FALLS LAKE

SUBSISTENCE SOCKEYE SALMON STOCK ASSESSMENT PROJECT

2001 ANNUAL REPORT

by

Jan Conitz
and
Margaret Cartwright
Alaska Department of Fish and Game, Division of Commercial Fisheries
and
Benjamin Van Alen
U.S. Forest Service, Juneau Ranger District

Regional Information Report[1] No. 1J02-33

Annual report to the U.S. Forest Service to fulfill obligations for
Sikes Act Contract Numbers 43-0109-0-0145, 43-0109-0-0126, and 43-0109-0-0174,
Study Number FIS00-044-1

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

This report has been prepared to assess project progress. Review comments have not been addressed in this report, but will be incorporated into the final report for this project.

July 2002

1 The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data, this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

ACKNOWLEDGMENTS

We acknowledge the vital role of our cooperator, the Organized Village of Kake, and the efforts and input of OVK executive staff members Dawn Jackson, Mike Jackson, and Gary Williams. The field crew was indispensable to the success of the first year of the project. Cameron Lingle of ADF&G served as the crew leader at Falls Lake and was responsible for collecting and summarizing the weir, creel survey, and mark-recapture data. Ken Martin, Rosalyn Jackson, Abraham Washington, and Jeremy Martin served as crew members for OVK. Burt Jackson and Tom Jackson of OVK and Mike Parker of ADF&G provided additional help on the Falls Lake crew and assisted with camp breakdown.

The authors acknowledge the expert assistance of the following groups and individuals at ADF&G: John Edmondson and the Soldotna limnology lab crew for processing of the zooplankton samples; Iris Frank, Mark Olsen, and the Douglas scale and age lab crew for analysis of scale, length, and age data; Xinxian Zhang for advice and programming for statistical analysis; Renate Riffe for the creel census study design, data analysis, and results; Malcolm McEwen for the juvenile sampling fieldwork and data analysis; Hal Geiger for editing, support, and advice. Terry Suminski of the U.S. Forest Service, Sitka Ranger District, and Dave Barto of ADF&G provided information about the Falls Lake weir and limnology sampling project in the 1980s. We also appreciate Mr. Suminski’s assistance in obtaining the land-use permits needed in the South Baranof Wilderness Area.

We especially wish to thank the subsistence fishers and members of the Organized Village of Kake who took part in the creel survey interviews. The interest of the Kake community in the resources and stewardship of Falls Lake provide the motivation for this project.

PROJECT SPONSORSHIP

The Federal Subsistence Board, managed by U.S. Fish and Wildlife Service — Office of Subsistence Management, approved the Falls Lake Sockeye Salmon Stock Assessment Project (Study Number FIS00-044). The project was funded by the U.S. Forest Service, and is a cooperative project between the U.S. Forest Service (USFS), the Alaska Department of Fish and Game (ADF&G), and the Organized Village of Kake. This annual report partially fulfills contract obligations for Sikes Act Contract (43-0109-0-0145, 43-0109-0-0126, and 43-0109-0-0174).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The return of adult sockeye salmon to Falls Lake in 2001 was estimated through a survey of subsistence and sport harvest in the terminal area, weir counts verified with a mark-recapture study, and an independent spawning grounds mark-recapture study. Age, length, and sex composition of the escapement was estimated using standard measurements and scale sampling and analysis. Sockeye salmon fry populations in Falls Lake were estimated using hydroacoustic and trawl sampling. Baseline information was collected on the physical characteristics and productivity of lake rearing habitat in Falls Lake using standard limnological sampling procedures. A return of about 4,600 sockeye salmon was documented, with a total harvest in the terminal area of at least 2,000 fish and an escapement of about 2,600 fish. The mark-recapture estimate validated the weir count and indicated that few sockeye salmon passed through the weir uncounted. Most of the sockeye salmon sampled from the Falls Lake escapement were age-1.3, representing 89% of the fish sampled, or 91% when weighted by weekly escapement. Overall average mid-eye to fork length was 549 mm, with little size difference between males and females. Sockeye salmon fry density was low to moderate compared to that in similar Southeast Alaska sockeye rearing lakes. Results of limnology sampling were comparable for the most part to those from previous studies in the 1980s. Falls Lake becomes thermally stratified during the summer and has a moderate euphotic zone depth averaging 10 m. Although total zooplankton density and biomass and species composition were similar, there was an apparent reduction in the number and biomass of *Daphnia*, a large cladoceran and preferred prey item for sockeye salmon fry, from levels found in the 1980’s. Good baseline data was gathered at Falls Lake in 2001 and most can be directly compared with data collected by ADF&G and the USFS between 1981–1989. More years of data will be needed to show trends in population and lake productivity over time, in order to set sustainable harvest limits and escapement goals.

INTRODUCTION

Falls Lake (ADF&G stream no. 109-20-013/014) produces a significant run of sockeye salmon and is an important subsistence resource for Kake residents (Figure 1). Falls Lake, along with other areas along the east coast of Baranof Island between Red Bluff Bay and Cape Ommaney, was in the traditional territory of both the Kake and Angoon people (Goldschmidt et al. 1998). In former times, the people of Kake were spread out among several villages on Kuiu, Kupreanof, Baranof, and Admiralty islands and the mainland until a government school was opened in the present-day Kake village in the early 1900s; for this reason, traditional harvest areas are relatively far from the present-day Kake village. During the early commercial fishing period, many Kake residents had access to Falls Lake and other locations along south Baranof Island while traveling in larger boats to and from fishing grounds in the vicinity of Port Alexander. Falls Lake continues to be an important subsistence fishing area for Kake residents, who now must travel the substantial distance from Kake and cross Chatham Straits in skiffs or small cabin cruisers. In a 1985 survey, 40–50% of Kake households reported using Falls Lake for subsistence fishing. Falls Lake has state and federal customary and traditional use designation for the village of Kake (federal subsistence fishing regulations, 2002).

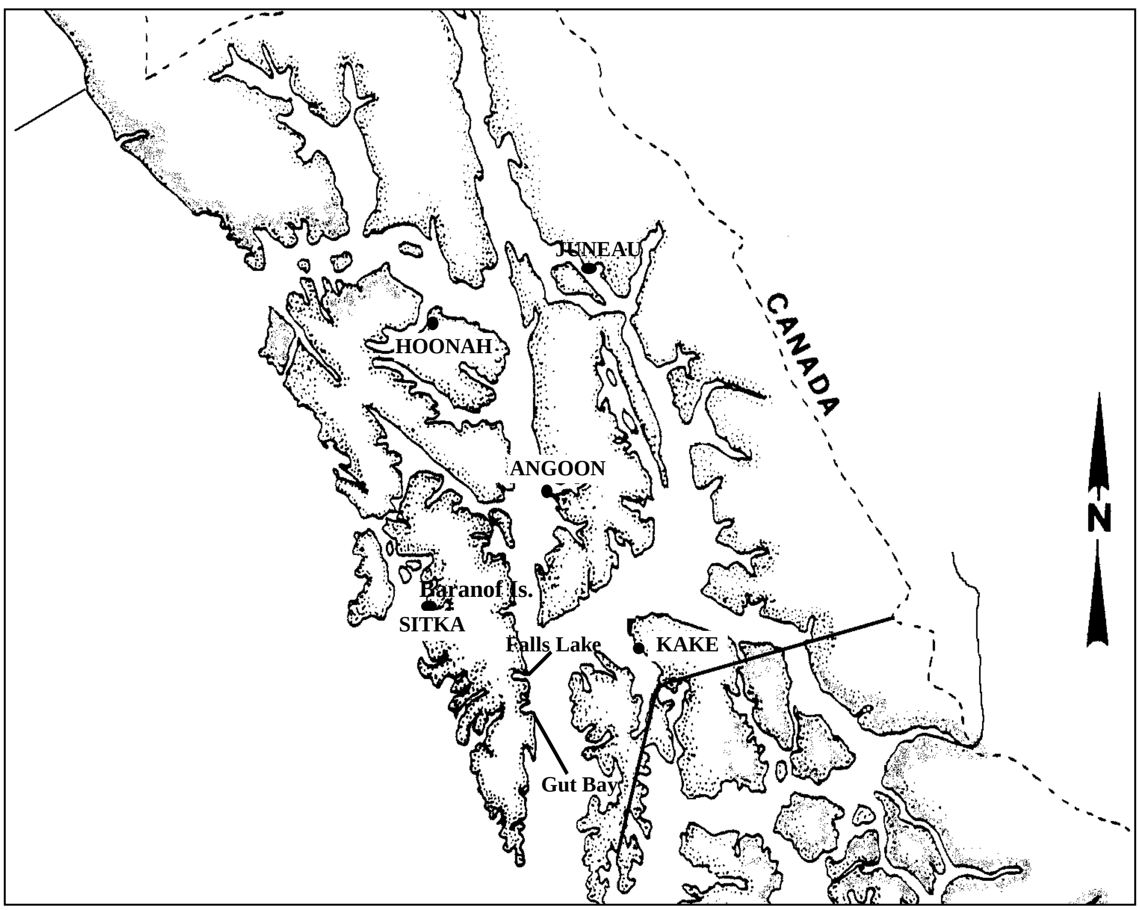


Figure 1. Map of Southeast Alaska showing location of Falls Lake and Kake.

Salmon is the most important subsistence resource for Kake residents and is shared widely within the community. However, many people feel that they cannot harvest enough salmon to meet their needs. In a 1985 household survey, an average annual harvest of eight sockeye salmon per household was reported, while the need was estimated at about 42 sockeye salmon annually. Low returns, resulting restrictive regulations, low possession limits, and the distance and expense of traveling to fishing areas were reasons given for being unable to harvest enough salmon (Firman and Bosworth 1990).

Use of Falls Lake for subsistence harvest of sockeye salmon has increased substantially in the last decade (Appendix A.1). From 1993–2000 the average annual harvest was 1,003 sockeye salmon on 62 permits compared with the 1985–1992 average harvest of 203 sockeye salmon on 15 permits (ADF&G, Alexander Database, 2002). This change may be partly explained by changes in the permit system and increased familiarity with the reporting system. But it is clear use is increasing, possibly due to socioeconomic factors, such as larger outboard motors giving greater access to Falls Lake, and increasing gear efficiency. The Federal Subsistence Fisheries Resource Monitoring Program funded a cooperative project in the winter of 2002 between the ADF&G Division of Subsistence and the Organized Village of Kake, to document Kake's historic and contemporary subsistence sockeye salmon harvests and use in Falls Lake, Gut Bay, and Pillar Bay (Larson 2001).

Historic commercial fishing records show irregular harvests at Falls Lake (Appendix A.2). The Falls Lake sockeye salmon run was one of the smaller runs along Chatham Strait, and commercial exploitation started later and was less intense than in other nearby areas. Commercial fishing was closed in the terminal area at Falls Lake in 1926 (Rich and Ball 1933). Although commercial fisheries no longer operate in the terminal area at Falls Lake, the purse seine fishery operating in the nearby waters of Chatham Strait is the largest user of sockeye salmon in this area. Individual stocks cannot be distinguished in the commercial harvest record, but there has been a dramatic increase in total numbers of sockeye salmon harvested in recent years in the areas nearest to Falls Lake and Gut Bay, as well as along the east side of Chatham. The average annual sockeye salmon harvest for the Falls and Gut Bay areas (Subdistricts 109-20, 112-11, 112-21, and 112-22) has increased from 1,113 sockeye salmon in the 1970s to 2,508 in the 1980s to 11,146 in the 1990s (Appendix A.3). Most of the increased harvest was not due to fishers targeting sockeye salmon but was an artifact of increased fishing opportunities due to the success of the nearby chum hatcheries (Larson 2001).

Sport fishing effort and harvest were documented for only four years between 1988–2000 by ADF&G Sport Fish mail surveys, showing a total harvest of 89 sockeye salmon and 98 fishing days in 1989, and sockeye harvests of zero in three other years, 1993–1996 (Robert Walker, ADF&G, personal communication, 2001). Other sport fishery data show a maximum possible contribution of 222 sockeye salmon from the Falls Lake and Gut Bay freshwater areas combined. Sport sockeye salmon harvests in marine waters were greater for the Falls Lake and Gut Bay area, with a generally increasing trend and a maximum possible contribution of 825 fish in 1999. However, these data include other areas and it is most likely however that each system contributed considerably fewer or no fish. Data from the Tongass National Forest Outfitter/Guide Logbooks indicate very small harvest and effort at Falls Lake in the freshwater areas. Charter vessel logbooks show an average annual harvest for the Gut Bay and Falls Lake marine area of about 20 sockeye salmon (Larson, 2001).

Falls Lake was considered for enhancement by ADF&G in the late 1970s (Koenings et al. 1983). A pre-fertilization study was conducted in 1981–1982 to determine whether the lake had potential for increased production, and the lake was fertilized from 1983–1985 (Appendix C.4). A fishpass was constructed in 1986 by the U.S. Forest Service to aid salmon migration. Sockeye and coho salmon escapements into Falls Lake were monitored jointly by the U.S. Forest Service and ADF&G with the aid of a weir in the lower part of the outlet stream from 1981–1989, to assess the effects of fertilization and the fishpass (Appendix B.1). In addition to escapement counts, population age and size structure were estimated

(Appendix B.2). The only other escapement information for Falls Lake is from occasional ADF&G aerial surveys (Appendix B.3). It is known that these surveys are subject to undercounting, bias, and variation due to habitat type, observer experience, and visibility of fish (Jones et al. 1998; Jones and McPherson 1997).

Data on sockeye salmon fry and smolt populations, lake zooplankton populations, and lake water physical and chemical characteristics were collected during the fertilization project between 1981–1986 (Appendix C). In three years of sampling, sockeye salmon fry density ranged from 0.037 to 0.136 fry $\cdot$ m^{-2} (Appendix C.1) Smolt were predominantly age-2, with average weights of 3.4 g (age-1 smolt averaged 2.6 g) (Appendix C.2). Average total macro-zooplankton density was 22,046$\cdot m^2$ and average total macro-zooplankton biomass was 71 mg$\cdot m^2$ between 1981–1986. Zooplankton density and biomass were greatly reduced in 1985 and 1986 compared to previous years (Appendix C.3). Species identified in monthly water samples were cladocerans *Bosmina longirostris*, *Daphnia longiremus*, and *Holopedium gibberum*, and copepods *Diaptomus franciscanus* and *Cyclops vernalis*, as well as four species of rotifers. Copepods dominated the macro-zooplankton community through mid-summer, and cladocerans, primarily *Bosmina*, became dominant in late summer (Koenings et al. 1983). Overall, *Bosmina* were dominant numerically, with a high seasonal mean density of about 30,000 per m^2 in 1984 (second year of fertilization), but declined sharply in 1985, the third year of fertilization, to a seasonal mean density of only 4,000 per m^2. The large copepod *Diaptomus* was dominant in biomass, averaging 60 – 72 mg m^{-2}; however, its seasonal mean biomass also dropped in 1985 to just 5 mg m^{-2}. The large cladoceran *Daphnia longiremus*, constituted a significant proportion of zooplankton biomass (3–8%) and numbers (4–9% in 1981–1984). As the overall zooplankton biomass and density dropped in 1985 and 1986, the proportion of *D. longiremus* increased to up to 25% of biomass and 16% of numbers. Nutrient and chlorophyll levels were low and levels of dissolved ions and other water chemistry parameters were typical of oligotrophic lakes along the southeast Alaska coast (Appendix C.5). The mean euphotic zone depth (EZD - depth to which 1% of sub-surface light penetrates) in 1981–1985 was about 9 m. A stable thermocline formed at 10–15 m in early summer, with maximum epilimnetic temperatures of about 16°C in late summer (Koenings et al. 1983).

The Falls Lake Sockeye Salmon Project was initiated in 2000 and funded through the Federal Subsistence Fisheries Resource Monitoring Program. The importance of the Falls Lake sockeye salmon resource to the village of Kake points to the need for quantifiable escapement goals, with the ability to regulate harvest opportunities and ensure that escapements are within goal ranges and adequately distributed through time. In addition to escapement data, fisheries harvest and lake ecology data are being collected at Falls Lake to support long-term escapement goals that incorporate lake productivity modeling. The study plan includes an assessment of the lake's physical characteristics, which support primary production, and the secondary production of its zooplankton populations. Zooplankton are the main food source for sockeye salmon and cladocerans are their preferred food within the zooplankton community. By estimating the biomass and number of zooplankton by species, we can evaluate whether food is a limiting factor for juvenile sockeye salmon in Falls Lake. The species composition over the season and between years may provide insight into how the zooplankton community responds to different fry densities and adult escapement levels. Fry and smolt population parameters, including density, size, and smolt age, are indicators of sockeye salmon response to conditions within the lake. Harvest and escapement data from returning adults will enable run reconstruction by brood year, and will indicate the overall status of the Falls Lake sockeye salmon stock. This report summarizes the sockeye salmon stock assessment data collected in 2001, the first year of this project.

OBJECTIVES

1) Count, length, sex, and scale sample, and finclip-mark adult sockeye and coho salmon that escape into Falls Lake as they are passed out of a trap operated at the outlet of the lake.

2) Estimate the escapement of sockeye and coho salmon into Falls Lake such that the estimates are within 10% of the actual abundance 95% of the time.

3) Estimate the subsistence harvest of sockeye salmon from Falls Lake Creek such that estimate is within 15% of the actual harvest 90% of the time.

4) Estimate the age, length, weight, and sex composition of the sockeye and coho salmon in the Falls Lake escapement such that these estimates are within 5%, 95% of the time.

5) Estimate a conversion between in-lake survey/mark-recapture estimates and the total estimated escapement of sockeye salmon such that the estimates have a coefficient of variation less than 20%.

6) Estimate the in-lake productivity of Falls Lake using established ADF&G limnological sampling procedures.

7) Estimate the sockeye salmon fry rearing density within Falls Lake such that the estimate is within 10%, 90% of the time.

8) Estimate the age, sex, and size composition of outmigrant sockeye salmon smolt such that these estimates are within 10%, 90% of the time.

After three to five years:

9) Make initial estimates of biological escapement goal ranges and sustainable escapement thresholds for sockeye and coho salmon based on current estimates of adult escapements, terminal runs, rearing juvenile densities, smolt age and size, in-lake productivity, and limnology-based habitat capacity modeling.

After five years of brood-year returns:

10) Refine these escapement goals using the estimates of spawners and recruits collected by this project and refine these goals as additional years of spawner-recruit data becomes available.

Changes to Objectives

The precision estimates for the population variables to be estimated were incorrectly stated in the original objectives listed above. Also, since sockeye salmon are the main spawning population in Falls Lake and the only species targeted there for subsistence use, coho salmon escapement will no longer be estimated, beyond counting and sampling at the weir/trap. Objectives 2, 3, 4, 7, and 8 will therefore be changed for subsequent years of the project as follows:

2) Estimate the escapement of sockeye salmon into Falls Lake at the weir and on the spawning grounds so that the estimated coefficient of variation is less than 10%.

3) Estimate the subsistence harvest of sockeye salmon from Falls Lake Creek so that the estimated coefficient of variation is less than 15%.

4) Estimate the age, length, weight, and sex composition of the sockeye salmon in the Falls Lake escapement so that the estimated coefficient of variation is less than 5%.

7) Estimate the sockeye salmon fry rearing density within Falls Lake so that the estimated coefficient of variation is less than 10%.

8) Estimate the age, sex, and size composition of outmigrant sockeye salmon smolt so that the estimated coefficient of variation is less than 10%.

A 95% confidence interval will also be reported for these population estimates, where appropriate.

METHODS

Study Site

Falls Lake (N 56^{o}49.5', W 134^{o}42.2') is located on the east side of Baranof Island just south of Red Bluff Bay, and about 50 km from the village of Kake. It lays in a steep mountain cirque basin at an elevation of about 20 m, and drains a watershed area of about 16.5 km^2. Two main inlet streams enter the southwest side of the lake, originating from hanging glaciers and steep mountain falls; the lower sections pass through old-growth spruce forest and willow and alder thickets, with partial or complete migration barriers a short distance upstream from the lake. The south inlet stream is frequently cloudy with glacial silt, while the north inlet stream is usually clear. A very short outlet stream plunges over two falls directly into Chatham Strait. The lake has a surface area of about 95 ha, an average depth of 32 m, and a maximum depth of 75 m (Figure 2). There is one large main basin in the center of the lake, separated by a shallow sill from a much smaller basin near the outlet. The lake is organically stained. Sockeye (*Oncorhychus nerka*) and coho (*O. kisutch*) salmon ascend the falls and spawn in the lake or inlet streams. Pink salmon (*O. gorbuscha*) spawn in lower section of the outlet stream, but most eggs are probably washed out due to lack of suitable gravel and high discharges. The lake supports resident and anadromous populations of Dolly Varden char (*Salvelinus malma*), as well as sticklebacks (*Gasterosteus aculeatus*) and a few sculpins (*Cottus cognatus*).

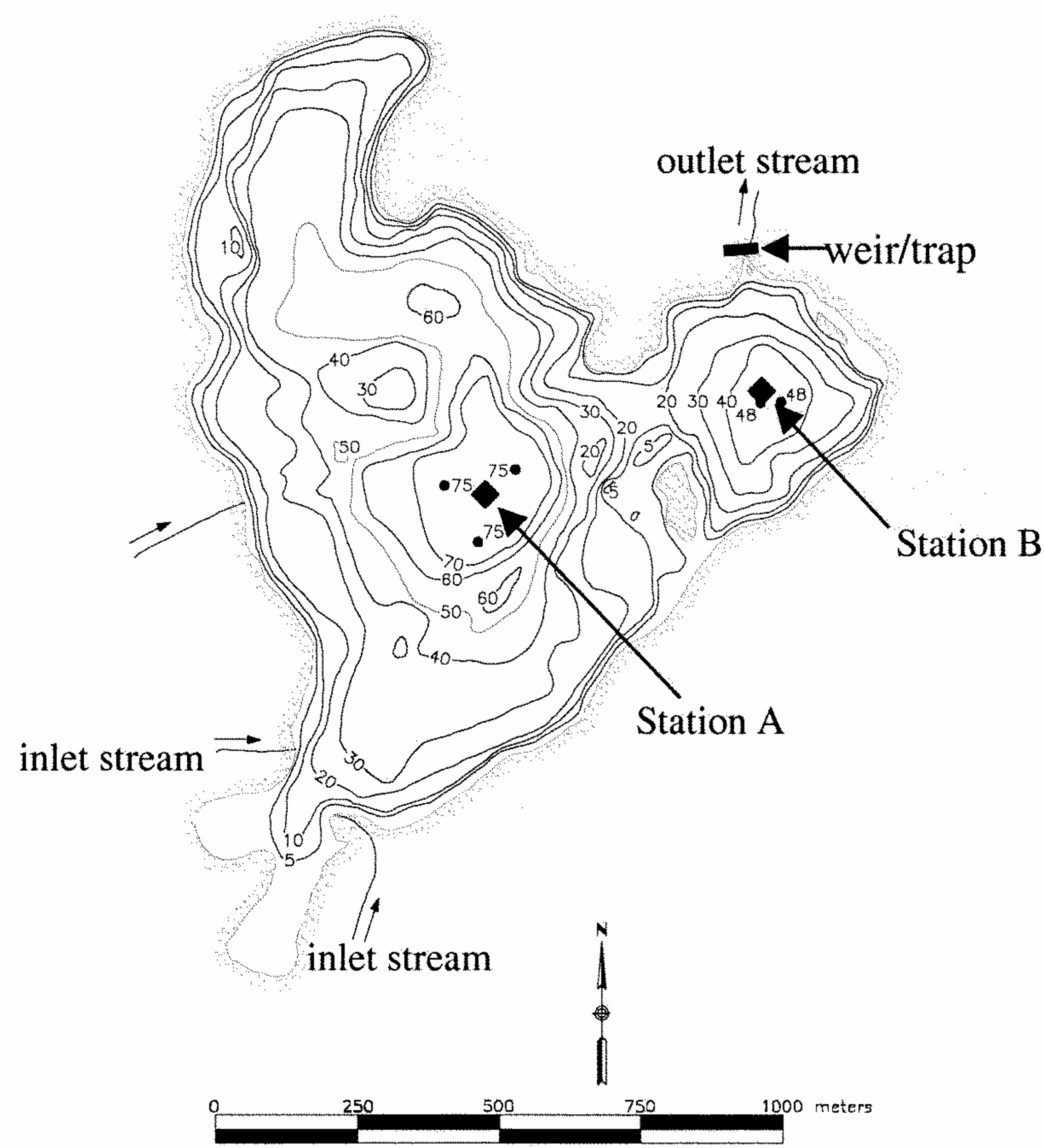


Figure 2. Bathymetric map of Falls Lake, showing 10 m depth contours, location of weir and trap at top of fishpass on the lake outlet, and two permanent limnology sampling stations.

Juvenile Sockeye Salmon Population Assessment

The distribution and abundance of rearing sockeye salmon fry were estimated by hydroacoustic and mid-water trawl sampling. The sampling was conducted on 18 August 2001 in the darkest part of the night. Falls Lake was divided into five sampling areas for the hydroacoustic portion of the survey. Prior to conducting a survey, one orthogonal transect was randomly chosen within each of the five sampling areas of the lake, and sampling was conducted on these transects. The cross-lake transects were started and ended at a depth of 10 m from the shore and each transect was surveyed twice to get a repeated measure. A constant boat speed of about 2.0 m $\cdot$ sec^{-1} was attempted for all transects. The acoustic equipment consisted of a Biosonics[2] DT-4000™ scientific echosounder[2] (420 kHz, 6° single beam transducer). Biosonics Visual Acquisition© version 4.0.2 software was used to record the data. Ping rate was set at 5 pings $\cdot$ sec^{-1} and pulse width at 0.4 ms. Data were analyzed using Biosonics Visual Analyzer© version 4.0.2 software. A target strength in the range of –50 dB to –68 dB represented fish within the size range of juvenile sockeye salmon and other small pelagic fish. Echo integration was used to generate a fish density (fish $\cdot$ m^{-2}) for each of the five sample areas (MacLennand and Simmonds 1992). A population estimate for each of the sample areas was calculated as the product of fish density and surface area. Summing the five area population estimates produced a total lake population estimate. A second estimate was calculated using the repeated measure transects. The average between these two estimates was used as the total population estimate for Falls Lake. A variance around the mean estimate was not possible because the survey was a repeated measures design instead of a true replicate design. We are revising our study design for hydroacoustic survey to incorporate true replicates and will report a variance in the future.

Trawl sampling was conducted in conjunction with hydroacoustic surveys to determine the species composition of targets. A 2 m × 2 m elongated trawl net was used to sample pelagic fish. Trawl depths and duration were determined by fish densities and distributions throughout the lake based on observations from the hydroacoustic survey. All captured fish were euthanized with MS-222 and preserved in 90% ethanol. In the laboratory, fish were soaked in water for 60 min before sampling. The snout-fork length was measured to the nearest millimeter (mm) and weight was measured to the nearest tenth gram (0.1g) on each fish. All sockeye salmon fry under 50 mm were assumed to be age- 0. Scales were collected from fish over 50 mm for age analysis. Sockeye salmon fry scale patterns were examined through the 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, and in instances of discrepancy between the two age determinations, a third independent examination was conducted.

Adult Escapement Estimates

Weir/Trap

Migrating fish that ascended the Falls Lake fishpass were channeled into a 1.25 m x 1.25 m x 2.5 m box frame trap. All fish that entered the trap were counted and passed upstream, and portions of the sockeye

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

and coho salmon were marked with finclips and sampled for sex, length, and scales. A 20 m x 4 m seine net was stretched across the remaining portion of the Falls Lake outlet, just upstream of the upper falls, to divert fish into the trap area and enable counting, marking, and sampling of all migrating fish not using the fishpass. The trap and net were reinforced against high water and possible washout using sandbags, and were anchored to shore with steel cables.

The trap was completed and fish tight by 11 June and the net was put into place on 21 June; the trap and net remained in place and fish were counted and passed upstream several times daily through 4 October, to obtain a direct count of all salmonids entering the Falls Lake system. In addition to counting fish that passed through the trap, a mark-recapture experiment was conducted to make a separate estimate of total escapement, given the possibility that fish may have passed into the lake uncounted. Biological sampling was conducted at the trap, including species identification and sockeye salmon length measurements and scale collection for aging.

A stratified, two-sample mark-recapture study was conducted to test the integrity of the weir/trap system by providing an independent estimate of sockeye salmon escapement into Falls Lake. Sockeye salmon passed through the trap were marked with fin clips, with marking stratified by time to allow separate estimation of different parts of the run should the weir fail or violations of mark-recapture assumptions occur during some part of the run (Arnason et al. 1995). A constant 50% daily marking rate was specified in the operating procedures, but uncertainty about run timing and an early error in the marking schedule caused the actual marking rate to differ between strata. The first stratum was 22–28 July; the second stratum was 29 July – 4 Aug., and the third stratum was 5 August–5 September. A cumulative total of 52% of all sockeye salmon passed through the trap was marked. All fish were first marked with an adipose clip, and then with a secondary clip indicating stratum: stratum 1 – left axillary, stratum 2 – left ventral, stratum 3 – dorsal.

Recapture events were conducted on the spawning grounds between 22 August and 11 October, at approximately weekly intervals. Fish were captured and examined for marks in all spawning areas, and marked with a secondary mark to prevent duplicate sampling. Darroch, maximum-likelihood, Schaefer population, and "pooled Petersen" estimates were calculated with the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995). Chapman's modification and the associated estimate of variance (Seber 1982, p. 61) were used with the pooled Petersen estimate. A 95% confidence interval for the number of recaptured fish (R) was estimated using the normal approximation in Seber (1982, p. 63), and the corresponding confidence interval for the population estimate (N^*) was calculated by multiplying the reciprocal of the confidence interval for R by the total number of marked fish (M).

Adult Population Age and Size Distribution

Age, sex, and length data were collected from adult sockeye salmon at the weir to describe the biological structure of the population. The goal was to collect 600 randomly selected samples through the season. A total of 634 sockeye salmon were sampled opportunistically between 22 July and 18 August. On each sampling day, a systematic sampling scheme was used to prevent any bias in sample selection. One scale was taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age and length data were paired for each fish sample. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes 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).

Spawning Grounds Mark-Recapture and Visual Survey

Two additional mark-recapture studies were conducted, once sockeye salmon began to appear on the spawning grounds, to obtain an independent estimate of escapement for comparison with the weir-based estimate. We observed that Falls Lake sockeye salmon followed one of two distinct spawning patterns, beach spawning and inlet stream spawning, and so we assumed that these fish formed separate populations or sub-populations. Separate series of four mark-recapture events were conducted in the beach spawning and inlet stream spawning areas, accompanied by visual surveys of the lake shore and inlet streams.

Beach Spawning Population

At the beginning of each trip, the numbers of spawners in defined shoreline strata around the lake were estimated to provide an escapement index and describe the distribution of spawners. A mark-recapture index area was selected in the beach area around the delta of the north inlet stream, where the majority of the fish were spawning, and its boundaries were recorded using Global Positioning Satellite (GPS). The mark-recapture study was conducted only within this area during subsequent trips. The beginning dates of the four trips were 29 August, 12 September, 27 September, and 10 October.

The study design consisted of two sampling stages: 1) a two-sample Petersen estimate for each trip (Seber 1982) and 2) a multiple trip estimate using a modified form of the Jolly-Seber method for multiple mark-recaptures in an open population (Seber 1982; Cook 1998). In the first stage, fish were marked on one day and examined for marks the next day; simple Petersen population estimates were generated from these data (Seber 1982). In the second stage, fish caught on both days of a given trip were marked with a unique mark for that trip, and in subsequent trips, recaptures of these marks were recorded. The sampling across trips used the first stage Petersen estimates to generate a population estimate within the study area for the entire season. The resulting population estimate for the index area was then expanded to an escapement estimate for the entire lake, based upon the visual survey counts. The whole lake estimates were considered minimum escapement estimates because we assumed that we were unable to observe all spawners present.

A 20 m long and 4 m deep beach seine was used to surround sockeye salmon, pulled by a small skiff with outboard motor and crew members on foot. All sockeye salmon caught were first inspected for previous marks, then marked with an opercular 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. Right opercular punches were used as the primary mark for each trip as follows: trip 1 – round, trip 2 – triangle, trip 3 – square, trip 4 – 2 round. A left opercular punch (any shape) was given each fish caught on the second day of each trip to indicate the fish had already been caught and should not be recounted on that trip.

Stream Spawning Population

For the inlet stream-spawning population, four mark-recapture events were conducted, beginning 1 September, 15 September, 1 October, and 12 October. A stratified, two-sample mark-recapture procedure was used to estimate escapement in the inlet stream (Arnason et al. 1995). The samples were stratified by time, and a distinct opercular punch pattern was used to distinguish between strata. In the first samples (marking phase), sockeye salmon were caught with a beach seine at the mouth of the inlet stream, and marked with an opercular punch to indicate the stratum number. In the second samples (recapture phase), fish were caught upstream with dipnets and examined for marks; carcasses were also examined for marks. The numbers of marked fish from each stratum and the number of unmarked fish were recorded. A second mark was given all fish in the second samples to prevent re-counting. The first event was marking only, and the last event was recapture only, while the second and third events were both mark and recapture. Therefore there were three marking strata and three recapture strata used in the analysis.

Data Analysis

The visual counts from each lake shore stratum were averaged across all observers, and the average counts from all strata inside and all strata outside the index area were summed. The number of observers varied from three to five. A bootstrap procedure was used to estimate the variance of counts between observers (X. Zhang, ADF&G, personal communication, 2001). The visual counts for the combined lake shore strata were compared with the mark-recapture estimates in the beach-spawning area (see below). The visual counts for the inlet stream stratum were kept separate and compared with the inlet stream-spawning mark-recapture results.

Chapman's form of the Petersen mark-recapture estimate and variance was used (Seber 1982, p. 60) for the first stage point population estimates within the index area. Confidence intervals for these estimators were estimated using the criteria given in Seber (1982, p. 63), according to sample size and marking fraction. If the criteria were met then Seber's eq. 3.4 was used; otherwise, the confidence interval bounds were found from Table 41 in Pearson and Hartley (1966).

In the second stage, the point population estimates, N^*_i, were used in a Jolly-Seber multiple mark-recapture estimator, in place of the derived parameter estimating the number of animals alive in the system at each sampling occasion. The N^*_i were also used in the estimation of two other parameters, B_i and M_i, below (Schwarz et al. 1993; J. Blick, ADF&G, personal communication, 1998; Cook, 1998). Given s sampling occasions,

N^*_i = number of fish alive in the system at sampling occasion i (the Chapman-Peterson point population estimates from the first stage),

n_i = number of unmarked fish and fish marked on previous trips, caught at sampling occasion i,

m_i = number of fish marked on previous trips, caught at sampling occasion i,

M_i = number of marked fish alive at time i,

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

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

B^*_i = number of animals that enter the system after occasion i, but before occasion $i+1$,

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

The specific intermediate estimates are:

$M_i = m_i N^*_i / n_i$,

$\phi_i = M_{i+1}/(M_i - m_i + n_i)$,

$B_i = N^*_{i+1} - \phi_i N^*_i$.

B^*_i (for $1 < i < s-1$) $= B_i log(\phi_i)/(\phi_i-1)$, where recruitment and mortality are assumed to be uniform between times i and i+1.

Because B_0, B_1, and B_{s-1} are not uniquely estimable, B_{s-1} was set to zero, assuming the sampling extended to the point where recruitment was virtually ended, and $B^*_0 + B^*_1$ was estimated by $N_2 log(\phi)/(\phi-1)$. The total abundance N was then estimated as,

$N = \Sigma B^*_i$. (Schwarz et al. 1993; Cook 1998; J. Blick, ADF&G, personal communication, 1998).

A bootstrap method was used to estimate the confidence interval for this estimator. This was based on two random variables: the number of marked fish caught in the second sample of the first stage mark-recapture as a random variable with hypergeometric distribution, and the number of marked fish caught in the second stage mark-recapture as a random variable with normal distribution (X. Zhang, ADF&G, personal communication, 2002).

Linear regression was used to compare mark-recapture escapement estimates to visual counts within the index areas across all lakes and sampling dates for the 2001 season (X. Zhang, ADF&G, personal communication, 2002). Mark-recapture and observer count data from four lakes in the Chatham Strait region (Kook, Sitkoh, Kanalku, and Falls lakes) were pooled since there were insufficient data from any one lake in this first sampling season with which to estimate a regression. The four lakes included in this regression had similar water color, shoreline characteristics, and spawning areas used by sockeye salmon. The slope obtained from the regression was 2.02 with an R^2 value of 0.94; this slope was used to predict escapement for the whole lake from the visual count for the whole lake.

Analysis of the stream spawning mark-recapture data was identical to analysis of the weir/trap mark-recapture data (see *Weir/Trap* sub-section, above).

Subsistence Harvest Estimate

Study Design

The study design for the Falls Lake marine subsistence fishery was originally based on a stratified two stage sampling design (Bernard et al. 1998; Cochran 1977). The crew was able to interview all the participants because the fishing grounds were easily visible from the camp. Thus, the two stage study design was eliminated.

Data Analysis

Due to relative efficiencies of different gear, the boat parties were stratified by gear type used. The strata were seine, gillnet, and sport fishing rod.

For strata where all boat parties were interviewed, the harvest estimate was simply the sum the harvest. No variance estimate was calculated.

$$\hat{\mathrm{H}}_{\mathrm{g}} = \sum_{i=1}^{M_g} \mathrm{h}_{\mathrm{ig}}\,, \tag{4}$$

where h_{jg} = harvest for boat group *i* in gear group *g*, and M_g = number of boat groups in gear group *g* interviewed throughout the season.

For strata where boat parties were missed, the harvest was estimated as:

$$\overline{\mathrm{H}}_l = \frac{\sum_{\mathrm{i}=1}^{\mathrm{m}_l} \mathrm{h}_{il}}{\mathrm{m}_l} \tag{5}$$

$$\hat{\mathrm{H}}_l = \mathrm{M}_l \overline{\mathrm{H}}_l\,. \tag{6}$$

The variance of the harvest by stratum was estimated as:

$$\mathrm{var}\left[\hat{\mathrm{H}}_l\right] = (1 - \mathrm{f}_l)\mathrm{M}_l^{\,2} \frac{\sum_{\mathrm{i}=1}^{\mathrm{m}_l} (\hat{\mathrm{H}}_{il} - \overline{\mathrm{H}}_l)^2}{\mathrm{m}_l(\mathrm{m}_l\text{ -1})}\,, \tag{7}$$

where f_l = sampling fraction for the gear type *l*, m_l= number of boat parties of gear type *l* interviewed, and M_l= total number of boat parties for gear type *l*. Total harvests for the season are the sums across strata, $\sum \mathrm{H}_\mathrm{h}$ and $\sum \mathrm{V}[\mathrm{H}_\mathrm{h}]$.

Limnology Sampling

Limnology sampling was scheduled at six-week intervals from mid-May through October, for a total of four sampling dates. Two stations were set up in the deepest part each of the two basins of the lake (Figure 1). Physical data were taken only at Station A (the main lake basin). Zooplankton samples were collected from both stations on each sampling date.

Light, Temperature, and Dissolved Oxygen Profiles

The depth at which underwater light intensity is attenuated to one percent its value just below the surface defines the part of the lake where photosynthesis is possible. We recorded underwater light intensity (footcandles) at 0.5 m intervals, from just below the surface to a depth equivalent to one percent of the surface light reading, using a Protomatic submarine photometer. Vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) is defined as the depth to which one percent of the subsurface light [photosynthetically available radiation (400-700nm)] penetrates the lake surface (Schindler 1971), and was calculated from the equation: EZD = 4.6205/ K_d (Kirk 1994).

Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe, calibrated each sampling trip with a 60 ml Winkler field titration (Koenings et al. 1987). Relative (%) and absolute (mg L^{-1}) DO values were recorded; temperature was measured in ºC. Measurements were made at 1 m intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreases to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 50 m).

Secondary Production

Zooplankton samples were collected at two stations on Falls Lake using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a depth of 50 m at both stations at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G, commercial fisheries limnology laboratory in Soldotna, Alaska. Cladocerans and copepods were identified using the taxonomic keys of Brooks (1957), Pennak (1978), Wilson (1959), and Yeatman (1959). Zooplankton were enumerated from three separate 1 ml subsamples taken with a Hensen-Stemple pipette and placed in a 1 ml Sedgewich-Rafter counting chamber. 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 versus zooplankter length regression equations (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.

RESULTS

Juvenile Sockeye Population Assessment

A hydroacoustic survey was successfully completed in Falls Lake on 18 August. Two mid-water tows were conducted, each lasting 10 minutes at 7 m depth. A total lake population of 75,000 sockeye salmon fry was estimated from the hydroacoustic survey and the estimated density of sockeye salmon fry in the lake was 0.088 fry · m^{-2} (Table 1). The majority of the sockeye salmon fry were less than 50 mm, comprising the dominant age-0 year class captured in the trawl net (Figure 3).

Table 1. Size and age distribution of sockeye salmon fry and stickleback estimated from midwater trawl samples, and population estimates based on hydroacoustic surveys with species and age apportionment based on trawl samples, for Falls Lake, 2001.

Species	Age	Sample size	Proportion of total	Mean length (mm) ± se	Mean weight (g) ± se	Population Estimate by Age	Total Population
Sockeye	0	84	89%	39.6 ± 0.6	0.56 ± 0.03	67,000	
Sockeye	1	10	11%	60.2 ± 1.1	2.01 ± 0.13	8,000	75,000

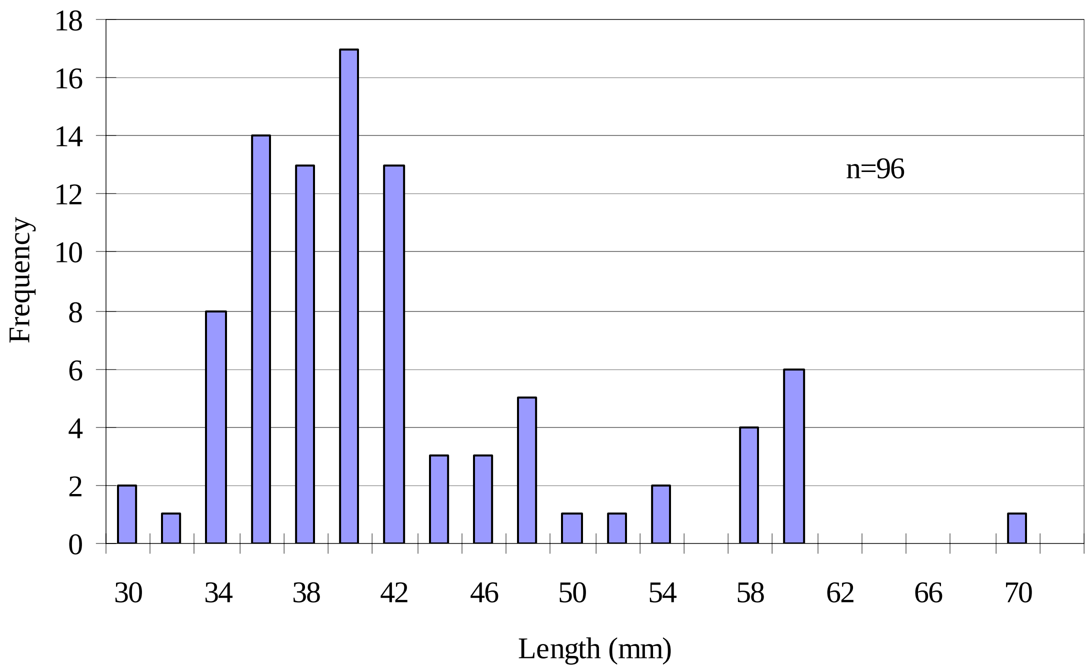


Figure 3. Length frequency distribution of sockeye salmon fry in Falls Lake, 2001. All fry under 50 mm in length were assumed to be age-0. Of the 14 fry in the sample over 50 mm in length, scale analysis showed ten were age-1 and four were age-0.

Adult Escapement Estimates

Weir/Trap

Between 22 July and 5 September, 2,570 sockeye salmon were counted through the Falls Lake trap system (Table 2). Although the trap was operated from 12 June through 4 October, no sockeye salmon passed through it before 22 July or after 5 September. Peak escapement was on 29 July, when 342 sockeye salmon were counted through the trap. Daily escapement was consistently high between 25 July and 13 August, and the water level at the gauge was less than 0.5 m throughout this period (Appendix D). No escapements of any species were recorded on days when the water level exceeded 0.5 m., and most of these high flow days were in September. Between 1 August and 20 September, 131 coho salmon entered Falls Lake, with daily escapements of fewer than 15 fish. It is possible that some coho salmon entered Falls Lake undetected near the end of or after the trap operation period, but the numbers are still likely to be very small. Very small numbers of pink salmon and Dolly Varden char were counted through the trap, and no chum salmon were observed.

Uncertainty about run timing and an early error in the marking schedule caused the actual marking rate at the weir/trap to differ between strata and deviate from the 50% rate specified in the procedures. In the first stratum (22 – 28 July) 95% of sockeye salmon passed were marked; in the second stratum (29 July – 4 August) 39% of the sockeye salmon were marked, and in the third stratum (5 August–5 September) 51% of the sockeye salmon were marked (Table 3). A consistent cumulative marking rate of 52% was achieved by 3 August, and a cumulative total of 52% of all sockeye salmon passed through the trap was marked.

Recapture events were conducted on the spawning grounds between 22 August and 11 October In order to achieve adequate sample sizes and sample all spawning areas, sampling was conducted opportunistically over a several-day period. Recapture samples were pooled into three strata, by date (Table 3). Eventually all marking and recapture strata were pooled, since the "pooled Petersen" estimate yielded the smallest confidence interval, and no errors, in the SPAS program (Arnason et al. 1995). The sockeye salmon escapement estimated by the mark-recapture experiment was slightly higher than the weir count (Table 2). However, the weir count fell within the 95% confidence interval of the mark-recapture estimate. It therefore appears likely that all sockeye salmon passing through the weir were counted. Coho salmon mark-recapture data were pooled because of small sample sizes. The mark-recapture estimate was very close to the weir count, but the precision of the estimate was low (Table 2).

Table 2. Weir counts and preliminary mark-recapture estimates for Falls Lake sockeye salmon and other salmonids during 2001.

Species	Count	Number and percent marked	Pooled Petersen mark-recapture estimate	95% Confidence Interval
sockeye	2,570	1,329 (52%)	2,633	(2,494 - 2,771)
coho	131	67 (51%)	138	(105 - 171)
pink	23			
Dolly Varden	13			

Table 3. Weir mark and recapture sample sizes and number of marked fish caught in recapture samples in Falls Lake, 2001, and pooled Petersen escapement estimate. Sockeye salmon were marked as they were passed through the weir/trap at the lake outlet. Recapture sampling was conducted in all spawning areas of the lake and its inlet streams throughout the spawning period.

				Marked fish in recapture strata (dates shown below stratum number), by marking stratum		
Marking strata	**Dates**	**Marking sample size**	**Number marked**	**1** (8/22-8/30)	**2** (9/1-9/9)	**3** (9/14-10/11)
1	7/22-28	394	376	71	53	22
2	7/29-8/4	1250	482	68	63	34
3	8/5-9/5	926	471	37	53	52
				Recapture sample size		
				341	342	215

Pooled data	
Total number marked at weir	1,329
Total in recapture samples	898
Total recaptures of marked fish	453
Pooled Petersen escapement estimate	**2,633** (2,494 - 2,771)*

*95% confidence interval is indicated in parentheses.

Adult Sockeye Salmon Population Age and Size Distribution

The sockeye salmon sampled at the weir were nearly evenly split between males and females. The dominant age class for both sexes was age-1.3 (Table 4). Only 6% of the sampled fish were age-1.2, and less than 3% were age-2.2 or -2.3. Males were only slightly larger than females, averaging 552 mm in mid-eye to fork length; females averaged 547 mm in length (Table 5). Age-1.3 fish averaged 554 mm in mid-eye to fork length, with both sexes very close to this average.

Table 4. Age composition of adult sockeye salmon in the Falls Lake escapement by sex and brood year, and weighted by weekly escapements, 22 July–18 August 2001.

Brood Year	**1997**	**1996**	**1996**	**1995**	
Age	**1.2**	**1.3**	**2.2**	**2.3**	**Total**
Male					
Sample Size	13	236		9	258
Percent	2.1	46		1.2	49.3
Std. Error	0.5	2.2		0.3	2.2
Female					
Sample Size	20	224	7	6	257
Percent	3.9	45	1	0.8	50.7
Std. Error	0.8	2.2	0.3	0.3	2.2
All Fish					
Sample Size	33	461	7	15	516
Percent	6	91	1	2	100
Std. Error	1	1.1	0.3	0.4	

Table 5. Mean fork length (mm) of adult sockeye salmon in the Falls Lake escapement by sex, brood year, and age, and weighted by weekly escapements, 22 July–18 August 2001.

Brood Year	**1997**	**1996**	**1996**	**1995**	
Age	**1.2**	**1.3**	**2.2**	**2.3**	**Total**
Male					
Avg. Length	497	554		552	552
Std. Error	13.2	1.5		8.6	1.7
Sample Size	13	236		9	258
Female					
Avg. Length	496	553	500	536	547
Std. Error	4	1.6	9	6.8	1.8
Sample Size	20	224	7	6	257
All Fish					
Avg. Length	498	554	500	544	549
Std. Error	5.6	1.1	9	5.7	1.3
Sample Size	33	460	7	15	515

Mark-Recapture and Visual Survey Escapement Estimates

The four surveys and mark-recapture events bracketed the entire spawning period of the Falls Lake sockeye salmon. Visual surveys and mark-recapture events were conducted and analyzed separately for the beach spawning areas and the main inlet stream used for spawning, in the southwest corner of the lake (Table 6a, 6b). The peak number of spawners was observed on 12–15 September, approximately six weeks after the day of peak escapement into the lake. The total beach spawning population in the index area was estimated at 570 sockeye salmon (Table 6a). This was expanded to give a total spawning population estimate of 748 beach spawning sockeye salmon in the shoreline areas of the lake. For the southwest inlet stream, a total spawning population of 1,084 (95% CI, 800 – 1,543) sockeye salmon was estimated (Table 6b). The inlet stream population estimate was not expanded, since the mark-recapture events encompassed the entire spawning area of the stream. The combined total escapement estimate, including both beach and inlet stream spawners, was 1,832 sockeye salmon, about 700 fish less than indicated by the weir/trap count.

Table 6a. Summary of visual survey counts and mark-recapture estimates within the defined index area on the Falls Lake shoreline.

Event starting date	Visual survey counts ± se: Entire lake shoreline	Visual survey counts ± se: M-R Index area	Petersen estimate, index area (95% CI)
8/22	140 ± 2	70 ± 2	246 (227 - 271)
9/12	407 ± 20	134 ± 19	288 (256 - 331)
9/27	184 ± 2	100 ± 0	144 (114 - 183)
10/10	90 ± 1	35 ± 0	95 (42 - 206)
[a] Modified Jolly-Seber escapement estimate for index area			**570** (535 - 606)
[(a, b)] Expanded escapement estimate for whole lake			**748** (670 - 845)

[a] 95% confidence interval is indicated.
[b] Expanded whole lake escapement estimates should be considered preliminary (see Discussion section).

Table 6b. Sample sizes in mark and recapture strata and number of marked fish caught in recapture strata in southwest inlet stream to Falls Lake, 2001. Mark and recapture events were conducted on the same dates, but there was no recapture event in stratum 1 (9/1). All mark and recapture strata were pooled for analysis since the sample sizes in the later strata were very small.

Marking strata	Dates	Visual survey count	Number marked	Marked fish in recapture strata, by marking stratum: 1	2	3	4
1	9/1/01	104 ± 6	161	-	17	7	1
2	9/15/01	210 ± 7	49	-	2	5	0
3	10/1/01	158 ± 0	6	-	-	-	0
4	10/12/01	5 ± 0	0	-	-	-	0
				Recapture sample size			
				-	123	38	3
Pooled data							
Total number marked				216			
Total in recapture samples				164			
Total recaptures of marked fish				32			
Pooled Petersen estimate for inlet stream				**1,084** (800 – 1,543)*			

*95% confidence interval is indicated in parentheses.

Subsistence Harvest Estimate

The crew members at Falls lake were confident that they had counted all fishing boats and had obtained all but one sport and one subsistence boat interview. The first boats for subsistence and sport appeared on 29 June and 11 July, respectively. The majority of boats participated in the fishery between 11 July and 9 August. The subsistence fishery ended 20 July, and an occasional sport boat fished in the area until to 2 September. A total of 56 boats fished in the marine waters near Falls Lake. Of those, 21 were sport boats and 35 were subsistence boats. The total reported harvest of sockeye salmon was 1,973 fish. Of these, 98.9% were caught by subsistence and 2.1% by sport fishers during the season (Table 7). The crew felt that the fishers accurately estimated their catch, with the exception of two subsistence boats that underestimated their catch by about 100 fish each.

The effort and catch per effort varied with time, fishery, and the type of gear used. The average number of subsistence boats per day was 1.8 from 29 June to 20 July. Average number of boats during weekdays was 1.5; during weekend days it was 2.5. The difference in participation was not statistically significant. The average number of sport boats was 0.54 per day between July 11 and August 9. Gillnets and beach seines were the types of gear used in the subsistence fishery. Sometimes gillnets were used as seines. Rods were used by sports fishers. Seines were the most efficient gear type used to harvest fish. The average CPUE was 44.43 fish per hour for beach seines, 6.66 fish per hour for gillnets, and 0.36 fish per hour for sport fishing rods. Average CPUE for gillnet and seine catches were strongly influenced by individual entries. This precluded analysis of harvest by week, as well as CPUE by week.

Table 7. Estimated number of salmon caught in the Falls Lake sport and subsistence fisheries during 2001, ± standard error.

Gear Type	**Number Counted**	**Number Sampled**	**Sockeye**[a]	**Chum**	**Pink**	**Chinook**	**Coho**
Gillnet	25	24	1,018 ± 27	113 ± 8	71 ± 6	1 ± 0.2	
Seine[(a)]	10	10	913 ± 0	81 ± 0	117 ± 0		
Sport	21	20	42 ± 3	0	7 ± 1		3 ± 1
Totals	56	54	1,973 ± 27	194 ± 8	195 ± 6	1 ± 0	3 ± 1

[a] At least 160 more sockeye salmon were caught than were reported.

Limnology Sampling

Limnology sampling was conducted in Falls Lake on 15 May, 29 June, 16 August, and 1 October.

Light, Temperature, and Dissolved Oxygen Profiles

The mean euphotic zone depth (EZD) at Falls Lake in 2001 was 9.71 m (Table 8). The minimum depth occurred in October, coinciding with heavy rainfall and maximum sediment input.

Table 8. Euphotic zone depth in Falls Lake, 2001.

Sample date	EZD (m)
15 May	9.07
29 June	10.01
16 Aug	12.75
1 Oct	6.99
seasonal mean	9.71

Water temperature vertical profiles for Falls Lake show a thermal stratification pattern typical of dimictic lakes (Figure 4). Although a true thermocline, defined as a temperature decrease of >1 ^oC in 1 m, did not fully develop by August, there was a strong temperature gradient from 0 to 10 m. The gradient had disappeared by October, as a result of cooling and mixing. The maximum temperature in August was 15.5 ^oC in the surface layer. The minimum temperature in the hypolimnion remained below 5 ^oC. Dissolved oxygen (DO) levels remained above 9.5 mg · L^{-1} at all depths during the summer.

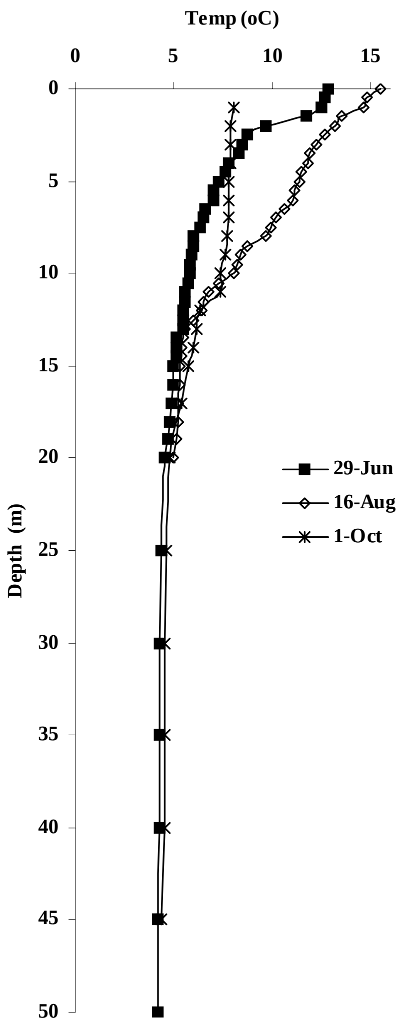


Figure 4. Temperature profiles from Falls Lake, Station A, in 2001.

Secondary Production

Macro-zooplankton species identified in Falls Lake water samples were cladocerans *Bosmina* sp., *Daphnia longiremus*, and *Holopedium gibberum*, and copepods *Cyclops vernalis* and *Diaptomus franciscanus* (Table 9). *Diaptomus franciscanus* was the largest species, with a mean weighted length of over 1.0 mm, when ovigerous individuals are included. *Daphnia longiremus* had a mean body length of 0.78 mm including ovigerous individuals. There was considerable difference in species apportionment between stations. Station A is in the main basin at the deepest part of the lake, while Station B is in a sub-basin near the lake outlet. The copepod species *Diaptomus franciscanus* was strongly dominant in biomass and in numbers at Station A, with *Bosmina* sp. the second most abundant species. *Bosmina* sp. represented the largest proportion (about 50%) of both biomass and numbers at Station B, and *Diaptomus franciscanus* represented the second largest proportion (about 30%) of both measures. The large cladoceran *Daphnia longiremus* was more present in low numbers and represented only a small percentage of the biomass at both stations, but was greater in both measures at Station B.

Table 9. The species distributions of macro-zooplankton in Falls Lake, 2001. Zooplankton densities (number · m^{-2}) and mean weighted biomass (mg · m^{-2}) are seasonal mean values from four samples, collected at six week intervals May through October, at two permanent sampling stations. Overigerous (egg-bearing) individuals in each taxon were enumerated separately.

Station A	**Density (no. · m^{-2})**	**Percent of total numbers**	**Biomass (mg · m^{-2})**	**Percent of total biomass**	**Weighted length (mm)**
Ergasilus	0				
Epischura	0				
Diaptomus	18,371	44.00%	155	80.25%	1.27
Ovig. Diaptomus	1,087	2.60%	15	8.00%	1.53
Cyclops	4,634	11.10%	4	2.12%	0.52
Ovig. Cyclops	13	0.03%	0.06	0.03%	1.11
Bosmina	9,352	22.40%	12	6.44%	0.38
Ovig. Bomsina	3,549	8.50%	6	2.89%	0.41
Daphnia l.	210	0.50%	0.35	0.18%	0.63
Ovig. Daphnia l.	26	0.06%	0.10	0.05%	0.93
Holopedium	38	0.09%	0.07	0.04%	0.47
Ovig. Holopedium					
Chydorinae	0				
Copepod nauplii	4,470	10.71%			
Total	41,750	100%	193	100%	
Station B					
Ergasilus	0				
Epischura	0				
Diaptomus	3,641	27.82%	5	33.26%	0.68
Ovig. Diaptomus	68	0.52%	1	6.12%	1.52
Cyclops	1,646	12.57%	1	7.57%	0.47
Ovig. Cyclops	13	0.10%			
Bosmina	5,429	41.48%	6	37.33%	0.34
Ovig. Bomsina	1,395	10.66%	2	12.32%	0.39
Daphnia l.	165	1.26%	0.35	2.27%	0.70
Ovig. Daphnia l.	30	0.23%	0.10	0.65%	0.87
Holopedium	27	0.20%	0.05	0.31%	0.47
Ovig. Holopedium	13	0.10%	0.03	0.17%	0.50
Chydorinae	0				
Copepod nauplii	662	5.06%			
Total	13,088	100.00%	16	100.00%	

DISCUSSION

All of the project objectives were met in the first field season, with the exception of collecting smolt data, which is being done starting in the 2002 field season. In order to meet the long-term objectives of the project, we will need to continue sampling for at least four more seasons.

A moderate return of sockeye salmon to Falls Lake was documented in 2001, with a total harvest in the terminal area of at least 2,000 fish and an escapement of about 2,600 fish. Without a several-year data series it is impossible to know whether the proportion of the return harvested and the size of the escapement are reasonable, but there is concern that the escapement is not distributed through the season. Since there was no escapement until after the subsistence fishing season closed by regulation on 20 July, it is possible that the entire early part of the run was harvested, leaving only later-returning sockeye salmon in the escapement. However, an alternative explanation is that the fish schooled up off the mouth of Falls Creek and held there in response to water level, temperature, or other environmental factors. Nevertheless, it is essential for conservation of this sockeye run that escapement be distributed throughout the season. New subsistence permit and state regulations attempt to address this issue by setting a fishing boundary line in front of the mouth of the lake outlet to provide a small refuge for sockeye salmon waiting to ascend the falls. The size of the sockeye salmon population returning to Falls Lake appears to be comparable to previous years. The average count of escapement from 1981–1989, when the previous Falls Lake weir project was operated, was about 2,500 sockeye salmon, and the maximum count was 6,000. Reported subsistence harvests have increased in the last decade to about 1,000–1,200 sockeye salmon annually. Considering that these harvest data are known to be biased low due to under-reporting, the harvest documented by the 2001 creel survey is probably within the range of harvests during the last 10 years.

The escapement count at the Falls Lake weir/trap was verified by the accompanying mark-recapture study, which showed that few sockeye salmon passed the trap undetected. Since we know that the escapement count was reliable, it can be compared with the visual and mark-recapture estimates made on the spawning grounds. The spawning grounds estimate was lower than the escapement estimated by the weir/trap by about 700 fish. The spawning grounds estimate of sockeye salmon within a selected index area represents an unknown part of the total escapement. In extrapolating the index area population to an entire lake system, we are making an untested assumption that the spawning sockeye population within the index area is representative of the population of the whole lake (Crabtree 2000, 2001). We most likely are not able to observe all the spawners. In Falls Lake, there is a large gravel delta with good upwelling off the mouth of the southwest inlet stream, and it is possible that some sockeye salmon spawn there below the visible depth of 1–2 m and out of range of the beach seine. Therefore, the whole lake estimates must be viewed as the minimum number of fish spawning, with an unknown proportion of the population unaccounted for in this estimate. More years of data from the weir/trap are needed to determine whether the visual and mark-recapture estimates on the spawning grounds can provide a reliable index of escapement in Falls Lake.

The density estimate of 0.088 fry m^{-2} in Falls Lake was lower than the median density of 0.094 fry m^{-2} for 19 sockeye salmon rearing lakes surveyed in southeast Alaska in 2001. Such a comparisons are very limited, however, without additional years of data as well as information about other physical and biological variables affecting sockeye salmon fry productivity between lakes. Measurements of physical parameters in 2001 were comparable with those from the 1980s. The zooplankton community observed in Falls Lake in 2001 was similar in overall density and biomass to what it was in the 1980s, falling in the middle of the ranges observed during the previous study. The dominant species in 2001 were similar to those in the 1980s. The most significant difference may be a drastic reduction in both numbers and biomass of the large cladoceran *Daphnia longiremus*. The *Daphnia* population peaked in Falls Lake in 1985, possibly in response to fertilization. The population dropped somewhat in the following year but was still high. Since there are no more data on zooplankton after 1986, it is impossible to know whether this population of *Daphnia* undergoes cyclic fluctuations, or responds in some other way to environmental variables. We cannot rule out the effect of predation by sockeye salmon fry, but the 2001 fry density in Falls Lake was within the range of fry populations estimated in the 1980s. Conversely, the effect of the smaller *Daphnia* population on the sockeye salmon fry population is also unknown at this point.

Additional years of sampling are needed in order to define the relationship between escapement levels and lake productivity in Falls Lake. Smolt sampling is being conducted in the 2002 season, and we will continue to assess sockeye salmon fry and zooplankton populations, light and temperature, and adult returns. The overlapping data collected from the various life history stages of sockeye salmon and the environmental factors that affect them will help future managers to ensure sustainable harvest levels and continued productivity of the Falls Lake sockeye salmon populations.

LITERATURE CITED

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1995. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences. 2106: 37p.

Bernard, D. R., A. E. Bingham, and M. Alexandersdottir. 1998. The mechanics of onsite creel surveys in Alaska. Alaska Department of Fish and Game, Special Publication No. 98-1, Anchorage.

Brooks, J. L. 1957. The systematics of North American *Daphnia*. Mem. Conn. Acad. Arts. Sci. 13.

Clutter, R. and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin of the International Pacific Salmon Fisheries Commission 9, New Westminster, British Columbia.

Cochran, W. G. 1977. Sampling techniques, third ed. John Wiley and Sons Inc. New York, NY.

Cook, B. T. 1998. Mark-recapture studies of Sitkoh Lake adult sockeye salmon stocks, 1997. Regional Information Report 1J98-19. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, Alaska.

Firman, A. S. and R. G. Bosworth. 1990. Harvest and use of fish and wildlife by residents of Kake, Alaska. Technical Paper No. 145. Alaska Department of Fish and Game, Division of Subsistence, Juneau, Alaska.

Goldschmidt, W. R. and T. R. Haas. T. F. Thornton, ed. 1998. *Haa Aaní*, Our Land: Tlingit and Haida land rights and use. University of Washington Press, Seattle and London. Sealaska Heritage Foundation, Juneau, Alaska.

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Vancouver, British Columbia.

Jones, E. L., III and S. A. McPherson. 1997. Relationship between observer counts and abundance of coho salmon in Steep Creek, Northern Southeast Alaska in 1996, Alaska Department of Fish and Game, Fishery Data Series No. 97-25, Anchorage.

Jones, E. L, III, T. J. Quinn II, and B. W. Van Alen. 1998. Accuracy and precision of survey counts of pink salmon in a Southeast Alaska stream. North American Journal of Fisheries Management 18:832-846.

Kirk, J. T. O. 1994. Light and photosynthesis in aquatic ecosystems. Cambridge University Press. England.

Koenings, J. P., B. Sele, J. McNair. 1983. Northern southeast Alaska lake fertilization progress report: limnological and fisheries investigations at Falls Lake (1981-1983). Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, and Development. Soldotna, Alaska.

Koenings, J. P., J. A. Edmundson, G. B. Kyle, J. M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Report No. 71. Alaska Department of Fish and Game, Div. of Fisheries Rehabilitation, Enhancement, and Development, Juneau, Alaska.

Larson, R. C. 2001. Draft staff analysis. RFR01-01. Regional Council Review for the Federal Subsistence Board. U.S. Forest Service, Petersburg Ranger District, Petersburg, Alaska.

MacLennand, D. N. and E. J. Simmonds. 1992. Fisheries Acoustics. Van Nostrand-Reinhold, New York, NY.

Mosher, K. H. 1968. Photographic atlas of sockeye salmon scales. Fishery Bulletin. 67(2): 243-281.

Pearson, E. S. and H. O. Hartley, eds. 1966. Biometrika Tables for Statisticians, Vol. 1. Cambridge University Press, Cambridge, England.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States, 2nd ed. John Wiley and Sons, New York.

Rich, W. H. and E. M. Ball. 1933. Statistical review of the Alaska salmon fisheries. Part IV: Southeastern Alaska. Bulletin of the Bureau of Fisheries, Vol. XLVII (47?), No. 13: 437-673.

Schindler, D. W. 1971. Light, temperature, and oxygen regimes of selected lakes in the experimental lakes area, northwestern Ontario. J. Fish. Res. Bd. Canada. 28: 157-169.

Schwarz, C. J ., R. E. Bailey, J. R. Irvine and F. C. Dalziel. 1993. Estimating salmon spawning escapement using capture-recapture methods. Can. J. Fish. Aquat. Sci. 50: 1181-1197.

Seber, G. A. F. 1982. The estimation of animal abundance, 2nd ed. Griffen, London. 654 pp.

Wilson, M. S. 1959. p.738-794 *in* W. T. Edmondson editor, Freshwater biology, 2nd ed., John Wiley and Sons, New York.

Yeatman, H. C. 1959. Cyclopoida. P. 795-815. In: W. T. Edmondson (ed.) Freshwater biology, 2nd ed., John Wiley and Sons, New York.

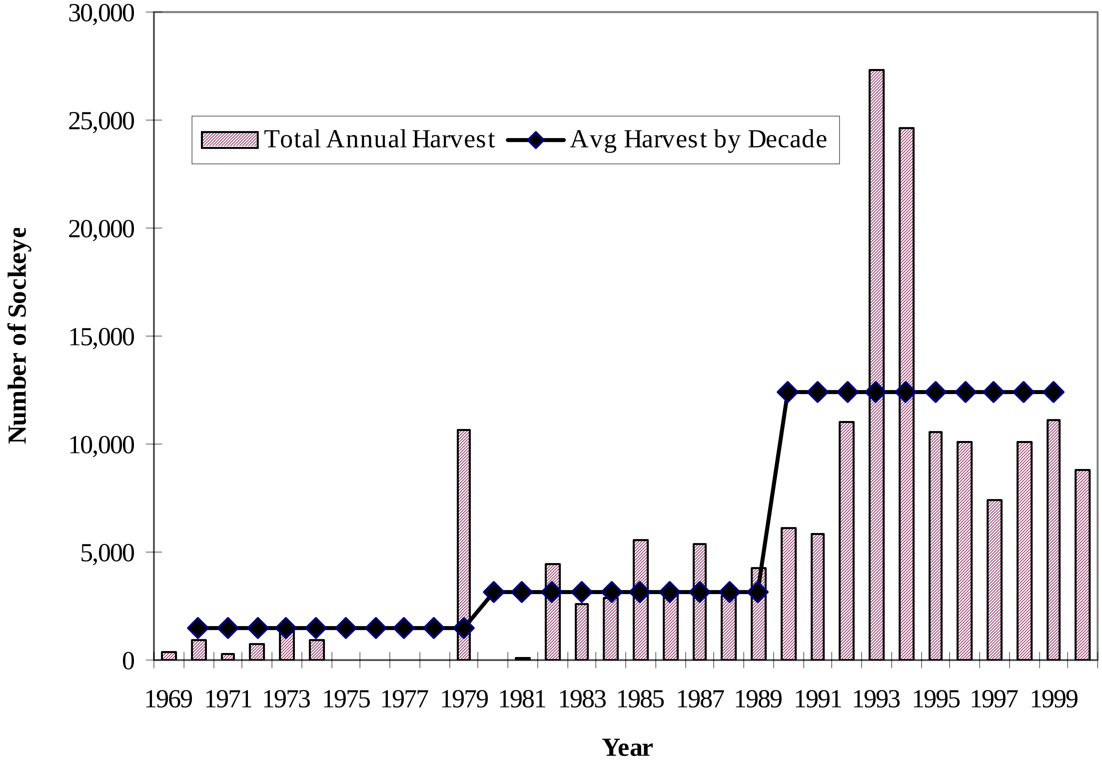
Appendix A. Historical sockeye salmon harvest information from Falls Lake and vicinity.

Appendix A.1. Subsistence harvest of sockeye salmon reported on permits from Falls Lake, 1985–2000 (ADF&G Alexander database, 2001).

Year	Number of Permits	Total Sockeye Harvest	Average Sockeye Harvest Per Permit
1985	2	17	9
1986	3	30	10
1987	3	30	10
1988	24	338	14
1989	26	390	15
1990	16	149	9
1991	10	122	12
1992	34	550	16
1993	51	1012	20
1994	51	911	18
1995	56	976	17
1996	70	1229	18
1997	68	977	14
1998	62	1101	18
1999	75	1020	14
2000	59	798	14
average	38	603	14

Appendix A.2. Historic catches of sockeye salmon in front of Falls Lake (Rich and Ball 1933).

Year	Sockeye
1913	1,279
1914	2,479
1915	3,586
1919	9,615
1920	3,717
1921	1,810
1922	3,214



Appendix A.3. Commercial sockeye harvest in vicinity of Falls Lake and Gut Bay (Subdistricts 109-20, 112-11, 112-21, and 112-22), all gear types (Larson 2001).

Appendix B. Sockeye salmon escapement data for Falls Lake.

Appendix B.1. Daily and total weir counts of sockeye salmon entering Falls Lake, 1981–1989.

(Note: the 1986 weir count is incomplete; the weir was installed on August 20, after most of the sockeye salmon had already ascended the stream.)

	Daily Weir Counts								
	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
6/20					0				
6/21					0		0		
6/22			5		0		0		
6/23			1	4	0		0		
6/24			0	0	0		0		0
6/25			2	0	0		0		0
6/26			2	0	0		0		0
6/27			0	6	0		3		0
6/28			0	1	0		0		0
6/29	60		1	0	0		0		2
6/30	24	1	0	1	17		12		1
7/1	13	1	1	1	8		4		11
7/2	2	0	0	2	8		4		4
7/3	11	0	20	0	2		5		1
7/4	3	1	7	0	0		7		0
7/5	9	18	12	0	1		32		2
7/6	3	3	1	8	6		12		0
7/7	0	1	40	14	6		30		0
7/8	0	2	25	16	5		22		3
7/9	0	0	2	18	1		40	13	1
7/10	0	0	1	86	24		22	13	13
7/11	0	0	28	211	12		47	21	14
7/12	2	0	68	407	17		41	15	14
7/13	1	0	41	250	19		30	9	3
7/14	5	1	155	46	20		39	15	0
7/15	21	0	84	71	28		13	55	27
7/16	31	0	47	210	35		13	50	34
7/17	52	2	52	230	191		15	48	38
7/18	31	9	72	191	121		70	53	75
7/19	20	6	88	72	95		149	8	135
7/20	3	1	34	75	167		172	0	41
7/21	16	18	44	55	238		231	59	159
7/22	22	78	15	66	78		236	38	134
7/23	14	106	27	49	131		359	72	122
7/24	19	274	118	219	65		347	126	79
7/25	20	432	84	184	68		258	63	65
7/26	31	92	58	149	47		258	62	57
7/27	32	187	41	101	43		211	34	6
7/28	33	96	79	55	8		156	13	97
7/29	26	90	67	107	51		123	11	76
7/30	19	63	28	147	88		199	14	103
7/31	20	19	39	74	108		190	10	132

-continued-

Appendix B.1. (page 2 of 3)

	Daily Weir Counts								
	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
8/1	33	38	37	57	106		163	51	81
8/2	32	26	30	53	140		185	26	60
8/3	30	14	46	63	99		206	37	60
8/4	21	7	24	29	72		185	57	26
8/5	85	12	18	18	74		246	7	39
8/6	148	8	13	52	47		170	2	33
8/7	51	2	7	37	53		156	4	50
8/8	19	12	5	56	46		94	69	31
8/9	27	5	10	20	60		86	47	20
8/10	31	0	8	12	22		134	8	14
8/11	32	0	25	11	44		168	4	14
8/12	31	0	11	8	19		147		14
8/13	5	7	9	11	5		131		11
8/14	7	0	3	12	42		106		16
8/15	8	18	5	5	25		86		6
8/16	8	2	6	3	22		64		23
8/17	25	2	0	5	15		44		24
8/18	27	9	1	8	8		35		24
8/19	45	0	2	0	5		33		27
8/20	22	1	2	5		71			19
8/21	1	3	1	5		80			14
8/22	7	6	0	0		53			0
8/23	4	4	0	4		62			
8/24	5	3	2	4		30			
8/25	4	2	0	3		26			
8/26	4	3	0	1		14			
8/27	3	2	0	1		8			
8/28	6		0	4		7			
8/29	2		0	1		10			
8/30	0		0	1		8			
8/31	2		0	1		7			
9/1	4		0	1		9			
9/2	1		0	0		10			
9/3	0		0	0		12			
9/4	0		0	0		1			
9/5	2		0	0		5			
9/6	0		1	0		1			
9/7	1		0	0		2			
9/8	0		0	0		10			
9/9	0		0	0		10			
9/10	1		1	0		2			
9/11	0		0	1		2			
9/12	0		0	0		0			
9/13	0		0	0		0			
9/14	0		0	0		0			
9/15	0		0	1		0			
9/16	1		0	0		0			

-continued-

Appendix B.1. (page 3 of 3)

	Daily Weir Counts								
	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
9/17	0		0	0		0			
9/18			0	0		0			
9/19			0	2		0			
9/20			0	0		0			
9/21			0	1		0			
9/22			0	0		1			
9/23			0	0		0			
9/24			0			0			
9/25			0			0			
9/26			0			0			
9/27			0			0			
9/28			0			0			
9/29			0			0			
9/30			0			0			
10/1			0			0			
10/2			0			0			
10/3			0			0			
10/4			0			0			
10/5			0			0			
10/6			0			0			
10/7			0			0			
10/8			0			0			
10/9			0			0			
10/10						0			
10/11						0			
10/12						0			
10/13						0			
total	**1278**	**1687**	**1656**	**3622**	**2612**	**441**	**5789**	**1114**	**2055**

Appendix B.2. a) Sample sizes, b) age, and c) length composition of sockeye salmon sampled in 1982-85 and 1988–1989 at the Falls Lake weir. The overall average ratio of males to females in the Falls Lake sockeye escapement was 1.1.

a) Sample sizes of sockeye salmon from the Falls Lake weir, 1982–1985 and 1988–1989, by age class.

	Sample Sizes by Age Class and Return Year					
Age class	**1982**	**1983**	**1984**	**1985**	**1988**	**1989**
0.2	1	0	0	0	0	0
0.3	1	0	0	0	0	0
1.2	175	142	40	15	192	14
1.3	105	370	125	167	169	638
1.4	0	0	0	0	2	0
2.1	0	0	1	1	0	0
2.2	158	166	61	199	17	180
2.3	89	45	418	387	26	49
2.4	2	0	0	5	0	0
3.1	0	0	0	4	0	0
3.2	0	4	0	66	0	0
3.3	1	0	43	35	0	0
Total	532	727	688	879	406	881

b) Percent age composition of sockeye salmon sampled at Falls Lake weir, 1982–1985 and 1988–1989.

	Percent in Age Class by Return Year							
Age class	**1982**	**1983**	**1984**	**1985**	**1988**	**1989**	**Average**	**SE**
0.2	0.2	0	0	0	0	0	0	0
0.3	0.2	0	0	0	0	0	0	0
1.2	32.9	19.5	5.8	1.7	47.3	1.6	14.1	0.5
1.3	19.7	50.9	18.2	19	41.6	72.4	38.3	0.8
1.4	0	0	0	0	0.5	0	0	0
2.1	0	0	0.1	0.1	0	0	0	0
2.2	29.7	22.8	8.9	22.6	4.2	20.4	19	0.6
2.3	16.7	6.2	60.8	44	6.4	5.6	24.7	0.7
2.4	0.4	0	0	0.6	0	0	0.2	0.1
3.1	0	0	0	0.5	0	0	0.1	0
3.2	0	0.6	0	7.5	0	0	1.7	0.2
3.3	0.2	0	6.3	4	0	0	1.9	0.2

c) Average lengths of sockeye salmon sampled at the Falls Lake weir, 1982–1985 and 1988–1989, by age class.

	Average Length by Age Class and Return Year							
Age	**1982**	**1983**	**1984**	**1985**	**1988**	**1989**	**Average**	**SE**
0.2	510	0	0	0	0	0	510	0
0.3	570	0	0	0	0	0	570	0
1.2	512	493	478	484	496	482	498	1
1.3	572	561	545	550	558	561	559	0.6
1.4	0	0	0	0	558	0	558	8.5
2.1	0	0	383	385	0	0	384	1
2.2	510	498	481	484	510	482	492	0.9
2.3	571	559	549	552	566	556	553	0.7
2.4	602	0	0	559	0	0	571	12.7
3.1	0	0	0	375	0	0	375	20.6
3.2	0	480	0	486	0	0	485	2.5
3.3	580	0	553	543	0	0	549	2.7
Average	533	533	538	529	527	543	535	
SE	23.4 1	9.9	20.6	17.8	6.7 1	8.3	8.4	

Appendix B.3. ADF&G escapement surveys conducted opportunistically at Falls Lake, 1963–2000. These surveys estimated an unknown portion of the escapement in each year. The peak counts are simply the highest count recorded in a given season and do not represent total or peak escapement (ADF&G Alexander Database, 2002).

Year	**Date**	**Peak Sockeye Count**	**Number of Surveys**	**Survey Type**
1963	07/23	5,000	2	AERIAL
1965	08/24	200	1	HELICOPTER
1974	08/29	500	1	AERIAL
1977	07/19	5,000	1	FOOT
1978	09/06	1,000	1	AERIAL
1984	07/22	300	2	AERIAL
1985	07/07	1,000	3	AERIAL
1985	07/14	1,000	3	AERIAL
1986	07/30	3,000	1	AERIAL
1987	07/23	500	2	AERIAL
1988	07/13	1,000	2	AERIAL
1989	07/17	200	1	AERIAL
1990	07/22	100	1	AERIAL
1992	07/30	500	1	AERIAL
1993	07/11	400	2	AERIAL
1997	07/02	1	1	AERIAL
1998	07/14	220	2	FOOT
2000	08/23	100	2	AERIAL

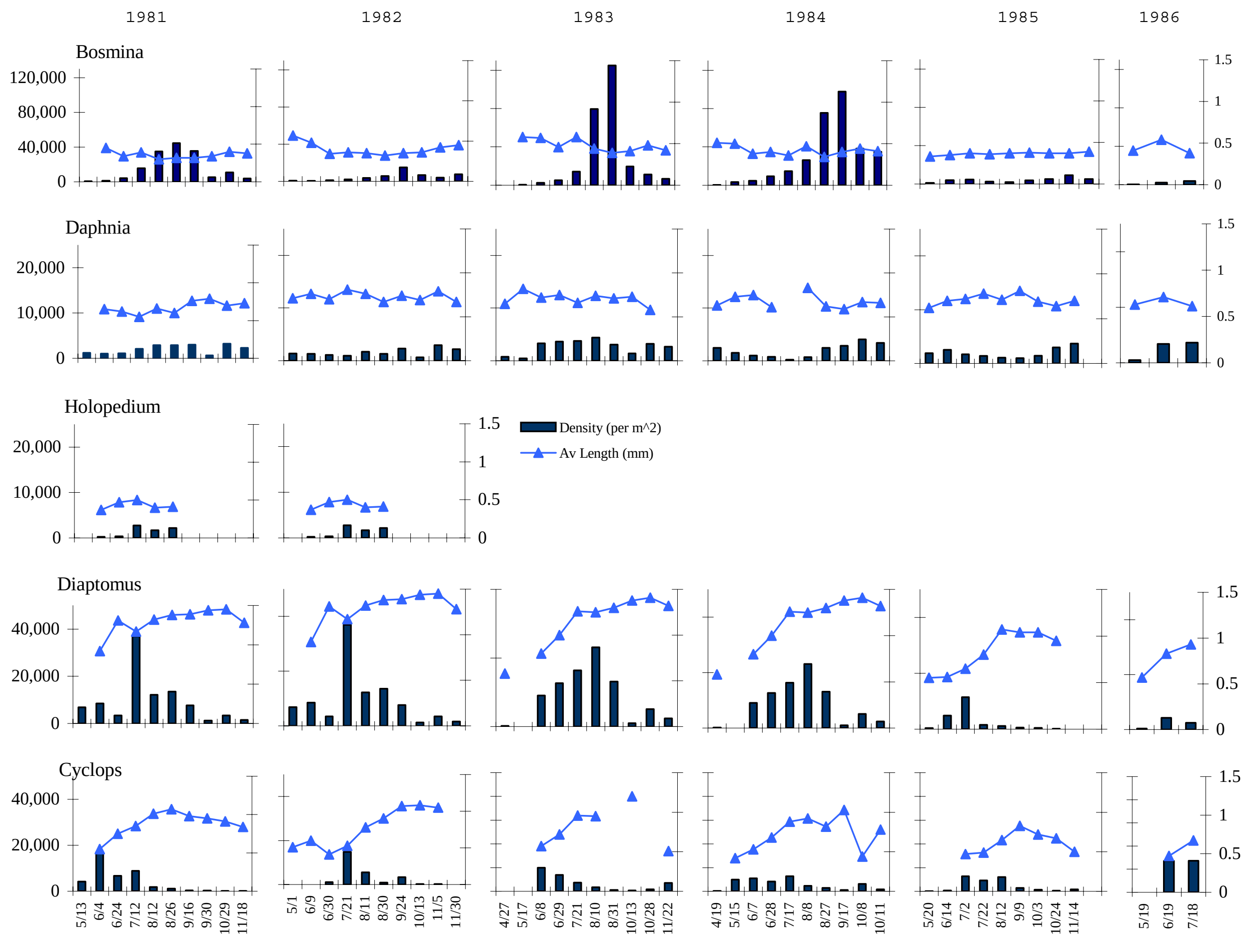
Appendix C. Falls Lake ecology and productivity, 1981–1986.

Appendix C.1. Juvenile sockeye salmon populations estimated using hydroacoustic and tow-net sampling in 1983–1985. Total fish populations were estimated with hydroacoustics, and species apportionments were determined with tow net samples; densities are the estimated number of sockeye fry per m^2 of lake surface area. The estimates are the average of two runs of five transects each.

Year	**Total sockeye fry population (range)**	**Density as sockeye fry · m^{-2} (range)**
1983	32,000 (29,000 – 35,000)	0.041 (.037 - .045)
1984	97,900 (89,600 – 106,000)	0.126 (.115 - .136)
1985	53,700 (45,300 – 62,100)	0.069 (.058 - .080)

Appendix C.2. Sockeye salmon smolt sampled during outmigration from Falls Lake in 1981–1985. Total smolt population estimates were attempted using mark-recapture techniques, but the methods used are no longer considered valid. Age structure of smolt populations from two brood years, 1981 and 1982, could be estimated from these data. In both years, the dominant age-class was age-2, comprising 66% and 76% of smolts, respectively.

Year	**Number caught**	**Number sampled**	**Age class**	**Average wt. (g)**	**Average length (mm)**
1981	725	548	1	2.1	65.9
			2	3.0	75.3
			3	4.5	86.5
1982	13,198	674	1	2.4	67.1
			2	2.8	70.2
			3	3.5	75.7
1983	9,714	631	1	2.6	68.8
			2	3.4	74.6
			3	4.8	83.1
1984	12,690	973	1	3.2	76.1
			2	4.3	83.3
			3	5.9	92.6
1985	16,976	1,207	1	2.7	72.0
			2	3.5	78.6
			3	4.7	86.9
all years	53,303	4,033	1	2.6	70.0
			2	3.4	76.4
			3	4.7	85.0



Appendix C.3. Zooplankton density (number per m^2, left axis) and average lengths (mm, right axis) at Falls Lake, 1981–1986.

Appendix C.4. Summary of fertilizer application at Falls Lake.

Year	Fertilizer formula	Application dates	No. of days	Total volume (gal)	Total weight (tons)
1983	27-7-0	6/9-10/4	117	2,400	13.6
1984	27-7-0	6/12-9/12	92	2,592	14.6
1985	27-7-0	5/15-8/19	96	2,945	16.6

Appendix C.5a. Falls Lake water chemistry seasonal mean values, 1980–1986, sampled at 1 m.

							fertilization years							
Epilimnion (1m)	1980		1981		1982		1983		1984		1985		1986	
Station	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Conductivity (mmhos cm^{-1})	21		17	17	18	18	20	19	21	20	22	20	24	18
pH	6.3		6.3	6.2	6.8	6.8	6.7	6.7	6.2	6.3	6.0	6.3	6.6	6.4
Alkalinity (mg L^{-1} as $CaCO_3$)	6.0		7.8	6.9	7.0	6.8	6.6	6.3	6.4	6.4	5.0	5.0	5.7	6.0
Turbidity (NTU)	NA		NA	NA	NA	NA	NA	NA	3.6	1.6	1.1	1.2	0.4	0.4
Color (PT units)	NA		NA	NA	NA	NA	NA	NA	11.7	13.1	11.1	12.1	5.6	5.7
Calcium (mg L^{-1})	2.6		2.8	2.7	3.6	4.2	3.1	3.1	2.9	2.5	2.2	3.0	NA	NA
Magnesium (mg L^{-1})	0.8		0.3	0.2	0.2	0.4	0.3	0.4	1.0	0.4	0.4	0.2	NA	NA
Iron (µg L^{-1})	30.3		116	102	30.6	56.9	33.2	24	62.5	56.9	38.1	46.4	27.3	28.3
Total Phosphorus (µg L^{-1} as P)	3.1		3.8	3.6	4.9	4.1	8.1	6.9	11.3	8.4	7.8	8.2	4.5	4.0
Total Filterable P (µg L^{-1} as P)	2.6		2.3	2.3	2.2	2.0	6.6	5.2	3.0	3.0	3.0	3.0	4.5	4.3
Filterable Reactive P (µg L^{-1} as P)	1.6		1.2	1.2	1.3	1.4	3.4	2.0	2.4	2.2	1.9	2.0	0.9	0.7
Total Kjeldahl Nitrogen (µg L^{-1} as N)	30.1		39.7	37.5	32.2	24.2	88.2	71.9	98.5	90.1	84.7	90.5	37.9	41.8
Ammonia (µg L^{-1} as N)	12.9		9.9	5.6	28.1	8.9	23.3	8.3	14.0	7.2	3.9	4.9	1.6	2.0
Nitrate + Nitrite (µg L^{-1} as N)	229.9*		18.4	17.8	15.5	12.7	26.7	20.5	19.9	8.3	25	21.5	31.5	15.8
Reactive Silicon (µg L^{-1} as Si)	479		490	542	363	355	426	444	419	430	575	562	574	517
Particulate Carbon (µg L^{-1} as C)	204		272	192	89	124	176	168	75	62	251	222	NA	NA
Total Particulate P (µg L^{-1} as P)	1.5		NA	NA	NA	NA	NA	NA	4.9	4.9	1.5	1.8	NA	NA
Total Particulate N (µg L^{-1} as N)	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N:P (atom ratio)	200:1*		36:1	37:1	23:1	21:1	34:1	32:1	25:1	28:1	34:1	33:1	37:1	34:1
Chlorophyll a (µg L^{-1})	0.90		0.30	0.40	0.40	0.40	1.20	1.10	1.00	0.80	2.50	2.20	0.80	0.50
Phaeophytin a (µg L^{-1})	0.30		0.20	0.40	0.30	0.30	0.70	0.70	1.80	1.90	1.30	1.20	0.10	0.30

NA — indicates not analyzed.
* This high N value is probably erroneous.

Appendix C.5b. Falls Lake water chemistry seasonal mean values, 1980–1986, sampled at 46 m (station 1) and 26 m (station 2).

							fertilization years							
Hypolimnion (46m, 26m)	1980		1981		1982		1983		1984		1985		1986	
Station	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Conductivity (μmhos cm^{-1})	23		16	21	20	19	21	20	22	21	22	23	21	20
pH	6.2		6.1	6.1	6.5	6.5	6.4	6.5	6.3	5.8	6.0	5.9	6.3	6.2
Alkalinity (mg L^{-1} as $CaCO_3$)	4.3		6.3	7.3	7.7	7.4	6.0	5.9	5.3	5.2	4.5	4.8	6.3	6.0
Turbidity (NTU)	NA		NA	NA	NA	NA	NA	NA	1.0	2.6	1.0	1.5	0.3	0.3
Color (PT units)	NA		NA	NA	NA	NA	NA	NA	12.2	12.4	10.9	NA	7.2	8.3
Calcium (mg L^{-1})	2.3		2.5	3.2	3.5	4.1	3.6	3.4	2.8	2.7	2.8	3.0	NA	2.2
Magnesium (mg L^{-1})	0.7		0.2	0.2	0.3	0.4	0.4	0.3	0.3	0.8	0.2	0.6	NA	0.2
Iron (μg L^{-1})	49.3		85.2	79.6	43	33.5	37.1	24	35.8	41.6	41.8	39	36.7	41.5
Total Phosphorus (μg L^{-1} as P)	2.9		4.8	5.5	4.9	4.5	3.2	3.6	3.9	3.7	3.5	3.1	3.0	3.2
Total Filterable P (μg L^{-1} as P)	2.0		2.5	3.3	2.7	2.2	2.8	2.5	2.5	1.8	2.7	2.6	3.3	2.1
Filterable Reactive P (μg L^{-1} as P)	1.2		1.3	2.2	1.8	1.3	1.2	1.1	2.0	1.6	2.0	1.8	0.8	0.5
Total Kjeldahl Nitrogen (μg L^{-1} as N)	38.2		38.7	57.3	24.5	24.1	49.2	52.7	47.5	46.6	52.8	49.7	43.7	42.0
Ammonia (μg L^{-1} as N)	5.5		11.7	9.3	9.5	6.1	11.4	9.2	6.6	7.8	4.0	7.3	1.6	3.1
Nitrate + Nitrite (μg L^{-1} as N)	68.0		40.6	36.6	47.9	43.6	45.8	42.4	28.9	31.2	62.9	56.5	37.4	40.9
Reactive Silicon (μg L^{-1} as Si)	526		510	478	501	478	617	538	596	633	729	696	662	612
Particulate Carbon (μg L^{-1} as C)	326		263	NA	82	48	137	156	54	80.1	110	114	NA	NA
Total Particulate P (μg L^{-1} as P)	2.1		NA	NA	NA	NA	NA	NA	1.8	NA	1.2	1.7	NA	NA
Total Particulate N (μg L^{-1} as N)	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N:P (atom ratio)	87:1		39:1	41:1	35:1	36:1	71:1	63:1	47:1	50:1	79:1	82:1	64:1	62:1
Chlorophyll a (μg L^{-1})	0.50		NA	NA	NA	NA	NA	NA	NA	NA	0.30	0.20	0.64	0.63
Phaeophytin a (μg L^{-1})	0.10		NA	NA	NA	NA	NA	NA	NA	NA	0.30	0.40	0.24	0.27

NA — indicates not analyzed.

Appendix D. Daily and cumulative counts of adult salmon at Falls Lake weir/trap and associated water levels for 2001.

	Sockeye		Coho		Pink		Dolly Varden		
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Water depth (m)
6/12	0	0	0	0	0	0	0	0	
6/13	0	0	0	0	0	0	0	0	
6/14	0	0	0	0	0	0	0	0	
6/15	0	0	0	0	0	0	0	0	
6/16	0	0	0	0	0	0	0	0	
6/17	0	0	0	0	0	0	0	0	0.34
6/18	0	0	0	0	0	0	0	0	0.34
6/19	0	0	0	0	0	0	0	0	0.35
6/20	0	0	0	0	0	0	0	0	0.56
6/21	0	0	0	0	0	0	0	0	0.47
6/22	0	0	0	0	0	0	0	0	0.38
6/23	0	0	0	0	0	0	0	0	0.32
6/24	0	0	0	0	0	0	0	0	0.31
6/25	0	0	0	0	0	0	0	0	0.29
6/26	0	0	0	0	0	0	0	0	0.28
6/27	0	0	0	0	0	0	0	0	0.28
6/28	0	0	0	0	0	0	0	0	0.33
6/29	0	0	0	0	0	0	0	0	0.31
6/30	0	0	0	0	0	0	0	0	0.29
7/1	0	0	0	0	0	0	0	0	0.28
7/2	0	0	0	0	0	0	0	0	0.30
7/3	0	0	0	0	0	0	0	0	0.30
7/4	0	0	0	0	0	0	0	0	0.31
7/5	0	0	0	0	0	0	0	0	0.31
7/6	0	0	0	0	0	0	0	0	0.34
7/7	0	0	0	0	0	0	0	0	0.38
7/8	0	0	0	0	0	0	0	0	0.35
7/9	0	0	0	0	0	0	0	0	0.42
7/10	0	0	0	0	0	0	0	0	0.39
7/11	0	0	0	0	0	0	0	0	0.34
7/12	0	0	0	0	0	0	0	0	0.36
7/13	0	0	0	0	0	0	0	0	0.39
7/14	0	0	0	0	0	0	0	0	0.33
7/15	0	0	0	0	0	0	0	0	0.28
7/16	0	0	0	0	0	0	0	0	0.27
7/17	0	0	0	0	0	0	0	0	0.26
7/18	0	0	0	0	0	0	0	0	0.26
7/19	0	0	0	0	0	0	0	0	0.26
7/20	0	0	0	0	0	0	0	0	0.28
7/21	0	0	0	0	0	0	0	0	0.30
7/22	46	46	0	0	0	0	1	1	0.33
7/23	42	88	0	0	0	0	2	3	0.31
7/24	22	110	0	0	0	0	0	3	0.28
7/25	85	195	0	0	0	0	0	3	0.28

-continued-

	Sockeye		Coho		Pink		Dolly Varden		
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Water depth (m)
7/26	71	266	0	0	0	0	6	3	0.26
7/27	80	346	0	0	0	0	0	3	0.26
7/28	48	394	0	0	0	0	0	3	0.24
7/29	342	736	0	0	0	0	1	10	0.24
7/30	169	905	0	0	0	0	0	10	0.23
7/31	198	1103	0	0	0	0	0	10	0.23
8/1	78	1181	1	1	0	0	0	10	0.33
8/2	115	1296	1	2	0	0	0	10	0.32
8/3	202	1498	1	3	0	0	0	10	0.29
8/4	146	1644	0	3	0	0	0	10	0.28
8/5	157	1801	0	3	0	0	0	10	0.25
8/6	93	1894	1	4	0	0	0	10	0.22
8/7	91	1985	1	5	0	0	2	12	0.22
8/8	89	2074	0	5	0	0	0	12	0.22
8/9	56	2130	0	5	0	0	0	12	0.22
8/10	103	2233	0	5	1	1	1	13	0.21
8/11	42	2275	0	5	1	2	0	13	0.21
8/12	71	2346	0	5	0	2	0	13	0.21
8/13	56	2402	0	5	0	2	0	13	0.20
8/14	48	2450	4	9	1	3	0	13	0.20
8/15	32	2482	4	13	1	4	0	13	0.22
8/16	22	2504	4	17	0	4	0	13	0.21
8/17	18	2522	8	25	0	4	0	13	0.22
8/18	8	2530	7	32	2	6	0	13	0.20
8/19	6	2536	1	33	2	8	0	13	0.20
8/20	8	2544	5	38	5	13	0	13	0.22
8/21	0	2544	0	38	0	13	0	13	0.98
8/22	3	2547	15	53	3	16	0	13	0.43
8/23	4	2551	8	61	5	21	0	13	0.36
8/24	0	2551	4	65	0	21	0	13	0.33
8/25	6	2557	13	78	2	23	0	13	0.46
8/26	4	2561	2	80	0	23	0	13	0.46
8/27	0	2561	0	80	0	23	0	13	0.70
8/28	2	2563	3	83	0	23	0	13	0.43
8/29	3	2566	7	90	0	23	0	13	0.31
8/30	1	2567	6	96	0	23	0	13	0.36
8/31	1	2568	10	106	0	23	0	13	0.31
9/1	0	2568	0	106	0	23	0	13	0.71
9/2	0	2568	0	106	0	23	0	13	0.69
9/3	0	2568	0	106	0	23	0	13	0.58
9/4	0	2568	1	107	0	23	0	13	0.34
9/5	2	2570	2	109	0	23	0	13	0.31
9/6	0	2570	1	110	0	23	0	13	0.38
9/7	0	2570	6	116	0	23	0	13	0.31
9/8	0	2570	4	120	0	23	0	13	0.33
9/9	0	2570	3	123	0	23	0	13	0.27

-continued-

Appendix D. (page 3 of 3)

	Sockeye		Coho		Pink		Dolly Varden		
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Water depth (m)
9/10	0	2570	5	128	0	23	0	13	0.22
9/11	0	2570	0	128	0	23	0	13	0.18
9/12	0	2570	0	128	0	23	0	13	0.22
9/13	0	2570	0	128	0	23	0	13	0.62
9/14	0	2570	0	128	0	23	0	13	0.44
9/15	0	2570	0	128	0	23	0	13	0.33
9/16	0	2570	0	128	0	23	0	13	0.35
9/17	0	2570	0	128	0	23	0	13	0.30
9/18	0	2570	0	128	0	23	0	13	0.39
9/19	0	2570	0	128	0	23	0	13	0.45
9/20	0	2570	3	131	0	23	0	13	0.33
9/21	0	2570	0	131	0	23	0	13	0.50
9/22	0	2570	0	131	0	23	0	13	0.49
9/23	0	2570	0	131	0	23	0	13	0.35
9/24	0	2570	0	131	0	23	0	13	0.36
9/25	0	2570	0	131	0	23	0	13	0.82
9/26	0	2570	0	131	0	23	0	13	0.46
9/27	0	2570	0	131	0	23	0	13	0.52
9/28	0	2570	0	131	0	23	0	13	0.51
9/29	0	2570	0	131	0	23	0	13	0.68
9/30	0	2570	0	131	0	23	0	13	0.55
10/1	0	2570	0	131	0	23	0	13	0.44
10/2	0	2570	0	131	0	23	0	13	0.39
10/3	0	2570	0	131	0	23	0	13	0.31
10/4	0	2570	0	131	0	23	0	13	0.23

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfield Drive, Suite 300, Arlington, VA 22203; or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-4120, (TDD) 907-465-3646, or (FAX) 907-465-2440.