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Fishery Data Series No. 98-24

Lake Trout Studies in the AYK Region, 1997

by

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and

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September 1998

Alaska Department of Fish and Game

Division of Sport Fish

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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, ~~χ²~~ 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

Standardized gillnet (Index fishing) and hook and line sampling were used in July and August, 1997, as capture methods for lake trout *Salvelinus namaycush* in Itkillik Lake to estimate the abundance, length composition, and CPUE. A two-sample mark-recapture experiment produced a July 1997 lake trout (> 315 mm) abundance estimate of 8,217 (SE = 1170) with density of 19.6 fish per ha. Lake trout in the 425-450 mm length category were most frequent in the sample ($\hat{p}$ =0.26, SE=0.02), with lengths ranging from 168 to 881 mm. Ages of 45 lake trout ranged from three to 15 years. The CPUE for Index fishing averaged 3.86 fish/net h. An age validation study comparing scales, otoliths, and opercular bones from a cohort of lake trout stocked in 1991 was conducted. The proportion of age structures which reflected the true age was 0.66 (SE = 0.036) for scales and 0.60 (SE = 0.035) for otoliths.

Key words: lake trout, *Salvelinus namaycush*, Index fishing, CPUE, abundance, length composition, age validation, Itkillik Lake.

INTRODUCTION

Lake trout population studies in four lakes north of the Brooks Range were initiated in 1994 due to concerns over increased fishing effort associated with the opening of the Dalton Highway (Haul Road). Results of these studies by the Alaska Department of Fish and Game (ADF&G), Sport Fish Division, provided the basis to close the Trans-Alaska Pipeline corridor lakes to the harvest of lake trout (Burr 1995). The need for further baseline population data from North Slope lakes prompted the investigation of a suitable method to provide an index of abundance or stock status. In Ontario a combination of sport fish harvest surveys and a standardized sampling procedure using gill nets (Index fishing), was used to monitor lake trout stocks (Lester et al. 1991).

Lake trout harvests within the Pipeline corridor averaged 95 fish between 1986 and 1993 (Mills 1987-1994). Harvests of this size would make collecting biological harvest data difficult, however an index could provide a measure of stock status. If CPUE from Index fishing with gillnets could be used as an index of abundance, it would provide a more cost effective method than more expensive mark-recapture experiments to evaluate stock status and to identify needs for further work. Research conducted in 1994 initiated evaluation of CPUE from Index fishing as a method for assessing lake trout populations north of the Brooks Range.

In 1994, ADF&G conducted a mark-recapture experiment at Galbraith Lake and incorporated Index fishing in the sampling methods. CPUE of Galbraith Lake was low (0.21 fish/hr) as was abundance (236 lake trout > 500 mm; Burr 1995). In contrast Irgnyivik Lake had a higher Index fishing CPUE (1.76 fish/hr), as well as abundance (492 lake trout > 368 mm; Taube 1996). In 1996 abundance and CPUE on Sevenmile and Nanushuk lakes were estimated. Sevenmile Lake had an estimated 1,241 (> 235 mm) lake trout and a CPUE of 2.90, while Nanushuk Lake had an estimated 7,391 (> 250 mm) lake trout with a CPUE of 3.68. Itkillik Lake was sampled in 1994 for CPUE and resulted in a rate of 8.17 fish/hr. If a correlation between CPUE and abundance exists, it was expected that the abundance of lake trout in Itkillik Lake would be greater than in the previously sampled lakes.

The project objectives for 1997 were to:

1. estimate the abundance of lake trout in Itkillik Lake such that the estimate is within 25% of the actual value 90% of the time;
2. estimate the length composition of lake trout in Itkillik Lake such that the estimate is

within 10 percentage points 95% of the time;

3. estimate the CPUE with standardized gillnet sampling (Index Fishing) for lake trout in Itkillik Lake;
4. collect otoliths and scales from lake trout in various roadside lakes in the Tanana River drainage known to be stocked in 1991 for age validation; and,
5. validate ages of lake trout stocked in 1991 as determined from otoliths, opercular bones and scales such that ages are within 10% of the true value 95% of the time.

METHODS

Itkillik Lake (68°24' N, 149°55' W) is located on the north facing slope of the Brooks Range west of the Dalton Highway in the Gates of the Arctic National Park (Figure 1). It is a narrow elongate basin with two depressions; each about 12 meters maximum depth (LaPerriere and Jones 1991). The surface area of Itkillik lake is 430 ha, volume is 22.8 X 10^6 m^3, mean depth is 5.8 m, and shoreline length is 10.8 km (Figure 2). The lake supports populations of lake trout *Salvelinus namaycush*, burbot *Lota lota*, Arctic grayling *Thymallus arcticus*, and round whitefish *Prosopium cylindraceum*.

SAMPLING PROCEDURES

Itkillik lake was sampled from July 5-10 and August 1-7, 1997. Two crews of two persons sampled lake trout with gillnets and by hook and line. One crew was assigned the task of fishing the index gillnets according to the sampling protocol (Index fishing) of Lester et al. 1991. Three sizes of sinking gillnets were used. All nets were 45.7 m (150 ft) long and 2.5 m (8 ft) tall. Mesh sizes were either 19 mm (0.75 in), 25 mm (1.0 in), or 32 mm (1.25 in) stretch measure. The Index nets were sampled every 30 min, and when water temperature exceeded 13^0 C, nets were sampled every 20 min to reduce mortality. Surface water temperatures were measured daily and a temperature profile of the lake was measured on two occasions (Appendix D). The sampling during July occurred during evening and early morning (1800-0200) hours. In August, sampling occurred and during the day (0800-1700 hour). Randomly selected sites were sampled for approximately 30 min each day, depending on number of fish captured and water temperature (set time: 12 - 37 min). Eighteen sites per day were sampled and the following procedure was used for selecting sample sites:

1. the shoreline was partitioned into 120 equal length sections;
2. for each sample day, 18 sections were randomly selected without replacement;
3. the optimum survey path (least distance) for visiting the 18 sections (sampled on one day) was determined and one gillnet gang was set in each section;
4. The nets of different mesh were set in sequence (19 mm at site 1, 25 mm at site 2, and 32 mm at site 3) so that different mesh sizes were distributed throughout the lake and six sites were sampled by each mesh per day.

Gangs were set perpendicular to the shoreline starting at a depth of 2 m and extending no deeper than 17 m. The starting location was random within the section sampled, with the exception that river mouths, debris strewn areas (likely to damage nets) and very steep gradients (> 45 degrees) were avoided. The nets were left to fish for approximately 30 min and the following data were obtained from each set:

1. total number of fish captured (by species);

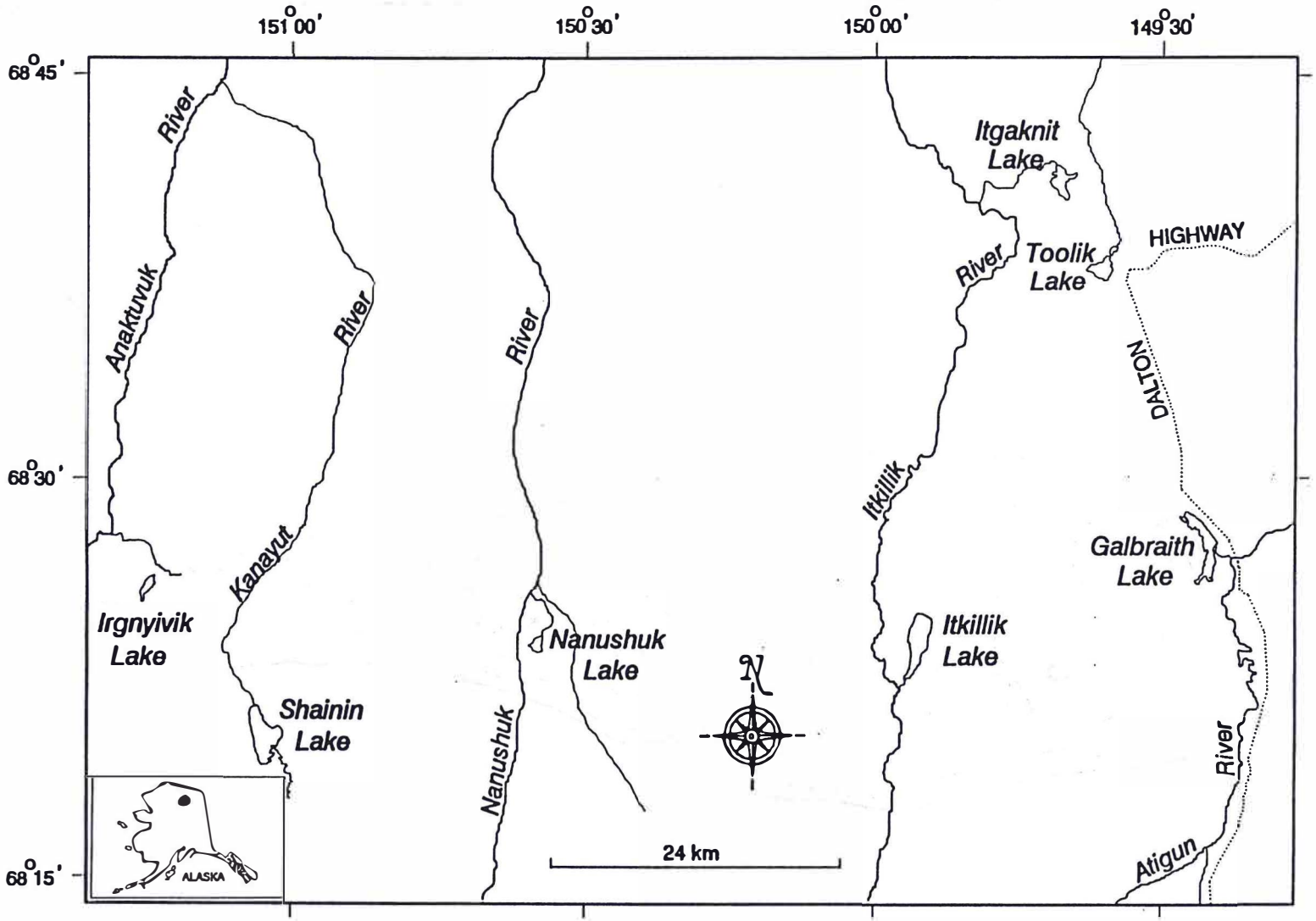

Figure 1.-Location of Itkillik Lake.

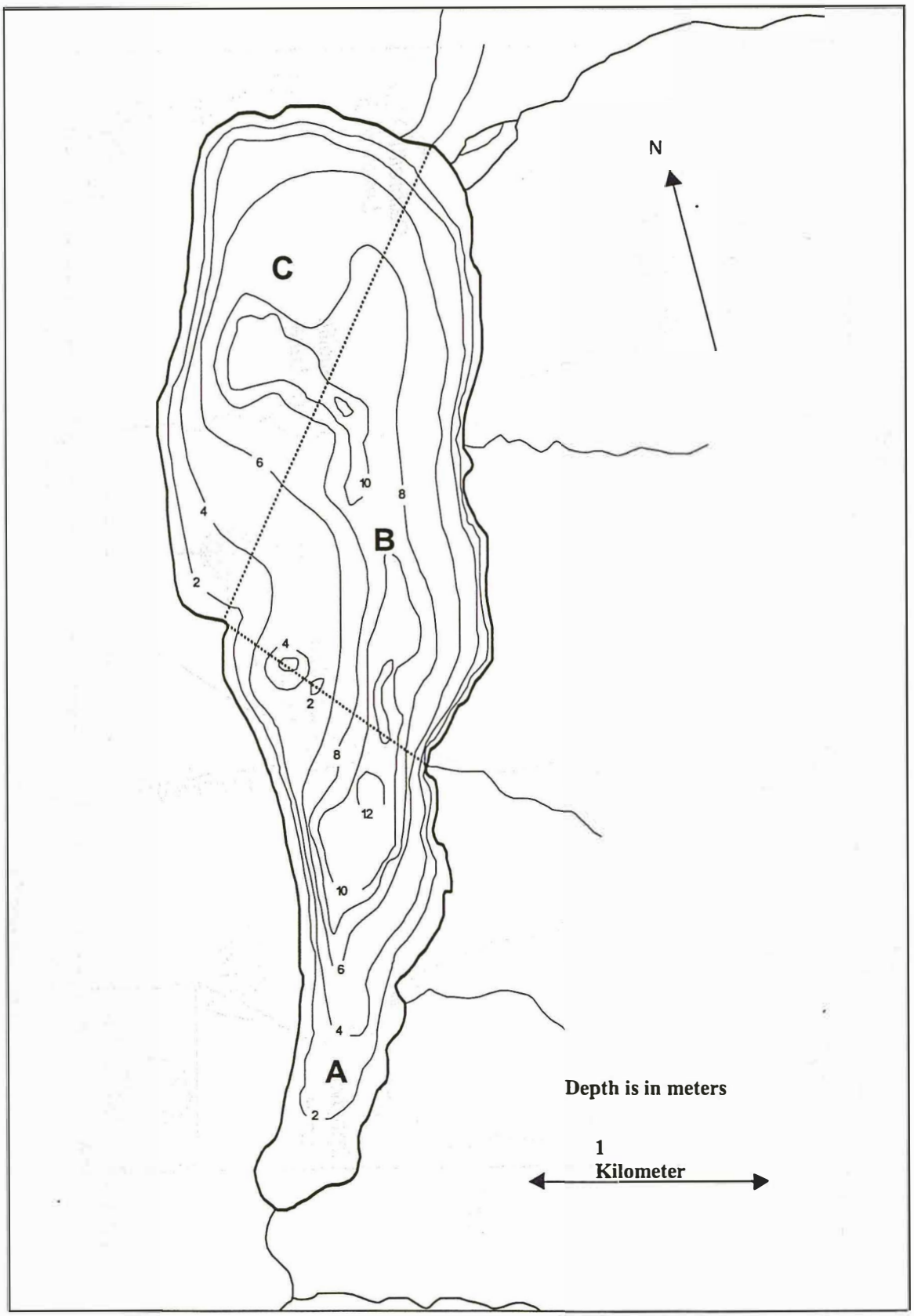

Figure 2.-Itkillik Lake and location of sampling areas A, B, and C, 1997.

2. fork length and round weight from each fish;
3. otolith and sex from dead lake trout; and,
4. record of fin clips and tag numbers.

The second crew fished gillnets in the middle portion of the lake (non-index fishing), the area of the lake the Index nets did not. This was done to test for mixing among lake areas A, B, and C (Figure 2) and among inshore and offshore areas, and also to more uniformly sample throughout the lake to satisfy assumptions of equal probability of capture for the mark-recapture experiment. Nets used for non-index fishing were identical to those used for Index fishing and were fished during the same times and duration as the Index nets.

Between net sets, both crews captured lake trout with hook and line gear in the vicinity of the gillnet sets. All lake trout captured and judged to be in good condition were individually marked with a numbered Floy anchor tag and lower caudal fin punch during the marking event and an upper caudal fin punch during the recapture event. All lake trout captured were measured to the nearest mm FL and recorded on mark-sense forms. Otoliths were taken from all lake trout killed during sampling and placed in coin envelopes with reference numbers (litho code and line number from mark-sense forms) and sex was recorded.

ABUNDANCE ESTIMATION

Abundance of lake trout in Itkillik Lake was estimated in 1997 with the Chapman modification of the Petersen two sample mark-recapture experiment (Seber 1982). Marking and recapture events occurred from July 5-10 and August 1-7, respectively.

Population abundance and the approximate variance of the estimate were calculated with the following formulae (Seber 1982):

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

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

where:

$\hat{N}$ = the population size;

M = the number marked during the first sampling event;

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

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

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 sampling event; or marked fish mix completely with unmarked fish between sampling events (Seber 1982).

The lake trout population in Itkillik Lake was considered closed. No significant outlets exist in this lake. Assumption 1 was thought to have been met because only lake trout that were judged to be in good condition after capture were marked prior to being released. Furthermore, a moderately long hiatus (21 d) should have minimized capture-induced behavioral responses. Assumption 2 was met by double marking each fish (tag and finclip) in order to determine if marks were lost between events. In regards to Assumption 3, lake trout are slow growing and the duration of the experiment (32 d) was relatively short such that and growth recruitment was likely minimal.

To evaluate Assumption 4, the hypothesis of equal probability of capture for fish of all sizes during the marking and recapture sampling events was tested using Kolmogorov-Smirnov two-sample tests. The first test compares the length frequency distribution of all fish captured during the marking event to those recaptured during the recapture event. The second test compares the length frequency distribution of all fish captured during the marking event to all fish captured during the recapture event. The procedure to be followed given each possible outcome of these tests is mapped in Appendix A.

To test the hypothesis of equal probability of capture by lake area, the lake was divided into three areas of approximately equal size (Figure 2). The marked-to-unmarked ratio (R/C) by lake area during the second event was examined using contingency table analysis.

LENGTH COMPOSITION

Length composition of lake trout in Itkillik Lake was estimated as multinomial proportions in 25 mm FL categories. Lake trout were measured during Index fishing, off-shore gillnet sampling, and hook and line sampling during both events.

The proportion of fish in each (25 mm FL) and age category was calculated as described by Cochran (1977):

$$\hat{p}_j = \frac{n_j}{n} \tag{3}$$

$$\hat{V}\left[\hat{p}_j\right] = \frac{\hat{p}_j\left(1-\hat{p}_j\right)}{n-1} \tag{4}$$

where:

n_j = the number in the sample from group j;

n = the sample size; and,

$\hat{p}_j$ = the estimated fraction of the population that is made up of group j.

The estimated abundance of each group j in the population was:

$$\hat{N}_j = \hat{p}_j \hat{N} \tag{5}$$

where:

$\hat{N}_j$ = estimated number of fish in the population in group j; and

$\hat{N}$ = estimated abundance.

The variance of $\hat{N}_j$ is approximated by the delta method (Seber 1982):

$$\hat{V}\left[\hat{N}_j\right] = \hat{V}\left[\hat{p}_j\right]\hat{N}^2 + \hat{V}\left[\hat{N}\right]\hat{p}_j^2. \tag{6}$$

Size selectivity of the three gill net mesh sizes during sampling was investigated by examination of plots of the cumulative distribution of lengths for each mesh size. The hypothesis of equal probability of capture for fish of all sizes with each mesh size was tested by using a K-Sample Andersen-Darling Test (Scholz and Stephens 1987).

CPUE INDEX NETTING

Average CPUE, measured as fish per hour, was calculated for all lake trout captured in Index nets. The length of time each gillnet was fished was recorded and totaled in hours. The total number of lake trout caught was then divided by the total amount of time gillnets were fished.

AGE VALIDATION

Sampling of stocked lakes occurred between May 19 - September 11, 1997. For age validation lake trout of known age were used to determine if ages estimated from otoliths, scales, and opercula represent the true ages of these fish. During June of 1991, a total of 52,900 young of the year lake trout were released into 10 lakes (Table 1) in the Tanana River drainage. These lake trout came from eggs taken in September 1990 from Paxson Lake and reared in Clear Hatchery. Lake trout stocked in the four lakes which were previously stocked were marked with an adipose fin clip to identify them as members of the 1991 group.

Table 1.-Location and number of fish sampled for the lake trout age validation study.

Lake	Date Stocked	Fin Clip	1992	1993	1995	1996	1997	Total
Chet	1991	Adipose	0	0	1	0	0	1
Coal Mine #5	1991	Adipose	0	0	7	5	0	12
Craig	1991	None	0	0	1	21	11	33
Fourteenmile	1991	None	12	14	36	5	18	85
Nickel	1991	Adipose	0	1	9	8	8	26
North Twin	1991	None	9	5	0	0	0	14
Rapids	1991	None	3	17	8	0	0	28
Total			24	37	62	39	37	199

Between 1992 and 1997 lake trout from the 1991 stocking cohort were sampled to collect otoliths, opercula bones, and scales. The initial sample size was set at 98 lake trout per year from all release sites combined. This sample size was calculated using standard methods for sample size for estimation of proportions (Freund 1984). However, of the lakes stocked only fish from 7 of the lakes were analyzed and yearly sample sizes were lower than the goal of 98 (Table 1).

Scales, otoliths, and opercular bones of lake trout of known age were read and compared with the true ages. Scales were sampled from immediately above the lateral line and posterior to the dorsal fin of each fish. Scales were mounted on microscope slides and examined with a microfiche reader. Criteria for determination of age from scales were taken from Cable (1956). Otoliths were placed in a shallow plate of water and viewed at 10X with a dissecting microscope under reflected light. For otoliths, the counting axis on the structure was the direction that had the largest count (Sharp and Bernard 1988). Opercular bones were examined under a dissecting microscope at low magnification (≈3X). Lengths of the fish were unknown to the reader.

Two blind readings were performed on each structure. The two ages were compared and a third reading conducted, if these differed. The estimated ages were then compared with the true ages. To determine if the ages obtained from otoliths, opercular bones, and scales were the true ages the proportion and variance of lake trout whose estimated age reflects the true age was calculated for each structure as:

$$\hat{p} = \frac{a}{n} \tag{7}$$

$$V[\hat{p}] = \frac{\hat{p}(1-\hat{p})}{n-1} \tag{8}$$

Where:

a = the number of fish whose assigned ages agreed with the true age; and,

n = total number of known age structures in the sample.

A one tailed z-test (Zar 1984) was performed to determine if the accuracy rate for any one structure was significantly less than 0.90. This test examined the difference between an estimated sample mean and hypothesized mean of zero. The H_0 tested was:

H_0: $P = 0.90$

H_a: $P < 0.90$

This one tailed z-test had the ability to detect a 10% difference with the probabilities of an experiment wise type I error being 0.05 and the probability of a type II error being 0.20. Opercular bones were excluded from this and subsequent analyses since only 1992 and 1993 fish had their opercular bones sampled. Knowledge of the age range biased opercular age estimates.

Contingency table analysis was used to determine if scales and otoliths were equally accurate by testing the hypothesis:

H_0: accuracy is independent of structure

H_a: accuracy is dependent on structure.

To examine differences in the estimated ages for any of the structures, the ages determined for each structure were compared using an analysis of variance (ANOVA) with structures as fixed effects. The ANOVA tested the hypothesis that:

$$H_0: \mu_{scales} = \mu_{otoliths}$$

$$H_a: \mu_{scales} \neq \mu_{otoliths}$$

Logistic regression was used to examine if the accuracy in determining the age of lake trout decreased as the true age increased. The structures were considered separately. The H_0 tested was:

$$H_0: \beta = 0$$

$$H_a: \beta < 0$$

RESULTS

ABUNDANCE ESTIMATION

The length of the smallest lake trout recaptured in 1997 was 315 mm. Lake trout < 315 mm captured during the marking event were culled from the sample, as were lake trout < 315 mm captured during the recapture event. The estimate therefore pertains to all lake trout (≥ 315 mm) in Itkillik Lake in July.

For fish ≥ 315 mm, there was no significant difference between the lengths of lake trout marked during the first event and lake trout examined during the second event (D = 0.08, P = 0.13). There was also no significant difference between length of lake trout marked during the first event and marked lake trout recaptured during the second event (D = 0.21, P = 0.56). These tests indicated that stratification by length was not warranted (Appendix B).

There was no significant difference in marked-to-unmarked ratios between lake areas A, B, and C (χ^2 = 0.48, P = 0.78; Table 2), therefore, stratification by area was not necessary for the abundance estimate.

Table 2.-Contingency table analysis of marked to unmarked ratios of lake trout caught during the second sample of the mark-recapture experiment in areas A, B, and C of Itkillik Lake, 1997.

	Area			
	A	B	C	Total
Marked	7	5	3	15
Unmarked	219	146	142	507
Total	226	151	145	522
Marked:unmarked	0.032	0.034	0.021	0.029

$\chi^2 = 0.48$, df = 2, P = 0.78

Mixing was also apparent between near-shore and off-shore areas. Of the 7 recaptured fish that were marked nearshore (Index nets), 5 of these were recaptured offshore (mid-lake nets) and, of the 8 recaptured fish that were marked off-shore, 3 were recaptured near-shore.

During the first event in July 277 lake trout were marked. Of these, 15 were recaptured during August of 472 lake trout examined. Estimated abundance was 8,217 (SE = 1,170) lake trout. Estimated density was 19.6 fish per ha.

LENGTH AND AGE COMPOSITION

The Kolmogorov-Smirnov tests conducted during the mark-recapture analysis indicated that probabilities of capture by length were similar between events, therefore lengths from both samples were pooled to estimate length composition.

The largest proportion of lake trout captured was in the 425 - 450 mm length category ($\hat{p} = 0.26$; SE=0.02; Figure 3: Appendix B1). Lake trout ranged in length from 168 to 881 mm. Ages of 45 lake trout mortalities were determined from examination of otoliths. Ages ranged from 3 to 15 years (Appendix B2). Population length composition was estimated for lake trout ≥ 315 mm in 25 mm length categories (Figure 3, Appendix B3).

CPUE INDEX NETTING

Index and non-index fishing was conducted July 5 - 9 and August 1 - 7 during which time 225 and 228 net sets were made, averaging 0.35 and 0.45 h/set respectively (Table 3). A total of 289 lake trout ≥ 315 mm were caught with 78.63 net-hours of effort by Index fishing for a CPUE of 3.68 fish/net h. CPUE varied among sampling events. CPUE was 3.86 fish/net h during the first event and 3.46 fish/net h during the second event.

A total of 334 lake trout were caught by non-Index fishing for a CPUE of 3.22 fish/net h. CPUE during the first event was 2.27 fish/net h, and 4.23 fish/net h during the second event.

Size Selectivity of Gillnets

A total of 657 lake trout were caught with Index and non-Index gillnets at Itkillik Lake and length distributions from the three different mesh sizes were examined (Figure 4). The hypothesis of equal probability of capture for fish of all sizes with each mesh size was not rejected (A2kn = 3.71, P = 0.07; Figure 5). By pairwise comparison, there were no significant differences in length distributions of lake trout caught in all mesh sizes: 25 mm and 32 mm nets (D = 0.07, P = 0.12); 19 mm and 25 mm nets (D = 0.09, P = 0.47); and 19 mm and 32 mm nets (D = 0.09, P = 0.40). Furthermore, a total of 188 lake trout were captured by hook-and-line and no significant differences were found by pairwise comparisons in length distributions of lake trout caught by hook-and-line gear and each gillnet mesh size: hook-and-line and 19 mm (D = 0.03, P = 0.15), hook-and-line and 25 mm (D = 0.13, P = 0.08), and hook-and-line and 19 mm (D = 0.10, P = 0.12).

AGE VALIDATION

A total of 178 scales and 199 otoliths were collected from known age lake trout. Of these, 177 were paired. The optimal sample size of 98 fish per year was not achieved. Therefore, for those analyses that did not require direct comparisons, the samples were combined to increase the statistical power.

The proportion of scales and otoliths which reflected the true age was 0.66 (SE = 0.04) and 0.60 (SE = 0.04), respectively. These values were similar to those deduced from the first and second readings of these structures (Table 4). Fifty-seven opercula 0.75 (SE = 0.06) were correctly aged. However, a second aging was not conducted and these structures were excluded from

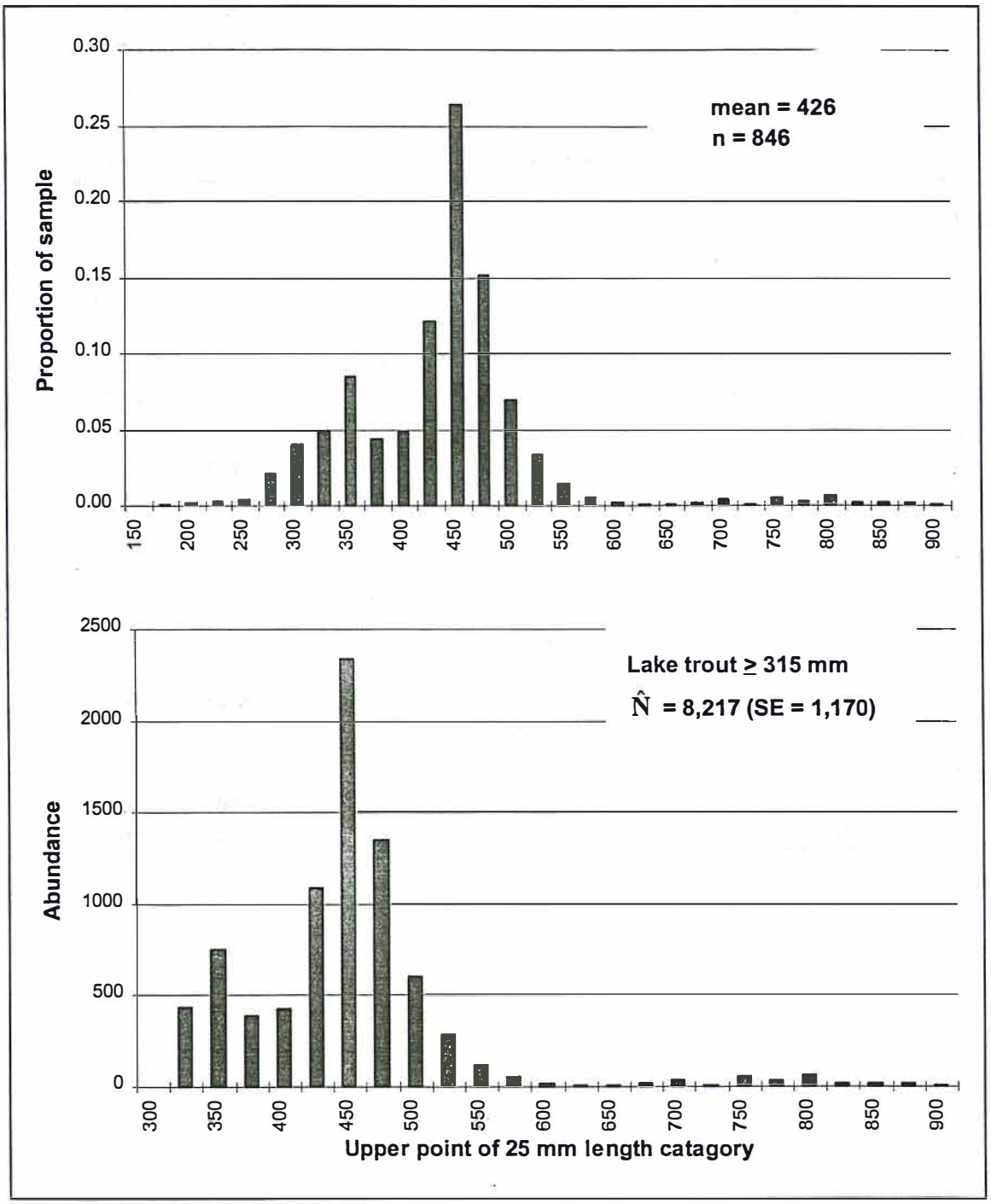

Figure 3.-Estimated length composition for lake trout in Itkillik Lake, 1997.

Table 3.-Catch per unit effort from Index and non-Index fishing in Itkillik Lake, 1997.

	Catch by Species				
	Lake Trout	Round Whitefish	Sets (n)	Effort (net hour)	
Indexed					
Event 1					
CPUE	3.86	5.73	118	Mean	0.34
Total Catch	159	236		Total	41.18
Event 2					
CPUE	3.46	6.28	107	Mean	0.35
Total	130	236		Total	37.56
Both events					
CPUE	3.68		225	Mean	0.35
Total Catch	289			Total	78.63
Non-indexed					
Event 1					
CPUE	2.27	5.29	126	Mean	0.42
Total Catch	121	282		Total	53.31
Event 2					
CPUE	4.23	5.11	102	Mean	0.48
Total Catch	213	257		Total	50.32
Both events					
CPUE	3.22		228	Mean	0.45
Total Catch	334			Total	103.63

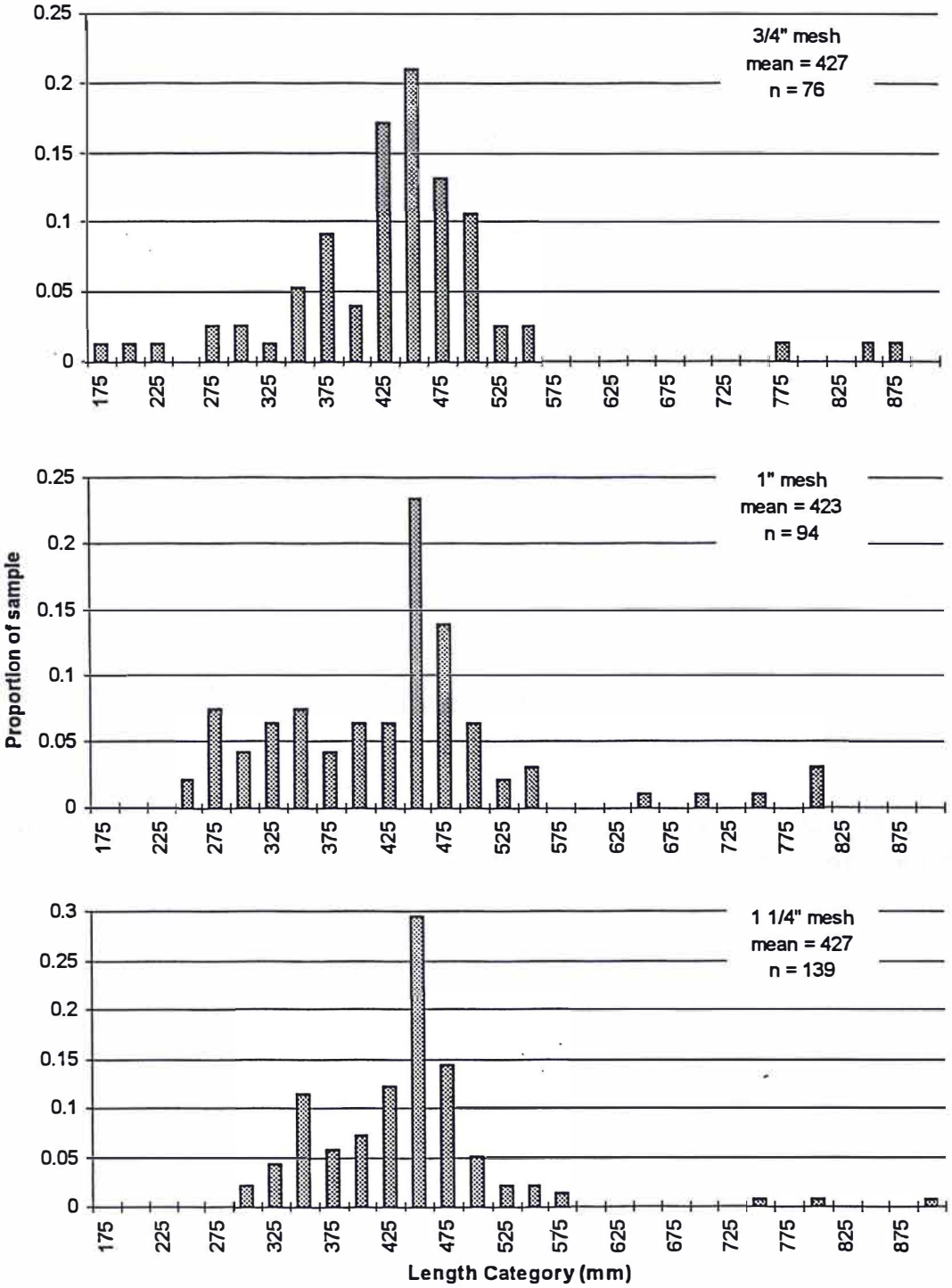

Figure 4.- Length frequencies of lake trout captured by gillnets of different mesh sizes during Index fishing at Itkillik Lake, 1997.

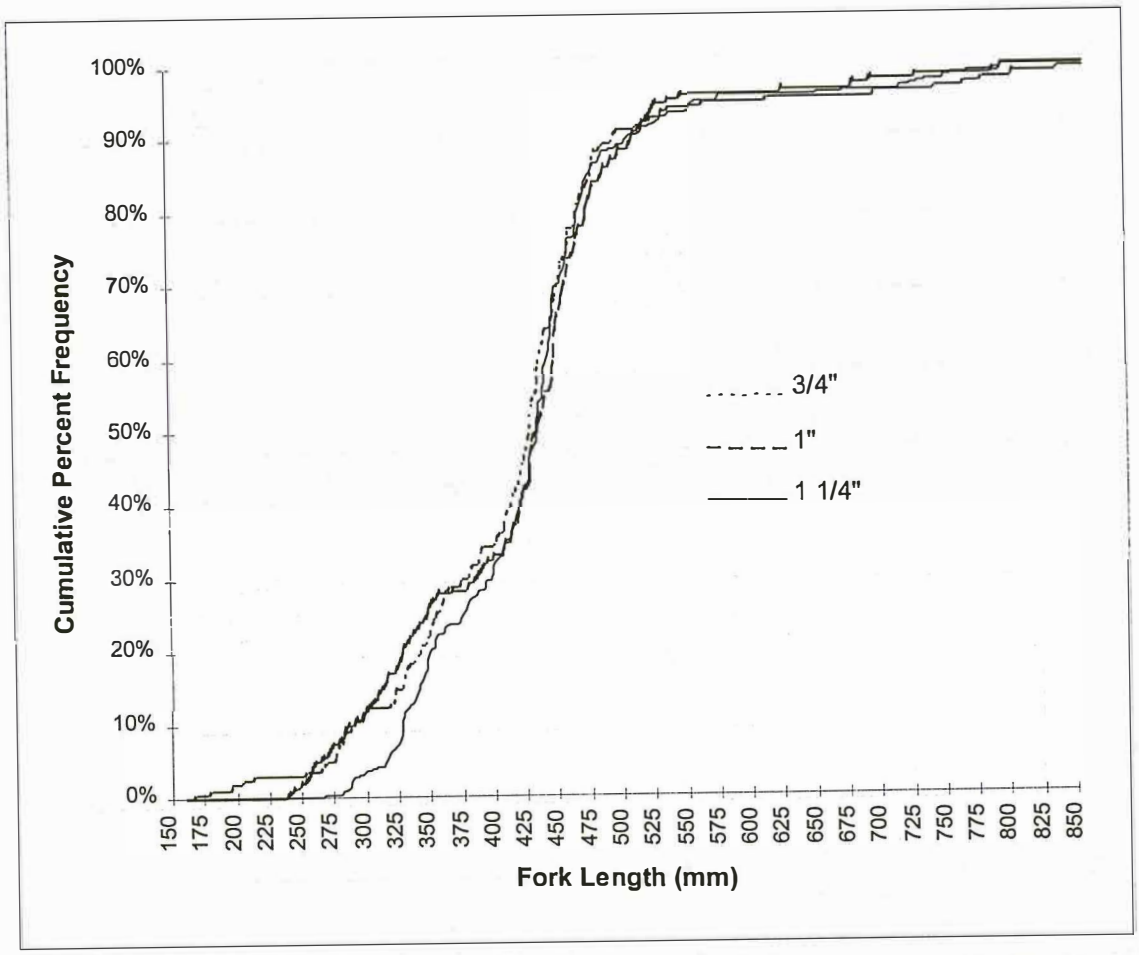

Figure 5.-Cumulative frequency distributions of all lake trout captured in different mesh sizes of gillnets (index and non-index) at Itkillik Lake, 1997.

Table 4.- Proportions of estimated ages of lake trout scales, otoliths, and opercula compared to known ages.

Reading	Structure	Age			$\hat{p}$	$V[\hat{p}]$	SE
		Total	Correct	Incorrect			
Final Reading	Scales	178	118	60	0.66	0.001	0.036
	Otoliths	199	120	79	0.60	0.001	0.035
	Opercula	57	43	14	0.75	0.003	0.058
	Scales & Otoliths	377	238	139	0.63	0.001	0.025
First Reading	Scales	178	119	59	0.67	0.001	0.035
	Otoliths	199	105	94	0.53	0.001	0.035
	Both	377	224	153	0.59	0.001	0.025
Second Reading	Scales	178	119	59	0.67	0.001	0.035
	Otoliths	199	115	84	0.58	0.001	0.035
	Both	377	234	143	0.62	0.001	0.025

further analyses. Percent frequencies of observed errors are shown in Figure 6 for scales and Figure 7 for otoliths.

The results for the one-tailed z-test rejected the null hypothesis that the proportion of correctly aged fish was ≥ 0.90 for both scales and otoliths ($z = 0.651$, $P = 0.257$ for scales; and, $z = 3.363$ with $P < 0.01$ for otoliths). Though rejected, the results showed that the accuracy rate for otoliths was lower than that for scales.

A 2 x 2 contingency table analysis failed to reject the null hypothesis that accuracy is independent of structure ($\chi^2 = 1.449$, df = 1, $P = 0.23$). The table was set up to compare the number of structures correctly and incorrectly aged for scales and otoliths.

Results from the ANOVA which compared the mean ages from scales and otoliths failed to reject the null hypothesis and showed similar means ($F = 0.426$, $P = 0.514$). Because this test was a direct comparison of ages given by each structure, only the 177 paired ages were used.

No relation between true age and accuracy of age determination from lake trout scales was found ($\beta_0 = -0.154$, $P = 0.131$). However, there was a relation between the true age and accuracy of age determination from lake trout otoliths ($\beta_0 = -0.431$, $P < 0.001$). The proportions of correctly aged lake trout with respect to the true ages of the lake trout are shown in Figure 8.

DISCUSSION

ABUNDANCE ESTIMATION

The in-season estimate of abundance is the first attained for Itkillik Lake. It is unlikely that bias was introduced because of inadequate mixing or unequal capture probabilities because sampling effort was applied equally throughout Itkillik Lake by using gillnets set in-shore and off-shore and angling to capture lake trout. Movements of recaptured lake trout indicated that the fish had mixed between near-shore and mid-lake areas as well as between sampling areas A, B, and C. The desired precision of the abundance estimate fell short of the objective criteria ($N \pm 25\%$, $\alpha = 0.10$). Greater precision could likely have been achieved by increasing sampling effort during the mark and recapture events. Based on the estimate of 8,217 lake trout, approximately 570 fish would have to be both marked and examined to attain the desired confidence level.

The density of lake trout in Itkillik Lake lies near the median values estimated for other Alaskan lakes (Table 5). Burr (1992) found a significant inverse relationship between lake surface area and density among several Alaskan lakes ($n = 7$). The predicted density in Itkillik Lake using this relationship would be 5.8 fish/ha as opposed to the 19.6 fish/ha found during 1997.

The relatively high density of lake trout in Itkillik Lake is likely attributed its physical and chemical characteristics (J. LaPerriere, University of Alaska-Fairbanks, personal communication 1997). Because Itkillik Lake is shallow and exposed to the climate of the northern Brooks Range, summer stratification is repeatedly broken by high wind events. It may be that during wind-driven mixing periods, nutrients released into the hypolimnion by decomposition or nutrients associated with resuspended bottom sediments may be entrained in the water column and by this internal loading mechanism provide stimulation of the algal food base (LaPerriere and Jones 1991). Of 12 lake examined in the Gates of the Arctic National Park during 1996 the zooplankton biomass was greatest in Itkillik (J. LaPerriere, University of Alaska-Fairbanks, personal communication 1997). Snails were also noted to be quite numerous and of good size in

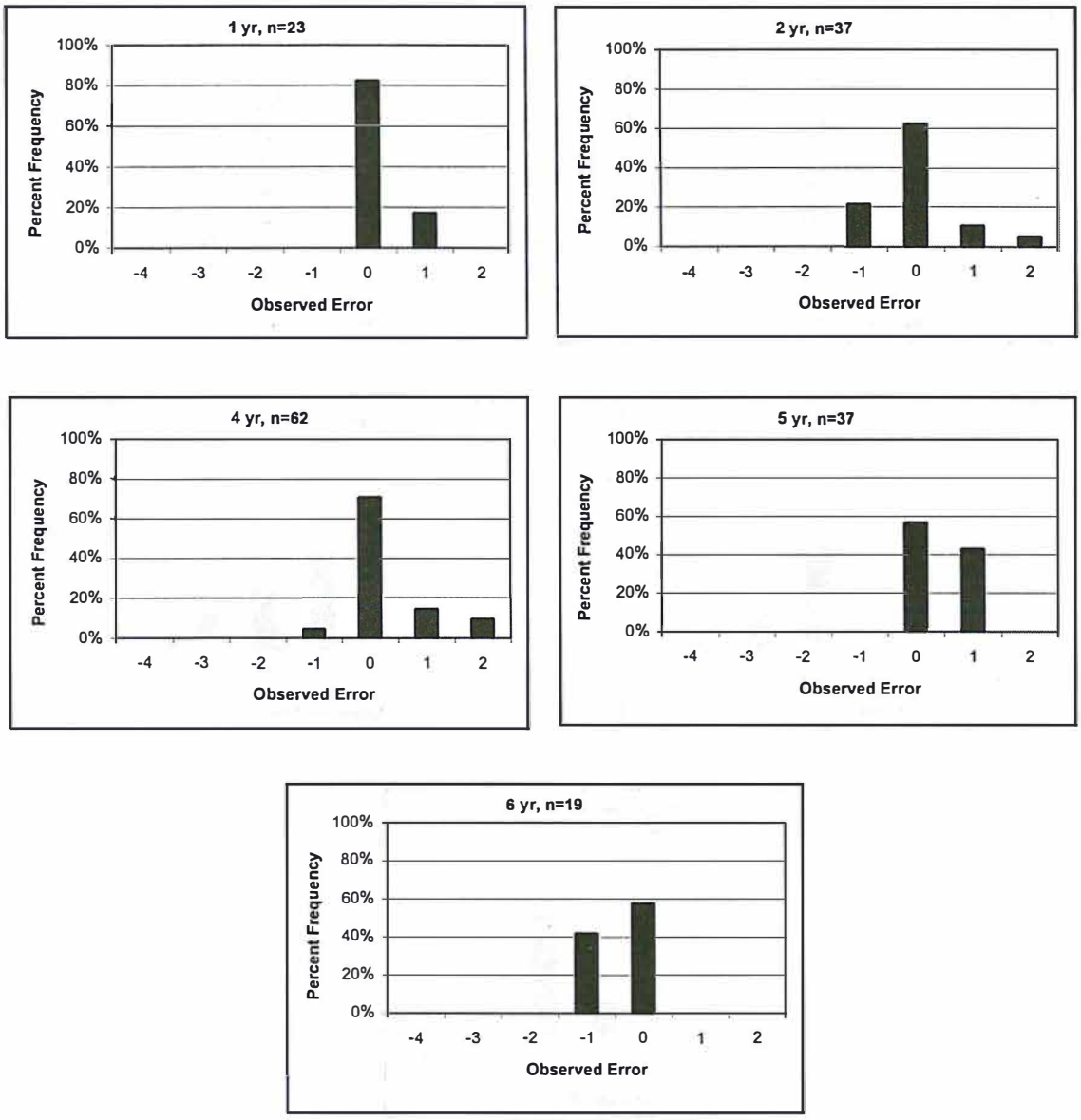

Figure 6.-Percent frequencies of observed reader errors for lake trout scales taken from known age fish.

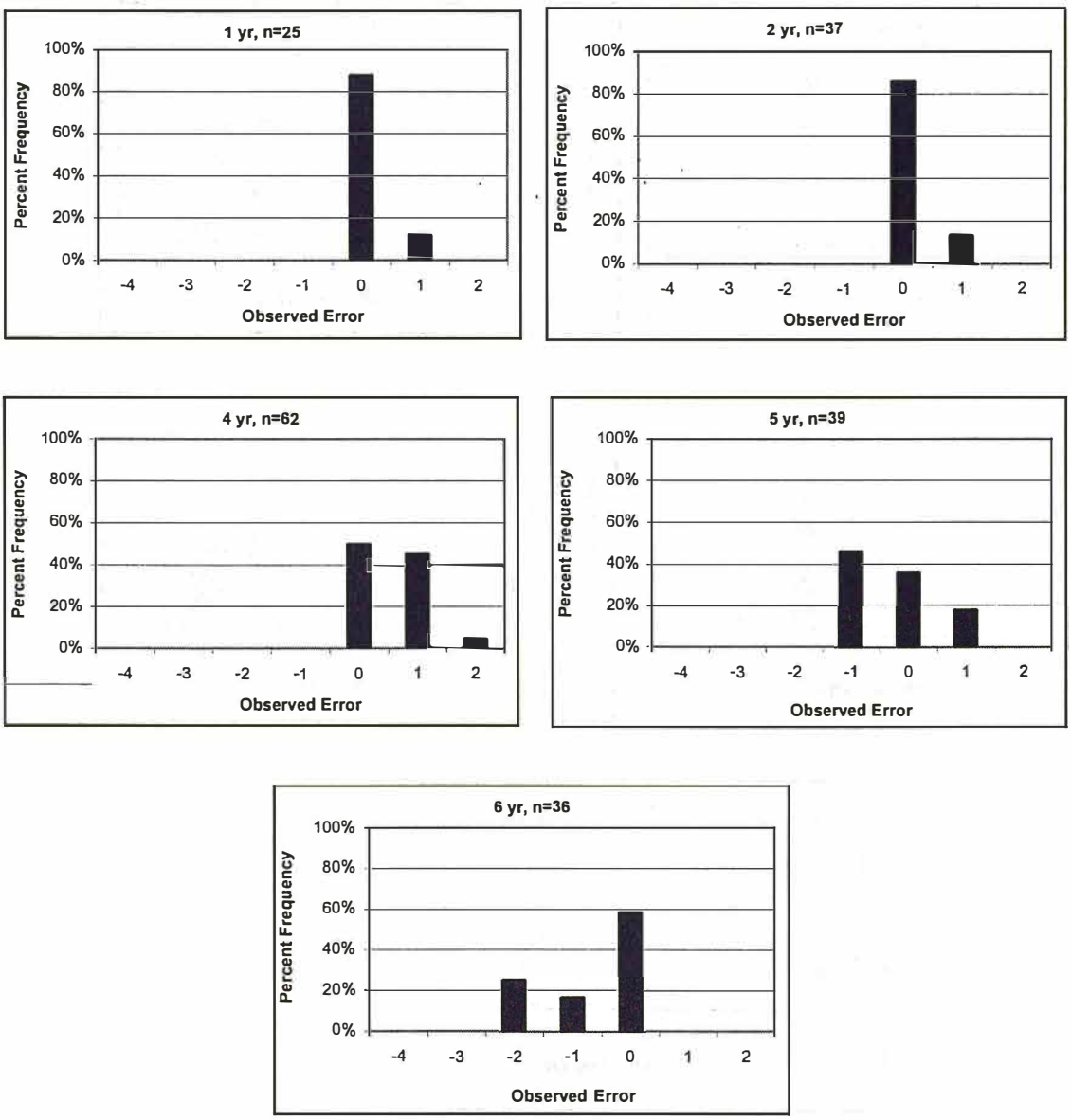

Figure 7.-Percent frequencies of observed reader errors for lake trout otoliths taken from known age fish.

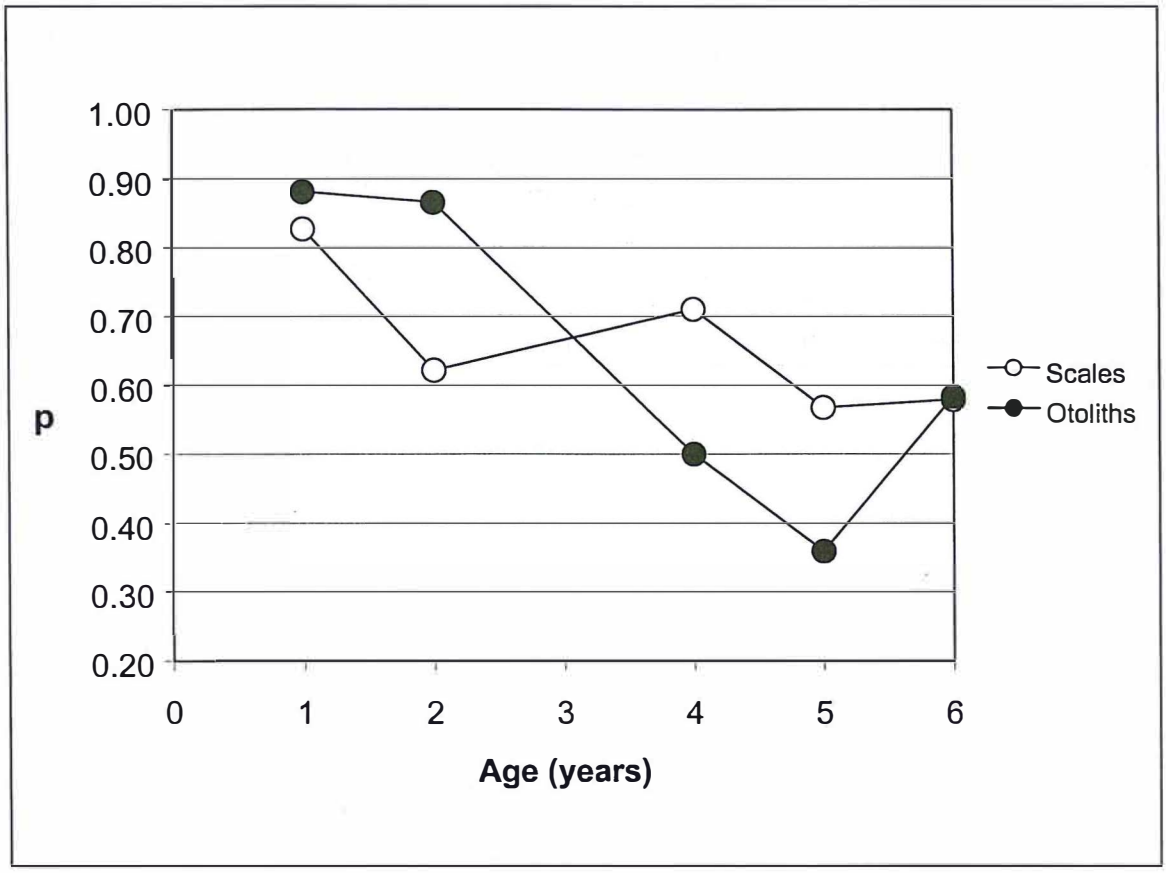

Figure 8.-Proportion values of correctly aged lake trout with respect to age from the logistic regression analysis.

Table 5.-CPUE and corresponding population parameters for lake trout sampled, 1994-1997.

Lake	ha	Year	N	SE	CPUE	Density
Galbraith	412	1994[a]	236 (>499 mm)	41	0.21	0.6
Irgnyivik	87	1995[b]	492 (>368 mm)	121	1.76	5.7
Nanushuk	81	1995[c]	2,913 (≥ 350 mm)	788	4.00	36.0
		1996[c]	5,037 (≥ 350 mm)	1,345	2.32	42.3
		1996[c]	6,179 (≥ 284 mm)	2,263	3.38	76.3
Sevenmile[c]		1996[c]	1,241 (≥ 235 mm)	188	2.90	37.6
Itkillik[d]	430	1994[a]	nd	nd	9.59	Nd
	430	1997	8,217 (≥ 314 mm)	1,170	3.41	19.6

[a] Burr (1995)

[b] Taube (1996)

[c] Taube (1997)

this lake. This is an indication that there are adequate minerals available for shell formation, and that there is adequate benthic algae for snail.

INDEX FISHING

CPUE estimated for Itkillik Lake may not provide an accurate index of abundance. Of the lakes for which CPUE and abundance estimates were attained (Table 5) a poor correlation ($R^2 = 0.49$) was found between abundance and CPUE as well as between density and CPUE ($R^2 = 0.48$). Given, the abundance estimates are not directly comparable due to the minimum length sizes, but the estimates are still useful for examining trends and the usefulness of Index fishing as a reliable stock assessment tool.

In order for CPUE data to serve as a management tool the assumption of equal probability of capture for lake trout among lakes must not be violated. The size distribution of a population, fish distribution within a lake, lake morphology, and sampling effort can all affect capture probability (Taube 1997).

Densities of lake trout populations examined (Table 4) adhere to the inverse relationship between density and lake area reported by Burr (1992). This would make comparisons of CPUE data among lakes invalid since large lakes would have low CPUE due to density and small lakes would have high CPUE. The area a gillnet set fishes in a lake section also varies among lakes since the sampling design divides each lake into 120 equal sections regardless of lake size. Sampling effort should be standardized (i.e. number and duration of net sets per lake area and length of shoreline) so that capture efficiencies are comparable among lakes. Gear saturation may occur, particularly in smaller lakes, if the same amount of effort is applied to a small lake as that of a large lake. In Nanushak Lake, a small lake, effort was increased each samping year, 20 net hours in 1994, 27 net hours in 1995, and 40 net hours in 1996 while CPUE decreased from 7.38 to 6.14 to3.95, respectively (Taube 1997). Furthermore, since Index gillnets have been used for capturing fish as part of a mark-recapture experiment, sampling effort is driven by the sample size needed to estimate the expected abundance.

The differences in CPUE in Itkillik Lake recorded in 1994 (9.59) and 1997 (3.27) can be attributed to sampling effort. In 1994, effort was only 7 net hours, as compared to 41 in 1997, and net set locations were not selected randomly, but were selected based on areas where fish densities appeared to be greater (e.g., lake morphometry). During 1997 there was only a slight decrease in CPUE from July to August for the Index nets. Although CPUE data are suspect, the closeness between CPUE from the July and August sampling events may suggest that in the case of Itkillik Lake CPUE may indicate lake trout abundance. The relatively constant CPUE between sampling events could be attributed to the lack of stratification which can cause lake trout to seek out cooler water in the center of the lake later in the summer and, therefore the distribution of lake trout was similar between sampling events.

The decrease in the Index CPUE was offset by an increase (2.27 to 4.23) in the mid-lake CPUE. The increase is probably not due to targeting or selecting lake areas with greater densities of lake trout since attempts were made to set mid-lake gillnets randomly among the sampling areas. Rather the increase is likely a function of the high winds that occurred during the August sampling period. Turbulent waters tended to increase catch rates in the center Itkillik Lake and other north slope lake perhaps by "driving" the lake trout away from near-shore areas (J. Burr, ADF&G Sport Fish Division, personal communication 1997). The increase in mid-lake CPUE is not attributed to food availability since the abundance of lake trout prey (round whitefish)

based on CPUE was not greater in mid-lake. The changes observed in the CPUE data lends support for the current sampling design which calls for Index fishing to occur before surface temperatures reach 13° C.

Clearly, the variability of the CPUE data found among the lakes of the pipeline corridor and other Alaskan lakes are too great to provide a reasonable assessment of lake trout abundance using Index fishing for management proposes. The stongest evidence is provided by Nanushak lake where the estimated abundance nearly doubled from 1995-1996 while CPUE decreased almost by half. If the assumptions of equal probability of capture and equitable sampling effort among and within lakes can be addressed, Index fishing could conceivably be used as an index of abundance lake trout. Index nets have been effective methods for capturing lake trout in Mark-recapture experiments and continuation in the use of Index sampling during mark-recapture experiments would help to assess the feasibility of Index fishing without additional effort or cost.

AGE VALIDATION

An accuracy rate of 0.66 for scales and 0.60 for otoliths was lower than expected for lake trout of such young ages. Fish were between ages 1 and 6, a fact of which the scale reader was aware. Otherwise, aging was done blindly. Generally, scales are not as reliable as otoliths for aging and tend to underestimate ages in fish older than 8 years (Scott and Crossman 1973). Scale growth slows relative to body growth while other structures such as otoliths continue growing (Johnson 1976). However, scales were found to be more accurate than otoliths. Lake trout usually attain sexual maturity at age 6 or 7 or later for some populations. Thus, the fish used in this study were still growing and were most likely immature. Therefore, scales could be considered as reliable as otoliths for younger ages. The reader also had more experience examining scales of different Alaska freshwater fish species than otoliths.

For otoliths, unlike scales, the accuracy of determining ages of lake trout were fairly high for age 1 and 2 fish, significantly decreased for ages 4 and 5, and increased for age 6 (Figure 8). Knowing that fish were no older than age 6 precluded assignment of older ages to the samples. Age error for both otoliths and scales was variable (Figure 7). It would have been of interest to have age 3 samples available, although a few scales and otoliths were assigned a 3.

Martin (1966) noted that variation in the estimated mean ages from otoliths was mainly a reflection of the differences in the abilities of individual readers. For this study, additional readers with various amounts of experience with scales and otoliths may have shown similar results to Martin (1966). However, for the aforementioned study, mature lake trout were included. A future study might allow the present reader to closely examine and maybe learn from present mistakes. Sharp and Bernard (1988) noticed in a study on precision of estimated ages from vertebrae, cleithra, opercular bones, otoliths, and scales measured in repeated trials that otoliths showed the most variation among replicate counts made between three fairly experienced readers. Although more reliable than scales for aging older fish, lake trout otoliths can be as difficult to age.

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APPENDIX A

Appendix A.-Methodologies for alleviating bias due to gear selectivity by means of statistical inference (Bernard and Hansen 1992).

Results of Hypothesis Tests (K-S and χ^2) on Lengths of Fish Marked during First Event and Recaptured during Second Event	Results of Hypothesis Tests (K-S) on Lengths of fish Captured during First Event and during Second Event
Case I:	
"Accept" H_o	"Accept" H_o
There is no size-selectivity during either sampling event.	
Case II:	
"Accept" H_o	Reject H_o
There is no size-selectivity during the second sampling event but there is during the first.	
Case III:	
Reject H_o	"Accept" H_o
There is size-selectivity during both sampling events.	
Case IV:	
Reject H_o	Reject H_o
There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

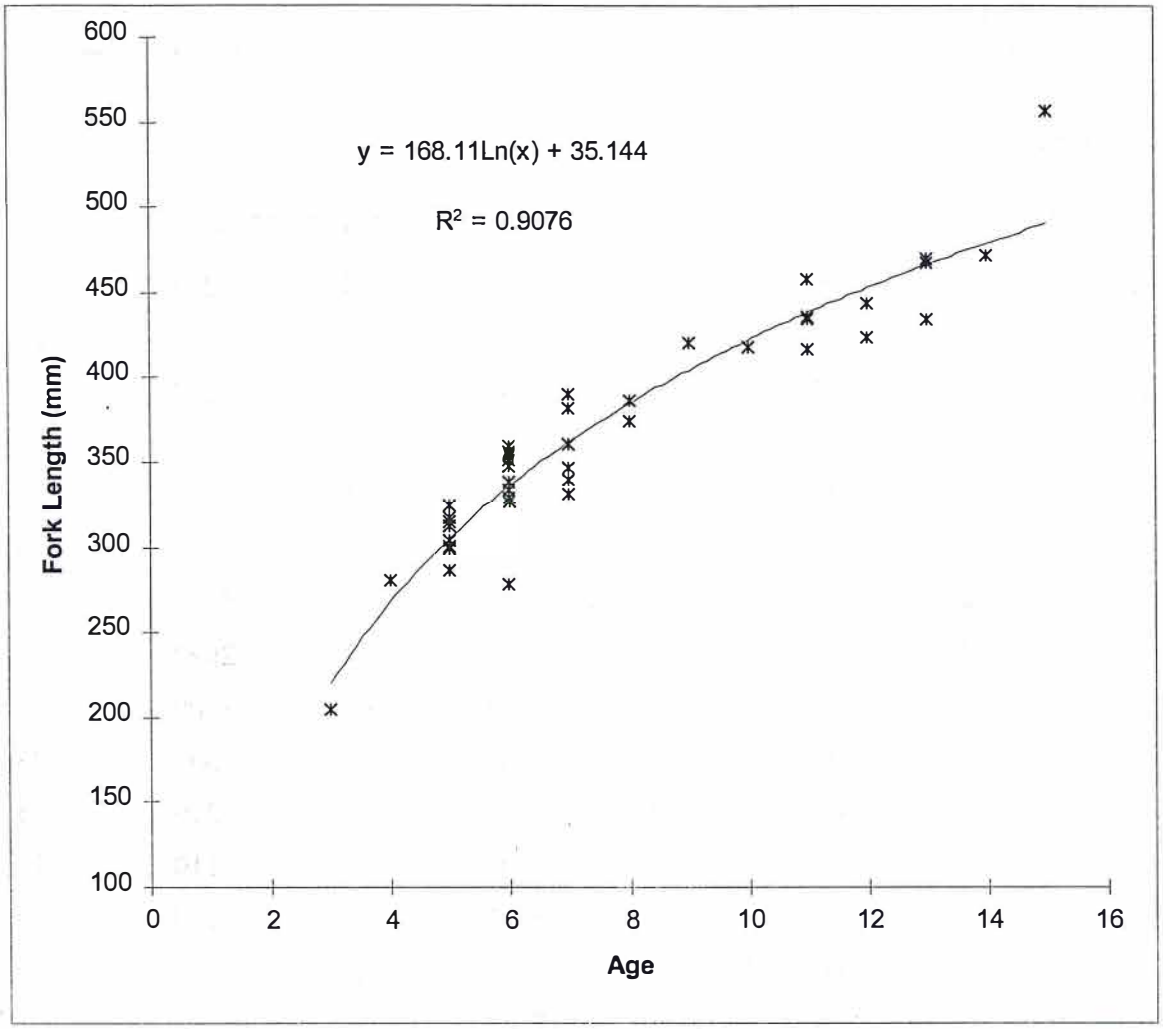
Case I:	Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.
Case II:	Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.
Case III:	Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.
Case IV:	Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.
Case IVa:	If the stratified and unstratified abundance estimates for the entire population are dissimilar, discard the unstratified estimate. Only use the lengths, ages, and sexes from the second sampling event to estimate proportions in composition, and apply formulae to correct for size bias to data from the second event.
Case IVb:	If the stratified and unstratified abundance estimates for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not apply formulae to correct for size bias.

APPENDIX B

Appendix B1.-Length composition of lake trout examined during 1997 sampling events at Itkillik Lake.

Upper Point of 25 mm Length Group	Frequency	$\hat{p}$	$V(\hat{p})$	SE
175	1	0.001	1.4E-06	0.001
200	2	0.002	2.79E-06	0.002
225	3	0.004	4.18E-06	0.002
250	4	0.005	5.57E-06	0.002
275	18	0.021	2.46E-05	0.005
300	34	0.040	4.56E-05	0.007
325	42	0.050	5.58E-05	0.007
350	72	0.085	9.21E-05	0.010
375	37	0.044	4.95E-05	0.007
400	41	0.048	5.46E-05	0.007
425	104	0.123	1.28E-04	0.011
450	223	0.264	2.30E-04	0.015
475	129	0.152	1.53E-04	0.012
500	58	0.069	7.56E-05	0.009
525	28	0.033	3.79E-05	0.006
550	12	0.014	1.65E-05	0.004
575	5	0.006	6.95E-06	0.003
600	2	0.002	2.79E-06	0.002
625	1	0.001	1.4E-06	0.001
650	1	0.001	1.4E-06	0.001
675	2	0.002	2.79E-06	0.002
700	4	0.005	5.57E-06	0.002
725	1	0.001	1.4E-06	0.001
750	5	0.006	6.95E-06	0.003
775	4	0.005	5.57E-06	0.002
800	6	0.007	8.33E-06	0.003
825	2	0.002	2.79E-06	0.002
850	2	0.002	2.79E-06	0.002
875	2	0.002	2.79E-06	0.002
900	1	0.001	1.4E-06	0.001
Total	846			

Appendix B2.-Length-at-age of lake trout mortalities from Itkillik Lake, 1997.



Appendix B3.- Estimated proportion and abundance of lake trout ≥ 300 mm by length category in Itkillik Lake, 1997.

Upper of 25 mm Length Group	Frequency	$\hat{p}$	$V(\hat{p})$	SE	$\hat{N}$	$V(\hat{N})$	SE
325	42	0.054	6.48E-05	8.05E-03	440	4377	66
350	72	0.092	1.07E-04	1.03E-02	755	7204	85
375	37	0.047	5.74E-05	7.58E-03	388	3881	62
400	41	0.052	6.33E-05	7.96E-03	430	4278	65
425	104	0.133	1.47E-04	1.21E-02	1090	9945	100
450	223	0.284	2.60E-04	1.61E-02	2337	17623	133
475	129	0.165	1.76E-04	1.33E-02	1352	11887	109
500	58	0.074	8.75E-05	9.35E-03	608	5916	77
525	28	0.036	4.40E-05	6.63E-03	293	2972	55
550	12	0.015	1.92E-05	4.39E-03	126	1300	36
575	5	0.006	8.09E-06	2.84E-03	52	547	23
600	2	0.003	3.25E-06	1.80E-03	21	219	15
625	1	0.001	1.63E-06	1.28E-03	10	110	10
650	1	0.001	1.63E-06	1.28E-03	10	110	10
675	2	0.003	3.25E-06	1.80E-03	21	219	15
700	4	0.005	6.48E-06	2.55E-03	42	438	21
725	1	0.001	1.63E-06	1.28E-03	10	110	10
750	5	0.006	8.09E-06	2.84E-03	52	547	23
775	4	0.005	6.48E-06	2.55E-03	42	438	21
800	6	0.008	9.70E-06	3.11E-03	63	655	26
825	2	0.003	3.25E-06	1.80E-03	21	219	15
850	2	0.003	3.25E-06	1.80E-03	21	219	15
875	2	0.003	3.25E-06	1.80E-03	21	219	15
900	1	0.001	1.63E-06	1.28E-03	10	110	10
Count	784				8,217		

APPENDIX C

Appendix C.-Lengths of lake trout captured by gear type from Itkillik Lake during July and August 1997.

Upper of 25 mm Length group	Index nets mesh size						Mid-lake nets mesh size						Hook and Line		All Gear	
	3/4"		1"		1 1/4"		3/4"		1"		1 1/4"					
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
175	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
200	1	1	0	0	0	0	1	1	0	0	0	0	0	0	2	0
225	1	1	0	0	0	0	1	1	0	0	0	0	1	1	3	0
250	0	0	2	2	0	0	0	0	2	2	0	0	0	0	4	0
275	2	3	7	7	0	0	2	2	4	4	1	1	2	1	18	2
300	2	3	4	4	3	2	9	10	5	5	6	4	5	3	34	4
325	1	1	6	6	6	4	3	3	8	7	6	4	12	6	42	5
350	4	5	7	7	16	12	8	9	8	7	18	12	11	6	72	9
375	7	9	4	4	8	6	6	7	1	1	6	4	5	3	37	4
400	3	4	6	6	10	7	4	5	4	4	11	7	3	2	41	5
425	13	17	6	6	17	12	10	11	13	12	13	9	32	17	104	12
450	16	21	22	23	41	29	17	19	23	21	38	26	66	35	223	26
475	10	13	13	14	20	14	15	17	19	17	21	14	31	16	129	15
500	8	11	6	6	7	5	4	5	10	9	8	5	15	8	58	7
525	2	3	2	2	3	2	1	1	9	8	5	3	6	3	28	3
550	2	3	3	3	3	2	0	0	2	2	2	1	0	0	12	1
575	0	0	0	0	2	1	1	1	0	0	2	1	0	0	5	1
600	0	0	0	0	0	0	0	0	0	0	2	1	0	0	2	0
625	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0
650	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0
675	0	0	0	0	0	0	0	0	0	0	2	1	0	0	2	0
700	0	0	1	1	0	0	1	1	2	2	0	0	0	0	4	0
725	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
750	0	0	1	1	1	1	1	1	0	0	2	1	0	0	5	1
775	1	1	0	0	0	0	0	0	0	0	3	2	0	0	4	0
800	0	0	3	3	1	1	1	1	0	0	1	1	0	0	6	1
825	0	0	0	0	0	0	2	2	0	0	0	0	0	0	2	0

-continued-

Appendix C.-Page 2 of 2.

Upper of 25 mm Length group	Index nets 3/4" n	Index nets 3/4" %	Index nets 1" n	Index nets 1" %	Index nets 1 1/4" n	Index nets 1 1/4" %	Mid-lake nets 3/4" n	Mid-lake nets 3/4" %	Mid-lake nets 1" n	Mid-lake nets 1" %	Mid-lake nets 1 1/4" n	Mid-lake nets 1 1/4" %	Hook and Line n	Hook and Line %	All Gear n	All Gear %
850	1	1	0	0	0	0	0	0	1	1	0	0	0	0	2	0
875	1	1	0	0	0	0	0	0	0	0	1	1	0	0	2	0
900	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
Total	76	100	94	100	139	100	88	100	111	100	149	100	189	100	846	
Mean	427		423		427		419		424		440		420		426	
SE	110		113		81		115		91		104		57		93	
Min	168		244		285		195		240		268		218		168	
Max	862		795		881		820		840		855		519		881	

APPENDIX D

Appendix D.-Water temperature (^{o}C) profiles from Itkillik Lake on July 5 and August 2, 1997.

Depth (m)	Temperature (^{o}C)	
	July	August
0	15.0	15.2
1	14.5	15.0
2	14.5	15.0
3	14.0	15.0
4	13.5	15.2
5	10.0	15.0
6	10.0	14.5
7	10.0	14.5
8	10.0	14.5
9	10.0	14.8
10	10.0	15.0
11	10.0	14.4
12	10.0	14.0
Bottom	9.5	14.0

APPENDIX E

Appendix E.-Data files used in the preparation of this report.

Data File	Description	Status
Z0860LAA.XLS	Lake trout biological data, Itkillik Lake, 1997	Included
97ITKCPU.XLS	Itkillik Lake set data; CPUE estimate, 1997	Included