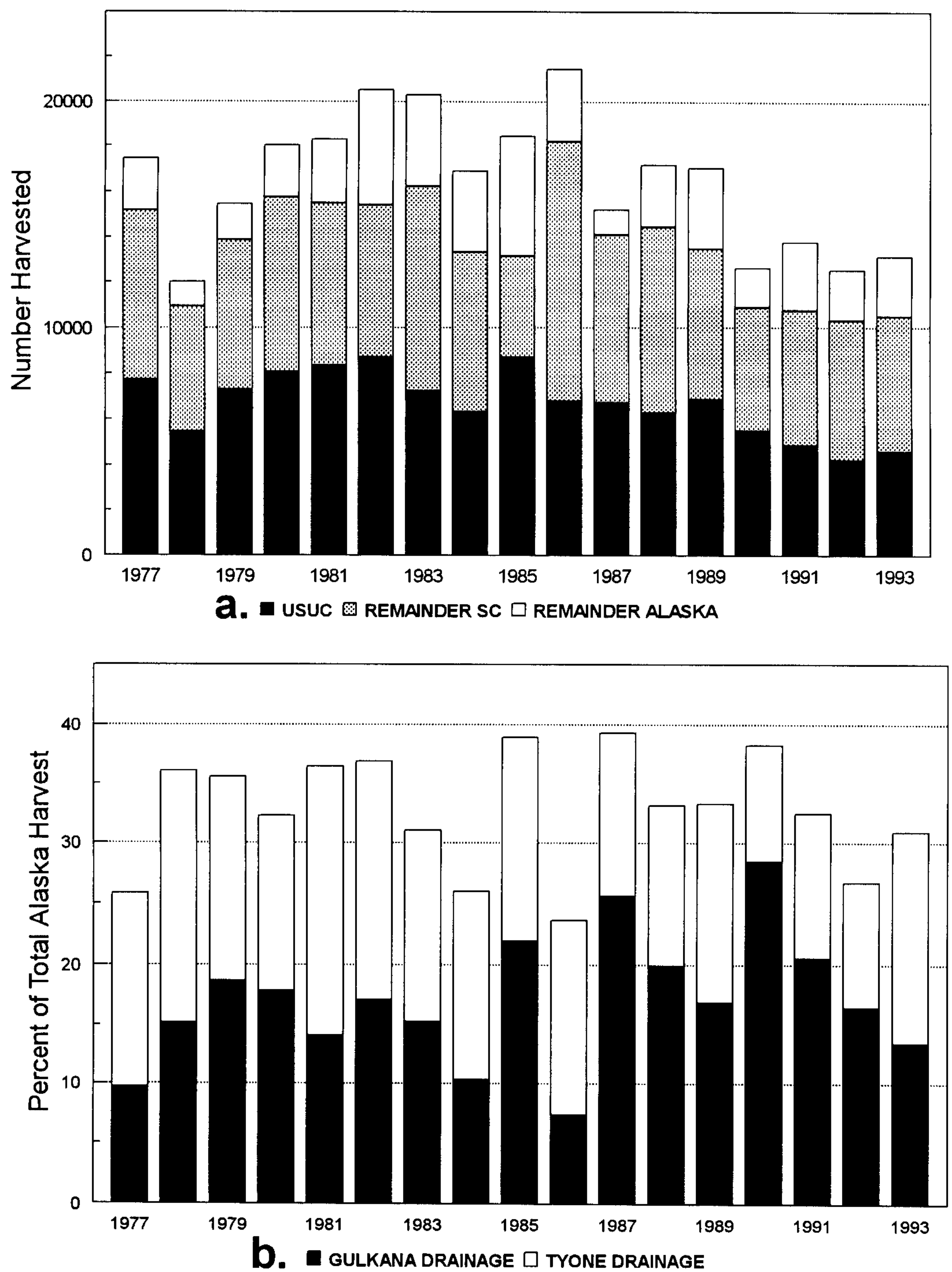


**Figure 1.-Lake trout harvested from Alaska 1977-1993 with (a) number harvested from upper Copper and upper Susitna river drainages (UCUS) and Southcentral (SC) Alaska; and (b) percent contribution of Gulkana and Tyone river drainages to the total Alaskan harvest (Mills 1979-1994).**

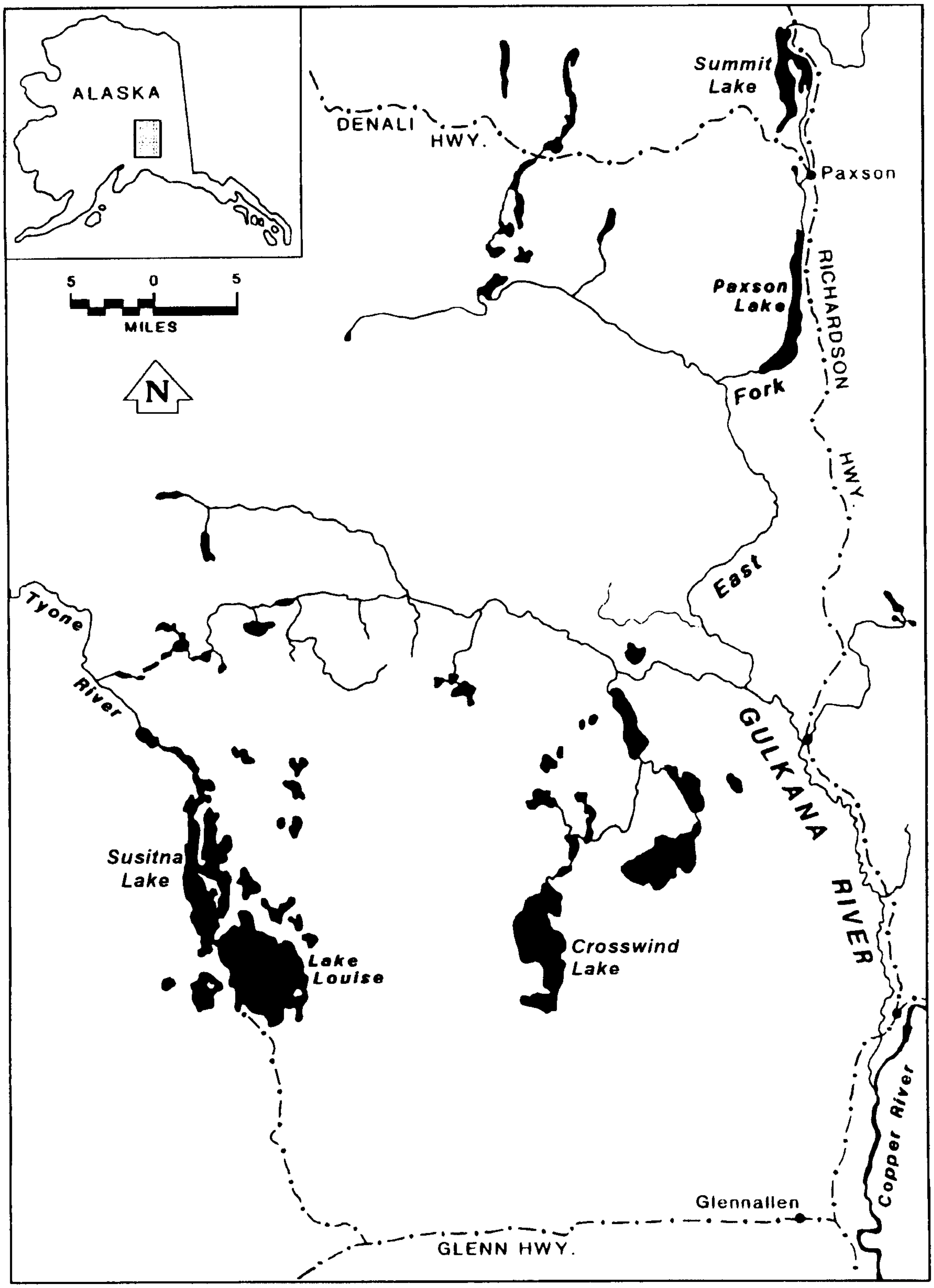


**Figure 2.-Major sport fisheries for lake trout in the upper Copper and upper Susitna river drainages.**

to 24 inches in the Tyone River drainage and in Paxson, Summit and Crosswind lakes because harvests exceeded sustainable levels in Paxson and Summit lakes and minimum size limits were not protecting spawners. The daily bag and possession limit was reduced from two to one lake trout in the Tyone River drainage.

The goals of our study of lake trout are to: 1) verify that yields from several local stocks conform to historical relationships developed for populations elsewhere and 2) monitor stocks to assure that fishing regulations sustain these yields. The specific objectives in 1994 were to:

1. estimate the abundance of mature lake trout in Paxson Lake;
2. estimate the abundance of spawning male lake trout in Paxson Lake and Lake Louise;
3. estimate the length composition of the lake trout populations spawning in Paxson Lake and Lake Louise;
4. estimate the length composition of lake trout from the harvestable population at Paxson Lake;
5. estimate the mean length and mean weight of lake trout from the harvestable population at Paxson Lake; and
6. estimate the thermal habitat volume of Paxson Lake, Lake Louise and Susitna Lake.

# METHODS

## SITE DESCRIPTIONS

Characteristics of Paxson Lake, Lake Louise and Susitna Lake (Figure 2) are:

**Paxson Lake** (62°50' N, 145°35' W) is located along the Gulkana River, and is part of the Copper River watershed. It lies beside the Richardson Highway, 8 km south of the community of Paxson. Paxson Lake is 1,575 ha with a maximum depth of 29 m and an elevation of 625 m. Numerous cabins are located along its shore. A Bureau of Land Management campground and two boat launches are located on the lake.

**Lake Louise** (61°53' N, 145°40' W) and **Susitna Lake** (62°25' N, 146°38' W) are part of a complex of lakes in the Tyone River drainage which ultimately flows into the upper Susitna River. Lake Louise is 6,519 ha with a maximum depth of 51 m and an elevation of 720 m. It is accessible from the Glenn Highway via a 32 km gravel road. A state maintained campground with a boat launch, four lodges and numerous cabins are located along the lake shore. Susitna Lake is 3,816 ha with a maximum depth of 37 m and an elevation of 720 m; a narrow channel connects Lake Louise and Susitna Lake.

## ABUNDANCE ESTIMATES

Sampling during the fall of 1994 occurred at previously identified spawning beds in Lake Louise and Paxson Lake (Szarzi 1992, 1993). Spawning beds were numbered consecutively and sampled throughout each night between sundown and 0600 hours, when weather permitted (Table 1). A beach seine, 60 m X 3 m X 38 mm (200 ft X 10 ft X 1 in), was used to capture lake trout. Sampling began at the bed identified by a random number and proceeded in a systematic fashion around the lake. If fish were not found at the chosen spawning location, the next spawning bed was sampled. The fish captured at each bed were sexed, measured for length from snout to the fork of the tail and marked with individually numbered Floy tags. Tags were inserted in the left

**Table 1.-Sampling dates at Paxson Lake, Lake Louise, and Susitna Lake, 1994.**

| | Paxson Lake | Lake Louise | Susitna Lake |
|---|---|---|---|
| Mark-recapture experiment | 6-9 Sep | 6-9 Sep | |
| | 12-16 Sep | 12-16 Sep | |
| | 19-23 Sep | 19-23 Sep | |
| | | 26-28 Sep | |
| Hook & Line Sampling | 3,5-7 Jun | | |
| | 9,13-16 Jun | | |
| | 19-23 Jun | | |
| | 25, 27-30 Jun | | |
| | 3-7 Jul | | |
| | 17-21 Jul | | |
| | 23-26 Jul | | |
| Thermal Sampling | 15-Jun | 8-Jun | 8-Jun |
| | 20-Jun | 22-Jun | 22-Jun |
| | 11-Jul | 1-Jul | 1-Jul |
| | 19-Jul | 13-Jul | 13-Jul |
| | 28-Jul | 19-Jul | 19-Jul |
| | 1-Aug | 29-Jul | 29-Jul |
| | 9-Aug | 8-Aug | 8-Aug |
| | 19-Aug | 17-Aug | 17-Aug |
| | 31-Aug | 29-Aug | 29-Aug |

side of the fish at the base of the dorsal fin. To estimate tag loss, the adipose fin was removed. The spawning bed where each fish was captured was recorded to allow the movement of fish to be traced between spawning locations in season and between seasons. Recaptured fish were noted, sexed and measured.

During the spring and early summer in 1994, lake trout were captured from Paxson Lake with hook and line (Table 1). Fish were weighed to the nearest 50 grams with a hand-held scale, measured to the nearest millimeter fork length and examined for tags and marks. In addition, the sagittal otoliths were collected from any fish that were killed. Ages of fish were estimated later as counts of concentric opaque zones (annuli) on whole otoliths under magnification as described in Sharp and Bernard (1988).

The abundance of mature lake trout was estimated with a combination of two mark-recapture experiments: the mark-recapture event on the spawning beds in the fall and samples from the harvestable population in the spring. Only males were included in the experiments because they generally spawn every year while female lake trout do not (Burr 1991). Numbers of male lake trout marked and recaptured each year on the spawning beds of each lake were used to estimate abundance, survival rates, surviving recruitment and number of tagged male lake trout in the spawning population with the program RECAP by Buckland (1980, 1982). RECAP is based on the Jolly-Seber model (Seber 1982). Four hundred bootstrapped samples were drawn from the original capture histories to produce variances for the estimates according to the procedures described in Efron (1982) and in Buckland and Garthwaite (1991). Sampling events in the first experiment have been conducted each fall in Paxson Lake from 1987 through 1994. Sampling in Lake Louise began in fall 1991. Sampling at Susitna Lake begun in 1992 was discontinued in 1994.

The second mark-recapture experiment was used to expand the estimated number of males from the spawning population that was sampled to the number of mature males in the entire lake. Lake trout are faithful to their spawning beds, returning each year to the same area to spawn (Szarzi 1992, 1993, 1994). However, lake trout cannot be captured on all spawning beds with benign sampling gear such as beach seines. Those fish sampled in the first experiment represent male lake trout that spawn in accessible locations and are, therefore, only a subset of all male lake trout. The abundance of all spawning males in the lake in year i ($\hat{N}_{mi}$) was estimated as:

$$\hat{N}_{mi} = \frac{\hat{M}_i + T_i}{\hat{q}_{(i+1)}} \qquad (1)$$

where:

$\hat{M}_i$ = estimated number of marked, male lake trout just prior to sampling during the fall in year i,

$T_i$ = number of newly marked, male lake trout added to the population during the fall sampling in year i, and

$\hat{q}_{(i+1)}$ = fraction of 7-year old and older male lake trout with marks in the population during the spring of year i+1.

By spring, all marked male lake trout should have mixed completely with unmarked males and be subject to sampling with hook and line. In prior years lake trout harvested by sport anglers were examined for marks to estimate the abundance of mature males in each lake. In 1994, the implementation of the 24 inch size limit confounded this method of estimation. Instead of a harvest sampling program, samples of lake trout captured by hook and line were used to estimate the fraction of marks in the harvestable population in the spring. This program was limited to Paxson Lake. To be consistent with samples collected from the harvest in prior years, only lake trout larger than the previous minimum size limit (18 inch total length) were included. Because males in Paxson Lake are fully mature at age 6 years in the fall (Burr 1993), the estimate of the marked fraction of males (q) in the hook and line sampling program in the spring was restricted age 7 and older fish to remove bias in the estimate of abundance from growth recruitment. Since lake trout sampled with hook and line were released alive, their age and sex could not be determined. The ages of lake trout were estimated from the length-at-age of lake trout from harvest samples collected prior to 1994. Lake trout larger than 472 mm fork length were assumed to be > 6 years of age. Sex ratios were assumed to 1:1 ( Szarzi 1992, 1993, Martin and Olver 1980). The variance of the estimate of abundance of males in year i was approximated according to the delta method:

$$V[\hat{N}_{mi}] \approx \left[\frac{\hat{M}_i}{q_{(i+1)}}\right]^2 \left[\frac{V[\hat{M}_i]}{\hat{M}_i^2} + \frac{V[\hat{q}_{(i+1)}]}{\hat{q}_{(i+1)}^2}\right]. \qquad (2)$$

$V[\hat{M}_{mi}]$ came from the first mark-recapture experiment while $V[\hat{q}_{(i+1)}]$ was estimated from the hook and line sampling program as follows:

$$\hat{q} = \frac{n_{mx}}{n_x} \quad ; \quad V[\hat{q}] = \frac{\hat{q}(\hat{q}-1)}{n_x - 1} \qquad (3)$$

where:

$n_x$ = the number of male lake trout sampled with hook and line in the spring that are mature (age 7+), and

$n_{mx}$ = the number in that sample with marks.

The hook and line sampling program occurred during the spring and early summer and was used to expand estimates of abundance of males (as described above) and to expand estimates of abundance to lake trout of both sexes. Estimated abundance of all mature lake trout of both sexes in the fall of year i was double that for the males alone; the estimated variance was $V[\hat{N}_{mi}]$.

Since abundance estimates are germane to just prior to sampling (September) and most of the harvest occurs in the spring, harvest estimates from Mills (1988-1993) were lagged one year. Almost all fishing for lake trout at Paxson Lake occurs between March and September, therefore much of the harvest would be composed of male lake trout newly recruited to the fishery, but not yet recruited to our mark-recapture experiments. Estimates from the Statewide Harvest Survey, which are based on a calendar year, were used directly to estimate instantaneous rates once they had been halved to estimate the harvest of males and dicounted for the fraction of the harvest not mature in the previous year $\left(1-\frac{n_x}{n}\right)$, where n is the number of lake trout sampled in the spring. Lake trout disperse across Lake Louise and Susitna Lake between spawning seasons (Szarzi 1994), therefore, lake trout in both lakes are treated as a single population.

## YIELD ESTIMATES

Maximum sustainable yields (MSY) in kg/ha/yr of lake trout were estimated for each population in our study from an empirical relationship between estimated harvests and thermal habitat volume (THV) from lakes in Ontario, Canada (Payne et al. 1990):

$$\log_{10} MSY = 2.15 + 0.714 \log_{10} THV \tag{4}$$

$$THV = \frac{(D_2 - D_1)\left(A_1 + A_2 + [A_1 \times A_2]^{1/2}\right)}{300} \tag{5}$$

where:

$D_1$ = the average depth at which water temperature in a lake is 12° C during the summer,

$D_2$ = the average depth at which water temperature is 8° C,

$A_1$ = the cross-sectional area of the lake at depth $D_1$, and

$A_2$ = the cross-sectional area of the lake at $D_2$.

Water temperatures should be measured after each lake has reached stable thermal stratification in the summer. To determine when this occurred, water temperatures were measured at 2.5 m depth intervals to the bottom of Paxson Lake, Lake Louise and Susitna Lake during June, July and August, 1994 (Table 1). A monthly temperature profile was estimated for each lake by averaging the readings at each depth interval during the month. The cross-sectional area of each lake at the depth where 12° C and 8°C temperatures were encountered was measured on a bathymetric map using a planimeter. The THV of each lake was estimated using Equation 5 with average mearsurements from a single month:

$$\bar{t}_{dj} = \frac{\sum_{i=1}^{p_{dj}} t_{dij}}{p_{dj}} \qquad S_j^2 = \sum_d \frac{\sum_{i=1}^{p_{dj}} (t_{dij} - \bar{t}_{dj})^2}{p_{dj} - 1} \tag{6}$$

where t is temperature, p is the number of profiles taken, i denotes profile, d depth, and j month. Measurments used to determine $D_1$ and $D_2$ were those taken in the month in which $S_j^2$ is a minimum. Depth $D_1$ = d' at which $\bar{t}_{d'j}$ = 12°C; depth $D_2$ is determined in the same manner.

Estimates of MSY were transformed into estimates of carrying capacity (K) for Lake Louise and Susitna and Paxson lakes according to the concept of logistic surplus production and the empirical relationship between instantaneous rates of natural mortality and the intrinsic rate of increase (r) (Gulland 1983):

$$K = \frac{(4)MSY}{r} \tag{7}$$

where r is double the instantaneous rate of natural mortality.

From Healy (1978), the instantaneous rate of natural mortality averaged over 14 sampled populations is 0.30. Considering estimates of the instantaneous rate of total mortality derived in our mark-recapture experiment at Paxson Lake (0.39, 0.18, 0.25, 0.16, 0.27, 0.18), 0.30 is too high. The instantaneous rate of natural mortality was calculated with estimates of harvest from the Statewide Harvest Survey (Mills 1989-1993), estimates of abundance of all mature males in Paxson Lake and the Baranov catch equation. Carrying capacity was estimated with the average of instantaneous rates of natural mortality between 1988 and 1992 (0.06) for lake trout in Paxson Lake. This mortality rate was used to estimate carrying capacity for Lake Louise and Susitna Lake as well.

The actual yields (Y) in kg/ha/yr from populations in Paxson Lake, Lake Louise and Susitna Lake in their sport fisheries was estimated from data collected during the hook and line sampling program (Paxson Lake) and previous catch sampling programs (Lake Louise) and estimates of annual harvest (H) from the Statewide Harvest Survey:

$$Y = H\overline{w} \tag{8}$$

where:

$\overline{w}$ = mean weight of lake trout sampled in hook and line and catch sampling programs.

The mean weight of lake trout greater than 24 inches in length captured by hook and line from Paxson Lake was used to estimate yields there.

Since most harvest occurs when the hook and line and catch sampling occurs, growth of lake trout after completion of sampling should not significantly bias estimates of mean weights.

# RESULTS

## ABUNDANCE ESTIMATES

The estimated abundance of mature male lake trout spawning on the sampled grounds in Paxson Lake during the fall, 1993, is 2,262; the estimated abundance of all mature males spawning during the fall throughout Paxson Lake in 1993 is 22,714; and the estimated abundance of all mature lake trout in the fall, 1993, is 45,427 (Table 2). One thousand one hundred and ninety three male lake trout were captured during fall sampling in 1994 of which 48% (578) had been marked in previous years (Table 3). An estimated 1,080 (SE = 47) male lake trout were extant with marks just prior to sampling during the fall, 1993 and 1,465 (SE = 47) just after (Table 2) (385 newly marked males were released during sampling in 1993). During hook and line sampling in the spring, 1994, 166 lake trout were sampled of which 124 were $\geq$ 7 years (472 mm). Of these, half (62) were assumed to be males of which 4 were marked, making q = 0.06 and SE[q] = 0.03. The estimated abundance of all lake trout 7 years of age or older is double that estimated for males alone (p was set to 0.5 and V[p] was set to 0).

An estimated 2,077 (SE = 112) male lake trout spawned on the sampled spawning beds of Lake Louise during fall, 1993 compared to 1,437 (SE = 80) in 1992 (Table 4). Of 993 lake trout captured from Lake Louise during fall sampling in 1993, 523 had been marked in previously (Table 5). The number of mature lake trout in Lake Louise and Susitna Lake was not estimated because no sampling of harvestable sized lake trout was conducted in Lake Louise during 1994.

**Table 2.-Statistics used to estimate abundance of mature lake trout in Paxson Lake.**

| Year | Sampled Population[a] | Number w/Marks[a] (M) | Fraction Marked[a,c] (q) | Abundance Males[a,b] ($N_m$) | Fraction Males[c] (p) | Abundance[a,b] (N) |
|---|---|---|---|---|---|---|
| 1987 | ----- | 144 | ----- | ----- | ----- | ----- |
| 1988 | 3,040<br>(447)<br>(2,164-3,916) | 773<br>(26) | ----- | 7,556 | 0.5[d] | 15,112 |
| 1989 | 2,560<br>(142)<br>(2,282-2,837) | 1,037<br>(32) | ----- | 6,362 | 0.5[d] | 12,724 |
| 1990 | 2,070<br>(96)<br>(1,882-2,257) | 1,381<br>(32) | 0.4<br>(0.07) | 3,442<br>(556) | 0.5[d] | 6,845<br>(1,112) |
| 1991 | 2,623<br>(131)<br>(2,367-2,879) | 1,149<br>(44) | 0.3<br>(0.07) | 3,858<br>(873) | 0.5 | 7,715<br>(1,746) |
| 1992 | 2,150<br>(119)<br>(1,916-2,368) | 1,291<br>(34) | 0.14<br>(0.06) | 9,553<br>(4,028) | 0.5 | 19,107<br>(8,056) |
| 1993 | 2,262<br>(126)<br>(2,015-2,509) | 1,465<br>(47) | 0.06<br>(0.03) | 22,714<br>(11,074) | 0.5 | 45,427<br>(22,148) |

[a] Standard errors and/or 95% confidence intervals in parentheses.

[b] Abundance is germane to just after spawning in the fall of the listed year.

[c] Fractions were estimated in the spring of the year following 1990, 1991, 1992, and 1993. Fractions prior to 1990 are assumptions based on later sampling.

[d] Assumed value based on I: I sex ratio.

**Table 3.-Numbers of mature male lake trout captured, marked and recaptured in Paxson Lake at sampled spawning grounds, 1987-1994.**

| | Year of Recapture | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
| Year of release: | | | | | | | | |
| 1987 | 0 | 39 | 38 | 8 | 8 | 3 | 2 | 2 |
| 1988 | | 0 | 217 | 122 | 84 | 26 | 22 | 13 |
| 1989 | | | 0 | 214 | 124 | 55 | 35 | 33 |
| 1990 | | | | 0 | 204 | 94 | 54 | 28 |
| 1991 | | | | | 0 | 106 | 51 | 54 |
| 1992 | | | | | | 0 | 187 | 157 |
| 1993 | | | | | | | 0 | 290 |
| 1994 | | | | | | | | 0 |
| Captures: | | | | | | | | |
| With tags | 0 | 39 | 255 | 344 | 420 | 284 | 351 | 578 |
| Without tag | 249 | 807 | 592 | 343 | 540 | 412 | 385 | 615 |
| TOTAL | 249 | 846 | 847 | 687 | 960 | 696 | 736 | 1,193 |
| Releases: | | | | | | | | |
| With tags | 212 | 817 | 821 | 647 | 420 | 695 | 736 | 1,193 |
| Without tags | 0 | 0 | 0 | 0 | 540 | 0 | 0 | 0 |
| TOTAL | 212 | 817 | 821 | 647 | 960 | 695 | 736 | 1,193 |

**Table 4.-Statistics used to estimate abundance of mature lake trout in Lake Louise and Susima Lake.**

| Year | Sampled Population[a] | Number w/Marks[a] (M) | Fraction Marked[a,c] (q) | Abundance Males[a,b] ($N_m$) | Fraction Males[c] (p) | Abundance[a,b] (N) |
|---|---|---|---|---|---|---|
| 1991 | ----- | 668 | 0.14 | 4,797 | 0.5 | 9,595 |
| | | | (0.04) | (1,351) | | (2701) |
| 1988 | 1,437 | 902 | 0.11 | 8,115 | 0.5 | 16,230 |
| | (80) | (24) | (0.04) | (3,153) | | (6,305) |
| | (1,299-1,609) | | | | | |
| 1989 | 2,077 | 1,345 | ----- | ----- --- | ----- ---- | ----- |
| | (112) | (42) | | | | |
| | (1,858-2,322) | | | | | |

[a] Standard errors and/or 95% confidence intervals in parentheses.

[b] Abundance is germane to just after spawning in the fall of the listed year.

[c] The fraction of marked fish was estimated in the spring of the year following 1991 and 1992.

**Table 5.-Numbers of mature male lake trout captured, marked and recaptured in Lake Louise at sampled spawning grounds, 1991-1994.**

| | Year of Recapture | | | |
|---|---|---|---|---|
| LAKE LOUISE: | 1991 | 1992 | 1993 | 1994 |
| Year of release: | | | | |
| 1991 | 0 | 210 | 97 | 55 |
| 1992 | | 0 | 247 | 136 |
| 1993 | | | 0 | 332 |
| 1994 | | | | 0 |
| Captured with tags | 0 | 210 | 344 | 523 |
| Captured without tags | 699 | 436 | 510 | 470 |
| Total captured | 699 | 646 | 854 | 993 |
| Released with tags | 699 | 646 | 854 | 991 |
| Released without tags | 0 | 0 | 0 | 0 |
| Total released | 699 | 646 | 854 | 991 |

## SURVIVAL AND RECRUITMENT

Estimates of annual survival rates of lake trout in Paxson Lake range from 0.68 to 0.86, while estimates of surviving recruitment indicate two weak and two strong year classes entering the population with the estimate for 1992 to 1993 falling in between (Table 6). Rates of total instantaneous mortality range between 0.16 and 0.39. The estimated survival rate of lake trout in Lake Louise between 1992 and 1993 was 0.93 (Table 7). The instantaneous rate of mortality was estimated at 0.08 during the same period. Fishing and natural mortality rates were estimated with the Baranov catch equation with estimates of harvest from the Statewide Harvest Survey (Mills 1989-1993) (Table 7) and estimates of abundance of all mature males in Lake Louise (Table 4) as described in the Methods section for fish in Paxson Lake.

## LENGTH AND WEIGHT INFORMATION

The fork lengths of 166 lake trout captured by hook and line from Paxson Lake, 3 June to 26 July were measured (Appendix A1). The average was 533 mm [standard deviation (s) = 77.3 mm]. A subset of 128 lake trout were weighed; the mean weight was 2.25 kg (s = 0.96 kg).

The fork lengths of 1,532 lake trout were measured from the spawning population in Paxson Lake (Table 8 and Appendix A2). Lengths were collected from 1,288 spawning lake trout captured in Lake Louise (Table 8 and Appendix A3). Spawning females were larger than male spawners in

**Table 6.-Estimates of annual harvest, survival rates, instantaneous rates and surviving recruitment for males in Paxson Lake.**

| Period: Fall-Fall | Estimated Harvest Males[a] | Fraction Recruited $n_x/n$ | Abundance Males ($N_m$) | Survival Rate[b] | Instantaneous Rates: Total[b] | Instantaneous Rates: Fishing[c] | Instantaneous Rates: Natural[c] | Surviving Recruitment[b] |
|---|---|---|---|---|---|---|---|---|
| 1987-1988 | 655 | ns[d] | -------- | 0.68 | 0.39 | -------- | -------- | -------- |
| | (249) | | | (0.05) | | | | |
| 1988-1989 | 779 | ns[d] | 7,556 | 0.84 | 0.18 | 0.11 | 0.06 | 35 |
| | (221) | | | (0.03) | | | | (490) |
| 1989-1990 | 1,070 | ns[d] | 6,362 | 0.78 | 0.25 | 0.19 | 0.06 | 106 |
| | (370) | | | (0.03) | | | | (112) |
| 1990-1991 | 624 | 0.83 | 3,442 | 0.86 | 0.16 | 0.16 | 0.00 | 884 |
| | (106) | | (556) | (0.04) | | | | (102) |
| 1991-1992 | 559 | 0.62 | 3,858 | 0.76 | 0.27 | 0.11 | 0.16 | 1,310 |
| | (112) | | (873) | (0.04) | | | | (104) |
| 1992-1993 | 389 | 0.85 | 9,553 | 0.84 | 0.18 | 0.03 | 0.14 | 464 |
| | (92) | | (4,028) | (0.04) | | | | (105) |

[a] Harvests are half those reported in the Statewide Harvest Survey for years 1988 through 1992 (Mills 1989-1993).

[b] Estimated for males on sampled spawning grounds only in the mark-recapture experiment based on the Jolly-Seber model (Seber 1982).

[c] Estimated with the Baranov catch equation with the presumption that estimated survival rates were indicative of survival rates for all mature male lake trout in Paxson Lake

[d] ns=no sample.

**Table 7.- Estimates of annual harvest, survival rates, instantaneous rates and surviving recruitment for males in Lake Louise and Susitna Lake.**

| Period: Fall-Fall | Estimated Harvest Males[a] | Fraction Recruited $n_x/n$ | Abundance Males ($N_m$) | Survival Rate[b] | Instantaneous Rates: Total[b] | Instantaneous Rates: Fishing[c] | Instantaneous Rates: Natural[c] | Surviving Recruitment[b] |
|---|---|---|---|---|---|---|---|---|
| 1991-1992 | 679 | 0.97 | 4,797 | 0.67 | 0.40 | 0.16 | 0.24 | -------- |
| | (124) | | (1,351) | (0.03) | | | | |
| 1992-1993 | 992 | 0.95 | 8,115 | 0.93 | 0.08 | 0.08 | 0.00 | 746 |
| | (213) | | (3,153) | (0.41) | | | | (91) |

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[a] Harvests are half those reported in the Statewide Harvest Survey for years 1991 through 1992 for Lake Louise and Susitna Lake combined (Mills 1992-1993).

[b] Estimated for males on sampled spawning grounds only in the mark-recapture experiment based on the Jolly-Seber model (Seber 1982).

[c] Estimated with the Baranov catch equation with the presumption that estimated survival rates were indicative of survival rates for all mature male lake trout in Lake Louise and Susitna Lake.

both lakes. On average, spawning lake trout were slightly larger in Paxson Lake. Lengths of spawning lake trout were more variable in Lake Louise.

### YIELD ESTIMATES

In 1993, harvests from Lake Louise and Susitna Lake remained below the threshold of MSY as established through measurement of the THV; harvests from Paxson Lake in 1993 remained slightly above MSY (Figure 3). Estimates of MSY at carrying capacity and carrying capacity are 769 and 21,891 lake trout in Paxson Lake, 2,123 and 56,489 for lake trout in Lake Louise and 1,191 and 32,185 for Susitna Lake (Table 9).

The harvest from Paxson Lake in 1993 was 778 lake trout or 0.8 kg $ha^{-1}$ based on the average weight of 1.68 kg estimated from harvest samples from 1993 (Szarzi 1994). The 1993 harvest of lake trout from Lake Louise was 1,316 fish or 0.6 kg $ha^{-1}$, based on the average weight of 2.9 kg estimated from the 1993 harvest (Szarzi 1994). An estimated 669 lake trout were taken from Susitna Lake in 1993, a yield of approximately 0.5 kg $ha^{-1}$ using the average weight of lake trout estimated from Lake Louise (2.87 kg).

## DISCUSSION

The estimate of mature lake trout in Paxson Lake increased dramatically between 1992 and 1993. It is likely that the estimate is inflated. The cause of the large estimate is perplexing. The dynamics of the sampled spawning population should reflect those of beds out of reach of the seines, therefore such a large increase in the number of mature lake trout in the lake should be mirrored by a relative increase in the sampled spawning population. The sampled spawning population increased by only 5 percent. Recruitment into the sampled spawning population was relatively low compared to the number of recruits that entered the population between 1990 and 1992. There was no tag loss observed from lake trout sampled with hook and line to explain the small proportion of tagged fish in the samples. It is possible that tagged lake trout had a capture probability lower than untagged lake trout due to sampling effort being concentrated on the north end of the lake while most of the sampled spawning beds were located on the south end. Although there is evidence that lake trout disperse after spawning (Martin and Olver 1980) there are also examples of lake trout remaining in the vicinity of the beds where they spawned, for periods exceeding a year. Most observations of faithfulness to spawning locations have occurred on lakes >500 $km^2$ (Martin and Olver 1980). Although lake trout in these studies were reported to remain fairly close to their spawning locations, closeness is a relative term. The distances they traveled in these large lakes were often >13 km. I recommend that we discontinue the second mark-recapture experiment but continue experiments on the spawning beds to monitor population trends.

## ACKNOWLEDGMENTS

The authors wish to thank the technicians and biologists who assisted with field data collection and data entry: Kathy Adler, Ron Burr, Austin Mahalky, Joe LeFaive, Matt Miller, Mark Stadtmiller and Molly McCormick. Thanks are due to the owners of the Wolverine Lodge at Lake Louise for their cooperation with the tagging operation. Thanks also to Dinty Bush Services for their assistance.

**Table 8.- Length statistics of spawning lake trout in Paxson Lake and Lake Louise, 1994.**

| | Paxson Lake | | | Lake Louise | | |
|---|---|---|---|---|---|---|
| | Female | Male | All[a] | Female | Male | All[a] |
| LENGTH (mm) | | | | | | |
| mean | 539 | 522 | 525 | 537 | 518 | 522 |
| mode | 550 | 525 | 525 | 525 | 500 | 513 |
| sample size | 303 | 1,229 | 1,532 | 292 | 981 | 1,288 |
| standard deviation | 45 | 47 | 47 | 73 | 66 | 68 |
| 95% upper confidence interval | 552 | 536 | 539 | 554 | 533 | 538 |
| 95% lower confidence interval | 526 | 509 | 512 | 520 | 502 | 506 |
| maximum | 864 | 975 | 975 | 814 | 905 | 905 |
| minimum | 441 | 386 | 386 | 433 | 415 | 413 |

[a] Sex was not determined for all samples. Therefore, the total sample size may be greater than that for each sex.

**Table 9.-Estimates of maximum sustained yield for mature lake trout and the carrying capacity for these fish in Paxson Lake and Lake Louise.**

| | Area (ha) | Year | THV ($hm^3$)[a] | Mean Weight (kg) | Yield kg/ha/yr | Yield Number | Carrying Capacity kg | Carrying Capacity Number |
|---|---|---|---|---|---|---|---|---|
| Paxson | 1,575 | 1991 | 28.9 | 1.80 | 0.99 | 866 | 51,975 | 28,875 |
| | | 1992 | 30.7 | 1.61 | 1.03 | 1,008 | 43,845 | 27,233 |
| | | 1993 | 17.9 | 1.68 | 0.70 | 656 | 29,797 | 17,736 |
| | | 1994 | 28.1 | 2.25 | 0.97 | 508 | 41,293 | 13,719 |
| | | Average | | 2.83 | 0.09 | 769 | 41,727 | 21,891 |
| Louise | 6,519 | 1991 | 52.6 | 3.19 | 0.37 | 754 | 65,190 | 20,436 |
| | | 1992 | 291.3 | 2.50 | 1.21 | 3,287 | 213,189 | 85,276 |
| | | 1993 | 210.9 | 2.92 | 0.99 | 2,210 | 174,427 | 58,735 |
| | | 1994 | 209.9 | 2.87 | 0.99 | 2,239 | 173,660 | 60,509 |
| | | Average | | 2.87 | 0.89 | 2123 | 156,617 | 56,489 |
| Susitna | 3,816 | 1992 | 40.8 | 2.87 | 0.52 | 691 | 53,630 | 18,687 |
| | | 1993 | 97.2 | 2.87 | 0.97 | 1,290 | 100,041 | 34,858 |
| | | 1994 | 130.1 | 2.87 | 1.20 | 1,591 | 123,441 | 43,011 |
| | | Average | | 2.87 | 0.90 | 1,191 | 92,371 | 32,185 |

[a] Thermal Habitat Volume in cubic hectometers.

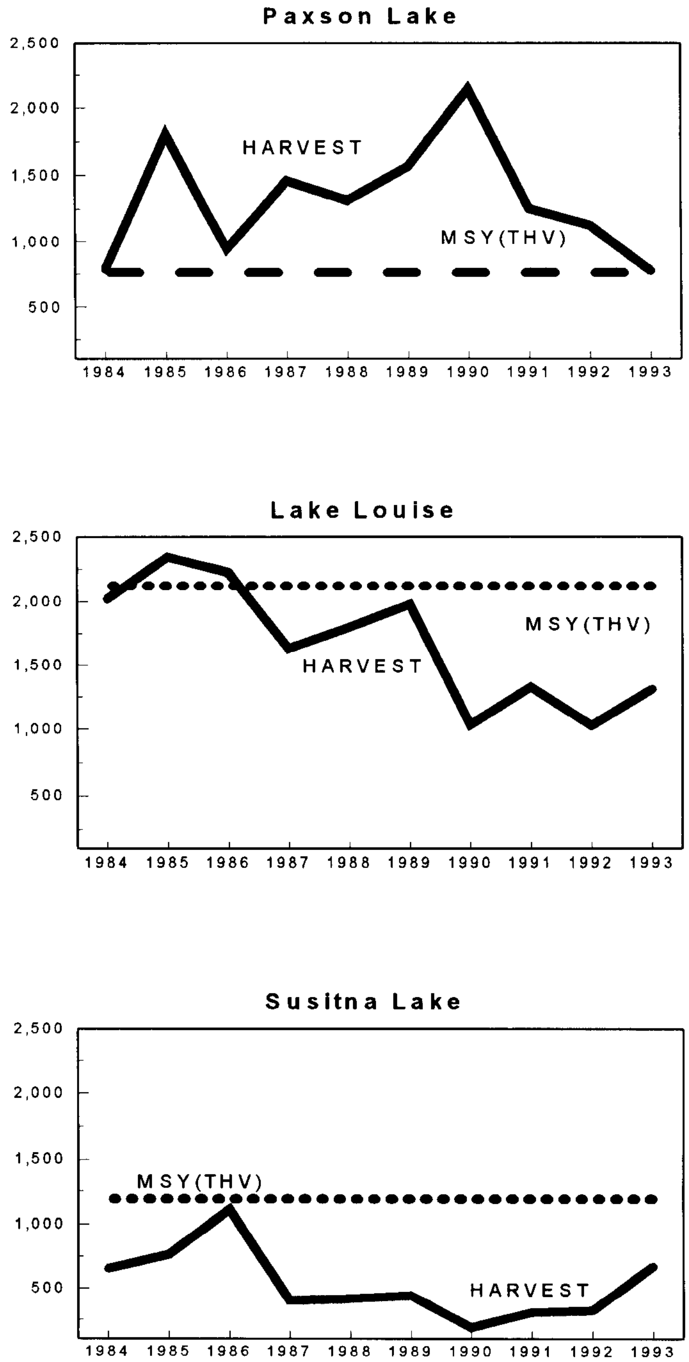


**Figure 3.-Lake trout harvests compared to estimates of maximum sustainable yield (MSY) as developed through measurements of thermal habitat volume (THV from Payne et al. 1990)**

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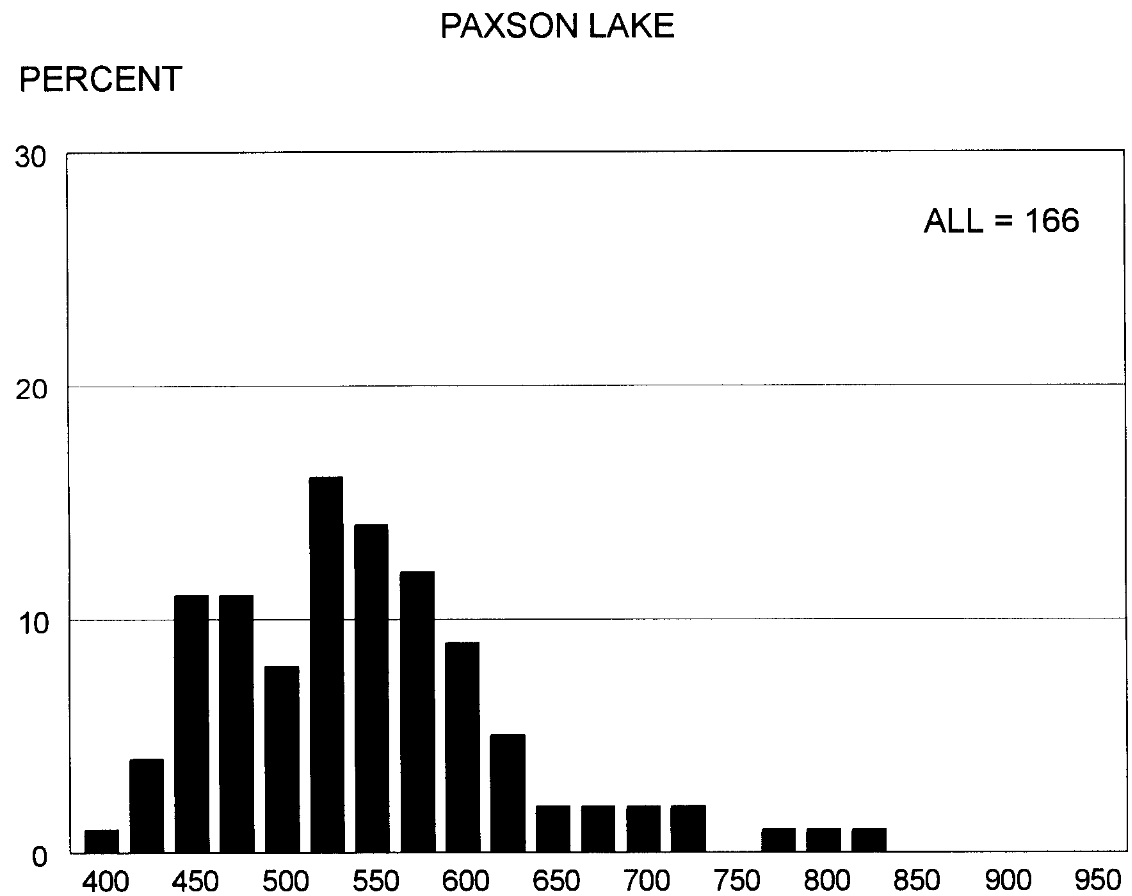
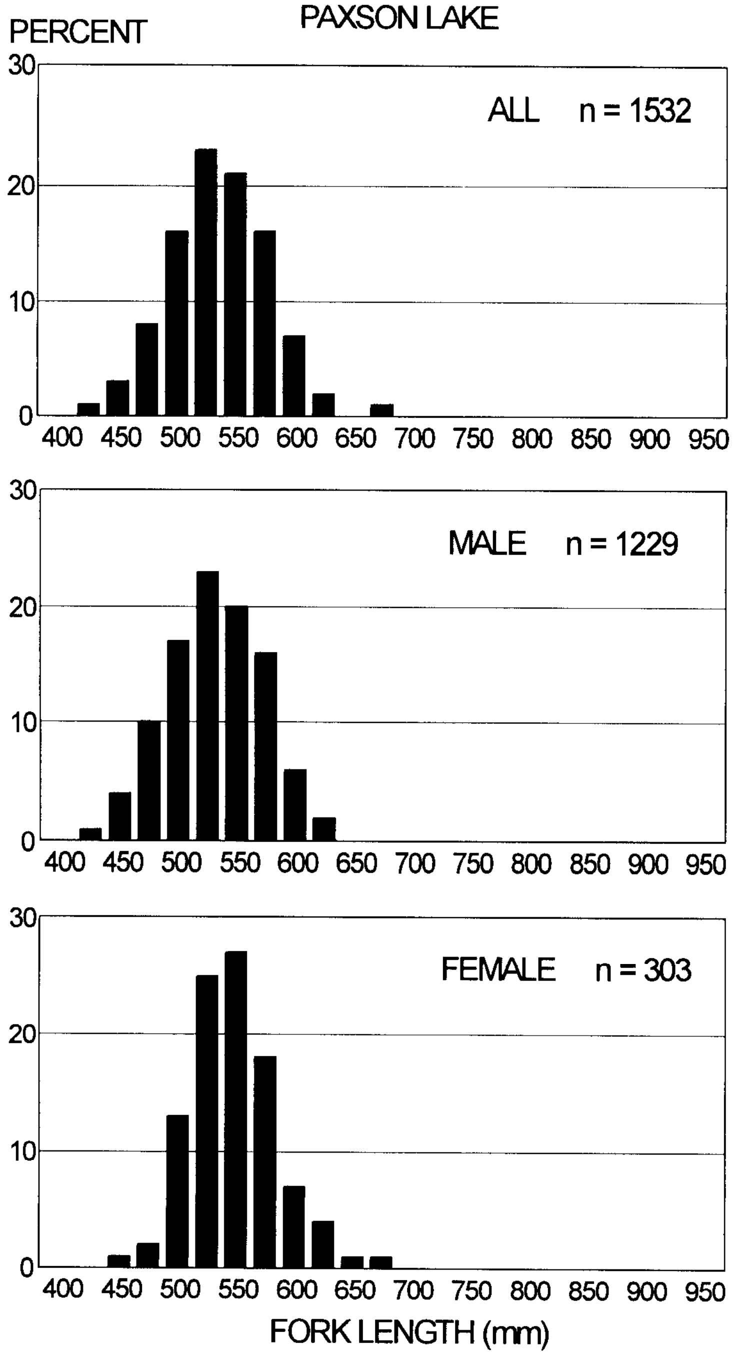
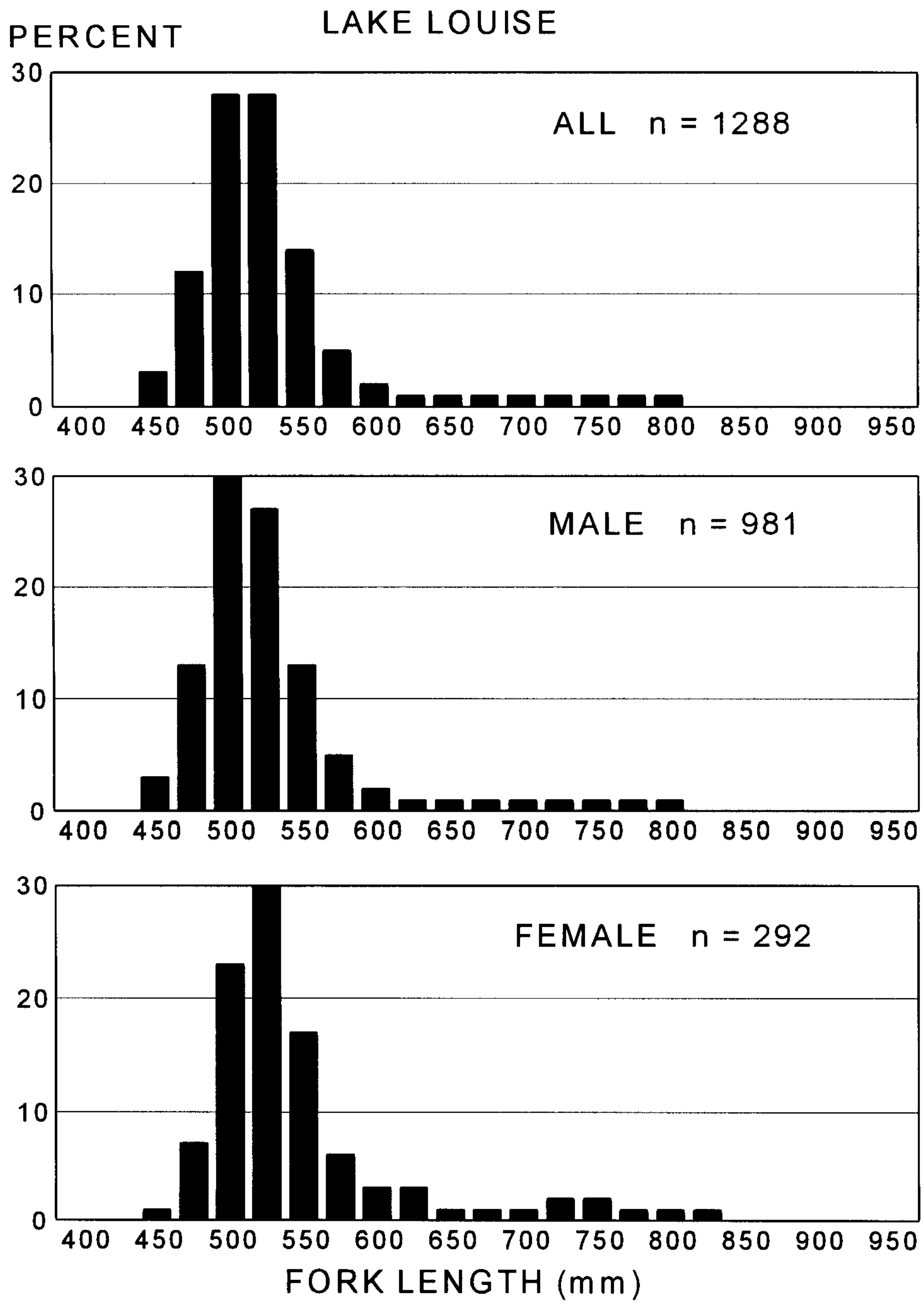
# APPENDIX A. LENGTH FREQUENCIES OF LAKE TROUT SAMPLED DURING 1994.




**Appendix A1.-Fork lengths of lake trout captured by hook and line from Paxson Lake, 1994.**




**Appendix A2.-Fork lengths of spawning lake trout captured by beach seine from Paxson Lake, 1994.**




**Appendix A3.- Fork lengths of spawning lake trout captured by beach seine from Lake Louise, 1994.**