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Hetta Lake Sockeye Salmon (*Oncorhynchus nerka*) Stock Assessment Project 2003 Annual Report and 2001–2003 Final Report

by

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June 2005

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

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
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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The Federal Subsistence Board, managed by US Fish and Wildlife Service–Office of Subsistence Management, approved the Hetta Lake Sockeye Salmon Stock Assessment Project (Study Number FIS01-130). The project was funded by the US Forest Service, and is a cooperative project between the US Forest Service (USFS), the Alaska Department of Fish and Game (ADF&G), and the Hydaburg Cooperative Association (HCA). This annual report partially fulfills contract obligations for Sikes Act Contract (43-0109-0-0182).

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

Direct interviews were used to census subsistence sockeye harvest around the outlet of Hetta Lake, and mark-recapture studies and visual surveys on spawning grounds were used to estimate sockeye escapement into Hetta Lake. To better understand the dynamics of this sockeye system, we also estimated sockeye fry and zooplankton populations in Hetta Lake. Total subsistence harvest in 2003 was 5,770 sockeye salmon, a six-fold increase from 950 sockeye salmon in 2002 and a 30% increase from 4,400 fish in 2001. We estimated 780 sockeye spawners in Hetta Creek in 2003, an increase from 330 spawners in 2002, but fewer than 2,400 spawners in 2001. In all three years, the stream spawning population in Hetta Creek represented 40–60% of the spawners counted in the lake and its tributaries. In 2003, we also estimated 510 sockeye salmon in a designated study area around the mouth of Old Hatchery Creek, representing about 22% of the later beach-spawning portion of the escapement. Numbers of beach spawners had not peaked by the end of October 2003. The estimated sockeye fry population was 324,000 in 2003, substantially less than the estimated 1.0 million in 2002 and 2.9 million 2001. In contrast, the population of threespine sticklebacks in Hetta Lake increased from 170,000 to 250,00 to 419,000 in 2001–2003. Hetta Lake zooplankton species assemblage is very simple and dominated by the small cladoceran *Bosmina*; the larger *Daphnia*, preferred by sockeye fry, contributed only 1% to total seasonal mean biomass in 2003, 4% in 2002, and a negligible fraction in 2001. We recommend installing a weir in the outlet stream of Hetta Lake in 2005 because of the difficulties in estimating the adult spawning population with mark-recapture methods and the late timing of the beach spawners.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Hetta Lake, Hydaburg, Prince of Wales Island, escapement, mark-recapture, fry, hydroacoustic, harvest census, zooplankton

INTRODUCTION

Sockeye lakes draining into Hetta Inlet (Figure 1) were some of the most productive in Southeast Alaska at the beginning of the commercial fishing period in the late 1800s, and the history of this area has revolved, in large part, around these sockeye runs. Tlingit people, whose population center in the area was at Klawock, had seasonal villages around Hetta Inlet from which they harvested sockeye and other salmon returning to nearby streams (Betts et al. 1997). Haida people arrived in the Cordova Bay area from the Queen Charlotte Islands in the late 17th century, originally settling along the outside margin of the islands where they had year-round access to productive halibut fishing grounds and other offshore resources. As the Haidas learned of the abundant salmon runs, and other land-based resources in the area, they gradually moved farther up the bays and inlets and eventually displaced the original Tlingit inhabitants (Langdon 1977; Betts et al. 1997). In 1911, the Haida people from the villages of Howkan, Klinkwan, and Sukkwan consolidated at Hydaburg, in order to modernize and provide better schooling (Betts et al. 1997). Hydaburg developed as a commercial fishing community (Betts et al. 1997), and the Hydaburg Cooperative Association operated a cannery there for a number of years (Bower 1940–1948b; Thompson 1950–1955).

Sockeye production in Hetta Inlet was dramatically reduced in the early 1900s by intense commercial fishing activity, and an ineffective hatchery on Hetta Lake. The earliest canneries, at Klawock and Hunter Bay, reported harvesting 140,000 to 250,000 sockeye salmon in Hetta Inlet in the 1890s (Moser 1899). Although it is unclear how many of these fish were bound for Hetta Lake, Hetta Lake sockeye salmon stocks were already showing signs of depletion (Moser 1899; Roppel 1982). In an attempt to bolster production of sockeye salmon, a private fish packing company built a hatchery on the Hetta Lake outlet in 1898–1899, and operated it through 1903, using barricades in the outlet stream to capture migrating salmon for broodstock (Roppel 1982). The original hatchery closed in 1903, but another company rebuilt and re-opened the Hetta Lake hatchery in 1908, collecting broodstock in the widely-scattered beach spawning locations around the lake. Between 1899 and 1918, about 221,000 female sockeye salmon and an unknown number of males were taken to produce 60 million fry (Ropel 1982)[1]. During the later period of hatchery operation, fisheries managers estimated that fewer than 10,000 sockeye salmon were escaping annually into Hetta Lake (Roppel 1982). Commercial sockeye catches in Hetta Inlet during this time period ranged from a high of 66,000 in 1914 to a low of 11,000 in 1916 (Rich and Ball 1933; Roppel 1982). In 1924 the Bureau of Fisheries designated Hetta Cove as a salmon breeding reserve and closed the entire Hetta Inlet north of Eek point to commercial fishing (Roppel 1982).

Unknown numbers of Hetta Lake sockeye salmon contribute to modern, mixed-stock commercial purse seine fisheries in Hetta Inlet (sub-district 103-25) and Cordova Bay (sub-districts 103-11 and –21; Figure 1). Commercial harvest of sockeye salmon in Cordova Bay, Hetta Inlet, and neighboring Nutkwa Inlet (sub-district 103-23) has fluctuated during the past 30 years (ADF&G Div. of Commercial Fisheries database 2004). In 1965, an exceptionally high annual harvest of 23,000 sockeye salmon was taken in Hetta Inlet (Appendix B). Commercial fisheries in Hetta Inlet have traditionally opened in mid-August (S. Heinl ADF&G, personal communication 2004). At present, we don't know the extent to which Hetta Lake sockeye salmon contribute to the overall commercial harvest in fishing districts along their migratory route.

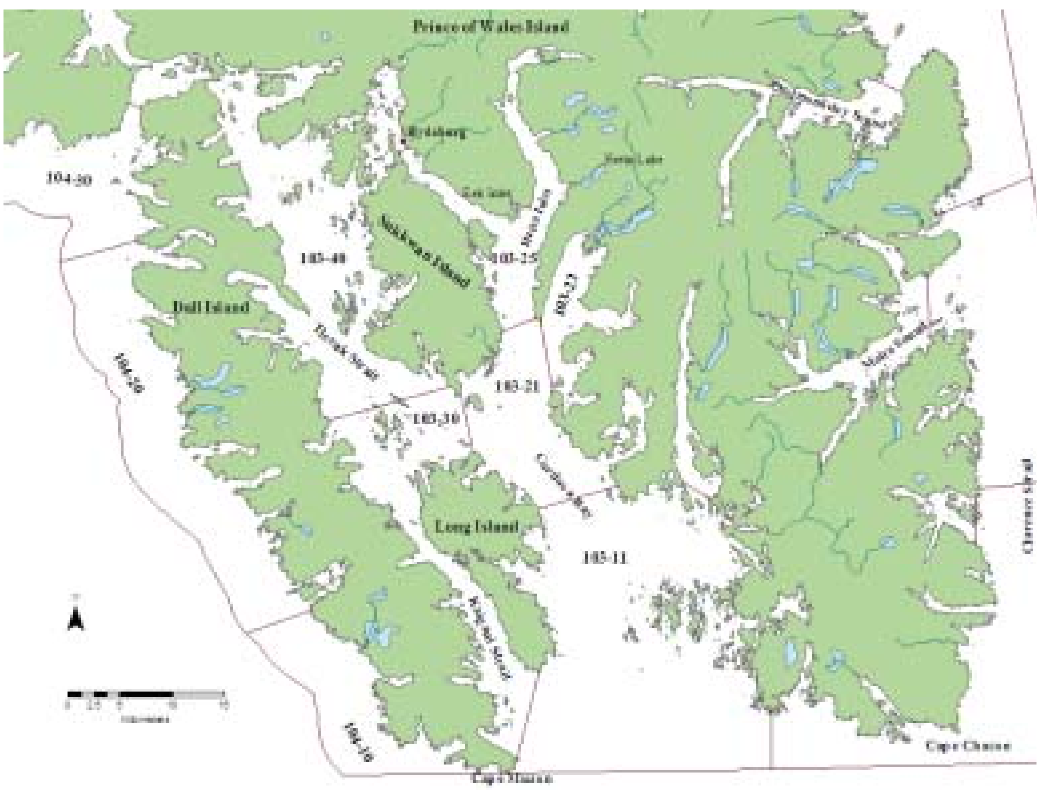

Figure 1.–Location of Hetta Lake on southwest Prince of Wales Island, in relation to commercial fishing sub-districts and the village of Hydaburg.

[1] The number of female sockeye salmon taken for broodstock is based on hatchery records of egg counts and fecundity estimate of 3,500 eggs per female.

Traditional harvesting of sockeye and other salmon continues to play a vital role in the economic and cultural life of Hydaburg. Many residents depend on subsistence harvests of sockeye salmon from local runs, including Hetta Lake, for part of their livelihood. In a recent survey, 100% of Hydaburg households reported using subsistence fish resources, with 82% specifically reporting use of sockeye salmon (Betts et al. 1997). Besides the area around the outlet of Hetta Lake, other areas used for subsistence fishing include Eek, Kasook, and Hunter Bay. The intensity of the subsistence harvest in any one system depends on the strength of the returns in any given year (Tony Christensen, Hydaburg Cooperative Association Hetta Lake Project Manager, personal communication 2004). When fuel costs are a factor, Hydaburg residents favor Eek and Hetta Inlets, 12 and 17 km from the village, over Kasook and Hunter Bay, 27 and 50 km distant.

Sockeye harvest reported on ADF&G subsistence permits can be underreported by as much as 75% in Hydaburg (Lewis and Cartwright 2004), but the reported information still may reflect trends in harvest and effort. The reported catch per permit varied considerably between years but was most often between 30–40 fish per permit over the last 14 years (Figure 1). This seemingly stable catch per permit may, however, just be an artifact of reporting the legal limit of fish rather than any meaningful pattern in harvest. Direct, on-site interviews were used in the Hetta Lake Sockeye Salmon Stock Assessment Project to obtain a more accurate estimate of harvest. Project technicians from Hydaburg collected the information and reported only the total number of fish harvested per fishing party, so participants were confident they would not be penalized if they reported harvesting more than the legal limit.

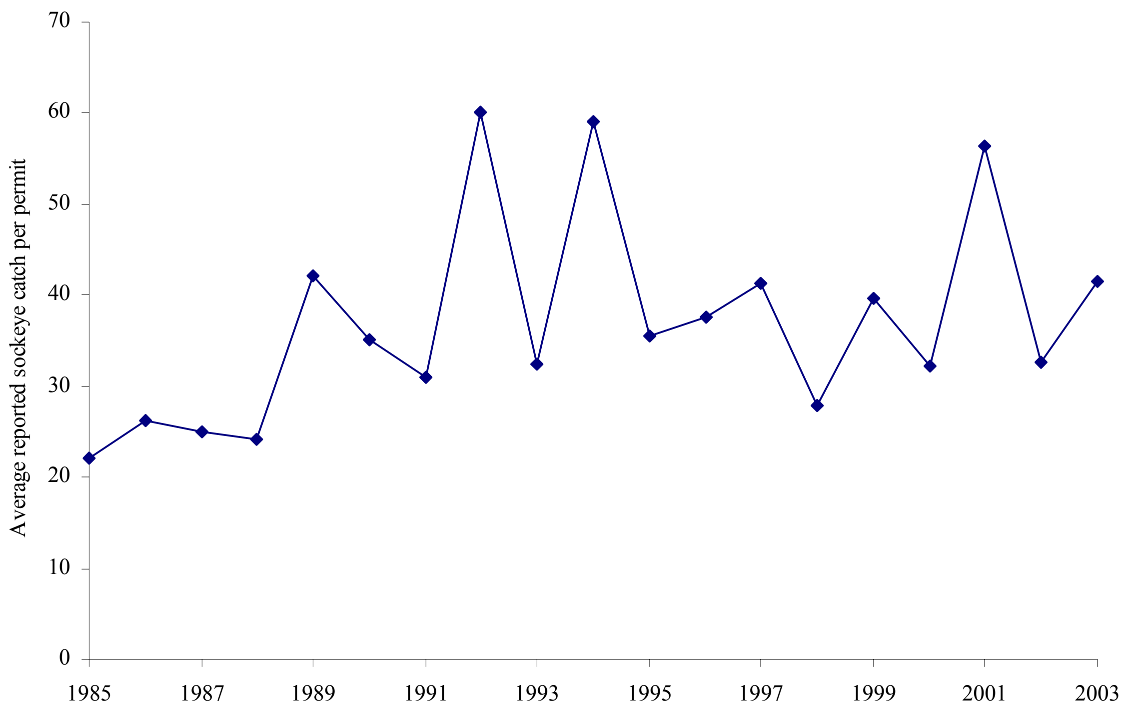

Figure 2.–Average reported sockeye salmon harvest per permit in Hetta Inlet, area around the Hetta Lake outlet. Harvest totals were submitted by holders of ADF&G subsistence permits in 1985–2003 (ADF&G Div. of Commercial Fisheries database 2004; see Appendix A for details).

ADF&G operated a fish-counting weir at Hetta Lake outlet from 1968 to 1971, and in 1982. Sockeye counts were much higher in the four earlier years, 1968–1971, than in 1982 (Table 1). These weir counts should be considered minimal escapements because they were not backed up with a mark-recapture or other independent estimate and we cannot rule out the possibility of fish passing the weir uncounted. Nevertheless, the three-fold drop in sockeye salmon escapement over one decade could signal a continued decline in sockeye production in the Hetta system.

Table 1.–Numbers of adult salmon, by species, counted through the Hetta Lake weir 1968–71 and 1982.

Year	Sockeye	Pink	Coho	Chum
1968	17,599	5,104	689	249
1969	16,202	12,432	2,133	191
1970	20,542	260	171	
1971	15,779	197	4	1
-	-	-	-	-
1982	5,387			

A cooperative project between ADF&G, Hydaburg Cooperative Association (HCA), and the U.S. Forest Service began in 2001. In the Hetta Lake Sockeye Stock Assessment Project, we focused on obtaining reliable estimates of escapement and subsistence harvest. We also estimated fry populations, juvenile and adult age, sex, and length compositions, and zooplankton populations, and we measured light, temperature, and dissolved oxygen levels by depth. By comparing habitat information and fry and adult populations, we hoped to identify bottlenecks in production. In this report, we summarize project results for 2003, synthesize the results from 2001 to 2003, and discuss implications for management and future research.

OBJECTIVES

1. Census subsistence sockeye salmon harvest from Hetta Cove.
2. Estimate escapement of sockeye salmon into Hetta Lake using mark-recapture methods, with estimated coefficient of variation less than 15%.
3. Describe age, length, and sex composition of sockeye salmon in the Hetta Lake escapement.
4. Estimate sockeye fry population in Hetta Lake using hydroacoustic and mid-water trawl methods, with estimated coefficient of variation less than 10%.
5. Collect baseline data on productivity in Hetta Lake using established ADF&G limnological sampling procedures.

STUDY SITE

Hetta Lake (ADF&G stream #103-25-047) is located on the southwestern side of Prince of Wales Island, approximately 16.9 kilometers east of Hydaburg (Figure 1). The Hetta Lake watershed drains 2,359 hectares, with tributary headwaters originating in steep mountainous terrain above 610 m. Fine-grained metamorphosed sedimentary and volcanic bedrock, steep topography, and prior logging within the watershed, create high potential for landslides, and high sediment loads throughout the drainage. Soils in lower elevations of the watershed are underlain with till, supporting forested and non-forested wetlands, and soils in the higher elevations are poorly drained, supporting alpine wetlands and slower growing forests (Nowacki et al 2001). One main inlet stream, Hetta Creek, and two minor inlet streams, Hatchery and Camp Creeks, enter Hetta Lake. This lake has a surface area of 207 hectares, a volume of 99.4 million cubic meters, a mean depth of 48 m, and a maximum depth of 92 m (Figure 3). The outlet stream flows 600 m to Hetta Inlet. Native fish species include sockeye (*Oncorhynchus nerka*), coho (*O. kisutch*), pink (*O. gorbusha*), and chum (*O. keta*), salmon, cutthroat (*O. clarkii clarkii*) and steelhead (*O. mykiss*) trout, Dolly Varden char (*Salvelinus malma*), threespine stickleback (*Gasterosteus aculeatus*), and cottids (*Cottus* sp.).

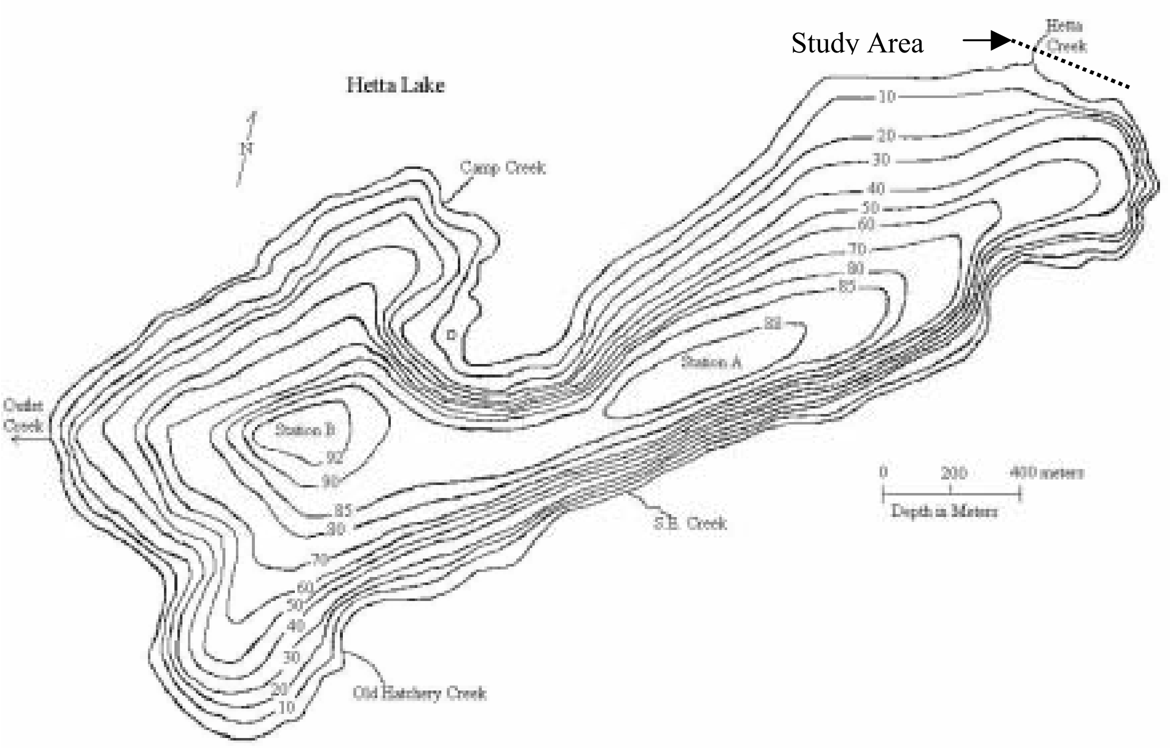

Figure 3.–Bathymetric map of Hetta Lake, showing limnology sampling stations A and B, inlet and outlet streams, and study area at Hetta Creek. The second study area was along the beach at Old Hatchery Creek.

METHODS

SOCKEYE FRY POPULATION ASSESSMENT

Hydroacoustic and mid-water trawl sampling methods were used to estimate abundance and age-size distributions of sockeye salmon fry and other small pelagic fish in Hetta Lake in 2003. The 14 transects selected in 2002 as the permanent transects for this lake were used in the 2003 hydroacoustic survey (two randomly chosen transects in each of seven sections of the lake).

Hydroacoustic survey

During acquisition of acoustic targets, each transect was surveyed from shore to shore, beginning and ending at the 5 m depth. Sampling was conducted during the darkest part of the night. A constant boat speed of about 2.0 $m \cdot sec^{-1}$ was attempted for all transects. Acoustic equipment used on the survey was the Biosonics[1] DT-4000™ scientific echosounder (420 kHz, 6° single beam transducer) and Biosonics Visual Acquisition © version 4.0.2 software was used to receive and record the data. Ping rate was set at 5 $pings \cdot sec^{-1}$ and pulse width at 0.4 ms. Only target strengths ranging from –40 dB to –68 dB were recorded because this range represented fish within the size range of juvenile sockeye salmon and other small pelagic fish.

Trawl Sampling

Midwater trawl sampling was conducted in conjunction with hydroacoustic surveys to determine species composition of pelagic fish and age distribution of sockeye fry. A 2 m x 2 m elongated beam-trawl net with a cod-end was used for trawl sampling. Trawl sampling was conducted in the area of the lake with highest concentration of fish, identified during the hydroacoustic survey. Within this area, replicate tows were conducted at two depths. The second tow, at a given depth, was started at the termination point of the first tow. Direction of the second tow, for each depth, was selected so a different area from the first tow would be sampled. Trawl duration was 7–10 minutes, depending on target density and lake depth. If warranted, a second complete set of tows was conducted in a morphologically distinct section of the lake or in a second area of high fish density.

All adult fish caught in the midwater trawl were identified, counted, and released. All small fish from the trawl net were euthanized with MS 222 and preserved in 90% alcohol. Samples from each tow were preserved in separate bottles, each labeled with date, lake name, tow number, tow depth, time of tow, and initials of collectors.

In the laboratory, fish were re-hydrated by soaking in water for 60 minutes prior to measurement. All fish were identified to species, and snout-fork length (to the nearest millimeter) and weight (to the nearest 0.1 gram) were measured on each fish. All sockeye salmon fry under 50 mm were assumed to be age-0. Scales were collected from sockeye fry over 50 mm and mounted onto a microscope slide for age determination. Sockeye fry scales were examined through a Carton microscope with a video monitor and aged using methods outlined in Mosher (1968). Two trained technicians independently aged each sample. Results of each independent scale ageing were compared. In instances of discrepancy between the two age determinations, a third independent examination was conducted.

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[1] Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

The proportion of each species caught in the trawls was used to allocate hydroacoustic target estimates by species; the estimate of sockeye fry was further allocated according to proportion of sockeye fry in each age class. The process of capturing juvenile fish with a trawl was modeled with a hieratical Bayesian model, assuming a separate random rate for each category of sonar target with each trawl pass. Rates of sockeye acquisition for each specific trawl pass were assumed to follow a Beta sampling distribution with a common set of parameters for the whole lake.

Data Analysis

The sonar record was analyzed with Biosonics Visual Analyzer © version 4.0.2 software. Echo integration was used to generate an estimate of target density (targets · m^{-2}) for each sample transect (MacLennand and Simmonds 1992). Recall that the lake was divided into sample sections, with two transects per section. Mean target density for each section was estimated using the two replicate target densities. Sample variance of this estimate was calculated with one-degree of freedom for two replicate observations. Mean target density for the whole lake was estimated as the average of target density estimates for each section, weighted by surface area of each section. Size of target population for each sample section was estimated as the product of mean target density and surface area for each section. Total target population for the lake was estimated as the sum of target population estimates for each section. Because each section was sampled independently from other sections, estimated sampling variance for the whole-lake target population estimate was simply the sum of variances for each section. Sampling error was measured and reported as coefficient of variation (CV; Sokal and Rohlf 1987).

We know from previous experience with many sockeye-producing lakes that number of sockeye salmon in a trawl sample is often much more variable than the usual binomial sampling model predicts. Thus in practice, the usual binomial confidence intervals can be very biased, and far too short.

We developed the following Bayesian procedure to measures uncertainty in the estimated proportion of sockeye salmon. Let T denote the total targets in the lake, and let $\hat{T}$ denote the usual sampling-based estimate of T, derived from the echo integration analysis of the sonar record. Conditioned on total number of fish caught in the ith trawl sample, we let number of sockeye salmon in each trawl follow a binomial sampling law. We denote trawl sample size as ni and we denote number of sockeye salmon in this sample as yi. We let parameter pi denote the unknown underlying proportion of sockeye salmon in the ith trawl sample, and we assume pi is a key parameter in the sampling distribution of yi. We assume each trawl sample has its own sampling distribution, possibly different from any other in the lake. Next, we suppose that pi is itself drawn from a beta probability distribution with mean $p = \dfrac{\alpha}{\alpha + \beta}$.

In other words, let y_i be distributed as a binominal random variable with parameters p_i and n_i and let p_i follow a beta probability distribution with parameters α and β. Again, α and β are the same for each transect in the lake at the occasion of trawl sampling. The hyperparameters α and β can be estimated through all of the samples from each transect, by Bayesian conditioning on all of the outcomes.

We chose a uniform distribution between 0 and 10 for both α and β parameters after experimenting with this distribution and truncated normal distributions. This prior distribution limits influence of prior distributions on posterior distributions, and ensures data have adequate influence once sample size is large. For example, for sample sizes less than 10, posterior distribution will be almost entirely controlled by prior distribution. However, for sample sizes approaching 100 prior distribution will have little influence on mean posterior distribution for each individual p_i, although this prior can lead to some unreasonable estimates of p. We note that if posterior probability is allowed to build up on larger and larger values of α and β, posterior means of each p_i will become more alike, and posterior variance of p overall will decline unrealistically. Therefore, limiting maximum values of both α and β to 10 seems to provide a compromise between allowing posterior means of individual p_i's to be either alike or unalike, and still allow data (likelihood) to dominate posterior distribution.

Bayesian posterior distribution of unknown parameter p was generated numerically using the Markov Chain Monte Carlo method. To compare and combine an estimate of T in the same context as Bayesian posterior mean of the distribution of p, we assumed a posterior distribution of T would be bounded by t-distribution with 5 degrees of freedom and normal distribution, both with mean and variance approximated by sample mean and variance of the sampling-based estimate. We then generated at least 5,000 random draws from the two approximate distributions. We previously generated 5,000 observations of posterior distribution of p. Denoting each random draw with subscript j, we calculated a random draw from posterior distribution of S as $S_j = p_j T_j$. From there we noted mean of the posterior distribution of S using the t-distribution, and posterior mean of the distribution of S using the normal distribution. We generated 95% credible intervals—the Bayesian counterpart to a confidence interval—using 2.5 and 97.5 percentiles of posterior distributions of S. All analyses were performed with the Winbugs software.

Adult Sockeye Escapement Estimates

Two distinct spawning populations were observed in Hetta Lake, one in the main inlet stream and another in beach areas around the lake. We assumed there was no exchange between these two spawning populations, and conducted separate mark-recapture studies in the inlet stream and beach spawning areas, accompanied by visual surveys of the lakeshore and inlet streams. Hetta Creek (the main inlet stream; N55°11.261', W132°31.875') and the area around its mouth were defined as the stream study area, and a nearshore section around Old Hatchery Creek (N55°09.981', W132°33.280') was designated as the beach study area.

A stratified two-sample mark-recapture study design was used for the inlet stream study area. Darroch and pooled Petersen estimates were calculated using the program SPAS (Arnason et al. 1995). ADF&G biologists have modified the methods described in Schwarz et al. (1993) for estimating salmon escapements in beach spawning systems (Cook 1998). Specifically, we used a two-sample Petersen estimate for each trip and a multiple-trip estimate using a modified Jolly-Seber method to estimate the number of spawners returning across all trips (Seber 1982; Schwarz et al. 1993; Cook 1998; J. Blick former ADF&G, personal communication 1998).

Visual Survey Counts

Prior to each mark-recapture event, crew members recorded visual counts of sockeye spawners in defined areas around the entire lakeshore and in any inlet stream where spawners were present. Separate counts were made within the inlet stream study area and the beach study area. Using polarized sunglasses, two or three crewmembers counted fish from a boat around the perimeter of the lake and while walking the main inlet stream. Rather than recording their counts separately, they discussed their counts and reported an average or consensus count for each area.

The counts gave a rough indication of proportion of sockeye spawners within the defined study area at each sampling event. The crew surveyed Hetta Creek from its mouth to the barrier falls (about 1 km). Other inlet streams, including Hatchery Creek, were also inspected for spawning fish. However, since no fish were seen in these streams, extent of the surveys was limited to the first 1 km upstream from the mouth of Hetta Creek.

Stream Spawning Population

Hetta Creek is the main tributary to Hetta Lake and the only one in which sockeye spawners were observed. The stream study area was defined as Hetta Creek from the mouth (N55° 11.261', W132° 31.875') to a barrier falls located about 1 km upstream (N55°11.475', W 132° 32.356'), and approximately 500 m around the mouth of the stream, (N 55°11.182', W132° 32.211' to N 55°11.233', W132°31.803').

A stratified, two-sample mark-recapture procedure was used to estimate escapement into Hetta Creek (Arnason et al. 1995). The marking phase was conducted at the mouth of Hetta Creek, using a beach seine 20 m long and 4 m deep to capture the fish. Only sockeye salmon without marks from previous sampling events were marked; these unmarked fish were given an opercular punch or pattern of punches indicating the event (trip) number, and released with a minimum of stress. Marking was stratified by time, using a distinct punch shape in the left operculum to distinguish among strata: stratum 1–round, stratum 2–triangle, stratum 3–square, stratum 4–double round. The mark-recovery phase was conducted mostly within Hetta Creek using dip nets, although some sampling was also conducted with the beach seine at the stream mouth. Live and dead fish were counted and examined for marks and given a second mark (right opercular punch) to prevent duplicate sampling at a later time. Numbers of marked fish from each stratum and number of unmarked fish were recorded. A secondary mark was given all live fish and carcasses in the second samples to prevent re-counting. Sample sizes were as large as practical while avoiding multiple same-day recaptures. Marking was conducted during four sampling trips about two weeks apart, beginning when spawners first appeared at the mouth of Hetta Creek and ending before the last recapture sampling trip. Recapture sampling started on the second trip, after spawners began moving upstream, and continued for four trips about two weeks apart. The last trip was timed well after new spawners had stopped entering the stream. All parts of the stream were sampled as evenly as possible during each recapture sampling trip.

Beach Spawning Population

Sockeye salmon spawn in widely scattered locations around the perimeter of Hetta Lake. In 2003, we designated a section of the shoreline around the mouth of Old Hatchery Creek, with a relatively high concentration of spawners, as the beach study area. The study design for the beach-spawning population consisted of two stages: 1) a two-sample Petersen estimate for each trip (Seber 1982) and 2) a multiple-trip estimate using a modified form of the Jolly-Seber method for multiple mark-recaptures in an open population (Seber 1982; Schwarz et al. 1993; Cook 1998). In the first stage, fish were marked on one day and examined for marks the next day. In the second stage, fish caught on both days of a given trip were given a unique mark for that trip. Then on subsequent trips recaptures of these marks were recorded. In the second stage we used the number of recaptures from each previous trip, together with the first-stage Petersen estimates of abundance from each trip, to generate an estimate fish that spawned within the study area over the entire season.

The crew used a 20 m long x 4 m deep beach seine, pulled by hand with the aid of a small skiff with outboard motor, to capture sockeye salmon on the spawning grounds. They first inspected all sockeye salmon for previous marks, then marked each fish with an opercular punch or pattern of punches indicating the trip and day number and released it with a minimum of stress. The crew leader recorded the total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark. Sampling in these small populations continued until the number of same-day recaptures exceeded the number of new fish caught. Right opercular punches were the primary mark for each trip: trip 1–round, trip 2–triangle, trip 3–square, trip 4–two round, trip 5–two star. A left opercular punch (any shape) was given each fish caught on the second day of each trip to indicate the fish had already been caught and should not be recounted on that trip.

Data Analysis

Stream Spawning Population

Darroch maximum-likelihood and least-squares, Schaefer population, and "pooled Petersen" estimates were calculated with the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995; for details, refer to www.cs.umanitoba.ca/~popan/). SPAS allows the user to pool together some or all capture or recapture strata for a more precise estimate of escapement, possibly at the expense of some bias. If a simple Petersen method is applied to stratified data that have been pooled, the resulting estimate is called the pooled Petersen estimate (Seber 1982). However, the Petersen estimate can be badly biased when the assumptions of equal probability of capture are violated. Briefly stated, the three assumptions of equal probability of capture are: 1) all fish have an equal probability of capture in the first event, 2) all fish have an equal probability of capture in the second event, and 3) fish mix completely between the first and second event. SPAS provides two types of chi-square tests to test whether the assumptions of equal probability of capture are likely to have been met. The software developers included the test labeled Complete Mixing to test the assumption that there is no difference in probability of movement for fish marked in any first-event stratum to any second-event stratum. This test is equivalent to testing for a difference in capture probability for fish in the second event. The software developers included the test labeled Equal Proportions to test the assumption that there is no difference in probability of capture for fish marked in the first event. If both tests were significant (p-value ≤ 0.05), we used the less precise Darroch stratified population estimate. If the test statistic from at least one of these tests was not significant (p-value > 0.05), we concluded that we met the assumptions of complete mixing and equal capture probability. Even if one of the test statistics was significant (p-value ≤ 0.05), we considered this to be insufficient evidence of a problem with the pooled Petersen estimate, and concluded that partial or complete pooling could still be valid (Arnason et al. 1995). Other criteria were also examined, including changes in the escapement estimate after pooling. If pooling led to a small change, we concluded that it was probably safe to pool; however, we interpreted a big change in the estimate as an indication the pooled Petersen estimate may be badly biased. Using the chi-square tests in SPAS as guidelines, we attempted to pool as many strata as possible to increase precision.

When use of the pooled Petersen method was warranted, we used the following method to estimate a 95% confidence interval for escapement size, rather than the method provided in the SPAS software. We let K denote the number of fish marked in a random sample of a population of size N. We let C denote number of fish examined for marks at a later time, and let R denote number of fish in the second sample with a mark. The number of fish in the escapement, N, is estimated by $\hat{N} = \frac{(K+1)(C+1)}{(R+1)} - 1$. In this equation, R is a random variable, and can b assumed to follow a Poisson, binomial, hypergeometric, or normal distribution, depending on circumstances of sampling. When R is large compared with the size of the second sample, C, its distribution can be assumed to be approximately normal (a practical check is to ensure R is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population, p, such that $\hat{p} = \frac{R}{C}$. We constructed approximate confidence interval bounds around $\hat{p}$ based on the assumption that R follows some sampling distribution. We defined the confidence bounds as ($a_{0.025}$, $a_{0.975}$). The 95% confidence interval bounds for the escapement size, N, were estimated by taking reciprocals of the confidence interval bounds for p, and multiplying by K. That is, confidence bounds for escapement size are estimated by ($K \cdot 1/a_{0.975}$, $K \cdot 1/a_{0.025}$). If $\hat{p} \geq 0.1$, and the size of the second sample C is at least the minimum listed in Table 2, a 95% confidence interval for p is estimated by $\hat{p} \pm \left[1.96\sqrt{\left(1-\frac{C}{\hat{N}}\right) \cdot \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C} \right]$, (Seber 1982, eq. 3.4).

Table 2. –Sample size criteria for using Seber’s (1982) eq. 3.4 to construct 95% confidence interval for a proportion.

$\hat{p}$ **or 1-** $\hat{p}$	0.5	0.4	0.3	0.2	0.1
Minimum sample size	30	50	80	200	600

Note: For given proportion of marked fish observed in the second sample $\hat{p}$, minimum sizes for the second sample are indicated.

Seber’s (1982) eq. 3.4 was also used when $\hat{p} < 0.1$ if $R > 50$. If these criteria were not met, the confidence interval bounds for p were found from Table 41 in Pearson and Hartley (1966).

Beach Spawning Population

First-stage estimates for beach-spawning populations, or “instantaneous” Petersen estimates within the study area, are formed using the method described above for stream spawning populations.

In the second-stage estimation process for beach-spawning populations, first-stage Petersen estimates are used to estimate total spawning population within the study area, N^*. Given s sampling occasions, we let $\hat{N}_i$ denote the first-stage Petersen population estimate from each sampling occasion i. The $\hat{N}_i$ values were used in place of the Jolly-Seber-derived parameter estimates of the number of animals alive in the system at each sampling occasion (J. Blick ADF&G, personal communication 1998; Cook 1998). We let n_i represent the number of unmarked fish and fish marked on previous trips, caught at sampling occasion i, and we let m_i represent the number of fish marked on previous trips, caught at sampling occasion i.

We also defined the following parameters (Schwarz et al. 1993; J. Blick ADF&G, personal communication, 1998; Cook 1998):

M_i = number of marked fish alive at time i,

ϕ_i = probability that a fish alive at time i is also alive at time i+1 (*i.e.* the survival rate)

B_i = number of fish that enter the system after occasion i and are still alive at time i+1 (*i.e.* immigration).

B_i^* = number of fish that enter the system after occasion i, but before occasion i+1,

N^* = total number of animals that enter the system before the last sampling occasion.

M_i was estimated as $\hat{M}_i = m_i \hat{N}_i / n_i$, for $i = 1, \ldots, s$;

ϕ_i was estimated as $\hat{\phi}_i = \hat{M}_{i+1} / (\hat{M}_i - m_i + n_i)$, for $i = 1, \ldots, s$-1;

B_i was estimated as $\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i \hat{N}_i$, for $i = 1, \ldots, s$-1;

B_i^* was estimated as $\hat{B}_i^* = \hat{B}_i \log(\hat{\phi}) / (\hat{\phi} - 1)$, for i = 2,…..,s-1, and

N^* was estimated as $\hat{N}^* = \sum_{i=0}^{s-1} \hat{B}_i^*$.

Recruitment and mortality were assumed to be uniform between times i and i+1. Because B_0^* and B_1^* are not uniquely estimable, $\hat{B}_0^* + \hat{B}_1^*$ was estimated by $\hat{N}_2 \log(\hat{\phi}) / (\hat{\phi} - 1)$.

A parametric bootstrap method (Buckland 1984) was used to construct confidence intervals for the parameter estimates in both stages. Let each bootstrap step be indexed by j (j=1,...G; for our purposes G=1,000). The parametric bootstrap distribution for $\hat{N}_i$ was developed by drawing G bootstrap observations of a hypergeometrically distributed random variable (that is, r_i) using parameters based on the observed values of C_i, K_i, and $\hat{N}_i$ at each sampling event i. At each step $\hat{N}_i(j)$ is developed as previously described. Denote each bootstrap observation in the first estimation stage as the pair of $r_i(j)$ and $\hat{N}_i(j)$, for j = 1,...G. Before proceeding on to the simulation of the second stage (the Jolly-Seber portion), the variance of the number of recaptures across all bootstrap replicates was calculated and denoted sb_i, for each trip i (*i.e.*, Var_j ($r_i(j)$)= sb_i). Note that this standard deviation is calculated from the bootstrap distribution of just the recaptures from the previous-day's marking event. To simulate the Jolly-Seber portion, for each bootstrap step, a bootstrap observation, $m_i(j)$, was drawn from a normal distribution with the mean determined from the actual observed value of m_i, and the standard deviation given by sb_i. Because this standard deviation is based on the simulated variability in just the previous-day's marking, it may tend to understate the sampling variability of m_i, which is the number of recaptures from all previous marking events. Even so, this assumption should provide a sensible approximation. We condition on the sample size, which we assume to be fixed and not a random variable, so that $n_i = n_i(j)$, for all j bootstrap observations. We then estimate $\hat{M}_i(j)$, $\hat{\phi}_i(j)$, and so on, as previously described, for all j = 1, ...G. The confidence interval for each parameter estimate is found from the quantiles of the bootstrap distribution (Rice 1995) for that estimate.

ESCAPEMENT AGE AND LENGTH DISTRIBUTION

Scales, matched with sex and length data, were collected from adult sockeye salmon on the spawning grounds in Hetta Lake to describe age and size structure of the population. The sampling goal was 600 fish. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age and length data were paired for each fish sample. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes a 4 year-old fish with the first year in the gravel, 1year in freshwater and 3 years saltwater; Koo 1962). Brood year tables were compiled by sex and brood year to describe age structure of the returning adult sockeye salmon population. Length of each fish was measured from mid-eye to tail fork to the nearest millimeter (mm).

The proportion p_k of each age-sex group k was estimated as $\hat{p}_k$ by the standard binomial formula, with associated standard error (SE), where n_k is the number of samples in age-sex group k and n is the total number of samples aged:

$$\hat{p}_k = \frac{n_k}{n} \text{ and } SE(\hat{p}_k) = \sqrt{\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}}$$ (Thompson 1992, p. 35–36).

Mean length and associated standard error for age-sex group k were calculated by standard normal methods:

$$\bar{y}_k = \frac{1}{n_k}\sum_{i=1}^{n_k} y_{ki} \text{ and } SE(\bar{y}_k) = \sqrt{\frac{1}{n_k}} \cdot \sqrt{\left(\frac{1}{n_k - 1}\right)\sum_{i=1}^{n_k}(y_{ki} - \bar{y}_i)^2}$$ (Thompson 1992, p. 42–43).

SUBSISTENCE HARVEST ESTIMATE

Subsistence fishers in Hydaburg were interviewed to determine fishing time, location, total duration, gear, and total harvest by species, for each boat or group of participants. Because of multiple exits between the harbor and the fishery, we were not able to follow a standard sampling design to select participants for interviews. Instead, the crew was able to independently interview all participants. This survey of participants in the subsistence fishery around Hetta Cove was considered a census; so total harvest was simply the sum of harvests by all participants, with no sampling error.

The crew conducted interviews every day that the fishery was open, and interviewed every party that fished. If they were unable to interview participants in the fishery or at the boat harbor, they contacted participants at their homes. The crew was certain they had interviewed all participants in the fishery.

LIMNOLOGY

Limnology sampling was conducted at two stations on Hetta Lake every six weeks throughout the summer to measure euphotic zone depth, and to collect zooplankton samples. Light, temperature and dissolved oxygen profiles were collected at the primary sample site, Station A. Zooplankton samples were collected from both stations on each sampling date.

Light, Temperature, and Dissolved Oxygen Profiles

The amount of light penetrating the water column drives the rate of conversion of sunlight into energy (photosynthesis) by primary producers. The total volume of the lake in which enough light is available for photosynthesis is called the euphotic volume of the lake. To estimate euphotic volume, we measured light intensity from just below the surface to the depth where 1% of the subsurface light penetrates the water column. Light measurements were recorded in foot-candles every 0.5 m, using a Protomatic light meter. The vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) was calculated from the equation, EZD = 4.6205/ K_d (Kirk 1994). The product of the euphotic zone depth and lake surface area provides an estimate of euphotic volume (Koenings et al. 1987).

The heat budget of a lake influences chemical reactions, nutrient turnover rate, and overall productivity. Dissolved oxygen is not only necessary for aerobic respiration; it affects most of the biochemical reactions in the aquatic environment. Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe, in relative (percent of saturation) and absolute (mg L^{-1}) values for DO and in ºC for temperature. Measurements were made at 1 m intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which change in temperature decreased to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 44 m). The dissolved oxygen meter reading at 1 m was calibrated at the beginning of a sampling trip using the value from a 60 ml Winkler field titration (Koenings et al. 1987).

Secondary Production

Zooplankton samples were collected at two stations in Hetta Lake using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a depth of 50 m at both stations at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G, Commercial Fisheries Limnology Laboratory in Soldotna, Alaska. Cladocerans and copepods were identified using the taxonomic keys of Brooks (1957), Wilson (1959), and Yeatman (1959). Zooplankton were enumerated from three separate 1 ml subsamples taken with a Hensen-Stemple pipette and placed in a 1 ml Sedgewich-Rafter counting chamber. Using a calibrated ocular micrometer, zooplankton body length was measured to the nearest 0.01 mm from at least 10 organisms of each species, along a transect in each of the 1 ml subsamples. Zooplankton biomass was estimated using species-specific dry weight versus zooplankter length regression equations (Koenings et al. 1987). The seasonal mean density and body size was used to calculate the seasonal zooplankton biomass for each species. Marco-zooplankters were further separated by sexual maturity where ovigorous (egg bearing) zooplankters were also identified.

RESULTS

SOCKEYE FRY POPULATION ASSESSMENT

Hydroacoustic survey and mid-water trawl sampling were conducted on 29 July, 2003. The estimate of total targets was 728,400 (SE=136,500; CV=17%), using the usual sampling-based (non-Bayesian) approach. Species apportionment was based on results of four 15-min trawl tows, with a total sample of 97 fish (Table 3). The posterior mean of the proportion of sockeye targets was calculated to be 0.432 (Table 4). Using the *t*-distribution posterior for *T*, the simulation-based posterior mean of *S*—the estimate of total sockeye targets—was 330,000 with posterior standard deviation of 95,000; the 95% credible interval was 155,000 to 528,000 fry (posterior CV=29%). Using the normal distribution posterior for *T*, the same simulation-based posterior mean of S was 323,000 with posterior standard deviation of 86,000; the 95% credible interval was 163,000 to 505,000 (posterior CV=27%), quite similar to the results using the *t*-distribution. Because the *t*-distribution and the normal distribution are both symmetric, distribution of *S* should have the same posterior mean, irrespective which of the two posterior distributions for *T* was used. As the product of the posterior means for *T* and *p* equals 0.432 (728,400), or 315,000 fry—which we took as our official estimate—we can see that there is a fair amount of Monte Carlo simulation error in these estimates. Considering all sources of uncertainty, we feel it is safe to conclude that the posterior coefficient of variation for *S* was less than 30% (i.e., posterior standard deviation divided by posterior mean of *S*).

Interestingly, the posterior standard deviation of the parameter *p* is about 75% larger than the usual sampling-based estimate of standard error of the estimate of *p* based on the binominal distribution. This is partially a function the dissimilarity of sample proportions of sockeye fry in each of the four trawl tows.

Sockeye fry density was about 17 fry per 100 m^2, with a range of 7–25 fry per 100 m^2. All 43 sockeye salmon fry caught in trawl samples were age-0. Mean snout-fork length was 45 mm (SE=0.6) and mean weight was 0.7 g (SE = 0.03). The length frequency distribution for age-0 sockeye fry was approximately normal, as would be expected with one age class (Figure 4). Sticklebacks were the only other fish caught in the trawl, so we assume the remaining 425,000 targets were sticklebacks. The mean snout-fork length of sticklebacks was 41.9 mm (SE = 0.49 mm) with a mean weight of 0.7 g (SE = 0.06 g).

Table 3.–Summary of Hetta Lake trawl sampling by tow, with depth and duration, and species, in 2003.

Tow	Depth (m)	Duration (min)	Species	Number of fish
1	7	15	Sockeye age 0	34
			Stickleback	40
2	7	15	Sockeye age 0	6
			Stickleback	6
3	8	15	Sockeye age 0	3
			Stickleback	4
4	8	15	Stickleback	4

Table 4.–Summary of Markov Chain Monte Carlo simulations of mean proportion of sockeye fry in four trawl samples. Distribution of the proportion of sockeye fry simulations are represented by the mean proportion (mu), se, and the lower (2.5%) and upper (97.5%) fry proportions generated by 5,000 simulations.

Parameter	Mean	Standard Error	2.50 Percent	Median	97.50 Percent
p_1	0.468	0.055	0.361	0.467	0.578
p_2	0.467	0.109	0.256	0.467	0.682
p_3	0.431	0.123	0.201	0.427	0.679
p_4	0.320	0.136	0.063	0.319	0.593
p_μ	0.432	0.089	0.248	0.437	0.596

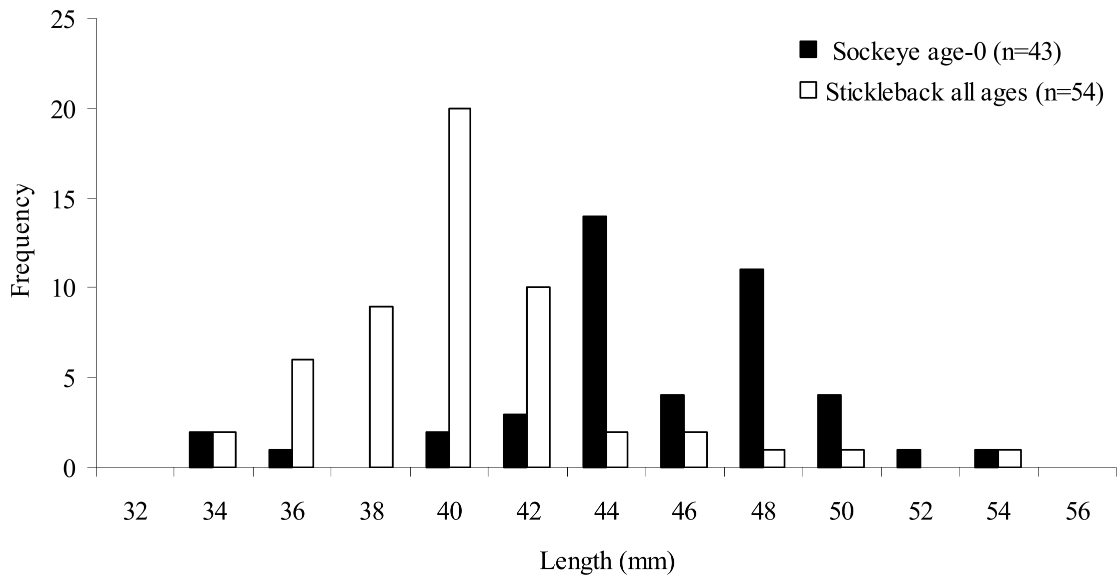

Figure 4.–Length frequency distribution of age-0 sockeye salmon fry and sticklebacks caught in the Hetta Lake mid-water trawl in 2003.

ADULT SOCKEYE ESCAPEMENT ESTIMATES

Visual Survey Counts

Five visual surveys of Hetta Lake were completed between 3 September and 31 October (Table 5). Hetta Creek was the only tributary that had spawning sockeye salmon. Counts for Hetta Creek included all sockeye spawners within the stream study area, including the mouth of the stream. Other spawning areas were along the lake shoreline, including the designated beach study area adjacent to the mouth of Old Hatchery Creek. Similar to previous years, counts of beach spawners exceeded counts of stream spawners by the beginning of October (Table 5). The last count of beach spawners on 30 October was only 125 fish less than the high count of 1,041 on 14 October, so we cannot be sure the peak number of spawners occurred before our surveys ended. The first count of 425 stream spawners, on 2 September, was the highest count in Hetta Creek, leaving the possibility the peak occurred before we began our surveys.

Table 5.–Number of sockeye spawners counted in visual surveys in 2003, by date and area. Hetta Creek is the only tributary with sockeye spawning habitat. The remaining spawning habitat is on beach areas around the lake.

Date	Beach study area[1]	Other beach areas	Total beach spawners	Hetta Creek[2]	Lake total
2 Sept	6	2	8	425	433
16 Sept	2	16	18	318	336
1 Oct	143	342	485	354	839
14 Oct	205	836	1,041	268	1,309
30 Oct	169	747	916	162	1,078

[1]Old Hatchery Creek area

[2]Hetta Creek inlet stream study area, including area around mouth

Stream Spawning Population

In 2003, five mark-recapture events were conducted in Hetta Creek, between 3 September and 30 October. The first event (3 September) was marking only, and the last event (30 October) was recovery only. During these sampling events we marked a total of 409 sockeye salmon (Table 6). Of 216 fish caught in the mark-recovery sampling, 74 marked fish were recovered. A Darroch estimate could not be formed with the data from four marking strata and four recovery strata. Furthermore, both chi-square tests for consistency were significant, with p-value < 0.005 (complete mixing, $X^2 = 23.95$; equal proportions, $X^2 = 35.37$, both with 3 degrees of freedom), indicating the pooled Petersen estimate might be biased. Inspection of the data showed several strata that had very different capture probabilities. Only 32 fish were sampled and no marks were recovered on the last recovery event (30 October). Also, only two marked fish were recovered from the last two marking events (1 and 14 October). Since sample sizes were very small and recapture probabilities were zero or near-zero for these strata, these three late-season strata were dropped from the analysis. We observed that no more fish were moving into the inlet stream in October, and fish seen later in the season around the mouth of the stream remained to spawn in beach areas, rather than migrating upstream. These observations provided further justification for dropping the late marking and recovery strata. Analysis in SPAS with two marking and three recovery strata (Table 7) yielded a pooled Petersen estimate of 782 (95% CI = 676–943; CV = 7.9%). The chi-square test for complete mixing was not significant (p-value = 0.60), indicating no detectable violations of the assumptions of complete mixing or equal probability of capture in the second event. The test of equal proportions was significant (p-value < 0.005), indicating capture probabilities may have been different between strata for fish marked in the first event. However, since at least one of the consistency tests was non-significant, we decided to use the pooled Petersen estimate to increase precision, possibly at the expense of some bias.

Table 6.–Sample sizes in mark and recapture strata and numbers of marked fish caught in recapture strata in the main inlet stream to Hetta Lake, 2003. Marking was conducted at the mouth of the stream; recapture sampling was conducted in the stream.

Phase	Stratum	Dates	Number marked				
Marking	1	3 Sep	206				
	2	17 Sep	102				
	3	1 Oct	70				
	4	14 Oct	31				
		Total marked:	409				
				Recaptured fish by stratum:			
			Sample size	**1**	**2**	**3**	**4**
Recapture	1	16 Sep	88	37	-	-	-
	2	2 Oct	60	13	19	-	-
	3	14 Oct	36	0	3	2	-
	4	31 Oct	32	0	0	0	0
		Total sampled:	216				
			Total recaps (all strata):	74			

Table 7.–Reduced mark and recapture strata and numbers of marked fish caught in recapture strata in the main inlet stream to Hetta Lake, 2003. The last two marking strata and the last recapture stratum were dropped; no new fish were moving into the inlet stream during the October sampling dates.

Phase	Stratum	Dates	Number marked		
Marking	1	3 Sep	206		
	2	17 Sep	102		
		Total marked:	308		
				Recaptured fish by stratum:	
			Sample size	**1**	**2**
Recapture	1	16-Sep	88	37	-
	2	2-Oct	60	13	19
	3	14-Oct	36	0	3
		Total sampled:	184		
			Total recaps (all strata):	72	

Beach Spawning Population

Five mark-recapture events were conducted in the beach spawning study area around Old Hatchery Creek in 2003, beginning on 2 September (Table 8). However, during the first two events very few spawners were present in the beach-spawning areas, sample sizes were very small, and no marked fish were recaptured on day two of either event, so it was not possible to generate a first-stage Petersen estimate for these events. Therefore the first two events, with 25 total marked fish from both, were dropped from the analysis. Between 1–31 October, three successful two-day mark-recapture events were completed, with adequate recaptures to generate first-stage Petersen estimates, although small sample sizes in the final mark-recapture event (30–31 October) resulted in an imprecise first-stage (Petersen) estimate for this event. Of 84 fish marked on 1–2 October, 32 were recaptured in later events, but only three of the 147 fish marked on 14–15 October were recaptured on the final trip. Nevertheless, an escapement estimate for this study area was generated that met our objective for precision (CV < 15%). A total of 514

(95% CI 429–662; CV = 11.5%) sockeye salmon were estimated within the beach spawning study area. This estimate represents only that portion of the beach-spawning population found within the study area. In visual surveys, between 18–29% of all beach spawners were counted in the study area during October (Table 5), so the seasonal average proportion of spawners in the beach study area, weighted by abundance at each sampling event, was 22%.

Table 8.–Sample sizes and numbers of recaptured fish in the beach spawning study area at Hetta Lake in 2003.

Event Dates	First Stage		
	Number marked (day 1)	**Number sampled (day 2)**	**Number recaps from day 1**
2–3 Sept[1]	13	6	0
16–17 Sept[1]	1	5	0
1–2 Oct	77	22	15
14–15 Oct	90	84	27
30–31 Oct	17	20	3

	Second Stage					
	Number marked	**Recaps from event:**	**1**	**2**	**3**	**4**
2–3 Sept[1]	19		-	-	-	-
16–17 Sept[1]	6		0	-	-	-
1–2 Oct	84		0	0	-	-
14–15 Oct	147		0	3	26	-
30–31 Oct	34		0	0	3	3

Note: In the first stage sampling, fish were marked on one day and examined for marks the following day, assuming the population to be closed over this short time period. In the second stage sampling, fish caught on both days of an event were given a unique mark for that event, and were also examined for marks given on previous events. The second stage allowed for an open population estimate. The first two sampling events were dropped from the analysis since there were no recaptures and no first-stage (Petersen) estimate could be generated.

[1] These strata were dropped from the analysis.

ESCAPEMENT AGE AND LENGTH DISTRIBUTION

Ages were determined by scale pattern analysis of samples from 504 adult sockeye salmon. The dominant age class in the 2003 escapement was age-1.3 (50%), followed by age-1.2 (41%; Table 9). The overall sex ratio was 52% male to 48% female. The mean fork length of age-1.3 fish was 554 mm and 496 mm for age-1.2 fish (Table 10).

Table 9.–Age composition of the 2003 sockeye salmon escapement by brood year, age class, and sex.

Brood Year:	2000	1999	1998	1998	1997	
Age:	1.1	1.2	1.3	2.2	2.3	Total
Male						
Sample Size	3	138	84	12	5	242
Percent	0.6%	27.4%	16.7%	2.4%	1.0%	48.0%
SE (%)	0.3%	2.0%	1.7%	0.7%	0.4%	2.2%
Female						
Sample Size		70	168	16	8	262
Percent	0.0%	13.9%	33.3%	3.2%	1.6%	52.0%
SE (%)	0.0%	1.5%	2.1%	0.8%	0.6%	2.2%
All Fish						
Sample Size	3	208	252	28	13	504
Percent	0.6%	41.3%	50.0%	5.6%	2.6%	100.0%
SE (%)	0.3%	2.2%	2.2%	1.0%	0.7%	0.0%

Table 10.–Mean fork length (mm) of sockeye salmon in the 2003 Hetta Lake escapement by brood year, age class, and sex.

Brood Year:	2000	1999	1998	1998	1997		
Age:	1.1	1.2	1.3	2.2	2.3	Not aged	All Fish
Male							
Av. Length (mm)	400	501	572	512	579	503	522
SE (av. length)	13.3	2.6	1.7	8.8	5.2	6.4	2.7
Sample Size	3	138	83	12	5	60	301
Female							
Av. Length (mm)		486	545	503	549	519	526
SE (av. length)		2.7	1.4	7.2	5.0	5.3	1.9
Sample Size		70	166	16	8	36	296
All Fish							
Av. Length (mm)	400	496	554	507	561	509	524
SE (av. length)	13.3	2.0	1.4	5.5	5.5	4.5	1.7
Sample Size	3	208	249	28	13	96	597

SUBSISTENCE HARVEST ESTIMATE

The Hydaburg crew interviewed 64 participants in the Hetta Lake sockeye salmon subsistence fishery between 17 June and 31 August 2003, and documented a total harvest of 5,770 sockeye salmon between 16 July and 30 August (Appendix C). Most harvest occurred during the month of August, with the highest daily harvest, 432 sockeye salmon, on 21 August (Figure 5). Subsistence fishers interviewed in Hydaburg also reported fishing in other areas in Hetta Inlet. Twenty-seven participants reported a total harvest of 1,202 sockeye salmon from Eek Inlet, and four participants reported harvesting a total of 451 sockeye salmon in the Kasook Lake terminal area.

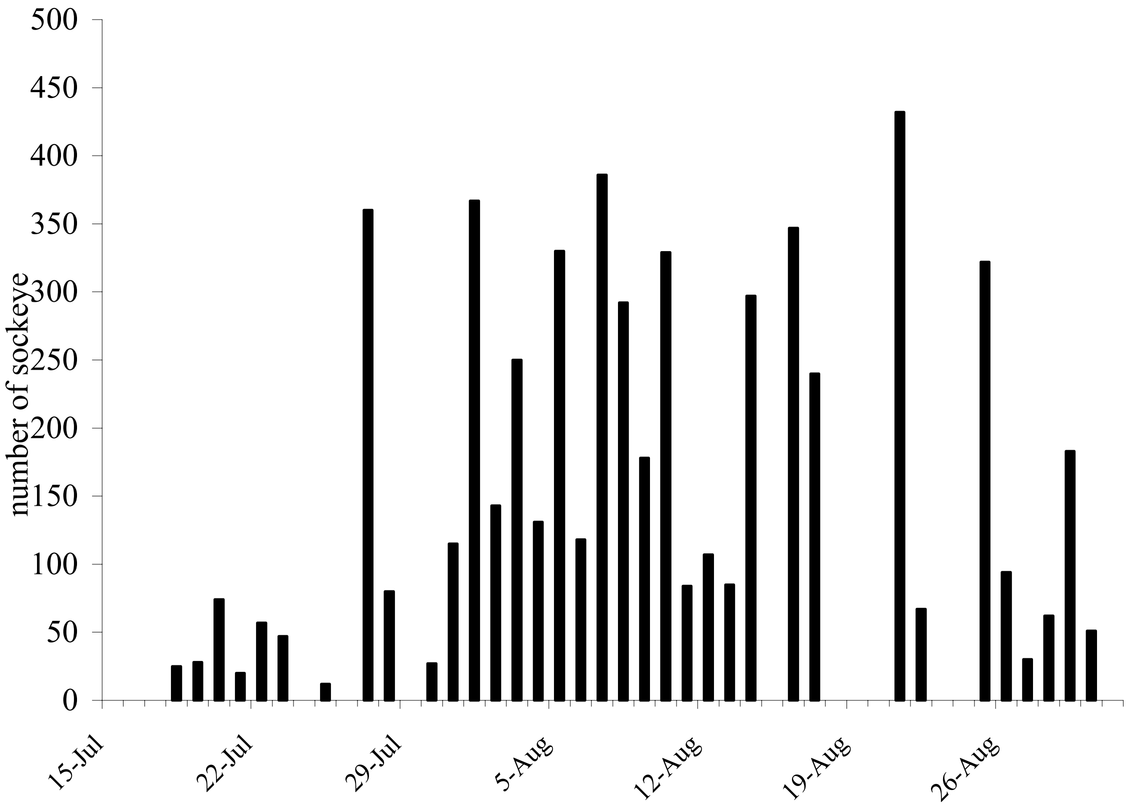

Figure 5.–Daily subsistence harvest of sockeye salmon reported for the Hetta Lake marine terminal area by participants interviewed in Hydaburg in 2003.

LIMNOLOGY

Light, temperature, and dissolved oxygen were measured in Hetta Lake at station A on 15 May, 25–26 June, 31 July, 5 September, and 15 October 2003. However, dissolved oxygen measurements were not taken on 31 July, and light measurements were omitted on 5 September. Zooplankton samples were taken at both stations on 15 May, 26 June, 29 July, 3 September, and 15 October.

Light, Temperature, and Dissolved Oxygen Profiles

The euphotic zone depth varied by no more than 1 m throughout the season from the seasonal mean of 10.3 m (Table 11). On 31 July, euphotic zone depth was deepest (11.3 m) among the four dates sampled.

Table 11. –Euphotic zone depths (EZD) in Hetta Lake, 2003.

Date	Depth (m)
15-May	10.4
26-Jun	9.6
31-Jul	11.3
15-Oct	9.9
Seasonal Mean	**10.3**

A strong thermocline had already formed between 5–10 m in Hetta Lake by 15 May, the first sampling date (Figure 6). By 31 July, the thermocline had deepened to about 16 m, with a maximum epilimnetic temperature of about 18 ^{o} C. Thermal stratification persisted through early fall (5 September), but by 15 October, the thermocline had nearly disappeared and the upper 12 m of the water column was isothermic just above 10°C. Hypolimnetic temperatures were between 5–7^{o} C throughout the season. Hetta Lake remained well oxygenated throughout the season; percent saturation of dissolved oxygen did not drop below 90% except at the beginning and end of the season below the thermocline (Table 12).

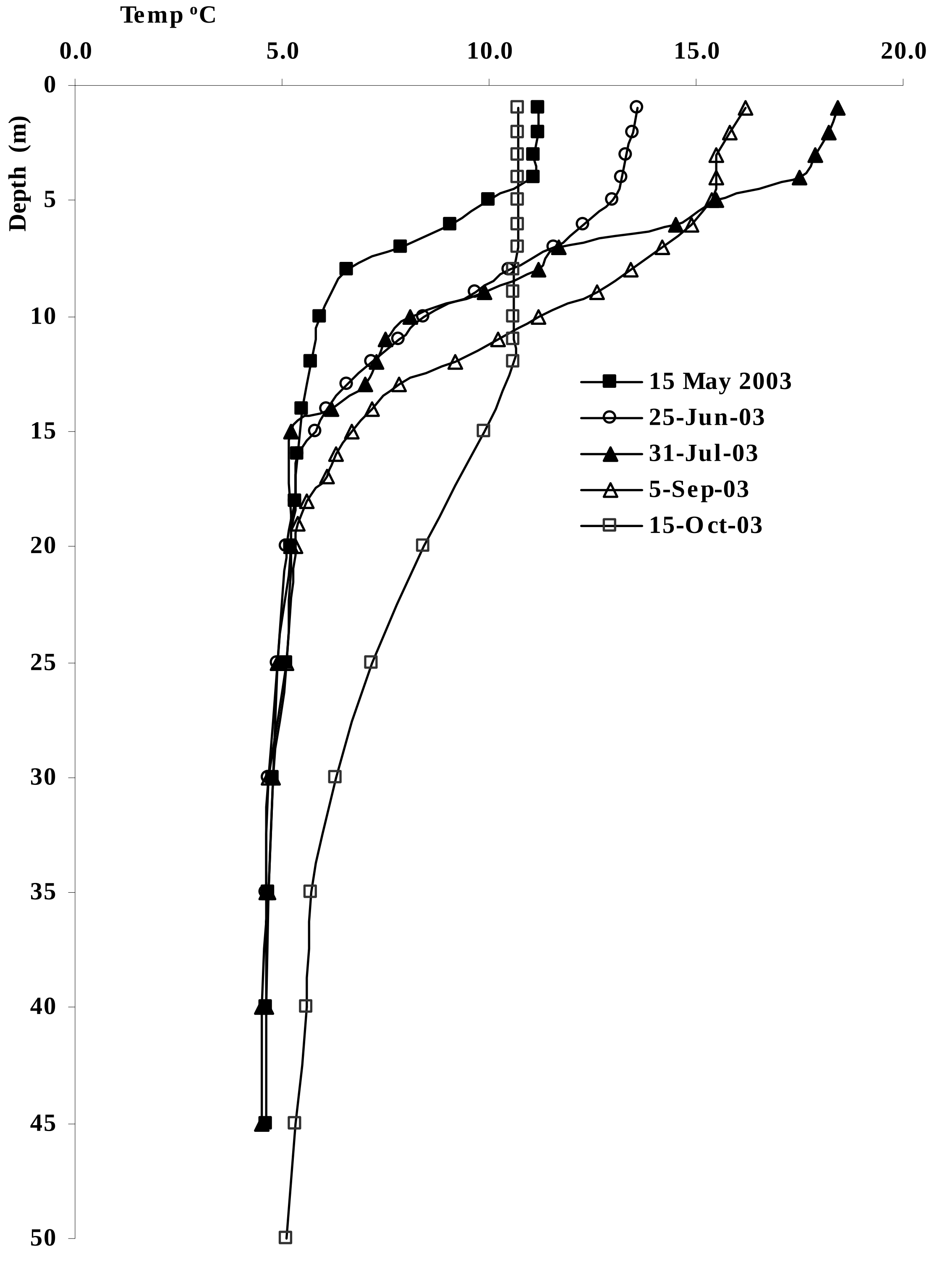

Figure 6.–Water column temperature profiles in Hetta Lake in 2003; measurements were taken at station A**.**

Table 12.–Dissolved oxygen (percent saturation) by depth and sample date in Hetta Lake, Station A in 2003.

Depth (m)	15-May	23-Jun	3-Sep	15-Oct
1	97%	97%	96%	94%
2	97%	96%	95%	94%
3	97%	96%	95%	94%
4	97%	95%	94%	94%
5	100%	95%	94%	94%
6	100%	93%	96%	94%
7	99%	94%	95%	94%
8	95%	93%	97%	93%
9		94%	97%	93%
10	92%	94%	96%	93%
11		93%	95%	93%
12	91%	93%	95%	90%
13		92%	94%	
14	90%	92%	93%	
15		92%	93%	89%
16	90%	92%	92%	
17			93%	
18	90%	91%	92%	
19			92%	
20	90%	91%	92%	87%
25	89%	90%	93%	86%
30	88%	90%	94%	87%
35	88%	90%	93%	85%
40	88%		93%	87%
45	88%		94%	87%
50				86%

Secondary Production

As seen in previous years, the zooplankton assemblage in Hetta Lake was very simple, with *Bosmina* spp. far outnumbering other taxa (Table 13). The only other taxa present in significant numbers were *Cyclops* sp. and *Daphnia longiremis*. Because of their larger sizes, *Cyclops* and *Daphnia* represented slightly higher proportions of total seasonal mean biomass than of total seasonal mean density.

Table 13.–Size (mm), density (no·m2), and biomass (mg·m2) of macro-zooplankton in Hetta Lake, 2003. Mean lengths were weighted by density at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxon were estimated separately.

Species	Mean length (mm)	Mean Density (no.·m^{-2})	Percent of total abundance	Mean Biomass (mg·m^{-2})	Percent of total biomass
Bosmina	0.29	40,837	68%	30.7	68%
Ovig. *Bosmina*	0.34	8,387	14%	8.8	19%
Daphnia longiremis	0.62	479	1%	1.0	2%
Ovig. *D. longiremis*		14	0%		
Cyclops	0.58	4,412	7%	5.0	11%
Ovig. *Cyclops*		10	0%		
Copepod nauplii		6,040	10%		
Total (all taxa)		**60,178**		**45.5**	

DISCUSSION

We successfully completed objectives for the third year of the Hetta Lake Sockeye Salmon Stock Assessment Project, except for obtaining a coefficient of variation less than 10% for the sockeye fry estimate. We obtained a complete census of subsistence sockeye harvest and effort at Hetta Lake, and two other subsistence sockeye systems used by Hydaburg residents. We estimated numbers of sockeye salmon in Hetta Creek and a beach-spawning area near Old Hatchery Creek, and using visual survey counts we extrapolated a rough escapement estimate for the whole lake. We estimated populations of sockeye fry and sticklebacks in Hetta Lake in August, and we described the zooplankton assemblage and estimated zooplankton density and biomass in May through October. We also measured profiles of water column light penetration, temperature, and dissolved oxygen in May through October.

By conducting subsistence harvest interviews as fishers returned to Hydaburg, the crew obtained harvest totals for the area around the outlet of Hetta Lake, and also for Eek and Kasook Inlets. It appears sockeye returns to Hetta were very low in 2002, and the harvest was consequently low compared with 2001 and 2003. More fish were harvested in Kasook Inlet than at the Hetta Lake outlet in 2002 (Table 16). Hetta Lake is generally the largest producer of sockeye salmon, and in most years probably supplies the largest number of subsistence sockeye salmon to the people of Hydaburg, as it did in 2003 (Table 16). But in some years, as in 2002, when sockeye returns to the Hetta system were very low, Eek and Kasook Inlets may become the primary source of subsistence sockeye salmon for Hydaburg residents. Ideally, as we gain information about Hetta and Eek sockeye production, Hydaburg residents can start basing their choice of fishing areas on conservation needs, fishing in more productive systems and leaving more depressed systems time to recover.

The subsistence harvest census revealed significant under-reporting of harvests by permit holders. Total sockeye harvests for Hetta Inlet, as reported by permit holders and compiled in the ADF&G commercial fisheries database, were underestimated by 75, 53, and 83 percent in 2001, 2002, 2003 respectively. Apparently, compiling user-reported totals from returned ADF&G subsistence permits has not been a reliable method of estimating harvest in the Hetta subsistence fishery. By contrast, locally-hired tribal employees were able to effectively monitor the fishery in season and obtain more accurate harvest numbers by interviewing subsistence fishers as they returned from fishing. The interview method protected anonymity of individual fishers because total catches were reported by boat or fishing party, rather than by individual permit-holder. Participants could report their true catches without fearing they might be penalized for taking more than the legal limit. We recommend continuing direct, on-site interviews for Hydaburg subsistence fisheries, to provide fishery managers with reliable harvest estimates. We recognize this method will only work in a small, closely-knit community such as Hydaburg. Success also depends on interest of community leaders in accurately documenting subsistence harvest. The HCA Hetta Project Leader took a leadership role in promoting accurate reporting, because he realized the importance of documenting subsistence needs in the community.

Table 14.–Comparison of subsistence sockeye harvests at the Hetta, Eek, and Kasook terminal areas in 2002 and 2003.

Area fished	2002 harvest (percent of total)	2003 harvest (percent of total)
Hetta	947 (28%)	5,800 (78%)
Eek	1,200 (36%)	1,200 (16%)
Kasook	1,200 (36%)	450 (6%)
Total harvest, all areas	3,347	7,450

If subsistence harvest were limiting escapement, we would expect to see lower escapements in years with high subsistence harvests. If other factors were limiting Hetta Lake sockeye production, we may not see such a correlation. Subsistence harvest in 2002 was much less than in 2003 or 2001 (Table 15). Escapement also appeared to be very low in 2002. Low escapement and harvest in 2002 were probably a result of low returns to the system. In 2003, the subsistence harvest was 30% higher than in 2001, which may have consequently lowered escapement, however we don’t have a whole lake escapement estimate for 2001 to support this relationship.

Although we don’t have complete sockeye escapement estimates for Hetta Lake, we can gauge strength of escapement to some degree by estimates of escapement into Hetta Creek each year. The estimated number of stream-spawners was much higher in 2003 than in 2002 but both of these estimates were much lower than the estimated number in 2001 (Table 15). We know that these are only minimum estimates of escapement, because substantial numbers of sockeye salmon were observed spawning in shoreline areas of the lake in the later part of the season each year (Table 5 in this report; McEwen et al. 2002; Lewis and Cartwright 2004). In 2003, we also obtained a partial estimate of beach-spawning sockeye salmon in Hetta Lake in addition to our estimate of the stream-spawning escapement (Table 15). If we assume the estimated 500 beach spawners represented 22% of all beach spawners in Hetta Lake, there were roughly 2,300 beach spawners in 2003 and a rough total escapement estimate (stream plus beach spawners) is 3,100 fish.

Table 15. –Comparison of subsistence sockeye harvest around the outlet of Hetta Lake and partial estimates of sockeye spawners in the lake in 2001–2003 (McEwen et al. 2002; Lewis and Cartwright 2004).

Year	Total Subsistence Harvest	Estimated number of stream spawners	Estimated number of beach spawners	Percent of beach spawners estimated[1]
2001	4,400	2,400	-	-
2002	1,200	330	-	-
2003	5,800	800	500	22%

[1] Applies to beach-spawners only, based on visual counts of sockeye salmon during boat surveys.

We are confident we can estimate the total spawning population in Hetta Creek because fish are available for sampling throughout the portion of the stream used for spawning; a barrier falls blocks passage of sockeye salmon above this study area. Timing of spawning in Hetta Creek is distinctly earlier than beach spawning, with some overlap in late September. Any mixing of fish from these two groups at the mouth of Hetta Creek could cause them to be confounded in mark-recapture studies during the mid-season when timing does overlap. Some fish marked at the mouth of Hetta Creek, in expectation they would travel upstream to spawn, may actually remain to spawn elsewhere in the lake. However, because the crew only marked fish that were schooling at the mouth of Hetta Creek and appeared ready to move upstream, we felt it was reasonable to treat the stream system as closed. Furthermore, we felt justified in excluding fish marked after the end of September from our estimate of stream spawners (see Stream Spawning Population subsection under Results section, Tables 5–7).

Significant populations of beach-spawning sockeye salmon, outside the stream study area, were not estimated in 2001 and 2002. The number of beach spawners starts to increase at the end of September, after the number of stream spawners has declined. We could not simply expand the escapement estimate from Hetta Creek to include these beach spawners, because visibility of fish within a stream and along a beach are too different. In 2003, we defined a beach study area at the mouth of Old Hatchery Creek so we could estimate the number of beach spawners. This area was full of floating and submerged logs, with only a small portion accessible to beach seine. We succeeded in estimating the number of sockeye spawners in this small area, but most beach spawners in the lake (78%) were outside of this area. Because beach-spawning escapement estimate is extrapolated from study area to whole lake based on visual survey counts, without a meaningful estimate of sampling error for visual counts, uncertainty associated with our total escapement estimates cannot be quantified. If sampling error for visual counts were large, the whole-lake escapement estimate may be too imprecise to be useful. In terms of timing, even by the end of October we still did not see a definitive peak in the visual count of beach spawners. Consequently, we do not have much confidence in our estimate of beach spawning sockeye salmon Hetta Lake. We think sockeye spawners arrive in the lake in July, and remain in deep parts of the lake for several months before commencing their protracted spawning around the lake shoreline. Some elders in Hydaburg remember harvesting sockeye salmon in Hetta Lake in winter as late as March. Because of safety concerns, logistics, and cost, we cannot extend the study past the end of October. Because of physical difficulties in sampling beach spawners, and protracted spawning timing in this lake, we may not be able to accurately estimate sockeye escapement using mark-recapture methods on the spawning grounds. A weir, planned for the 2005 season, will provide inseason escapement counts and should enable us to estimate escapement with greater certainty.

The Bayesian approach to estimate uncertainty associated with our sockeye fry estimates incorporated high variation of species composition in mid-water trawl samples. As a result, the estimate was not very precise; coefficient of variation was 30% and difference between lower and upper estimates based on credible intervals was 3.5 times. To evaluate trends in fry estimates between years and in comparison with parent-year escapement estimates, we need to reduce uncertainty around the mean estimate. We intend to increase number of tows in an effort to resolve this problem. However, the number of tows needed to increase precision and reduce the coefficient of variation to less than 10% is difficult to determine in advance. We will use empirical data collected each year to balance cost and effort (i.e. number of trawls) with the need for increased precision. In 2004, we performed 20 trawls, a number the ADF&G biometrician thinks will be more than adequate to describe the highly variable proportion of sockeye fry in the trawl samples. We may also consider increasing the threshold value of the coefficient of variation should the 10% benchmark prove to be too difficult to obtain and we are able to estimate fry abundance at a higher coefficient of variation.

Sockeye fry abundance estimated in Hetta Lake was highest, or nearly highest, among sockeye lakes studied in 2001–2003 in Southeast Alaska. In 2001, Hetta Lake fry density was much higher than in other, similar sockeye fry rearing lakes, such as Klawock (Lewis and Cartwright 2002a), Luck (Lewis and Cartwright 2002b), Gut Bay (Conitz and Cartwright 2002), or Falls (Conitz et al. 2002). Fry estimates from 2001 could not be directly compared with those from 2002 due to changes in the sampling design. However, in 2002 the Hetta Lake sockeye fry density was highest out of 12 sockeye-producing island lakes in Southeast Alaska (Table 14). Average weight of the age-0 fry sampled in Hetta Lake in July 2002 was small compared with these other lakes. The small size could be an effect of high density; however, considerable weight gain could be expected after July (compare with Klawock I and Klawock II, Table 14).

Table 16. –Sockeye fry densities and average weights of age-0 fry in selected Southeast Alaska lakes with important subsistence runs, 2002.

Lake	Date sampled	Fry·100 m^{-2}	Av. wt. age-0 fry (g)
Hetta	Jul 18	44	0.3
Kutlaku	Aug 9	41	1.1
Gut Bay	Aug 23	25	0.5
Klag	Aug 25	23	1.1
Luck	Jul 22	23	0.4
Hoktaheen	Oct 13	18	1.4
Sitkoh	Aug 13	11	1.1
Klawock I	Jul 17	4	0.6
Kanalku	Aug 10	3	1.0
Klawock II	Oct 2	3	1.8
Falls	Aug 24	2	0.7
Kook	Aug 11	2	0.8
Salmon Bay	Sep 22	2	1.0

Note: Total population estimates of small pelagic fish were based on hydroacoustic surveys of each lake, and sockeye populations were estimated from proportions of sockeye fry in tow net samples. Fry density estimates are total sockeye population divided by estimated surface area for each lake. Average weights of age-0 fry vary with sample date; in general, the later in the season the lake was sampled the larger the fry.

Because we do not have even rough total lake escapement estimates for 2001 and 2002, we cannot compare numbers of offspring (fry) produced by adult escapements the previous year. However, we can examine the relationship between sockeye fry, sticklebacks and zooplankton abundance. Information collected in three years of this study indicates limiting factors to sockeye fry production could be stickleback populations (competition) and zooplankton biomass (food limitation). The stickleback population increased more than two-fold from 2001 to 2003 (Table 15). In 2001, sticklebacks were estimated to be about 6% of the total population of small pelagic fish in Hetta Lake; in 2002 and 2003, stickleback proportions had increased to about 20% and 57% of the population. Zooplankton biomass remained at very low levels in 2001–2003, consistent with evidence of high densities of planktivores in Hetta Lake. Of 14 sockeye-producing lakes in Southeast Alaska studied from 2001 to 2003, only Gut Bay and Falls Lakes were lower in total zooplankton biomass, and zooplankton biomass was at least two- to three-fold lower in Hetta Lake than in all the other lakes studied (Appendix D). Very low levels of *Daphnia*, a preferred prey for sockeye fry, also suggest predation pressure is high in this lake.

Table 17. –Comparison of fry populations with threespine stickleback population and zooplankton biomass in Hetta Lake, 2001–2003.

	Fish populations (number x 1000)		**Zooplankton biomass ($mg{\cdot}m^{-2}$)**	
Year	**Sockeye fry**	**Sticklebacks**	**Total**	***Daphnia***
2001	2,900	170	34	0
2002	1,000	250	47	4
2003	324	425	45	1

Our first three years of study in Hetta Lake revealed a highly productive system, with widely fluctuating escapements, resulting most likely from escapement-limited productivity in some years and rearing-limited productivity in others. However, uncertainties in our escapement estimates limit our ability to make comparisons between productivity at various stages in this system. Given the intensive subsistence fishery taking place in the terminal area and high rates of under-reporting on subsistence fishing permits for Hetta Inlet, we strongly recommend the Hetta Lake sockeye project be continued, focusing on the relationships between terminal area harvest, escapement, and freshwater productivity. Monitoring the subsistence fishery locally will provide valuable information to fishery managers. In addition to obtaining better estimates of escapement using a weir, we think continued study of fry and zooplankton production in Hetta Lake is necessary in order to understand the dynamics of this heavily-utilized sockeye stock.

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APPENDIX A. HETTA LAKE SOCKEYE SUBSISTENCE PERMITS

Appendix A1.–Harvest of sockeye salmon at the head of Hetta Inlet and in Hetta Lake Creek, reported by subsistence permit holders, 1986–2003.

Year	Location	Permits	Sockeye	Sockeye per permit
1985	Hetta Inlet	57	1265	22
1986	Hetta Inlet	73	1911	26
1987	Hetta Inlet	44	1099	25
1988	Hetta Inlet	21	507	24
1989	Hetta Inlet	27	1,135	42
1990	Hetta Inlet	25	879	35
1991	Hetta Inlet	22	680	31
1992	Hetta Inlet	33	1,982	60
1993	Hetta Inlet	55	1,778	32
1994	Hetta Inlet	41	2,424	59
1995	Hetta Inlet	42	1,491	36
1996	Hetta Inlet	27	1,014	38
1997	Hetta Inlet	34	1,407	41
1998	Hetta Inlet	26	726	28
1999	Hetta Inlet	58	2,298	40
2000	Hetta Inlet	46	1,483	32
2001	Hetta Inlet	20	1,129	56
2002	Hetta Inlet	17	553	33
2003	Hetta Inlet	23	954	41
Average, 1985–1993:		40	1,248	33
Average, 1994–2003:		33	1,348	40

APPENDIX B. HETTA INLET AND CORDOVA BAY SUB-DISTRICTS

Appendix B1.–Commercial harvest of sockeye salmon in Hetta Inlet and Cordova Bay sub-districts, 1960–2003 (ADF&G Div. of Commercial Fisheries database 2004; refer to Figure 1 for location of sub-districts).

		Harvest by Sub-District					
YEAR	**GEAR**	**103-11**	**103-15**	**103-21**	**103-23**	**103-25**	**103-30**
1960	Purse Seine	65	3	217	69	9686	131
1961	Purse Seine	3016	335	5707	1903	3336	6
1962	Purse Seine	435	48	687	229	15	1
1963	Purse Seine	1592	7	932	621	4010	399
1964	Purse Seine	429	25	213	142	37	134
1965	Purse Seine	1481	116	4047	2698	23259	531
1966	Purse Seine	2393	14	2034	1357	1736	598
1967	Purse Seine	384	2364	825	549	4873	96
1968	Purse Seine	682	0	871	579	2871	172
1969	Purse Seine	14	0	328	10	0	21
1970	Purse Seine	441	2	966	863	1184	101
1971	Purse Seine	590	0	2204	1249	5158	118
1972	Purse Seine	194	0	2160	1285	34	50
1973	Purse Seine	172	0	387	777	534	67
1974	Purse Seine	729	0	780	339	88	139
1975	Purse Seine	72		3510	3763	2321	24
1976	Purse Seine	106	85	1012	977	1630	1
1977	Purse Seine	1145	0	3262	0	670	0
1978	Purse Seine	89	3	184	25	57	35
1979	Purse Seine	1126	8	653	11	750	85
1980	Purse Seine	1894	10	3612	940	152	251
1981	Purse Seine	5062		3434	5659	8166	912
1982	Purse Seine	356		80	327		8
1983	Purse Seine	347		586			214
1984	Purse Seine	526		460	39	87	23
1985	Purse Seine	3955		2645	254	2192	40
1986	Purse Seine	2337		1895	146	1140	193
1987	Purse Seine	1197		221		35	
1988	Purse Seine	1121		332	36	74	38
1989	Purse Seine	3420		2917	39	1509	15
1990	Purse Seine	5534		1891	356	251	416
1991	Purse Seine	2919	0	1326	5	70	470
1992	Purse Seine	1179		825	193	69	264
1993	Purse Seine	1949		3828	499	1795	761
1994	Purse Seine	1994	0	1946	1793	2514	174
1995	Purse Seine	1989	9	450	66	12	4
1996	Purse Seine	458		4895	2140	8092	5
1997	Purse Seine	688		0			127
1998	Purse Seine	666		596	947	102	24
1999	Purse Seine	9		49	14		
2000	Purse Seine	1421		1495	2086	2787	38
2001	Purse Seine	350		174	48	11	68
2001	Power Troll	8	22	2	0	0	0
2002	Purse Seine	109		823	416	308	17
2003	Purse Seine	91		153	51	113	1
2003	Power Troll	4		1	0	0	1
Annual averages by decade							
1960–1969		1049	291	1586	816	4982	209
1970–1979		466	11	1512	929	1243	62
1980–1989		2022	10	1618	930	1669	188
1990–1999		1739	3	1581	668	1613	249
2000–2003		331	22	441	434	537	21
Annual Average, all years		1190	127	1426	779	2184	154

APPENDIX C. INTERVIEW RESULTS FOR THE HETTA LAKE TERMINAL AREA SUBSISTENCE FISHERY

Appendix C1.–Detailed interview results for the Hetta Lake terminal area subsistence fishery, 2003. Interviews were conducted in Hydaburg. All participants in the subsistence fishery in 2003 were interviewed.

Date	Interview #	Time	Gear type (G =Gillnet S=Seine)	Hours fished	Number of sets	Total sockeye	Cumulative total sockeye	Interviewer's initials	Comments
6/17/03						0	0		no activity
6/18/03						0	0		no activity
6/19/03						0	0		no activity
6/20/03						0	0		no activity
6/21/03						0	0		no activity
6/22/03						0	0		no activity
6/23/03						0	0		no activity
6/24/03						0	0		no activity
6/25/03						0	0		no activity
6/26/03						0	0		no activity
6/27/03						0	0		no activity
6/28/03						0	0		no activity
6/29/03						0	0		no activity
6/30/03						0	0		no activity
7/1/03						0	0		no activity
7/2/03						0	0		no activity
7/3/03						0	0		no activity
7/4/03						0	0		no activity
7/5/03						0	0		no activity
7/6/03						0	0		no activity
7/7/03						0	0		no activity
7/8/03						0	0		no activity
7/9/03						0	0		no activity
7/10/03						0	0		no activity
7/11/03						0	0		no activity
7/12/03						0	0		no activity
7/13/03						0	0		no activity
7/14/03						0	0		no activity
7/15/03						0	0		no activity
7/16/03		3			2	0	0		no activity
7/16/03		4			2	0	0		4 pinks
7/17/03		6			3	0	0		1 chum
7/17/03		4	G		1	0	0		2 chum
7/18/03	1	1250	S	2.0	1	25	25	DE	**First Sockeye**
7/19/03	1	1900	G	6.0	3	28	53	BS	
7/20/03	2	1300	S	4.0	3	74	127	DE	
7/21/03	3	1900	S	1.0	1	20	147	DE	
7/22/03	1	1900	S	1.0	1	57	204	PA	
7/23/03	4	2000	S	1.0	1	47	251	DE	
7/24/03							251		
7/25/03	5	2100	S	2.0	1	12	263	DE	
7/26/03							263		
7/27/03	2	2000	S	6.0	5	206	469	BS	
7/27/03	6		S	6.0	5	154	623	DE	time not recorded

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Date	Interview #	Time	Gear type (G =Gillnet S=Seine)	Hours fished	Number of sets	Total sockeye	Cumulative total sockeye	Interviewer's initials	Comments
7/28/03	2	1900	S			80	703	pa	hrs sets not recorded
7/29/03						0	703		
7/30/03	3	2000	S	3.0	1	27	730	pa	long set!
7/31/03	3	1930	S	9.0	5	115	845	bs	
8/1/03	1	1300	S	3.0	2	38	883	LC	
8/1/03	4	1800	S	6.0	4	75	958	bs	
8/1/03	5	1200	S	6.0	5	41	999	bs	
8/1/03	4	2030	S	8.0	5	91	1090	bs	
8/1/03	5	2100	S	5.0	6	122	1212	bs	
8/2/03	2	1535	S	2.0	2	37	1249	LC	
8/2/03	4	1800	S	6.0	6	106	1355	pa	
8/3/03	3	1400	S	3.0	4	132	1487	LC	
8/3/03	8	1900	S			26	1513	bs	hrs not recorded
8/3/03	7	1900	S	5.0	4	92	1605	de	
8/4/03	5	1900	S	2.0	1	35	1640	pa	
8/4/03	4	1320	S	0.5	1	30	1670	LC	
8/4/03	9	2000	S			66	1736	bs	hrs not recorded
8/5/03	10	1950	S	7.0	7	230	1966	BS	
8/5/03	5	1700	S	2.0	1	100	2066	LC	
8/6/03	11	1950	S	2.0	2	61	2127	BS	
8/6/03	6	1835	S	6.0	7	57	2184	LC	
8/7/03	7	1900	S	4.0	7	225	2409	LC	
8/7/03	8	1835	S	1.0	1	47	2456	LC	
8/7/03	8	2100	S	3.0	4	94	2550	DE	
8/7/03	9	2100	S	6.0	3	20	2570	DE	
8/8/03	10	1700	S	7.0	6	97	2667	DE	
8/8/03	11	1700	S	6.0	6	70	2737	DE	
8/8/03	12	1830	S	6.0	5	21	2758	BS	
8/8/03	13	1930	S	5.0	7	80	2838	BS	
8/8/03	6	1800	S	1.0	1	24	2862	PA	
8/9/03	14	2030	S	7.0	5	23	2885	BS	
8/9/03	15	2030	S	8.0	7	77	2962	BS	
8/9/03	9	1700	S	6.0	4	78	3040	LC	
8/10/03	12	2100	S	6.0	10	329	3369	DE	
8/11/03	16	1430	S	2.0	2	84	3453	BS	
8/12/03	17	2030	S	4.0	5	87	3540	BS	
8/12/03	18	1600	S	1.0	1	20	3560	BS	
8/13/03	13	1800	S	2.0	1	20	3580	DE	
8/13/03	14	1800	S	4.0	4	65	3645	DE	
8/14/03	19	1930	S	5.0	3	297	3942	BS	
8/15/03							3942		
8/16/03	20	2100	S	7.0	7	157	4099	BS	
8/16/03	21	2100	S	6.0	7	190	4289	BS	
8/17/03	15	2030	S	6.0	5	71	4360	DE	
8/17/03	16	2030	S	5.0	4	51	4411	DE	

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Date	Interview #	Time	Gear type (G =Gillnet S=Seine)	Hours fished	Number of sets	Total sockeye	Cumulative total sockeye	Interviewer's initials	Comments
8/17/03	17	2030	S	6.0	6	56	4467	DE	
8/17/03	18	2030	S	5.0	4	62	4529	DE	
8/18/03							4529		
8/19/03							4529		
8/20/03							4529		
8/21/03	19	1900	S	4.0	4	206	4735	DE	
8/21/03	20	1900	S	4.0	4	146	4881	DE	
8/21/03	21	1900	S	2.0	1	80	4961	DE	
8/22/03	22	2000	S	5.0	5	67	5028	DE	
8/23/03							5028		
8/24/03							5028		
8/25/03	22	2030	S	7.0	7	322	5350	BS	
8/26/03	23	1900	S	4.0	5	94	5444	BS	
8/27/03	24	1900	S	1.0	1	30	5474	BS	
8/28/03	25	1400	S	3.0	2	62	5536	BS	
8/29/03	26	1700	S	7.0	6	183	5719	BS	
8/30/03	27	1930	S	3.0	3	51	5770	BS	
8/31/03						0	5770	BS	no activity
Totals	**64**			**263.5**	**245**	**5770**			

APPENDIX D

Appendix D1.–Seasonal mean biomass of all zooplankton and of *Daphnia* sp. and mean length of *Daphnia* sp. (weighted by abundance) in selected sockeye-producing lakes in Southeast Alaska.

	2001 Seasonal mean biomass (mg ·m^2)				2002 Seasonal mean biomass (mg ·m^2)				2003 Seasonal mean biomass (mg ·m^2)		
Lake	**All zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**	**Lake**	**All zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**	**Lake**	**All Zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**
Sitkoh	651	93	0.73	Hoktaheen	651	20	0.91	Kutlaku	618	84	0.51
Kanalku	371	119	0.95	Sitkoh	579	201	0.79	Tumakof	500	0	0.66
Salmon Bay	364	85	0.94	Tumakof	496	2	0.65	Klawock	431	37	0.97
Hoktaheen	328	32	0.87	Klawock	499	16	0.90	Kanalku	371	78	0.75
Kook	299	37	0.87	Kanalku	420	137	0.75	Salmon Bay	351	32	0.93
Luck	234	17	0.86	Kook	315	52	0.80	Klag	316	7	0.68
Klawock	217	12	0.94	Luck	316	18	0.77	Luck	201	6	0.73
Klag	181	4	0.65	Klag	222	5	0.97	Thoms	163	7	0.55
Kutlaku	177	32	0.63	Salmon Bay	205	19	0.75	Eek	147	0	na
Falls	104	0	0.66	Kutlaku	131	35	0.51	Hetta	45	1	0.68
Thoms	144	9	0.60	Thoms	119	7	0.57	Falls	29	1	0.66
Hetta	34	0	0.63	Hetta	47	4	0.67	Sitkoh	na	na	na
Gut Bay	33	1	0.60	Falls	29	1	0.69	Kook	na	na	na
				Gut Bay	24	1	0.61	Gut	na	na	na
Average	245	34	0.76	Average	311	40	0.75	Average	288	23	0.71
Median	217	17	0.73	Median	269	17	0.75	Median	316	7	0.68