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Stock Assessment of Lake Trout in Sevenmile Lake, 1999

by
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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, χ^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

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ABSTRACT

The abundance of lake trout *Salvelinus namaycush* in Sevenmile Lake in 1999 was estimated from a two-sample mark-recapture experiment. Gillnets were used in June and August to capture lake trout for the marking event. A combination of gillnets and beach seines were used to capture lake trout from a single spawning location in September for the recapture event. Abundance was estimated to be 1,260 (SE=185) lake trout > 361 mm FL. Abundance of lake trout ≥ 375 mm FL, the length range for estimates from previous years, was 1,109 (SE=170). This estimate was similar to estimates obtained from 1987-1993, which represent years prior to the first egg-take from this stock for hatchery production. This population has maintained a stable level of abundance since 1987 indicating that the removal of eggs and sport harvest have not deleteriously affected abundance of adult lake trout. Lake trout in the 400-425 mm length category comprised 0.32 (SE=0.03) of the population. Male lake trout comprised 0.70 (SE =0.03) of the population. Mean lengths were 416 (range 244-512) mm FL for males and 452 (range 400–520) mm FL for females. Mean length of all fish examined was 427 mm FL. During September, weights were attained for 88 males and averaged 5.51 kg. A total of 86,800 eggs were live-spawned from 69 female lake trout. This accounted for an estimated 12% of the annual production. A total of 3,888 eggs were placed in artificial substrate boxes and distributed on the spawning bed.

Water temperature, DO, and pH were monitored in Sevenmile Lake. From 23 June to 15 September 1999, water temperatures at 1 m (surface), 5.5 m (midpoint), and 10 m (bottom) averaged 13.0°, 11.4°, and 9.5 °C, respectively. On 25 July, dissolved oxygen and pH measured at the deepest portion of the lake were 11 mg L^{-1} and 7.0, respectively.

Key words: lake trout, *Salvelinus namaycush*, abundance, length composition, Sevenmile Lake, temperature.

INTRODUCTION

Sevenmile Lake on the Denali Highway (Figure 1) was selected as a brood source for the Tanana drainage lake trout stocking program in 1993. Eggs taken from these fish are reared in the Fort Richardson hatchery, and provide about 43,000 subcatchable (approximately 155 mm FL) and catchable (approximately 200 mm FL) lake trout for stocking in both Region II and III lakes (ADF&G 2000). Egg-takes have been conducted in 1993, 1995, 1997 and 1999. The target number of eggs to take has been 100,000 based on a population size of about 1,000 mature fish. Lake trout harvests by recreational anglers typically are not estimated in the annul statewide harvest survey due to few survey respondents. However, sport harvests likely do occur because of the roadside location and boat ramp access to the lake. Harvest is believed to be 50 fish or less annually. At issue, and thus the purpose of this study, is whether the removal of production associated with the egg-takes negatively impacts the population. Burr (1992) determined the age at 50% maturity for female lake trout in Sevenmile Lake is five years. Impacts from the removal of production from the first egg-take would be noticed in recruitment in the adult population beginning in 1998.

Average abundance of female lake trout from 1987-1992, prior to the first egg-take, was estimated to be 500 fish (Burr 1994). Two-sample mark-recapture experiments were conducted in two of the four years that egg takes occurred (1993 and this study for 1999) and also in 1996. During the other two years that egg-takes occurred (1995 and 1997), two-sample mark-recapture experiments were not conducted, but all fish sampled were marked and released. In this study we used the methods of Jolly (1965) and Seber (1965) to estimate abundance for 1995 and 1997.

Potential annual egg production was calculated as half the estimated abundance (because the true sex composition is unknown at the time of most sampling) times the average fecundity per female for that given year (Burr 1994). The percentage of annual egg production removed during the egg takes was then the number of eggs taken divided by the total estimated

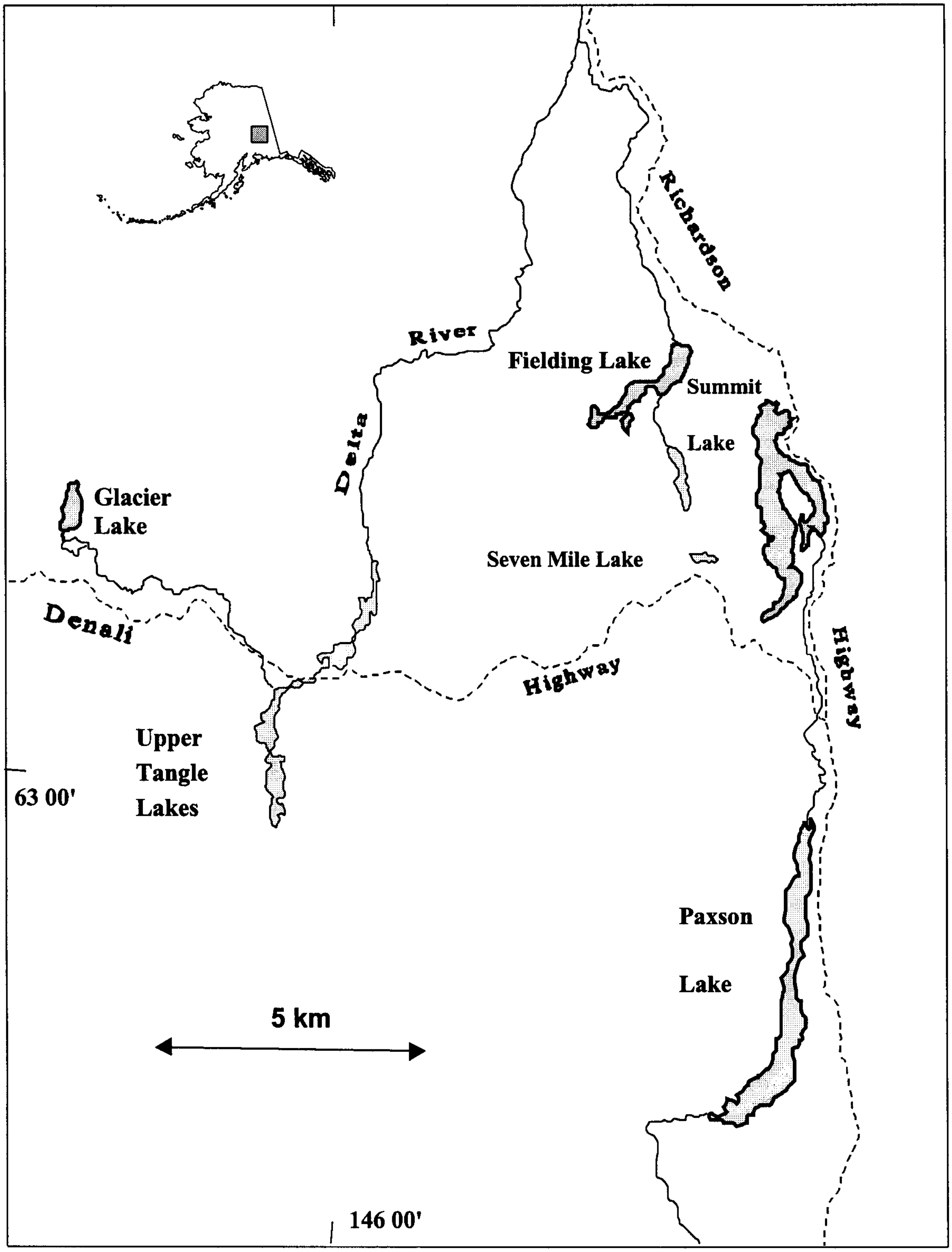

Figure 1.-Location of Sevenmile Lake.

production. The percentage of potential annual production removed has varied from 12% to 26% over the four years (Table 1). Burr (1994) estimated a removal of 20% of the potential annual production in 1993 based on a population size of 500 females with the assumption that all female lake trout spawned that year. Burr (1994) cautioned that if some portion of the females do not spawn every year, a greater portion of the potential production would be removed. For that reason, it was recommended that egg-takes be conducted every-other-year. To further minimize the potential negative effects of the egg takes on lake trout production, the target number of eggs was reduced to 80,000 beginning in 1999.

A previous study in Sevenmile Lake (Taube 1997) sought to evaluate the effects of egg removal on the growth of age-0 and age-1 lake trout. The hypothesis was that there would be increased growth compensation and survival occurring during years following egg takes because of less competition from reduced numbers of young lake trout. To test this hypothesis sampling was conducted in 1995 (year of first egg take) and 1996 to compare length and weight of captured age-0 and age-1 lake trout. Mean length of age-1 lake trout was less in 1996 and mean weight was considerably greater (Table 1). This assessment was confounded by small sample sizes, inappropriate time of sampling, and possible measurement error (Taube 1997). Condition factors for both age-0 and age-1 lake trout calculated for 1996 were much higher than those for 1995 (Table 1). In addition, sampling in 1996 was conducted a month earlier than in 1995. There was no conclusive evidence of improved growth as a result of egg-takes, as environmental variables may have played a greater role than competition.

One method to offset the reduction in production from egg removal is to increase the survival of eggs to fry stage. Experimental incubation of lake trout eggs in artificial spawning substrates was tested in Donnelly Lake in 1995 with hatch success estimated at 43% (Viavant 1996). Efforts began in 1997 to increase survival of fry in Sevenmile Lake. Subsequent contributions to the adult population, if any, will be measurable in 2002. In 1997, 5,417 eggs were placed in artificial substrate in Sevenmile Lake and hatching success was 66% or about 3,600 fry (Viavant 1998). In 1999, another 3,800 eggs were placed into substrate boxes after the egg-take.

Objectives for this project were to:

1. estimate the abundance of adult lake trout ≥ 350 mm FL in Sevenmile Lake in June, 1999;
2. estimate the length composition of lake trout in Sevenmile Lake; and,
3. examine the estimates of abundance, survival rates and surviving recruitment in the historical database to determine if egg removal in Sevenmile Lake influences growth recruitment.

In addition, project tasks were to:

1. collect water quality data from Sevenmile Lake; and,
2. estimate the number of eggs per female collected in the egg take.

Table 1.-Data collected during egg-takes, estimates of abundance (375 mm FL), and data collected from juvenile lake trout in Sevenmile Lake, 1993-1999.

Egg-takes	1993	1995	1996	1997	1999
Number of eggs taken	107,500	63,100	None	90,200	86,800
Number of females sampled	90	120	--	94	69
Eggs/female	1,194	526[a]	--	960	1,258
Percent of production removed (@50% females)	0.16	0.26	--	0.19	0.12
Population data					
Population estimate [b]	1,139	548	877	997	1,109
Standard error	152	44	21	163	170
Estimator	Petersen	Jolly/Seber	Petersen	Jolly/Seber	Petersen
Number of eggs placed in artificial substrate boxes	none	none	None	5,417[c]	3,800
Juvenile fish collection					
Dates of sampling		7/22-8/24	7/15-7/18		
Mean length (mm) of age-0		63.4 (7.2)	50.3 (2.5)		
Mean wt. (g) of age-0		2.7 (0.7)	11.8 (1.9)		
Sample size		50	21		
Fulton's condition factor (wt/length^3)		1.1×10^{-5}	9.3×10^{-5}		
Mean length (mm) of age-1		147.1 (11.0)	126.7 (8.3)		
Mean wt. (g) of age-1		25.0 (6.8)	181.9 (34.7)		
Sample size		14	63		
Fulton's condition factor (wt/length^3)		0.78×10^{-5}	8.9×10^{-5}		

a Egg take occurred too early when females were green.

b These eggs hatched in 1998. Survival to hatch was 66.2%.

c Estimates are for fish $\geq$ 375 mm fork length.

METHODS

SITE DESCRIPTION

Sevenmile Lake (63° 06'N, 145° 37'W) is road accessible from the Denali Highway, and is located seven miles from the community of Paxson (Figure 1). The lake is situated at an elevation of 975 m in the foothills of the Alaska Range. The estimated surface area is 33 ha and the maximum recorded depth is 12.5 m (Burr 1991). Sevenmile Lake is landlocked with no remarkable inlet or outlet streams.

SAMPLING PROCEDURES

A two-sample mark-recapture experiment was conducted to estimate the abundance and length composition of lake trout in Sevenmile Lake. For the marking event, lake trout were sampled on two occasions: the first during 21 -25 June, and the second from 2-3 August. A two-person crew captured lake trout with both sinking and floating gillnets. Nets were 47–61 m long and 2.5-3 m deep with 25 mm stretch mesh. These nets were set throughout the lake at varying depths ranging from 1-12 m. Nets were fished from 2000 to 0400 and were checked at 30 to 40 minute intervals. All lake trout captured and judged to be in good condition were individually marked with a numbered Floy internal anchor tag and were given a lower caudal punch. Lengths (mm FL), old marks, and Floy tag numbers were recorded. Tags deployed in June and August were green and numbered from 13,000–13,105 and 13,106–13,151, respectively.

Sampling of lake trout for the recapture event was conducted in conjunction with an egg take from 9–11 September. All fish were captured at night (2300–0400) from a single spawning area located at the northeast quartile of the lake. Lake trout were captured when they had aggregated in sufficient numbers. Gill nets and a beach seine (120 m long and 2.5 m deep) with a large bag (3.7 m wide) were used to capture fish. Gill nets were deployed around the spawning aggregation and fish were spooked into the net by disrupting the water inside of the net. The beach seine was used by anchoring one end to shore, deploying it from a 3.5 m boat around a portion of the aggregation, and retrieving it back to shore. All lake trout captured were segregated by sex and held in separate, floating net pens until sampling was completed to avoid recapture. On 12 September, all lake trout were sampled and released. Sex, length (mm FL), weight (kg), old marks, Floy-tag numbers, and spawning condition (defined as green, ripe, partially spent, and spent) were recorded. All lake trout judged to be in good condition were individually marked with individually numbered Floy internal anchor tags and were given a lower caudal clip. Tags were green and numbered from 13,153–13,294. Prior to release, a portion of the female lake trout had gametes removed and were held until fully recovered.

ABUNDANCE ESTIMATION

The abundance of lake trout in Sevenmile Lake was estimated using the Chapman modification of the Petersen mark-recapture population estimator (Seber 1982). The use of the Chapman estimator is appropriate if the following assumptions are met:

1) catching and handling the fish does not affect the probability of recapture;
2) fish do not lose marks between events;
3) recruitment and mortality do not occur between sampling events (recruitment or mortality can occur, but not both); and,

4) every fish must have an equal probability of being marked and released alive during the first sampling event; or every fish must have an equal probability of being captured during the second event; or marked fish mix completely with unmarked fish between sampling events.

The lake trout population in Sevenmile Lake is geographically closed. Assumption 1 was met because all fish were judged to be in good condition prior to marking and release. Also, the one and three month hiatuses between the two marking occasions and the recapture event were judged sufficient for marked lake trout to mix with unmarked lake trout and to completely recover from any capture-induced behavior. Assumption 2 was met by double-marking all fish. Concerning assumption 3, it is likely that some growth recruitment as well as mortality from the sport fishery occurred over the summer. Growth recruitment was accounted for by making the estimate pertain those fish greater than or equal to the length of the smallest lake trout recaptured during the second event at the time of marking. That is, lake trout that were less than the length of the smallest marked lake trout captured during the second event were culled from the second sample. Lake trout from the first sample that were less than the length of the smallest recaptured fish at the time of marking were also culled (Taube 1997).

To evaluate assumption 4, the hypothesis of equal probability of capture for fish of all sizes during the mark and recapture events, Kologorov-Smirnov two-sample tests were used (Zar 1984). The first test compared the lengths of fish from the June and August sampling dates to determine if the two samples could be pooled. No significant differences were found and the samples were pooled to constitute the marking event. The second test compared the lengths of tagged lake trout recaptured during the second event with those marked during the first event. The third test compared the lengths of lake trout from the first event to lengths of all fish captured during the second event. The second and third tests indicated there was size selective sampling. To alleviate any bias associated with this selective sampling, the data were stratified by size. The stratification point was identified by choosing the maximal distance between the cumulative frequency plots of fish captured during the first and second events. The breakpoint for the two strata was 385 mm FL. Abundance for each stratum was estimated by:

$$\hat{N}_j = \frac{(C_j + 1)(M_j + 1)}{R_j + 1} - 1 \qquad (1)$$

$$\hat{V}[\hat{N}_j] = \frac{(M_j + 1)(C_j + 1)(M_j - R_j)(C_j - R_j)}{(R_j + 1)^2 (R_j + 2)} \qquad (2)$$

where:

$\hat{N}_j$ = abundance of lake trout in size stratum j;

M_j = the number marked during the first sampling event;

C_j = the number examined during the second sampling event; and,

R_j = the number captured during the second sampling event with marks from the first sampling event.

Total abundance ($\hat{N}$) was estimated by:

$$\hat{N} = \sum_{j=1}^{s} \hat{N}_j \tag{3}$$

$$\hat{V}[\hat{N}] = \sum_{j=1}^{s} \hat{V}[\hat{N}_j] \tag{4}$$

To facilitate comparisons with previous estimates of mature lake trout in Sevenmile Lake, an estimate was calculated for lake trout ≥375 mm FL by summing the estimate for the large length stratum and the proportion of the estimate for the small stratum corresponding to 375-385 mm FL (described below).

Abundance, survival rates, and surviving recruitment of lake trout ≥375 mm FL in 1995 and 1997 were estimated using the mark-recapture histories of fish sampled since 1991 according to the models of Jolly (1965) and Seber (1965, 1982). The computer program Jolly (model A) as described in Pollock et al. (1990) was used to do the calculations. Mark-recapture estimates and capture histories for the population are listed in Appendix A1. The multi-year design promotes mixing of marked and unmarked fish and allows for mortality and recruitment. Jolly-Seber estimates were generated for Sevenmile Lake using combined sampling events from each sampling year since 1991. The capture history database consists of combined mark-recapture experiments in 1991, 1993, 1996 and 1999, as well as single sampling events in 1995 and 1997. Lake trout from Sevenmile Lake were not sampled in 1992, 1994, and 1998. Abundance estimates were for fish ≥375 mm, which includes the smallest spawning-sized fish found in September (Burr 1994).

The assumptions necessary for reliable estimation of abundance, survival, and recruitment are as follows (taken from Seber 1982):

1. all fish (≥375 mm FL) in the population have the same probability of capture in the *i*th sample;
2. all fish in the population have the same probability of surviving from the *i*th to the (i+1)th sample;
3. all fish caught in the ith sample have the same probability of being released alive into the population;
4. all marked fish do not lose their marks and all marked fish are reported on recovery; and,
5. all samples are instantaneous (sampling time is negligible) and each release is made immediately after the sample.

Assumptions 1 and 2 are central to reliable parameter estimation. If the unmarked fish behave as do marked fish, then the data would fit the Jolly-Seber model. Assumption 3 is assumed to be valid because less than 3% of fish captured per year were either killed or released without a tag. Assumption 4 has not been met by double-marking fish during all sample years. Some level of tag-shedding is unavoidable because gill nets used to capture fish tend to pull tags free. Fish were not double-marked when released after egg-takes in 1995 and 1997. Marks in 1991 and 1996 were good (caudal fin punches) for the within year estimate of tag-loss. However, these secondary marks became less detectable in multi-year estimates. In 1999, seven fish had tag scars but no tag or recognizable fin clip (some could be from events prior to 1991); six tag-loss fish had adipose fin clips that were applied prior to 1991; four other tag-loss fish were identified with the 1991 sampling (2 fish) and 1996 sampling (2 fish). Therefore a maximum of 11 tag-loss captured fish in 1999 can be attributed to events since 1991. Assumption 5 is met by the short sampling schedule relative to the duration between events.

Abundance and survival rate was estimated for 1992 - 1998 by first estimating the number of fish marked in the *i*th sample that survive to the (*i*+1)th sampling event:

$$\hat{M}_i = \frac{R_i z_i}{r_i} + m_i, (i = 1,2,3,...s-1); \quad (5)$$

where: R_i = numbers of marked fish released after the *i*th sampling event;

z_i = numbers of individual fish caught prior to or not observed during the *i*th sampling event, but subsequently recaptured;

r_i = numbers of fish recaptured from the *i*th sampling event (recaptures from R_i);

m_i = numbers of marked fish caught during the *i*th sample (recaptures); and

s = number of capture events.

With estimates of M_i, survival rate ($\hat{\phi}_i$) was calculated from the relation of those surviving to those initially marked and released:

$$\hat{\phi}_i = \frac{\hat{M}_{i+1}}{\hat{M}_i - m_i + R_i}, (i = 2, 3, ..., s\text{-}2) \quad (6)$$

Abundance ($\hat{N}_i$) was then calculated by substituting estimated marks alive for marks released in a standard Petersen estimate:

$$\hat{N}_i = \frac{\hat{M}_i n_i}{m_i}, (i = 2, 3, ..., s\text{-}1) \quad (7)$$

where: n_i = the number of lake trout caught during the ith sample.

If assumption 2 does actually apply to unmarked fish, then the estimated number of recruits added to the population between the *i*th sample and (*i*+1)th sample and surviving to the (*i*+1)th sample (B_i) becomes:

$$\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i\left(\hat{N}_i - n_i + R_i\right), (i = 2, 3, ..., s\text{-}2) \quad (8)$$

Length Composition

The 1999 length composition of lake trout in Sevenmile Lake was estimated as multinomial proportions adjusted by the stratified estimate. Proportions were based on 25 mm length categories. First the conditional proportions from each stratum were estimated:

$$\hat{p}_{jk} = {n_{jk}}/{n_j} \tag{9}$$

where:

- n_j = the number sampled from stratum *j* in the mark-recapture experiment;
- n_{jk} = the number sampled from stratum *j* in length category *k*; and,
- $\hat{p}_{jk}$ = the estimated proportion of fish in length category *k* in stratum *j*.

The variance for $\hat{p}_{jk}$ was estimated as:

$$\hat{V}[\hat{p}_{jk}] = \frac{\hat{p}_{jk}(1-\hat{p}_{jk})}{n_j - 1} \tag{10}$$

The estimated abundance of fish in each length category in the population was then:

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk}\hat{N}_j \tag{11}$$

where:

- $\hat{N}_j$ = the estimated abundance in area stratum *j*, and ;
- s = the number of strata.

In this case, the variance for $\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk}\hat{N}_j$ was calculated as the variance of a product (Goodman 1960):

$$\hat{V}[\hat{N}_k] \approx \hat{V}[\hat{p}_{jk}]\hat{N}_j^2 + V[\hat{N}_j]\hat{p}_{jk}^2 - \hat{V}[\hat{p}_{jk}]V[\hat{N}_j] \tag{12}$$

where j is the size stratum that contains the k^{th} length class.

The estimated proportion of the population that length category *k* $(\hat{p}_k)$ was then:

$$\hat{p}_k = \hat{N}_k / \hat{N} \tag{13}$$

Variance of the estimated proportion was approximated with the delta method (Seber 1982):

$$\hat{V}[\hat{p}_k] = \frac{\hat{N}_j}{\hat{N}}\hat{V}[\hat{p}_{jk}] + \frac{V(\hat{N}_j)(p_{jk} - p_k)^2}{\hat{N}^2} \tag{14}$$

where j is the size stratum that contains length class k.

Water Quality

Water temperatures were measured in Sevenmile Lake from 23 June to 15 September. Three temperature data loggers were placed at depths of 1 m, 5.5 m, and 10 m (1 meter from the bottom). Optic StowAway temperature data loggers manufactured by Onset Corporation were used with temperatures recorded at 1 hr intervals. Dissolved oxygen and pH were measured on 25 July.

RESULTS

1999 PETERSEN ABUNDANCE ESTIMATE

The estimated abundance of lake trout ≥361 mm FL in Sevenmile Lake in June 1999 was 1,260 (SE=185; Table 2). During the marking events in June and August, 149 lake trout ≥361 mm FL were captured. No significant difference in length composition was found between the June and August sampling events (DN = 0.197, P= 0.09) and the two samples were pooled to comprise the marking event. Two hundred ninety fish ≥361 mm FL were captured between 9-11 September, and 27 of these fish were recaptures from the marking event. The length of the smallest recaptured lake trout was 366 mm FL. This fish measured 361 mm FL when marked in June. This was consistent with the average growth (5 mm) of recaptured lake trout 366- 400 mm FL in length. The Petersen model can accommodate recruitment through growth, but makes the estimate germane to the time of marking (Seber 1982). Therefore, the abundance estimate pertained to lake trout ≥ 361 mm at the time of marking.

Cumulative length distribution of lake trout ≥ 361 mm marked during the first event differed from that of fish examined during the second event (DN = 0.30, P = 0.34; Figure 2). Cumulative length distribution of lake trout marked during the first event differed from that of marked fish recaptured during the second event (DN = 0.40, P < 0.01). These test results suggest that probabilities of capture were dissimilar and the estimate was stratified for fish < 386 mm and ≥ 386 mm (Table 3). Abundance of lake trout ≥375 mm FL, the size range comparable to historic estimates, was 1,109 (SE=170).

1995 AND 1997 JOLLY–SEBER ABUNDANCE ESTIMATE

The Jolly-Seber model was used to estimate abundance for 1995 and 1997 because sampling in those years consisted of a single event as part of the egg-take project. Two-event mark-recapture experiments were conducted in 1991, 1993, 1996 and 1999 to estimate abundance of lake trout. Data from these events were pooled within years to form the annual sampling events used by the multi-year model as recommended by Pollock (1982). Only fish ≥375 mm FL were considered for consistency in estimates. Tagged lake trout recruited into this size from previous markings were treated as new fish. The estimated abundance for 1995 was 549 (SE=44) lake trout and for 1997 was 997 lake trout (SE=163, Table 2 and Appendix A2). Because the Petersen estimates of abundance for 1993 and 1996 (Table 2) were more precise and were shown to be unbiased, they were preferred over the Jolly-Seber estimates.

LENGTH COMPOSITION

Kolmonov-Smirnov tests indicated that there was size selectivity for fish ≥ 386 mm FL. Therefore, adjusted proportions were used to estimate abundance for 25 mm FL categories ranging from 361-525 mm FL (Appendix A3).

Mean length of all fish examined during the marking event was 391 (range 254 - 497) mm FL (Figure 3). Mean length of all fish examined during the recapture event was 427 mm FL. Mean lengths were 601 (range 471 - 781) mm FL for spawning males and 667 (range 508 – 778) mm FL for spawning females. Sex ratio for the lake trout captured from the spawning grounds was 0.70 (SE =0.03) males and 0.30 (SE = 0.03) females. During September, weights were attained

Table 2.-Estimated abundance of mature lake trout ($\geq$ 375 mm FL) in Sevenmile Lake, 1987 to 1999.

Year Estimated	Estimated Abundance (SE)	Source
1987	459 (85)	Burr 1988
1988	791 (158)	Burr 1989
1989	1,054 (138)	Burr 1990
1990	1,084 (175)	Burr 1992
1991	505[a] (57)	Burr 1992
1991	931[b] (73)	Burr 1994
1993	1,139 (152)	Burr 1994
1993	624[c] (59)	This study
1995	549[c] (44)	This study
1996	854[c] (104)	This study
1996	877 (21)	Taube 1997
1997	997[c] (163)	This study
1999	1,109 (170)	This study

[a] Petersen mark-recapture experiment in 1991.

[b] Petersen mark-recapture experiment from 1991 – 1993.

[c] Jolly Seber experiment from 1991-1999.

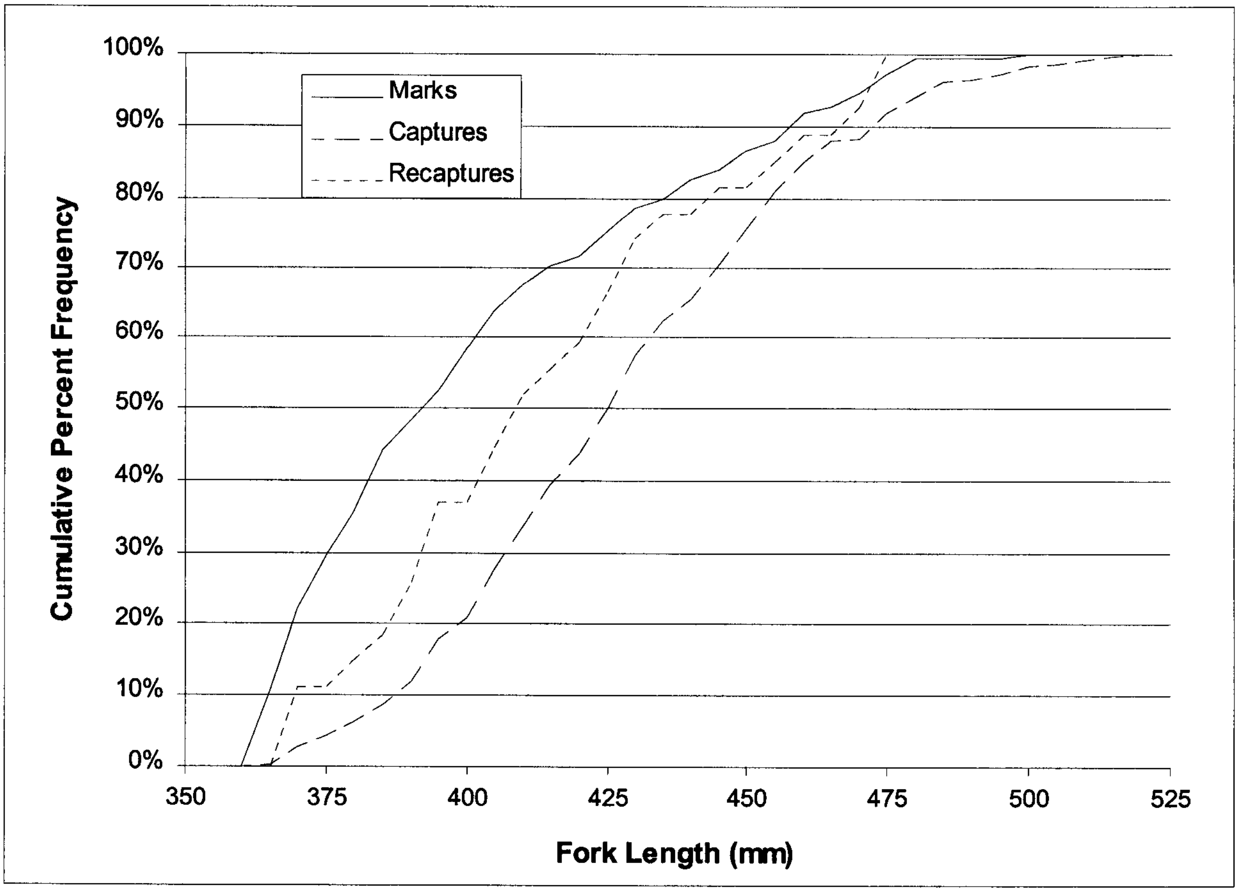

Figure 2.-Cumulative length-frequency distributions of all lake trout caught during the first event (marks), all fish captured during the second event (captures) and all recaptured fish captured during the second event (recaptures) during the mark-recapture experiment in Sevenmile Lake, 1999.

Table 3.-Estimated abundance of lake trout in Sevenmile Lake in 1999.

	Number of Lake trout				
Stratum	Marked	Recaptured	Captured	Abundance	SE
361- 385 mm	66	5	25	289	92
≥ 386 mm	83	22	265	970	161
Total	149	27	290	1,260	185

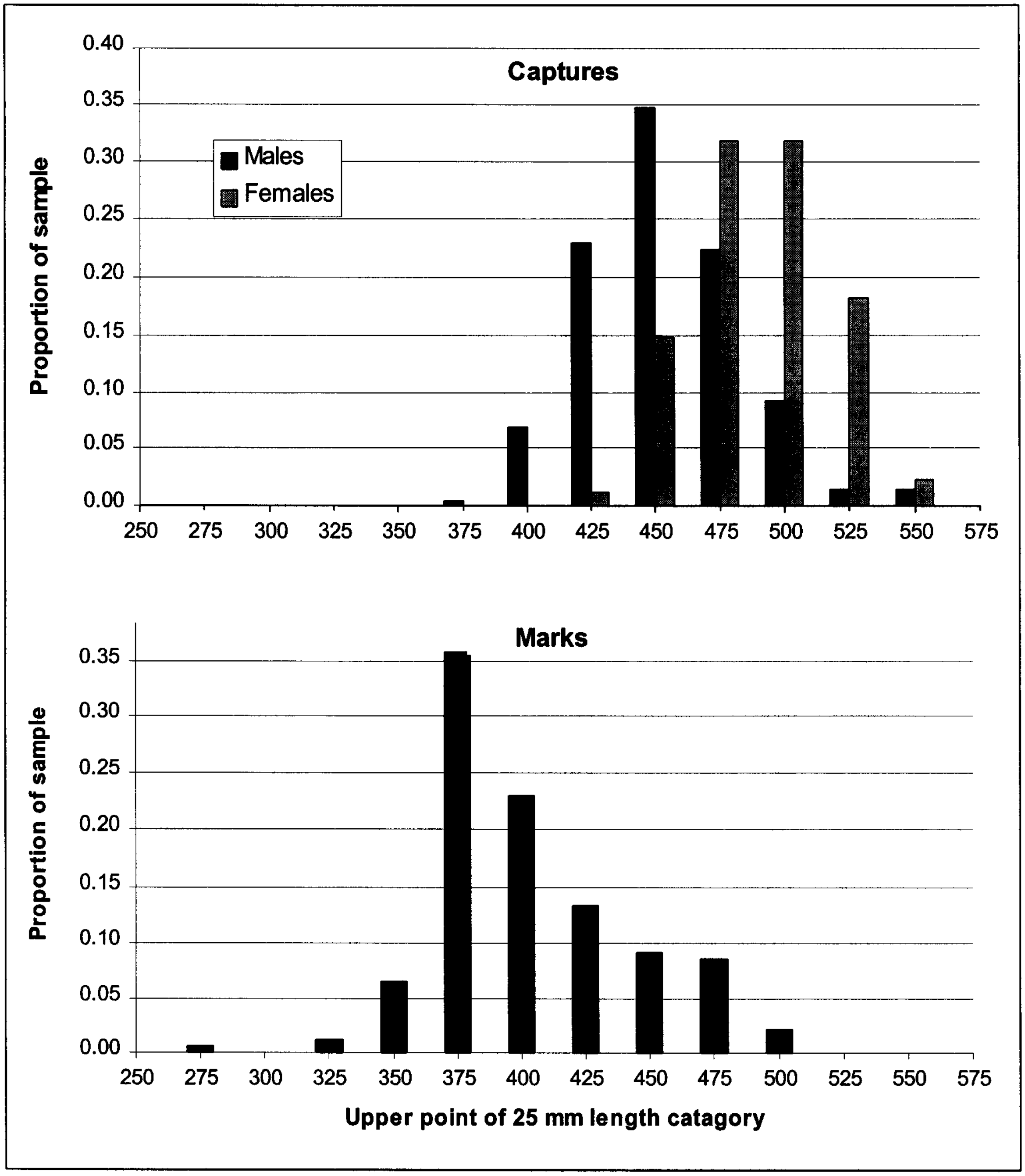

Figure 3.-Length frequencies of lake trout captured during the marking (bottom panel) and recapture events (top panel) in Sevenmile Lake, 1999.

for 88 males and averaged 5.51 kg (Appendix B). No weights were attained during the June and August sampling events.

WATER QUALITY

From 23 June to 15 September water temperatures at 1 m (surface), 5.5 m (midpoint), and 10 m (bottom) averaged 13.0°, 11.4°, and 9.5° C, respectively (Figure 4). Maximum temperatures of 17.1°, 15.1°, and 13.4° C were recorded. On 25 July, dissolved oxygen and pH were measured at 11 mg L^{-1} and 7.0, respectively, at the deepest portion of the lake.

DISCUSSION

Burr (1994) concluded that between 1987 and 1993 abundance of mature lake trout was consistently 1,000 adults of which 500 were females. The estimated abundance for 1999 is not significantly different than estimates prior to the start of the egg-takes (Figure 5).

The 1995 estimate generated from the Jolly-Seber model is the only estimate significantly lower than other estimates (Figure 5). This low estimate cannot be attributed to egg-takes conducted in 1993 or 1995 as progeny from those fish would not yet have recruited into the catchable population. An increasing trend in abundance since 1995 indicates that neither egg-takes nor sport harvest have negatively impacted the population. The sport harvest, although not detectable with the statewide harvest survey, is likely less than 50 fish annually. The daily bag and possession limit for lake trout in Sevenmile Lake is two per day with no size or season limit.

Size selectivity was detected within the 1999 experiment. However, stratification of the estimate into two size groups should have alleviated any bias in the estimate associated with this selectivity. The growth observed between sampling events was not problematic in terms of calculating an estimate for fish > 375 mm FL that could be compared to previous years. Burr (1992) describes rapid growth rates of lake trout in Sevenmile Lake until length of maturity (375 mm FL). After reaching maturity, growth declines rapidly and gear selectivity is not an issue because of the relatively small range of lengths in the population (lake trout in this population do not exceed 550 mm FL). Future mark-recapture studies should be conducted as two-sample experiments over a 1-year period where adult lake trout are captured on the spawning grounds. The relatively small recruitment through growth can be culled out for an estimate of the adult spawning population, and sex can be positively identified during this time.

In 1999, a beach seine was used to determine its effectiveness verses gillnets. On 11 September a 2.5 cm mesh seine (120 m long and 2.5 m deep) with a large bag (3.7 m wide) was deployed around spawning lake trout and 80 fish were caught in three hauls. Sharp, angular rock caused the lead line to lift up and many fish trapped on the inside were able to roll under the net and escape. During the first haul an estimated 300 fish were inside the net and only 50 fish were caught. There were four concentrations of lake trout on the spawning beds in 1999. A smaller seine of approximately 50 m deployed around one of these concentrations may be more effective in pushing fish back into the bag and keeping them there. Lake trout caught by seine are in better physical shape than those caught in gillnets.

The 86,800 eggs taken from spawning population in 1999 represented approximately 12% (Table 1) of the potential annual production if all adult female lake trout in the population spawned in 1999. If some portion of the adult females did not spawn every year, the proportion of the annual production lost would have been greater. Using the Jolly-Seber estimates for 1995

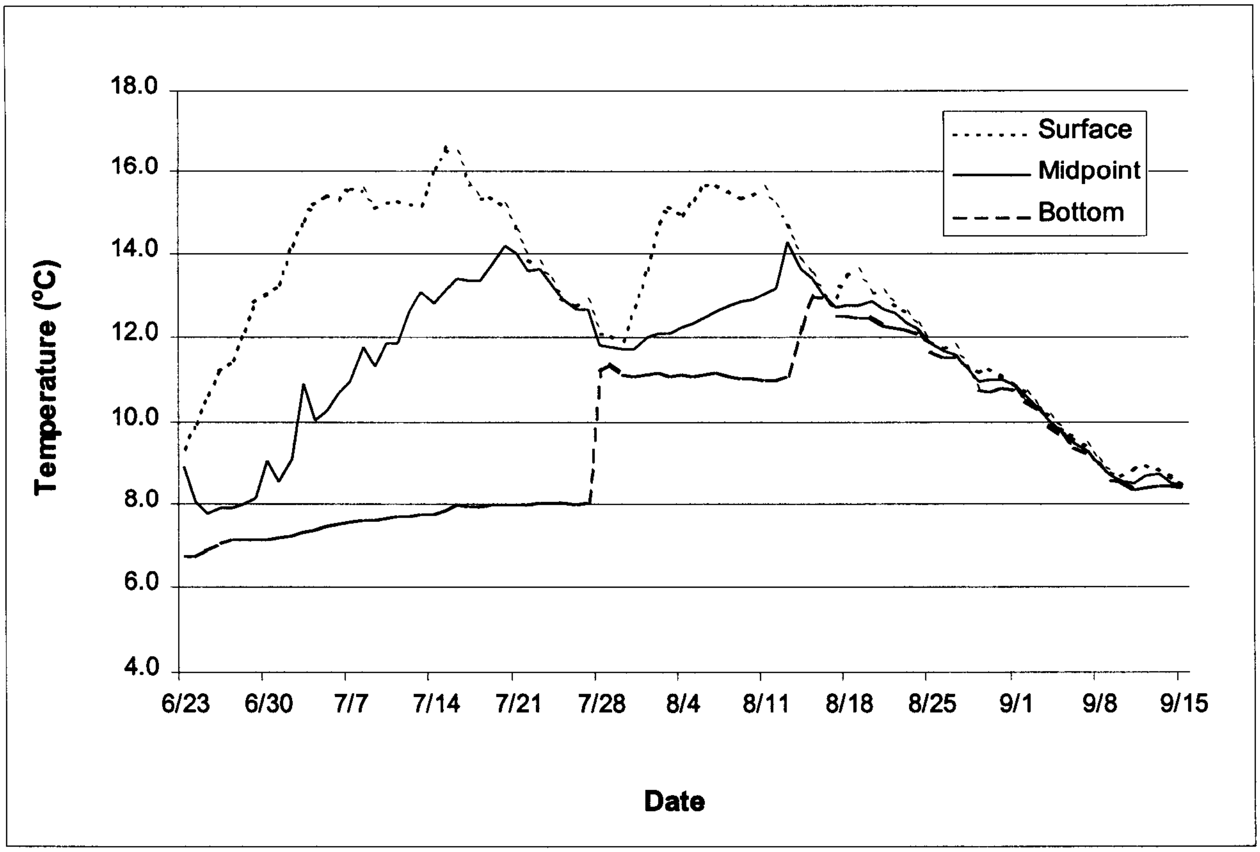

Figure 4.-Water temperatures at 1 m (surface), 5.5 m (midpoint), and 10 m (bottom) in Sevenmile Lake from 23 June to 15 September, 1999.

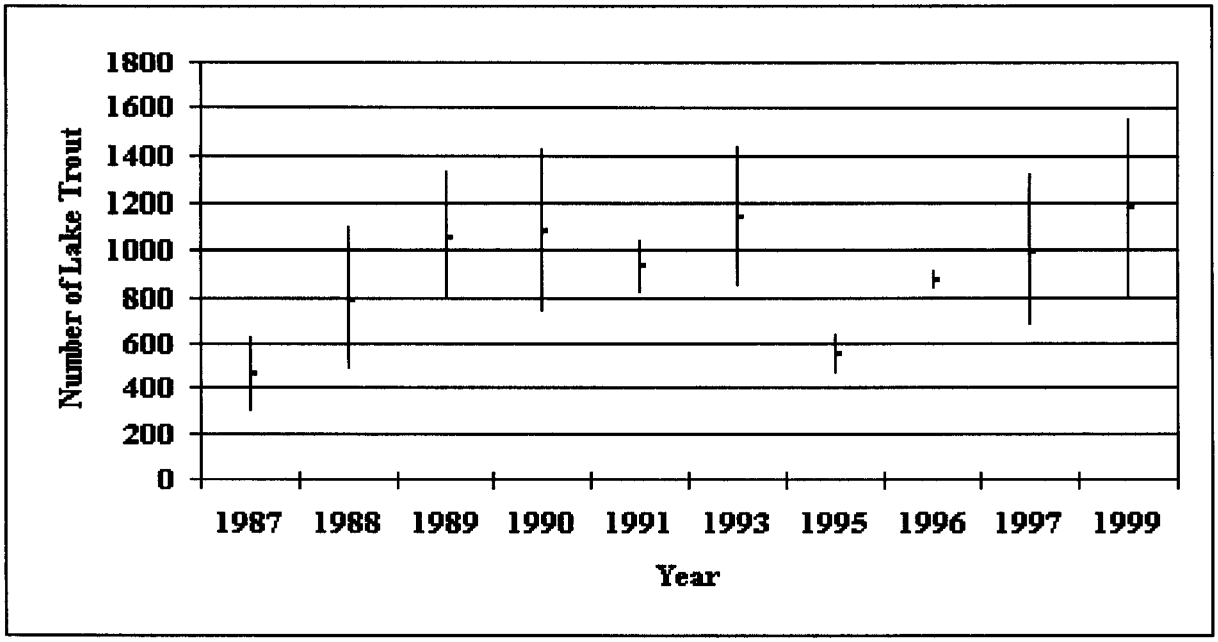

Figure 5.-Estimates of abundance for adult lake trout (± 2 SE) in Sevenmile Lake from 1987-1999.

and 1997 egg production removed from the population was 26% and 19%, respectively (Table 1). In 1999, an additional 3,800 eggs were place in artificial substrate boxes to increase egg survival to hatching stage. It is unknown if such compensation will have a positive impact. The next scheduled egg-take from Sevenmile Lake will occur in September 2001.

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Appendix A

Appendix A1.-Mark-recapture histories of adult lake trout (≥ 375 mm FL) by year in Sevenmile Lake.

Year	1991	1993	1995	1996	1997	1999
Beginning date	8/01	9/08	9/08	6/17	9/11	6/21
Ending date	10/3	9/24	9/14	7/19	9/22	9/15
Number of adult Lake trout:						
Recaptured from Event 1	0	73	9	2	2	0
Recaptured from Event 2	0	0	118	18	15	6
Recaptured from Event 3	0	0	0	58	34	28
Recaptured from Event 4	0	0	0	0	49	29
Recaptured from Event 5	0	0	0	0	0	35
Recaptured from Event 6	0	0	0	0	0	0
Captured with Tags	0	73	127	78	100	98
Captured with out Tags	231	360	174	144	122	264
Captured	231	433	301	222	222	362
Released with Tags	230	405	296	208	200	261

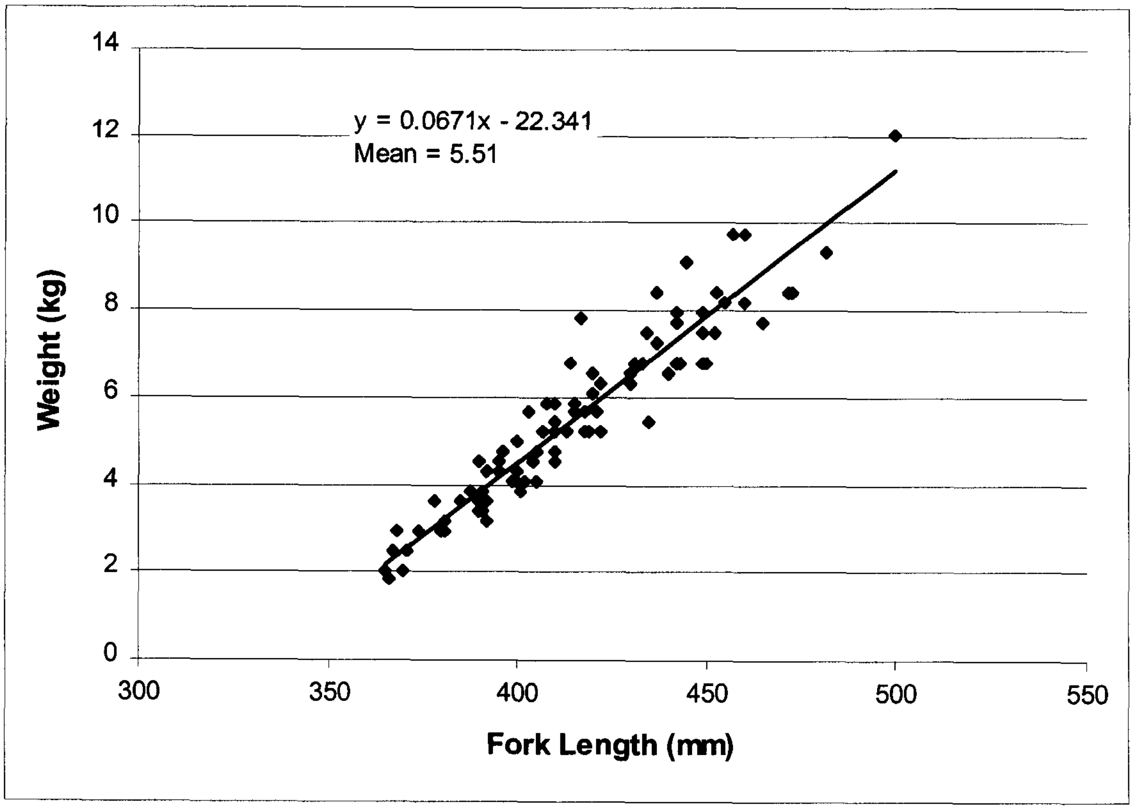
Appendix A2.-Estimates of abundance, survival rate, and recruitment lake trout ≥ 375 mm FL in Sevenmile Lake, 1991-1999.

Midway	Days Between	Abundance			Survival Rate		Recruitment	
Date	Events	Est.	(SE)	CV %	Est.	(SE)	Est.	(SE)
8/11/91								
	769				46.2	4.6		
9/09/93		624	59	9.5				
	735				53.0	4.2	233	43
9/14/95		549	44	8.0				
	299				75.3	7.7	445	82
7/10/96		855	104	12.2				
	430				1.0	16.9	123	99
9/13/97		997	163	16.3				
	365							
9/13/99								
Average		756			69.6		267	

Appendix A3.-Estimated proportion and abundance of lake trout ≥ 361 mm by length category in Sevenmile Lake, 1999.

Length Category	Frequency	$\hat{P}_j$	$\hat{V}(\hat{P}_j)$	$SE(\hat{P}_j)$	$\hat{N}_j$	$\hat{V}(\hat{N}_j)$	$SE(\hat{N}_j)$
361 - 375	13	0.12	0.0025	0.050	150	2,382	49
376 - 385	12	0.11	0.0021	0.046	139	1,976	44
386 - 400	36	0.10	0.0008	0.028	132	478	22
401 - 425	84	0.24	0.0017	0.041	308	2,677	52
426 - 450	74	0.22	0.0015	0.039	271	2,070	46
451 - 475	47	0.14	0.0010	0.032	172	823	29
476 - 500	19	0.06	0.0004	0.021	70	129	11
501 - 525	5	0.01	0.0001	0.011	18	7	3
Total	290				1,260		

Appendix B



Appendix B.-Weight-at-length of male lake trout captured from spawning grounds in Sevenmile Lake, 1999.