LIMNOLOGICAL AND FISHERIES INVESTIGATIONS AT

HUGH SMITH LAKE, SOUTHEAST ALASKA

1998

by
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and
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The Hugh Smith Lake sockeye salmon *Oncorhynchus nerka* fry stocking program was initiated in 1985 to help rehabilitate the depressed population. Fry stocking occurred every year that escapement goals were not met except for 1998 due to a planned hatchery move. Zooplankton production and euphotic volume in 1998 was capable of sustaining sockeye densities far above the population observed in 1998 based on the ZB-EZD model. The fall rearing sockeye salmon fry population was estimated to be 216,387 fish on 3 September 1998. The commercial harvest of Hugh Smith Lake sockeye salmon in 1998 was estimated to be 3,384 with an exvessel value of $29,827 in southern Southeast Alaska. The escapement was 1,138 sockeye salmon in 1998, and the total adult return was estimated to be 4,522 sockeye salmon. The Canadian harvest proportion of Hugh Smith Lake sockeye salmon was unknown. The marine survival of the adult sockeye salmon returning in 1998 was less than 5%. This poor marine survival was also observed at other Southeast sockeye systems where evaluation programs occurred and can be attributed to one smolt year failure in the marine environment. This age-3 ocean group normally comprises over 70% of the adult return for any given brood year. Based on 12% marine survival, the total adult return in 1999 is projected to be 27,162 sockeye salmon.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, Hugh Smith Lake, Southeast Alaska, limnology, zooplankton, escapement, survival, rearing, hydroacoustics, mid-water trawl, coded wire tag, commercial harvest, escapement, brood stock

INTRODUCTION

Sockeye salmon *Oncorhynchus nerka* stocks in the southern boundary area of Alaska are very important to commercial, sport, and subsistence fisheries in Southeast Alaska and Canada. Hugh Smith Lake, located in Boca de Quadra, was historically an important producer of sockeye salmon *Oncorhynchus nerka* in southern Southeast Alaska (Rich and Ball 1933, Roppel 1982). That stock has been depressed since the turn of the century when Moser (1898) suggested that despite overfishing, the lake should produce 50,000 fish on an average year. In recent times the Alaska Department of Fish and Game operated a weir at Hugh Smith Lake from 1967 to 1971, and from 1980 to the present. The current escapement goal at Hugh Smith Lake, based on a production model, is 15,835 spawners (Zadina, et al. 1995). This escapement goal has only been met five times since 1980. Studies to assist in keeping the sockeye salmon population and lake productivity above severely depressed levels have been ongoing since the early 1980s. Enhancement and rehabilitation efforts to boost productivity and prevent further population declines have been incorporated in the form of lake fertilization and planting of sockeye fry. In years when the escapement goal was not met a lake stocking program was activated, where gametes were taken by the Southern Southeast Regional Aquaculture Association and incubated at their Central Incubation Facility. The fish were then planted back to Hugh Smith Lake as emergent fry, fed fry, or pre-smolt to boost the survival of this population. This lake stocking program should remain in operation during years where escapement goals are not met.

This report incorporates the results of studies undertaken at Hugh Smith Lake during the 1998 field season. These studies included: (1) recovery and analysis of coded wire tag data to determine the commercial harvest contribution, exploitation rate, and total adult return of Hugh Smith Lake sockeye salmon, (2) recovery of thermal marked otoliths from sockeye salmon smolt to determine the proportion of hatchery-reared fish, (3) assessment of the secondary production in the lake through limnological sampling, (4) estimation of the rearing sockeye salmon fry population through hydroacoustic sampling, (5) determination of the individual brood year components of the total adult return through scale aging studies, and (6) forecast the total adult returns for 1999 and 2000.

STUDY SITE

Hugh Smith Lake (55°06’01” N., 130°42’21” W.) is located 97 km southeast of Ketchikan in Southeast Alaska (Figure 1). The lake is organically stained with a surface area of 319.7 ha, mean depth of 70.0 m, maximum depth of 121 m, and volume of $222.7 \cdot 10^6$ m^3 (Figure 2). The lake empties into Boca de Quadra inlet via Sockeye Creek (50 m).

PROJECT SPONSORSHIP

Funding to evaluate the limnological and lake stocking assessment program was provided by the Southern Southeast Regional Aquaculture Association through the Alaska Department of Fish and Game. This is the final report fulfilling contract obligations for Cooperative Agreement 99-005. Funding to evaluate the adult sockeye weir and harvest assessment program was provided by the U.S. / Canada Pacific Salmon Treaty through the Alaska Department of Fish and Game, Cooperative Agreement NA87FPO356.

METHODS

Limnological Assessment

Limnological sampling was conducted at two stations on Hugh Smith Lake on 25 May, 29 June, 7 August, and 11 September, to determine the euphotic zone depth and to collect zooplankton data.

Light Regime

Measurements of underwater light penetration (footcandles) were recorded at 0.5 m intervals, from the surface to a depth equivalent to one percent of the subsurface light reading, using a Protomatic[1] submarine photometer. Vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (ln of percent subsurface light) versus depth. The euphotic zone depth (EZD), the depth to which 1% of the subsurface light [photosynthetically available radiation (400-700nm)] penetrates the lake surface (Schindler 1971), was calculated from the equation: $EZD = 4.6205/ K_d$ (Kirk 1994). Euphotic volume (EV) is the product of the EZD and lake surface area and represents the volume of water capable of photosynthesis.

Secondary Production

Zooplankton samples were collected using a 0.5 m diameter, 153 μm mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a depth of 50 m to the surface at a constant speed of $0.5 \text{ m} \cdot \text{sec}^{-1}$. 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 pipet and placed in a 1 ml Sedgewick-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. Macro-zooplankters were further separated by sexual maturity where ovigorous (egg bearing) zooplankters were also identified.

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[1] Mention of trade names does not constitute endorsement by Alaska Department of Fish and Game.

Juvenile Sockeye Salmon Assessment

Rearing Fry Population

The distribution and abundance of rearing sockeye salmon fry was estimated by hydroacoustic and mid-water trawl sampling conducted in the fall. Hugh Smith Lake was divided into five sampling areas based on surface area. Sample design consisted of a series of ten stratified, randomly chosen orthogonal transects across the lake, two from each sampling area. Transect sampling was conducted during post-sunset darkness in one night. A constant boat speed of about 2.0 m · sec^{-1} was attempted for all transects. A Biosonics DT-4000™ scientific echosounder (420 kHz, 6° single beam transducer) with Biosonics Visual Acquisition © version 2.3.0 software was used to collect data. Ping rate was set at 5 pings · sec^{-1} and pulse width at 0.4 ms. Data was analyzed using Biosonics Visual Analyzer © version 2.1.1 software after returning to the office. Samples collected from mid-water trawls were used to estimate fish species and age composition. A 2 m × 2 m tapered trawl net was used for sampling. Trawl depths and duration were determined by fish densities and distributions throughout the lake based on observations during the hydroacoustic survey. Captured fish were euthanized in MS-222 prior to preservation in 70% ethanol. Samples were analyzed after a minimum of two weeks in preservative. Prior to measuring, the fish were soaked in freshwater for 30 minutes. The samples were blotted dry, measured to the nearest millimeter and weighed to the nearest 0.1 g. In addition, a preferred area scale smear (Clutter and Whitesel, 1956) was taken from each fish, affixed to a 2.5 cm × 7.5 cm glass slide, and aged using a television/video linked microscope.

Lake Rearing Model

This report uses a new model (ZB-EZD) that attempts to combine zooplankton biomass and euphotic zone depth; (Stan Carlson, ADF&G Commercial Fisheries, Soldotna, personal communication):

$$SB = 1.95(ZB) + 15.5(EZD) - 183.0, R^2 = 0.94$$

Where:
SB = Total smolt biomass ($kg \cdot km^{-2}$)
ZB = zooplankton biomass ($mg \cdot m^{-2}$)
EZD = Euphotic zone depth (m)
Optimum smolt production individual fish weight is 4.0 g
Maximum smolt production individual fish weight is 2.4 g
Survival rate from spring fry to smolt is estimated at 20%
Survival rate from fall rearing fry to smolt is estimated at 70%

Smolt Evaluation

A smolt weir has been operated at Hugh Smith Lake since 1980. The methods for enumeration of smolts and collection of age-weight-length data were described by Peltz and Haddix (1989). In 1998, the ADF&G, Commercial Fisheries coho research staff operated the smolt fence. Sockeye salmon smolts were enumerated, but not coded wire tagged in 1998.

Thermal otolith marking was used on all sockeye planted in 1996 to evaluate any potential survival differences and proportion of wild versus enhanced fish for this brood year. In 1998 smolts were randomly collected over the course of the season, in proportion to the run, and preserved in 90% ethanol. Otoliths were extracted and examined for the presence of thermal marks at the ADF&G Coded Wire Tag and Otolith Processing Laboratory, Juneau, using the half section technique (R. Berning, personal communication). This year's analysis, in conjunction with the 1997 data, will provide insight about survival differences between hatchery and wild fish in the freshwater rearing phase.

Adult Sockeye Salmon Assessment

Harvest Contribution

The commercial harvest contribution was estimated from coded-wire tag returns. Hugh Smith Lake sockeye salmon smolts tagged in 1994, 1995, and 1996 were expected to return in 1998 as ocean age-2, 3, and 4 adults. Coded wire tagged fish were recovered from the Alaska commercial salmon fisheries by the ADF&G Port Sampling Program as described by Oliver (1990). Tags were decoded at the ADF&G Coded Wire Tag and Otolith Processing Laboratory in Juneau. Equations for estimating the number of tags harvested by designated fishery strata are detailed in Clark and Bernard (1987). The calculations of fishery contribution and exploitation rate of Hugh Smith Lake sockeye salmon follow Shaul (1994).

Escapement Sampling

Biological sampling of adult sockeye salmon was conducted at the weir, located at the outlet of Hugh Smith Lake on Sockeye Creek. Sampling included enumeration of coded wire tagged fish, length measurements, and scale collection. All adipose clipped salmon were tested with a Northwest Marine Technology field detector wand for the presence of a coded wire tag. If a tag was not detected the head was removed at the weir for further examination at the ADF&G CWT lab. If a tag was detected, a scale sample and length measurement were taken and the fish was released upstream. In addition, two tagged fish per ten-day period were taken to verify the scale age by comparison with the tag code. These tagged fish scale samples were used to estimate age composition of the tagged fish in the escapement.

A two-sample mark-recapture program was used to test the integrity of the weir and to estimate the total escapement given the possibility that fish may have passed into the lake before the weir was in place. Two of every three sockeye salmon passed through the weir were marked with a fin-clip. Marking was stratified through time: (1) A right ventral fin clip from 16 June to 18 July, (2) a left ventral fin clip from 19 July to 15 August, and (3) a partial posterior dorsal fin clip from 16 August to the end of the run. Surveys were conducted at Buschmann and Cobb Creeks, every two days, to recover marked fish from the spawners. Carcasses were examined, and live fish were captured using dip nets and examined for marks. All fish that were sampled in the spawning streams were marked with a single left operculum punch and released to avoid duplicate sampling. Stratified Population Analysis System (SPAS) software (Arnason et al. 1996) was used to analyze mark-recapture data and to generate an estimate of the spawning population of sockeye salmon. This program was used to analyze two-sample mark-recapture data in a stratified population, and computes, among other things, Darroch and pooled Petersen estimators, and tests for goodness-of-fit and the validity of pooling (as described by Seber 1982). If the mark-recapture estimate was greater than 105% of the weir count the mark-recapture estimate was adopted as the final escapement estimate. The sum of the escapement and the estimated commercial harvest equals the total adult return.

The age composition for brood year analysis was determined from a random set of scale samples collected at the weir over the course of the season, weighted by the total count for each statistical week, and expanded to the total adult return. All scale analysis was conducted at the ADF&G, Commercial Fisheries Aging Lab in Douglas, Alaska.

Projected Returns and Marine Survival

Projected adult returns at Hugh Smith Lake are calculated based on two methods 1) actual smolt population and age structure and 2) hydroacoustic population estimate of rearing fall fry which produces an estimated smolt population. Standard survival and age at adult return assumptions derived from previous data at Hugh Smith and McDonald Lakes are presented in Table 1 (Zadina and Haddix, 1989). From these assumptions a matrix is produced which uses multiple brood years to produce estimated adult returns. When the actual adult population for each brood return and age composition are obtained they are entered into the matrix. The actual marine survival is calculated based on the corresponding juvenile estimate and adult return estimates.

RESULTS

Limnological Assessment

Light Regime

The euphotic zone depth (EZD) had an annual mean of 5.10 m. The mean EZD for 1990-1997 was 4.66 m. Euphotic volume (EV) in 1998 was estimated at $16.30 \cdot 10^6$ m^{-3} or 16.3 EV units. This volume capable of photosynthesis composed about 7.8% of the total lake volume.

Secondary Production

The macro-zooplankton community in Hugh Smith Lake in 1998 comprised one species of copepod (*Cyclops* sp.), and five species of cladocerans (*Bosmina longirostris*, *Daphnia longiremus*, *Daphnia rosea, Holopedium gibberum,* and *Polyphemus* sp.). The dominant form by biomass and density was *Cyclops* sp. The seasonal mean total macrozooplankton population was 319,833 plankters $\cdot$ m^{-2} and the seasonal mean macrozooplankton biomass was 543 mg $\cdot$ m^{-2} in 1998 (Table 2).

Juvenile Sockeye Salmon Assessment

Lake Stocking

No sockeye salmon were planted at Hugh Smith Lake in 1998.

Smolt Evaluation

A total of 64,667 sockeye salmon were enumerated at the smolt weir from 21 April to 1 June 1998. Weir mortalities totaled 449 of which 417 smolts were collected for otolith analysis. A total of 64,218 live fish were released downstream. Age-weight and length data were collected from 1,062 smolts (Table 3). The sockeye salmon smolt population was composed of 53.2% wild and 46.8% thermal marked fish. From the total population, 2.9% were age-2 thermal marked from brood year 1995 and 43.9% were age-1 thermal marked from brood year 1996.

Rearing Fry Population

A total lake population of 216,387 sockeye salmon fry was estimated from the hydroacoustic survey conducted on 3 September 1998. The optimum fall fry production at Hugh Smith Lake, based on the ZB-EZD model, was approximately 1,078,000 sockeye salmon fry in 1998.

Adult Sockeye Salmon Assessment

Escapement

The adult weir at Hugh Smith Lake was operated from 16 June to 11 November 1998. The total salmon enumerated in 1998 by species were 1,138 sockeye, 1,129 coho, 5,875 pink, and 145 chum (Table 4). A total of 745 sockeye salmon were released at the weir with a fin-clip for the mark-recapture population estimate. Escapement surveys conducted at Buschmann and Cobb Creeks through the spawning season recorded 69 unmarked fish and 157 marked fish out of a total sample of 226 fish (Appendix Table 1). This data generated a pooled-Petersen mark-recapture population estimate of 1,071 sockeye salmon (s.e.= 42; 95% normal C.I. = 989 to 1,152; Appendix). The 1,138 weir count was within the 989 to 1,152, 95% confidence interval generated by the mark-recapture estimate. The mark-recapture estimate of 1,071 did not exceed 105% of the weir count, thus the weir was judged to have been intact and no significant numbers of adult sockeye salmon entered Hugh Smith Lake in early June prior to the weir installation. The age composition of the escapement was determined from 139 random scale samples (Table 5). A total of 218 adult sockeye salmon (313,000 eggs) were taken by SSRAA from Hugh Smith Lake for a brood source to plant fry back into Hugh Smith Lake in 1999. The wild spawning population of sockeye salmon in 1998 was 920 fish.

A total of 320 coded wire tagged adults were enumerated at the weir from 1,134 examined. Expansion factor for the commercial catch was 3.54 per tag harvested.

Harvest Contribution

A total of 211 coded wire tagged Hugh Smith Lake sockeye salmon were recovered from Alaska commercial fisheries in 1998. Coded wire tags were recovered from three ADF&G commercial fishing districts, and from Annette Island (MIC). The total estimated harvest was 3,384 fish. The primary harvest areas were the District 101 drift gillnet and purse seine areas (Table 6, Figure 3). The 1998 commercial exvessel value was estimated at $29,827. Hugh Smith Lake sockeye salmon were harvested in the commercial fisheries from statistical weeks 26 to 37 (Figure 4). No subsistence harvest of Hugh Smith Lake sockeye salmon was reported in 1998.

Total Adult Return

The total adult return to Hugh Smith Lake in 1998 was estimated at 4,522 sockeye salmon. That total does not include an unknown Canadian harvest. The exploitation rate in 1998 was thus a minimum of 74.8%. Marine survival was estimated at 2.1% for the entire return based on actual smolt estimates and 1.3% based on projected smolt estimates (Appendix Tables 2 and 3).

Projected Adult Returns

The projected total adult return of Hugh Smith Lake sockeye salmon is estimated at 27,162 fish in 1999 and 23,720 fish in 2000 (Table 7). This includes all age classes and combined hatchery reared and wild components based on a conservative 12% marine survival.

DISCUSSION

Zooplankton Abundance and Distribution

Zooplankton biomass and densities at Hugh Smith Lake in 1998 were similar to the 16-year mean (Figures 5 and 6). Zooplankton productivity has remained fairly constant since 1992. Macrozooplankton distribution by Order has also remained fairly constant, with copepods being dominant (Figures 7 and 8). The secondary production indicates an abundant food supply. The estimated pre-smolt sockeye salmon population of 151,470, based on fall hydroacoustics, was still below the optimum level of 755,000, 4.0 g smolt that the ZB-EZD model predicts. Regardless of the number of fry and pre-smolt planted, the zooplankton standing crop has not varied much on an annual basis. This demonstrates that the lake stocking program, at current levels, has not taxed the zooplankton standing crop and the optimum fry rearing capacity has not yet been reached. Stocking levels could be increased dramatically if escapement levels increased.

Other models have been developed to estimate sockeye smolt production but are not used in this report. These models have limitations that are described in further detail. A euphotic volume (EV) model by Koenings and Burkett (1987) predicts the total smolt biomass (kg), based on the surface area and euphotic depth of a lake. This model only uses physical data derived from a particular lake and does not incorporate any biological information critical to a particular lake. For instance, a clear water system would appear to have higher productive capabilities over an organically stained system because of deeper light penetration. Another model was based on zooplankton biomass (ZB) and relates zooplankton standing crop to biomass ($kg \cdot km^2$) of sockeye salmon smolt (SB) produced annually in a non-fertilized, natural system (Koenings and Kyle 1997). The measurable standing crop of zooplankton represents the zooplankton biomass remaining after consumption by rearing sockeye juveniles. The unknown portion of the zooplankton production that was consumed, was assumed to be proportional to the standing crop. Application of this model usually assumed the nursery lake will produce a maximum number of threshold size (about 63 mm and 2.0g) smolt at approximately twice the zooplankton standing crop (unless some information about smolt size is known). The ZB model was based on lakes considered to be at or near carrying capacity, thus it would be hard to predict how the model would perform for lakes under or over carrying capacity (Stan Carlson, ADF&G Commercial Fisheries, Soldotna, personal communication).

Sockeye Salmon Production

Since 1996, the Hugh Smith Lake smolt weir has been operated primarily for the coho salmon coded wire tagging project. The smolt weir was operated during the peak period of coho salmon smolt migration. The project does not enumerate all sockeye salmon smolt, nor does it attempt to do so. Sockeye salmon smolt were sampled for scales and otoliths to estimate the age composition and enhanced versus wild proportions of the sockeye salmon smolt population. The smolt operations have attempted to tag 100% of all coho and sockeye salmon smolt captured annually. However, based on CWT adult coho return information the actual marked fraction was closer to 25% (Shaul 1994). The 1998 adult sockeye returns were 28% coded wire tagged. Normally this tag rate at return has been less than 10% annually. The smolt years (1995 and 1996) associated with the 1998 returns were coded wire tagged at a rate of 91% and 82%, respectively. This incomplete smolt capture and enumeration indicates that the fall hydroacoustic population estimate of sockeye salmon fry was a more appropriate method for forecasting adult returns.

Analysis of the thermal marked otolith information demonstrated that the hatchery component survived at a slightly higher rate than the wild fish for brood year 1995. The 1996 hatchery component of fall fry (including the pre-smolt release) comprised approximately 72% of the total rearing population. The age-1 (1997) hatchery component comprised 89% of the age-1 smolt and the age-2 (1998) hatchery component comprised 16% of the age-2 smolt. The combined hatchery component for brood year 1995 smolt was 77%. This increase in proportion of hatchery fish was probably due a higher survival rate of the pre-smolt group because of their large size (9.5 g) at release. After these adults return from 1999 to 2001 the marine survival can be evaluated for any differences. This thermal mark program demonstrated that survival rate comparisons between hatchery and wild fish can be used in evaluating hatchery programs where both wild and hatchery fish coexist.

The 1998 escapement of 1,138 fish was the lowest since the program started in the late 1970s. The total adult return of 4,522 fish was well below the conservative forecast of 25,000-40,000 fish that were predicted to return in 1998. This was attributed to a survival failure in the marine environment for smolt year 1995. The low survival was also found in other systems in southern Southeast in 1998 including McDonald and Salmon (Karta) Lakes which indicated the problem was probably not associated with the freshwater environment. The lake stocking program was invoked again in 1998 because of the poor escapement. Approximately 20% of the spawning females were used for gametes. This hatchery component should produce about 80% of the rearing sockeye salmon fry in 1999.

RECOMMENDATIONS

Without efforts to increase sockeye productivity during weak returns to Hugh Smith Lake the sockeye salmon population will continue to decline. The use of pre-smolt releases of hatchery incubated fish is strongly recommended during years of extremely weak escapement like that observed in 1998. If the incubation facility is not capable of rearing these fish within the confines of the hatchery then we suggest the use of pen rearing at Hugh Smith Lake as another alternative. Without continued evaluation of both the limnological and fisheries programs, the ability to keep Hugh Smith Lake functioning as a viable sockeye population will diminish drastically.

LITERATURE CITED

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of marking data from stratified populations for estimation of salmonid escapements and the size of other populations. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2106.

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

Clark, J. E. and D. R. Bernard. 1987. A compound multivariate binomial-hypergeometric distribution describing coded microwire tag recovery from commercial salmon catches in Southeastern Alaska. Alaska Department of Fish & Game, Division of Commercial Fisheries, Technical Data Report 202, Juneau.

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.

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

Koenings, J. P., J. A. Edmundson, G. B. Kyle, and J.M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, FRED Division Report Series 71: 221 p.

Koenings, J.P. and R. D. Burkett. 1987. Population characteristics of sockeye salmon (*Oncorhynchus nerka*) smolts relative to temperature regimes, euphotic volume, fry density and forage base within Alaska lakes, p. 216-234. *In*: H. S. Smith, L. Margolis, and C.C. Wood [ed.]. Sockeye Salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Koenings, J. P. and G. B. Kyle. 1997. Consequences to juvenile sockeye salmon and the zooplankton community resulting from intense predation. Alaska Fishery Research Bulletin. 4(2).

Moser, J. F. 1898. The salmon and salmon fisheries of Alaska: Report of the operations of the United States Fish Commission Steamer Albatross for the year ending June 30, 1898. Bulletin of the U.S. Fish Commission, Annual Report.

Oliver, G. T. 1990. Southeast Alaska port sampling project. Annual report for the period July 1, 1989 to June 30, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries Regional Information Report 1J90-34.

Peltz, L. and M. Haddix. 1989. Coded-wire tagging of wild sockeye salmon smolt at Hugh Smith Lake, Alaska. Alaska Department of Fish and Game, FRED Division Report Series. 91.

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. U. S. Department of Commerce, Bulletin of the Bureau of Fisheries, Volume XLVII, Bulletin No. 13, Washington, D. C.

Roppel, P. 1982. Alaska's salmon hatcheries, 1891-1959. National Marine Fisheries Service, Alaska Historical Comm. Studies in History No. 20.

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.

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

Shaul, L. D. 1994. A summary of 1982-1991 harvests, escapements, migratory patterns, and marine survival rates of coho salmon stocks in Southeast Alaska. Alaska Fishery Research Bulletin 1(1).

LITERATURE CITED (Continued)

Wilson, M. S. 1959. Calanoida. p. 738-794. In: W. T. Edmondson [ed.], Freshwater biology, 2nd. ed., John Wiley and Sons, New York.

Yeatmann, H. C. 1959. Cyclopoida. p. 795-815. In: W. T. Edmondson [ed.], Freshwater biology, 2nd. ed., John Wiley and Sons, New York.

Zadina, T., and M. Haddix. 1989. Fry stocking program evaluation in Southeast Alaska. *In:* Proceedings of the 1989 Alaska Sockeye Culture Workshop, Soldotna, Alaska. *Edited by*: T. Ellis. Alaska Dept. Fish and Game, Juneau, Alaska.

Zadina, T. P., M.H. Haddix, and M. A. Cartwright. 1995. Production potential of sockeye salmon nursery lakes in southern Southeast Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries Regional Information Report. 5J95-03.

Table 1. Age distribution assumptions of adult sockeye salmon returning to Hugh Smith Lake by brood year and return year.

	Based on Projected Smolt Population from Fall Hydroacoustic Estimate				Based on Smolt Weir Enumeration			
Brood Year	Smolt Years	Projected Adult Age Distribution of Unknown Age Smolt	Adult age class	Return Year	Smolt Years	Projected Adult Age Distribution of Known Age Smolt	Adult age class	Return Year
1992	1994 or 1995	10.5%	1.2	1996	1994	16.0%	1.2	1996
		65.1%	1.3	1997	1994	84.0%	1.3	1997
		5.5%	2.2	1997	1995	25.0%	2.2	1997
		18.0%	2.3	1998	1995	75.0%	2.3	1998
1993	1995 or 1996	10.5%	1.2	1997	1995	16.0%	1.2	1997
		65.1%	1.3	1998	1995	84.0%	1.3	1998
		5.5%	2.2	1998	1996	25.0%	2.2	1998
		18.0%	2.3	1999	1996	75.0%	2.3	1999

Table 2. Seasonal mean macrozooplankton density and biomass distribution in Hugh Smith Lake, 1998.

	Density		Biomass	
Species	No./m^2	Percent	mg/ m^2	Percent
Cyclops	201,329	62.9%	244	44.9%
Cyclops – ovig.	2,229	0.7%	6	1.1%
Bosmina	71,319	22.3%	111	20.4%
Bosmina – ovig.	488	0.2%	1	0.2%
Daphnia l.	11,823	3.7%	34	6.3%
Daphnia l. – ovig.	552	0.2%	3	0.5%
Daphnia r.	4,914	1.5%	12	2.1%
Daphnia r. – ovig	85	0.0%	1	0.1%
Holopedium	26,501	8.3%	130	23.9%
Holopedium – ovig.	212	0.1%	2	0.3%
Polyphemus	382	0.1%	0	0.0%
Total	319,833		543	

Table 3. Mean length and weight by age class, and number of wild and hatchery reared (thermal marked) Hugh Smith Lake sockeye salmon smolt, 1998.

	Smolt Weir Data				Total	BY95	BY96	
Age	Length (mm)	Weight (g)	Weighted Percent	Enumerated Smolt	Estimated Smolt	Thermal Marked	Thermal Marked	Wild Fish
1	74.5	3.67	80.7%	51,814	127,347		69,240	58,107
2	103.2	9.44	18.2%	11,704	28,720	4,569		24,151
3	125.0	18.55	1.1%	701	1,736			1,736
Total				64,218	157,803	4,569	69,240	83,994

Table 4. Adult salmon weir count by species and month at Hugh Smith Lake, 1998.

	Month						
Species	Jun	Jul	Aug	Sep	Oct	Nov	Total
Sockeye	95	482	540	16	5	-	1,138
Percent	8.3%	42.4%	47.5%	1.4%	0.4%	0.0%	
Coho	-	1	101	455	372	200	1,129
Percent	0.0%	0.1%	8.9%	40.3%	32.9%	17.7%	
Pink	-		5,106	764	5	-	5,875
Percent	0.0%	0.0%	86.9%	13.0%	0.1%	0.0%	
Chum	-	-	47	81	17	-	145
Percent	0.0%	0.0%	32.4%	55.9%	11.7%	0.0%	

Table 5. Age composition of the adult sockeye salmon escapement, weighted by statistical week, at Hugh Smith Lake, expanded to the total adult return, 1998.

Brood Year	Age	Sample Size	Weighted Percent	Expanded Escapement	Expanded Adult Return
1995	1.1	2	2.6	29	116
1994	1.2	10	7.5	86	340
1994	2.1	3	0.7	9	34
1993	1.3	78	45.6	519	2,061
1993	2.2	7	4.5	51	203
1992	1.4	5	6.2	70	279
1992	2.3	34	32.9	375	1,489
	Total	139		1,138	4,522

Table 6. Distribution and value of the commercial harvest of Hugh Smith Lake sockeye salmon, 1998.

District and Gear	Tags[a]	Sockeye	%	Exvessel Value
101 Gillnet	159	2,211	65.3%	$ 20,014
106 Gillnet	5	48	1.4%	$ 458
MIC Gillnet	13	140	4.1%	$ 1,267
Total Gillnet	177	2,399	70.9%	$ 21,739
101 Seine	22	786	23.2%	$ 6,454
104 Seine	12	199	5.9%	$ 1,634
Total Seine	34	985	29.1%	$ 8,088
Total Harvest	211	3,384		$ 29,827

[a] Includes only randomly recovered tags.

Table 7. The forecasted total adult return of Hugh Smith Lake sockeye salmon by age class and hatchery and wild components based on the projected smolt population, 1999 and 2000.

Return Year	Brood Year	Age Class	Hatchery	%	Wild	%	Total Adult Return
1999	1993	2.3	2,899	11%	4,177	15%	7,076
1999	1994	1.3	4,795	18%	11,541	42%	16,336
1999	1994	2.2	459	2%	1,104	4%	1,563
1999	1995	1.2	1,574	6%	613	2%	2,187
Total			9,727	36%	17,435	64%	27,162
2000	1994	2.3	1,385	6%	3,335	14%	4,720
2000	1995	1.3	9,757	41%	3,803	16%	13,560
2000	1995	2.2	824	3%	321	1%	1,145
2000	1996	1.2	2,259	10%	2,036	9%	4,295
Total			14,225	60%	9,495	40%	23,720

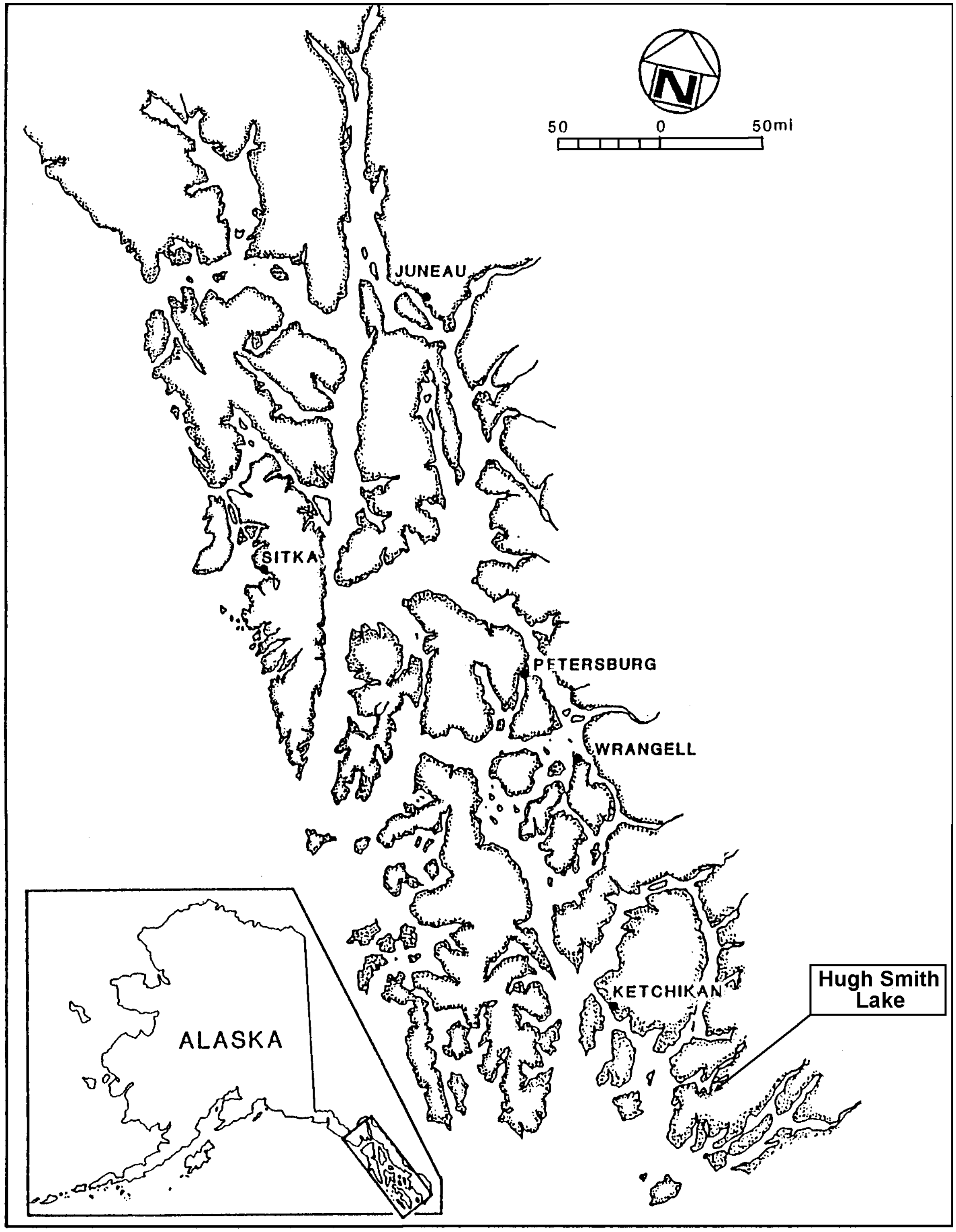

Figure 1. The geographic location of Hugh Smith Lake, within the State of Alaska, and relative to cities within Southeast Alaska

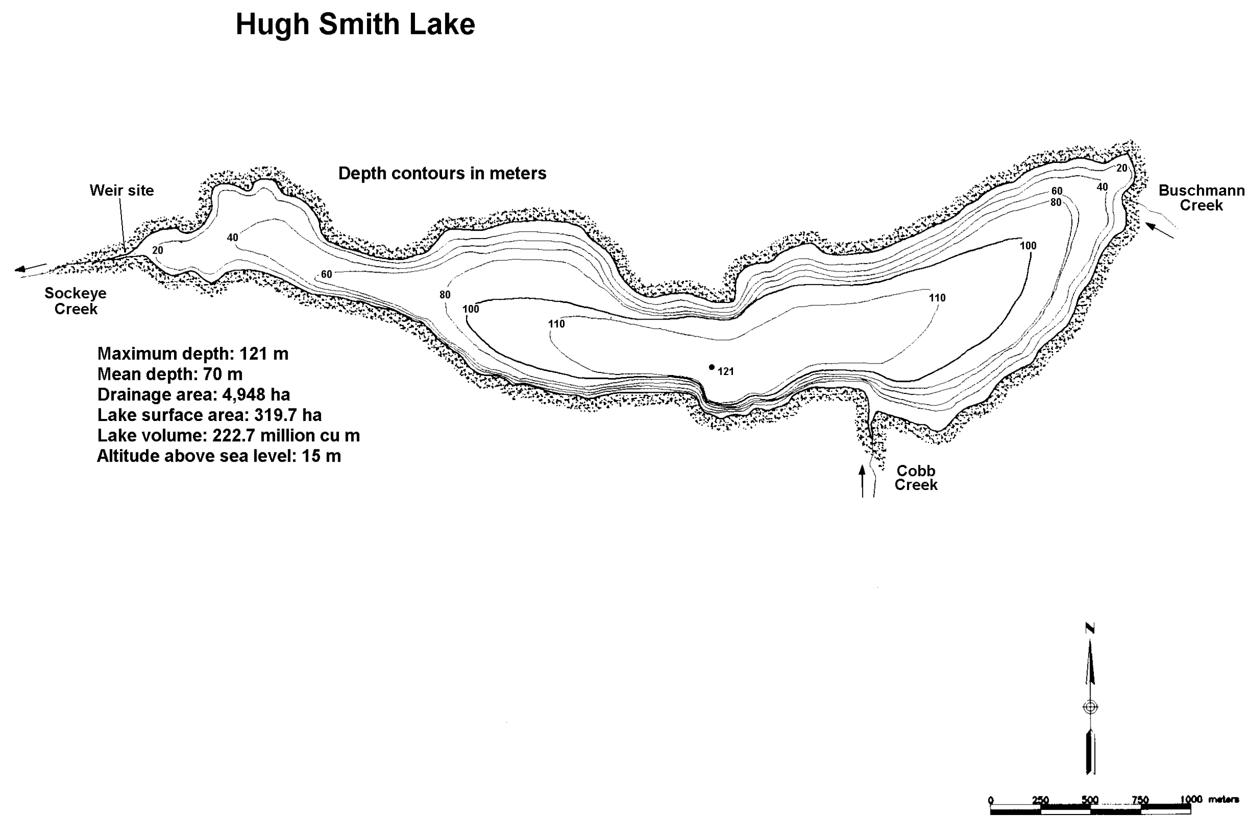

Figure 2. Bathymetric map of Hugh Smith Lake, Southeast Alaska

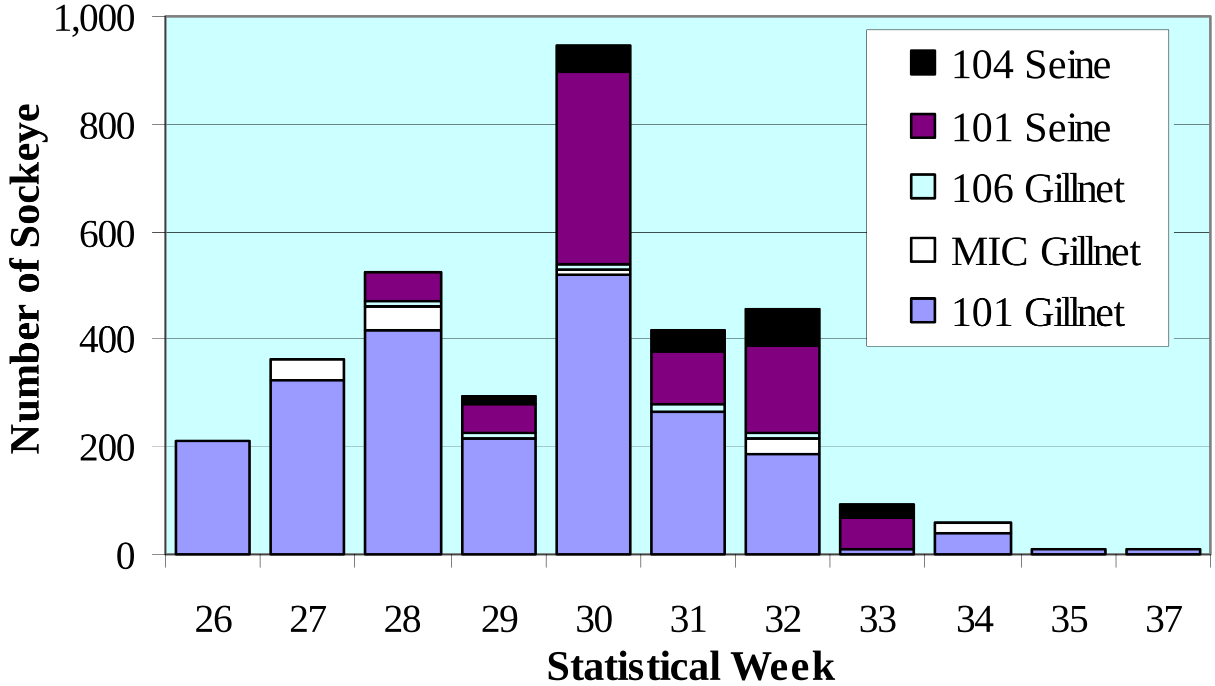

Figure 3. Estimated commercial harvest of Hugh Smith Lake sockeye salmon by management district and statistical week, 1998.

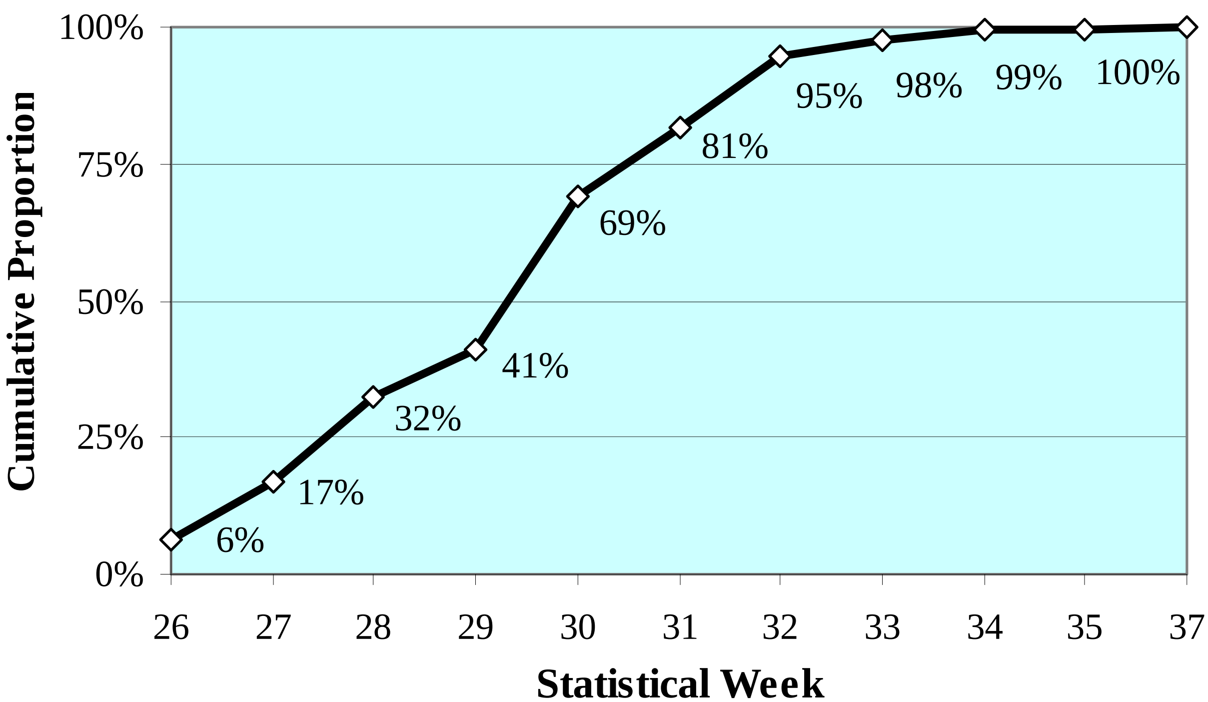

Figure 4. Cumulative weekly harvest proportions of Hugh Smith Lake sockeye salmon illustrating overall run timing through the commercial fisheries, 1998.

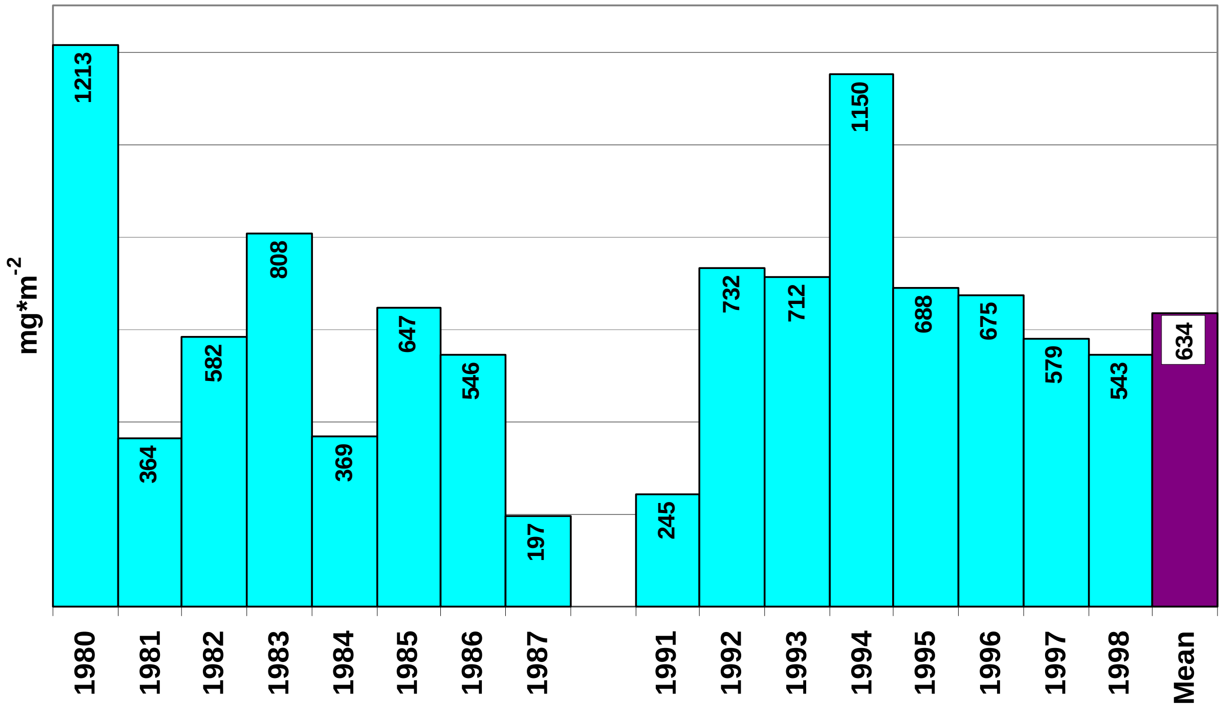

Figure 5. Mean seasonal macrozooplankton biomass (mg * m^{-2}) at Hugh Smith Lake from 1980 to 1987, and from 1991 to 1998, and 16-year mean.

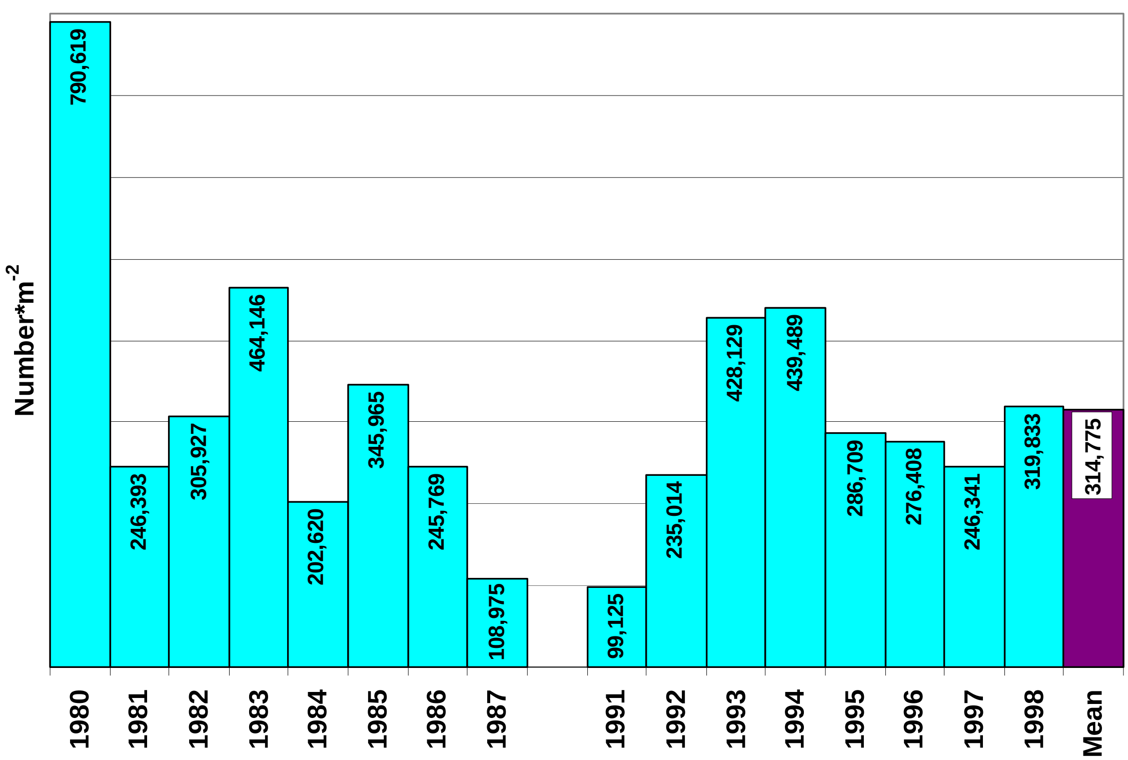

Figure 6. Mean seasonal macrozooplankton density (number * m^{-2}) at Hugh Smith Lake from 1980 to 1987, and from 1991 to 1998, and 16-year mean.

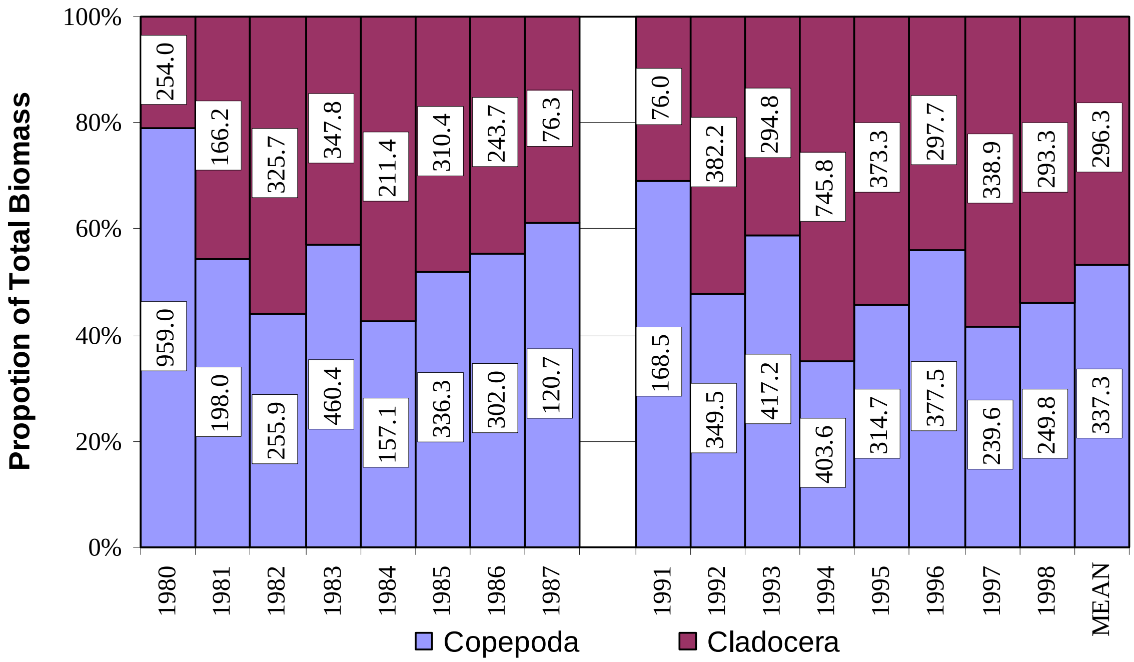

Figure 7. Mean seasonal distribution of macrozooplankton biomass (mg * m^{-2}) by plankter order at Hugh Smith Lake from 1980 to 1987, and from 1991 to 1998, and 16-year mean.

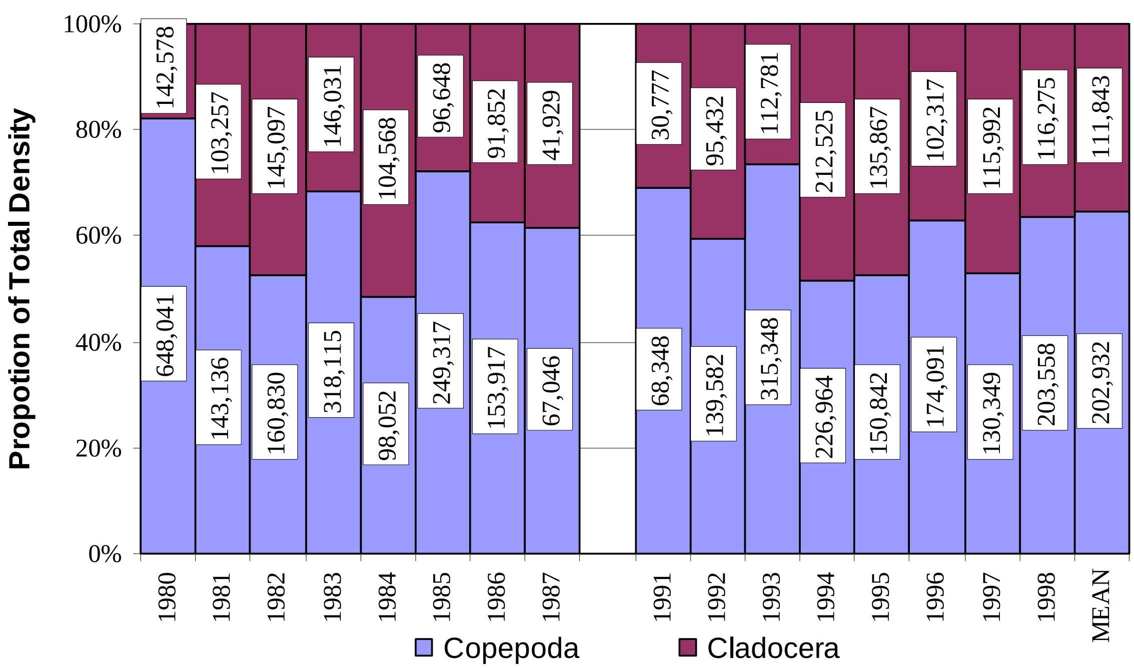

Figure 8. Mean seasonal distribution of macrozooplankton density (number * m^{-2}) by plankter order at Hugh Smith Lake from 1980 to 1987, and from 1991 to 1998, and 16-year mean.

APPENDIX

Appendix A.1. Total number of marked and unmarked adult sockeye salmon recovered at Buschmann and Cobb Creeks, Hugh Smith Lake, 1998.

		Fin Clip				
Date	Stream	Right Ventral	Left Ventral	Dorsal	Unmarked	Total Sampled
26-Aug	Buschmann					
27-Aug	Buschmann	1	2	-	1	4
1-Sep	Buschmann	2	1	-	1	4
1-Sep	Cobb	-	1	-	-	1
4-Sep	Buschmann	6	9	-	3	18
5-Sep	Cobb	-	1	-	1	2
13-Sep	Buschmann	-	5	-	1	6
16-Sep	Buschmann	-	30	20	25	75
18-Sep	Cobb	-	-	-	-	-
23-Sep	Buschmann	1	50	27	36	114
4-Oct	Buschmann	-	-	-	1	1
13-Oct	Cobb	-	-	1	-	1
13-Oct	Buschmann	-	-	-	-	-
	Total	10	99	48	69	226
Number of Clips Released at Weir		117	496	132		745

Analysis of 1998 Hugh Smith Lake adult sockeye salmon mark-recapture data by stratified population analysis system (SPAS) software (Arnason et al. 1996). All release and recovery strata were pooled:

Chi-square Test Statistics:

Complete Mixing:	29.96 (2 df)	Significance... 0.00
Equal Proportions:	2.42 (4 df)	Significance... 0.66

Pooled Petersen Estimate:

Estimate (std. err):	1,071 (42)
95 % normal C I:	(989, 1,152)
95 % transform C I:	(993, 1,157)

Appendix A.2. Adult sockeye salmon forecasts by adult age class based on fall fry hydroacoustic populations and actual smolt enumeration for brood years 1991-1996.

Brood Year	Age Class	Return Year	Projected Adult Age Distribution of Unknown-Age Smolt[a]		Projected Adult Age Distribution of Known-Age Smolt[b]		Actual Returns
			Wild	Enhanced	Wild	Enhanced	
	1.2	1995	2,042	2,204	205	225	1,690
1991	1.3	1996	10,675	11,518	1,078	1,183	7,579
	2.2	1996	1,021	1,102	133	146	3,568
	2.3	1997	3,084	3,328	399	437	
	Totals		**16,822**	**18,152**	**1,815**	**1,991**	**12,837**
	1.2	1996	6,903	0	6,753	0	2,178
1992	1.3	1997	36,071	0	35,452	0	23,246
	2.2	1997	3,451	0	4,221	0	886
	2.3	1998	10,422	0	12,664	0	1,489
	Totals		**56,847**	**0**	**59,090**	**0**	**27,799**
	1.2	1997	2,766	1,920	1,009	700	525
1993	1.3	1998	14,456	10,034	5,297	3,676	2,061
	2.2	1998	1,383	960	1,471	1,021	203
	2.3	1999	4,177	2,899	4,414	3,064	
	Totals		**22,782**	**15,813**	**12,191**	**8,461**	**2,789**
	1.2	1998	2,209	918	1,062	441	340
1994	1.3	1999	11,541	4,795	5,576	2,316	
	2.2	1999	1,104	459			
	2.3	2000	3,335	1,385			
	Totals		**18,189**	**7,557**	**6,638**	**2,757**	**340**
	1.2	1999	613	1,574	934	2,398	
1995	1.3	2000	3,803	9,756	4,906	12,588	
	2.2	2000	321	824			
	2.3	2001	1,052	2,697			
	Totals		**5,789**	**14,851**	**5,840**	**14,986**	**0**
	1.2	2000	2,036	2,259			
1996	1.3	2001	12,624	14,006			
	2.2	2001	1,067	1,183			
	2.3	2002	3,490	3,873			
	Totals		**19,217**	**21,321**	**0**	**0**	**0**

[a] Based on projected smolt population from fall hydroacoustic estimate.
[b] Based on smolt weir enumeration.

Appendix A.3. Adult sockeye salmon forecasts by return year based on fall fry hydroacoustic populations and actual smolt enumeration for brood years 1991-1996, marine survival estimates, and hatchery proportion of stock by return year.

Adult Return Year	Forecast based on Projected Smolt Population from Fall Hydroacoustic Estimate			Forecast Based on Smolt Weir Enumeration			Actual Return	Marine Survival		Proportion Hatchery Produced
	Wild	Enhanced	Total	Wild	Enhanced	Total		Estimated Smolt	Actual Smolt	
1994	4,467	12,584	17,051	2,317	6,359	8,676	19,307	13.6%	26.7%	73.8%
1995	3,883	2,818	6,701	1,294	536	1,830	6,313	11.3%	41.4%	42.1%
1996	19,004	12,621	31,625	9,113	1,328	10,441	15,561	5.9%	17.9%	39.9%
1997	45,373	5,248	50,621	41,081	1,138	42,219	26,319	6.2%	7.5%	10.4%
1998	28,469	11,912	40,381	20,494	5,139	25,633	4,522	1.3%	2.1%	29.5%
1999	17,436	9,726	27,162	10,925	7,778	18,703				35.8%
2000	9,495	14,224	23,719	4,906	12,588	17,494				60.0%