State of Alaska
Department of Fish and Game
Division of Sport Fish

Nomination Form
Anadromous Waters Catalog

mg /dB

Region

USGS Quad(s) SEWARD B-7, B-8

Anadromous Waters Catalog Number of Waterway 244-30-10010-0020

Name of Waterway Kenai Lake ☐ USGS Name ☐ Local Name

☐ Addition ☐ Deletion ☐ Correction ☑ Backup Information

For Office Use

Nomination # 08-176

Revision Year: 2009

Revision to: Atlas ____ Catalog ____ Both X

Revision Code: B-2

Role	Date
Fisheries Scientist	10/6/08
Habitat Operations Manager	10/6/08
AWC Project Biologist	5/28/08
Cartographer	11/24/08

OBSERVATION INFORMATION

Species	Date(s) Observed	Spawning	Rearing	Present	Anadromous
Sockeye salmon	6/26/1905		X		☑
					☐
					☐
					☐
					☐

IMPORTANT: Provide all supporting documentation that this water body is important for the spawning, rearing or migration of anadromous fish, including: number of fish and life stages observed; sampling methods, sampling duration and area sampled; copies of field notes; etc. Attach a copy of a map showing location of mouth and observed upper extent of each species, as well as other information such as: specific stream reaches observed as spawning or rearing habitat; locations, types, and heights of any barriers; etc.

Comments: Add sockeye salmon rearing to Kenai Lake based on juvenile sockeye salmon studies conducted in Skilak and Kenai lakes 2004
Fishery Data Series "Juvenile Sockeye Salmon Population Estimates in Skilak and Kenai Lakes, Alaska, by use of Split-beam Hydroacoustic Techniques in September 2004" by Robert DeCino & Mark Willette

Name of Observer (please print): J. Johnson

Signature:

Date: 5/28/2008

Agency: ADF&G - SF

Address: 333 Raspberry Road
Anchorage, AK 99518

This certifies that in my best professional judgment and belief the above information is evidence that this waterbody should be included in or deleted from the Anadromous Waters Catalog.

Signature of Area Biologist: ____________ Date: ________

Name of Area Biologist (please print):

Revision 05/08

Fishery Data Series No. YY-XX

Juvenile Sockeye Salmon Population Estimates in Skilak and Kenai Lakes, Alaska, by Use of Split-beam Hydroacoustic Techniques in September 2004

by

Robert D. DeCino

and

T. Mark Willette

Month year

Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

FISHERY DATA SERIES NO. YY-XX

JUVENILE SOCKEYE SALMON POPULATION ESTIMATES IN SKILAK AND KENAI LAKES, ALASKA, BY USE OF SPLIT-BEAM HYDROACOUSTIC TECHNIQUES IN SEPTEMBER

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Month Year

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ABSTRACT

During 13-15 September 2004, hydroacoustic surveys were conducted on Skilak and Kenai Lakes using split-beam sonar. A second hydroacoustic survey was conducted on Skilak Lake (5 October 2004), because the first population estimate for this lake appeared low and could have been biased. The population estimates from these two surveys of Skilak Lake were 15,812,800 and 27,070,000 fish respectively. But, these two population estimates were not significantly different ($F = 1.198$; $P = 0.388$), so a pooled estimate was calculated. The population estimates for Skilak and Kenai Lakes were 20,999,000 and 2,513,700 fish. Annual midwater trawl surveys were conducted to estimate age composition, mean weight, and mean length of juvenile sockeye salmon. For Skilak Lake, age-0 sockeye salmon composed 97 % of the total population estimate. The mean population weight and length of this cohort was 0.62 g and 40.7 mm with the weight being the smallest on record. In comparison, age-0 sockeye salmon accounted for 100 % of the total fish population in Kenai Lake. The age-0 fry in Kenai Lake were more than double the weight of fry in Skilak Lake (mean=1.30g), but they were only slightly longer at 48.9 mm when compared to Skilak Lake fry.

Key words: Alaska, Cook Inlet, hydroacoustics, Kenai River, salmon, *Oncorhynchus nerka*, split–beam, sonar.

INTRODUCTION

In September 2004, the Alaska Department of Fish and Game (ADF&G) conducted hydroacoustic and tow-net surveys in Skilak and Kenai lakes (Kenai River drainage) to determine population abundance, age distribution, and size of juvenile sockeye salmon, *Oncorhynchus nerka*. These surveys have been performed annually since 1986 (DeCino 2001, DeCino and Degan 2000, Tarbox and King 1988a, 1988b, Tarbox, et. al. 1993, Tarbox and Brannian 1995, Tarbox et. al. 1996). The information obtained on fall fry rearing in these major nursery lakes are used to help biologists forecast the number of sockeye salmon returning to the Kenai River (Eggers 2005). Moreover, the biological basis for the brood interaction spawner-recruit model (Carlson et al. 1999; Edmundson et al. 2003) is thought to be heavy grazing on cyclopoid copepods by large fry populations reducing survival of the subsequent year class. Thus, a major goal of this project, coupled with limnological studies, is to gain a better understanding of the factors regulating the production of sockeye salmon in the Kenai River, which supports the largest runs of sockeye salmon in Upper Cook Inlet (Fox and Shields 2002).

For the 2004 fish surveys, population sizes were estimated using an echo integration (MacLennan and Simmonds 1992) procedure of data obtained from split-beam sonar. The condition of the juvenile sockeye was based on the size and age of fish captured in mid-water trawls. In addition, transects across each lake were geo-referenced during the hydroacoustic surveys (DeCino and Degan 2000). In this report, we describe the methods used in our lake surveys, and we provide (1) abundance estimates for juvenile sockeye salmon rearing in Skilak and Kenai lakes, (2) distributions of age, weight and length of fall fry, and (3) assessments of the pre-winter condition of fry.

METHODS

Hydroacoustic Surveys

We used a stratified-random sampling design for the hydroacoustic surveys to distribute sampling effort in proportion to abundance and reduce the variance of the population estimate. Each lake was divided into areas or sub-basins and survey transects were randomly selected within each area. The number of transects were chosen to reduce relative error to ~25% for Skilak Lake and 30% for Kenai Lake. This sample size was based on recommendations in

Tarbox et al (1996). Because of the configuration of Skilak Lake, transects perpendicular to shore were surveyed within three sub-basins (Figure 1), whereas in Kenai Lake, transects were surveyed within five sub-basins (Figure 2). Transects were chosen based on a stratified-random design (DeCino and Degan 2000, Tarbox et. al. 1996, Jolly and Hampton 1990, Figures 1 & 2). Transects were traversed at approximately 2 m/s. The acoustic vessel (7.2 m long) was powered by two 2-stroke outboard engines.

In Skilak Lake, two hydroacoustic surveys were completed. The first using a downlooking configuration only, whereas the second utilized two transducers in a multiplexing (side and down looking) configuration. In Kenai Lake only, a single down looking hydroacoustic survey was conducted.

For all the hydroacoustic surveys, juvenile sockeye salmon were sampled acoustically at night with a BioSonics DTx-6000[1] split beam echosounder. For specific data collection parameters on all surveys see AppendixA 1. The down-looking transducer was mounted to a 1.5-m long aluminum towbody. The towbody was attached to a cable connected to a boom and towed off the boat's starboard side approximately 1-m below the water surface. The side looking transducer was mounted to a pole on the port side of the acoustic vessel at a depth of 1-m. The transducers transmitted digital data via a direct connection data cable to the echosounder. The echosounder was connected to a laptop computer via ethernet data connection. For geo-referenced transect routes, we used a Garmin[1] GMAP model 175 global positioning system (GPS). Acoustic digital data were collected and stored on a laptop computer hard-drive. Configuration parameters (Appendix A 1) were input into BioSonics[1] Visual Acquisition data collection software. Environmental variables (temperature) were measured with a YSI[1] model 58 digital thermistor and input to the environmental variables of the program. Twelve-volt batteries powered the acoustic system and the laptop computer.

Acoustic data were stored (hard-drive) and transported to the area office where they were uploaded into the Area office network for access by analysis programs. The acoustic data were edited by use of SonarData[1] Echoview analysis software. Acoustic data were first bottom edited to remove bottom echoes. After bottom editing was complete, individual target information was processed and saved for estimation of in-situ target strength and sigma (σ) the absolute backscattering coefficient.

Target strength and σ computations were performed using a macro built by Aquacoustics Inc[1]. For each lake, this macro appended all transects and calculated in-situ target strengths and σ's from each detected target. Targets were filtered to include only those echoes near the beam center (0 to –3dB off axis). Target number and average σ were derived and put into 5 m strata. Generally, the entire lake average σ was input to a spreadsheet to compute densities for each transect using echo-integration. However, if the stratum differed by more than 20% of the mean σ computed for the entire lake and target density was greater than 5% of total targets used to compute average σ then a different σ would be used to compute densities of other fish targets (Appendix A:2 and :3).

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[1] Use of a company name does not constitute endorsement by ADF&G.

A fish density estimate was computed for each transect and expanded for each area from which they were collected. The echo integrator compiled data in one report along each transect and sent outputs to computer files for further reduction and analysis. The total number of fish (N_{ij}) for area stratum i based on transects j was estimated across depth stratum k. N_{ij} consisted of an estimate of the number of fish detected by hydroacoustic gear in the mid-water (1-51 m from transducer face) layer (M_{ij}) and an estimate of the number of fish in the surface layer (0-2 m). In order to estimate the number of fish unavailable to the hydroacoustic gear in a down looking configuration because of their location near the surface (S_{ij}), the fish density in the upper stratum was assumed equal to the density in the first stratum echo integrated in the lake. That assumption is based on lake morphometry and percent volume sampled in post-processing analysis

$$\hat{N}_{ij} = \hat{S}_{ij} + \hat{M}_{ij}$$

The mid-water component was estimated as

$$\hat{M}_{ij} = a_i \sum_{k=1}^{K} M_{ijk}$$

where a_i represented the surface area (m^2) of area stratum i which was estimated using a planimeter and USGS maps of Skilak and Kenai Lakes, and M_{ijk} (number/m^2) was the estimated mean fish density in area i depth k across transect j. The depth would be less than the maximum 50 m if the bottom was detected within depth stratum k anytime along the transect. The estimated numbers of fish near the surface (0–2 m) in area i was

$$S_{ij} = a_{ij} m_{ij}$$

where a_{is} was the estimated area (m^2) of the surface stratum (0–2 m), and m_{ijk} is 2/5 the mean fish density for in the first ensonified depth stratum (1–5 m below transducer face) of transect j.

Fish abundance in area i (N_i) was estimated from the mean abundance for all transects j in the area, or

$$\hat{N}_i = J^{-1} \sum_{j=1}^{J} N_{ij}$$

and its variance was estimated as

$$v(\hat{N}_i) = \sum (\hat{N}_{ij} - \hat{N}_i)^2 (J-1)^{-1} J^{-1}$$

Total fish abundance (N) for each lake was estimated as the sum of the area estimates and the variance of N was estimated as the sum of the area variance estimates.

The abundance of juvenile sockeye salmon in each lake (N_s) was estimated as

$$N_s = \hat{N}\hat{P}$$

where $\hat{P}$ was the estimated proportion of total fish targets that were juvenile sockeye salmon in the lake. Age-specific numbers of juvenile sockeye salmon (N_{sa}) were estimated as

$$N_{sa} = \hat{N}\hat{P}_a$$

where $\hat{P}_a$ was the estimated proportion of age-a sockeye salmon in the fish population.

Variance estimates were calculated as

$$v(\hat{N}_s) = \hat{N}^2 v(\hat{P}) + P^2 v(\hat{N}) - v(\hat{P})v(\hat{N})$$

$$v(\hat{N}_{sa}) = \hat{N}^2 v(\hat{P}_a) + P_a^2 v(\hat{N}) - v(\hat{P}_a)v(\hat{N})$$

Two surveys were completed in Skilak Lake on 13 September and 5 October 2004. These two surveys were done at night in dark moonless conditions. A randomized block ANOVA with survey as the treatment and the three areas as the blocks was utilized to test whether the two population estimates differed.

AGE, WEIGHT, AND LENGTH (AWL) SURVEYS

Mid-water trawl (tow netting) surveys were conducted in both lakes to estimate the species composition of acoustic targets and the age composition, mean wet weight (g), and mean fork length (mm) of juvenile sockeye. Sampling in Skilak Lake utilized a stratified cluster and stratified two-stage sampling technique (Scheaffer et al. 1986, Cochran 1977). Areas were the same as those used in the hydroacoustic sampling. Depth strata were developed to account for potential vertical variation in species and age composition. Three depth strata were defined: surface (0-10 m), mid-depth (15-25 m) and deep (30-40 m). Each tow was defined as a primary sampling unit and a minimum of three tows were conducted in each stratum. All fish captured in each tow were identified to species. Approximately 10 % of total fish collected from all tows of sockeye fry were used to estimate age composition and average length and weight.

We used the same stratified random sampling technique in Kenai Lake; however, three areas and two depth strata were defined. The three sampling areas consisted of area one (identical to the hydroacoustic area one), area two (combining hydroacoustic areas two and three) and area three (combining hydroacoustic areas four and five). Two depth strata were defined: surface (0-10 m) and mid-depth (15-25 m) because historically very few fish were captured in the 30-40 m stratum and the cost savings of not sampling this stratum.

Fish captured in Skilak Lake were measured to the nearest 1 mm in the field. Scales were removed from sockeye salmon juveniles greater than 55 mm and all fry placed into individual pre-weighed scintillation vials. Vials were returned to the laboratory in Soldotna where they were weighed and frozen for subsequent lipid and bomb calorimetry analysis. Fresh wet weights were converted to formalin-fixed weight based on Shields and Carlson (1996) conversion data. All fish collected from Kenai Lake were enumerated, identified, and preserved in 10% formalin. In the laboratory juvenile sockeye salmon were measured to the nearest millimeter (fork length), weighed (wet) to the nearest 0.1 g, and the age determined from scale samples using criteria outlined by Mosher (1969).

RESULTS

SKILAK LAKE

Two hydroacoustic surveys were conducted on Skilak Lake. One on 13 September and the other 5 October 2004. For target strength estimation, a total of 42,196 and 28,027 echoes were used to calculate mean target strengths of –55.3 and –56.3 dB with a standard deviation's (SD) of 3.02 and 3.06 dB for survey 1 and 2, respectively. The mean and standard deviation for the backscattering coefficient (σ) used for echo integration were $4.06 \times 10^{-6} \pm 1.76 \times 10^{-5}$ and $3.28 \times 10^{-6} \pm 1.43 \times 10^{-6}$ (Table 1). However, in survey 1 the backscattering coefficient reported was applied to the upper 45 meters of the water column and a different, larger, (σ) was used for greater depths which for the purposes of this survey are not reported. The population estimates obtained from the two surveys were 15,812,800 and 27,086,170 fish, but the two estimates were not significantly different from each other based ($F = 1.198$; $P = 0.388$). Therefore, data from the two surveys were combined, providing a pooled estimate of 20,999,000 fish with a standard error (SE) of 2,780,051 fish. Of the estimated total population of juvenile sockeye salmon, approximately 53% were detected in Area 1 (Table 2, Figure1). In addition, the largest proportion of total fish targets in the 0-5 m depth strata was detected in Area 1 (Table 2), causing our estimate of the fish population in the surface layer (0-2 m) to also be greatest in this area. We estimated the total fish population in the upper 2 m of the water column in Skilak Lake was approximately 813,440 fish.

During our tow-net surveys, approximately 10,432 fish were captured of which 10,421 fish or 99.9 % were juvenile sockeye salmon. Of these, 1,000 were subsampled to estimate mean wet weight and fork length (AWL). From these 1000 fish, scales were collected from only 47 individuals (>55 mm length) to estimate their age. Age-0 juvenile sockeye salmon accounted for 97.1 % (SE = 0.009 %) of the total fish population estimate. The remaining 2.7 % (SE = 0.009 %) were age-1 sockeye salmon. Therefore, approximately 20,394,647 (SE = 2,699,486) and 582,211 (SE = 203,483) sockeye salmon were aged 0 and 1+ fish, respectively (Table 3). The mean population weight (converted to a formalin-preserved weight) and length of age-0 sockeye salmon was 0.62 g (SE = 0.06 g) and 40.1 mm (SE = 1.16 mm). In comparison, age-1 juvenile sockeye averaged 1.94 g (SE = 0.09 g) and 60.5 mm (SE = 1.68 mm, Table 4, Figure 3).

KENAI LAKE

A total of 9,888 echoes were used to estimate target strengths in Kenai Lake. The mean target strength was –54.7 dB with a SD of 3.69 dB. The mean σ was 4.69×10^{-6} with a SD of 4.69×10^{-6}. This σ produced a population estimate of 2,513,700 (SE = 203,919) fish. Of these 2,513,700 fish, 192,235 fish were estimated to occur in the surface layer (upper 0-2 m) (Table 2). The greatest density and proportion of the total juvenile sockeye salmon population was located in Area 4 (Table 2).

Based on our mid-water trawls conducted in Kenai Lake, sockeye salmon accounted for 100 % of the population. Of the apportioned juvenile sockeye, 100 % (SE = 0 %) were age-0 fish (Table 3). The mean population weight and length of the age-0 cohort was 1.30 g (SE = 0.01 g) and 48.9 mm (SE = 0.27 mm), respectively.

DISCUSSION

The 2004 population estimates of juvenile sockeye salmon in both Skilak and Kenai lakes ranked the 7th largest since surveys were initiated in 1986 (Figure 4). These juvenile sockeye salmon abundance estimates exhibit considerable year-to-year variation and there appears to be little overall trend in the time series (Figure 4). However, the combined lake 2004 population estimate is about 4.7 million more than the 18.6 million 18 year mean.

Skilak Lake consistently supports more sockeye salmon fry than Kenai Lake. The Skilak Lake population estimate is approximately 5.0 million fish more than its historical mean. The highest population estimate (1993) was approximately 33 million fry (Tarbox et al 1996), and the lowest population estimate (1996) was 5.2 million fish. The average population size since 1986 is 16 million fish with a SD of 8.58 million fish.

The 2004 Kenai Lake population estimate of 2.5 million fish is the ninth highest since inception of acoustic estimates in 1986 (Figure 4). Juvenile sockeye salmon estimates have ranged from 768,000 in 1996 to 6.2 million in 1988 (Tarbox et al 1996). The average population since 1986 is 2.67 million fish with a SD of 1.59 million. The 2004 sockeye salmon population estimate for Kenai Lake is about 150,000 fish below the historical mean population size.

The target strengths of the juvenile sockeye salmon measured with the split-beam transducer in 2004 were within reported ranges of target strengths measured using a dual-beam hydroacoustic system (see Tarbox et al 1996). In addition, juvenile sockeye salmon lengths and weights followed historical trends. Kenai Lake, on average, has produced larger fish in both length and weight compared with Skilak Lake. Juvenile sockeye salmon in Kenai Lake were both significantly longer ($F = 629.2$, $p = 0.00$) and heavier ($F = 1075.8$, $p = 0.00$) than the Skilak Lake fish in 2004.

Similar to the historical population estimates, historical length and weight measurements show considerable year to year variation in Skilak Lake (Figure 6). For age-0 sockeye salmon in Skilak Lake, the 2004 mean length and weight were 16 and 50 percent less, respectively, than the historical means. A regression equation relating fall fry weight to their abundance (Edmundson et al 2003) predicted a 1.1 g mean weight for sockeye fry in Skilak Lake, whereas actual mean weight was 0.62 g. The small size of the sockeye salmon fry in Skilak Lake this year was likely due in part to the low total copepod biomass in the lake (mean=282 mg/m^2, 2nd lowest biomass observed since 1986). We are concerned that these small fry may suffer elevated overwinter mortality, if they lack sufficient energy reserves to survive the winter fast. We are developing an overwinter mortality model employing measurements of whole body energy content of juvenile sockeye salmon sampled in the fall. In 2005, we will initiate a project to estimate the population size of smolts emigrating from the Kenai River watershed as a means to validate model estimates of overwinter mortality.

We conducted two acoustic surveys on Skilak Lake in 2004, because the population estimate from the first survey was lower than predicted from a regression relating fall fry abundance to number of spawners. This observation led us to speculate that the population estimate from the first survey could have been biased low. In the second hydroacoustic survey on Skilak Lake, we employed downlooking and sidelooking transducers in a multiplexing configuration. We used the down looking transducer to estimate the fish population in Skilak Lake as in the first survey. We used the data from the sidelooking transducer to estimate fish density in the upper 2 m of the water column for comparison to surface-layer density estimates derived from the 0-5 m layer (below the downlooking transducer).

Our effort to estimate fish density in the upper 2 m of the water column in 2004 had mixed results. The transducer was attached to a rigid mount on the gunwale and any slight disturbance (movement) in the vessel would result in noise/reverberation registered in the digital data stream. In addition to the movement, a slight breeze would produce noise on the surface. Transducer aiming was also difficult. For instance, if the transducer attitude was oblique to the horizontal/perpendicular axis of the boat and looking upward, noise could be produced in the entire ensonified range. Therefore transducer aiming by this method was accomplished by lowering the transducer to a depth of 1 m and then rotating the transducer up to detect surface noise at 20-25 m range. After surface noise was detected then one would have to not "rock" the boat to get a noise free range. This however turned out to be difficult for several reasons. First at the end of each transect, the pole-mounted transducer was brought to the surface in order to travel to the next transect. On the subsequent transect the pole and transducer were lowered and re-aimed. This was very time consuming and the transducer attitude would change as noted before. Second, if surface water conditions were very calm (approaching mirror like), the surface could not be detected, because sound waves were not reflected back to the transducer. Third, if the wind speed increased too much, the entire ensonified range was too noisy to estimate fish density.

We feel that it may be important to ensonify the 0-2 m layer of the water column, because of behavior often exhibited by juvenile sockeye salmon. For instance, fry could be feeding in the surface layer under full moon conditions, so we could underestimate fish density in that portion of the water column using our standard method. Even though our data do not indicate high numbers in the upper layer of the water column in either survey (1% and 2% of total targets in Skilak Lake surveys one and two, respectively, Appendix A2 & A3), other researchers have noted that juvenile sockeye salmon can occur in high concentrations near the surface in glacially turbid lakes. For example, it has been demonstrated, at certain times of the year, a high proportion of total copepod biomass is located near the surface in Tustumena Lake likely causing juvenile sockeye salmon to aggregate in a shallow surface layer. This is most likely due to the high glacial silt load in the water column (Shields 2005, personal communication).

In 2003, DeCino et al (2003) observed more fish targets in the upper three depth strata during the first survey compared to the second survey. This could be due to greater light penetration and possible foraging behavior in full moonlight conditions (Gliwicz 1986). During their second survey, no moonlight conditions existed and greater numbers of targets were observed. Their distribution was shifted more toward the middle of the water column compared to the first survey. This change in vertical distribution may have been due to differences in fish behavior or perhaps sampling error.

In 2004, 91% and 99% of all fish targets occurred in the upper 45 m of the water column during surveys 1 and 2, respectively (Appendix A2 & A3). In the first survey there were larger targets at depth (45 m and deeper) and a different sigma was used to integrate those "other" fish (Figure 5). These "other" deep targets are most likely other adult salmonids such as: rainbow trout (*O. mykiss*), Dolly Vardin (*Salvelinus malma*) lake trout (*S. namaycush*), and adult salmon.

Even though our two population estimates of juvenile sockeye salmon in Skilak Lake differed by approximately 11 million fish, they were not significantly different from each other, so the data were pooled. MacLennon and Simmonds (1992) suggested that data from replicate surveys can be pooled. Although, conducting multiple acoustic surveys is more costly, this approach allows us to better understand effects of survey conditions on the estimate and increase the precision of the estimate.

However the question remains why relatively large, non-significant, differences in population estimates existed in 2004. Historically, until the last two years, one hydroacoustic survey in fall was used to estimate juvenile sockeye salmon populations in Kenai and Skilak Lake. In 2004 the mean fish weight was the smallest since 1986. Fish targets appear to aggregate in certain areas of the lake, particularly near shore, and these smaller fish could recruit to the pelagic population later in the fall. In addition to behavioral movements of fish, sampling error is likely to cause no significant difference between population estimates. If more transects per area were surveyed then whole lake surveys would take greater than one night to complete, potentially biasing the results due to fish movement between surveys. This potential bias could be reduced by conducting the second survey as soon as possible after the first. We believe that at a minimum we conduct two hydroacoustic surveys on Skilak Lake as a standard procedure to examine the temporal variability of the population estimates. However, the use of a more intensive adaptive sampling protocol in detected areas of greater juvenile sockeye salmon abundance (i.e. near shore environments) may allow us to further reduce the variance of population estimates. Using an adaptive sampling strategy to sample fish concomitant with limnological studies would also provide robust data sets to help us better understand abiotic and biotic factors influencing the distribution, behavior and ecology of juvenile sockeye salmon.

ACKNOWLEDGEMENTS

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TABLES AND FIGURES

Table 1.–Target strength (dB) and mean backscattering coefficient (σ) for echo integration used to estimate the population size of juvenile sockeye salmon (O. nerka) in Skilak and Kenai lakes.

Lake	n	Target Strength (dB)	σ
Skilak 1*	42,196	-55.31(3.02)	4.06×10^{-6} (1.76×10^{-5})
Skilak 2**	28,027	-56.33(3.06)	3.28×10^{-6} (1.43×10^{-6})
Kenai	9,888	-54.66(3.69)	4.69×10^{-6} (5.16×10^{-6})

* survey 1 September 13, 2004

** survey 2 October 05, 2004

Table 2.–Estimated number of total fish in Skilak and Kenai Lakes, Alaska in September 2004.

			Estimated Number of Fish				
Lake	Area	Transect	Surface	Midwater	Total	Mean	Area Variance
Skilak	1-1*	1	5.12E+05	1.14E+07	1.20E+07		
		2	2.20E+04	6.87E+06	6.90E+06		
		3	3.20E+04	4.21E+06	4.24E+06	1.13E+07	6.44E+12
		4	3.25E+04	5.07E+06	5.10E+06		
		5	2.84E+05	6.23E+06	6.52E+06		
		6	6.63E+04	6.09E+06	6.16E+06		
	1-2*	1	5.63E+05	9.79E+06	1.03E+07		
		2	4.48E+05	1.98E+07	2.03E+07		
		3	4.36E+05	1.00E+07	1.05E+07		
		4	4.07E+05	9.21E+06	9.62E+06		
		5	2.53E+06	3.04E+07	3.29E+07		
	2-1*	1	3.50E+04	3.41E+06	3.45E+06		
		2	5.26E+04	3.38E+06	3.44E+06	5.69E+06	1.06E+12
		3	5.15E+04	7.27E+06	7.32E+06		
		4	3.96E+04	3.39E+06	3.43E+06		
	2-2*	1	1.06E+05	4.74E+06	4.84E+06		
		2	9.12E+04	3.28E+06	3.38E+06		
		3	1.38E+05	1.04E+07	1.06E+07		
		4	1.90E+05	8.91E+06	9.10E+06		
	3-1*	1	3.00E+05	3.51E+06	3.81E+06		
		2	5.12E+05	2.71E+06	3.22E+06	4.00E+06	1.84E+11
		3	1.51E+05	5.76E+06	5.91E+06		
		4	2.89E+05	5.14E+06	5.43E+06		
	3-2*	1	5.23E+04	2.75E+06	2.80E+06		
		2	1.46E+05	3.22E+06	3.36E+06		
		3	2.33E+05	4.47E+06	4.70E+06		
		4	2.40E+05	2.48E+06	2.72E+06		
	TOTAL					2.10E+07	7.69E+12

-continued-

Table 2.-Page 2 of 2.

Lake	Area	Transect	Surface	Midwater	Total	Mean	Area Variance
			Estimated Number of Fish				
Kenai	1	1	0.00E+00	9.32E+04	9.32E+04		
		2	2.16E+03	7.95E+04	8.16E+04	1.30E+05	1.01E+09
		3	0.00E+00	2.22E+05	2.22E+05		
		4	0.00E+00	1.25E+05	1.25E+05		
	2	1	0.00E+00	7.55E+05	7.55E+05		
		2	2.26E+04	5.97E+05	6.20E+05		
		3	5.87E+04	4.58E+05	5.16E+05	5.67E+05	9.14E+09
		4	1.68E+04	2.06E+05	2.23E+05		
		5	7.07E+04	6.49E+05	7.20E+05		
	3	1	6.61E+04	6.67E+05	7.33E+05		
		2	4.50E+04	8.65E+05	9.10E+05		
		3	0.00E+00	5.23E+05	5.23E+05	6.57E+05	8.06E+09
		4	2.14E+03	3.92E+05	3.94E+05		
		5	4.69E+04	6.77E+05	7.24E+05		
	4	1	2.40E+05	8.52E+05	1.09E+05		
		2	1.43E+05	1.21E+06	1.36E+05		
		3	5.96E+04	5.15E+05	5.75E+05	9.02E+05	2.01E+10
		4	2.92E+04	6.98E+05	7.27E+05		
		5	1.03E+05	6.55E+05	7.59E+05		
	5	1	2.64E+03	1.22E+05	1.25E+05		
		2	0.00E+00	1.57E+05	1.57E+05		
		3	1.37E+03	1.89E+05	1.90E+05	2.58E+05	3.30E+09
		4	6.11E+04	3.53E+05	4.15E+05		
		5	0.00E+00	4.56E+05	4.56E+05		
		6	0.00E+00	2.04E+05	2.04E+05		
TOTAL						2.51E+06	4.16E+10
TOTAL FOR BOTH LAKES						2.35E+07	7.73E+12

*11 = area 1 survey 1, 12= area 1 survey 2

Table 3.–Estimated fish population sizes and contributions of age-0 and age-1 sockeye salmon to the total fish population in Kenai and Skilak lakes, night surveys, September and October 2004.

Lake	Estimated Total Fish	Standard Error (SE)	Estimated Juvenile Sockeye	Standard Error (SE)	% Age-0	Total Age-0	Standard Error (SE)	% Age-1	Total Age-1	Standard Error (SE)
Skilak	20,999,000	2,772,562	20,976,858	1,282,629	97.5	20,394,647	2,699,486	2.5	582,211	203,483
Kenai	2,513,700	203,919	2,513,700	203,919	100	2,513,700	203,919	0	0	0
Total	23,512,700	2,780,051	13,184,989	1,294,062		22,908,347	2,707,177		582,211	203,483
Variance	7.7×10^{12}		7.7×10^{12}			7.3×10^{12}			4.1×10^{10}	

Table 4.–Age, weight and length of juvenile sockeye salmon captured in midwater trawl surveys, September 2004.

Lake	Age-0 n	Age-0 mean l (mm)	Age-0 mean wt (g)	Age-1 n	Age-1 mean l (mm)	Age-1 mean wt (g)
Skilak[1]	975	40.1 (1.16)	0.52 (0.06)	25	60.5 (1.68)	1.77 (0.08)
Skilak [2]	975	40.1 (1.16)	0.62 (0.06)	25	60.5 (1.68)	1.94 (0.09)
Kenai [2]	561	48.9 (0.27)	1.30 (0.01)	0	0	0

Note: Standard Errors (SE) are in parenthesis

[1] fresh weight

[2] formalin preserved weight

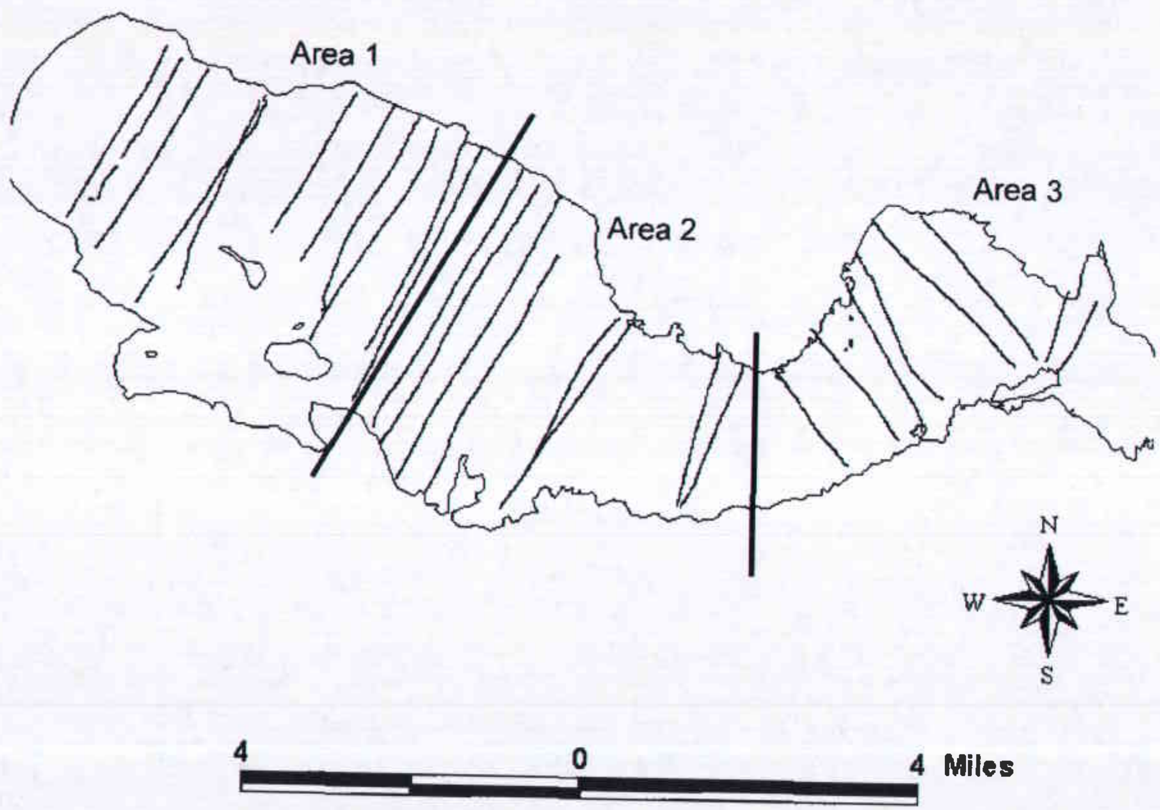

Figure 1. Transects for Skilak Lake hydroacoustic survey on September 13 and October 5, 2004. Olive is survey 1 and blue is suvery2.

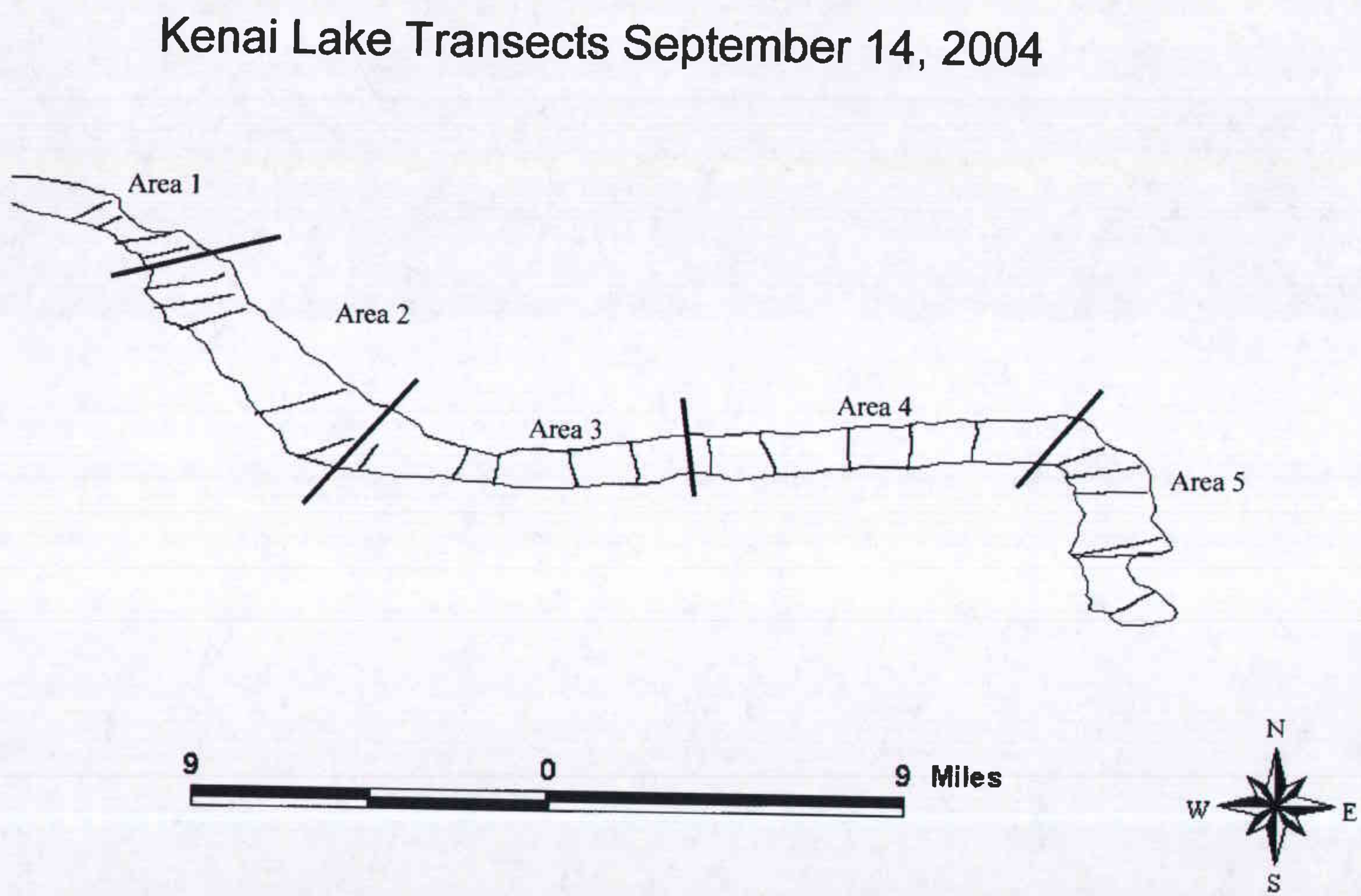

Figure 2. Transects run in Kenai Lake September 14, 2004.

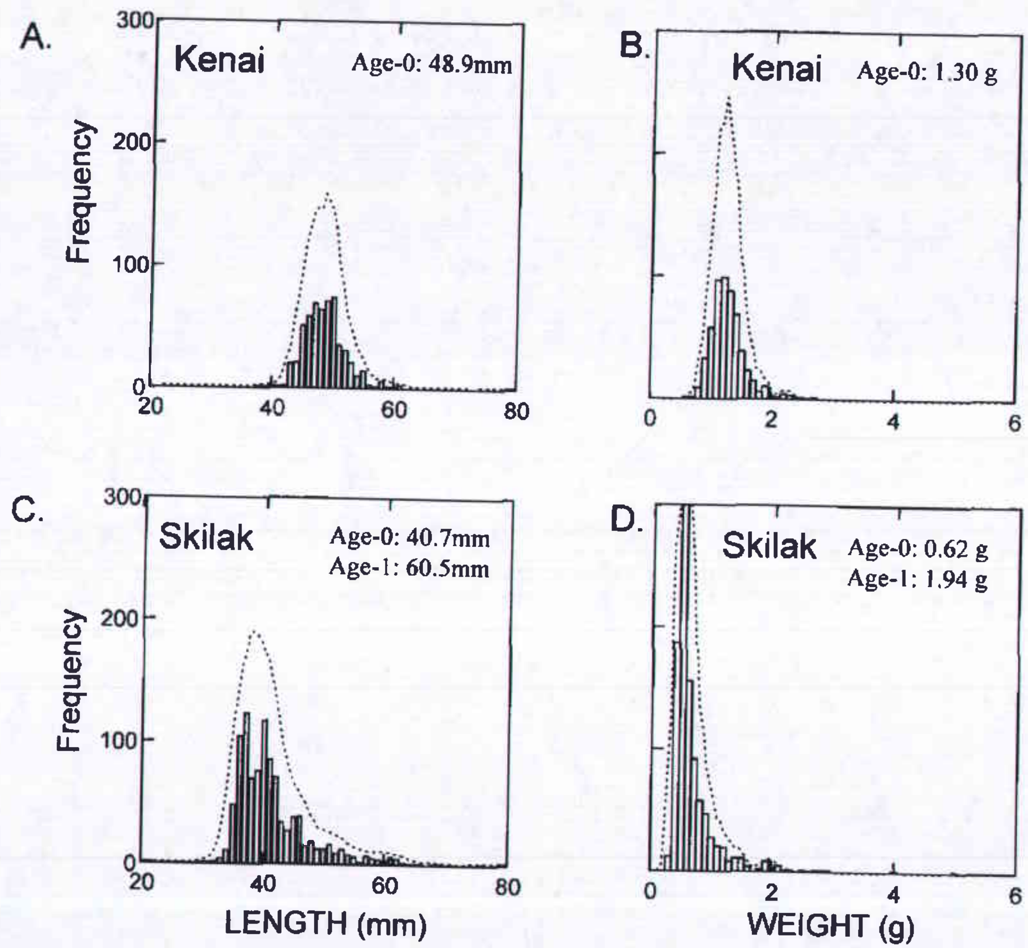

Figure 3. Size distribution of sockeye fry collected from (A-B) Kenai and (C-D) Skilak lakes in September 2004. Also shown are the mean sizes for the age-0 and age-1 cohorts. Dashed line is the non-parametric (kernal) density function.

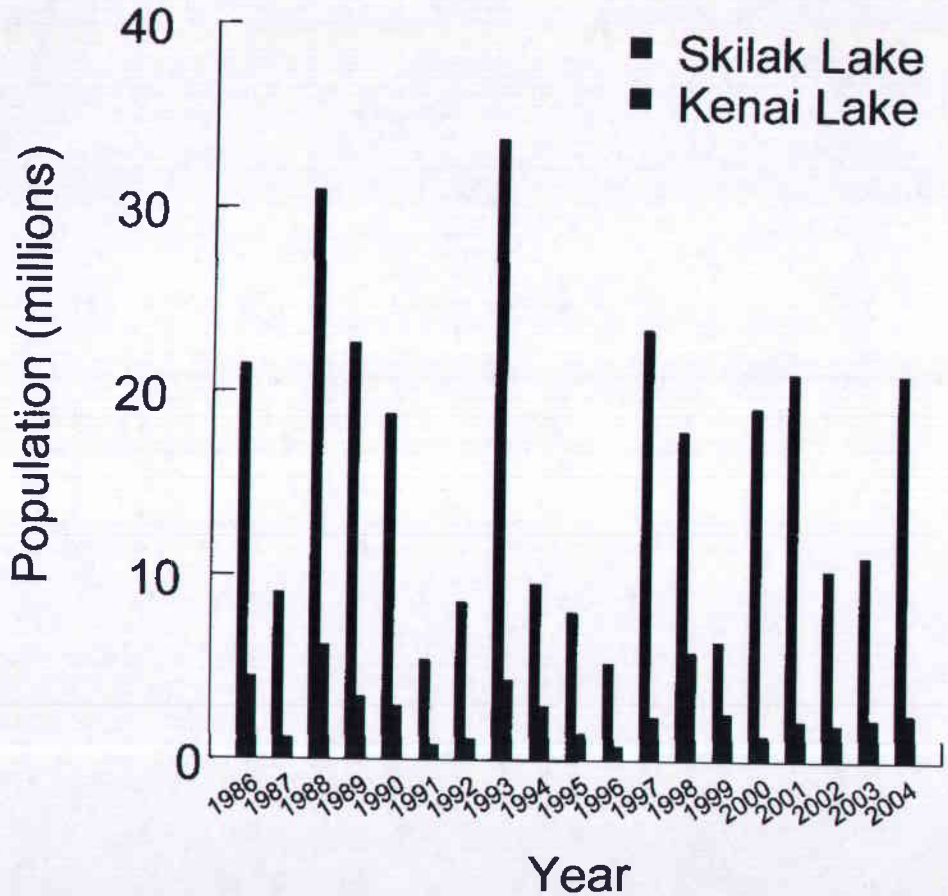

Figure 4. Historic population estimates for Kenai and Skilak Lakes.

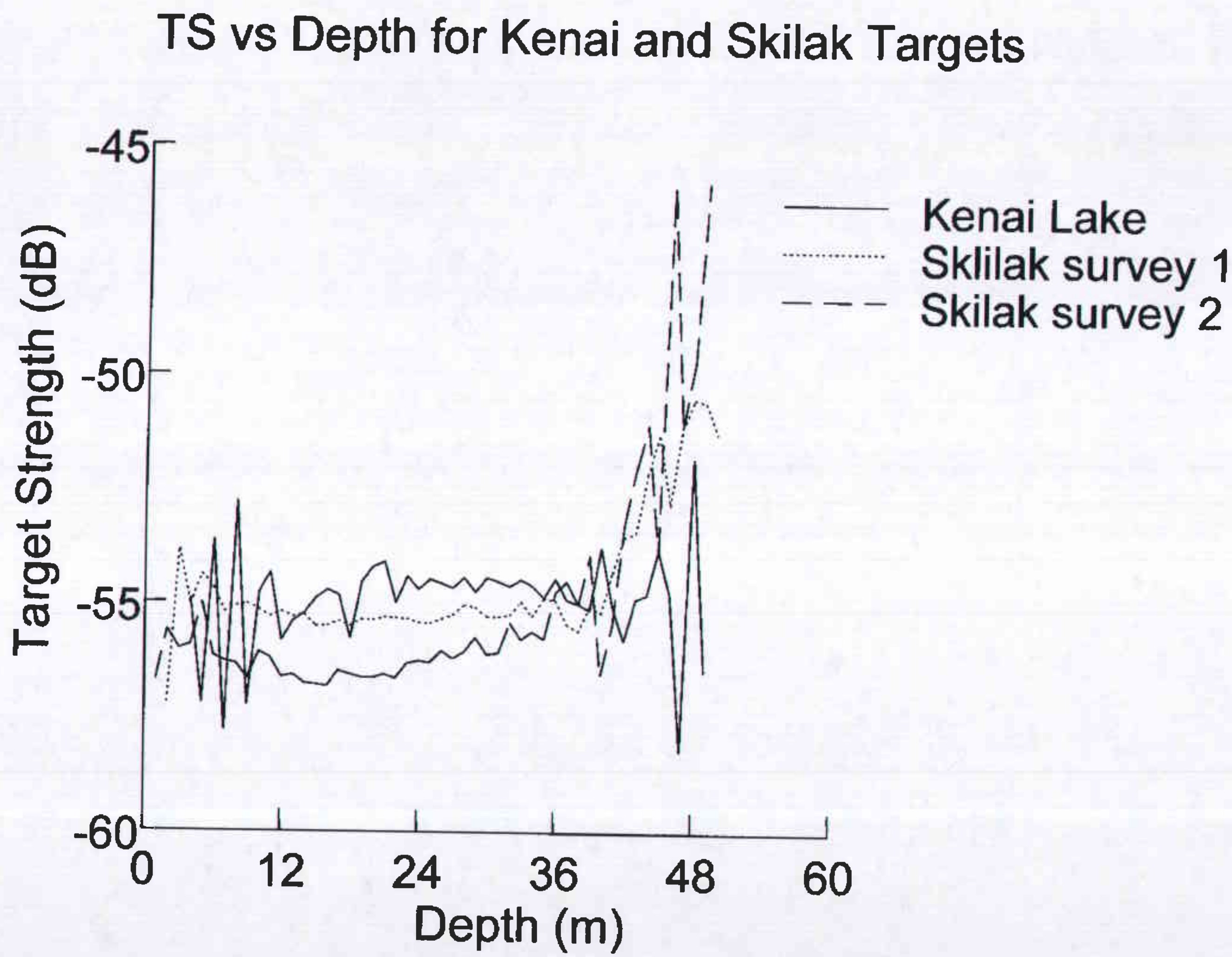

Figure 5. Target Strength vs Depth for Kenai and Skilak Lake hydroacoutic surveys in September 2004. Skilak Lake had two surveys, Septermber 13 and October 5, 2004.

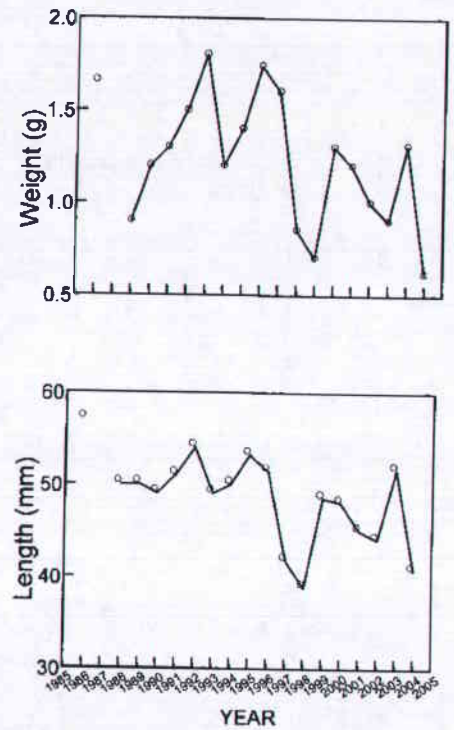

Figure 6. Historical mean lengths and weights for Age-0 Skilak Lake juvenile sockeye salmon.

APPENDIX A

Appendix A 1.–Acoustic data collection parameters for Skilak Lake surveys.

	Survey 1 Down	Survey 2 Down	Survey 2 Side
Frequency (kHz)	208	201	201
Beam size (degree)	6.6 Circular	8.4 X 3.8 Elliptical	6.4 Circular
Mode	Split	Split	Split
Pulse duration (ms)	0.4	0.2	0.2
Sample range (m)	Jan-65	Jan-75	Jan-35
Water temperature (C)	10	7	7
Transducer depth (m)	1	1	1
Threshold (dB)	-65	-65	-65
Ping rate (pps)	2	4	4

Appendix A 2.–Mean backscattering coefficient (s) for the September 13, 2004 hydroacoustic survey in Skilak Lake.

Skilak Strata	Number	s	Mean s Depth s
0 –5 m	4	2.25E-06	0.44
5 – 10 m	526	4.25E-06	0.83
10 – 15 m	2164	4.62E-06	0.9
15 – 20 m	6702	3.96E-06	0.77
20 – 25 m	12663	3.91E-06	0.76
25 – 30 m	11765	3.91E-06	0.76
30 – 35 m	5624	4.24E-06	0.83
35 – 40 m	2019	4.48E-06	0.87
40 – 45 m	729	5.97E-06	1.16
45 – 50 m	576	1.38E-05	2.69
50 – 55 m	740	1.86E-05	3.63
55 – 60 m	1005	1.83E-05	3.58
60 – 65 m	1031	1.72E-05	3.35
65 – 70 m	732	1.05E-05	2.05
Grand Total	46301	5.13E-06	1

Appendix A 3.–Mean backscattering coefficient (s) for the October 5, 2004 hydroacoustic survey in Skilak Lake

Skilak Strata	Number	s	Mean s / Depth s
0 –5 m	14	4.64E-05	1.41
5 – 10 m	622	3.24E-06	0.99
10 – 15 m	2583	3.05E-06	0.93
15 – 20 m	5041	2.80E-06	0.85
20 – 25 m	8377	2.95E-06	0.9
25 – 30 m	7055	3.10E-06	0.94
30 – 35 m	3208	3.62E-06	1.1
35 – 40 m	844	4.69E-06	1.43
40 – 45 m	149	9.13E-06	2.78
45 – 50 m	39	1.75E-05	5.34
50 – 55 m	27	3.05E-05	9.29
55 – 60 m	42	4.22E-05	12.86
60 – 65 m	23	4.72E-05	14.36
65 – 70 m	3	1.96E-05	5.97
Grand Total	23846	3.28E-06	1

Appendix A 4.–Mean backscattering coefficient (s) for the September 2004 hydroacoustic survey in Kenai Lake.

Kenai Strata	Number	s	Mean s Depth s
0 – 5 m	5	2.12E-06	0.45
5 – 10 m	18	4.04E-06	0.86
10 – 15 m	70	5.16E-05	1.1
15 – 20 m	272	5.07E-06	1.08
20 – 25 m	916	4.94E-06	1.05
25 – 30 m	2165	4.75E-06	1.01
30 – 35 m	3549	4.66E-06	0.99
35 – 40 m	2287	4.52E-05	0.96
40 – 45 m	383	4.53E-05	0.97
45 – 50 m	80	3.88E-06	0.83
50 – 55 m	9	5.30E-06	1.13
55 – 60 m	10	8.61E-06	1.83
60 – 65 m	36	1.55E-05	3.3
65 – 70 m	88	1.60E-06	0.34
Grand Total	9888	4.69E-06	1

Windows XP Printer Test Page

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The information below describes your printer driver and port settings.

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Printer name:   HP Color LaserJet 1600
Printer model:  HP Color LaserJet 1600
Color support:  Yes
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Share name:
Location:
Comment:
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Data file:      SDhp1600.SDD
Config file:    ZSDNT5UI.DLL
Help file:      SDhp1600.chm
Driver version: 6.02
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Default datatype: RAW
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Additional files used by this driver:

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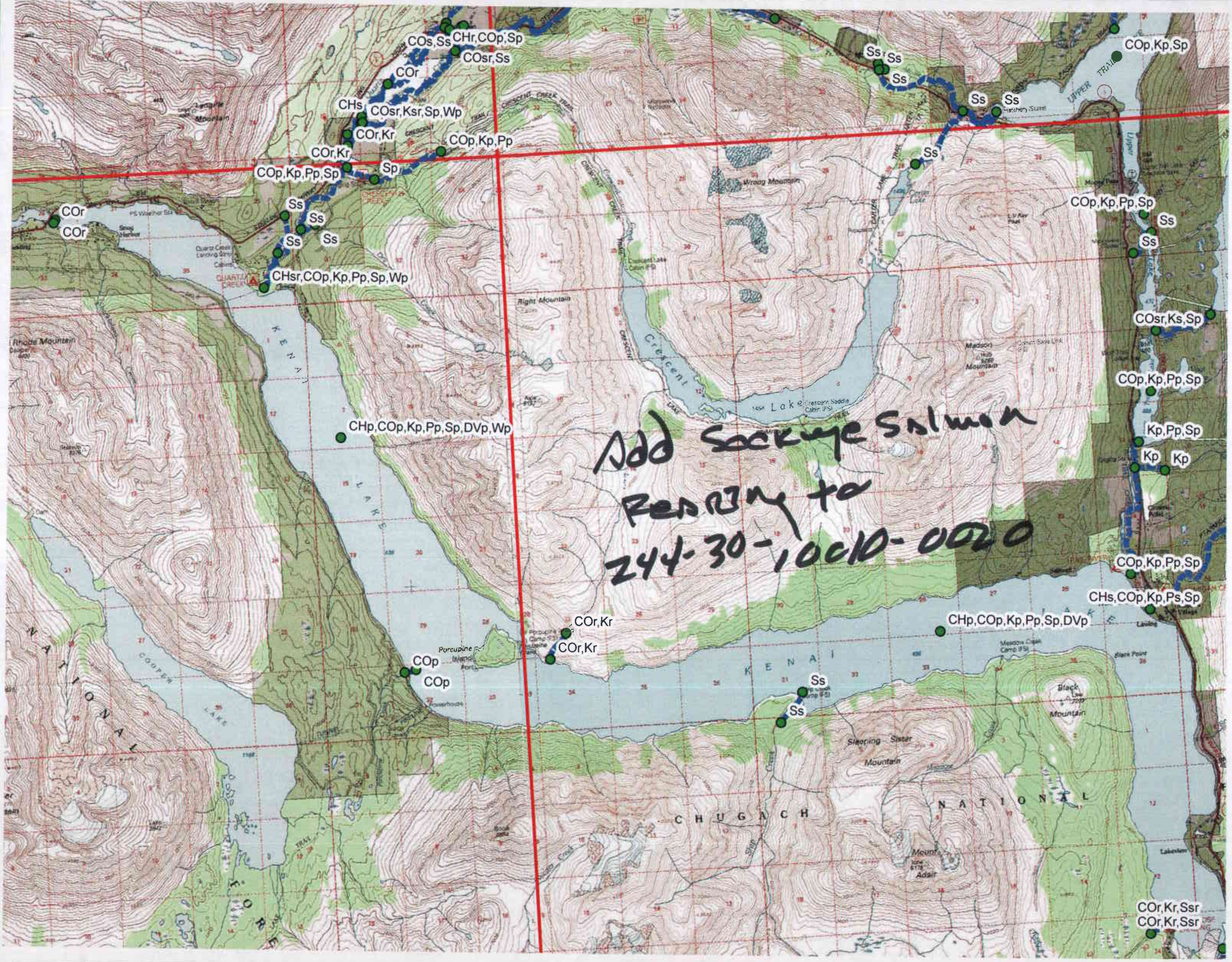
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