Fishery Data Series No. 04-14

Composition and Yield Potential of Lake Trout in Paxson Lake, 2002

by
Brendan Scanlon

September 2004

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL
Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
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.
minute (angular)	'
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
variance	
population	Var
sample	var

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TABLE OF CONTENTS

LIST OF TABLES....ii

LIST OF FIGURES....ii

LIST OF APPENDICIES....ii

ABSTRACT....1

INTRODUCTION....1

OBJECTIVES....4

METHODS....4

- Description of Study Area....4
- Study Design and Sampling Methods....4
- Yield Potential....8
- Length Composition....9
- Growth....9

RESULTS....9

- Catch Summary....9
- Length and Weight Composition....10
- Yield Potential....12
- Growth....13

DISCUSSION....13

ACKNOWLEDGEMENTS....17

REFERENCES CITED....17

APPENDIX A CAPTURE SUMMARIES....19

APPENDIX B DATA FILE LISTING....25

LIST OF TABLES

Table **Page**

1. Estimated number of angler days, lake trout harvested, lake trout caught, lake trout caught per angler day, and lake trout harvested per catch in Alaska, 1985-2000, and harvest and catch of lake trout in Paxson Lake, 1985-2000.... 2
2. Locations and sport fishing regulations for lake trout in Region III........ 3
3. Length and weight statistics for lake trout sampled in Paxson Lake in September 2002.... 10
4. Summary of Kolmogorov-Smirnov test results comparing length and weight compositions of lake trout captured in Cluster A and Cluster B. 13
5. Summary of Kolmogorov-Smirnov test results comparing length compositions of lake trout captured in 1995 with beach seines, in 1997 with hook-and-line, and in 2002 with beach seines. 15
6. Sex ratios and mean fork lengths by sex for lake trout sampled in Paxson Lake in 1995, 1997, and 2002. 15
7. Number of fish sampled on the spawning grounds, proportion of fish ≥ 600 mm TL, and estimates of abundance of lake trout in Paxson Lake 1987-1995 and 2002 (1997 lake trout were sampled via hook-and-line and no estimate of abundance was calculated).. 16

LIST OF FIGURES

Figure **Page**

1. Location of Paxson Lake 5
2. Paxson Lake with lake trout spawning locations denoted with open circles 7
3. Length distributions of male and female lake trout sampled from Paxson Lake in September 2002. 11
4. Length-weight relationship for lake trout sampled on the spawning grounds in Paxson Lake, September 2002, and by hook-and-line in 1997 12
5. Number of lake trout harvested from Paxson Lake, 1991-2001. 14
6. Annual harvest (with standard errors) of lake trout from Paxson Lake 1996 – 2001, and estimated yield potential of lake trout (in numbers of fish) for 1997 and 2002 14

LIST OF APPENDICIES

Appendix **Page**

A1. Capture history of lake trout from Paxson Lake tagged in previous experiments that were also sampled in 2002 20

A2. Summary of weight statistics from weighed subsample of lake trout (106 females, 105 males) captured in Paxson Lake in September, 2002. 23

B1. Data file used to estimate parameters of the Paxson Lake lake trout population, 2002 26

ABSTRACT

In 2002, length and weight information was collected from spawning lake trout *Salvelinus namaycush* in Paxson Lake in order to estimate yield potential (YP) using a model based on lake surface area. Based on the average weight of 63 fish sampled on the spawning grounds, the model predicted a harvest of 294 lake trout ≥ 600 mm TL/yr (SE = 49) can be sustained. The estimated YP of 294 lake trout/year was nearly identical to the estimated harvest of lake trout from Paxson Lake in 2001 (302 fish), and higher than the average of annual harvest from 1999 to 2001 (258 fish). The proportion of lake trout sampled on the spawning grounds that were ≥ 600 mm TL was 0.09 (SE = 0.01), compared to 0.06 (SE = 0.02) for lake trout sampled on the spawning grounds in Paxson Lake during 1987-1995. Based upon the estimated YP, lake trout in Paxson Lake are not being over-harvested, and therefore a change in the regulation to further reduce harvests is not warranted at this time.

Key words: lake trout, *Salvelinus namaycush*, Paxson Lake, yield potential, lake area, length and weight composition, growth.

INTRODUCTION

Lake trout *Salvelinus namaycush* support important recreational fisheries in Alaska roadside and remote lake systems. The life history of lake trout, however, allows this species to be easily over-exploited when not managed properly. Lake trout are characterized as having slow growth rates, low fecundity, alternate-year spawning regimes, strict habitat requirements (cold, deep, oligotrophic lakes with a sufficient prey base and few competitors), and extreme susceptibility to changes in habitat (Martin and Olver 1980). Careful monitoring of these populations is important to help manage the many popular lake trout fisheries.

Sport fishing for lake trout in Alaska is popular throughout the year. From 1985 to 2000, the average yearly sport catch of lake trout in Alaska was 37,703 fish, and the average harvest was 12,542 (Mills et al. 1986 – 1994; Howe et al. 1995, 1996, 2001a-d; Jennings 2004; Walker et al. 2003). From 1990 to 2000, the greatest catch of lake trout in Alaska was in 1993 (53,578 fish) and the greatest harvest (13,772) was in 1993 (Table 1). In most lakes in Region III (Arctic-Yukon-Kuskokwim region and the Upper Copper River and Upper Susitna River drainages) sport fishing harvest regulations for lake trout are composed of a minimum-size limit, and a limit of one or two fish per day (Table 2). Minimum length restrictions are usually enacted to allow lake trout to spawn at least once before recruiting to the sport fishery, and also serve to reduce harvest.

Because lake trout inhabit deep water and typically occur in low densities, stock assessment research is difficult, costly, and may result in biased estimates, particularly in large or remote lakes. In lieu of stock assessments, researchers and managers are increasingly using models to estimate yield potential (YP), or maximum potential harvest, of lake trout based upon environmental variables such as lake surface area (LA), thermal habitat volume (THV), and concentration of total dissolved solids (Evans et al. 1991; Marshall 1996; Szarzi and Bernard 1997). Both THV and LA models have been applied to lakes in Alaska.

Table 1.–Estimated number of angler days, lake trout harvested, lake trout caught, lake trout caught per angler day, and lake trout harvested per catch in Alaska, 1985-2000, and harvest and catch of lake trout in Paxson Lake, 1985-2000.

		Number of Lake Trout				Paxson Lake	
Year	Angler Days	Harvested	Caught	Caught/Angler Day	Harvested/Caught	Harvest	Caught
1985	1,336,717	18,473	N/A[a]	N/A	N/A	1,803	N/A
1986	1,449,474	21,463	N/A	N/A	N/A	944	N/A
1987	1,486,310	15,209	N/A	N/A	N/A	1,457	N/A
1988	1,626,244	17,193	N/A	N/A	N/A	1,310	N/A
1989	1,555,327	17,070	N/A	N/A	N/A	1,557	N/A
1990	1,589,087	12,602	42,443	0.04	0.20	2,139	4,466
1991	1,607,317	13,772	35,670	0.03	0.41	1,248	2,047
1992	1,651,296	12,525	43,295	0.05	0.26	1,118	2,383
1993	1,669,388	13,094	53,578	0.04	0.27	778	2,402
1994	1,695,551	11,374	45,107	0.03	0.26	262	1,221
1995	1,738,924	8,412	28,262	0.02	0.25	507	1,746
1996	1,262,580	9,772	34,781	0.07	0.21	297	1,928
1997	1,263,675	7,486	30,701	0.07	0.20	452	2,040
1998	1,153,277	5,985	22,807	0.06	0.20	205	1,738
1999	1,574,744	9,948	45,910	0.07	0.19	342	3,031
2000	1,649,833	6,292	32,176	0.06	0.21	228	2,067
Average	1,519,359	12,542	37,703	0.05	0.24	915	2,279

[a] N/A indicates data are not available.

Table 2.-Locations and sport fishing regulations for lake trout in Region III.

Location	Daily Bag and Possession Limit	Special Harvest Regulations
Summit Lake	2	Must be 24" or larger
Paxson Lake	2	Must be 24" or larger
Fielding Lake	1	Must be 26" or larger
Harding Lake	1	Must be 26" or larger
Crosswind Lake	1	Must be 24" or larger
Tyone Lake	1	Must be 24" or larger
Lake Louise	1	Must be 24" or larger
Trans Alaska Pipeline Corridor	0	Catch and release all year
North Slope Drainages	4	No size limit

Christie and Regier (1988) developed a THV model for estimating yield potential of lake trout, and defined THV as the volume of water bounded by the 8^{o} C and 12^{o} C temperature isotherms (representing optimal habitat, where neither temperature nor oxygen is limiting) averaged over the summer (June – September) period. Optimal levels of dissolved oxygen for lake trout occur in this temperature range (4 mg/L to 6 mg/L; MacLean et al. 1990). However, in applying this THV model for lake trout in Paxson Lake and Lake Louise, Szarzi and Bernard (1997) found that measurements of THV could vary by up to a factor of three from one year to the next, generating wide fluctuations in both available habitat and YP estimates. Because of this variability and the additional requirements of having to accurately measure the THV, this model was not adopted for managing Alaskan lakes. Lake area models use surface area as a measure of available preferred habitat. As lakes increase in size, so generally does their depth and THV (Marshall 1996). In contrast to THV, LA is relatively static, resulting in more stable YP estimates. In the absence of stock assessments, the LA model developed by Evans et al. (1991) has been applied to Alaskan lakes in Region III to determine if annual harvests (biomass per year) for lake trout exceed the estimated YP (J. Burr and T. Taube, Sport Fish Biologists, Alaska Department of Fish and Game, Fairbanks, personal communication).

When applying the LA model to Alaskan lakes, it is recognized that the predicted yields attained from the model are more conservative than from other yield models based on other environmental variables (Evans et al. 1991). Therefore, lake-specific harvests of lake trout that exceed the estimated YP's are used only as an indication that there may be a potential concern with the stock and that additional stock assessment work may be needed. Inherent uncertainties in the model were not quantified as part of this project because the model is used solely as an indicator of potential concern.

This study was undertaken to estimate the mean weight for lake trout ≥ 600 mm TL (i.e., those vulnerable to harvest) in Paxson Lake in order to update the estimated number of lake trout that can be harvested in a year (YP_{number}) and compare this value with current harvest levels. If the mean of annual harvests for the most recent three years (1999 to 2001) exceeded YP_{number} for Paxson Lake then a study would be proposed to further assess the population status and the need for a change in regulation. Otherwise, the results would not trigger an intensive stock assessment project.

OBJECTIVES

The research objectives for this experiment were to:

1. estimate the proportion of lake trout ≥ 600 mm TL on the known spawning grounds of Paxson Lake such that the estimate was within five percentage points of the true proportion 95% of the time; and,
2. estimate the mean weight of lake trout ≥ 600 mm TL (i.e., vulnerable to harvest) in Paxson Lake with precision sufficient to be 95% confident that the estimated threshold number of lake trout that can be harvested each year (i.e., YP_{number}) did not exceed the true value by more than 20%.

In addition, project tasks were to:

1. weigh ten fish of sex ratio in rough proportion to that found on the spawning grounds (approximately four males to one female) in each of 7, 25-mm length categories from 425 to 600 mm;
2. describe the length composition of the lake trout captured and the weight composition of those weighed; and,
3. affix a uniquely-numbered internal anchor tag to all captured lake trout, and give all captured fish a left pectoral fin clip for future identification.

METHODS

DESCRIPTION OF STUDY AREA

Paxson Lake (62˚50' N, 145˚35' W) is located in the Gulkana River drainage, which is part of the Copper River drainage (Figure 1). The East Fork Gulkana River parallels the Richardson Highway past the community of Paxson downstream from Summit Lake. Paxson Lake is 1,575 ha, has a maximum depth of 29 m, and is at an elevation of 625 m (Szarzi 1992). Several cabins are located along the shoreline, and a campground and two boat launches are located on the lake. In addition to lake trout, other species found in Paxson Lake include sockeye salmon *Oncorhynchus nerka*, Arctic grayling *Thymallus arcticus*, lake whitefish *Coregonus clupeaformis*, round whitefish *Prosopium cylindraceum*, Alaska whitefish *Coregonus nelsonii*, and burbot *Lota lota*. Since 1991, 5% of the lake trout harvested in Alaska came from Paxson Lake, and annual harvests have ranged between 2% and 9% of the total Alaska harvest (Mills et al. 1986 – 1994; Howe et al. 1995, 1996, 2001a-d; Jennings 2004; Walker et al. 2003). After increasing the minimum size limit from 18 inches to 24 inches in 1994, annual harvests of lake trout in Paxson Lake dropped off markedly (Table 1).

STUDY DESIGN AND SAMPLING METHODS

This experiment was designed to estimate the mean weight of lake trout ≥ 600 mm (24 in TL) in Paxson Lake in order to estimate annual yield potential using the LA model. In previous studies, mean weights of lake trout were obtained by conducting creel surveys and sampling the harvested lake trout (Szarzi and Bernard 1997). Because of the high cost of conducting a creel survey, the weights of spawning lake trout were measured instead, and were sampled at relatively low cost. Implicit in this design was the assumption that the lake trout sampled on the spawning grounds that were ≥ 600 mm TL were representative of the population of fish that was vulnerable to anglers, and that the average weight of lake trout sampled on the spawning grounds

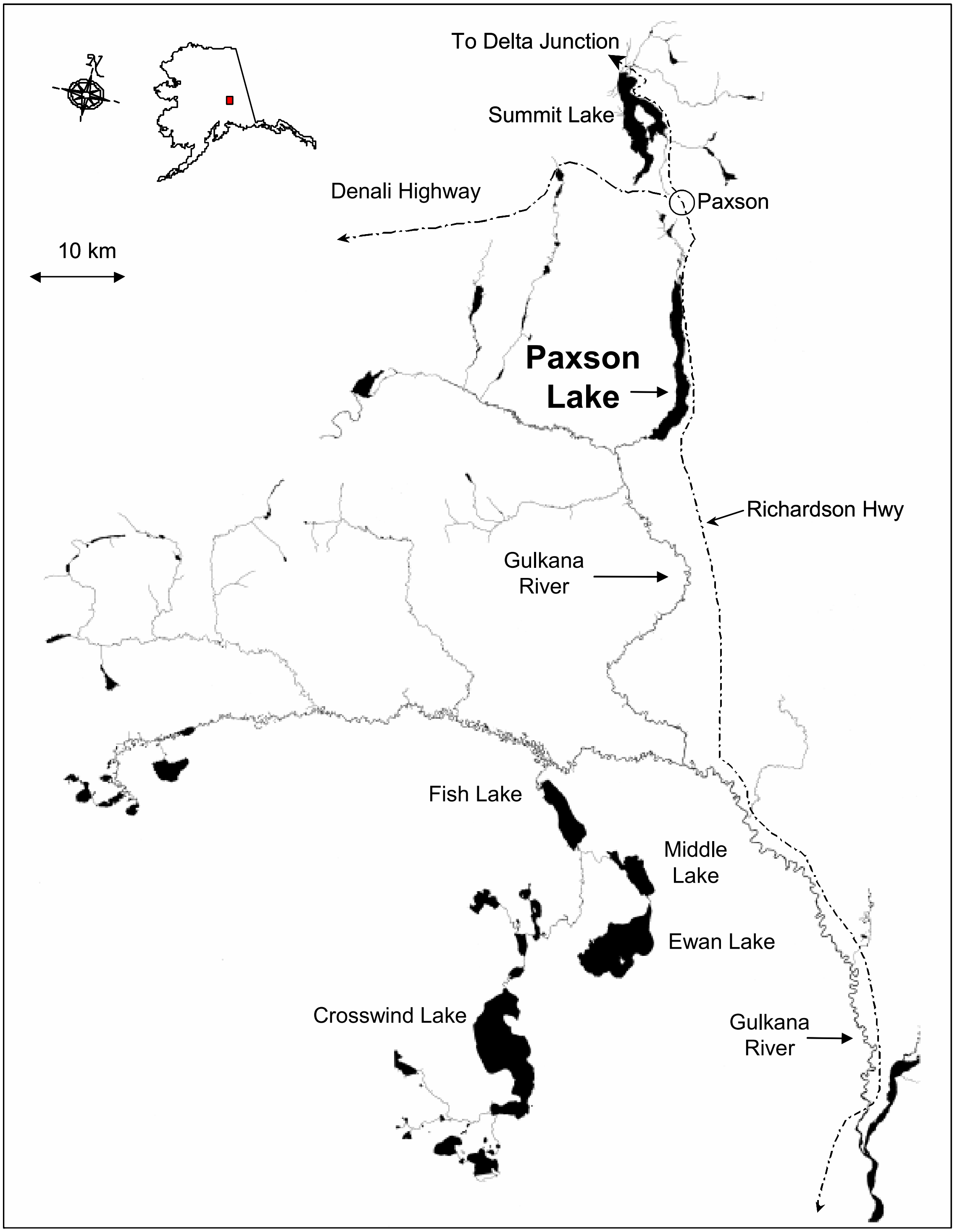


Figure 1.-Location of Paxson Lake.

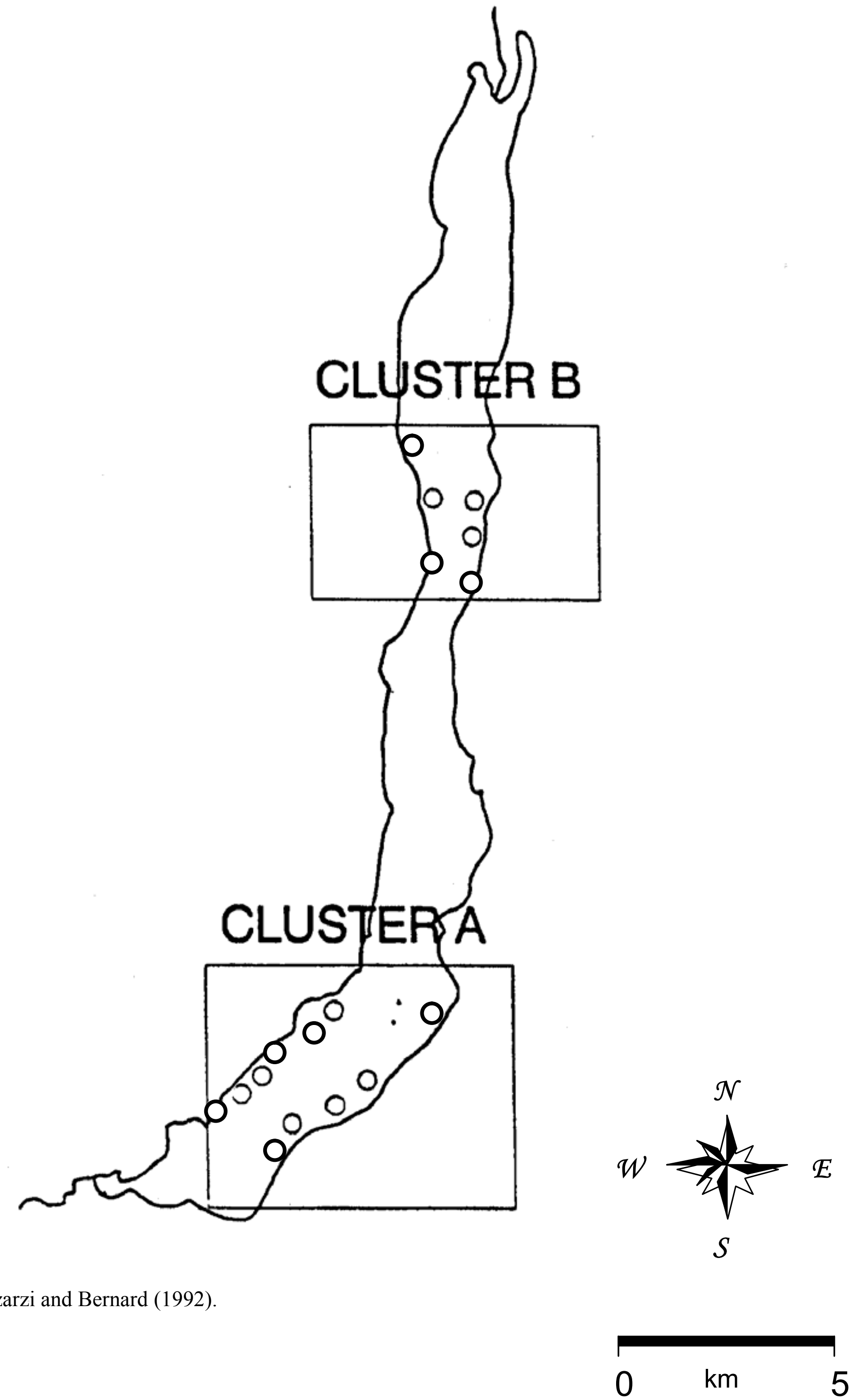
was equal to that harvested by anglers. It was recognized that spawning fish (especially females) would likely weight more than the same fish at other times of the year, thus leading to an estimate of YP which was conservative from a conservation perspective.

In the fall, mature lake trout congregate on rocky shoals to spawn, generally over cobble that is 3-15 mm in diameter (Healy 1978; Martin and Olver 1980; Burr 1988). Lake trout can readily be captured using beach seines and gill nets during this time. Previous research conducted by the Alaska Department of Fish and Game identified several spawning locations on Paxson Lake (Figure 2), those spawning locations have been sampled successfully to estimate abundance of lake trout (Burr 1989 and 1990; Szarzi 1992).

Spawning occurs in two general areas in the lake; one area comprises 11 spawning locations (Cluster A), and the other area comprises five locations (Clusters B; Figure 2). In comparison to many lakes in Canada that support lake trout populations, Paxson Lake is relatively small (Evans et al. 1991). Therefore, heterogeneity in size composition of lake trout resulting from spawning habitat differences along with a high fidelity to those areas was not anticipated (J. Burr, Alaska Department of Fish and Game, Fairbanks, personal communication). Insufficient weight data existed to test this hypothesis. As a surrogate for weight, lengths of males ≥ 600 mm TL captured on the spawning grounds in 1991, 1994, and 1995 were examined for geographic heterogeneity by spawning areas. Kolmogorov-Smirnov (K-S) tests failed to demonstrate significant spatial or temporal variability in size of lake trout among spawning areas. Analysis of historical sampling data from Szarzi (*Unpublished*) found that mature lake trout in Paxson Lake were frequently captured on different spawning grounds from year to year. The results of the K-S tests, along with the analysis of historical capture data showing movement among spawning locations, suggested that there were not segregated spawning subpopulations. Therefore, sampling some but not all spawning areas was likely sufficient to provide a representative sample of lake trout by length for the entire spawning population.

Because weights from prespawning lake trout were desired and lake trout spawn over a narrow window of time (5-10 days), it was important to obtain the samples as quickly as possible. Therefore, the larger spawning areas were targeted first and time was not spent monitoring and seining locations not likely to have many fish. However, precautions were taken to avoid bias by sampling with similar effort in both clusters and by sampling as many spawning locations as was possible. In each cluster, the larger spawning locations that were suitable for seining were targeted first, and then as many other others as was feasible were inspected and sampled given the resource constraints and weather conditions. In doing so, sampling moved in a geographically ordered sequence around the lake. On subsequent days in the same cluster, the sampling sequence was continued.

Sampling occurred during night because it was when fish densities on the spawning grounds were highest. Crewmembers scanned the shoals where lake trout spawn until they observed a large congregation of adult fish. A 400-ft by 8-ft beach seine was deployed around spawning aggregations to capture mature fish. The seine was deployed from a boat in a semi-circle with both ends eventually being drawn up on the shore, effectively keeping fish from swimming out into deeper water. The fish were drawn into shore by slowly pulling on the ends of the net until the middle part of the net was near shore. Fish were dip-netted into tubs and were sampled immediately.



Redrawn from Szarzi and Bernard (1992).

Figure 2.–Paxson Lake with lake trout spawning locations denoted with open circles.

Data from all captured lake trout were collected and recorded on an ADF&G Tagging-Length Form, Version 1.0 mark-sense forms. The spawning condition (i.e., whether pre or post spawning) was determined and recorded. All fish were measured for total length to the nearest millimeter, affixed with a uniquely-numbered Floy FD-94 internal anchor tag, given a left pectoral fin clip for future identification, and then the sex was determined when possible by presence of sex products. Only fish that appeared to be in good condition (i.e., vigorous, good color, etc.) were tagged. Initial protocol was to measure the weight and length of the first ten fish caught in each 25-mm length category beginning at 425 mm and extending to 600 mm with a male to female ratio that reflected that of the lake trout on the spawning grounds (we expected a 4:1 ratio of males to females). Instead, in anticipation of potential difficulty in reaching the desired sample size for females, all females that were captured were measured and weighed. For males, an attempt was made to weigh at least eight males in each 25 mm length category under 600 mm TL. All fish ≥ 600 mm TL of either sex were weighed. Lake trout were measured to the nearest millimeter total length and were weighed to the nearest 10 g.

YIELD POTENTIAL

Yield potential was estimated using the empirical relationship between estimated yield potential of lake trout (kg/ha^{-1}/yr^{-1}) and lake surface area (ha) developed by Evans et al. (1991):

$$\log_{10} YP = 0.60 + 0.72 \log_{10}(Area) \quad (1)$$

The YP (kg/yr) was converted to YP_{number} (fish/yr) taking the expected value of the quotient YP divided by the average weight of sampled fish ≥ 600 mm TL. Both the point estimate and the variance were estimated using the Delta method (Seber 1982):

$$\hat{YP}_{number} = \frac{YP}{\overline{X}} + \frac{YP}{\overline{X}^3}\hat{V}[\overline{X}] \quad (2)$$

$$\hat{V}[\hat{YP}_{number}] = YP^2 \frac{\hat{V}[\overline{X}]}{[\overline{X}]^4} \quad (3)$$

Where:

$\overline{X}$ = mean fish weight (kg/fish)

The variance estimate for YP_{number} is a minimum estimate, as uncertainty contributed by the LA model (i.e., in YP) was not quantified in this study.

Lake trout populations are usually characterized by having a 1:1 sex ratio for mature fish (Martin and Olver 1980) and the sex ratio of the sport harvest of lake trout normally reflects that of the underlying population. Therefore, to determine the mean weight of harvestable fish, weights of male and female lake trout were combined in a 1:1 ratio for yield estimation. In doing so, it was assumed that:

1. a representative sample of the spawning population in the lake was taken;
2. the weight of fish at the time of spawning was, in general, near a maximum for the year; and,
3. the weights of males and females ≥ 600 mm TL on the spawning grounds when combined in a 1:1 ratio provide an estimate of the mean weight of harvestable fish.

Assumption 1 was evaluated by comparing length and weight composition of all lake trout in Cluster A and Cluster B against each other for significant differences. Historical tagging data were examined to assess movement among spawning areas. In addition, the experiment was designed to sample all known spawning areas in both clusters multiple times. Assumption 2 was ensured by collecting data at the time when all fish were in a prespawning condition. Although evidence suggests that lake trout reach their maximum yearly body weight in late July, followed by a gradual decrease until the following spring (Hanson and Cordone 1967), pre-spawning lake trout are still near their maximum yearly weight-at–length in early September. Assumption 3 can be inferred by 1:1 ratio of males to females found in creel survey data for previous studies of lake trout harvest in Paxson Lake (Szarzi *Unpublished*) and in several lakes throughout Canada (Martin and Olver 1980).

LENGTH COMPOSITION

The proportion of lake trout on the known spawning grounds of Paxson Lake that was ≥ 600 mm TL was estimated. The proportion and variance estimators were:

$$\hat{p} = \frac{x}{n}, \text{ and} \tag{4}$$

$$\hat{V}[\hat{p}] = \frac{\hat{p}(1-\hat{p})}{n-1} \tag{5}$$

where:

$\hat{p}$ = the estimated proportion of lake trout on the spawning grounds that are ≥ 600 mm TL;

x = the number of lake trout on the spawning grounds that are ≥ 600 mm TL; and,

n = the total number of lake trout captured on the spawning grounds of known length.

GROWTH

During the data collection phase of this experiment, lake trout that were captured were tagged in previous experiments from 1987 through 1995. For these fish, individual capture histories were summarized and calculated the change in length from time of initial sampling to the present. For archival purposes, this information is reported in the results and summarized in Appendix A1.

RESULTS

CATCH SUMMARY

From 11 September through 18 September, 711 unique lake trout were captured (603 males, 108 females) on the spawning grounds. Of these, 211 (105 males, 106 females) were weighed (Table 3). There was no observed tag loss or mortality during the experiment, no spent fish were observed, and 70 lake trout with Floy tags from prior experiments were identified. All raw data used for data analysis were archived as described in Appendix B.

Table 3.–Length and weight statistics for lake trout sampled in Paxson Lake in September 2002.

Statistic	Males	Females	All
Total number sampled	603	108	711
Number sampled ≥ 600 mm TL	41	22	63
Mean length (mm)	518	570	525
SD (mm)	60	75	65
Range (mm)	405 - 955	460 - 895	405 – 955
$\hat{p}$ ≥ 600 mm TL	0.07	0.20	0.09
SE ($\hat{p}$)	0.01	0.04	0.01
Total number weighed	105	106	211
Mean weight	1.6	1.8	1.7
SD (kg)	1.2	1.2	1.2
Range (kg)	0.5 – 10.4	0.7 – 8.9	0.5 – 10.4
Number weighed ≥ 600 mm TL	41	22	63
Mean weight (kg)	2.6	3.0	2.7
SD (kg)	1.6	1.9	1.7
Range (kg)	1.2 – 10.4	1.5 – 8.9	1.2 – 10.4

Of the 711 unique lake trout sampled, 616 came from eight of 12 locations within Cluster A, and 95 came from three of five locations in Cluster B. Due to inclement weather and choppy water conditions, Cluster B was not sampled with the same intensity as Cluster A. Sampling occurred over two nights and part of a third in Cluster B compared to five nights and part of a sixth in Cluster A.

Length and Weight Composition

The mean length of all sampled lake trout was 525 mm TL (SE = 2.4). For males, the mean length was 518 mm TL (SE = 2.4), and for females was 570 mm TL (SE = 7.2; Table 3; Figures 3 and 4; Appendix A2). The length composition of males and females was found to be significantly different using a K-S test (D = 0.34; P ≤ 0.01). The proportion of all lake trout on the known spawning grounds that were ≥ 600 mm TL was 0.09 (SE = 0.01; Figure 3; Table 3). The proportion of lake trout ≥ 600 mm TL in the sample was 0.07 (41 of 603) for males and 0.20 (22 of 108) for females (Table 3).

Male and female lake trout had similar length-weight relationships with males weighing slightly more at large sizes. Similar data collected earlier in August, 1997 with hook and line gear showed fish to be heavier at size than fish sampled in this study (Figure 4).

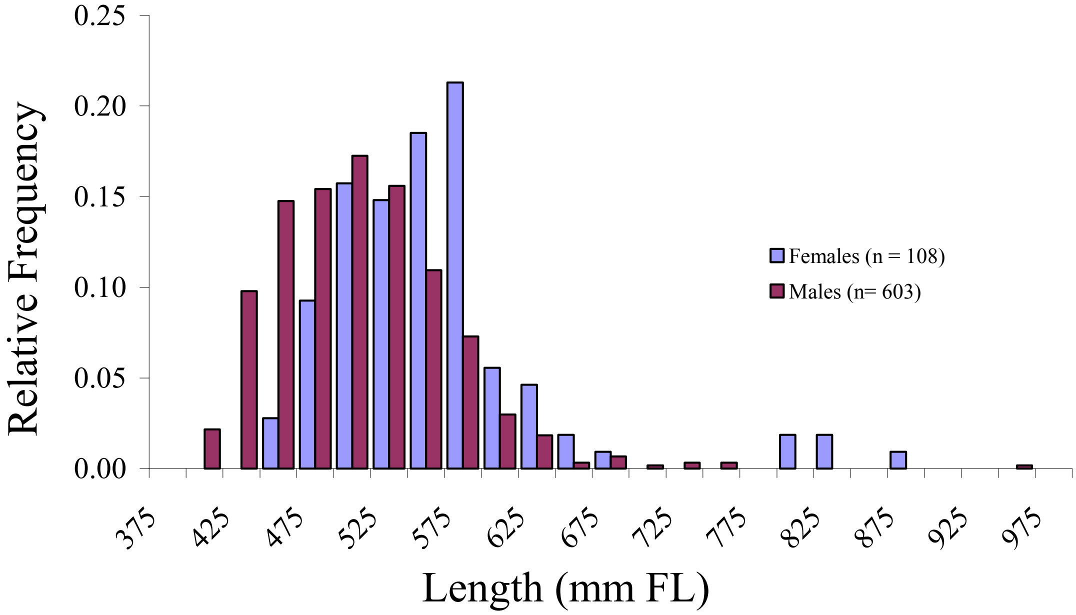


Figure 3.–Length distributions of male and female lake trout sampled from Paxson Lake in September 2002.

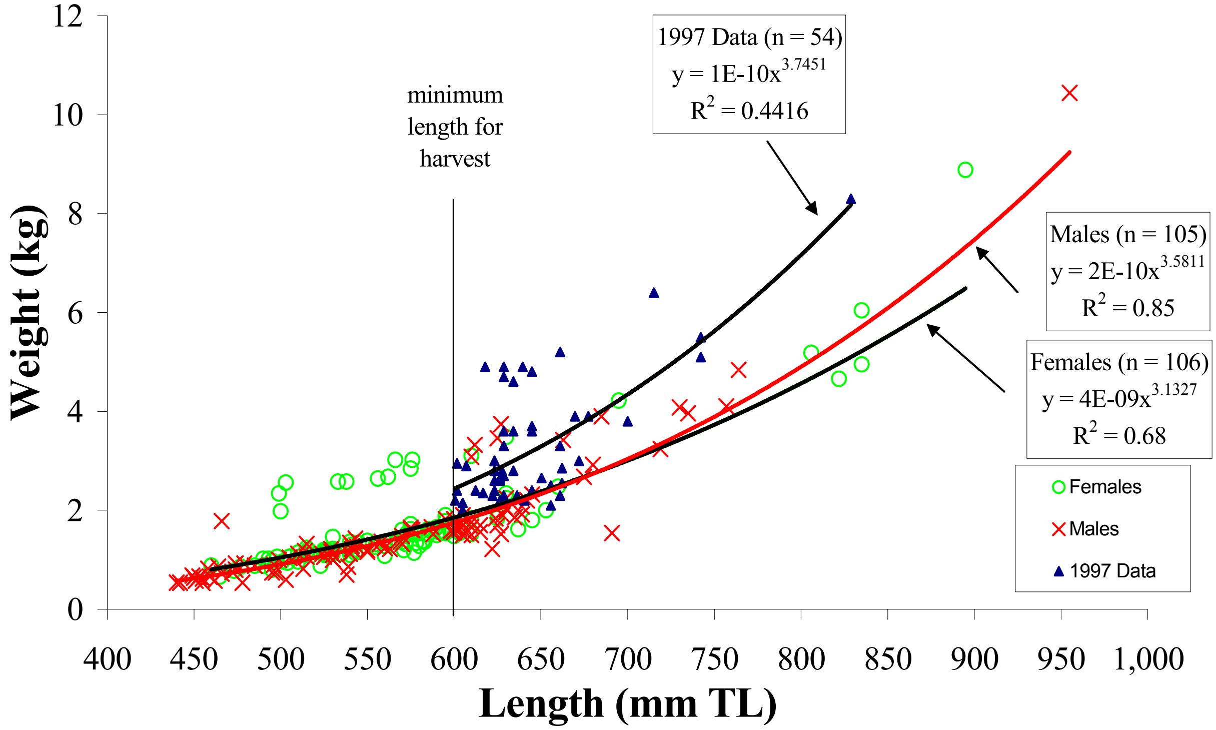


Figure 4.–Length-weight relationship for lake trout sampled on the spawning grounds in Paxson Lake, September 2002, and by hook-and-line in 1997.

Based on comparisons of length and weight composition of fish between clusters, it was determined that a representative sample of lake trout on the spawning grounds was captured. The mean length of all lake trout sampled in Cluster A (524 mm TL; SD = 66) was nearly identical to that for Cluster B (531 mm TL; SD = 60). Cumulative length distributions of all sampled lake trout between clusters was significantly different at 92% confidence ($D = 0.11$; $P = 0.08$). For lake trout ≥ 600 mm TL there was no significant difference in length distributions between clusters ($D = 0.39$; $P = 0.62$). The mean weight of all lake trout sampled in Cluster A was 1.7 kg (SD = 1.3) and in Cluster B was 1.7 kg (SD = 0.9). Although the mean weights between clusters were similar, the results of the K-S test for differences in weight composition of all weighed fish indicated that lake trout in Cluster B were significantly larger ($D = 0.17$; $P = 0.02$). However, weight composition for lake trout ≥ 600 mm TL was not significantly different between clusters ($D = 0.02$; $P = 0.71$).

Yield Potential

The mean weight for males ≥ 600 mm TL was 2.6 kg (SD = 1.6 kg), the mean weight for females ≥ 600 mm TL was 3.0 kg (SD = 1.9 kg), and the mean weight of all fish ≥ 600 mm TL was 2.7 kg (SD = 1.7 kg; Table 3). Applying the relationship of annual yield potential to surface area Paxson Lake (1,575 ha) and mean weight of harvestable fish in the sample resulted in a YP of 798 kg/yr, and an annual YP_{number} of 294 lake trout/yr ≥ 600 mm TL (SE = 49).

GROWTH

Growth information was attained from 67 of the 70 lake trout recaptured from previous experiments conducted between 1987 and 1997 (Appendix A2). The greatest amount of observed growth was 185 mm (from 510 mm TL to 695 mm TL) from a female originally sampled on 21 September 1992, and the least amount of growth observed was 3 mm (from 552 mm TL to 555 mm TL) from a fish of unknown sex originally sampled on 16 September 1994 (Appendix A2). One measurement of negative growth was observed and was excluded due to likely measurement error. For a detailed examination of growth rates of lake trout in Paxson Lake and other lakes in Alaska, see Burr (1997).

DISCUSSION

Principle to attaining reliable estimates of yield potential was the assumption that a representative sample of the lake trout population ≥ 600 mm TL was collected. In Paxson Lake, a non-representative sample could have been collected if heterogeneity in size composition by spawning areas existed and effort was not distributed proportional to spawning abundance. However, the sampling protocol and study results strongly suggest that a representative sample was attained. First, sampling was conducted in proportion to the number of individual spawning sites. That is, a higher proportion of sampling time was spent in Cluster A than in Cluster B (5.5 nights vs. 2.5), which is proportional to the number of sites found in each cluster (12 sites in A vs. 5 in B). Secondly, for fish ≥ 600 mm TL, no differences were observed in the length or weight distributions and means weights between sampling clusters (Table 4). Finally, there was evidence of considerable mixing of spawning lake trout between clusters from year-to-year. In September 2003, 949 mature lake trout in Paxson Lake were captured and sampled using procedures identical to those used in 2002 (Scanlon *Unpublished*). Of these 949, fish 202 were recaptures from 2002, and only 106 (52%) of these were captured in the same cluster they were the year before.

Table 4.–Summary of Kolmogorov-Smirnov test results comparing length and weight compositions of lake trout captured in Cluster A and Cluster B.

Comparison	*D*-Statistic	P-Value
A vs. B Lengths (all fish)	0.11	0.08
A vs. B Lengths (≥ 600 mm TL)	0.39	0.62
A vs. B Weights (all fish)	0.17	0.02
A vs. B Weights (≥ 600 mm TL)	0.02	0.71

Although the 2002 estimate of YP was within the range of estimates from previous experiments in 1991 - 1994, and 1997 (236 – 501 lake trout 24 in TL/yr; Figures 5 and 6), differences in the estimates are partially attributed to: 1) differences in sampling procedures; and, 2) changes in the population parameters. Sampling procedures in 1991 – 1994 differed in that weights of lake trout were taken over the entire spawning period, and included fish that had already released some of their gametes. The YP estimate from 1997 (236 fish) is lower than the 2002 estimate in part due to temporal differences in sampling. In 1997, lake trout were collected using hook-and-line gear during July when lake trout were likely at their maximum yearly body weight (Hanson and Cordone 1967).

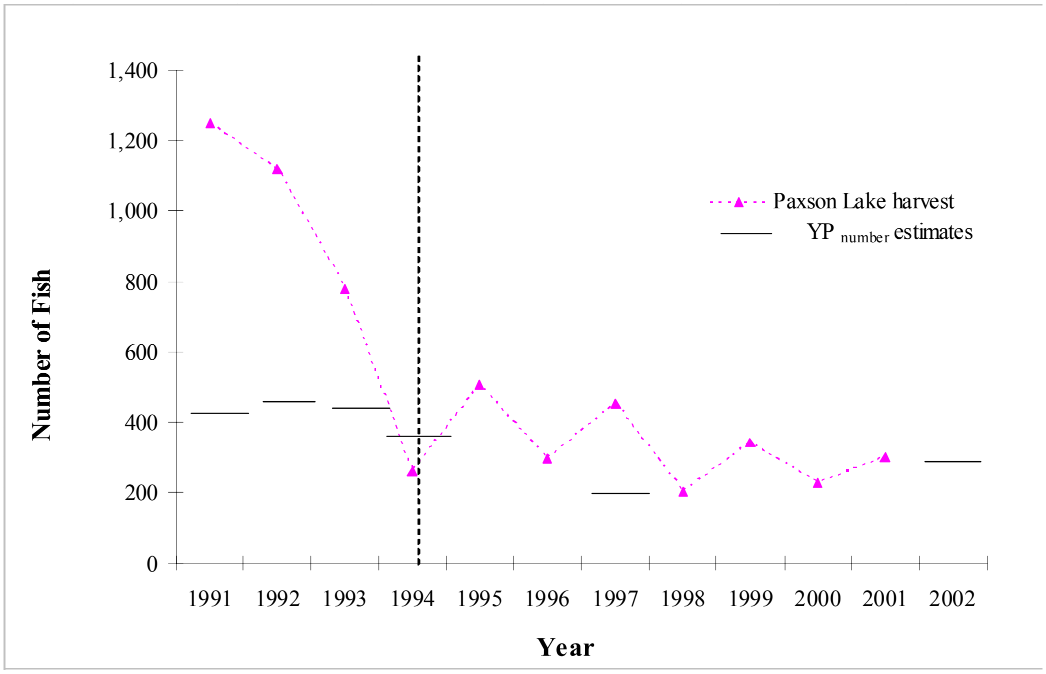


Figure 5.–Number of lake trout harvested from Paxson Lake, 1991-2001. Dotted vertical line denotes regulation change in minimum length for harvest from 18 in to 24 in (April 1994). Solid horizontal lines denote potential yields of lake trout determined using the LA model (Evans et al. 1991) and the mean weight of fish harvested in 1991, 1992, 1993, 1994, and 1997.

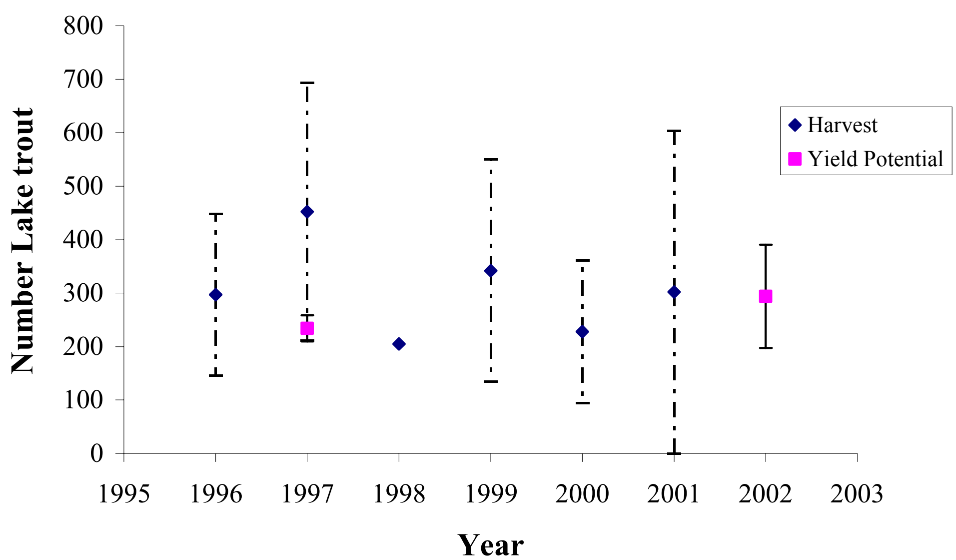


Figure 6.–Annual harvest (with standard errors) of lake trout from Paxson Lake 1996 – 2001, and estimated yield potential of lake trout (in numbers of fish) for 1997 and 2002. No standard error estimate was available for the harvest in 1998.

Variability in YP estimates may also be attributed to natural variability in the population parameters and the inherent effects of the 1994 regulatory changes. Variability in sex ratios, average weight, and length composition has been observed (Tables 5 and 6). For example: the length-frequency distribution of lake trout sampled on the spawning grounds in 2002 was significantly different than the length distributions of lake trout sampled using the same procedures in 1995, and by rod-and-reel in 1997. The degree to which the regulatory changes has influenced this variation is uncertain, however, the larger YP estimates during 1991 to 1994 may also be partially explained by a smaller abundance of fish greater than ≥ 600 mm TL in the population due to higher exploitation rates.

Table 5.–Summary of Kolmogorov-Smirnov test results comparing length compositions of lake trout captured in 1995 with beach seines, in 1997 with hook-and-line, and in 2002 with beach seines.

Comparison	*D*-Statistic	P-Value
1995 vs. 1997	0.33	< 0.01
1995 vs. 2002	0.21	< 0.01
1997 vs. 2002	0.18	< 0.01
2002 Males vs. 2002 Females	0.34	< 0.01

Table 6.–Sex ratios and mean fork lengths by sex for lake trout sampled in Paxson Lake in 1995, 1997, and 2002.

Year	Male to Female Ratio	Mean Length Males (SD) (mm TL)	Mean Length Females (SD) (mm TL)	Mean Length Combined (SD) (mm TL)
1995	4.5:1	540 (48)	539 (48)	540 (48)
1997[a]	N/A[b]	N/A	N/A	499 (68)
2002	5.6:1	518 (60)	570 (75)	525 (65)

[a] Lake trout sampled in 1997 were caught in the summer with hook-and-line, and external identification of sex was not possible. In addition, the hook-and-line gear used in 1997 caught a larger size range of lake trout, both mature and immature fish, resulting in a wider length distribution in the sample when compared to 1995 and 2002, where seines were used to catch primarily mature fish.

[b] N/A indicated data are not available.

Based on an estimated yield potential of 294 lake trout/year in 2002, the harvest of lake trout, as defined by the mean of annual harvests from 1999 to 2001 (291 fish; SE = 33) is within prescribed management objectives. It appears that the 1994 regulatory change has been effective in reducing harvest to prescribed levels defined by the LA model, and therefore, neither a population assessment nor regulatory changes are necessary at this time. However, because of the observed variability in samples taken between years (e.g., sex ratio and length-frequency distributions) periodic assessments (at least once every six years) should be conducted to generate updated estimates of yield potential using the LA model (Martin and Olver 1980).

Because the LA model is thought to produce conservative estimates of yield potential (Marshall 1996), it may be that the population in Paxson Lake is able to sustain a greater annual harvest than predicted by the LA model. In order to test this hypothesis, more intensive population assessments are necessary. Estimates of total abundance (or biomass), age composition, and natural mortality are needed to investigate alternative surplus production models. Some of this information has been collected. Abundance of mature lake trout was estimated each year from 1988-1995 (Table 7). Abundance in these years was estimated by sampling spawning male lake trout in the fall and doubling the estimate using the assumption of a 1:1 sex ratio to estimate total abundance of spawners. However, this methodology does not account for fish that are not spawning in a given year (skip-spawners and immature fish). Thus, it is recommended that future research endeavors investigate methods of estimating abundance for a larger proportion of the population in order to correct or adjust historic estimates of spawner abundance and subsequently use those estimates in alternative production models.

Table 7.–Number of fish sampled on the spawning grounds, proportion of fish ≥ 600 mm TL, and estimates of abundance of lake trout in Paxson Lake 1987-1995 and 2002 (1997 lake trout were sampled via hook-and-line and no estimate of abundance was calculated).

	Year										
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1997	2002
No. sampled	264	967	947	741	1,221	829	910	1,487	1,655	271	711
$p \geq 600$ mm TL	0.08	0.05	0.06	0.05	0.05	0.04	0.06	0.04	0.09	0.06	0.09
Abundance	N/A[a]	5,944	5,238	4,240	5,204	4,306	4,550	4,876	3,714	N/A	N/A

[a] N/A indicates data are not available to estimate abundance.

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APPENDIX A

Capture Summaries

Appendix A1.–Capture history of lake trout from Paxson Lake tagged in previous experiments that were also sampled in 2002.

Tag #	Date First Caught	Sex	Length (mm)[a]	2002 Sample Date	New Length (mm)[a]	Δ Length (mm)	Years Since Last Capture	Average Annual Growth[b]
2088	9/13/91	M	491	9/15/02	612	121	11	11.00
36447	9/16/89	M	436	9/16/02	605	169	13	13.00
38685	9/15/90	M	400	9/18/02	583	183	12	15.25
38741	9/15/90	M	434	9/16/02	580	146	12	12.17
38870	9/15/90	M	438	9/18/02	574	136	12	11.33
46966	9/10/87	M	485	9/12/02	624	139	15	9.27
78384	9/14/88	M	441	9/14/02	576	135	14	9.64
78629	9/13/88	M	445	9/11/02	615	170	14	12.14
78721	9/15/88	M	561	9/12/02	625	64	14	4.57
78821	9/14/88	M	487	9/12/02	625	138	14	9.86
78860	9/14/88	M	413	9/12/02	536	123	14	8.79
86202	9/13/88	M	419	9/14/02	562	143	14	10.21
86206	9/13/88	M	478	9/14/02	585	107	14	7.64
316002	9/7/95	M	555	9/17/02	596	41	7	5.86
316033	9/7/95	M	580	9/12/02	680	100	7	14.29
316145	9/11/95	F	550	9/13/02	630	80	7	11.43
316155	9/11/95	M	500	9/16/02	570	70	7	10.00
316288	9/12/95	M	490	9/11/02	590	100	7	14.29
316265	9/13/95	M	470	9/12/02	525	55	7	7.86
316282	9/13/95		560	9/16/02	588	28	7	4.00
316303	9/13/95	M	555	9/16/02	691	136	7	19.43
316322	9/14/95	M	515	9/14/02	570	55	7	7.86
316363	9/14/95	M	515	9/18/02	565	50	7	7.14
316365	9/14/95	M	475	9/13/02	532	57	7	8.14
316367	9/14/95	M	535	9/13/02	589	54	7	7.71
316369	9/14/95	M	480	9/16/02	530	50	7	7.14

-continued-

Tag #	Date First Caught	Sex	Length (mm)[a]	2002 Sample Date	New Length (mm)[a]	Δ Length (mm)	Years Since Last Capture	Average Annual Growth[b]
316386	9/14/95	F	535	9/13/02	595	60	7	8.57
316488	9/18/95	M	495	9/18/02	535	40	7	5.71
316490	9/18/95	M	500	9/14/02	545	45	7	6.43
316647	9/19/95	M	530	9/18/02	600	70	7	10.00
316660	9/20/95	M	530	9/14/02	585	55	7	7.86
316694	9/20/95	M	520	9/16/02	557	37	7	5.29
316724	9/21/95	M	530	9/18/02	599	69	7	9.86
324045	9/7/94	M	468	9/17/02	570	102	8	12.75
324135	9/9/94	M	523	9/17/02	610	87	8	10.88
324144	9/9/94	M	499	9/13/02	580	81	8	10.13
324282	9/13/94	M	479	9/14/02	565	86	8	10.75
324290	9/13/94		552	9/16/02	555	3	8	0.38
324291	9/13/94	M	469	9/16/02	530	61	8	7.63
324293	9/13/94	M	483	9/16/02	558	75	8	9.38
324302	9/13/94	M	493	9/16/02	588	95	8	11.88
324304	9/13/94	M	467	9/14/02	543	76	8	9.50
324336	9/13/94	M	505	9/16/02	565	60	8	7.50
324499	9/15/94	M	521	9/13/02	584	63	8	7.88
324654	9/19/94	M	518	9/14/02	615	97	8	12.13
324657	9/11/95	M	530	9/17/02	585	55	7	7.86
324700	9/20/94	M	462	9/16/02	549	87	8	10.88
324719	9/19/95	M	510	9/17/02	557	47	7	6.71
324772	9/21/94		542	9/11/02	645	103	8	12.88
364122	9/16/92	M	477	9/11/02	628	151	10	15.10
364135	9/16/92	M	455	9/16/02	595	140	10	14.00
364196	9/17/92	M	428	9/16/02	564	136	10	13.60

-continued-

Appendix A1.–Page 3 of 3.

Tag #	Date First Caught	Sex	Length (mm)[a]	2002 Sample Date	New Length (mm)[a]	Δ Length (mm)	Years Since Last Capture	Average Annual Growth[b]
364206	9/17/92	M	443	9/14/02	565	122	10	12.20
364213	9/18/92	F	558	9/18/02	550	-8	10	-0.80
364284	9/18/92	M	420	9/13/02	525	105	10	10.50
364303	9/21/92	F	510	9/17/02	695	185	10	18.50
364400	9/10/92	M	431	9/14/02	580	149	10	14.90
364508	9/7/93	M	422	9/16/02	560	138	9	15.33
364585	9/9/93	M	516	9/14/02	675	159	9	17.67
364593	9/9/93	M	480	9/15/02	567	87	9	9.67
364596	9/9/93	M	450	9/18/02	558	108	9	12.00
364622	9/9/93	M	486	9/11/02	630	144	9	16.00
364756	9/10/93	M	436	9/17/02	505	69	9	7.67
364776	9/10/93	F	680	9/17/02	835	155	9	17.22
364824	9/14/93	M	505	9/18/02	605	100	9	11.11
364825	9/14/93	M	505	9/14/02	588	83	9	9.22
364839	9/14/93	M	565	9/15/02	663	98	9	10.89

[a] These lengths fall in the area of maximum curvature on the growth curve for lake trout in Paxson Lake developed by Burr (1997).

[b] These values do not account for changing growth rates between sampling events.

Appendix A2.–Summary of statistics from weighed subsample of lake trout (106 females, 105 males) captured in Paxson Lake in September, 2002.

Length Category (mm TL)	Female Mean Weight (kg)	Number of Females in Category	Male Mean Weight (kg)	Number of Males in Category
425-449	0.00	0	0.59	3
450-474	0.77	3	0.78	14
475-499	1.09	9	0.82	7
500-524	1.24	14	1.03	9
525-549	1.34	19	1.13	14
550-574	1.62	16	1.30	10
575-599	1.66	23	1.64	7
600-624	1.84	7	1.82	18
625-649	2.18	7	2.25	12
650-674	2.24	2	3.42	1
675-699	4.22	1	2.38	4
700-724	0.00	0	3.24	1
725-749	0.00	0	4.02	2
750-774	0.00	0	4.47	2
775-799	0.00	0	0.00	0
800-824	4.92	2	0.00	0
825-849	5.50	2	0.00	0
850-874	0.00	0	0.00	0
875-899	8.88	1	0.00	0
900-924	0.00	0	0.00	0
925-949	0.00	0	0.00	0
950-974	0.00	0	10.44	1
975-999	0.00	0	0.00	0

APPENDIX B

Data File Listing

Appendix B1.–Data file used to estimate parameters of the Paxson Lake lake trout population, 2002.

Data File[a]	Description
Bscanlon2002paxsonlaketroutraw.xls	Population and marking data for Paxson Lake lake trout captured 11 September through 19 September, 2002.

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