THOMS, SALMON BAY AND LUCK LAKES SOCKEYE SALMON (*Oncorhynchus nerka*) STOCK ASSESSMENT PROJECT 2002 ANNUAL REPORT

By

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and
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REGIONAL INFORMATION REPORT[1] NO. 1J04-11

Annual report to the
U.S. Forest Service to
fulfill obligations for
Sikes Act Contract
Number 43-0109-1-0112
Study Number FIS01-127

Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 240020
Douglas, Alaska 99824-0020

April 2004

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ACKNOWLEDGMENTS

We wish to thank John Feller, Kate Frabel, Kris Collins, Hal Geiger, Kim Vicchy, Andy Piston, Xinxian Zhang, and Steve Heinl for their editing, technical assistance, and advise. The comments from reviewer Doug McBride from the Office of Subsistence Management, US Fish and Wildlife contributed greatly to the overall clarity and quality of this report. The Wrangell Cooperative Association liaison, Paul Rushmore, provided invaluable technical and logistical assistance. We would also like to thank Malcolm McEwen and Conan Steele for the hydroacoustic and mid-water trawl fieldwork, data analysis, and write-up. We thank Annabelle Reedy, the ADF&G publication specialist for preparing the final report for publication. We are grateful to the ADF&G scale age and limnology labs for processing all the scale and limnology samples.

PROJECT SPONSORSHIP

The Federal Subsistence Board, managed by US Fish and Wildlife Service – Office of Subsistence Management, approved the Thoms, Salmon Bay, and Luck lakes Subsistence Sockeye Salmon Project (Study Number FIS01-127). 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 (ADFG), and the Wrangell Cooperative Association (WCA). This annual report partially fulfills contract obligations for Sikes Act Contract (43-0109-1-0112).

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ABSTRACT

Sockeye salmon (*Oncorhynchus nerka*) returning to Thoms, Salmon Bay, and Luck lakes are an important subsistence resource for the people of Wrangell, Petersburg, and Prince of Wales Island. The Thoms, Salmon Bay, and Luck Lakes Sockeye Salmon Stock Assessment Project was initiated because of concerns about the potential increase in harvest of sockeye salmon returning to these lake systems. Unfortunately, not much was known about these sockeye stocks until this project was initiated. In this report, we summarize work conducted during the second year of project operations, 2002.

In Thoms Lake, the mark recapture study of the spawning population estimated the minimum sockeye escapement at 5,900 fish. A hydroacoustic survey was confounded by high densities of Chaoborus and did not provide a valid estimate of sockeye fry densities or a total lake population. Sockeye fry comprised 94% of the mid-water trawl sample and the remaining 6% were sticklebacks. The mid-water trawl also provided an estimate of age and species composition; 88% age-0 sockeye fry and 12% were age-1 fry. Thoms Lake had a seasonal mean zooplankton density of 66,000 plankters per m^2 and a seasonal mean weighted biomass of 119 mg per m^2. The seasonal mean euphotic zone depth was 2.61 m.

In Salmon Bay Lake, a mark recapture study of the spawning population estimated the minimum sockeye escapement at 43,600 fish. A hydroacoustic survey estimated a sockeye fry density of 0.02 fry per m^2 and a total lake population of 62,168 sockeye fry. Sockeye fry comprised 70% of the mid-water trawl sample and the remaining 30% were sticklebacks. Ninety-eight percent of the sockeye fry captured in the mid-water trawl were Age-0; 2% were Age-1. Salmon Bay Lake had a seasonal mean zooplankton density of 132,000 plankters per m^2 and a seasonal mean weighted biomass of 195 mg per m^2. The seasonal mean euphotic zone depth was 4.46 m.

In Luck Lake, a mark recapture study of the spawning population estimated the minimum sockeye escapement at 16,100 fish. A hydroacoustic survey estimated a sockeye fry density of 0.23 fry per m^2 and a total lake population of 255,887 sockeye fry. Ninety-nine percent of the sockeye fry captured in the mid-water trawl were age-0. Sockeye fry comprised 97% of the mid-water trawl sample and the remaining 3% were sticklebacks. Luck Lake had a seasonal mean zooplankton density of 199,000 plankters per m^2 and a seasonal mean weighted biomass of 311 mg per m^2. The seasonal mean euphotic zone depth was 4.66 m.

This year's results provide the foundation for a multiple-year study to assess the health of the sockeye salmon stocks in Thoms, Salmon Bay, and Luck lakes and to set a range of escapement goals capable of sustaining these populations for many generations.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, Thoms Lake, Salmon Lake, Luck Lake, Prince of Wales Island, Wrangell Island, stock assessment, limnology, zooplankton, harvest, subsistence, escapement, hydroacoustic

INTRODUCTION

Sockeye salmon (*Oncorhynchus nerka*) returning to Thoms, Salmon Bay, and Luck lakes are an important subsistence resource for the people of Wrangell, Petersburg, and Prince of Wales Island. The Thoms, Salmon Bay, and Luck Lakes Sockeye Salmon Stock Assessment Project was initiated in 2001 because of concerns about the potential increase in harvest of sockeye salmon returning to these lake systems (Lewis and Cartwright 2002). Information on the health of the sockeye populations of these systems is limited. Thoms and Salmon Bay lakes produce moderate numbers of sockeye salmon and have a long history of subsistence fishery exploitation. Although Luck Lake has very little history of subsistence fishing, the residents on Prince of Wales Island (POW) are interested in increasing fishing opportunities in this system. Salmon Bay Lake has sporadic limnology and escapement information available from foot and aerial surveys and a weir operated during the 1980s. Luck and Thoms lakes have even less escapement, fisheries, and limnology information.

The goal of these multiple-year studies is to gather enough information about these sockeye salmon populations and their habitat, to set a range of escapement goals and monitor the response of the system to these ranges. Because we only have access to the freshwater component of the life history of sockeye salmon, we focused on determining if sockeye production is low and if so, is it limited by insufficient escapement, spawning area or rearing habitat? The management action would be different for each situation. For example, if escapement is limiting production, managers might impose closures on the commercial and subsistence fisheries to allow more fish to escape into the lake. If production is limited by spawning area or food availability (rearing habitat), managers might consider harvesting more fish in the fisheries (up to some threshold) so that over-escapement does not occur. This study begins to collect baseline data to determine if we should be concerned about these three sockeye lake systems and to describe emerging patterns that might shed light on the mechanisms limiting production. This annual report summarizes the information collected in 2002, the second year of this study, and compares it to 2001.

HISTORY OF THE HUMAN USE OF THE AREA

Native Subsistence History

The Tlingit Indians have occupied the area surrounding present day Wrangell for centuries. The local Tlingit are part of the Stikine *kwaan* and were historically one of the most influential Tlingit groups (Betts et al. 1994a, 1994b). Their territory covered a large area, including the mainland coast from Cape Fanshaw to the Cleveland Peninsula, the eastern half of Kupreanof Island including the current Petersburg area, the northeast coast of Prince of Wales Island from Red Bay to Thorne Bay and the islands of Mitkof, Zarembo, and Etolin (Betts et al. 1994a, 1994b, Goldschmidt et al. 1998). The Stikine Tlingit also occupied, traveled, and traded as far as 160 miles up the Stikine River. Fish camps for subsistence resource harvest were located near the main fish producing river and lake systems throughout their territory. These areas include the

sockeye systems Thoms, Salmon Bay, and Luck lakes that are the subject of this project (Figure 1). The remains of a large fish camp with a stone fish trap still remains at Salmon Bay. Thoms Creek has also had a long history of use by the Stikine Indians and still is part of their permanently occupied fishing territory today. Scattered camps in the Coffman Cove, Thorne Bay, and Whale Pass area provided access to the Luck Lake fishery although little lake-specific information is available (Goldschmidt et al. 1998). By the early 1900's, the Stikine Tlingit population, much reduced by disease, had moved their main village to what is now Wrangell (Betts et al. 1994a).

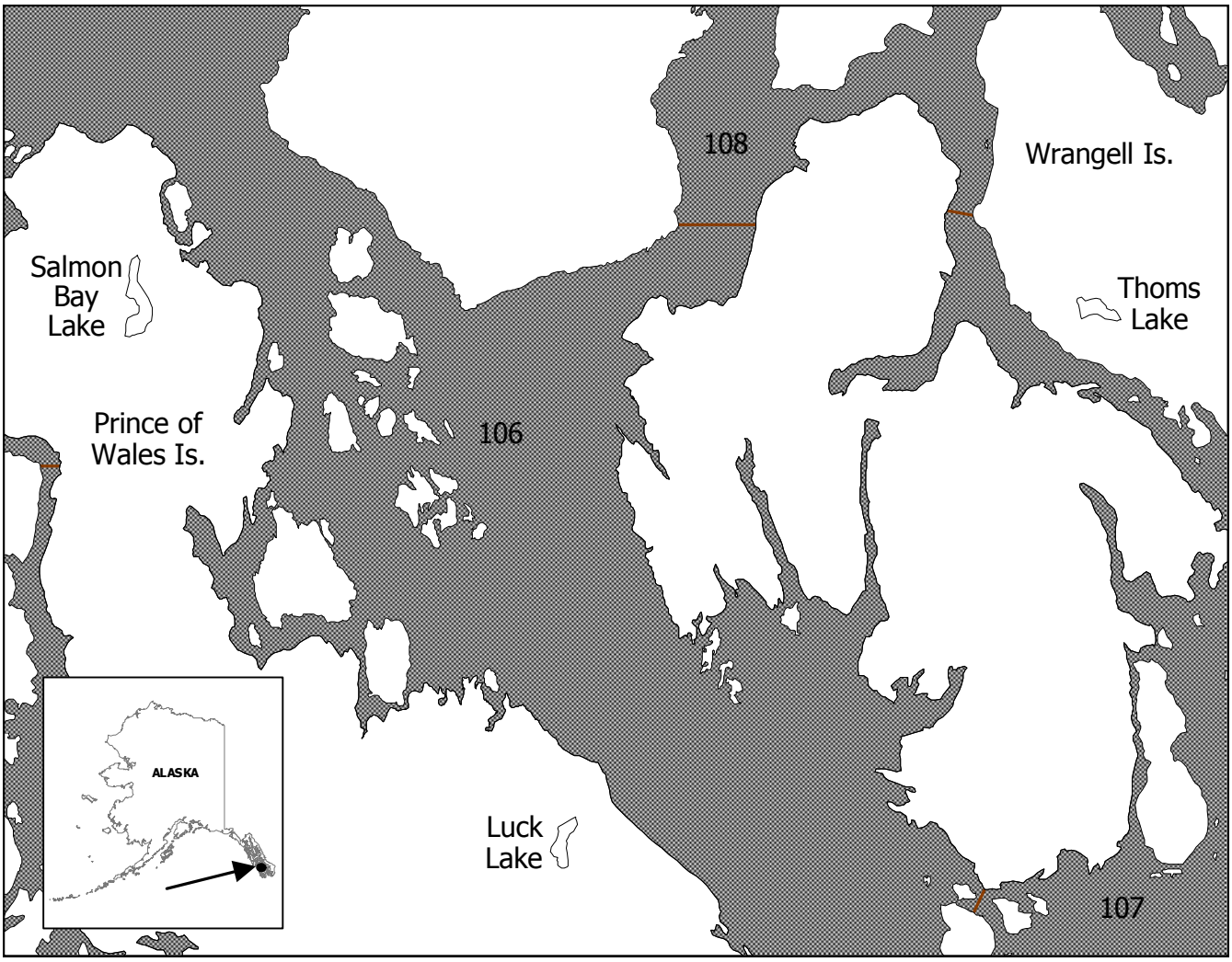

Figure 1. The geographic location of Thoms, Luck, and Salmon Bay lakes within the State of Alaska, and relative to commercial fishing districts.

Early commercial fishery operations and canneries shaped the evolution of Petersburg and Wrangell as economic and population centers. The town of Petersburg grew up around the Icy Strait Packing Company. The Aberdeen Packing Company built a salmon processing plant at the mouth of the Stikine River in 1887 and the Glacier Packing Company was established in

Wrangell in 1889. This time of transition was reflected in the Native American community by a transformation to a combination subsistence and cash economy (Betts et al. 1994a, 1994b). The combination subsistence and cash economic demographic structure continues today to various degrees.

Community Subsistence Fishery History

The ADF&G subsistence permit system, started in 1985, requires users to voluntarily return harvest information on a permit each year. The harvest reported on these permits is considered to be a conservative estimate of harvest due to under reporting (TRUCS, 1988). Each fisher must obtain a State Subsistence Salmon and Personal Use Permit for the Petersburg/Wrangell Management Area to take fish in the terminal subsistence fishery in the marine waters (State jurisdiction) adjacent to Thoms and Salmon Bay Lakes. Even though Luck Lake is not specifically listed on the ADF&G Petersburg/Wrangell permit, the Area Management Biologist will issue a limited number of permits for this system (William Bergmann, ADF&G Petersburg, personal communication).

Several factors influence salmon harvest patterns in Wrangell, Petersburg, and Prince of Wales Island including weather conditions, resource abundance, availability of boats, harvest area access, and regulations (Betts et al. 1994a, Betts et al. 1994b). The near shore areas and creeks around Wrangell are currently fished by a greater number of households than other areas. This is due primarily to their proximity to town. In a recent survey, 95% of Wrangell households reported using subsistence fisheries resources and 24% specifically reported using sockeye salmon (Betts et al. 1994a).

At Thoms Lake, the number of permits, reported subsistence harvest, and catch per permit (CPP) is relatively stable through time (Figure 2). From 1985-1993, there was an average of 285 fish harvested per year on an average of 26 returned permits and a CPP of 11. From 1994 to 2001, there was an average reported harvest of 307 fish on an average of 26 returned permits and a CPP of 12. In 2001, 20 permit holders reported harvesting 163 sockeye salmon for a CPP of 8.2 from Thoms Lake. In 2002, 17 permit holders' harvested 320 sockeye salmon, 19 fish/permit.

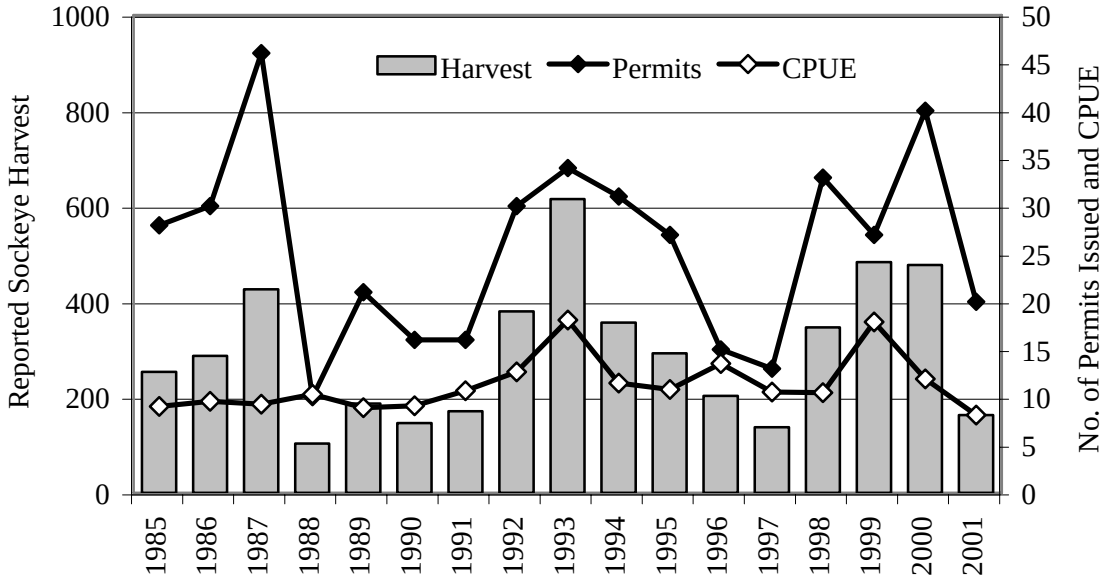

Figure 2. Summary of Thoms Lake subsistence fishery salmon harvest by species, 1985–2001 based on returned permits.

The reported sockeye salmon catch in the subsistence fishery at Salmon Bay Lake between 1985 and 2000 averaged 400 sockeye salmon per year, and varied from 83 fish (1988) to 724 fish (1998). The average reported subsistence harvest and number of permits at Salmon Bay Lake doubled from 320 during 1985-1993 to 610 fish during 1994-2001 and from 26 to 53 permits over the same time periods, respectively. Salmon Bay Lake catch per permit remained stable at 11 for both time periods (Figure 3). In 2001, 52 permits reported 900 sockeye salmon taken from the terminal area of the Salmon Bay Lake system for a CPP of 17.3. Although this system is open to subsistence fishing June 1 through July 31, 98% of the reported subsistence catch of sockeye salmon is landed in July. In 2002, 61 permits landed 1,160 sockeye salmon, averaging 19 fish/permit.

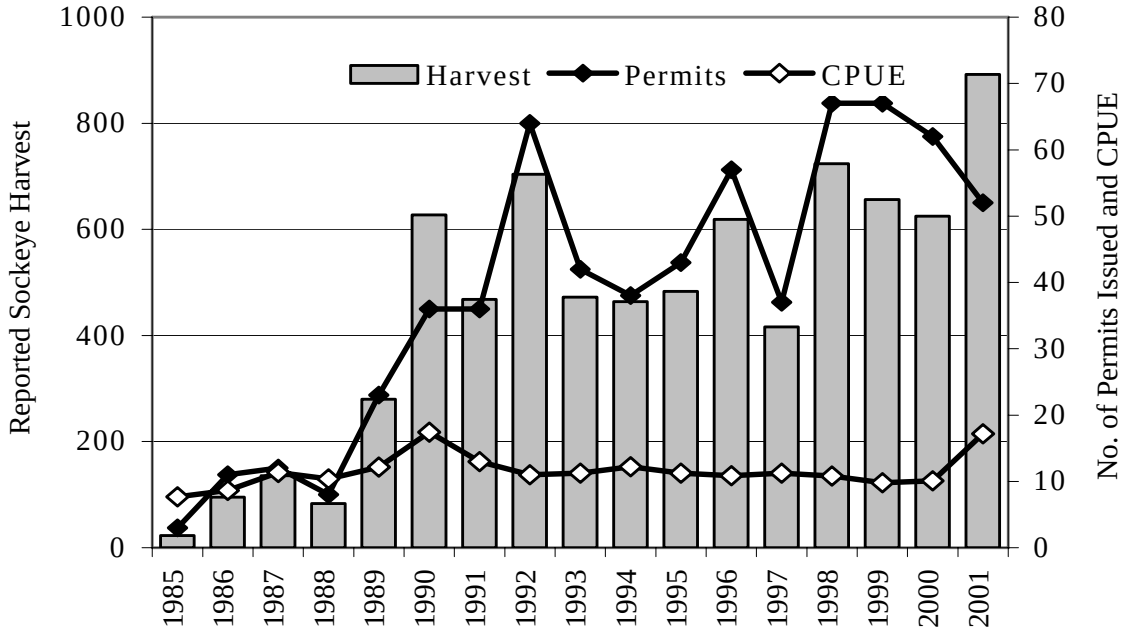

Figure 3. Summary of Salmon Bay Lake subsistence fishery salmon harvest by species, 1985–2001 based on returned permits.

The reported subsistence catches of sockeye salmon in the Luck Lake area are very low; only 22 sockeye salmon, caught in 1990, were reported between 1985 and 2001. No sockeye harvest was reported in 2001 and 2002. However, because the residents of Prince of Wales (POW) Island have road access to this lake, the unreported catch is most likely higher. The residents of POW Island are interested in Luck Lake as an alternative to Klawock Lake and Hatchery Creek for subsistence sockeye salmon if the stock assessment study shows a strong sockeye run in this system.

Commercial Fisheries History

Early commercial harvest records of sockeye salmon provide background information about the level of harvest attributed to each of these three systems. The average annual harvest attributed to Thoms Lake from 1897 to 1926 was 10,800 sockeye salmon with a range of 1,300 to 24,000 (Rich and Ball, 1933; Appendix A). Presently, there are two commercial fisheries in the area adjacent to Thoms: the purse seine fishery in Subdistrict 107-20 and the drift gillnet fishery in Subdistrict 108-40. The most recent 5-year average seine harvest in these subdistricts (6,300) is nearly twice the latest 20-year average of 3,100 sockeye salmon. In the gillnet fishery, the most recent 5-year (4,100) declined compared to the 20-year (5,500) average (ADF&G Div. of Commercial Fisheries database, 2003). The harvest of sockeye salmon in this area peaks the first week in July over all years and the majority of fish were caught between June 23 and July 23. Approximately 7,000, 20,000, and 3,000 sockeye salmon were caught in these subdistricts in

2000, 2001 and 2002 respectively. Purse seining is prohibited north of Thoms Point, 7 km from Thoms Creek. Gillnet fishing is prohibited south of Nemo Point, 16 km from Thoms Creek. Although these area closures are designed to ensure adequate escapement and subsistence opportunities, the number of Thoms Lake sockeye salmon caught in the commercial fisheries is unknown.

The average annual harvest attributed to Salmon Bay Lake from 1896 to 1926 was 26,000 sockeye salmon with a range of 3,500 to 45,000 (Rich and Ball, 1933; Appendix A). Presently the majority of sockeye salmon caught in the vicinity of Salmon Bay Lake, District 106, are caught in the drift gillnet fisheries (69%) and 31% are caught in the purse seine fishery. Approximately 37% of the sockeye salmon were landed in Subdistrict 106-30 and 63% in Subdistrict 106-41. Commercial harvest in Subdistrict 106-30 averaged 58,000 sockeye salmon between 1983 and 2002 and the most recent 5-year annual average was 37,500 sockeye salmon (1998-2002). In Subdistrict 106-41, the commercial harvest averaged 100,000 sockeye salmon between 1983 and 2002 and the most recent 5-year annual average was 69,000 sockeye salmon (1998-2002; ADF&G Database). The sockeye salmon catch in Subdistrict 106-30 was 68,000 and 17,100 sockeye salmon in 2001 and 2002 respectively. In Subdistrict 106-41, commercial fishermen landed 99,200 sockeye salmon in 2001 and 39,000 sockeye salmon in 2002. Approximately 70% of the sockeye catch was taken between June 30 and August 3. The number of sockeye salmon specific to Salmon Bay Lake caught in these commercial fisheries is unknown.

The average annual harvest attributed to Luck Lake from 1904 to 1926 was 11,000 sockeye salmon with a range of 200 to 21,000 (Rich and Ball, 1933; Appendix A). Commercial fisheries harvesting stocks adjacent to Luck Lake (106-10, 106-20, 106-22, 106-30) harvested an average of 40,000 sockeye salmon between 1998 and 2002, and the 20-year average commercial harvest between 1977 and 1997 was 62,000 sockeye salmon with a range of 23,000 (1983) fish to 94,000 fish (1985). The number of Luck Lake sockeye salmon harvested in these fisheries is unknown. However, to ensure adequate escapement, commercial gillnet fishing is not allowed within about 2 km of the stream. Purse seining in waters adjacent to the outlet of Luck Lake, does not usually start until the first or second week in August. This period is after of the majority of Luck Lake sockeye have entered the system.

Stock Assessment Information

Currently there is no escapement goal for sockeye salmon returning to any of these three lakes. However, a variety of data provide some background information on escapements. For example, foot surveys on Thoms Lake in the late 1980s and 1990s recorded an average of 2,000 sockeye salmon in the inlet stream for the last 17 years (1985-2002) and an average of 3,800 sockeye salmon in the early 1980s (1980-1985; ADF&G Database).

Foot surveys were also sporadically conducted by ADFG on Salmon Bay Lake in the 1960s and performed annually for the last 26 years (1974-2000). In September surveys, the average number

of sockeye salmon counted was 3,500 fish with a range between 200 fish in 2000 and 10,800 in 1985. A weir was operated between 1965 and 1968 and then again between 1982 and 1988. The average sockeye salmon escapement counted at the weir between 1965 and 1968 was 8,000 with a range of 3,700 to 11,600. The average sockeye salmon escapement counted at the weir between 1982 and 1988 was 18,300 with a range of 9,000 to 34,000.

The U.S. Bureau of Fisheries maintained a weir on Eagle Creek, the outlet of Luck Lake, from 1928-31, a few hundred yards upstream from the mouth. The average sockeye escapement for that time period was 6,700 fish, with a range of 2,000 to 15,700 fish. In the 1980s and 1990s, aerial and foot survey recorded peak counts between 3,000 and 4,000 sockeye salmon in the outlet stream (ADF&G Database).

OBJECTIVES

1. To estimate escapement of sockeye salmon into each lake so that the estimated coefficient of variation is less than 15% using a mark-recapture program.
2. Describe the age and size structure of the sockeye spawning population by sex and lake.
3. To estimate rearing density of sockeye salmon fry in each lake through hydroacoustic and trawl surveys so that the estimated coefficient of variation is less than 15%.
4. Collect baseline data on in-lake productivity of each lake using established ADF&G limnological sampling procedures, which may include water chemistry, zooplankton sampling, hydroacoustic fry assessments, and smolt sampling.

STUDY SITES

Thoms Lake (Figure 1), in the Thoms Creek system (Alaska Department of Fish and Game [ADF&G] stream #107-30-30) is located on the southwest side of the Wrangell Island on lower Zimovia Strait (56° 11' 01" N, 132° 08' 18" W). This dimictic lake is approximately 2.7-km long, has a surface area of 153 hectares, an elevation of 85 meters, and a max depth of 33 meters. The lake water is clear with some seasonal organic staining. The lake empties 9.6 km via Thoms Creek into Thoms Place off of Zimovia Strait. Native fish species include cutthroat trout (*Oncorhynchus clarki* spp.), Dolly Varden (*Salvelinus malma*), three spine stickleback (*Gasterosteus aculeatus*), cottids (*Cottus* sp.), steelhead (*O. mykiss*), and pink (*O. gorbusha*), chum (*O. keta*), coho (*O. kisutch*), and sockeye (*O. nerka*) salmon. There are two main tributaries, East and Little East creeks, on the north end of the lake with several small inflows scattered along the shore. East Creek represents the primary sockeye and coho salmon spawning area.

Salmon Bay Lake (Figure 1) in the Salmon Bay Creek system (ADF&G stream #106-41-010) is located on the northeast side of the Prince of Wales Island (56° 15' 53" N., 133° 10' 33" W.). This dimictic lake is approximately 4.8-km long, has a surface area of 400 hectares, an elevation of 15

meters, a mean depth of 26.7 meters, and a max depth of 60 meters. The lake water is organically stained and has a volume of 103.9 million cubic meters. The mean euphotic zone depth is 4.7 meters. The lake empties 2 km via Salmon Bay Creek into Salmon Bay on Clarence Straight. Native fish species include cutthroat trout, Dolly Varden, stickleback, cottids, steelhead, and pink, chum, coho, and sockeye salmon. There are three unnamed tributaries at the south end of the lake referred to as southwest head, south head, and east head. These streams represent the primary sockeye and coho salmon spawning areas.

Luck Lake (ADF&G stream #106-10-034) is located at 55° 58' N., 132° 46' W. on the northeast side of Prince of Wales Island, adjacent to Clarence Strait (Figure 1). This dimictic lake has an area of 210 hectares and is 3.2-km long and 0.8 km wide, with its outlet in Eagle Creek at the north end and one major inlet stream, Luck Creek, at the south end. The total drainage area of the system is about 77 km^2. Eagle Creek is about 2.8-km long. It empties into salt water about 2.9-km south of Luck Point in a steep, rocky inter-tidal zone. Sockeye salmon school and hold in the lake near the mouth of Luck Creek. Luck Creek, the primary spawning area, is about 12-km long and has several tributaries. Cascade falls at about 1.9 and 1.6-km upstream impede migration, but some sockeye salmon do pass the falls and spawn above them. The lower part of the east fork tributary is also heavily used by spawning sockeye salmon, coho salmon, and Dolly Varden. An old landslide on the tributary created a 2.4 m barrier falls at about 1.2 km from the confluence with the mainstem stream.

METHODS

Sockeye Fry Population Estimates

Hydroacoustic and mid-water trawl sampling were used to estimate the distribution and abundance of sockeye salmon fry in Thoms, Salmon Bay, and Luck Lakes. Prior to conducting the 2002 lake survey, Luck Lake was divided into seven sections, and Salmon Bay and Thoms Lakes were divided into ten sections each, based on lake area and shape. Ten evenly spaced orthogonal transects were identified within each section and two of these were randomly selected to be surveyed. Transects selected in 2002 became permanent and will be repeated during future surveys. The decision to keep the transects fixed each year reflected a decision to emphasize year-to-year changes in population size in our estimates.

Hydroacoustic Survey

During the acquisition of acoustic targets, we surveyed each selected transect from shore to shore, beginning and ending the sampling at the depth of 10 m. 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. The acoustic equipment consisted of a Biosonics[1] DT-4000™ scientific echosounder (420 kHz, 6° single beam transducer). Biosonics Visual Acquisition © version 4.0.2 software was used to collect and record the data. Ping rate was set at 5 pings · 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 the hydroacoustic surveys to determine the species composition of pelagic fish and the age distribution of sockeye fry. A 2 m x 2 m elongated beam-trawl net with a cod-end was used for the trawl sampling. Trawl sampling was conducted in the area of the lake with the highest concentration of fish, identified during the hydroacoustic survey. An exploratory surface tow was conducted to determine if there were fish on the surface not detected by the down-looking hydroacoustic gear. A surface tow was conducted on clear and stained lakes and will not be repeated in future surveys if no fish were caught. The surface tow was conducted by attaching floats to the top of the tow net so that it floated just beneath the lake surface 30 m back from the boat. Additional tows were conducted at two depths, also identified during the hydroacoustic survey in the same area of highest fish concentration. Two replicate tows were conducted at each depth. The second tow at a given depth was started at the termination point of the first tow. The direction of the second tow for each depth was selected such that it did not sample the same area as the first tow. The trawl duration ranged from 15 to 30 minutes, depending on fish density and lake size and morphology. 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 densities.

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. Fish were preserved with 90% alcohol. Samples from each tow were preserved in separate bottles. The bottle was labeled with the date, lake name, tow number, tow depth, time of tow, and initials of collectors. Fish captured in the tow samples were analyzed at the laboratory to determine species composition and ages of sockeye juveniles. The species composition of the midwater trawl samples was pooled and applied to the total target estimate to calculate each species-specific population estimate. The sockeye fry density and age composition was also calculated using the sockeye fry trawl sample data.

In the laboratory, fish were soaked in water for 60 minutes before sampling to re-hydrate the samples. All fish were identified and the 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. The results of each independent scale ageing were compared. In instances of discrepancy between the two age determinations, a third

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

independent examination was conducted. A proportion of each age class of sockeye fry is used to allocate the hydroacoustic sockeye fry estimates by age. Data were recorded onto a form and then entered into an MS EXCEL spreadsheet.

Data Analysis

Data were analyzed using Biosonics Visual Analyzer © version 4.0.2 software. Echo integration was used to generate a fish density (targets x m^{-2}) for each of the sample sections (MacLennand and Simmonds 1992). The target density for each section was estimated as the mean of these two replicate target densities, with their sample variance. The 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. A target population for each sample section was estimated as the product of mean target density and surface area for each section. The 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, the estimated sampling variance for the whole lake target population estimate was simply the sum of the variances for each section, and was reported as a coefficient of variation (CV; Sokal and Rohlf 1987). If the CV for an estimate was greater than 10% for any of the lakes, more sample sections will be added in that lake in future years.

The apportionment of targets into species composition categories allowed us to get a rough estimate of sockeye fry abundance in those lakes where we had adequate trawl data. An obvious way to estimate the sockeye fry abundance in the entire lake is to simply pool all fish caught in all trawl samples (except the surface tow) into one sample, calculate the proportion of sockeye fry in the pooled sample, and then use this proportion to adjust the estimate of total sonar targets in the lake to an estimate of total sockeye fry. Although this approach should give a reasonable and very usable estimate of the number of sockeye juveniles present in the lake, unfortunately, this approach leaves us without a means to estimate the sampling error in the estimate.

We first assumed that sockeye fry are completely randomly distributed within the lake, and therefore within the multiple trawl samples. If so, we reasoned that the estimate of sampling error could be based on an approximation to the binomial distribution, which is well studied, and formulas for confidence intervals or standard errors can be found in any elementary statistical textbook. We began by developing rules for sample size requirements and using chi-squared tests for heterogeneity to test for similarity among trawl samples. We reasoned that if we had greater than 30 fish targets per trawl sample, if the assumptions of the chi-squared test were met (greater than 5 expected counts per cell and a fairly uniform distribution), that small observed chi-squared statistics would mean that the binomial approximation would be a usable assumption. However, we found that we had inadequate sample sizes to compare trawls at the same depth with these chi-squared tests. When we pooled the samples into one or more depth categories, in general we got small chi-squared statistics with small sample sizes and larger chi-squared statistics with larger sample sizes. In the end, we concluded that a simple, defendable estimate of the variance associated with the estimate of the proportion of sockeye fry is not possible because of the non-uniform distribution of sockeye fry in the lake, the clustering of sockeye fry within the samples and the small sample sizes. If we assume that the distribution is clumped, a negative binomial distribution to account for the clusters could be used if we had adequate trawl samples

at each depth. It is a fairly complex problem to figure out what is an adequate sample. The biometrician has agreed to work on this using existing data.

Sockeye Escapement Estimates

Adult salmon were captured in inlet streams over the entire spawning period. The probability that fish will be captured is likely to vary over time. So, a stratified, two-sample mark-recapture procedure was used to estimate escapement (Seber 1980; Arnason et al. 1995). In a temporally stratified mark-recapture experiment, all individuals released during each of a series of non-overlapping periods (strata) bear the same distinct mark, so that each recaptured fish can be identified by the period during which it was released and period during which it was recaptured. The three assumptions are required to justify the estimate: 1) Closure - no fish enter or leave between the two sample times, 2) No mark loss - fish retain their marks and are correctly identified as marked or unmarked, 3) Equal catchability - all fish in a given recapture stratum, whether marked or unmarked, have the same probability of being sampled.

The field crew conducted four to six mark-recapture sampling efforts in each system, approximately every two weeks over the entire spawning period. Prior to each mark-recapture event, visual counts of sockeye spawners were made by each crewmember in the inlet stream(s), as well as all shoreline areas, where spawners were present. Each inlet stream, or portion of an inlet stream, with sockeye spawners present was defined as a separate stratum. Each crewmember recorded his or her counts separately. At the mouth of inlet streams, beach seines 20 m long and 4 m deep were used to surround sockeye salmon, pulled by a small skiff with outboard motor and crewmembers on foot. Sockeye salmon were sampled in inlet streams using dip nets. All sockeye salmon caught were first inspected for previous marks, then marked with an opercle punch or pattern of punches indicating the trip and day number, and released with a minimum of stress. The total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark were recorded. Mark recovery surveys were conducted on the spawning grounds of each lake every two weeks. Live and dead fish were counted and examined for marks and given a second mark (opercle punch) to prevent duplicate sampling at a later time. In Thoms Lake, all mark-recapture and stream counts were conducted on Thoms Creek on the northeast side of the lake. Mark-recapture and stream counts were conducted to a point on the stream where gradient increases and no more fish were present, approximately 2 km from the mouth. In Salmon Bay Lake, all mark-recapture and stream counts were conducted on two tributaries on the south end of the lake referred to as southwest head (Stream A) and south head (Stream B). Counts and recapture efforts were conducted as far as was feasible on each stream in a single day. In Luck Lake, all mark-recapture and stream counts were conducted on Luck Creek on the south end of the lake. Mark-recapture and stream counts were conducted on the mainstem to the partial barrier falls approximately 2.5 km up stream from the mouth. Additional mark-recapture and stream counts were conducted on the tributary to Luck Creek that enters from the east approximately 1 km above the mouth. Survey efforts on that tributary continued to a barrier falls approximately 2 km upstream from the confluence or until no fish were present.

Data Analysis

We used SPAS program (Stratified Population Analysis System) for the analysis of 2-sample mark-recapture experiments in the stratified populations (Arnason et al. 1996). SPAS, uses a number of analysis and testing methods: Darroch maximum likelihood estimates, Schaefer estimates, and pooled Petersen estimates. For the details, refer to http://www.cs.umanitoba.ca/~popan/. Since only the estimate of escapement is required for our project, SPAS has the advantage of allowing us to pool together some or all of the capture or recapture strata so that we can have a more precise estimate of escapement if doing so will not introduce a serious bias. If a simple Petersen estimate is applied to the stratified data that have been pooled, it is called the pooled Petersen method (Seber 1982). However, the Petersen estimate can be badly biased when the assumption of equal catchability is violated. SPAS gives two types of the chi-square tests (labeled Complete Mixing and Equal Proportions, respectively) to see if pooling strata is acceptable. If either test passes (i.e. $p > 0.05$), it should be safe to use the pooled Petersen estimate. However, even if the tests indicate rejection of pooling, this does not mean that partial or complete pooling is invalid. Other criteria should be examined, including seeing if pooling produces big changes in the estimate of escapement. If pooling leads to a small change, it is probably safe to pool; however, if pooling leads a big change in the estimate, the pooled Petersen estimate may be badly biased. Using the chi-square tests in SPAS as guidelines, we attempted to pool as many of strata as possible to increase precision. In the case that both the ML Darroch model and the pooling approach fail, the estimate of abundance cannot be made.

If we could pool the data, we used the Chapman's form of the pooled Petersen mark-recapture estimate (Seber 1982, p. 60). We let M denote the number of fish marked in a random sample of a population of size N. We let C denote the number of fish examined for marks at a later time, and let R denote the number of fish in the second sample with a mark. Then the estimated number of fish in the entire population, $\hat{N}$, is given by

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

The conditions for accurate use of this methodology are that all sockeye salmon within a strata:

1. have an equal probability of being marked at Klawock Lake; or
2. have an equal probability of being inspected for marks; or
3. marked fish mixed completely with unmarked fish in the population between events; and
4. it is a closed population; and
5. there is no mark-induced mortality; and
6. fish do not lose their marks and
7. all marks are recognizable.

The standard error of that estimate will be calculated as:

$$\mathrm{SE} = \sqrt{v\left(\hat{N}\right)} \tag{2}$$

where $v(\hat{N})$ is

$$v\left(\hat{N}\right) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \approx \frac{\hat{N}(M-R)(C-R)}{(R+1)(R+2)} \tag{3}$$

In the pooled Petersen mark-recapture equation used to estimate $\hat{N}$, R is a random variable, and it can be assumed to follow a Poisson, binomial, or hypergeometric distribution, depending on the circumstances of the sampling. Moreover, 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 such that $\hat{p} = \frac{R}{C}$. We used approximate confidence interval bounds for $\hat{p}$ based on the assumption that R follows a hypergeometric distribution. We defined the confidence bounds for $\hat{p}$ as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, $\hat{N}$, were found by taking reciprocals of the confidence interval bounds for $\hat{p}$, and multiplying by M. That is, the confidence bounds for the Petersen estimate are given by ($M * 1/a_{0.975}$, $M * 1/a_{0.025}$).

Sample size criteria are given in Seber (1982, p. 63). If $\hat{p}$ = 0.1, and the size of the second sample C is at least the minimum given as follows:

$\hat{p}$ (or 1- $\hat{p}$)	0.5	0.4	0.3	0.2	0.1
minimum C	30	50	80	200	600

a 95% confidence interval for $\hat{p}$ is given by

$$\hat{p} \pm \left[1.96\sqrt{\left(1-\frac{C}{\hat{N}}\right) * \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C}\right], \quad \text{(Seber 1982, eq. 3.4).} \tag{4}$$

and the 95% CI bound for the estimated N is

$$95\%CI_{N*} = M * \frac{1}{95\%CI_{\hat{p}}} \tag{5}$$

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 $\hat{p}$ were found from Table 41 in Pearson and Hartley (1966).

Sockeye Escapement Age and Length Distribution

Length, sex and scales of the adult sockeye salmon were collected at each lake during the mark-recapture study to describe the biological structure of the population. The goal was to collect 600 samples through the spawning season (Thompson 1992). 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 aged at the ADF&G salmon aging laboratory in Douglas, Alaska. Age classes were designated following the European aging system where freshwater and saltwater years are separated by a period (e.g., 1.3 denotes 1 year freshwater and 3 years saltwater). Brood year tables were compiled by sex and brood year to describe the age structure of the returning adult sockeye salmon population. The length of each fish was measured from mid eye to tail fork to the nearest millimeter (mm).

The proportion of each age-sex group k and associated standard errors of the proportions were calculated by the standard binomial formula:

$$\hat{p}_k = \frac{n_k}{n} \tag{6}$$

$$SE(\hat{p}_k) = \sqrt{\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}} \tag{7}$$

where n_k is the number of samples in age-sex group k, n is the total number of samples aged, and N is the estimated escapement (Thompson 1992, p. 35-36).

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

$$\bar{y}_k = \frac{1}{n_k} \sum_{i=1}^{n_k} y_{ki} \tag{8}$$

$$SE(\bar{y}_k) = \sqrt{\frac{1}{n_k^{\,2}}} * \sqrt{\left(\frac{1}{n_k - 1}\right) \sum_{i=1}^{n_k} (y_{ki} - \bar{y}_i)^2} \tag{9}$$

(Thompson 1992, p. 42-43).

Limnology

Limnology sampling was conducted at two stations on each lake five times between May and October, 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 at both stations, A and B, on each lake. Sampling was conducted at Thoms Lake on May 7, June 6, July 25, September 6, and October 8. Sampling was conducted at Salmon Bay and Luck Lakes on the same dates, with the exception that the September sampling date was the 10th in these two lakes.

Vertical Light Penetration, Temperature, and Dissolved Oxygen

Measurements of under-water light penetration (footcandles) were taken at 0.5 m intervals, from the surface to a depth equivalent to one percent of the subsurface light reading (5 cm), using a Protomatic International Light submarine photometer. Vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface) versus depth. The euphotic zone depth (EZD) is defined as the depth to which 1% of the subsurface light (phototsynthetically available radiation [400-700 nm]) penetrates the lake surface (Schindler 1971). EZD was calculated from the equation: EZD = 4.6205/ K_d (Kirk 1994).

Temperature (^oC) was measured at 1 m intervals from the lake surface to generate a vertical temperature profile and to measure the depth of the thermocline. Dissolved oxygen (mg $\times$ L^{-1}) was measured at 1 m depth intervals from the lake surface to within 2 m of the lake bottom, with an YSI model 58 meter dissolved oxygen and temperature meter. Dissolved oxygen was calibrated each sampling trip with a 60 ml Winkler field titration (Koenings et al. 1987).

Secondary Production

Zooplankton is the primary food for sockeye salmon and cladocerans are their preferred food within the zooplankton community. By estimating the biomass and number of zooplankton by

genera and in some cases by species throughout the season, we can observe how the species composition changes over the season and between years. This information may provide insight into how the zooplankton community responds to different fry densities and adult escapement levels. Zooplankton samples were collected at two stations on each lake with a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from 1 m above the station depth 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), Pennak (1978), Wilson (1959), and Yeatman (1959). Zooplankton were counted from three separate 1 ml subsamples taken with a Hensen-Stemple pipette and placed in a 1 ml Sedgewich-Rafter counting chamber. 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 using a calibrated ocular micrometer (Koenings et al. 1987). Zooplankton biomass was estimated using species-specific dry weight (Y-axis) regressed against zooplankter length (X-axis; Koenings et al. 1987). The seasonal mean density and body size was used to calculate the seasonal zooplankton biomass (ZB) for each species. Marco-zooplankters were further separated by sexual maturity where ovigorous (egg bearing) zooplankters were also identified. Zooplankton was reported by genera and in some cases species and by the sum of all species (referred to as total zooplankton density).

RESULTS

Sockeye Fry Assessment

Thoms Lake

A hydroacoustic survey and mid-water trawls were conducted on September 23, 2002. Unfortunately, high densities of phantom midges (*Chaoboridae*) confounded the hydroacoustic survey and we could not calculate a valid estimate of sockeye fry densities or a total lake population (Figure 4). The midwater trawling at about 8 m was overwhelmingly phantom midges. Although some fish were present in the trawl sample, the density of midges was so high that the software was unable to distinguish small pelagic fish from these aquatic insects. A total of 212 fish, including 206 sockeye fry and 6 sticklebacks, were caught in five mid-water trawls (Table 1). One hundred and seventy-six (88%) sockeye salmon fry were age-0 and 24 (12%) were age-1. The age-0 fry had a mean snout-fork length of 51.9 mm (SE = 0.5 mm) and a mean weight 1.3 g (SE = 0.2 g). The age-1 fry had a mean snout-fork length of 80.2 mm and a mean weight of 5.0 g. The bimodal length frequency distribution shows the size difference between the two age classes of sockeye fry (Figure 5). Due to small sample size, the age-1 fry lengths were not normally distributed. The average snout-fork length of the 12 sticklebacks was 75.0 mm (SE = 2.5) with a mean weight of 4.1 g (SE = 0.3). Although a hydroacoustic population estimate was not possible, it appears that the sockeye fry dominated the small pelagic fish community in 2002.

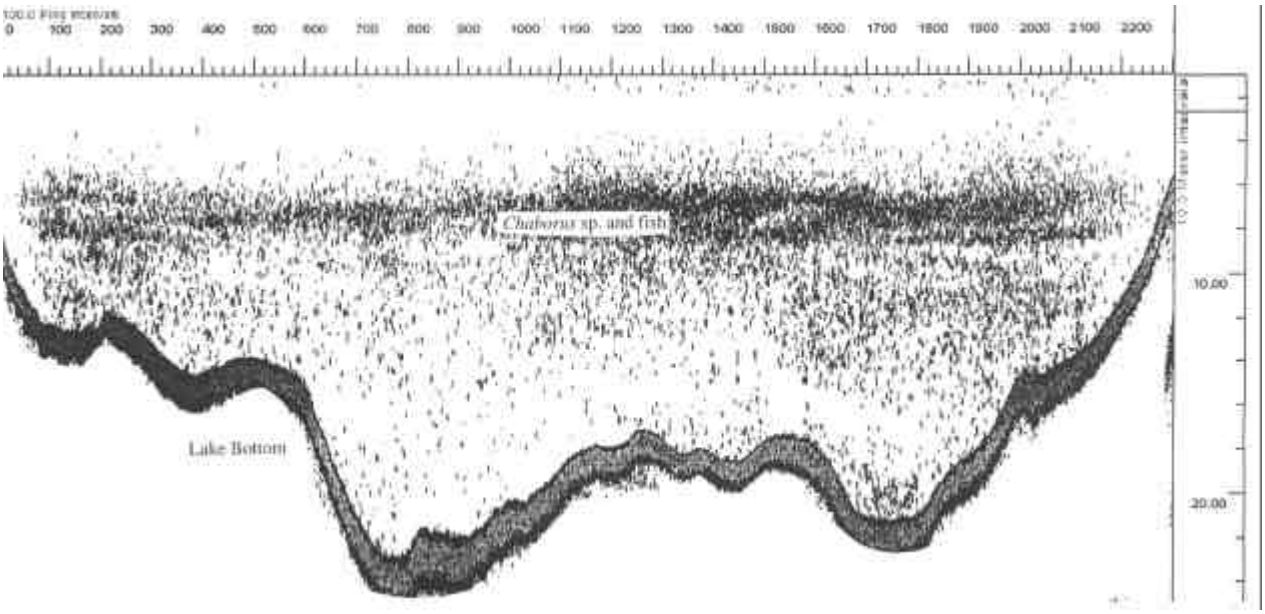

Figure 4. Thoms Lake hydroacoustic echogram showing clouds of *Chaborus* sp. that interfered with hydroacoustic data analysis, 2002.

Table 1. Summary of Thoms Lake tow netting results by tow, depth (m), time (min) species, mean length (mm) with standard error and mean weight (g) with standard error in 2002.

Tow	Depth	Time (min)	Species	Count (*n*)
5	1	15	Sockeye age 0	1
			Stickleback	4
1	7	15	Sockeye age 0	12
			Sockeye age 1	1
			Stickleback	1
2	7	15	Sockeye age 0	41
			Sockeye age 1	5
			Stickleback	4
3	9	15	Sockeye age 0	26
			Sockeye age 1	7
			Stickleback	1
4	9	15	Sockeye age 0	96
			Sockeye age 1	11
			Stickleback	2

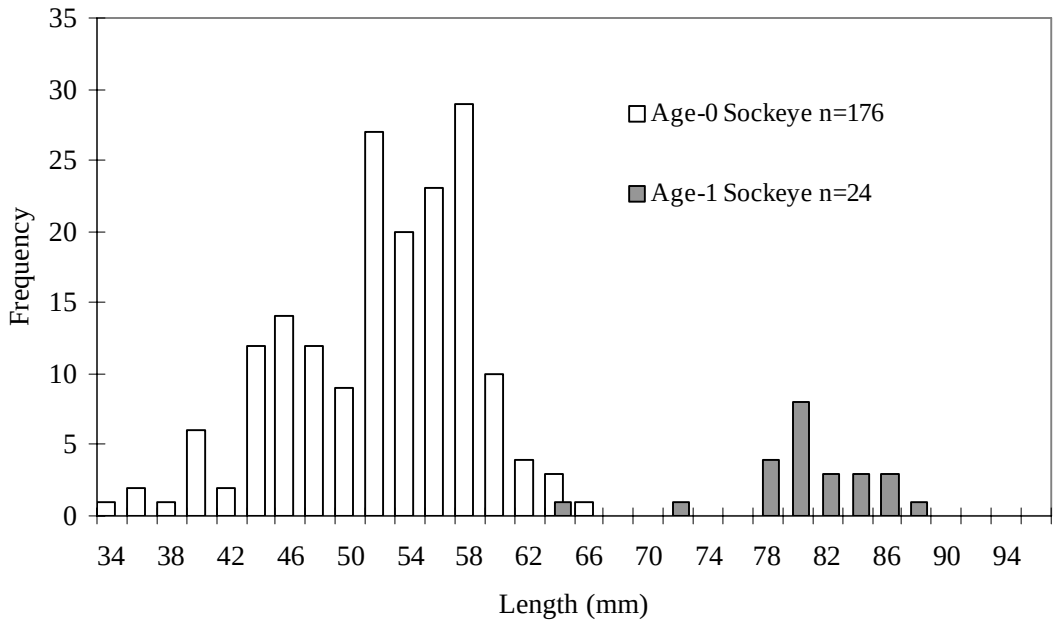

Figure 5. Length frequency distribution of fish caught in the Thoms Lake mid-water trawl 2002.

Salmon Bay

A hydroacoustic survey and mid-water trawls were conducted on September 22, 2002. The total hydroacoustic target estimate was 88,500 small pelagic fish (CV = 15%) for Salmon Bay Lake. A total of 84 fish were caught in 9 mid-water trawls, of which 59 were sockeye fry and 25 were sticklebacks (Table 2). Fifty-eight sockeye salmon fry were age-0 and one was age-1. The age-0 fry had a mean snout-fork length of 47.6 mm (SE = 0.8 mm) and a mean weight 1.0 g (SE = 0.1 g). The age 1 fry had a snout-fork length of 94.0 mm and weighed 5.8 g. There was no overlap in the size distribution between age-0 and age-1 sockeye fry and sticklebacks (Figure 6). The average snout-fork length of the 25 sticklebacks was 77.9 mm (SE = 2.5) and the mean weight was 4.8 g (SE = 0.2). If we can assume that the species composition of the trawl samples is roughly proportional to the species composition in the lake, the estimated total lake population of sockeye fry was 62,168, and the sockeye fry density was 0.02 fry $\cdot$ m^{-2}. However, we were unable to estimate the sampling error associated with this approximate estimate of sockeye fry in Salmon Bay Lake.

Table 2. Summary of Salmon Bay Lake tow netting results by tow, depth (m), time (min) species, mean length (mm) with standard error and mean weight (g) with standard error in 2002.

Tow	Basin	Depth	Time	Species	Count (*n*)
1	A	1	15	Stickleback	3
2	A	8	15	Sockeye age 0	3
				Stickleback	3
3	A	8	15	Sockeye age 0	10
				Sockeye age 1	1
				Stickleback	12
4	A	10	15	Sockeye age 0	3
				Stickleback	1
5	A	10	15	Sockeye age 0	12
				Stickleback	6
6	B	8	15	Sockeye age 0	16
7	B	8	15	Sockeye age 0	7
8	B	10	15	Sockeye age 0	2
9	B	10	15	Sockeye age 0	5

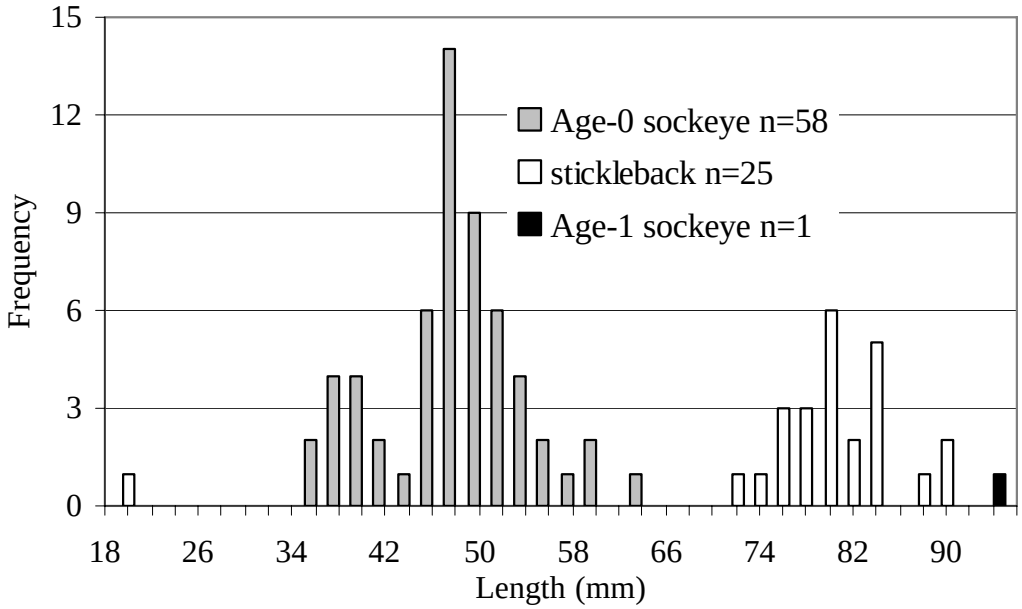

Figure 6. Length frequency distribution of fish caught in the Salmon Bay Lake mid-water trawl 2002.

Luck Lake

A hydroacoustic survey and mid-water trawls were conducted on July 22, 2002. The total hydroacoustic target estimate for the lake was about 262,600 small pelagic fish (CV = 7%). A total of 666 fish were caught in five mid-water trawls, of which 649 were sockeye fry and 17 were sticklebacks (Table 3). Six hundred and forty-six sockeye salmon fry were age-0 and 3 were age-1. The age-0 fry had a mean snout-fork length of 38.4 mm (SE = 0.1) and a mean weight 0.42 g (SE = 0.004). The age-1 fry had a mean snout-fork length of 64.0 mm (SE = 2.0) and a mean weight of 2.35 g (SE = 0.2). The bimodal length frequency distribution reflects the size difference between sockeye fry and stickleback (Figure 7). The average snout-fork length of the 17 sticklebacks was 65.2 mm (SE = 2.1) with a mean weight of 2.43 g (SE = 0.2). If we can assume that the species composition of the trawl samples is roughly proportional to the species composition in the lake, the estimated total lake populations were 255,887 sockeye fry and 6,700 sticklebacks, and the sockeye fry density was 0.23 fry $\cdot$ m^{-2}. However, we were unable to estimate the sampling error associated with this approximate estimate of sockeye fry in Luck Lake.

Table 3. Summary of Luck Lake tow netting results by tow, depth (m), time (min) species, mean length (mm) with standard error and mean weight (g) with standard error in 2002.

Tow	Depth	Time	Species	Count (*n*)
1	1	15	Stickleback	7
2	7	15	Sockeye age 0	491
			Sockeye age 1	1
			Stickleback	1
3	7	15	Sockeye age 0	81
			Sockeye age 1	1
			Stickleback	3
4	10	15	Sockeye age 0	38
			Stickleback	4
5	10	15	Sockeye age 0	36
			Stickleback	2

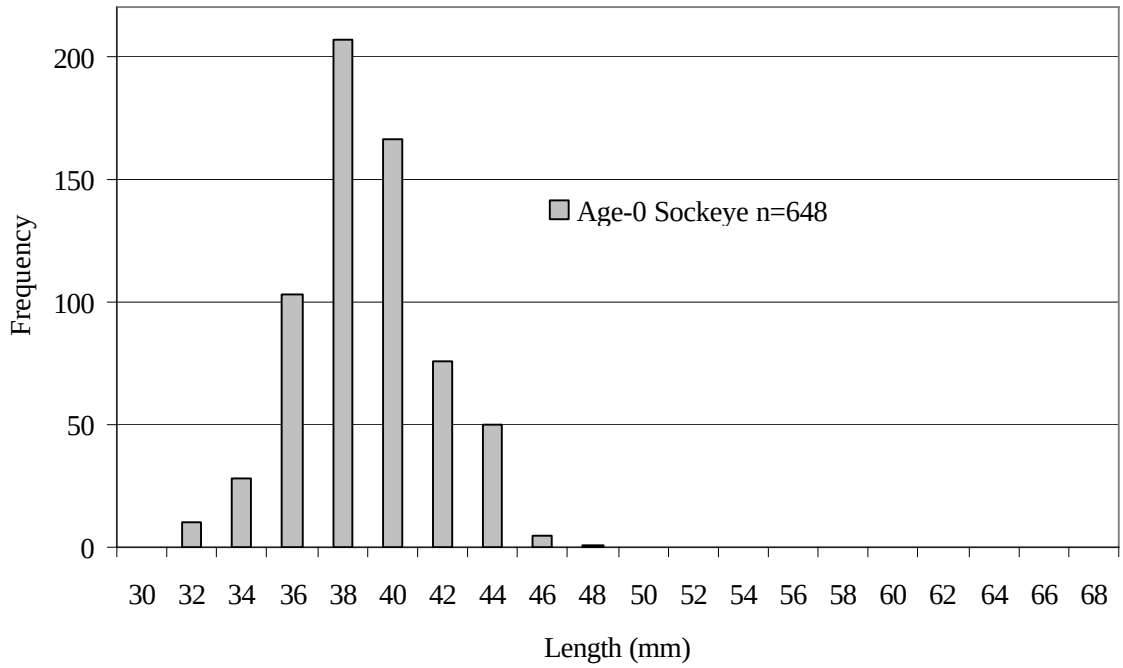

Figure 7. Length frequency distribution of fish caught in the Luck Lake mid-water trawl 2002.

Sockeye Escapement Estimates

Thoms Lake

A total of 939 sockeye salmon were marked and released in Thoms Lake for the mark-recapture population estimate. During the recovery phase, 962 sockeye salmon were examined in Thoms Creek for marks, and 153 were found to be marked (Table 4a). We pooled the first three recovery samples taken on August 27, 28, and 29 because those recovery events occurred on consecutive days and we don't think fish catchability differs much among those strata. Similarly, we pooled two recovery samples taken on September 10 and 11 (Table 4b).

Table 4a. Marking and recapture sample sizes and numbers of marked fish found in Thoms Lake sockeye salmon mark-recapture studies, 2002.

			Number marked fish recovered, by date					
Marking date	**Mark**	**Number released with marks**	**Aug 27**	**Aug 28**	**Aug 29**	**Sep 10**	**Sep 11**	**Sep 25**
Aug 13-15	Round	352	1	5	5	39	3	2
Aug 27-28	Triangle	340	0	0	1	45	4	18
Sep 9-10	Square	247	0	0	0	13	0	17
	Total marked	939						
		Total marks recovered	153					
		Number in recapture samples, by date	2	19	58	645	46	192
		Total of all recapture samples	962					

Table 4b. Partial pooling of marking and recapture samples, and numbers of marked fish in partially pooled strata from Thoms Lake sockeye salmon mark-recapture studies, 2002.

			Number marked fish recovered, by date		
Marking date	**Mark**	**Number released with marks**	**Aug 27-29**	**Sep 10-11**	**Sep 25**
Aug 13-15	Round	352	11	42	2
Aug 27-28	Triangle	340	1	49	18
Sep 9-10	Square	247	0	13	17
	Total marked	939			
		Total marks recovered	153		
		Number in recapture samples, by date	79	691	192
		Total of all recapture samples	962		

The chi-square test for "complete mixing" yielded the statistic X^2 = 6.66 with 2 degrees of freedom and p-value = 0.04. The chi-square test for "equal proportions" test yielded the statistic X^2 = 2.03 with 2 degrees of freedom and p-value = 0.36. Because one of the two tests passed ("equal proportions" test, $p > 0.05$), it is valid to use a pooled Petersen estimate.

Using the pooled Petersen method, the estimate of escapement was 5,877 sockeye salmon. Because the proportion of marked fish in the population ($\hat{p}$) was greater than 0.1 (0.16), R was greater than 30 (153), and C was greater than 600 (962), we used equation 3.4 in Seber (1982) to estimate the 95% CI the point estimate; 5,196-6,835 sockeye salmon. This escapement estimate should be considered minimum because the estimate is only for the study area. However, we did not observe spawning sockeye salmon in any beach areas or tributary except Thoms Creek. The peak sockeye count from the foot survey was 1,400 sockeye salmon on September 9, 2002 (Table 7).

Salmon Bay Lake

A total of 1,169 sockeye salmon were marked and released in Salmon Bay Lake for the mark-recapture population estimate. During the recovery phase, 1,675 sockeye salmon were examined in two inlet streams for marks, and 44 of these fish had marks (Table 5).

Table 5. Marking and recapture sample sizes and numbers of marked fish found in Salmon Bay Lake sockeye salmon mark-recapture studies, 2002.

			Number marked fish recovered, by date			
Marking date	**Mark**	**Number released with marks**	**Sep 8**	**Sep 24**	**Sep 9**	**Sep 23**
7/28-8/12/02	Round	489	10	6	7	0
8/26-27/02	Square	325	5	4	3	2
9/7/02	Triangle	355	1	2	0	4
	Total marked	1,169				
		Total marks recovered	44			
		Number in recapture samples, by date	274	287	536	578
		Total of all recapture samples	1,675			

The chi-square test for "complete mixing" yielded the statistic X^2 = 4.6 with 2 degrees of freedom and p-value = 0.1. The chi-square test for "equal proportions" yielded the statistic X^2 = 20.68 with 3 degree of freedom and p-value of nearly 0. Because one of the two tests passed ("equal proportions" test, $p > 0.05$), it is valid to use pooled Petersen estimate.

By the pooled Petersen method, the estimate of escapement is 43,575 sockeye salmon in Salmon Bay Lake. Because the proportion of marked fish in the population ($\hat{p}$) was less than 0.1 (0.03) and R was less than 50 (44), we used the confidence interval bounds from Table 41 in Pearson and Hartley (1996) to estimate the 95% CI around the point estimate; 32,034-59,584 sockeye salmon. This estimate should be considered a minimum escapement estimate for this system. The peak count from foot surveys of this system was 8,110 sockeye salmon on September 3, 2002, obtained by Petersburg ADF&G personnel (Table 7).

Luck Lake

A total of 2,332 sockeye salmon were marked and released in Luck Lake for the mark-recapture population estimate. During the recovery phase, 2,223 sockeye salmon were examined in Luck Creek for marks, and 321 of these fish had marks (Table 6a). We pooled the recovery samples taken on consecutive days, i.e., September 5 and 6, were pooled and September 19 and 20 were pooled (Table 6b). For the "complete mixing" test, the chi-square statistic is X^2 = 18.7 with 3 degrees of freedom and a p-value of nearly 0; for the "equal proportions" test, X^2 = 33.3 with 2 degrees of freedom and a p-value of nearly 0. Since neither of these tests passed ($p<0.001$), the pooled Petersen estimate is not justified, and it is possible that partial or fully pooled estimates are seriously biased. Goodness of fit test for maximum-likelihood Darroch model gave test

statistic $X^2 = 5.84$ with 2 degrees of freedom and $p = 0.05$; this is on the edge of rejection, but we still considered it passed the test. The maximum-likelihood Darroch estimate of escapement was 13,841 with standard error of 976. By comparison, pooled Petersen method gave a considerably biased estimate of 16,113. Because the proportion of marked fish in the population ($\hat{p}$) was greater than 0.1 (0.14), R was greater than 30 (321), and C was greater than 600 (2,223), we used equation 3.4 in Seber (1982) to estimate the 95% CI around the point estimate, 14,741-17,855 sockeye salmon. The peak count from foot surveys was 5,200 sockeye salmon on September 4, 2002 (Table 7).

Table 6a. Marking and recapture sample sizes and numbers of marked fish found in Luck Lake sockeye salmon mark-recapture studies, 2002.

			Number marked fish recovered, by date			
Marking date	**Mark**	**Number released with marks**	**Sep 5**	**Sep 6**	**Sep 19**	**Sep 20**
7/26/02	Round	73	2	1	5	0
8/8-9/02	Square	342	20	20	6	4
8/23-25/02	Triangle	1,455	66	61	47	53
9/4/02	2 Round	462	0	2	3	31
	Total marked	2,332				
		Total marks recovered	321			
		Number in recapture samples, by date	773	719	333	398
		Total of all recapture samples	2,223			

Table 6b. Partial pooling of marking and recapture samples, and numbers of marked fish in partially pooled strata from Luck Lake sockeye salmon mark-recapture studies, 2002.

			Number marked fish recovered, by date	
Marking date	**Mark**	**Number released with marks**	**Sep 5-6**	**Sep 19-20**
	Round	73	3	5
	Square	342	40	10
	Triangle	1,455	127	100
	2 Round	462	2	34
	Total marked	2,332		
		Total marks recovered	321	
		Number in recapture samples, by date	1,492	731
		Total of all recapture samples	2,223	

Table 7. Peak adult sockeye salmon escapement counts in 2002 from foot surveys listed by location and date. High water prevented August survey of Salmon Bay Lake streams.

Stream	Date	Live	Dead
Thoms Creek	Jul 30	0	0
	Aug 14	314	0
	Aug 29	1,080	54
	Sep 5	470	325
	Sep 9	1,400	370
	Sep 25	9	192
Luck Creek	Jul 26	0	0
	Aug 8	0	0
	Sep 3	3,900	na
	Sep 4	5,200	na
	Sep 20	1,600	na
Salmon Bay	Jul 28	0	0
	Aug 12	na	na
	Sep 3	8,110	675
	Sep 24	220	847

Sockeye Escapement Age and Length Distribution

Thoms Lake

A total of 517 adult sockeye salmon from Thoms Lake was sampled for scales, sex and length during 2002 field activities. Scale pattern analysis showed that age-2.2 fish dominated both sexes of adult sockeye salmon at 62% (n = 317) of this sample, followed by 13% age-2.1 jacks (n = 67; Table 8). The overall sex ratio was 52% male to 48% female. The mean fork length of age-2.2 fish was 530 mm (SE = 1.5 mm, n = 315) and 376 mm (SE = 3 mm, n = 67) for age-2.1 fish (Table 9).

Table 8. Age composition of sockeye salmon in Thoms Lake escapement by sex, brood year, and age class, August 19 to October 6, 2002.

Brood Year	**1999**	**1998**	**1998**	**1997**	**1997**	**1996**	
Age	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**	**Total**
Male							
Sample Size	8	19	67	16	148	12	270
Percent	1.6	3.7	13	3.1	28.7	2.3	52.3
Std. Error	0.5	0.8	1.5	0.8	2	0.7	2.2
Female							
Sample Size		30		31	168	17	246
Percent		5.8		6	32.6	3.3	47.7
Std. Error		1		1	2	0.8	2.2
All Fish							
Sample Size	8	49	67	47	317	29	517
Percent	1.5	9.5	13	9.1	61.3	5.6	100
Std. Error	0.5	1.3	1.5	1.2	2.1	1	

Table 9. Mean fork length (mm) of sockeye salmon in Thoms Lake escapement by sex, brood year, and age class, August 19 to October 6, 2002.

Brood Year	**1999**	**1998**	**1998**	**1997**	**1997**	**1996**	
Age	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**	**Total**
Male	363	532	376	602	532	595	495
Std. Error	9.7	6	3	5.7	2.6	4.4	5
Sample Size	8	19	67	16	147	12	269
Female		531		588	529	586	540
Std. Error		3.3		3.3	1.6	4.5	1.9
Sample Size		30		31	168	17	246
All	363	531	376	593	530	590	517
Std. Error	9.7	3.1	3	3	1.5	3.3	3
Sample Size	8	49	67	47	315	29	515

Salmon Bay Lake

A total of 522 adult sockeye salmon from Salmon Bay Lake was sampled for scales, sex and length during 2002 field activities. Scale pattern analysis showed that the dominant age class of adult sockeye salmon was age-1.3, at 53% (n = 337) of this sample, followed by age-1.2 (n = 103) at 19% of the sample (Table 10). The overall sex ratio was 65.5% male to 34.5% female. The mean fork length of age-1.3 fish was 595 mm (SE = 1.5 mm, n = 275) and 518 mm (SE = 2.3 mm, n = 218) for age-1.2 fish (Table 11).

Table 10. Age composition of sockeye salmon in Salmon Bay Lake escapement by sex, brood year, and age class, August 12 to September 29, 2002.

Brood Year	**1999**	**1998**	**1997**	**1997**	**1996**	
Age	1.1	1.2	1.3	2.2	2.3	Total
Male						
Sample Size	2	152	172	8	7	341
Percent	0.4	29.2	33	1.5	1.3	65.5
Std. Error	0.3	2	2	0.5	0.5	2.1
Female						
Sample Size		66	102	11	1	180
Percent		12.7	19.6	2.1	0.2	34.5
Std. Error		1.4	1.7	0.6	0.2	2.1
All						
Sample Size	2	218	275	19	8	522
Percent	0.4	41.8	52.7	3.6	1.5	100
Std. Error	0.3	2.1	2.2	0.8	0.5	

Table 11. Mean fork length (mm) of sockeye salmon in Salmon Bay Lake escapement by sex, brood year, and age class, August 12 to September 29, 2002.

Brood Year	**1999**	**1998**	**1997**	**1997**	**1996**	
Age	**1.1**	**1.2**	**1.3**	**2.2**	**2.3**	**Total**
Male	343	517	603	541	579	561
Std. Error	17.5	3	1.9	8.1	6.2	3
Sample Size	2	152	172	8	7	341
Female		521	581	525	580	556
Std. Error		2.9	1.8	7.9		2.7
Sample Size		66	102	11	1	180
All	343	518	595	532	579	559
Std. Error	17.5	2.3	1.5	5.8	5.4	2.2
Sample Size	2	218	275	19	8	522

Luck Lake

A total of 553 adult sockeye salmon from Luck Lake scale samples was sampled for scales, sex and length during 2002 field activities. Scale pattern analysis showed that the dominant age class of adult sockeye salmon was age-1.2, at 63% (n = 337) of this sample, followed by age-1.3 at 19% (n = 103) of the sample (Table 12). The sex ratio was 63% male to 37% female. The mean

fork length of age-1.2 fish was 480 mm (SE = 1.9 mm, *n* = 336) and 591 mm (SE = 2.6 mm, *n* = 103) for age-1.3 fish (Table 13).

Table 12. Age composition of sockeye salmon in Luck Lake escapement by sex, brood year, and age class, July 29 to September 29, 2002.

Brood Year	**1999**	**1998**	**1998**	**1997**	**1997**	**1996**	
Age	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**	**Total**
Male							
Sample Size	14	254	19	27	22	3	339
Percent	2.6	47.5	3.6	5	4.1	0.6	63.4
Std. Error	0.7	2.1	0.8	0.9	0.8	0.3	2.1
Female							
Sample Size		1	82	76	22	15	196
Percent		0.2	15.3	14.2	4.1	2.8	36.6
Std. Error		0.2	1.5	1.5	0.8	0.7	2.1
All							
Sample Size	15	337	19	103	44	18	536
Percent	2.8	62.9	3.5	19.2	8.2	3.4	100
Std. Error	0.7	2.1	0.8	1.7	1.2	0.8	

Table 13. Mean fork length (mm) of sockeye salmon in Luck Lake escapement by sex, brood year, and age class, July 29 to September 29, 2002.

Brood Year	**1999**	**1998**	**1998**	**1997**	**1997**	**1996**	
Age	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**	**Total**
Male	335	471	355	601	474	597	470
Std. Error	7	1.8	3.7	5.4	6.7	16.7	3.4
Sample Size	14	254	19	27	22	3	339
Female		380	510	587	517	586	546
Std. Error			3.9	2.9	5.9	6.8	3.5
Sample Size		1	82	76	22	15	196
All	338	480	355	591	495	588	498
Std. Error	7.2	1.9	3.7	2.6	5.5	6.2	2.9
Sample Size	15	336	19	103	44	18	535

Limnology

Vertical Light Penetration, Temperature, and Dissolved Oxygen

Light penetration was measured in Thoms, Salmon Bay, and Luck lakes on May 7, June 6, July 25, September 6 (Thoms only), September 10 (Salmon Bay and Luck), and October 8, at Station A. In 2002, the euphotic zone depth (EZD) on Thoms Lake ranged from 2.01 to 3.34 m; at Salmon Bay Lake the EZD ranged from 3.66 to 4.86 m, and the EZD at Luck Lake ranged from 2.67 to 6.00 m (Table 14).

Table 14. Euphotic zone depth in meters for Thoms, Salmon Bay, and Luck Lakes by date, 2002.

	Eupohotic zone depth (EZD) by sample date					
Lake	**May 7**	**Jun 6**	**Jul 25**	**Sep 6**	**Oct 8**	**Season Mean**
Thoms	2.38	3.13	3.34	2.01	2.20	2.61
Salmon Bay	4.59	4.42	4.86	4.45	3.66	4.46
Luck	5.12	5.78	6.00	3.72	2.67	4.66

In 2002, the seasonal water temperature profiles confirmed the dimictic pattern of thermal stratification in these three lakes. The lakes were isothermal in May, thermally stratified during summer, and returning to the isothermal state in early October (Figures 8, 9, and 10). However, the thermocline persisted in Thoms Lake through early October (Figure 8). Peak epilimnetic temperatures in September 2002 for Thoms, Salmon Bay and Luck lakes were 13.8, 14.1, and 13.9^{o} C respectively. Hypolimnetic temperatures varied between 4.0 ^{o} C in Salmon Bay Lake and 5.8^{o} C in Luck Lake. Dissolved oxygen (DO) levels for 2002 were normal for lakes in Southeast Alaska and ranged between 8 and 11 mg $\cdot$ L^{-1} (Figures 8, 9, and 10). Thoms Lake hypolimnetic oxygen saturation levels ranged from 65% to 75% and epilimnetic oxygen saturation levels ranged from 70 to 90% during the season. Salmon Bay Lake hypolimnetic oxygen saturation levels ranged from 67 to 85% and epilimnetic oxygen saturation levels ranged from 85 to 90% during the season. Luck Lake hypolimnetic oxygen saturation levels ranged from 65% to 85% and epilimnetic oxygen saturation levels ranged from 80 to 90% during the season.

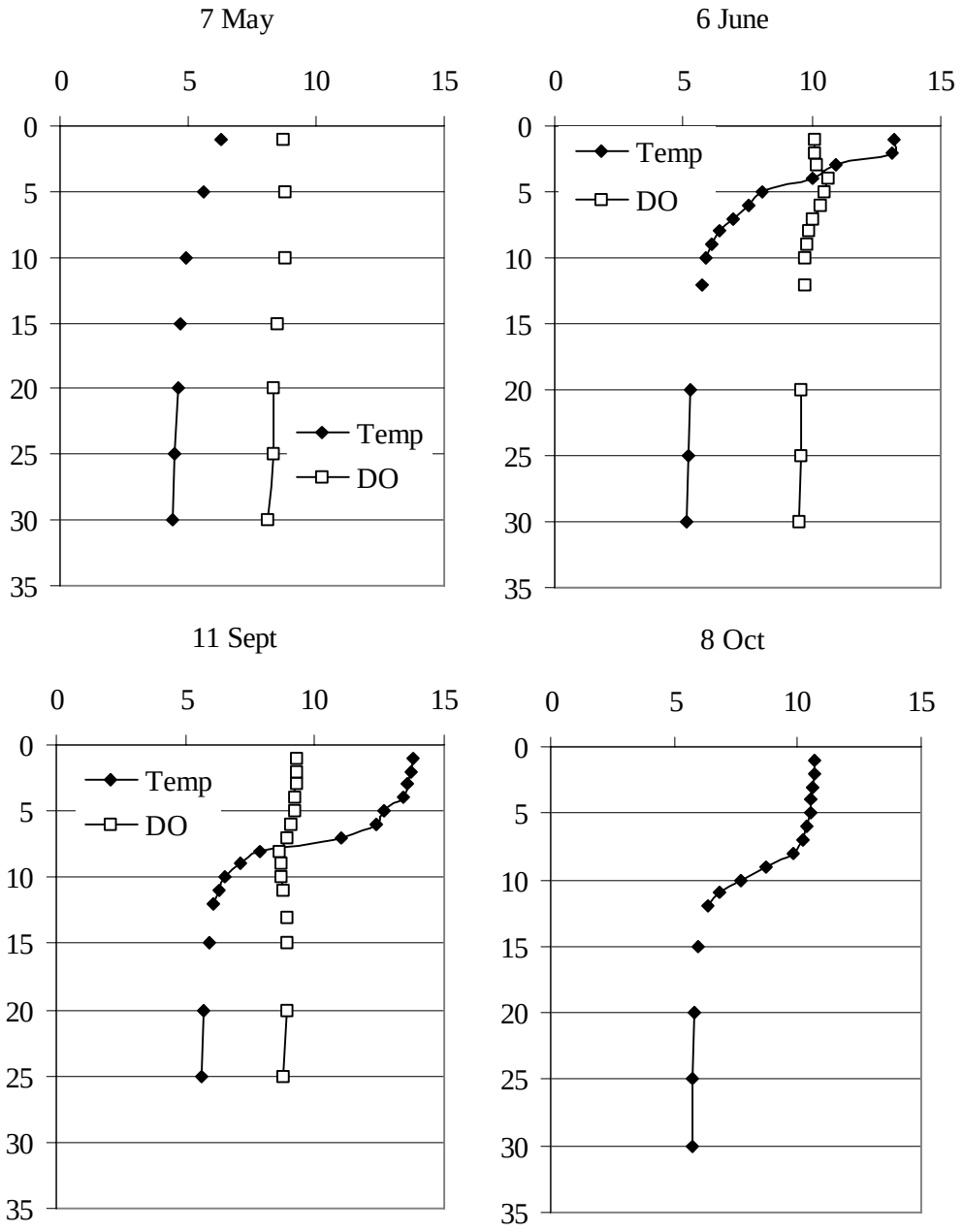

Figure 8. Temperature (^{o}C) and dissolved oxygen ($mg \cdot L^{-1}$) profiles for Thoms Lake, 2002.

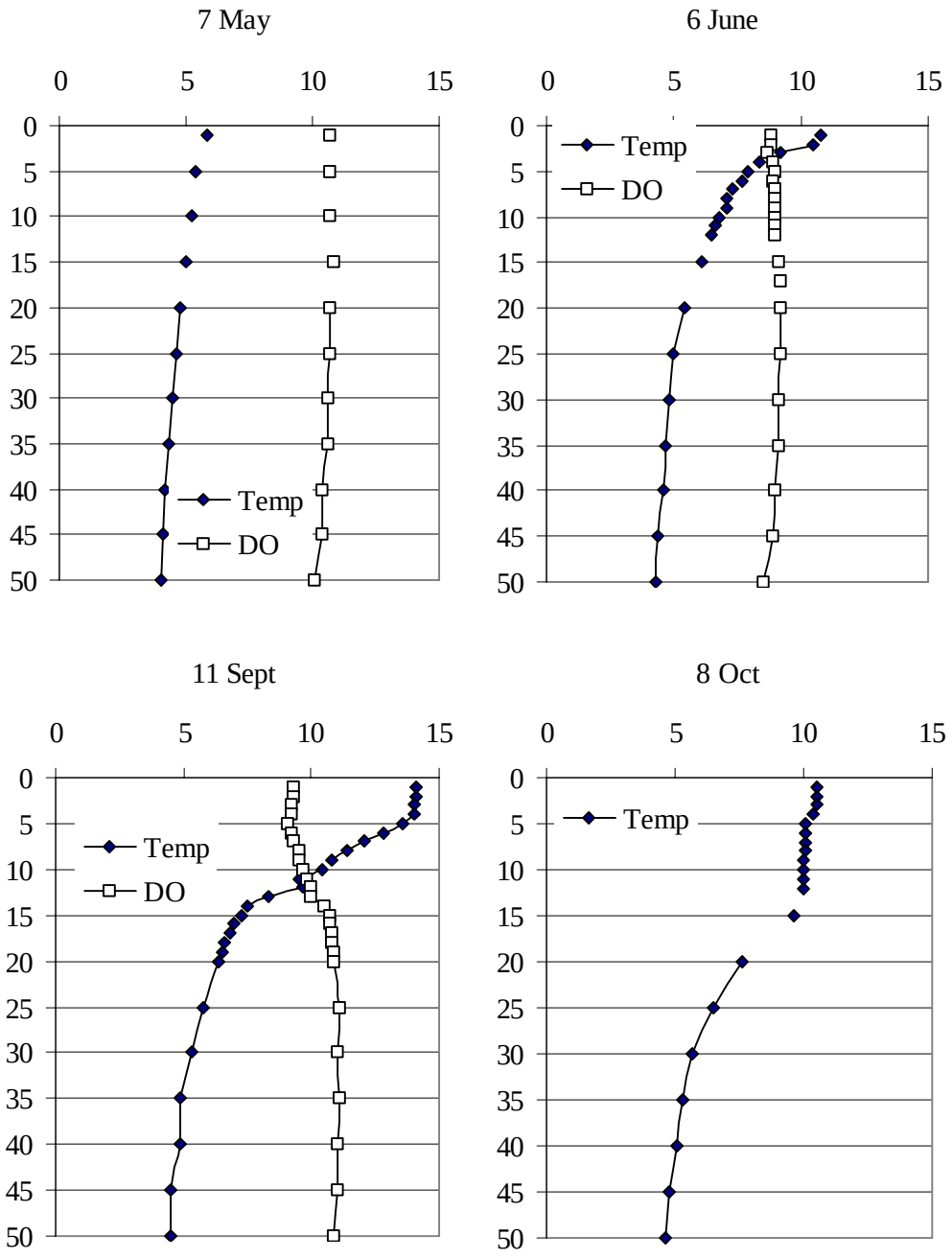

Figure 9. Temperature (^{o}C) and dissolved oxygen (mg•L^{-1}) for Salmon Bay Lake, 2002.

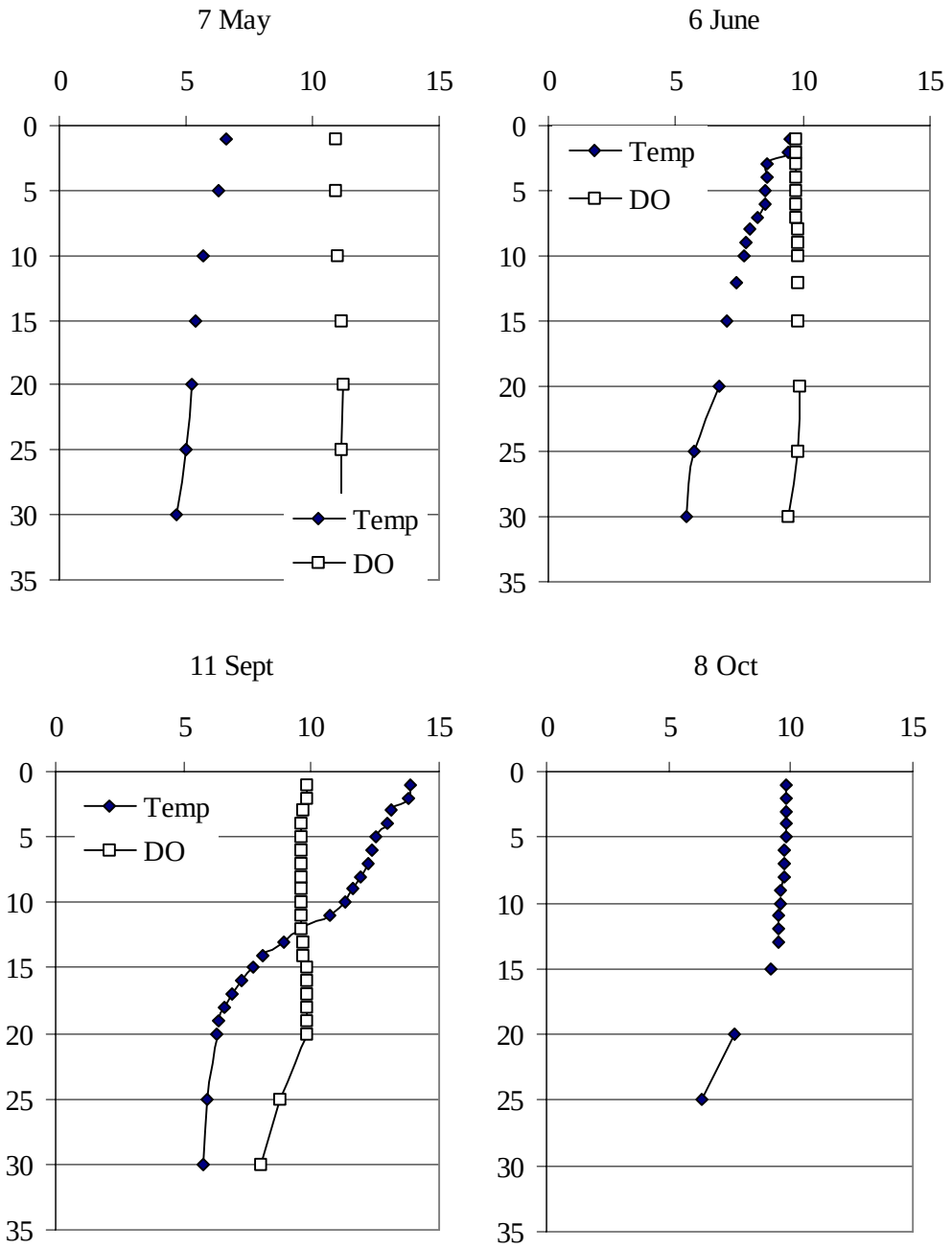

Figure 10. Temperature (^{o}C) and dissolved oxygen (mg•L^{-1}) profiles for Luck Lake, 2002.

Secondary Production

Zooplankton samples were collected from Thoms, Salmon Bay, and Luck lakes on May 7, June 6, July 25, September 6 (Thoms only), September 10 (Salmon Bay and Luck), and October 8 at two stations, A and B, on each lake.

Thoms Lake

Similar to 2001, *Bosmina* sp. dominated the zooplankton assemblage in density in Thoms Lake in 2002 (Table 15). However, the large bodied *Diaptomus* sp. had a higher total biomass than *Bosmina* sp. due to their larger size (Tables 16 and 17). The seasonal mean total macrozooplankton density was 67,000 plankters · m^{-2} compared to 105,000 plankters · m^{-2} in 2001. The seasonal mean weighted macrozooplankton biomass was 118 mg · m^{-2} (Table 16). *Diaptomus* sp. was the largest species present (Table 15). The dipteran insect larvae of the family *Chaoboridae* (phantom midges) were present in high numbers in Thoms Lake but not quantified by density or biomass.

Table 15. Thoms Lake zooplankton species density (No./m^2) by station, date, season mean, and percent, 2002.

Station A	May 4	Jun 8	Jul 10	Aug 23	Oct 16	Mean	Percent
Diaptomus	1,698	15,894	5,502	1,936	645	5,135	8%
Ovig. Diaptomus	102	0	0	713	1,019	367	1%
Cyclops		611	1,087	1,121	781	900	1%
Bosmina	11,819	17,015	43,539	102,496	10,732	37,120	56%
Ovig. Bosmina				18,034	34	9,034	14%
Daphnia l.	4,007	1,325	2,106	4,177	3,906	3,104	5%
Ovig. Daphnia l.	1,019	153	475	3,057	2,174	1,376	2%
Diaphanosoma		1,019	6,521	12,939	5,875	6,589	10%
Holopedium	170	917	9,305	3,770	34	2,839	4%
Ovig. Holopedium		0	408	815	34	314	0%
Polyphemus		51	1,019			535	1%
Chaoborus	183	97	423	10	15	146	0%
Copepod nauplii	26,083	1,426				13,755	21%
Station B							
Diaptomus	2,089	17,728	10,868	2,955	458	6,820	10%
Ovig. Diaptomus		68	340	408	357	293	0%
Cyclops		272	1,358	1,426	484	885	1%
Bosmina	12,277	10,664	71,150	100,458	9,348	40,779	60%
Ovig. Bosmina		68		3,260	51	1,126	2%
Daphnia l.	2,802	1,019	2,208	5,502	2,776	2,861	4%
Ovig. Daphnia l.	815	340	1,528	2,038	458	1,036	2%
Diaphanosoma		204	7,472	17,219	1,426	6,580	10%
Holopedium	153	951	15,962	2,445		4,878	7%
Ovig. Holopedium		68	1,698	509	25	575	1%
Polyphemus		68	509	0		192	0%
Chaoborus	102	433	31	15	153	147	0%
Copepod nauplii	23,230	1,426		1,223		8,626	13%

Table 16. Thoms Lake zooplankton seasonal mean weighted biomass (mg/m^2) by station, species, mean, and percent, 2002.

Species	Station A	Percent	Station B	Percent	Mean	Percent
Diaptomus	38.6	35%	60.9	48%	49.7	42%
Ovig. Diaptomus	10.3	9%	6.7	5%	8.5	7%
Cyclops	0.8	1%	0.9	1%	0.9	1%
Bosmina	36.8	33%	36.7	29%	36.7	31%
Ovig. Bosmina	4.5	4%	0.8	1%	2.7	2%
Daphnia l.	4.3	4%	4.1	3%	4.2	4%
Ovig. Daphnia l.	3.1	3%	2.5	2%	2.8	2%
Diaphanosoma	5.3	5%	5.9	5%	5.6	5%
Ovig. Diaphanosoma	0.2	0%	0.3	0%	0.3	0%
Holopedium	5.8	5%	6.8	5%	6.3	5%
Ovig. Holopedium	0.6	1%	1.1	1%	0.9	1%
Polyphemus	0.0	0%	0.0	0%	0.0	0%
Total	110.5		126.9		118.7	

Table 17. Thoms Lake zooplankton species mean length (mm) by date and season mean, 2002.

Species	May 7	Jun 6	Jul 25	Sep 10	Oct 8	Mean
Diaptomus	0.93	1.01	1.67	1.81	1.49	1.38
Ovig. Diaptomus	2.26	2.16	1.98	1.92	1.94	2.05
Cyclops		0.54	0.62	0.63	0.57	0.59
Bosmina	0.32	0.33	0.30	0.34	0.37	0.33
Ovig. Bosmina		0.38		0.37	0.38	0.38
Daphnia l.	0.60	0.54	0.57	0.59	0.57	0.57
Ovig. Daphnia l.	0.81	0.83	0.71	0.71	0.72	0.75
Diaphanosoma		0.45	0.42	0.55	0.54	0.49
Ovig. Diaphanosoma			0.51	0.61		0.56
Holopedium	0.36	0.47	0.48	0.51	0.49	0.46
Ovig. Holopedium		0.50	0.53	0.53	0.64	0.55
Polyphemus		0.36	0.45	0.50		0.44

Salmon Bay Lake

In 2002, the macrozooplankton density and biomass in Salmon Bay Lake were dominated by the copepod *Cyclops* sp., and the cladoceran *Bosmina* sp., similar to 2001 (Tables 18 and 19). The seasonal mean total macrozooplankton density was 132,000 plankters · m^{-2}. The seasonal mean weighted macrozooplankton biomass was 195 mg · m^{-2} (Table 19). The largest species was *Daphnia middendorffiana*, averaging almost 2 mm across the season (Table 20). However, they

represented less than 1% of the biomass because of the very low estimate of abundance (Table 18 and 19).

Table 18. Salmon Bay Lake zooplankton species density (No./m^2) by station, date, season mean, and percent, 2002.

Station A	May 7	Jun 6	Jul 25	Sep 10	Oct 8	Mean	Percent
Epischura		2,038	7,336	27,679	9,424	11,619	7%
Cyclops	68,365	53,184	49,210	108,507	124,554	80,764	50%
Ovig. Cyclops		4,075	204			2,140	1%
Bosmina	4,890	7,438	128,782	47,207	103,413	58,346	36%
Ovig. Bosmina	102	102		9,170	1,528	2,726	2%
Daphnia l.	7,336	7,336	8,966	1,019	2,038	5,339	3%
Ovig. Daphnia l.	1,223	3,872	1,528	679	255	1,511	1%
Daphnia sp.		0	306	1,358	255	480	0%
Ovig. Daphnia sp.		204		509	0	238	0%
Holopedium			204			204	0%
Daphnia m.	611	102	0		0	178	0%
Copepod nauplii				8,151		8,151	5%
Station B							
Epischura		866	12,736	14,264	11,105	9,743	9%
Cyclops	22,109	22,262	63,848	104,602	108,813	64,327	62%
Ovig. Cyclops		2,904	594			1,749	2%
Bosmina	1,936	1,681	30,375	59,603	36,271	25,973	25%
Ovig. Bosmina	0	0		10,698	509	2,802	3%
Daphnia l.	1,426	2,700	3,396	679	815	1,803	2%
Ovig. Daphnia l.	306	1,325	509	340	917	679	1%
Daphnia sp.	102	0	0	509	917	306	0%
Ovig. Daphnia sp.				340		340	0%
Holopedium			0			0	0%
Daphnia m.				170	0	85	0%
Copepod nauplii			1,783	1,528		1,656	2%

Table 19. Salmon Bay Lake zooplankton seasonal mean weighted biomass (mg/m^2) by station, species, mean, and percent, 2002.

Species	Station A	Percent	Station B	Percent	Mean	Percent
Epischura	46.1	19%	28.3	19%	37.2	19%
Cyclops	106.5	44%	84.5	56%	95.5	49%
Ovig. Cyclops	2.4	1%	2.0	1%	2.2	1%
Bosmina	58.4	24%	22.6	15%	40.5	21%
Ovig. Bosmina	3.2	1%	3.1	2%	3.2	2%
Daphnia l.	13.1	5%	4.4	3%	8.8	4%
Ovig. Daphnia l.	6.8	3%	3.4	2%	5.1	3%
Daphnia sp.	1.0	0%	0.9	1%	1.0	0%
Ovig. Daphnia sp.	0.7	0%	0.3	0%	0.5	0%
Holopedium	0.2	0%	0.0	0%	0.1	0%
Daphnia m.	0.0	0%		0%	0.0	0%
Copepod nauplii	1.8	1%	0.4	0%	1.1	1%
Total	240.3		150.1		195.2	

Table 20. Salmon Bay Lake zooplankton species mean length (mm) by date and season mean, 2002.

Species	May 7	Jun 6	Jul 25	Sep 10	Oct 8	Mean
Epischura		0.74	0.79	1.03	1.21	0.94
Cyclops	0.74	0.75	0.59	0.55	0.63	0.65
Ovig. Cyclops		0.90	0.89			0.89
Bosmina	0.41	0.39	0.32	0.33	0.32	0.35
Ovig. Bosmina	0.46	0.48		0.40	0.39	0.43
Daphnia l.	0.67	0.69	0.83	0.85	0.73	0.75
Ovig. Daphnia l.	0.89	0.91	1.14	1.15	1.20	1.06
Daphnia sp.	0.78	0.82	0.73	0.77	0.88	0.79
Ovig. Daphnia sp.	1.06	1.01		1.01	1.03	1.03
Holopedium			0.66			0.66
Daphnia m.	1.56	1.77	2.80	1.60	1.99	1.94
Ovig. Daphnia m.					2.61	2.61

Luck Lake

In 2002, the macrozooplankton density and biomass in Luck Lake was dominated by *Cyclops* sp. and *Bosmina* sp., similar to 2001 (Tables 21 and 22). The proportion of *Bosmina* spp. biomass increased from 18% in 2001 to 32% in 2002. Similar to 2001, the proportion of *Daphnia* spp.

was low. The seasonal mean total macrozooplankton density was 199,000 plankters · m^{-2}. The seasonal mean weighted macrozooplankton biomass was 311 mg · m^{-2} (Table 22). *Epischura* sp. was the largest species present (Table 23). Hydracarina (water mites) were also identified in the Luck Lake zooplankton samples.

Table 21. Luck Lake zooplankton species density (No./m^2) by station, date, season mean, and percent, 2002.

Station A	May 7	Jun 6	Jul 25	Sep 10	Oct 8	Mean	Percent
Epischura		2,989	3,940	2,717	2,887	2,507	1%
Cyclops	90,474	34,505	164,510	171,710	191,374	130,515	74%
Ovig. Cyclops	9,102	14,196	272			4,714	3%
Bosmina	27,577	10,460	63,984	17,796	24,622	28,888	16%
Ovig. Bosmina	0	68	408	272	0	150	0%
Daphnia l.	24,181	10,732	1,358	679		7,390	4%
Ovig. Daphnia l.	4,619	815	136	0	170	1,148	1%
Daphnia g.						0	0%
Copepod nauplii		6,521				1,304	1%
Station B							
Epischura		3,872	4,890	2,547	4,755	3,213	1%
Cyclops	10,294	36,067	166,004	238,411	384,446	167,044	75%
Ovig. Cyclops	1,698	6,826	679			1,841	1%
Bosmina	41,094	33,724	45,780	15,113	68,602	40,863	18%
Ovig. Bosmina		0	1,087	0		217	0%
Daphnia l.	17,660	12,532	1,902	509	1,019	6,724	3%
Ovig. Daphnia l.	4,075	713	0	170	0	992	0%
Daphnia g.						0	0%
Copepod nauplii		5,094	5,298			2,078	1%

Table 22. Luck Lake zooplankton seasonal mean weighted biomass (mg/m^2) by station, species, and mean, 2002.

Species	Station A	Percent	Station B	Percent	Mean	Percent
Epischura	14.1	5%	19.4	6%	16.8	5%
Cyclops	188.0	68%	232.0	67%	210.0	67%
Ovig. Cyclops	14.0	5%	6.0	2%	10.0	3%
Bosmina	40.2	15%	72.3	21%	56.2	18%
Ovig. Bosmina	0.6	0%	0.7	0%	0.6	0%
Daphnia l.	14.5	5%	13.3	4%	13.9	4%
Ovig. Daphnia l.	3.8	1%	3.5	1%	3.6	1%
Total	275.2		347.1		311.2	

Table 23. Luck Lake zooplankton species mean length (mm) by date and season mean, 2002.

Species	May 7	Jun 6	Jul 25	Sep 10	Oct 8	Mean
Epischura		0.74	1.08	1.12	1.44	1.09
Cyclops	0.86	0.85	0.56	0.60	0.67	0.70
Ovig. Cyclops	0.93	0.92	0.94			0.93
Bosmina	0.52	0.49	0.35	0.29	0.43	0.41
Ovig. Bosmina	0.56	0.46	0.65	0.46	0.56	0.54
Daphnia l.	0.69	0.63	0.80	0.82	0.93	0.77
Ovig. Daphnia l.	0.87	0.85	0.86	0.97	1.07	0.92

DISCUSSION

We met all the objectives for this project in 2002, with the exception of estimating the sampling error associated with sockeye fry population estimate. The CV describing the hydroacoustic target variance (different than sockeye fry variance) between sample sections was less than or equal to 15% in Luck and Salmon Bay lakes, which indicates that we do not need to increase the number of sample sections in these lakes. The CVs around the escapement estimates were less than 15% in all three lakes. Adult sockeye age and size population characteristics by sex were described for each lake. Consistent sampling of limnological measurements throughout the season was executed with few problems.

We did not, however, estimate the variance around the sockeye fry point estimates. In addition to sample size problems, comparative studies between trawl gear and smolt weirs, showed that larger and older sockeye fry can avoid the trawl gear (Paul Rankin personal comm.). Because these problems are common to remote acoustic surveys, we consider the hydroacoustic estimates of sockeye fry a work in progress and plan on forming a working group with other sockeye biologists in Canada and Washington to discuss similar problems. Nevertheless, these surveys will be eliminated from most of the lakes until these problems can be solved. High concentrations of *Chaoboris* in the Thoms Lake survey may be avoided by conducting the survey in early August similar to 2001.

These mark-recapture studies are estimates and we assume we are meeting the assumptions of the model used. We considered possible violations of these assumptions and reasoned, tested (Arnason et al. 1996) or observed information that would indicate we had satisfied these assumptions that all sockeye within a strata:

1. have an equal probability of being marked or
2. have an equal probability of being inspected for marks or
3. marked fish mixed completely with unmarked fish in the population between events and
4. it is a closed population and

5. fish do not lose their marks and
6. all marks are recognizable.

Because the mark-recapture was conducted only in study areas, the mark-recapture estimate represents a minimum of the total lake escapement for all three lakes. However, the majority of sockeye salmon in Thoms, Salmon Bay and Luck lakes spawned in restricted and readily delimited areas. All spawning occurred in one main lake tributary in both Thoms and Luck lakes. The majority of spawning in Salmon Bay Lake occurred in a pair of tributaries that are located in close proximity to each other. Consequently, we think these estimates represent the majority of sockeye adults on the spawning grounds in these three lakes.

Total sockeye returns to the terminal area (escapement and subsistence harvest) were significantly greater in 2002 compared to 2001. The adult sockeye salmon escapement doubled in all three systems between these two years. Reported harvest on ADF&G subsistence permits increased 23% in Salmon Bay Lake and 49% in Thoms between 2001 and 2002 (ADF&G Database). This increase could be a result of higher marine survival of recruits, a reduced harvest in the commercial fisheries or a strong brood year. It is unlikely that higher survival rates in the marine environment alone accounted for this increase because we would see increases in other systems. Klag Lake was the only other system that had significantly higher returns in 2002 compared to 2001 (Figure 11, Table 23). Although the harvest rate of these stocks by the commercial fisheries fleet is unknown, the sockeye salmon catches adjacent to Salmon Bay and Luck systems (District 106-10, -20, -22, -30, and -41) dropped by more than half from 2001 to 2002 (ADF&G Database). The commercial seine fishery adjacent to the Thoms Lake system (District 107-20, -35 and 108-10, -20, -40) dropped from about 20,000 to 3,000 between 2001 and 2002 (ADF&G Database). It is possible that the project has been operating during a period of high escapement driven by strong brood years. For example, age-1.2 fish dominated the Salmon Bay Lake escapement in 2001, suggesting that 1997 may be a dominant brood year (Lewis and Cartwright 2002). The escapement of an estimated 22,000 age-1.3 fish in 2002 provides additional evidence of a dominant 1997 brood year. Similarly, age-1.2 fish dominated the Luck Lake escapement in 2002 suggesting that 1998 may be a dominant brood year.

Table 23. A summary of the estimated total sockeye salmon return to the terminal area of a selected group of Southeast sockeye salmon lake systems in 2001 and 2002. The total return to each system is apportioned into subsistence harvest and escapement.

Lake System	Sockeye Salmon Subsistence Harvest		Sockeye Salmon Escapement		Total Returns to Terminal Area		Percent of Terminal Area Returns Harvested	
	2001	2002	2001	2002	2001	2002	2001	2002
Sitkoh	275	154	15,200	12,500	15,475	12,654	2%	1%
Hetta	740	120	6,000	400	6,740	520	11%	23%
Falls	1,300	1,800	1,800	1,000	3,100	2,800	42%	64%
Klawock	4,300	3,800	14,100	13,100	18,400	16,900	23%	22%
Klag	1,300	3,900	11,900	17,300	13,200	21,200	10%	18%
Thoms	163	319	3,000	5,900	3,163	6,219	5%	5%
Salmon Bay	892	1,166	20,800	43,600	21,692	44,766	4%	3%
Luck	0	0	7,900	16,000	7,900	16,000	0%	0%

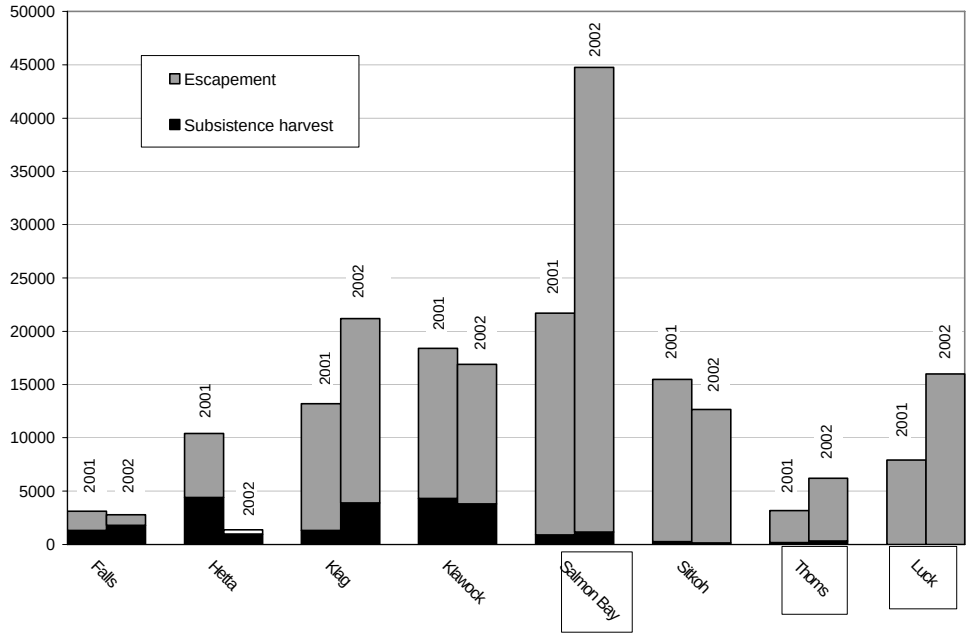

Figure 11. The estimated total return of adult sockeye salmon to 8 sockeye systems in Southeast Alaska in 2001 and 2001. Estimated total return includes the estimate of subsistence harvest in the area plus estimate of sockeye escapement into each lake. Subsistence harvest estimates in Hetta, Falls, Klawock and Klag lakes were obtained by on-grounds harvest surveys. Other harvest estimates were obtained from permit data in the ADF&G Commercial Fisheries database. No harvest was reported for Luck Lake.

With just two years of sockeye escapement estimates in these three lakes, our preliminary conclusion is that the stocks appear to be healthy, i.e., not significantly depressed in numbers. At least for these two years, the percent of the sockeye return harvested in the subsistence fisheries appears to be very low compared to other Southeast systems (Table 23 and Figure 11). However, favorable or unfavorable weather conditions can influence the catch rates in the terminal areas. In Thoms Lake, for example, the subsistence fishery in the marine waters adjacent to the outlet is capable of harvesting a substantially greater number of sockeye salmon in low water years when fish are forced to remain in the staging area for a longer period of time (William Bergmann ADF&G, personal communication). Low water conditions were not present in 2001 or 2002. Therefore, the proportion of sockeye salmon returns harvested in the subsistence fishery may not be representative of typical years.

Comparing fry densities between years and between lakes allows us to evaluate the lake rearing environment, up to and including the sockeye fry life-history stage. Sockeye fry densities were above the median in Luck Lake and Salmon Bay Lake had the lowest densities relative to other Southeast Alaska sockeye-producing lakes in 2002 (Table 24). However, sockeye fry densities are not directly comparable between 2002 and 2001, because we changed the sampling design in 2002 to replicate transects within each lake section instead of a repeated measure on the same transect.

Table 24. Sockeye fry densities (fry/m^2·100) in Southeast Alaska lakes producing important subsistence runs, 2001 and 2002.

Lake	2001	2002
Hetta	75	44
Kutlaku		41
Gut	17	26
Luck	5	23
Klag		23
Sitkoh	6	11
Klawock	6	4
Kanalku	1	3
Kook	2	2
Falls	6	2
Salmon Bay	3	2

Because zooplankton densities and size are an intermediate measure of lake productivity (bottom-up controls) and predator pressures (top-down controls), these data can be used to compare trophic level responses to changes in fry densities and ultimately the adult sockeye spawning population. The 2002 Luck Lake zooplankton biomass density were slightly above the median of 15 Southeast Alaska sockeye salmon lakes and slightly below in 2001 (Table 25). Although we cannot directly compare sockeye fry estimates between years, the 5-fold difference between the 2002 sockeye fry density (0.24 fry·m^{-2}) and the 2001 density (0.05 fry·m^{-2}) suggests there was at least an increase in fry in 2002. This lack of similar changes in zooplankton densities between years in Luck Lake may mean that this system is not food limited at these fry densities.

Salmon Bay Lake ranked close to the median in seasonal mean biomass of all zooplankton and *Daphnia* spp. compared to other Southeast lakes in 2002 (Table 25). Sockeye fry densities were low both years, despite the fact that zooplankton densities in 2002 were almost half of the 2001 density estimate (Table 25). Lake productivity may vary widely from year to year in this system with little or no influence on sockeye fry densities at this low level of fry production. The adult sockeye returns to Salmon Bay are some of the highest in the region and the fry densities some of the lowest. Although these data are preliminary, this may mean that production could be limited by spawning area or some early life history stage rather than the lake rearing environment.

Table 25. The 2001 and 2002 zooplankton density and *Daphnia* density and size in selected lakes in Southeast Alaska.

2001 Lake	Zooplankton Density (mg per m$^{2)}$	Daphnia avg. size (mm)	2002 Lake	Zooplankton Density (mg per m$^{2)}$	Daphnia avg. size (mm)
Sitkoh	647	0.73	Sitkoh	569	0.79
Kanalku	371	0.95	Klawock	421	0.90
Salmon Bay	347	0.94	Kanalku	419	0.75
Kook	299	0.87	Kook	311	0.80
Luck	233	0.86	Luck	311	0.77
Klawock	217	none	Salmon Bay	195	0.75
Thoms	142	0.60	Thoms	119	0.57
Hetta	128	0.63	Hetta	47	0.67
Falls	105	0.66	Falls	28	0.69
Gut	33	0.60	Gut	21	0.61

Thoms Lake presents some contrary information about trophic level responses to changes in production. It is one of the most stained lakes with a 1% light levels (3 meters or less). As expected, the zooplankton biomass estimates are below average but some clearer lakes have even less zooplankton production in the last 2 years (Table 25). Yet the sockeye fry density was one of the highest in 2001 (0.89 fry/m^2). In addition, adult sockeye returns to Thoms Lake (153 ha) in 2002 (6,000 fish) were similar to other lakes that were larger and clearer such as Hetta (207 ha; 9m EVD), Luck (210 ha; 5m EVD) and Kook (240 ha; 6m EVD) lakes. The decline of commercial fishing in the subdistricts close to the Thoms Lake system may have been the primary reason for increased escapement into this system in 2002.

The presence of large numbers of phantom midges in the mid-water trawl samples taken from Thoms Lake could further complicate the trophic structure of this aquatic ecosystem. Although the adult midges are found mostly in the profundal zone of the lake (just above the bottom), the juvenile instars are limnetic, adults migrate vertically in the water column similar to sockeye fry and zooplankton and they are veracious predators on pelagic zooplankton (Wetzel 1983). However, they prefer copepods and oligochaetes over Daphnia and other cladocerans, the favorite food of sockeye fry (Wetzel 1983). Nevertheless, competition for food between sockeye fry and *Chaoborus* could also limit sockeye production in this system.

This year's results provide information important to the Thoms, Salmon Bay and Luck Lakes Sockeye Salmon Stock Assessment Project but they represent only the preliminary step in the construction of a complete sockeye stock assessment. A complete stock assessment requires monitoring, at a minimum, through a five-year life cycle of sockeye salmon and several weather conditions in the freshwater and marine environment. Additionally, we will continue to develop cooperative partnerships, jobs, and training opportunities with the community of Wrangell. None of these research and project directions can be completed in a few years. Instead, they require consistent attention, on-gong re-evaluation and coordination with the community to work

toward maintaining sockeye returns to Thoms, Salmon Bay and Luck lakes that are sustainable for many years to come.

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APPENDICES

Appendix A. Annual commercial harvest of sockeye salmon for Thoms, Salmon Bay, and Luck Lakes in the early 1900's (Rich and Ball 1933).

	Annual Harvest of Sockeye Returning to:		
Year	**Thoms**	**Salmon Bay**	**Luck**
1896	na	19,725	na
1897	17,138	15,012	na
1898	10,000	22,000	na
1899	na	25,401	na
1900	24,661	33,290	na
1901	na	na	na
1902	na	na	na
1903	na	na	na
1904	na	33,285	15,747
1905	na	49,025	16,576
1906	22,177	45,198	16,782
1907	20,057	86,019	11,809
1908	12,926	35,477	3,949
1909	7,985	43,035	1,678
1910	3,246	14,201	12,057
1911	10,259	10,307	7,488
1912	30,953	41,413	12,242
1913	10,663	9,192	196
1914	10,857	3,519	2,087
1915	13,807	23,421	7,328
1916	4,125	17,620	3,445
1917	4,817	28,600	na
1918	6,596	29,736	12,395
1919	14,870	29,777	21,038
1920	3,553	21,152	14,688
1921	1,337	3,930	10,187
1922	2,920	6,598	5,648
1923	5,046	39,184	13,260
1924	1,472	16,817	15,779
1925	na	na	12,183
1926	na	365	22,024
1927	na	Na	16,086
Average	**10,885**	**26,048**	**11,073**

Appendix B1. Numbers of adult sockeye salmon sampled from Thoms Lake by age and year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
0.2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	57	16	1	4	10	0	1	20	13	0	28	1	0	117	5	12	35	44	34	0	8
1.2	6	33	33	8	27	25	9	96	32	0	36	127	0	11	69	15	75	154	109	21	49
1.3	174	73	305	162	4	99	2	6	82	0	54	100	0	6	56	209	145	91	161	253	47
2.1	15	31	2	0	114	45	2	82	83	0	30	43	0	151	62	42	4	41	23	5	67
2.2	27	45	19	68	132	117	192	215	289	0	297	102	0	173	153	79	23	127	25	77	317
2.3	230	221	246	95	80	77	52	155	52	0	58	173	0	93	218	147	14	89	104	36	29
2.4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1	0	0	0	0	5	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3.2	0	0	0	0	1	16	0	0	3	0	0	1	0	1	0	0	0	0	0	0	0
3.3	0	0	1	0	2	2	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0
4.1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	510	419	607	337	375	387	259	574	554	0	504	548	0	553	564	504	296	546	456	392	517

Appendix B2. Percentages of adult sockeye salmon sampled from Thoms Lake by age and year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	11.2	3.8	0.2	1.2	2.7	0	0.4	3.5	2.3	0	5.6	0.2	0	21.2	0.9	2.4	11.8	8.1	7.5	0	1.5
1.2	1.2	7.9	5.4	2.4	7.2	6.5	3.5	16.7	5.8	0	7.1	23.2	0	2	12.2	3	25.3	28.2	23.9	5.4	9.5
1.3	34.1	17.4	50.2	48.1	1.1	25.6	0.8	1	14.8	0	10.7	18.2	0	1.1	9.9	41.5	49	16.7	35.3	64.5	9.1
2.1	2.9	7.4	0.3	0	30.4	11.6	0.8	14.3	15	0	6	7.8	0	27.3	11	8.3	1.4	7.5	5	1.3	13
2.2	5.3	10.7	3.1	20.2	35.2	30.2	74.1	37.5	52.2	0	58.9	18.6	0	31.3	27.1	15.7	7.8	23.3	5.5	19.6	61.3
2.3	45.1	52.7	40.5	28.2	21.3	19.9	20.1	27	9.4	0	11.5	31.6	0	16.8	38.7	29.2	4.7	16.3	22.8	9.2	5.6
2.4	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1	0	0	0	0	1.3	1.3	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0
3.2	0	0	0	0	0.3	4.1	0	0	0.5	0	0	0.2	0	0.2	0	0	0	0	0	0	0
3.3	0	0	0.2	0	0.5	0.5	0	0	0	0	0	0.2	0	0.2	0.2	0	0	0	0	0	0
4.1	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B3. Numbers of adult sockeye salmon sampled from Salmon Bay Lake by age and year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
0.2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	9	63	2	17	1	161	9	7	0	11	19	48	24	37	37	15	25	11	16	2	2
1.2	195	180	286	120	322	173	1721	31	0	254	35	207	20	184	32	257	55	86	57	244	218
1.3	981	205	298	1055	762	1490	224	488	0	180	141	91	405	109	302	219	370	316	131	196	275
1.4	1	0	0	1	9	3	6	0	0	1	1	4	0	1	0	0	1	0	0	0	0
2.1	1	3	0	4	1	27	8	1	0	22	0	47	12	23	17	6	11	13	1	1	0
2.2	68	36	1	37	70	78	64	30	0	19	22	48	45	45	27	30	23	32	30	6	19
2.3	43	40	5	108	91	139	47	10	0	30	14	101	25	104	28	27	44	26	42	50	8
2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
3.1	0	0	0	0	0	2	0	0	0	4	0	5	0	1	0	1	3	0	0	0	0
3.2	3	0	0	0	0	17	0	0	0	11	2	1	2	2	1	3	17	0	0	0	0
3.3	0	0	0	0	0	0	0	0	0	1	4	14	1	1	0	0	11	0	2	6	0
Total	1301	527	592	1342	1257	2092	2079	567	0	533	238	566	534	507	445	558	560	484	279	505	522

Appendix B4. Percentages of adult sockeye salmon sampled from Salmon Bay Lake by age and year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
0.2	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	0.7	12	0.3	1.3	0.1	7.7	0.4	1.2	0	2.1	8	8.5	4.5	7.3	8.3	2.7	4.5	2.3	5.7	0.4	0.4
1.2	15	34.2	48.3	8.9	25.6	8.3	82.8	5.5	0	47.7	14.7	36.6	3.7	36.3	7.2	46.1	9.8	17.8	20.4	48.3	41.8
1.3	75.4	38.9	50.3	78.6	60.6	71.2	10.8	86.1	0	33.8	59.2	16.1	75.8	21.5	67.9	39.2	66.1	65.3	47	38.8	52.7
1.4	0.1	0	0	0.1	0.7	0.1	0.3	0	0	0.2	0.4	0.7	0	0.2	0	0	0.2	0	0	0	0
2.1	0.1	0.6	0	0.3	0.1	1.3	0.4	0.2	0	4.1	0	8.3	2.2	4.5	3.8	1.1	2	2.7	0.4	0.2	0
2.2	5.2	6.8	0.2	2.8	5.6	3.7	3.1	5.3	0	3.6	9.2	8.5	8.4	8.9	6.1	5.4	4.1	6.6	10.8	1.2	3.6
2.3	3.3	7.6	0.8	8	7.2	6.6	2.3	1.8	0	5.6	5.9	17.8	4.7	20.5	6.3	4.8	7.9	5.4	15.1	9.9	1.5
2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0
3.1	0	0	0	0	0	0.1	0	0	0	0.8	0	0.9	0	0.2	0	0.2	0.5	0	0	0	0
3.2	0.2	0	0	0	0	0.8	0	0	0	2.1	0.8	0.2	0.4	0.4	0.2	0.5	3	0	0	0	0
3.3	0	0	0	0	0	0	0	0	0	0.2	1.7	2.5	0.2	0.2	0	0	2	0	0.7	1.2	0

Appendix B5. Numbers adult sockeye salmon sampled from Luck Lake by age and year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1.1	142	45	46	64	20	40	0	0	61	58	150	17	134	186	47	137	30	86	58	57	15
1.2	39	237	32	111	56	11	36	0	323	142	92	174	23	177	211	146	158	69	268	95	337
1.3	133	84	207	26	72	14	10	0	12	95	96	105	186	32	181	152	130	173	52	357	103
1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
2.1	1	36	12	36	17	1	0	0	38	76	107	63	20	29	61	77	73	11	15	5	19
2.2	25	6	29	16	40	3	10	0	80	32	42	60	22	22	51	20	113	52	19	26	44
2.3	27	36	9	12	17	1	0	0	31	23	45	85	38	22	11	22	35	30	35	15	18
3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
3.2	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
3.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Total	367	444	335	265	222	70	56	0	550	426	532	504	423	468	562	554	540	421	448	555	536

Appendix B6. Percentages of sockeye salmon sampled from Luck Lake by age and year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1.1	38.7	10.1	13.7	24.2	9	57.1	0	0	11.1	13.6	28.2	3.4	31.7	39.7	8.4	24.7	5.6	20.4	12.9	10.3	2.8
1.2	10.6	53.4	9.6	41.9	25.2	15.7	64.3	0	58.7	33.3	17.3	34.5	5.4	37.8	37.5	26.4	29.3	16.4	59.8	17.1	62.9
1.3	36.2	18.9	61.8	9.8	32.4	20	17.9	0	2.2	22.3	18	20.8	44	6.8	32.2	27.4	24.1	41.1	11.6	64.3	19.2
1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0
2.1	0.3	8.1	3.6	13.6	7.7	1.4	0	0	6.9	17.8	20.1	12.5	4.7	6.2	10.9	13.9	13.5	2.6	3.3	0.9	3.5
2.2	6.8	1.4	8.7	6	18	4.3	17.9	0	14.5	7.5	7.9	11.9	5.2	4.7	9.1	3.6	20.9	12.4	4.2	4.7	8.2
2.3	7.4	8.1	2.7	4.5	7.7	1.4	0	0	5.6	5.4	8.5	16.9	9	4.7	2	4	6.5	7.1	7.8	2.7	3.4
3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0
3.2	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0
3.3	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0

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