KLAWOCK LAKE
SOCKEYE SALMON (*Oncorhynchus nerka)*
STOCK ASSESSMENT PROJECT
2002 ANNUAL REPORT

By
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This cooperative project was also funded by the Southeast Sustainable Salmon Fund (SSSF) in 2002. These funds augmented the existing stock assessment project, evaluated some of the impacts of the enhancement activities on Klawock Lake and looked at the long-term productivity of this system. This annual report partially fulfills contract obligations for Klawock Lake Project number, contract number 11145305. The results of this 2-year study will be reported under separate cover.

TABLE OF CONTENTS

AUTHORS ii
ACKNOWLEDGMENTS ii
PROJECT SPONSORSHIP ii
TABLE OF CONTENTS iii
LIST OF TABLES iv
LIST OF FIGURES v
LIST OF APPENDICES vi
ABSTRACT 1
INTRODUCTION 2
OBJECTIVES 2
HISTORY OF SUBSISTENCE USE 3
STUDY SITE 4
METHODS 4
Juvenile Sockeye Population Assessment 4
Sockeye Fry Estimates 4
Data Analysis 6
Sockeye Smolt Age and Length 7
Adult Sockeye Escapement Estimates 7
Data Analysis 8
Handling Mortality Monitoring 11
Escapement Age and Length Distribution and Origin 11
Subsistence Harvest Estimate 12
Harvest Survey 12
Harvest Data Collection 12
Data Analysis 13
Limnology 13
RESULTS 14
Juvenile Sockeye Population Assessment 14
Sockeye Smolt Age and Length Characteristics 14
Adult Sockeye Escapement Estimates 15
Escapement Age, Length, and Sex Information 16
Subsistence Harvest Estimate 16
Limnology 17
General Water Chemistry 17
Vertical Light Penetration, Temperature, and Dissolved Oxygen 17
Secondary Production 18
DISCUSSION 18
LITERATURE CITED 22
TABLES 24
FIGURES 34
APPENDIX 43

LIST OF TABLES

Table **Page**

Table 1. Hydroacoustic sockeye salmon fry densities (fry · m^{-2}) estimates in Basin A and Basin B in Klawock Lake. 24
Table 2. Summary of hydroacoustic trawl data by basin, date, depth and species collected on Klawock Lake in 2002....24
Table 3. Summary of the hydroacoustic estimates of sockeye salmon fry in Klawock Lake 1986-1988, 1995, 2000-2002. 25
Table 4. Comparison of sockeye salmon smolt age, percent composition (not weighted by total emigration), length, and weight data, by year....25
Table 5. Summary of adult sockeye salmon marking at the Klawock River weir by date and mark type, 2002. 25
Table 6. Mark recovery data for Klawock Lake adult sockeye salmon by stream in 2002....26
Table 7. Foot escapement counts of adult sockeye salmon in the Klawock Lake system by stream and date, 2002. 27
Table 8. Numbers of fish sampled in Klawock Lake sockeye salmon escapement by age and brood year, 1982-2002....28
Table 9. Percent of fish sampled in Klawock Lake sockeye salmon escapement by age and brood year, 1982-2002. 28
Table 10. Mean fork length (mm) of adult sockeye salmon in the Klawock Lake escapement by sex, brood year, and age class, July 1 to September 22, 2002. 29
Table 11. TKN and TP concentrations (*u*g/l) for Klawock Lake by basin, date and depth strata, 2002. 29
Table 12. Chlorophyll *a* and phaeophyton concentrations for Klawock Lake by station, date and strata, 2002 30
Table 13. Euphotic zone depth (m) of Klawock Lake by year at Station A and B, 1986–2002....31
Table 14. Seasonal mean macro-zooplankton size (mm), density (No. · m^{-2}) and mean weighted biomass (mg · m^{-2}) distributions by species in Basin A (Station A and C) of Klawock Lake, 2002. 32
Table 15. Seasonal mean macro-zooplankton density (No. · m^{-2}) and mean weighted biomass (mg · m^{-2}) distributions by species in Basin B (Station B and D) of Klawock Lake, 2002. 33
Table 16. The 2001 and 2002 zooplankton density and *Daphnia* density and size in selected lakes in Southeast Alaska....33

LIST OF FIGURES

Figure **Page**

Figure 1. The geographic location of Klawock Lake, within the State of Alaska, and relative to commercial fishing districts 103 and 104 on west Prince of Wales Island. 34
Figure 2. Bathymetric map of Klawock Lake, Southeast Alaska with limnological sampling stations and inlet stream references. 35
Figure 3. Length frequency distribution for age-0 sockeye salmon fry captured in the mid-water trawl during hydroacoustic surveys in July and October 2002. 36
Figure 4. Length frequency histogram of Klawock Lake sockeye smolts, 2002. 36
Figure 5. Foot escapement counts of adult sockeye salmon in the Klawock Lake system by stream and date, 2002. 37
Figure 6. Estimated Klawock Inlet subsistence harvest of sockeye salmon on sampled dates in 2002. 37
Figure 7. Temperature (^{o}C) and dissolved oxygen (mg · L^{-1}) vertical (in meters) profiles by date at Station A in Klawock Lake, 2002. 38
Figure 8. Temperature (^{o}C) and dissolved oxygen (mg · L^{-1}) vertical (in meters) profiles by date at Station B in Klawock Lake, 2002. 39
Figure 9. The mean seasonal density and weighted biomass of zooplankton in Klawock Lake 1986-88 and 2000-02. 40
Figure 10. The daily weir count in 2001 shows that very few sockeye salmon were counted through the weir after the August 27 high water event (A). A cumulative percent of the run through the weir showed that 48% of the sockeye adults entered the system after August in 2002 (B). The timing of the run through the weir was very similar between 2001 and 2002 until the high water event at the end of August in 2002 (C). 41

LIST OF APPENDICES

Appendix **Page**

Appendix 1. Summary of hydroacoustic population and mid-water trawl abundance estimates of rearing sockeye salmon fry and other captured species in Klawock Lake, 1986–2002.....43
Appendix 2. Sockeye salmon counts at the Klawock River weir during 2002.....44
Appendix 3A. Klawock Lake epilimnetic water quality data by date, station, and depth, 2002.....47
Appendix 3B. Klawock Lake hypolimnetic water quality data by date, station, and depth, 2002.....47
Appendix 4A. Zooplankton density estimates (no./m^2) by station and date in 2002.....48
Appendix 4B. Zooplankton size (mm) by station and date in Basin A in 2002.....49
Appendix 4C. Zooplankton size (mm) by station and date in Basin B in 2002.....50

ABSTRACT

The sockeye salmon (*Oncorhynchus nerka*) subsistence fishery in the Klawock estuary is one of the largest in Southeast Alaska, harvesting about 6,000 fish annually. Residents of Klawock and ADF&G were concerned about the apparent declines in sockeye salmon returning to the fishery and Klawock Lake. This is the second year of the research project, which evaluates sockeye salmon production at various life stages and assesses lake productivity. In 2002, the hydroacoustic and trawl surveys in July and October estimated a sockeye salmon fry population of 384,500 and 300,300 sockeye salmon fry respectively. The majority of the trawl samples were sockeye salmon fry, 88% in July and 82% in October. A subsample of 419 emigrating sockeye salmon smolt was composed of 91% age-1 and 9% age-2 fish. A total of 13,600 sockeye salmon were counted at the weir and the escapement was estimated to be 12,600 fish after subtracting the mortalities and brood stock taken above the weir. The mark-recapture study estimated 13,100 (SE = 460) sockeye adults entered the lake, confirming that fish did not pass the weir undetected in 2002. The subsistence harvest was estimated to be about 6,000 sockeye salmon (SE = 389). Seasonal mean zooplankton density was 175,000 plankters per m^2 and a seasonal mean weighted biomass of 420 mg per m^2. This year's results provide the foundation for a multiple-year study to assess the health of the sockeye salmon stock and to set a range of escapement goals capable of sustaining this population for many generations.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, Klawock River, Klawock Lake, Prince of Wales Island, stock assessment, limnology, zooplankton, hatchery, harvest, subsistence, escapement, hydroacoustic

INTRODUCTION

Klawock Lake is one of the few major sockeye salmon *(Oncorhynchus nerka*) producers on Prince of Wales Island. The Klawock sockeye salmon stock is an important subsistence resource for the people of Klawock and other communities on Prince of Wales Island. Klawock River sockeye salmon returns (subsistence fishery and escapement) appear to have declined during the past 20 years and have remained below historic levels (Lewis and Zadina 2001). The residents of Klawock and the Alaska Department of Fish and Game (ADF&G) were concerned about this apparent decline. Numerous human activities have most likely contributed to this decline (Lewis and Zadina 2001, Lewis and Cartwright 2002).

The goal of this multiple-year study is to gather enough information about the sockeye salmon population and their habitat, in Klawock Lake, 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.

Unfortunately, data collected in the past are incomplete and sporadic, making it difficult to get a reliable estimate of escapement (Lewis and Zadina 2001). Although the weir operated sporadically for 34 years, the weir pickets were often pulled during high water or after the brood stock was collected. The weir was fully operated in 2000; the pickets were installed for the entire sockeye and coho salmon season. However, mark-recapture techniques to test the integrity of the weir were not conducted until to 2001. The mark-recapture estimate in 2001 was twice the weir count, confirming the weir leaked or mark-recapture assumptions were violated (Lewis and Cartwright 2002). Thus, the mark-recapture component of the 2002 project was especially important due to this two-fold discrepancy and the history of incomplete sockeye salmon escapement counts at the Klawock weir. We summarize the information collected in 2002, the second year of this study, and compare it to 2001.

OBJECTIVES

1) Estimate sockeye fry densities using hydroacoustic and mid-water trawl methods so that the estimated coefficient of variation is less than 10%.
2) Describe the size and age distribution of sockeye salmon fry, smolt, and adult populations by sex.
3) Estimate the escapement into the lake using mark-recapture methods so that the estimated coefficient of variation is less than 15%.

4) Estimate the subsistence sockeye salmon harvest in Klawock Inlet so that the estimated coefficient of variation is less than 15%.
5) Describe and evaluate the water chemistry, primary and secondary production of Klawock lake.

HISTORY OF SUBSISTENCE USE

The use of fish as a primary source of subsistence food in the Klawock area is well documented. Prior to European contact, the west coast of Prince of Wales Island had the densest assemblage of Tlingit historic sites in Southeast Alaska (Langdon 1977). The Klawakkwan and Henyakwan were the primary occupants of the central west coast of the island including Klawock Inlet. The original Klawakkwan, were a splinter of the Ganaxadi and Tewedih clans, migrating from the east coast of Prince of Wales Island after a conflict over a woman (Langdon 1977). This first group built a small group of houses and one large communal house on the Klawock River, 1 km above the present town site (Langdon 1977). They were later joined by a group of Tekwedih, at which time they jointly built a defensive palisade. Oral history is the only source of this information and no exact date can be identified for these events. However, accounts of the structure being rebuilt for the sixth time in 1830-1840, indicate that the site had been occupied for 375-500 years prior to 1830 (Langdon 1977). Because of stable, multi-species salmon runs, and a concentration of other resources in the area, it is likely that Klawock was a relatively permanent settlement. Klawock served as a hub and small groups split off to start other small villages on the island (Langdon 1977). As the population grew, the village expanded towards the estuary of Klawock Inlet. A Paleolithic salmon weir was built in the estuary to support the increasing population. This shift occurred at the same time as larger canoes began to be employed. Olson (1967) noted that the use of larger canoes, used to travel greater distances, was a response to the local disappearance of marine resources that had been overexploited. Langdon (1977) infers that the weir was a community addition that followed; an increase in population, the construction of large canoes in response to overexploitation of local non-salmon resources, and community movement toward saltwater. Langdon (1977) felt that these events point to expanded exploitation of salmon resources.

Klawock Inlet remains the primary sockeye salmon source for the people of Klawock (Betts et al. 1998). In a recent survey, 97% of Klawock households reported using subsistence fisheries resources and 69% specifically reported using sockeye salmon (Paige et al. 1998). Several factors currently influence salmon harvest patterns in Klawock including: weather conditions, resource abundance, availability of boats, harvest area access and regulations (Betts et al. 1998). During the 1992 interviews, residents mentioned that weekend closures were negatively affecting their subsistence harvest. Residents also repeatedly stated that the Prince of Wales Hatchery was hurting salmon of the Klawock watershed and that run strength had diminished (Betts et al. 1998).

STUDY SITE

The Klawock River system (ADF&G stream number 103-60-047) is located on the southwestern side of Prince of Wales Island (55° 32'58" N., 133° 02'39" W.; Figure 1). The lake has a surface area of 11.9 km^2, an elevation of 9.1 m, a mean depth of 17.7 m, a maximum depth of 49.0 m and a volume of 209 x 10^6 m^3 (Figure 2). This dimictic lake is organically stained with a mean euphotic zone depth (EVD) of 4.2 m based on the 1986–1988 and 2001 limnological data.

Klawock Lake is divided into two basins (Figure 2). Basin A, near the outlet, contains sample stations A and C, and Basin B contains sample stations B and D (Figure 2). Basin A has a maximum depth of 30 m and is generally shallower than Basin B. Basin B has a maximum depth of 49 m. There are four main tributaries to Klawock Lake: Hatchery Creek, Half-Mile Creek, Three-Mile Creek, and Inlet Creek at the head of the lake (Figure 2). Basin A is fed by three of the four larger inlet streams in Klawock Lake. Except for several small-unnamed tributaries, only Inlet Creek at the head of the lake flows into Basin B. The drainage area for Basin A and B are 76.1 km^2 and 37.6 km^2 respectively. The lake empties into Klawock Inlet via the Klawock River (2.85 km). The Prince of Wales hatchery, adult weir, and smolt trap are located on the Klawock River approximately 300 m below the lake.

Native fish species include cutthroat trout (*Oncorhynchus clarki* spp.), Dolly Varden (*Salvelinus malma*), threespine stickleback (*Gasterosteus aculeatus*), cottids (*Cottus* sp.), steelhead (*O. mykiss*), pink (*O. gorbusha*), chum (*O. keta*), coho (*O. kisutch*), and sockeye (*O. nerka*) salmon. Mysid shrimp (*Neomysis mercedis*) are also present in the lake.

METHODS

Juvenile Sockeye Population Assessment

Sockeye Fry Estimates

Hydroacoustic and mid-water trawl sampling were used to estimate the distribution and abundance of sockeye salmon fry in Klawock Lake. We decided to do the first survey of the year in Klawock Lake in 2001 (July) because of its proximity to town in the event we needed additional parts for the gear or the acoustic gear malfunctioned. Upon reviewing the fry estimates from previous years, we realized that most were performed in mid-September to early November (Lewis and Cartwright 2002). The timing of the survey could be important if emerging fry continue to enter the lake throughout the summer. Consequently, we decided to do an additional survey in October to compare estimates in the same year.

As in previous years, the lake was divided into 10 sampling sections. Ten evenly spaced orthogonal transects were identified within each section and two of these were randomly selected to be surveyed in each sample section (20 transects total). Transects selected in 2002 became permanent and will be repeated during future surveys. The decision to keep the transects fixed

each year reflects a decision to emphasize year-to-year changes in population size in our estimates.

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 · 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.

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. 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 identified during the hydroacoustic survey in the area of highest target 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 target density and lake size and morphology. A complete set of tows was conducted in each basin because of their morphological differences.

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

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

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 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 was analyzed using Biosonics Visual Analyzer © version 4.0.2 software. Echo integration was used to generate a fish density (targets $\cdot$ 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 the target estimate was greater than 10%, more sample sections will be added in Klawock 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 of 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 Smolt Age and Length

Sockeye salmon smolts emigrating from Klawock Lake were collected from April 20 through June 12, 2002, to estimate stock age structure and size distribution and describe the run timing. All trapping efforts were conducted at the weir located adjacent to the Prince of Wales Hatchery on the Klawock River. Smolts were collected with a fyke net during the early part of the emigration due to low river discharge. As spring discharge increased an eight-foot diameter screw trap was used in place of the fyke net. The number of smolts present in the trap was tallied daily to determine the peak of the run. Twenty smolts were sub-sampled daily for biological characteristics and frozen. If less than twenty fish were caught in a day, all smolts were sampled. Smolts were weighed to the nearest 0.1 g and snout-fork length was measured to the nearest mm. Scales were collected and mounted on microscope slides for subsequent ageing. An estimate of the total smolt population was not determined.

Sockeye salmon smolt scales were aged using a Carton microscope with a video monitor and interpreting scale growth patterns per Mosher (1968). Two trained technicians using independent examination aged each smolt. The results of each independent scale ageing were compared and where instances of discrepancy between the age determinations was observed, a third independent examination was conducted.

Adult Sockeye Escapement Estimates

Daily counts of all fish species were made at the weir to estimate escapement. A portion of the sockeye run was marked to assess the accuracy of the weir count and to provide an alternative estimate in the event that the weir failed. The POW hatchery staff was responsible for the daily operation of the weir and escapement counts. Additional biological data were collected on sockeye salmon including sex, mid-eye to fork length, and scales for ageing. The dimensions of the weir are described in Lewis and Cartwright (2002). However, due to concerns about weir integrity, some changes were made in 2002. Additional channel was added to the bottom of the pickets along most of the weir to prevent splaying. This year, the weir was monitored more closely than in previous years. Visual inspections of the weir were conducted on a daily basis in addition to weekly SCUBA and snorkel inspections. Hatchery personnel also began keeping daily records of the river water level on a stage gage.

A two-sample mark-recapture study was conducted to test the integrity of the weir and to provide an independent estimate of sockeye salmon into Klawock Lake. The mark-recapture was considered important due to the history of incomplete sockeye salmon escapement counts at the Klawock weir (Lewis and Zadina 2001), and especially in view of the two-fold discrepancy

between the weir count and the mark-recapture estimate in 2001 (Lewis and Cartwright 2002). The first component of the two-sample mark-recapture study occurred at the weir where sockeye salmon were marked daily at a rate of 30% throughout the duration of the run. Marking was stratified through time: a left ventral fin clip was used from June 20 to July 17, a right ventral fin clip from July 18 to August 17, and a dorsal fin clip during the remainder of the run.

The second component of the two-sample mark-recovery study was the recapture portion, conducted on the spawning grounds every week in Half-Mile, Three-Mile, Inlet and Hatchery creeks beginning on August 15. Live and dead fish were counted and examined for marks. Each fish captured was given a second mark (opercle punch) to prevent duplicate sampling in a later sampling period. Weekly foot escapement surveys of spawning sockeye salmon in Three-Mile, Half-Mile, Hatchery, and Inlet creeks were used to describe the distribution and timing of spawning sockeye salmon in the tributaries of Klawock Lake. Streams were walked and sockeye salmon counted by technicians wearing polarized sunglasses. Three-mile, Half-mile, and Inlet creeks are walked to the highway and areas up-stream from the highway are inspected for additional fish during peak fish periods. Hatchery Creek is walked until no additional fish are found. Shoreline surveys from the boat are also conducted to identify potential beach spawning congregations.

Data Analysis

To test assumptions, pool or stratify the data and to calculate a mark-recapture estimate, we used the Stratified Population Analysis System (SPAS) software program (Arnason et al. 1995). SPAS are designed to evaluate 2-sample mark-recapture data where marks and recoveries take place over a number of strata.

The SPAS program calculated the 1) maximum likelihood (ML) Darroch estimates and pooled-Petersen (Chapman's modified) estimates. The ML Darroch model takes full advantage of stratification in the data and estimates abundance and its precision for each of the strata. The SPAS program produces a goodness of fit test for this model. If the test gives a p-value bigger than 0.05, we think the model passes the test and the estimates of abundances and their precisions are valid. Because we want to estimate the escapement only, the advantage of SPAS is that it allows us to pool together some or even all of capture or recapture strata, so that we can have a more precise estimate of escapement without introducing a serious bias. If a simple Petersen estimate is applied to the stratified data that have been pooled, it is called the pooled Petersen estimate (Seber 1982).

However, the Petersen estimate can be badly biased when the assumption of equal catchability is violated. SPAS use chi-square tests to test for complete mixing and equal proportions. If either test passes (i.e., $p > 0.05$), it should be safe to use the pooled Petersen estimate. 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 a small change, it appears safe for pooling, otherwise, if pooling leads a big change in the estimate, it may be badly biased. In the exercise of pooling using SPAS, we expected to pool as many strata as possible to increase precision, although we may have up to

4 capture and 6 recapture strata in our mark-recapture experiments. In case that both ML Darroch model and pooling approach fail, the estimates of abundances cannot be made.

If we can pool the data, a 95% confidence interval for the pooled Petersen estimate was constructed by pooling the data from all marking and all recapture strata and treating the pooled data as a single estimate. We used Chapman's modification of the Petersen Method (Seber 1982) to estimate abundance of sockeye escapement as:

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

where: $\hat{N}$ = estimated abundance of sockeye salmon escapement,
M = number of marked sockeye salmon;
C = number of adults inspected for marks; and
R = number of adults with marks in samples.

The conditions for accurate use of this methodology are that all sockeye 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:

$$\text{SE} = \sqrt{v(\hat{N})} \tag{2}$$

where $v(N)$ is

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

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 $\hat{p} \geq 0.1$, 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

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

And the 95% CI bounds 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).

Handling Mortality Monitoring

Because of the large discrepancy between the weir count and the mark-recapture count in 2001, and the fact that several hundred unspawned salmon wash up on the weir each year, we conducted a study to determine if there was different mortality rate between marked and unmarked fish. The crew held a daily subset of 20 marked sockeye salmon for 24 hours throughout the season to assess potential handling mortality of marked fish. If less than twenty fish were caught in a day, all fish were held that day. These fish were treated the same as other handled fish including being anesthetized, measured, scale sampled and marked with an opercle punch. In addition, the crew collected sockeye mortalities on the weir daily and recorded the number of fish that were marked and unmarked. If the marked-to-unmarked ratio on the weir was greater than the ratio on the spawning grounds, this would indicate that either 1) marked fish had a lower long-term survival rate than unmarked fish, or 2) that unmarked fish passing through the raceway had a different survival rate than unmarked fish passing through the weir undetected, or 3) both.

Escapement Age and Length Distribution and Origin

Adult sockeye salmon scales and lengths were collected at the weir during the mark-recapture study to describe the age, sex and size 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:

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

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

(Thompson 1992, p. 42-43).

Subsistence Harvest Estimate

Harvest Survey

The subsistence fishery season is open from July 7 through July 31, 2002, starting Monday at 0800 and ending Friday at 1700 by regulation. A two-stage harvest survey design was used to estimate fishing effort and sockeye salmon harvest that takes place in the estuary at the mouth of the Klawock River. The first stage of the survey was days. Three days of the 5-day fishery were randomly selected for sampling each week. The second stage of the survey was boat-parties. A boat-party was defined as one or more boats fishing one net. We assumed that we would not be able to interview all parties and missed interviews would be random. On the days selected for sampling, a sampler was present from 0600 to 2200. Two shifts were defined within each day; the first shift started at 0600 and ended at 1400, and the second one lasted from 1400 to 2200.

The sampling unit was an individual seine set for a given boat-party. Each boat-party was interviewed as the net was hauled out of the water. The interviewer drove the skiff over to the participants and interviewed them. If the sampler was busy with another interview, some fishers used fingers to indicate to the sampler how many fish were caught in a given set. The sampler wrote the type of interview on the datasheet. If an interview was missed, it was recorded as such. In the cases where a group refused to give the samplers any information, the sampler wrote down any known information in the comment section. If an interviewer felt that the fisher was underestimating their catch by a large amount, he made a note in the comments and estimated the true catch.

Harvest Data Collection

The sampler introduced himself to the party to be interviewed, giving a short explanation of the harvest survey methods and objectives, before asking a series of questions on the survey interview form. Information collected included date, type of gear, hometown, number of hours fished, and the number and species of fish caught. In addition, the sampler added an interview number, date and time of interview and the type of interview (hand signal or verbal interview).

Data Analysis

The Klawock harvest survey was stratified by week. Let $h_{g,j,k}$ denote the harvest on boat j using gear g on shift k. Let $m_{g,k}$ denote the number of boat parties interviewed using gear g on day k. Finally, let $M_{g,k}$ denote the number of boat-parties counted using gear g and let d denote the total number of shifts in the sample out of a possible D shifts for the whole week. Then for some specific species, the harvest for gear group g in during each individual week was estimated as,

$$\hat{H}_g = \frac{D}{d}\frac{M_{g,k}}{m_{g,k}}\sum_{k=1}^{d}\sum_{j=1}^{m_g} h_{g,j,k} \ . \qquad (10)$$

The variance of the harvest will be estimated as,

$$\mathrm{var}(\hat{H}_g) = M_g^2(1-\frac{m_g}{M_g})\frac{\sum_{j=1}^{m_g}(h_{g,i,k}-\bar{h}_{g,k})^2}{m_{g,k}(m_{g,k}-1)} + D^2(1-\frac{d}{D})\frac{\sum_{k=1}^{d}(\bar{h}_{g.k}-\bar{h}_g)^2}{d(d-1)} \ , \qquad (11)$$

where $\bar{h}_{g,k}$ denotes the mean harvest, per boat, for the gth gear group on day k and $\bar{h}_g$ denotes the weekly total.

Weekly harvest estimates and estimated sampling variances were totaled to estimate the total harvest for the entire fishery. Effort was estimated similarly, substituting E for H in the two immediately preceding equations.

Estimated sampling variances for the entire season were transformed into standard error estimates or confidence intervals for the purposes of reporting.

Limnology

Limnology sampling was conducted at Stations A (Basin A) and B (Basin B) on Klawock Lake on May 9, June 12, July 26, September 6, and October 18 in 2002. We measured euphotic zone depth, temperature, and dissolved oxygen by depth during each sampling event. We also collected water samples for water quality, metals and nutrients using procedures outlined in Koenings et al. 1987 at these 2 stations. Zooplankton was sampled on the same dates at all four stations (after Koenings et al. 1987; Figure 2).

RESULTS

Juvenile Sockeye Population Assessment

The sockeye fry population estimate was slightly higher in the July survey compared to the October survey. The July and October hydroacoustic surveys estimated the sockeye fry population to be 384,500 and 300,300 fish respectively. The mean weighted sockeye fry density for July and October was 0.037 and 0.034 fry $\cdot$ m^{-2} respectively. Similar to most years, Basin B has a higher density of fry than Basin A (Table 1).

The July 10 tow net effort yielded a total of 35 sockeye fry, 4 sticklebacks and 1 sculpin in 10 tows (n=40; Table 2). All sockeye fry caught in July were less than 50 mm, and assumed to be age-0 (Figure 3). The October tow net efforts yielded a total of 46 sockeye fry, 4 sticklebacks, and 4 sculpin in 19 tows (n=52; Table 2). Forty-three sockeye fry caught in October were less than 50 mm, and assumed to be age-0 (Figure 3). A single age-1 fry and two age-2 fry were also captured in October. Age-0 sockeye salmon fry had a July mean snout-fork length of 37.0 mm (SE = 0.6) and an October mean snout-fork length of 54.2 mm (SE = 1.1). This is similar to other years in that sockeye fry exceed 30 mm by mid-summer and approach 50 mm by the end of September and continue to grow in October (Appendix 1). Despite nearly doubling the tow effort in October compared to July, only 13 more fish were caught in the mid-water trawls.

The type of hydroacoustic equipment used, the type of analysis performed and the season of the survey varied widely between the 7 acoustic surveys completed on this lake (Table 3). However, the sockeye fry estimates are all around 300,000 fry except 1986 and 2001. In these two years, the fry estimate is double compared to other years. Interestingly, these two years are 15 years apart, most likely representing the same first and fourth generation of progeny, if age 1.3 sockeye spawners are the dominate age class. Unfortunately, the 1985 and 2000 escapement years were one of the few years not sampled in a 20-year ASL data set collected at Klawock Lake.

In addition to naturally produced sockeye salmon fry, the Prince of Wales Hatchery released total of 510,000 emergent sockeye salmon fry into Klawock Lake in 2002. Approximately 35,500 fry were released on March 10, 133,500 fry on April 10, 96,800 fry on April 17, 113,300 fry on April 24, and 131,100 fry on May 3, 2002 (John Bruns, PWHA, personal communication). These fry originated from eggs taken from Three-Mile and Half-mile creeks in Basin A. All fry were released into Inlet Creek, which flows into Basin B (Figure 2).

Sockeye Smolt Age and Length Characteristics

The age and length characteristics of the emigrating 2002 smolts were similar to past years; the majority of the smolts were age-1 and their average length and weight were within the range recorded in previous years (Table 4). Of the 419 sockeye salmon smolts aged, 91% were age-1 (n=382) and 9% were age-2 (n=37). Age-1 smolt had a mean length of 84 mm (SE = 0.35) and a

mean weight of 5.6 g (SE = 0.06). Age-2 smolt had a mean length of 127 mm and a mean weight of 18.0 g. Age distribution determined by scale analysis corresponded well with the bimodal sockeye salmon smolt length frequency distribution (Figure 4).

Adult Sockeye Escapement Estimates

A total of 13,631 sockeye salmon adults were counted through the Klawock River weir in 2002. Approximately 30% (3,836 fish) of the sockeye salmon were marked to obtain a second estimate of escapement using mark-recapture methods (Table 5; Appendix 2). The following marks were applied: 252 left round opercle punches (July), 2,099 double left round opercle punches (August), and 1,485 left triangle opercle punches (September; Table 5).

The percent of marks recovered in the streams was fairly consistent between the four streams with an overall average of 29% (494 marks out of 1,685 sockeye salmon examined) and a range of 20.0% to 27.0% (Table 6).

For "complete mixing" test, the chi-square statistic is $X^2 = 88.82$ with 3 degree of freedom, and p-value = 0.00; for "equal proportions" test, $X^2 = 4.27$ with 3 degree of freedom, and p-value = 0.23. Because it passed the "equal proportions" test, it is valid to use pooled Petersen estimate. The data were pooled across strata to get an estimate of 13,068 (SE=460, CV = 3.5%) sockeye salmon returning to the spawning grounds in Klawock Lake. Because $\hat{p} > 0.1$ and $R/M > 0.1$, we used the normal approximation equation (Seber 1982) to calculate the 95% CI bounds around the estimate: 11,535 to 15,115 sockeye salmon.

Mortalities above the weir include removal of brood stock, pre-spawning mortalities collected against the weir, and handling mortality estimated by holding tagged fish for 24 hours. The Prince of Wales Hatchery removed 576 of these sockeye salmon, by seining in the lake for brood stock. These fish were then held in net-pens until they were ripe. The brood stock had a pre-spawn mortality of 255 fish (44%) in 2002. A total of 419 pre-spawned sockeye salmon washed up on the weir, of which 24% (102) were marked. Mortalities due to handling and marking sockeye salmon at the Klawock weir appear to be negligible. Of the 503 sockeye salmon held, 2 died, for a mortality rate of <0.4 %. The estimated number of mortalities due to handling expanded to all tagged fish was 15 fish.

The 2002 mark-recapture estimate confirmed that the weir remained fish-tight throughout the season. Therefore, the weir count is considered an accurate measurement of escapement in 2002. The weir count minus the 1,010 sockeye adults known to die before spawning, places the total number of naturally spawning sockeye at 12,621 fish in Klawock Lake. In 2001, the mark-recapture estimate was used as the best guess about how many sockeye salmon passed through the weir 14,057 fish. This estimate minus the 891sockeye adults taken for brood stock, places the 2001 escapement at 13,166 naturally spawning sockeye adults. Mortalities on the weir and handling mortality due to marking were not assessed in 2001.

Foot escapement surveys in on the three major inlet streams showed the peak spawning period was about the same for Inlet and Three-Mile creeks and later in September for Half-Mile Creek (Table 7; Figure 5). Three-Mile Creek had the highest sockeye salmon peak count of 520 on 13 September, followed by Inlet Creek with 430 on 12 September, and Half-Mile Creek with 156 on 26 September. Hatchery Creek had a peak count of 47 sockeye salmon on September 27 (Table 7; Figure 5). There were never more that 10 fish seen above the highway on Three-mile, Half-mile, and Inlet creeks. No beach spawning congregations were observed in Klawock Lake during 2002 during periodic shoreline surveys.

Escapement Age, Length, and Sex Information

A total of 571 adult sockeye salmon were sampled for sex, length, and scales at the Klawock River weir during 2002 field activities. The dominant age class of adult sockeye salmon weighted by statistical week was age-1.2 fish (34.7%, n = 198) followed by age 1.3 (34.3%, n = 196; Table 8 and 9). The mean fork length of age 1.2 fish was 513 mm (SE = 2 mm; n= 197) and 578 mm (SE = 2 mm; n= 195) for age-1.3 fish (Table 10).

Subsistence Harvest Estimate

A subsistence fishery harvest survey was conducted from July 7 to 31, 2002. Klawock Cooperative Association personnel conducted the interviews and the harvest survey was reasonably well received by the community. All sockeye salmon were caught in the estuary area near the bridge in the town. Of the 382 boat-parties counted, 375 were interviewed during subsistence fishing season and 7 interviews were missed. The harvest survey estimated approximately 6,000 sockeye salmon were harvested with a 95% CI range between 5,300 and 6,800 fish. The pattern of harvest through time for each sample day varied throughout the fishery (Figure 6). A total of 3,778 sockeye salmon were reported on ADF&G permits, about 62% of the number reported in the on-grounds harvest survey.

At the time of the 2001 annual report (Lewis and Cartwright 2002), the numbers of fish reported on permit returns were not available. The final number of sockeye salmon reported on returned permits in 2001 was 4,353 fish. The on-grounds harvest survey estimated approximately 6,400 sockeye salmon were harvested in 2001. About 68% of the on-grounds harvest estimate was reported on subsistence permits.

Limnology

General Water Chemistry

Typical of lakes in Southeast Alaska, Klawock Lake is a stained, oligotrophic, and dimictic lake. Although multiple water properties were analyzed, only a select number of parameters are presented in Table 11 and 12 (see Appendix 3A and B for details). Seasonal mean epilimnetic total phosphorous (TP) concentrations were higher in Basin B than in Basin A (Table 11; Appendix 3A). Nitrogen is also essential for phytoplankton production. Seasonal mean epilimnetic Total Kjeldahl Nitrogen (TKN) concentrations were higher in Basin B than in Basin A (Table 11; Appendix 3A).

Primary productivity parameters include chlorophyll *a* (chl *a*) and phaeophyton *a*. Algal biomass, essential for sockeye salmon nursery lakes, is defined as the phytoplankton standing crop and is represented by the algal pigment production of chlorophyll *a*. The seasonal mean epilimnetic Chl *a* concentration at Station A was 0.45 ug · L^{-1} and ranged from 0.14 to 0.70 ug · L^{-1} (Table 12). The seasonal mean epilimnetic Chl *a* concentration at Station B was 0.59 ug · L^{-1} and ranged from 1.33 to 0.22 ug · L^{-1} (Table 12). These low concentrations are typical of Southeast Alaska stained lakes with shallow euphotic zones (Zadina and Heinl 1999, Zadina and Weller 1999). Because chl *a* degrades to phaeophyton *a* from changes in light, temperature, and pH, we also measure it and include it in the primary productivity assessment. Phaeophyton *a* concentrations ranged from 0.16 to 0.48 ug · L^{-1} at Station A and 0.17 to 0.35 ug · L^{-1} at Station B (Table 12).

Vertical Light Penetration, Temperature, and Dissolved Oxygen

The mean 1% light level in Klawock Lake appeared to be 1 meter deeper in 2002 compared to other years (Table 13). At Station A, the 2002 euphotic zone depth (EZD) ranged from 3.5 to 6.6 m with a season mean of 5.4 m (Table 13). At Station B, the 2002 EZD ranged from 3.9 to 5.7 m with a season mean of 5.1 m (Table 13).

The dimictic pattern in Klawock Lake is documented by the water temperature profiles showing stratification in the summer and isothermic patterns in October and May (Figures 7 and 8). The near-surface temperature (depth = 1 meter) peaked in July at 15.4ºC at Station A and 15.8^{o} C at Station B. Hypolimnetic temperatures varied between 4.5 and 9.1^{o} C at Station B, located at the deeper of the two lake basins. Despite the fact that the bathymetries of the two basins are very different, the development and depth of their thermoclines were similar. The thermocline did not develop on the lake until July in both basins (Figure 7 and 8). The beginning of the thermocline was 9m (Basin A) and 19m (Basin B) in July and 15m (Basin A) and 13m (Basin B) in September. Dissolved oxygen (DO) levels for 2002 ranged between 7.1 and 11.2 mg · L^{-1} (64% and 100% saturation respectively) at Station A and 5.7 and 11.3 mg · L^{-1} (75% and 100% saturation respectively) at Station B.

Secondary Production

In 2002, the macrozooplankton assemblage in Klawock Lake was composed of two copepods (*Cyclops* sp. and *Epischura* sp.), and three cladocerans (*Bosmina* sp., *Daphnia rosea*, and *Holopedium* sp.; Appendix 4A). At all stations the dominant form by biomass and density was *Cyclops* sp. (Tables 14 and 15). The seasonal mean total macro-zooplankton density in Basin A was 144,000 plankters · m^{-2} (Station A) and 112,000 plankters · m^{-2} (Station C). The seasonal mean weighted macro-zooplankton biomass in Basin A was 252 mg · m^{-2} (Station A) and 222 mg · m^{-2} (Station C; Table 14). The seasonal mean total macro-zooplankton density in Basin B was 330,000 plankters · m^{-2} (Station B) and 311,000 plankters · m^{-2} (Station D; Table 15). The seasonal mean weighted macro-zooplankton biomass in Basin B was 615 mg · m^{-2} (Station B) and 590 mg · m^{-2} (Station D) in 2002 (Table 15). The seasonal mean zooplankton density and weighted biomass has been consistently higher in Basin B compared to Basin A in all years that samples were collected (Figure 9). *Epischura* sp. was the largest zooplankton (1.3 mm) followed by *Holopedium* sp. (1.0 mm), *Daphnia rosea* (0.9 mm), *Cyclops* sp. (0.7 mm), and *Bosmina* sp. (0.3 mm; Appendix 4B and C).

DISCUSSION

In 2002, we investigated components of weir operations and the mark-recapture study to identify the cause of the discrepancy between the 2001 weir count (7,000 sockeye) and the mark-recapture estimate (14,000 sockeye; Lewis and Cartwright 2002). In the 2001 annual report, we explored several hypotheses to account for this difference (Lewis and Cartwright 2002). The most likely explanation for this discrepancy was 1) handling-induced mortality of marked fish or 2) fish passing undetected through the weir. The 2002 handling stress/mortality study indicated that there was minimal (<1%) handling mortality. The percent of marks recovered on fish dead against the weir (24%) was within this range observed on the spawning grounds (20%– 27%). We considered other possible violations of mark-recapture 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. In 2002, the modifications to the weir and consistent SCUBA diving to look for gaps, most likely resulted in few fish passing the weir undetected and contributed to the close agreement of the weir count and mark-recapture estimate.

Consequently, the discrepancy between the weir count and mark-recapture estimate in 2001 was probably due to sockeye salmon passing through the weir undetected. A comparison between the timing of the run through the weir in 2001 and 2002 and the occurrence of a high water event on August 27, 2001 reinforces this conclusion (Figure 10). Very few sockeye adults passed through the weir after August in 2001 (Figure 10 A). The 2002 cumulative percent of the sockeye adults through the weir indicates that about 50% entered the system after August 27, the date of the high water event in 2001 (Figure 10 B). Figure 10 C shows that the timing of run in these two years was almost identical until August 27. If the timing of the run continued to be the same in 2001 as it was in 2002, then the weir count missed half the run, the difference between the weir count and the mark-recapture estimate in 2001.

Although careful maintenance of the weir and handling of the marked fish most likely contributed to the agreement between weir count and mark-recapture estimate of escapement in 2002, the integrity of the weir can never be guaranteed because of the high water events in this system. If a mark-recapture experiment is not done annually to back up the weir count, in years when the weir is obviously compromised (or not so obviously), the data and effort for that year will be worthless. Therefore, it is critical to get an independent estimate of escapement, especially in Southeast Alaska and especially at the Klawock weir. The vulnerability of the Klawock weir to leaking is further elevated by high water events due to the extensive logging of the drainage, the high volume of water leaving this system and an unstable substrate. Indeed, incomplete escapement counts and past weir leaks have plagued this system for a long time. Although fish counts have been collected for 34 years at this weir, none of them were considered accurate until 2001; the first year a mark-recapture study was done (Lewis and Zadina 2001; Lewis and Cartwright 2002). After two years of estimating the sockeye adult returns to this system, the sockeye salmon adult population does not appear to be as low as previous weir counts suggested. However, the sockeye escapement needed to maximize production and returns to the subsistence fishery is still unknown.

Currently, the subsistence fishery takes 30% of the adult return (20,000 fish) to the Klawock estuary. Although we do not know how many of the Klawock sockeye salmon are caught in the 103 and 104 purse seine fisheries, these fisheries have fluctuated dramatically in the last 2 years with no apparent effect on the subsistence fishery or escapement into Klawock Lake. For example, 412,000 and 23,000 sockeye salmon were harvested in Districts 103 and 104 in 2001 and 2002 respectively. Yet the subsistence fishery harvest and the escapement (returns) were about the same for both years. Possible explanations for this include 1) sockeye salmon traveling through these areas are bound for other systems, 2) the concentration of Klawock sockeye salmon in the commercial fishery is so dilute that an 18-fold decrease in harvest does not result in a substantial increase in sockeye salmon returns to this system, 3) the majority of the adult sockeye salmon returning to Klawock River travel inside islands close to the Prince of Wales Island, away from the main commercial fishery, or 4) a combination of the above.

In the second year of the Klawock Lake Project, we met all the objectives for this project in 2002, with the exception of estimating the sampling error associated with sockeye fry population. The sockeye salmon return was accurately estimated by the subsistence harvest and the adjusted weir count. The age and size structure of the population was described as well as lake conditions and zooplankton abundance. Although we obtain an approximate estimate of the number of sockeye fry in Klawock Lake, we were unable to estimate the sampling error associated with this estimate. Hydroacoustic surveys will be eliminated from most of the lakes after this year because of the difficulty in obtaining an adequate sample size with the current mid-water trawl gear in these oligotrophic lakes. 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. Improvements in the study design and trawl methods

will hopefully allow us to get a more precise measurement with error bounds needed for observing smaller changes in trophic level responses.

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 fry densities and ultimately the sockeye spawning population. The sockeye fry abundance in 2002 was about half of the 2001 estimate in July. Although they are not directly comparable because of change in study design, the 2-fold difference suggests that there was a decline in sockeye fry in 2002 compared to 2001. The increase in zooplankton biomass from 2001 to 2002 lends additional evidence to this decline (Figure 9). If more favorable weather conditions were the cause of this increase, we would expect to see similar increases in other lakes in Southeast. This is not the case, most declined between 2001 and 2002 (Table 16). If the sockeye fry population is closely coupled with trends in zooplankton abundance, then this lake may be food limited or approaching it.

The changes in fry and zooplankton densities through time and space allow us to see overlaps in distribution and consider their implications to the study design or the ecology of the system. Because of the 20% decline in the sockeye densities between July and October, future acoustic surveys in Klawock should be performed in the fall to eliminate the potential effects of season on the fry estimate. On the other hand, performing surveys in the fall, further exacerbates the bias against collecting larger fish in the trawl gear because of the substantial growth of sockeye fry between July and October. The fact that doubling the trawl effort yielded only 20% more fish could be, in part, a result of this bias.

The movement of sockeye salmon fry from basin to basin is an ecological example. At the time of the October hydroacoustic survey, fry densities in Basin B were twice as high as in Basin A. The majority of naturally produced sockeye fry emerge in Basin A, which has three of the four primary spawning streams. This suggests that emerging fry in Basin A migrate to Basin B over the course of the summer. This fry migration pattern is apparent in five of six years sampled (Lewis and Cartwright 2002). The higher densities of zooplankton in Basin B in all years sampled (Figure 10) could explain this migration pattern. In addition, Basin B is deeper, perhaps providing a better over-wintering habitat.

Although the dominant age class of sockeye smolt populations in Klawock Lake is age-1 in all years, the proportion in 2002 was the highest observed (Table 4). In 2002 the proportion of age-1 smolt was 91%, above the range seen in other years (79% to 87% during 1987-88, 1995, and 2001). Age-1 smolt in 2002 was also larger and heavier than age-1 smolt from the three of four years sampled. The high percentage of large age-1 smolts leaving the system suggests this cohort had the ideal environment for growth i.e., adequate food, forage opportunities, and good temperature regimes at critical life history stages.

Water chemistry and the physical characteristics of Klawock Lake have been sporadically collected for 8 years beginning in 1979, to evaluate the system's response to stocking sockeye fry. The Soldotna Limnology Laboratory will review this data and summarize the salient changes observed in this system over the years. The final report will contain an interpretation of this data.

Despite the long history of assessment and enhancement efforts in the Klawock watershed, the number of sockeye salmon required to sustain production in Klawock Lake remains unknown. The integration of other research will be required to identify other limitations in the Klawock watershed. For example, restoration of the riparian areas and stabilization of the stream hydrology are also essential elements of the recovery of healthy stocks in Klawock Lake and these activities are being initiated by other agencies. The Southeast Sustainable Salmon (SSSF) project will evaluate components of the sockeye fry stocking enhancement program, describe the distribution of potential predators through time and space, and to reconstruct the long-term productivity of Klawock Lake using sediment core records. We will continue to develop cooperative partnerships, job, and training opportunities with the community of Klawock. None of these research and project directions can be completed in a few years. Instead, they require consistent attention, on-going re-evaluation and coordination with the community to work toward sustaining the sockeye salmon returns to Klawock Lake.

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TABLES

Table 1. Hydroacoustic sockeye salmon fry densities (fry · m^{-2}) estimates in Basin A and Basin B in Klawock Lake.

Year	Date	Basin A	Basin B
1986	Sep 21	0.096	0.091
1987	Oct 22	0.025	0.064
1988	Oct 26	0.023	0.035
2000	Nov 7	0.024	0.036
2001	Jul 9	0.055	0.079
2002	Jul 10	0.036	0.039
2002	Oct 1	0.020	0.049

Table 2. Summary of hydroacoustic trawl data by basin, date, depth and species collected on Klawock Lake in 2002.

					Sockeye			Stickleback	Sculpin	Total
Basin	Date	Tow	Depth (m)	Time (min)	Age-0	Age-1	Age-2			(n)
A	07/10/02	1	1	15	2					2
		2	7	15	1					1
		3	7	15	1					1
		4	7	15						0
		5	7	15	4			1		5
B	07/10/02	1	7	15	11					11
		2	7	15	2					2
		3	1	15	11			1	1	13
		4	7	15				1		1
		5	7	15	3			1		4
Total		10			35	0	0	4	1	40
A	10/02/02	1	6	15	1					1
		2	6	15	3					3
		3	8	15						0
		4	8	15	1					1
B	10/02/02	1	8	20	1		1			2
		2	8	20	7		1			8
		3	10	30	10			1		11
		4	10	30						0
		5	1	15						0
A	10/03/02	1	1	15						0
		2	10	15	2					2
		3	10	15						0
		4	8	15	5					5
		5	8	15	3			2	4	9
B	10/03/02	1	14	40	1			1		2
		2	14	40	4	1				5
		3	10	15	4					4
		4	10	15						0
		5	1	20						0
Total		19			42	1	2	4	4	53

Table 3. Summary of the hydroacoustic estimates of sockeye salmon fry in Klawock Lake 1986-1988, 1995, 2000-2002.

Year	Survey Season	Type of Estimate	Sockeye Fry Population Estimate
1986	Fall	Duration-in-beam	912,000
1987	Fall	Duration-in-beam	272,000
1988	Fall	Duration-in-beam	364,000
1995	Spring	Echo Integration	322,000
2000	Fall	Echo Integration	311,000
2001	Summer	Echo Integration	718,000
2002	Summer	Echo Integration	384,000

Table 4. Comparison of sockeye salmon smolt age, percent composition (not weighted by total emigration), length, and weight data, by year.

Year	Age	Percent	Length (mm)	Weight (g)
1987	1	70%	79.2	4.3
	2	29%	115.9	12.8
1988	1	82%	87.1	6.0
	2	15%	110.2	11.0
	3	3%	129.4	17.4
1995	1	83%	83.0	5.0
	2	17%	114.0	11.5
2001	1	87%	79.4	4.3
	2	13%	127.0	17.4
2002	1	91%	84.5	5.6
	2	9%	127.0	18.0

Table 5. Summary of adult sockeye salmon marking at the Klawock River weir by date and mark type, 2002.

Date	Clip	Marked	Unmarked	Total
June-July	Left Round	252 (32%)	535	786
August	Left Double Round	2,099 (31%)	4,729	6,828
September	Triangle	1,485 (25%)	4,873	6,324
Total		3,836 (28%)	10,103	13,920

Table 6. Mark recovery data for Klawock Lake adult sockeye salmon by stream in 2002.

Stream	Date	Unmarked	Double	Single	Triangle	Total	%Marked
Three Mile	Aug 8	2					0.0%
	Aug 15	85	10	17		112	24.1%
	Aug 27	77	42	2		121	36.4%
	Sep 5	157	69	2	6	234	32.9%
	Sep 6	84	26	4	1	115	27.0%
	Sep 11	85	19		19	123	30.9%
	Sep 13	5		2	3	10	50.0%
	Sep 18	21	5		4	30	30.0%
	Sep 20	7	5			12	41.7%
	Sep 23	6	1		3	10	40.0%
	Sep 25	5				5	0.0%
	Sep 25	10				10	0.0%
	Oct 3	5		1	2	8	37.5%
	Oct 11	8		1	2	11	27.3%
	Oct 21	1				1	0.5%
Average							**27.0%**
Half Mile	Aug 26	67	19	5		91	26.4%
	Sep 3	3	1			4	25.0%
	Sep 4	111	50	2	6	169	34.3%
	Sep 9	12	3	1	3	19	36.8%
	Sep 10	51	8	1	7	67	23.9%
	Sep 17	32	10	1	6	49	34.7%
	Sep 24	1				1	0.0%
	Sep 27	18	3		4	25	28.0%
	Oct 3	54	12	1	9	76	28.9%
	Oct 11	32	5		4	41	22.0%
	Oct 21	2	1			3	33.3%
Average							**26.7%**
Inlet	Sep 4	117	29	7		153	23.5%
	Sep 12	105	29		10	144	27.1%
	Sep 24	4	1	1		6	33.3%
	Sep 30	9			3	12	25.0%
	Oct 10	5			1	6	16.7%
Average							**25.1%**
Hatchery	Sep 7	1				1	0
	Sep 20	1			1	2	50%
	Sep 26	2	1		1	4	50%
	Oct 4	1				1	0
	Oct 17	2				2	0
Average							**20.0%**

Table 7. Foot escapement counts of adult sockeye salmon in the Klawock Lake system by stream and date, 2002.

Stream	Date	Live	Dead
Three Mile	Jul 29	0	0
	Jul 31	0	0
	Aug 8	0	0
	Aug 11	0	0
	Aug 18	0	0
	Aug 21	7	0
	Aug 29	10	0
	Sep 6	361	0
	Sep 13	520	0
	Sep 20	290	36
	Sep 25	159	5
	Sep 30	75	4
	Oct 3	30	4
	Oct 12	50	2
	Oct 21	6	0
	Oct 26	2	1
Half Mile	Jul 31	0	0
	Aug 14	0	0
	Aug 18	0	0
	Aug 21	0	0
	Aug 24	2	0
	Sep 3	15	0
	Sep 9	75	0
	Sep 18	113	2
	Sep 26	156	13
	Oct 3	131	10
	Oct 11	55	12
	Oct 21	14	1
	Oct 27	10	0
Hatchery	Jul 31	0	0
	Aug 14	0	0
	Aug 18	0	0
	Aug 21	0	0
	Sep 7	7	0
	Sep 20	22	2
	Sep 27	47	4
	Oct 4	42	3
	Oct 17	10	2
	Oct 28	0	0
Inlet	Jul 31	0	0
	Aug 11	0	0
	Aug 18	0	0
	Aug 24	10	0
	Sep 4	340	1
	Sep 12	430	12
	Sep 24	119	22
	Sep 30	24	5
	Oct 10	15	2
	Oct 15	8	0
	Oct 23	1	0
	Oct 29	0	0

Table 8. Numbers of fish sampled in Klawock Lake sockeye salmon escapement 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	0	0	140	0	3	100	0	15	100	71	101	37	26	144	16	46	0	0	0	5	0
1.2	112	0	117	0	194	145	198	34	28	100	252	109	36	170	44	147	0	0	0	59	198
1.3	608	0	144	0	513	278	235	334	17	69	170	273	395	160	344	231	0	0	0	297	196
1.4	0	0	1	0	0	1	2	0	1	0	0	1	0	0	1	1	0	0	0	1	3
2.1	1	0	18	0	1	29	0	4	1	11	32	22	4	13	6	3	0	0	0	2	16
2.2	3	0	45	0	53	121	69	50	25	14	14	45	79	25	48	55	0	0	0	74	153
2.3	7	0	29	0	61	70	56	59	8	4	5	51	16	41	52	58	0	0	0	166	5
2.4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.2	4	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.3	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Totals	735	0	494	0	826	748	561	496	180	269	574	542	556	553	511	541	0	0	0	604	571

Table 9. Percent of fish sampled in Klawock Lake sockeye salmon escapement 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	Average	SE
1.1	0	0	28.3	0	0.4	13.4	0	3	55.6	26.4	17.6	6.8	4.7	26	3.1	8.5	0	0	0	0.8	0	9.2	0.3
1.2	15.2	0	23.7	0	23.5	19.4	35.3	6.9	15.6	37.2	43.9	20.1	6.5	30.7	8.6	27.2	0	0	0	9.8	34.7	22.2	0.4
1.3	82.7	0	29.1	0	62.1	37.2	41.9	67.3	9.4	25.7	29.6	50.4	71	28.9	67.3	42.7	0	0	0	49.2	34.3	48.7	0.5
1.4	0	0	0.2	0	0	0.1	0.4	0	0.6	0	0	0.2	0	0	0.2	0.2	0	0	0	0.2	0.5	0.1	0
2.1	0.1	0	3.6	0	0.1	3.9	0	0.8	0.6	4.1	5.6	4.1	0.7	2.4	1.2	0.6	0	0	0	0.3	2.8	1.9	0.1
2.2	0.4	0	9.1	0	6.4	16.2	12.3	10.1	13.9	5.2	2.4	8.3	14.2	4.5	9.4	10.2	0	0	0	12.3	26.8	10	0.3
2.3	1	0	5.9	0	7.4	9.4	10	11.9	4.4	1.5	0.9	9.4	2.9	7.4	10.2	10.7	0	0	0	27.5	0.9	7.9	0.3
2.4	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.2	0.5	0	0	0	0.1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0
3.3	0	0	0	0	0	0.3	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0.1	0

Table 10. Mean fork length (mm) of adult sockeye salmon in the Klawock Lake escapement by sex, brood year, and age class, July 1 to September 22, 2002.

Brood Year	1998	1998	1997	1997	1996	1996	Total
Age	1.2	2.1	1.3	2.2	1.4	2.3	
Male							
Avg. Length	520	414	590	517	616	614	546
Std.	3.7	4.7	2.9	4.3	3.3		
Sample size	93	5	96	45	1	1	241
Female							
Avg. Length	506	421	566	506	598	568	523
Std.	2.7	4.7	2.7	3.2	37.5	10.5	2.5
Sample size	101	10	98	107	2	4	322
All							
Avg. Length	513	418	578	509	604	577	533
Std.	2.3	3.5	2.1	2.6	22.5	12.2	2
Sample size	197	15	195	153	3	5	568

Table 11. TKN and TP concentrations (*u*g/l) for Klawock Lake by basin, date and depth strata, 2002.

Basin	Strata	May 9	Jun 12	Jul 18	Sep 5	Oct 16	Average
TKN							
A	EPI	95.5	85.8	109.5	136.4	136.2	112.7
B	EPI	105.2	86.8	122.5	135.4	144.0	118.8
A	HYP	112.8	90.1	121.3	133.2	178.4	127.2
B	HYP	86.9	81.5	122.5	116.0	121.4	105.7
TP							
A	EPI	5.0	3.9	5.2	4.5	7.3	5.2
B	EPI	5.6	4.2	3.9	3.5	6.4	4.7
A	HYP	6.0	5.9	5.4	6.6	12.4	7.3
B	HYP	4.6	4.9	4.6	4.9	5.2	4.8

Table 12. Chlorophyll *a* and phaeophyton concentrations for Klawock Lake by station, date and strata, 2002

Station A		May 9	Jun 12	Jul 17	Sep 5	Oct 16
EPI	CHL A	0.32	0.14	0.59	0.49	0.70
	PHAEO	0.30	0.21	0.48	0.16	0.16
EZD	CHL A	0.28	0.23	0.21	0.16	0.30
	PHAEO	0.14	0.19	0.18	0.15	0.14
HYP	CHL A	0.25	0.06	0.13	0.13	0.09
	PHAEO	0.14	0.30	1.36	0.29	0.12
MEU	CHL A	0.33	0.22	0.20	0.41	0.34
	PHAEO	0.16	0.25	0.19	0.18	0.14
Station B						
EPI	CHL A	1.33	0.22	0.63	0.54	0.22
	PHAEO	0.35	0.24	0.26	0.18	0.17
EZD	CHL A	1.26	0.36	0.42	0.23	0.27
	PHAEO	0.37	0.27	0.42	0.10	0.15
HYP	CHL A	0.31	0.05	0.05	0.02	0.08
	PHAEO	0.16	0.13	0.16	0.17	0.25
MEU	CHL A	1.24	0.33	0.50	0.61	0.29
	PHAEO	0.38	0.24	0.33	0.16	0.16

EPI=epilimnion, CHL A= chlorophyll *a*, PHAEO=phaeophyton, MEU=mid-euphotic zone, EZD=euphotic zone depth, HYPO=hypolimnion

Table 13. Euphotic zone depth (m) of Klawock Lake by year at Station A and B, 1986–2002.

Year	Date	Station A	Station B	Mean
1986	May 19	6.12	NA	6.12
	Nov 4	3.14	2.67	2.91
	Seasonal Mean	**4.63**	**2.67**	**3.65**
1987	Apr 27	4.60	5.66	5.13
	Nov 20	2.79	2.50	2.65
	Seasonal Mean	**3.69**	**4.08**	**3.89**
1988	Mar 15	3.31	NA	3.31
	Aug 11	NA	4.01	4.01
	Nov 16	3.78	4.77	4.28
	Seasonal Mean	**3.55**	**4.39**	**3.97**
2000	May 19	4.72	4.54	4.63
	Jun 27	5.21	5.00	5.11
	Aug 17	4.07	4.72	4.40
	Sep 26	3.62	3.95	3.79
	Seasonal Mean	**4.41**	**4.55**	**4.48**
2001	May 9	3.72	3.83	3.78
	Jun 12	NA	4.48	4.48
	Jul 26	4.71	4.98	4.85
	Sep 6	3.67	4.47	4.07
	Oct 16	3.76	4.75	4.26
	Seasonal Mean	**3.97**	**4.50**	**4.24**
2002	May 9	5.28	5.72	5.50
	Jun 11	5.97	5.65	5.81
	Jul 17	5.65	5.96	5.81
	Sep 5	6.75	4.28	5.52
	Oct 16	3.46	3.93	3.70
	Seasonal Mean	**5.42**	**5.11**	**5.27**

Table 14. Seasonal mean macro-zooplankton size (mm), density (No. · m^{-2}) and mean weighted biomass (mg · m^{-2}) distributions by species in Basin A (Station A and C) of Klawock Lake, 2002.

Station A	Size	Density	Percent	Biomass	Percent
Epischura	1.40	1,718	1.2%	20.3	8.1%
Cyclops	0.69	113,989	79.2%	186.0	73.8%
Ovig. Cyclops	0.94	214	0.1%	0.7	0.3%
Bosmina	0.34	22,062	15.3%	23.8	9.4%
Ovig. Bosmina	0.44	99	0.1%	0.2	0.1%
Daphnia r.	0.83	4,116	2.9%	9.6	3.8%
Ovig. Daphnia r.	1.30	516	0.4%	3.4	1.4%
Holopedium	0.76	1,104	0.8%	6.5	2.6%
Ovig. Holopedium	0.97	153	0.1%	1.6	0.6%
Station C					
Epischura	1.28	4,992	4.5%	45.3	20.4%
Cyclops	0.66	83,810	74.9%	122.5	55.1%
Ovig. Cyclops	0.90	469	0.4%	1.4	0.6%
Bosmina	0.34	13,300	11.9%	13.9	6.3%
Ovig. Bosmina	0.43	88	0.1%	0.2	0.1%
Daphnia r.	0.96	5,128	4.6%	16.9	7.6%
Ovig. Daphnia r.	1.31	849	0.8%	5.8	2.6%
Holopedium	0.66	2,928	2.6%	12.0	5.4%
Ovig. Holopedium	1.05	333	0.3%	4.2	1.9%

Table 15. Seasonal mean macro-zooplankton density (No. · m^{-2}) and mean weighted biomass (mg · m^{-2}) distributions by species in Basin B (Station B and D) of Klawock Lake, 2002.

Station B	Size	Density	Percent	Biomass	Percent
Epischura	1.31	7,479	2.3%	72.2	11.7%
Cyclops	0.67	292,304	88.6%	451.3	73.4%
Ovig. Cyclops	0.94	167	0.1%	0.5	0.1%
Bosmina	0.37	15,680	4.8%	20.0	3.2%
Ovig. Bosmina	0.46	5,098	1.5%	13.8	2.2%
Daphnia r.	0.88	781	0.2%	5.8	0.9%
Ovig. Daphnia r.	1.36	7,074	2.1%	35.9	5.8%
Holopedium	0.72	1,308	0.4%	15.6	2.5%
Ovig. Holopedium	1.02	526	0.2%	3.4	0.6%
Station D					
Epischura	1.32	7,879	2.5%	77.4	13.1%
Cyclops	0.67	274,257	88.1%	418.1	70.9%
Ovig. Cyclops	0.94	425	0.1%	1.3	0.2%
Bosmina	0.37	11,598	3.7%	14.2	2.4%
Ovig. Bosmina	0.53	0	0.0%	0.0	0.0%
Daphnia r.	0.91	7,251	2.3%	20.8	3.5%
Ovig. Daphnia r.	1.29	1,240	0.4%	8.1	1.4%
Holopedium	0.71	7,811	2.5%	38.0	6.4%
Ovig. Holopedium	1.05	934	0.3%	12.0	2.0%

Table 16. The 2001 and 2002 zooplankton density and *Daphnia* density and size in selected lakes in Southeast Alaska.

2001			2002		
Lake	Zooplankton Density (mg per $m^{2)}$	Daphnia avg. size (mm)	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

FIGURES

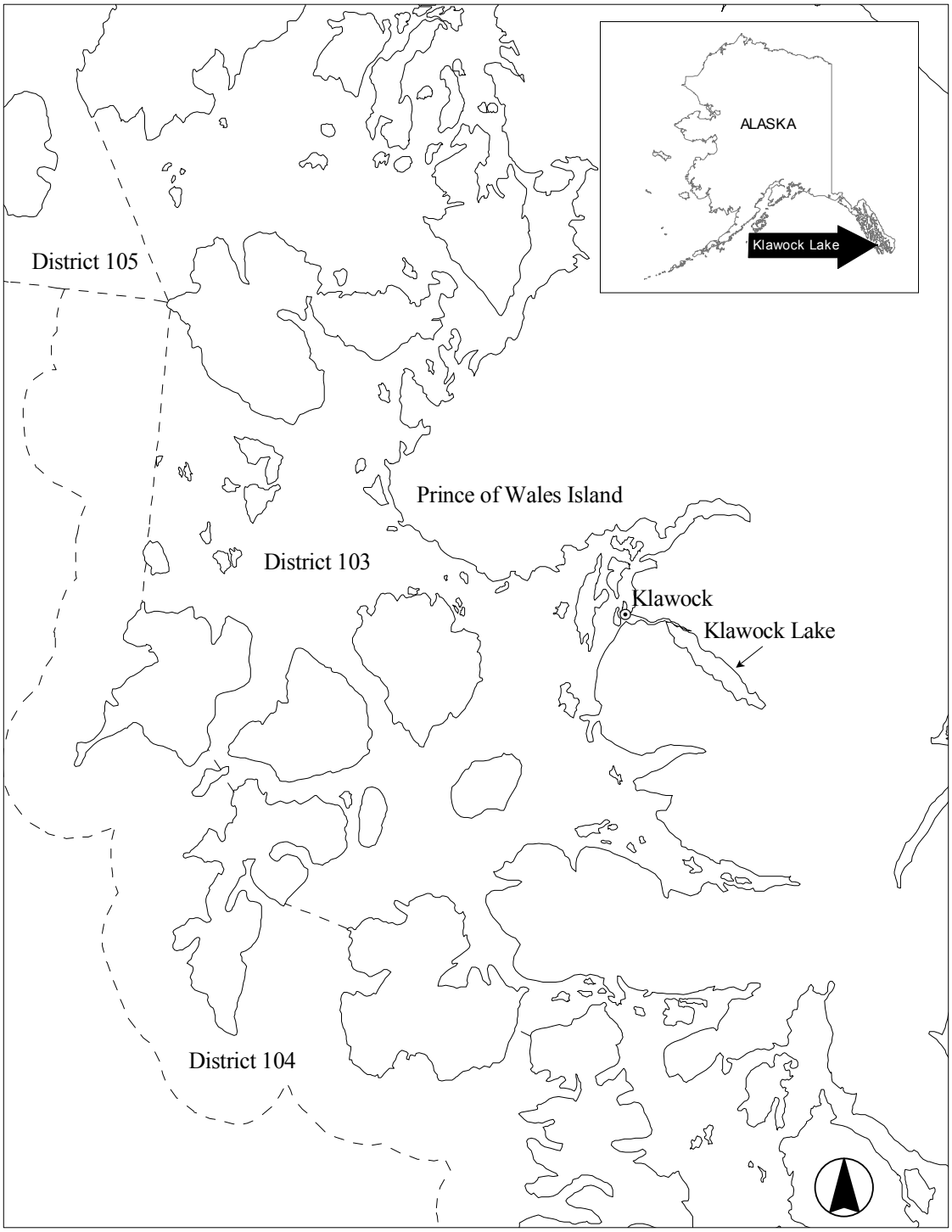

Figure 1. The geographic location of Klawock Lake, within the State of Alaska, and relative to commercial fishing districts 103 and 104 on west Prince of Wales Island.

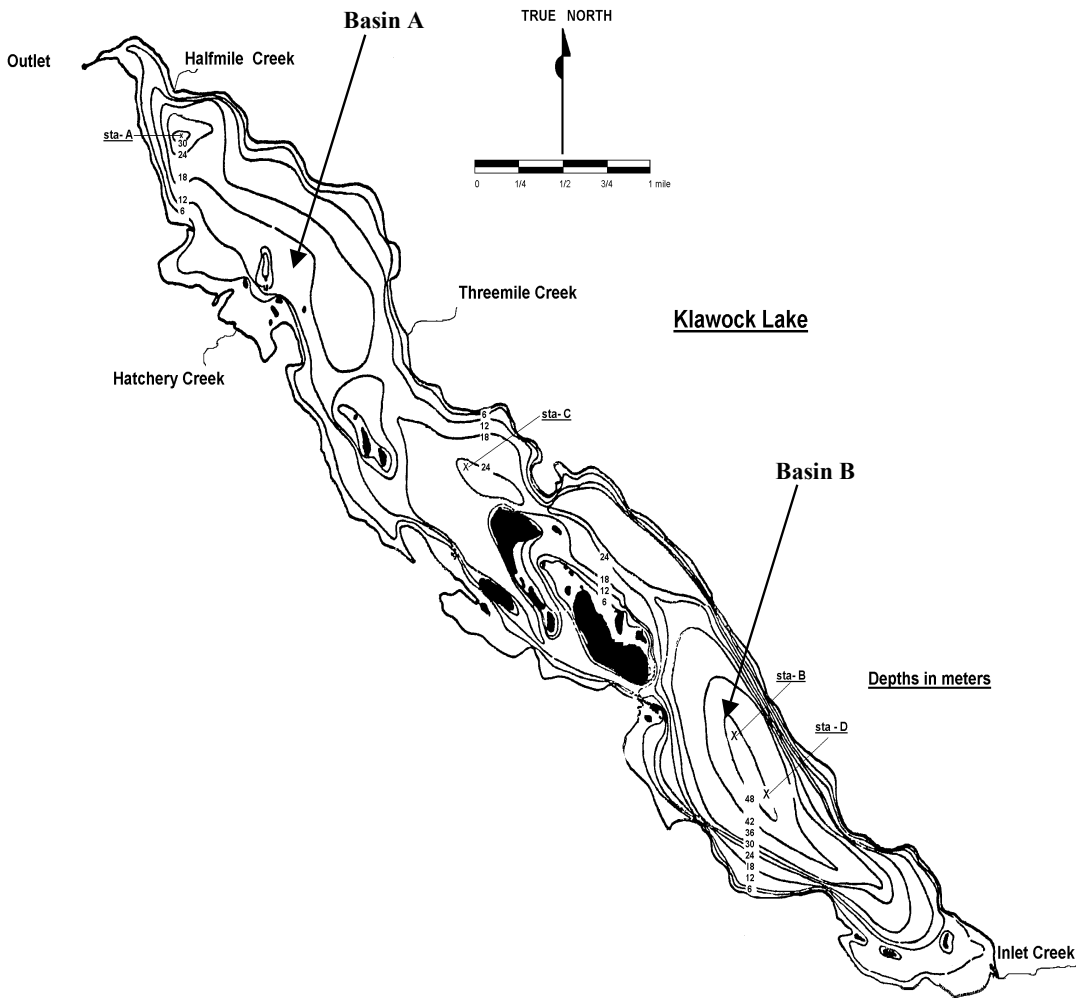

Figure 2. Bathymetric map of Klawock Lake, Southeast Alaska with limnological sampling stations and inlet stream references.

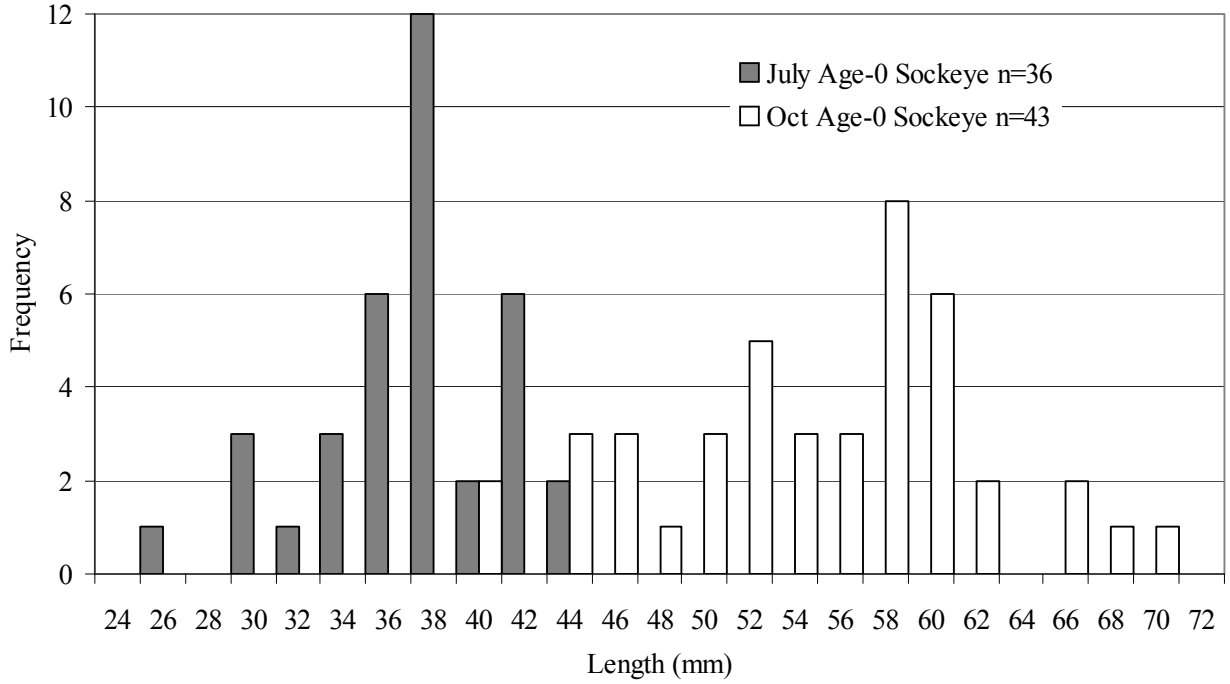

Figure 3. Length frequency distribution for age-0 sockeye salmon fry captured in the mid-water trawl during hydroacoustic surveys in July and October 2002.

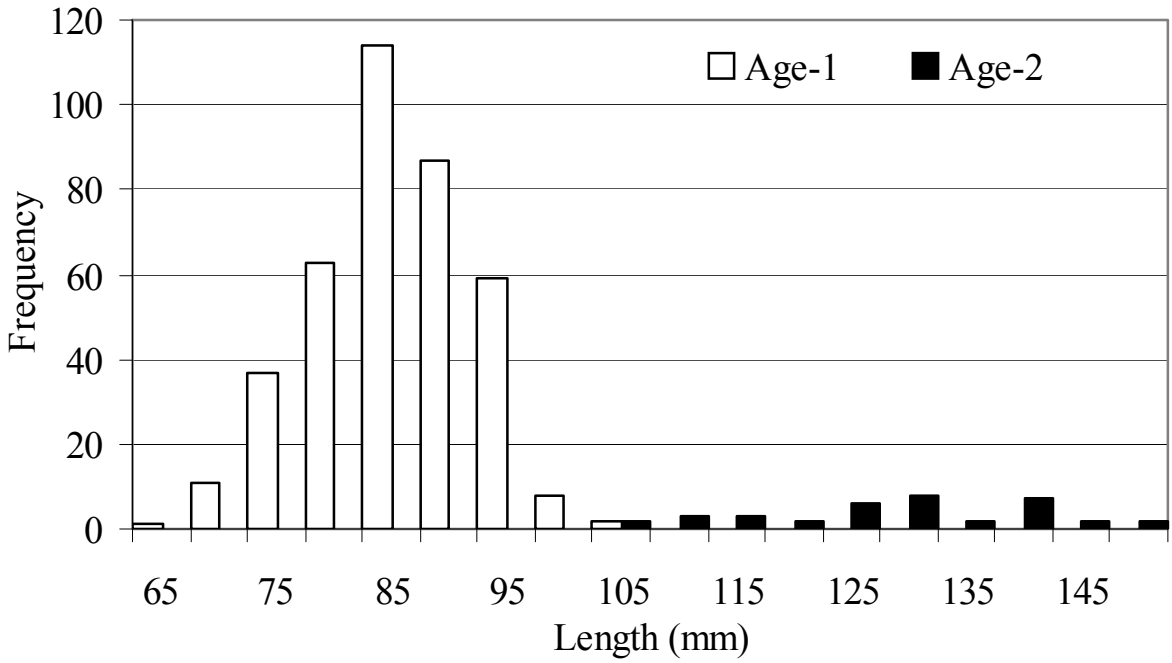

Figure 4. Length frequency histogram of Klawock Lake sockeye smolts, 2002.

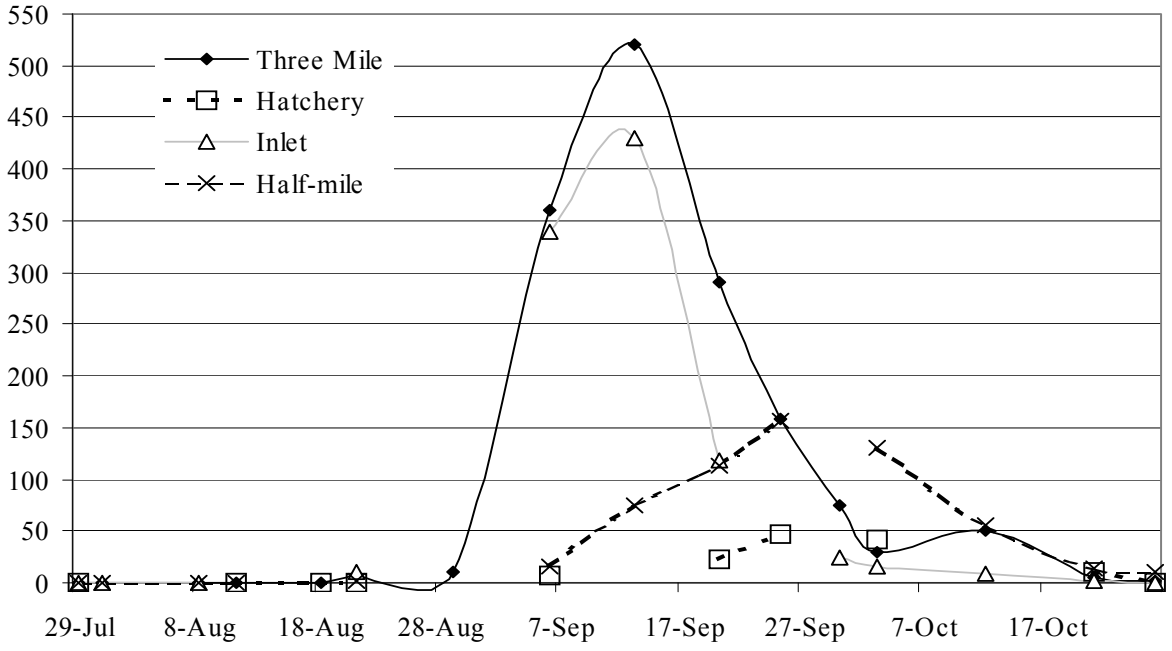

Figure 5. Foot escapement counts of adult sockeye salmon in the Klawock Lake system by stream and date, 2002.

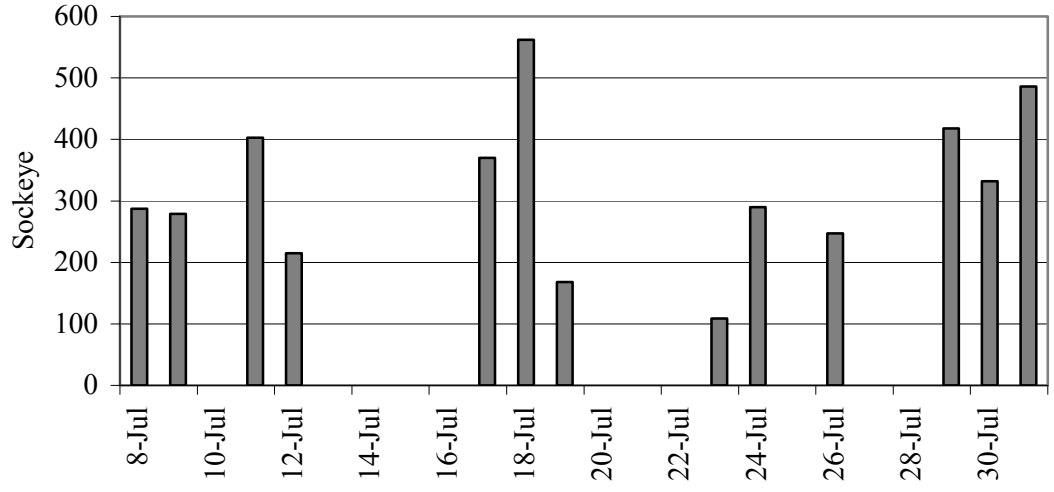

Figure 6. Estimated Klawock Inlet subsistence harvest of sockeye salmon on sampled dates in 2002.

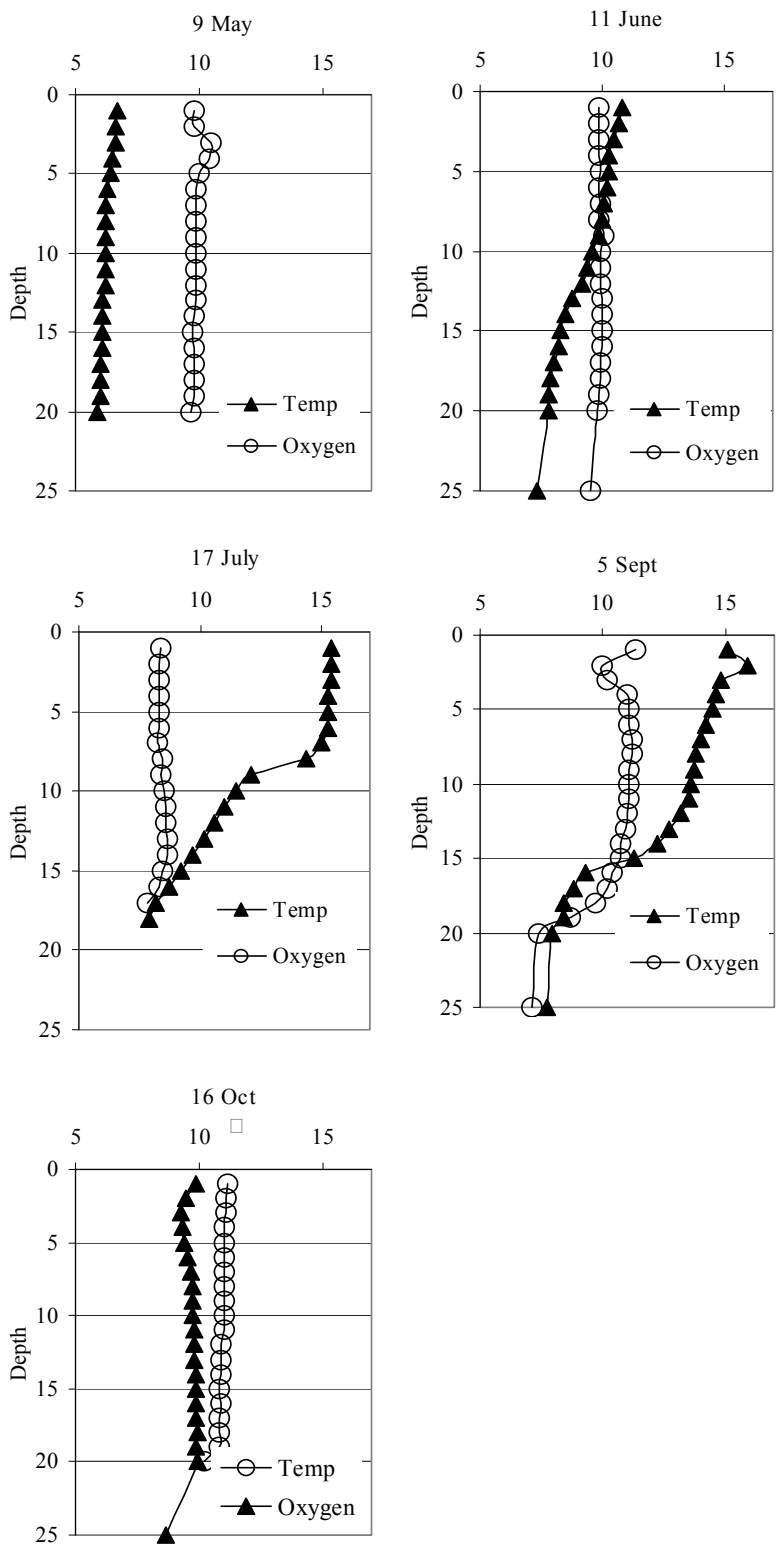

Figure 7. Temperature (^{o}C) and dissolved oxygen ($mg \cdot L^{-1}$) vertical (in meters) profiles by date at Station A in Klawock Lake, 2002.

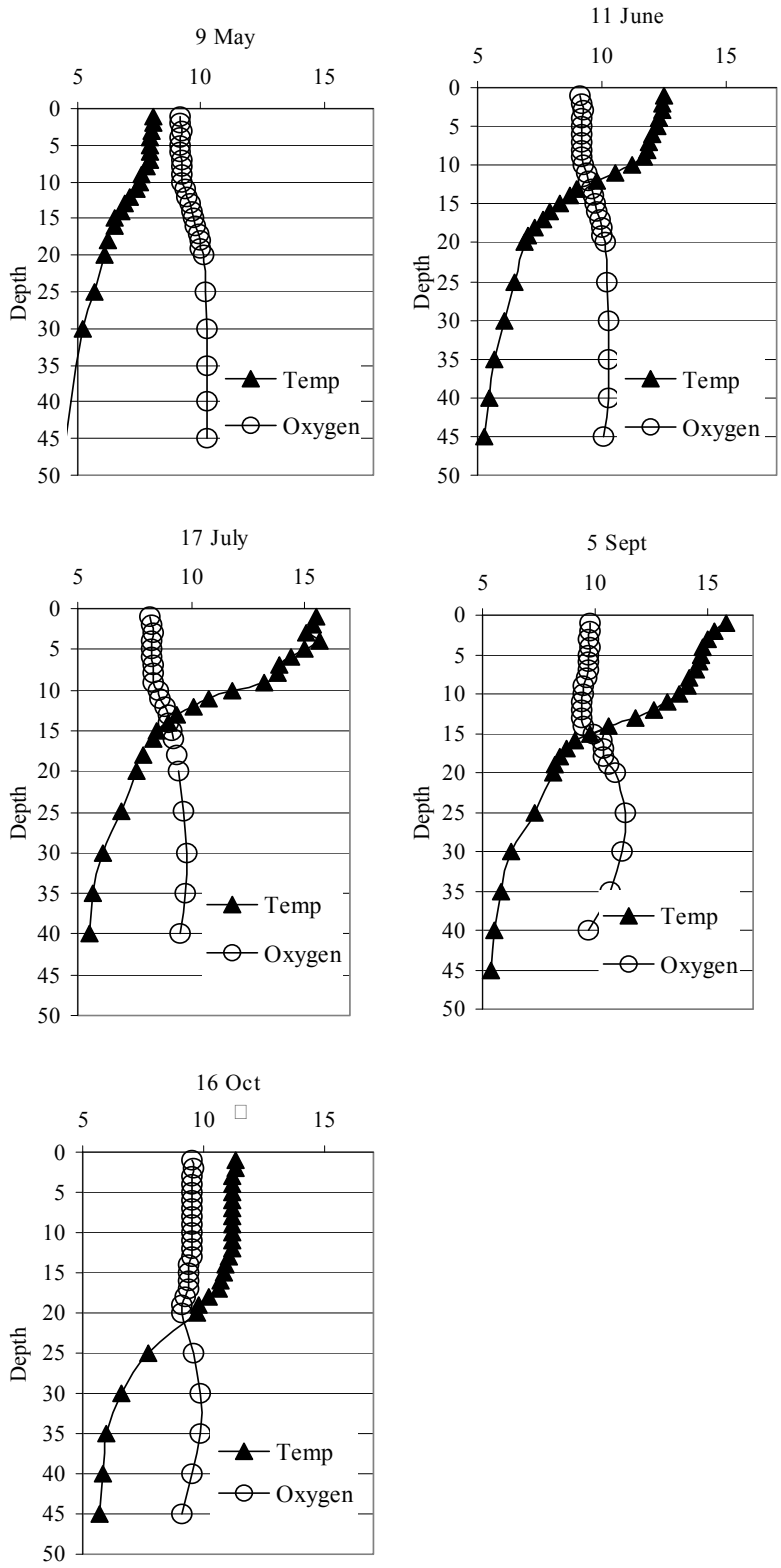

Figure 8. Temperature (^{o}C) and dissolved oxygen ($mg \cdot L^{-1}$) vertical (in meters) profiles by date at Station B in Klawock Lake, 2002.

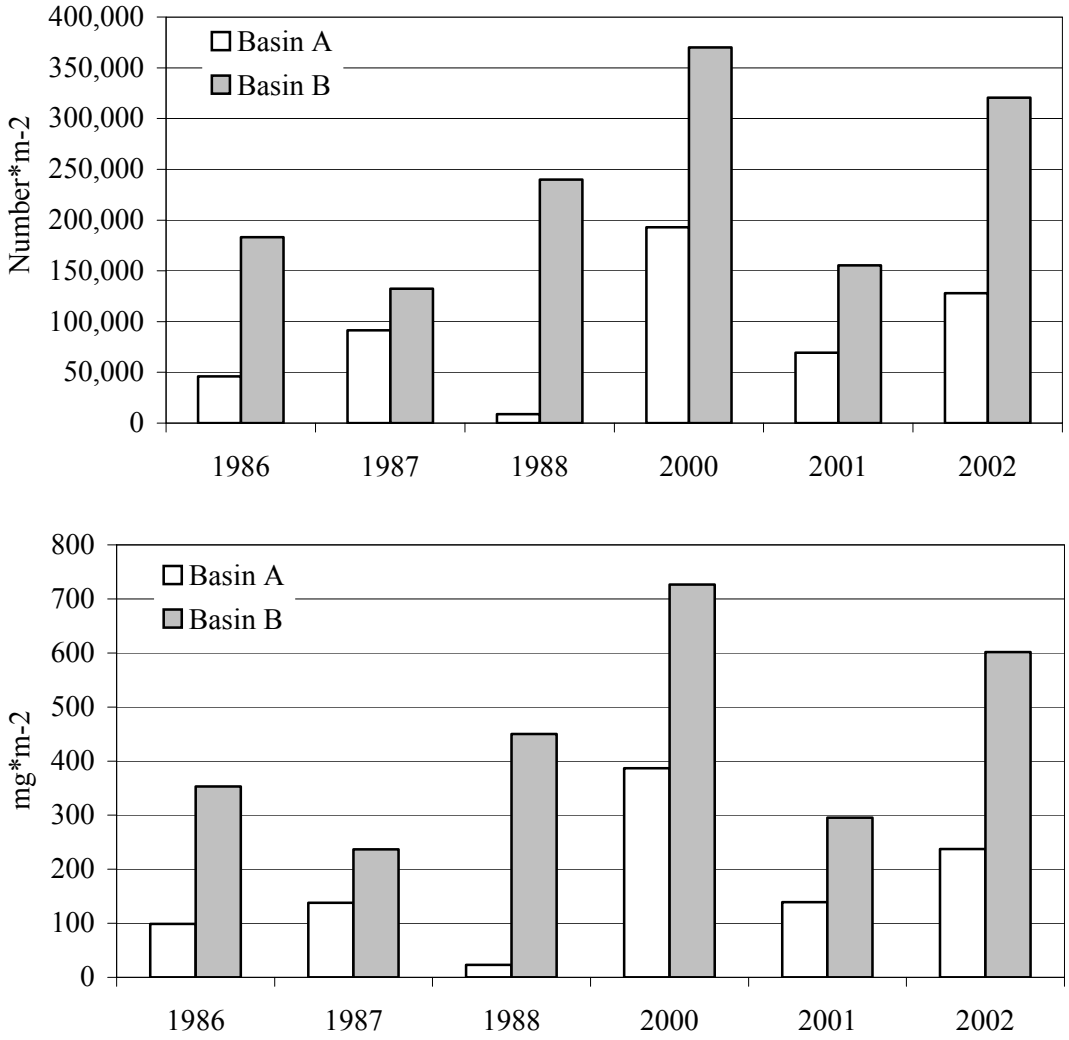

Figure 9. The mean seasonal density and weighted biomass of zooplankton in Klawock Lake 1986-88 and 2000-02.

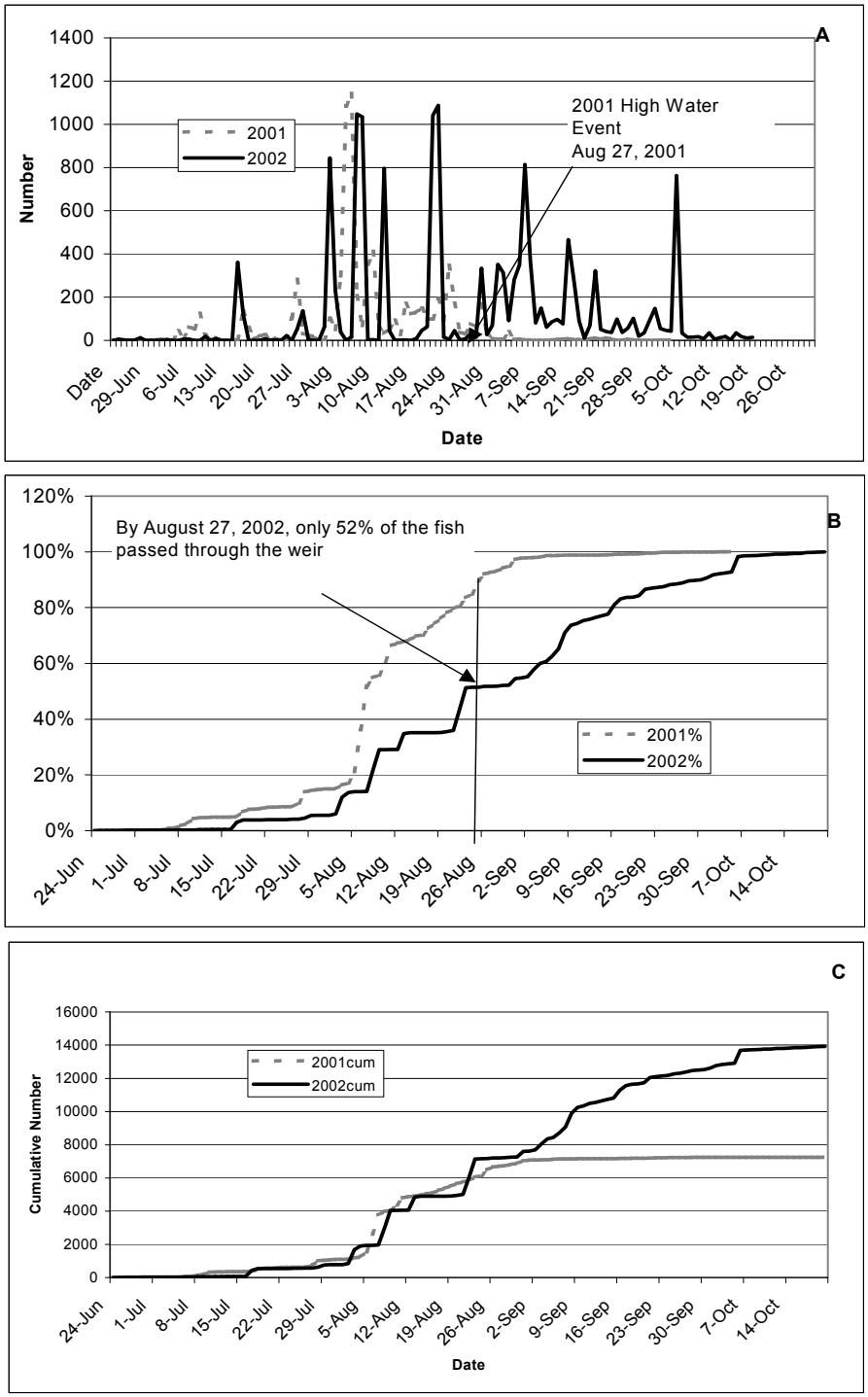

Figure 10. The daily weir count in 2001 shows that very few sockeye salmon were counted through the weir after the August 27 high water event (A). A cumulative percent of the run through the weir showed that 48% of the sockeye adults entered the system after August in 2002 (B). The timing of the run through the weir was very similar between 2001 and 2002 until the high water event at the end of August in 2001 (C).

APPENDICES

APPENDIX

Appendix 1. Summary of hydroacoustic population and mid-water trawl abundance estimates of rearing sockeye salmon fry and other captured species in Klawock Lake, 1986–2002.

Sample Date	Total Population Estimate	Species	Percent of Species	Total No. of Species	Age (*n*)	Mean Length (mm)	Mean Weight (g)
9/21/86	1,009,000	Sockeye	90.38%	912,000	0	46.1	1.04
		Stickleback	7.69%	78,000	N/A	74.3	6.50
		Cottids	1.92%	19,000	N/A	66.0	3.00
3/24/87	503,000	Sockeye	92.59%	466,000	0	31.3	0.23
					1	52.6	1.48
					3	110.0	14.40
		Stickleback	3.70%	19,000	N/A	96.0	10.10
		Coho	3.70%	19,000	2	130.0	24.00
7/08/87	Tow Net	Sockeye	95.65%		0	37.0	0.55
	Only	Cottids	4.35%		N/A	35.0	0.40
10/22/87	311,000	Sockeye	87.50%	272,000	0	58.1	2.24
		Stickleback	12.50%	39,000	N/A	93.0	8.60
4/14/88	350,000	Sockeye	100.00%	350,000	0	29.5	0.21
					1	52.6	1.37
					2	101.0	9.70
10/26/88	375,000	Sockeye	97.06%	364,000	0	66.8	3.24
					1	87.3	7.53
		Stickleback	2.94%	11,000	N/A	108.0	12.70
4/20/95	383,000	Sockeye	84.09%	322,000	0 (18)	36.1	0.39
					1 (14)	70.9	3.04
					2 (5)	94.6	7.78
		Stickleback	15.91%	61,000	N/A (7)	82.9	5.73
9/7/2000	311,000	Sockeye	100.00%	311,000	0 (5)	48.0	0.84
7/10/2001	718,000	Sockeye	100.00%	718,000	0 (121)	31.6	0.24
7/10/2002	439,000	Sockeye	88%	384,549	0 (35)	37.0	0.6
		Stickleback	10%	43,949		73.4	6.80
		Sculpin	3%	10,987		26	0.1
10/1/02	368,000	Sockeye	80%	293,300	0 (43)	54.2	1.8
			2%	6,821	1 (1)	88.0	7.1
			4%	13,642	2 (2)	129.5	26.30
		Stickleback	15%	54,567		47.7	1.8

Appendix 2. Sockeye salmon counts at the Klawock River weir during 2002.

Date	Mark Type	Daily Mark	Cumulative Mark	Daily Unmark	Cumulative Unmark	Daily Total	Cumulative Total	% Marked
Jun 24	LO	0	0	0	0	0	0	
Jun 25	LO	0	0	6	6	6	6	
Jun 26	LO	0	0	2	8	2	8	
Jun 27	LO	0	0	0	8	0	8	
Jun 28	LO	0	0	2	10	2	10	
Jun 29	LO	0	0	12	22	12	22	
Jun 30	LO	0	0	0	22	0	22	
Jul 1	LO	0	0	0	22	0	22	
Jul 2	LO	0	0	0	22	0	22	
Jul 3	LO	0	0	0	22	0	22	
Jul 4	LO	0	0	4	26	4	26	
Jul 5	LO	0	0	0	26	0	26	
Jul 6	LO	0	0	0	26	0	26	
Jul 7	LO	0	0	6	32	6	32	
Jul 8	LO	0	0	6	38	6	38	
Jul 9	LO	0	0	0	38	0	38	
Jul 10	LO	0	0	0	38	0	38	
Jul 11	LO	17	17	1	39	18	56	30%
Jul 12	LO	0	17	0	39	0	56	30%
Jul 13	LO	0	17	8	47	8	64	27%
Jul 14	LO	0	17	0	47	0	64	27%
Jul 15	LO	0	17	0	47	0	64	27%
Jul 16	LO	0	17	0	47	0	64	27%
Jul 17	LO	95	112	265	312	360	424	26%
Jul 18	LO	41	153	78	390	119	543	28%
Jul 19	LO	0	153	0	390	0	543	28%
Jul 20	LO	0	153	0	390	0	543	28%
Jul 21	LO	0	153	0	390	0	543	28%
Jul 22	LO	5	158	2	392	7	550	29%
Jul 23	LO	0	158	0	392	0	550	29%
Jul 24	LO	2	160	0	392	2	552	29%
Jul 25	LO	0	160	0	392	0	552	29%
Jul 26	LO	0	160	21	413	21	573	28%
Jul 27	LO	0	160	0	413	0	573	28%
Jul 28	LO	42	202	11	424	53	626	32%
Jul 29	LO	44	246	92	516	136	762	32%
Jul 30	LO	6	252	0	516	6	768	33%
Jul 31	LO	0	252	0	516	0	768	33%
Aug 1	L2O	0	252	1	517	1	769	33%
Aug 2	L2O	28	280	35	552	63	832	34%
Aug 3	L2O	236	516	609	1,161	845	1,677	31%
Aug 4	L2O	98	614	132	1,293	230	1,907	32%
Aug 5	L2O	29	643	10	1,303	39	1,946	33%

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Appendix 2. (page 2 of 3)

Date	Mark Type	Daily Mark	Cumulative Mark	Daily Unmark	Cumulative Unmark	Daily Total	Cumulative Total	% Marked
Aug 6	L2O	1	644	0	1,303	1	1,947	33%
Aug 7	L2O	16	660	0	1,303	16	1,963	34%
Aug 8	L2O	21	681	1,027	2,330	1048	3,011	23%
Aug 9	L2O	94	775	940	3,270	1034	4,045	19%
Aug 10	L2O	0	775	3	3,273	3	4,048	19%
Aug 11	L2O	3	778	0	3,273	3	4,051	19%
Aug 12	L2O	1	779	0	3,273	1	4,052	19%
Aug 13	L2O	604	1,383	191	3,464	795	4,847	29%
Aug 14	L2O	41	1,424	3	3,467	44	4,891	29%
Aug 15	L2O	0	1,424	0	3,467	0	4,891	29%
Aug 16	L2O	2	1,426	0	3,467	2	4,893	29%
Aug 17	L2O	0	1,426	2	3,469	2	4,895	29%
Aug 18	L2O	0	1,426	0	3,469	0	4,895	29%
Aug 19	L2O	9	1,435	0	3,469	9	4,904	29%
Aug 20	L2O	45	1,480	1	3,470	46	4,950	30%
Aug 21	L2O	54	1,534	9	3,479	63	5,013	31%
Aug 22	L2O	389	1,923	653	4,132	1042	6,055	32%
Aug 23	L2O	366	2,289	722	4,854	1088	7,143	32%
Aug 24	L2O	0	2,289	16	4,870	16	7,159	32%
Aug 25	L2O	3	2,292	1	4,871	4	7,163	32%
Aug 26	L2O	23	2,315	22	4,893	45	7,208	32%
Aug 27	L2O	2	2,317	0	4,893	2	7,210	32%
Aug 28	L2O	0	2,317	7	4,900	7	7,217	32%
Aug 29	L2O	10	2,327	21	4,921	31	7,248	32%
Aug 30	L2O	3	2,330	11	4,932	14	7,262	32%
Aug 31	L2O	21	2,351	313	5,245	334	7,596	31%
Sep 1	L □	18	2,369	9	5,254	27	7,623	31%
Sep 2	L □	0	2,369	68	5,322	68	7,691	31%
Sep 3	L □	151	2,520	201	5,523	352	8,043	31%
Sep 4	L □	30	2,550	282	5,805	312	8,355	31%
Sep 5	L □	27	2,577	65	5,870	92	8,447	31%
Sep 6	L □	66	2,643	215	6,085	281	8,728	30%
Sep 7	L □	120	2,763	229	6,314	349	9,077	30%
Sep 8	L □	150	2,913	664	6,978	814	9,891	29%
Sep 9	L □	313	3,226	56	7,034	369	10,260	31%
Sep 10	L □	25	3,251	56	7,090	81	10,341	31%
Sep 11	L □	26	3,277	124	7,214	150	10,491	31%
Sep 12	L □	27	3,304	34	7,248	61	10,552	31%
Sep 13	L □	0	3,304	87	7,335	87	10,639	31%
Sep 14	L □	0	3,304	97	7,432	97	10,736	31%
Sep 15	L □	0	3,304	77	7,509	77	10,813	31%
Sep 16	L □	67	3,371	400	7,909	467	11,280	30%
Sep 17	L □	169	3,540	115	8,024	284	11,564	31%

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Appendix 2. (page 3 of 3)

Date	Mark Type	Daily Mark	Cumulative Mark	Daily Unmark	Cumulative Unmark	Daily Total	Cumulative Total	% Marked
Sep 18	L □	31	3,571	57	8,081	88	11,652	31%
Sep 19	L □	2	3,573	8	8,089	10	11,662	31%
Sep 20	L □	0	3,573	69	8,158	69	11,731	30%
Sep 21	L □	0	3,573	323	8,481	323	12,054	30%
Sep 22	L □	0	3,573	51	8,532	51	12,105	30%
Sep 23	L □	22	3,595	19	8,551	41	12,146	30%
Sep 24	L □	16	3,611	21	8,572	37	12,183	30%
Sep 25	L □	54	3,665	45	8,617	99	12,282	30%
Sep 26	L □	0	3,665	37	8,654	37	12,319	30%
Sep 27	L □	0	3,665	57	8,711	57	12,376	30%
Sep 28	L □	0	3,665	102	8,813	102	12,478	29%
Sep 29	L □	0	3,665	19	8,832	19	12,497	29%
Sep 30	L □	0	3,665	36	8,868	36	12,533	29%
Oct 1	L □	0	3,665	92	8,960	92	12,625	29%
Oct 2	L □	110	3,775	38	8,998	148	12,773	30%
Oct 3	L □	10	3,785	45	9,043	55	12,828	30%
Oct 4	L □	10	3,795	37	9,080	47	12,875	29%
Oct 5	L □	0	3,795	43	9,123	43	12,918	29%
Oct 6	L □	0	3,795	763	9,886	763	13,681	28%
Oct 7	L □	14	3,809	20	9,906	34	13,715	28%
Oct 8	L □	8	3,817	6	9,912	14	13,729	28%
Oct 9	L □	4	3,821	11	9,923	15	13,744	28%
Oct 10	L □	3	3,824	14	9,937	17	13,761	28%
Oct 11	L □	0	3,824	8	9,945	8	13,769	28%
Oct 12	L □	0	3,824	35	9,980	35	13,804	28%
Oct 13	L □	0	3,824	6	9,986	6	13,810	28%
Oct 14	L □	12	3,836	0	9,986	12	13,822	28%
Oct 15	L □	0	3,836	18	10,004	18	13,840	28%
Oct 16	L □	0	3,836	3	10,007	3	13,843	28%
Oct 17	L □	0	3,836	35	10,042	35	13,878	28%
Oct 18	L □	0	3,836	17	10,059	17	13,895	28%
Oct 19	L □	0	3,836	11	10,070	11	13,906	28%
Oct 20	L □	0	3,836	14	10,084	14	13,920	28%
Oct 21	L □							
Oct 22	L □							
Oct 23	L □							
Oct 24	L □							
Oct 25	L □							
Oct 26	L □							
Oct 27	L □							
Oct 28	L □							
Oct 29	L □							
Oct 30	L □							
Oct 31	L □							

Appendix 3A. Klawock Lake epilimnetic water quality data by date, station, and depth, 2002.

Date	May 9	Jun 12	Jul 18	Sep 5	Oct 16	May 9	Jun 12	Jul 18	Sep 5	Oct 16
Station	A	A	A	A	A	B	B	B	B	B
Depth (m)	1	1	1	1	1	1	1	1	1	1
Conduct. (umhos·cm^{-1})	38.0	37.0	39.0	38.0	35.0	39.0	38.0	39.0	40.0	38.0
pH	6.7	6.8	6.4	6.7	6.6	6.8	7.0	6.5	6.7	6.6
Alkalinity (mg·l^{-1})	12.3	14.4	14.5	13.0	13.1	11.5	14.2	13.4	13.5	11.2
Turbidity (ntu)	0.4	0.4	0.4	0.4	1.4	0.5	0.2	0.3	0.3	1.0
Color (pt units)	27.0	27.0	29.0	38.0	40.0	29.0	29.0	22.0	32.0	38.0
Calcium (mg·l^{-1})	4.9	4.7	5.0	5.0	4.8	4.8	4.8	5.0	5.1	4.9
Magnesium (mg·l^{-1})	1.0	1.0	1.0	0.7	0.9	0.9	1.1	1.1	0.7	1.0
Iron (ug · l^{-1})	84.0	87.0	83.0	81.0	124.0	74.0	67.0	75.0	84.0	76.0
TP (ug · l^{-1})	5.0	3.9	5.2	4.5	7.3	5.6	4.2	3.9	3.5	6.4
TFP (ug · l^{-1})	2.8	3.5	4.9	2.9	3.5	5.6	3.1	2.1	2.6	13.2
FRP (ug · l^{-1})	1.9	2.5	2.9	2.3	2.5	3.5	2.4	1.6	2.1	5.9
TKN (ug · l^{-1})	95.5	85.8	109.5	136.4	136.2	105.2	86.8	122.5	135.4	144.0
Ammonia(ug · l^{-1})	5.1	4.7	12.0	6.8	6.4	4.7	1.3	2.1	13.1	5.8
Nitrate+Nitrite (ug · l^{-1})	21.0	20.0	15.0	12.0	22.0	26.0	28.0	7.0	13.0	14.0
TN (ug · l^{-1})	116.5	105.8	124.5	148.4	158.2	131.2	114.8	129.5	148.4	158.0
RSi (ug · l^{-1})	1141	1111	1078	1117	1284	1162	1101	1112	1113	1293
Carbon (ug · l^{-1})	88.0	91.0		105.0	181.0	139.0	102.0		63.0	105.0

Appendix 3B. Klawock Lake hypolimnetic water quality data by date, station, and depth, 2002.

Date	May 9	Jun 12	Jul 18	Sep 5	Oct 16	May 9	Jun 12	Jul 18	Sep 5	Oct 16
Station	A	A	A	A	A	B	B	B	B	B
Depth (m)	20	20	20	20	20	40	35	35	40	40
Conductivity (umhos·cm^{-1})	38.0	38.0	39.0	42.0	37.0	39.0	39.0	40.0	41.0	41.0
PH	6.8	6.6	6.4	6.3	6.5	6.7	6.7	6.5	6.4	6.4
Alkalinity (mg·l^{-1})	12.0	15.7	13.1	13.1	13.9	11.5	13.7	14.6	12.1	12.9
Turbidity (ntu)	0.5	0.4	0.3	0.8	2.0	0.4	0.3	0.6	0.6	0.6
Color (pt units)	29.0	27.0	28.0	24.0	41.0	29.0	30.0	27.0	26.0	24.0
Calcium (mg·l^{-1})	4.7	4.9	4.8	5.0	4.6	4.8	5.0	4.8	5.1	4.8
Magnesium (mg·l^{-1})	1.3	0.9	1.0	0.7	1.1	1.0	0.9	1.1	0.7	1.1
Iron (ug · l^{-1})	83.0	116.0	111.0	144.0	135.0	77.0	76.0	79.0	68.0	60.0
TP (ug · l^{-1})	6.0	5.9	5.4	6.6	12.4	4.6	4.9	4.6	4.9	5.2
TFP (ug · l^{-1})	2.5	2.5	5.2	7.7	3.4	3.1	2.5	2.5	2.6	2.6
FRP (ug · l^{-1})	1.7	1.7	3.8	3.0	2.6	2.2	1.8	1.8	1.8	1.7
TKN (ug · l^{-1})	112.8	90.1	121.3	133.2	178.4	86.9	81.5	122.5	116.0	121.4
Ammonia(ug · l^{-1})	8.0	7.6	13.3	2.0	5.9	4.1	4.5	8.4	3.2	12.3
Nitrate+Nitrite (ug · l^{-1})	31.0	22.0	31.0	63.0	29.0	29.0	26.0	56.0	80.0	62.0
TN (ug · l^{-1})	143.8	112.1	152.3	196.2	207.4	115.9	107.5	178.5	196.0	183.4
RSi (ug · l^{-1})	1,145	1,161	1,211	1,262	1,307	1,176	1,160	1,189	1,223	1,330
Carbon (ug · l^{-1})	88.0	100.0		114.0	164.0	55.0	86.0		167.0	91.0

Appendix 4. 2002 Zooplankton densities and sizes by species and station.

Appendix 4A. Zooplankton density estimates (no./m^2) by station and date in 2002.

Basin A	May 9	Jun 11	Jul 17	Sep 5	Oct 16
Station A					
Epischura	0	1,528	2,717	2,445	1,902
Cyclops	30,735	195,110	167,363	74,716	102,021
Bosmina	2,275	87,112	18,611	272	2,038
Daphnia r.	204	0	16,166	4,211	0
Total zooplankton	34,811	289,863	206,895	82,323	105,961
Station C					
Epischura	0	13,415	5,162	4,347	2,038
Cyclops	58,142	143,658	72,134	66,239	78,878
Bosmina	747	44,490	14,400	2,921	3,940
Daphnia r.	475	170	9,509	15,419	68
Total zooplankton	65,545	214,469	103,243	91,235	84,992
Basin B	May 9	Jun 11	Jul 17	Sep 5	Oct 16
Station B					
Epischura	204	21,651	7,472	4,670	3,396
Cyclops	181,253	184,242	313,805	474,189	308,032
Bosmina	5,807	35,235	24,113	6,792	6,453
Daphnia r.	2,140	4,245	13,585	5,519	0
Total zooplankton	194,194	282,307	363,051	492,019	317,881
Station D					
Epischura	0	21,651	7,811	8,151	1,783
Cyclops	236,882	201,647	393,955	349,805	188,996
Bosmina	7,472	17,830	19,019	7,811	5,858
Daphnia r.	509	3,821	12,905	19,019	0
Total zooplankton	249,787	285,280	436,407	388,861	196,637

Appendix 4B. Zooplankton size (mm) by station and date in Basin A in 2002.

Basin A						
Station A	May 9	Jun 11	Jul 17	Sep 5	Oct 16	Weighted Season Mean
Epischura		1.22	1.56	1.39	1.35	1.40
Cyclops	0.67	0.66	0.70	0.72	0.72	0.69
Ovig. Cyclops	0.95	0.93				0.94
Bosmina	0.39	0.34	0.36	0.33	0.36	0.34
Ovig. Bosmina	0.47	0.45	0.41	0.38		0.44
Daphnia sp.	0.62	1.16	0.78	1.03	1.08	0.83
Ovig. Daphnia sp.		1.10	1.30	1.29		1.30
Holopedium	0.38	0.87				0.76
Ovig. Holopedium		0.97				0.97
Station C						
Epischura		1.23	1.33	1.31	1.42	1.32
Cyclops	0.47	0.68	0.68	0.69	0.70	0.67
Ovig. Cyclops	0.92	0.90				0.94
Bosmina	0.39	0.33	0.37	0.36	0.32	0.37
Ovig. Bosmina	0.47	0.44			0.36	0.53
Daphnia sp.	0.58	0.81	0.73	1.12	1.21	0.91
Ovig. Daphnia sp.		1.27	1.34	1.29		1.29
Holopedium	0.38	0.83				0.71
Ovig. Holopedium		1.03	1.22			1.05

Appendix 4C. Zooplankton size (mm) by station and date in Basin B in 2002.

Basin B						
Station B	May 9	Jun 11	Jul 17	Sep 5	Oct 16	Weighted Season Mean
Epischura		1.29	1.31	1.25	1.50	1.31
Cyclops	0.51	0.70	0.68	0.71	0.69	0.67
Ovig. Cyclops	0.94					0.94
Bosmina	0.39	0.37	0.38	0.37	0.35	0.37
Ovig. Bosmina	0.46					0.46
Daphnia sp.	0.69	0.88	0.87	1.00		0.88
Ovig. Daphnia sp.		1.21	1.38	1.28		1.36
Holopedium	0.42	0.76	1.17			0.72
Ovig. Holopedium		1.02				1.02
Station D						
Epischura		1.34	1.19	1.34	1.48	1.32
Cyclops	0.55	0.72	0.69	0.67	0.72	0.67
Ovig. Cyclops		0.94				0.94
Bosmina	0.41	0.37	0.36	0.35	0.34	0.37
Ovig. Bosmina	0.56	0.49				0.53
Daphnia sp.		0.82	0.80	1.00		0.91
Ovig. Daphnia sp.		1.20	1.33	1.28		1.29
Holopedium	0.37	0.74	1.20			0.71
Ovig. Holopedium		1.05	1.21			1.05

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