An Assessment of the Juvenile Sockeye Salmon (*Oncorhynchus nerka*) Populations of Babine Lake

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ABSTRACT

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Juvenile sockeye salmon (*Oncorhynchus nerka*) rearing in Babine Lake were re-examined 22 years after the initiation of the Babine Lake Development Project (BLDP). Abundance, distribution, size, and species composition of the limnetic fish populations, including juvenile sockeye salmon, were determined by hydroacoustic and midwater trawl surveys in the autumn of 1993 and the summer and fall of 1994 and 1995 and compared to results collected before and shortly after the start of the BDLP. Our objectives were to look for: 1) changes in the abundance of juvenile sockeye relative to spawning numbers; 2) changes in the utilization of the available nursery area; and 3) the effects of increased population size and density on the size and growth of juvenile sockeye. Abundance of fall sockeye fry ranged from $52.0 \bullet 10^6$ (1,400 fry/ha) in the fall of 1993 to $\sim 16.5 \bullet 10^6$ (455 fry/ha) in the autumns of 1994 and 1995. While the acoustic estimates appeared to be valid estimates of abundance, they were considerably lower than the smolt estimates from the same brood years. The dispersal and subsequent distribution of juvenile sockeye fry was similar to that found in the years before and immediately after the start of the BLDP. The size and growth rate of juvenile sockeye was similar to the earlier years and did not vary with density over the ranges studied. Our study found that Babine Lake has not reached nor exceeded its rearing capacity for juvenile sockeye salmon.

RÉSUMÉ

Hume, J.M.B., and S.G. MacLellan. 2000. An assessment of the juvenile sockeye salmon (*Oncorhynchus nerka*) populations of Babine Lake. Can. Tech. Rep. Fish. Aquat. Sci. 2327: 37 p.

Les populations de saumons rouges juvéniles (Oncorhynchus nerka) du lac Babine ont été réexaminées 22 ans après le lancement du Projet d’aménagement du lac Babine (BLDP). L’abondance, la distribution, la taille et la composition des populations limnicoles, notamment les populations de saumons rouges juvéniles, ont été déterminées par des études hydroacoustiques et pélagiques à l’automne 1993, et à l’été et l’automne 1994 et 1995, puis comparées aux résultats recueillis avant et peu après le début du projet BLDP. Nous avions trois objectifs : 1) déterminer s’il y avait eu des changements dans l’abondance des populations de saumons rouges juvéniles par rapport aux effectifs de géniteurs; 2) déterminer s’il y avait eu des changements dans l’utilisation de la zone de croissance disponible; 3) étudier les effets de l’accroissement des effectifs et de la densité de la population sur la taille et le taux de croissance des saumons rouges juvéniles. L’abondance des alevins de saumons rouges d’automne variait de $52{,}0 \bullet 10^6$ (1 400 alevins/ha) à l’automne de 1993 et $\sim 16{,}5 \bullet 10^6$ (455 alevins/ha) à l’automne de 1994 et celui de 1995. Les chiffres produits par les études hydroacoustiques semblaient donner une juste idée du taux d’abondance, mais ils étaient considérablement plus bas que les chiffres concernant l’abondance des smolts pour les mêmes pontes. La dispersion et la distribution subséquente des alevins de saumons rouges étaient similaires à celles observées lors des années précédant et suivant immédiatement le début du projet BLDP. La taille et la vitesse de croissance des saumons rouges juvéniles étaient semblables à celles des années antérieures et ne variaient pas avec la densité, sur les populations étudiées. Notre étude a révélé que le lac Babine n’a ni atteint ni dépassé sa capacité d’accueil des recrutements de saumons rouges.

INTRODUCTION

Babine Lake is the rearing area for the second largest sockeye salmon (*Oncorhynchus nerka*) population in British Columbia (Sprout and Kadowaki 1987). In his pioneering studies on the distribution and growth of juvenile sockeye in the major basins of Babine Lake, Johnson (1956, 1958, 1961) concluded that sockeye production from the Main Arm was limited by spawning ground capacity and not by lake rearing capacity. This work led directly to the Babine Lake Development Project (BLDP) consisting of two spawning channels on Fulton River, one channel on Pinkut River and flow control on both rivers (Fig. 1). The first Fulton River channel opened in 1965 and by 1971 the project was fully operational. Since full operation was achieved, the BLDP has produced 90% of the Main Arm fry (Shortreed et al. 1998). This has increased the total number of juvenile sockeye entering the lake from a mean of 114 million prior to the BLDP to 248 million in the last 10 years (1987 –1996) (Wood et al. 1998). Seaward migrating smolts have increased from a mean of 29 million prior to the BLDP to 70 million in the last 10 years.

Based on studies carried out as the BLDP became operational (1965-1967), during its start up phase (1970-1972), and 6 years after it was in full operation (1977), McDonald and Hume (1984) examined five major lines of evidence designed to test the assumptions predicating the building of the BLDP. These lines of evidence were: “(1) evidence of change in annual fry outputs as a result of the BLDP and subsequent changes in the abundance of underyearlings and seaward migrants; (2) comparisons of the distribution, growth, and survival in the lake of distinctively marked wild fry and channel-produced fry to test the assumption of equal viability; (3) evidence of the dispersal and subsequent distribution of fry and juveniles in the lake to determine the extent to which the available lake nursery area is utilized; (4) the effects of increased population size and density on the size and growth of fry, to the seaward migrant stage; and (5) change in the abundance and age composition of returning adults in response to increased outputs of seaward migrants.” They found that the increased spawning area and egg-to-fry survival in the BLDP resulted in increased abundance of all stages of juvenile sockeye from emergent fry through lake rearing fry to seaward migrating smolts. Wild and channel fry showed no difference in distribution, growth, or survival in the main basin of Babine Lake. There was no effect of increased density on survival or growth of juvenile sockeye salmon. In spite of the increased production of juvenile sockeye salmon, the production of adult returns did not meet expectations by the late 1970’s (McDonald and Hume 1984).

Although adult returns were substantially higher than before the BLDP in most years during the 1980’s and 1990’s (Wood et al. 1998), smolt size was showing slight but consistent declines indicating the possibility that rearing capacity of the lake was being reached (Wood et al. 1998). Objectives of our study, more than 20 years after the BLDP reached full production, were to test the continued validity of the conclusions of McDonald and Hume (1984). Specifically, our objectives were to determine:

- evidence of changes in the abundance of juvenile sockeye relative to spawning numbers;

- evidence of the dispersal and subsequent distribution of juveniles in the lake to determine the extent to which the available lake nursery area is utilized;

- the effects of increased population size and density on the size and growth of juvenile sockeye, to the seaward migrant stage; and

- at the initiation of the study, Fisheries and Oceans Canada was considering enhancing the sockeye populations which spawn in the tributaries to Morrison Arm. We therefore investigated the juvenile sockeye rearing capacity of this arm.

DESCRIPTION OF BABINE LAKE AND ITS FISH SPECIES

Babine Lake is about 500 km upstream from the ocean and drains through Nilkitkwa Lake and Babine River into the Skeena River. It is located on the Interior Plateau (712 m elevation) and has a continental climate, with warm summers and cold winters. It is in the sub-boreal spruce biogeoclimatic zone with an estimated mean annual precipitation of 40-50 cm (Farley 1979). It is by far the largest (461 km^2) of all Skeena River lakes, comprising 71% of the total surface area (671 km^2) of sockeye nursery lakes in the system. The lake consists of one large, deep basin -- the Main Arm (mean depth is 71 m, maximum depth is 235 m) and three smaller, shallower basins (Hagan, Morrison, and North arms) which are separated from the Main Arm by shallow sills (Fig. 1). Babine Lake is dimictic, with winter ice cover lasting from December to May. Human activities on the lake and its surrounding drainage include fishing, boating, logging, mining, residential and recreational development, and salmon enhancement. In addition to sockeye salmon, Babine Lake supports a number of fish species important to the commercial and/or recreational fisheries. These include coho salmon (*O. kisutch*), rainbow and steelhead trout (*O. mykiss*), cutthroat trout (*O. clarki*), lake char (*Salvelinus namaycush*), and lake whitefish (*Coregonus clupeaformis*).

Babine Lake has the largest sockeye stock in the Skeena River system, comprising more than 85% of the spawning escapement in almost all years since 1950. Total spawners ranged from 60,000 to 910,000 before enhancement and 265,000 to 1,235,000 since the construction of the spawning channels at Pinkut and Fulton streams (Wood et al. 1998). In the past, the North Arm stocks were the major escapements to the lake, but since the completion of the BLDP, the escapements to the Main Arm have generally been the largest (Fig. 2).

Babine Lake has three distinct sockeye runs -- early, middle, and late (Wood et al. 1998). Early run sockeye (1990-96 mean = 300,000) are unenhanced and spawn in 18 small tributaries to the Main Arm, 2 tributaries to the North Arm, and a few spawn in the Babine and Nilkitkwa rivers in some years. Middle-run sockeye (1990-96 mean = 820,000) are enhanced and spawn primarily in Fulton River, Pinkut Creek, and the spawning channels at both locations. A relatively small number of middle-run sockeye spawn in the Morrison River (1990-96 mean = 6,000) and in tributaries flowing into Morrison Lake (1990-96 mean = 4,000). Late run sockeye (1990-96 mean = 255,000) are unenhanced and spawn in the upper and lower Babine River (above and below Nilkitkwa Lake). Fry tend to rear in the same arm as their natal stream and there is little movement of fry between the North and Main arms (McDonald and Hume 1984).

METHODS

ADULT SOCKEYE

All sockeye entering the Babine Lake system are counted through a fence downstream of Nilkitkwa Lake. Sockeye spawning between the fence and Nilkitkwa Lake are estimated by a mark-recapture program. Sockeye spawning in Pinkut and Fulton rivers are all counted through fences while smaller stocks in tributary streams are visually counted by foot and from the air (Sprout and Kadowaki 1987). Accuracy and precision of these latter methods are poorer than for fence counts (Cousens et al. 1982; Williams and Brown 1994). In most years the sum of the escapements to individual spawning streams is less than the Babine fence count (Wood et al. 1998). Visual counts are known to underestimate the true population size by two to eight times (Johnston et al. 1986) and there is no evidence of significant lake spawning in Babine Lake (Wood et al. 1995). Wood et al. (1995) used a simple but parsimonious algorithm to correct escapement estimates to unenhanced streams and considered any remaining uncounted fish to be surplus enhanced fish (fish that were prevented from entering Pinkut or Fulton spawning grounds). We use the spawning escapements published in Wood et al. (1998).

In Babine Lake, we used numbers of female spawners (FS) as estimators of fry recruitment. Female spawners are not specifically enumerated in the Skeena system and we have therefore assumed a 50% sex ratio. Since comprehensive data on egg-fry survival are not available, we assumed that numbers of FS are directly related to numbers of fry entering the lake. Female spawners in Babine Lake are roughly equivalent to effective female spawners (EFS) enumerated in the Fraser River system (Hume et al. 1996). Effective female spawners are female sockeye that have successfully spawned, as determined by examination of carcasses on the spawning grounds. Direct comparisons between Fraser River EFS and Babine Lake FS are complicated by the increased egg-to-fry survival of enhanced BLDP sockeye.

JUVENILE SOCKEYE

General

Limnetic fish were surveyed from a 7-m boat. The vessel was equipped with a Biosonics 105 dual beam echo sounder and a 3-m by 7-m closing trawl system (Enzenhofer and Hume 1989). Population estimates were made with echo integration and in situ target strength estimation techniques as described in Burczynski and Johnson (1986).

All sampling was done during the hours of darkness when the fish were dispersed and within the working range of the midwater trawl and hydroacoustic system (McDonald and Hume 1984; Burczynski and Johnson 1986; Levy 1990). Hydroacoustic and trawl data presented in this paper were collected in the summer (August 13-16) of 1995 and the fall (September 21-October 7) of 1993, 1994, and 1995. A complete survey was attempted in the summer of 1994 but only the trawl portion was completed due to hydroacoustic equipment failure. The lake was divided into a number of trawling sections based on lake morphometry. These are the same sections sampled by purse seine by McDonald and Hume (1984). Within each section, two to three evenly spaced hydroacoustic transects for estimating population abundance and density were established (Fig. 1). The same transects were used on all subsequent surveys.

Hydroacoustic Population Estimates

Data Collection

Data were collected with a Biosonics Model 105 dual beam echo sounder/ Biosonics Model 171 tape recorder interface system using a 420 kHz dual beam (6°/15°) transducer and were digitally recorded using a Sony TCD-D7 digital audio tape recorder for later processing. The sounder was calibrated by Biosonics Inc. (Seattle, Washington) prior to each field season and soundings on standard targets were done periodically throughout the season to verify the sounder was operating properly. We collected two types of acoustic data on each transect: 20 log(R) data (where R = distance between the transducer and target) to estimate fish population and distribution using echo integration techniques; and 40 log(R) data to determine target strengths for estimating fish size and scaling the relative 20 log(R) data to provide actual fish density estimates.

Data Processing

Acoustic data were processed similarly to Burczynski and Johnson (1986) using a Biosonics Echo Signal Processor which incorporates the model 221 echo integrator and model 228 dual beam processor along with the Biosonics post processing computer programs ESPCRUNCH and ESPTS. Two separate processes are involved. First, mean target strength and backscattering cross section of fish were determined from data collected at 40 log(R) for each 2 m depth strata (1 m-81 m) of each transect or section. A table showing the distribution of target strengths of individual echoes by depth was also produced. Second, data recorded at 20 log(R) on each transect was echo integrated to give relative density of targets in each 2-m depth strata. Target strength (TS) and equipment scaling factors were then used to scale the echo integration to provide an estimate of fish density (fish/m^3). In those depth strata where TS sample size was small and TS scaling factors unreasonable, TS scaling factors from adjacent strata were substituted.

Calculation of Population Estimates

Total fish, and sockeye only, abundance estimates were first calculated for each transect and then combined into section and lake estimates. Fish abundance for each 2-m depth strata within a transect was calculated by multiplying fish density (fish/m^3) by the volume of the depth strata in that portion of the lake represented by the transect area. These volumes were derived from a combination of area measurements and interpolation of depth contours from bathymetric maps. Total population for the transect area is the sum of fish in each strata.

Juvenile sockeye abundance was estimated by applying two factors to the fish estimate for each depth strata. The first factor, target strength (TS), was used to remove fish which were significantly larger than age-0 and age-1 sockeye. Since the efficiency of our midwater trawl decreases markedly for these larger fish (Parkinson et al. 1994; Hume et al. 1996), TS was used to estimate the percentage of large and juvenile sockeye sized fish in each depth strata. We used the TS depth distribution table to generate the percentage of sockeye size echoes to total fish echoes. Echoes with a TS ranging from –62 dB to –42 dB were considered to be from juvenile sockeye size fish (15-150 mm); larger TS echoes were considered to be from large fish and smaller TS echoes from non-fish. The second factor, catch proportion by taxa, was applied directly from the midwater trawl catches and was used to estimate the percentage of sockeye relative to all sockeye-sized fish. Application of both factors to fish abundance for each depth strata results in a juvenile sockeye abundance estimate for each depth strata. The sockeye abundances by depth strata were summed to produce a sockeye estimate for the transect area and a mean surface density (fish/ha) calculated by dividing this estimate by the surface area (ha) of the transect area.

Results from each transect were used to provide a mean estimate of density (n/ha) for each lake section. The mean density was then multiplied by the surface area of the section to provide a population estimate for the section. The section population estimates were summed to provide a total population estimate for the lake. Mean lake density was calculated by dividing the lake population estimate by the total surface area. Variances were calculated for the density of each section from the transect densities and were then weighted by the square of the section area. The sum of the weighted variances was divided by the square of the lake area to provide a variance for the lake population estimate. Estimates for all limnetic fish in each section are given in Appendix Table 1, age-0 *O. nerka* in each section in Table 3, all limnetic fish for each transect in Appendix Table 2, and age-0 *O. nerka* for each transect in Appendix Table 3.

Fish Biology

Fish samples were collected from each lake section with a midwater trawl. Trawl location, depth, and duration (3 to 30 min) were based on locations, depths, and densities of fish targets recorded on the echosounder chart. All fish captured were anaesthetized and killed upon capture with an overdose of 2-phenoxy-ethyl alcohol and then preserved in 10% formalin. Fish were kept in formalin for at least 1 month until weight had stabilized before lengths and weights were recorded (Parker 1963). Trawl data was used to determine species and age composition of the limnetic fish community. Trawling conditions for each tow are given in Appendix Table 4 and summary statistics for the catch of each tow are given in Appendix Table 5.

Other Juvenile Sockeye Data Sources

Abundance estimates of two other juvenile sockeye salmon life history stages are available for comparison to the hydroacoustic estimates of summer and fall lake resident fry in Babine Lake (Wood et al.1998). They are: 1) emergent fry numbers based on fry counts at Pinkut and Fulton channels and natural spawners multiplied by a fry-to-spawner ratio of 233; and 2) mark-recapture estimates of smolt numbers in the Babine River. In addition to the 3 years of hydroacoustic surveys conducted by us in 1993 to 1995, a hydroacoustic survey was conducted in October, 1975 (Mathisen and Smith 1982).

RESULTS

FISH TAXA COMPOSITION

Of the 3,156 fish caught by midwater trawl in the Main Arm, 99% were age-0 sockeye fry (Table 1). Less than 1% were older *O. nerka* (age -1 and -2+). Two whitefish (*Coregonus* sp. or *Prosopium* sp.), one sculpin (*Cottus* sp.), and three unidentified juvenile fish were the only other species caught. There was little variation between surveys or years with age-0 sockeye always being the dominant taxa caught and never comprising less than 98% of any one trawl catch.

The midwater population of the North Arm was similarly dominated by age-0 sockeye, which comprised 97% of the total catch of 286 fish over all surveys (Table 2). Six age-1 *O. nerka* and two sculpins were the only other taxa caught in the North Arm.

Morrison Arm had a much more diverse fish taxa. Age-0 sockeye comprised 33% of the catch of 148 fish while 6% were age -1 and -2+ older *O. nerka*. We also caught high proportions of whitefish (31%) and sculpins (26%). As well, the occasional juvenile sucker (*Catostomus* sp.), peamouth chub (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*), lake trout and bull trout (*S. confluentus*) were caught for a total of 4%. The two fall surveys had a lower proportion of age-0 sockeye (25%) than did the one summer survey (82%).

Only one trawl survey of Hagan Arm was conducted because the hydroacoustic echograms indicated that there would be few if any fish caught in the trawls. The two trawls conducted in the fall of 1995 caught only 12 age-0 sockeye, two age-1 sockeye, and two sculpins.

The results of these trawls and target strength data organized by depth were used to allocate hydroacoustic density estimates for each 2-metre depth interval into the age-0 sockeye component and other non-sockeye components. The data in Appendix Table 1 includes all fish-sized targets. As the catch of fish other than age-0 sockeye was so low in most cases, we did not attempt to estimate abundance of the other fish taxa present.

VERTICAL DISTRIBUTION AT NIGHT

In the Main and North arms, during the summer of 1995, 80% of the limnetic fish were found in a 6 m wide band centred on average at 11 m (Fig. 3). Bandwidth varied from 16 m to 2 m but on most transects it was less than 8 m wide. On most transects, 80% of the fish were deeper than 8 m but on a few transects they extended up to 4 m from the surface, especially in the North Arm.

Bandwidth was generally broader in the fall (8-13 m) than in the summer. Limnetic fish were deepest in the fall of 1993 with a median depth of 17 m and 80% of the fish between 13 and 21 m. Fish were shallower in the fall of 1994 and 1995. During the fall of 1994, the median depth was 12 m and 80% of the fish were found in a band 13 m wide. In the fall of 1995, the average median depth was 15 m and 80% of the fish were found in a band 13 m wide. While median depth varied from transect to transect, there was no apparent trend in depth from one end of the Main Arm to the other.

ONSHORE-OFFSHORE DISTRIBUTION

We examined the horizontal nighttime distribution of acoustic fish targets during the fall 1993 survey. Fish density in deep (arbitrarily set at ≥ 20 m), offshore water was on average 2.5 times higher than in shallower (<20 m), onshore water (1360 fish/ha vs. 530 fish/ha). In only 5 of the 25 transects were densities higher in the shallower waters. The portion of the water column being occupied by onshore and offshore sockeye fry is similar as offshore 80% of the sockeye are found in a band between 13 and 21 m wide. Therefore, the observed differences in density between onshore and offshore are not a function of a larger volume of water being utilized by the offshore fish.

These lower shallow water densities result in fewer fish found in shallow water than would be expected, relative to the surface area of shallow water. Twenty-eight percent of the lake surface area is <20 m deep but shallow waters contained only 16% of the total acoustic fish population.

ABUNDANCE AND DISTRIBUTION

Main Arm

During late September, 1993, the total Main Arm hydroacoustic estimate of age-0 sockeye fry was $52.0 \cdot 10^6$ ($\pm 22.8 \cdot 10^6$), or an average of 1,400 ± 640 fry/ha (Table 3). Section 4 had the highest density (2,900 ± 7,000) while the lowest was just down lake in Section 3 (500 ± 360). Highest densities of sockeye were found at either end of the Main Arm but there was no significant difference between the sections (ANOVA $p>0.05$, Fig. 4).

In early October, 1994, the acoustic estimate was $16.2 \cdot 10^6$ age-0 fry ($\pm 4.5 \cdot 10^6$), or an average of 450 fry/ha (± 130). This is about one-third of the abundance and density observed in the fall of 1993. As in 1993, there was no significant difference between any of the Main Arm sections. We did not successfully complete a summer survey in 1994 due to equipment failure.

The hydroacoustic survey in mid-August, 1995, resulted in a population estimate of $22.6 \cdot 10^6$ age-0 fry ($\pm 8.5 \cdot 10^6$) or an average of 630 fry/ha (±240). There was a general gradient of increasing age-0 fry density from the north to the south ends of the lake, but no significant differences were found between lake sections (ANOVA, $p>0.05$, Table 3, Fig. 4).

In late September, 1995, the acoustic estimate was $16.7 \cdot 10^6$ age-0 fry ($\pm 4.0 \cdot 10^6$) or an average of 460 fry/ha (±110). Again, this is about 1/3 of the abundance and density observed in the fall of 1993 and as in the fall of the other years, there was no significant difference between any of the Main Arm sections. The decrease in abundance from summer to fall of 1995 resulted in a calculated instantaneous mortality of 23%/month.

North Arm

During late September, 1993, the total North Arm hydroacoustic estimate of age-0 sockeye fry was $1.11 \cdot 10^6$ ($\pm 1.98 \cdot 10^6$), or an average of 211 fry/ha (± 376, Table 3). Densities ranged from 13 to 118 fry/ha except for transect 6 at 1,008 fry/ha (Appendix Table 3). Transect 6 is south of McKendrick Island and could be considered part of Section 1. Densities in Section 1 were similar to those of transect 6.

In early October, 1994, the acoustic estimate was $3.80 \cdot 10^6$ age-0 fry ($\pm 2.01 \cdot 10^6$), or an average of 720 fry/ha (±381). This is the highest abundance observed in the North Arm during our 3 years of sampling. Transect densities ranged from 96 to 1,273 fry/ha. Transect 6 (1,199 /ha) was again more similar to area 1 transects than to nearby North Arm transects (Appendix Table 3).

The hydroacoustic survey in mid-August, 1995, resulted in a population estimate of $0.54 \cdot 10^6$ age-0 fry ($\pm 0.45 \cdot 10^6$) or an average of 102 fry/ha (±85). In late September, 1995, the acoustic estimate was $1.49 \cdot 10^6$ age-0 fry ($\pm 1.22 \cdot 10^6$) in 1995 or an average of 282 fry/ha (±231). Although there was an apparent increase in the age-0 population between the summer and fall (possibly due to incomplete fry recruitment to the limnetic zone before the summer survey), there was no significant difference between the surveys (t-test $P>0.05$).

Morrison and Hagan Arms

We estimated a population of $0.51 \cdot 10^6$ age-0 sockeye fry ($\pm 0.01 \cdot 10^6$) in Morrison Arm during September, 1993, or an average of 420 fry/ha (±12). This was the largest number of fish we estimated in this arm during our 3 years of surveying Babine Lake. Surveys in subsequent years found $0.17 \cdot 10^6$ age-0 sockeye fry ($\pm 0.52 \cdot 10^6$) or an average of 140 fry/ha (±439) in October, 1994, and only $0.047 \cdot 10^6$

(±0.067•10^6) in September, 1995 (39 fry/ha ±54). The summer of 1995 survey was lower 0.017•10^6 (± 0.11•10^6).

Hagan Arm had the lowest density of age-0 sockeye fry of any lake section in the first two sample years. It had 120 fry/h (±248) in 1993 and 172 fry/ha (±227) in 1994. The 1995 survey enumerated about two times as many fish as in the previous surveys, 286 sockeye fry/ha (± 349).

AGE-0 SOCKEYE SIZE

Main Arm

Summer age-0 fry averaged less than 1.5 g (50 mm) in 1994 and 1995 (Table 1). The smallest mean size was found towards the southern end of the lake (Sections 4 and 5) and the largest were found in the northern two Sections (1 and 2) in both years (Table 4). In 1994, these differences were in most cases not significant (Table 4, ANOVA, LSD, $P>0.05$). In 1995, there was a definite size gradient from north to south ($P<0.05$). Age-0 sockeye in Section 1 (2.4 g) were 1.8 times larger than in the southern Sections 4 and 5 (<1.4 g).

Fall age-0 fry mean size decreased from 4.3 g in 1993 to 3.6 g in 1994 and to 2.9 g in 1995 (Table 1). Mean size was significantly smaller in each sample year (ANOVA, LSD, $P<0.05$). Within the Main Arm, size varied significantly between lake sections but there was no consistent size trend observed (Table 4). In 1993, Sections 4 and 5 had significantly larger age-0 sockeye than found in Sections 1 and 2. In 1994 and 1995, almost the reverse was true with Sections 4 and 5 having the smallest age-0 sockeye.

North, Morrison, and Hagan Arms

Catches were relatively small in the North Arm ranging from only 29 to 118 age-0 sockeye (Table 2). Fry captured during the summer were slightly larger (1.9 g) than those found in the Main Arm in both 1994 (n=118) and 1995 (n=80). By the fall of 1994 and 1995 fry were 3.2 g (n=29) and 2.9 g (n=51), respectively, about the same size as those found in the Main Arm.

Morrison Arm age-0 sockeye had the largest mean size of any in the Babine system, but low densities resulted in small sample sizes. Age-0 sockeye averaged 3.0 g (n=18) in the summer of 1994 and were 5.5 g (n=28) in the fall of that year. Only three fish were captured in the fall of 1995 but they ranged from 5.5 to 7.5 g. In general, Morrison Arm age-0 sockeye were one and one half to two times the size of the Main Arm or North Arm fry.

Hagan Arm was only sampled by trawl in the fall of 1995. The age-0 sockeye captured averaged 2.6 g (n=12), about the same size as Main Arm fry.

DISCUSSION

ESTIMATES OF JUVENILE SOCKEYE POPULATIONS

Although there appears to be internal consistency between the hydroacoustic estimates (all estimates are within the same order of magnitude and the summer and fall estimates are comparable), the acoustic estimates of age-0 fry appear to be low in some years when compared to other juvenile estimates of abundance (Table 5, Fig. 5). In the 4 years that acoustic estimates were made, emergent fry from the BLDP and the spawning creeks ranged from 132 to 221•10^6 fry/year (Wood et al. 1998). Emergence to fall survival ranged from 9 to 34% in the 4 years acoustic estimates are available (Table 6, 1974 brood year estimate from Mathisen and Smith (1982). In 2 years (1974 and 1992 brood years) survival to the fall acoustic survey was estimated at over 25%. This is well within the range reported by Hume et al. (1994) in Quesnel and Shuswap lakes of 21 to 61%. In the last 2 years of the study (1993 and 1994 brood years) survival to the fall was only 9 and 13%, respectively, considerably below that reported for Quesnel and Shuswap lakes. Low fry to fall fry survival in the 1994 brood may be partly attributed to after affects of high levels of pre-spawning mortality caused by the “ich” parasite (Traxler et al. 1998). However, egg-to-fry survival was also below average for the 1993 brood, which was not affected by the ich parasite. Wood et al. (1998) speculated that IHN, detected in low concentration during these years of low survival, may have had some effect but did not know of any evidence.

The relationship to smolt estimates is even more puzzling as smolt numbers were higher than or nearly the same as the three acoustic estimates made in 1993 to 1995. Obviously, an increase in juvenile numbers from fall to the following spring indicates that at least one of the estimates of abundance is inaccurate. Precision errors can be high for the acoustic estimates (95% CI’s of 23 – 53%). They tended to be smaller for the smolt estimates (2 SE’s of 5 – 26% in the comparable years). The estimates of error do not overlap in 1992 or 1993 brood years but do overlap considerably in the 1994 brood year, possibly indicating no significant difference in that year (Fig. 5). Using the extremes of the 95% CI’s, fall to spring survival could be as low as 75% in the 1994 brood year, but still above 100% in the 1992 and 1993 brood years.

Estimated densities of emergent fry in the North Arm were two to five times higher than in the Main Arm during the years we studied (Table 5), but the apparent survival to either fall fry or smolts was considerably lower than observed for the Main Arm (Table 6). There is little evidence to explain the low survival rates but they may be related to problems with estimating emergent fry numbers or possibly with poor rearing conditions in the North Arm, such as a lack of suitably deep water, exposing the sockeye fry to increased predation risks and increased temperatures (Levy 1990).

NORTH-SOUTH DISTRIBUTION

Distribution of sockeye in the 1990’s has not changed significantly from the 1960’s or 1970’s. Marking experiments conducted from 1965 to 1971 showed that fry from the Fulton spawning channel actively migrated to the southern portion of the lake where they mixed with the fry originating from the Pinkut system (McDonald and Hume 1984). In the early summer, this migration of Fulton River fry resulted in a north-south gradient of juvenile sockeye with most fry in the southern sections of the Main Arm (Fig. 6). This north-south density gradient of juvenile sockeye was also observed in our 1995 mid-August survey (Fig. 4).

In later sessions, during October, McDonald and Hume (1984) found that there were no consistent differences in density between lake sections, although Section 4 usually had the highest density of juvenile sockeye (Fig. 7). The October, 1975, hydroacoustic survey found the highest densities in areas 1, 3, and 4 (Fig. 4). Similarly, we found that Section 4 had the highest density in the fall of each year but there was no significant differences between any of the acoustic estimates in the sections of the Main Arm (Table 3, Fig. 4,ANOVA $P>0.05$).

ABUNDANCE AND DENSITY

Densities of juvenile sockeye salmon in the smaller Skeena River sockeye rearing lakes ranged from 77 to 1,994 fry/ha, with most lakes having more than 300 fry/ha. These densities were considered to be well below the optimum rearing capacity of most of the lakes investigated by Shortreed et al. (1998). Estimated fall densities of juvenile sockeye salmon in the Main Arm and the various arms were also within the same range. The Main Arm and the North Arm had densities between 200 and 1,500 fry/ha. Hagan and Morrison arms usually had lower densities dropping to as few as 40 fry/h in Morrison Arm. The 1975 acoustic survey by Mathisen and Smith (1982) estimated 1,150 fry/ha in the Main Arm but about 2,400 fry/ha in the North Arm. All of these densities are considerably lower than the maximum observed fall densities in Shuswap (~5,000/ha) and Quesnel (~3,000/ha) lakes (Hume et al. 1996).

Comparisons of relative density between the North and Main arms in the 1960’s and ‘70’s (purse seine catches of Mcdonald and Hume 1984) indicate at least twice the density of sockeye fry in the North Arm during these earlier years. Our acoustic estimates in the 1990’s found higher densities in the Main Arm in 2 of 3 years. These differences reflect the decrease in North Arm spawners relative to the Main Arm since the implementation of the BLDP.

SIZE AND GROWTH

In spite of a four-fold difference in fry recruitment (1,600 – 6,300 emergent fry/ha) to the Main Arm from 1966 to 1995, we were unable to detect any significant effect on either the size of summer or fall juvenile sockeye or on their instantaneous growth rate (Fig. 8, $P > 0.05$). Similarly, Hume et al. (1996) found that fry collected during August in Shuswap and Quesnel lakes were all approximately the same size over a much wider range of densities (approximately 400 to 26,000 emergent fry/ha). In contrast to our results, they did find that juveniles collected later in the fall were significantly smaller at the higher densities and attributed this to decreased prey abundance (especially *Daphnia*) in the summer and fall, probably caused by the high grazing rates.

Using 45 years of Babine Lake smolt size data covering a larger range of fry densities (200 – 6,900 emergent fry/ha), we found a small but significant decrease in smolt size with increasing fry density (Wood et al. 1998, $P < 0.05$, Fig. 9). This small decrease in smolt size since enhancement does not indicate that these spawner and fry recruitment levels are excessive. Smolt size is greater than 4 g at even the highest fry densities, as large or larger than those from many coastal B. C. lakes (Hyatt and Stockner 1985) and Shuswap Lake (Hume et al. 1996). Babine Lake smolts are about 0.5 g larger at similar densities than those from Chilko Lake where 40 years of smolt data exists (Fig. 9).

Smolt size explained 30% of the variation in smolt to adult survival (SAS) in six stocks from B. C., Alaska, and Russia (Koenings et al.1993). Survival increased at a rate of 0.3 to 0.5%/mm from 60 to 90 mm (~2 to 7 g) but was not related to larger smolt sizes. Henderson and Cass (1991) demonstrated that SAS for Chilko lake sockeye increased with smolt size within a given year class while Bradford et al. (2000) showed that marine survival between years was also related to smolt size in Chilko Lake sockeye. In contrast, smolt sizes of 75 to 85 mm (3.9 to 5.8 g) did not affect SAS in Babine Lake (Wood et al. 1998). The lack of a significant relationship between smolt size and SAS in Babine Lake may be due to the small range in smolt size and the low explanatory value of the relationships found by Koenings et al. (1993) and Bradford et al. (2000). Wood et al. (1998) suggested that recent shifts in oceanic regimes (Welch et al. 1997) may add additional variation, and account for the recent high return rates. In general, smolt to adult survival rates for Babine Lake are low, averaging only 3.9% (range 0.8 - 8.1%) while SAS averaged 9% in Chilko Lake (Hume et al. 1996).

KOKANEE AND OTHER SPECIES

Resident populations of kokanee (landlocked *O. nerka*) can complicate the interpretations of size and abundance data. Kokanee are resident in Babine Lake (McDonald and Hume 1984) but their abundance has not been estimated in recent years. McDonald and Hume (1984) cited reports of over 1 million spawners in 1955, 1956, and 1963 but only 18,000 to 64,000 in the years from 1964 to 1972. They estimated that the progeny of these spawning populations would comprise 1-3% of the underyearling *O. nerka* population. While older kokanee are readily distinguished from sockeye by their size, it is much more difficult to distinguish underyearlings. Techniques to distinguish kokanee fry involving protein electrophoresis (Wood and Foote 1990) or elemental composition of the otolith nucleus (Rieman et al. 1994) were not used in the present study.

Based on Parkinson et al.’s (1994) comparisons between trawls of differing selectivity, Hume et al. (1996) concluded that the bias in our midwater trawl is restricted to *O. nerka* greater than 150 mm. As underyearling *O. nerka* captured by the trawl were < 85 mm and age-1 *O. nerka* were <150 mm, we also conclude that the bias in our trawl data is restricted to underestimating the proportion of older kokanee (age 2 and 3).

The majority of limnetic fish captured in the Main Arm were age-0 sockeye fry in both the purse seining done prior to 1977 (McDonald and Hume 1984) and in our trawl catches. The trawl catches during 1993-1995 contained < 1.3% of age-1 kokanee (Table 1). Assuming that the trawl catches of age-1 kokanee are unbiased and an underyearling to age-1 mean survival of 40% (mean sockeye fry to smolt survival, Wood et al. 1998) then, by back-calculation, the proportion of kokanee in the underyearling population ranges from 1 to 3%, the same as estimated for the 1960’s (McDonald and Hume 1984).

Based on these calculations and the mean size from the trawl catches, age-0 and -1 kokanee would comprise about 8% of the total *O. nerka* biomass in the lake.

Because of the nature of the purse seining used in the 1960's and 1970's, it is likely that there is less bias associated with the catch of older kokanee than there is with the midwater trawl. During 6 years of purse seining from 1967 to 1977, the proportion of age-1 or older kokanee ranged from 2 to 10% of the total catch in the Main Arm (Scarsbrook and McDonald 1970, 1972, 1973, 1975; Scarsbrook et al. 1978). Since the catch of kokanee was not aged nor was size reported, it is not possible to separate older kokanee by age.

Fish other than *O. nerka* are very rare in the limnetic zone of the Main Arm or the North Arm. Only juvenile sizes (whitefish, sculpins and unidentified < 60 mm) were caught during our study, where they comprised less than 0.2% of the catch. In 1977, more species were captured by purse seine in the Main Arm (Scarsbrook et al. 1978). These included juvenile coho (*O. kisutch*), rainbow trout, lake trout, lake whitefish, Rocky Mountain whitefish (*Prosopium williamsoni*), pygmy whitefish (*P. coulteri*), sculpins, suckers, and squawfish (*Ptychocheilus oregonensis*). No size or age data was provided but the dominant species were rainbow trout, lake trout, lake whitefish and sculpins. This larger number of species is probably a result of greater fishing effort as the non-*O. nerka* still only comprised 0.2% of the total catch of >70,000 fish during 1977.

MORRISON AND HAGAN ARMS

Both Morrison and Hagan arms had low densities of age-0 sockeye in the 3 years that we sampled, although not as low relative to the Main Arm as reported by Scarsbrook et al. (1978) during 1977. Both the seine sets and the 1993-95 trawling caught a high proportion of fish that were not age-0 sockeye. More than 50% of the catch in both cases were not juvenile sockeye. Scarsbrook reported a species composition similar to the one we found, with sculpins and whitefish dominating the catch of non-*O. nerka*. They identified both lake and pygmy whitefish as the primary whitefish species but also captured the occasional Rocky Mountain whitefish. In addition to the suckers, peamouth chub, redside shiner, and lake char we captured they also captured the occasional rainbow trout, squawfish and juvenile coho salmon. We only captured one species not reported in Scarsbrook et al. (1978) -- a single bull trout.

In Morrison Arm, one major difference between the 1977 purse seining and our trawl catches was a much higher incidence of age-1 (*O. nerka*) in the purse seine catches. The trawl catches in the 1990's had only 0-9% age-1 or older *O. nerka* while they comprised 40-60% of the purse seine catches in 1977. This may represent different gear biases but the incidence of age-1 and older *O. nerka* in the Main Arm was less than 2% in both sample periods.

UTILIZATION OF MORRISON ARM BY SOCKEYE FRY

The Morrison Arm sockeye fry population

Morrison Arm is a relatively small and shallow arm of Babine Lake populated by a large variety of potential sockeye competitors and predators. Our midwater trawls often caught considerably fewer age-0 sockeye than other taxa including older *O. nerka*, whitefish, sculpins, suckers, peamouth chub, redside shiner, bull trout, and lake trout, few of which are caught elsewhere in the lake. Given the limited rearing area and the potential competitor/predator populations, we might expect the sockeye fry to migrate out of this Arm. However, we can find no evidence to support this hypothesis.

Seven years of purse seining (1966-68, 1971-1973, and 1977) found that Morrison Arm fry were larger than Main Arm fry from early summer to late fall. Our trawl data from 1994 and 1995 revealed similar size differences. In August, 1994, Morrison Arm age-0 sockeye were twice as large (3.0 g) as those in the Main Arm (1.5 g). By fall of that year, Morrison Arm sockeye weighed 5.5 g while Main Arm sockeye averaged 3.5 g. This suggests that Morrison Arm fry comprise a separate population, which grows at a faster rate than Main Arm fry. If there were frequent movements in and/or out of Morrison Arm then fry sizes would be similar. Further, if Morrison fry migrated out of the arm during summer then average fry size near Old Fort would be larger than in other Main Arm areas. This has not been observed.

In all sample years, there has been very little difference in fry size between any Main Arm areas. As well, if length-frequency data from near Old Fort showed a bimodal distribution, then an influx of fry from Morrison Arm could be inferred. Again, this has not been observed. These data and the fact that there is a narrow and shallow (<25 m) entrance to Morrison Arm indicates that there is little movement between Morrison and Main arms. One possible contrary hypothesis is that migration out of Morrison Arm is size dependent and that smaller fish migrate more than larger fish. There is no supporting data either way and the simplest explanation is that there is little migration occurring.

Rearing capacity of Morrison Arm

Both purse seine and the hydroacoustic estimates indicate that Morrison Arm has a relatively low density of sockeye fry. Age-0 densities in Morrison Arm were 3 to 12 times lower than those measured in the Main Arm during 1993, 1994, and 1995. These density differences could explain much of the difference in fry growth rate between Morrison Arm and the Main Arm. The extensive littoral areas in Morrison Arm may also contribute to fry growth as they do in other shallow nursery lakes such as Fraser Lake (Shortreed et al. 1996). Morrison Arm had over twice the density of the macrozooplankton *Heterocope* than did the north end of the Main Arm. These are a large and attractive copepod prey item to sockeye and dominated the diet of the Morrison Arm age-0 sockeye (Shortreed and Morton 2000).

The observed Morrison Arm fall fry densities of 39 to 423 fry/ha were produced from spawning escapements between 4,000 and 6,000. Historically, spawner escapements have ranged as high as 35,000 but more recently have ranged from 3,000 to 13,000. The trawl and acoustic data indicate densities of other species are 200 to 400 fish/ha. As many of these fish are potential competitors with sockeye, they may significantly reduce the carrying capacity of the Arm. Non-age-0 sockeye in the Main Arm ranged from 32 to 112 fish/ha, considerably less than in Morrison Arm.

Total fish density in Morrison Arm did not exceed 600 fish/ha in the 3 years we conducted surveys and it therefore should have considerable room for more sockeye fry. Hume et al. (1996) and Shortreed et al. (1999) devised a model to predict the juvenile sockeye rearing capacity of a lake nursery area based on primary production as measured by the photosynthetic rate (PR). This PR model predicts an escapement of 42,000 spawning sockeye will produce 2.3 million smolts (~2,000 smolts/ha) from Morrison Arm. Morrison Arm has a large abundance of potential competitors to juvenile sockeye salmon, which will reduce the rearing capacity of the Arm. Exact estimates were difficult to obtain but trawl catches indicate that over 50% of the limnetic fish population are not sockeye. Application of this proportion to the PR model estimate as done in Shortreed et al. (1998) resulted in an estimated escapement of 21,000 sockeye to reach the rearing capacity of Morrison Arm.

CONCLUSION

In the 3 years of our study, emergent fry-to-smolt survival rates in the Main Arm were amongst the highest (83% for the 1992 brood year) and the lowest recorded (17 and 13% for the 1993 and 1994 brood years) in Babine Lake. Survival from emergent fry to fall fry showed a similar trend between years but as noted before there were considerable discrepancies between the smolt and fall fry estimates. The “ich” parasite (Traxler et al. 1998) or the IHN virus (Wood et al. 1998) may have been a factor in the low survivals but there was no direct evidence to that effect.

Our study did not find any lake-related impediments to sockeye growth or survival. Density of juvenile sockeye was low to moderate, never exceeding 1,500 fry/ha, well below optimum densities estimated in other productive B.C. sockeye lakes (Hume et al. 1996). The north to south distribution of sockeye juveniles was the same in our study as it was in the 1970’s. As in past years, more fry were found in the southern regions of the Main Arm during summer but they were dispersed throughout the lake in the fall.

Shortreed and Morton (2000) found that the primary productivity of Babine Lake in 1994 and 1995 had increased by about 140% since 1973. They attribute this primarily to increased sockeye carcasses resulting in a current annual phosphorous load to Babine Lake 38% higher than in the years before the BLDP. There is no evidence of any effect on juvenile sockeye production rates. Neither fall size nor growth rate showed any significant change over previous years nor did size or growth show any relationship to increased spawner abundances.

Shortreed and Morton (2000) found that there was no significant difference between the *Daphnia* densities or fish diet in pre- and post- BLDP study years, although some estimates of fish abundance (smolts) indicate that there was also little difference in fish density in these years. Apparent growth rates were as high or higher than observed at similar densities in other years. In spite of the observed low freshwater survival rates in 2 of the 3 years examined, our study indicates the lake appears to be well within its rearing capacity at the current levels of sockeye spawners.

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Table 1. Midwater trawl catch and size statistics for the Main Arm of Babine Lake. Data are summarized by survey.

Catch		Weight (g)					Length (mm)				
			+/-95%					+/-95%			
Taxa	N	Mean	C.I.	SD	Min.	Max.	Mean	C.I.	SD	Min.	Max.
Summer Surveys											
Survey 9402 - August 4-7, 1994											
age-0	771	1.39	0.05	0.69	0.07	5.94	50	0.5	7.6	25	83
age-1	5	6.57	1.24	1.00	5.65	8.09	83	5.8	4.6	77	90
Survey 9503 - August 13-16,1995											
age-0	855	1.49	0.05	0.72	0.26	5.77	50	0.5	8.1	30	80
age-1	6	8.88	4.26	4.06	5.42	16.77	92	11.1	10.5	82	111
age-2+	1	63.97			63.97	63.97	176			176	176
Other	1	0.27			0.27	0.27	30			30	30
Fall Surveys											
Survey 9305 - September 26-29, 1993											
age-0	478	4.31	0.13	1.42	0.46	8.35	72	0.7	8.0	36	87
age-1	6	25.94	15.37	14.64	7.89	40.42	126	28.5	27.2	91	150
Whitefish	2	1.16	0.06	0.01	1.15	1.16	49	12.7	1.4	48	50
Other	2	1.45	3.18	0.35	1.20	1.70	54	57.2	6.4	49	58
Survey 9406 - October 4-7,1994											
age-0	445	3.54	0.10	1.10	0.84	6.81	69	0.7	7.4	42	85
age-1	1	8.04			8.04	8.04	93			93	93
age-2+	2	120.35	45.11	5.02	116.8	123.9	207	19.1	2.1	205	208
Survey 9505 - September 21-24, 1995											
age-0	354	2.93	0.11	1.09	0.57	6.09	65	0.9	8.7	38	85
	220	Not measured – collected for another agency									
age-1	4	17.36	28.21	17.73	7.48	43.89	108	45.7	28.7	90	150
Age-2+	2	Not measured – released									
Sculpin	1	0.14			0.14	0.14	23			23	23

Table 2. Midwater trawl catch and size statistics for North, Morrison and Hagan arms of Babine Lake. Data are summarized by survey. The three arms were not trawled in 1993.

Catch		Weight (g)					Length (mm)				
Taxa	N	Mean	+/-95% C.I.	SD	Min.	Max.	Mean	+/-95% C.I.	SD	Min.	Max.
Area 9 – North Arm											
Survey 9402 - August 4-7, 1994											
age-0	118	1.86	0.14	0.78	0.45	4.81	54	1.5	8.1	35	74
age-1	3	5.77	2.65	1.07	4.97	6.98	80	13.7	5.5	76	86
Survey 9406 - October 4-7,1994											
age-0	29	3.16	0.34	0.90	1.21	5.03	66	2.6	6.9	50	79
Survey 9503 - August 13-16,1995											
age-0	80	1.89	0.11	0.48	0.78	3.00	56	1.1	5.0	43	65
age-1	1	5.52			5.52	5.52	80			80	80
Survey 9505 - September 21-24, 1995											
age-0	51	2.91	0.23	0.82	0.89	4.91	65	1.9	6.9	43	80
age-1	2	44.17	19.00	2.11	42.67	45.66	153	0.0	0.0	153	153
Sculpin	2	0.50	2.22	0.25	0.32	0.67	35	57.2	6.4	30	39
Area 8 – Morrison Arm											
Survey 9402 - August 4-7, 1994											
age-0	18	2.96	0.68	1.38	0.90	5.40	62	5.1	10.3	44	77
age-2+	2	99.80	73.70	8.20	94.00	105.60	199	44.5	4.9	195	202
Whitefish	2	7.04	48.73	5.42	3.20	10.87	87	190.6	21.2	72	102
Survey 9406 - October 4-7,1994											
age-0	28	5.50	0.58	1.48	2.39	8.44	80	2.5	6.4	63	90
Whitefish	28	7.64	2.55	6.57	0.93	26.91	84	10.1	26.0	44	135
Sculpin	20	0.33	0.09	0.18	0.11	0.84	32	2.5	5.3	23	44
bull trout	1	42.08			42.08	42.08	165			165	165
pea-mouth chub	1	42.42			42.42	42.42	154			154	154
Survey 9505 - September 21-24, 1995											
age-0	3	6.32	2.61	1.05	5.50	7.50	83	13.7	5.5	79	89
age-1	3	15.89	20.69	8.33	9.62	25.34	114	37.7	15.2	98	128
age-2+	1	120.60			120.60	120.60	212			212	212
	3	Not measured - released									
Whitefish	11	9.69	4.36	6.50	0.82	20.12	90	20.4	30.4	43	122
	5	Not measured - released									
Sculpin	18	0.27	0.04	0.08	0.14	0.43	28	1.4	2.9	23	33
Sucker	1	90.00			90.00	90.00	187			187	187
pea-mouth chub	1	16.36			16.36	16.36	112			112	112
redside shiner	1	2.11			2.11	2.11	55			55	55
lake trout	1	Adult not measured – released									
Area 10 - Hagan Arm											
Survey 9505 - September 21-24, 1995											
age-0	12	2.60	0.61	0.96	0.90	3.92	63	5.4	8.5	45	73
age-1	2	43.27	19.19	2.14	41.76	44.78	150	12.7	1.4	149	151
Sculpin	2	0.26	1.08	0.12	0.17	0.34	27	38.1	4.2	24	30

Table 3. Hydroacoustic estimates of density and population of age-0 sockeye for each lake section.

	Surface	Density			Population		
	area (ha)	N	(N/ha)	95% C. I. (N/ha)	N	95% C. I. N	95% C. I. (% of N)
Survey 9305 – September 26-29,1993							
1. Old Fort	5,385	2	1,697	4,568	9,139,850	24,598,695	269%
2. Fulton	13,601	4	950	737	12,923,006	10,030,854	78%
3. Sandspit	4,528	3	496	361	2,244,999	1,634,105	73%
4. Pendleton	6,538	3	2,898	6,980	18,944,892	45,633,828	241%
5. Pinkut	5,906	3	1,477	2,261	8,720,677	13,351,800	153%
Main Arm	35,957	5	1,445	636	51,973,424	22,852,539	44%
8. Morrison Arm	1,195	2	423	12	505,788	14,245	3%
9. North Arm	5,279	6	211	376	1,114,214	1,983,416	178%
10. Hagan Arm	3,689	2	120	248	441,918	913,452	207%
Total lake	46,121	8	1,172	497	54,035,344	22,902,958	42%
Survey 9406 – October 4-7, 1994							
1. Old Fort	5,385	2	501	262	2,695,327	1,413,218	52%
2. Fulton	13,601	4	380	402	5,174,070	5,462,181	106%
3. Sandspit	4,528	3	295	306	1,335,918	1,384,998	104%
4. Pendleton	6,538	3	684	833	4,473,693	5,444,806	122%
5. Pinkut	5,906	3	432	506	2,550,309	2,987,856	117%
Main Arm	35,957	5	451	126	16,229,317	4,536,706	28%
8. Morrison Arm	1,195	2	140	439	167,530	523,927	313%
9. North Arm	5,279	6	720	381	3,803,072	2,012,701	53%
10. Hagan Arm	3,689	2	172	227	633,233	837,142	132%
Total lake	46,121	10	452	102	20,833,152	4,705,844	23%
Survey 9503 - August 13-16, 1995							
1. Old Fort	5,385	2	83	24	445,067	127,824	29%
2. Fulton	13,601	4	385	299	5,230,869	4,072,205	78%
3. Sandspit	4,528	3	509	816	2,305,935	3,695,154	160%
4. Pendleton	6,538	3	743	1,562	4,859,367	10,212,024	210%
5. Pinkut	5,906	3	1,652	2,313	9,753,350	13,659,063	140%
Main Arm	35,957	5	628	237	22,594,588	8,505,531	38%
8. Morrison Arm	1,195	2	14	92	16,615	110,218	663%
9. North Arm	5,279	6	102	85	536,909	446,445	83%
10. Hagan Arm	3,689	2	278	276	1,026,002	1,018,748	99%
Total lake	46,121	10	524	181	24,174,113	8,343,865	35%
Survey 9505 – September 21-24, 1995							
1. Old Fort	5,385	2	358	1,676	1,929,317	9,026,503	468%
2. Fulton	13,601	4	548	345	7,457,703	4,690,655	63%
3. Sandspit	4,528	3	399	825	1,804,330	3,735,728	207%
4. Pendleton	6,538	3	627	480	4,101,698	3,141,261	77%
5. Pinkut	5,906	3	238	180	1,404,028	1,065,098	76%
Main Arm	35,957	5	464	112	16,697,076	4,012,591	24%
8. Morrison Arm	1,195	2	39	54	47,067	64,456	137%
9. North Arm	5,279	6	282	231	1,489,527	1,217,680	82%
10. Hagan Arm	3,689	2	286	349	1,055,931	1,287,652	122%
Total lake	46,121	10	418	88	19,289,600	4,045,350	21%

Table 4. Mean size of age-0 sockeye in each section of the Main Arm. Mean weights that are underlined are not significantly different from each other (ANOVA, LSD, P > 0.05).

Summer Surveys

Survey 9402 - August 4 - 7, 1994

Section	3	5	4	1	2
Length (mm)	47.9	50.8	47.9	51.6	50.9
Weight (g)	1.27	1.34	1.38	1.49	1.60

Survey 9503 - August 13 - 16, 1995

Section	4	5	3	2	1
Length (mm)	49.5	48.3	51.8	53.9	59.1
Weight (g)	1.34	1.36	1.58	1.81	2.37

Fall Surveys

Survey 9305 - September 26-29, 1993

Section	2	1	3	4	5
Length (mm)	69.6	69.2	73.4	73.3	74.0
Weight (g)	3.67	3.80	4.42	4.48	4.92

Survey 9406 - October 4 - 7, 1994

Section	5	4	1	2	3
Length (mm)	67.4	67.5	68.1	69.4	72.6
Weight (g)	3.33	3.36	3.50	3.63	4.14

Survey 9505 - September 21- 24, 1995

Section	5	4	3	2	1
Length (mm)	55.8	63.7	66.3	68.1	68.4
Weight (g)	2.01	2.82	3.01	3.25	3.35

Table 5. Summary of juvenile population estimates from years when hydroacoustic estimates were made. Emergent fry and smolt estimates from Wood et al. (1997).

Brood	Emergent fry		Summer fry		Fall fry		Smolts
Year	(millions)	(N/ha)	(millions)	(N/ha)	(millions)	(N/ha)	(millions)
A. Main Arm (including Morrison and Hagan arms)							
1974	141.6	3,940			47.6	1,320	38.6
1992	228.1	6,340			51.9	1,445	188.7
1993	181.7	5,050			16.2	451	30.9
1994	131.9	3,670	22.6	630	16.7	464	17.3
B. North Arm							
1974	67.9	12,860			12.9	2,450	7.0
1992	137.2	25,990			1.1	210	5.5
1993	138.7	26,270			3.8	720	3.9
1994	30.8	5,830	0.5	100	1.5	280	0.8
C. Total Babine system							
1974	209.5	4,540			60.5	1,310	45.6
1992	365.3	7,920			54.0	1,170	194.1
1993	320.4	6,950			20.8	450	34.8
1994	162.7	3,530	24.2	520	19.3	420	18.1

Table 6. Summary of juvenile sockeye survival estimates from years when hydroacoustic estimates were made. Fall fry from 1974 were estimated by Mathisen and Smith (1982).

Brood Year	Emerg. - Fall (%)	Emerg. - Smolt (%)	Fall - smolt (%)
A. Main Arm (including Morrison and Hagan arms)			
1974	34	27	81
1992	23	83	363
1993	8.9	17	190
1994	13	13	104
B. North Arm			
1974	19	10	54
1992	1.4	3.8	265
1993	3.3	2.8	85
1994	8.4	2.5	30
C. Total Babine system			
1974	29	22	75
1992	15	52	369
1993	6.5	11	170
1994	12	11	94

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Fig. 3. Vertical distribution of all limnetic fish in Babine Lake at each transect. The median fish distribution is indicated by the solid line (50% are above and below). Eighty percent of the fish are within the dotted lines. Vertical lines indicate the beginning and end of the thermocline, where data are available (Shortreed et al. 2000).

Fig. 4. Distribution of juvenile sockeye in Babine Lake based on hydroacoustic surveys. October, 1975, data are from Mathisen and Smith (1982).

Fig. 5. Comparison of juvenile sockeye estimates for the main lake (including Morrison and Hagan arms) and North Arm of Babine Lake. Vertical lines are 95% confidence limits for the fall fry estimates and 2 SE for the smolt estimates. Emergent fry and smolt estimates are from Wood et al. (1998)

Fig. 6. June and July distribution of juvenile sockeye in Babine Lake based on purse-seine catches. Data from McDonald and Hume (1984).

Fig. 7. October distribution of juvenile sockeye in Babine Lake based on purse-seine catches. Data are from McDonald and Hume (1984).

Fig. 8. A. Increase in mean weight from late summer underyearlings to smolts for Main Arm sockeye. Relationship between emergent fry estimates and instantaneous growth rates between sample periods are shown in the insets. B. Relationship between emergent fry estimates and Main Arm late summer (solid symbols) and fall underyearling size (open symbols). Underyearling data for 1965-1977 are from McDonald and Hume (1984).

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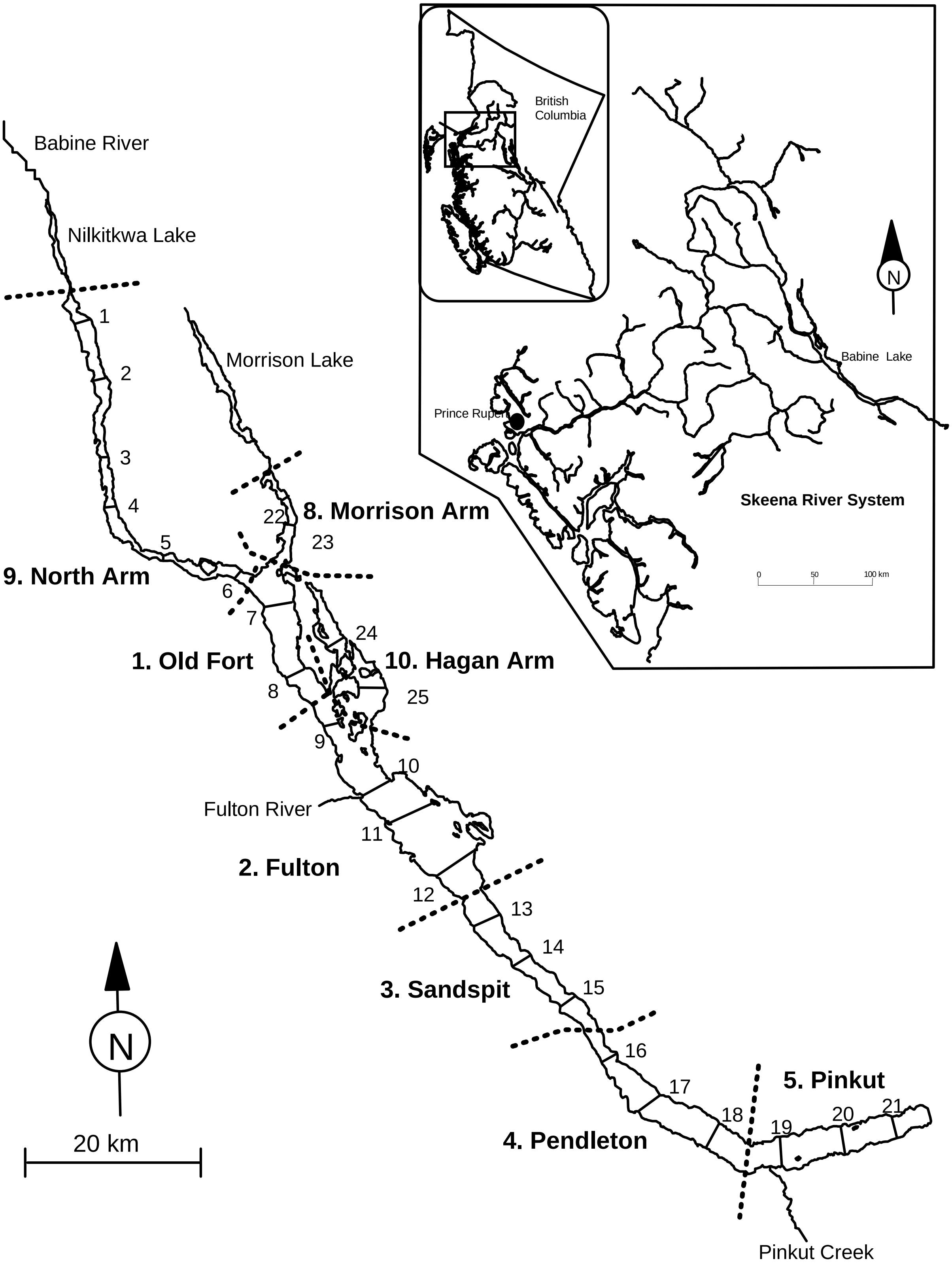

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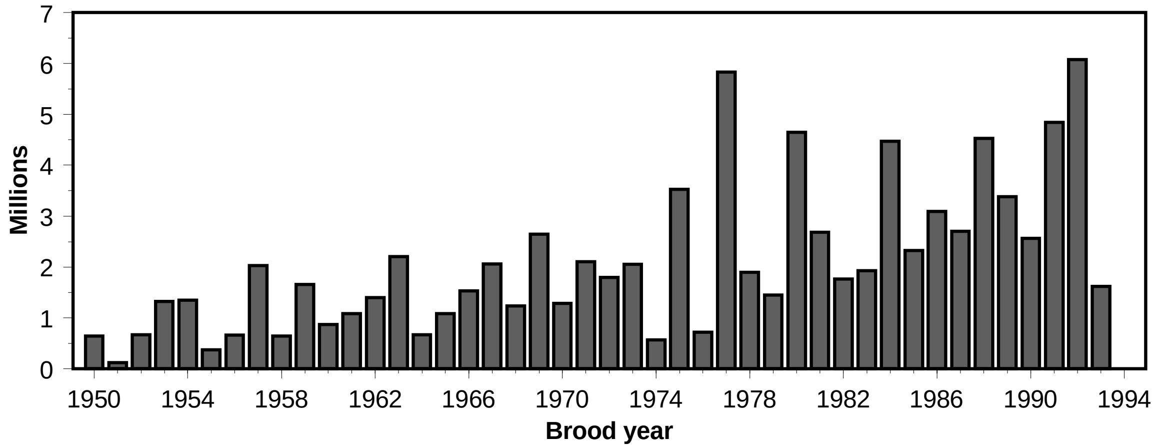
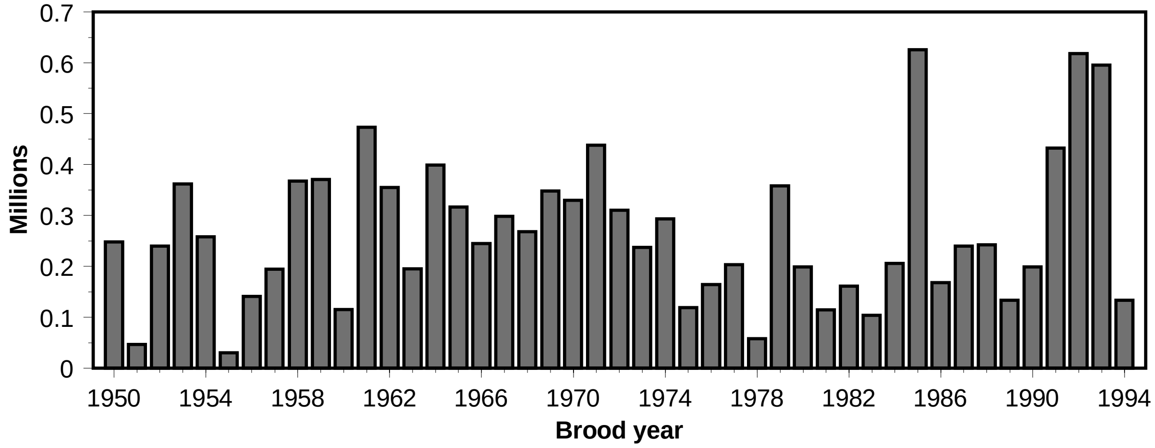
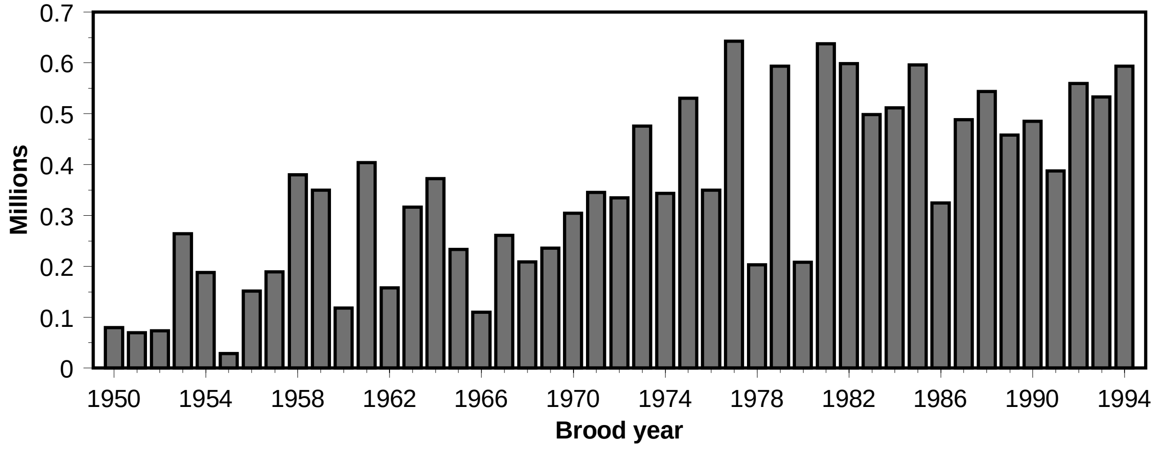
Adult returns (catch & escapement)



North Arm spawners (escapement)



Main Lake spawners (escapement)



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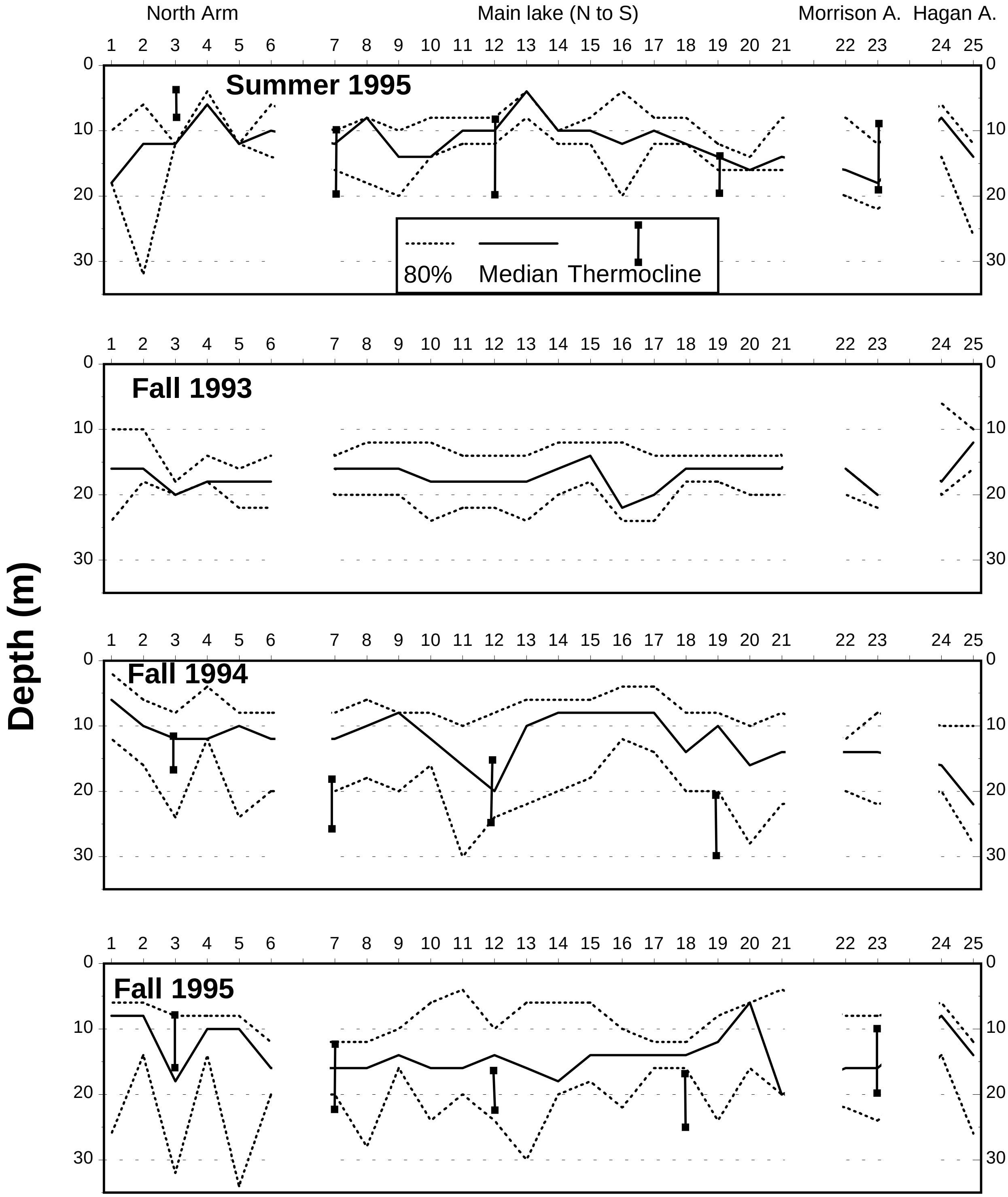

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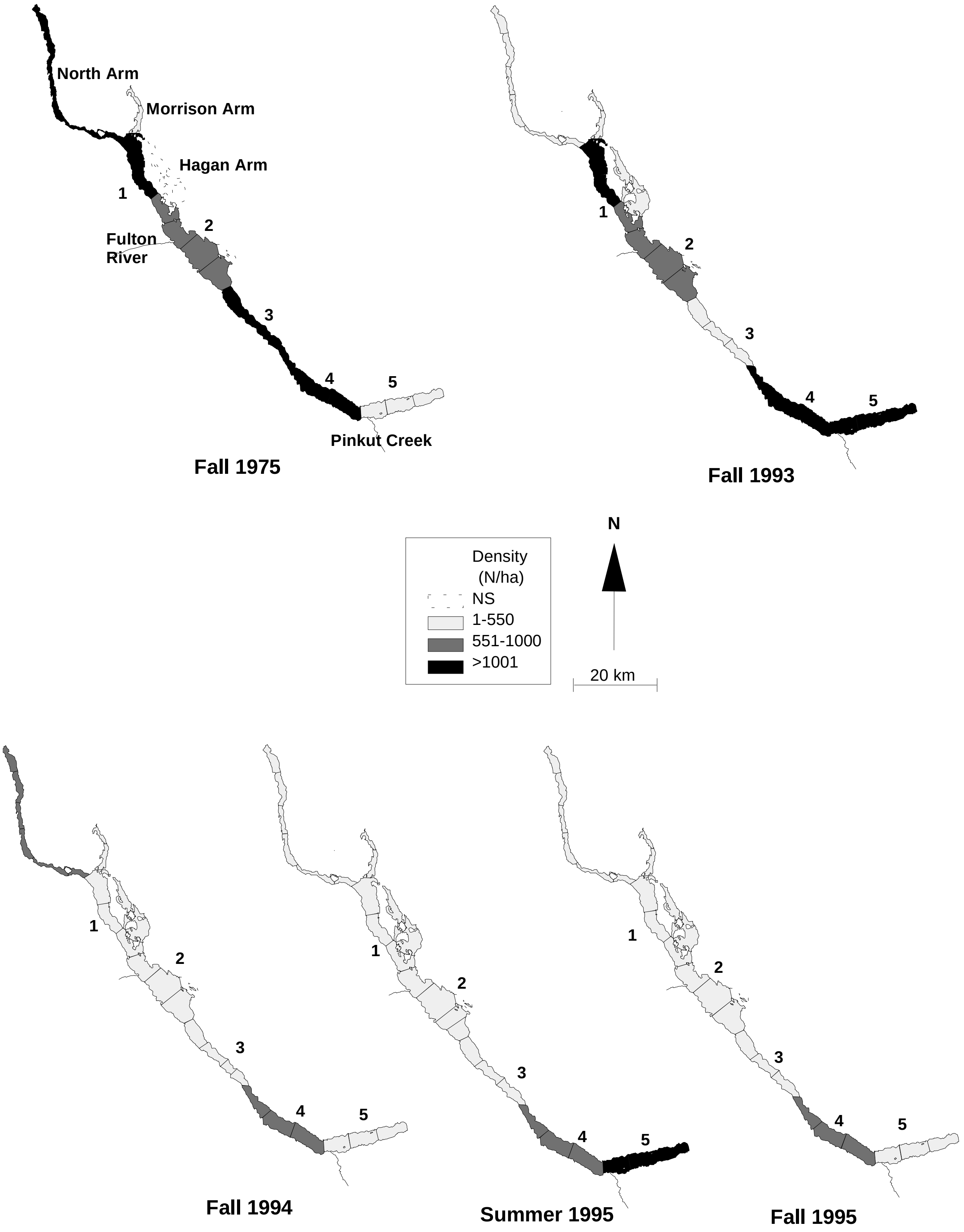

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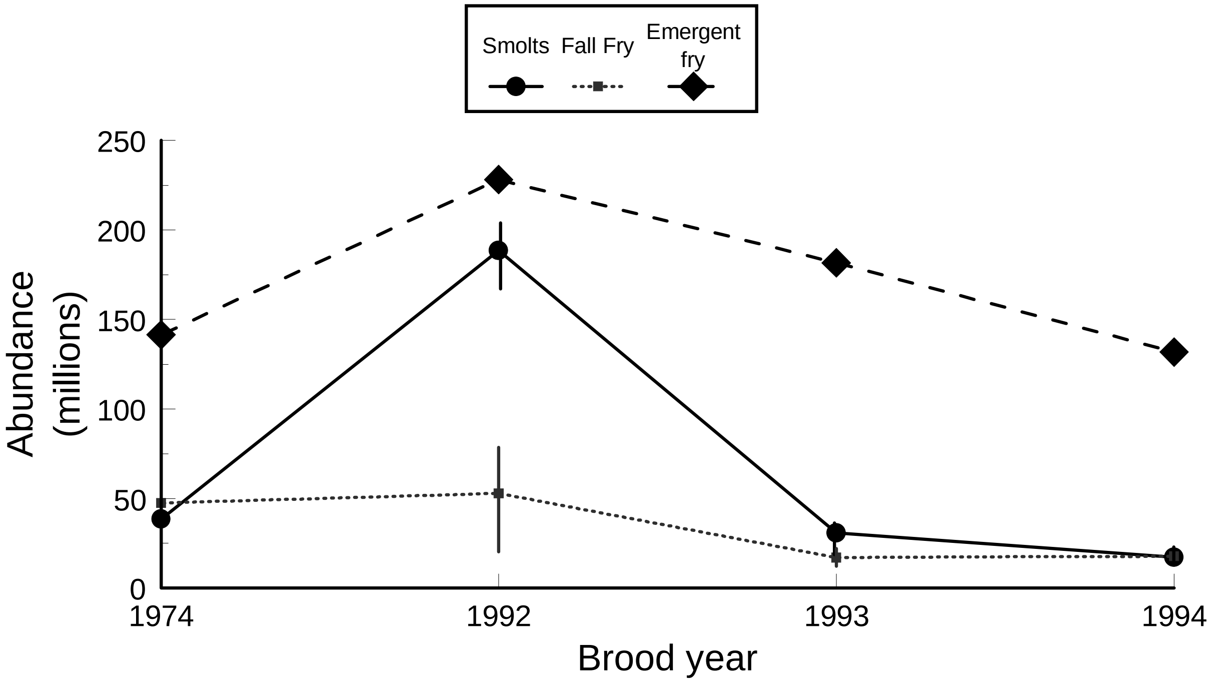
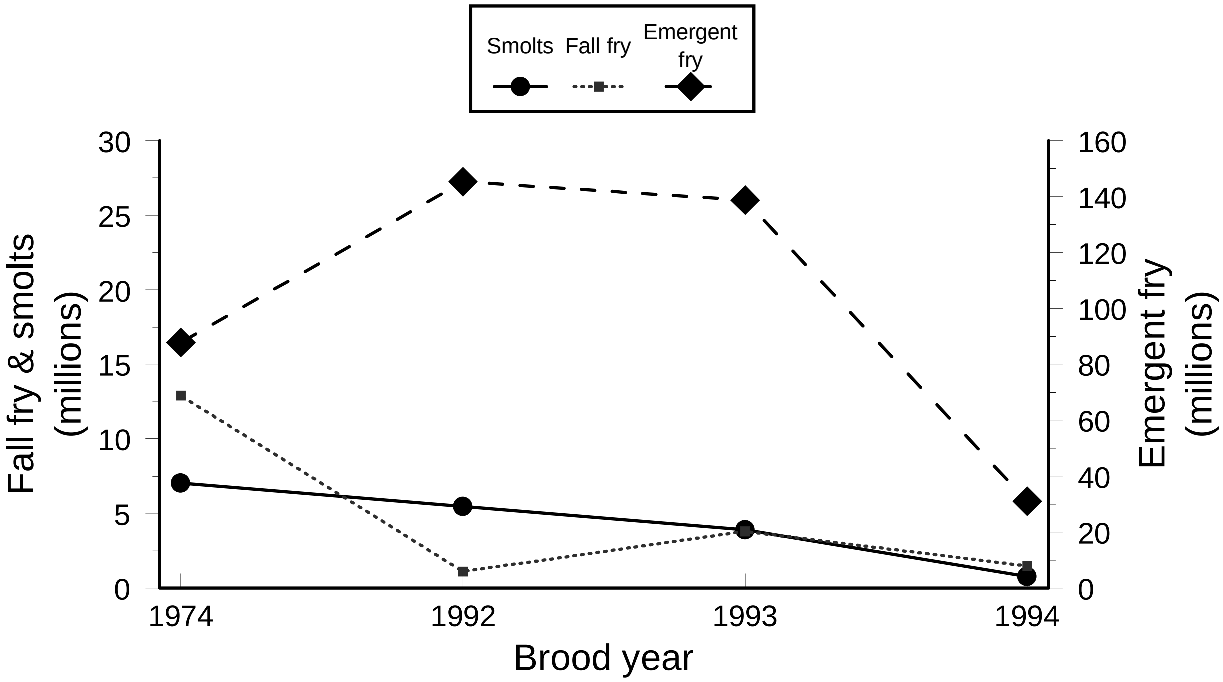
A. Main Lake



B. North Arm



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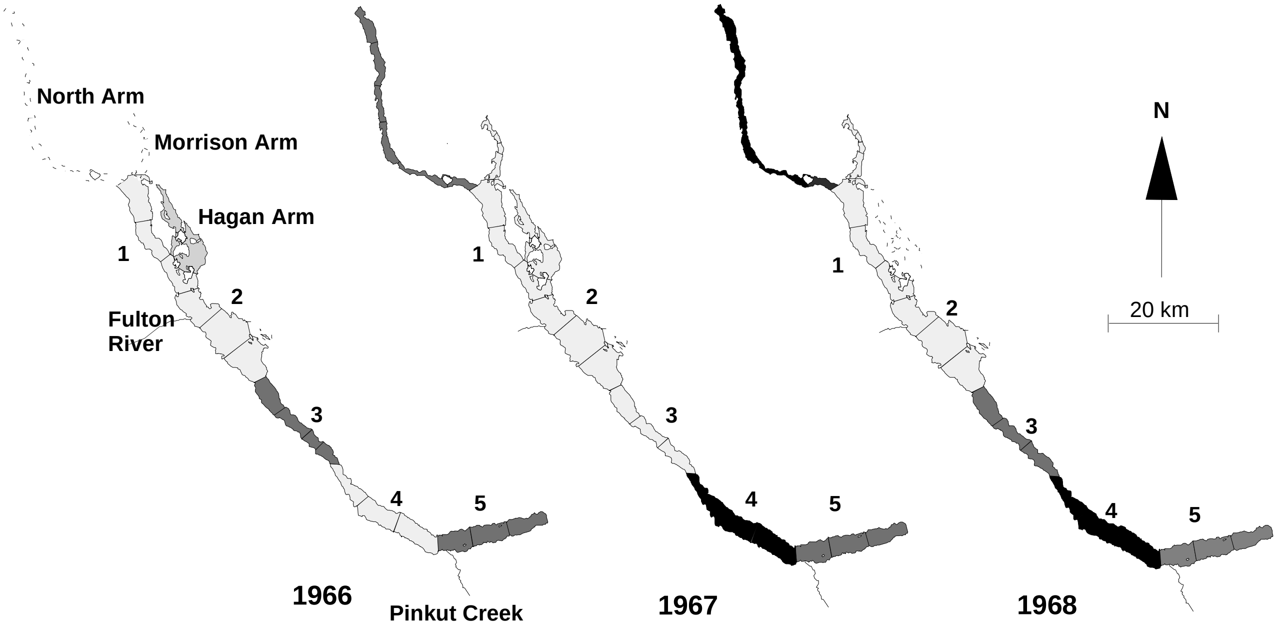
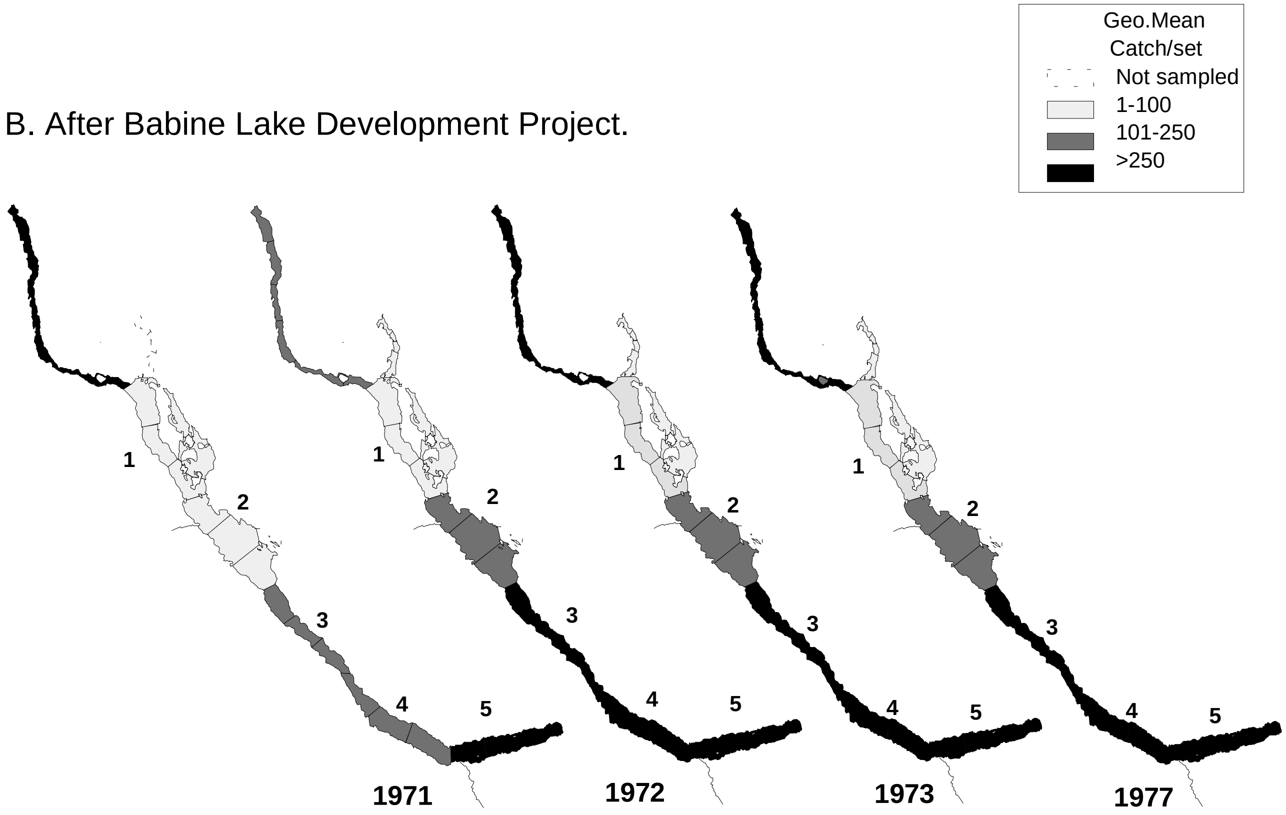
A. Before Babine Lake Development Project.



B. After Babine Lake Development Project.



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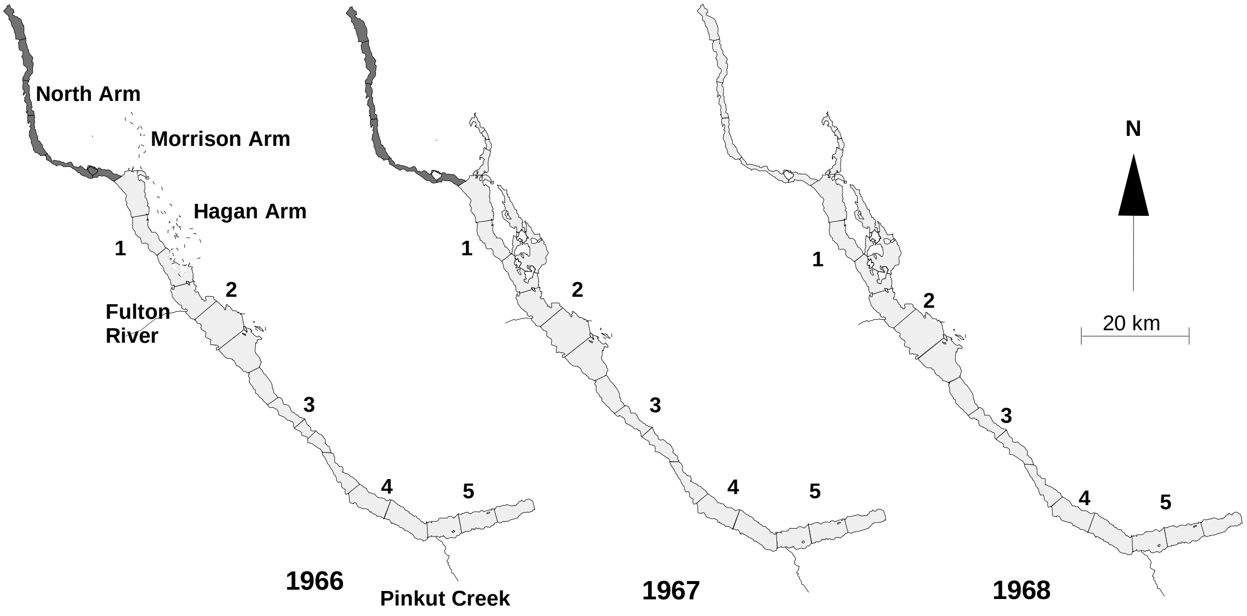


B. After Babine Lake Development Project.

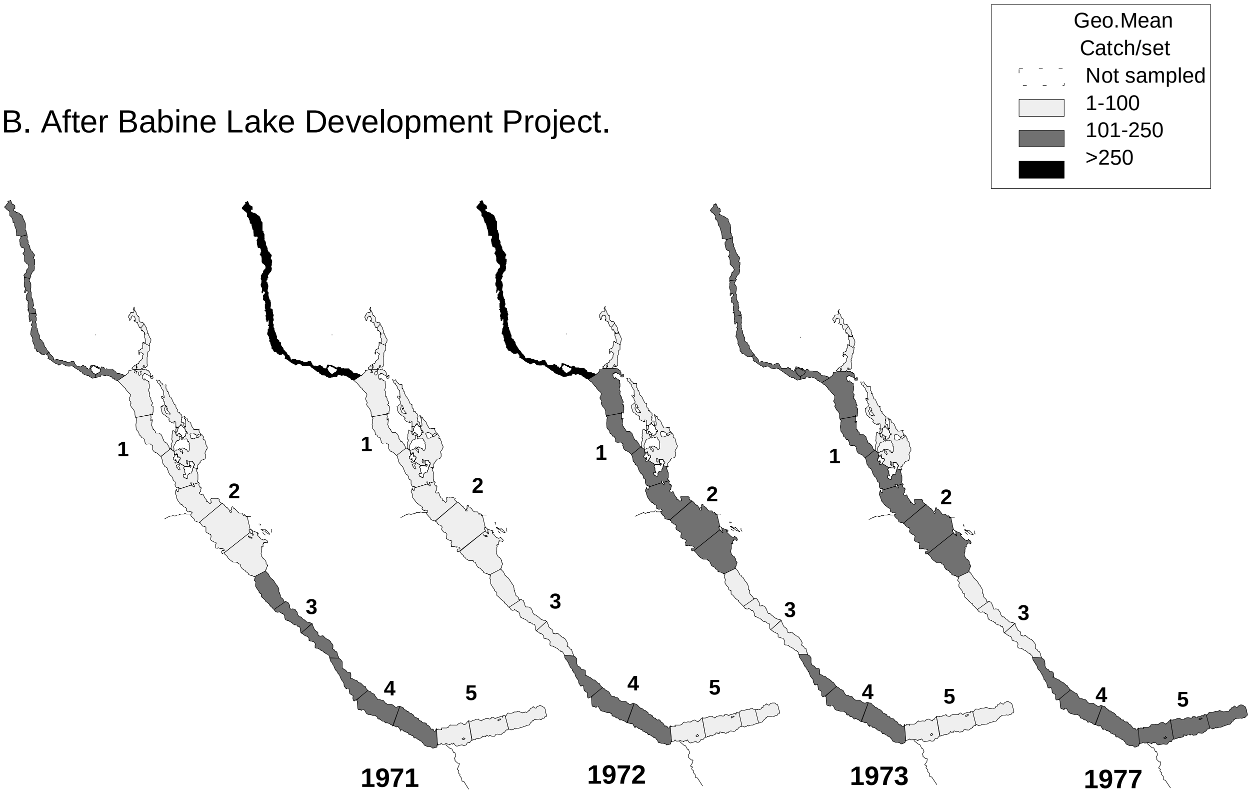
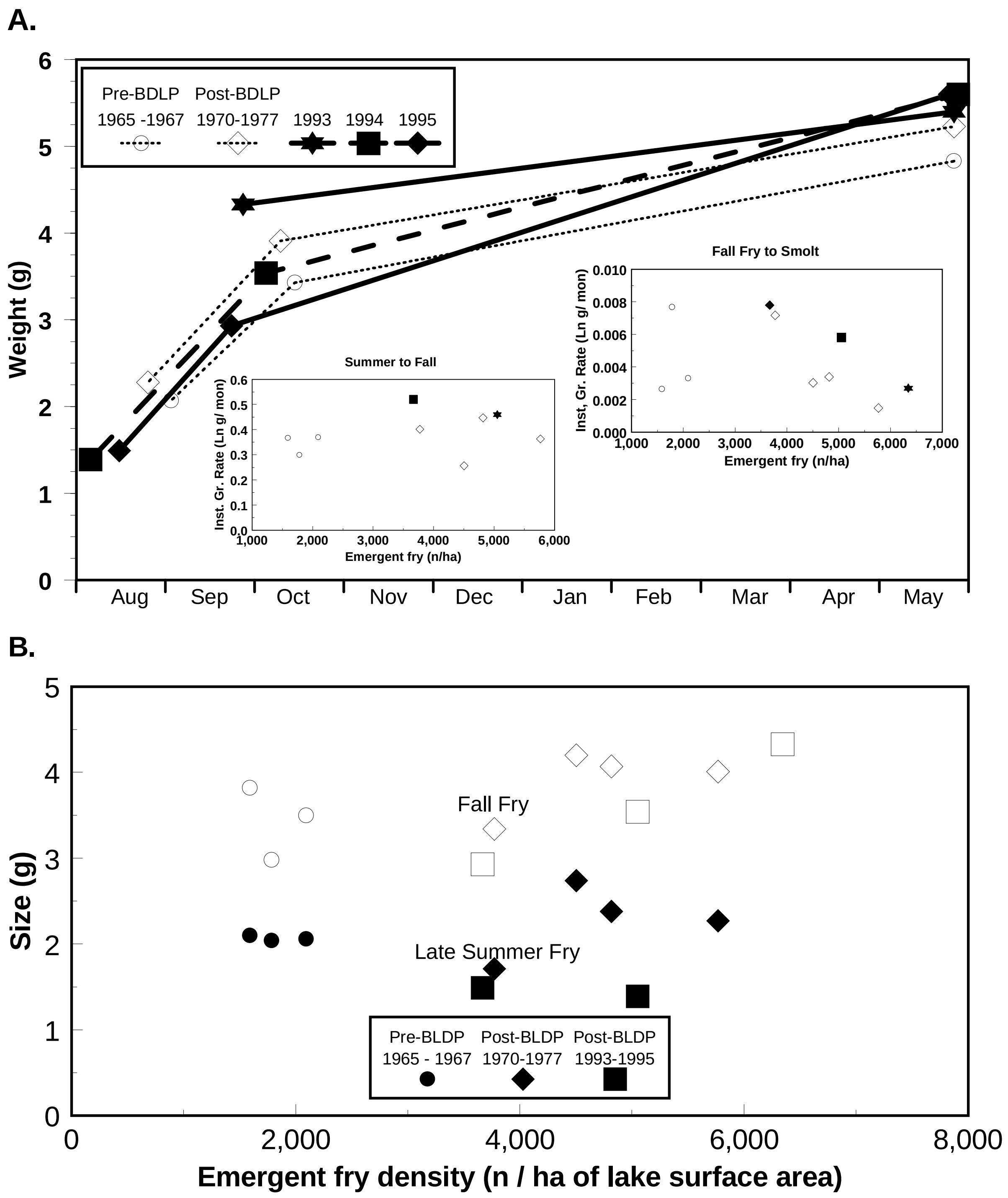


Fig. 7. October distribution of juvenile sockeye in Babine Lake based on purse-seine catches. Data are from McDonald and Hume (1984).



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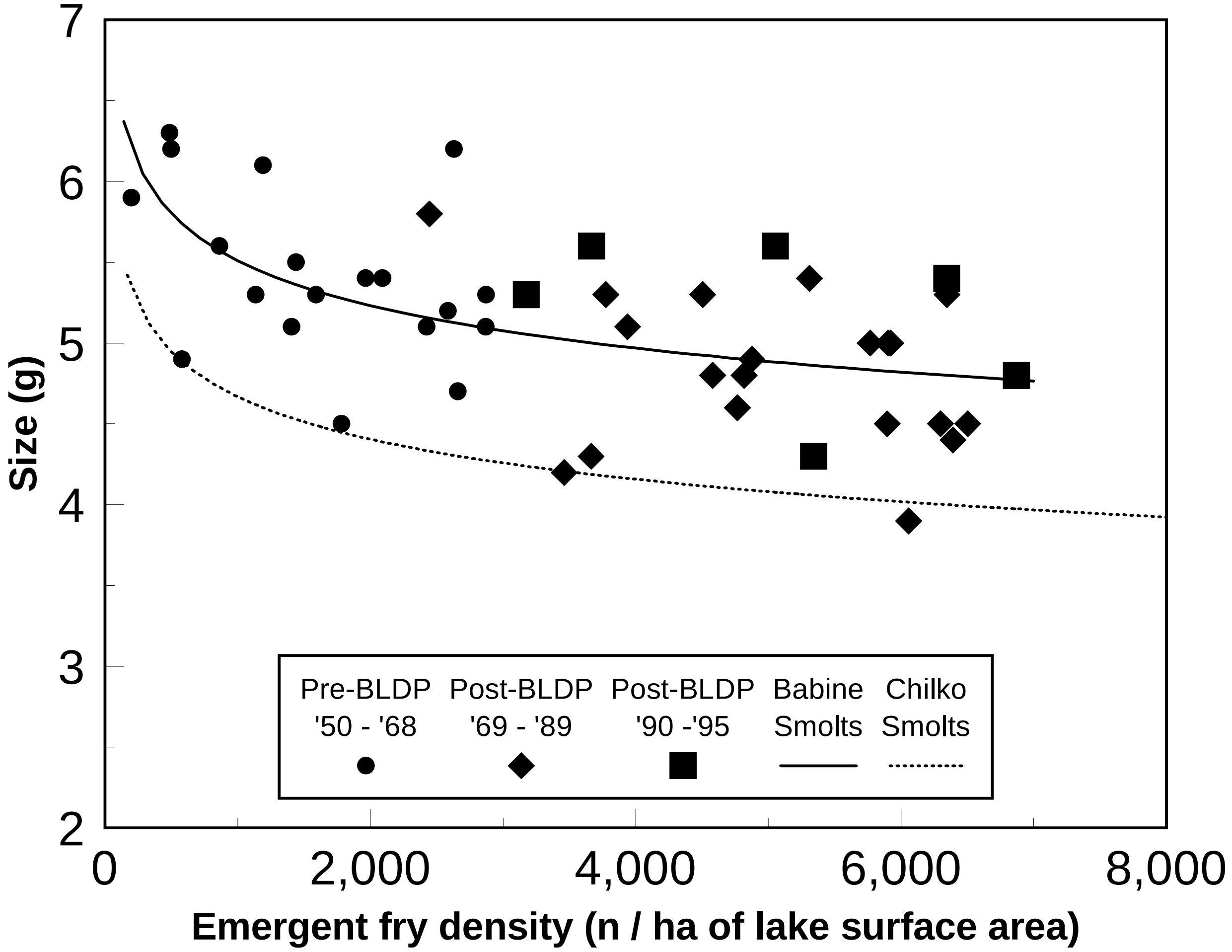

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Appendix Table 1. Hydroacoustic estimates of density and population of all limnetic fish for each lake section for all depths.

	Surface area (ha)	N	Density		Population		
			(N/ha)	95% C. I. (N/ha)	N	95% C. I. N	95% C. I.
Survey 9305 - Sept 26/93							
1. Old Fort	5,385	2	1,973	7,524	10,623,905	40,516,348	381%
2. Fulton	13,601	4	963	865	13,102,627	11,768,202	90%
3. Sandspit	4,528	3	673	691	3,045,624	3,129,227	103%
4. Pendleton	6,538	3	2,905	8,539	18,991,612	55,821,778	294%
5. Pinkut	5,906	3	1,487	2,788	8,780,669	16,463,304	187%
Main Arm	35,957	5	1,517	785	54,544,437	28,222,037	52%
8. Morrison Arm	1,195	2	588	74	702,122	87,834	13%
9. North Arm	5,279	6	325	446	1,715,405	2,354,397	137%
10. Hagan Arm	3,689	2	240	700	883,837	2,583,643	292%
Total lake	46,121	8	1,254	613	57,845,801	28,281,885	49%
Survey 9406 - Oct 4/94							
1. Old Fort	5,385	2	576	347	3,103,859	1,869,517	60%
2. Fulton	13,601	4	411	421	5,583,715	5,727,679	103%
3. Sandspit	4,528	3	318	328	1,441,390	1,485,897	103%
4. Pendleton	6,538	3	702	854	4,588,899	5,580,155	122%
5. Pinkut	5,906	3	447	511	2,640,132	3,014,857	114%
Main Arm	35,957	5	483	128	17,357,995	4,618,720	27%
8. Morrison Arm	1,195	2	399	1,273	477,101	1,521,244	319%
9. North Arm	5,279	6	802	447	4,235,478	2,357,899	56%
10. Hagan Arm	3,689	2	181	277	668,732	1,021,459	153%
Total lake	46,121	10	493	108	22,739,306	4,964,341	22%
Survey 9503 - Aug 13/95							
1. Old Fort	5,385	2	105	36	563,107	195,403	35%
2. Fulton	13,601	4	406	311	5,526,512	4,230,332	77%
3. Sandspit	4,528	3	537	789	2,433,293	3,573,699	147%
4. Pendleton	6,538	3	882	1,369	5,765,964	8,952,506	155%
5. Pinkut	5,906	3	1,692	2,356	9,994,402	13,911,612	139%
Main Arm	35,957	5	675	226	24,283,277	8,138,213	34%
8. Morrison Arm	1,195	2	229	1,189	273,420	1,420,450	520%
9. North Arm	5,279	6	132	104	697,438	550,900	79%
10. Hagan Arm	3,689	2	414	581	1,526,824	2,144,306	140%
Total lake	46,121	10	581	177	26,780,959	8,158,699	30%
Survey 9505 - Sept 21/95							
1. Old Fort	5,385	2	407	1,714	2,190,681	9,227,794	421%
2. Fulton	13,601	4	627	425	8,533,476	5,781,445	68%
3. Sandspit	4,528	3	469	970	2,122,146	4,393,646	207%
4. Pendleton	6,538	3	728	597	4,758,934	3,901,910	82%
5. Pinkut	5,906	3	426	30	2,512,924	174,434	7%
Main Arm	35,957	5	560	130	20,118,162	4,677,175	23%
8. Morrison Arm	1,195	2	425	608	507,821	726,485	143%
9. North Arm	5,279	6	410	266	2,165,418	1,405,807	65%
10. Hagan Arm	3,689	2	414	581	1,526,824	2,144,306	140%
Total lake	46,121	10	527	104	24,318,225	4,811,121	20%

Appendix Table 2. Hydroacoustic estimates of density and population of all limnetic fish for each transect at all depths.

		Surface	Density		Population		
Section	Transect	area (ha)	(N/ha)	95% C. I. (N/ha)	N	95% C. I. N	95% C. I. (% of N)
Survey 9305 - September 26-29,1993							
9. North Arm	1	1,066	114	95	121,032	101,607	84%
	2	1,046	453	429	473,744	448,537	95%
	3	757	182	287	137,535	217,563	158%
	4	1,003	19	30	19,109	29,623	155%
	5	830	50	59	41,448	48,973	118%
	6	577	1,132	389	653,794	224,385	34%
1. Old Fort	7	3,303	2,565	541	8,471,953	1,786,432	21%
	8	2,082	1,381	449	2,874,826	935,058	33%
2. Fulton	9	2,154	496	158	1,067,610	339,872	32%
	10	2,776	1,749	584	4,854,977	1,620,760	33%
	11	5,214	781	130	4,070,943	677,592	17%
	12	3,458	828	177	2,863,293	611,941	21%
3. Sandspit	13	1,902	894	348	1,699,852	662,615	39%
	14	1,259	764	221	962,030	278,382	29%
	15	1,366	360	176	492,318	240,355	49%
4. Pendleton	16	1,575	1,170	322	1,843,016	507,921	28%
	17	2,403	6,864	1,724	16,490,937	4,143,098	25%
	18	2,560	681	196	1,743,217	501,862	29%
5. Pinkut	19	2,100	2,127	417	4,468,127	876,666	20%
	20	2,107	2,142	367	4,513,096	773,003	17%
	21	1,698	191	100	324,471	169,822	52%
8. Morrison Arm	22	408	593	880	242,037	359,099	148%
	23	787	582	714	457,891	561,921	123%
10. Hagan Arm	24	1,353	295	147	398,828	199,316	50%
	25	2,336	184	40	430,859	93,737	22%
Survey 9406 - October 4-7 1994							
9. North Arm	1	1,066	1,273	768	1,356,962	819,246	60%
	2	1,046	849	329	888,175	344,369	39%
	3	757	1,002	332	759,174	251,411	33%
	4	1,003	394	362	394,649	362,520	92%
	5	830	96	117	79,876	97,540	122%
	6	577	1,199	504	692,437	291,126	42%
1. Old Fort	7	3,303	615	252	2,031,374	832,629	41%
	8	2,082	538	204	1,119,656	424,090	38%
2. Fulton	9	2,154	252	127	543,592	273,125	50%
	10	2,776	861	303	2,390,106	840,494	35%
	11	5,214	334	139	1,740,694	722,646	42%
	12	3,458	195	111	674,094	385,335	57%
3. Sandspit	13	1,902	132	69	251,825	130,703	52%
	14	1,259	427	162	537,803	203,681	38%
	15	1,366	396	223	540,547	305,359	56%
4. Pendleton	16	1,575	1,016	316	1,600,251	498,044	31%
	17	2,403	866	292	2,080,741	701,659	34%
	18	2,560	224	112	572,833	287,597	50%
5. Pinkut	19	2,100	388	159	814,513	333,689	41%
	20	2,107	230	72	485,152	151,551	31%
	21	1,698	723	185	1,228,133	313,942	26%
8. Morrison Arm	22	408	258	157	105,066	64,054	61%
	23	787	541	302	425,755	237,378	56%

Appendix Table 2 (*continued*). Hydroacoustic estimates of density and population of all limnetic fish for each transect at all depths.

Section	Transect	Surface area (ha)	Density (N/ha)	Density 95% C. I. (N/ha)	Population N	Population 95% C. I. N	Population 95% C. I. (% of N)
10. Hagan Arm	24	1,353	212	161	287,030	218,057	76%
	25	2,336	150	67	351,426	156,560	45%
Survey 9503 - August 13 - 16, 1995							
9. North Arm	1	1,066	46	52	49,138	55,941	114%
	2	1,046	184	154	192,479	161,154	84%
	3	757	50	101	37,622	76,720	204%
	4	1,003	13	24	12,724	24,385	192%
	5	830	237	433	196,757	359,290	183%
	6	577	263	200	151,906	115,413	76%
1. Old Fort	7	3,303	101	52	332,042	171,191	52%
	8	2,082	109	119	226,135	246,850	109%
2. Fulton	9	2,154	80	84	171,950	181,454	106%
	10	2,776	600	394	1,664,713	1,094,992	66%
	11	5,214	475	282	2,476,271	1,471,335	59%
	12	3,458	471	280	1,628,165	969,550	60%
3. Sandspit	13	1,902	983	968	1,869,497	1,841,332	98%
	14	1,259	264	182	332,534	229,118	69%
	15	1,366	365	290	499,116	395,846	79%
4. Pendleton	16	1,575	623	555	981,361	873,498	89%
	17	2,403	375	133	900,048	319,816	36%
	18	2,560	1,648	465	4,219,382	1,191,125	28%
5. Pinkut	19	2,100	3,032	1,812	6,369,454	3,805,438	60%
	20	2,107	979	435	2,061,813	917,312	44%
	21	1,698	1,066	409	1,810,410	694,021	38%
8. Morrison Arm	22	408	97	100	39,367	40,695	103%
	23	787	361	288	284,214	226,289	80%
10. Hagan Arm	24	1,353	349	326	472,560	441,170	93%
	25	2,336	479	270	1,117,821	631,370	56%
Survey 9505 - September 21- 24, 1995							
9. North Arm	1	1,066	97	60	103,219	64,168	62%
	2	1,046	469	467	490,423	488,616	100%
	3	757	442	329	334,886	248,845	74%
	4	1,003	63	65	63,292	65,060	103%
	5	830	673	845	558,679	701,615	126%
	6	577	717	237	413,923	137,115	33%
1. Old Fort	7	3,303	598	256	1,973,601	846,089	43%
	8	2,082	216	124	449,914	259,058	58%
2. Fulton	9	2,154	686	370	1,477,105	797,566	54%
	10	2,776	1,032	281	2,864,428	779,861	27%
	11	5,214	472	173	2,459,238	903,898	37%
	12	3,458	320	287	1,107,525	991,842	90%
3. Sandspit	13	1,902	109	64	206,976	122,102	59%
	14	1,259	286	141	359,712	178,112	50%
	15	1,366	1,012	558	1,382,422	762,211	55%
4. Pendleton	16	1,575	931	380	1,466,442	599,042	41%
	17	2,403	862	480	2,071,789	1,152,539	56%
	18	2,560	390	213	999,579	545,351	55%
5. Pinkut	19	2,100	415	243	870,740	509,913	59%
	20	2,107	442	232	931,270	488,851	52%
	21	1,698	420	252	713,258	428,721	60%
8. Morrison Arm	22	408	357	262	145,749	106,974	73%
	23	787	493	461	387,727	362,594	94%
10. Hagan Arm	24	1,353	349	326	472,560	441,170	93%
	25	2,336	479	270	1,117,821	631,370	56%

Appendix Table 3. Hydroacoustic estimates of density and population of age-0 sockeye for each transect.

		Surface area	Density		Population		
Section	Transect	(ha)	(N/ha)	95% C. I. (N/ha)	N	95% C. I. N	95% C. (% of N)
Survey 9305 – September 26- 29, 1993							
9. North Arm	1	1,066	31	54	32,990	57,342	174%
	2	1,046	67	192	69,562	199,088	286%
	3	757	118	240	89,082	181,245	203%
	4	1,003	13	24	13,376	24,784	185%
	5	830	30	46	24,869	37,935	153%
	6	577	1,008	368	581,902	212,697	37%
1. Old Fort	7	3,303	2,206	502	7,285,191	1,658,906	23%
	8	2,082	1,189	418	2,475,330	870,845	35%
2. Fulton	9	2,154	490	157	1,054,798	337,827	32%
	10	2,776	1,723	580	4,783,675	1,610,874	34%
	11	5,214	770	129	4,012,254	673,416	17%
	12	3,458	818	176	2,828,934	608,259	22%
3. Sandspit	13	1,902	562	213	1,069,305	404,707	38%
	14	1,259	631	201	794,637	253,006	32%
	15	1,366	294	160	402,098	218,286	54%
4. Pendleton	16	1,575	1,150	320	1,811,605	504,185	28%
	17	2,403	6,862	1,724	16,487,340	4,143,093	25%
	18	2,560	681	196	1,743,217	501,862	29%
5. Pinkut	19	2,100	2,127	417	4,468,127	876,666	20%
	20	2,107	2,113	367	4,451,931	772,469	17%
	21	1,698	190	100	322,020	169,773	53%
8. Morrison Arm	22	408	422	762	172,115	310,680	181%
	23	787	425	618	334,176	486,564	146%
10. Hagan Arm	24	1,353	147	104	199,414	140,938	71%
	25	2,336	92	28	215,430	66,282	31%
Survey 9406 - October 4-7, 1994							
9. North Arm	1	1,066	933	634	994,814	675,623	68%
	2	1,046	817	326	854,891	340,448	40%
	3	757	967	327	732,560	247,941	34%
	4	1,003	394	362	394,649	362,520	92%
	5	830	84	116	69,993	96,217	137%
	6	577	1,126	492	650,354	283,812	44%
1. Old Fort	7	3,303	530	238	1,749,652	786,643	45%
	8	2,082	471	194	981,333	402,895	41%
2. Fulton	9	2,154	224	120	483,315	258,980	54%
	10	2,776	811	297	2,251,945	825,174	37%
	11	5,214	303	134	1,580,448	697,233	44%
	12	3,458	183	109	632,655	378,542	60%
3. Sandspit	13	1,902	124	67	235,834	126,772	54%
	14	1,259	409	160	514,862	200,958	39%
	15	1,366	352	213	481,433	291,403	61%
4. Pendleton	16	1,575	997	314	1,571,167	495,111	32%
	17	2,403	836	289	2,008,534	693,328	35%
	18	2,560	219	112	561,704	285,440	51%
5. Pinkut	19	2,100	359	153	753,139	322,312	43%
	20	2,107	227	72	478,764	151,120	32%
	21	1,698	710	183	1,205,412	311,119	26%
8. Morrison Arm	22	408	91	94	37,282	38,211	102%
	23	787	189	181	148,749	142,233	96%
10. Hagan Arm	24	1,353	197	158	266,482	213,938	80%
	25	2,336	146	67	341,939	155,392	45%

Appendix Table 3 (*continued*). Hydroacoustic estimates of density and population of age-0 sockeye for each transect.

		Surface area	Density		Population		
Section	Transect	(ha)	(N/ha)	95% C. I. (N/ha)	N	95% C. I. N	95% C. (% of N)
Survey 9503 – August 13- 16. 1995							
9. North Arm	1	1,066	20	35	21,570	36,958	171%
	2	1,046	133	130	138,865	136,396	98%
	3	757	44	95	33,125	71,949	217%
	4	1,003	11	23	11,154	22,683	203%
	5	830	203	403	168,618	334,910	199%
	6	577	199	177	115,005	102,388	89%
1. Old Fort	7	3,303	80	46	264,256	152,563	58%
	8	2,082	85	106	177,587	220,477	124%
2. Fulton	9	2,154	72	82	154,795	177,138	114%
	10	2,776	575	388	1,596,877	1,077,228	67%
	11	5,214	441	273	2,298,075	1,422,272	62%
	12	3,458	451	275	1,557,739	950,798	61%
3. Sandspit	13	1,902	973	965	1,849,905	1,834,527	99%
	14	1,259	248	178	312,345	223,950	72%
	15	1,366	307	280	419,787	382,773	91%
4. Pendleton	16	1,575	232	142	365,820	224,183	61%
	17	2,403	369	132	885,496	317,013	36%
	18	2,560	1,629	462	4,170,289	1,183,846	28%
5. Pinkut	19	2,100	2,967	1,793	6,232,489	3,765,328	60%
	20	2,107	949	430	2,000,187	905,238	45%
	21	1,698	1,038	403	1,762,867	684,939	39%
8. Morrison Arm	22	408	4	9	1,484	3,766	254%
	23	787	24	73	19,023	57,783	304%
10. Hagan Arm	24	1,353	309	313	417,983	424,287	102%
	25	2,336	247	193	577,823	450,579	78%
Survey 9505 – September 21-24, 1995							
9. North Arm	1	1,066	42	43	44,966	46,165	103%
	2	1,046	276	376	288,918	392,834	136%
	3	757	253	261	191,596	197,807	103%
	4	1,003	29	45	28,922	44,999	156%
	5	830	429	683	355,904	567,205	159%
	6	577	664	230	383,268	132,965	35%
1. Old Fort	7	3,303	545	245	1,799,552	808,877	45%
	8	2,082	172	104	357,520	216,853	61%
2. Fulton	9	2,154	620	355	1,335,192	764,916	57%
	10	2,776	863	249	2,395,831	691,766	29%
	11	5,214	423	166	2,204,212	867,794	39%
	12	3,458	288	281	994,176	972,307	98%
3. Sandspit	13	1,902	90	60	170,309	113,252	66%
	14	1,259	247	135	310,518	169,749	55%
	15	1,366	859	529	1,174,386	722,634	62%
4. Pendleton	16	1,575	719	332	1,132,300	522,822	46%
	17	2,403	805	465	1,933,894	1,117,981	58%
	18	2,560	358	206	917,498	527,377	57%
5. Pinkut	19	2,100	233	160	490,006	336,535	69%
	20	2,107	329	209	692,717	440,291	64%
	21	1,698	151	135	256,697	228,968	89%
8. Morrison Arm	22	408	33	80	13,618	32,795	241%
	23	787	45	140	35,725	109,808	307%
10. Hagan Arm	24	1,353	325	315	439,942	425,668	97%
	25	2,336	247	193	577,823	450,579	78%

Appendix Table 4. Summary of midwater trawls completed on Babine Lake from 1993 to 1995.

Survey	Tow (#)	Sect (#)	Date	Time (PST)	Dura (min)	Depth		Sky Conditions	Light Conditions	Wind Conditions
						Start (m)	End (m)			
9305	930016	1	29/Sep/93	21:07	15	18.0	18.0	≤10% cloud	br. moon	
	930015	2	27/Sep/93	22:18	20	18.0	18.0	≤10 cloud	br. moon	
	930014	3	27/Sep/93	20:39	20	18.0	25.0	≤10 cloud	br. moon	
	930013	4	26/Sep/93	23:44	11	18.0	18.0	≤10% cloud	br. moon	
	930012	5	26/Sep/93	20:56	8	18.0	18.0	≤10% cloud	br. moon	
9402	940003	1	04/Aug/94	22:06	30	6.0	6.0	>50% cloud	dark	light breeze
	940002	2	04/Aug/94	0:35	20	11.0	11.0	Interim. rain	dark	mod. breeze
	940008	3	07/Aug/94	1:02	10	11.0	11.0	>50% cloud	dark	fresh breeze
	940006	4	06/Aug/94	2:03	10	11.0	11.0	>50% cloud	dark	light air
	940005	5	05/Aug/94	22:25	10	11.0	11.0	>50% cloud	dark	gentle breeze
	940007	8	07/Aug/94	22:00	10	18.0	18.0	≤10% cloud	dark	calm
	940004	9	05/Aug/94	2:40	20	6.0	6.0	>50% cloud	dark	light air
9406	940037	1	07/Oct/94	2:50	15	11.0	11.0	11-50% cloud	dark	light air
	940031	2	04/Oct/94	20:25	20	18.0	11.0	>50% cloud	dark	light breeze
	940034	3	06/Oct/94	2:25	15	18.0	18.0	>50% cloud	dark	light air
	940033	4	05/Oct/94	23:45	15	11.0	11.0	>50% cloud	dark	light air
	940032	5	05/Oct/94	21:10	30	18.0	18.0	≤10% cloud	dark	light air
	940036	8	06/Oct/94	23:30	30	18.0	18.0	11-50% cloud	dark	light air
	940035	9	06/Oct/94	19:35	15	15.0	15	>50% cloud	dark	mod. breeze
9503	950013	1	16/Aug/95	2:57	30	18.0	18.0	>50% cloud	mod. moon	light breeze
	950011	2	15/Aug/95	22:58	15	11.0	11.0	≤10% cloud	mod. moon	light air
	950010	3	14/Aug/95	22:16	15	11.0	11.0	≤10% cloud	br. moon	light air
	950009	4	14/Aug/95	1:25	15	11.0	11.0	Cont. rain	dark	light breeze
	950008	5	13/Aug/95	22:12	15	18.0	18.0	Cont. rain	dark	gentle breeze
	950012	9	15/Aug/95	22:13	20	11.0	11.0	>50% cloud	mod. moon	light air
9505	950020	1	22/Sep/95	22:45	5	18.0	18.0	≤10% cloud	dark	calm
	950021	2	23/Sep/95	2:07	10	18.0	18	≤10% cloud	dark	gentle breeze
	950018	3	22/Sep/95	2:50	30	25.0	25.0	≤10% cloud	dark	calm
	950017	4	22/Sep/95	0:11	15	18.0	18.0	≤10% cloud	dark	calm
	950016	5	21/Sep/95	21:00	20	11.0	11.0	≤10% cloud	dark	calm
	950019	8	22/Sep/95	20:15	30	18.0	18.0	≤10% cloud	dark	calm
	950022	9	23/Sep/95	21:18	30	11.0	11.0	≤10% cloud	dark	gentle breeze
	950023	9	23/Sep/95	23:40	3	18.0	18.0	≤10% cloud	dark	gentle breeze
	950024	10	24/Sep/95	1:20	30	15.0	15.0	≤10% cloud	dark	gentle breeze
	950025	10	24/Sep/95	3:20	20	18.0	18.0	≤10% cloud	dark	gentle breeze

Appendix Table 5. Midwater trawl catch and size statistics for each tow.

		Catch		Weight					Length				
Sect.	Tow	Taxa	N	Mean	+/-95% C.I.	SD	Min	Max	Mean	+/-95% C.I.	SD	Min	Max
Survey 9305 – September 26- 29, 1993													
1	930016	Age-0	30	3.8	0.66	1.77	0.99	8.09	69	4.1	10.9	46	91
		Age-1	1	27.64			27.64	27.64	135			135	135
		Other	1	1.2			1.2	1.2	49			49	49
2	930015	Age-0	158	3.67	0.18	1.13	0.55	5.93	70	1.1	7.2	38	83
		Age-1	1	38.99			38.99	38.99	145			145	145
		Other	1	1.7			1.7	1.7	58			58	58
3	930014	Age-0	19	4.42	0.6	1.24	2.46	7	73	3.2	6.6	60	85
		Age-1	2	36.52	49.55	5.52	32.62	40.42	146	57.2	6.4	141	150
		Whitefish	2	1.16	0.06	0.01	1.15	1.16	49	12.7	1.4	48	50
4	930013	Age-0	101	4.48	0.28	1.4	0.46	7.11	73	1.7	8.6	36	85
5	930012	Age-0	172	4.92	0.21	1.38	1.08	8.35	74	1.1	7.5	46	87
Survey 9402 – August 4-7, 1994													
1	940003	Age-0	83	1.49	0.12	0.53	0.48	2.94	52	1.4	6.6	36	66
		Age-1	1	6.07			6.07	6.07	82			82	82
2	940002	Age-0	100	1.6	0.19	0.98	0.12	4.95	51	1.9	9.7	27	75
		Age-1	3	6.93	3.04	1.22	5.65	8.09	83	16.2	6.5	77	90
3	940008	Age-0	27	1.27	0.26	0.65	0.07	2.61	48	3.5	8.9	25	62
4	940006	Age-0	374	1.38	0.06	0.61	0.32	5.94	51	0.7	6.7	33	83
5	940005	Age-0	187	1.28	0.1	0.69	0.22	4.47	48	1.1	7.8	28	73
		Age-1	1	5.98			5.98	5.98	83			83	83
8	940007	Age-0	18	2.96	0.68	1.38	0.9	5.4	62	5.1	10.3	44	77
		Age-2+	2	99.8	73.7	8.2	94	105.6	199	44.5	4.9	195	202
		Whitefish	2	7.04	48.73	5.42	3.2	10.87	87	190.6	21.2	72	102
9	940004	Age-0	118	1.86	0.14	0.78	0.45	4.81	54	1.5	8.1	35	74
		Age-1	3	5.77	2.65	1.07	4.97	6.98	80	13.7	5.5	76	86
Survey 9406 – October 4-7, 1994													
1	940037	Age-0	68	3.5	0.23	0.96	1.29	5.45	68	1.6	6.4	51	80
		Age-2+	1	116.8			116.8	116.8	205			205	205
2	940031	Age-0	101	3.63	0.22	1.14	0.88	6.23	69	1.5	7.7	45	82
		Age-1	1	8.04			8.04	8.04	93			93	93
3	940034	Age-0	64	4.14	0.25	1	1.43	6.81	73	1.4	5.6	52	85
4	940033	Age-0	68	3.36	0.27	1.12	1	6.45	67	1.8	7.6	44	83
5	940032	Age-0	144	3.33	0.18	1.08	0.84	6.32	67	1.3	7.7	42	83
		Age-2+	1	123.9			123.9	123.9	208			208	208
8	940036	Age-0	28	5.5	0.58	1.48	2.39	8.44	80	2.5	6.4	63	90
		Whitefish	28	7.64	2.55	6.57	0.93	26.91	84	10.1	26	44	135
		Sculpin	20	0.33	0.09	0.18	0.11	0.84	32	2.5	5.3	23	44
		Bull trout	1	42.08			42.08	42.08	165			165	165
		Peamouth chub	1	42.42			42.42	42.42	154			154	154
9	940035	Age-0	29	3.16	0.34	0.9	1.21	5.03	66	2.6	6.9	50	79

Appendix Table 5 (*continued*). Midwater trawl catch and size statistics for each tow.

		Catch		Weight					Length				
Sect.	Tow	Taxa	N	Mean	+/-95% C.I.	SD	Min	Max	Mean	+/-95% C.I.	SD	Min	Max
Survey 9503 – August 13 - 16, 1995													
1	950013	Age-0	30	2.37	0.49	1.3	0.49	5.77	59	4.5	12.1	35	80
		Age-1	3	8.29	0.41	0.17	8.1	8.41	92	6.3	2.5	90	95
		Age-2+	1	63.97			63.97	63.97	176			176	176
2	950011	Age-0	60	1.81	0.2	0.78	0.64	3.36	54	2.2	8.4	38	68
		Age-1	1	6.19			6.19	6.19	82			82	82
		Other	1	0.27			0.27	0.27	30			30	30
3	950010	Age-0	251	1.58	0.08	0.64	0.43	3.52	52	0.9	7.3	34	70
		Age-1	1	5.42			5.42	5.42	83			83	83
4	950009	Age-0	185	1.34	0.07	0.46	0.38	3.32	49	0.8	5.8	33	67
5	950008	Age-0	329	1.36	0.08	0.72	0.26	4.56	48	0.9	8.3	30	73
		Age-1	1	16.77			16.77	16.77	111			111	111
9	950012	Age-0	80	1.89	0.11	0.48	0.78	3	56	1.1	5	43	65
		Age-1	1	5.52			5.52	5.52	80			80	80
Survey 9505 – September 21-24 1995													
1	950020 [a]	Age-0	132	3.35	0.16	0.93	1.39	6.09	68	1.1	6.3	52	85
		Age-1	2	9.03	13.28	1.48	7.98	10.07	95	63.5	7.1	90	100
2	950021 [b]	Age-0	43	3.25	0.28	0.89	1.26	5.03	68	1.9	6.3	50	80
		Age-1	1	7.48			7.48	7.48	90			90	90
3	950018	Age-0	8	3.01	0.82	0.98	2.18	5.06	66	5.7	6.9	60	80
		Age-1	1	43.89			43.89	43.89	150			150	150
4	950017	Age-0	105	2.82	0.2	1.01	0.57	5.77	64	1.5	7.8	38	82
		Sculpin	1	0.14			0.14	0.14	23			23	23
5	950016	Age-0	66	2.01	0.27	1.08	0.75	5.21	56	2.3	9.3	41	77
8	950019 [c]	Age-0	3	6.32	2.61	1.05	5.5	7.5	83	13.7	5.5	79	89
		Age-1	3	15.89	20.69	8.33	9.62	25.34	114	37.7	15.2	98	128
		Age-2+	1	120.6			120.6	120.6	212			212	212
		Whitefish	11	9.69	4.36	6.5	0.82	20.12	90	20.4	30.4	43	122
		Sculpin	18	0.27	0.04	0.08	0.14	0.43	28	1.4	2.9	23	33
		Sucker	1	90			90	90	187			187	187
		Peamouth chub	1	16.36			16.36	16.36	112			112	112
		Redside shiner	1	2.11			2.11	2.11	55			55	55
9	950022	Age-0	5	2.95	1.89	1.52	0.89	4.91	64	16.7	13.5	43	80
		Sculpin	2	0.5	2.22	0.25	0.32	0.67	35	57.2	6.4	30	39
9	950023	Age-0	46	2.9	0.22	0.73	1.38	4.09	65	1.8	6	50	76
		Age-1	2	44.17	19	2.11	42.67	45.66	153	0	0	153	153
10	950024	Age-0	5	1.84	1	0.8	0.9	3	56	9.8	7.9	45	65
10	950025	Age-0	7	3.14	0.6	0.65	1.9	3.92	67	4.6	5	58	73
		Age-1	2	43.27	19.19	2.14	41.76	44.78	150	12.7	1.4	149	151
		Sculpin	2	0.26	1.08	0.12	0.17	0.34	27	38.1	4.2	24	30

[a] An additional 216 age-0 sockeye were released. [b] An additional 4 age-0 and 2 age-2+ sockeye were supplied to another research group. [c] An additional 3 age-2+ sockeye and 5 whitefish were supplied to another research group. One large lake trout was released.